BIBLIOGRAPHY AND ABSTRACTS ON ELECTRICAL CONTACTS*

1835 to 1951

1835–1838

No. 1. P. S. Munck af Rosenschold, *Pogg. Ann.*, Vol. 34, p. 437 (1835); Vol. 43, p. 193 (1838).

1860

No. 2. W. Beety, *Pogg. Ann.*, Vol. 111, p. 619 (1860).

1875

No. 3. T. du Moncel, *Compt. rend.*, Vol. 81, p. 766 (1875).

1878

No. 4. D. E. Hughes, *Chem. News*, London, Vol. 37, p. 197 (1878); Vol. 37, p. 246 (1878); also *Nature*, Vol. 18, pp. 20, 57, and 129 (1878).

1879

No. 5. D. E. Hughes, Letter to J. J. Fahie (1879). Published in Fahie's "History of Wireless Telegraphy," First Edition, p. 289 (1884, 1899).

No. 6. J. Ochoswicz, *Telegraphic J.*, Vol. 7, p. 348 (1879).

1880

No. 7. A. Stroh, *Journ.*, Soc. Telegraph Eng., Vol. 9, p. 182 (1880).

1883

No. 8. S. Bidwell, *Journ.*, Soc. Telegraph Eng., Vol. 12, p. 173 (1883).

1884–1885

No. 9. Borns, *ETZ.*, Vol. 5, p. 122 (1884).

No. 10. T. Calzecchi-Onesti, *Nuov. Cim.*, Vol. 16, p. 61 (1884); Vol. 17, p. 38 (1885).

1886

No. 11. F. Auerbach, *Wied. Ann.*, Vol. 28, p. 604 (1886).

1890

No. 12. E. Branly, *Compt. rend.*, Vol. 111, p. 785 (1890).

No. 13. F. Uppenborn, *ETZ.*, Vol. 11, p. 212 (1890).

1891

No. 14. E. Branly, *Compt. rend.*, Vol. 112, p. 90 (1891); also *Eclairage Electr.*, Vol. 40, pp. 301, 506 (1891).

1892

No. 15. G. S. Ohm, *Ges. Abhandl.*, Leipzig, pp. 1, 9 (1892).

1893

No. 16. G. Vincentini, *Lum. electr.*, Vol. 49, p. 281 (1893).

1895

No. 17. E. Branly, *Compt. rend.*, Vol. 120, p. 869 (1895); also *Zeits. f. Instrumentenk.*, Vol. 15, p. 346 (1895).

1896

No. 18. A. Raps, *ETZ.*, Vol. 17, p. 100 (1896).

No. 19. K. Strecker, *ETZ.*, Vol. 17, p. 98 (1896).

1897

No. 20. F. Kohlrausch, *Wied. Ann.*, Vol. 60, p. 333 (1897).

No. 21. O. Lodge, *Electrician*, Vol. 40, p. 87 (1897).

No. 22. G. Troll, *ETZ.*, Vol. 18, p. 701 (1897).

1898

No. 23. L. Arons, *Wied. Ann.*, Vol. 65, p. 567 (1898).

No. 24. E. Aschkinaas, *Wied. Ann.*, Vol. 66, p. 284 (1898).

No. 25. F. Auerbach, *Wied. Ann.*, Vol. 66, p. 611 (1898).

No. 26. E. Dorn, *Ann. d. Phys.*, Vol. 66, p. 146 (1898).

***A key to the abbreviations of the publications appearing in the bibliography may be found on p. 253.**

No. 27. D. van Gulik, *Wied. Ann.*, Vol. 66, p. 136 (1898).

No. 28. R. Malagoli, *Nuovo Cim.*, Vol. 8, p. 109 (1898).

No. 29. A. Meyer "Ofversikt Vet. Ak's. Forhandl," Stockholm, p. 215 (1898).

No. 30. T. Tommasina, *Compt. rend.*, Vol. 127, p. 1014 (1898).

1899

No. 31. J. C. Bose, *Electrician*, Vol. 43, p. 441 (1899); also *Proc.*, Roy. Soc., Vol. 65, p. 166 (1899).

No. 32. E. Branly, *Journ. d. Phys.*, Vol. 8, p. 274 (1899).

No. 33. R. Malagoli, *Nuovo Cim.*, Vol. 10, p. 279 (1899).

No. 34. T. Sundorph, *Wied. Ann.*, Vol. 68, p. 594 (1899).

No. 35. T. Tommasina, *Compt. rend.*, Vol. 129, p. 40 (1899).

No. 36. A. Trowbridge, *Am. J. Science*, Vol. 8, p. 199 (1899).

1900

No. 37. J. C. Bose, *Proc.*, Roy. Soc., Vol. 66, p. 450 (1900).

No. 38. E. Branly, *Rapp. au Congres. Int. de Phys.*, Paris (1900).

No. 39. K. E. Guthe and A. Trowbridge, *Phys. Rev.*, Vol. 11, p. 22 (1900).

No. 40. W. Duddell, *Electrician*, Vol. 46, p. 269 (1900).

1901

No. 41. J. C. Bose, *Electrician*, Vol. 47, pp. 830, 877 (1901).

No. 42. W. H. Eccles, *Electrician*, Vol. 47, pp. 682, 715 (1901).

No. 43. K. E. Guthe, *Ann. d. Phys.*, Vol. 4, p. 762 (1901).

No. 44. G. Schlabach, *Phys. Z.*, Vol. 2, p. 383 (1901).

No. 45. R. F. Earhart, "The Sparking Distances Between Plates for Small Distances," *Phil. Mag.*, Vol. 217, Series 6, Vol. 1, No. 1., January, 1901, pp. 147–159.

1902

No. 46. A. Fisch, *Journ. de Phys.*, Vol. 3, p. 350 (1902).

No. 47. H. Ayrton, "The Electric Arc," *The Electrician*, Publishing and Printing Co., London (1902).

1903

No. 48. A. H. Taylor, *Phys. Rev.*, Vol. 16, p. 199 (1903).

No. 49. T. E. Auren, *Arkiv. f. Mat.-Astr. och Fysik*, Stockholm, Vol. 1, p. 25 (1903).

No. 50. P. E. Robinson, *Ann. d. Phys.*, Vol. 11, p. 755 (1903).

No. 51. W. Duddell, *Electrician*, Vol. 51, p. 902 (1903).

1904

No. 52. J. Stark, *Phys. Z.*, Vol. 5. pp. 51, 750 (1904).

No. 53. J. Busch, *ETZ.*, Vol. 25, p. 160 (1904).

No. 54. P. E. Shaw and A. B. Garrett, *Phil. Mag.*, Vol. 8, p. 165 (1904).

1905

No. 55. G. M. Hobbs, "The Relation Between P. D. and Spark-Length for Small Values of the Latter," *Phil. Mag.*, Series 6, Vol. 10, No. 60, December, 1905, pp. 617–631.

No. 56. H. T. Simon, *Phys. Z.*, Vol. 6, p. 297 (1905).

No. 57. P. Weiss, *Journ. de Phys.*, Vol. 5, p. 462 (1905).

No. 57a. G. M. Hobbs, "Relation of P.D. and Spark-Length," *Phil. Mag.*, Vol. 10, December, 1905, pp. 617–631.

Using, like Earhart, an interferometer method of measuring the spark gap, the author shows: (1) A minimum spark potential is found in all cases where the poles are flat; if not flat, but convex, this minimum condition is complicated by discharge of the material of the electrodes. (2) This discharge of the material of the electrodes exerts an important influence upon spark potentials at small distances. (3) The carriers of the discharge for small distances come from the metal and not from the gas. Various metal electrodes give various potential gradients. (*Science Abstracts*)

No. 58a. A. Blanc, *Journ. de Phys.*, Vol. 4, p. 743 (1905); also *Ann. Chim. Phys.*, Vol. 5, p. 433 (1905).

1906

No. 58b. A. Blanc, *Ann. Chim. Phys.* Vol. 6, p. 5 (1906).

No. 59. W. Browning, *J.*, I.E.E., Vol. 37, p. 372 (1906).

No. 60. K. C. Nandi, "Brush Contact Resistance," *Elect. Engg.*, London, January 5, 1906.

No. 61. S. Salto, "Measurement of Transition Resistance of Metal Carbon Brushes," *ETZ.*, September 20, 1906.

No. 62. F. G. Baily, "Some Phenomena of Commutation," *J.*, I.E.E., Vol. 38, pp. 150–190 (1906).

No. 63. H. T. Simon, *Phys. Z.*, Vol. 7, p. 433 (1906).

No. 63a. F. G. Baily and W. S. H. Cleghorne, "Commutation," J., I.E.E., Vol. 38, February, 1907, pp. 150–182. Discussion, pp. 182–189. Paper read before the Glasgow Local Section. *Electrician*, Vol. 58, November 23, 1906, pp. 202–205 and December 21, 1906, pp. 365–367. Abstract, *Elec. Eng.*, Vol. 38, November 30, 1906, pp. 779–782, December 8, 1906, pp. 813–816, and December 28, 1906, pp. 919–920.

The authors describe the results of numerous elaborate experiments on bruch contact resistance, friction of carbon brushes, effect of lubrication on contact resistance and friction, effect of vibration resistance of brush contact with commutator at rest, effect of time on contact resistance, the sparking emf., between the trailing brush edge and the receding segment, the flux distribution and the effect of the short circuit currents in the case of a motor with commutating poles, and the variation of the current in the segment under the brush. The results of the experiments on brush contact resistance confirm generally the work of Arnold (*Abstract No. 1056 (1906), Science Abstracts*) and others. With a stationary slipring the contact p.d. was found to increase practically in proportion to the increase of current, thus following a different law from that which holds good in the case of a rotating slipring. The use of paraffin wax as a lubricant was found advantageous decreasing friction while not affecting voltage drop. It is desirable to use a high-current density at the brush contact, as this reduces the frictional loss while not affecting the electrical loss. The main practical conclusion deduced by the authors from their experiments are that while a low self-inductance is necessary in the coils, a uniformly high brush contact resistance is not advantageous, for while it hastens the fall of current in the receding segment, it also retards the rise of current in the advancing one; and that a wide interpolar space, a short air-gap, good brush holders, and narrow brushes are important factors in bringing about sparkless commutation. A reversing emf. is desirable, but not necessary. (*Science Abstracts*)

1907

No. 64. Righi-Dessau, "Die Telegraphie ohne Draht," Second Edition, Braunschweig, Vieweg (1907).

1908

No. 65. H. Diesselhorst, *Zeits. f. Instrumentenk.*, Vol. 28, p. 1 (1908).

1909

No. 66. G. J. Meyer, "Investigations on Switchgear Contacts," *ETZ.*, Vol. 30, pp. 243, 275 (1909).

1910

No. 67. W. H. Eccles, *Phil. Mag.*, Vol. 19, p. 869 (1910).

No. 68. Wietlisbach-Zacharias, "Handbuch der Telephonie" (Handbook of Telephony), Wien and Leipzig, p. 85 (1910).

No. 69. J. S. Townsend, "The Theory of Ionization of Gases by Collision," London (1910).

No. 70. E. Phillippi, "Switching Phenomena and the Magnetic Quenching of Sparks," Verlag L. Simion Nf. (1910).

No. 71. B. Schaefer (Dissertation), Darmstadt (1910).

No. 72. E. F. W. Rasch, "Electric Arc Phenomena," Translated from the German by K. Thornberg, D. Van Nostrand Co., Inc., New York, N. Y., 194 pp. (1913). Original, "The Electric Arc; Physical and Technical Bases of the Excitation of Light by the Passage of Electricity," Braunschweig, Vieweg, u. Sohn (1910).

1911

No. 73. A. G. Collis, "Circuit-Breakers for High and Low Voltages," *Elec. Rev.*, Vol. 68, March 3, 1911, pp. 364–366. Discussion, pp. 366–367. Abstract of paper read before South Wales Inst. of Engg., Cardiff, February 23, 1911. *Electrician*, Vol. 66, March 10, 1911, pp. 869–872 and pp. 894–895. Discussion, March 17, 1911, pp. 895–896.

Direct-current circuit breakers with oil-immersed contacts have not been largely used, because of rise of pressure owing to the rapid disruption of the arc, and because of the carbonization of the oil. In collieries the question is of great importance, as gas-tight cases have been found impracticable. A number of oscillograms are given showing the results of opening circuit breakers of different types and makes under varying conditions that is with and without magnetic blowouts,

etc. The author considers that within the limits of the tests the system of opening direct-current circuits by breaking contact under oil is safe and efficient. Tests were also made on alternating current, and the oscillograms showed that after the current has died down to the zero value it never rises again. In no case was there abnormal pressure rise, but the tests were only made with comparatively small currents. In the discussion, E. B. Wedmore considered that experiments carried out with larger powers would give different results. Oil-immersed contacts were rapidly worn away by the concentration of the arc on the point of starting. There had been found to be excessive carbonization of the oil in oil-immersed tramway controllers. W. B. Woodhouse said carbonization was serious with direct current. E. W. Cowan thought carbonization was only serious if the carbon particles settled on the immersed insulators. J. S. Peck thought that other types of circuit breakers were known to be more satisfactory with direct current. (*Science Abstracts*)

1912

No. 74. L. Binder, "Contact Resistance," *E.u.M.*, Vol. 30, September 22, 1912, pp. 781–788.

Experiments made with stationary carbon-copper contacts showed the specific resistance to be constant and independent of the direction of the current, so long as the current density did not exceed a certain figure which is a function of the pressure at the contact. Beyond this figure the readings became irregular, the specific resistance diminishing with increasing current density. The cause of the irregularity was found to be hot spots formed at the points of contact, which were continually moving about. The resistance of the contact may be taken to be a true resistance as defined by Ohm's law. The nature of the contact between two bodies is then discussed. However carefully the surfaces may be prepared, the actual area of the contact is necessarily small, and the pressure between the surfaces will have an influence depending on the hardness of the two materials. At the points of real contact the electric stream lines converge and pass from one piece to the other across a short bridge of intervening material where the current density will be very great. The resistance of the contact is due partly to the bridge and partly to the constriction in the main body of the materials. The author then shows that the resistance of the contact between two balls should be proportional to $P^{-1/3}$, P being the total force with which they are pressed together. Experiments on steel balls gave approximately $R \propto P^{-1/4}$. For contact between a ball and a flat plate the author deduces $R \propto P^{-1/2}$. Experiments made with steel ball on copper plate, steel ball on lead plate, steel ball on carbon plate and ordinary carbon-copper contacts gave $R \propto P^{-1/1.6}$ approximately. (*Science Abstracts*)

No. 75. R. H. Goddard, "Conduction of Electricity at Contacts of Dissimiliar Solids," *Phys. Rev.*, Vol. 34, pp. 423–451 (1912).

Chips of tellurium and quartz prepared and examined in a vacuum or in oxygen lost almost entirely their power to "cohere." Copper chips prepared and examined in hydrogen and in a vacuum did not show the anomalies in condensation which they display in air and in oxygen. The departure from Ohm's law is explained by supposing that the chips set themselves so as to make their longer axes parallel with the current. Both a surface and an internal effect are involved in the phenomenon; the one is characteristic of that which takes place with pure elements in a chemically active gas, the other, that which obtains with impure elements or compounds independently of the nature of the gas. (*Science Abstracts*)

No. 76. R. Edler, "Switches for Controlling the Charging of Accumulators," *E.u.M.*, Vol. 30, July 14, 1912, pp. 577–581, and July 21, 1912, pp. 603–607.

This paper gives an account of a new method of designing switches, described in a book entitled "Schaltlehre," by R. Lischke (Hachmeister and Thal, Leipzig, (1911)). In the system of charging wherein the battery is divided into three groups, the charging is carried out in two stages. Lischke's method serves for determining a foolproof arrangement of switches for effecting the connections above mentioned. The switches contemplated are two-way. A full description of the mode of operation is given, and from this it will be seen that both the number of switch levers and the connection of the contacts are obtained in a perfectly systematic manner. The mental labor is completed when the arranged path-line groups are set up, since the preparation of the switching tables and switches themselves can follow a process which is almost mechanical. (*Science Abstracts*)

1913

No. 77. F. Streintz and A. Wesely, "Resistance Between Plates in Contact," *Phys. Z.*, Vol. 14, June 1, 1913, pp. 489–497.

A first investigation of the influence of pressure, temperature, current strength, state of surface, and duration of contact on the transition resistance of two brass blocks. The greatest stability of resistance was obtained with large surfaces of contact. The resistance due to air films cannot be got rid of by pressure. But an electrically perfect contact can be obtained by a film of bone oil pressed between the surfaces with about 1000

g. per sq. cm. The oil is pressed out, taking the air with it. This justifies Kohlrausch's advice to oil the sliding contacts of rheostats. (*Science Abstracts*)

No. 78. C. D. Child, "Electric Arcs; Experiments Upon Arcs Between Different Electrodes in Various Environments and Their Explanation," D. Van Nostrand Co., Inc., New York, N. Y. 194 pp. (1913).

No. 79. F. Kraus, "Conditions Under Which an Arc Cannot Be Formed," *E.u.M.*, Vol. 31, August 24, 1913, pp. 717–720, and August 31, 1913, pp. 744–748.

The paper deals with arcs between various materials with special reference to switchgear design. Experiments are described by which the maximum current which can be broken in an inductionless circuit containing various emf.'s was found. The results are shown in the figures. These figures may be utilized in the design of lightning arresters of the multigap type with series resistance, and they also show that flashing over on the commutators of electrical machinery cannot occur so long as the voltage between adjacent segments is less than 16 v. In switches for regulating resistances, starters, etc., no arc will form in passing from contact n to contact $n + 1$ provided the voltage between the contacts with the switcharm on $n + 1$ is not greater than corresponds on the curve to the current which flows when the switch-arm is on n. The effects of self-induction and capacitv are briefly considered, and also the bearing of the experimental results on Mrs. Ayrton's formula for the arc voltage. (*Science Abstracts*)

No. 80. W. Höpp, "Arc Formation at Switch-Gear," *ETZ.*, Vol. 34, pp. 33–38 and 55–58 (1913).

The author points out that whereas methods have been developed for switching off large amounts of alternating-current energy, the same facility is not obtainable with direct current. The first part of the paper is devoted to a study of the different forms taken by the arc with varying types of electrodes. The mathematical theory of arc formation applied to knife switches is then given. The questions of rate of opening of switch and maximum opening are dealt with theoretically and experimentally. The author gives as rules for the velocity of switching and length of opening: (1) on inductive load the switching velocity should be small, (2) on mixed load, slow switching is advantageous with big currents, (3) with alternating current the electrodes should have a high thermal conductivity. (*Science Abstracts*)

No. 81. O. E. Gunther, "Energy and Resistance of Sparks Caused by Closing and Breaking Electric Circuits," *Ann. der Phys.*, Vol. 42, No. 11, August 26, 1913, pp. 94–132. (Abbreviated Dissertation, Leipzig.)

The heat generated by sparks due to making and interrupting an electric current is determined by an air thermometer. The current circuit is closed and broken by means of a special contact which is carefully described. The p. d. was varied from 3 to 100 v. and the current from 0.2 to 1 amp. When a capacity is connected in parallel with the contact, the energy of the spark on closing the circuit agrees with that to be expected from theory and the resistance of the spark would appear to be a constant. With no capacity parallel to the contact the resistance of the spark made by interrupting the current appears as a function of the speed of interruption. This is shown by oscillograms which give results agreeing with those of the air thermometer. When no capacity is parallel to the contact the spark on interruption is of the nature of an arc. A condenser placed parallel to the arc suppresses the arc, and a spark discharge takes its place. The larger the capacity the smaller the spark on breaking the circuit and the larger the spark on closing it. The curve connecting the capacity with total spark energy on both making and interrupting shows a minimum energy for a particular capacity. A formula for the calculation of this capacity is given. An oscillogram shows the increase of spark resistance with oxidation of the place of contact. (*Science Abstracts*)

No. 82. A. G. Collis, "High and Low Tension Switchgear Design," London (1913).

No. 83. W. Burstyn, "New Process for Quenching the Electric Arc," *ETZ.*, Vol. 34, No. 43 (1913).

No. 84. O. E. Gunther, "Energy and Resistance of Opening and Closing Sparks in Inductive Circuits; Spark Quenching by Condensers" *Ann. der Phys.*, Vol. 42, No. 11, pp. 94–132 (1913). (Dissertation, Leipzig)

No. 84a. H. F. T. Erben and A. H. Freeman, "Brush Friction and Contact Losses," *J.*, A.I.E.E., Vol. 32, p. 559 (1913).

It is apparent from the foregoing that the niceties of adjustment found necessary in obtaining coefficient of friction show the hopelessness of determining the true friction loss by the method outlined in the existing Standardization Rules. It is evident that in measuring brush friction by reading the input to the machine with brushes up and brushes down there is a great element of error due to the fact that the value of brush friction is such a small percentage of the total input. It would, therefore, seem obvious that the Standardization Rules should be so amended as to allow the determination of brush losses by calculation from data which have been

obtained by the most reliable methods and approved by the Institute. (Authors' abstract)

No. 84b. F. W. Harris, "Electrical Contact Resistance," *Elec. J.*, Vol. 10, p. 637 (1913).

When an electric current is passed between two pieces of matter there is a loss of energy at the point of contact and a certain drop in potential results, which may be measured by a millivoltmeter. The voltage drop across such contacts, or through the whole structure of the apparatus considered, is a common measure of the efficiency of the apparatus, the drop being ordinarily taken at the full load of the apparatus. To secure a more complete understanding of the subject the writer has at various times examined the effect on this potential drop, of current, pressure, materials composing the contacts, surface conditions of the contacts, and area of the contacts. The effect of these factors is generally and correctly understood in a very general way, with the exception of the last one. That is, it is generally understood that the voltage drop across contacts can be reduced by decreasing the current, increasing the pressure between them, using a material of lower resistance, cleaning the surfaces, or increasing the area of the contacts themselves.

There can be no more fundamental and universally involved set of facts than those that surround the phenomena of the transference of current from one body to another. It is necessary in all apparatus to make such transference, and in the design of such apparatus to allow for the losses that always accompany such transference. Certain empirical formulae have been developed in the various branches of the profession for the valuation of these losses. They have a variable importance in different classes of apparatus, being of very little value in some and in others of very great value. In the design of switches, circuit breakers, and the like this factor becomes of the greatest importance. (Author's abstract)

No. 84c. H. R. Edgecomb and W. A. Dick, "Method of Determining Brush Losses Due to Contact and Friction," *J.*, A.I.E.E., Vol. 32, pp. 565–575 (1913).

In discussing brush losses due to contact and friction we have done little more than indicate the avenues along which investigation should proceed and the nature of the results which will be useful to designing engineers. Some troublesome variables have been pointed out, the controlling of which should materially increase the accuracy of results.

Because of the complexity of these tests and the length of time and expense of apparatus necessary to produce dependable results, it may be argued that commercial tests, those made on machines actually in course of manufacture and awaiting shipment, should be sufficient to give all necessary information. Our experience in attempting to correlate results of such tests and establish laws therefrom has been exceedingly discouraging, and we are convinced that improvements in the design of electrical apparatus as related to brushes and in the quality of the brushes themselves must result from the establishment of more accurate values for the losses due to brush contact and friction.

There is also every reason to believe that accurate values thus established will be found so much more reliable than actual performance tests that they will be substituted for such tests in the majority of cases. (Authors' index)

No. 84d. Alfred Hay, "Some Experiments on Brush Contact Resistance," *Electrician*, Vol. 71, p. 524 (1913).

In the method used care was taken to eliminate the effect of emf. in the armature due to imperfect commutation. The conclusion is reached that the brush contact loss when a machine is running is, for all practical purposes, identical with that which occurs in a stationary armature, so that the loss could be easily determined by measurement with the armature at rest. (Author's abstract)

1914

No. 85. F. Rother, "Passage of Electricity at Contact Gaps, and Electron Atmospheres of Metals," *Ann. der Phys.*, Vol. 44, No. 8, August 4, 1914, pp. 1238–1272. (Dissertation, Leipzig)

An experimental research of which the chief results may be summarized as follows: An optical method is described by which the tiny gap between two balls, or contacts, could be made any very small measurable distance. When this gap or distance between the contacts was less than a wave length of light, even 1 v. would give a current. This was measured and found to be of the order 10^{-14} amp. The current passing across the small space between different metals was found to be different. In the case of the metals tested (gold and iridium) the better conducting metal gave the better conducting gap, but the ratio of the gap conductivities was about three times that of the metals themselves. From this difference of gap conductivities with different metals it is concluded that the conductivity is due to electrons. The phenomenon was not measurably different in air at atmospheric pressure and under a vacuum of about 0.5 mm. An attempt to determine the conductance of this electron atmosphere in the gap showed that it varied with the distance between the con-

tacts. The apparent conductivities of these atmospheres were of the order: for gold 10^{-14} and for iridium 10^{-15} (the ohm being the unit). (*Science Abstracts*)

No. 86. J. C. McLennan, "Fluorescence of Iodine Vapour Excited by Ultra-Violet Light," *Proc. Roy. Soc.*, Vol. 91, November 2, 1914, pp. 23–29.

In a recent paper a new fluorescence spectrum of iodine vapor was described which could be stimulated by the light from the mercury arc. This fluorescence spectrum consists of a set of narrow bands extending from λ4600 to λ2100, the most intensely marked portion consisting of seven equally spaced bands between λ3315 and λ3175. It was found that the exciting light was of shorter wave length than λ2893.7. The present paper contains the results of experiments made to determine the range of the exciting light, together with a statement of some points of interest in connection with the fluorescence spectrum which developed while these experiments were being made. It was shown that iodine vapor can be stimulated to the emission of a fluorescence spectrum excited by ultraviolet light at temperatures ranging from room temperature to at least as high as 1000 C. Iodine vapor ceases to be capable of emitting the resonance spectra discovered by Wood at some temperature below 326 C. The wave lengths of the light which can stimulate the ultraviolet fluorescence spectrum of iodine vapor lie between λ2100 and a lower limit, probably about λ-1800. Resonance spectra cannot be obtained with iodine vapor when illuminated with light from the mercury arc of wave length shorter than λ5460.74. Portions of the ultraviolet fluorescence spectrum of iodine vapor were obtained with iodoform and mercuric iodide at a temperature of about 326 C. Mercuric iodide and potassium iodide at a temperature of about 326 C. exhibit characteristic fluorescence spectra of their own when excited by light from the mercury arc. (*Science Abstracts*)

1915

No. 87. J. S. Townsend, "Electricity in Gases," Clarendon Press, Oxford, 496 pp. (1915).

The book treats electrical discharges through gases, ionization of gases, and electrical conductivity of gases. (*Science Abstracts*)

No. 88. A. G. Collis, "Arc Phenomena," *Proc.*, A.I.E.E., Vol. 34, September, 1915, pp. 2081–2100.

This paper deals with critical phenomena in large-power high-tension circuits, particularly as regards oil switchgear. Experiments are described bearing on the influence of differently shaped arcing contacts. The natural formation of an arc can be modified by contact design, considerably increasing the capacity of switches. Cone contacts give a good shape of arc and increase rupturing capacity of switch. With five types of contact the pressure near the arc ranged from 54 to 78 psi. when rupturing currents varied from 125 to 300 amp. at 6600 v. The bearing of the cavitation theory on the arc phenomena of oil switches is discussed. Designers should reduce and distribute the explosive forces. The larger the lateral size of contacts the greater the effects of explosion felt. The effect of quick moving contacts in creating a vacuum is important in reducing distributive forces. For high-pressure heavy duty the multiple break is becoming essential, but it is important that all breaks should be simultaneous. Particulars are given of tests made to determine the pressure rise on closing h.t. circuits. The inductive rise from a weak-field magnetic blowout breaker is greater than in the other breakers tested. The capacity of a switch is affected by power factor; time to open circuit; current generated on short circuit; wave position at time of rupture; circuit impedance and reactance. The rupturing capacity must be increased at power factors less than unity. The effect of internal and external reactance on switch rating and protection is discussed. (*Science Abstracts*)

1916

No. 89. T. F. Wall, "Sparkless Break of an Inductive Circuit," *Electrician*, Vol. 76, February 4, 1916, pp. 640–642.

Attempts have been made to provide means for obtaining a sparkless break of an inductive circuit in which a large amount of energy is involved, one of the most recent being that of L. Schuler. A new method is now given that is based on the following considerations: If a coil of inductance L and of negligible resistance be switched on to a circuit of voltage $E \sin wt$ at the moment when the voltage is zero, the current is given by $i = (E/wL) \times (1-\cos wt)$. Thus the current is unidirectional and passes through its zero values at moments when the voltage is zero; the circuit can therefore be opened sparklessly if the switch acts when the current and the voltage are both zero or at a time near to this. If the circuit has resistance the equation must be modified, and it appears that the current that flows is then made up of a sinusoidal function superimposed on a logarithmic function that decays at a rate depending on the ratio of the resistance to the inductance of the coil. The current and the voltage are now never zero at the same time and sparkless switch operation is not possible.

If a source of constant emf. be connected in series with the a-c. circuit it is possible so

to choose the value of the constant emf. as to cause the current and a-c. voltage to be related in a manner similar to the first case discussed, in which there was no resistance in circuit. When the necessary conditions are satisfied it is therefore possible to obtain sparkless switching. If the resistance in circuit is R, the required d-c. voltage is given by $V = ER/\sqrt{(R^2 + w^2L^2)}$ and the current is $i = (E/\sqrt{(R^2 + w^2L^2)}) \times (1 - \cos wt)$.

The correctness of these conclusions is borne out by an oscillogram taken on a circuit in which the above conditions were fulfilled. (*Science Abstracts*)

No. 90. J. C. McLennan, "Single-line Spectra of Magnesium and Other Metals and Their Ionising Potentials," *Proc.*, Roy. Soc., Vol. 92, March 1, 1916, pp. 305–312.

When heated mercury vapor is traversed by electrons possessing kinetic energy slightly above that acquired in a fall of potential of 4.9 v., the vapor is stimulated to the emission of the single spectral line λ2536.72. McLennan and Henderson have shown that mercury vapor gives this single-line spectrum when bombarded by electrons possessing energy corresponding to any fall of potential within a range beginning at about 5 v. and extending to slightly over 10 v. The corresponding range within which zinc and cadmium yield single-line spectra is about 4 to 13.6 v. The single lines of which the spectra of these three metals consist are the first members of Paschen's combination series v 2, $p - m$; s for the three metals. It has now been found that a single-line spectrum can be obtained with magnesium vapor if the electrons bombarding the vapor possess energy lying within a certain range, whose limits have not as yet been definitely determined. With magnesium the single-line spectrum consists of light of wave length λ2852.22. It has also been shown that the absorption spectrum of magnesium vapor is exactly analogous to that of mercury, zinc, and cadmium, consisting of two bands, one at λ2852.22 and the other at λ2073.36. The analogy with the absorption spectrum of mercury is closer still, for the mercury absorption band at λ2536.72 comes out with small vapor densities as two narrow bands of wave lengths λ2536 and λ2539. The magnesium band at λ2852.22 has also been found to consist of two narrow sharply defined bands very close together. The corresponding zinc and cadmium bands have not as yet been resolved into analogous doublets. The ionizing potentials have been deduced for the atoms of magnesium, mercury, zinc, and cadmium; they are, respectively, from calculations based on the conclusions of Franck and Hertz, 4.28, 4.9, 3 96, and 3.74 v. (*Science Abstracts*)

No. 91. J. T. Tate, "Low-Potential Discharge Spectrum of Mercury Vapor in Relation to Ionization Potentials," *Phys. Rev.*, Vol. 7, pp. 686–687 (1916).

Tate has repeated the experiments of Franck and Hertz, showing that collision between electrons accelerated in an electric field and atoms of mercury vapor are elastic for velocities of the electrons less than 4.9 v. and obtained 4.90 ± 0.03 for the critical velocity. A secondary critical velocity is to be expected at which the energy they give up is emitted as radiation of many frequencies corresponding to the many-lined spectrum of mercury. A marked ionization occurs when the velocity of the colliding electrons reaches a critical value 10.0 ± 0.3 v. This is very nearly the value (10.2 v.) to be expected on the basis of Bohr's theory of the atom. The energy lost by these collisions is radiated as the many-lined spectrum of mercury. Although ionization of mercury vapor at 4.9 v. is not definitely disproved it is certainly much less complete than the ionization taking place at 10.0 v. (*Science Abstracts*)

No. 92. P. O. Pedersen, "Microphones and Microphonic Contacts," *Electrician*, Vol. 76, January 28, 1916, pp. 589–591, and February 4, 1916, pp. 625–627. Abstract from "Elektroteknikeren," *Lum. electr.*, Vol. 32, March 18, 1916, pp. 281–286, and Vol. 33, April 1, 1916, pp. 17–22; *Elettrotecnica*, Vol. 3, March 25, 1916, pp. 179–183.

Warming the front of a transmitter increases the sensitiveness greatly, due to the bending forward of the diaphragm caused by the difference in expansion of the two sides. This effect is accompanied by an increase in resistance (measured by the ammeter and voltmeter method, using an emf. of 220 v. and a series resistance so high that the current can be considered independent of the microphone resistance). The result of several series of tests in which the displacement was measured by optical interference, by air pressure, or by a micrometric device, was that an outward displacement of either front or back electrode of 1 or 2 μ causes an increase in resistance of 100 to 200 per cent. Similar results were found for a microphone in which the diaphragm was gradually released by withdrawing a pin pressed against its center. The final resistance was between 3.1 and 6.8 times the initial resistance, depending on the amount of the initial displacement. (*Science Abstracts*)

1917

No. 93. R. A. Millikan, "Theoretical Considerations Relating to the Single-Lined and the Many-Lined Spectrum of Mercury," *Phys. Rev.*, Vol. 9, pp. 378–382 (1917).

It is probable that the emission of the line λ2536 is not truly a single-line emission. Due to the great absorbing and emitting power of mercury vapor for this line and its trans-

parency for other lines, with increasing volume excitation the other lines become relatively more intense but with weak excitations this line, coming from the surface only, may be so much more intense as to appear to be alone. On Bohr's theory of the atom the line λ2536. being the longest of the series converging at λ1188, should be the only one of that series to appear at 4.9 v., though the whole series, should appear at 10.6 v., when the electron is knocked entirely out of the atom. But the many-lined spectrum of mercury has lines of lower frequency than λ2536 and coming from more external electronic orbits and these should all appear whenever the potential is sufficient to give the λ2536 line. Furthermore, the λ2536 line when emitted should act photoelectrically on surrounding atoms to give the lines of series corresponding to the outer electronic orbits. Support for these views is found in the work of Hebb. (*Science Abstracts*)

No. 94. T. C. Hebb, "The Single-Lined and the Many-Lined Spectrum of Mercury," *Phys. Rev.*, Vol. 9, pp. 371–377 (1917).

The mercury arc can be made to strike at any potential greater than 4.9 v., producing the many-lined spectrum, and once having struck will operate and produce that spectrum at a p. d. as low as 3.2 v. The single-lined spectrum can be obtained for all potentials between 21.5 and 2.5 v. Its production below 5 v. requires either that the velocity of electron emission be several times larger than has been experimentally observed or that ionization is not necessary for the emission of light. It may be that ionization is needed to produce the many-lined spectrum but that a jarring effect is all that is necessary to produce the single-lined spectrum. Which of the two spectra appears above 5 v. depends on the density of the electronic discharge. One photograph even seems to show that there is a definite minimum density of electronic discharge which is necessary to produce the many-lined spectrum, the line λ2536.72 Å appearing alone below it. (*Science Abstracts*)

No. 95. H. J. van der Bijl, "Ionization and Single-Lined Spectra," *Phys. Rev.*, Vol. 10, November, 1917, pp. 546–556.

The collision of an electron with an atom of a monatomic gas is elastic when the electron collides with energy less than a certain definite amount. Transference of energy should give rise to a single line. It is shown that a consideration of the three factors: (1) the increase in atomic potential energy by successive impacts, (2) the photoelectric effect of the light emitted by the stimulated atoms, and (3) the initial velocities of the electrons emitted from the cathode, affords an explanation of the results obtained by workers in this field. (*Science Abstracts*)

1918

No. 96. H. v. Fleischbein, "Improved Contact Design and Material," *ETZ.*, Vol. 39, November 7, 1918, pp. 445–446.

Causes of trouble in delicate contacts are discussed and means are suggested for their elimination; further developments in tungsten contacts represent a considerable improvement.

There are innumerable applications in which it is of great importance that weak-current contacts should give good and reliable service. The advantages of platinum as a contact material are freedom from oxidation, relative hardness, and high melting point. Nevertheless, contact troubles are common, owing to dust and dirt, and sticking of contacts. Fouling can be counteracted by careful cleaning and by making the lower contact pointed, so as to offer minimum lodgment for dust. If current, voltage, and frequency of operation be fixed, sparking can be suppressed by connecting suitable resistance and capacity in parallel with the gap; otherwise, sparking can be suppressed at the average load and reduced at other loads. The best preventive of sticking and trouble from dust is the use of wiping contacts.

Advantages are claimed for tungsten contacts. Tungsten is unaffected by steam and acids at ordinary temperatures. Tests were made with contacts interrupting from $^1/_2$ to 10 amp. up to 20 times a second. Sparking could not be eliminated completely by parallel capacity and resistance. A pencil of tungsten 3 mm. in diameter used as a stationary contact, working against a platinum contact on a steel spring, after 6 months showed no sign of wear, but the steel spring showed colors indicative of severe heating. Successful results were obtained by increasing the cooling facilities and making the second contact of tungsten. Vigorous arcing resulted in no damage even after prolonged trial. (*Science Abstracts*)

No. 97. T. C. Hebb, "The Ionization Potential of Mercury Vapor and the Production of the Complete Spectrum of This Element," *Phys. Rev.*, Vol. 11, pp. 170–179 (1918).

The apparatus employed was essentially the same as that used in the author's previous work on the mercury arc (*Chem. Abst.*, 11, 1926). It had been suggested by Millikan (*Chem. Abst.*, 11, 1926) that the complete spectrum observed previously by Hebb at an electron velocity of 4.9 v. was due to ionization of the mercury vapor photoelectrically by the radiation of the line λ = 2536.7. Hebb substantiates his former result, that is, that the arc could be caused to strike at a p. d. as low as 4.9 v., and suggests that this may be due to the unusual precautions taken to obtain an absolutely pure vapor. The experiments of McLennan

and Henderson (*Chem. Abst.* 9, 3155) and of Tate (*Chem. Abst.*, 10, 2664) led them to assign a value of 10.3 v. as the ionization potential. The paper contains data on current-potential relations, striations, ionization potential, and photoelectric effect. Although ionization occurred at 4.9 v. under favorable conditions, it was also possible to get it to occur at any p. d. above this, by simply varying the temperature of the furnace. The crucial test regarding the photoelectric effect consisted in arranging a mercury arc in air directly outside the experimental tube (exchanged for one of quartz) and so placed that its light passed into the front end of the ionization chamber. After a large ionization current was produced by the electrons from the Wehneldt cathode the voltage between the electrodes was reduced to zero, and the mercury arc in air started. With an effective radiation probably hundreds of times greater in intensity than the radiation $\lambda = 2536.7$ originating in the experimental tube, the same current was produced in some cases. Hebb concludes that it is not probable that the ionization produced by 5 v. could have been due to the radiation $\lambda = 2536.7$. (*Chemical Abstracts*)

No. 98. T. C. Hebb, "Ionization of Mercury, Sodium and Potassium Vapors and the Production of Low Voltage Arcs in These Vapors," *Phys. Rev.*, Vol. 12, pp. 482–490 (1918).

The experiments prove that in the case of potassium and probably of sodium ionization can occur at a voltage V given by the equation $Ve = h\nu$, where ν is the frequency of the first member of the principal series of the element. These elements thus fall in line with mercury and more or less with the cases of hydrogen and helium. It appears that ionization at the resonance voltage was due either to repeated collisions or to a combination of collision and photoelectric effect, but that in either case a minimum velocity of collision was necessary, this minimum velocity corresponding to the resonant voltage. Potassium vapor can be ionized at 1.6 v., its resonant voltage, while sodium vapor can be ionized at 2.5 v., which is very close to its resonant voltage. The D lines of sodium can be excited at less than 1.0 v. These results are in agreement with those of Wood and Okano (*Chem. Abst.*, 11, 3163). The sodium and potassium arcs in mercury vapor can operate below their resonance potentials and as low as 1.4 v. for sodium and 0.5 v. for potassium. The mercury spectrum can be produced as low as 0.5 v. in an atmosphere of mercury and potassium. (*Chemical Abstracts*)

No. 99. P. Hunter-Brown, "Carbon Brushes," *J.*, I.E.E., Vol. 57, February, 1919, pp. 193–203. Discussion, pp. 203–223. *Electrician*, Vol. 81, December 20, 1918, pp. 720–722, and December 27, 1918, pp. 738–740.

The properties of carbon brushes are stated, including their specific resistance, coefficient of friction, and contact drop. Figures and tests relating to this last point are given for different materials used in the manufacture of carbon brushes. The questions of thermal conductivity, hardness, and abrasiveness are also considered. Brushes of the slide type are much better than those of the grip type; all unnecessary fittings should be avoided, and suggestions as to their design are given; the brush width should not be greater than $1^1/_4$ in., and the thickness not more than 1 in. The suitability of the various grades for different conditions is discussed, especially in regard to current density, peripheral speed, and sliprings. The ultimate test as to suitability must be made on the machine itself. As for operating conditions, these are considered under the headings of bedding, mixing grades on the same machine, rate of wear, and lubrication. A few suggestions follow on the matter of standardization, which would have to proceed slowly, beginning with the mechanical design of the brush for certain specified purposes. (*Science Abstracts*)

No. 100. H. J. van der Bijl, "Theory of the Thermionic Amplifier," *Phys. Rev.*, Vol. 12, September, 1918, pp. 171–198.

This paper gives an outline of the mathematical theory of the operation of amplifying devices of the three-electrode type. It deals with (1) current-voltage characteristics of simple thermionic devices; (2) effect of residual gas on the characteristic; (3) action of the auxiliary electrode; (4) current-voltage characteristics of the thermionic amplifier; (5) experimental verification of the characteristic equation; (6) characteristic of circuit containing thermionic amplifier and ohmic resistance in series; (7) amplification equations of the thermionic amplifier; (8) experimental verification of amplification equations. It is shown that by proper choice of the structural parameters, tubes may be designed to give voltage or power amplification covering a wide range. A voltage amplification of several hundred-fold is not difficult to obtain, while a power amplification of 3000-fold was found possible, using an anode voltage of only about 100 v. Tubes used as wireless detectors can be designed to operate on very low voltages, a very efficient type of detector having been made to give satisfactory operation with 2 v. on the filament and an anode voltage of 12 v. or less. The structure of the device is a particularly important function, since on it depend the constants involved in the amplification equations, and which are involved explicitly and implicitly in the fundamental equation of the characteristic. (*Science Abstracts*)

1920

No. 101. W. Burstyn, "Current Break Without Arcing; Voltage and Current Limits for Different Metals," *ETZ.*, Vol. 41, No. 26, June 30, 1920, pp. 503–505.

For each metal and each medium voltage there is a limiting current value up to which the current can be broken without arcing. Below a minimum voltage, about 15 v., any current can be broken without arcing. Above the cathode drop (about 300 v.) even the smallest current ultimately causes a discharge; for weak currents the discharge is a glow and not an arc.

It is shown that the condition for no-arc on opening the circuit is: $w = (E - a)^2/4c$, where w = series resistance; E = d-c. voltage; a, c = constants. The conditions are fulfilled by $E = a$ (that is direct-current voltage less than the back emf. of an infinitely short arc). It is also fulfilled by higher finite values.

Values are given for the critical voltage "a," namely, lead, 15; iron, 16; gold, 20; copper, 18; brass, 15; German silver, 15; nickel, 19; platinum, 20; silver, 15; steel, 16; zinc, 14; and tin, 14 v. It is found that the limiting current values for no arcing can be found only approximately; they depend greatly upon the cleanness of the electrode surfaces.

Below these limiting values there are in most cases second limits below which the current is broken with a thin quiet spark, and above which an explosive spark occurs.

The critical cathode drop is determined by the cathode material and by the gas and is generally about 300 v. The author's values for electrodes in air are: copper, 310; nickel, 285; platinum, 305; carbon about 220 v. (*Science Abstracts*)

No. 102. W. Höpp, "The Calculation of Contacts," *ETZ.*, Vol. 41, pp. 205–208 and 232–235 (1920).

With the aid of oxidation measurements, directions are given for the calculations of contacts; and a calculation formula is developed under consideration of additional losses through contact resistances and influence of cross-sectional changes. It is shown that contact losses are practically independent of size of contact surface and only total pressure and cleanness of surfaces are of importance. (*Engineering Index*)

No. 103. F. Kraus, "Experiments on Contact Resistance," *E.u.M.*, Vol. 38, January 4, 1920, pp. 1–5.

The experiments were made by compressing a pile of perforated stamped disks of the metal to be tested by means of a weighted lever. The current passing through the pile and the potential difference at its terminals were measured. The dimensions of the disks were 21 mm. external and 10 mm. internal diameter; the thickness varied from 0.34 to 1 mm. Disks of copper, brass, zinc, aluminum, iron, and tin were tested. The following are some of the results obtained: The measurements had to be taken after the disks had been several times heated and cooled, since the resistance falls to a constant value after such successive heatings and coolings. Copper against copper was found to give the lowest resistance when oxidized as compared with other metals. Brass also oxidizes very slowly in the air. Zinc shows a higher normal contact resistance, and very easily forms surface layers of high resistance. Aluminum forms surface layers of very high resistance, so that bobbins have been used wound of bare wire. The practice of putting a layer of tin foil between copper contact surfaces was found to be unjustified, since the ordinary, cleaned copper surfaces gave a better result. As regards variation of contact resistance with mechanical pressure, it was found that the resistance decreased as the pressure increased until a definite value was reached, after which the decrease was very slight. The resistance of a soldered joint was also investigated. The original paper includes curves and a long table giving numerical results of the experiments. (*Science Abstracts*)

No. 104. M. N. Saha, "Ionization in the Solar Chromosphere," (Paper A), *Phil. Mag.*, Vol. 40, pp. 72–88 (1920).

From a discussion of the high-level chromospheric spectrum of the sun it is shown that the region is composed chiefly of ionized atoms of calcium, barium, strontium, scandium, titanium, and iron. The enhanced lines are the same ones which are brightest in the spark spectrum, which can best be explained by ionization. In the lower layers both ionized and neutral atoms occur. An attempt is made to account for this on the basis of Nernst's theory of the "reaction isobars" by assuming that ionization is a reversible process according to the equation $Ca = Ca^+ + e - U$. U, the energy of ionization, can be calculated from the ionization potential of the elements. For the determination of Nernst's chemical constant and specific heat the electron is assumed to be a monatomic gas of atomic weight 1/1836. A great influence of pressure on the relative degree of ionization is marked. Almost complete ionization of calcium, strontium, and barium atoms in the high-level chromosphere is due to the low pressure. Hydrogen is shown to be completely dissociated into atoms at all points in the solar atmosphere. It is also shown that the higher the ionization potential of an element the more difficult will be its ionization thermally. Calculations show that hydrogen and helium cannot be appreciably ionized anywhere in the sun. Helium can

be ionized only in the stars having the highest temperatures (>16,000 K.). (*Chemical Abstracts*)

No. 105. W. Höpp, "Characteristics of Time-Element Overload Relays," *ETZ.*, Vol. 41, May 13, 1920, pp. 370–374, and May 20, 1920, pp. 392–393.

The working requirements of time-element overload relays are considered. It is shown that these conditions are best fulfilled by thermal time relays, the heat inertia of which is approximately equal to that of the supply leads.

In an installation consisting of a supply conductor, fuse, and motor the heat capacity of the several components determines the rate of temperature rise. The fuse attains the permissible maximum temperature most rapidly, then the supply conductor, and lastly (usually much later) the motor. The time element of the protective device must not be longer than the time taken to reach the limiting temperature in that component which is to be protected. (*Science Abstracts*)

No. 106. H. Rohmann, "Electric Contacts," *Phys. Z.*, Vol. 21, August 15, 1920, pp. 417–423.

A torsion arrangement is described by means of which displacements of the order of 1 $\mu\mu$ could be determined. With this apparatus the variations of current, due to close approach of the electrodes of a contact, could be followed. The "contact distance" for different materials was of the order of magnitude of 1 to 50 $\mu\mu$. The results made it possible to produce an efficient metal microphone and a reliable coherer. It was also found that the electrolysis of metal salts between two electrodes of different size and near to each other produces a certain amount of rectification. (*Science Abstracts*)

No. 107. W. Höpp, "Non-Arcing Switches for Alternating Current," *ETZ.*, Vol. 41, No. 38, September 23, 1920, pp. 748–750.

The author develops a theory for the approximate predetermination of the current strength below which the a-c. arc is self-extinguishing. The theory is based on the fact that an arc can be established only if there is a sufficient "ignition voltage." The theory is also applicable to oil-immersed contacts.

An a-c. arc is extinguished at each zero point in the current curve, and is only restruck if there is a sufficient p. d. available. It is not difficult to obtain a relatively long a-c. arc between carbon electrodes, but with copper electrodes and noninductive load a gap of 1 to 2 mm. is sufficient to prevent arcing with circuit voltages up to 1000 v. This non-arcing characteristic of metal electrodes is due to the high thermal conductivity of the latter; with cold electrodes the "ignition" voltage is equal to the "flash-over" voltage for the gap in question. A certain minimum voltage is required to restrike the arc immediately after its extinction that increases with the time which elapses before reignition.

Arcing characteristics are investigated for cases where resistance and inductance are in series and in parallel, respectively; the influence of high capacity is also considered. Parallel connection of resistance and inductance makes arcing more difficult because instantaneous reignition cannot occur, the available voltage being always zero when the current is zero. In many cases arcing can be avoided completely by connecting ohmic resistance in parallel with inductance. The most difficult problem is to break a purely inductive load. (*Science Abstracts*)

No. 108. K. T. Compton, E. G. Lilly, and P. S. Olmstead, "The Minimum Arcing Voltage in Helium," *Phys. Rev.*, Vol. 16, pp. 282–289 (1920).

Recent investigations (cf. Horton and Davies, *Chem. Abst.*, 13, 1669; Franck and Knipping, *Chem. Abst.*, 14, 2126) have shown that the minimum radiating potential of helium is close to 20.2 v. and its minimum ionizing potential is 25.5 v. One of the authors (Compton, *Phil. Mag.*, in print) has shown that these values apply to radiation and ionization set up by a single electron impact against a normal unexcited atom, whereas, if the electron current and gas density are relatively large, ionization may occur at any voltage above 20.2 v. The present experiments were made to determine the voltage at which the arc strikes under various conditions of gas pressure and electron current density in very pure helium. It was found that the arc could be made to strike at voltages as low as 20 v. but never lower. Under favorable conditions, however, the arc could be maintained at much lower voltages, the lowest voltage observed being 8 v., with a gas pressure of 5 mm. and a current of about 1 amp. through the gas. Observations of the spectrum of helium were also made under various conditions. Apparently the ordinary helium and parhelium series lines and the bands are excited whenever the arc strikes. The line λ 4686 of the enhanced system was never observed below 55 v., and was stronger above 80 v. The lines of the sharp subordinate series of pairs are peculiar in that their intensity decreases, relatively to that of the rest of the spectrum, as the voltage is increased. The results are in accord with Bohr's theory of radiation and atomic structure. The fact that the lines of the so-called parhelium series appear at the same voltages as those of the helium series renders untenable Stark's conclusion that they are due to atoms which have lost more electrons than those atoms which give rise to the helium series lines. (*Chemical Abstracts*)

No. 109. T. C. Hebb, "Arcing Voltages in Mercury Vapor as a Function of the Temperature of the Cathode," *Phys. Rev.*, Vol. 16, pp. 375–386 (1920).

Using an improved apparatus designed to produce a uniform mercury vapor atmosphere, a linear relation was observed between the striking voltage and the current through the cathode for the larger currents. For a platinum cathode covered with calcium oxide this is shown to mean that the striking voltage bears a linear relation to the cathode temperature in the range 1630 to 1925 K. The temperature was calculated from the observed electrical resistance of the platinum cathode strip, assuming a linear temperature-resistance relation above 1100 K. The results suggest that the difference between the potential at which ionization takes place and the accepted ionization potential is directly proportional to the absolute temperature. The lowest striking voltage obtained with a calcium oxide coated platinum cathode was approximately 4.9 v. With a tungsten cathode, uncoated, a striking voltage as low as 3.2 v. was obtained. A thinly coated platinum cathode produced an arc at 6.0 v. whereas a thickly coated one produced an arc at 4.9 v. A hot anode used with a thinly coated platinum cathode produced an arc at a lower voltage than when the anode was not heated. The results are briefly discussed but no definite theory is offered to explain them. (*Chemical Abstracts*)

No. 110. W. Höpp, "Uber den Kontaktwiderstand," (Concerning Contact Resistance), *ETZ.*, Vol. 41, No. 46, November, 1920, pp. 910–913.

No. 111. L. Binder, "On the Phenomena Occurring at the Brushes of Sliprings and Commutators," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 2, p. 158 (1920).

With sliding surfaces at rest the passage of electricity follows the same rules as with solid conductors. When motion sets in, small projections between the sliding surfaces rub off to act as rollers and as bridges for the current. For small current densities, the flow of current is similar to that through solid conductors. With increasing current density heating of the bridges sets in, until finally glowing and burning occur. Then new particles must take up the conduction of the current. With the heating of the bridges polarity sets in; even a trace of motion is sufficient to introduce polarity phenomena. To secure more information on the subject, arcs of very short lengths were investigated, such as occur when the brushes are separated. The polarity observed agreed with the phenomena observed at the brush surface At the brushes arcs occur as the result of irregular motion and imperfect commutation.

No. 112. F. Kraus, "Contact Resistance," *E.u.M.*, Vol. 38, pp. 1–5 (1920).

Account of experiments carried out for purpose of obtaining bases for calculation of contact resistance. Variation of intensity of current is said to follow Ohm's law. Results are given of investigations on effect of heating, temperature coefficient, contraction, and specific pressure. (*Engineering Index*)

1921

No. 113. A. M. Nocon (Dissertation), Creifswald (1921).

No. 114. F. Piola, "Researches Upon the Microphone," *Electtrotecnica*, Vol. 8, July 25, 1921, pp. 466–471.

The working of the microphone has been explained by two hypotheses. The first one, of purely mathematical character, is the sinusoidal hypothesis, and consists in admitting that the microphone resistance varies sinusoidally when the diaphragm pressure varies according to the same law, in such manner, however, that to an increase of the pressure corresponds a diminution of the resistance, and *vice versa*. The second hypothesis, called the elastic hypothesis, admits that the resistance variations are due to the elastic deformations of the carbon granule produced by the sound variations. The author develops the mathematical theories corresponding to the two hypotheses, the results of which are in part quite different. Experiments made with a view to determining which of the two cited hypotheses has to be chosen are reported in the article. A Braun tube was used for obtaining the current curves, a Weston milliammeter for obtaining the rms. values of the current; the sounds were produced either by a diapason or by a Galton hiss or by closed or open pipes, etc. The microphones experimented with were those of Mix and Genest, Kellogg, Deckert, Erikson, Angelini, Siti, "Solid Back," etc. The chief results of the experiments were the following: (1) The sinusoidal theory is contrary to the experimental results, (2) the elastic hypothesis generally agrees with the experimental results but the quantitative results of the theory do not agree with those given by the experiments. (*Science Abstracts*)

No. 115. O. H. Eschholz, "The Action of Magnetic Blow-Out Switches," *Elect. World*, Vol. 78, September 3, 1921, pp. 461–464.

The author traces the successive phenomena of the formation of the arc, and shows how it acts as a rapidly increasing resistance in the circuit until it is drawn out to a point of instability and breaks. It is pointed out that excessive volatilization of the contact metals can be avoided by suitable design. The length to which the arc can be drawn

out before becoming unstable was investigated experimentally, and the unstable length (in inches) was found to agree approximately with the formula L equals $0.0028\ E-\sqrt{L}$. An interesting series of arc photographs is reproduced, showing the formation of the arc in an actual magnetic blowout switch. Simultanous oscillograph records were also taken. From curves expressing the relation between initial current and arc voltage from the results of these experiments, it appears that the voltage per inch of arc is asymptotic to 22 v., for all currents, when employing a magnetic blowout. Further photographs are given to show the effect of baffles in splitting up the arc. (*Science Abstracts*)

No. 116. M. N. Saha, "Physical Theory of Stellar Spectra," *Proc.*, Roy. Soc., Vol. 99 A, pp. 135–152 (1921).

By means of the ionization potential for the series lines of various elements, Saha computes the temperature which would give rise to these lines at atmospheric pressure and at one-tenth atmosphere. Then by noting the presence or absence of these lines in stellar spectra the temperatures of the stars of the various stellar classes are estimated. The results are in fair agreement with those derived by radiation methods, the most important difference being the higher temperature found for the red stars by the present method. (*Chemical Abstracts*)

No. 117. O. W. Richardson, "The Emission of Electricity from Hot Bodies," published in "Monographs on Physics," edited by Sir J. J. Thomson, O.M., F.R.S., Second Edition, pp. viii + 320, with 35 figures, Longmans, Green & Co., London (1921).

The study of the emission of electrons from hot bodies has now assumed great theoretical and practical importance. The practical side has developed to a most unexpected extent, and Professor Richardson has found it necessary to omit from his treatment of the subject all account of the technical applications, although he gives references to the principal publications dealing with them. The thermionic value, which has transformed the practice of wireless telegraphy, and the Coolidge tube, which has made possible the modern refinement of X-ray practice, are based on this remarkable phenomenon, which only a few years ago must have seemed to have only a purely academic interest. The present work gives a very full and thorough account of the scientific part of the subject, with details of the experimental methods. (*Journal*, Institute of Metals)

1922

No. 118. R. Holm, "Contact Resistances. Especially at Carbon Contacts," *Zeits. f. Techn. Phys.*, Vol. 3, No. 9, pp. 290–294; Vol. 3, No. 10, pp. 320–327; and Vol. 3, No. 11, pp. 349–357 (1922).

This investigation concerns microphone effects, and the paper commences (1) with a reference to previous work by Abbott, Wietlisbach, Bidwell, and Pedersen. The subject is then considered in the following sections: (2) theory of the contact resistance; (3) theory of the dependence of contact resistance on current density; (4) methods of measurement; (5) properties of material; (6) measurements with single grains between plates using a weak current; (7) measurements at different contacts with a weak current; (8) comparison of the measurements; (9) results with several layers of grains; (10) the dependence of contact resistance on current; (11) microscopic observations at carbon contacts; (12) the influence of the surrounding medium (air, other gases, or vacuo) and its pressure on the carbon contact resistance; (13) the pressure coefficient of the electrical conductivity of carbon; (14) experiments with an oscillator; (15) the detector theory; (16) a nonconducting layer in the contacts and the dimensions of the πa^2 surfaces; (17) summary of results. The fundamental assumption is made that the contact resistances are such that a current passes through a sieve of small, conducting, contact surfaces (πa^2) which constitute a small part of the microscopic touching surfaces, and for contact are pressed together. From this standpoint formulas are derived for the resistance and its dependence on current strength. It is assumed that the Joule effect partly influences the conductivity of the contact material, and partly increases the metallic conducting contact surfaces. The formulas were experimentally confirmed. The relation between resistance M and load P at a contact is given by $M = M_0P - a$, where for small pressure $a = 1$, but at higher pressures $a < 1$. The data obtained support the thermoelectric theory of contact detectors in certain respects. The effect of the Rohmann layer is to complicate greatly the behavior of contact resistances. Earlier observers have considered too few variables. The paper is amply illustrated by diagrams and tables of data. (*Science Abstracts*)

No. 119. S. W. Melsom and H. C. Booth, "Efficiency of Overlapping Joints in Copper and Aluminum Bus-Bars," *J.*, I.E.E., Vol. 60, August 1922, pp. 889–899.

This paper describes an investigation conducted with a view to obtaining data concerning the contact resistance between overlapping flat rectangular conductors.

The usual assumption that contact between any two surfaces is at three points only would lead to the conclusion that, with the same total pressure, the resistance would be independent of the areas of the surfaces

pressed together. All the tests made by the authors showed that in copper and aluminum bars clamped under the pressures used in practice, the contact resistance is nearly inversely proportional to the area when the pressure per unit area is the same. The contact resistance between aluminum bars was determined with various types of surface and at pressures from 1000 to 10,000 psi. The contact resistance in microhms per square inch averages about 17 microhms at 1000 psi.; 10 microhms at 2000 psi.; and 4.5 microhms at 5000 psi.; lower values can be obtained if the surfaces be prepared properly. Curves and tables are given for use in determining the amount of overlap required for various thicknesses and with different pressures in order that the resistance of the joint may not exceed that of an equal length of straight conductor.

The results obtained with bolted joints are somewhat conflicting. With the thinner strips the effective pressure for a given size of bolt is much higher than with the thicker strips, there being a slight bending in the neighborhood of the bolts. (*Science Abstracts*)

No. 120. R. Rüdenberg, "The Switching-Out of Direct and Alternating Current in Inductive Heavy Current Circuits," *Bull.*, Schweiz. Elek. Verein, Vol. 13, pp. 248–263 and 286–297 (1922).

With direct current the resistance between switch contacts cannot be increased instantaneously from zero to infinity, and the phenomena accompanying the interruption of the current depend upon the variation of the contact resistance and the accompanying changes in voltage across the contacts. Several different cases are considered. With alternating current the phenomena are very different from those in a d-c. switch because the voltage varies continuously. In a-c. circuits the problem is to prevent reignition of the arc rather than to interrupt the current. Several cases are considered in some detail. (*Science Abstracts*)

No. 121. J. F. Tritle, "Air-Break Magnetic Blow-Outs for Contactors and Circuit Breakers Both A.C. and D.C.," *J.*, A.I.E.E., Vol. 41, April, 1922, pp. 257–265.

While there are many different types of magnetic blowouts this paper deals largely with the "individual" type, in which a blowout coil is connected in series with each pair of current-rupturing contacts. Contactors and circuit breakers with the "individual" type of blowout are now used almost exclusively in the main d-c. power circuits of the 1500 and 3000-v. d-c. railway systems. Oil circuit breakers have been tried for this service, but they are rather unsatisfactory because there is no periodic zero point in the current wave at which the oil can form an insulating seal between contacts. The oil under d-c. conditions carbonizes rapidly and involves the possible danger from explosive gases. Recently the use of magnetic blowout contactors on a-c. circuits has been extended to moderately high voltage and capacity. Short circuit tests on a 6600-v. 26,700-kva. alternator are described. During these three-phase tests the air-break magnetic blowout contactors successfully ruptured 17,500 amp., the full short circuit current, at 5500 v. This is 170,000 kva. three-phase. The maximum asymmetrical peak current through the contacts during this test was 67,500 amp., but during a 2500-v. short circuit test this peak current reached 80,000 amp. Oscillograph records of the voltage and current in each phase are shown and also illustrations of the arcs.

The contactors used were rated at 5000 v., 3000 amp., but they successfully ruptured a circuit of 9000 v., 3500 amp. In all of the tests the circuit was ruptured within the first half-cycle after the tips started to part, indicating the effectiveness of this type of blowout. (*Science Abstracts*)

No. 122. A. Günther-Schulze, "Behavior at the Kathode of the Mercury Vacuum Arc-Light," *Zeit. f. Phys.*, Vol. 11, pp. 74–87 (1922).

The cathode fall of the mercury vacuum arc light is 5.27 ± 0.09 v. and is independent of the current. The heat conducted from the cathode spot to the mercury cathode is proportional to the current and amounts to about 51 per cent of the total cathode fall energy. The size of the cathode spot is proportional to the current. The current density at the spot is about 4000 amp. per sq. cm. The loss of weight by vaporization from the mercury cathode is proportional to the current strength and amounts to 7.2×10^{-3} g. per amp-sec. Nearly the whole current at the cathode is transported by mercury ions and only a small fraction by electrons. The small number of electrons emitted by the cathode are essential for the existence of the arc. (*Science Abstracts*)

No. 123. F. M. Kannenstine, "Formation and Life of Metastable Helium," *Astrophys. J.*, Vol. 55, pp. 345–353 (1922).

By means of an oscillograph, current-potential curves were obtained for alternating and intermittent arcs in pure helium at pressures of 0.06 to 2 mm. At frequencies of 200 cycles or less the striking potential was 29 v., but for frequencies greater than 220 the current started at 5 v., remained constant until 25 v. was reached, then increased. The breaking potential was always about 5 v. In the intermittent arc the voltage was dropped from 36 to a lower value; if the latter was less than 4.6 the arc was suddenly extinguished; if between 4.6 and 23.7 the arc died out gradually; the arc was not extinguished

by a drop to 25.3 or more volts. This behavior suggests that helium atoms, partially ionized at 20.8 v. and hence capable of complete ionization by further impacts of 4.8 v., remained in this metastable condition for an appreciable time, which is estimated to be of the order of 0.0024 sec. (*Chemical Abstracts*)

1923

No. 124. Irving Langmuir, "Positive Ion Currents from the Positive Column of Mercury Arcs," *Science*, Vol. 58, pp. 290–291 (1923).

A preliminary paper giving the results of some experiments in which Langmuir obtained positive ion currents from an electrode placed in the positive column of a mercury arc which were largely independent of the impressed voltage on the electrode. It is shown that the mechanism of the phenomenon depends on the formation of a positive ion sheath about the electrode whose thickness under most conditions is so small that the variations in thickness produced by the change in the impressed potential do not alter the current. Where the thickness of the electrode becomes comparable with the thickness of the sheath, the effective collecting area of the electrode is influenced by the changes in the dimensions of the sheath caused by the changing potential. Thus the current varies with the applied potential and from a theoretical equation derived on the basis of these assumptions Langmuir obtains an excellent quantitative verification of the explanation proposed. (*Chemical Abstracts*)

No. 125. W. B. Nottingham, "New Equation for the Static Characteristic of the Normal Electric Arc," *J.*, A.I.E.E., Vol. 42, pp. 12–19 (1923).

The normal arc is defined as one in which the current intensity is greater than the maximum for the glow arc and less than the minimum for the hissing arc, and which is free from external electric, magnetic, atmospheric and physical disturbances. If the arc length is assumed to be constant the Ayrton and the Steinmetz equations can be written $E = A + (B/i^n)$, in which E is the p. d. across the arc, i the current flowing in the arc, A and B are constants depending on the arc length, and n is a constant dependent only on the electrode material; n is determined for arcs in air between cathodes of carbon and anodes of carbon, cadmium, copper, aluminum, nickel, silver, zinc, lead, antimony, and bismuth and found to be proportional to the absolute temperature of the b. p. of the anode material. The anode material is taken to be the oxide in the case of cadmium, copper, aluminum, nickel, and zinc anodes. The static characteristics of the normal arc can be represented without apparent systematic error by an equation (see original) involving arc length, arc current, and n. (*Chemical Abstracts*)

No. 126. K. T. Compton, "Theory of the Electric Arc," *Phys. Rev.*, Vol. 21, pp. 266–291 (1923).

The fundamental phenomena of the arc are the cathode fall of potential and the copious emission of electrons from the cathode. The escape of an adequate supply of electrons is made possible by sufficient ionization of the gas near the cathode to form a positive space charge. The calculations of Compton support this view and indicate that the thickness of the region of the cathode drop is of the order of the electronic mean free path in the gas. J. J. Thomson first suggested that this emission of electrons is of thermionic origin. Compton's computations indicate that the thermionic emission from the cathode is sufficient to account for the observed primary arc currents. The evidence favors the thermionic theory rather than the photoelectric and canal-ray theories of the origin of the electronic emission. The current carried by the positive ions is also calculated. Ionization occurs in the region between the electrodes of a carbon arc in sufficient amount to neutralize the space charge due to the electrons. Reasons are given for concluding that this ionization is primarily of thermal origin and not due to emission from the anode or ionization by collision. The anode drop of potential is accounted for in a qualitative way by a deficiency of positive ions near the anode due to decreased recombination. Thermionic emission from the anode may also play a part. (*Chemical Abstracts*)

No. 127. Y. T. Yao, "Studies on the Low-Voltage Arc in Mercury Vapor and Its Relation to Fluorescence," *Phys. Rev.*, Vol. 21, pp. 1–21 (1923).

A discussion is given of the effect of velocity of thermal emission of electrons from a heated filament on the potential necessary to maintain a low-voltage arc. Comparison of the results of Yao with those of others shows that this correction is from 2 to 3 v. A table is given from which the proportion of electrons having energies above any value for any filament current can be computed. Measurements of the minimum arc voltage were made as follows: (*a*) with an anode of liquid mercury; (*b*) with a nickel anode and liquid mercury at distances of 7 and 180 cm.; (*c*) with a nickel anode and mercury in a separate reservoir connected to the discharge tube by tubes of varying length; (*d*) with the discharge tube so arranged that the arc could be observed either in a stream of mercury vapor or with stationary vapor. The voltage necessary to maintain the arc decreased with increasing filament current, becoming constant. For case (*a*) with high-filament currents the

arc struck at 5.5 v., the difference between the ionization potential (10.4 v.) and the resonance potential (4.9 v.). The atoms were therefore ionized by two successive impacts. In case (*b*) the arc voltage was 1.21 v. higher with liquid mercury at a distance of 180 cm. than at a distance of 7 cm. Results were analogous in case (*c*), and in case (*d*). This indicates that at some distance from the mercury surface the radiation λ1849 determines the arc voltage rather than λ2536. Conclusion: Some influence increases the probability of ionization along the $1S - mp_2$ path as compared with the $1S - mp$ path in freshly distilled vapor. (*Chemical Abstracts*)

No. 128. R. Bar, M. von Laue, and Edgar Meyer, "The Low-Voltage Luminous Discharge in Helium," *Phys. Z.*, Vol. 20, pp. 83–95 (1923).

The low-voltage discharge takes place in helium below 20 v., only when inductance and capacity relations cause oscillatory fluctuations, during which the maximum instantaneous voltage exceeds 20 v., resonance potential of helium. (*Chemical Abstracts*)

No. 129. A. Hagenbach and M. Wehrli, "Alternating-Current Measurements in the Arc Light," *Zeit. f. Phys.*, Vol. 20, No. 2, pp. 96–108 (1923).

A new method of determining high-frequency alternating current resistances, and with it the counter emf. of the arc light is described. Full details of the experimental arrangements are given. With the amalgam lamp a positive emf. of 12 v. is found in the ascending part of the characteristic. The resistance measurements are found to be independent of the measured current strength in the interval between 0.0017 and 0.11 amp. The results of Duddell and also those of Hagenbach and Percy are confirmed. The counter emf. is found to be independent of the length of the arc up to great arc length, and from this it is concluded that in the gas column the resistances to alternating and direct currents are equal. From this it follows that the seat of the counter emf. is in the neighborhood of, or actually in, the electrodes. (*Science Abstracts*)

No. 130. W. Schottky, "Cold and Hot Electron Discharges," *Phys. Z.*, Vol. 14, pp. 63–106 (1923).

A series of phenomena involving the expulsion of electrons from metals is considered in terms of the old Richardson conception of the work involved in expelling an electron in the presence of an electrostatic surface field, together with the assumption of the existence of electrons in the metal in the condition of an ideal gas. The maximum surface field for the removal of an electron from a metal is 10^8–10^9 v. per cm. A theory is developed connecting spontaneous thermionic emission with cold emission in a very strong field. At submicroscopic irregularities on the surface the field strength is about ten times as great as would be calculated from the contour determined microscopically. The experiments of Lilienfeld on autoelectronic discharge and cathode X-rays (*Chem. Abst.*, 15, 3930; 16, 1181) are discussed as well as the work of Rother (*Chem. Abst.*, 16, 925) and Hoffmann (*Chem. Abst.*, 15, 2384) on electronic action from minute points. The mechanism of certain classes of crystal detector is explained on the assumption of certain points having very large and suddenly reached work of expulsion. Experimental results are in agreement with this qualitative view. For surfaces about 10^{-8} cm. apart there is a critical voltage of about 1 v. below which no conduction takes place. Conduction is supposed to take place from or between points. On this basis a theory of the mechanism of the microphone is discussed. The resistance of a submicroscopical point of contact is about 10^7 ohms for carbon and about 10^3 ohms for platinum. Then with a plausible assumption as to the number of contact points the unsuitability of good conductors for microphones is readily understandable. The distinction between the mechanism of the detector and the microphone is considered and the existence of an atomic cushion of nonconducting material as a necessary condition for the detector action is assumed. The whole theory is discussed and explained on the standpoint of modern atomic and quantum theories. (*Chemical Abstracts*)

No. 131. G. Hoffmann, "Electron Emission From Metals Under the Action of High Electric Fields," *Phys. Z.*, Vol. 24, pp. 109–111 (1923).

This is a brief review of investigations by Hoffmann and by F. Rother (*Chem. Abst.*, 10, 15), the latter's results being interpreted rather as a study of the properties of a poorly conducting layer. The experiments of Hoffmann establish that when the field strength between metals in vacuum increases, a current begins to flow after the potential reaches a value characteristic for the metal, for example, 4×10^6 v. per cm. for platinum. This is explained as a removal of negative electricity from the metal. Some of the experimental difficulties and inconsistencies are discussed. (*Chemical Abstracts*)

1924

No. 132. G. E. Luke, "Resistance of Connections," *Elec. J.*, Vol. 21, February, 1924, pp. 66–69.

Tests of contact resistance of clamped connections were made by measuring the resistance of piles of washers under varying mechanical pressure. In the case of copper, the degree of oxidation made an enormous difference. Under a pressure of 690 psi. clean

copper gave a contact resistivity of 1.1 microhms per sq. in.; but after being heated and allowed to oxidize the figure rose to 27, which appears to be a stable point. When the copper was tinned, the contact resistivity was slightly less than for cleaned copper. The curves for increasing and decreasing pressure do not coincide. The contact resistivity of brass as received was 7.3 microhms per sq. in. and was reduced to 3.5 after cleaning with sandpaper. Iron showed a very high figure, reaching 98,500 after partial sand papering, but cleaning with acid brought this down to 36. All these figures relate to a pressure of 690 psi. The contact drop was in all cases strictly proportional to the current and increased slightly with temperature in case of copper, although brass and iron show the reverse effect. The results show that in general a material of high volume resistivity has also high contact resistivity. Melsom and Booth's recommendation that the best way of cleaning copper contacts is with a file or emery after applying vaseline, and the clamping up without removing the filings and vaseline, is confirmed. Tests of soldered piles of washers give a contact resistivity of 0.019 microhm per sq. in. in comparison with the best figure obtained for cleaned copper under 1000 psi. of 3.90. Tests of a large number of soldered lap connections in machines gave an average conductivity of the joint of 2.66 times that of an equal length of the conductor. It is stated that the limitation to overload capacity of a machine with mica and asbestos insulation is usually found in the internal joints unless a high fusing point solder, such as silver solder, is employed. (*Science Abstracts*)

No. 133. A. R. Enger, "Contact Resistance of Large Conductors," *Elec. J.*, Vol. 21, July, 1924, pp. 316–318.

Contact resistance depends largely on the total pressure with which the surfaces are forced together. Two smooth surfaces, loosely bolted together, will have a higher contact resistance than two roughish surfaces firmly bolted together. Under the application of increased pressures, the roughnesses tend to break down, or the metal flows, and in this way a good permanent joint of low resistance is obtained. A firmly bolted joint is less exposed to oxidation. A series of tests are given which show the dependence of contact resistance on different variables. (*Science Abstracts*)

No. 134. H. E. Ives, "Minimal Length Arc Characteristics," *J.*, Frank. Inst., Vol. 198, pp. 437–473 (1924).

This paper gives a general survey of the subject under the heads: arc characteristics; the break arc; determination of voltage-current characteristics from the break arc; methods and apparatus; distinction between the break arc and break spark; isolation of the break arc by means of a shunted valve; experimental determination of arc characteristics; anode and cathode of different metals; phenomena in various gases; the complete voltage-current characteristics of the discharge between separating contacts. The discharge between separating electrodes is, for large currents, an arc; for small currents, an atmospheric spark. A method for isolating the arc is described. Characteristics of arcs of extremely short length are obtained experimentally, and the relationship between these minimal arcs and arcs of finite length is discussed. The minimal length characteristics are used to develop an expression for the voltage-current-time relations in break arcs. (*Science Abstracts*)

No. 135. W. Schaelchlin, "The Electrical Resistance of Contacts," *Bull.*, Schweiz. Elek. Verein, Vol. 15, March, 1924, pp. 106–116.

The author examines theoretically the value of contact resistances, and gives a formula, showing the effect of mechanical pressure. It also depends on other factors, such as the nature and cleanliness of the surfaces, their state of oxidation, etc. He gives also a summary of various experimental tests, and concludes with a practical examination of various kinds of contacts. Among these are included screw contacts and brush contacts. Suggestions are made as to constructive details for the improvement of contacts of these kinds. (*Science Abstracts*)

No. 136. R. Edler, "Silver-Copper Alloys for Fusible Cut-Outs," *ETZ.*, Vol. 45, pp. 1397–1398 (1924).

Copper fuses have the objection that their carrying capacity is gradually reduced by corrosion in service. Silver is immune to such deterioration, but is expensive. Particulars are given concerning a series of tests on silver-copper alloys with a view to finding an inexpensive alloy of merit. "Zeus" wire, containing 20 per cent silver and 80 per cent copper is found a cheap and satisfactory substitute for pure silver fuses. (*Science Abstracts*)

No. 137. Angelika Szekely, "Passage of Currents through Loose Contacts," *Zeit. f. Phys.*, Vol. 22, Nos. 1 and 2, pp. 51–69 (1924).

Résumé of literature and full bibliography of (*a*) coherers and (*b*) passage across minute intervals. The author finds that between two metals bridges may be built up, which can be photographed; these bridges consist of the material of the anode, the cathode being without influence. Numerous analogies to the behavior of coherers occur, and support the old hypothesis that in coherers bridges are formed. (*Science Abstracts*)

No. 138. R. Wilmeth, "Commercial Methods of Carbon Resistance Measurements," *Elec. J.*, Vol. 21, pp. 309–315 (1924).

Several methods for carbon resistance measurement are given and it is shown how contact errors are treated in each, from an inspector's viewpoint. (*Chemical Abstracts*)

No. 139. E. B. Wedmore and H. Trencham, "Switchgear for Electric Power Control," Oxford University Press, London (1924).

Includes a four-page bibliography of patents.

No. 140. H. Stolt, "Rotation of the Electric Arc," *Ann. d. Phys.* Vol. 74, No. 1, April, 1924, pp. 80–104.

Using a method similar to that of Nicol, the rotation of the electric arc under atmospheric pressure by a magnetic field is investigated, using electrodes of various materials. Magnetic field strength and length of arc are also varied. With constant current, i, but increasing magnetic field, and therefore increasing velocity of rotation, the potential difference, e, between the electrodes is found to increase. With decreasing i, e is found, for copper, silver, and gold electrodes, to increase more rapidly than would be the case if Mrs. Ayrton's equation for the carbon arc held. Except for small currents, the velocity of rotation is found to be proportional to the current for all metals, lengths of arc, and field strengths. The velocity seems to be determined by the material of the anode. In the case of copper it seems to be unaffected by the length of arc, but in the case of silver, for which the experiments were most accurate, an increase in length of arc results in a diminution of velocity. Assuming that the arc can be treated as a convection stream of positive and negative ions, Wilson and Martin deduced the relation $v = HXk_1k_2$, where v is the velocity of rotation, H the magnetic field strength, X the fall of potential in the arc, k_1 and k_2 the respective mobilities of the positive and the negative ions. Using this relation, and assuming that the positive ions are normally of the size of air molecules, and the negative ions are electrons, taking the arc temperature to be about 2000 C., a value for the velocity of rotation is calculated which agrees with that observed for various electrodes with a current of 1.5 amp. Further support is given to this relation by the fact that, on the basis of the assumptions that lead to it, almost all the changes in rotation velocity that are observed in practice can be explained. Such explanations are given in detail. An amplification of the research is contemplated. (*Science Abstracts*)

No. 141. H. Stolt, "The Existence of the Luminous Arc With a Non-Incandescent Cathode," *Phys. Z.*, Vol. 26, pp. 95–101 (1924).

While Stark and Cassuto (*Phys. Z.*, Vol. 5, p. 264 (1904)) were unable to produce a luminous arc between a fixed anode and a cathode cooled by rotation, Stolt has succeeded by using a polished brass disk as the rotating cathode and using a small distance between the electrodes. With a copper disk in place of the brass, a much more stable arc was obtained. Contrary to the results of previous investigators Stolt has shown that with an arc rotating in a magnetic field, the cathode is probably nonincandescent. The arcs between Ag^+–Ag^-; C^+–Cu^-; Ag^+–Cu^-; and Cu^+–Ag^- were also studied. (*Chemical Abstracts*)

No. 142. A. Günther-Schulze, "Arc Lights with Non-Glowing Kathode," *Zeits. f. Phys.*, Vol. 28, pp. 325–328 (1924).

This paper is a criticism of the work by Stolt, who generated an arc between a fixed anode and a rotating cathode. A cathode spot was not visible, and Stolt concluded that a cathode spot is not necessary for the arc. The present paper raises several objections to this conclusion. (*Science Abstracts*)

No. 143. G. Holst and E. Oosterhuis, "The Low-Voltage Arc," *Physica*, Vol. 4, pp. 42–45 (1924).

Oscillating potentials with high peak voltages, assumed by Bar, von Lau, and Meyer as a general explanation of the low-voltage arc, could not be detected experimentally. The voltages of argon or neon arcs (1 cm. pressure, hot tungsten cathode) measured with rectifier and condenser were always equal to the reading of the voltmeter. The minimum ignition potentials for these gases were 14.5 and 18.5 v., the lowest burning potentials were 3.5 and 7.5 v. At a p. d. of at least 16 v. the blue argon spectrum (excitation potential 30 v.) appeared. The explanation offered is that during the neutralization of a positive ion near the hot cathode the energy is transferred as kinetic energy to a second electron, which acquires an abnormally high speed. These electrons can produce new positive ions and for the case that arc potential + ionization potential $\geq$ its excitation potential the blue argon spectrum appears. (*Chemical Abstracts*)

No. 144. H. Nagaoka and Y. Sugiura, "Distribution of Electric Field in Metal Arcs and the Stark Effect Observed in Arcs of Ag, Cu, Mg, Cr, Ni, Co, Fe, and Ten Other Metals," *Jap. J. Phys.*, Vol. 3, pp. 45–73 (1924). (In English.)

By using a 500-v. d-c. generator, together with large capacity and self-inductance, a 7-cm. arc was steadily maintained, carbon being the anode and a drop of metal the cathode. The fall of potential along the arc was measured and from it the field was deduced. Electrodes are the seats of strong electric fields due to the presence of an electric double layer. Fields of 20×10^4 to 6×10^4 v. per cm. are obtained. For silver, copper, mag-

nesium, zinc, cadmium, aluminum, lines belonging to the same series are similarly affected, the nature of the change differing with the series and the effect increasing with the term number. Many new lines were observed. (*Journal*, Institute of Metals)

No. 145. A. Hagenbach and M. Wehrli, "Sound Measurements in Arc Lights with High-Frequency Currents," *Zeits. f. Phys.*, Vol. 26, No. 1, pp. 23–39 (1924).

The authors have recently published a method of determining the high-frequency, alternating current resistance in an arc light. By this means it was possible to calculate its counter emf. It was then found that this counter emf. is situated in or near the electrodes. In the present paper the distribution of resistance in the arc is investigated, and at the same time the counter emf. at the anode and at the cathode is determined. The results obtained by Duddell are confirmed.

A diagram of the experimental arrangements is given, as are also the tabulated results obtained with different kinds of carbon electrodes. The result obtained in the previous experiments, that the counter emf. in the gas column vanishes, is confirmed. A connection is found to exist between the resistance in the gas column and the spectral light emission. The counter emf. at the anode mounts with increasing crater temperature; at the same time the anode fall increases. (*Science Abstracts*)

No. 146. I. Langmuir and H. Mott-Smith, Jr., "Studies of Electric Discharges in Gases at Low Pressure, Parts I, II, III, IV, and V," *G. E. Rev.*, Vol. 27, No. 7, July, 1924, pp. 449–455; No. 8, August, 1924, pp. 538–548; No. 9, September, 1924, pp. 616–623; No. 11, November, 1924, pp. 762–771; No. 12, December, 1924, pp. 810–820.

I. This is part of a study of the complicated phenomena of gaseous discharges such as those of the mercury arc rectifier, using collecting electrodes. In this article the theory of plane, cylindrical, and spherical collectors, with retarding and accelerating fields, is presented. The mechanism of sheath formation around the electrodes is described, showing how the volt-ampere characteristics of a collector gives indications as to the distribution of velocities among the electrons in the ionized gas. The derivation of the equations is given in detail. The solution of the equations as applied to definite surfaces and limited as mentioned above is presented.

II. Electrode H is used as a collector electrode. At a mercury pressure of 33 bars, with a current of 6.0 amp. flowing to the anode A and with the sum of the electron currents flowing to H and B kept constant at 2.0 amp., the variation of the current to H with the voltage between H and the anode was determined. Between -20 and -12 v. i_H increases rapidly owing to the electrons taken up because of their proper velocities. The current finally becomes saturated again when the collector is at a positive potential with respect to space. At E_H -5 v. ionization by collision within the sheath becomes sufficient to neutralize the electron space charge so that the current can increase indefinitely. At E_H -17.8 v., the number of electrons and ions collected is equal and i_H becomes zero. The temperature corresponding to the electron velocities is found to be 9200 K. with 2 amp. flowing to B and 9660 K. with 1 amp. flowing to B. When the mercury vapor pressure is varied from 1.05 bars to 33 bars, another series of experiments shows that the electron temperature varies from 8900 K. to 25,000 K.

III. When r is the radius of the collector, a the sheath radius, V the drop of potential in the sheath, T the temperature corresponding to the Maxwellian distribution of velocities, e the charge on the electron, k the Boltzmann constant, I the current density of the ions, A the surface area of the collector, m the mass of the ion, m_e the mass of the electron, l the length of the cylinder, and β a function of a/r, then $\eta = eV/kT$, and when η is large compared at a/r, the current taken by the collector will be limited by the size of the sheath, and is as follows: $i = (a/r)AI$, and the volt-ampere characteristic will follow the space-charge formula $i = (14.69 \times 10^{-6}/\sqrt{m/m_e})(IV^3/2/r\beta^2)(1 + \sqrt{T/1640}\ V)$. When η is small compared with a/r, the orbital motion limits the current and we have: $i = Alf_\infty$, where f_∞ stands for the limiting value reached by the function of equation (25) in Part I (*G. E. Rev.* Vol. 27, pp. 449–455). The variations of these equations with changing relations of η and a/r are discussed in detail, and confirmed by experimental data.

IV. This is a review of the data obtained with collectors F and G.

V. Because of the troublesome end corrections with plane collectors, it is sometimes desirable to use spherical collectors. The current I, collected by a sphere of surface A is given by $i = AIF$, where I is the random current density of the electrons or ions in the gas, and F is a function given by $F = (a^2/r^2)(1 - {}^{(-\phi)}\gamma\epsilon^{-\phi} = (r^2/(a^2 - r^2))\eta$ and $\eta = (V_2/kT) = 11{,}600\ V/T$. Spherical collectors have volt-ampere characteristics very much like those obtained with plane collectors. The sheath thickness is generally so small compared to the diameter of the collector that the currents are limited by space charge. Either negative or positive ion- or electron-saturated currents are obtained. Tables of data on volt-ampere characteristics are given. (*Chemical Abstracts*)

No. 147. W. G. Palmer, "The Use of the Coherer to Investigate Adsorption Films," *Proc.*, Roy. Soc., Vol. 106 A, pp. 55–68 (1924).

No investigation appears to have been made of the effect of the gas surrounding the contact on the coherers used as detectors of electric waves. It has been suggested that the cohering effect may be due to the desorption of a badly conducting film between the metal surfaces at the point of contact. The theory that the effect depends on the thermoelectric properties of the metals appears untenable when it is known that the cohering action can occur with a frequency of 10^6 times per second. In the present investigation filaments of tungsten, platinum and carbon were used. The filaments were glowed to secure a clean surface, which was tested by determining the resistance of the contact under a low potential. The following carefully purified gases were used: O_2, H_2, CO, N_2O, NO, NH_3, SO_2, CO_2, H_2O, C_2H_6, C_2H_4, C_2H_2, and the critical voltage to remove the gas films and bring about metallic contact was determined. It was assumed that the energy for the evaporation of the gas film adsorbed on the filaments was derived from the electrical energy in the condenser formed at the contact, which can be calculated according to the formula $(k - 1)(E/300)^2/8\pi d$ ergs per unit area of contact, where k is the dielectric constant, E, the potential, and d, the thickness of the film. To evaluate this formula it is further assumed that the films are one molecule thick and that k may be calculated either by Lorenz's expression or Jona's. With these assumptions the heat of desorption per gram-molecule was calculated for the different gases and compared with the heat of vaporization of the liquefied gas. It was found that for platinum the two heats, though not checking closely, were in general of the same order of magnitude. For tungsten, in the cases of oxygen, carbon monoxide, and water, the maximum heats of desorption, obtained with "aged" films, were very much higher, and for the hydrocarbons very much lower. For carbon the heats of desorption of the hydrocarbons were not greatly different from the heats of liquefaction, but the heat of desorption of carbon dioxide was very small. It is concluded that high heats of desorption indicate a chemical effect, but that the adsorption, for example, of carbon dioxide in carbon is merely a physical solution. (*Chemical Abstracts*)

No. 147a. Arne E. Enger, "The Contact Resistance of Large Conductors," *Elec. J.*, Vol. 21, No. 7, July, 1934, pp. 316–318.

The test results show clearly that the universal tendency toward mechanical perfection in joint making incurs needless expense in surface preparation and alignment, whereas results as good or better are obtained by simply getting the joint tight.

Increasing the pressure of a contact results in: (*a*) lower contact resistance, (*b*) smaller I^2R loss, and (*c*) a closer union of contact surfaces, which in turn cuts down contact oxidation and makes the joint more permanent. (Author's abstract)

1925

No. 148. R. Holm, "On Contact Resistance," *Zeits. f. Techn. Phys.*, Vol. 6, No. 5, pp. 166–172 (1925).

This paper continues a previous investigation (*Zeits. f. Techn. Phys.*, Vol. 3, pp. 290, 320, and 349 (1922), see A.S.T.M. Abstract No. 118) in which a contact theory is advanced on the essential assumption that only very minute parts (πa^2 surfaces) of a Hertzian contact surface experience metallic contact. By resistance measurements for currents applied during short periods, it is found how quickly the vicinity of πa^2 surfaces assumes the temperature elevation due to the current. This period appears to be essentially less than 10^{-5} sec., so that a becomes less than 3×10^{-5} cm., thereby affording strong support for the theory. The paper is replete with experimental details, data, etc. (*Science Abstracts*)

No. 149. H. Rohmann, "Electric Currents Through Short Distances Between Metallic Electrodes in Vacuo," *Zeits. f. Phys.*, Vol. 31, Nos. 1–4, pp. 311–325 (1925).

H. Rohmann, "Electric Contact Between Glowing and Cold Electrodes in a Vacuum," *Zeits. f. Phys.*, Vol. 34, Nos. 2 and 3, pp. 94–102 (1925).

In the first paper the author has investigated the relation of current to potential difference across metal electrodes separated by 10 mμ to 1000 mμ in vacuo. For electrodes a constant distance apart, the value of the applied potential corresponding to effective contact between the electrodes seems to be independent of current strength and proportional to the distance as part of the electrodes within wide limits.

In the second paper it is shown that the positive charging up of a brightly glowing platinum electrode which is placed opposite a cold electrode in a high vacuum causes a passage of electricity when the electric field strength between the electrode exceeds a critical value of the order of 100,000 v. per cm. The critical field strength increases with diminishing temperature. (*Science Abstracts*)

No. 150. K. T. Compton and C. Ekart, "Diffusion of Electrons Against an Electric Field in the Non-Oscillatory Abnormal Low Voltage Arc," *Phys. Rev.*, Vol. 25, No. 2, February, 1925, pp. 139–146.

It is well established that arcs may be maintained in gases or vapors at voltages as low as their ionizing potentials, or, in cases where cumulative ionization is possible, as low as their radiating potentials, provided a hot cathode is used as a source of electrons Considerable discussion has been occasioned

by arcs which have been maintained at still lower voltages, since at such voltages the electrons are known not to effect either partial or complete ionization of the molecules with which they collide. Recently Bär, von Laue and Meyer, and, independently, the present writer (*Sci. Abst.*, 192 (1925)) have shown that some of these arcs, notably those in helium, may be accounted for by the existence of electrical oscillations, the peak voltages of which always exceed the lowest radiating potential of the gas. Experiments with a tube provided with an anode and a hot filament cathode, built and used with elaborate precautions for excluding mercury vapor, disprove the suggestion that traces of mercury vapor as an impurity play an essential role in permitting arcs in helium to operate at abnormally low voltages. An arc tube, provided with a movable exploring electrode which is used according to Langmuir's method, enables measurements of potential, of ion concentration, and of average energy to be made in all parts of the arc. With arcs operating on about 6 v., the cathode drop is invariably very near to 11.5 v. (the minimum radiating potential if argon), so that there is a reverse field of about 5 v. existing throughout the greater part of the arc. The fact that the arc current of almost an ampere flows against this field is due to the effect of diffusion arising from the large concentration gradient. The electron concentration varies from the order of 10^{12} per cu. cm. just outside the cathode to about 10^{10} near the anode. The reverse field is due to the difference between the mobilities of electrons and of positive ions, and is therefore most pronounced in the case of argon, in which electron-free paths are abnormally long. The most interesting single feature of this research is the proof of the importance of ion diffusion in low-voltage arcs. (*Science Abstracts*)

No. 151. A. Günther-Schulze, *Phys. Z.*, Vol. 31, p. 508 (1925).

No. 152. H. Stolt, "Temperature Relationship of the Cathode Spot of an Arc Light," *Zeits. f. Phys.*, Vol. 31, No. 104, pp. 240–252 (1925).

The objections raised by Günther-Schulze (*Sci. Abst.*, 191 (1925)) on the results obtained in a previous communication by the author are here criticized. It is claimed that recent experiments with rotating arcs as well as the estimations of the temperature of the cathode spot by Langbeins seem to support the author's views. The presence of cathodic metallic vapors in the layer lying next to the cathode appears to be a necessary condition for the arc discharge. It also seems possible for a photoelectric generation of electrons at the cathode of the arc light to take place without a necessarily high temperature. (*Science Abstracts*)

No. 153. S. D. Norberg, "The Properties of the Electric Arc with Respect to the Arcing of Circuit Breakers," *Proc.* Roy. Swedish Inst. for Eng. Res., No. 44, 55 pp., A. B. Gunnar Tisells Tekniska Forlag, Stockholm (1925). (In English.)

A study of the dynamic and static characteristics of the arc is applied to circuit breakers and switches so that calculations of arc length may be made for both a-c. and d-c. circuits with both noninductive and inductive loads. Results of calculations are verified by tests.

1926

No. 154. C. E. Magnusson, "Electric Transients," Second Edition, McGraw-Hill, New York, N. Y. (1926).

No. 155. J. Slepian, "Theory of Current Transference at the Cathode of an Arc," *Phys. Rev.*, Vol. 27, pp. 407–412 (1926).

The relatively low temperature of the cathode in the case of such metals as copper and mercury suggests that thermionic emission from the cathode is not essential, and that some other factor may be more important in determining the current carried to the cathode in such cases. It appears that if the gas next to the cathode is sufficiently hot, thermal ionization in accordance with Saha's equation may account for much of the current to the cathode. Calculation shows that an upper limit for the required temperature is somewhat in excess of 4000 K. for calcium, and 6000 K. for copper. (*Science Abstracts*)

No. 156. J. Slepian, "Temperature of a Contact," *J.*, A.I.E.E., Vol. 45, pp. 930–933. Discussion, pp. 1308–1309 (1926).

A spark or an arc often results from opening a pair of contacts in a circuit carrying a current, although the voltage may be quite low. This phenomenon calls for explanation since 15 v. or more are required to maintain an arc discharge. An analysis of the thermal conditions at the last point of contact of a pair of separating electrodes suggests an explanation. As the electrodes separate, the area of contact decreases and the ohmic resistance through the electrode material increases. If a discharge does not start, the voltage of the circuit ultimately concentrates on the last point, which means that there is a large concentration of power and current at that contact, and hence a high temperature. The author develops a formula for the temperature rise of the last contact point of a pair of separating electrodes. The relation of this to arcing at a switch, brush drop, and commutation is discussed. (*Science Abstracts*)

No. 157. J. Slepian, "Theory of the Autovalve Arrester," *J.*, I.E.E., Vol. 45, January, 1926, pp. 3–8.

The author discusses the theory of the autovalve arrester, where the film is a thin layer of air next to a cold cathode, which is the seat of the cathode drop in a glow discharge. With the application of sufficient voltage this air film becomes highly ionized, but the discharge of these ions into the electrodes and reconstruction quickly restore the normal resistivity where the voltage is reduced. (*Science Abstracts*)

No. 158. E. Friman and R. Holm, "Contact Resistance," *Zeits. f. Techn. Phys.*, Vol. 7, No. 4, pp. 198–200 (1926).

Measurements have been made of carbon contact resistance at different temperatures in a vacuum. The resistance diminishes slowly at first, then more rapidly with increasing temperature, falling from its normal value at 0 C. to about one fifth at 1000 C. The decreased resistance is ascribed to the increase of area of contact as the temperature of the carbon contact rises. (*Science Abstracts*)

No. 159. R. Kelch, *Zeits. f. Swachstr. u. Hochfreq.*, Vol. 1, pp. 1–25 (1926).

No. 160. (1) H. Rohmann, "Electric Contact of Glowing Platinum in Vacuum," *Zeits. f. Phys.*, Vol. 36, Nos. 11 and 12, pp. 803–813 (1926).

(2) H. Rohmann, "Passage of Electricity Between Platinum Electrodes in a Vacuum," *Zeits. f. Phys.*, Vol. 39, Nos. 5 and 6, pp. 427–436 (1926).

(1) This is a continuation of previous work on platinum wires. In the present experiments two platinum wires are used which have glowed for a long time in vacuum, and attempts are made to cause passage of current from one to the other when the field strength reaches a critical value. It is shown that the passage of current with a kind of electric contact can be made arbitrarily unipolar if the electrode wires glowing under tensions of some 100 v. at some megohm governing resistance are brought in contact and slowly moved apart. Experimental details given. (*Science Abstracts*)

(2) A continuation of the previous work, using platinum iridium electrodes, and involving a more thorough study of the discharge. (*Science Abstracts*)

No. 161. F. Rother, *Ann. der. Phys.*, Vol. 81, p. 317 (1926).

No. 162. R. W. Sorensen and H. E. Mendenhall, "Vacuum Switching Experiments," *Trans.*, A.I.E.E., Vol. 45, September, 1926, pp. 1102–1107.

Successful experiments in switching or breaking a circuit in a high vacuum have been made at the California Institute of Technology. This paper is a report on three sets of these experiments which extended over a period of three years. The conclusions drawn from the experiments may be summed in the statement that vacuum breakers of the laboratory type have been successful in breaking circuits and offer a possible solution to the circuit breaker problem. The results show that switching in vacuum affords the advantages of no pitting of contacts, quick break, the arc always going out on the first half-cycle, small voltage rise across the switch, and small distance of travel necessary for the switch blades. Making the vacuum switch practical calls for a solution of the problem of making commercial apparatus with vacuum-tight joints, and the elimination of the use of liquid air with the vacuum pump. (Authors' synopsis)

No. 163. R. Seeliger, "Phenomena at the Cathode of the Arc Discharge," *Phys. Z.*, Vol. 27, January 1, 1926, pp. 22–41.

The subject is dealt with at some length along the following lines: The different forms and the definition of the arc discharge; qualitative theory of the cathode fall; the current distribution at the cathode; the burning spot; and difficulties in the way of the thermionic arc theory. Bibliography appended. (*Science Abstracts*)

No. 164. Anonymous "The Reliability of Contacts in Circuits Where Very Small Voltages Are Present," P. O. Eng. Dept., *Res. Rep. No. 4031* October 4, 1926.

1927

No. 165. R. Holm, "Contact Resistance," *Zeits. f. Techn. Phys.*, Vol. 8, No. 4, pp. 141–154 (1927).

Discusses contact resistance from the point of view of elastic contact between discrete particles, using the Hertz equations for the deformation of elastic spheres under pressure and "Hertzian surfaces" to obtain macroscopical results. Experiments to determine the numerical values of various factors occurring in the theoretical expression are described. (*Science Abstracts*)

No. 166. S. Q. Hayes, "Switching Equipment for Power Control," McGraw-Hill, New York, N. Y. (1927).

No. 167. K. T. Compton, "The Electric Arc," *Trans.*, A.I.E.E., Vol. 46, June, 1927, pp. 868–883.

The arc is here defined as a discharge of electricity between electrodes in a gas or vapor, which has a voltage drop at the cathode of the order of the minimum ionizing or minimum exciting potential of the gas or vapor. Arc characteristics are discussed, including the relation of arcs to glow discharges and coronas. The cathode spot, theories of cathode fall, and the energy balance at the cathode are the other chief points considered. A useful bibliography is appended. (Abstracted in *J.*, A.I.E.E., Vol. 46, p. 1192 (1927).) (*Science Abstracts*)

No. 168. R. Kelch, "Deterioration in Microphones," *E. N. T.*, Vol. 4, August, 1927, pp. 335–338.

An investigation into the cause and possible avoidance of coherence of granules and consequent loss in efficiency in the carbon microphones in central battery operator sets. Oscillograms show that the effect is due to oscillations set up on making the current in the microphone circuit, the corresponding oscillations being absent on opening the circuit. It was found that a condenser shunted across the key eliminated the undesirable oscillations, and hence the coherence among the granules. Oscillations of a much lower frequency were, however, introduced at break, but these proved ineffective with respect to the granules. (*Science Abstracts*)

No. 169. A. Roth, "Das Telephon und Sein Werden" (The Telephone and Its Possibilities), Springer, Berlin (1927).

No. 170. F. Schröter, "Brush Contact Resistance," *Arch. f. Elektr.*, Vol. 18, April 7, 1927, pp. 111–122.

Experiments described lead to the theory that between a brush and a rotating metallic surface (that is sliprings) there exists an insulating layer or skin which is broken down at a number of points. The resistance is concentrated at these points and decreases with rise in current due to increased temperature. At about 800 C., the insulating layer begins to disintegrate, and the number of contact points to increase. The author estimates the true temperature of the contact points to lie between 1000 C. and 1500 C. The assumption of an insulating layer with an increasing number of puncture points explains the increasing wear of the brushes with increase of load and the difference in the frictional loss between no load and full load. (*Science Abstracts*)

No. 171. F. Sieber, "Operation of Contacts by Electrical Instruments," *Bull. Schweiz. Elek. Verein*, Vol. 18, August, 1927, pp. 484–490.

A description is given of various contact devices which can be operated by electrical measuring instruments, and which are sufficiently robust to carry the few watts necessary for the operations of relays. The usual requirements are end contacts, and difficulty is sometimes experienced in getting sufficient torque. One arrangement derives its torque from bimetal springs which are heated by the operating current. In this system an increase of 10 to 20 times the operating torque obtainable in an equivalent moving-coil system is claimed. (*Science Abstracts*)

No. 172. M. Leblanc, M. Charpentier, *et al.*, "Contact Resistance," *Bull., Soc. Fr. d. Elec.*, Vol. 7, pp. 263–275 (1927).

Notes on a round table discussion covering contact resistance theories and arcing at contacts.

No. 173. C. C. Garrard, "Electric Switch and Controlling Gear," Third Edition, D. Van Nostrand Co., Inc., New York, N. Y. (1927).

A description of various types of switches, their design, construction, and servicing. Also circuit connections for various applications. Appendices contain summaries of standardization rules of the British Engineering Standards Association, and also those of other countries, with switchgear requirements for the same.

No. 174. S. D. Norberg, "Arc Formation and Breaking Characteristics of Switches," *J.*, A.S.E.A., Vol. 4, March, 1927, pp. 28–37.

The author discusses the theory of arc formation on breaking switch contacts for both airbreak and oil-immersed switches, and develops formulas by means of which the electrical and geometrical dimensions of the arc can be calculated within close limits under all conditions. The uses of the formulas are directed chiefly to calculating the length of the arc on the breaking circuit, from which the designer can determine a satisfactory length of break for any form of switch. Oscillograph records are given showing the agreement between calculated and observed results. (*Science Abstracts*)

No. 175. A. Hagenbach, "The Electric Arc Light," Handbuch der Physik, Vol. 14 (Electrical Conduction in Gases), Chapter 6, pp. 324–354, Julius Springer, Berlin (1927).

No. 176. G. I. Finch and J. C. Stimson, "The Electrical Condition of Hot Surfaces During the Adsorption of Gases. Part I. Gold and Silver Surfaces at Temperatures up to 850 C.," *Proc.*, Roy. Soc., Vol. 116, October 1, 1927, pp. 379–400.

This investigation was undertaken with the object of confirming and extending Hartley's work (*Sci. Abst.*, 1318 (1914)). It has been found that a gold or silver surface becomes charged when heated either in contact with a gas or in a high vacuum, the charge being characteristic of the gas and dependent on temperature but not on pressure. Evacuation of a gas removes the corresponding charge slowly in the case of oxygen or air on gold, and oxygen, air, or hydrogen on silver, but rapidly in the case of the other gases examined. The influence of variations in the rates of evacuation on the charges has been studied and also the effects of gas mixtures. Previous heat treatment of the surface has a profound effect on its powers of activation. It is concluded (1) that the charge on a hot gold or silver surface in contact with a gas is due to an "activation" of the gas, whereby its molecules become electrically charged; and that (2) the activation of a

compound molecule such as water vapor or carbon dioxide involves at least its dissociation. (*Science Abstracts*)

No. 177. B. W. Jones, "Contact Resistance," *G. E. Rev.*, Vol. 30, No. 2, pp. 85–86 (1927).

When copper is used as a contact material difficulty is often experienced because of the high resistance caused by the oxide film. High temperatures increase this film, so a single instead of a multiple form of contact is better because it dissipates heat more readily. The oxide may be removed by arcing or by mechanical rubbing. Line contacts have been found superior to flat ones.

Silver contacts have given remarkable results and are the most satisfactory substitute for copper ones which have yet been found.

1928

No. 178. E. F. Kingsbury, "The Use of Noble Metals for Electrical Contacts," *Technical Publication No. 95*, A.I.M.E., March, 1928; *Inst. Metals Div.*, A.I.M.E., Vol. 78, pp. 804–824, March, 1928; *Reprint B-298*, Bell Telephone Laboratory, April, 1928.

The paper describes the results of an investigation of the behavior of the gold, the silver, and the platinum metals as electrical contacts in communication circuits. Platinum has heretofore been considered the standard, although some alloys of the platinum metals have been used. The economic situation has encouraged the use of cheaper substitutes, and such are mentioned here. The resistance, erosion, and transfer of contacts are discussed for a variety of materials under various circuit conditions and in different atmospheres. (*Mining and Metallurgy*)

No. 179. A. Clerc, "Reclosing of Circuit Breakers on Short Circuit," *R.G.E.*, Vol. 24, August 11 and 18, 1928, pp. 217–223 and pp. 255–259.

The attempt is frequently made to close a circuit breaker before a short circuit is cleared, with the result that enormous currents may pass through the contacts. The effect can be disastrous, particularly in damaging and burning the contacts, serious arcs even causing explosion or welding up of the contacts so that the circuit breaker will not open. These results are largely due to the electrodynamic forces produced by currents in the contacts and the conductors immediately leading thereto, preventing sufficient pressure between the contacts. Various types of main and auxiliary contacts are discussed from this point of view, and researches are described into the magnitude of the forces produced, the currents required to produce burning, or welding up of the contacts at various contact pressures. Oscillograms are given illustrating the action, and forms of contacts are described and illustrated in which the electrodynamic forces are equilibrated. (*Science Abstracts*)

No. 180. "Standardization of the Spark Quench Capacity and Resistance Values for Impulsing Circuits in Automatic Telephone Exchanges," P. O. Eng. Dept., *Res. Rep. No. 4662*, August, 1928.

No. 181. J. Slepian, "Breakdown of Spark Gaps," *Elect. World*, Vol. 91, April, 1928, pp. 761–765.

The great speed of breakdown of spark gaps at atmospheric pressures observed experimentally contradicts sharply the classical Townsend theory of sparkover. To solve this dilemma, it is suggested that thermal ionization of the gas takes place in the single passage of an electron from cathode to anode, and before the Townsend process can develop. Calculation, taking space charge into account, confirms this view. Sparkover takes place at those gradients which produce thermal ionization, and good agreement is obtained between breakdown gradients calculated on this basis and those observed experimentally. The "suppressed discharges" figures of Torok, which are difficult to explain otherwise, are a natural consequence of the theory developed here. The time for breakdown with moderate overvoltages comes out satisfactorily of the order of 10^{-7} sec. (*Science Abstracts*)

No. 182. J. Slepian, "Extinction of an A.C. Arc," *J.*, A.I.E.E., Vol. 47, October, 1928, pp. 706–710.

The transition from high conductivity to high resistivity which an a-c. arc undergoes on extinction is studied. Theory and approximate calculations are given for the rate of recovery of the dielectric strength of the arc space for short arcs, and results are given of experiments on short arcs and arcs in holes and slots in insulating material and insulating plates. The influence of chemical activity in arc gases is discussed. Factors contributing to the success of the a-c. oil circuit breaker are suggested. (*Science Abstracts*)

No. 183. C. A. Hartmann, "New Investigation of the Carbon Microphone," *E. N. T.*, Vol. 5, September, 1928, pp. 344–357.

The previous investigation of the frequency and amplitude dependence (*Sci. Abst.*, 124 (1928)) is here extended by the determination of the nonlinear distortion and the threshold of sensation, the experiments being made on a high-grade carbon microphone. The experiments show that improvement must still be strived for in limiting the nonlinear distortion for average sound pressures, and especially for small sound pressures in the region of the threshold of sensation. (*Science Abstracts*)

No. 184. R. H. Wright and M. J. Marshall, "The Effect of Adsorbed Gas on the Contact Resistance of Carbon," *Trans.*, Am. Electrochem. Soc., Vol. 54, September, 1928, pp. 149–162.

The effect of adsorbed gas on the contact resistance of carbon has been investigated, in the light of the hypothesis that adsorbed gas films on the carbon surface may be responsible for part of this contact resistance. The contact resistance of carbon filaments was measured, both in air and after outgassing at 1700 C. in a high vacuum. Curves were obtained showing the variation of resistance with pressure under these conditions. For contacts too light to be measured, much lower resistances could be obtained after outgassing. For intermediate contact pressures outgassing reduced the resistance to about two thirds of its original value. Heavy contacts showed about the same resistance for the two conditions. It is shown that this is in accordance with the theory proposed. (Authors' abstracts)

No. 185. W. Schaelchlin, "Contact Resistance of Electric Switching Apparatus," *Elec. J.*, Vol. 25, August, 1928, pp. 386–391.

The theory of contact resistance, as outlined in this paper, is based on the assumption that the so-called contact resistance is nothing but the ohmic resistance of microscopic projections or points which actually make up the contact surface. However carefully the surfaces are ground, the actual contact is obtained at one or several points only, depending upon the flexibility of the material. These contact points which carry all of the current are of a certain length and hence have a definite ohmic resistance. On these assumptions the contact resistance depends upon contact pressure, specific resistivity of the material, and the crushing strength of the material.

No. 186. R. Holm, "Contact Resistance," *Zeits. f. Techn. Phys.*, Vol. 9, No. 11, pp. 454–457 (1928).

The author distinguishes between surfaces which give metallic conduction and those in which contact is made only at a number of points. From an analogy with thermal conduction the resistance is stated in the equations

$$R_t = R_0 \ (1 + 2\alpha t/3)$$
$$t + t^2\alpha/2 = \lambda V^2/8k$$

where t is the temperature of the surface, R the contact resistance, V the contact potential difference, λ and k the electrical and thermal conductivities at room temperature, and α the temperature coefficient of the specific resistance. Diagrams illustrate the connection between log R_t and log V. The curve departs from theory near the recrystallization temperature of the surface. Characteristic curves are shown for gold, silver, nickel-graphite, and charcoal. (*Science Abstracts*)

No. 187. W. B. Nottingham, "Probe Measurements in the Normal Electric Arc," *J.*, Frank. Inst., Vol. 206, July, 1928, pp. 43–55.

Probe measurements have been made in cadmium, thallium, and carbon arcs by sweeping the probe through the arc at a constant velocity and measuring the current collected by the throw on a ballistic galvanometer with different probe potentials applied. The voltage-current characteristic was analyzed to get a measure of the positive ion concentration, the average electron temperature and the space potential by the Langmuir method. The cathode falls found were each equal to, or only slightly higher than, the ionization potential of the active gas, and were 9.0 v. in the cadmium arc, 6.5 v. in the thallium arc, and 5.0 v. in the carbon arc. The last value is to be compared with the ionization potential of the cyanogen molecule of 4.4 v. The anode fall found in the carbon arc was 16.5 v. These values for the carbon arc agree almost exactly with the "forward" and "back" emf.'s measured by Duddell and others at the cathode and the anode, but not identified by them as the cathode and anode falls. (*Science Abstracts*)

No. 188. J. V. Issendorff, "Evaporation at the Cathode in the Mercury Arc," *Phys. Z.*, Vol. 29, December, 1, 1928, pp. 857–864.

Experimental determinations of the evaporation at the cathode in a mercury vapor arc for different surface temperatures showed that the quantity evaporated varied largely with the temperature, but only slightly with the arc current. As regards evaporation, the results show a vanishingly small loss of material from the cathode; there may even be a gain of material due to incoming ions. As regards the quantity ejected from the surface, this increases more than linearly with the current. A critical discussion is given of the balance of energy at the cathode in the mercury vapor arc with special reference to the results of Compton and Van Voorhis. (*Science Abstracts*)

No. 189. F. E. Carter, "The Platinum Metals and Their Alloys," *Technical Publication No. 70*, A.I.M.E., February, 1928, 24 pp.,

Discusses briefly the melting, working, soldering, and welding of metals of the platinum group. Platinum alloys of commercial interest are listed, and one section deals with the uses of the metals and alloys of this group. (*Mining and Metallurgy*)

No. 190. R. von Dallwitz-Wegner, "Contact Electricity, Thermoelectricity and Cohesion Pressure," *Z. Elektrochem.*, Vol. 34, pp. 42–49 (1928).

Values of the cohesion pressure K, of various substances at 0 and 100 C. are calculated from the relation: $K = 84.1d((1 + at)/a)/M$, where d = density, M = molecular weight, t = temperature, and a = coefficient of cubical expansion. For solids the values of K range from 13×10^6 for diamond to 56.5×10^3 for lead at 0 C., the sequence of the various substances corresponding with the order of hardness. For mercury at 0 C., $K = 31 \times 10^3$. The relation of the cohesion pressure to contact electricity and thermoelectricity is discussed, and an equation is developed whereby the emf. of a thermoelement with a temperature difference of 100 deg. between the hot and cold junction can be calculated from the cohesion pressure data. For a platinum-silver element satisfactory agreement is obtained with the observed value, but for many thermoelements there are notable discrepancies. These discrepancies are attributed to the fact that small quantities of impurities in the metals can have a large effect on the emf. and on K, so that agreement can be expected only if K is determined for the particular samples of metal used in the thermoelement. (*Chemical Abstracts*)

No. 191. "An Analysis of the Causes of Wear of Relay Contacts," P. O. Eng. Dept., *Res. Rep. No. 4288*, January, 1928.

1929

No. 192. E. Holm and R. Holm, "Characteristics of Contact Resistance," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 7, Part 2, pp. 217–304 (1929).

A theoretical consideration of the dependence of contact resistance on the pressure with which the two conductors are pressed together. The further relation is obtained:

$$R = R_0(1 + {}^2/_3\alpha t)$$

$$t + \frac{\alpha}{2}t^2 = {}^1/_8\frac{\lambda_0}{K_0}V^2$$

where:

V = potential difference,
t = temperature of the a-surfaces,
R = contact resistance,
α = temperature coefficient of the specific resistance,
λ_0 = electrical conductivity at room temperature, and
K_0 = electrical conductivity at room temperature.

Abstracted in *Elektrotecknik und Machinenbau*, Vol. 46, pp. 584–585 (1929).

No. 193. R. Audubert and M. Quintin, "Mechanism of Asymmetric Conductivity for Imperfect Contact," *Compt. rend.*, Vol. 188, January 2, 1929, pp. 52–54.

For the silicon-carbon couple the characteristic is given by:

$$i = aV^2 + bV \text{ for } V > 0$$
$$i = -a'V^2 + bV \text{ for } V < 0$$

The silicon particles make a pitted surface at the junction and rectification appears there. The authors show that with this junction electronic emission occurs, the current emission being given by:

$$i = 9KV^2/32\pi l^3$$

where K is the mobility of the ions. Since K is much greater for negative than positive corpuscles, this agrees with the observed fact that the current flows more easily when carbon is negative with respect to silicon. The hypothesis of electronic emission accompanying ionization phenomena explains the facts qualitatively and quantitatively for this imperfect contact and probably acts also as the mechanism for silver sulfide and lead sulfide. (Previous work along the same lines reported in *Compt. rend.*, Vol. 187, pp. 972–974 (1928).) (*Science Abstracts*)

No. 194. P. S. Olmstead, "Effect of Gases on the Resistance of Granular Carbon Contacts," *J.*, Phys. Chem., Vol. 33, January, 1929, pp. 69–80.

Studies of the adsorption of gases by carbon indicate not only that gas condenses on the surface of carbon, but also that there are capillary forces sufficient to hold additional gas within. Moreover, Holm has found that in the case of two granules of carbon brought close enough together to conduct electricity, the areas of contact were less than 3×10^{-5} cm. in diameter and the current path was from carbon to carbon. These facts and views are confirmed and it is shown that (1) gas adsorbed on the surfaces of a carbon contact increases its resistance and decreases the effective area of contact; (2) pores exist in the material opening into the contact area and when this area is partly outgassed these pores act as reservoirs for additional gas, which may have an effect on the resistance of the contacts; (3) a resistance may have a relation to the hydrogen content of the granules. The experiments indicate that the resistance of a granular carbon contact is due in part to the gas adsorbed on the carbon surface. (*Science Abstracts*)

No. 195. H. Pelabon, "Electronic Theory of Bad Contacts," *Compt. rend.*, Vol. 188, February 25, 1929, pp. 620–622.

If the conductors are in perfect contact, then Ohm's law governs the passage of current and the electrons move among themselves with very great velocity. If bad contact predominates, and the conductors are separated by a small interval, the state of affairs may be likened to evaporation of a

part of the electrons at one of the surfaces and the condensation on the other. This mode of transport is slow and depends on the value of the field. This problem is discussed theoretically for direct and alternating currents, as well as for electromagnetic waves. (*Science Abstracts*)

No. 196. A. von Engel, "Length and Duration of Arcs in Air by Switching Off Direct Current," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 7, Part 2, pp. 50–66 (1929).

The breaking length of arcs in air can be explained by using the Ayrton equation. It is demonstrated that by the introduction of a simplification rule an easily solvable solution is found for ohmic circuits, and also for circuits with resistance and inductance. The product of the electromagnetic time constant and the velocity of the change in arc length is important in the equation. The results of theory agree well with experiments. (*Zeits. f. Techn. Phys.*)

No. 197. T. E. Stern, B. S. Gossling, and R. H. Fowler, "Emission of Electrons from Cold Metals," *Proc.*, Roy. Soc., Vol. 124, July 1, 1929, pp. 699–723.

An extension of the theory of the emission of electrons from cold metals under the effect of an intense electric field is discussed. In particular detailed examinations are given of (1) the space charge effect, and (2) the effect of surface films on the emission coefficient. Existing experimental data are discussed and an account is given of experiments by the authors and other investigators, the results of which support the improved theory. (*Science Abstracts*)

No. 198. C. Schenfer, "Low-Frequency Alternating-Current Arc," *Arch. f. Elektr.*, Vol. 22, September 28, 1929, pp. 633–636.

Shows, from an oscillographic study of the voltage and current wave forms for cored and solid carbon arcs at frequencies of 11.5 and 5.0 cycles per second, that the cooling of the electrodes as the current passes through zero greatly influences the shape of the voltage and current waves. The lower the supply frequency the greater is the voltage required to restrike the arc after each extinction and the length of time for which the arc is extinguished becomes much longer. A change from cored to solid carbons at the same frequency also appears to increase the striking voltage and the time of extinction. Dynamic characteristics obtained from the oscillograms are given, and these again show marked differences. (*Science Abstracts*)

No. 199. J. Slepian, "The Deion Circuit Breaker," *Elect. Times*, Vol. 76, October 10, 1929, pp. 551–553.

See Abstract **No. 201.**

No. 200. C. Paulus, "Circuit Breaking by Fusible Cut-Outs and Contactors," *ETZ.*, Vol. 50, December 19 and 26, 1929, pp. 1829–1835, pp. 1875–1878.

An extensive theoretical and oscillographic examination of the circuit conditions when fusible cut-outs and contactors operate through short circuits. (*Science Abstracts*)

No. 201. J. Slepian, "Theory of the Deion Circuit Breaker," *Trans.*, A.I.E.E., Vol. 48, April, 1929, pp. 523–527, Discussion, pp. 545–553.

Three major features incorporated in the Deion circuit breaker are discussed. They are: deionization at solid surfaces; the function of the static balancer; and cold electrode arcs. (Author's synopsis)

No. 202. E. B. Wedmore, W. B. Whitney, and C. E. R. Bruce, "Circuit Breaking," *J.*, I.E.E., Vol. 67, pp. 557–578 (1929). Discussion, May, 1929, pp. 578–593, and August, 1929, pp. 1059–1061.

An introduction to the researches of the Electrical Research Association on arc rupture, which has been in progress since 1922. The investigation aimed at means for preventing the arc from restriking rather than attacking the arc when heavy current is flowing, which may cause heavy energy release. It is shown that in oil switches the arc is often broken while the contacts are still within the gas bubble, so that in such cases arc extinction is not due to the quenching effect of the oil. Novel methods of gas sampling during arcing are described, and the results are given of gas collection and analysis covering a wide range of currents and powers. Experimental results on arc-voltage characteristics are included which indicate that Norberg's application of Steinmetz's formula, if used over the range considered in this present paper, would lead to large errors in the results obtained for arc energy; whereas his experimental results, though few in number, are consistent with the results here obtained. A formula for arc energy when arcing takes place in gas is developed. Among practical applications is a new device for arc rupturing by gas blast. (*Science Abstracts*)

No. 203. E. Contius, "Der Einfluss der Grosse des Druckes und der Flache auf den Kontakwiderstand" (The Influence of the Magnitude of the Pressure and the Surface on Contact Resistance) (Dissertation), Dresden (1929).

No. 204. H. Franken, "Low-Voltage Oil Switches," *E.u.M.*, Vol. 47, March 10, 1929, pp. 192–196.

The author discusses the advantages of using oil switches for low voltages, the chief of which is a saving of space. Care must be taken to insure rapid extinction of the arc when used on d. c., as a d-c. arc disintegrates

the oil. Curves are given showing the relation between the rupturing current and the number of switch operations before failure for a certain range of switches from which the approximate life of the switch can be determined. Some examples showing the application of the curves are given. (*Science Abstracts*)

No. 205. J. A. Crowther, "Ions, Electrons and Ionizing Radiations," Fifth Edition, Edward Arnold & Co., London (1929).

Discusses conduction of current by gaseous ions, the spark discharge, and discharge tubes.

No. 206. K. G. Emeleus, "The Conduction of Electricity Through Gases," E. P. Dutton and Co., Inc., New York (1929).

This book gives an outline of the main phenomena which can be studied quantitatively in connection with the passage of electricity through gases at low pressures. The book is particularly devoted to the glow discharge. The table of contents is as follows: Introduction, Initiation of the Discharge, Cathode Phenomena, Exploring Electrodes, The Negative Glow, Faraday Dark Space, and Anode Glow, Positive Column of Glow-Discharges, and Miscellaneous Phenomena.

No. 207. R. C. Dickinson and B. P. Baker, "Structural Development of the Deion Circuit Breaker," *Trans.*, A.I.E.E., Vol. 48, April, 1929, pp. 528–534. Discussion, pp. 545–553.

An experimental model of the Deion circuit breaker was constructed consisting of three single-pole units, each of which comprises a Deionizing chamber, an arc drawing mechanism, main contacts for the load current, and the necessary operating mechanism. Short circuit currents in excess of 15,000 amp. at 12,000 v. from a 20,000-kva. generator have been consistently broken in field and laboratory tests. (*Abstracts in J.*, A.I.E.E., Vol. 28, February, 1929, pp. 96–110.) (*Science Abstracts*)

No. 208. S. S. Mackeown, "The Cathode Drop in an Electric Arc," *Phys. Rev.*, Vol. 34, August 15, 1929, pp. 611–614.

By making the assumption that the total cathode drop occurs in a distance less than one mean free path from the cathode, Poisson's equation can be solved. If the experimental values of 4000 amp. per sq. cm. and 10 v. are used for the current density at the cathode, and the cathode drop in a mercury arc, values for the electric field existing at the surface of the cathode can be determined for varying percentages of the current carried by positive ions. If 5 per cent of the current at the cathode is carried by positive ions, the field existing at the surface of the cathode exceeds 5×10^6 v. per cm. This is probably sufficient to furnish the necessary electron current by "field" currents produced by this high field. The whole cathode drop occurs within a distance of approximately 2×10^{-5} cm., so that the original assumption is justified. (*Science Abstracts*)

No. 209. W. B. Nottingham, "Copper Arc," *J.*, Frank. Inst., Vol. 207, March, 1929, pp. 299–314.

The Langmuir probe has been used to explore the copper arc. The average energy of electrons throughout the arc is between 2.1 and 2.7 v. (*Science Abstracts*)

No. 210. J. Slepian and E. J. Haverstick, "Arcs with Small Cathode Current Density," *Phys. Rev.*, Vol. 33, January, 1929, pp. 52–54.

Arcs with cathode current densities of less than 100 amp. per sq. cm. have been found to exist at gas pressures of from 10 to 50 mm. The theory that electrons are drawn from the cathode by intense electric fields maintained by space charges cannot apply to these arcs. (*Science Abstracts*)

No. 211. "Work and Equipment of the Material-Testing Departments," *Brown Boveri Rev.*, Vol. 16, No. 1, pp. 61–62 (1929).

Measurements of temperature and voltage drop in a mercury arc.

No. 212. W. Wilson, "Design of Low Tension Switchgear," *World Power*, Vol. 12, October, 1929, pp. 321–327.

The chief principles underlying the design of low tension switchgear are reviewed. Curves are given of the current and voltage at which arcs appear on breaking for various contact materials. Notes are given on the design of contact surfaces, and the following types are described: radial arm, knife, drum and finger wedge, horn (contactor) laminated and the "V" type. The design of the actual breaking surfaces and the arrangements for minimizing the effect of arc are treated, and the electrodynamic effect of current is also treated. (*Science Abstracts*)

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No. 213. J. Frenkel, "The Electrical Resistance of Contacts Between Solid Conductors," *Phys. Rev.*, Vol. 36, Part II, December, 1930, pp. 1604–1618.

A contact between two solid conducting bodies is visualized as a small gap between them. This gap can be described as a potential hill over which electrons, according to the wave-mechanical theory, can pass even with insufficient kinetic energy. The general expression of the resulting current intensity as function of the potential difference is obtained and discussed for the case of two identical or different bodies in connection with the resistance of granular structures (thin metal-

lic films) and the rectifying action of certain contacts.

No. 214. M. Bergstein, "Studies in Contact Rectification. Classification of Contact Rectifiers," *Trans.*, Am. Electrochem. Soc., Vol. 57, p. 419 (1930).

Preliminary to a general study of contact rectification, the known contact rectifiers are classified according to mechanical structure and the chemical nature of the more electronegative member. In contact rectifiers current flows generally from the more electronegative member to the more electropositive, but at lower a-c. voltages (as indicated for copper sulfide-magnesium) the current flow may be in the reverse direction. An adequate theory of contact rectification must explain both these phenomena. (*Chemical Abstracts*)

No. 215. F. S. Goucher, "Contact Resistance and Microphonic Action," *Phys. Rev.*, Vol. 36, Part II, July, 1930, p. 375.

Previous work has shown that the conducting portions of contacts between single granules of microphone carbon are of the nature of carbon and that variations in contact area occur when the contact resistance is varied in a reversible resistance force style. An experimental study of the slopes of these reversible characteristics both for single contacts and aggregates shows them to be of the form R = constant $(F)^{-n}$. The exponent n varies from cycle to cycle for equal force limits and the average value depends on the force limits. A maximum mean value, independent of the force limits over a wide range, is obtained with the aggregates. This value is in agreement with the exponent in the second term of Gray's equation $R = (A/F^{1/3}) + (B/F^{7/9})$ which indicates that an aggregate of contacts may, under certain conditions, behave as though it were a single contact between spheres having a rough surface. Values of n less than $1/3$ are obtained with both single contacts and aggregates. This is attributed to the effect of cohesive forces, the existence of which was demonstrated by the sticking of contacts. (*Science Abstracts*)

No. 216. F. Gray, "Contact Resistance and Microphonic Action," *Phys. Rev.*, Vol. 36, Part II, July 1930, p. 375.

A mathematical theory is developed to explain the fact that conductivity of a contact between two carbon spheres changes with the force pressing the spheres together. It is assumed that the surface roughness of the carbon is equivalent to an assembly of minute spherical hills. On account of the elasticity of the material, both the microscopic area of contact between the spheres and the microscopic areas of contact between the hills increase with contact force. The resulting relation between the contact resistance R and the contact force F is $R = A/F^{1/3} + B/F^{7/9}$ where A and B are constants. The last term of this equation, contributed by surface roughness, is almost the same as the corresponding term of the equation, $R = A/F^{1/3} + B/F^{6/9}$ which was developed by Professor P. O. Pedersen (*Electrician*, February 4, 1916) on the assumption that carbon is covered with a thin, high-resistance film. In other words, surface roughness behaves almost identically with a nonvariable, high-resistance film. Higher degrees of roughness increase the exponent of the last term. In the limit it becomes unity, and the roughness resistance then varies inversely as the contact force. (*Science Abstracts*)

No. 217. M. Bergstein, J. F. Rinke, and C. M. Gutheil, "Studies in Contact Rectification," Part II. The Cupric Sulfide-Magnesium Junction, *Phys. Rev.*, Vol. 36, pp. 587–599 (1930).

The commercial copper sulfide-magnesium junction consists of a disk of heat treated, compressed copper sulfide powder contacted under pressure with the suitably oxidized face of a magnesium disk. This rectifier is of the nonintegral class and sulfide group. Oscillographic evidence indicates the formation of a film which possesses relatively high resistance to current flow from the magnesium to the cupric disk, slow partial destruction of the film on continued current flow in the opposite (low resistance) direction and "reformation" of the film within 0.004 sec. when sufficient voltage is applied to send a current in the high-resistance direction. Similar evidence indicates that there is no battery or thermoelectric effect within the junction of sufficient magnitude to account for rectification, and that film "formation" and "destruction" are consequently electrothermic rather than electrolytic in origin. The phenomenon of "reverse rectification" is described. It is related to the a-c. voltage across the junction. Preliminary results for the relationship between efficiency and operating temperature of a bridge-type unit are in quantitative agreement with the theories which require film formation. (*Chemical Abstracts*)

No. 218. R. Holm, "A Method for Determination of the Heat Conductivity of Metals, Particularly at High Temperatures," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 9, pp. 300–311 (1930).

Following a discussion of the theory of the method, calculations are made concerning the lateral heat loss by radiation and gaseous conduction and the establishment of temperature equilibrium in the requisite time. (*Chemical Abstracts*)

No. 219. R. Holm and R. Störmer, "Measurement of the Heat Conductivity of a Platinum Test Piece in the Temperature

Region 19–1020°," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 9, pp. 312–322 (1930).

For platinum, 99.95 per cent pure, from 15 to 1020 C, the specific resistance, $p = 1.048 \times 10^{-6}(1 + 3.695 \times 10^{-3}(t - 15) - 5.98 \times 10^{-7}(t - 15)^2 + 5.25 \times 10^{-11}(t - 15)^3)$; and the heat conductivity, $k = 0.699\ (1 + 2.83 \times 10^{-4}(t - 19.5))$. (*Chemical Abstracts*)

No. 220. R. Holm and R. Störmer, "A Study of the Character of Purified Platinum Contacts," *Wiss. Veröff. a. d. Siemens-Konzern* Vol. 9, pp. 323–330 (1930).

Measurements of contact resistances at various temperatures and pressures show agreement with resistances calculated by formulas. (*Chemical Abstracts*)

No. 221. E. W. Engle, "Design and Metallurgy of Contact Points," *Elec. Mfg.*, Vol. 6, No. 2, August, 1930, pp. 39–41 and 78.

Relays, fire alarms, and annunciator systems are among electrical products that depend at all times upon reliable contact points to make and break electrical circuits; author describes great care that must be taken in selecting materials for and manufacturing of contact points used in electrical apparatus. (*Engineering Index*)

No. 222. Ward B. Kindy, "Control Contacts and Arc Lengths in Low-Capacity, Direct-Current Circuits," *Elec. J.*, Vol. 27, December, 1930, p. 727.

A knowledge of the characteristics of the arc which is drawn when a low-capacity, low-voltage, direct-current circuit is opened by a set of contacts is quite essential in the design of the control circuits of modern automatic and remotely controlled electrical equipment. The control circuits often seem insignificant when compared with the larger pieces of apparatus carrying heavy current, and may not receive so much consideration in their design. Also, on account of their low capacity, control contacts are usually small; and their poor condition, in many cases, is not evident until a serious failure of the whole equipment takes place.

The final conclusion is that, for the minimum heating of contacts during the breaking of a circuit, the contacts should be designed with a sufficient final separation to break the arc completely before the movable contact reaches the end of its travel. This is especially true for noninductive circuits. Excessively long arcs may be drawn out in highly inductive circuits, and improved operation can be effected by decreasing the opening speed of the contacts. (Quoted from the paper)

No. 223. "Life of Break-Make Impulsing Contacts of Horizontal Type 200–200 Ohms Relays," P. O. Eng. Dept., *Res. Rep. No. 4025*, December 1, 1930.

No. 224. A. L. Müller, "Duration of Arc in Oil Switches," *Arch. f. Elektr.*, Vol. 24, November 7, 1930, pp. 503–524.

Oil switch troubles due to defective insulation or mechanism can be remedied by constructive measures, but the conditions in the arc during the actual period of interruption of the circuit are not easily susceptible to calculation. The author attempts to reduce the complicated phenomena to terms of specific coefficients. The action of circuit breaking under oil is discussed; also the physical properties of the arc. The greater part of the paper deals with the duration of the arc and the influence on it of the voltage of the terminals, the power factor of the circuit, the rate of voltage increase after the current passes through zero, the supply frequency, and the constructional characteristics of the switch (velocity, pressure, material and shape of contacts, blowout effect, etc.). In conclusion, the time characteristics of the arc voltage and the arc voltage-current characteristic are examined. (*Science Abstracts*)

No. 225. R. Seeliger and H. Wulfhekel, "Loss of Material from the Cathode in Metal Arcs," *Ann. d. Phys.*, Vol. 6, No. 1, p. 87 (1930).

Experimental investigation of loss of material from iron, silver, or copper cathodes in arcs in air, nitrogen, or neon. Curves given of such loss against current density, cathode thickness, arc length, and gas pressure. (*Science Abstracts*)

No. 226. M. J. Druyvesteyn, "Low-Voltage Arc," *Zeits. f. Phys.*, Vol. 64, Nos. 11 and 12, pp. 781–798 (1930).

Two theories of the low-voltage arc, that of Holst and Oosterhuis and that of Compton and Eckart, are discussed. The latter is extended somewhat and furnishes the most probable explanation of low-voltage arc phenomena. The extension of the theory consists in the assumption of a transfer of energy from rapid to slow electrons; this transfer must take place very frequently for high electron concentration (greater than 10^{12}). The spectrum of the low-voltage arc in argon is next discussed, and experiments on low-voltage arcs in argon and neon are described. The results obtained by probe measurements showed a potential maximum of about 11.4 v. (in relation to the potential of the cathode) for argon and 18.5 v. for neon, corresponding to the excitation potential of the ls-level for argon (11.7 v.) and of the 2p-level for neon (18.5 v.). The highest electron concentration was approximately 2×10^{12} electrons per cu. cm. The probe theory of Langmuir and Mott-Smith is extended and from one formula and the probe characteristic it is found possible, by differentiating twice, to obtain the velocity distribution of the electrons. (*Science Abstracts*)

No. 227. M. Wehrli, "Probe Characteristics, Space Potentials and Electron Groups in the Tungsten Arc," *Helv. Phys. Acta*, Vol. 3, Nos. 3 and 4, pp. 180–204 (1930). (In German.)

Measurements are made of the probe characteristics of stationary probes in a tungsten arc in nitrogen at a pressure of 260 mm., both near the anode and near the cathode. Under these experimental conditions the probes are caused to glow and for this reason the behavior of glowing probes, heated by some external means, was specially investigated. A definite connection was found between the position of the space charge and the probe characteristic. The cathode fall of potential calculated from the space potential was found to be nearer to that obtained by the method of impeded discharge than to the value determined statically. In front of the cathode three electron groups were found: a primary mobile group, a secondary group with an electron temperature of 43,000 K., and third irregular group at 11,000 K. In the middle of the arc the primary group is small and only a secondary group at 79,800 K, is found. In front of the anode is found only the irregular group with a high temperature of 121,000 K. (*Science Abstracts*)

No. 228. K. Steimel, "Stability and Self-Excitation of Electric Circuits, Including Devices with Falling Characteristics," *Hochfreq. u. Elektroaeitik*, Vol. 36, p. 161, November, 1930.

No. 229. W. Cramp and A. P. Jarvis, "Geometrical Analysis of Open Carbon Arc Phenomena," *J.*, I.E.E., Vol. 68, p. 1301, October, 1930.

No. 230. A. Cohn, "Circuit Breaker Arcing and Commutator Flashover," *AEG-Mitt*, February, 1930, p. 130.

Describes construction and experimental use of high speed camera, 4000 pictures per second, which was used to photograph arcing in circuit breakers and commutator flashovers. Simultaneously taken oscillograms given for comparison with photos. (*Science Abstracts*)

No. 231. J. Slepian, "Flames from Electric Arcs," *Trans.*, A.I.E.E., Vol. 49, No. 1, pp. 56–59, January, 1930.

No. 232. L. W. Dyer, "Field Tests on Deion Grid Circuit-Breakers," *Elect. World*, Vol. 95, April 19, 1930, pp. 786–792.

Describes further tests (*Sci. Abst.*, 1061 and 2016 (1929)) of the "Deion" circuit breaker for high-voltage transmission circuits, at 66 and 110 kv. and ruptures up to 1,170,000 kva. Oscillographs are given which show that the arcing is extinguished in a few cycles, after short circuits lasting approximately 10 cycles. (*Science Abstracts*)

No. 233. L. W. Dyer, "220-Kv. Tests on Deion Grid Circuit-Breakers," *Elec. World*, Vol. 95, April 26, 1930, pp. 844–848.

Field tests at 66 kv. have been described (see preceding Abstract). This article describes tests at 220 kv. with faults up to 3000 amp. The circuit breaker cleared in 7.5 cycles. All the line-to-earth faults were cleared satisfactorily. Some slight distress was shown in the line-to-line tests, suggesting some slight alteration in the design of the grid. The good results of the tests are emphasized. (*Science Abstracts*)

No. 234. Y. Asai, "Available Life and Current Consumption of Contact Metals in Automatic Telephone Switches," *Circ. Electrot. Laborat.* Tokyo, Japan, No. 67, February, 1930.

No. 235. F. C. Todd and T. E. Browne, Jr., "Restriking of Short A.C. Arcs," *Phys. Rev.*, Vol. 36, August 15, 1930, p. 732.

The restriking after zero current of short stationary a-c. arcs with brass, copper, zinc, iron, tungsten, and carbon electrodes, and of arcs moving rapidly over copper electrodes was investigated with a cathode-ray tube of the Braun type. The volt-ampere traces on the fluorescent screen showed clearly the voltage necessary to restrike the arc after current zero, and the effect of the electrode vapor on the magnitude and variation of the restriking voltage. The arcs with refractory electrodes, that is, carbon and tungsten, showed traces differing from the arcs with the other metals in that no high voltage for restriking the arc appeared. This is believed to be due to the refractory electrodes being at a temperature high enough for thermionic emission. For the other electrode materials, reignition voltages of several hundred volts were observed, suggesting that reignition of the arc required breakdown of a gas layer by ionization by collision alone. The arcs which were rapidly moving over their electrodes usually restruck to a glow before breaking down to an arc. The magnitudes of the restriking voltage and the glow current depended upon the condition of the electrodes, magnitude of the driving magnetic field, and the transient characteristic of the circuit in which the arc was playing. (Author's abstract)

No. 236. S. D. Norberg, "Oil Circuit Breakers," *Proc.*, Roy. Swed. Inst. Eng. Res., No. 102, Svenska Bokhandelscentralen A.-B., Stockholm (1930).

No. 237. J. Slepian, "Extinction of a Long A-C. Arc," *Trans.*, A.I.E.E., Vol. 49, No. 2, p. 421 (1930); *J.*, A.I.E.E., Vol. 49, April, 1930, p. 310.

The extinction of an a-c. arc is analyzed as depending on two factors: the rate of recovery of dielectric strength of the arc space after current zero, and the rate at which

voltage tending to reignite the arc is applied by the external circuit. In the short arc, most of the recovered dielectric strength resides in a deionized layer next to the cathode but in the long arc the rest of the arc space contributes largely to the dielectric strength. The breakdown gradient of the still ionized arc space is defined, and using a thermal ionization theory, a formula for growth of breakdown gradient is derived.

The extinction of long a-c. arcs in the open is greatly influenced by the sectional area which the arc stream has at current zero. By confining arcs to slots and holes, the rate of deionization at current zero is greatly increased, and so large voltages per centimeter of arc can be interrupted.

A gas blast passing turbulently through an arc stream greatly accelerates deionization at current zero and so is effective in increasing the capacity of the a-c. arc to interrupt high-voltage circuits. The expulsion fuse is an example of a gas blast circuit interrupter, the gas blast resulting from the decomposition of the fiber fuse case.

The oil circuit breaker is also a gas blast circuit interrupter, the blast arising from the gases produced by the decomposition of the oil. Means which increase the rate of oil decomposition improve the operation of the breaker. The magnetic blowout in oil breakers is effective by causing an increased rate of oil decomposition.

Electrostatic unbalance may lower the volts per centimeter which a long arc can interrupt. The use of static balancing devices may then become advisable. (Author's synopsis)

No. 238. T. E. Browne, Jr., "Extinction of Short A-C Arcs Between Brass Electrodes," *Phys. Rev.*, Vol. 36, August 15, 1930, pp. 726–731.

Results are given which show that the dielectric recovery after current zero, of short, stationary a-c. arcs between brass electrodes is similar to that of cold cathode arcs previously investigated and described. These results also show that the rate of recovery of dielectric strength of hot electrode arcs after a current zero may be greatly increased by reducing, within limits, the electrode separation. A possible explanation on the basis of ionic diffusion to the electrode surfaces and the deionizing action of blast metal vapor from the boiling electrodes is mentioned. (*Science Abstracts*)

No. 239. F. Wenner, G. W. Nusbaum, and B. C. Cruickshanks, "Electrical Resistance of Contacts Between Nuts and Bolts," *Journ. Res., Nat. Bur. Stds.*, Vol. 5, September, 1930, pp. 757–766.

Measurements were made of the electrical resistance between nuts and bolts, using two radically different types of threads, the American National and the Dardelet, and different materials. It was found that under similar conditions the resistance of the Dardelet thread is, in general, not more than one fourth that of the American National thread. The maximum resistances found were for steel bolts having the American National thread, and the minimum resistances found were for copper bolts having the Dardelet threads.

No. 240. W. Kaufmann, "Specified and Actual Switching Capacities of Circuit Breakers," *ETZ.*, Vol. 51, June 19, 1930, pp. 895–901.

The object of the paper is to examine the relation between the switching capacity (maximum current for a given voltage), as given from calculations based on the electrical and physical characteristics of the circuit breaker and the true capacity of the circuit breaker as obtained from practical tests. For this purpose the results of a large number of experimental measurements are first examined for the simple case of symmetrical nonresonating currents, and it is shown that even in this case the short-circuit capacities of the switches, as obtained when applying the definitions given in the German, Swiss, or American specifications, do not really reproduce values obtained under practical working conditions. For more complicated nonsymmetrical short-circuit currents no formula can be devised which would cover the requirements under working conditions. The conclusion is arrived at that it would be best to express the short-circuit rupturing capacity of a circuit breaker in terms of the maximum current which can be interrupted and the magnitude of the reestablished voltage. (*Science Abstracts*)

No. 241. A. von Engel, "Electric Arc in Oil," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 9, No. 1, pp. 7–41 (1930).

An investigation was made for the electric arc of the minimum potential required for maintenance, the field strength in the positive column, and also the striking and quenching potentials using an oscillograph. The quantity of gas set free by an arc in a steady state was found to depend on the current, and for short arcs also on the arc length. A spectroscopic examination was made of the light from an arc in oil. A table of the lines observed is given. (*Science Abstracts*)

No. 242. L. C. Grant, "Breaking Performance of High-Power Switch Gear and of a New Form of Quenched-Arc Switch," *J.*, I.E.E., Vol. 68, January 31, 1930, pp. 1089–1110.

The oil switch, as usually constructed, in the very act of breaking a circuit under oil brings a high-temperature arc into contact with the oil, with the result that pressures are set up which are not necessarily dependent

upon the actual circuit power being broken. The effect of phase angle, influence of layout of system, speed of breaking, and the effect of oil head have important effects upon the process of circuit rupture. A description is given of investigations to assess the effect of these and other factors. A large number of curves and drawings are given. A circuit breaker involving new principles was evolved and tested under short circuit conditions. Its performance is stated to be superior to that of the usual switch. (*Science Abstracts*)

No. 243. F. Kesselring, "Expansion Switch," *ETZ.*, Vol. 51, April 3, 1930, pp. 499–508.

The stability equation for an a-c. arc burning in a vapor is given in terms of the absolute temperature of the vapor and the instantaneous voltage. It is shown that the quenching effect depends only on the Wilson effect, from which the quenching process in vapors and the action of the oil switch can be satisfactorily explained. This leads to the expansion switch or high-power switch without oil, which consists experimentally of a switch situated in a chamber filled with vapor, for example, water vapor at a pressure of several atmospheres, connected by a thin tube to a vapor-generating chamber. In the base of the switch is a valve having a large area compared with the connecting tube. On the breaking of the switch, the valve opens giving rise to a rapid adiabatic expansion of the vapor in the switch base and quenching the arc. A comparison of the quenching curves for compressed air and the expansion switch is given. (*Science Abstracts*)

No. 244. A. Cohn and Ulbrich, "Multiple Spark Chambers for Air Switches," *Forsch. u. Techn.*, p. 333 (1930).

No. 245. E. Kobel, "Pressure and High-Velocity Vapor Jets at the Cathode of a Mercury Vacuum Arc," *Phys. Rev.*, Vol. 36, December 1, 1930, pp. 1636–1638.

The amount of vaporization of copper from the cathode of a copper arc as measured by Tanberg, as well as the velocity of this vapor calculated from the force of reaction on the cathode, agree closely with the values obtained by another method from the cathode of a mercury arc. With a mercury arc and fixed cathode spot, the mercury vaporization is 0.017×10^{-3} g. per amp. sec. and the vapor velocity 16 to 43×10^5 cm. per sec. (*Science Abstracts*)

No. 246. K. T. Compton and E. S. Lamar, *Science*, Vol. 71, p. 517 (1930).

No. 247. R. Tanberg, "Cathode of an Arc Drawn in Vacuum," *Phys. Rev.*, Vol. 35, May 1, 1930, pp. 1080–1089.

It has been found that the cathode is the only electrode which contributes vapor for the maintenance of an electric arc under very low gas pressure. The velocity of this vapor was determined by two methods and both methods gave a velocity of the order of 16×10^5 cm. per sec. (*Science Abstracts*)

No. 248. E. G. Bern and W. Specht, "Joints in Heavy Electrical Conductors," *G. E. Rev.*, Vol. 33, July, 1930, pp. 389–393.

The subject is dealt with under the following headings: preparation of contact surfaces; effects of pressure; maintenance of bolted and clamped joints; design of joints; preservation of contacts. A draw-file contact surface finish is recommended; also a film of oil or vaseline to prevent oxidation. A table of standard arrangements for the bolting of busbars and connection bars of copper $1/_2$ in. thick is given. (*Science Abstracts*)

No. 249. R. H. Park and W. F. Skeats, "Circuit-Breaker Recovery Voltages," *J.*, A.I.E.E., Vol. 49, December, 1930, pp. 1017–1021.

The duty of a circuit breaker was found to be more severe when connected direct to the generators than when a transmission line was interposed. The difference can be explained by the brief "kicks" which occur in the recovery voltage and the time delay required for their establishment. The phenomena of recovery voltage are divided into l. f. and h. f. effects. These effects are examined by means of oscillograms and curves. (*Science Abstracts*)

No. 250. J. Frenkel, "Electrical Resistance of Contacts Between Solid Conductors, *Phys. Rev.*, Vol. 36, December 1, 1930, pp. 1604–1618.

A contact between two solid conducting bodies is visualized as a small gap between them. This gap can be described as a small potential hill over which electrons, according to the wave-mechanical theory, can pass even with insufficient kinetic energy. The general expression of the resulting current intensity as a function of the potential difference is obtained and discussed for the case of two identical or different bodies in connection with the resistance of granular structures (thin metallic films) and the rectifying action of certain contacts. (*Science Abstracts*)

No. 250a. H. G. Taylor, "Phenomena Connected with the Collection of Current from Commutators and Slip-Rings," *J.*, I.E.E., Vol. 68, p. 1356 (1930).

One of the troubles experienced in the collection of current is that of "copper picking." A description is given of an experimental investigation of this phenomenon, and this is followed by a critical survey of existing data, leading to an explanation to account for this disposition of metal, and an investigation into the mechanism of the

passage of current from the slipring or commutator to the brush.

The variation of contact voltage drop with speed, brush pressure, and current is shown. Peripheral speeds higher than previously have been used and an investigation has been made at very low current densities.

In order to show the variation of contact voltage drop oscillograms have been taken which show its fluctuating nature. These oscillograms show the effect of increased speed and brush pressure, and the change in nature of the contact as the latter is reduced. Intermittent contact is shown to account for rising voltage drop with speed, but a speed is attained at which an air film is drawn between the brush and the ring. (Author's abstract)

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No. 251. G. Hara, "Contact Conduction and Rectification," *Ryojun Coll. Eng., Mem.*, Vol. 3, No. 4a, February, 1931, pp. 223–244.

Theories of conduction across surfaces in contact and their use for rectification have been propounded since the beginning of the century. Houston, using Sommerfeld's theory of metallic conduction, has built up a theory of cold electron emission. Here the theory has been carried still further to account for contact conduction, and to clear up its mechanism and also that of rectification. Diagrams are shown of both theoretical and experimental results. (*Science Abstracts*)

No. 252. R. Holm, "Theory of Metallic Contacts," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 10, No. 4, pp. 1–19 (1931).

A foreign layer in a contact causes, as a rule, a transition resistance far surpassing the extension resistance, and this is nearly proportional to the thickness of the layer. Where, however, a foreign layer only a few molecules thick may be assumed, there appear transition resistances which are smaller by several powers of ten than would be expected from proportionality to the thickness. It is possible that such "extended skins" play for the conducting electrons the easy role for penetrating potential surges. Yet it is probable that in the observations made the stretched skin material in the metal was pressed in so that "disturbed metallic" contact existed. The actual foreign layers could, in general, be frittered or caked (coherence effect) by field strengths of the order of magnitude of 10^6 v. per cm. Therefore, there exist in them small metallic bridges between the electrode surfaces whereby an improved conductivity comes into existence which lasts as long as the bridges remain intact. The frittering can develop into destructive penetration. The collision ionization penetration is thereupon changed in nature. The principles for the calculation of the dimensions of the bridges are given. The resistance-tension characteristics of a virgin contact experiences a dissolution falling off if the current raises the contact surfaces to the dissolution temperature. (*Science Abstracts*)

No. 253. R. Holm, "Metallic Contacts with Very Thin Foreign Layers," *Zeits. f. Techn. Phys.*, Vol. 12, No. 12, pp. 663–665 (1931).

This is a preliminary paper giving the results of experiments on contacts between metallic surfaces. Thin foreign skins form quickly in air on ordinary metals (not noble). They remove the metallic adhesion but change only slightly the electric resistance of the contact at room temperature. Their conduction is of a special kind; it changes but little with falling temperature, until it eventually, as in the case of *Sw*, passes over into superconduction. (*Science Abstracts*)

No. 254. R. Holm, F. Güldenpfennig, Else Holm, and R. Störmer, "Metallic Contacts," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 10, No. 4, pp. 20–64 (1931).

An account of the experimental basis for R. Holm's theory of metallic contacts (*Sci. Abst.*, 252 (1931)), in which the results are given of observations on the contact of nickel-nickel oxide against gold, nickel, or graphite, nickel flake against gold or graphite, copper-cupric oxide against gold. In certain cases the dimensions of the caking bridges could be calculated. Their mechanical rigidity is what was expected. The thickness of the layers was estimated by means of observations on the interference colors. The formation of stretched skins and foreign layers at metal surfaces is followed up till contact. Various observations on the influence of contact pressure as well as adhesion of contacts, are discussed. (*Science Abstracts*)

No. 255. J. B. Seth, B. Gulate, and S. Singh, "E. M. F. Between Two Metals in Relative Motion," *Phil. Mag.*, Vol. 12 August, 1931, pp. 409–429.

In 1928 Lafay found that when against the rim of a metal disk rotating at a known speed another metal pressed, an emf. was developed which he gave as proportional to the relative speed of the two rubbing surfaces and independent of the pressure between them. The authors have repeated and extended Lafay's experiments and have obtained much higher emf.'s than those got by Lafay, and have examined a large number of metals pressed against a rotating steel disk moving at high speeds. The order of the metals when arranged according to the emf. developed is generally that of the Volta contact potential series, but there are important exceptions wbich may be due to the particular treatment

of some of the metals in the author's experiments. (*Science Abstracts*)

No. 256. "The Effect of Fumes from Wax Floor Polish on the Fault Liability of Relay Contacts and the Lubrication of Apparatus," P. O. Eng. Dept., *Res. Rep. No. 5351*, January, 1931.

No. 257. H. Poole, "Switchgear Practice," Chapman (1931).

No. 258. A. Boyajian, "Mathematical Analysis of Non-Linear Circuits," *G. E. Rev.*, Vol. 34, September, 1931, p. 531; December, 1931, p. 745.

No. 259. G. M. Schrum and H. G. Wiest, Jr., "Experiments with Short Arcs," *Elec. Engg.*, Vol. 50, October, 1931, pp. 827–829.

This investigation is concerned chiefly with short arcs of a few millimeters between iron and copper electrodes in air and in certain inert gases, the pressures ranging from atmospheric to about 1 mm. mercury. Rather than the temperature of the cathode, the current density at the electrode is shown to be the factor determining when the transition from the abnormal glow discharge to the striking of the arc takes place. Steady arcs could be maintained in argon, nitrogen, and hydrogen after the cathode had been oxidized to prevent wandering of the cathode spot. Increased stability and a greater voltage drop across the arc were observed when moist gas was used instead of dry air. Diagrams are given of the apparatus and the circuit employed.

No. 260. G. G. Grissinger, "Air Circuit-Breaker Tests," *Elec. J.*, Vol. 28, August, 1931, pp. 464–465.

Gives details of some large capacity tests carried out on a 4000-amp. carbon-break air circuit breaker which successfully interrupted 70,000 amp. at 750 v. d.c. From this and other tests it appears that the ability of a breaker to interrupt a large short circuit depends but little on the voltage between 220 and 750 v. but largely on the inductance of the circuit. Further, a d-c. load may be handled more easily than an a-c. load of less rms. magnitude on account of the asymmetric peak of the first half cycle of the latter.

No. 261. H. Klemperer, "Dynamic Behavior of the Electric Arc Observed in Investigations with the Cathode-Ray Oscillograph," *Arch. f. Elektr.*, Vol. 25, January 27, 1931, pp. 73–80.

In observations of electric breakdown in air at atmospheric pressure it has been found that frequently the residual potential at the spark gap after the breakdown gives rise to an arc. Experiments were carried out to see whether such arcs, immediately after their formation, have properties similar to those of static arcs. It was found that within 10^{-6} sec. after the breakdown the normal characteristics of static arcs were found at the spark gap, though the arc potential initially is higher than with normal arcs. (*Science Abstracts*)

No. 262. F. Thornton, Jr., and O. S. Jennings, "Domestic Circuit-Breaker," *Elec. J.*, Vol. 28, February, 1931, pp. 117–119.

Description of the construction and application of a simple circuit breaker for branch circuits little larger than an ordinary tumbler switch, depending for its action on the deformation of a bimetallic strip when heated by an overload current. (*Science Abstracts*)

No. 263. J. B. MacNeill, "Development Trends in Circuit-Breakers," *Elec. Engg.*, Vol. 50, April, 1931, pp. 260–265.

Several novel circuit breakers are showing possibilities of commercial importance. Some representing improvements to oil circuit breakers and others indicating a possible trend toward the nonoil type of equipment. Deion, compressed-gas, expansion, vacuum, and oil breakers are discussed briefly in the light of present laboratory knowledge. (*Science Abstracts*)

No. 264. K. Kesl, "New Electric Contact for Heavy Currents," *Bull. 22*, Assoc. Suissel, March 6, 1931, pp. 105–112.

The author describes a new type of finger contact for use in heavy current switchgear. The movable contact is forced between two fixed fingers which are pivoted at a point near their centers, the remote ends being provided with a spiral spring which maintains the contact pressure. An oil damping device can also be used and is described. With this contact currents up to 30,000 amp. have been dealt with satisfactorily. The last section of the article contains a full mathematical treatment of the problems connected with mechanical forces and damping, and is illustrated by a numerical example. (*Science Abstracts*)

No. 265. C. Cippitelli and O. Schwenk, "Switch Contacts for Breaking Heavy Short-Circuit Currents," *ETZ.*, 52, February 26, 1931, pp. 263–264.

The authors describe and illustrate a new type of contact for isolating switches, which they claim is able to break short circuit currents considerably in excess of those which can be handled with ordinary knife switches without destructive arcing of the contacts. The contacts are of the plug type and consist of a large number of V-shaped contact strips arranged in a ring formation. The outer edges of the strip make contact with the inside of a cylindrical socket mounted on the fixed insulator in which the rings are inserted, while the inner edges form the contacts for the plug in the movable arm. (*Science Abstracts*)

No. 266. W. Schilling, "Switching Process in a Capacity-Loaded Finite Conductor Investigated by Operator Calculations, *Arch. f. Elektr.*, Vol. 25, April 15, 1931, pp. 241–252.

The process of switching a current with a wave-front of finite steepness into a circuit of finite conductance with capacity loading is investigated by operator methods. The paper is mainly mathematical, but some oscillograph records are given which show good agreement with the calculated wave forms. (*Science Abstracts*)

No. 267. S. S. Attwood, W. C. Dow, and W. Krausnick, "Reignition of Metallic A.C. Arcs in Air," *Trans.* A.I.E.E., Vol. 50, p. 845 (1931).

Developments made in circuit breakers in the last two years have emphasized the necessity for obtaining experimental evidence of the current-voltage-time relationships that exist during the period when the a-c. arc between metallic electrodes passes through its cyclic current zero. Twenty nine cathode-ray oscillograms of these relationships are presented.

During the current zero period the arc electrode voltage is determined by the circuit constants and rises until the electrode voltage reaches the breakdown or reignition value, which is determined by the deionizing influences at work while the arc is extinguished. Alteration of the circuit constants permits a variation in the rate of voltage rise with a consequent change in the reignition voltage.

Permanent extinguishment of the arc occurs when the gap breakdown voltage has risen, due to deionizing influences, to a value that cannot be reached by the electrode voltage controlled by circuit constants.

The action of a circuit breaker in extinguishing an arc is greatly influenced by the presence of adjacent load circuits and by the presence of distributed inductance and capacity in the connecting lines. (Authors' synopsis)

No. 268. T. E. Browne, Jr., "Extinction of Short A.C. Arcs," *Trans.*, A.I.E.E., Vol. 50, December, 1931, p. 1461.

This paper presents the results of a study made with short, stationary a-c. arcs between metallic electrodes, in order to determine the effect of arc length, electrode material, and current magnitude on the rate of recovery of dielectric strength of the arc space following a current zero.

The experimental results show (1) that the arc space recovers the ability to withstand 100 v. or more within a few microseconds after a current zero, as predicted by Slepian's theory, (2) that the maximum allowable rate of rise of voltage across the arc space which will just permit arc extinction is much greater for very short arcs (1 cm. or less) than for longer arcs, (3) that the critical rate of rise of voltage depends largely on the electrode materials used and tends to vary as a decreasing linear function of the boiling point, and (4) that the higher current arcs have a much lower critical rate of rise of voltage than the lower current arcs. (Author's synopsis)

No. 269. D. C. Prince and E. B. Noel, "Efficacy of the Oil-Blast Principle Confirmed by Photography," *G. E. Rev.*, Vol. 34, December, 1931, pp. 722–724.

Describes the procedure adopted for photographing the interior of the circuit breaker while in operation, and shows motion picture records of the contacts of impulse-type oil circuit breakers and oil-blast circuit breakers clearing short-circuit currents of 4500 amp., 5900 amp., and 1220 amp. The tests were made on, and the records obtained from full-size circuit breakers.

No. 270. H. Franken, "Contact Wear as Criterion of Quality for Electrical Switchgear," *Werkstattstechnik*, Vol. 15, No. 2, p. 1 (1931).

The discussion concerns the cost of electrical switching equipment and the use to which it will be applied. It is pointed out that particular care must be given to consider the factors of contact life and wear so that contact replacement does not become a big part of the cost. Examples of life of various types of switching equipment under operating conditions are given.

No. 271. H. Gubler, "Calculation of the Natural Frequencies of Circuit-Breaker Recovery Voltages," *VDE. Fachberichte*, pp. 48–51 (1931).

Recent theories of arc rupture show that the recovery voltage after interrupting a circuit has an important effect on the rupturing capacity of a circuit breaker. The more rapid the rise in the recovery voltage the more difficult it is to extinguish the arc, and therefore the less is the rupturing capacity. The author works out formulas by means of which the natural frequency of the network may be calculated in terms of its inductances and capacities. A number of cathode-ray oscillograms of circuit breaker operation are reproduced showing the h. f. oscillations. (*Science Abstracts*)

No. 272. H. Schaffer, "Introduction to Electrical Breakdown and Types of Discharge of the Spark Path" (Dissertation), Aachen (1931).

No. 273. S. S. Attwood, W. C. Dow, and W. Krausnick, "Oscillograph Tests on Low-Current Arcs," *Elec. Engg.*, Vol. 50, December, 1931, pp. 949–952.

A study of the dependence of the reignition of a-c. arcs on the arc voltage relations during current zero. The arc employed

was a 25-amp., 600-v., 60-cycle arc $^3/_4$ in. long supplied from a transformer in series with an inductance having appreciable distributed capacity. The effect of shunting the arc with a variable resistance and a variable condenser is indicated, and typical oscillograms are given. The application and limitations of the results when applied to circuit breaker behavior are mentioned. (*Science Abstracts*)

No. 274. C. C. Van Voorhis and K. T. Compton, *Phys. Rev.*, Vol. 37, p. 1596 (1931).

No. 275. E. S. Lamar, *Phys. Rev.*, Vol. 37, p. 842 (1931).

No. 276. E. S. Lamar and K. T. Compton, *Phys. Rev.*, Vol. 37, p. 1069 (1931).

No. 277. K. T. Compton, *Phys. Rev.*, Vol. 37, p. 1077 (1931).

No. 278. A. von Engel and M. Steenbeck, "Arc Temperature," *Wiss. Ver ff. a. d. Siemens-Konzern*, Vol. 10, No. 2, pp. 155–171 (1931).

A comprehensive review of arc investigations precedes the description of a method of measuring the mean temperature of an arc in which a beam of X-rays is passed through the arc longitudinally and measured. (*Science Abstracts*)

No. 279. W. Ehrenberg and H. Houl. "Theory of the Electric Contact," *Zeits. f. Phys.*, Vol. 68, Nos. 5 and 6, March 24, 1931, pp. 289–308.

On the basis of the Fermi-Summerfeld statistics of the metal electrons and of wave mechanics, the passage of currents over a place of contact is investigated. It results that the strength of current under normal conditions remains practically constant up to a distance apart of the ends of the conductor of 10 Å, although the penetrability of the place of contact calculated by wave mechanics only amounts to about 10^{-9}, and then the coefficient is quickly immeasurably small. Further, it appears that an explanation of the detector action on the ground of the assumptions made is not possible. (*Science Abstracts*)

No. 280. R. Fürth, "Contact Potentials," Part III, *Zeits. f. Phys.*, Vol. 68, Nos. 11 and 12, April 20, 1931, pp. 735–757.

A theory is put forward to account for the experimental results obtained in Parts I and II by Polidnik and Lederer, respectively. To obtain the general conditions of equilibrium from which the contact potentials may by calculated, the author adopts the principle that in a system of bodies which are in contact, the potentials can be independent of the time only, if the currents due to spontaneous emission of charged particles cancel everywhere in the system. The special cases considered are: the contact potentials between a metal and an insulator, between two metals, and those involving electrolytes. A formula is attained for the contact potential between two insulators which is ultimately connected with Coehn's law for charges in dielectrics. (*Science Abstracts*)

No. 281. Life of Single and Twin Impulsing Contacts of Proposed Standard Dome Shape," P. O. Eng. Dept., *Res. Rep. No. 5454*, February 11, 1931.

No. 282. J. Frenkel, "On the Electrical Resistance of Contacts Between Solid Conductors," Review Générale de l'Électricité, Vol. 30, pp. 209–210 (1931).

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No. 283. F. Kesselring, "The Elements of Switchgear Design," Chapter 1, Switching Phenomena, (English Translation) Pitman & Sons, Ltd., London, pp. 1–31 (1932).

No. 284. "Abnormal Wear of B Relay Contacts at Burnley Automatic Exchange," P. O. Eng. Dept., *Res. Rep. No. 579*, January 20, 1932.

No. 285. L. Binder, "The Dependence of Contact Resistance on the Number of Contact Points," *Zeits. f. Techn. Phys.*, Vol. 13, pp. 442–443 (1932).

No. 286. D. Nukiyama, "On the Electromotive Forces Generated by Friction Between Two Metals," *Proc.*, Phys.-Math. Soc. Japan, Vol. 14, pp. 93–107 (1932).

Rods of various materials, carbon, magnesium, aluminum, iron, cobalt, nickel, copper, zinc, cadmium, silver, tin, lead, and bismuth, gripped by a metal collar, impinge vertically with variable pressures at various distances from the vertical axis of a horizontal rotating steel plate; plate and rod are in electrical connection through a galvanometer, and a steel wire attached to the rod enables its temperature to be determined thermoelectrically. Curves relating the emf. to the velocity of the point of contact for various pressures, and to pressure for various velocities, are given, showing no definite regularities. (*Science Abstracts*)

No. 287. R. Holm and W. Meissner, "The Measurements with Liquid Helium," Part XIII. Contact Resistance Between Super Conductors and Those Now Showing This Effect, *Zeit. f. Phys.*, Vol. 74, pp. 715–732 (1932).

No. 288. T. H. Osgood and E. Hutchisson, "The Nature of Electrical Contact Between Metals" (Summary), *Phys. Rev.*, Vol. 40, p. 129 (1932).

Two circular, optically flat, metal plates about 4 cm. in diameter, supported at their edges, are separated by a distance of a few thousandths of a centimeter. One is bent toward the other by a variable load applied at its center. The gap is thus one between a sphere and a plane. Electrical currents across the gap are measured for varying voltages and separations of the plates. The smallest currents measured are about 10^{-9} amp.; the voltages used range from 0.5 v. for large gaps to 0.0001 v. for small gaps. The method of investigation possesses advantages in (*a*) control of gap distance and (*b*) use of voltages far below any known ionization potential. Results indicate, at atmospheric pressure, the presence of a conducting layer at least 1×10^{-4} cm. thick at the surface of each plate. Similar highly elastic layers are found in ordinary experiments on Newton's rings. At 0.01 mm. pressure, after mild heat treatment (250 C.) the thickness of the layer does not alter appreciably. The current across the gap decreases, for a fixed voltage, approximately exponentially as the gap widens. Ohm's law is not obeyed. Simple applications of wave mechanics, in conjunction with the work of contemporary investigators, suggest that the transfer of electricity across thin films of air or liquids is more akin to electrolysis than to metallic conduction. Plans are being made to extend the investigations to surfaces which are as free as possible from absorbed gases. (*Science Abstracts*)

No. 289. T. Takeuchi, "Resistance at a Vacuum Junction," *Proc.*, Phys.-Math. Soc. Japan, Vol. 14, pp. 296–298 (1932).

No. 290. J. Frenkel and A. Joffe, "On the Electric and Photoelectric Properties of Contacts Between a Metal and a Semi-Conductor," *Phys. Rev.*, Vol. 39, pp. 530–531; *Phys. Zeit. Sowjetunion*, Vol. 1, pp. 60–87 (1932).

Formulas are developed by means of wave mechanics for the contact resistance of the connection between metals and semiconductors which indicate the effect of rectification. The effect of illumination on this contact is discussed and formulas are developed for the photoelectric potential and current.

No. 291. R. M. Baker, "Effect of Mercury Vapour on Sliding Contacts," *Elec. J.*, Vol. 29, February, 1932, pp. 64–65.

Some previous tests (*Sci. Abst.*, 1870 (1931)) showed that the contact drop of brushes on sliprings was much lower in hydrogen than in air. Further tests have now shown that the reduction was entirely due to the pressure of mercury vapor. It is now concluded that the atmosphere surrounding a contact has little effect on the electrical characteristics of the contact; that a small amount of mercury vapor in a nonoxidizing atmosphere around a sliding contact will result in a very low contact drop; and that the change in the contact with the introduction of mercury vapor is such as to make it behave like a constant ohmic resistance. (*Science Abstracts*)

No. 292. C. Benedicks and J. Harden. "Investigations of Metal Transfer in Contacts and the Suitable Gold Alloys," *Zeits. f. Techn. Phys.*, Vol. 13, Nos. 2, 3 and 4, pp 71–76, 111–117, and 166–171 (1932).

Experiments and theoretical analysis regarding metallic electric contacts and suitable gold alloys for this purpose. Study was originated by desire of electrical concern which wanted improved material for contact price for certain type of voltage regulators. Influence of temperature is studied in tests with cooling fans. Determination of anode temperature test with cooling fans. Experiments with changing temperature. (*Science Abstracts*)

No. 293. S. P. Chakravarti and S. R. Kantebet, "Current Rectification at Metal Contacts," *Proc.*, Inst. Radio Engr., Vol. 20, September, 1932, pp. 1519–1534.

Six different contacts of copper-iron, copper-tin, tin-zinc, zinc-iron, and lead-tin studied for rectifying properties; small lengths of cylindrical rods used; when thermopositive element was of positive polarity, characteristic reached saturation conditions, while reversed polarities contact behaved like ohmic resistance. (*Science Abstracts*)

No. 294. B. Duschnitz, "Closed and Intermittent Contacts of Light, Heavy and Difficult Fusible Materials," *Helios Frachzeitschrift*, Vol. 38, pp. 300–301; *Elektr. Anzeiger*, Vol. 49, Nos. 42 and 43, pp. 961 and 988 (1932).

No. 295. W. A. Zisman, "New Method of Measuring Contact Potential Differences in Metals," *R. Sci. Inst.*, Vol. 3, pp. 367–370 (1932).

A new method is described for measuring the contact p. d. between dissimilar metals. It enables the p. d. to be measured to $^1/_{1000}$ v. in a few seconds of manipulation. An apparatus is described for studying metals in air and another for high vacuum work. (*Science Abstracts*)

No. 296. H. A. Schwab, "Theory of Glow Discharge and of Low Voltage Arc," *Zeits. f. Phys.*, Vol. 75, Nos. 11 and 12, May 6, 1932, pp. 823–828.

A theoretical explanation is put forward to account for the potential falls observed in gas discharges. This is applied to give an explanation of the abnormal low-voltage arc. (*Science Abstracts*)

No. 297. H. A. Schwab, "Theory of Arc Discharge," *Zeits. f. Phys.*, Vol. 75, Nos. 11 and 12, May 6, 1932, pp. 829–834.

The theory developed to explain the phenomena of glow discharges and low-voltage arcs (see preceding abstract) is here applied to the arc between carbon electrodes and gives an explanation of certain features hitherto unexplained theoretically. (*Science Abstracts*)

No. 298. H. A. Schwab, "Theory of Arc Discharge," *Zeits. f. Phys.*, Vol. 77, Nos. 11 and 12, September 3, 1932, pp. 823–828.

The results of various investigators on the spreading of explosions in electric fields, ignition by electric arcs, and on the behavior of enclosed arcs are discussed in this, bearing on the theory previously advanced. (See preceding abstracts by this author.) (*Science Abstracts*)

No. 299. W. Ramberg, "Mechanism of the Electric Arc," *Ann. d. Phys.*, Vol. 12, No. 3, January 8, 1932, pp. 314, 319.

The first part of this article discusses the general theory of the arc discharge and gives detailed information concerning the question of thermal or field emission at the cathode spot. Experimental work on cathode temperatures and current densities in the cathode spot are compared with the theoretical work, with the conclusions that metals may be put into two classes, depending in general upon the boiling point. Those with high boiling points follow the laws of thermal emission at the cathode spot, and those with low boiling points appear to be more in line with the emission theory.

A great deal of experimental data have been collected concerning the properties of materials which affect their operation in maintaining or resisting the arc. This information is presented for all metals and includes atomic weight, density, melting point, boiling point, specific heat, heat conductivity, temperature conductivity, minimum ionization potential, thermionic work function, normal cathode drop, and maximum electron emission at the boiling point in amperes per square centimeter. Further information includes the possibility of generating an arc which rotates a magnetic field, the mobility of the cathode spot, the voltage region in which an arc may be obtained, and extinguishing properties of the materials.

The table prepared by Ramberg is given below, in which:

A is atomic weight,
D is density in grams per centimeter cube,
T_m is the melting point in degrees C. at 760 mm. mercury,
T_b is the boiling point in degrees C. at 760 mm. mercury,
C is specific heat in calories per gram degree C.,
K is the heat conductivity in calories per degree C. per centimeter per second,
P is temperature conductivity, square centimeter per second,
V_i is minimum ionization potential in volts,
O is thermionic work function,
NCF is normal cathode drop in air volts,
i is maximum electron emission at the boiling point in amperes per square centimeter,
Rot is the possibility of generating an arc which rotates in a magnetic field—A does not rotate, B average, C rotates readily,
v is mobility of cathode spot—A, v = 0–10 centimeters per second; B, v = 10–125 centimeters per second; C, v greater than 125 centimeters per second,
V is voltage region in which a 3-amp. a-c. arc in nitrogen can be maintained.—A, V = 0–500 v.; B, V = 500–720 v.; C, V is greater than 720 v.,
LF is extinguishing characteristic—A is bad, B average, C is good.

Metal	A	D	T_m	T_b	C	K	P	V_i
Carbon	12.0	1.82	3700	4400	0.266	0.105	0.215	...
Calcium	40.1	1.53	808	1200	0.168	...	...	6.01
Magnesium	24.3	1.74	650	1086	0.242	0.36	0.856	7.61
Tungsten	184.0	19.1	3890	4830	0.035	0.42	0.629	...
Platinum	195.2	21.4	1770	3804	0.032	0.165	0.240	...
Tin	118.7	7.3	232	2218	0.055	0.145	0.362	...
Solder	...	9.4	240	...	...	...	...	...
Lead	207.2	11.34	327	1525	0.0308	0.079	0.216	7.9
Nickel	58.7	8.8	1452	3075	0.110	0.14	0.145	...
Nickel-silver	...	8.4	...	...	0.095	0.070	0.0878	...
Zinc	65.4	7.14	419	918	0.094	0.255	0.380	9.4
Aluminum	27.1	2.7	660	2000	0.21	0.444	0.785	6.0
Iron	55.8	7.8	1411	3235	0.113	0.15	0.185	...
Brass	...	8.4	940	...	0.088	0.260	0.352	...
Cadmium	112.4	8.64	321	766	0.055	0.20	0.421	8.96
Mercury	200.6	13.6	−39	357	0.035	0.025	0.0525	10.4
Gold	197.2	19.3	1063	2200	0.032	0.705	1.14	9.2
Silver	107.9	10.5	960	200	0.056	1.00	1.70	7.5
Copper	63.6	8.93	1083	2310	0.091	0.92	1.13	7.8

Metal	*O*	*NCF*	*i*	Rot	*v*	*V*	*LF*
Carbon	3.92	...	2 190 5 760	A	A	A	A
Calcium	...	...	...	...	...	...	A
Magnesium	...	224	...	...	...	...	A
Tungsten	...	...	53 400 52 000	...	...	A	...
Platinum	4.04	277	621 000 241 000	...	...	...	...
Tin	...	266	...	...	...	...	...
Solder	...	...	...	...	B	B	...
Lead	...	207	...	...	B	B	...
Nickel	...	226	...	...	B	...	B
Nickel-silver	...	...	...	...	B	B	...
Zinc	...	277	...	...	B	B	B
Aluminum	...	229	...	B	B	B	B
Iron	...	269	...	B	B	B	...
Brass	...	...	...	B	B	B	C
Cadmium	...	266	...	...	B	C	...
Mercury	...	...	...	C	...	C	C
Gold	4.0	285	0.0364 0.0450	C	...	...	C
Silver	3.8	279	0.0479 0.0074	C	...	...	C
Copper	4.5	375	0.344 0.037	C	C	C	C

No. 300. E. H. Bramhall, "Langmuir Probe Measurements in the Normal Copper Arc," *Phil. Mag.*, Vol. 13, March, 1932, p. 682.

A series of tests were run on the vertical copper arc in air. Probe measurements were made by swinging the probe through the arc at a constant velocity and measuring the effect with the oscillograph. The following results were noted:

1. Langmuir's probe theory may be applied to normal arc in air to obtain space potentials, but extraneous factors prevent an accurate interpretation of the volt ampere probe characteristic for indicating the electron density and energy on this theory.
2. Probe characteristics are shown to approach a certain definite form corresponding to a relatively small temperature motion of the electrons superimposed on a relatively high drift velocity.
3. Sectional area measurements with the probe give current densities from 70 to 310 amp. per sq. cm. increasing beyond this near the electrode. Rough estimates on the ratio of the drift to random currents show that it may exceed 100.
4. Electron density in the arc is in the order of 7×10^{11} per cc., with an average energy of about 2 v.
5. From space potential measurements, it was found that:
   (*a*) Potential may not be the same throughout any sectional area.
   (*b*) Uniform gradient assumption not true—gradient gradually increases toward the electrodes.
   (*c*) Cathode fall in the range 11 to 13 v. comparable to the ionization potential of copper.
6. Equation similar to those Steinmetz and Ayrton are untenable for short arcs.

No. 301. J. Thomson, "Arc, Spark and Glow: A Note on Nomenclature," *Phil. Mag.*, Vol. 13, April, 1932, p. 824.

Definitions are suggested for the arc, spark and glow discharge which are as follows:

Spark.—Initial unstable stage in any discharge between cold electrodes.

Arc.—A discharge in which the current is carried by the metal of the electrode as well as the gas between them.

Glow.—A discharge between cold electrodes when current is carried entirely by gaseous ions.

No. 302. L. Magrini, "Arc Characteristics in Relation to Circuit Interruption," *L'Elettrotecnica*, Vol. 19, November 25, 1932, pp. 809–815, and December 5, 1932, pp. 837–848.

The author deals at considerable length with the subject of arc characteristics and refers to the work of Rudenberg and Norberg on the same subject. He states that it is necessary for the purposes of calculation to presuppose a certain hypothetical arc characteristic in which the voltage across the arc is expressed as a function of the arc current. There is, in fact, no absolute arc characteristic, the relation between voltage and current depending upon the manner in which the stored energy in the circuit can maintain the arc. He shows that this stored energy is the only active agent in the ionization of the air, and that the maintenance of the arc is governed not by the voltage existing at the moment of interruption, but by the variation in the intrinsic energy of the current produced by changes in the ionization. In the first part of the paper the author deals with the problem of an arc maintained between two fixed points, and in the second part with that of an arc between mov-

ing contacts as in circuit-breaker operation. The article is illustrated with curves and diagrams. (*Science Abstracts*)

No. 303. A. Léauté, "Mercury Switches," *Bull., Soc. Fr. d. Elec.*, Vol. 2, November, 1932, pp. 1178–1190.

A number of developments in the construction of mercury contact switches is described. (*Science Abstracts*)

No. 304. E. Pawelka, "Mechanics of Rolling Contacts," *E.u.M.*, Vol. 50, November 27, 1932, pp. 657–661.

The operating forces and the velocity ratios involved in contactor-type switches with rolling contacts, in particular where an actuating magnet and a toggle movement are used, are analytically considered. (*Science Abstracts*)

No. 305. F. Kesselring. "Recent Researches on the Arcing of A.C. Circuit-Breakers," *Bull., Assoc.* Suisse des *Elec.*, Vol. 23, November 11, 1932, pp. 610–618. (In German.)

As the result of practical tests the author illustrates the effect of voltage, current, quenching medium, and expansion chambers on the length and duration of high power arcs. The length of the arc was found to depend to a considerable extent on the surrounding medium, hydrogen reducing the length of the arc to one tenth, and expanding steam in a multistage expansion chamber to one-one hundredth, of the length obtained in dry air. The distance of the surface of a fluid from the axis of the arc has a very important effect. There is not much difference to be observed between insulating oil and water. The author discusses theoretical explanations of the observed phenomena. (*Science Abstracts*)

No. 306. L. Binder, "Heating of Contacts During Short Circuit," *ETZ.*, Vol. 53, No. 52, December 29, 1932, pp. 1241–1244.

Binder points out that contact resistance compares with the resistance of a conductor 5 to 27 cm. long, and that the heat generated during short circuit is all dissipated in the neighborhood of one spot.

The actual surface is 0.01 to 0.001 of the surface proper even though no surface oxide layers are present. The current lines are sharply concentrated at the boundary of this contact area. The contact resistance with pure metallic contact lies completely in the metal itself. Bad contact caused by oxides and so forth will increase the voltage drop across the contacts.

With large stationary contacts the contact pressures are so high that the oxide films are not important. Evidences for this are the lack of breakdown voltage, validity of Ohm's law, and the fact that no rectifying effect of surface oxides exists.

Formulas are given for the variation of the contact resistance with the pressure for different types of contact. These are worked out for elastic deformation, for plastic deformation and are compared with experimental results on flat and polished surfaces of various smoothness.

Heat calculations are based upon the heat developed in the contact surface and the heat generated due to restriction of current flow in the material itself. Additional formulas are given for the temperature rise as a function of the heat conductivity of the material, specific heat of the material, specific gravity of the material, time, and the current and voltage.

No. 307. E. E. King, "Durability of Signal-Relay Contacts," *Bull. No. 250*, Univ. of Ill., Engg. Exp. Stat., July, 1932, 16 pp.

An extensive series of tests was run on railway signal relays to find out whether the trouble experienced on these devices was due to electrical wear or due to the weather and atmospheric conditions. Contacts were operated 60 times per hour over a period from February, 1927, to July, 1931, with time out only for short intervals. Approximately twenty million operations on each set.

Contact materials tested:

1. Copper graphite against silver,
2. Silver against silver,
3. Carbon against silver,
4. Carbon against laminated silver, and
5. Carbon against silver gauze.

Thirty-watt railway service lamps were the load on the contacts—both sides of the line opened up. Eight-volt lamps were used.

It was found that the trouble usually encountered in signal relays is due to atmospheric and weather disturbances of the contacts and not to normal electrical operation.

No. 308. S. S. Mackeown, "Cathode Drop in Arc Discharges," *Elec. Engg.*, Vol. 51, June, 1932, pp. 386–388.

For an arc to exist there must be some mechanism for producing electrons at or near the cathode. The author suggests that with arcs between highly refractory electrodes such as carbon or tungsten these electrons are emitted from the cathode by thermionic action, while with electrodes such as copper or brass they are emitted by the action of the intense electric field at the cathode surface. Theories of electron production in the glow discharge are discussed, and results of experiments are given which indicate that most of the current is carried by electrons leaving the cathode. At high currents the electrons leaving the cathode cause ionization and set up a space charge which produces a sufficiently high field to extract further electrons from the cathode, the effect being cumulative

and finally converting the glow into an arc discharge. (*Science Abstracts*)

No. 309. J. Slepian, "Electric Arc in Circuit Interrupters," *J.*, Frank. Inst., Vol. 214, No. 1282, October, 1932, pp. 413–442.

The arc plays a useful function in the operation of a circuit breaker by dissipating the electromagnetic and electrostatic energy of the circuit. It prevents the development of excessive voltage by continuing the current.

The function of the arc and behavior of the current and voltage during the opening time are discussed for inductive circuits. Formulas are given for the characteristics of current and voltage during the opening time.

Arc resistance as a function of current, voltage, and frequency is discussed and applied to a-c. circuits of different characteristics.

The problem of extinction of a-c. arc is considered and these effects are discussed in their relation to contact size, thermal effects, and so forth. The operation of all circuit breakers and expansion breakers is finally considered based upon the information which has been given previously. The effect of turbulence upon the arc is considered as that of dividing the arc into many parallel arcs and of cooling and deionizing the gas. A correlation is found between the effects observed in circuit breakers and the static characteristics of the arc.

No. 310. R. C. van Sickle and W. M. Leeds, "Recent Developments in Arc-Rupturing Devices," *Trans.*, A.I.E.E., Vol. 51, March, 1932, pp. 177–184. Discussion, pp. 191–197.

Describes the theory and application of deion grid rupturing devices and discusses automatic reclosing feeder circuit breakers and power house circuit breakers. Test results of high-voltage oil circuit breakers equipped with deion grids are given and are illustrated by curves and oscillograms. The paper is confined to describing the later development of the deion grid to the 15-kv. and 23-kv. outdoor circuit breakers of low capacity and for automatic reclosing service and to the powerhouse class of circuit breaker of 15 kv. The paper was discussed by several speakers, and in this connection the original should be consulted. (*Science Abstracts*)

No. 311. F. S. Marcellus and S. W. Spengler, "Contact-Making Instruments," *G. E. Rev.*, Vol. 35, No. 6, June, 1932, p. 351.

Instrument contacts must operate at a very low torque and must not affect the calibration of the instrument. Where high torque is available silver and silver alloys are satisfactory. On indicating instruments, however, where torque is low, other methods must be used.

A method is described in which a small pool of mercury sticks out of a hole in a copper cup. The hole is 0.05 in. in diameter. Contact with the mercury is made by a platinum wire attached to the moving part of the instrument. The voltage must be greater than 6 v. and must break down any oxide film which may form on the mercury, but the voltage should not be greater than about 15 v. Currents up to 25 ma. may be handled. For rugged instruments the torque required to break a contact is a small percentage of the full scale deflection torque. On more sensitive instruments it may be a higher percentage.

No. 312. J. A. Wilcken, "Transient Phenomena on Breaking an Inductive Circuit," *Phil. Mag.*, Vol. 13, May, 1932, pp. 1001–1006.

When a switch in an a-c. circuit is opened, the electromagnetic energy, which is oscillating between source and circuit, vanishes in the integral over a whole number of periods as long as the current wave-form is symmetrical, and the problem of switch design is relatively simple; in a d-c. circuit, however, the stored up energy has to be dissipated as heat in the switch, giving rise to arcing in the switch jaws. Assuming that at some time after breaking the switch the resistance is given by $Rt/(T - t)$, where T is the total time of breaking, the instantaneous voltage is given by

$$L\frac{di}{dt} + \frac{R}{1 - t} = E$$

and the energy dissipated by $\int_0^1 e_1 i dt$, where e_1 (p. d. at switch) can be derived from the expression for E; in the latter two expressions the total time of breaking is set equal to unity.

The expression $\int_0^1 e_1 i dt$ cannot in general be integrated, but particular cases are worked out, and it is shown that a switch opening a 500-v. circuit of 5 ohms' resistance and 0.25 henry inductance in $1/15$ sec. must dissipate energy at the rate of 40 kw. towards the last third of the time of breaking. (*Science Abstracts*)

No. 313. "Principle of Similitude.—Generalization of Paschen's Law," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 11, p. 36 (1932).

No. 314. T. E. Browne, Jr., "Extinction of A.C. Arcs in Turbulent Gases," *Trans.*, A.I.E.E., Vol. 51, pp. 185–191 (1932).

A recent theory of a-c. arc extinction in gas-blast circuit interrupters is reviewed. It is predicted on the basis of this theory that the interrupting ability of an a-c. arc should increase very considerably with the degree of turbulence to which the arc gases are sub-

jected, and also that the recovery of dielectric strength by a turbulent arc space during a period of zero current should be very rapid for the first few microseconds and then comparatively slow for a considerable time thereafter. Experimental results obtained with an arc in atmospheres of various common gases verify these predictions, and also reveal the importance of the gas medium.

A curve has also been obtained showing recovery of dielectric strength with time during the current zero period by an arc in an expulsion fuse tube. This curve has the characteristic shape predicted by the turbulence theory, thus proving the validity of the theory as applied to the behavior of a practical gas-blast device. (*Trans. A.I.E.E.*)

No. 315. E. G. Newton, "Fuse Cutouts," *G. E. Rev.*, Vol. 35, March, 1932, pp. 166–172.

The operating principles of the expulsion and oil types of fuse cutouts are explained, and the various factors to be considered in the design of a fuse cutout are discussed. Some new expulsion fuse link designs for 1 to 20 amp. and 15 to 150 amp. are described and illustrated. The requirements to be fulfilled by the fuseholder and housing are discussed, and various types of housings and mountings are illustrated. The effects of radio interference, circuit voltage, and load current are considered, and the necessary correlation between heating and operating speed is pointed out. The interruption of fault currents and the effect of short circuit power factor on a-c. arc interruption are also discussed. The author points out the advisability of making tests for interrupting ability, at or close to zero shortcircuit power factor. (*Science Abstracts*)

No. 316. W. Burstyn, Funk, p. 126 (1932).

No. 317. J. Kopeliowitch, "Results of Recent Researches on the Disconnection Process in the A.C. Arc and Their Application in Switch Construction," *Bull., Schweiz. Elek. Verein*, pp. 565, 605, 610 and 619 (1932).

No. 318. M. J. Druyvesteyn, "The Transfer from Glow Discharge to the Arc in Inert Gases," *Phys. Z.*, Vol. 73, p. 727 (1932).

The change from glow discharge to the arc in neon and argon at pressures above 3 cm. with tungsten spherical electrodes has been measured. The relation of the maximum voltage, the cathode temperature, and the power in watts at the maximum voltage on the gas pressure is measured and qualitatively explained on the basis of the thermal arc theory.

No. 319. "Dust Faults on Relay Contacts," P. O. Eng. Dept., *Res. Rep. No. 4959*, February 1, 1932.

No. 320. K. K. Darrow, "Electrical Phenomena in Gases," Williams and Wilkins Co., Baltimore, Md. (1932).

No. 320a. L. R. Ludwig and R. M. Baker, "Influence on Commutation of Brush Contact Drop," *J.*, A.I.E.E., Vol. 51, pp. 959–965 (1932).

In the designing of electrical commutating machinery, an attempt is usually made to produce a linear change of current with time during commutation. In this case the current density under the brush is uniform, and, therefore, the voltage drop at the contact between brush and commutator will also be uniform over the brush surface. It is well known, however, that straight-line commutation is rarely achieved. Furthermore, there is some doubt as to whether straight-line commutation is the most desirable form. In the case of nonlinear commutation the current density is not constant across the brush surface, and consequently the contact drop will not be constant. This means that calculations made to determine the change in current in a commutating coil will be greatly in error if constant contact drop is assumed. Another difficulty is introduced by the fact that the contact drop will change with time in any small area on the brush surface, and therefore, the static curve between voltage and current measured at the brush contact cannot be used and the transient characteristics of the brush contact drop must be known.

The usual lack of consideration of the nature of contact drop in dealing with commutation problems leads to the result that many observed phenomena cannot be explained by means of the calculation made. For example, the classical theory of commutation can in no way explain sparking underneath the brush, peculiarities found in brush and commutator wear, the choice of certain brushes in order to obtain good commutation, etc. (Authors' abstract)

No. 320b. P. Hunter-Brown and C. J. Hews, "Design of Brushes and Brush Holders," *J.*, I.E.E., Vol. 71, November, 1932, pp. 799–818.

A systematic investigation with the aid of an oscillograph into the behavior of brushes running on a short circuited commutator is described. Each brush was divided into two or more parts insulated from each other so that the distribution of current across the face of the brush could be examined. The difficult problem of reversible running received special consideration. The commutator contained a slightly high bar and two flats in order to determine the relative merits of different brush and brush holder arrangements on an imperfect commutator. A distinction is drawn between the effect of "sudden" irregularities as exhibited by high bars, and of a "gradual" irregularity such as

eccentricity of the commutator. The advantages of using a pressure finger of high inertia and the importance of low inertia in the brush itself are demonstrated. Finally, suggestions are made concerning the lines along which further investigation should proceed. (*Science Abstracts*)

1933

No. 321. W. Höpp, "Modern Switchgear Construction" (Refers to silver contacts), *ETZ.*, Vol. 54, March 2, 1933, pp. 203–205.

Oxidation of switch contacts is a frequent source of trouble, and due to recent falls in the price of silver the author proposes the use of silver contacts and describes switches built in this way. The contacts are 12 mm. in diameter and each carries 2500 amp.; by using several such contacts, switches for current up to 15,000 amp. have been built. (*Science Abstracts*)

No. 322. B. W. Jones, "Keep Electrical Contacts Clean," *Maintenance Engg.*, January, 1933, p. 4.

Necessity of regular cleaning advocated; increase of resistance shown on chart giving resistance of copper-to-copper and silver-to-silver contacts when held together with pressure of 20 lb. and kept at temperature of 85 C.

NOTE.—Magazine article 1 1/2 pages—graph shown—"copper-to-copper" contacts. Time measured in hours —"silver-to-silver" contacts. Time measured in days.

No. 323. R. Paxton and H. E. Strang, "Designs of Current-Carrying Contacts in Modern Switchgear," *G. E. Rev.*, Vol. 36, No. 12, December, 1933, pp. 524–528.

Comparative time temperature characteristic curves of copper, copper hot-tin dipped, and silver surface contacts in oil; initial pressure-resistance characteristic curves of copper and silver line-to-line and surface-to-surface contacts; momentary (1 sec.) current-carrying capacity through single pair of silver point contact buttons. (*Science Abstracts*)

No. 324. M. Anastassiades, "Contact Rectifier," *Compt. rend.*, Vol. 197, pp. 677–678 (1933).

No. 325. R. Holm and W. Meissner, "Contact Resistance Measurements at Low Temperatures," *Zeits. f. Phys.*, Vol. 86, pp. 787–791 (1933).

No. 326. C. L. Denault, "Electrical Contact of Bus-Bar Joints," *Elec. J.*, Vol. 30, pp. 281–283 (1933).

The operation of bus-bar joints is studied from the viewpoint of various types of contact surfaces, the effect of pressure on contact resistance. Some rather interesting studies are made using the photoelastic method to study the pressure distribution in a bolted bus-bar connection. The effect of corrosive gases in the atmosphere is also discussed.

Other effects of temperature such as permanent set and thermal expansion are also considered.

No. 327. B. A. Rose, "Measurements on Contact Potential Differences Between Different Faces of Copper Single Crystals," *Phys. Rev.*, Vol. 44, pp. 585–588 (1933).

No. 328. "Putting the Silver Where You Want It," *Elec. Mfg.*, May, 1933.

No. 329. P. Mabb, "Contact Metals and Contact Care," *Metal Ind.*, London, Vol. 43, No. 1, July 7, 1933, pp. 3–5.

Principal characteristics which contact material must possess to be satisfactory; platinum group metals; need for polished surface.

No. 330. J. Slepian, "Conduction of Electricity in Gases" (Lecture Series), Course No. 38, Educational Dept., Westinghouse E. & M. Co., East Pittsburgh, Pa., April, 1933.

This is a series of lectures given by Dr. Slepian discussing the fundamentals of the conduction of electricity in gases and the application of this information to the problem of circuit breakers. It includes much of the original work which Dr. Slepian contributed to this field.

No. 331. J. J. Thomson and G. P. Thomson, "Conduction of Electricity Through Gases," Third Edition, Two Volumes. Cambridge University Press, Cambridge, Mass., (1933).

A voluminous work on electrical conduction in gases, including properties of a gas when in a conducting state, properties of gaseous ions, properties of cathode rays, and various methods of ionization. Chapters IX and X, Vol. II, are entitled: "Spark Discharge" and "The Electric Arc." Mathematical explanations, as well as many tables and figures, accompany the text.

No. 332. R. Rudenberg, "Electrical Switching Phenomena," Third Edition. Julius Springer, Berlin (1933). (In German.)

An extensive work which describes typical switching phenomena and gives the physical explanation for them. The treatment is quite mathematical, and includes many curves. Also included is a very complete bibliography in which the references are classified according to subject matter under 64 headings.

No. 333. R. Mannkopff, "Electron Density and Electron Temperature in Electric

Arcs," *Zeit. f. Phys.*, Vol. 86, Nos. 3 and 4, October 31, 1933, pp. 161–184.

From observations of ionic migration in electric arcs and also from measurements of the degree of ionization of additions to the arc gas, values may be found for the electron density and the degree of ionization. Both methods give a degree of ionization of 10^{-2} to 10^{-3}, which exceed the expected value by 10 to 100 times. Line spectra free from self-reversals, which are necessary for intensity measurements, may be obtained by observation in the direction of the axis of the arc. The observed degree of ionization shows that in arcs between carbon or metal electrodes in air at atmospheric pressure, excitation and ionization due to electron impact are much greater than that due to atom impact. A temperature estimation based on the degree of ionization of auxiliary gases thus gives the electron temperature and not the gas temperature. For the carbon arc the value obtained is 6000 to 8000 K., which is in agreement, within the limits of error, with the value of 6700 K. obtained by Ornstein for the gas temperature from observations of the CN bands. Under certain assumptions it is found that the difference between the electron temperature and the gas temperature should be less than 20 K. for arcs at atmospheric pressure. The temperature equilibrium is almost complete and the application of Saha's equation appears to be perfectly legitimate. (*Science Abstracts*)

No. 334. J. L. Meyer, "Probe Measurements in the Electric Arc in Air at Atmospheric Pressure," *Zeits. f. Phys.*, Vol. 87, Nos. 1 and 2, December 13, 1933, p. 1.

No. 335. F. Ludi, "Mechanism of the Liberation of Electrons at the Cathode Spot of an Arc Discharge," *Zeits. f. Phys.*, Vol. 82, Nos. 11 and 12, May 30, 1933, p. 815.

The problem of electron release from the cathode spot of an arc has not received a satisfactory quantitative explanation.

Electron release by elastic collision of ions is impossible since the possible energy available is in order of magnitude too low.

Several thermal theories have been considered which appeared to be satisfactory for the high melting point materials, but fail when they are expanded to include the low melting point metals. Thermal theories must postulate either a very high surface temperature by ion bombardment or thermal ionization of the gas next to the metal. Calculations show that the pressure required at the surface of the cathode is 10,000 times that which has actually been measured.

The best possible theory appears to be the combination of field and thermal effects. Combining the two, it is possible to show that results of the proper order of magnitude may be obtained.

The theory is carried further in which the microscopic picture of the field of an ion in front of a conductor is considered for a single ion moving toward the conductor. The effects of many ions and the effects of the released electrons are considered. The results show that a combination of the field and thermal theories together with the possibility of multiple ionization by multiple collision should give the effects the correct order of magnitude.

No. 336. E. F. Richter, "Temperature Measurement in an A.C. Carbon Arc," *Zeits. f. Phys.*, Vol. 81, Nos. 7 and 8, March 30, 1933, pp. 539–542.

The temperature of an arc operating on a.c. is determined by the spectrum line reversal method, a tungsten lamp being used as standard. The phase of the a.c. is obtained stroboscopically. The temperature is a minimum when the phase is 180 deg. At the center of a sodium-saturated arc of 4 amp. the temperature is about 2700 K. The distribution of temperature in the various parts of a 5-amp. arc is also investigated. (*Science Abstracts*)

No. 337. T. Toniszewski and T. Maciejewski, "Electric Arc Between Metal Electrodes," *Acta Physica Pol.*, Vol. 2, No. 1, pp. 67–74 (1933). (French Abstract.)

The static characteristics of arcs between metal electrodes of hemispherical or plane shape were studied for all possible combinations of iron, copper, molybdenum, tungsten, and brass. Two characteristics were obtained for each pair of metals by changing the direction of the current and values were found for the coefficient of asymmetry $(e_1 - e_2)/e_2$, where e_1 is the potential for the upper characteristic and e_2 that for the lower. Graphical methods were used to find the constants α, β, γ, and δ in the Ayrton equation for the pairs copper-copper, molybdenum-molybdenum, tungsten-tungsten. For copper and tungsten two ranges of current intensity were found having different constants. For molybdenum, on the other hand, the constants were the same for all current intensities used. (*Science Abstracts*)

No. 338. H. Dziewulski, "Arcs in Air Between Metallic Electrodes," *Acta Physica Pol.*, Vol. 2, No. 1, pp. 51–58 (1933). (In French.)

Measurements were made of the counter emf. in arcs in air between similar electrodes of tungsten, tantalum, molybdenum, copper, nickel, and iron in all possible combinations. A study was also made of the dependence of the counter emf. on the nature of the electrodes, the length of the arc, the electrode diameter, and the current intensity. The counter emf. was found to depend not at all, or only very little, on the length of the arc,

and, within the current limits of 3 to 4 amp. no variation with current was observed. The counter emf.'s at the cathode and at the anode were found to be constant, both in value and sign, for each of the metals studied, independent of the combination used, provided the arc conditions were the same. The results support the conclusion that the counter emf. is localized in the layer in immediate proximity to the electrode, in agreement with hypotheses of Duddell, Hagenbach, and Wehrli. (*Science Abstracts*)

No. 339. J. J. Sommer and J. Bott, "Characteristics of A.C. Arcs Between Metal Electrodes," *Phys. Z.*, Vol. 34, April 15, 1933, pp. 324–330.

The characteristics for a-c. arcs between electrodes of copper, iron, zinc, magnesium, and carbon were investigated under varied conditions. It was found that different types of characteristics were obtained according to the value of the effective current strength. With small current strengths a type of characteristic was obtained associated with the glow discharge, but with high current strengths a different type of characteristic, corresponding to the arc discharge, was obtained. In the intermediate region both types of characteristics occur, so that a double characteristic is observed. The dependence of the different types of characteristics and, in particular, the limiting current strengths, for which one type changes over to the other, on the nature of the gas (oxygen, hydrogen, nitrogen), the frequency of the source (50–8000 p.p.s.), the kind of resistance in circuit (inductive or ohmic) and on the gas pressure was investigated. A graphical representation of the limiting current strengths as dependent on the gas pressure for the different metals shows that the metals can be arranged in a series agreeing with that given by Ramberg and which, on the thermal theory of the arc, corresponds to the increased conductivity from carbon to copper. (*Science Abstracts*)

No. 340. S. Timoshenko, "Return Arc as Breakdown in Strongly Ionised Gas," *Zeits. f. Phys.*, Vol. 84, Nos. 11 and 12, August 21, 1944, pp. 783–793.

The phenomena of the reignition of short a-c. arcs between metal electrodes, which can be considered as breakdown in strongly ionized gas, were investigated by means of potential measurements in the gap in passing through the null-current stage. The phenomena take place in about 50×10^{-6} sec. The potential distribution indicates the formation of a glow discharge, which precedes the new arc discharge, and the formation of a positive space charge layer at whichever electrode happens to be the cathode, so that the total potential difference at the arc electrodes during the null-current stage may be some hundreds of volts. Experiments with currents of 300 to 3000 amp. exhibit the influence of the material of the electrodes on the breakdown. A critical review is given on the most important results of other workers bearing on the theory of a-c. arc reignition. (*Science Abstracts*)

No. 341. R. Seeliger and K. Bock, "Theory of the Arc Discharge," *Phys. Z.*, Vol. 34, October 15, 1933, p. 767.

The older, purely thermal theory of the arc discharge is at variance with experiments on the copper arc open to the atmosphere. In this instance, the sudden change from the glow into the arc discharge is dependent on the current density at the cathode but is not controlled by the temperature of the surface of the cathode. (*Science Abstracts*)

No. 342. A. von Engel, R. Seeliger, and M. Steenbeck, "Glow Discharge at High Pressure," *Zeit. f. Phys.*, Vol. 85, pp. 144–160 (1933). (In German.)

The cathode current density of a normal glow discharge between copper electrodes in both air and hydrogen and over a large range of pressures (10–760 mm. mercury) is described, and the results of the measurements are compared with the experiments of Thoma and Heer. Further, the pressure dependence of the normal current density on similar applications is computed by considerations of the temperature dependence which is especially important at high pressures. Orientation experiments on the change from the glow to the arc discharge at various cathode temperatures show that still no decision can be made between thermal and "autoelectric" explanations.

No. 343. W. C. Dow, S. S. Attwood, and G. S. Timoshenko, "Probe Measurements and Potential Distribution in Copper A.C. Arcs," *Trans.*, A.I.E.E., Vol. 52, September, 1933, pp. 926–932. Discussion, December, 1933, pp. 932–933.

An account is given of cathode-ray oscillograph measurements made to determine the distribution of potential between copper electrodes during the reignition period of an a-c. arc between them in air. It is concluded that when the arc current is passing through zero and the electrode voltage is reversing its polarity, the major part of the potential drop is in the space adjacent to the cathode, the larger portion of the arc space being free from potential gradient. The electronic activity during the reignition period is discussed, and it is also concluded that under suitable conditions probe methods of determining potential distribution are justified. (*Science Abstracts*)

No. 344. J. Slepian, "Extinction of A.C. Arcs in a Gas Stream," *E.u.M.*, Vol. 51, April 2, 1933, pp. 180–184.

The author discusses the various theories

of arc extinction and describes some experiments to determine the rapidity with which the dielectric strength builds up; it is found that at least 100 microseconds are required and that the process begins before the zero point in the current cycle. (*Science Abstracts*)

No. 345. C. Ramsauer, "Temperatures in the Electric Arc," *E.u.M.*, Vol. 51, April 2, 1933, pp. 189–193.

The high temperature of the electric arc may be due to relative movement between the atoms such as occurs in an ordinary heated gas or it may be due to atoms being in the excited state and emitting radiation of the appropriate wave lengths, or, finally, it may be due to the dissociation of molecules containing more than one atom. Experiments carried out by the A.E.G. for investigating each of these effects are briefly described. (*Science Abstracts*)

No. 346. R. Gourjon, "Protective Circuit-Breaker for Lighting Installations and Domestic Apparatus," *R.G.E.*, Vol. 33, July 1, 1933, pp. 861–863.

The circuit breaker described in the paper is arranged so as to trip either with a certain lag or small overloads, or instantaneously in the case of heavy overloads. For the retarded action relay, which, in large switches controls the trip, a bimetallic strip of special type is substituted, which forms part of the apparatus. Test results on the circuit breaker are reproduced at the end of the article. (*Science Abstracts*)

No. 347. H. J. Lingal and O. S. Jennings, "Circuit Breaker Protection for Industrial Circuits," *Trans.*, A.I.E.E., Vol. 52, June, 1933, pp. 568–576. Discussion, p. 576.

Increase in design knowledge, the development of new materials, together with an increase in knowledge of arc phenomena, and of arc interrupters has made possible the construction of circuit breakers occupying small space. These devices are capable of rendering performance superior to that given by older apparatus. The same low cost to the user is obtained, together with safer and more satisfactory service.

No. 348. J. L. Meyer, "New Studies of the Arc Discharge," *Trans.*, A.I.E.E., Vol. 52, March, 1933, pp. 250–259. Discussion, p. 259.

The equation $V = A + B/I^n$ which correctly represents all normal arc characteristics is used as the starting point for a general discussion of arc phenomena and industrial applications. Tests of the equation are applied to iron arcs in various gas atmospheres to obtain a series of values for A and B. A value of n is predicted from arc stream geometry, and compared with actual values of n for various arcs. From energy considerations by this equation new concepts of the "minimum energy" and the "excess energy" requirements in the arc conduction process are gained. On this basis high temperature arcs are shown to be the most efficient. Light intensity and probe measurements on the arc stream suggest a new physical picture of high current arcs. Some difficulties are removed in accounting for energy equilibrium of the welding arc cathode.

No. 349. M. Pirani, "Considerations of Modern Light Sources," *E.u.M.*, Vol. 51, pp. 222–225 (1933). (In German.)

Concerns mercury arc lamps, fluorescent lights, etc.

No. 350. E. B. Shand and C. E. Valentine, "Bolting of Bus-Bar Joints," *Elec. J.*, Vol. 30, September, 1933, pp. 377–380.

Tests on bolted copper bus-bar joints are described, in which the contact surfaces of the bars are milled away, except just under the washers surrounding the bolts. Very little difference was found in the millivolt drop across the joint. Larger bolts give better results than smaller ones up to $^3/_4$ in. Four $^1/_2$-in. bolts are recommended. Tables are given of contact forces required for various thicknesses of copper bars, and of estimated forces per bolt of different diameters in use, when pulled up with a hand wrench. Painting over the joints is recommended when corrosion may be feared. (*Science Abstracts*)

No. 351. D. C. Prince, "Compression-Type L. T. Air Circuit-Breaker," *G. E. Rev.*, Vol. 36, July, 1933, pp. 315–318; *Trans.* A.I.E.E., Vol. 52, No. 3, September, 1933, pp. 844–847.

Reviewing the theory of gas conduction the author points out the dependence of arc p. d. on gas pressure as well as on current strength, and that an arc may be made non-self-maintaining by securing that either the arc length or the gas pressure increases with increase of current. Devices using the former method, such as circuit breakers with carbon break or with magnetic blowout, are inadmissible in comparison with an enclosed fuse because of the noise and flame. A device is described wherein the breaking contacts are sealed in a small nonconducting chamber in which a high pressure is built up by a short cirtuit arc of quite short duration. The pressure is estimated to reach 1000 psi. with a current of 20 ka. The operation on both a.c. and d.c. is illustrated by oscillograms; these show interruption to take place within $^1/_2$ cycle for 60∼ a.c., and in about $^1/_{40}$ sec. for d.c., the currents being about 6 and 4 ka. Constructional and operating features of the new circuit breaker are described. (*Science Abstracts*)

No. 352. R. C. Dickinson, "Deion Circuit Breakers for Steel-Mill Service," *Elec.*

J., Vol. 30, No. 10, October, 1933, pp. 415–417.

A description of the operation and application of the deion circuit breaker in steel-mill service, where contacts are made to carry large currents and at high voltages (that is, 600 amp., 5000 v.).

No. 353. A. M. Cassie, "Arc-Gap Conditions," *Electrician*, Vol. III, December 22, 1933, pp. 771–772; *Report Ref. G/XT 46* of the E.R.A.

This report discusses the effect of arc-gap conditions upon the curve of recovery voltage with time which occurs across switch terminals after a current zero at which the arc is extinguished. It is concluded that the recovery voltage curve cannot be calculated from circuit constants for all types of switches, as a small conductivity in the gap may be responsible for considerable changes in the curve in circuits of high natural frequency. (*Science Abstracts*)

No. 354. R. C. van Sickle and W. E. Berkey, "Arc Extinction Phenomena in H. T. Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 52, September, 1933, pp. 850–857. Discussion, December, 1933, pp. 857–860.

A paper describing a new type of cathode-ray oscillograph for use in investigations involving frequencies of 25 to 200,000 $\sim$ and giving the results obtained in a study of circuit-breaker arc transients around current zero. The oscillograph is a medium speed instrument in which the film is wrapped around a drum and rotated in a vacuum at high speed. Each film is self-calibrated and shows in a continuous trace the formation of the arc, subsequent reignitions and final extinction. More than 15 $\sim$ may be recorded without excessive blurring. Oscillograms and their analysis are given and the following conclusions are drawn. (1) Arc extinction depends on the deionization taking place before and after current zero. (2) The effective resistance of the arc space increases in a curve which is a function of the rate of deionization. (3) The effective resistance may become several thousand ohms several microseconds before or after the voltage zero. (4) The rate of rise of recovery voltage is a function of the circuit and of the breaker. (5) The specifying of certain rates of rise of recovery voltage for circuit-breaker testing is not advisable at present. (*Science Abstracts*)

No. 355. A. von Engel and M. Steenbeck, "Periodic Course of the Gas Temperature in the Column of an A.C. Air Arc Light," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 12, No. 1, pp. 74–89 (1933).

The periodic course of the gas temperature in the axis of the positive column of a 50-period a-c. air arc light of 2 amp. in an inductive current circuit was determined by a stroboscopic measurement of gas density. The gas density was ascertained from the absorption capacity of the arc gas toward α-rays of a polonium preparation. The absorption capacity was obtained by an intensity measurement with a Geiger spark counter, in which the α-ray beam was led along the axis of a long straight arc stabilized by an air vortex. The gas temperature was found to oscillate in the 100-period interval between 3700 and 4900 K. (*Science Abstracts*)

No. 356. E. S. Lamar, "Momentum Transfer to Kathode Surfaces by Impinging Positive Ions in Helium Arc," *Phys. Rev.*, Vol. 43, February 1, 1933, pp. 169–176.

A study was made of the momentum transfer to an auxiliary cathode in the positive column of a l.t. helium arc. The auxiliary cathode was a flat molybdenum plate insulated on one side by glass and suspended so that its deflection gave a measure of the pressure against it. The measured pressure is thought to be due (*a*) to the recoil of those ions which retain some of their kinetic energy after neutralization, and (*b*) to a radiometer effect caused by heating of the cathode by positive ion bombardment. On these assumptions the experimental data gave an accommodation coefficient for helium positive ions and the fraction of the measured current carried by electrons. The accuracy of measurement was not high, but the values of the accommodation coefficient are in qualitative agreement with the results of Compton and Van Voorhis and the fraction of the current carried by electrons agrees fairly well with the results of Harrison. (*Science Abstracts*)

No. 357. K. T. Compton and E. S. Lamar, "Test of the Classical 'Momentum Transfer' Theory of Accommodation Coefficients of Ions at Cathodes," *Phys. Rev.*, Vol. 44, September 1, 1933, pp. 338–344.

On the classical theory of momentum transfer at impact of a moving particle with a stationary particle, Compton has suggested that the accommodation coefficient for positive gas ions striking a metal cathode should be less than unity only if the mass of the metal atom exceeds that of the gas ion. To test this hypothesis, momentum experiments of the type already reported for helium ions striking a molybdenum cathode have been continued for argon ions striking molybdenum and aluminum, respectively. From the experimental data the accommodation coefficient (*a*) for the positive ions and also the fraction of the current carried by electrons at the cathode were calculated. The value found for *a* for argon ions on molybdenum was 0.8, in good agreement with the value obtained by Compton and Van Voorhis by thermal measurements. For argon ions on aluminum *a* was found to be unity, in accord-

ance with the above hypothesis. Three types of impact of ions are analyzed and the experimental values of a are shown to conform sufficiently close to the predictions of the analysis to indicate that the phenomena of loss of energy and momentum are at least approximately described by the postulates of this analysis. (*Science Abstracts*)

No. 358. G. Dechene, "On the Discontinuities of Potential at the Contact of a Semi-Conductor and a Metal," *Compt. rend.*, Vol. 196, May 22, 1933, pp. 1577–1579.

A brief account is given of experimental work upon the influence of physical conditions upon contact resistances. The production of discontinuities of potential at a semiconductor metal interface is attributed to the difficulty of transfer of electrons from one medium to another. Near each electrode the electric force produces an excess charge of one sign. The substance then possesses a volume density ρ penetrating to a depth d. If E_0 is the electric field at the contact then the discontinuity of potential is $KE_0^2/8\pi\rho$ and the capacity of contact per square centimeter is $C = K/2\pi d$, where K is the dielectric constant of the substance. The effect of pressure, raising the temperature, and illuminating the surface, should be to facilitate the exchange of charge between the semiconductor and the metallic electrode and so to reduce E_0 and consequently the discontinuity of potential (for a given current density). This was verified by experiment, and from a measurement of the capacity C a value for d was obtained of the order of 10^{-4}–10^{-2} cm. (*Science Abstracts*)

No. 359. R. Holm and R. Störmer, "Contacts of Two Different Conductors," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 12, No. 1, pp. 61–73 (1933).

The one-body and one-metal contact problem is further dealt with. Formulas are deducted by which the potential and the temperature at any desired spot on the conductor between the end surfaces can be calculated on the assumption of the validity of the Wiedemann-Franz law. Similar formulas are deduced for contacts between two different conductors. Contacts between graphite or carbon and metal are dealt with. It is found that under certain circumstances very high temperatures can occur in the carbon without the corresponding touching surface appearing to be highly heated. The characteristic of two metal contacts is considered. (*Science Abstracts*)

No. 359a. H. E. Strang, "Oil-Blast Circuit Breakers of Medium Capacity. Shorter Arcs and Quicker Extinction, Coupled with Elkonite Arcing Contacts, Reduce Maintenance," *G. E. Rev.*, Vol. 36, February, 1933, p. 94.

By employing the oil-blast principle it has been possible to build an entirely new type of breaker for 50,000 and 100,000-kva. ratings, having increased efficiency by comparison with existing breakers of similar capacity, and of smaller over-all dimensions. For ratings of 150,000, 250,000 and 500,000 kva. the existing range of plain break breakers has been modified to operate by oil-blast action.

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No. 360. G. L. E. Metz, "Electromagnetic Forces Set Up Between Current-Carrying Conductors During Short-Circuit," *J.*, I.E.E., Vol. 75, October, 1934, p. 527.

This paper deals in a general manner with the electromagnetic forces exerted between current-carrying conductors. The factors introduced by the use of alternating current are taken into account and the effects upon the forces of conductor shape, current distribution, and proximity of inductive material, are considered. The characteristics of the forces, the reactions they produce, and the effects of resonance are also examined. The results of the investigation are given either in general terms or in the form of equations, which are presented in a manner convenient for use in the calculation of electromagnetic forces on a-c. circuits. (*Science Abstracts*)

No. 361. M. Quintin, "Action of Separating Layer in Rectification at Imperfect Contacts," *Compt. rend.*, Vol. 198, pp. 347–349 (1934).

Experiments are described which show that rectification effects can easily be obtained when two conductors of different material are separated by a layer of thickness considerably greater than 10^{-5} cm. The tests were carried out with silicon and either copper, carbon, tin, or cadmium. With copper and carbon the current passes more easily than when the silicon is positive, but the reverse is the case for tin and cadmium used with silicon. This shows that the sense of the passage of current in such cases is not essentially connected with the difference of electrical conductivity of the two electrodes, since silicon is the worst conductor of all the electrode substances used. (*Science Abstracts*)

No. 362. G. Dechene, "Semi-Conductors," *Ann. d. Phys.*, Vol. 2, pp. 241–245 (1934).

The properties of semiconductors are studied in detail and under widely differing conditions. Substances such as yellow oxide of mercury, sodium carbonate, zinc oxide, and lead chloride are used. The author attempts to complete the previous experimental work on the subject and to obtain a satisfactory explanation of the phenomena observed. The exposition is divided into two parts. The first consists of a detailed

investigation of the discontinuities of potential produced when the surface of separation of a semiconductor and a metallic electrode is traversed by an electric current, and of the effects of various physical conditions such as time, temperature, illumination of the electrodes, and pressure on the semiconductor. Voltages between a fraction of a volt and 20,000 v. are used. The discontinuity of potential is attributed to the formation of a space charge in a thin layer of the semiconductor and the hypothesis developed gives a satisfactory explanation of the observed effects. A-c. measurements show that the contact has a capacity from the value of which the order of magnitude of the layer in which the rapid variations of potential are produced is calculated to be about 10^{-2} or 10^{-3} cm. The second part of the work deals with an investigating of the properties of the absorbable radiation produced at high voltages when the electrode is in the form of a grid. Various hypotheses are reviewed and arguments are advanced in favor of the one which suggests that the origin of the radiation is in the air and not in the semiconductor. The study of the radiation by the ionization method and its analysis in the vacuum spectrograph give concordant results. The radiation is found to be complex and contains radiations whose wave length is between some ten and some hundreds of Ångström units. (*Science Abstracts*)

No. 363. B. Kirschstein and F. Koppelmann, "Photography of Electric Arcs," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 13, No. 3, pp. 52–62 (1934).

Photographic methods have been developed to determine the diameter of an electric arc at various points along its length and thus find the current density at those points. Three experimental methods are described: (1) mirror photographs, in which the light from one particular portion of the arc passed through a slit in a disk rotating about an axis perpendicular to the length of the arc and then fell upon a concave mirror rotating about an axis perpendicular to both the disc axis and the length of the arc. The light was focussed by the mirror upon a photographic plate. The speed of the disk gave the time for which the arc was exposed. (2) Kinematograph method, in which the light from one portion of the arc passed through a lens system and was focussed upon a revolving drum carrying film. Additional mirrors could be placed in the system to allow photographs of as many as 3 different portions of the arc simultaneously. (3) Camera method, in which the whole of the arc was photographed by an ordinary camera, the length of the exposure being adjusted by the speed of rotation of a disk carrying a slit. Four types of arc were examined: (*a*) a low-current stabilized a-c. or d-c. arc (current approximately 10 amp.) placed in an air stream inside a 5-cm. diameter tube; (*b*) a free-burning arc occurring between copper or tungsten electrodes about 40 cm. apart, the arc being started by means of a thin copper wire; (*c*) an arc occurring inside a tube so that there was an axial stream of compressed gas along the arc. One electrode consisted of a 3-mm. diameter rod of tungsten, while the other was a grid constructed of 4-mm. diameter copper rods; (*d*) an arc occurring between electrodes so arranged that a stream of compressed gas passed through an opening at the side of the arc and then through two steatite nozzles to flow along the length of the arc in both directions toward the electrodes. The gas was heated initially and its speed was equal to that of sound in some of the tests. These arcs were examined by the methods described and very large variations in current density occurred along the length of the majority. The type *d* arc gave the most uniform illumination and current density. (*Science Abstracts*)

No. 364. George A. Ruehmling, "One Piece Electrical Contact Units of Laminated Metal," *Prod. Engg.*, March, 1934.

Silver or platinum contact metal fused to base metal increases rate of heat conduction away from contact; contacts are also less expensive; various forms shown.

No. 365. R. Holm, "Vaporization of Electrodes in Butt Contacts," *Zeits. f. Techn. Phys.*, Vol. 15, No. 11, pp. 483–487 (1934).

The vaporization of material in the arc of butt contacts is investigated and it is found that a particular characteristic voltage is found for this condition for each metal. The vaporized material is proportional to the electric charge which flows through the arc. The proportionality factor is determined and a method is developed for calculating the electric charge. Experiments were run on various materials and the proportionality factors determined. For the more complicated case in which the contact spark does not develop into the arc, a method is found for calculating the vaporization.

No. 366. E. W. Seeger, "Electromagnets and Contacts for Magnetic Contactors," *Prod. Engg.*, Vol. 5, No. 5, May, 1934, pp. 181–182.

Materials for contacts; types of electromagnets.

No. 367. H. Williams, "Contacts Suitable for Instruments," *J. Sci. Inst.*, Vol. 11, No. 9, September, 1934, pp. 273–279.

Considerable information of a detailed character, bearing upon the construction and the choice of material for electrical contact-making devices, is given covering wear-resisting properties and reliability generally. One table gives the arcing limits of current for a few metals, and a second correlates

melting points and life, expressed in terms of the effective number of "makes" and "breaks." The main conclusions reached during the testing of a special type of contact and spring are described. Fault liability is shown to decrease with increase of contact pressure, and to be much smaller with twin than with single contacts. Humidity does not, and current conditions only slightly, affect the liability of faults, but sparking reduces it. For all-round reliability, pure twin silver contacts of dome shape are recommended. Where very small voltages are present, platinum should be used. Spring oscillation or any other disturbing influence reacts unfavorably on the reliability of contacts. (*Science Abstracts*)

No. 368. A. L. Riemann, "Thermionic Emission," John Wiley & Sons, Inc., New York, N. Y. (1934).

No. 369. A. Kotecki, "Electric Discharge Between Rotating Copper Electrodes," *Acta Physica Pol.*, Vol. 3, pp. 105–114 (1934). (In French.)

Observations were made on the electric arc between rotating copper and aluminum electrodes. It was found impossible to obtain a constant arc between rotating aluminum electrodes due to the formation of a layer of oxide on the surfaces. The point of excitation of the arc was displaced on both the anode and cathode either continuously or by jumps. After the experiments there were irregular traces on the electrodes where the surfaces were more or less used. Spectroscopic examination, which gives in addition to the characteristic spectrum of the metal a weak continuous spectrum similar to an ordinary copper arc, points to the fact that there are hot spots on the cathode. The observations can be explained on the theory of the autoelectric emission of electrons by the cathode, rather than a thermoelectric emission. (*Science Abstracts*)

No. 370. G. E. Doan and A. M. Thorne, "Arcs in Inert Gases, Part II," *Phys. Rev.*, Vol. 46, July 1, 1934, pp. 49–52.

(1) The degree of purity of the elements of metallic arcs in inert gases, and particularly the degree of purity of the gas, determines the boundaries within which stable arcing may occur. Further, for elements of a high degree of purity, the boundary values of the region of unstable operation are quite definite and readily determinable experimentally; beyond these boundaries much more stable arcs are encountered. (2) The extinction of an unstable arc is not characterized by any marked change in the current or voltage of the arc at the instant immediately preceding extinction. (3) Higher purity of the electrode material and the inert atmosphere appears to move the voltage *versus* current curve in the direction of higher voltage. (*Science Abstracts*)

No. 371. L. S. Ornstein and H. Brinkman, "Thermic Mechanism in the Column of the Arc Light," *Physica*, Vol. 1, July, 1934, pp. 797–824. (In German.)

It is shown that in the ordinary arc light the impacts between atoms and molecules are by far the most important cause of the generation and extinction of excited particles, while the impacts of particles with electrons and ions and the emission and absorption of radiation play quite a subordinate part, as is also the case with ionization and dissociation processes. The thermic mechanism of the arc discharge leads to Boltzmann's law for the distribution of the molecules and atoms among the different energy states, with the gas temperature as the distribution modulus. The equilibrium between ions, electrons, and neutral particles is given by Saha's ionization formula, but it is found that the velocity distribution of the neutral gas particles and of the electrons does not depart much from the Maxwellian distribution for the temperature of the gas. It is shown that the gas temperature can be derived from measurements of the arc temperature and intensity measurements in the arc spectrum. The conditions of the change over from the arc to the glow discharge and also departures from Boltzmann's law are discussed. Finally, the possibility of a discharge of the arc type in the rare gases is considered, but this appears improbable since for these gases the discharge mechanism is not of the thermic type. (*Science Abstracts*)

No. 372. F. H. Newman, "Electric Arc," *Phil. Mag.*, Vol. 18, August, 1934, pp. 365–368.

The author discusses briefly various theories of the electric arc and suggests that the starting of an arc under conditions where the electrodes are separated and a momentary electrical discharge is passed probably occurs in the following manner. When the high tension (electrical discharge) is suddenly applied the bombardment of the cathode active spots by the positive ions results in thermionic emission therefrom. Ionization occurs in the cathode fall space with the high applied field, and the positive ions form a dense positive space charge which produces the requisite electric field for cold emission. It is stated that this does not preclude some thermionic emission from the active spots. (*Science Abstracts*)

No. 373. C. G. Suits, "Arcs at Atmospheric Pressure," *Phys. Rev.*, Vol. 46, August 15, 1934, pp. 252–254.

In the equation for the static characteristic of the electric arc at atmospheric pressure, $E=A+B/I^n$, the exponent n has been

interpreted by Nottingham and others as a constant independent of arc length and dependent linearly upon the boiling point of the anode material. This view is criticized from a consideration of new experimental data showing that the spread in measurements of n is necessarily very large. The conclusion that n varies directly as the boiling point of the electrode (anode) material is not given support by these experiments. (*Science Abstracts*)

No. 374. H. Witte, "Separation of Temperature and Field Excitation in the Electric Arc," *Zeits. f. Phys.*, Vol. 88, Nos. 7 and 8, April 21, 1934, pp. 415–435.

When the arc voltage is abruptly reduced to zero by means of an interrupter, any electrons excited by the field to energies greater than those corresponding to temperature equilibrium with the arc gas lose their excess energy in a time of the order of 10^{-5} sec. Thus light emission due to field excitation ceases in about 10^{-5} sec., whereas emission by temperature excitation follows the cooling of the arc gas, and decrease in such emission becomes appreciable only after a time of the order of 10^{-3} sec. Working with a cadmium or zinc oxide cored carbon arc and measuring the decay in light emission for the spectral lines of the core metal (cadmium or zinc), the author established that light emission was by pure temperature excitation save just before the cathode where field excitation contributed a part. When the arc was restruck (2×10^{-3} sec. after being extinguished) field excitation predominated temporarily until the normal temperature excitation took charge. (*Science Abstracts*)

No. 375. R. Thoma, "Operation of Small Circuit-Breakers," *V.D.E. Fachberichte*, pp. 54–57 (1934). Discussion, pp. 57–58.

Deals with automatic cutouts rated at 6 to 10 amp. for use on 220 v. lighting circuits, especially on d.c., where the fire risk due to slow clearing is higher. Typical time-current characteristics are reviewed in the light of operating experience. (*Science Abstracts*)

No. 376. H. Besold, "Selective Protection of L. V. Networks," *V.D.E. Fachberichte*, pp. 59–61 (1934). Discussion, pp. 61–62.

Contrasting fuse and automatic circuit breaker for small current applications, the latter, if fitted with time-delay, may remain in on short circuit, although tripping before the fuse blows on moderate overload. This tendency can be avoided by the provision of an instantaneous release on the circuit breaker operating at definite overload current. (*Science Abstracts*)

No. 377. A. von Engel and M. Steenbeck, "Electrical Gas Discharges," Julius Springer, Berlin, Vol. 1, 248 pp. (1932); Vol. 2, 352 pp. (1934).

Volume 1.—The authors present the first volume of a German treatise on conduction of electricity through gases. It was written primarily for the technical worker and engineer rather than for the physicist. Involved mathematics has, therefore, been avoided, and the material is presented in such form that any technically trained reader, even one with little knowledge of the science of electrical discharge in gases, will have no difficulty in following the text. The authors make free use of the graphic form of presentation, and give a wealth of data in the form of curves and tables. The topics considered in this first volume are: the ionization of gases; the dynamics of ions and electrons; and the destruction and the recombination of charge carriers. An appendix considers some phases of the kinetic theory of gases. A reference list of 119 items, and a subject index conclude the work. (*General Electric Review*)

Volume 2.—This is the second and concluding volume of a German treatise on electric discharges in gases, their nature and applications. The first volume dealt primarily with the fundamental laws of electric discharges and of conduction of electricity through gases. This second volume discusses the behavior of the various types of electric discharges and reviews, in a series of brief chapters, their industrial significance and applications. Some of the topics discussed are: gaseous discharges as a basis for measuring devices; the phenomena of corona; electric precipitation; protective devices based on the principle of electric discharge, such as the glow relay, etc.; discharges as a source of light; gaseous discharge rectifying devices; arc welding processes; switching phenomena; and the like. An 18-page bibliography is provided, and an adequate subject index completes the volume. (*General Electric Review*)

No. 378. R. M. Baker, "Voltage Drop in Sliding Contacts," *Elec. J.*, Vol. 31, November, 1934, p. 448.

A description of a series of experiments which show that the voltage drop of a sliding contact is principally due to the presence of oxide. It is suggested that a carbon commutator might be satisfactory and experiments along this line are contemplated. (*Science Abstracts*)

No. 379. R. Seeliger, "Electric Arcs," *Elettrotecnica*, Vol. 21, June 5, 1934, p. 350.

The physical processes underlying arc discharges are first discussed and the most important properties, especially in the region of the cathode, are dealt with. The phenomenon of the liberation of the electrons from the cathode is then discussed. Mercury-

arc rectifiers and h.t. switchgear for a-c. work are considered from both theoretical and practical standpoints. (*Science Abstracts*)

No. 380. R. Holm, B. Kirschstein, and F. Koppelmann, "Physics of Heavy-Current Arc with Particular Reference to Quenching in High-Power A.C. Switches," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 13, No. 2, p. 63 (1934). (In German.)

This paper gives at first an introduction to the theory of a permanent arc, the electron and energy balance of which is studied. For the energy that flows off by heat convection an upper limit is calculated. The radiation is taken into account according to measurements by R. Holm and A. Lotz.

In the electron balance of the permanent arc in air, the diffusion plays a minor part. On the other hand, it is decisive for thin arcs in hydrogen. Herewith connected is the electron density of the arc in air, being substantially determined thermically, hence probably calculable after the Saha equation. On the other hand, the thin arc in hydrogen works chiefly with shock ionization.

The condition for extinguishing strong a-c. arcs can briefly be summarized as follows: The electron density of the remaining column (at zero phase) has to decay to below 10^9 electrons per cubic centimeter on a substantial part of the arc length. In air (nitrogen) this condition can hardly be reached because of the small thermal conductivity and diffusion velocity. Hence, an additional quenching effect in air has to be considered, the lifting of the column from the electrode (by axial gas flow) and, for the rest of the column, the shearing off by turbulent gas motion. Both effects have the supposition that the arc is already thin enough while burning. Most of the effects dealt with are quantitatively summarized in formulas.

No. 381. F. Kesselring, "Experiments with Electric Arcs," *ETZ.*, Vol. 55, January 25, 1934, p. 92; February 1, 1934, pp. 116 and 165. Discussion, February 15, 1934, p. 176.

Gives results of a number of experiments to determine diameter, voltage drop, and temperature at various points along an electric arc in air, hydrogen, and nitrogen. It is shown that the diameter plays an important part in arc extinction, and that hydrogen, which is present in the expansion switch, has the best arc-extinguishing properties. (*Science Abstracts*)

No. 382. W. Wanger, "Contact Heating in High-Power Switches," *Bull.*, Assoc. Suisse des Elec., Vol. 25, No. 16, August 3, 1934, p. 532. (In German.)

Discusses the temperature rise of the contacts of high-power switches due to short circuit currents. Differential equations are developed for the flow of heat from the contact surface and expressions given for the temperature rise both with a.c. and d.c. When the contact surface is small the calculations indicate temperatures approaching the melting point of copper, but actually before this is reached the increased plasticity of the metal so increases the contact area that the temperature is reduced and welding together of the contacts rarely occurs. (*Science Abstracts*)

No. 383. T. Nishi and S. Fukuda, "Arc-Extinguishing Power of Various Substances," *J.*, I.E.E., Japan, Vol. 54, July, 1934, p. 683. (English abstract.)

Results of experiments carried out to compare the arc-extinguishing power of various organic compounds and inorganic ammonium salts, when used as the fillers of cartridge fuses. The arc extinguishing power is estimated by the minimum electrode separation at which the test circuit can be ruptured with the arc duration less than one-half cycle. (*Science Abstracts*)

No. 384. S. Dushman, "Electron Emission," *Elec. Engg.*, Vol. 53, July, 1934, p. 1054.

Edison's observation of the discharge of negative electricity from the carbon filament of an incandescent lamp to an auxiliary electrode in the bulb, commonly known as the "Edison Effect," remained unexplained until the beginning of the twentieth century. Since that time, an entire new industry—radio—has grown up as a result of continued research in the emission of electrons from hot cathodes. This article reviews some of the more important observations and conclusions obtained from investigations in this field. (Author's abstract)

No. 385. Lewi Tonks, "Electric Discharges in Gases, Part I—Ionization and Excitation," *Elec. Eng.*, Vol. 53, February, 1934, pp. 239–243.

This article is one of a series of general articles on electric discharges and gases and deals with the basic concepts involved in the microphysics of the electric discharges, in the interactions of electrons and photons with atoms, and various types of energy interchange.

No. 386. Karl K. Darrow, "Electric Discharges in Gases, Part II—Ions in Dense Gases," *Elec. Eng.*, Vol. 53, March, 1934, pp. 388–395.

This article is one in the series of articles on electric discharges and gases in which the field of discharges between the glow and arc is considered. The article is a general review of such subjects as drifting of electrons through a gas in a field, diffusion of electrons through gases, diffusion of ions, and re-

combination and other effects which take place in glow and arc discharges.

No. 387. J. Slepian and R. C. Mason, "Electric Discharge in Gases, Part III—Self-Maintained Discharges," *Elec. Engg.*, Vol. 53, April, 1934, pp. 511–517.

This is the third of a series of articles of this subject discussing the various types of electric discharges and gases. The various sections included ones concerning sparking, corona, glow discharge, and arcs. The discussion of each of these sections is more or less general, with reference to specific data in some cases. The article is a general discussion of the background of these effects.

No. 388. S. S. Mackeown, F. W. Bowden, and J. D. Cobine, "Reignition of an Arc at Low Pressures," *Elec. Eng.*, Vol. 53, July, 1934, pp. 1081–1085.

Results of a study of the factors influencing the reignition potential of an alternating current arc at low pressures are presented in this paper. The data were obtained from oscillograms of arcs at different currents, between electrodes of different materials in air at pressures ranging from 2 cm. of mercury to atmospheric pressure, and for a gap setting of one millimeter.

At low current densities and at low pressures the reignition potentials using electrodes of carbon, copper, and graphite were approximately the same, proportional to the pressure, and lower than the sparking potential. At low pressures a high reignition potential is necessary to establish the arc even when the electrodes are carbon. At higher pressures and at higher current densities the reignition potential of carbon and graphite decreased with increase in pressure; no such decrease was found for copper electrodes. Impurities having a low work function decreased the reignition potential markedly. Conditions favoring high temperature of the electrodes also tended to decrease the reignition potential.

The experimental results are consistent with the theory that the transition from a glow discharge to an arc is due to the establishment of a high positive space charge at the surface of the cathode producing an electric field of high intensity.

No. 389. R. Holm and A. Lotz, "Measurement of the Total Radiation from an Alternating-Current Arc in Air," *Wiss. Veröff. a. d. Siemens-Konzern*, Vol. 13, No. 2, p. 87 (1934). (In German.)

A method for measuring the strengh of transient radiant impulses is described. The method employs an alternating current bolometer installation operating on medium frequency, whose measuring currents, rectified and amplified, are recorded on an oscillograph. A stroboscopic disk lets the radiation fall on the bolometer band only at intervals which are always of the same duration. The radiation impulses which reach the instrument in this manner are measured by the jumps of the beam.

With the aid of this method the total radiation emitted by an alternating current arc in the open air or strongly blown axially has been measured for the first time in a predetermined phase, particularly that phase region where current and temperature attain their maximum values, and for effective currents in the region from 20 to 2000 amp. at 50 cycles. The radiation from an arc in the open air without metallic vapor amounted to 7 to 14 per cent of the current energy. Apparently, a maximum value of 14 per cent is reached at an effective current strength of about 400 amp. With blown arcs the percentage of the radiation is a little higher. (Author's summary)

No. 390. C. G. Suits, "Stabilizing Arcs by Electrode Surfacing," *Physics*, Vol. 5, No. 12, December, 1934, pp. 380–383.

The effect of electrode surfacing on arc stability is studied for arcs between copper and silver electrodes in air at atmospheric pressure. For the copper arc it is shown that the random fluctuations in arc voltage and light intensity may be reduced to a very small value by giving the anode surface a high polish. Observations of the spectrum and volt-ampere characteristic are described. For the silver arc partial stability of arc voltage and light is obtained by electrode polishing. (*Science Abstracts*)

No. 391. R. M. Baker, "Electrical Sliding Contacts," *Elec. J.*, Vol. 31, September, 1934, pp. 359–360.

The nonohmic characteristic of the contact resistance between carbon and metal is attributed to oxide film, as tests made on a sliding contact between a graphite brush and graphite ring show a constant contact resistance of 0.0103 ohm over a current-density range of 18 to 180 amp. per sq. in. Reckoning on 50 to 100 point contacts per sq. in., each will have an effective radius of some 0.0005 in. and the current density at the highest loading will be about a million amperes per square inch for a temperature rise of 22 C. (*Science Abstracts*)

No. 392. A. Schulze, "Electrical Resistance of Various Alloys," *Zeit. f. Metallkunde*, Vol. 26, June, 1934, p. 140.

Electrical resistance materials are usually alloys, for these possess the necessary qualities of high specific resistance, small temperature coefficient, and resistance to corrosion. The alloys concerned are those derived from high melting point metals which form solid solutions (copper, nickel, iron, chromium, and manganese). The alloys in use are discussed under two headings: (1) those for precision

work; and (2) those for use in commerce. Manganin is a typical alloy of the first group, for it is extremely stable under favorable conditions. Commercial alloys fall into three classes: (*a*) copper alloys; (*b*) copper-nickel alloys; and (*c*) chromium-iron alloys. The first class usually contains additions of zinc, but as this is volatile at high temperatures it is preferable to keep the zinc content as small as possible. Constantan is the most frequently used alloy of this type and is stable up to 400 C. The specific resistance of chromium-nickel alloys is very much greater than the copper alloys and they are more stable at high temperatures. The alloys of this class may, or may not, contain iron; iron raises the specific resistance, while alloys free from it are more resistant to acids. The characteristic feature of the chromium-iron alloys is their great stability at temperatures up to 1400 C. A graph shows the specific resistance of a number of important alloys as a function of the temperature. (*Science Abstracts*)

No. 392a. R. W. Bauer and J. W. Seaman, "A Circuit Breaker for Radio Speech-Control Circuits," *G. E. Rev.*, Vol. 37, November, 1934, p. 495.

The requirements of a circuit breaker for use on radio speech-control circuits at Radio City are outlined, and a breaker is described which was designed to isolate a fault whether it was of comparatively high value or of a value far below the normal carrying capacity of a convention breaker. The specification for this breaker included the requirements that the contact resistance must be constant throughout the operating day, and that the contacts must withstand repeated openings under load without undue burning. The size of the breaker had to be smaller than any standard breaker heretofore available to handle the same voltage and current. To meet the requirements a combination of arcing horns with a series of arcing tips were so arranged that magnetic reaction caused the arc to loop out and transfer to the horns, thereby rapidly increasing the break and interrupting the circuit. Split primary contacts, silver-plated, were used having a slight wiping action.

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No. 393. L. B. Loeb, "Kinetic Theory of Gases," Second Edition, McGraw-Hill, New York, N. Y. p. 106 (1935).

This book gives one of the best presentations available of the fundamental theories of the kinetic theory of gases, its further development, and many applications. One section includes the theory of electrical discharges in gases; however, the main part of the book deals with the thermodynamic aspects of the kinetic theory. Quantum mechanics is introduced in the discussion of specific heats.

No. 394. R. Holm, F. Guldenpfennig, and R. Störmer, "The Metal Migration of Electrical Break Contacts," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 14, No. 1, p. 30 (1935). (In German.)

This paper is an original exhaustive research work. The metal migration of contacts which in the average are only slightly heated by the contact sparks is investigated and said to be made calculable for the first time by setting up empirical rules. The authors find that metal migration takes place away from the anode if the arc is shorter than the free path of the electrons, that is, always in the case of make contacts; exceptions are carbon and lead, otherwise the migration occurs away from the cathode. The migration is subject to the rule: the transferred metal's weight G is proportional to the quantity of electricity that flowed through the spark. Therefore $G = \gamma \cdot q$, whereby γ is a proportionality factor which depends on the contact shape but which is fundamentally a material constant. However, γ is different for make and for break contacts. Formulas are given to calculate the quantity of electricity, or in certain cases, a fictitious quantity q_r, for the most important circuits that come in question. The coefficients are given in tables and by certain rules.

No. 395. V. P. Hessler, "The Effect of Various Operating Conditions upon Electrical Brush Wear and Contact Drop," *Bull. 122*, Iowa Engg. Exp. Station, Ames, Iowa, November, 1935.

The results of previous investigations of electric brush wear and contact drop are presented and the theories of the sliding contact are checked against these early investigations. There are practically no quantitative data concerning electrical brush wear in the literature, and no theories of the mechanism of electrical brush wear were found.

Apparatus and a method of procedure were developed for obtaining reasonably consistent electrical brush wear measurements. All measurements were made upon sliprings since it was desired to eliminate as many variables as possible. Humidity and temperature conditions were held constant at all times except when varied purposely to determine their effects upon brush wear.

Direct current was used for all except one brief series of tests.

The effects of humidity, brush pressure, ring speed, brush circuit potential, and current density upon electrical brush wear were investigated. Tentative conclusions are drawn concerning the effect of each of the above factors upon electrical brush wear and contact drop.

A new theory of the sliding contact based

on the negative temperature coefficient of resistance of copper oxide is proposed.

A bibliography is included for the convenience of those who wish to consult the original articles from which citations have been made.

No. 396. A. Deubner, "Versuche mit Zwei Aufeinandergepressten dunner Metallschichten" (Experiments with Two Thin Metal Layers Pressed Together), *Die Naturwissenschaften*, (Berlin) Vol. 23, p. 557 (1935).

No. 397. W. Meissner, "Kontaktwiderstand" (Contact Resistance), *Wien. u. Harms*, Handbuch der Experimentalphysik, Vol. 11, No. 2, pp. 160–171 (1935).

No. 398. R. Holm and B. Kirschstein, "Resistance of Very Thin Layers of Foreign Substances in Metallic Contacts," *Zeits. f. Techn. Phys.* Vol. 16, No. 11, pp. 488–495 (1935); *Phys. Z.*, Vol. 36, December 1, 1935, pp. 882–888.

The work of Holm and Meissner (*Sci. Abst.*, No. 3161 (1933)) on the contact resistance of two different conductors is extended to the case when a layer of a foreign body, a few molecules thick, is present between two similar conductors. It has been shown that the "specific resistance per square centimeter" is of the same order for all metals, is independent of temperature and over a range of 0.6 to 20 mv. Ohm's law applies. An explanation of these results has been offered on the basis of the electron theory of metals with the help of a formula derived by Frenkel; the assumptions made by Frenkel now appear to be invalid and an attempt is made to derive a new formula which shall give results which are in accord with experiment. Certain assumptions are made but it is found that the inaccuracy of the results deduced from this formula are not greater than the uncertainty in the values of the work functions of the conductor. (*Science Abstracts*)

No. 399. J. Roulleau, "Metal-Cuprous Oxide Contact Resistance," *Compt. rend.*, Vol. 201, pp. 947–948 (1935).

By a special arrangement the copper-cuprous oxide contact resistance is shown to depend on (*a*) the age of the surface, (*b*) temperature, (*c*) specific resistance of the cuprous oxide, and (*d*) treatment of the surface. With (*a*), (*b*), and (*d*) constant it is proportional to (*c*); variation in (*d*), for example, attack by dilute acid, alkali, or salts, affects only the factor of proportionality. For high resistance the surface must be crystalline. (*Chemical Abstracts*)

No. 400. G. Dechene, "Sur les Resistances Electriques au Contact de deux Substances Semi-Conductrices" (Contact Resistance Between Two Semi-Conductors), *Compt. rend.*, Vol. 200, pp. 648–651 (1935).

The author investigated the contact resistances between the contacts mercuric oxide-sodium carbonate, and mercuric oxide-copper sulfate, and sodium carbonate-cuprous oxide with voltages varying from a few volts to a few hundred volts. The two substances were compressed in a hydraulic press. The effects of the direction of current, the degree of compression of the substances, temperature and polarization of the contact surfaces were studied. The results are similar to those obtained at the contact between a semiconductor and a metal and the explanation is the same, *viz.*, that the passage of ions or electrons across the surface of a semiconductor necessitates the production of an intense electric field at this surface. (*Sci. Abst.*, 5197 (1934).) (*Science Abstracts*)

No. 401. I. W. Kurtschatow, T. Z. Kostina, and L. I. Rusinow, "Kontakterscheinungen in Karborundwiderstanden" (Contact Effects in Carborundum Resistors), *Phys. Zeit. Sowjetunion*, Vol. 7, pp. 129–154 (1935).

No. 402. "Contacts and Contact Alloys," *Search No. 4749*, Engineering Societies Library of the United Engineering Trustees, Inc., 29 W. 39th St., New York, N. Y. (1935).

No. 403. "Building Up Oil Circuit-Breaker Contacts," *Power* (Readers' Problems), Vol. 79, No. 5, May, 1935, pp. 267–268.

No. 404. "Contact Heating in High-Power Switches by Short-Circuit Currents," *ETZ.*, Vol. 56, No. 23, June 6, 1935, pp. 645–646.

The heating of electrical contacts under short circuit conditions is considered from the viewpoint of actual contact surface area compared with the total contact surface and the other physical properties of the contact materials. Formulas are given for the maximum temperature in the contact surface as a function of the current, the heat conductivity, electrical conductivity, and the area of cross-section of the actual contact surface. A formula according to the work of L. Bender is also given for the time required to reach this temperature.

The results of a series of calculations show that maximum temperature approaches the melting temperature in the contact surface even though the parts of the contact away from this actual surface area are still cold.

A formula is also given for the probability of welding of contacts under short circuit conditions.

No. 405. "When Selecting Rare Contact Metals," *Elec. Mfg.*, Vol. 16, September 1, 1935, pp. 26–27.

No. 406. C. Dannatt and S. E. Goodall, "Circuit Interruption," *Electrician*, Vol. 114, p. 539 (1935).

Modern circuit breaker research has demonstrated that one of the main factors determining the short circuit rating of a circuit breaker is the rate of rise of recovery voltage across its terminals immediately following arc extinction. The author develops methods for calculating the rate of recovery voltage applicable to networks on which either short circuit tests can be carried out, or on which impedance frequency characteristics can be taken; the latter involving the assumption that the network can be freed from voltage. It is suggested that a direct method of test would be to examine oscillographically the reaction of the networks to impressed surges of current of special form, and an illustration is given of a cathode-ray oscillograph with rotating drum camera developed by the Research Department of the Metropolitan Vickers Electrical Co. (*Science Abstracts*)

No. 407. J. O. Knowles, "Questions for Research on Operating Duty and Breaking Capacity of Contactors," *Memorandum G/F/Rl*, E.R.A., May 10, 1935.

No. 408. V. P. Hessler, Electrical Brush Wear," *Trans.*, A.I.E.E., Vol. 54, October, 1935, p. 1050.

No. 409. R. E. Hellmund, "Flashing of Railway Motors Caused by Brush Jumping," *Trans.*, A.I.E.E., Vol. 54, November, 1935, p. 1178.

No. 410. R. N. Varney, H. J. White, L. B. Loeb, and D. Q. Posin, "Mechanism of Static Spark Breakdown," *Phys. Rev.*, Vol. 48, November 15, 1935, p. 818.

The mechanism of spark breakdown has been investigated largely by the study of the deviations of the pre-spark current from the simple electron ionization law, $i = i_0 e^{\alpha d}$. The deviations indicate for large separations a current greater than that given by the formula. It is suggested that the increased current is not due to new ionization processes, but to distortion of the spark gap field by space charge, giving an apparent increase in α, which is a function of the field strength. Analysis of previous experimental results shows that for small fields α increases exponentially with the field strength; for larger fields, α increases with the square of the field strength, while for very large fields α becomes more nearly constant. A solution of Poisson's equation shows that these variations of α are to be expected on theoretical grounds. Space charge is the primary cause of spark breakdown in the low field range, but only in the case of high fields are the ordinary Townsend ionization processes effective. (*Science Abstracts*)

No. 411. H. Hörmann, "Temperature Distribution and Electron Density in Open Electric Arcs," *Zeits. f. Phys.*, Vol. 97, Nos. 9 and 10, November 12, 1935, p. 539.

Measurements were made of the field strength in freely burning and in stabilized electric arcs at atmospheric pressure. The results for the carbon arc show that the value hitherto accepted for the constant b in the Ayrton formula is about twice too high. Measurements with extremely pure carbons showed that the ionization in the carbon arc is not appreciably affected by the presence of impurities in the carbons. From the intensity distribution of the spectral lines about the cross-section of the arc making use of Abel's integral equation, it was found possible to calculate the specific radiation density for the arc cross-section. This was done for the arc between pure carbons and for arcs between electrodes of the alkali metals. From the radiation density the temperature distribution over the arc cross-section was determined for the carbon arc. From Saha's equation the degree of ionization could then be found as a function of the temperature and the ionization potential. In this way it was found that the temperature on the axis of the arc should be between 6000 and 7000 K., which is in agreement with the results of Ornstein. (*Science Abstracts*)

No. 412. O. Becken and R. Seeliger, "Mechanism of Arc Discharge," *Ann. der Phys.*, Vol. 24, No. 7, November, 1935, p. 609.

It is explained that arc discharges may be either thermal arcs, field arcs, or a combination of the two, depending on the nature of the electron emission from the cathode and the nature of the cathode. The paper describes a theoretical and practical investigation of the conditions appertaining to these types of arcs, and describes the apparatus and technique employed. A calculation of the cathode temperature is given, an investigation of the current strength at the striking of the arc for various electrodes in nitrogen is described and also the characteristics and appearance of the discharge, and current density measurements. The results for tungsten are discussed in detail. (*Science Abstracts*)

No. 413. C. G. Suits, "Temperature of the Copper Arc," *Proc.*, Nat. Acad. Sci., Vol. 21, January, 1935, p. 48.

The temperature of a long arc burning between copper electrodes was calculated from measurements of the velocity of sound waves in the arc. The sound waves were generated by means of a condensed discharge between an auxiliary electrode immersed in the arc and the cathode. Upon breakdown of an external sphere gap, synchronized with a cathode-ray oscillograph by means of ultra-

violet light, a sound wave was generated directly in the arc discharge. A nonoscillatory spark discharge between two electrodes was used as a detector for the sound waves passing through the arc; the incidence on this spark gap of the sound waves resulted in an abrupt change in spark voltage which could be observed on the cathode-ray oscillograph with amplification. Time intervals were plotted for different values of arc length and from this curve the velocity was directly determined. For a 6 amp. copper arc the velocity was found to be 1.42×10^5 cm. per sec. for the shorter arcs and 1.36×10^5 cm. per sec. for the longer arcs. From these velocities the corresponding temperatures, after making all corrections, were found to be 4200 ± 200 K. and 4000 ± 200 K. For a constant arc length of 9 cm. and an arc current varying between 4 and 26 amp. the velocity of sound was found to be constant within the spread of the measurements. The results are applied to calculations of the density of ionization in the arc. (*Science Abstracts*)

No. 414. O. Stübing, "Helium-Tungsten Arcs," *Helv. Phys. Acta.*, Vol. 8, No. 2, p. 165 (1935). (In German.)

Helium-tungsten arcs were examined in the pressure range 11 to 500 mm. to determine the relations between current, potential, arc length, and pressure. By means of the current-potential curves for a tungsten probe a study was made of the behavior of the primary electrons emitted by the cathode. The electron group with a volt velocity of the order of the cathode fall observed in nitrogen by Wehrli and Bächtiger at pressures below 29 mm. of mercury was found also in helium, but on account of the large mean free path in helium the group could be observed at pressures as high as 198 mm. As is to be expected on theoretical grounds, the total number of all elastically scattered electrons was found to decrease exponentially with increase of the product of pressure and distance from the cathode. The sudden disappearance of the anode fall on reduction of the arc length is also found in helium, but at much greater arc lengths than in the case of hydrogen. This effect was also observed when the pressure was decreased, keeping the arc length constant. (*Science Abstracts*)

No. 415. H. Plesse, "Electric Arc," *Ann. der Phys.*, Vol. 22, No. 5, April, 1935, p. 473.

The transition stage between the glow and the arc discharge is investigated by means of an alternating current, the pressure, current, and potential being appropriately chosen. Arcs are distinguished by the cathode spot being movable or stationary, according to the metal used as electrode. The spot moves in the case of silver, tungsten, platinum, nickel, and iron, and remains fixed in the case of cadmium, zinc, lead, magnesium, calcium, and carbon. It is shown that wherever metallic vapor forms sufficiently densely in front of the cathode a glow discharge transforms into an arc discharge. It appears that the production of vapor is not in every case due to heating, but that the impact of positive ions on the cathode may also lead to metallic atoms being ejected. H. f. vibrations are shown to occur in the transition stage between glow and arc discharge, the frequency varying from 10^5 to 2×10^6 according to the self-induction and capacity in the current circuit. The thermal data of the metals used as electrodes are found to account well for the respective tendencies of these metals toward the arc discharge. (*Science Abstracts*)

No. 416. C. G. Suits, Part I; H. Poritsky and C. G. Suits, Part II; "Determination of Arc Temperature from Sound Velocity Measurements," *Physics*, Vol. 6, June, 1935, pp. 190 and 196.

A method of determining the temperature of an arc is described based on measurements of the velocity of sound in it. Allowance is made for the effect of ionization upon the velocity. The velocity is measured by producing an intense spark in the arc and measuring the time on a cathode-ray oscillograph for the sound pulse produced to reach a detector. For the latter a second spark gap was used, it having been found by the authors that the spark voltage rapidly increases when a pressure wave falls on the spark. By varying the arc length, end effects, etc., can be satisfactorily allowed for. The corrected temperature, which is independent of the arc current, is found for the copper arc to be 4100 ± 300 K. (*Science Abstracts*)

No. 417. D. T. J. ter Horst, H. Brinkman, and L. S. Ornstein, "Time Variations of Temperature in A.C. Arc Discharges," *Physica*, Vol. 2, July, 1935, p. 652.

Measurements were made of the time variations of temperature of arc gases, as dependent on the phase of the applied a-c. potential, for a series of frequencies between 50 and 500 cycles. Oscillographic measurements enabled the energy production per unit volume to be determined. A graphical solution of the differential equation for the energy equilibrium gives results in good agreement with the observations. The theory of the thermal mechanism in the arc column, previously given by Ornstein and Brinkman on which rests the determination of the temperature from the spectral intensities, is confirmed by the results obtained. In the calculations account was taken of the dependence on temperature of the heat conductivity and the specific heat of the arc gases. These functions (for nitrogen in dis-

sociation equilibrium) show a well defined behavior in the temperature region near the dissociation temperature of nitrogen. (*Science Abstracts*)

No. 418. E. Hutchisson, T. H. Osgood, and R. E. Pearon, "Electrical Conductance of Short Gaps in Air," *Proc.*, Nat. Acad. of Sci., Vol. 21, September, 1935, p. 542.

The dependence of conductance upon gap width under ordinary conditions, such as those found in switch contacts operated in air, are investigated experimentally. The gaps used are effectively those between a spherical electrode of radius 14×10^2 cm., 14 cm. or 25×10^{-4} cm. and a plane, the surfaces being of steel in some cases, of tungsten wire in others. The results indicate that appreciable current can pass between surfaces of approximately 4 cm. diameter which are separated by as much as 10,000 Å in air. The current passing is proportional approximately to the square of the applied p. d.; this indicates that the conduction is effected by charged dust particles moving cyclically from one electrode to the other. At very small separations of the electrodes the current definitely obeys Ohm's law, and is probably carried by metallic bridging. (*Science Abstracts*)

No. 419. A. Kotecki, "Characteristics of the Electric Arc," *Acta Physica Pol.*, Vol. 4, Nos. 1 and 2, p. 113 (1935). (In French.)

The characteristics of electric arcs ($e = f(1/i)$) were studied for electrodes of copper, iron, aluminum and carbon for the cases when both electrodes were of the same material and of different materials, e.g., carbon-copper, iron-carbon, carbon-carbon, etc. The experiments were carried out with d.c. at 220 v. in the region of 1 to 20 amp. at electrode distances of 1 to 5 mm. and the results are given graphically in a series of curves. These are discussed and compared with both practical and theoretical results of other workers. (*Science Abstracts*)

No. 420. C. G. Suits, "A Study of Arc Temperatures by an Optical Method," *Physics*, Vol. 6, October, 1935, p. 315.

Sound waves passing through arcs in air are photographed with a rotating mirror camera, whereby the sound velocity in the arc core is determined. From the observed sound velocity the arc temperature may be calculated by a method previously described. The arcs measured by this method, together with the sound velocities and corresponding temperatures are:

Cored carbon	1.85×10^5 cm. sec.$^{-1}$	5500 K.
Sodium chloride cored carbon	1.57×10^5 cm. sec.$^{-1}$	4740 K.
Aluminum cored carbon	2.14×10^5 cm. sec.$^{-1}$	6160 K.
Aluminum cored carbon	2.17×10^5 cm. sec.$^{-1}$	6220 K.
Tungsten, 6-mm. electrodes	2.04×10^5 cm. sec.$^{-1}$	5950 K.
Tungsten, 9.5-mm. electrodes	2.27×10^5 cm. sec.$^{-1}$	6440 K.
Tungsten-iron	2.13×10^5 cm. sec.$^{-1}$	6150 K.
Iron-iron welding arc	2.08×10^5 cm. sec.$^{-1}$	6020 K.

The experimental error corresponds to ±100 at 5500 K. The experimental requirements of the sound source are discussed in detail. The gas temperature across the arc core is found to be constant within the error of observation. For most of the arcs studied the current density and electric gradients have also been measured, so that the data may be used as a test of the thermal ionization theory. The "effective ionization potential (i.p.)" of the arc gas is in all cases above the i.p. of the metallic vapor and below that of nitrogen. For the tungsten arcs the effective i.p. is 15 v., midway between the first i.p. of oxygen and nitrogen. For the arcs other than tungsten, this quantity is lowered appreciably by electrode vapor. A small partial pressure of sodium lowers the arc temperature by approximately 1500 C. The temperature of a welding arc between a coated iron welding rod and a steel plate is measured to be 6000 C, from which the dissociation of the arc atmosphere is found to be 81 per cent. This high degree of dissociation points to the importance of the dissociation-diffusion-recombination process for heat transfer in welding arcs and explains the recently reported negative results of attempts to arc weld in pure argon. (Author's abstract)

No. 421. J. S. E. Townsend, "Theories of Ionization," *Phil. Mag.*, Vol. 20, August, 1935, p. 242.

The experimental results of different workers on ionization in gases and related phenomena are examined and found to be in good agreement with theories of long standing proposed by the author. It is claimed that in many cases, application of Franck and Hertz's theory of collisions of the second kind leads to definitely wrong results. It is concluded that the general Townsend theory in which single collisions produce atomic excitation and ionization is adequate to explain all known phenomena in the ionization of gases, and many experiments of the Oxford school, using both pure and impure gases, are quoted in support of the contention. (*Science Abstracts*)

No. 422. A. J. Kling, "New Vacuum Switch," *G. E. Rev.*, Vol. 38, November, 1935, p. 525.

Because there is no corrosive agent present, contacts in vacuum remain clean, permitting positive contact with very light pressure. Also the motion required for break is small because there is less arcing, none with a.c. because of the effective "deionization" at the

current zero; and none with d.c. up to about 50 amp., depending on the contact material, after which a cold-cathode electron discharge may be initiated and metal vapor evaporated. To sustain an arc, however, requires a higher current than in the air. The switch described is built on the lines of the all metal radio receiving valves. It is sealed off through a tubular operating lever which is mounted in a diaphragm which acts as its fulcrum and closes one end of the cylindrical body. The moving contact, molybdenum, travels 0.018 in. between the fixed ones, copper. It may be operated faster than 30 times per second. Its life is many million operations. It is single-pole, two-way, and has a rating of 10 amp. at 250 v. (*Science Abstracts*)

No. 423. G. D. Walker, "Arcs in Air and Circuit-Breaking," *Trans.*, S. African I.E.E., Vol. 26, March, 1935, p. 48.

An account of tests on an experimental circuit breaker in which a sectionalized arc follows a spiral path between cold copper plates; in the interspaces are gauze grids which may be connected in various ways. The control is mainly magnetic. Results up to 2000 amp. (the available limit) at 500 v., d. c., and 850 amp., rms., a. c. were satisfactory, the circuit being interrupted in 0.03 sec. and 1/4 cycle, respectively. A review of the physics of the problem and an extensive bibliography are included. (*Science Abstracts*)

No. 424. F. Kesselring and F. Koppelmann, "H. V. Switching," *Arch. f. Elektr.*, Vol. 29, January 11, 1935, p. 1.

Gives a comprehensive survey of the various factors affecting the extinction of the arc in h. v. circuit breakers. The first part deals with the external factors affecting the problem and their effect in reducing the arc energy, chief among these are the magnitude and the rate of rise of recovery voltage and the contact speed. The second part of the paper deals with the physical properties of the arc and the processes whereby restriking takes place after the zero pause. (*Science Abstracts*)

No. 425. G. Windred, "Electrical Contacts," *Engineer*, Vol. 160, August 30, 1935, p. 222.

The selection of suitable materials is briefly considered. The effect of oxides in increasing contact resistance is pointed out. The following details of contact metals are given:

TABLE II.—CONTACT ALLOYS.

Alloys	Fusing Point, deg. Cent.	Brinell Hardness, Annealed	Specific Gravity
Coin silver	890	59	...
10 per cent gold-silver	1000	28	11.38
10 per cent iridium-platinum	1820	150	21.50
20 per cent iridium-platinum	1880	230	21.64

Contact resistance for normal materials and pressures equals a constant over the pressure between contacts. A bibliography is given. (*Science Abstracts*)

No. 426. R. Holm and F. Guldenpfennig, "The Metal Migration in Electrical Break Contacts Particularly with Quenched Circuits," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 14, No. 3, p. 53 (1935). (In German.)

This paper is a continuation of the research commenced by the same authors and R. Störmer. However, the metal migration that was investigated in the previous article for simple circuits only is here made calculable for the particularly important case that a quenched circuit, condenser and resistance, is connected in parallel with the contacts. Besides the condition is set up that no spark flashes over the contact gap. The evidence for the calculation of favorable quenched circuits is given herewith. In addition, the former investigations are completed for the presence of a high resistance in the circuit.

The measurements give proof for the conception that the cathode dispersion is a direct utilization of the energy delivered and not merely an evaporation due to temperature.

No. 427. G. T. Tretjak, V. V. Kaplan, E. I. Kender, and Smouroff, "Open Arcs on A.C. Systems," *Papers* of the C.I.G.R.E., Paris, 18 pp. (1935). (In French.)

Results are presented of tests made at 3.6 and 35 kv. on a-c. open arcs in order to determine the conditions for extinction, and the

TABLE I.—CONTACT METALS.

Metals	Fusing Point, deg. Cent.	Thermal Conductivity, cal. per sq. cm. per sec. per deg. Cent.	Resistance, $\mu\Omega$ per cubic centimeter	Temperature Coefficient of Resistance	Brinell Hardness, Annealed	Specific Gravity
Copper	1083	0.92	1.72	0.0040	..	8.93
Silver	961	1.006	1.62	0.0036	30	10.50
Platinum	1760	0.170	10.5	0.0037	47	21.40
Palladium	1550	0.168	10.7	0.0036	49	11.40
Tungsten	3370	0.360	5.5	0.0052	..	18.80

factors governing their length, resistance, and duration. Based on the results of this and other investigations formulas are derived for the arc gradient, arc length, and the initial and critical resistances. Formulas are also developed for arc duration and stability with no wind, and for arc duration when exposed to the wind. (*Science Abstracts*)

No. 428. L. Weiler, "Switching Capacity and Life of Copper-Contacts for Switch and Control Gear," *ETZ.*, Vol. 56, Part 1, No. 3, January 17, 1935, p. 52.

Results of experimental investigations into the relation between controlled power and length of life of switch contacts in switchgear and control equipment are given, for open and oil-immersed conditions. Reference is made to the possibility of lengthening the life of contact pieces in switchgear by making them of special metals. The use of noble metals in such connection is indicated in the cases of rolling mill and foundry practice where the switching operations are frequent. (*Science Abstracts*)

No. 429. R. Holm, "Electrical Contacts," *ETZ.*, Vol. 56, May 9, 1935, p. 537.

The author shows that a pure metal contact can only be recognized in a vacuum. In a quiescent contact, the resistance is simply related to the tempertaure, the p. d., the heat, and electrical conductivities of the metal, up to the melting voltage, depending on the pressure, and hence to the total area of contact. Curves are given for a pure metal contact and with a foreign film. With increasing potential difference, the resistance remains constant until the contact coheres, when the resistance falls to a low value. The author also studies the breakdown of the foreign film and the movement of metal under the action of an arc when the voltage exceeds 15 v. and the current 0.2 amp. Translation of atoms of the metal depends on the gap and the field strengths and temperature. (*Science Abstracts*)

No. 430. R. Holm, "Heating of Metallic Contacts," *Arch. f. Elektr.*, Vol. 29, March 12, 1935, p. 207.

A mathematical treatment dealing with the heating of current-carrying metallic contacts. Formulas and curves are given for the temperature rise in terms of time, contact surface, and material. (*Science Abstracts*)

No. 431. A. Lotz, "Voltage Drop of an Arc in Water," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 14, No. 1, p. 25 (1935).

The author measures the voltage gradient of the positive column of an arc struck in water, in searching for the reason why arcs in water and oil are shorter, for the same p. d., than arcs in air, a subject of some importance since the introduction of water into circuit breakers. Electrodes 20 mm. in diameter were used, fed by a machine giving up to 500 amp. at 900 v. Illustrations of arcs between the specially formed electrodes are given. It is concluded that the gradient rises if the arc is confined in a constriction. (*Science Abstracts*)

No. 432. W. M. Leeds, "Calculation of Arc Energy from Oscillograms," *Elec. J.*, Vol. 32, No. 2, February, 1935, pp. 78–80.

Formulas and simplified methods of calculation are given for calculating the arc energy when oscillograms of current and voltage are available.

No. 433. J. W. Flowers, "Initiation of Electrical Discharges by Field Emission," *Phys. Rev.*, Vol. 48, December 15, 1935, pp. 954–959.

The initiation of highly overvolted discharges produced in effectively ion-free gases by voltage impulses is shown to be independent of the nature and pressure of the gas between the electrodes, from pressures of 1 atmosphere until the vacuum spark stage is reached. Oscillograms showing time lags and potential falls in such discharges between spheres and between points and planes have been obtained, together with those of an ordinary discharge for comparison. When the breakdown is due to high cathode fields, the initiation is explained by field emission of electrons, but in the case of high anode fields, the initiation depends on the character of the surface. Oscillograms of the wave fronts produced by 60 negative discharges between magnesium electrodes, and the potential fall across such discharges have been obtained. (*Science Abstracts*)

No. 434. C. H. Flurscheim, "Rates of Rise of Restriking Voltage Subsequent to Interruption of A.C. Power Circuits," *J.*, I.E.E., Vol. 76, March, 1935, p. 323.

The observed effect of restriking-voltage rates of rise on the performance of various types of circuit breakers is given, and high rates are shown to increase greatly the severity of the interrupting duty independently of kva., and consequently to be a factor of considerable importance in the choice of circuit breakers. An indication is made as to where severe conditions are likely to occur on a system. The causes of h. f. oscillations consequent to interrupting fault power are analyzed, the rate of rise of restriking voltage is defined, and the effect on this rate of different factors which cannot normally be controlled, such as asymmetry and arc characteristics, are discussed. The physical constants and factors inherent to the type of system and fault affecting these oscillations, and formulas for the rate of rise for simple circuits, are given. (*Science Abstracts*)

No. 435. G. Windred, "Electrical Contacts," *Engineer*, Vol. 160, August 30, 1935, pp. 222–223.

The selection of suitable materials is briefly considered. The effect of oxides in increasing contact resistance is pointed out, contact resistance for normal materials and pressures equals a constant over the pressure between contacts.

Data giving fusing point, Brinell hardness, specific gravity, and temperature coefficient of resistance of several contact metals and contact alloys are given. (*Science Abstracts*)

No. 436. J. Anderson, "A Study by Means of Photography of the Interruption of Medium-Power Electrical Circuits," Allday, Birmingham (1935).

No. 437. F. M. Penning and J. G. W. Mulder, *Physica*, Vol. 7, p. 724 (1935).

No. 437a. A. Kotecki, "Characteristics of the Electric Arc," *Acta Physica Polonica*, Vol. 4, Nos. 1 and 2, pp. 113–122 (1935). (In French.)

The characteristics of electric arcs ($e = f(l/i)$) were studied for electrodes of copper, iron, aluminum, and carbon for the cases when both electrodes were of the same material and of different materials, for example, C-Cu, Fe-C, C-C, etc. The experiments were carried out with d.c. at 220 v. in the region of 1–20 amp. at electrode distances of 1–5 mm. and the results are given graphically in a series of curves. These are discussed and compared with both practical and theoretical results of other workers. (*Science Abstracts*)

No. 437b. E. Hutchisson, T. H. Osgood, and R. E. Fearon, "Electrical Conductance of short Gaps in Air," Nat. Acad. Sci., *Proc.*, Vol. 21, September, 1935, pp. 542–548.

The dependence of conductance upon gap width under ordinary conditions, for example, such as those found in switch contacts operated in air, are investigated experimentally. The gaps used are effectively those between a spherical electrode of radius 14×10^2 cm., 14 cm., or 25×10^4 cm. and a plane, the surfaces being of steel in some cases, of tungsten wire in others. The results indicate that appreciable current can pass between surfaces of approximately 4 cm. diameter which are separated by as much as 10,000 Å. in air. The current passing is proportional approximately to the square of the applied p.d.; this indicates that the conduction is affected by charged dust particles moving cyclically from one electrode to the other. At very small separations of the electrodes the current definitely obeys Ohm's law, and is probably carried by metallic bridging. (*Science Abstracts*)

No. 437c. W. Deans, "D.C. Circuit Breakers for Steel Mill Service," *Trans.*, A.I.E.E., Vol. 54, June, 1935, p. 594.

With several large motors and generators operating in parallel in a system that is coupled very closely electrically, short circuit currents in d.-c. steel mill circuits may be as high as several hundred thousand amperes. Breakers for this service must, therefore, have high interrupting capacity and quick response. The breakers and associated equipment, for a typical modern strip mill are described in this paper. The breakers are tripped not only by overload current, but also by current having too high a rate of rise. They are all of the 2-pole air type, with 6000-amp. rating for the motors and 8000-amp. rating for the generators.

The movable contact structure consists of a group of silver-faced laminated copper bridges as the main current-carrying member, a secondary contact, and an arcing contact. These contacts are so pivoted and the current is led to them in such a manner that the contact pressure between stationary and movable members of both secondary and arcing contacts is increased by the mechanical forces resulting from the magnetic action of the current. Thus, the resistance of the paths through the secondary contact and through the arcing contact are reduced greatly so that the current is transferred more easily from the main current-carrying member, while as both the auxiliary contacts are pivoted on a rigid extension of the main bridge arm, these same forces serve to accelerate the opening of the breaker.

The arcing contacts are of nonwelding alloy, and open in the field of the iron blowout magnet, which is excited by a coil of copper worked into the stationary contact.

No. 437d. D. C. Prince, "Circuit Breakers for Boulder Dam Line," *Trans.*, A.I.E.E., Vol. 54, p. 366 (1935).

An account of the development and testing of the 287-kv. oil-blast breaker for the Boulder Dam transmission line. Essentially the same paper as that abstracted in paper No. 119, ASTM No. 437e.

No. 437e. D. C. Prince, "Further Developments in Oil Blast Breakers," Conference Internationale des Grands Reseaux Electriques à Haut Tension, *Paper No.* **119**, 1935.

This paper covers briefly the extension of the application of the oil-blast principle of arc interruption to oil circuit breakers of practically all interrupting capacities since the subject was first presented to the International Conference on Large High Tension Systems in 1931. It stresses particularly the latest 287-kv., 2,500,000-kva. impulse breaker. The decrease in size of breaker effected by oil blast is shown on four capacities from 50,000 kva. to 1,000,000 kva., and an improved explosion chamber for high-voltage breakers is illustrated.

The construction of the 287-kv. breaker for the Boulder Dam-Los Angeles transmission

is given in detail. It is characterized by low weight, small oil content, and fast interrupting time as compared with the typical tank-type breaker.

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No. 438. K. Meier, "Special Metal Contacts for Oil-Immersed Contacts," *EZT*, Vol. 57, April 30, 1936, pp. 493–495.

Tungsten contacts are very suitable for such purposes as interrupters in ignition circuits (h. v., low-current). For heavy-current, medium-voltage applications, mixtures of tungsten with high-conductivity metals, copper or silver, give better results, the physical properties of the constituents of the mixture being retained side by side. Tungsten-silver mixtures are mainly used for air-break switches, especially high-speed regulators. Mixtures of 60 to 80 tungsten, 40 to 20 copper are used principally for oil-immersed contactors; such contact pieces have from 6 to 8 times the life of copper contacts. Possible causes of the more severe burning of oil-immersed contacts are discussed. Test data in the original show the relation between motor capacity and contact life under specified conditions. Breaking a load of 18 kw. the life of copper contacts is about 5 m. operations and that of 60-tungsten, 40-copper contacts is 30 m. operations; alternatively, for a life of 30 m. operations, the tungsten-copper contacts break 18 kw. and the copper contacts only 8.5 kw. Only a 2 to 3 mm. layer of the special metal is required on the contacts. The lower conductivity and higher contact resistance of the special contacts constitute no serious objections, especially in contactors operated at short intervals. The performance of the special contacts is favorable where arcing conditions are severe and the risk of welding considerable. (*Science Abstracts*)

No. 439. W. Schaelchlin, "150,000-A Contactor," *Elec. J.*, Vol. 33, August, 1936, pp. 363–366.

Discusses the cause of contact burning, the theory of the design, and the construction and results of a 150,000 amp. contactor used in a pipe-welding equipment. In reality the contactor consists of four 50,000 amp. units in parallel operated from a common shaft. To prevent contact burning on opening, the switch is arranged to reduce the current before opening by the insertion of resistance into the circuit. This is achieved by the provision of a main contact with several auxiliary contacts in parallel. Each contact opens in sequence and the auxiliary contacts, before opening, are each arranged to decrease gradually the pressure they exert on a stack of contact disks. This reduction in contact pressure constitutes the means of inserting the resistance necessary to obviate burning on final interruption of the circuit. An oscillogram of making and breaking a circuit shows clearly the effective action of the contacts and the reduction of current before opening. It is claimed that full load is opened with practically no visible sparking. (*Science Abstracts*)

No. 440. R. M. Baker, "Sliding Contacts —Electrical Characteristics," *Trans.*, A.I.-E.E., Vol. *55, January, 1936, pp. 94–100.*

Experiments with oxidized and oxide free materials indicate that the electrical characteristics of the ordinary sliding contact, such as that between a carbon or graphite brush and a copper slipring, are dependent upon the oxide film on the surface of the ring. Tests to determine the effects of liquid films on the contact voltage drop, and the variation of thermal voltage in a sliding contact are made. The principal findings and conclusions reached are:

(1) It is shown that the oxide film on the ring surface accounts for the electrical characteristics of ordinary sliding contacts. This film is broken down by the passage of current, and the contact, resistance, therefore, decreases with increasing current. The process of breakdown is probably through the building of metallic bridges and through the oxide.

(2) Liquid films can affect contact drop directly only when these films are of oil or some liquid having a low vapor pressure. Water films probably produce a very desirable lubricating effect in a sliding contact, but do not tend to raise the brush off the ring and, thereby, increase the contact drop. The water films which lubricate the contact are thin in comparison with the unevenness in the contact and are extremely tough. The current flows through these very thin films with no appreciable loss in voltage.

(3) Appreciable thermal voltages can be measured in a sliding contact if the ring carries an oxide film. These voltages disappear immediately when the oxide film is removed by sanding the ring surface. (*Science Abstracts*)

No. 441. J. Dunaev and D. Nasledov, "Effect of Mechanical Deformation of Properties of Copper-Oxide Rectifiers," *Tech. Phys.*, U.S.S.R., Vol. 3, pp. 268–278 (1936).

No. 442. J. Roulleau, "Temperature Effect in Cu_2O Rectifier Photocells," *Compt. rend.*, Vol. 202, pp. 749–751 (1936).

No. 443. L. Rebuffe, "Average Electric Resistance and Duration of Collision Between Two Metallic Bodies," *Compt. rend.*, Vol. 203, December 7, 1936, pp. 1230–1232.

A spherical ball of steel or one elongated with spherical cap (mass m, radius of curvature r) suspended by a copper wire, forms the bob of a pendulum. This is connected

through the wire, a source of emf. (E), a resistance R, and a ballistic galvanometer, with a metal plate against which the bob strikes, thus completing the circuit. If p be the average resistance of the contact and t the duration of a collision, experiments show that p varies with the metal of the plate, m and r, and increases, but not linearly with the velocity of the collision (v); t is proportional to $(m^2/r)^{1/5}$ and also to $(1/v)^{1/5}$ for very hard metals; it is independent of the form of the bob provided m and r are the same. pt is approximately constant for all metals, and definitely so for the same metal. It is suggested that the resistance is due to the current passing through a thin layer of air retained by viscosity between the colliding bob and plate. Errata, *ibid.*, December 14, 1936, p. 1408. (*Science Abstracts*)

No. 444. Anonymous "What Contact Materials to Use and Why," *Elec. Mfg.*, Vol. 17, pp. 36–40 (1936).

No. 445. G. Suzuki, "Electrical Contact Point Materials," *Japan Nickel Rev.*, Vol. 4, No. 1, January, 1936, pp. 63–74.

No. 446. C. G. Suits, "High-Pressure Arcs," *G.E. Rev.*, Vol. 39, April, 1936, pp. 194–200.

The author reviews the evidence bearing on the mechanism of high-pressure arc discharges. It has been established that in the arc discharge in air the electrical and neutral particles are in thermal equilibrium, the equilibrium state being reached in about 0.001 sec. Many methods for determining arc temperatures, including the measurement of the velocity of sound and the absorption of soft X-rays, have been tried and yield accurate information. From the current density and voltage variation in the arc and the arc temperature the electron density and degree of ionization can be calculated. The special conditions in welding arcs indicate the optimum range of welding temperatures. (*Science Abstracts*)

No. 447. R. M. Baker and G. W. Hewitt, "Brush Wear in Hydrogen and in Air," *Elec. J.*, Vol. 33, June, 1936, pp. 287–289.

The results are given of tests made to determine the performance of graphite brushes on sliprings operating in hydrogen. By changing from air to hydrogen, the life of slipring brushes can be increased from 2 or 3 yr. to 50 or 100 yr.

No. 448. R. T. Kintzing, "Contacts Under Oil and in Air" (Reply to a Query), *Elec. J.*, Vol. 33, July, 1936, p. 340.

No. 449. H. W. Baxter, "Air Break Contactor Contacts," *Report G–T81*, E.R.A., July 20, 1936.

No. 450. F. Schroter, "Physical Aspects of Sliding Contacts and Commutation," *ETZ*, Vol. 57, No. 32, August 6, 1936, p. 927.

The author discusses the simple commutating effect both from the theoretical and practical viewpoint. The maximum voltage which occurs in commutation in an iron free inductance is calculated from the contact resistance on an experimental commutator and from other data of the setup and is also measured with a vacuum tube voltmeter. This voltage, which depends on the current, and particularly the voltage in the neighborhood of 10 v. at which severe sparking takes place on the commutator, did not check out with the calculated data. The brushes commutated worse than would be expected from the calculations.

The causes for this were investigated using the cathode-ray oscillograph. It was then found that the contact surface in the tangential direction is considerably smaller than the brush thickness. As a result, the actual commutating time is less than calculated. Further, commutation is seldom a continuous effect, but is broken off during the current reversal by the individual contact points of the contact surface. This makes the commutation much more difficult.

This effect was tested on various types of brushes.

No. 451. L. S. Hobson, "Oil Blast Breaker Arcs Photographed," *Elect. World*, Vol. 106, November 7, 1936, pp. 3478, 3534.

No. 452. D. R. Davies and C. H. Flurscheim, "Single-Break Oil Circuit-Breaker Development for Metal Clad Switch Gear," *J.*, I.E.E., Vol. 79, August, 1936, pp. 129–150. Discussion, pp. 151–178.

The theoretical considerations for selecting the number of breaks are analyzed and it is shown that, while for plain circuit breakers multi-break construction may have its advantages, the more efficient the arc control devices employed, the less the advantages of additional breaks become with normal design. (*Science Abstracts*)

No. 453. B. W. Jones and O. R. Schurig, "Performance of Contactors," *G.E. Rev.*, Vol. 39, February, 1936, pp. 78–87.

This article is devoted to a consideration of the factors affecting the normal circuit interrupting performance of air-break contactors, and to a review of the results of recent researches which have led to improved operation. Characteristics by which interruption performance may be determined are also discussed in detail. (*Science Abstracts*)

No. 454. S. Keilien, "Testing Snap Switches," *Elec. J.*, Vol. 33, December, 1936, p. 521.

Conditions required for testing common

snap switches to operate tungsten filament lamps are outlined. The problem is considered from the standpoint of the current inrush and the effect of the entire circuit on the maximum value of this current. The generator on which these loads are placed must be able to furnish the necessary current inrush within a minimum required time.

No. 455. J. S. E. Townsend, "Distribution of Energies of Electrons," *Phil. Mag.*, Vol. 22, July, 1936, p. 145.

An approximate formula for the distributions of energies of electrons in a steady state of motion has been given which is independent of the electric force, of the gas pressure and of the constants λ and L, where λ is the factor giving the loss of energy, in a collision, and L is the mean free path of the electron. In experiments the actual distribution differs considerably from that obtained on the above hypothesis. By the method previously employed, the energy distributions are now calculated, when λ and L are functions of the energy of the electron. It is also shown that in steady motion under a uniform electric field the energies of the electrons are widely distributed about a mean energy. (*Science Abstracts*)

No. 456. A. Wallraff, "Characteristics of High-Current, Short-Period Arcs," *Zeits. f. Techn. Phys.*, Vol. 17, No. 2, p. 44 (1936).

Apparatus is described for the production of momentary atmospheric pressure arcs, carrying currents up to 5000 amp. The characteristics of these arcs are investigated by means of a cathode-ray oscillograph. It is shown that the arc voltage is independent of the strength of the current. (*Science Abstracts*)

No. 457. D. T. J. ter Horst, "Variations of Field Strength and Current Density in A.C. Arcs," *Physica*, Vol. 3, March, 1936, p. 131.

A series of cathode-ray oscillograph measurements is made on a-c. arcs with frequencies of 50 and 250 cycles. It is shown that the field strength is a periodic function of the phase, but the sharp maximum in the impressed voltage curve almost disappears. The Ayrton law relating field strength and current is shown to hold at all points in the cycle. The mean value of the field strength is in good agreement with that found in a d-c. arc under similar current conditions. Measurements of current density show that this is independent of arc length and mean effective current. (*Science Abstracts*)

No. 458. M. J. Druyvesteyn, "Spark Potential of a Low Voltage Arc," *Physica*, Vol. 3, July, 1936, p. 724 (In German.)

The author investigates the dependence of arc voltage on the condition and nature of the glowing cathode. Under certain conditions the voltage for a glowing tungsten cathode is essentially different from that of an oxide cathode. The differences found between different cathodes are now ascribed to the temperature of the gas near the cathode, since for the same gas pressure the gas density at the oxide cathode is twice as great as that at the tungsten cathode. (*Science Abstracts*)

No. 459. O. Becken and K. Sommermeyer, "Cathodic Processes in Arc Discharges," *Zeits. f. Phys.*, Vol. 102, Nos. 9 to 10, p. 551 (1936).

Two forms of arcs are described. In arcs of type I the focal point emits very little light and is in a state of great agitation; its fall of potential varies very little with the gas pressure. In type II it is bright and stationary; its fall of potential increases with decreasing gas pressure. Experiments show that arcs of type I are to be regarded as "field arcs" and that they exist only when the cathode has on it a layer of gas. Arcs of type II are "thermal arcs." Tungsten and carbon can both give, in nitrogen gas, arcs of the two types depending on conditions, while copper and iron only give the field arc. (*Science Abstracts*)

No. 460. H. Puppikofer, "Development of Arc-Extinguishing Devices in Modern Circuit-Breakers," *Bull.*, Assoc. Suisse des Elec., Vol. 27, December 25, 1936, p. 749.

A good descriptive article on the development of circuit breaker design from the Frankfort Exhibition of 1891 to the present day. It is shown that air-blast, water, and "little oil" circuit breakers were built many years ago, but that the lack of modern testing facilities prevented many designs from being successfully developed. Modern types of circuit breakers are described, particular reference being made to the products of Swiss firms. The author considers that the normal oil circuit breaker will compete with the newer types up to 30 kv. owing to its low price and small space requirements. Particularly where the number of switches is small the fire risk may be accepted. For voltages above 50 kv. the decision rests between the air blast and the "little oil" breaker as the water circuit breaker has an upper voltage limit of about 25 kv. (*Science Abstracts*)

No. 461. E. Marx, "Tests of High-Capacity Switchgear," *ETZ.*, Vol. 57, May 21, 1936, p. 583.

A method of testing high-load arc-quenching apparatus is described in which there are two sources of electric power, one supplies high current and the other a high voltage. With an arc-quenching device operating upon a-c. gear, it is essential to prevent the arc restriking by reason of the reactive voltage after the current has been reduced to zero. The above mentioned method of test

employing two sources of power is so arranged that it is possible to vary the time between the instant of reducing the arc current to zero and the application of the test voltage from a few milliseconds to a fairly long interval. The phenomena occurring at the arc are watched by a Braun tube or by means of a cathode-ray oscillograph. The apparatus described is capable of being operated at peak values of current and voltage of 2000 amp. and 150 kv., respectively. (*Science Abstracts*)

No. 462. F. Werthmann and H. Thommen, "H. V. Circuit-Breakers," *R.G.E.*, Vol. 39, May 23, 1936, p. 755.

After briefly discussing the general conditions of stability in any electrical network and the correct means of obtaining the stability conditions, two new circuit breakers are described. These have been built not only to extinguish the arc on opening, but also to produce the necessary stability. One of the types described is a "convector" circuit breaker and is constructed for voltages from 50 to 220 kv., the other type, relying on compressed air from an external supply to extinguish the arc, is used for voltages up to 50 kv. (*Science Abstracts*)

No. 463. S. Fukuda, "Determination of Wave-Forms of Restriking Voltages of Circuit-Breakers," *J.*, I.E.E. Japan, Vol. 56, March, 1936, p. 222.

When a circuit carrying current is broken the restriking voltage depends to some extent on the type of circuit breaker. The "inherent restriking voltage" is therefore more universally applicable to circuit breaking problems; this is the voltage which appears when a sinusoidal current at system frequency is broken when passing through zero without the production of an arc. A formula is given for calculating this voltage from the measured restriking voltage when unit current is interrupted. A thermionic valve circuit is used for this measurement. By repeating the interruption synchronously with the time sweepage of the electron beam of a cathode-ray oscillograph a stationary figure of the unit restriking voltage is made visible on the screen. A similar circuit is described for giving a visible figure of the inherent restriking voltage. (*Science Abstracts*)

No. 464. E. Wurth, "Magnetic Arc Quenching in D.C. Switches" (Dissertation), Stuttgart (1936).

No. 465. G. C. Armstrong, "Rupturing Difficulty—Alternating-Current Circuits," *Elec. J.*, Vol. 33, May, 1936, p. 221.

The various factors which affect arc-rupturing difficulty are considered. It is assumed, in general, that rupturing difficulty is proportional to the critical length required for the extinction of an unconfined arc. It is also proportional to the supply voltage minus a constant. The effect of overvoltage is shown in a table of data. The effect of current depends on the design of the switch. That of distributed capacitance and circuit arrangement is difficult to predict. The effect of power factor is shown in tables and curves. The operation of the arc arrestor is also discussed. (*Science Abstracts*)

No. 466. W. Kruger, "Changes in Shape of Highly Loaded Silver Contacts in Communication While Switching d.c.," Verlag von R. Oldenbourg, *Zeits. f. Fernmeldetechnik*, Werk- und Geratebau, Berlin, Vol. 17, January 22, 1936, p. 1; February 3, 1936, p. 24; March, 1936, p. 41; April, 1936, p. 56. (In German.)

The basis for this paper was a Doctor's thesis. The experimental setup and the possible margins of error are discussed.

Summary: (1) For silver contacts in non-inductive circuits for a range up to 100 v. it was established that above certain marginal current intensities, depending on the voltage, a metal transfer from the negative to the positive contact takes place. This metal transfer is caused by the breaking arcs. Information on the dependence of the marginal current intensity on the voltage is given. Furthermore, a dependence of this critical current value on the humidity of the air and on the purity of the silver is established.

(2) Current intensities are determined above which, at voltages up to 25 v. with noninductive load, metal transfer from plus to minus takes place.

(3) The changes in shape of silver contacts that are used to charge or discharge condensers can be avoided by series resistance. For the size of this resistance a dependence on the square of the condenser voltage has been found.

(4) A calculation method is established to ascertain the greatest possible spark quench resistance that just allows to prevent a breaking arc.

(5) Similarly, the conditions are established for circuits with iron core inductance and a spark quench circuit consisting of a condenser with a resistance parallel to the contacts to open the contacts arc and spark-free. The necessity of limiting the voltage of the contacts is considered to prevent glow discharge.

(6) The size of the spark quench condenser depends mainly on the bouncing of the contacts at break. The voltage of the condenser must not reach such a value that the condenser discharges that pass through the spark quench resistance cause a metal migration from plus to minus contact.

(7) A limit of capacity for contact metals can be determined only if requirements are given regarding the admissible change in shape. A comparison of the efficiencies of

different contact metals is possible if tests are conducted with the same number of breaks and with the best possible spark-quench circuits. Comparative tests with a gold-platinum silver alloy and pure platinum showed a higher limit of capacity for platinum only as compared with silver.

(8) The use of contacts of more efficient contact metals ought to be determined from economical points of view.

(9) An improvement of the efficiency of contacts can be obtained by a spark quench circuit which has a small inductance instead of a resistance. This quenching coil reduces the effect of the condenser discharges on bouncing contacts without increasing the voltage of the breaking contact as a spark-quench resistance.

No. 467. A. von Engel, "Characteristics of Arc Discharges and Their Industrial Significance," *E.u.M.*, Vienna, Vol. 54, No. 28, July 12, 1936, p. 325.

A survey is given of the gaseous discharges falling under the collective term arc discharge, such as may be distinguished from one another by their varying cathode mechanisms. The effect of charge carriers at the cathode and anode and in the column as well as the effect of the energy conditions are described and important characteristic curves are given. Reignition and hysteresis as phenomena peculiar to the a-c. arc are also dealt with. In conclusion the author discusses a number of applications of arcs such as welding, chemical purposes, rectifiers, etc.

No. 468. T. Jurrianse and M. J. Druyvesteyn, "Transition from Glow Discharge to Arc Discharge," *Physica*, Vol. 3, August, 1936, p. 825. (In English.)

The probability is studied of a glow discharge to an arc discharge when the cathode is touched by a conductor. It is found that the probability of this transition (called arcing) depends on a number of variables, for example, on the capacity and the p. d. between the conductor and the cathode, the current density, and the cathode fall of the glow discharge. Arcing may occur in the case of contact making as well as of contact breaking between the conductor and the cathode. The energy of the discharge between the conductor and the cathode is of primary importance to the probability of arcing. (*Science Abstracts*)

No. 469. L. B. Loeb, "Mechanism of Static Spark Discharge," *Rev. Modern Phys.*, Vol. 8, July, 1936, p. 267.

A comprehensive review of the phenomena of spark discharges and of the mechanisms which have been proposed to account for the observed effects. The effect of the numerous variables on the sparking voltage in normal static breakdown is discussed at length and the conditions for the occurrence of the different secondary sparking mechanisms are fully dealt with. It is concluded that there is no single definite secondary process which occurs universally in all discharge phenomena, but that there are at least five or, including very low pressures, six mechanisms which may account for the self maintaining character of spark discharges. Any one or two of these mechanisms in combination may predominate, according to the experimental conditions, to the exclusion of the others. In many cases the conditions indicate at once the favored mechanism or mechanisms. (*Science Abstracts*)

No. 470. C. C. Paterson, "Escape of Electricity from Metals," *J.*, Inst. Metals, Vol. 58, p. 313 (1936).

The lecture traces the effect which the liberation of the electron from the metals has had on the trend of electrical engineering during the past 20 yr. Experimental demonstrations with valves, photo cells, electric discharge lamps, and other electronic devices were used in the lecture to exemplify the theme. (*Science Abstracts*)

No. 471. M. Cook, "Physical Properties and Annealing Characteristics of Standard Nickel-Silver Alloys," *J.*, Inst. of Metals, Vol. 2, *Paper No. 721* (advance copy) December, 1936 pp., 551–565; *J.*, Inst. Metals, Vol. 58, 8 pp. (1936).

A study of the hardness and mechanical properties of seven nickel-silver alloys, as affected by cold working and annealing. The copper content was constant and the nickel increasing from 10 per cent to 30 per cent. The modulus of elasticity increases progressively with the nickel content, and in the annealed condition the hardness also increases with nickel content. But the extent to which the alloys can be work hardened decreases with the nickel content, and the temperature at which softening commences on annealing increases as the nickel proportion increases. Information is also given on the density, electrical and thermal conductivity and thermal expansion of the alloys. (*Science Abstracts*)

No. 472. F. Kesselring and F. Koppelmann, "H. V. Switchgear," *Arch. f. Elektr.*, Vol. 30, February 18, 1936, p. 71.

This is Part III of a comprehensive survey of the problem of h. v. switching. The gas-pressure switch is dealt with and a discussion, largely theoretical, is given of the effect of various forms of construction on the gas flow, the extinction of small and heavy currents, and the effect of the natural frequency of the circuit to which the switch is attached. (*Science Abstracts*)

No. 473. F. Schoof, "L. V. Switchgear," *ETZ.*, Vol. 57, February 27, 1936, p. 225.

Descriptions are given of the recently developed types of switches and circuit breakers for working upon circuits at voltages less than about 1000 v. The models described include a push-button type of switch and circuit breaker for controlling motors at 500 v., 16 amp., together with an oil-filled switch for similar purposes. Details are also given of circuit breakers for operation at very large breaking currents. (*Science Abstracts*)

No. 474. G. Mönch, "Mercury Switches," *Zeits. f. Techn. Phys.*, Vol. 17, No. 2, p. 61 (1936).

Description is given of a mercury switch which is used to safeguard hot cathode X-ray tubes against failure of the cooling water, the switch being operated by a change in pressure of the water supply and used to either disconnect the apparatus or give an alarm signal. There are two types of switch, both being U-tubes about half filled with mercury, with one limb open to the atmosphere and the other connected with the water supply. The tubes are made of glass and one electrode is taken through the glass to make contact with the mercury at the bottom of the U. In one type of switch the second electrode is led up through an insulated tube to be exposed at a point just below the normal mercury level in the limb connected with the water supply. In the other type the second electrode is taken down from the top of the limb open to the atmosphere and is set at a height just above the normal mercury surface, the position being adjustable. In the first type, when the water supply is on, the mercury is depressed in the water supply limb and the circuit is broken, while, in the second, the level is raised on the atmospheric side and the circuit is completed. (*Science Abstracts*)

No. 475. R. Holm and B. Kirschstein, "Adhesion of Metal Surfaces in a Vacuum," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 15, No. 1, p. 122 (1936).

Describes an experimental investigation into the adhesion between two metal surfaces, in this case a wire inside a cylinder, in a vacuum and in certain gases at low pressures. The materials investigated were nickel, platinum, and graphite and the gases were wet and dry air, argon, nitrogen, hydrogen, and water vapor. It is seen that air and water vapor tend to reduce the friction between surfaces. (*Science Abstracts*)

No. 476. J. D. Cobine, "Low Pressure Arc Characteristics," *Physics*, Vol. 7, April, 1936, pp. 137–142.

The results of an oscillographic study of the short a-c. arc between pure graphite electrodes show that the reignition potential is a linear function of the gas pressure for air, nitrogen, oxygen, and carbon dioxide. The relation is expressed by $V_r = A + Bp$. The constant A follows the minimum sparking potential of the gas, increases with rate of rise of the impressed voltage and is independent of the arc current, except for carbon dioxide. The constant B depends on the gas, arc current, and rate of rise of impressed voltage. The reignition potential is closely related to the glow discharge and is shown to approach the sparking potential of the gas as the rms. value of the current approaches zero. The factors that affect reignition are indicated and a reasonable mechanism of the phenomenon is stated. (*Science Abstracts*)

No. 477. D. I. Vinogradoff, "European Developments in Circuit Interruption," *Elec. J.*, Vol. 33, No. 3, March, 1936, pp. 129–133.

No. 478. Karl Gaulrapp, "Investigation of the Electrical Properties of the Breaking Arc," *Ann. der Phys.*, Series 5, Vol. 25, p. 705 (1936).

This exhaustive original research gives a detailed description of the experimental setup used to generate breaking arcs between electrodes of various kinds of metals in different gases at various pressures. Current, voltage, and arc length are registered by a "3-loop oscillograph." The calibration method is given.

The method used for registering the arc length (suggested by E. Manz) is unique and may be of some interest for the solution of similar problems. It consists mainly of an insulated condenser plate which, while the electrodes are breaking, approaches a second stationary plate which is connected with the grid circuit of a valve transmitter. The increase in capacity caused by the movable condenser plate increases hereby the wave length of the transmitter, thus enabling a receiver (anode rectifier) due to its detuning to decrease its anode current which can be registered by the third loop of the oscillograph. Other details of the experimental setup are given in two illustrations.

The current and voltage characteristics have been ascertained by the author especially for zinc in air and in hydrogen. He found that the burning voltage is independent of the intensity of the current and of the arc length if the arc lengths and the gas pressures are small.

A table shows the minimum voltages for a number of metals that are necessary to generate arcs in air at normal pressure.

Metal	Zinc	Tungsten	Copper	Cadmium
U minimum volts	10.9	15.2	12.6	9.8
Metal	**Magnesium**	**Antimony**	**Lead**	**Platinum**
U minimum volts	12.5	9.9	9.1	15.3

Metal	Gold	Silver	Aluminum	Tellurium
U minimum volts	12.6	12.3	18.3	3

The minimum voltage in hydrogen is higher. That of zinc, for instance, is 14 v. No relationship between minimum voltages and material properties could be found. The author refers to tables established by Kraus and Burstyn dealing with marginal voltages. Burstyn, who ascertained his figures by an admittedly crude setup, did not pretend a great accuracy for his figures but he gave values for marginal currents, at different voltages between 24 and 220 v. which may have some importance for practical contact problems inasmuch as they give the maximum currents that can be interrupted by an infinitesimal gap, that is, without an arc of finite length.

The author succeeded further in determining the current densities of carbon and zinc cathodes and their dependence on the gas pressure. He classifies the metals in three groups according to the appearance of the cathode spot traces that apply to the classification made by Ramberg for "Stolt" and a-c. arcs. These three groups are:

1. Metals that show a definite single cathode spot, as, for instance, carbon, zinc, magnesium, calcium, and cadmium.
2. Metals with indefinite scattered cathode spots especially typical of copper and also silver and gold.
3. Metals forming a transition from group 1 to 2 are platinum, tungsten, lead, aluminum, antimony, and iron, respectively.

The paper contains a great number of current voltage characteristics as well as other diagrams, especially in the chapters "Current Voltage Characteristics" and "Cathode Spot and Current Density." It is of great theoretical interest inasmuch as it throws light on some of the theories involved in arcing problems. A minor paragraph is devoted to the description of an a-c. breaking arc and hints are given as to its generation. This arc may be used as a light source for quantitative spectral analysis.

No. 479. I. S. Stakolnikoff, "Experimental Investigation of Spark Discharge," *Elektrichestvo*, November, 1936, 8 pp.

No. 480. G. Windred, "Maintenance of Electrical Contacts," *Elec. Engg.*, July 17, 1936, p. 353.

No. 481. G. Windred, "Protection of Electrical Contacts," *Elec. Ind.*, August 12, 1936, p. 1220.

No. 482. L. Tonks, "Force at an Anchored Kathode Spot," *Phys. Rev.*, Vol. 50, August 1, 1936, pp. 226–233.

The steadying effect of a metallic anchor for the cathode spot of a mercury-pool arc is used to make measurements on the force at the cathode. Two methods are used. One is based on the depression of the meniscus edge carrying the cathode line, due to the pressure on it. This measures only the horizontal component exerted on the liquid and gives 19 dynes per ampere. The other uses a torsion pendulum to measure the total horizontal force component and gives 33 to 43.5 dynes per ampere over the current range zero to 10 amp. This is supplemented by a determination of the direction of the force based on the deflection of the cathode line by a magnetic field, giving 35 to 66 dynes per ampere for the resultant in the same current range. The results show interaction of current streams from different emitting areas to increase the force, and are not inconsistent with other determinations. (*Science Abstracts*)

No. 483. G. Windred, "Electrical Contacts," *World Power*, Vol. 25, May, 1936, pp. 262–264.

A review of literature upon the subject of electrical contacts is given, and the present state of knowledge regarding contact resistance, life of contacts, precious metal contacts and other associated problems is described. The contact resistance is shown to depend upon a constant divided by the pressure at the contact, the constant being characteristic of the material used and its surface conditions. Mechanical contact between two surfaces may be point contact between, say, n points of radius a. If ρ is the specific resistance of the metal, then the contact resistance is given by $r = \rho/2an$. If the temperature at the contact face is t and the contact voltage drop is v, then it is shown that $t = v^2/8\lambda\rho$, and $r = r_0(1 + 2\alpha t/3)$, where: λ is the thermal conductivity of the metal, α its temperature coefficient of resistance, r_0 the resistance at room temperature, and r that at temperature t. It can be deduced that for every value of v there is a corresponding definite contact temperature t independent of the size and arrangement of the points of contact; t can be taken as the melting point to fix an upper limit to v and this gives a voltage range from 0.2 to 1.0 v. for most metals and 2.5 v. for carbon. The problem of wear and life of contacts is mentioned. (*Science Abstracts*)

No. 483a. B. A. Rogers, Irl C. Schoonover, and Louis Jordon, "Silver: Its Properties and Industrial Uses," Nat. Bureau Standards, *Circular C412*, Washington (1936).

Information concerning the properties and industrial uses of silver as obtained from the literature, from visits to plants, and from correspondence is given. The variation in physical properties by mechanical working

and heat treatment is emphasized. The chemical properties are discussed with respect to resistance to corrosion. In discussing the alloy systems, emphasis has been placed on those of the base metals which enjoy a considerable consumption. The bactericidal uses of silver, its employment in chemical equipment, and also its application in electrical switching devices have been described.

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No. 484. R. R. Fowler, "A Study of Electrical Contact Reliability," *Strowger Tech. J.*, Vol. 6, No. 1, pp. 9–16 (1937).

An account is given of the factors affecting the reliability of electrical contacts used in telephone engineering. One of these factors is the choice of the right contact metal or alloy for any particular duty. A list of contact materials is given. (*Chemical Abstracts*)

No. 485. R. M. Baker and G. W. Hewitt, "Contact Drop and Wear of Sliding Contacts," *Elec. Engg.*, Vol. 56, January, 1937, pp. 123–128.

The results of a series of experiments, in which the processes of contact voltage drop and ring wear in sliding contacts are demonstrated by means of a direct method, are presented in this paper. The results show that the wear of metal-graphite brushes and the rings upon which they operate can be reduced if they are operated in an oxygen-free gas instead of air. (*Science Abstracts*)

No. 486. R. Holm and F. Guldenpfennig, "Migration of the Contact Material at the Surfaces of Interrupter Contacts," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 16, No. 1, p. 81 (1937).

Switch technique has in recent times placed constantly higher demands for the performance of contacts. In this it has been an important task to investigate those phenomena which limit the safe period of the serviceable contacts. Under these phenomena the so-called migration of material is of the utmost importance. Under the designation "Stoffwanderung," or migration of material, is included, both the material loss of the electrodes conditioned by the switch spark in the surroundings as well as the considerable material transfer from one electrode to the other. In this publication there have appeared already two treatments of this subject; the present paper is one of the series. The aim of this work is to develop rules by which we can calculate in advance the migration of material in practical electric contacts. In the treatment of this problem will be considered the choice of contact material and the construction of all possible necessary spark-free circuits that can occur.—Introduction translated by W. S. Huxford.

This paper is the continuation of the research work commenced by the same authors ("The Metal Migration in Electrical Break Contacts, Particularly with Quenched Circuits," see A.S.T.M. Abstract No. 426). It gives a general survey of the phenomena of metal migration of electrical-break contacts and in addition tries to render it calculable.

The authors succeeded in setting up (mainly empirical) formulas that refer to relatively simple proceedings as far as possible. Simultaneously, the material data in question were determined for an extended number of metals partly for the first time and partly more exactly. Also the dependence of these data on the atmosphere was investigated. The new measurements concern the materials: carbon, aluminum, iron, nickel, copper, molybdenum, rhodium, silver tungsten, platinum, gold, Platit (about 90 per cent tungsten), Widia (cemented tungsten carbide similar to carboloy), and silver alloys with gold and magnesium. The intensities of current used were between 0 and 30 amp.

In practical cases, the point is to find out such simple conditions that the above formulas can be applied immediately.

The problem of the quenched circuit is, however, so complicated, that a perfect reduction to the previous formulas becomes impossible. The authors derived, therefore, certain special formulas which was for them the reason to treat the quenched circuit with more detail. At last the application of some important formulas is illustrated by means of a number of examples.

No. 487. "Sintered Silver Alloys for Electrical Contacts," *Metal Industry*, London, Vol. 51, p. 461 (1937).

The excessive wear exhibited on opening and closing electrical contacts may be eliminated by sintered materials consisting of silver and lead, and, alternatively, molybdenum or tungsten developed and patented by the A.E.G. [ED. NOTE: G.E. Co.] Best results are obtained with an alloy containing 95 per cent silver, 3 per cent lead dioxide, and 2 per cent molybdenum. Equally good results are obtained with 35 per cent silver, 1 per cent lead dioxide, and 64 per cent molybdenum. (*Science Abstracts*)

No. 488. J. Neukirchen, "Carbon Brushes," English translation by E. I. Shobert II, Telegraph Press, Harrisburg, Pa. (1937).

The general problem of conducting current from a stationary to a moving part is discussed. Consideration is given to various aspects of the problem of current collection from sliprings and commutators. These effects are considered from the standpoint of the materials, surface area, surface layers on films, elastic effects, atmospheric effects,

and various other electrical and mechanical considerations which affect the performance of brushes. No general solution can be given to all of the problems involved in the extremely complicated phenomena of current collection. A sufficient discussion is given of most of these problems, however, to permit an analysis of various difficulties and methods of attack in the solutions of these problems.

No. 489. Edmund Downs, "Electrical Contacts," *Elec. Rev.*, Vol. 120, January 29, 1937, pp. 168–169.

Field for precious metals—gold, silver, platinum, palladium, rhodium and iridium, and their alloys—for contact work in electric industry.

No. 490. W. Burstyn, "Elektrische Kontakte" (Electrical Contacts), Julius Springer, Berlin, 79 pp. + vii (1937).

This monograph is devoted to ordinary switch contacts, and it does not deal with devices for high voltage or large currents. As the author truly remarks, the physical facts concerning ordinary switch contacts are not widely understood. Many engineers, he states, if asked what air-gap can be broken down by 220 v., could not answer correctly. Much of the experimental work was carried out by the author, using for contacts round rods 4 to 5 mm. in diameter and 20 mm. in length, one of which was movable.

The chief sections are: Interruption of d-c. and of a-c. circuits; switching-in; contact resistances; heating; wear. The fundamental facts brought out include the minimum current to produce an arc with different metals. The curves of current as a function of voltage for tungsten, graphite, platinum, gold, silver, zinc, etc., are all hyperbolic in character—copper is omitted because of the uncertainty due to oxide formation. The lowest voltage to maintain an arc when any current is broken is stated to lie between 12 to 15 v. for metals. This then the author considers to be the suitable voltage for unreliable circuits, such as for automobiles or bells. The minimum voltage to maintain a glow discharge is given as approximately 300 v. for most electrodes. This, too, is the lowest voltage that will break down an air gap, however short; whence it follows that the testing of insulation at lower voltage is meaningless. The author further deduces therefrom that it is undesirable to exceed an alternating voltage of 220 v. for domestic purposes.

Throughout the treatment remains practical. Mathematics, where used, are straightforward; while the author keeps close to his subject. Though engineers may find points to disagree with, their gratitude to the author will not be lessened, while the incentive to further research work will be awakened. (*The Electrician*)

No. 491. V. P. Hessler, "Abrasion—A Factor in Electrical Brush Wear," *Elec. Engg.*, Vol. 56, January, 1937, pp. 8–12 and 16.

An investigation of the effect of abrasion upon an electrical brush wear is reported in this paper. Tests of the rate of wear of anode and cathode brushes, and of brushes carrying current and those that did not, show that abrasion is an important factor in electrical brush wear.

No. 492. G. Windred, "Electrical Contacts," *World Power*, Vol. 27, May, 1937, pp. 145–147.

A review of literature published since summary given in 1936 by this author, dealing almost entirely with brush wear. Found greatest wear occurred where current flowed from ring to brush, minimum with current flow in reverse direction. Mention is made of silver-tungsten and copper-tungsten contacts. (*Science Abstracts*)

No. 493. T. Ogawa, "Current Collection Under Brushes," *ETJ.*, Vol. 1, July, 1937, pp. 49–57.

A general survey of the present knowledge of the phenomena of current collection. (*Science Abstracts*)

No. 494. G. Windred, "Electrical Contact Resistance," *Elec. Eng.*, August 20, 1937, p. 614.

No. 495. V. P. Hessler, "Probe Studies of Collector-Ring Films," *G.E. Rev.*, Vol. 40, No. 8, August, 1937, pp. 358–362.

The nature of the mechanical contact between the brush and the ring is one of the important factors in the voltage drop of sliding contacts. The brush is not considered to be in contact with the ring at more than a few isolated points at any given instant, and these points probably move about the contact surface rather rapidly. The effect of this factor is so large and variable as to make it rather difficult to study the other factors with any degree of satisfaction. It was found that most of the effect of riding characteristics could be eliminated by the use of probes or point brushes, and some rather interesting effects of the oxide film have been obtained with the aid of these probes. Presentation of the oxide-film theory will be omitted here since it has been considered at length by Baker and other writers.

No. 496. A. Ohlans, "Contact Instruments with Mechanical Contacts," *Siemens-Zeits.*, Vol. 17, p. 486 (1937).

Description of voltmeter with mechanical contact making and breaking equipment as manufactured by Siemens and Halske. (*Science Abstracts*)

No. 497. G. Windred, "Resistance of Silver Contacts," *Electrician*, September, 1937, 266 pp.

The author rightly disagrees with published literature stating that silver monoxide is a good conductor. He points out that the reason for this common belief is that silver oxide readily decomposes on heating. He suggests that tarnishing of silver is not an oxide but rather a sulfide film. Methods of testing these ideas are presented. (*Science Abstracts*)

No. 498. W. C. Kalb, "Carbon Brushes for Steel-Mill Equipment," *Elec. Engg.*, Vol. 56, No. 9, September, 1937, p. 1165.

The problems associated with brush application on commutating type equipment in the iron and steel industry are discussed in relation to type of equipment and conditions encountered in service. The paper also discusses a newly defined measure of brush performance, termed "commutation factor," which provides an improved basis for control of the performance characteristic of brushes. Mention is made of the development of electrographite brushes having a mild polishing action, designed to prevent the formation of troublesome surface films on commutators exposed to the contaminating atmospheric conditions frequently encountered in steel mill applications. (*Science Abstracts*)

No. 499. G. Windred, "Compound Metals for Electrical Contacts," *Elec. Eng.*, Vol. 56, October 29, 1937, p. 1045.

No. 500. R. E. Hellmund, "Arc Characteristics Applying to Flashing on Commutators," *Elec. Engg.*, Vol. 56, January, 1937, pp. 107–113.

This paper gives the results of experimental investigations relating to arc characteristics as they apply in commutator flashing. A knowledge of these characteristics is necessary for the application of the theory outlined in a previous paper (*Sci. Abst.*, 143 (1936)) on flashing of commutators, as well as for the investigation of flashing due to other causes. (*Science Abstracts*)

No. 501. F. Unger, "Rating of Commutators," *ETZ.*, Vol. 58, February 11, 1937, pp. 153–154.

By assuming average values of brush density, brush pressure and coefficient of friction, curves are given showing the minimum commutator surface per ampere for 60 C. temperature rise plotted against peripheral speed both for electrographite and copper-carbon brushes. (*Science Abstracts*)

No. 502. W. M. Thornton, "The Micro-Gap Switch," *J.*, I.E.E., Vol. 80, No. 485, May, 1937, pp. 457–459.

No. 503. F. Kesselring, "Expansion-Type and Synchronous-Type Circuit-Breakers," *ETZ.*, Vol. 58, February 25, 1937, pp. 195–199.

Reviews the present state of development of the indoor type of expansion switch. The use of water as the extinction medium instead of oil leads to a smaller switch and is satisfactory up to 60 kv. For $16^2/_3$-cycle circuits, such as are usual for traction systems in Central Europe, the length of a cycle is so great that, even with a switch designed to extinguish the arc in half a cycle, the arc energy is considerable; the synchronous switch employs a special relay which causes the contacts to separate at a fixed time before the current zero. Oscillograms taken in a particular case show a reduction in the arc energy for 202 kw.-sec. to 11 kw.-sec. after equipping with a synchronizing arrangement. (*Science Abstracts*)

No. 504. P. L. Betz and S. Karrer, "Characteristics of the Copper Arc During the Formative Period," *J. App. Phys.*, Vol. 8, December, 1937, p. 845.

This paper gives the results of an investigation of the voltage characteristic of the copper arc in air during the process of arc formation. A pair of copper electrodes, initially in contact and carrying current, were separated and the voltage rise across the air gap was studied. Cathode-ray oscillograms indicate that at the instant of contact separation there develops across the gap a voltage of about 12.2 v. This voltage was attained in less than 10^{-5} sec. This rapidly developed voltage was found to be independent of arc current for current values up to 100 amp., which suggests that the rapidly developed initial voltage corresponds to the cathode fall of the arc. (*Science Abstracts*)

No. 505. M. Steenbeck, "Investigation of Electric Arc in Gravity-Free Space," *Zeits. f. Techn. Phys.*, Vol. 18, No. 12, p. 593 (1937); *Phys. Z.*, Vol. 38, December 1, 1937, p. 1019.

An arc between carbon electrodes, with a separation of 3 cm. and arc current of 1 to 8 amp., was maintained in a vessel which could fall freely, between guides practically free from friction, through a height of 3.5 m. The disturbing warm air current which is found in the case of a stationary arc in air was thereby eliminated. The arc in the falling tube differs from the ordinary arc in its lower potential for the air column, greater stability, especially for long arcs, and much smaller current density with increasing arc current. In the arc plasma a mechanical tractive effect occurs, which is due to the electrostatic forces between the individual ions and the plasma electrons. Calculation of the tractive effect in a similar manner to that for determining the cohesive pull in strong electrolytes according to the Debye-Hückel theory

gives results of the right order of magnitude. (*Science Abstracts*)

No. 506. W. Elenbaas, "Gradient in High-Pressure Discharge in Metal Vapours," *Physica*, Vol. 4, August, 1937, p. 747. (In German.)

The gradient in the high-pressure cadmium and zinc discharge is measured as a function of the diameter of the tube d, the amount of metal vapor per centimeter of arc length m, and the energy input per centimeter of length L, and is compared with previous measurements of the gradient in the high-pressure mercury discharge. The gradients in the three vapors can be described by one formula in which the constants have different values for the different vapors. Furthermore, the ratio of these constants for the three vapors is near the expected ones. (*Science Abstracts*)

No. 507. R. C. Mason, "Probe Measurements on High-Pressure Arcs," *Phys. Rev.*, Vol. 51, January 1, 1937, p. 28.

Experiments show that the introduction of a probe into a carbon arc at atmospheric pressures increases the arc voltage, the increase depending on the size of the probe, but not on the rate at which it moves in the arc. It is shown that this effect is due to the local cooling of the gas, the probe being surrounded by a dark space of cold gas in which little ionization takes place. The rate of flow of energy to a probe in a carbon arc was measured and it is shown that half the energy is carried by thermal conduction across the dark space, and half comes from recombination of dissociated molecules on the probe surface. In view of these difficulties it is suggested that the interpretation of probe current-voltage characteristics developed for low pressure discharges cannot be used at high pressures. A qualitative explanation is, however, given for the characteristics of the arc used. (*Science Abstracts*)

No. 508. R. W. Schmidt, "Distribution of Emission and Heat Conduction in Arcs and Sparks, *Zeits. f. Phys.*, Vol. 106, Nos. 1 to 2, p. 35 (1937).

An investigation is made of the influence of external conditions on the distribution of light emission in arcs and sparks. The various influences affecting the emission in front of the cathode are traced back to a single cause; namely, the transfer of heat from the cathode region. The experiments were carried out with arcs and sparks between copper, gold, and iron electrodes at three different arc temperatures and two different spark temperatures. The results of the experiment with copper electrodes are given in detailed tabular form for the region 2246 to 3036 Å; the results for silver and iron electrodes were similar to those for copper electrodes. From the relation between electrical and optical phenomena in front of the cathode interesting deductions are made relative to the mechanism of electron escape from the cathode and connected questions. (*Science Abstracts*)

No. 509. E. Flegler, "Formation of Electrical Discharge in Gases," *ETZ.*, Vol. 58, November 25, 1937, p. 1262.

Extending the work of Raether, of Rogowski, and of others, the expansion chamber is used to show that discharge currents are produced in homogeneous electric fields at a critical onset potential, the process commencing with a canal discharge. The time and the velocity of the discharge vary according to the relative abundance of free and bound electrons. Examination is made of the transition to the steady discharge which, owing to photoionization, may glow from either electrode. The mechanism of lightning discharges is discussed with reference to these experiments. (*Science Abstracts*)

No. 510. F. Koppelmann, "Investigation of an Arc Discharge with Rapid Potential-Impulses," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 16, No. 3, p. 1 (1937).

An investigation was made of the behavior of d-c. arcs in nitrogen to which potential impulses were applied by the periodic discharge of a condenser. It was found that up to a certain potential, which was a multiple of the arc potential, the peak values of current and potential were accurately proportioned. With increased potentials the peak value of the current rises faster than the proportional values and for impulses of 10^{-5} sec. duration is about 2.5 times, and for impulses of 10^{-6} sec. duration about 7.5 times the arc potential. In the first case the departure from proportionality is due to heating and thermal ionization by electrons. The measurements enable the rate of electron production by thermal ionization to be deduced. The recombination coefficient is found to be of the order of 10^{-10}. The ionization in the arc was found to be purely thermal. For a high multiple of the normal arc potential the rate of ionization by electrons was of the same order as the thermal ionization. Disturbance of the thermodynamic ionization equilibrium by diffusion was found to be small. With potential impulses in the opposite direction to the original arc current no reverse current was obtained until the potential had reached a certain value, above which current began to flow in the direction of the applied impulses. (*Science Abstracts*)

No. 511. B. Kirschstein and F. Koppelmann, "Minimum Theory of Electric Arc Column. Comparison Between Theory and Experiment," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 16, No. 3, p. 56 (1937).

It is shown that the principle of the smallest potential for maintenance of an arc can

most probably be taken as a criterion of stability for the arc column. The original assumption due to Steenbeck is extended to apply to electric arcs burning under very different conditions. The results of this theory are compared with measurements on arcs stabilized by means of eddying gases and on arcs in rapid gas currents (see A.S. T.M. Abstract No. 530 (1937)). In both cases agreement is found, to a first approximation, between theory and experiment. (*Science Abstracts*)

No. 512. B. Kirschstein, "Electrode Loss in Arcs," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 16, No. 3, p. 69 (1937).

Experiments confirming earlier investigations. (See A.S.T.M. Abstract No. 513.) (*Science Abstracts*)

No. 513. B. Kirschstein, "Electrode Loss in Electric Arcs in a Mixture of Air and Nitrogen," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 16, No. 1, p. 72 (1937).

An investigation was made of the cathode loss in electric arcs and in particular of its dependence on the oxygen content of the gas atmosphere, on the cathode material, on the current strength, and on the velocity of flow of the gas. With decreased oxygen content, the cathode loss continually decreases. For a definite limiting value of the oxygen content, which is dependent on the metal used for the cathode, on the current strength and gas velocity, there is a change to another type of discharge. The behavior of the arc can be explained by the assumption that the base of the cathode has a layer of oxide which is continuously broken down by the arc and then renewed by the fresh oxygen in the gas stream. The measured loss values are in agreement with the results obtained by Holm and his collaborators, in spite of the difference of discharge conditions. (*Science Abstracts*)

No. 514. A. H. Heatley and R. S. Soanes, "Potential Distribution in High Current Carbon Arcs in Air," *Trans.*, Electrochem. Soc., Vol. 72, p. 281 (1937).

Probe characteristics of carbon arcs in air carrying 300 amp. are straight lines in contrast to those obtained by previous investigators in arcs carrying 5 or 10 amp., which show a greater slope for positive currents (electrons received by probe) than for negative currents. From the linearity of the characteristics, it is a reasonable assumption that the potential of zero probe current is the arc potential. Probe voltmeter readings agree with voltages obtained from the probe characteristic. The cathode fall is 14 v., the gradient in the arc between the electrodes is 1 v. per mm. and the anode crater fall at the beginning of a run averages $^1/_3$ v. per mm. of crater depth; during a run the crater fall (and the arc voltage) rises while ash volatilizes from the anode. The relation of these results to those of Westman and of Graham is discussed. (*Science Abstracts*)

No. 515. L. Tonks, "Theory and Phenomena of High Current Densities in Low Pressure Arcs," *Trans.*, Electrochem. Soc., Vol. 72, p. 167 (1937).

When a low pressure arc, considered as an electrical conductor, is "overloaded," it opens circuits with a suddenness which can create surges of many thousands of volts. Starting from the theory of the arc for moderate current densities, four factors are seen to be possible causes of such a limitation, namely: the longitudinal pressure gradient, a pressure difference arising in double sheaths, the transverse pressure gradient, and the magnetic pinch effect. These are discussed relative to the scant experimental material available and found to be of the right order of magnitude to form the basis of an explanation in various cases. (*Science Abstracts*)

No. 516. R. Edler, "Protection," *E.u.M.*, Vol. 55, October 24, 1937, p. 521.

A comprehensive gazetteer of the subject, with a résumé of various methods of electromagnetic switching, followed by an exhaustive bibliography. (*Science Abstracts*)

No. 517. B. H. Leeson, "Standardization of British Circuit-Breakers," *Elec. Times*, Vol. 92, December 2, 1937, p. 750.

A comparative review of the 1923, 1929, and 1937 editions of B.S.S. No. 116, with special reference to making capacity and breaking capacity. (*Science Abstracts*)

No. 518. D. Müller-Hillebrand, "Recent Developments in L.V. Switchgear," *Siemens-Zeits.*, Vol. 17, October, 1937, p. 506.

Improvements in breaking capacity, reduction in cost and size, and increase in durability are discussed. A chart shows the usual ranges of breaking capacities and life (number of operations) for automatic circuit-breakers, contactors, and isolating switches. Changes in the construction of air-break circuit breakers are explained, resulting from the use of block contact pieces, means of eliminating blowout coils, and improved forms of arc chutes or chambers. Oil-immersed contactors offer advantages in freedom from corrosion, small dimensions, small wear, and rapid interruption of circuit. Statistical analyses are given of breaking periods for oil contactors under various conditions. The characteristics and advantages of bimetal strip releases for oil contactors are examined with special reference to their use where there is risk of explosion. The life of contacts is 5 to 20 or more times greater in air-break than in oil immersed contactors. Dimensions of apparatus for various services are compared. (*Science Abstracts*)

No. 519. M. Herklotz and C. Pelz, "Applications of A.E.G. Rapid Regulators of Tirrill-Type," *AEG-Mitt.*, No. 11, November, 1937, p. 416.

Automatic regulators of the Tirrill type combine rapidity and accuracy of control with reliability, wide range, and simplicity of application. Wiring diagrams are given showing arrangements for the automatic voltage control of 3-phase alternators and d-c. generators of all types, and for furnace-electrode regulation, limitation of sustained short-circuit current, p. f. regulation, and motor speed control. Notes are included on these and other applications. (*Science Abstracts*)

No. 520. V. A. Brown and A. C. Ehrenberg, "High-Power Short Circuit Testing," *J.*, Beama, Vol. 41, September, 1937, p. 67; October, 1937, p. 107; November, 1937, p. 152.

The paper deals with high-power short-circuit testing technique and the interpretation of performance from oscillograph records in conjunction with observed behavior during, and condition of the apparatus after, a series of tests. Those characteristics of a testing circuit (particularly the inherent restriking voltage wave), which contribute to the severity of interrupting conditions, are discussed. Methods of varying the severity of the testing circuit are described. A typical testing plant is described in the Appendix. (*Science Abstracts*)

No. 521. E. Krohne and F. Kesselring, "Restriking Voltage and Dielectric Resistance," C.I.G.R.E., *Paper No. 112*, 23 pp. (1937).

Rupturing tests with different types of circuit breaker were carried out at 6 kv. and 100 mva. and variations of restriking voltage and resistance were measured. The factors affecting the stress on a circuit breaker and the precautions in testing are discussed. The time variation of restriking resistance under conditions analogous to those in circuit breakers of high rupturing capacity were measured, and the deionization conditions of different types investigated. Water and oil circuit breakers have a high, compressed-gas circuit breakers a low, restriking voltage. Comparison with previous theory shows satisfactory agreement. (*Science Abstracts*)

No. 522. R. Gasser, "Fuses or Circuit-Breakers in L.V. Circuits," *Bull.*, Assoc. Suisse des Elec., Vol. 28, April 30, 1937, p. 176.

Up to a few years ago, the protective element for circuits and consuming apparatus was the fuse. Practice has shown that so far as the protection of the apparatus was concerned the fuse was not in many cases suitable. The circuit breaker more frequently replaced the fuse for adequate protection. It costs more initially, but fuse replacements are saved. The author refers to the S.E.V. Regulations as to the operation of fuses and circuit breakers for the protection of electrical plant, and on the basis of these rules he discusses the characteristics—time-current curves—of the ordinary use, thermal, and electromagnetic circuit breakers. He shows in a simple way by means of examples how, by suitable combinations of these protective devices, fuses, etc., the costs for installation and operation are reduced. (*Science Abstracts*)

No. 523. E. Pugno-Vanoni and G. Someda, "A. C. Tests on Circuit Breakers," C.I.G.R.E., *Paper No. 130*, 10 pp. (1937). (In French.)

The difficulties and disadvantages of direct circuit-breaker tests are discussed and the merits of indirect tests are pointed out. Two indirect test methods are described. In one, a high restriking voltage is supplied by a h. f. alternating current or an impulse generator, thereby increasing the duration of the arcing current and the power and energy absorbed. A second method is a modification of the first in which the circuit breaker is fed with direct current in a highly inductive, low-resistance circuit, the conditions being capable of adjustments so that the circuit breaker absorbs a predetermined amount of energy upon operation. Oscillographs obtained by these methods are given and discussed. (*Science Abstracts*)

No. 524. S. Teszner and L. Gorjup, "Circuit-Breaker Testing," C.I.G.R.E., *Paper No. 131*, 26 pp. (1937). (In French.)

A description of the high-power testing laboratory for circuit breakers, built by Merlin and Gerin-Grenoble, is followed by details of some of the results obtained and of the influence of such research on circuit breaker design. (*Science Abstracts*)

No. 525. H. Puppikofer, "Effect of the Breaking Arc on the Form of the Voltage-Recovery Curve," C.I.G.R.E. *Paper No. 141*, 29 pp. (1937).

Until recently it was believed that the form of the curve of voltage recovery after interrupting a short circuit depended solely on the network constants and could not be influenced by the operation of the circuit breaker used. Tests described in this paper show that, where small currents are concerned, the extinction of the arc in any type of circuit breaker occurs shortly before the passage through zero of the current. The amplitude of the subsequent oscillations of voltage is increased, but the rate of increase is usually not dangerous, and at heavy currents this phenomenon is of no practical importance. The relatively high p. f. of normal supply, compared with short-circuit conditions, results in heavy damping and

practically eliminates h. f. oscillations in the recovery curve. The only case in which steep voltage oscillations of large amplitude occur in practice is that of the disconnection of transformers on light load. Representative oscillograms from works' tests and from part of the Zurich network are reproduced and discussed. The tests include observations with the same circuit breaker at normal and reduced voltages, and with different types at the same voltage. The form of the recovery curve is not the same at reduced voltages the voltage at the terminals of the circuit breaker at the moment of zero current becoming more important as the service voltage decreases. Also the type of circuit breaker and the relation between its designed voltage and breaking capacity and the actual conditions have an important effect on the earlier extinction of the arc. The sensitivity of different types of circuit breakers to increase in the rate of voltage recovery is in the sequence oil (least sensitive), water and compressed air. (*Science Abstracts*)

No. 526. J. Slepian and R. C. Mason, "Paschen's Law and Reignition Voltage of an A.C. Arc," *J. App. Phys.*, Vol. 8, September, 1937, p. 619.

Cobine and Power have recently reported a relation analogous to Paschen's law for the reignition voltage of an a-c. arc. Such a relation is not to be expected on theoretical grounds and it therefore appears questionable whether the usual method for demonstrating the validity of Paschen's law is well suited for the purpose. It is suggested that a method of plotting the results on double logarithmic paper give a far better clue to the existence of a law of the Paschen type. If this method is adopted, a series of straight lines is obtained, all having the same slope, which for Paschen's law is unity. The method is applied to experimental data given by Fricke and by Carr and in both cases the resulting lines are found to have practically the same slope throughout and the slope is unity or nearly so. Applications of the method to the results of Cobine and Power give a set of lines of widely different slopes, and hence it appears that a law of the Paschen type does not apply to the reignition voltage of a-c. arcs. (*Science Abstracts*)

No. 527. J. D. Cobine and R. B. Power, "Application of Paschen's Law to the Reignition of an Arc," *J. App. Phys.*, Vol. 8, April, 1937, p. 287.

An a-c. arc, in order to restrike after passing through current zero, requires a voltage considerably higher than the normal burning voltage. This reignition voltage is investigated for short gaps in nitrogen, using pure graphite electrodes with spacing up to 2 mm. and the pressures up to 500 cm. mercury. The reignition voltage is found to have two characteristics. One of these is followed for the arcs in which the cathode spot is maintained by field emission, and the other is followed for the "thermionic" arc. Relations are obtained between this reignition voltage and both the gas pressure and the gap spacing, with the arc current as parameter. These relations may then be combined into a single relation between the reignition voltage and the product of the pressure and spacing. This gives a function that is of the same form as the Paschen law for the initial sparking voltage of a gap. The constants of this function are dependent on the arc current, the gas in the space, and the constants of the circuit. That the constants of the reignition function are not the same as those for the sparking voltage law is to be expected from the very dissimilar conditions applying in the space. Extreme care in obtaining the experimental results is essential. (*Science Abstracts*)

No. 528. J. C. Simmonds, "Contact Resistance," *Elec. Times*, Vol. 92, September 30, 1937, p. 427.

Experimental research is carried out to determine the law connecting the resistance of a contact between similar metal surfaces for different contact pressures and currents. No variation of resistance with current was detected; a curve connecting resistance with contact pressure was found to obey the law:

$$R = 0.00276P^{-1/3} + 0.00162,$$

from which, and from theory, the general formula

$$R = \rho/(KP^{1/3})$$

is derived, where ρ is the resistivity of the material forming the contacts, K is a constant and P the pressure per unit area. It is further stated that for minimum contact resistance a material should have low resistivity, a small rigidity modulus, and a bulk modulus which is large compared with the rigidity modulus. (*Science Abstracts*)

No. 529. U. Eberhardt, "Contacts," *Zeits. f. Fernmeldetechnik*, Vol. 18, September, 1937, p. 137; October, 1937, p. 157.

A comprehensive survey of the theory and practice of transmitting contacts in circuits where indications are transmitted to remote repeaters. (*Science Abstracts*)

No. 530. B. Kirschstein and F. Koppelmann, "Electric Arc in Rapid Current of Gas," *Wiss. Veröff. a. d. Siemens-Werken.* Part I, Vol. 16, No. 1, p. 51; Part II, Vol, 16, No. 3, p. 26 (1937).

Part I.—High current arcs were produced between metal electrodes provided with axial holes through which gas could be supplied at high velocities. Measurements

were made of the arc voltage, the arc diameter, and the surface luminosity as dependents on the gas velocity up to the velocity of sound, with pressures up to 11 atmospheres and arc currents up to a few thousand amperes. The results are given in numerous diagrams. Current densities up to 50,000 amp. per sq. cm. were observed and the voltage gradients up to several hundred v. per cm. The total radiation reached values as high as 8 kw. per cm. of arc length. (*Science Abstracts*)

Part II.—The experimental results given in Part I are summarized and discussed. For the degree of ionization of the arc plasma lower limits of 7 to 14 per cent are obtained, the value depending on the pressure and current strength. The corresponding arc temperature is about 15,000 K. Pressure and current strength, which were varied within wide limits, have a relatively small effect on the degree of ionization and the arc temperature. The electron density of more than 10^{17} electrons per cc. and the current densities of 20,000 to 50,000 amp. per sq. cm. give rise to a number of effects which find no place in less highly ionized arc plasmas. These effects cannot be fully dealt with until means are devised to measure them properly. The power involved reaches values of over 1000 kw. per cu. cm. and this power is dissipated almost entirely as heat in the arc gas which is flowing away with a velocity of the same order as that of sound. (*Science Abstracts*)

No. 531. W. C. Kalb, "Characteristics of the Carbon Arc," *Elec. Eng.*, Vol. 56, March, 1937, p. 319.

In this paper the carbon arc is considered in its three characteristic forms: the low-intensity arc, the high-intensity arc, and the flame arc. The influence of arc current on the energy emission is discussed in relation to each of the three types, as well as the effects of the variation in arc voltage. The discussion covers characteristics which should be given consideration in order to make most effective application of the various types of arcs. (*Science Abstracts*)

No. 532. W. Cramp and E. G. Ashton, "Open Arc Dynamic Cyclograms," *Electrician*, Vol. 119, August 27, 1937, p. 231; September 3, 1937, p. 261; and September 10, 1937, p. 287.

An account of oscillographic investigations which supplements an earlier paper on the causes and character of the oscillations set up by an open carbon arc. The cathode-ray oscillograph enables the form of the dynamic characteristic or cyclogram to be examined far outside the range of a mirror oscillator. The author deals with forced and natural oscillations and with the crossing of characteristic lines. When the arc is forced to oscillate by being run on a-c supply, the arc gap is always conducting, owing to the presence of hot gases when the arc is out. Also, the characteristic loop is asymmetric as regards the two halves of the cycle because of slight differences between the conditions at the electrodes. For natural oscillations, such as those of the singing arc, it is shown that when the inductance is small compared with the capacitance, the arc voltage becomes negative, although the arc current is still positive. When the surge impedance is above a certain value, the arc nearly always hisses during part of the cycle. There seems to be little change in the wave form of these oscillations with frequency, at least up to 600 cycles per sec. The crossing of the characteristic loop is due to the arc length varying during the cycle; it does not occur when the arc burns steadily under the action of a strong draft, but it can be exaggerated by causing the arc to move. (*Science Abstracts*)

No. 533. A. S. Fry, "Four Forms of the Copper Arc in Air," Introduced by W. S. Huxford, *Phys. Rev.*, Vol. 51, January, 1937, p. 63.

Four distinct and reproducible forms of the copper arc in air at atmospheric pressure have been identified. The following table indicates the main features of each arc form:

Electrode	Potential,* v.	Gradient, v. per cm.	Fall near Cathode, v.	Fall near Anode, v.
1. Clean copper.	46	52	11	10
2. Cold copper oxide.....	41	25–31	10.5	7
3. Hot copper oxide.....	37	25	14	7
4. Hot cuprous oxide.....	34	25	14.5	4

* Voltage across 6 amp. arc, electrode separation, 3 mm.

That the controlling gas in the first arc is nitrogen is confirmed by gradient measurements carried out in a pure nitrogen atmosphere. The gradient in arcs (3) and (4) is determined by the presence of copper vapor furnished by thermal decomposition of the oxides. Space potentials were measured by means of a Langmuir probe consisting of a tungsten wire 0.07 mm. in diameter. Although the field near the center of the arc column is uniform, a continuously increasing gradient occurs within the space extending from 1 mm. to $\frac{1}{2}$ mm. from the electrode surfaces. The decrease in anode fall from 10 to 4 v. is accompanied by an increase in potential at the cathode. The lowering of the anode fall is due to several effects which combine to cause a decrease in electron concentration in the anode sheath. The changes in cathode fall are most easily explained

on the basis of the field theory of electron emission. (*Science Abstracts*)

No. 534. S. Keilien, "Short-Time Measurements Without Oscillograph," *Elec. J.*, Vol. 34, April, 1937, pp. 145–148.

For measuring the time interval of operation of a snap switch, a cam shaft and auxiliary contact are used; the position of the latter can be varied to synchronize either with the opening or closing of the snap-switch contacts, the coincidence being determined by the actuation of a relay (lighting a lamp) by the current passing through the two contacts in series. The angular motion of the auxiliary contact together with the speed of the cam shaft give the required time. Variations are described. (*Science Abstracts*)

No. 535. H. Trencham and K. J. R. Wilkinson, "Restriking Voltage and Its Import in Circuit-Breaker Operation," *J.*, I.E.E., Vol. 80, No. 485, May, 1937, pp. 460–468.

Restriking voltage and its principal significance are described, and the problem of relating these to circuit breaker operation in power systems is stated. (*Science Abstracts*)

No. 536. H. Trencham and H. E. Cox, "Mechanism of A. C. Circuit Interruption," *Engineering*, Vol. 143, May 28, 1937, pp. 597–599.

A review is made of the possible phenomena which may occur during successful arc rupture, and the operating methods of different types of circuit breaker are outlined. The conclusions obtained from a study of explosion pots are given and the characteristics of an efficient arc control chamber are detailed. The effect of different factors on efficiency is discussed and a specially designed arc-quenching chamber is described (*Science Abstracts*)

No. 537. C. G. Suits and H. Poritsky, "Interpretation of High Pressure Arc Data," *Phys. Rev.*, Vol. 52, No. 2, July 15, 1937, p. 136.

By applying conduction and convection heat transfer data to the arc column, and determining the temperature variation experimentally, a simple formulation of the electrical characteristics of the arc and their variation with pressure are obtained. In the high pressure arc, the dependence of electric gradient E (v. cm.$^{-1}$) and current density I (amp. cm.$^{-2}$) on the nature of the gas and its pressure p has been studied for argon, nitrogen, helium, and hydrogen over a portion of the pressure range up to 1200 atmospheres. (*Science Abstracts*)

No. 538. C. G. Suits, "High Pressure Arc Phenomena," General Electric Co., August 1, 1937.

A comprehensive investigation of the properties of the electric arc in the high pressure range has been partially completed. Several pressure chambers and some new measurement methods allow observations of total arc voltage e as a function of current i up to 3600 atmospheres; e, electric gradient E (v. cm^{-1}), current density I (amp. cm.$^{-2}$) assumed constant over the arc cross-section, and light output up to 220 atmospheres. In gases of 99 per cent purity the measurements extend, in nitrogen from 1 to 1200 atmospheres, hydrogen from 0.01 to 200 atmospheres, argon from 1 to 100 atmospheres, and helium from 1 to 200 atmospheres for copper, tungsten, and carbon electrodes. In all gases e, E, and I increase with pressure; at constant pressure e, E, and I increase with gas in order mercury, argon, nitrogen, helium, hydrogen. The pressure effect is such that e increases approximately 2 times, E 3 times, and I 15 times when p increases 100 times. Since $(n^2/N) = (I/E)^2$ for each gas, the gas temperature can be calculated from the Saha equation for an assumed ionization potential. At 1 atmosphere and 10 amp., the following temperatures are obtained: argon, 6500 K.; helium, 5900 K.; mercury, 5400 K.; nitrogen, 6100 K. (measured by sound velocity); and nitrogen at 100 atmospheres, 7100 K. The dependence of arc temperature on current and arc length is known to be small from sound velocity measurements. The arc temperature is thus relatively constant over a large range of experimental conditions. The interpretation of the measurements in terms of conduction and convection heat loss from cylinders will be treated in a paper now in preparation. Because the arc temperature is relatively constant, a generalization which predicts the trends with pressure and gas is: The arc properties E and I are the same in various gases at the pressure at which the conduction and convection heat loss is the same. Because the temperature is not perfectly constant, some anomalies occur. The measurements of I, and especially E, are subject to considerable uncertainty due to experimental error and lack of reproducibility of experimental conditions, and are to be regarded as tentative in absolute magnitude but correct in trend. Initial data have been obtained with a new method of simultaneously measuring e, I, and E as $f(i)$ with a relatively high accuracy. (*Science Abstracts*)

No. 539. T. A. Rich, "The Ballistic Use of Instruments," *G. E. Rev.*, Vol. 40, December, 1937, p. 583.

No. 540. G. W. O'Keefe, "Making Sparks from Arcs," Allis-Chalmers Mfg. Co. *Elec. Rev.*, December, 1937, pp. 31–32.

No. 541. J. A. Chiles, "Photographic Study of the Vacuum Spark Discharge," *J. App. Phys.*, Vol. 8, p. 622 (1937).

No. 542. G. Windred, "Magnetic Quenching of Arcs," *Electrician*, September 3, 1937, p. 264.

A discussion of the dissertation presented by Dr. Ernst Würth on "Magnetic Arc Quenching in Direct Current Circuits." Dr. Würth maintains, on his research, that the arc-quenching effect of the magnetic field must be ascribed to limitation of the ionization process rather than simply lengthening of the arc. Hence, good switch design will have the arc subjected to highest possible magnetic flux. Secondly, to keep down vaporization of the contact material, the arc must be free to travel across face of contact. (*Science Abstracts*)

No. 543. Anonymous, "Silvered Contacts for Heavy Currents," *Elec. Eng.*, October 8, 1937, p. 920.

No. 544. H. H. Renner, "Suppression of Electric Arcs by Air Currents" (Dissertation), Braunschweig (1937).

No. 545. L. B. Loeb, W. F. Hillebrand, H. J. White, R. N. Varney, and F. C. Miller, "Potential Gradients in Direct-Current Metal Arcs Determined from Stark Effect Studies," *Phys. Rev.*, Vol. 49, May 1, 1937, p. 703.

The apparent discrepancy on the Stark effect broadening of metal lines in arcs lies in the mistake of ascribing the Stark effect to linear potential gradients down the arc. An explanation is given on the basis that there are no clear-cut field gradients and that the broadening can be ascribed to the ionic force existing in the intensely ionized plasma of the arcs. (*Science Abstracts*)

No. 546. F. A. Westbrook, "Manufacturing and Assembling Radio Instruments," *Met. Ind.*, New York, Vol. 35, No. 3, pp. 97–101 (1937).

An illustrated description is given of the manufacture of silver switch contacts, air condensers, lacquered aluminum panels, brass oscillator shelves, and copper linings for radio cabinets. (*Chemical Abstracts*)

No. 547. H. Williams, "Resistance of Silver Contacts," *Electrician*, Vol. 119, 3103, p. 596 (1937).

Referring to a letter by G. Windred (*Met. Abst.* (1937), Vol. 4, p. 486), H. Williams states that twin contacts, of 99.9 per cent pure silver, have been standardized by the Post Office for light current relays in automatic exchanges for currents up to 0.3 amp. at 12 v., in place of a platinum-gold-silver alloy formerly used. Provided that the silver is pure, it only tarnishes in concentrations of hydrogen sulfide greater than are encountered in practice, and proves as good as any other material in resisting dust faults. (*Chemical Abstracts*)

No. 548. "Contact Resistance," Science Museum Libras, London, *Bib. Series No.* 348 (1937)

No. 549. "Why Silver Contacts Are Used," *Elec. Ind.*, March 31, 1937.

No. 550. "Silver in a Vapor-Proof Snap-Action Switch," *J. Sci. Inst.*, No. 12, p. 416 (1937).

No. 550a. "Annual Tables of Constants and Numerical Data," *Monograph No. 7*, Paris, 1937.

This monograph contains a section on metallic electrical resistivity which contains a great deal of information of interest in this connection.

No. 550b. A. R. Blandford, "Some Considerations in the Testing and Application of Modern High Rupturing Capacity Switchgear," *English Elec. J.*, Vol. 8, March, 1937, p. 134.

Discusses the progress which has been made in oil circuit breaker design due to the establishment of short circuit testing stations and the acceptance of B.S.S. 116 as the agreed standard of performance. The more important points brought out in the specification and discussed here in detail are: (1) limitation of ampere short circuit rating; (2) tests at other than the full rated rupturing capacity; (3) full cognizance of the importance of recovery voltage; (4) restriction of the value of the d.-c. component for determining breaking capacity performance on average speed breakers; and (5) control of test plant decrement.

The principal feature of the "English Electric" arc control device, deion grid contacts, are then set out. These include ample mechanical strength, limited internal pressures, sufficient margin of length over and above the length of the arc, definite control of the arc, easily replaceable sections, and facilities for inspection of contacts.

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No. 551. D. P. Miles, "An Investigation of the Use of Silver in Sliding Electrical Contacts," Thesis, Rensselaer Polytechnic Institute (1938).

No. 552. G. Windred, "Electrical Contacts: Effect of Contact Pressure," *Elec. Engg.*, August 12, 1938, p. 533.

No. 553. G. Windred, "Electrical Contacts: Contact Resistance," *Elec. Engg.*, August 5, 1938, p. 493.

No. 554. L. L. Stoffel, "Plating Generator Brushes and Their Job," *Products Finishing*, November, 1938.

No. 555. T. E. Allibone and J. M. Meek, "Development of the Spark Discharge," *Proc. Roy. Soc.*, Vol. 166A, Part I, May 4, 1938, p. 97; Vol. 169A, Part II, December 22, 1938, p. 246.

Part I.—A general account is given of the development of the h. v. electric spark, based on the study of over 1000 photographs taken with a rotating film camera. The electric spark is shown to consist of two principal components, a leader stroke and a main stroke—analogous to the lightning flash. A leader stroke invariably starts from a positive electrode, and sometimes also starts from a negative electrode: sometimes the structure of the leader stroke is simple, sometimes it is of the "stepped" variety. The leader stroke is always branched at many places, and the direction of branching is the direction of its propagation in space: branching thus forms a criterion of the direction of leader-stroke development. The main stroke develops in the reverse direction to that of the leader stroke and at a velocity too high to be recorded. The velocities of the positive and negative leader strokes are of the order of 10^6 to 10^7 cm. per sec., the positive leaders being the faster. Oscillograms of current and voltage support the photographic results. Multiple stroke discharges have been produced and show the characteristics of the multiple lightning flashes: the first is initiated by a slow leader stroke and is branched, the subsequent main strokes are either without leader strokes or the resolution of the camera is inadequate to show them: they are not branched. (*Science Abstracts*)

Part II.—Further work on the development of the spark at pressures from 76 to 0.3 cm. mercury confirms the conclusions previously drawn regarding the major differences between the positive and the negative spark discharge. Even for the longest gap (150 cm., breakdown voltage = 1600 kv.) the negative discharge from a point electrode is always met by an ascending positive leader stroke from the earthed plane and the length of this leader is not less than 30 per cent of the gap. In the case of the positive discharge the positive leader stroke is only infrequently met by an ascending negative leader stroke. The subatmospheric discharges afford assistance in the interpretation of the discharges at atmospheric pressure. The leader-stroke/main-stroke mechanism persists at least down to 5 cm. mercury with the same general distinction between positive and negative types of discharge. The individual-stepped leader strokes become more sharply defined and more widely separated in time as the pressure is reduced down to 10 cm. mercury. At low pressures the positive leader predominates to an even greater extent than at atmospheric pressure. A comprehensive discussion is given of the results of numerous researches with impulse voltages by Rogowski, Flegler, Tamm, Krug, and Kohler. Study of the effect of resistance on the velocity of propagation of leader stroke indicates that this is an important factor in discharge development. (*Science Abstracts*)

No. 556. V. Voss, "Arcs of Various Metals in Capillary Tubes," *Phil. Mag.*, Vol. 26, December, 1938, p. 1000.

The easiest type of mercury arc to construct is one in which the arc is run in a capillary tube. Similar arcs have now been obtained with cadmium, zinc, thallium, tellurium, bismuth, antimony, and lead. The metal was cast in a narrow Pyrex tube, which was then cracked off. A portion was introduced into a silica tube with two small bulbs connected by a capillary tube and suitable molybdenum wire electrodes. The metal was melted by means of a heating coil and the arc started by tapping so as to break the metal thread in the capillary. Such arcs run at pressures equal to or greater than atmospheric pressure. Photographs of the spectra obtained are given, with characteristic details. In each spectrum some of the lines are reversed. As the temperature and pressure rise the continuous background is enhanced, the reversals become more pronounced and new reversals may appear. Some lines which are sharp at lower temperatures broaden out and become more and more diffuse as the temperature rises. Thus the mercury group λ diffuses into one vague blur as the arc wattage is increased from 5 to 28 w.

No. 557. H. Haake and W. Walcher, "Cathode Jump of Potential," *Zeits. f. Phys.*, Vol. III, Nos. 3 and 4, p. 174 (1938).

The existence conditions and general features of a typical "thread-ray" discharge are investigated; for all conditions of voltage, current, and gas pressure at which the discharge is observed an Aston dark space occurs immediately in front of the cathode. The appearance of this dark region in the discharge is a visible proof of the nonexistence of the large cathode potential jump of 0.3 to 0.7 times the discharge potential which Westphal asserted to exist at the cathode in this type of discharge. Westphal's experiments on the deflection of thread-ray discharges by transverse magnetic fields are repeated; the deflection characteristics obtained are readily explicable on the assumption that the potential/distance curve rises steeply near the cathode and then remains constant up to the anode and there is no need to involve the cathode-jump hypothesis by way of explanation. (*Science Abstracts*)

No. 558. M. Pierucci and L. Barbanti-Silva, "Arc between Electrodes of Fused Non-Metals," *Nuov. Cim.*, Vol. 15, May, 1938, p. 265.

Continuing previous work, examination is made of the spectra emitted by arcs between fused nonmetallic electrodes. Photographs of the spectra are reproduced. In general, a high degree of luminosity is observed ac-

companied by much self reversal of the lines. (*Science Abstracts*)

No. 559. C. V. Fragstein and M. Arndt, "Probe Method for Carbon Arc at Atmospheric Pressure," *Ann. d. Phys.*, Vol. 33, No. 6, November, 1938, p. 532.

The probe method for the investigation of discharges in gases consists in the introduction of a conductor into the discharge and the measurement of the emf. and current of this conductor with respect to one of the electrodes. Conclusions may then be drawn with respect to potential, electronic temperatures, etc., and the method enables localization at definite points in the discharge. The introduction of the test conductor, however, causes disturbances, the chief of which is thermal, a cooling zone being established around the test piece. For any theory of the current obtained by the probe method to be valid, the movement of the carriers in the cool zone must be known, the magnitude of this current being very sensitive to temperature. On this account all previous measurements have led to incorrect values of carrier concentrations and potentials. The experimental part of the paper is very full and comprehensive, and is illustrated by 16 diagrams. The method has proved to be particularly useful for low pressure discharges. (*Science Abstracts*)

No. 560. E. Olsson, "Transition from Field Excitation to Thermal Emission in the Arc Light," *Arkiv f. Mat.-Astr. och Fysik*, Vol. 26B, No. 4, 4 pp. (1938). (In German.)

The predissociation bands of aluminum are sensitive indicators for studying excitation conditions in the arc as the predissociation levels only appear in thermal emission. From intensity measurements it is found that thermal radiation is insignificant in the core of the arc and below 100 mm. pressure but preponderates above 1 atmosphere of pressure unless the arc is strongly cooled. At all pressures the aureole radiation is thermal and independent of the core. At intermediate pressures the core radiation is of mixed character. In this transition region intensity anomalies occur; these are described and discussed in detail. It is deduced that the life periods of anomalous lines are of the order 10^{-9} to 10^{-10} sec. compared with 10^{-13} sec. for ordinary predissociation lines. (*Science Abstracts*)

No. 561. J. S. Townsend and E. W. B. Gill, "Generalization of the Theory of Electric Discharges," *Phil. Mag.*, Vol. 26, August, 1938, p. 290.

The authors' well known general collision theory of the actions of electrons and positive ions in discharges is now extended to cover different kinds of discharges in gases at low pressures, and the conditions are investigated as to how the electric forces required to maintain the discharges are effected by a magnetic force. The most convenient method was found to be a comparison of the motion of electrons or the rate of ionization under various conditions with the motion or rate of ionization in a uniform electric field where there is no magnetic force. The theoretical results obtained have been tested experimentally by measuring the electric force required to start a discharge in dry air in a large spherical bulb. (*Science Abstracts*)

No. 562. R. M. Robertson, "Force on Cathode of a Copper Arc," *Phys. Rev.*, Vol. 53, April 1, 1938, p. 578.

The force on the cathode in the electric arc, previously examined either in air at atmospheric pressure or in a vacuum, is studied as a function of pressure. For the copper arc in nitrogen the force is found to remain of the order of magnitude of the values observed in air down to pressures of about 5 mm., and then to increase sharply but smoothly to the much larger forces observed in a vacuum. Various aspects of the arc are examined in the transition region. Curves showing force as a function of current at various pressures of hydrogen and nitrogen are given. A brief study of the stability of the vacuum arc is included, as well as a summary of the various theories put forward to explain the phenomena. (*Science Abstracts*)

No. 563. L. Tonks, "Rate of Vaporization of Mercury from an Anchored Cathode Spot," *Phys. Rev.*, Vol. 54, October 15, 1938, p. 634.

Two major difficulties which interfere with the measurement of the vaporization of mercury at a free cathode spot are the spray and the normal evaporation from the free surface. By anchoring the spot the spray has been eliminated, and by a specially designed, water-cooled cathode structure the free surface has been limited to small areas of controllable size. By means of a calibrated feed mechanism, mercury was fed to the cathode as fast as it vaporized. Measurements were made over a range of arc current, cooling water temperature, and exposed area. The rate of vaporization (g. per coulomb) increased with arc current, temperature, and exposed area, all due to increased normal evaporation. The rate may also increase with arc current, because of cumulative effects within the spot itself. Extrapolated to zero arc current the rate was found to be approximately 2.5×10^{-4} g. per coulomb. This lies within the limits set by von Issendorf. It means that eight elementary charges pass through the arc for every atom evaporated. (*Science Abstracts*)

No. 564. "Calculation of Short-Circuit Currents in Networks," *A.C.E.C.*, No. 160,

October, November, December, 1938, p. 147. (In French.)

Theory and examples of three-phase applications, including alternator characteristics, transient terms, and oscillographic investigation of circuit breaker performance. A nomogram of cable inductance is included. (*Science Abstracts*)

No. 565. W. Schilling, "Calculation of Short-Circuit Currents in Rectifier Circuits," *E.u.M.*, Vol. 56, December 4, 1938, p. 653. (In German.)

Where high-power rectifiers are concerned, the investigation of short circuit conditions relates chiefly to the development of the current up to the moment of operation of the high-speed circuit breaker or other protective device. In medium power installations, however, the overload protection generally allows full development of the short circuit current and the value of the latter is important from the standpoint of the rectifier bulb or vessel. The magnitude and form of the short circuit current depend on the magnetic coupling of the current limiting reactances. The author deals with short circuit current values to be expected in a six-phase rectifier under various circumstances. The relevant vector diagrams, wave forms, and general equations are presented, with typical values of short circuit current ratios. (*Science Abstracts*)

No. 566. A. M. Schmidt, "New Automatic Switches," *AEG-Mitt.*, No. 12, December, 1938, p. 583. (In German.)

A description is given of one-, two-, and three-pole automatic switches operated by means of bimetallic strips. The current rating of the one- and two-pole types ranges from 0.5 to 25 amp., that of the three-pole type from 2 to 25 amp. Examples are given of the use of such switches as current-limiting devices or automatic circuit breakers when a prescribed current is exceeded. (*Science Abstracts*)

No. 567. E. Müller, "Survey of Types of Compressed Gas Switches," *AEG-Mitt.*, No. 11, November, 1938, p. 518. (In German.)

Attention is drawn to the great saving of space effected by the use of compressed gas instead of oil-immersed switchgear. Various patterns and sizes of circuit breakers are illustrated with air blast or autogeneration of gas for interruption of the arc. Switches capable of interrupting up to 220 mva. are built with tubes of special insulating material from which sufficient gas is generated by the heat of the arc to extinguish the latter without the use of a compressed air blast. Wall-mounted and pedestal types of circuit breakers are illustrated. The air blast circuit breaker is specially suitable for use in remote control systems operating by the momentary interruption of one phase of the supply; it is also useful in electric locomotives and can be mounted on the roof to save space. Standardized units comprising compressed gas circuit breakers, instrument transformers, and controls are available for voltages up to 30 kv. Various patterns of rotary arm circuit breakers are described for indoor and outdoor use. (*Science Abstracts*)

No. 568. F. Kassau, "Air Break Contactors for Control of Large H. V. Motors," *VDE-Fachberichte*, Vol. 10, p. 42 (1938). Discussion, p. 45.

No. 569. R. Paxton, "Modern Trends in Switchgear Development," *G. E. Rev.*, Vol. 41, November, 1938, p. 504.

The trends in the development in modern switchgear equipment are discussed, dealing mainly with panel board breakers and large types of equipment.

No. 570. H. Rissik, "Circuit Breaker Standards," *Engineer*, Vol. 166, November 4, 1938, p. 495.

No. 571. W. Herden, "Mechanical Releases for High Speed, D.C. Circuit Breakers," *ETZ.*, Vol. 59, November 17, 1938, p. 1231.

No. 572. R. C. Dickinson, "Deion Air Circuit Breakers for A.C. Feeder, Motor Starting and Station Auxiliary Service," *Trans.*, A.I.E.E., Vol. 57, November, 1938, p. 649.

Describes a new range of "deion" air circuit breakers for 2500- and 5000-v. ratings to extend the advantage of this type of construction to power station auxiliary service, general motor-starting service, and substation feeder applications.

In addition to the short circuit tests, three series of endurance runs were made. After closing and opening 7700 times at 235 amp., 2300 v., and then 7700 times at 1350 amp., 300 v. without any maintenance whatever, the breaker was in good operating condition. The third test involved 35,000 operations, and the breaker still remained in good condition.

No. 573. J. Sandin, "Enclosed Low Voltage 'Deion' Air Circuit Breaker of High Interrupting Capacity," *Trans.*, A.I.E.E., Vol. 57, November, 1938, p. 657.

The demand for protection against fault currents up to 20,000 amp. at 250 v. d.c. or 600 v. a.c. had led to the development of air circuit breakers of higher interrupting capacity. Tests at 20,000 amp. on breakers of lower capacity showed that certain modifications were necessary. By increasing the gap between the contacts, by using Elkonite contacts to resist welding, and by using a modified arc chamber and construction it was

found possible to make the breaker described satisfactory for 20,000 amp. short circuits.

The original 600-amp. circuit breaker of 10,000 amp. capacity had silver main and secondary contacts and Elkonite arcing contacts of 30 per cent silver, 70 per cent tungsten composition. The first modifications included greater contact pressure and a change of main contacts from silver against silver to silver against Elkonite (60 per cent silver, 40 per cent tungsten) to prevent welding. These contacts did not weld when the short circuits (20,000 amp.) were thrown on the breaker in the closed position, but welding occurred in about half of the tests when the breaker was closed on the short circuits. A change to 60–40 silver tungsten Elkonite on both sides did not entirely eliminate the possibility of welding when the breaker was closed on 20,000 amp. short circuits, but the percentage was reduced.

No. 574. L. E. Markle, "Control for Wound Rotor and Synchronous Motors," *Elec. J.*, Vol. 35, November, 1938, p. 440.

No. 575. "Voltage Regulators," *Engineer*, Vol. 165, May 13, May 20, May 27, June 3, June 10, June 17, and June 24, 1938.

No. 576. S. Hoh and Y. Hanawa, "Effect of Gas Pressure on the Dielectric Recovery in an A.C. Arc," *ETJ.*, Vol. 2, No. 7, July, 1938, pp. 151–154.

No. 577. H. P. Fink, "Investigation of Origination of Contact Arcs," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 17, No. 3, pp. 45–70 (1938).

Results of investigation with oscilloscope on very small arcs between clean, reproducible contact surfaces when opened in normal pressure air. Pure metal contacts. Gives curves of voltage *versus* short circuit current and develops equations therefor. Apparatus described. (*Science Abstracts*)

No. 578. H. Franken, "Development of L. V. Switchgear," *ETZ.*, Vol. 59, May 5, 1938, pp. 461–464.

Stages in the development of low voltage switchgear are illustrated by reference to the products of a particular firm; reasons for changes in design and construction are noted and approximate dates are given. Most of the changes have been brought about by external factors, for example, starters have been replaced by plain switches in many cases where squirrel-cage motors are used instead of slipring or d-c. machines. Developments noted include remote control, increased scope and durability to suit machines with built-in motors; extended use of die castings, drop forgings, and molded parts; use of block contacts instead of brush contacts; thermal overload trips instead of fuses; unit-assembly panels meeting different requirements by the use of standardized components; ironclad and other totally enclosed gear; and changes in methods of rating. (*Science Abstracts*)

No. 579. C. C. Shumard, "Some Electronic Switching Circuits," *Elec. Eng.*, Vol. 57, May, 1938, p. 209.

No. 580. S. Fukuda and S. Hoh, "Some Characteristics of Arc Discharge in a Coaxial Magnetic Field," *ETJ.*, Vol. 2, No. 9, September, 1938, pp. 202–205.

No. 581. F. Braby, "Precious Metals for Contacts," *Elec. Times*, Vol. 93, January 20, 1938, p. 85.

No. 582. A. Lang, "Characteristics of Tirrill Regulator for High Speed Regulation," *Arch. f. Electr.*, Vol. 32, October 14, 1938, p. 675.

No. 583. F. G. Spreadbury, "Reducing Sparking at Voltage Regulator Contacts," *Electrician*, Vol. 120, January 7, 1938, pp. 3–4.

The maximum voltage across the contacts of a "Tirrill" type voltage regulator for d-c. generators of variable-speed variable-load service is the product of the maximum field current and the regulator resistance which the contacts bridge. A method of reducing contact sparking, and at the same time increasing the speed at which control is lost, consists in placing a nonreactive resistance in parallel with the field winding. This provides an alternative path for the voltage due to field inductance and lowers the sparking voltage appearing across the contacts. (*Science Abstracts*)

No. 584. E. Ortensi, "Evolution of Functions and Technical Requirements of Modern Circuit Breakers of Medium and Large Capacity. Factors of Determining Choice," *Elettrotecnica*, Vol. 25, September 25, 1938, p. 646.

No. 585. E. L. E. Wheatcroft, "Gaseous Electrical Conductors," Clarendon Press, Oxford, 265 pp + xi (1938).

The metallic conductors which the electrical power engineer commonly uses for carrying his current have electrical properties sufficiently simple and sufficiently unvarying so that there is no pressing need for the engineer to delve into the physical theory of the electrical conductivity of metals. When, however, gaseous electrical conductors enter his apparatus, as in circuit breakers, the engineer must drop his aloofness, and appeal loudly to the present-day physicist for help, or do some physics research himself. The complexities of conduction in gases are so great, that even only for the purpose of

keeping the experimental facts well in mind, some physical theory, dealing with atoms, ions, and electrons, is necessary.

The present volume aims to supply the electrical engineer with such physical theory as is now available, and which will be helpful, or which promises to be helpful in the design of engineering apparatus involving gaseous conductors. The book is divided into two parts: the first dealing with physical theory, and the second discussing engineering apparatus with gaseous conductors. All important parts of the theory seem to be included in 149 pages, so that obviously space required that the treatment of each topic be short. The engineering apparatus described in the second part includes vacuum and gas-filled tubes, mercury arc rectifiers, circuit breakers, and luminous discharge tubes.

No. 586. S. Keilien, "Oscillograph Is Versatile Tool in Studying Transients," *Elec. J.*, Vol. 35, No. 2, p. 61 (1938).

A general article describing methods for using an up-to-date electromagnetic type of oscillograph with a photographic attachment for the study of electrical transients. The two usual cases where the phenomenon is brought into synchronism with the oscillograph or the oscillograph is brought into synchronism with the phenomenon to be photographed are covered in detail.

A valuable article for those using an electromagnetic oscillograph for the study of arcing in contacts.

No. 587. Y. Miyoshi, "Discharge Characteristics and Circuital Constants," *ETJ.*, Vol. 2, No. 2, p. 27 (1938).

The present author has previously pointed out that there exist two kinds of discharge characteristics at the high-tension side of ignition coils, namely, the arc discharge occurring continuously immediately after the spark discharge and the intermittent discharge, which indicates the intermittent generation of some number of times of spark discharges, and has given a general discussion of their generating mechanism. In the present paper the author further gives the results of the experiments which were carried out with the impulse-voltage generator for the purpose of making the previous discussion a more general one and also his theoretical explanation with the circuital theory. (Author's abstract)

No. 588. J. Biermanns, "Progress in the Construction of Compressed Gas Switches," *ETZ.*, Vol. 59, Nos. 7 and 8, pp. 165 and 194 (1938).

After enumerating the types of h. v. switches now available, the author discusses the relative merits of storing the extinguishing medium in gaseous, liquid, and solid form. Certain combinations of synthetic resins generate suitable extinguishing gases when exposed to the arc, but it is not possible to limit the duration of the arc to half a cycle at all current values. Such switches are specially recommended for 6-, 10-, and 20-kv. unattended substations and the like. Alternative methods of producing the requisite blast of extinguishing medium in different types of switches are discussed. Extinction after one cycle, and correspondingly increased separation of contacts, is more economical than the construction required to effect extinction at half a cycle and to guard against restriking. Reference is made to the indifference of air blast switches of the rotary isolator type to ice coatings, and to their relatively quiet operation and standardized design. The second part of the paper deals with the theory of arc interruption, developments in high power testing equipment by artificial increase of restriking voltage, and notes on the economy and performance of modern air blast switches. (*Science Abstracts*)

No. 589. C. G. Suits, "Multiple States in the High Pressure Discharge," *Phys. Rev.*, Letter to the Editor, Vol. 53, No. 7, p. 609 (1938).

"In studying the arc discharge in the one atmosphere range of pressure we have for some time accumulated evidence that there exists, in addition to the 'normal arc' and a glow discharge, additional glow states.

"The results thus point conclusively to the presence of a new discharge type in the high pressure discharge, and suggest the existence of still others. The data are too incomplete at present to allow a conclusion as to the mechanism." (Quoted from the letter.)

No. 590. C. G. Suits and J. P. Hocker, "Role of Oxidation in Arc Cathodes," *Phys. Rev.*, Letter to the Editor, Vol. 53, No. 8, April 15, 1938, p. 670.

"We have recently made some observations which point to the importance of an oxide film on the cathode of arcs in the atmospheric pressure range.

"We believe that these results point definitely to the importance of an oxide film in the case of cold cathode arcs. A likely interpretation is that with electrode materials like silver and copper (in this current range) the cathode cannot supply sufficient emission without an oxide mechanism. This result agrees with calculations of field emission for cold cathode arcs which have always shown that the available field is too small.

"It is a fact well known to welders and easy of verification that in air attempts to strike an arc between clean, bright iron welding rods and a clean, steel plate are unsuccessful until, by repeatedly restriking an incipient discharge, a visible oxide layer

is formed on the cathode (the plate)." (Quoted from the letter.)

No. 591. T. A. Rich and E. J. Hatfield, Jr., "The Ballistic Wattmeter," *G. E. Rev.*, Vol. 41, No. 6, p. 288 (1938).

The ballistic wattmeter described lends itself to a variety of uses. As has been mentioned, it is suitable for measurements of the phenomena that take place when a circuit is interrupted. It can also be adapted for use as a ballistic ammeter; or, if steady-state deflections are obtained, it operates as a true wattmeter with a comparatively low full-scale rating. It is applicable to either a.c. or d.c., and can be supplied in ratings over wide ranges of current and potential. It has long been recognized that the energy in an arc is an important factor in design, and it is hoped that this convenient device will encourage its measurement. (Author's conclusion)

No. 592. J. D. Cobine, "Effect of Oxides and Impurities on Metallic Arc Reignition," *Phys. Rev.*, Letter to the Editor, Vol. 53, No. 11, June 1, 1938, p. 911.

"When the copper electrodes were prepared by filing them smooth, the arc in air was at first extremely erratic and the reignition voltage varied widely from cycle to cycle. Oscillograms indicated that for about the first 30 cycles the reignition consisted of first striking a high current glow which quickly changed into an arc. This phenomenon disappeared after about one second and then subsequent tests with these same electrodes, for different currents and pressures, always resulted in a stable arc. When freshly filed electrodes were oxidized in a gas flame before using, this high current glow did not appear.

"It is evident from these tests that the discharge is influenced markedly by the condition of the copper cathode. Since the glow disappeared after a time in both air and nitrogen it is probable that this stage is associated with the absence of copper oxide, or of some other impurity. The work function of copper oxide is relatively low compared with that of copper and by its presence would lower the effective work function of the surface.

"The reignition voltages of freshly filed surfaces of cadmium, iron, aluminum, and zinc were found to exhibit the same random variation during the first second of arcing as was found for similarly prepared copper." (Quoted from the letter.)

No. 593. C. G. Suits, "Welding Arcs from the Standpoint of Recent Investigations," *Welding J.*, Vol. 17, October, 1938, p. 35 (Supplement). Discussion, November, 1938, p. 63.

There are: (1) low pressure arcs, such as cold-light mercury vapor lamp, in which tiny particles (electrons) at a temperature of 30,000 F. move at high speeds in a neutral gas at room temperature, and (2) high pressure arcs in which the tiny moving particles that constitute the arc current are at the same temperature as the surrounding gas. The temperature of the high pressure arcs, of which welding arcs are one type, is 7000 to 12,000 F., which has been determined by a method involving the velocity of sound. The arc temperature, therefore, is about the same as the temperature of the sun.

The tiny particles (ions and electrons) carrying the arc current in metal arc welding move through an atmosphere of metal vapor as has been found from a study of welding arcs from bare and covered electrodes. These particles, therefore, are metallic and must come from the surface of the electrode or metal being welded. The space in which the particles acquire their current carrying characteristics is less than $1/2$ a hundred-thousandth of an inch thick, which is still equivalent to several hundred layers of solid metal atoms. What happens in this space depends on whether the metal surface is clean or dirty. If the surface is clean it is difficult to obtain a supply of particles to form an arc, especially an arc easy for the welder to manipulate. On the other hand, if the metal is dirty, that is, oxidized, the high fields necessary for emission are produced by the surface charge on the very thin oxide film. It is this oxide film which is believed to assist the welder in maintaining his arc. (*Society Abstracts*, American Welding Society)

No. 594. W. Baer, "Arc Discharges in Air at Pressures Varying From 1 to 30 Atmospheres," *Arch. f. Elektr.*, Vol. 32, No. 10, p. 684 (1938).

Needle point discharge in air at pressures from 1 to 30 atmospheres; various forms of discharge show different range of resistance; disruptive strength does not increase proportionally with pressure. (*The Engineering Index*)

No. 595. F. Denk, "Low Tension Control Equipment," *V. D. I. Zeit.*, Vol. 82, October 22, 1938, p. 1251.

Describes the types of switches available for motor control and industrial purposes and discusses the choice and application of the various protective devices. (*Science Abstracts*)

No. 596. Anonymous, "Finish of Contact Surfaces," *Elec. Times*, Vol. 94, November 24, 1938, p. 711.

No. 597. A. W. Clement, "Relay Contacts —Their Ailments," *Electronics*, Vol. 11, No. 12, p. 29 (1938).

The author discusses various factors which affect contacts in telephone relays operating

on d-c. circuits from 22 to 48 v. The main difficulty with telephone contacts, and especially in relays having low contact force, is in obtaining a circuit through films of greases which deposit on the contact surface from the atmosphere or due to handling.

The effect of contact shape is discussed and it is pointed out that to break through various films which deposit on telephone relay contacts, rough contact surfaces are preferable to smooth, polished surfaces. The mounting of contacts in either the vertical or horizontal position is discussed; and it is shown that, generally, dust will settle on contacts in either position.

The effect of type of circuit on which the relays operate is gone into in considerable detail, and suggestions are made for operation of such contacts on both inductive and noninductive circuits.

The author describes various ways of cleaning contacts, and suggests washing and wiping contacts with chamois, one of which is dipped in carbon tetrachloride and the other dry as the best procedure.

The article as a whole brings out a number of interesting and, in some cases, important points regarding the performance and servicing of small contacts for operation on low-voltage circuits.

No. 598. W. H. Teare, "The Vacuum Switch and Its Applications," *G. E. Rev.*, Vol. 41, June, 1938, p. 280.

The advantages of interrupting current in vacuum are: (1) There is no gas to ionize, hence no arc forms, (2) the absence of oxygen precludes oxidation of the contacts, (3) absence of arcing increases the life of contacts and makes possible the breaking of d.c. with a contact separation of only a few thousandths of an inch, (4) the contacts remain bright and clean, hence contact pressures need not be increased as the switch ages, (5) metal vapor liberated at the cathode spot at the moment of breaking is rapidly dispersed, there being no restraining molecules of gas, (6) the switch is small, simple, and requires low operating force. Interrupting ability is limited by the rate of voltage rise across the contacts, the characteristics of the contact metal, and the completeness of degassing of the contacts. A single-pole double-throw switch is illustrated. The requisite motion is obtained by using a thin metal diaphragm as fulcrum for the operating lever. The life of the switch is determined by diaphragm fatigue and the building up of one contact by metal transferred from the other. The switch is rated at 8 amp., 125 v. d.c. or 250 v. a.c., decreasing to 0.5 amp. at 1500 v. a.c. or d.c.; about 1 oz. and 0.026 in. motion $2^3/_8$ in. from the diaphragm are required to operate the switch. Slow operation has no ill consequences; operation hundreds of times a minute is practicable; the use of discharge circuits is recommended. (*Science Abstracts*)

No. 599. G. Windred, "Switch Contacts," *Elec. Engg.*, August 19, 1938, p. 572; August 26, 1938, p. 611.

No. 600. G. Windred, "Electric Contacts for Low-Current Switchgear" (Review of "Elektrische Kontakte," by W. Burstyn), *Elec. Engg.*, February 11, 1938, p. 514.

No. 601. R. Strigel, "Building-Up Period in the Spark Delay," *ETZ.*, Vol. 59, January 6, 1938, p. 1.

A summary is given of researches by cited authorities on the minimum time lag in breakdown when the applied impulse voltage exceeds the static breakdown voltage. Experimental data relating to uniform and asymmetric fields are applied to consideration of the physical phenomena and to the initiation of lightning discharges. Typical records obtained by rotating cameras are produced and discussed. (*Science Abstracts*)

No. 602. N. F. Mott, "Contact Between Metal and Insulator or Semiconductor," *Proc.*, Cambridge Phil. Soc., Vol. 34, October, 1938, pp. 568–572.

When a semiconductor is placed in contact with a metal an electrical double layer is set up, either between the metal and the semiconductor or in the semiconductor itself. This paper gives a mathematical investigation of the width of this double layer under certain assumptions. Results are discussed in relation to sodium chloride in contact with sodium and to the cupric oxide rectifier. (*Science Abstracts*)

No. 603. R. Strigel, "On the Statistics of Spark Delay in Air at Atmospheric Pressure," *ETZ.*, Vol. 59, Nos. 2 and 3, pp. 33 and 60 (1938).

The spark delay is made up of a "statistical scatter period" or time interval during which the initiating electrons are formed for the electron avalanches, and the actual building-up period during which one of these electrons establishes such an avalanche that breakdown occurs. The author deals with the statistics of spark delay in air, on the basis of tests relating to short gaps in which the impulse voltage always causes breakdown. It is shown that the results can be applied to the consideration of gaps of industrial dimensions. Representative distribution curves are given showing the percentage of tests in which the time lag exceeds stated periods, as influenced by the material and surface condition of the electrodes, and by aging due to atmospheric effect or repeated discharge. Uniform and asymmetric fields are considered. The building-up component of the time lag varies only slightly from its mean value and represents the minimum lag that can occur. The

statistical scatter period is a probability factor which may be nearly zero, in the case of large cathodes with strong u.v. irradiation, and in the case of pointed cathodes, and which may be minutes or hours in the case of small nonirradiated cathodes. In a uniform field the scatter period decreases toward a minimum as the overvoltage increases, and is dependent upon the energy required for emission of electrons from the cathode. In asymmetric fields the scatter period is shortened by emission of electrons due to curvature of the cathode, but increasing the curvature of the anode increases the scatter period. (*Science Abstracts*)

No. 604. G. Windred, "Arcs and Discharges," *Elec. Eng.*, November 18 and 25, 1938, pp. 30 and 82.

No. 605. D. C. Prince, "European Switchgear Developments," *Elec. Engg.*, Vol. 57, April, 1938, p. 155.

This is an illustrated survey of the design principles and construction of h. v. circuit breakers in England, France, Sweden, Germany, and Switzerland, and there is also reference to outdoor h. v. switching stations. Photographs and line sectional drawings are reproduced and the following types of breakers are dealt with: M. V. Co. metalclad, single-break, 33 and 66 kv.; Delle air blast; A.S.E.A. "contraction" (oil blast) 220 kv.; Voigt and Haeffner air blast; Siemens (Germany) water expansion up to 40 kv. and oil-base liquid expansion up to 200 kv.; A.E.G. gas blast, water type, and air blast; and Brown Boveri air blast. An analysis of cost comparisons of three breaker ratings is given. (*Science Abstracts*)

No. 606. G. Windred, "Arcing Effects in D. C. Switchgear," *Elec. Eng.*, April 8, 1938, p. 860.

No. 607. A. H. Jacquest and L. H. Harris, "Sparking and Arcing at Relay Contacts and the Use of Spark Quench Circuits," Inst. P.O.E.E., *Paper No. 118* (1938).

No. 608. L. R. Ludwig and G. G. Grissinger, "A New High Capacity Air Breaker," *Trans.*, A.I.E.E., Vol. 58, No. 8, August, 1938, p. 414. Discussion, p. 418.

Air circuit breakers for lower voltages of simple design are being replaced by improved types, which incorporate specially designed current interrupting devices for the purpose of improving the interrupting efficiency and minimizing the formation of arc flame and gases. A new form of deionizing arc interrupter is described which is equally effective for both d-c. and a-c. circuits. A new air circuit breaker has been designed to utilize this interrupter in which carbon arcing contacts are replaced by refractory metal, and laminated brush type main contacts are replaced by silver-faced solid copper. These improvements have led to greatly increased current-carrying capacity in breakers of a given size and also large increases in interrupting capacity with a minimum of noise and flame, which permits the breakers to be readily mounted in enclosures and cubicles of small physical size. (*Science Abstracts*)

No. 609. E. Lisitzin, "Ionization Potentials of Elements Under Different Ionization Conditions," Soc. Scien. Fennica, *Comm. Phys.-Math.*, Vol. 10, Nos. 1–5, 121 pp. (1938).

Section I discusses the significance of ionization potentials and also stable atomic configurations; Section II, the fundamental term of Millikan and Bowen. Section III deals with regularities in the values of ionization potentials and in particular with Payne's investigations, Moseley's law, and the Laporte-Young relation. Section IV discusses theoretical calculations of ionization potentials, the various subsections being concerned with (1) different quantum methods and the helium problems, (2) the electron affinity of hydrogen, (3) other two-electron structures, (4) three-electron structures, (5) structures similar to that of the rare gases, (6) Slater's method, (7) the method of Bacher and Goudsmit, and (8) the equation of Kruger and Shoupp. Section V collects and arranges in tabular form the available data on ionization potentials. Section VI deals with the representation of ionization potentials by a polynomial of the second degree and Section VII gives the results of calculations and comprehensive tables of the ionization potentials of the elements. The bibliography appended is unusually full and includes 335 papers. (*Science Abstracts*)

No. 610. J. Meixner, "Wiedemann-Franz Law in Metals," *Ann. d. Phys.*, Vol. 33, No 7, December, 1938, pp. 682–688.

A proof is given of the Wiedemann-Franz law for a metal of any crystal structure in a field of any strength or orientation. It is only necessary to assume that T is greater than *Theta* and that the degeneration temperature of the electron gas in the metal is sufficiently high. (*Science Abstracts*)

No. 611. A. M. Sidorenko, "The Variation of Contact Resistance over a Surface," Acad. Sci. Ukrainian S. S. R., Kiev (1938).

No. 612. W. Betteridge and J. A. Laird. "Wear of Electrical Contact Points," *J.*, I.E.E., Vol. 82, June, 1938, pp. 625–632.

Four main stages in the break of a current have been observed, of which the resistance rise, the arc, and the spark are well known; intermediate between the resistance rise and the arc is a stage in which the gap between the contact points is bridged by a drop of molten metal; this latter is of great practical

importance since it is of almost universal occurrence, causes well marked transference of contact material, and, as the potential difference between the contact points is then only about two volts, it cannot be suppressed by modifications of the interrupted circuit. The voltage-current length characteristics of the molten bridge between electrodes of platinum-iridium (25 per cent Ir) have been determined and are found to be of a similar form to those for an ordinary arc, that is, voltage inversely proportional to current and directly proportional to length. The reason for such characteristics is not known. The conditions of voltage and current necessary for the formation of the different stages are described, and the effects produced by typical simple circuits are dealt with. Suggestions are made which should help to reduce the wear of contact points to a minimum. (*Science Abstracts*)

No. 613. G. W. Nicholson, "Oxidation of Contacts—Effect on Silver and Its Alloys," *Elec. Rev.*, London, Vol. 123, No. 3177, October 14 1938, p. 544.

The effect of solubility of oxygen in molten silver and its consequent release during cooling through the melting point is discussed with respect to its effect on the operation of silver contacts. The effects of various alloying ingredients are discussed and it is pointed out that $2^1/_2$ per cent copper in silver prevents spitting. It is pointed out that most silver alloys will show some tendency to oxidize at temperatures below the melting point of silver while pure silver is not affected by oxygen. Various other effects are discussed briefly.

No. 614. G. Windred, "Joints in Electrical Conductors," *J., Beama*, Vol. 42, No. 8, pp. 52–55 (1938).

The primary requirement in the limitation of the heating of a joint in electrical conductors is a low contact resistance, and careful attention must be given to the means by which conductors are connected together. To insure that a joint is not overheated, it should possess a large effective radiating surface. An increase in temperature accelerates the deterioration of the joint, due to lack of intimate contact, and increases corrosion of the interfaces and the formation of oxides and sulfides. The alternative methods of jointing, including bolting, riveting, clamping, soldering, brazing, and welding, are described in detail, and their relative advantages discussed. (*Chemical Abstracts*)

No. 615. G. Windred, "Electrical Contact Resistance. A Review of Developments," *J. Beama*, Vol. 42, No. 10, April, 1938, pp. 122–125.

A review of the development of the subject with a comprehensive bibliography. (*Science Abstracts*)

No. 615a. R. M. Spurck and H. E. Strang, "A New Multibreak Interrupter for Fast Clearing Oil Circuit Breakers," *Trans.*, A.I.E.E., Vol. 57, December, 1938, p. 705.

A description is given of a new multibreak interrupter for fast clearing of short circuits applicable to high-voltage conventional tank-type oil circuit breakers. Breakers equipped with such interrupters were subjected to interrupting tests on large 138- and 2380-kv. systems during which short circuits as high as 2,000,000 kva. were interrupted in less than five cycles.

A series of 15 tests were made at the Saugus substation of the Southern California Edison Co. at 220 kv. All the tests were made in one day with no inspection or adjustment of contacts. After these tests the contacts (illustrated) were only slightly burned.

A further series of 13 tests were carried out out at 138 kv. at the Philo substation of the Ohio Power Co. at duties from 382,000 to 2,030,000 kva.

No. 615b. P. Sporn, "Logan Auxiliaries Have 2,300 Volt Air Breakers," *Elect. World*, Vol. 110, October 22, 1938, p. 30.

The installation of a 50,000-kva. high pressure turbo-generator at the Logan, West Virginia, plant of the Appalachian Electric Power Co. called for a considerable increase in auxiliary power capacity and for switching equipment of the utmost reliability. Owing to the fire hazard—several serious oil fires having occurred—the I.T.E. Circuit Breaker Co. was requested to develop suitable air circuit breakers for this duty. The switchboard eventually installed consisted of seventeen breakers, three rated at 1200 amp. and the remainder at 600 amp., the former being used for the transformer supply and bus tie connections, and the latter for the feeders.

Tests were made to determine the performance of the air circuit breaker during short circuit conditions, 25 interruptions being made with short circuit currents ranging from 3000 to 23,000 amp. and with voltage from 2300 to 4300. Burning of the arcing contacts was so slight as to require no attention.

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No. 616. K. L. Emmert, J. W. Wiggs, and V. E. Heil, "Before You Specify Electrical Contacts," *Elec. Mfg.*, Vol. 24, No. 6, December, 1939, p. 42.

Proper contact material and proper physical design are the two fundamental factors involving practical designing of electrical contacts. The proper material depends upon such specific operating factors as a-c. or d-c. circuits, high or low voltages, contact pressures, and resistances. Backing materials are important in order to satisfy rigid re-

quirements as to corrosion resistance, high conductivity, and availability of material.

Proper physical design of contacts generally available are of the following types: rivet, either solid head or fabricated contact; composite, projection or button type, concave convex, electrobrazed type, solder backed type, composite rivet, or fused type.

Tables of recommended contact dimensions for basic types of assemblies are given along with maximum resistance values, and resistance data. Another table gives conductivity, hardness, tensile strength, and elongation of common contact alloys.

No. 617. L. B. Loeb, "Fundamental Processes of Electrical Discharge in Gases," John Wiley & Sons, Inc., New York, N. Y., 717 pp. (1939).

It is often possible to trace, in the history of scientific activities, the progress of knowledge and developments resulting therefrom, and to quite definitely indicate crests of achievements as well as troughs or relative periods of inactivities and lesser accomplishments. When this can be done, the reasons for variations in activity can be assigned. The author of this book points out that the field of study of electrical discharge in gases developed with amazing rapidity from 1895 to about 1910 as a result of studies of one of the most able group of scientific investigators in a given field at one time. The peak of this work was reached when coordination and correlation of the studies of J. J. Thomson and J. S. Townsend brought forth the classics "The Conduction of Electricity Through Gases" and "Electricity in Gases." Then activity gradually subsided, due to rapid advance in other fields and the difficulty of overcoming drawbacks in existing techniques. At the present time, the reasons for inactivity having been gradually removed, revival in interest is taking place and activity is on the increase.

The two above-mentioned classics have seen considerable use these many years. No other work has approached their popularity for they have been the standard and for a fact they have contributed largely to present studies as is evidenced by the references being made to them in the many recent papers in the periodical literature and society transactions the world over. This literature by its very nature cannot be a summation of existing knowledge. Therefore it remains for a work such as this book to pick up the loose threads of literature, present the facts and conflicting views, and present opinions with regard to facts of importance, giving reasons.

This book is remarkable for its thoroughness of coverage. It opens with a treatment on ionic mobilities giving first a review of a few accurate and significant modern methods of measurement, then presenting in an orderly fashion results of studies of ionic mobilities with conclusions of the author, followed by a treatment of theory. The status of the subject recombination of ions is next treated which precedes an interesting explanation of an elementary nature of the character of diffusion of ions. This leads to a discussion on the fundamental classical researches of Townsend and a survey of one or two problems showing qualitatively how ionic diffusion operates in a gas. The topic of measurements and theory of electron mobilities is covered historically, and furnishes a basis for the study of the complex concepts involved in energy distribution. Advances in the knowledge on the formation of negative ions goes into the use of newer apparatus and techniques as well as the presentation of later theories. These together with the treatment along lines of conduction currents in gases and the first and second Townsend coefficients, provide adequate prerequisites for the applications to problems of spark discharge, glow, and the arc to which the latter part of this book is devoted.

There is an enormous amount of data in the form of curves and tables. At the end of each chapter references are listed, the total amounting to a very large number, an indication of the exhaustive work in this phase alone. A comprehensive subject and author index is to be found in the book.

Without doubt the book is a useful tool to those interested in this subject, and as such is destined to give added impetus to activities in this and related fields. (*Journal of the Franklin Institute*)

No. 618. C. G. Suits, "The Temperature of High Pressure Arcs," *J. App. Phys.*, Vol. 10, No. 10, p. 728 (1939).

From measured values of arc gradient E (v. cm.$^{-1}$) and current density I (amp. cm.$^{-2}$) the arc temperature is calculated for nitrogen in the pressure range 1 to 30 atmospheres and current range 1 to 10 amp. and in hydrogen at one atmosphere pressure for the current range 1 to 10 amp.

NITROGEN ARC TEMPERATURE (T K.) FOR $v_e = 15$.

	i, amp.	1	2	5	10
p = 1 atmos.	T K.	5950	6020	6250	6 400
p = 5 atmos.	T K.	6400	6450	6770	7 050
p = 10 atmos.	T K.	6680	6780	7160	7 470
p = 20 atmos.	T K.	7030	7150	7620	7 980
p = 30 atmos.	T K.	7230	7400	7920	8 320
p = 100 atmos.	T K.	..	..	..	8 800[a]
p = 1000 atmos.	T K.	..	..	..	10 200[a]

[a] Extrapolated values.

HYDROGEN ARC TEMPERATURES ($v_e = 14$).

	i, amp.	1	2	5	10
p = 1 atmos.	T K.	6500	6600	7000	7 400

(Author' abstract)

No. 619. C. G. Suits, "Current Densities, Lumen Efficiency and Brightness in A, N_2, He, and H_2 Arcs," *J. App. Phys.* Vol. 10, No. 10, p. 730 (1939).

From oscillographic records of arc diameter D, gradient E, current i, and comparative brightness data, the lumen efficiency and current densities are determined for the positive column of arcs in argon, nitrogen, helium, and hydrogen in the pressure range between 1 and 100 atmospheres.

CURRENT DENSITIES IN NITROGEN.

	i, amperes	1	2	5	10
p = 1 atmos...	I (amp. cm.$^{-2}$)	6.3	6.1	5.8	5.7
p = 5 atmos...	I (amp. cm.$^{-2}$)	11.8	9.9	11.6	13.3
p = 10 atmos...	I (amp. cm.$^{-2}$)	18.9	16.7	20.2	24.5
p = 30 atmos...	I (amp. cm.$^{-2}$)	60.0	48.0	63.0	79.0

CURRENT DENSITIES IN HYDROGEN.

	i, amperes	2	5	8	10
p = 1 atmos...	I (amp. cm.$^{-2}$)	590	550	540	570

CURRENT DENSITIES IN HELIUM (PURE CARBON ELECTRODES).

	i, amperes	1	2	3	4	5	6	10
p = 1 atmos....	I (amp. cm.$^{-2}$)	46	45	48	48	48	46	46

CURRENT DENSITIES IN ARGON (PURE CARBON ELECTRODES).

	i, amperes	1	2	3	4	6	10
p = 1 atmos.....	I (amp. cm.$^{-2}$)	42	36	33	31	27	25

(Author's abstract)

No. 620. C. G. Suits and H. Poritsky, "Application of Heat Transfer Data to Arc Characteristics," *Phys. Rev.*, Vol. 55, June 15, 1939, p. 1184.

The chief experimental results of a study of the electric gradient E and current density I in the arc for various gases and pressures (see A.S.T.M. Abstract No. 631 (1939)) can be correlated by means of conduction-convection heat loss data from solid bodies in fluids, and lead to an explanation of the variation of E and I with current and pressure in good agreement with measurements. This is shown with the help of the Nusselt-type equation, neglecting radiation, and the calculation of relations and evaluation of constant is given, including the cases of forced convection and of arcs in a variable gravity field. (*Science Abstracts*)

No. 621. E. S. Lamar, A. M. Stone, and K. T. Compton, "The Positive Column of the Nitrogen Arc at Atmospheric Pressure," *Phys. Rev.*, Vol. 55, June 15, 1939, p. 1235.

Extending earlier work by one of us, a theory of the positive column in an arc has been developed, from considerations of energy balance, from which good values of nitrogen arc parameters are calculated from known properties of the gas. The power generation per unit volume is obtained in terms of the potential gradient, the electron mobility, and the electron concentration. The electron concentration is computed with the aid of the Saha equation for thermal ionization. The power loss is calculated in terms of a generalized heat conductivity which includes the heat transport that results from the diffusion of dissociated atoms. Convection is neglected, so that the theory applies only to low current arcs in ordinary space or to arcs below 30 amp. in gravity-free space. Equating power generation and power loss lead to a differential equation that can be solved numerically once the center temperature is known. Without solving the equation a change of variable is evident, which shows the potential gradient to be independent of the total power. This gives an arc equation of the Ayrton type. The arc is shown to be free from certain constraints which might otherwise set the center temperature. However, the center temperature is determined by introducing the additional consideration that the arc operates to make the power loss a maximum. The agreement with experiment is satisfactory. The inclusion of convection in a more complete theory is discussed, and it can be asserted that departure from the above simplified theory, for arcs of larger currents, is qualitatively of the type to be expected from the influence of convection. These results supply convincing evidence that the mechanism of the positive column of arcs is now understood. (Authors' abstract)

No. 622. H. B. Lobstein, "Variation of Temperature in a Metal-Carbon Arc," *Physica*, Vol. 6, July, 1939, p. 581. (In English.)

The temperature and the electric force are measured in various phases of a pulsating arc between a metal and a carbon electrode. (*Science Abstracts*)

No. 623. J. S. Townsend, "Ionization by Collisions of Positive Ions," *Phil. Mag.*, Vol. 28, July, 1939, p. 111.

The author considers the validity of his theory that ionization by collisions of electrons and positive ions with molecules of a gas explains photoelectric currents and gaseous conductivity in various forms of discharges. Objections advanced on the ground that such ionization is impossible at higher pressures than the critical value for minimum sparking potential are shown to lead to theories which are themselves unable to explain photoelectric phenomena and corona discharges. It is pointed out that much divergence of opinion exists in modern knowledge of atomic processes, but that the hypothesis is at least not inconsistent with any well-established physical principle. The conductivity of air at high pressures between parallel plates is shown to be consistent with the hypothesis that a mole-

cule is ionized in a small proportion of the total number of collisions of ions with energies greater than 30 v. Recent experiments in hydrogen and helium at critical pressures for minimum sparking potential, designed to separate the effects of secondary cathode emission and positive-ion ionization, also support the theory. (*Science Abstracts*)

No. 624. A. de Stefano and B. Ferretti, "Spark-Gap Discharges," *Nuov. Cim.*, Vol. 16, January, 1939, p. 20.

The authors show that the times through which a spark-gap discharge lasts can assume constant values of the order of 10^{-8} sec. if rectangular wave fronts are used and if the electric field is of sufficient intensity. An electrooptic method based on the Kerr effect is described for measuring the time of discharge. The electric field of the discharge has been measured with a similar arrangement. (*Science Abstracts*)

No. 625. J. D. Cobine, R. B. Power, and L. P. Winsor, "The Reignition of Short Arcs at High Pressures," *J. App. Phys.*, Vol. 10, No. 6, p. 420 (1939).

An investigation has been made of the reignition of short a-c. arcs in air at pressures from one to eight atmospheres, for currents less than 3.25 amp. (and with a resistance circuit). Pure graphite electrodes were used and were separated by a distance of 1 mm. The reignition voltage under these conditions increases with pressure and decreases as the current is increased. The characteristic of reignition potential *versus* current has been found to exhibit a discontinuity at a critical current. For this current the reignition potential decreases by about 1000 v. to a new characteristic typical of the higher currents. This critical current increases with the gas pressure to a maximum of 2.25 amp. As the rms. current is increased from low values to values near the critical, the number of cycles during which the reignition potential has the value given by the higher characteristic decreases. For currents equal to, or greater than the critical value, only the low reignition potentials are obtained. This transition is accompanied by an increase in the burning voltage of the arc. (Authors' abstract)

No. 626. H. Fuhrmann, "Electron-Collision Excitation Functions of Metals with High Boiling Points," *Ann. der Phys.*, Vol. 34, No. 7, p. 625 (1939).

It appeared to be of interest to examine the excitation of an element whose lowest term from which the excitation starts is a triplet. On technical grounds only lead comes into consideration. In contrast with the easily vaporized metals whose highest temperature needed was 540 C. there occur with metals possessing high boiling points greater experimental difficulties, the observing of which was the object of the research described. With two newly constructed electron tubes the excitation functions of three metals with high boiling points were measured. Thallium as typical of the third division of the periodic system of the elements was investigated by two different methods. The green thallium line so unique in the visible spectrum was measured by visual means by comparison with the thallium spectral lines. The excitation function of five other lines was obtained photographically and some earlier values obtained by Strohmeier were improved upon. Then six lines of the visible silver spectrum as representative of the first division of the regular elements were excited and there were found equally legitimate results as well as similar form of the E.F. as found with thallium and sodium: (1) Lines from the same upper terms have similar E.F. of the same lines of a series, since they proceed from similar upper terms; (2) within a series the maximum of the E.F. shifts with increasing member number by an amount proportional to the shifting of the E.F. Finally the course of the E.F. was determined for 13 lead lines and examination was especially made regarding the difference between singlet and triplet excitation as it is known in the second division of the periodic system (cadmium, zinc, and mercury). These have as ground terms a singlet term; lead on the contrary has a triplet term. (*Science Abstracts*)

No. 627. Hsu Yun Fan, "Transition from Glow Discharge to Arc," *Phys. Rev.*, Vol. 55, April 15, 1939, p. 769.

A paper describing experiments on glow discharges in air, oxygen, and nitrogen at 1 atmosphere, and in hydrogen at pressures ranging from 1 to 13 atmospheres, using various combinations of electrode materials. Electrode materials were copper, platinum, aluminum, and molybdenum. Glow discharges between copper electrodes may exist in hydrogen with currents as large as 14 amp. and, although not simultaneously, at pressures as high as 13 atmospheres. With other gases and electrode combinations tested the glow was less stable than in hydrogen. Continuous stability of the glow over long periods may not be expected even with small currents. Additional evidence was found for the hypothesis of electron emission in arcs under high surface field strengths, and characteristic changes of the electrodes in glow discharges have been observed due to sputtering and chemical reaction. The apparatus used is described and the procedure adopted is stated. (*Science Abstracts*)

No. 628. H. Kaiser and A. Wallraff, "Transition Forms Between Arc and Glow Discharge in Spark Sequences," *Zeits. f. Phys.*, Vol. 112, Nos. 3 and 4, p. 215 (1939).

In a previous paper the authors established that the normal form of the spark discharge produced by a Feussner spark generator between copper, iron, and platinum electrodes was a l. v. h. f. arc. It has been noticed that under the influence of changes of the electrode surfaces the arc discharge changes into a markedly different type of glow discharge. The transition from one form of discharge to the other is examined by rotating mirror and cathode-ray oscillograph methods. Methods for preventing the occurrence of the abnormal discharge form are indicated. (*Science Abstract*)

No. 629. W. Finkelnburg, "Current-Potential Characteristics of Different High-Current Carbon Arcs," *Zeits. f. Phys.*, Vol. 112, Nos. 5 and 6, p. 305 (1939).

The current-potential characteristics of d-c. arcs between homogeneous carbons and also between different cored carbons were determined in the region of very high current densities, anode loading up to 280 amp. per sq. cm., as dependent on the diameter of the carbon electrodes, for different arc lengths and different location of the electrodes, such as coaxial or inclined arrangements. Over 6000 individual measurements were made. All the arc characteristics obtained show after the known falling portion a potential minimum and then, for very high loading, a rise whose steepness is about four times as great for the Beck type of arc as for the other arcs used. Arcs between homogeneous carbons and also carbons cored with K_2SiO_3, with the higher current densities occur in two forms, a noiseless and a hissing form, the latter being more stable for very high current densities with homogeneous carbons, the noiseless being the more stable at lower current densities. The arc potential of the noiseless type is 10 to 15 v. higher than the other, while in the case of carbons cored with K_2SiO_3 the reverse is the case. Measurements on Beck arcs show that the occurrence of the Beck effect is connected with an irregular rise of the arc potential, shown by a kink in the characteristic. The current strengths of the Beck effect and of the arc potential minimum vary proportionally with the diameter of the positive carbon. The Beck arc characteristic is independent of the nature of the negative carbon and there is also practically no difference between the Beck arc characteristics when the carbon electrodes are coaxial or perpendicular to one another. (*Science Abstracts*)

No. 630. A. F. Kip, "Onset of Positive Point-to-Plane Corona in Air at Atmospheric Pressure," *Phys. Rev.*, Vol. 55, March 15, 1939, p. 549.

Continued investigations with special reference to pre-onset regions are reported. Two kinds of current pulses, shown by oscillographic and photographic studies, and occurring below onset voltages are described. At voltages approaching corona onset, streamers which extend far out into the gap are observed. The steady corona process is normally initiated by one of these streamers. The mechanism for both bursts and streamers is shown to involve space-charge intensification of the field. Streamer propagation and stable burst corona both depend on photoelectric ionization in the gas. Streamer length is found to depend primarily on point size, and for very fine points no distinction can be made between bursts and streamers. The number of ions produced was found to be approximately 5×10^9 per cm. of visible streamer, and about 2×10^9 in an average burst pulse. The time necessary for positive ions produced by a streamer to cross the gap was found to be of the order 10^{-3} sec., and to vary with gap geometry. (*Science Abstracts*)

No. 631. C. G. Suits, "High-Pressure Arcs in Common Gases in Free Convection," *Phys. Rev.*, Vol. 55, March 15, 1939, p. 561.

An oscillographic method is described for measuring the electric gradient E (v. cm^{-1}), current density I (amp. cm.$^{-2}$), total voltage e (volts) as a function of current i in the discharge. The method is applied to arcs in the 0 to 10 amp. range under conditions of free convection in nitrogen, argon, and helium in the 1 to 50 atmosphere pressure range, and to air, carbon dioxide, and steam at atmospheric pressure. The exponent n and B in $E = Bi^{-n}$ are determined for these cases. The range of n is $0.54 < n < 0.73$, and some dependence on pressure is observed. The exponent m in $E = B_0 p^m$ is measured for nitrogen, hydrogen, helium, and argon, and is found to be 0.31, 0.32, 0.20, and 0.16, respectively, with some dependence on current. The method is applied to arcs between electrodes of a number of common metals in air. (*Science Abstracts*)

No. 632. H. Büttner, "Starting Characteristics of the Townsend Discharge in Inert Gases," *Zeits. f. Phys.*, Vol. 111, Nos. 11 and 12, p. 750 (1939).

The characteristic of the Townsend discharge in pure inert gases is, as shown by Schade, a falling straight line. In order to ascertain the dependence of the inclination of the starting characteristic (K_1) on the pressure and electrode distance, measurements were made in the pressure region of 1 to 20 atmospheres. K_1 in pure inert gases in discharges with constant p. d. was found to be inversely proportional to the pressure. Holm's similarity rule therefore does not hold for the characteristic. At constant pressure K_1 increases more strongly than linearly with the distance apart of the electrodes. At constant electrode distance

K_1 increases approximately proportionally to the pressure. K_1 is greater in dense gases than in light gases. Measurements in mixtures which show the Penning effect indicate that substantial deviations from Paschen's law occur and K_1 greatly depends on the proportion of the mixture. In mixtures with small amount of one constituent the reciprocal inclination ($1/K_1$) is a linear function of the proportion of the mixture. The explanation of these experimental results may be based on Townsend's theory as extended by Schade. (*Science Abstracts*)

No. 633. R. Grigorovici, "Striking Voltage in Pure Mercury Vapor," *Zeits. f. Phys.*, Vol. 111, Nos. 9 and 10, p. 596 (1939).

Using electrodes of platinum, iron, aluminum, and mercury, the striking voltage curves for a discharge in mercury vapor between equal and parallel plane electrodes have been investigated with reference to their dependence on the material of the cathode. The results obtained are discussed in relation to the processes occurring in the gas, such as the formation of negative ions, the energy transfer and ionization by electronic collision, and also to the processes occurring at the cathode, when the mechanism of the release of electrons by the impact of positive mercury ions is considered. It is shown that the formation of negative ions is of secondary importance in the discharge striking process; the energy transfer by electron collision is small and the Townsend ionization coefficient in mercury vapor is relatively high. It is further suggested that the mechanism of electron release by means of mercury ions is a predominantly thermal effect. Experiments were carried out on the effect of a thin layer of mercury on the cathode and the curves given show an almost constant value for the striking voltage under these circumstances. (*Science Abstracts*)

No. 634. R. Schade, "Ignition Process of the Electric Discharge at Atmospheric Pressure," *Zeits. f. Phys.*, Vol. 111, Nos. 7 and 8, p. 437 (1939).

Calculation from Townsend's theory gives, for the ionization number γ for electrical breakdown at atmospheric pressure, a marked dependence on the field strength. This is at variance with other considerations. An attempt to overcome this difficulty is made by assuming that in effect it is not the γ-mechanism, but photoelectric electron release from the cathode, which is essential for the discharge process. In this connection it must be remembered that the u. v. radiation determining the electron release from the cathode is very strongly absorbed in the gas space. The resulting ignition conditions, when absorption losses are taken into account, include the law of similarity. Quantitative estimation leads to very high absorption coefficients, which are, however, in agreement as regards order of magnitude with values deduced from other considerations. The potential breakdown is ascribed to the reduction of the absorption losses in consequence of the removal of the excitation zone in the neighborhood of the cathode. Further experimental work is necessary to test the theory advanced. (*Science Abstracts*)

No. 635. L. B. Loeb and A. F. Kip, "Electrical Discharges in Air at Atmospheric Pressure," *J. App. Phys.*, Vol. 10, No. 2, p. 142 (1939).

A lengthy study of the nature of the positive and negative point-to-plane coronas and the mechanism of spark propagation. Frequent references are made to the previous work of other investigators. (*Science Abstracts*)

No. 636. C. G. Suits, "Measurement of Some Arc Characteristics at 1000 Atmospheres Pressure," *J. App. Phys.*, Vol. 10, No. 3, p. 203 (1939).

By an oscillographic method the total arc voltage e is measured as a function of arc current i at high pressure in a 1500-v. d-c. circuit in which i (in the 1 to 7 amp. range) is independent of changes in e. The $e-i$ characteristics are taken for copper electrodes in nitrogen up to 1275 atmospheres pressure, with the result that e increases two times at $p = 100$ atmospheres and five times for $p = 1000$ atmospheres. The pressure effect in helium is similar to nitrogen. Attempts to obtain measurements in hydrogen showed a striking instability of the hydrogen arc at high pressure. (Author's abstract)

No. 637. G. Rudolph, "Temperature Measurements in a Glow Discharge," *Zeits. f. Phys.*, Vol. 111, Nos. 7 and 8, p. 523 (1939).

By the use of a compensation method, which is described, one of the chief difficulties in discharge temperature measurements, namely, the difference in temperature between the probe and the surrounding gas, is eliminated. The probe used is a platinum bolometer wire stretched across almost the full width of the discharge space. Measurements have been made of the relationships between gas temperature and current, position of probe, and gas pressure for air and hydrogen. From an analysis of the temperature distribution curves obtained it is shown that the rate of heat production in any part of the discharge can be approximately estimated. (*Science Abstracts*)

No. 638. R. B. Quinn, "Sparking Potentials at Low Pressures," *Phys. Rev.*, Vol. 55, March 1, 1939, p. 482.

At gas pressures less than the Paschen critical value the sparking potential rises rapidly with decrease in pressure. Measure-

ments are difficult because of undesired discharges over longer paths than the intended one. A sparking tube has been constructed with which measurements have been made on air, carbon dioxide, hydrogen, and helium up to 24 kv. with nickel electrodes, and on air with a stainless steel cathode. The results are compared with those of Carr, of Cerwin, and of Penning. The equations of the straight portions of the sparking potential curves are of the form $V = a + b \log p.d.$ From these equations the number of electrons released by the cathode per positive ion impact has been calculated by a method described by Dempster. (*Science Abstracts*)

No. 639. A. Zaitzev, "Calculation of Townsend Ionization Coefficient," *J. Exp. and Theo. Physics (U.S.S.R.)*, Vol. 9, No. 4, p. 469 (1939). (In Russian.)

The author calculates the values of the ionization coefficient and the ratio of energy loss of the electrons by ionization to that by excitation, under two different assumptions as regards the velocity distribution of the electrons. The relation between the electron temperature, and the ratio of electric field to pressure in a positive column of a glow discharge is obtained and compared with experiment. (*Science Abstracts*)

No. 640. C. van Geel, "Dynamical Properties and Stability of Gas Discharge," *Physica*, Vol. 6, August, 1939, p. 806. (In German.)

The theory of the gas discharge employing a cold cathode is briefly described. It is assumed that n new electrons as well as positive ions are produced by electrons from the cathode; a factor q is defined which has a value of n times the ratio of electronic to ionic discharge current. It is also assumed that q is a function of the p. d. between anode and cathode and of the discharge current. On these assumptions the static and dynamic properties of a discharge are discussed theoretically and mention is also made of the conditions affecting the stability of the discharge. (*Science Abstracts*)

No. 641. W. Funk and R. Seeliger, "Internal Oscillations of L.V. Arcs," *Zeits. f. Phys.*, Vol. 113, Nos. 3 and 4, p. 203 (1939).

In l. v. arcs under certain experimental conditions, internal oscillations occur spontaneously. A systematic investigation was made of the ignition potential characteristics of l. v. arcs in the rare gases and also of the distribution, amplitude, and frequency of the internal oscillations of such arcs. The results are presented graphically. Study of distance characteristics and the results obtained by the use of probes furnishes an explanation of the production of oscillations. From the measurement point of view the disturbance of the discharge by probes is of interest. A new and simple arrangement for the displacement of probes is described. (*Science Abstracts*)

No. 642. H. Thommen, "Research on the High Speed Reclosing in Case of Short Circuit on Overhead Lines and the Application of the Ultrarapid Air Blast Circuit-Breaker for This Purpose," C.I.G.R.E., *Report No. 108*, 27 pp. (1939); *Brown Boveri Rev.*, Vol. 26, No. 3, p. 55 (1939).

It is shown by results of tests on the stability of transmission systems that in case of single-phase faults in three-phase systems it is advantageous to open and reclose only one pole of the circuit breaker. The method of single-pole switching, however, cannot be applied under all circumstances, since due to the capacitive transmission of residual currents at the fault the deionization can be impaired. In long transmission lines at high voltages, particularly in systems with isolated neutral or neutral earthed through extinction coils, the deionization can even be completely prevented. Under these conditions only three-pole opening and reclosing can be considered. Further, it is shown that the air blast high speed circuit breaker is specially suited for service involving high speed reclosing, as it has a very short tripping time and no complication of the circuit breaker is caused by the additional devices required for reclosing. Finally, some information is given regarding the development of the air blast high speed circuit breaker for different service conditions and for installations in indoor and outdoor plants. (*Science Abstracts*)

No. 643. A. M. Cassie, "Arc Rupture and Circuit Severity," C.I.G.R.E., *Report No. 102*, 14 pp. (1939).

A new theory of the operation of an a-c. circuit breaker is put forward, based on the conception of energy equilibrium at zero current instead of that of a race between a curve of dielectric strength and the restriking voltage transient. For this purpose an equation representing the behavior of the arc column at zero current is developed from the principles governing steady arcs carrying appreciable current. Solutions of this equation in conjunction with the circuit equations, before and after zero current, lead to a new definition of circuit severity. This theory has been applied to experimental results obtained with the gas blast switch and very close agreement is found. The new expression for severity is in the nature of an impedance and is readily calculated from the circuit constants. It is only indirectly connected with circuit frequency or with rate of rise of restriking voltage and has already given consistent results where the latter has led to ambiguites. Further, it explain

much that was obscure in the rate of rise theory. The formula is extended to include rms. current and voltage and it is in good agreement with experimental results. (*Science Abstracts*)

No. 644. C. Bresson, "The Opening of Idle Lines by Circuit-Breakers," C.I.G.R.E., *Report No. 109*, 19 pp. (1939). (In French.)

The breaking on short circuit is not the only case to be considered for the safe operation of h. t. switchgear. The rupture of weak currents such as those due to the capacitance of long lines can give rise to dangerous characteristics. Some oscillograph researches have been made in connection with networks, which have enabled the phenomena to be analyzed. (*Science Abstracts*)

No. 645. H. Puppikofer and H. Habich, "Test on the Interruption of Transformers and Overhead Lines," C.I.G.R.E., *Report No. 130*, 27 pp. (1939). (In French.)

Interrupting tests carried out in high capacity testing stations show that the arc between the contacts of a circuit breaker extinguishes before the passage of the normal sinusoidal through zero, when low currents are interrupted, thus increasing the amplitude of the high frequency of the recovery voltage. The authors investigated the interruption of low currents in a 66-kv. system. Comparison of the results of this investigation with similar laboratory test results proves that in the case of transformers being interrupted at no load, the h. f. amplitude is far below that resulting from laboratory tests, and that the surges do not reach dangerous values. Field tests show also that the recovery voltage is heavily damped in case of short circuit interruption and that the natural frequency of the system has a lower value than that resulting from laboratory tests, when the short circuit occurs near the transformer station. (*Science Abstracts*)

No. 646. S. Teszner and L. Gorjup, "On the Interdependence of the Recovery Voltage Conditions and the Dielectric Regeneration in the Interruption Pause," C.I.G.R.E., *Report No. 127*, 24 pp. (1939). (In French.)

The object of the present paper is to determine the influence of the operational characteristics of the circuit breaker on the recovery voltage characteristics during the a-c. zero pause, and the effects which result from this influence on the conditions of breaking. For this purpose an analytical study of the phenomena is made which in the first place provides a formula governing the rate of rise of recovery voltage and in particular the amplitude at the point of the arc extinction as a function of the characteristics of the circuit and the difference in time between the occurrence of the extinction point voltage and the theoretical current zero pause. An experimental investigation is given by means of cathode-ray oscillograms and is discussed. The essential conclusion of this discussion is that the breaker has an effect not only on the formation of the extinction point voltage (and from this point of view satisfactory agreement between the experimental and theoretical results is shown) but again in limiting the latter if the rate dielectric strength recovery during the pause is less than the rate of formation of the extinction point voltage. In the same way it is shown that there is a certain adaptation of the general rate of recovery voltage rise with respect to the rating of the breaker. An explanation of this adaptation phenomenon which appears to play an important part in the physical mechanism of arc rupture is attempted and gives rise to conclusions in regard to the operational characteristics of circuit breakers and the conditions which have to be satisfied in various types of breakers. (*Science Abstracts*)

No. 647. F. Kesselring and W. Kaufmann, "New Type of Circuit Breaker for Rupturing an Earth Fault or Short Circuit," C.I.G.R.E., *Report No. 104*, 16 pp. (1939). (In French.)

The influence of arcs on conductors and insulators is examined, and the time function of the resistance of the residual column is determined from the results of extensive tests. A statistical evaluation shows that the deionization and cooling off have generally proceeded to such an extent after 0.1 to 0.15 sec., that a closing of the circuit breaker is then possible without causing reignition, so long as the flashover is not initiated by multiple lightning strokes. The possibility of the occurrence of "pumping" of circuit breakers in the case of networks fed from two sides is mentioned, and thence the requisite conditions for the cooperation of circuit breakers with different characteristic times are deduced. Ordinarily, it is not possible in difficult cases to combine the requirements of adequate deionization times with those of the maintenance of stability. The influence of the clearing of the short circuit on the selective protection is touched upon. Finally, new indoor expansion circuit breakers for the clearing of short circuits are described, and it is shown that the outdoor expansion circuit breakers, by slight modification, can be made applicable for the clearing of arcs produced by earth faults and short circuits. (*Science Abstracts*)

No. 648. O. Mayr, "H. T. High-Speed Circuit Breakers and Their Application for Ultrarapid Rupture and Reclosing," C.I.G.R.E., *Report No. 121*, 19 pp. (1939). (In French.)

The author shows that a compressed air circuit breaker is well suited to the progress

made in the construction of circuit breakers, particularly in regard to ultra high speed breaking and reclosure. The results obtained are so favorable that an improvement in the time of rupture can only be considered if it is possible to make simple and robust relays whose time of operation is definitely less than 0.05 sec., and should, if possible, drop to 0.01 sec., in which case they can be installed in large numbers in distribution networks. (*Science Abstracts*)

No. 649. E. Pugno-Vanoni and G. Someda, "Indirect Testing of Circuit-Breakers," C.I.G.R.E., *Report No. 118*, 11 pp. (1939). (In French.)

See abstracts below.

(1) E. Pugno-Vanoni and G. Someda, "The Testing of High Rupturing Capacity Circuit-Breakers," *l'Ingegnere*, Vol. 13, January, 1939, pp. 29–34. (In Italian.)

The authors give a brief summary of the phenomena attending the interruption of a.c. and point out that the direct experimental testing of the performance of high rupturing capacity breakers necessitates large and costly equipment and that no such testing plants exist in Italy. In order to meet this difficulty experiments have been made during the last three years with indirect methods of testing which have been aimed at reproducing the phenomena accompanying the breaking of heavy short circuits by means of apparatus of moderate size. In this apparatus an a.c. generator produces the current at a voltage sufficient to maintain the arc and an auxiliary h. f. oscillating circuit is introduced for restarting the arc at the zero points of the normal current wave. A description, with circuit diagrams, is given of the apparatus and also oscillographic records of some of the results obtained. (*Science Abstracts*)

(2) E. Pugno-Vanoni and G. Someda, "Indirect Testing of Circuit-Breakers in Italy," *ETZ.*, Vol. 60, February 9, 1939, pp. 157–159. (In German.)

E. Marx has suggested methods for synthetic tests on circuit breakers. The authors describe experiments using these methods carried out at Venice and Padua. To generate the h. f. voltage a damped oscillator and then a Poulsen generator were tried, but it was found that the output required was very large. Condensers were then tried in conjunction with a synchronizing device and thus proved very satisfactory. In one circuit four condenser banks were used, which were arranged to discharge at four successive instants of zero current. A further series of tests were made on the breaking of d.c. in a circuit of low resistance and high reactance. By suitable choice of inductance and capacitance any desired amount of energy can be put into the arc before extinction; the behavior of the switch was the same as when breaking a.c. with the same arc energy. The experiments were only made on a small scale, but the results warrant large scale tests. (*Science Abstracts*)

No. 650. G. Carli, "Research on Indirect Testing of Circuit-Breakers," *Ricerca Scientifica*, Vol. 10, May, 1939, p. 452. (In Italian.)

A summary of results of some modifications to a circuit (*Sci. Abst.*, No. 2426[a] (1938)) designed for indirect circuit breaker tests. (*Science Abstracts*)

No. 651. A. F. P. J. Heydorn, "Recent Developments of Circuit-Breakers Without Oil and Notes on the Breaking Process of Arcs," *Trans.*, S. African I.E.E., Vol. 30, April, 1939, p. 70.

A summary of the developments, during the past few years, in the design of circuit breakers without oil, with special reference to the air blast and solid gas breakers. The trend of theoretical and experimental arc physics is indicated. (*Science Abstracts*)

No. 652. K. Reche, "Progress in the Development of Relays," *ETZ.*, Vol. 60, Part 1, No. 25, June 22, 1939, p. 753.

Various types of problems can be solved with electromechanical relays. In technical work the electromagnetic relay is the most important. The viewpoint for determining the form of the contacts, the armature, and the magnetic circuit is discussed in this article. The advance in the development of relays in line of capacity, free vacuum relays, highly sensitive telegraph relays, alternating current relays, and resonance relays, is presented. Special consideration is given in the development of contact assemblies.

Considering the development of relays in its entirety, it can readily be seen that many fields of physics and technology are used in the development of relays. Most of the relays which are discussed in this article are made in 10,000 lots. As a result the methods are developed for mass production with tools and supervision of a high degree of specialty. It is necessary for large volumes to develop test methods which will be rapid but still satisfactory. It can be seen that in the field of relay development that the laboratory engineer must work very closely with the designer and the factory. The way to get the most value from the laboratory is when the relays can be tested during the design procedure by personnel familiar with the details. Tests should be made under vibration and under severe climatic conditions. In spite of the difficulties, it is to be expected in the near future that the reliability of the electromagnetic relays will be improved and that new fields of application will be open.

[a] G. Carli, "Indirect Testing on Electrical Interrupters," *Ricerca Scientifica*, Vol. 9, February, 1938, pp. 116–129.

Describes investigations recently carried out in Italy on the subject of the determination, by indirect methods, of the current and voltage variations through and across an interrupter in an electrical a-c. circuit. (*Science Abstracts*)

No. 653. B. D. Bedford and M. A. Edwards, "Vibrating Switch Inverter Applied to Railway Car Lighting," *G. E. Rev.*, Vol. 42, June, 1939, p. 255.

To overcome contact arcing difficulties a series type of circuit is used, a reactor and condenser being connected in series with each set of contacts on the vibrating reed in such a way that when one set of contacts is closed the condenser is charged. The charging impulse is approximately one half of a sine wave and the reversing of the current, by the closing of the other pair of contacts, discharges the condenser which supplies the other half of the sine wave. With a non-linear reactor characteristic the contacts are allowed to close before current starts to flow at the beginning of each half-cycle of the current wave, or the current is limited to a value not injurious to the contacts. With the wide range of battery voltage on railway cars it was found advantageous to use two types of lamp circuits, in one of which the current is limited by capacitance and in the other by inductance. By proper proportioning of the magnetic circuits of the lamp units the power factor can be made to increase with the d-c. voltage when this rises above a certain value. In a complete installation described six inverters are used to supply the necessary power. At the same time the use of this number was found to increase the reliability and give a high over-all operating efficiency. (*Science Abstracts*)

No. 654. S. Hoh, "Electrode Consumption Due to Arc Discharge," *ETJ.* (Japan), Vol. 3, No. 5, p. 99 (1939).

Upon examination of the electrode consumption due to alternating current arc in air, nitrogen, hydrogen, carbon dioxide, water vapor, oil vapor, etc., about arc electrodes of copper, aluminum, carbon, tungsten, silver plus tungsten mixture, it has been found that those electrodes of the so-called "cold-cathode arc type," such as copper and aluminum, show a remarkably larger consumption than in air when the arc is generated in hydrogen or in any other gas which liberates hydrogen by decomposition. The greater the arc current, the more obvious is the tendency. Furthermore those electrodes of the "thermionic arc type" show a smaller consumption in hydrogen than in air, and silver plus tungsten shows intermediate characteristics. It is a well-known fact that electrical contacts wear down remarkably in the arc-suppressing substance such as oil, and this research seems to explain some of the causes. (Author's abstract)

No. 655. A. Avramescu, "On the Heating of Pointed Contacts Under Constant Current Load," *Arch. f. Elektr.*, Vol. 33, April 16, 1939, p. 261. (In German.)

The physical phenomena underlying the behavior of pointed contacts are explained and in order to approach the problem by mathematical means the actual contact area is replaced step by step by a flat area of circular shape with an evenly distributed insulated interspace of small thickness, and this latter shape is replaced by a hemisphere of infinite conductivity. The possibilities of mathematical treatment are critically investigated and use is made of the temperature influences known for different materials (copper and aluminum). The calculations are different for the pure metallic conduction, for which the spreading resistance plays the principal part, and for the presence of layers of foreign material (oxides and the like) on the contact area, in which case the transitional resistance must be taken into account. For either case the highest temperature and the temperature distribution are given for the stable state with constant current supply. For the spreading resistance the true behavior of the materials has been considered and this has led to conclusions of practical value. A comparative representation of both methods of calculation is given. (*Science Abstracts*)

No. 656. K. Gundlfinger, "Relay Operating Times and Their Measurement," *Zeits. f. Fernmeldetechnik*, Vol. 20, Nos. 2 and 3, pp. 17 and 47 (1939). (In German.)

The author analyzes the electrical and mechanical events in the operation of a relay and suggests terminology for the periods occupied by each, in relays of various types. The prediction of operating times from the electrical and mechanical characteristics is of limited practicability and importance. Rapid and complete experimental determination of the operating characteristics is increasingly necessary in commercial production as applications become more complex. Photographic, photoelectric, and allied methods of recording the armature movement are described. Electromechanical methods of time measurement are of limited value. The use of the ballistic galvanometer is described at length; an accuracy of 0.15 per cent is attainable with suitable connections. The principle of a new null method of time measurement is explained, and a commercial apparatus described; its sensitivity is about 10^{-5} sec. and errors range from 1.0 to 0.1 per cent for measurements of from 10^{-3} to 10^{2} sec. Time extending arrangements of condensers, discharged during a known multiple of the charging period, enable periods down to some 10^{-8} sec. to be multiplied by 10^{7}. A fully automatic apparatus is described which prints measured times and

characteristics on a recorder strip, or gives signals when prescribed values are exceeded. A bibliography of 43 items is appended. (*Science Abstracts*)

No. 657. J. Bethenod, "Determination of the Operating Conditions of an a. c. Arc," *Compt. rend.*, Vol. 208, February 20, 1939, p. 562. (In French.)

The equation connecting a-c. supply voltage, arc terminal voltage, current, time, and circuit reactance is generally incapable of solution since the arc voltage is a complex function of time and current. In some cases the are voltage is a simple function of time and the ignition and extinction points of the arc may be neglected. Under these conditions equations can be developed to give the required solution with the aid of geometrical representation. The fundamental equations are analogous with these representing the reciprocal movement of a body under the action of a harmonically varying force and subject to constant frictional forces, and the solution given is therefore applicable to certain cases of mechanical oscillation. By introducing an approximation, the solution may also be applied to the automatic maintenance of oscillations in electric circuits comprising similar generators. (*Science Abstracts*)

No. 658. Y. Miyoshi, "On the Transition From Spark to Arc Discharge," *ETJ.*, Vol. 3, No. 3, April, 1939, p. 60. Erratum, *ibid.*, p. 89.

Up to the present time, for the mechanism of spark discharge the explanation has been given that the discharge is developing with space charge effect by the action of the positive ions which were created on account of the successive progress of ionization by collision of electrons. For stationary self-sustaining discharge (either arc or glow) it is generally considered that the positive ions are maintaining the discharge by developing some convection current of stationary nature.

In the actual discharges it is common that the spark discharge precedes the self-sustaining arc or the glow discharge, any discharge theory to connect these two discharge forms, however, has been established in the past. The present article reveals a brief investigation in connection with this point. (Author's synopsis)

No. 659. S. Mochizuki and Y. Miyoshi, "Discharge Characteristics of Switch-Gaps," *ETJ.*, Vol. 3, No. 4, p. 86 (1939).

In a high-tension circuit in which the spark gap is made to act as a switch, when some high resistance is placed in series with the gap, or when some static capacity is placed in parallel with the resistance, although the resistance is not high, the gap g does not necessarily reach the condition of short circuit with an arc in it. Hence, it can be stated that there is no short circuiting function to be expected. As practical examples for such a case an impulse circuit and an ignition coil with jumped spark distributors have been treated. (Authors' conclusion)

No. 660. M. Gerlach, "Methods of Calculating Steady Short-Circuit Currents," *ETZ.*, Vol. 60, March 23, 1939, p. 363. (In German.)

A semigraphical method is given in R.E.H. 1929. Following the same general principles the author develops a mathematical method which has wider application. Examples are worked out. (*Science Abstracts*)

No. 661. W. Kaufmann, "Suppression of Arc Phase Faults by Rapid Switching," *ETZ.*, Vol. 60, March 2, 1939, p. 241. (In German.)

Most line faults are of such short duration that supply can be restored by automatic reclosing switches without motors falling out of synchronism. As phase faults are infrequent, it is satisfactory to allow one such switch to protect a fairly large area, sustained faults being cleared by the discriminative protection on the faulty feeder. Another proposal is that low voltage due to fault should cause a switch to earth the system momentarily but extinguishing the arc. This produces a heavy shock to plant, but is cheap, as only one earthing switching is required. Experiment on a model overhead line is described, which shows that there is little likelihood of the arc restriking if supply is restored within 0.1 sec. A normal switch cannot be reclosed in this time, and the author proposes to use a modified expansion switch. The isolator, which is normally open, closes immediately after the fault has been cleared on the main break. By the use of a second isolator and suitable interlocking, the switch may also be used in the normal way. The proposals are mainly applicable to distribution systems of 6 to 30 kv; for h. v. systems longer times would be necessary, but little experience is available. (*Science Abstracts*)

No. 662. T. Katayama, "Dynamic Characteristics of High Frequency Arc Discharge," *ETJ.*, Vol. 3, February, 1939, p. 40.

When the dynamic characteristics of an arc discharge due to undamped h. f. oscillations in the atmosphere were measured by means of a Braun tube, it was recognized that there exist two kinds of arc forms. The present paper deals with the behavior of these discharges developing out of glow and also with relative difficulty of producing an arc when different substances were used as electrodes for arc discharges. (*Science Abstracts*)

No. 663. C. J. O. Garrard, "Arc Control Pots," *J.*, G. E. Co. Ltd., Vol. 10, February, 1939, p. 69.

The physical basis of the action of oil circuit breaker is briefly described and the necessary characteristics of an effective arc control device derived therefrom. The operation of the side-blast arc control pot is discussed in detail and a description given of the range of arc control pots. (*Science Abstracts*)

No. 664. K. J. R. Wilkinson, "Arc Suppression Coils," *J., Beama*, Vol. 44, January, 1939, p. 10.

An article reviewing the effect of arc suppression and the mechanism of its action. Methods of assessing the relevant system capacitance values are given and some of the aspects of coil behaviors under working conditions when the system is unfaulted are cited. (*Science Abstracts*)

No. 665. T. Harada, "Characteristics of A. C. Mercury Arcs," *ETJ.*, Vol. 3, February, 1939, p. 33.

The relations between the instantaneous values of voltage, current, and intensity of spectral lines of high and low vapor pressure mercury arcs lighted by an a-c. source are deduced on the assumption of thermal ionization and temperature equilibrium in the case of high pressure and from the consideration of electron temperature in the case of low pressure. These relations are verified with the commercial h. p. and super h. p. mercury lamps lighted by a 50-cycle per second a-c. source at 0.005, 1000 mm. and 30 atmospheric pressure. Further, it is shown that a h. p. mercury arc can be stably lighted by a constant voltage a-c. source without the use of series impedance and the assumption of thermal ionization is verified also in this case. (*Science Abstracts*)

No. 666. C. G. Suits, "Convection Currents in Arcs in Air," *Phys. Rev.*, Vol. 55, January 15, 1939, p. 198.

Convection currents in and around arcs in air have been studied by Kenty's method of photographing solid particles in gas stream. By the use of BN powder the air velocities around an arc column with vertical axis are measured throughout the entire region of convection currents. These velocities vary from 130 cm. per sec. at the arc axis to zero at a distance of 2.5 cm. By integrating over the velocity curve the total heat flow is found to be 75 per cent of the electrical input; that portion of the heat flow included in the luminous arc core is 7 per cent of the total. By equating the buoyancy force and the viscous force at the arc boundary, the gas viscosity is measured. The gas temperature corresponding to this is 7000 K. in agreement with known arc temperature measurements. (*Science Abstracts*)

No. 667. J. Kuntz, "Contribution to the Study of Electrodynamic and Mechanical Forces on the Moving Parts of an Oil-Immersed H. V. Circuit Breaker," *R.G.E.*, Vol. 45, No. 1, January 7, 1939, p. 17. (In French.)

The author develops and resolves differential equations governing the motion of the moving parts of an oil-immersed h. v. circuit breaker, taking into account the weight of the parts, the electrodynamic forces due to the current to be interrupted, the accelerating and damping springs, and the retardation due to the viscosity of the oil. The complete operation of the opening consists of four stages with different forces in action. Within limits, increased speed of movement assists the interruption of current but excessive speed imposes detrimental stresses on the mechanism. The optimum speed depends on the current and on the type of apparatus. (*Science Abstracts*)

No. 668. K. L. Parker, "Statistical Theory Applied to Testing of Mass-Produced Articles," *J.*, Inst. P.O.E.E., Vol. 31, Part 4, January, 1939, p. 305.

The article describes how analysts of the deviations of a mass produced article from the average may give a manufacturer useful information concerning the degree of control exercised in its production. Conversely, the consumer, by the same analysis, is helped to compare the products of different manufacture. (*Science Abstracts*)

No. 669. C. G. Suits, "Heat Transfer Methods in Arc Interruption," *G. E. Rev.*, Vol. 42, No. 10, October, 1939, p. 432.

From consideration of the dependence on gas pressure of the voltage gradient and current density of electric arcs burning in various gases, it is observed that suitable adjustment of the respective gas pressures enables the electrical properties of an arc in a given gas to be duplicated in any other gas. It is concluded that the electrical properties of an arc are determined by the thermal properties of the gas. Arc in gases have the same electrical properties at the pressure for which the convection heat transfer is the same. The thermal environment of an arc must be taken into account in the design of circuit breakers. (*Science Abstracts*)

No. 670. J. D. Findley, "Circuit Breaker Theory" (A reply to the question, "Why d.c. cannot with advantage be broken under oil?"), *Elec. J.*, Vol. 36, No. 2, February, 1939, p. 81.

In direct current interruption the current can be brought to zero only by producing an arc voltage greater than the applied circuit voltage. In addition to the energy stored in the magnetic system, the interrupter must dissipate the energy fed to arc from the supply during the existence of the arc. The latter energy may be minimized by making the arcing period as short as possible and by

causing the current to decrease rapidly at the beginning of the arcing period. If attempt is made to produce rapid rise of arc voltage with contacts immersed in oil, the large amount of arc energy will be released before the arc is surrounded by a cushioning bubble of gas, with consequent production of high impulse pressure. Furthermore, as a result of the turbulence in oil and gas surrounding the arc, the curve representing the relationship between the arc voltage and time will not be smooth. The median value of this voltage, represented by a smooth curve, is necessarily higher than the circuit voltage and therefore the maximum value of the momentary variations of the arc may approach and even exceed the insulation strength of the circuit.

No. 671. S. Horikosi, "Experimental Research on the Restriking Phenomena of Arcs", *ETJ.*, Vol. 3, December, 1939, p. 283.

This paper gives the results of a study made to determine the electrical characteristics of arcs by a cathode-ray oscillograph. The restriking of a-c. arcs may be actuated by ionization by collision or by thermal ionization, either independently or in combinations. These two aspects of the phenomenon are dealt with. (*Science Abstracts*)

No. 672. Anonymous, "Where Contacts Count", *Inco Mag.*, Vol. 16, No. 3, p. 10 (1939).

A new contact material was developed by a process consisting of mixing pure nickel and pure silver powders in the proportion desired and having this mixture "sintered" under pressure at a temperature considerably below the melting point of either metal. The resulting alloy is a ductile mass easily workable to desired shapes. This process makes possible the combination of silver and nickel since the smelting process is not practical due to little mutual solubility of these metals. Curves showing the relation between the contact pressure and contact resistance are given for pure silver and for sintered metal (40 per cent nickel and 60 per cent silver).

No. 673. R. F. Wyer, "Stability and Heat Transfer in the Welding Arc," *G. E. Rev.*, Vol. 42, No. 4, April, 1939, p. 170.

It is shown that the electrical characteristics of the welding arc depend upon the mechanism of heat transfer in the arc, and the electrical characteristics of the welding circuit do not affect the heat transfer characteristics except insofar as they do or do not permit the arc to be maintained. Arc stability results from sufficient voltage recovery speed in the welding circuit to meet the requirements of the arc characteristics and is not necessarily a consequence of high a.c. voltage. Penetration and electrode melting rates are affected only by the heat distribution, given a stable arc and a fixed total heat input. (*Science Abstracts*)

No. 674. G. L. Pearson, "Formation of Metallic Bridges Between Separated Contacts," *Phys. Rev.*, Series 2, Vol. 56, September 1, 1939, p. 471.

Low resistance bridges were formed between gold, steel, and carbon electrodes having separations of 2–70 $\times$ 10^{-6} cm. by applying voltages less than the minimum potential. For a given pair of electrodes the field required to form the bridges is a constant and is 5–16 $\times$ 10^{6} v. per cm. Measurements of the temperature coefficient of resistance of the bridges identify them as consisting of the material of the electrodes. A study of their resistance as a function of the displacement of one of the electrodes shows that they may be pulled out as well as crushed. At voltages less than those required to form the bridges, field current exists. These increase rapidly as the field is raised and attain a value around 10^{-10} amp. before the bridges are formed. Calculations of the maximum electrostatic stress on the electrodes at the time of breakdown gives a value 0.05 to 0.0005 times the tensile strength of the electrode material at room temperature. The field is locally higher than that calculated because of surface roughness and the tensile strength is probably lowered by the local heating known to accompany field currents. The data therefore indicate that electrostatic force pulls material from the electrodes to bridge the gap. (*Science Abstracts*)

No. 675. E. W. Boehne and L. J. Linde, "Magne-Blast Air Circuit Breaker for 5000-Volt Service," *G. E. Rev.*, Vol. 42, No. 9, September, 1939, p. 401.

The arc chute of the breaker is formed by long tapered fins alternating from either arc chute wall and extending from the throat and arc runner to the mouth of the chute. Placed parallel to each other and spaced to leave room for the arc to fold in and out between opposite fins, their gradual taper away from the side walls permits the arc to form in a straight line. As the arc is driven deeper into the chute, it is "buckled" as the fins cross deeper into the space between fins opposite. Arc resistance is increasing, causing a decrease in phase angle, which facilitates final interruption. The circuit breaker is described in detail, test results and diagrams being given. (*Science Abstracts*)

No. 676. S. Fukuda and S. Hoh, "Arc Diameter Measured by a New Method," *ETJ.*, Vol. 3, No. 9, September, 1939, p. 195.

By a new method the authors have measured the natural diameter of an a-c. arc within

a range of arc current 33 to 100 amp. and of gas pressure 1 to 25 kg. per sq. cm. According to this method, the arc diameter may be measured with comparative ease under high gas pressure. From the results of the experiments it has been revealed that the current density of the arc column and the energy to be dissipated per unit surface area of arc column increase with increase in gas pressure or arc current. The engineering meaning of the various quantities treated in this paper is also explained. (*Science Abstracts*)

No. 677. C. G. Suits, "Hydrogen Arc," *J. App. Phys.*, Vol. 10, No. 9, September, 1939, p. 648.

The gradient E, total voltage e, and current density I in 1 atmospheric hydrogen arc between pure carbon electrodes in the 0 to 10 amp. range are measured by an oscillographic method. An abrupt change in e takes place at 2 and 0.6 amp. and in E at 2 amp. leading to the identification of three states of the hydrogen discharge in this current range and pressure. Rapid motion pictures of this arc at pressures above atmospheric show violent arc movements originating from convection forces. The exponent of the $E - i$ relation is found to be 0.70 for the normal arc state at p = 1 atmosphere. (*Science Abstracts*)

No. 678. G. Windred, "Rating of Contacts and Switching of Different Circuits," *Elec. Eng.*, September 2 and 9, 1939, pp. 662, 721.

No. 679. A. H. Howell, "Breakdown Studies in Compressed Gases," *Trans.*, A.I.E.E., Vol. 58, May, 1939, p. 193.

A paper outlining the scope of former studies of the subject, giving an introduction to the physics of breakdown in gases and presenting experimental data for gas pressures, principally air, up to 600 psi. and direct voltages up to 450 kv. (*Science Abstracts*)

No. 680. J. Slepian, "Theory of the Deion Circuit Breaker," *J.*, A.I.E.E., Vol. 48, February, 1939, p. 93.

In view of the importance of the arc in breaking electrical circuits, the Westinghouse Company has studied the arc as it occurs in switches and the conditions for its extinction (see A.S.T.M. Abstract No. 182 (1928)). The results have led to the design of a new type of circuit breaker. The feature of the breaker is a stack of copper plates of thickness $^1/_{16}$ in., separated by $^1/_{16}$-in. insulating spacers. The arc, drawn on contacts below this structure, is blown by a magnetic field onto the stack and is broken into a large number of short arcs in series. At the current zero each cathode layer is almost instantly deionized and acquires the ability to withstand a faster rate of rise in voltage (up to about 250 v.), than can be supplied by the interrupted circuit. For the more uniform distribution of the applied voltage over the stack an electrostatic shield is used. The deionization is also accelerated by causing the arc to play through openings of gauze sheets, thus avoiding the development of arc terminations on the deionizing structure, it having been shown that arcs on cold cathodes were possible. (*Science Abstracts*)

No. 681. L. R. Ludwig and G. G. Grissinger, "A New High-Capacity Air Breaker," *Trans.*, A.I.E.E., Vol. 58, No. 8, August, 1939, pp. 414–418. Discussion, pp. 418–420.

No. 682. R. C. Dickinson, "High Power Deion Air Circuit Breakers for Central Station Service," *Trans.*, A.I.E.E., Vol. 58, No. 8, August, 1939, p. 421. Discussion, p. 425.

The deion principle of arc interruption in air has been applied over a wide range of a-c. services. Difficult switching problems have been met by them. A new breaker has been developed and tested in excess of 37,000 amp. for the 15-kv. powerhouse class. It may be supplied for masonry or steel cell mounting or as a part of complete metal clad switching equipment. (*Science Abstracts*)

No. 683. L. B. Hunt, "Heavy-Duty Contacts," *Elec. Rev.*, Vol. 124, No. 3201, March 31, 1939, p. 459.

By combining the metals, each possessing desirable characteristics for current carrying or current rupturing functions, suitable alloys for contacts of circuit rupturing devices are obtained. By a method of high temperature treatment it is possible to prepare alloys in which particles of each metal are very finely divided and evenly distributed. Some of the most suitable combinations employ copper with tungsten or molybdenum or their carbides, while other combinations utilize silver with refractory metals. Tables of properties of metal combinations are given.

No. 684. W. A. Coates and H. Pearce, "Switchgear Handbook, Vol. 1—Apparatus," Pittman Publishing Corp., New York, N. Y. (1939).

A symposium on apparatus, written by members of the engineering staff of Metropolitan-Vickers Corp., it covers an intensive field, embracing theory, construction design, and practice, and ranges from insulation materials, *via* circuit breakers, switches, and fuses, to instrument transformers, excess voltage protective gear, and systems of automatic voltage regulation. (*Engineer*)

No. 685. Anonymous, "Contacts That Don't Bounce," *Elec. J.*, Vol. 36, No. 1, January, 1939, p. 12.

The nonbounce contacts are similar in design to conventional relay contact points, except that they are hollow, and this hollow chamber is filled with grains of tungsten.

When moving contact is stopped, the interfriction between tungsten grains absorbs the impact energy which would be dissipated ordinarily by repeated bounce. Oscillograms disclose no indications of contact opening after their initial closure.

No. 686. C. G. Suits, "Arc Interruption by Cooling," *G. E. Rev.*, Vol. 42, No. 9, September, 1939, p. 375.

The most important element affecting the thermal factors of the electric properties of arcs is the fact that the electrons in a high pressure discharge are in thermal equilibrium with the neutral gas. Investigations disclosed that the pressure of one atmosphere is sufficiently high to establish this thermal equilibrium, even at low-current arcs in air. This fact has the following important effects in current interruption: ionization density is fixed by the gas temperature, and it is impossible to change the direction of momentum of the conducting electrons without acting upon the neutral gas. Moving the arc magnetically past an insulating plate and cooling it reduces its ionization density. These have been incorporated in the design of magneblast circuit breakers.

No. 687. A. B. Hendricks, Jr., H. S. Hubbard, and G. L. Vallin, "10,000,000 Volt Sparks and 1,000,000 Volt Arcs," *G. E. Rev.*, Vol. 42, No. 10, October, 1939, p. 420.

A description of equipment used in h. v. demonstrations at the New York Worlds' Fair. Two 5,000,000-v. impulse generators are operated in series. Each generator consists of 51 capacitor units of 0.33 μf assembled in six vertical columns. Two full-wave bridge-connected kenetron rectifiers supply 300,000 v. d.c. for charging. As the equipment is used for demonstration purposes only, no voltage dividers or wave-form control devices are required. Another demonstration consists of a three-phase, 60 cycles per second arc at 1,000,000 v. which takes place between spinning electrodes, rotation of which is produced by corona. The supply for this is obtained from a 1500-hp. motor generator through six 350,000-v., 1000-kva. transformers connected two in cascade in each limb of a star. Details are given of other auxiliary equipment. (*Science Abstracts*)

No. 688. W. Weizel, R. Rompe, and M. Schön, "Theory of Kathode Fall," *Zeits. f. Phys.*, Vol. 112, Nos. 5 and 6, pp. 339–349 (1939).

The necessity is emphasized of separating the theoretical treatment of the different phases of a glow discharge. In the negative glow space charge and field are very small, the particle densities are high, ion diffusion is important, while the quite different assumptions made by Rogowsky (*Sci. Abst.*, 5192 (1932)) for the discharge as a whole are justified for the cathode fall only. An application of Rogowsky's differential equation for the field to this region only should then lead to a successful theory of the cathode fall. So instead of Rogowsky's boundary conditions at anode and cathode, two conditions at the cathode boundary of the negative glow are used where the field is supposed to vanish and the ion current to equal a constant which remains undetermined but is not arbitrary (its value would follow from a theory of the negative glow). Further, the usually assumed variation of the ionization coefficient with the field, which is correct only for low fields, when an electron is completely stopped by a collision, is replaced by the opposite assumption of a constant ionization coefficient which is considered plausible for a highly anomalous cathode fall at least. In these conditions the integration is simple and leads to formulas expressing thickness and potential distribution of the cathode fall in terms of the current density i and the undetermined incoming ion current i_0. If experimental values of V, i, and i_0 are used the formulas lead to reasonable values for the Townsend coefficient γ. (*Science Abstracts*)

No. 689. W. Weizel, R. Rompe, and M. Schön, "Theory of Kathode Fall, Part II," *Zeits. f. Phys.*, Vol. 113, Nos. 1 and 2, pp. 87–95 (1939).

The theory is based on the following model: the glow region is a quasi-neutral plasma, almost free of field and fed by a bundle of fast electrons from the cathode space which produce positive ions by collision. From the plasma, positive ions are lost both by diffusion into the cathode space (where they neutralize the major portion of the current on the cathode) and also by recombination. By equating these rates of gain and loss current carriers, an equation is obtained giving quantitative formulation to the theory and identical in form with that obtained by considering the energy balance of the process. Application to experimental data is discussed. (*Science Abstracts*)

No. 690. H. J. Höfert, "Passage from Glow to Arc Discharge Arising from Short Current Pulses," *Ann. d. Phys.*, Vol. 35, No. 6, July, 1939, pp. 547–576.

When a glow discharge is subjected to short-time current pulses, the discharge, with not too high a cathode temperature, changes to the arc type, if the steepness and the amplitude of the current pulse are sufficiently great. The amount of energy contributed by each pulse to the discharge is not the determining factor in the change to the arc type, which depends more on the pulse current, the probability increasing with increasing pulse current. The duration of the change is of the

order of 10^{-8} sec. With high gas pressures, metal vapors in very small concentrations, corresponding to a pressure of only a few torr., favor the arc formation. The thermic arc obtained with hot tungsten electrodes differs from the ordinary type in its longer change time, which is of the order of 10^{-4} sec., and in its regular starting and production with high cathode temperature. The effects observed can be explained on the usual assumptions regarding thermal emission. (*Science Abstracts*)

No. 691. B. Davydov, "Contact Resistance of Semiconductors," *J. Exp. and Theor. Physics* (U.S.S.R.), Vol. 9, No. 4, pp. 451–458 (1939). (In Russian.)

The volume charge appearing at the surface of a semiconductor, when there is a contact p. d. between it and the electrode, is formed at the expense of the concentration of free electrons. This causes a change of conductivity of a surface layer whose thickness is determined by diffusion equilibrium. The author calculates the consequent field in the semiconductor and the contact resistances, and shows that for an apropriate sign of the p. d. these resistances appear as a "blocking layer" and cause rectification. The case when there is a potential barrier at the contact is also discussed. (*Science Abstracts*)

No. 692. A. Shalnikov, "Electrical Conductivity of Thin Metallic Layers," *J. Exp. and Theor. Physics* (U.S.S.R.), Vol. 9, No. 3, pp. 255–259 (1939). (In Russian.)

A technique is developed for obtaining thin films of low melting point metals by evaporation, which had reproducible properties. The resistance of cadmium films was measured as a function of temperature and thickness; for a film of thickness 1.4×10^{-6} cm. the specific resistance was only twice that of the bulk metal, while the temperature coefficient between 90 K. and 300 K. was three times smaller than for the bulk metal. The mechanism of formation of the films is discussed on the basis of the experimental data as regards the variation of resistance with thickness. (*Science Abstracts*)

No. 693. R. Holm, "Fundamentals of Metallic Contact," *Zeits. f. Techn. Phys.*, Vol. 20, No. 12, p. 332 (1939).

In considering the conditions of wear between metallic electrical contacts, the author shows the difference between cases in which an arc occurs and those in which it does not occur. In the first case a kind of evaporation of the metal takes place, in the second, craters and high spots are formed. Oxidation of surfaces is also a source of trouble. Suitable choice of the contact metals can be of assistance. (*Science Abstracts*)

No. 694. R. Rompe and P. Schulz, "Thermal Conduction in High Pressure Discharge Column," *Zeits. f. Phys.*, Vol. 113, Nos. 1 and 2, pp. 10–17 (1939).

In the high pressure discharge electrical energy is dissipated by radiation and thermal conduction; the latter includes "classical" conduction by transfer of kinetic energy as well as conduction by diffusion of excited atoms, light quanta, ions, and electrons. It is shown in the case of high pressure mercury discharge that only thermal conduction by diffusion of ions is comparable with the "classical" conduction in magnitude. In discharges with constant column width (power = 500 w. per cm., p is greater than 10 atmospheres) thermal conduction by ions is taken into account theoretically by a term which has the same dependence on temperature and hence power dissipation as the emission of radiation. For discharges with radius dependent on current density (20 to 80 w. per cm.) consideration of ionization heat conduction together with a constant "classical" heat conduction leads to a complet interpretation of the discharge and its properties. (*Science Abstracts*)

No. 695. L. Tonks, "Theory of Magnetic Effects in Plasma of Arc," *Phys. Rev.*, Vol. 56, August 15, 1939, pp. 360–373.

The equations governing electron drift in the presence of a magnetic field are applied to the low pressure uniform positive column plasma with reference to electron concentration and the effect of a longitudinal magnetic field. With the latter the plasma exhibits a diamagnetic susceptibility proportional to the electron current density to the tube walls, in agreement with theory. With nonconducting walls the magnetic polarization varies through a maximum beyond which the plasma is paramagnetic for small variations in the field. The magnetic field of the arc itself has a concentrating pinch effect, favored by large diameter arc columns and higher pressures, which would cause infinite axial concentration of electrons at a finite arc current if other limitations did not intervene. This may be the cause of rapidly increasing arc gradients at critical currents in large mercury arc rectifiers. (*Science Abstracts*)

No. 696. F. H. Newman, "Electric Glow Between Carbon Electrodes," *Phil. Mag.*, Vol. 28, November, 1939, pp. 544–547.

In previous work (*Sci. Abst.*, 835 (1927)) with graphite electrodes at low pressure the radiation from the glow discharge was due to the ionized residual gases, there being no thermionic effect at the electrodes. Further experiments on this type of glow are described. Specially pure electrodes were used, since it was found that the presence of impurities on the cathode facilitates the striking of high-vacuum arcs. Observations were confined to the first few seconds after the glow discharge, which tends

to fill the whole of the space surrounding the ends of the electrodes, had been started. Photographs show that the glow gives little continuous spectrum, but the Swan bands of carbon are prominent, particularly those at 4381, 4737, 5165, and 5635, and the carbon-nitrogen and carbon-hydrogen bands are very marked. On the other hand, the Ångström bands of carbon monoxide are faint. Comparison with observations of the spectra obtained when an electrical discharge was sent through the discharge tube indicates that the excitation potential of the Ångström bands is higher than that for the Swan, carbon-nitrogen, and carbon-hydrogen bands. (*Science Abstracts*)

No. 697. W. Finkelnburg, "Luminous and Total Radiation Intensities and Black-Body Temperature of High-Current Carbon Arcs," *Zeits. f. Phys.*, Vol. 113, Nos. 9 and 10, pp. 562–581 (1939).

Measurements were made of the luminous intensity of different high-current carbon arcs as dependent on the current strength, power, and anode diameter. The contribution of the anode flame to the total luminous intensity was also measured. With Beck arcs the maximum intensity reached 180,000 stilbs (1 stilb = 1 Hefner candle per sq. cm.), while ordinary high-current carbon arcs reached about 40,000 stilbs. The total radiation density was measured and found to reach a maximum value of 3000 w. per sq. cm. for homogeneous carbon arcs and 6000 w. per sq. cm. for Beck arcs. Calculation from the Stefan-Boltzmann law gave black-body temperatures of 4700 and 5800 A. for the crater gases of the homogeneous carbon and Beck arcs, respectively. Gas and electron temperatures are considerably higher than these values. The properties of low and high current carbon arcs are contrasted, particularly as regards anode evaporation and anode flame radiation. All measurements confirmed the law of similarity previously stated (*Sci. Abst.*, 2602 (1939)), that with similar high current carbon arcs the current strength is proportional to the anode diameter. The significance of this is discussed. Energy balance considerations for the anode-fall region explain the different slopes of the characteristics of homogeneous carbon and Beck arcs with different current strengths. (*Science Abstracts*)

No. 698. F. Walter, "Short Circuit Currents and Displacement of the Neutral in the Electric 3-Phase Net of an Arc Furnace," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 18, No. 3, pp. 113–136 (1939). (In German.)

Due to a short circuit in an arc furnace the neutral of the system is displaced and the phase voltages are changed. The author investigates this displacement and calculates the current and voltages and their phase relations for various practical cases. Even in the undisturbed service such a displacement takes place due to differing coefficients of mutual inductance in the leads connecting the electrodes to the supply system. The calculations are given in detail for the 3-phase fault, for faults between two phases and for faults in one phase. (*Science Abstracts*)

No. 699. K. H. Kyser, "Calculation of Short-Circuit Breaking Capacity and Making Current by Aid of the Percentage Voltage Drops," *Siemens-Zeits.*, Vol. 19, November, 1939, pp. 508–515. (In German.)

The calculation of short circuit current from the voltage and impedance concerned is compared with the determination of breaking requirements and making current from the rated capacities and percentage voltage drops of the transmission components of the circuit. It is shown that the latter method is specially suitable for the purpose of rapid estimates. Numerical examples are fully worked, and it is shown how to take into account, where necessary, the percentage ohmic voltage drop of overhead lines and cables. A tabulated form of calculation is recommended. The methods advocated are used by Siemens-Schuckert. (*Science Abstracts*)

No. 700. J. Wrana, "Phenomena with Fusing and Evaporating of Wires Under Very High Current Densities," *Arch. f. Elektr.*, Vol. 33, October 20, 1939, pp. 656–672. (In German.)

Wires 0.1 to 0.25 mm. in diameter and lengths up to 30 cm. were fused by discharging two condensers of 10 μf and 10 kv. maximum charging voltage connected in series or parallel. Thus, with an energy content of 2 $\times$ 500 w-sec., current densities up to 10^6 ka. per sq. mm. were obtained. Fusing and evaporating were accomplished within 1 to 10 microseconds. Current and voltage records were taken with a cathode-ray oscillograph. Even with very high current densities the times taken for the fusion and evaporation can be exactly distinguished. The sharp rise of resistance during the change from solid to liquid state of the test wire causes a distinct change of slope in the current-time line. The condenser discharge is stopped by the evaporation as the metal vapor is nonconducting at temperatures reached by the ordinary process of discharge. Only with short wires does the overvoltage due to the break suffice for restriking an arc by which the condenser is totally discharged. Restriking may also be caused by thermo-ionization, especially with materials of high combustive heat, for example, iron and aluminum. The product of time and current density is constant as is also the product of time and energy required for fusing and evaporating for times up to

about 7 microseconds, while for higher times the energy remains practically constant. (*Science Abstracts*)

No. 701. W. M. Thornton, "The Electric Strength of Gases, Measured by Corona Discharge," E.R.A. Report. Ref. L–T99., *Phil. Mag.*, Vol. 28, December, 1939, pp. 666–678.

When the electrical potential of a wire surrounded by a gas or near atmospheric pressure is slowly raised a glow or corona appears on the wire. This is the first stage of spark discharge in the gas that is prevented from developing farther by the rapid divergence of the field. The electric gradient at which it occurs is much higher than that at which a spark passes in a uniform field of force, but the latter can be derived from measurements of the corona starting voltage, the radius of the wire, and the density of the gas. In the present work the electric strength of some fifty gases has been found in this way. When set down against the reciprocal of the electron mean free path the gases are found to fall into several groups which lie on straight lines converging to the origin. In each of these the product of the electric strength and the free path is constant. This is interpreted to mean that the energy of ionization by collision that starts spark discharge is constant in each group of gases. Since the free path is inversely proportional to the cross-sectional area of the molecules, it follows that the molecular areas of gases that have the same electric strengths in the several groups differ by finite and nearly equal steps. The electric strengths of gases having the same molecular area change only by such steps. Chlorine has the greatest strength of the elements examined, the monatomic gases the least. The paraffin series is most uniform; its chlorine substitution compounds show a regular change and reach remarkably high values. (*Science Abstracts*)

No. 702. H. Trencham, "Restriking Voltage in Service and on Test," *Engineering*, Vol. 148, November 10, 1939, pp. 521–522.

The article briefly discusses the importance of restriking voltage in switchgear testing. The rates of rise obtained on testing plant are generally higher than on power systems, but recent research indicates that on certain types of switch a slower rise may result in greater distress. The B.E.A.I.R.A. have accordingly formulated certain revised theories on circuit severity. These are based, not on the appearance of voltage across the arcing space, but on the energy which can appear and on its change with change of resistance in the arcing space. (*Science Abstracts*)

No. 703. W. A. Coates, "A Review of National Standards for the Short-Circuit Rating of H. V. Circuit-Breakers," *Elec. Times*, Vol. 96, November 16, 1939, pp. 525–527, and November 23, 1939, pp. 549–551.

Only Britain, America, and Germany have drawn up standards for h. v. circuit breakers which have progressively been kept up to date. Part I of B.S.S. 116/1937 embodies all the recommendations of I.E.E. Wir. Reg. No. 56 and the author compares these with American and with German practice. In America rupturing capacity is based on total or asymmetrical current, so that a breaker would have a rupturing capacity about 20 per cent less than that of a British breaker of the same nominal rating. It is, however, not customary in America to issue certified test sheets on switchgear testing to customers. N.E.M.A. includes provisions for highspeed and autoreclosing breakers which are not included in the British document. The V.D.E. rules generally follow I.E.E. recommendations, but are more detailed. According to V.D.E. a breaker must be capable of breaking any current up to rated rupturing current at a voltage 15 per cent in excess of rated voltage. The German rating is thus about 13 per cent less than as expressed by B.S.S. The V.D.E. clause on standard rated voltages also provides that the highest working voltage shall not exceed the rated voltage of the apparatus by more than 15 per cent. A comparative table of minimum clearance is given. (*Science Abstracts*)

No. 704. Anonymous, "Air-Break Circuit-Breakers of Series AL and SBL," *J.*, A.S.E.A., Vol. 16, September, 1939, pp. 121–125.

An illustrated description of open-type and ironclad air-break circuit breakers, designed for a maximum of 10 switching-in operations per hr. There are a-c. and d-c. designs, in the former case for voltages up to 800 v. and for rated currents and breaking currents up to 6000 amp. and 55,000 amp., respectively (open type) and rated currents 1000 amp. (ironclad type). (*Science Abstracts*)

No. 705. J. J. Went, "The Electrical Resistance of Metal Contacts," *Philips Techn. Rev.*, Vol. 4, November, 1939, pp. 332–335.

The electrical resistance of contacts depends in the first instance upon the specific resistance of the material of the contacts, the hardness of the material, and the contact pressure. In addition, the properties of the surface of contact are also important. On the basis of these facts a study is made in this article of the methods by which a contact with a high resistance may be improved. (*Science Abstracts*)

No. 706. S. Hopferwieser, "Small Contactors," *Brown Boveri Rev.*, Vol. 26, August, 1939, pp. 202–204.

A short description of the design and the applications of a new line of small contactors

for low voltage a-c. or d-c. light and power plant. They are built with or without thermal release and may be operated from the distance by push buttons. Simple and double units of open or enclosed type with or without connecting pieces, cable end boxes and ammeter, are illustrated. The contactors are especially suited as reversing or pole-changing gear for small and medium size induction motors. (*Science Abstracts*)

No. 707. C. H. Flurscheim, "A New Rural Oil Circuit-Breaker," *M. V. Gazette*, Vol. 18, December, 1939, pp. 279–281.

After a discussion of the special requirements of a rural circuit breaker, in respect of dielectric and mechanical reliability, short-circuit interruption, maintenance, and interchangeability, the author describes the design of a new breaker in which these features have been given special attention. Tests on these breakers in accordance with B.S.S. 116 show that the total break time does not exceed three cycles for 11-kv. operation, from 10 per cent to 100 per cent rating; a complete breaker has withstood a type test of 50 kv. for 1 min., and the impulse level is over 140 kv. with a 1/50 positive wave. The oil quantity required is $11\frac{1}{2}$ gal. (*Science Abstracts*)

No. 708. O. Naef, "Considerations on the Use of Quick-Acting Circuit-Breakers with Automatic Reclosing in Overhead Lines," *Bull.*, Assoc., Suisse des Elec., Vol. 30, December 8, 1939, pp. 761–765. (In German.)

When automatic reclosing of circuit breakers is used to deal with temporary short circuits so as not to cause interruption of service, it is necessary to add protective arrangements for isolating the faulty section of the line in case the short circuit persists. It is shown that any of the known systems of protection is adequate, provided a further quick-acting circuit breaker is used, functioning before the selective relay. The danger of transients bringing the selective apparatus into action is also obviated by this method. (*Science Abstracts*)

No. 709. I. J. W. Lewis, "Short-Time Rating of Circuit Breakers: Time-Current Integrating Device for Testing," *BTH Act.*, Vol. 15, November, December, 1939, pp. 217–218.

In the verification of the 1-sec and 5-sec. current ratings of oil circuit breakers, the current and time must be controlled and their appropriate value shown by oscillograph records. The method given in B.S.S. No. 116, Part I, Appendix H, for determining the rms. equivalent of the short-time currents comprising the tests involves a somewhat complicated analysis after the oscillogram is available, and until this is completed it is not certain that the required conditions of testing have been fulfilled. A short-time current integrator, giving an immediate indication of the integrated products I^2t, of current squared by time in seconds, is of great assistance in tests which do not demand official status. During the short time concerned the whole of the energy appearing in the apparatus under test is utilized in heating it. A current transformer applies part of the current to a lagged heater coil, the temperature of which is measured by a thermocouple. An instrument reading is thus obtained proportional to the I^2t value for the main circuit. The maximum error is ± 4 per cent with the arrangement described, and the actual error in examples cited is of the order of 1 per cent. (*Science Abstracts*)

No. 710. G. Reinhardt, "Measurement of the Arc Drop in Mercury Vapour Rectifiers," *E.u.M.*, Vol. 57, October 13, 1939, pp. 497–501. (In German.)

The arc voltage can be determined by means of a cathode ray or electromagnetic oscillograph. The former requires no protection against the reverse arc voltage but the electromagnetic oscillograph must be protected, for example, by valves in series or in parallel with it. Examples of oscillograph connections are given. A method is also described for reading the arc voltage on a voltmeter. A wattmeter can be employed to register the arc loss if the reverse voltage can be kept away from the pressure circuit and if the anode current does not exceed the rated current of the instrument. In large rectifiers this latter condition has to be obtained by the use of a current transformer of the universal type, the secondary of which is excited by a.c.; a diagram is given. (*Science Abstracts*)

No. 711. T. Bervquist, "Contactor-Type Circuit-Breaker Type DEA 10," *J.*, A.S.E.A., Vol. 16, November, 1939, pp. 157–159.

A description of a circuit breaker intended for small 3-phase squirrel-cage or slipring motors for a maximum of 500 v. 16 amp. rated current and 100 amp. starting current. The contacts open and close in air; the contact studs are of silver and each contact has two stainless-steel springs. The operating armature closes at 85 per cent of rated voltage and drops out at 50 per cent. The operating coil will stand 110 per cent voltage continuously. A bimetal overload relay is provided. The breaker is capable of breaking the short circuit current of the motor but not the line short circuit current, and a triple-pole fuse is required in front of the breaker. (*Science Abstracts*)

No. 712. A. Deutgen, "ASEA Oil-Minimum Circuit-Breakers," *J.*, A.S.E.A., Vol. 16, November, 1939, pp. 146–149.

An illustrated description of a series of oil-poor circuit breakers which have been de-

veloped for voltage up to 220 kv. One breaking point per phase is employed except for voltages above 150 kv. when two are used. At voltages above 44 kv. each pole is provided with a series isolating switch which provides a visible air break. A typical oscillogram is given of a rupture test. (*Science Abstracts*)

No. 713. R. Störmer, "The Inductance of a Small Contact Area," *Wiss. Veröff. a. d. Siemens-Werken*, Vol. 18, No. 2, pp. 45–53 (1939). (In German.)

When two pieces of metal are in electrical contact over a very small area only, the electric current converges toward it as does a stream of water to the center of a sieve. The resulting effects are consequently termed "sieve resistance" and "sieve inductance." The latter is calculated, the assumption being that it is concentrated in a small hollow sphere with the contact areas as a diametrical plane. The higher and lower limits are computed in general and for a numerical case and illustrated graphically. It is pointed out, however, that in practice a film of foreign matter is always present and in general swamps the "sieve effects" by its resistance. (*Science Abstracts*)

No. 714. Charles Hardy, "Powder Metallurgy in the Electrical Field," *Metal Progress*, Vol. 35, No. 1, pp. 57–59 (1939).

The requirements for copper commutator segments are enumerated, and it is shown that suitable segments may be produced by compacting powdered copper. The size and hardness of pure copper powder specimens before and after the various stages in sintering and repressing are compared with those of specimens containing admixtures of silver, cadmium, zinc, and certain binary alloys. The special methods adopted in working the sintered products are described, and an account is given of the use of copper powder in the production of squirrel-cage rotors. (*Chemical Abstracts*)

No. 715. H. H. Skilling, "The Electric Strength of Air at High Pressure," A.I.E.E. *Technical Paper No. 38-117*, July, 1939; *Trans.*, A.I.E.E., Vol. 58, April, 1939, p. 161.

Experimental data show that the strength of compressed air as an insulator increases with pressure until a critical value is exceeded. At higher pressures the sparking voltage fails to rise, and may even drop. The maximum voltage and the critical pressure are largely dependent on the shape of the electrodes of the spark gap. (*Science Abstracts*)

No. 716. S. G. Eskin, "Effect of Contact-Opening Speed on Arc Energy in A-C Switching," *G. E. Rev.*, Vol. 42, No. 2, p. 81 (1939).

Results of arc-energy measurements while interrupting a noninductive 60-cycle alternating current of 35 amp. at 115 v. with contact speed varying between 0.2 and 16.7 in. per sec., show that the arc energy decreases as the speed is reduced to 1.5 in. per sec. and increases with further reduction in speed.

With contacts operated at high speed, the gap at the instant of zero current is large and may result in high arc voltage thus producing larger arc energy. At very low speeds, with gaps of the order of half a thousandth of an inch, reignition of the arc may take place.

Presence of materials resulting from arcing at the contact surface reduces the arc energy developed while interrupting noninductive alternating current circuits.

The results of this investigation show that contact speeds between 1 and 4 in. per sec. produce the lowest arc energy and confirm the practical experience obtained with automatic thermostatic controls for electric heating appliances for alternating current only. (Author's summary)

No. 717. R. B. Jacobs and C. Starr, "Thermal Conductance of Metallic Contacts," *R. Sci. Inst.*, Vol. 10, April, 1939, p. 140.

The thermal conductance between two clean metallic surfaces, in contact in a vacuum, is of importance for the design of cryogenic apparatus. The thermal conductances between various surfaces in a high vacuum were studied as a function of contact pressure, and results are given for gold, silver, and copper at 25 C. and −195 C. The surfaces were polished to approximately optical flatness. (*Science Abstracts*)

No. 718. V. P. Hessler and R. H. Savage, "Collector-Ring Films: Formation and Influence," *G. E. Rev.*, Vol. 42, No. 5, p. 192 (1939).

A description of experiments carried out with a probe of electrographitic material in contact with a rotating copper ring. The current flowing was measured with various values of mechanical pressure and applied voltage. Measurements were taken before and after running the apparatus for some hours without current. It is shown that the results are consistent with those obtained with brushes but greater accuracy is possible. A critical disruptive voltage was observed and also a disruptive pressure, the film being reestablished upon return to the initial pressure. An explanation of the polarity effect is suggested. (*Science Abstracts*)

No. 719. C. P. Rhine, "Hydro Maintenance. Part II," *Elect. West*, Vol. 83, No. 4, October, 1939, p. 43.

Switchgear and various circuit breakers, using copper or brass contacts and operating at their rated loads, require frequent overhauling, due to cumulative increase in temperature of the contacts with time as a result of oxidation of the contacts. This difficulty can be completely eliminated by silver plating

contacts with thicknesses from 0.003 to 0.006 in.

The results of resistance measurements on silver plated and original copper contacts are described for circuit breakers rated 1000 and 2000 amp.

A method of silver plating suitable for field work is described in detail, and information is given on the type of materials necessary for such plating.

No. 720. S. G. Eskin, "Energy Measurements of Reigniting A-C. Arcs," *J. App. Phys.*, Vol. 10, No. 9, p. 631 (1939).

An oscillographic study of arcs formed between silver contacts in the rupturing of 120-v. a-c. circuits containing resistive loads shows that reignition of the arc occurs at low speeds of contact separation. Data have been obtained by means of a ballistic wattmeter showing the effect of current and line voltage on arc energy for silver contacts opening at speeds from 0.024 to 16.7 in. per sec. In the low speed range reignition is more prevalent at 225 v. than at 115 v., and restriking of the arc occurs at higher speeds for higher currents. The formation of an arc in reigniting cycles is believed to be due to field emission of electrons, an average field of 0.30×10^6 v. per cm. being found for all cases of reignition observed. Reignition occurred at potentials as low as 72 v. and the intermediate glow discharge normally observed in the interruption of inductive circuits did not appear. (Author's abstract)

No. 721. K. L. Emmert, J. W. Wiggs, and V. E. Heil, "Electrical Contacts—Factors Affecting Their Life and Performance. Parts I and II," *Prod. Eng.*, Vol. 10, Nos. 5 and 6, pp. 194 and 249 (1939).

Broadly, this article is concerned with the effect of inductance in low voltage, direct current circuits on the life of silver and tungsten contacts. This discussion in the first part is quite general since it is intended to show the effects of inductance, contact pressure, and peak voltage on the current capacity and transfer tendency of fine silver contacts. In the second part, the behavior of tungsten contacts as governed by various protective condenser values is discussed. From these data, explanations of behavior are derived which are thought to be a contribution to the existing knowledge on tungsten contacts. The second part also deals with the development of a new differential contact combination which has been successful in eliminating contact troubles on such devices as voltage regulators operating at low voltage. (Authors' summary)

No. 721a. S. Keilien, "Improving Products Through Research and Tests for Quality," *Prod. Engg.*, January, 1939.

Wiring devices are relatively inexpensive, and in the mind of a layman sockets, switches, and convenient outlets are merely devices for occasional use, carrying small currents and, therefore, not particularly needing dependability in operation, space, and labor saving features, strength or long life and safety, all of which are required of more expensive electrical apparatus, such as motors, domestic and industrial appliances.

Such a viewpoint is erroneous, for wiring devices fall in the category of electrical equipment, and as such they must process the same basic qualities of performance and of safety demanded for more elaborate and more costly apparatus. As a result of imposing these stringent requirements the hazard caused by any imperfection in construction of the devices or by their use has been almost eliminated.

To bring about such a degree of dependability, wiring devices must be subjected to a thorough investigation prior to their acceptance for quality production, and must be tested during their manufacture to assure the maintenance of the standard set up by engineering considerations. (Author's abstract)

No. 721b. Frank J. Studer, "Contact Resistance in Spot Welding," Supplement to *J.*, Am. Welding Soc., Vol. 4, No. 10, October, 1939, pp. 374–380.

The actual importance of contact resistance in the spot welding process has not proved to be easy to determine. This is because the characteristics of contact resistance under welding conditions have not been known. The opinion is often expressed that surface resistance is, in most cases, necessary for effective welding by this method, since it brings about the production of heat right at the boundary where welding occurs. On the other hand, it has been the feeling of some that boundary resistance really plays a rather minor part in the welding process; that under conditions where it is high enough to be of any consequence, it produces too localized heating, which results in a very thin weld nugget of low strength. The present study was undertaken to determine the characteristics of contact resistance under circumstances that occur in spot welding, from which it should be possible to tell more about its action during the welding cycle. (Author's abstract)

No. 721c. V. P. Hessler and R. H. Savage, "Collector-Ring Films: Formation and Influence," *G. E. Rev.*, Vol. 42, pp. 192–197 (1939).

An understanding of the origin and effect of collector ring and commutator films would dispel much of the mystery which shrouds the sliding contact. Faraday, anticipating somewhat our present difficulties, carefully amalgamated the disk edge and brush face before attempting his historic experiments.

At the brush-ring contact as we now know it, most of the wide variation of resistance with current must be attributed to film because a film-free ring exhibits essentially a constant resistance. Carbon brushes operating on either carbon or hot silver rings show straight-line voltage-current characteristics. The laws of formation and action of the thin film are clearly fundamental to sliding-contact theory. It is the purpose of this paper to show something of the formation, nature, and influence of the film, and to formulate a preliminary interpretation of it. (Authors' abstract)

No. 721d. G. L. Pearson, "Formation of Metallic Bridges Between Separated Contacts," *Phys. Rev.*, Vol. 56, September 1, 1939, pp. 471–474.

Low-resistance bridges were formed between gold, steel, and carbon electrodes having separations of 2–70 $\times$ 10^{-6} cm. by applying voltages less than the minimum sparking potential. For a given pair of electrodes the field required to form the bridges is a constant and is 5–16 $\times$ 10^{6}v./cm. Measurements of the temperature coefficient of resistance of the bridges identify them as consisting of the material of the electrodes. A study of their resistance as a function of the displacement of one of the electrodes shows that they may be pulled out as well as crushed. At voltages less than those required to form the bridges, field currents exist. These increase rapidly as the field is raised and attain a value around 10^{-4} amp. before the bridges are formed. Calculation of the maximum electrostatic stress on the electrodes at the time of breakdown gives a value of 0.05 to 0.0005 times the tensile strength of the electrode material at room temperature. The field is locally higher than that calculated because of surface roughness and the tensile strength is probably lowered by the local heating known to accompany field currents. The data, therefore, indicate that electrostatic force pulls material from the electrodes to bridge the gap. (*Science Abstracts*)

No. 721e. J. B. MacNeil and A. W. Hill, "Multiple-Grid Breakers for High-Voltage Service," *Trans.*, A.I.E.E., Vol. 58, August, 1939, p. 427.

A deion grid interrupter is described for use in multiple unit groups for apparatus rated at 138 to 230 kv.

A group of ten field tests were made on a 220-kv. line, current varying from 565 to 6000 amp. An illustration shows the contacts after these tests.

No. 721f. C. H. Flurscheim, "A New High-Speed 132 kv Circuit Breaker," *Engineer*, April 21, 1939, p. 492.

Among the problems presented by the interconnection of power stations by extra high-voltage transmission lines, that of instability and consequent spreading of disturbance under faulty conditions has assumed greater importance as the size of such systems has grown. For a system of this type, such as the British grid, it is evident that the shorter the time taken for complete isolation of a fault, the less the probability of loss of synchronism between stations with the consequent extensive loss of supply. The design of an ultra high-speed high-voltage breaker described represents a recent development with this primary object in view. The recovery voltage duty on such a high-speed breaker is, however, likely to be considerably more severe than was the case with its slower predecessors, and it was, therefore, necessary to ensure that, while designing for increased speed, the necessary increase in efficiency was incorporated to deal with the more severe conditions. The design, which is set out in detail, employs one compressed air mechanism driving the center phase directly and the outer phases by torsion shafts. There is only one break actuated by oil pressure being provided for certain voltages.

A series of seventy-one tests, carried out over a wide range of currents, showed that the total interrupting time from receipt of trip impulse to extinction of three phase short circuits was consistently of the order of 0.055 sec. An illustration shows the condition of the (Elkonite) contacts after completion of one set of seventeen tests to B.S.S. 116, Part 2, and after undergoing all the seventy-one short circuit tests.

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No. 722. L. Gosland, "Restriking-Voltage Characteristics Under Various Fault Conditions at Typical Points on the Network of a Large City Supply Authority," E.R.A. Report. Ref. B/T 104. *J.*, I.E.E., Vol. 86, March, 1940, pp. 248–274.

No. 723. J. J. Went, "Electrical Resistance of Metal Contacts," *Philips Techn. Rev.*, Vol. 4, No. 11, November, 1939, pp. 332–335 (1940).

Resistance of contacts depends in first instance upon specific resistance of material of contacts, hardness of material, and contact pressure; properties of surface of contact are also important; on basis of these facts study is made of methods by which contact with high resistance may be improved. (*Engineering Index*)

No. 724. H. Franken, "Metals in Switchgear Construction" *ETZ.*, Vol. 61, December 5, 1940, pp. 1123–1125. (In German.)

A number of examples are given showing how imported materials may be saved by reducing the quantity of inactive material, by shortening the current paths, and by re-

placement by indigenous metals or synthetic resins. The advantages of silver as a contact material are stressed. In die-casting and pressed material metal reinforcements are frequently used. The insulating properties of pressed material may lead to a considerable saving in constructional elements and in the size and weight of the apparatus. (*Science Abstracts*)

No. 725. A. Seidemann, "Limit Switches for Electrically Driven Cranes," *VDI Zeit.*, Vol. 84, April 6, 1940, pp. 236–238. (In German.)

The author reviews critically the different types of switches used for interrupting the current of lifting motors when the rope block reaches its highest position. The rod gear actuating the limit switch should be so arranged that it is met by the rising rope block not in a single point or on an edge but in a full plane so that safe operation is assured even if the rope block oscillates. The rods of the gear must be safely guided against buckling. Quick-acting switches should be used which interrupt all conducting paths to the motor and to the magnetic brake. (*Science Abstracts*)

No. 726. J. Boysen, "Contact Pieces for Selectors," *Zeits. f. Fernmeldetechnik.*, Vol. 21, April, 1940, pp. 58–60.

After surveying different types of contact pieces the author proposes a new design using a metallic diaphragm between fixed and movable contact transmitters. The diaphragm serves as a protection against troubles caused by dusts. (*Science Abstracts*)

No. 727. G. Mierdel, "Probe Measurements in Gas Dischargers," *Arch. Tech. Messen*, Vol. 31, No. 105, March, 1940, p. 7.

A progress review of theory and methods (*Sci. Abst.*, No. 764 (1927)). In plasma, that is, a highly ionized gas in which carriers of positive and negative charges are present in equal densities, all quantities characterizing the discharge, for example, electron speed, carrier density and temperature, space and contact potential, may be computed from the probe characteristic. The ideal probe characteristic is described and formulas for the computations are given for plane, cylindrical, and spherical probes. The sources of error are discussed and a bibliography is given. (*Science Abstracts*)

No. 728. U. Müller, "Switching Time and Permissible Frequency of Operation of High Speed Circuit Breakers," *ETZ.*, Vol. 61, May 23, 1940, pp. 467–469.

A novel design of a high speed circuit breaker of the holding-magnet type is described and illustrated. The switching time is kept small even if a large reserve of contact material is used for increasing the life of the circuit breaker (*Sci. Abst.*, 570 (1941)). This is accomplished by a special distribution of the masses of the movable contact piece and by a proper choice of the point on which the spring acts. The tripping current is practically independent of the rate of increase of the short circuit current. The interruption occurs during the rise of short circuit current. (*Science Abstracts*)

No. 729. V. Grosse, "Development of Solid-Gas Circuit-Breakers," *VDI Zeit.*, Vol. 84, May 11, 1940, pp. 321–324.

In the solid-gas circuit breaker the arc, passing through a tube of fibrous material, causes a small quantity of the material to evaporate and is extinguished by the pressure of the gas thus generated (*Sci. Abst.*, 419 (1937)). The circuit breaker has the properties of an air-blast breaker but needs no compressor. The development and design are described and illustrated and a table is given showing progress made in the choice of fibrous material. The apparatus is built for 10 and 20 kv. and for rupturing capacities of 5 and 20 mva. if used as an isolating switch working on load, and of 200 mva. if used as a circuit breaker. With a special design of the explosion chamber the arc is extinguished within one-half period. Connected in series with high power fuses the medium-size breaker may be used for a total short-circuit energy of 400 mva. Its main field of application is in stations with little attendance. (*Science Abstracts*)

No. 730. E. E. Schumacher and W. C. Ellis, "Metallic Materials in the Telephone System," *Metal Progress*, Vol. 36, No. 5, November, 1939, p. 617; also *Bell System Technical J.*, Vol. 19, January, 1940, p. 138.

A paper discussing a few of the developments arising from the metallurgical researches carried out by the Bell System with special reference to 'the telephone handset. These cover lead alloys, copper, zinc, and aluminum, the precious metals, and magnetic materials. (*Science Abstracts*)

No. 731. A. M. Curtis, "Contact Phenomena in Telephone Switching Circuits," *Bell System Technical J.*, Vol. 19, No. 1, January, 1940, p. 40.

The phenomena occurring at the closing and opening of contacts carrying mean currents have been investigated by means which include a study of the h. f. transient voltages and currents. These influence the erosion in a complex manner which varies with contact materials, surface conditions, surrounding atmosphere. Three principal classes of effect have been distinguished: (1) disruptive sparkover initiating a series of metallic arcs lasting less than 1 micro-sec. each; (2) a nitrogen gas glow discharge at about 300 v., preceded by a brief group of dis-

ruptive sparkovers; (3) high field breakdowns due to cold point discharges which cause transient metallic closures of approaching contacts and similar transient reclosures of separating contacts. (*Science Abstracts*)

No. 732. C. G. Suits, "Arcing Phenomena in Mercury Switches," *G. E. Rev.*, Vol. 43, No. 3, March, 1940, p. 120.

The results of investigation show that the arc duration for both the make and break positions of the mercury switch is very sensitive to the kind of gas with which the switch is filled and to a lesser extent to the pressure of the gas. The best gas for short arc duration and maximum interrupting ability is hydrogen at the highest possible pressure. (*Science Abstracts*)

No. 733. J. D. Cobine and H. Klemperer, "Residual Currents in A.C. Discharges," *J.*, Frank. Inst., Vol. 229, No. 4, April, 1940, p. 477.

A point by point determination is made of the residual current flowing during the reignition period of an a-c. arc between pure graphite electrodes in atmospheric air. The air is varied from 0.14 to 5.4 atmospheres absolute and the gap varied from 0.25 to 5 mm., alternating current of 60 cycles per second is supplied to the arc by a 10-kv. power transformer and the rms. discharge current is limited by ohmic resistance to values between 0.05 and 2 amp. The residual current rises to a peak shortly after the voltage reverses and the current then decreases as the recovery voltage increases to its reignition value. The peak of the residual current increases directly with the rms. current of the arc, and is essentially independent of both the length of the gap and the pressure of gas. The reignition voltage is shown to be a function of the value of residual current existing just prior to ignition. The rate of decay of residual current decreases as gas pressure and gap length are increased. (*Science Abstracts*)

No. 734. C. G. Suits and J. A. Van Lund, "New Condenser Circuits for Suppressing D.C. Arcs," *Prod. Engg.*, Vol. 11, No. 5, May, 1940, p. 206.

A circuit of connecting condenser for a more effective arc suppression of d-c. circuit is described. Condenser is connected so as to discharge in direction opposite to that of the arc, thus causing the current to pass through zero. Curve showing the relation between the required capacitance and current interrupted indicates that the new method permits interruption of current ten times as great as that possible with a permanently connected condenser, and six times as great as that obtainable with a method of suddenly applying an uncharged condenser across the arc. Curve showing the effect gap length has on the arc rupturing capacity of contacts is also given.

No. 735. G. Windred, "Electrical Contacts," Macmillan & Co., Ltd., London; and D. Van Nostrand Co., Inc., New York, N. Y. (1940).

The book is divided into eight chapters dealing with electrical contact phenomena, joints in electrical conductors, switch contacts, circuit phenomena, arcs and discharges, suppression of arcs, contact materials, and sliding contacts. Most of these subjects are dealt with in great detail and are of practical value in analyzing and designing current rupturing devices.

No. 736. P. Rossbach and R. Seeliger, "The So-Called Minimum Discharge Voltage," *Zeits. f. Phys.*, Vol. 116, Nos. 1 and 2, June 29, 1940, p. 68.

According to the usual methods of procedure the electrodes together with the minimum voltage of the arc discharge cannot be measured closer than one volt particularly in the case of electrodes which vaporize or burn away readily. It is therefore not possible to get the sum of the cathode and anode drops to any great accuracy.

No. 737. Lawrence Addicks, "Silver in Industry," Reinhold Publishing Corp., New York, N. Y. (1940).

This book covers the results of a three-year program of intensive work done under the auspices of the Silver Products Research Project, the purpose of which was the stimulation of interest in the industrial possibilities of the metal. The investigations were made at the Bureau of Standards and at many universities. In addition to the particular uses treated, such as soldering bearings, cuttings, electrical contacts, catalytic action, corrosion resistance, and germicidal effects, there are useful chapters on the properties of silver, the constitution of silver alloys, and the physical metallurgy of silver. (*Chemical and Metallurgical Engineering*)

No. 738. J. M. Meek, "Theoretical Determination of Breakdown Voltage for Sphere Gaps," *J.*, Frank. Inst., Vol. 230, August, 1940, p. 229.

The potentials required for breakdown between spheres are calculated on the basis of the streamer theory of spark discharge. This theory is founded on atom-physical considerations, so that the calculations are not of usual empirical nature. Agreement within about three per cent of the values determined experimentally is obtained in the case of the symmetrical sphere gap for spacings up to a sphere diameter. The effect of variation of air density is also considered and the calculations are again found to be in close agreement with experiment. The Toepler discontinuity is explained in terms of the new theory, which predicts a transition region between two types of mechanism in the range of spacings where the discontinuity is ob-

served, and which further accounts for the known increase in scattering of the measured potentials in that region. (*Science Abstracts*)

No. 739. H. H. Race, "Effect of Small Projections on Breakdown in Air," *G. E. Rev.*, Vol. 43, No. 9, September, 1940, p. 365.

Projections in the form of arcs of circles were mounted on the surface of one of the spheres of a sphere gap and the reduction in spark-over voltage measured for various heights of projections, both metallic and dielectric. On 60 cycles per second tests small projections of either metal or dielectric have about the same relatively large effect on the spark-over voltage, apparently due to the increased gradient in the air adjacent to the projections. Large projections of wet pressboard are comparable to metal and are worse than dry insulation. On positive impulse tests wet pressboard is comparable to metal and to 60 cycles per second tests; dry pressboard projections gave higher spark-over voltages. On negative impulse tests small projections of either metal or solid dielectric had negligible effect, while large projections of dry dielectric gave higher spark-over voltages than metal or wet pressboard. (*Science Abstracts*)

No. 740. W. Lochte-Holtgreven and H. Maecker, "New Discharge Form in the Stabilized Arc," *Zeits. f. Phys.*, Vol. 116, Nos. 5 and 6, September 12, 1940, p. 267.

A stabilized arc which was discussed in detail in a previous article is compared with the discharge in the mercury high pressure arc lamp. The discharge effects are discussed.

No. 741. J. W. Seaman, "Modern Trends of L. V. Air Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 59, January, 1940, pp. 24–29. Discussion, pp. 29–30.

The history of l. v. circuit breakers has paralleled the development of power distribution. The desire for improved contacts led from an automatic knife-switch type to an air circuit breaker equipped with a laminated copper brush. The trend from d-c. systems to polyphase a-c. systems led from the "non-trip free" type to the "trip free" breaker. The requirements for low maintenance, safety of operation, and increased continuity of service, together with the trend toward steel enclosing of switchboards and individual devices, are being met by new types equipped with solid silver main contacts, alloy arcing tips, and an arc interrupter described in the paper. (*Science Abstracts*)

No. 742. W. F. Skeats and W. R. Saylor, "High Capacity 'Hydro-Blast' Circuit Breaker for Central Station Service," *Trans.*, A.I.E.E., Vol. 59, February, 1940, pp. 111–114. Discussion, pp. 114–116.

The increasing demand for oilless circuit breakers has resulted in a number of contributions in that field. Outstanding among these from the standpoint of interrupting capacity at generator voltages is the "hydro-blast" circuit breaker, which has been developed in ratings up to 1,500,000 kva. This breaker has the feature of complete interchangeability with the standard H-type oil circuit breaker and thus combines all of the well-known advantages of that type with the total absence of inflammable material. This paper describes in detail the construction and operation of the 500,000-kva. "hydro-blast" circuit breaker for power stations. (*Science Abstracts*)

No. 743. S. Horikosi, "Arcing Phenomena of Circuit Interruption," *ETJ.*, Vol. 4, January, 1940, pp. 17–21.

An investigation of arc extinction when the arc suppression power is high. It is shown how to obtain the arc characteristic equation which, correlated with the equations of the circuit, enables a study to be made of the principles of arc suppression. (*Science Abstracts*)

No. 744. L. Gosland, "Restriking-Voltage Characteristics Under Various Fault Conditions at Typical Points on the Network of a Large City Supply Authority," E.R.A. Report Ref. B/T104, *J.*, I.E.E., Vol. 86, March, 1940, pp. 248–274.

This report deals with the rates of rise of voltage at the clearance of different types of fault at given points on a network, with the relation between the power-frequency parameters of the various plant units concerned and those effective during the occurrence of the transients of restriking voltage, and with the range of values of rates of rise to be expected at different types of bus-bar location. Rates of rise of voltage under different types of fault condition are first expressed in general terms. These are shown to agree with the values measured under different conditions in particular situations on the network of the Birmingham Corporation, by means of the restriking-voltage indicator. The application of the method of symmetrical components to the calculation of transients of restriking voltage on the clearance of all types of fault is discussed with particular reference to generators. Rates of rise of voltage in concrete instances on an 11-kv. system are given, the values ranging from approximately 200 to 7000 v. per microsecond; it is considered that the latter figure may well represent an upper limit in British practice at this voltage. (*Science Abstracts*)

No. 745. E. Podszus, "Boiling Point of Carbon and Heavy Current Arcs," *Zeits. f. Phys.*, Vol. 116, Nos. 5 and 6, September 12, 1940, p. 352.

Even without a large anode flame it has been possible to get such strong vaporization in the carbon arc as has been described by Finkelnburg that the temperature of the crater is increased. Examples of arcs in the higher range have already been described which have an increasing characteristic and these are further considered. Several forms of arc at not too low pressures are discussed with their particular characteristics from several points of view with the experimental conditions such as structure and composition of the anode, convection, motion, cooling, and so forth, are carefully considered.

No. 746. A. R. Blandford, "New Developments in Air-Break Circuit Breakers," *English Elec. J.*, Vol. 10, April, 1940, pp. 5–19.

A description of the design and construction of air-break circuit breakers which have been designed for operating voltages of 400 and 3300 v. The arcing chamber consists of a number of plates arranged along the arc path and perpendicular to it; in the l. v. design they are of insulating material and are spaced at intervals of $^3/_{16}$ in. the voltage drop in the chamber being about 50 v. rms. per in.; in the h. v. design the plates are of magnetic material with insulated plates at the top, the spacing is $^1/_8$ in., and the voltage drop about 500 v. per in. High-pressure line contact is made between silver plates brazed on to the contact faces of both moving and stationary main contact members. In the l. v. design secondary contacts and arcing contacts are provided; in the h. v. design arcing contacts transfer the arc to fixed arcing horns. Short circuit tests on the two designs have been made up to breaking currents of 40,000 and 20,000 amp., respectively. Constructional details and photographs are given as well as test oscillograms. (*Science Abstracts*)

No. 747. G. Brockhaus, "Suitability of the Air-Blast Circuit-Breaker for Clearing Short-Circuits," *ETZ.*, Vol. 61, February 29, 1940, pp. 191–193. (In German.)

The author shows that the air-blast circuit breaker is well suited for use as an automatic reclosing switch. For this purpose only the main contacts open, the isolator not being opened until it has been found that the fault is persistent. (*Science Abstracts*)

No. 748. L. B. Loeb and J. M. Meek, "The Mechanism of Spark Discharge in Air at Atmospheric Pressure, Part I," *J. App. Phys.*, Vol. 11, June, 1940, pp. 438–447.

The Townsend equation for the passage of a spark is analyzed and its inadequacy for explaining sparks in air at near atmospheric pressure is demonstrated. The mechanism active in air at higher pressure, *viz.*, the electron avalanche and its tip field, photoionization in the gas, and positive streamer formation, are presented. A quantitative criterion for streamer formation is applied to give a quantitative theory for spark breakdown in air at atmospheric pressures. The theory gives quantitative agreement with experiment and predicts departures from Paschen's law. At values of the product pressure $\times$ (gap length) less than 200 mm. $\times$ cm. in air the new mechanism is unimportant. The theory is applied to longer sparks at atmospheric pressures and the effect of the decrease in density of photoionization in longer avalanches considered. This leads to a modification of the Meek mechanism by which the electron avalanche slows down while a retrograde positive streamer moves at high speed to the cathode and then advances again. This mechanism enables one to discuss the breakdown potentials of unsymmetrical gaps showing the difference in sparking potential between positive and negative points. The mechanism is correlated with the passage of lightning discharges. Alterations of Meek's theory of the stepped leader are indicated. (*Science Abstracts*)

No. 749. H. Nomoto, "The Influence of Anode Material on a Stepped Discharge," *ETJ.*, Vol. 4, May, 1940, pp. 116–119.

Discusses the minimum electric breakdown voltage *versus* electrode material from the standpoint of the stepped discharge, in the case where the anode and the cathode are of the same material. The stepped discharge is also investigated using various combinations of electrode materials, in order to study the influence of anode and of cathode materials, respectively, on the discharge. (*Science Abstracts*)

No. 750. H. B. Dwight, G. W. Andrew, and H. W. Tileston, Jr., "Temperature Rise of Busbars," *G. E. Rev.*, Vol. 43, May, 1940, pp. 213–216.

Calculating radiation and convection separately for outer and enclosed surfaces, and making due allowance for skin effect in estimating losses, comparisons are made with various published data relating bus-bar current to temperature rise. Agreement is for the most part good. (*Science Abstracts*)

No. 751. M. J. Druyvesteyn and F. M. Penning, "The Mechanism of Electric Discharges in Gases at Low Pressure," *Rev. Modern Phys.*, Vol. 12, April, 1940, pp. 87–174.

A review of the results of the work of the past ten years. The first part deals with discharges in which space charge is negligible ("breakdown") and the second part discusses glow and arc discharge. A survey of theoretical development is given, starting from electron velocity distribution and leading to the definition of breakdown potential, with application to corona between coaxial cylinders.

In the second part Poisson's equation is the starting point in general theory. The attempts at a theoretical explanation of the cathode phenomena are discussed and the various forms of glow discharge and arcs (tungsten, metal, carbon, mercury) are dealt with. A section on the positive column concludes the paper (*Science Abstracts*)

No. 752. F. V. Roeschlaub, "Effect of Sequential Switching on Short Circuit Currents in Synchronous Machines," *G. E. Rev.*, Vol. 43, June, 1940, pp. 256–261.

During a short circuit test on a synchronous machine all three phases may not close at the same instant, and sequential switching is said to take place. The article analyzes mathematically the currents which result from this type of switching. It is concluded that only the asymmetrical components of the currents are affected and not the fundamental alternating components. The peak transients may exceed the maximum possible peak transients for simultaneous short-circuiting in the ratio 2.37 to 2.00 in certain cases, and tests indicate the possibility of greater ratios. The method of measuring subtransient reactance by the direct component of the short-circuit current is only valid for simultaneous contact closure, and sequential switching may introduce negative errors of about 30 per cent or infinite positive errors. Theoretically, the measurement of subtransient reactance by the fundamental alternating component method is not affected, but accuracy may actually be considerably reduced by saturation effects. (*Science Abstracts*)

No. 753. G. Windred, "Switchgear Contracts," *Engineer*, Vol. 169, June 21, 1940, pp. 558–559, and June 28, 1940, pp. 567–568.

After a summary of the relationship between contact resistance, contact pressure, and contact form, the author deals with the effect of arcing on the switch contacts and stresses the need for avoiding in the design of the switch the weakening of the contact pressure which can result from heavy electromagnetic forces. Bouncing of the contacts may be avoided by arranging for the energy of the moving contact member to be absorbed by a resilient stationary member. Auxiliary contacts must be carefully designed as, under certain circumstances, it is possible for an arc to occur when the main contacts open and before the arcing contact breaks the circuit. While copper and silver are the only individual metals which have found any extensive application in ordinary practice, alloys are also of service, and considerable work has been carried out in the development of sintered materials for contact purposes. The following are properties of a typical tungsten-copper and a typical tungsten-silver material, respectively: specific weight 13.2 and 15 g. per cu. cm.; specific resistance, 5.1 and 3.9 micro ohms per cu. cm.; thermal conductivity, 0.36 and 0.44 cal. per cm. per sec. per deg. Cent.; linear expansion coefficient, 11×10^{-6} and 8×10^{-6}; hardness (Rockwell B), 90 and 95. (*Science Abstracts*)

No. 754. Anonymous, "Re-Closing Air-Blast High-Speed Circuit-Breakers," *Engineer*, Vol. 170, July 26, 1940, pp. 62–63.

The reclosing circuit breaker must fulfill requirements; it must reestablish normal conditions after an interval varying between 0.3 and 0.7 sec., and the circuit must remain open for at least 0.2 sec. in order to clear the arc. All three poles must also be capable of individual operation. The article discusses the suitability of the Brown-Boveri air-blast high speed breakers. The opening time is shown to be 0.05 to 0.06 sec. Each pole is equipped with a system of electropneumatic valves, a double compressed-air distributor, and a hollow insulator to conduct the air to the arcing contacts. An oscillogram is given of a typical reclosing cycle. (*Science Abstracts*)

No. 755. L. B. Loeb and J. M. Meek, "Mechanism of Spark Discharge in Air at Atmospheric Pressure," Part II, *J. App. Phys.*, Vol. 11, July, 1940, pp. 459–474.

The second part of an article of which a full abstract has been previously given (*Sci. Abst.*, 1497 (1940)). This part discusses the quantitative criterion for streamer formation. (*Science Abstracts*)

No. 756. S. Horikosi, "A Note on Circuit Interruption," *ETJ.*, Vol. 4, July, 1940, pp. 153–155.

Discusses the characteristics of the interrupting arc in relation to circuit interrupting phenomena and, in particular, circuit interrupting phenomena when thermal ignition of the arc and reignition due to ionization by collision are likely to occur. The relation between arc extinguishing power and circuit interrupting power is shown. (*Science Abstracts*)

No. 757. M. C. Hunter, "Mechanical Integrity in the Design of Electrical Circuit-Breakers," *BTH Act.*, Vol. 16, July, August, 1940, pp. 131–139.

To ensure reliable opening of a circuit breaker after several months under load in the closed position the mechanical design of the breaker must be such as to guarantee a large enough expelling force, and a "factor of assurance" must be allowed to provide for "glueing-in" and "freezing" of the contacts, erosion and roughness due to wear, etc. The author confines his attention to oil circuit breakers and investigates the closing force characteristics of various arrangements and types of contact and the contribution of the various components to the total force required

for closing and opening. A suggested design sequence is outlined. The characteristics of varying operating mechanisms are compared, and values of the factor of assurance are suggested for breaker and operating mechanisms. Factory tests are described for verifying the factors of assurance. (*Science Abstracts*)

No. 758. W. S. Edsall and S. R. Stubbs, "Circuit Interruption by Air Blast," *Trans.*, A.I.E.E., Vol. 59, September, 1940, pp. 503–509.

By using the pre-stored energy of compressed air, the two-fold function of the circuit interrupter has been evolved. This air-blast circuit breaker has a guillotine-like arc-interrupting characteristic and can be made practically immune to the adverse effects of circuit recovery voltage. The historical background of oilless circuit breakers is discussed with particular reference to European designs. The electrical and mechanical design of air-blast circuit breakers for indoor use, and the factors affecting that design, are described in some detail. (*Science Abstracts*)

No. 759. D. C. Prince, J. A. Henley, and W. K. Rankin, "Cross-Air-Blast Circuit-Breaker," *Trans.*, A.I.E.E., Vol. 59, September, 1940, pp. 510–517.

The designs of European air-blast circuit breakers are not wholly satisfactory for operation in the United States as they do not handle high enough currents, cannot economically be built for high enough interrupting capacities, and do not conform to United States installation arrangements. A new type of air cross-blast circuit breaker has been developed which conforms to the above requirements. The paper analyzes the theory of performance of the foreign and cross-blast circuit breakers and presents evidence from a number of sources which throw light on the method of operation. The circuit breaker is found to operate predominantly on the displacement theory. The nature of its performance makes it much less sensitive to recovery rate and high currents and much more economical in air consumption than air-blast breakers previously available. (*Science Abstracts*)

No. 760. H. E. Strang and A. C. Boisseau, "Design and Construction of High-Capacity Air-Blast Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 59, September, 1940, pp. 522–527.

Discusses the commercial design of circuit breaker referred to above. An increasingly strong demand exists for ratings at least up to 100 ka. at 15 kv. Circuit breakers for 60 ka. at 15 kv. have been built and tested and design tests have been made which assure the availability of circuit breakers of higher ratings when required. Two circuit breakers rated at 500 mva. have been in service since November, 1939, in addition to a number of 250-mva. circuit breakers of the same general type. The paper discusses theory of operation, design features, blast valve, operating mechanism, control valves, general arrangement of circuit breaker installation, air supply, and factory short circuit interrupting tests. A review of the design and tests on air-blast circuit breakers discloses the following: complete elimination of fire hazard; positive operation, with arcing time closely approaching the irreducible minimum; contacts and arcing compartment built for long life, and minimum deterioration; arcing contact exposed for ease of inspection; flexibility of mounting arrangement, permitting either bottom, back, or top connections; space requirements equal to, or less than, correspondingly rated oil circuit breakers, which is of importance in modernization of old stations or extensions of existing switchhouses; simplicity and compactness of application to steel cubicle construction which is easy to install, safely interlocked and having all design features coordinated; high inherent current-closing ability. (*Science Abstracts*)

No. 761. L. R. Ludwig and R. H. Nau, "Magnetic Deion Air Breaker for 2,500–5,000 V," *Trans.*, A.I.E.E., Vol. 59, September, 1940, pp. 518–522.

The theory of quenching an arc by deionizing the normally conducting arc stream, utilizing a gas blast produced by means of an intense transverse magnetic field, is elaborated. Application of design principles dictated by this theory has made it possible to develop a new form of air circuit breaker for 2500 to 5000-v. service. These circuit breakers are completely described, the theory of the deion interrupter is discussed, and test results are submitted. The problem of adequately enclosing the circuit breakers is considered and it is shown that excellent interruption can be obtained in an enclosure of small over-all dimensions. (*Science Abstracts*)

No. 762. L. R. Ludwig, H. L. Rawling, and B. P. Baker, "New 15 Kv. Pneumatic Circuit Interrupter," *Trans.*, A.I.E.E., Vol. 59, September, 1940, pp. 528–533.

A brief historical review of the trend toward the development of oilless circuit breakers is given. A comparison of the available methods of circuit interruption in air is made. The particular applicability of compressed air is stressed and a new circuit interrupter is described which can reach an interrupting capacity of 1,500,000 kva. at 15,000 v. Among the outstanding features of this interrupter are extremely high operating speed and rapid interruption with minimum energy dissipation. Test results are

given indicating the adequacy of this type of design. (*Science Abstracts*)

No. 763. G. Windred, "Sliding Electrical Contacts," *J. Beama*, Vol. 47, September, 1940, pp. 42–44.

A summary of recent researches by various investigators mainly relating to contact between brushes and sliprings or commutators. Among various conclusions the following are prominent: rating of brushes in terms of current density on nominal area is purely empirical, the actual contact surface being very much less; rate of wear in air or oxygen greatly exceeds that in an inert gas, and the oxide film on the metal surface augments the contact drop considerably; current division between brushes in parallel is by no means equal, 98 to 99 per cent of the resistance being due to the (variable) contact. Metallic graphite brushes tend to more even division since the contact resistance is more nearly ohmic. (*Science Abstracts*)

No. 764. M. Trautweiler, "Artificial Testing Circuit for Large Circuit Breakers," *Bull.*, Assoc. Suisse Elec., Vol. 31, August 9, 1940, pp. 349–357. (In German.)

From an examination of the behavior of current and voltage during the rupturing of a circuit breaker the author deduces the following conditions to which any method of test must conform: (1) it must be possible to make the short circuit current as large as may be necessary; (2) the short circuit current must remain sinusoidal during the arc and must not prematurely pass through zero; (3) the restriking voltage must be adjustable at will as regards both steepness and peak value; (4) the arc and the restriking voltage must be repeatable at will. The author shows that the normal short circuit test does not fulfill condition (3) and does not completely fulfill condition (2). The Marx circuit does not fulfill condition (2) and leaves something to be desired in respect of conditions (3) and (4). A new method of test is then outlined which satisfies all these conditions and only requires about 0.5 per cent of the power necessary for the normal short circuit test. The test switch forms part of a resonant circuit and the arc voltage on rupturing is used to initiate a voltage impulse derived from a separate transformer which simulates the restriking voltage. A brief account is given, together with oscillograms of tests actually carried out on a somewhat restricted scale. (*Science Abstracts*)

No. 765. Anonymous, "Marine Circuit-Breaker," *Elec. Rev.*, London, Vol. 127, October 25, 1940, p. 345.

Describes a contactor type air-break circuit breaker designed for naval use but equally suitable for many industrial purposes.

The cut-out is built in units, each comprising one pole, which can be mounted one above the other or side by side, according to space available. Particular features are ease of dismantling with a minimum of tools and arcing horns designed to minimize arcing and to eliminate welding of contacts. The operating mechanism works on the usual "broken tie-rod" principle. (*Science Abstracts*)

No. 766. H. Franken, "Wear and Tear Resisting Switchgear," *E.u.M.*, Vol. 58, March 9, 1940, pp. 124–133. (In German.)

The use of wear and tear resisting switchgear is necessitated by the increasing frequency of operations and use of squirrel-cage motors. A distinction is made between the total life of the apparatus and the wear and tear of the contact pieces. The author analyzes in detail the controlling factors regarding either of these, gives some hints regarding the selection of materials and designs (for example, the use of bakelite, and the like, working together with metal parts, a comparison of silver and copper contacts with regard to burning, apparatus working in air or oil), and describes some examples of recent wear and tear resisting gear. (*Science Abstracts*)

No. 767. J. Slepian and W. E. Berkey, "Spark Gaps with Short Time Lag," *J. App. Phys.*, Vol. 11, December, 1940, p. 765.

Short spark gaps (order of 1 mm.) in air at atmospheric pressure, unless specially radiated, show large spark lag when tested at little above the sparking potential. In engineering literature this property is measured by the impulse ratio, that is, the ratio of the voltage at which breakdown occurs under a voltage surge rising at a specified rate (about 50 kv. per sec.) to the voltage at which breakdown occurs with slowly increasing impressed 60 cycles per second voltage. The spark lag shows statistical variations and its mean has been shown to be nearly equal to the mean time for emission of an electron from the cathode, prior to the spark. The electron current from the cathode prior to the spark is greatly increased by the presence of a pointed projection on the cathode, so that the mean spark lag at a given voltage is greatly reduced. However, if a single pointed projection is used of sufficient size to reduce the spark lag at a given voltage, it also reduces the 60 cycles per second sparking potential, so that the impulse ratio, which is the quantity important in engineering applications, is not reduced. By using a very large number of extremely small pointed projections on the cathode the spark lag can be reduced without appreciable lowering of the 60 cycles per second sparking potential. Thus impulse ratios little greater than unity can be obtained. Small particles of carborundum, rutile, alumina, and porcelain of various

sizes were attached to the cathodes of spark gaps and the impulse ratios tested. Minimum impulse ratios were obtained when the particle linear dimensions were between 2×10^{-3} and 15×10^{-3} cm. (*Science Abstracts*)

No. 768. W. Finkelnburg, "Brightness of the Positive Crater of the Pure Carbon Arc and the Temperature of Volatilization of Carbon," *Phys. Z.*, Vol. 41, December 15, 1940, p. 559. (In German.)

Measurements are made of the mean brightness at the center of the crater with a photocell having a diameter $^1/_3$ to $^1/_5$ of the diameter of the image of the crater. The luminous surface of the crater is strongly magnified on the cell and the mean brightness is calculated from the intensity of illumination of the image and the geometrical relationship. With the positive pure and homogeneous carbon arc the brightness increases almost linearly with the currrent, as shown by the curves embodying the results of the measurements. A rise above 18,000 to over 19,000 stilb (1 stilb = 1 Hefner candle per sq. cm.) is in general interrupted by the hissing which sets in at the higher loads. It can, however, be occasionally continued to at least 25,000 stilb, as the experiments with heavily overloaded nonhissing 7-mm. homogeneous carbons show. Corresponding to this increase of brightness with load of the positive crater the temperature of the crater must depend upon the current, and this temperature cannot be the sublimation temperature of carbon. The true crater temperature corresponding to the brightness of 18,500 stilb, the value usually adopted for calibration purposes since Lummer, amounts to 4000 K., and the temperature of volatilization of carbon must be several hundred degrees higher. This result is in agreement with the work of other investigators. (*Science Abstracts*)

No. 769. F. Metzger, "Contact Burning of High-Speed Circuit-Breakers," *ETZ.*, Vol. 61, October 31, 1940, pp. 989–992. (In German.)

A sufficient amount of reserve of contact material is required to allow for burning in order to increase the life of high speed circuit breakers. The author investigates mathematically the influence of this contact reserve on the operating times of the circuit breaker. A distinction is made between the proper time and the reversing time of operation, the former being the time taken from the tripping moment to the starting of the rise in contact voltage, the latter the time from the tripping moment till the current curve reaches its max. Both times should be as small as possible in order to increase the life of the contacts. For circuit breakers with holding magnet (*Sci. Abst.*, 77 (1939)) and with impact armature (*Sci. Abst.*, 92 (1935)) it is shown that a sufficient reserve of contact material does not unduly increase the proper time. Examples of designs are described which allow of easy inspection and replacement of the contact parts subjected to burning. (*Science Abstracts*)

No. 770. W. Weizel, R. Rompe, and P. Schulz, "Theory of the Modulation of High Pressure Arcs by an Alternating-Current Component Superposed on Direct Current," *Zeits. f. Techn. Phys.*, Vol. 21, No. 12, December, 1940, p. 387.

The modulation effects on high pressure arcs is considered theoretically. A discharge is considered as a section with the center temperature constant from whose boundary the laws of heat conduction satisfy. The energy which is carried away by heat conduction is considered by means of a term in which this energy is proportional to the temperature of the conducting zone. This leads to satisfactory results in stationary discharges but gives only a rough approximation to the results. A much better approximation is found from the explicit solution of the differential equation for heat conduction for nonstationary case.

No. 771. W. Weizel and J. Fassbender, "On the Cause of the Hiss in a Carbon Arc," *Zeits. f. Techn. Phys.*, Vol. 21, No. 12, December, 1940, p. 391.

Pictures show that the hissing arc is composed of a cathode spot which moves with high velocity around the anode Oscillograms show that the voltage variations and the noise are directly tied together. The effect is caused by the heating of this anode spot, the sublimation temperature of carbon, the form of a stream of vapor which increases the anode drop, and the reignition near the anode spot which repeats the condition.

No. 772. R. W. Jones, "Discharge Across Very Small Gaps" (Thesis), Dept. of Physics, Graduate School, Northwestern Univ., Evanston, Ill. December, 1940.

Results of investigations conducted with arc discharges with gaps of an order 10^{-5} cm. under various conditions. Results obtained indicate some variation from Paschen's law. Discharges were classified as Type I, basically distinguishable by a pronounced fall in potential across the contacts and readily visible and audible, and Type II in which fall in voltage is not readily observed and which are visible only in a completely darkened room. Results of both types of discharges are analyzed graphically and photomicrographically.

No. 773. W. B. Kouwenhoven and J. Tampico, "Measurement of Contact Resistance," *Weld. J.*, Vol. 19, No. 10, pp. 408s-413s (1940).

The methods and apparatus used for the

accurate determination of the magnitude of contact resistance, the results of several studies of the variation of the contact resistance with pressure and temperature, and the effect of the contact resistance on the temperature at the contacts are reported. Measurements were made at currents up to 600 amp., corresponding to a density of 3000 amp. per sq. in. of contact surface, and pressures up to 40,500 lb. per sq. in. The measurements were carried out on a cold-rolled steel and commercial aluminum; for both the contact resistance was found to decrease with increasing pressure. The resistance also decreased with heating of the contact areas. The initial decrease of contact resistance with pressure was greatest at high temperatures. The temperature attained at a contact carrying a given current depended on the contact resistance. The temperature attained by a contact carrying current and under pressure is a function of both. If high initial contact resistance is desired, therefore, the initial pressure should be of a relatively low value. (*Journal*, Institute of Metals)

No. 774. M. Kohler, "Elektrisches und Thermisches Übergangswiderstand von Metalkontaken" (Electrical and Thermal Surface Resistance of Metal Contacts), *Die Naturwissenschaften*, Vol. 11, March, 1940, p. 164.

No. 775. E. L. E. Wheatcroft and H. Barker, "Transition from Glow to Arc Discharge," *Phil. Mag.*, Vol. 29, January, 1940, pp. 1–15.

Experiments of Issendorf, Schenkel, and Seeliger have indicated that, in the transition from glow to arc discharges, there occurs an intermittent breakdown similar to the relaxation of an intermittent spark. In the present work experiments are described in which this transition in air at pressures from 0.2 to 1.2 mm. mercury were recorded by means of a cathode-ray oscillograph. In order to avoid the difficulties of excessive discharge energy the tube was excited by means of a bank of condensers charged to 12 kv. A full description is given of the tube and oscillograph circuits and arrangements. The analysis of the oscillograms indicates clearly the transient breakdowns at the transition point and is interpreted as showing that the breakdowns are initiated by a sudden drop in the interelectrode potential, corresponding to a partial discharge of the self capacity of the electrodes. The shape of the voltage-current characteristic justifies the view that the point at which the intermittent breakdowns start is the commencement of the transition from glow to arc discharge. A series of experiments was carried out to determine the critical upper limit of voltage for the glow discharge. Several theories of the transition are examined, the most satisfactory being that of positive-ion bombardment of the cathode. (*Science Abstracts*)

No. 776. J. D. Cobine and H. Klemperer, "Residual Currents in A.C. Discharges," *J.*, Frank. Inst., Vol. 229, April, 1940, pp. 477–489.

A point by point determination is made of the residual current flowing during the reignition period of an a-c. arc between pure graphite electrodes in atmospheric air. The air pressure is varied from 0.14 to 5.4 atmospheres absolute and the gap varied from 1/4 to 5 mm. Alternating current of 60 cycles per second is supplied to the arc by a 10-kv. power transformer and the rms. discharge current is limited by ohmic resistance to values between 0.05 and 2 amp. The residual current rises to a peak shortly after the voltage reverses and the current then decreases as the recovery voltage increases to its reignition value. The peak of the residual current increases directly with the rms. current of the arc, and is essentially independent of both the length of the gap and the pressure of the gas. The reignition voltage is shown to be a function of the value of residual current existing just prior to ignition. The rate of decay of residual current decreases as gas pressure and gap length are increased. (*Science Abstracts*)

No. 777. W. Weizel, R. Rompe, and M. Schön, "Theory of the Cathodic Discharge Particles of an Arc," *Zeits. f. Phys.*, Vol. 115, Nos. 3 and 4, pp. 179–201 (1940).

The assumption is made that the cathode of an arc does not emit electrons. Three regions are to be distinguished near the cathode; a region of heat conduction in which the current is represented by electrons only, a region of ionization in which the charge carriers are produced, and immediately at the cathode the space-charge region in which the electrons can be neglected. In the case of a mercury high pressure arc, the potential in the first region is approximately 8 v., in the second region of the order of the ionization potential of the carrier gas. Since these regions have no stability in the direction perpendicular to the arc, the discharge contracts at the cathode. For a contraction to a tenth of the former cross-section, the potential of the space-charge region is 13 v. for the mercury high pressures arc. The discharge near the anode shows analogous regions. (*Science Abstracts*)

No. 777a. L. B. Hunt, "Air Circuit-Breaker Contacts. Stages in Arc Interruption," Reprint, *Elec. Rev.*, June 21, 1940.

During the past few years air break circuit breakers of high interrupting capacity have acquired many of the merits of oil circuit

breakers without the risk of secondary damage by fire in case of failure.

The development of air circuit breakers of this type, which will safely and repeatedly interrupt a.c. up to 40,000 amp. (rms.) has involved advances considerably in the design of arcing chambers and contact systems. This paper discusses the contact design and shows the use of current carrying contacts and arcing tips each to provide its own special function. Contacts consist of solid copper blocks with a facing of fine silver for the main contacts and sintered contact materials consisting of silver and one or more of the refractory metals such as tungsten, molybdenum and tungsten carbide. In operation the silver contacts open first and the refractory metal contacts open last absorbing the energy of the arc. At the close the operation is reversed since the circuit is made on the arcing contacts and the current is later carried by the main contacts.

No. 777b. L. B. Hunt, "Contact Problems in Switchgear," *Elec. Ind.*, March, 1940, p. 82.

Arcing contacts in circuit breakers must withstand the destructive effects of arcing and yet give continued service with minimum attention. The article describes the metallurgical developments which have resulted in the Elkonite range of contact materials for such a severe duty. Details are given of the copper-tungsten Elkonite contacts fitted to a Metropolitan-Vickers 132 kv. high-speed impulse oil circuit breaker, and to a typical "English Electric" medium voltage oil circuit breaker, and of the silver-tungsten Elkonite contacts adopted for use on a new design of air circuit breaker for use at 650 v. where a breaking capacity up to 50,000 kva. is required.

No. 777c. E. Christeler, "The Oerlikon Automatic Plug Switch, Type St., for Use as Automatic Switch in L.V. Installations," *E. Bull. Oerlikon*, No. 225, pp. 1379–1384 (1940).

Application and design are described with photographs and diagrams; release can be either by definite time overcurrent relay or inverse time relay with or without instantaneous s.c. tripping. Rated currents up to 500 amp. (*Science Abstracts*)

No. 777d. L. B. Hunt, "Air Circuit-Breaker Contacts," *Elec. Rev.*, June 21, 1940, p. 656.

Reviews the development of air circuit breakers of high interrupting capacity, with particular reference to modern tendencies in contact materials and arrangement. The disadvantages of the laminated brush-type copper main contacts and carbon arcing contacts are set out, and a description is given of the three-stage contact arrangement adopted in the "English Electric" 400-v. air circuit breaker. This design employs fine silver for main contacts and Elkonite intermediate and arcing contacts. For the intermediate contacts, which must withstand a certain amount of arcing, but have as low a contact resistance as possible, a silver base Elkonite is employed of only moderate refractory metal content. At the final arcing stage contact resistance is not so important and an Elkonite of high tungsten content is used to give maximum resistance to arcing but a contact resistance still sufficiently low not to interfere with rapid current transfer.

No. 777e. L. B. Hunt, "Contact Problems in Switchgear," *Elec. Ind.*, March, 1940, p. 82.

Arcing contacts in circuit breakers must withstand the destructive effects of arcing and yet give continued service with minimum attention. The article described the metallurgical developments which have resulted in the Elkonite range of contact materials for such severe duty. Details are given of the copper-tungsten Elkonite contacts fitted to a Metropolitan-Vickers 132-kv. high speed impulse oil circuit breaker, and to a typical "English Electric" medium voltage oil circuit breaker, and of the silver-tungsten Elkonite contacts adopted for use on a new design of air circuit breaker for use at 650 v. where a breaking capacity up to 50,000 kva. is required.

No. 777f. H. E. Cox and L. Drucquer, "Oilless Metal Clad Switchgear for Medium Voltage A.C. Circuits Up to 660 Volts 3 Phase," *J.*, I.E.E., Vol. 87, November, 1940, p. 461.

This paper reviews the problems relating to medium voltage switchgear and its application. Certain conclusions are arrived at as representing solutions to these problems, and the construction and design of appropriate air circuit beakers and switch fuse gear is described. The a.-c. air circuit breaker does not need magnetic blow-out coils, and test data are provided showing the effectiveness of design without such coils. High rupturing capacity fuses are also dealt with insofar as they affect the design of switchgear equipments. Finally, the paper considers complete switchboards built up, from the apparatus described earlier, into metal enclosed units. (*Science Abstracts*)

No. 777g. R. Holm, H. P. Fink, and F. Güldenpfenning, "Wiss. Veröff. Siemens-Werk," pp. 103–124, Werkstoff-Sonderh. (1940). (In German.)

Empirical results derived in a previous paper (*Science Abstracts* No. 1668 (1937)) are placed on a firmer theoretical basis. Improved formulae are given for the arcing times and the rates of loss of contact material, both for make and break contacts. A table of substances is given indicating their suitability for particular switching operations. (*Science Abstracts*)

No. 777h. J. Rezicek and S. Matena. "Determination of Steady Three-Phase Short Circuit Currents in Complex Networks," *R.G.E.*, Vol. 48, December, 1940, pp. 346–352. (In French.)

A semigraphical method which neglects saturation of the machines, the system load before short circuit, and the effects of no-load currents and of automatic voltage regulators; it allows for unequal voltages at different stations. Numerical examples and a short bibliography are given. (*Science Abstracts*)

No. 777i. H. Freiberger, "Wandering of Arcs in Switchgear," *ETZ*, Vol. 61, September 19, 1940, pp. 865–869. (In German.)

The tendency of arcs due to short circuits to wander along busbars and associated gear was investigated. The use of separating walls affords some protection but impairs the easy survey of the switchgear. Numerous tests were made and motion pictures taken with currents between 1 and 30 ka. at 6 kv. for examining the behavior of the arc, the speed of wander, and the possibility of directing the arc to a place where it can do the least possible damage. (*Science Abstracts*)

No. 777j. R. Jerkel, "The Test of Short-Circuit Elimination in Transmission Systems, *ETZ*, Vol. 61, August 22, 1940, pp. 769–772. (In German.)

A 30-kv. overhead network (pin-type insulator) fed by 4 turbo-generators, total power 44 mva., and interconnected with some small (260 kva.) hydro-power system, was protected against short circuit on more than 1 phase by a 400-mva. compressed-gas reclosing (0.3 sec.) circuit breaker. Diagrams of connections and oscillogram of a test are shown and the effects on consumers' light and power installations are discussed. Experience during 16 operations of the circuit breaker shows that it is satisfactory. (*Science Abstracts*)

No. 777k. G. Someda, "Tests on Circuit Breakers," *Elettrotecnica*, Vol. 27, September 25, 1940, pp. 434–437. (In Italian.)

An oscillatory circuit consisting of a 96-mf. capacitor, which is charged up through a rectifier, and a 33.3 Ω (50 c./s.) air-cored reactor generates 174 kv. (max.), 50 c./s. oscillations which decrease by only 10 per cent during the seven half-periods necessary for testing a 300-mva. single-pole circuit breaker and obviates the use of special generators and transformers. Oscillograms show restriking and recovery voltage. Dimensions of the reactor are given, and the cost of the installation is considered. (*Science Abstracts*)

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No. 778. E. Contius, "The Influence of the Magnitude of the Pressure and Area on Contact Resistance" (Dissertation), Dresden (1941). Summarized by G. Windred, *J.*, Frank. Inst., Vol. 231, July, 1941, pp. 577–581.

The area of contact s between two cylinders was determined as $s = kP$ when P is the force pressing them together. From the data thus determined, a formula for the contact resistance, in terms of pressure, is developed. Contact tips of various shapes are discussed, and the relation of the contact resistance to the pressure for each is discussed.

No. 779. J. Slepian and T. E. Browne, Jr., "Photographic Study of A-C Arcs in Flowing Liquids," *Trans.*, A.I.E.E., Vol. 60, p. 823 (1941).

The importance of fluid flow in aiding arc extinction in circuit interrupters has long been known. Two general types of explanation of the large effect found have been offered. Slepian who seems to have been the first to stress the importance of the motion of the gases liberated by the arc from the surrounding oil or solid insulation in oil breakers and expulsion fuses, sought the explanation in reduced arc section at current zero, and increased diffusion rate of ions and molecules arising from the turbulence. Other investigators have expressed similar views, at least in part.

Another theory attributes the rapidly rising dielectric strength at current zero to the cutting of the arc path by a film of cool, un-ionized fluid, which grows in thickness at a rate comparable with the fluid velocity, so that a simple relation may be expected between fluid velocity, fluid dielectric strength, and limiting recovery rate of circuit voltage at which extinction takes place. Such a relation is said to have been established experimentally for an oil flow breaker, but this has not been universally accepted.

The immediate objectives of this research were: (1) to determine the effect on the arc's interrupting ability of independent variations in fluid velocity, static pressure, type of fluid, arc length, electrode shape, baffle arrangements, and circuit natural frequency; and (2) to photograph the arc under these controlled conditions, hoping thus to learn something about the actual mechanism of the interaction between the flowing liquid and the arc in its gas bubble, especially near current zero. In this paper only the photographic results will be described.

From a study of many hundreds of arc photographs represented here by only a few samples, the following conclusions have been drawn:

1. The gas bubble surrounding an arc under a flowing liquid is generally not displaced by a liquid barrier until some appreciable fraction of a half-cycle after the arc has been extinguished.

2. The existence of a large bubble section

at current zero favors reignition of the arc while the existence of a small section favors its extinction.

3. Even under apparently identical conditions, the shape and size of the gas bubble may show very wide variations. These variations are the result of rapid bubble oscillations which are usually not synchronous with the arc current variation.

4. Where the arc bubble is uniformly small, there is no consistent difference between its appearance at a current zero at which the arc is extinguished and one at which it reignites, or between the characteristic bubble appearance at pressures or velocities just above the critical values for extinction and those just below these values. (Quoted from the paper.)

No. 780. G. H. Fett, "Cathode Drop of an Arc," *J. App. Phys.*, Vol. 12, No. 5, May, 1941, p. 546.

By use of the method of Betz and Karrer the cathode drop of an arc has been measured for a number of electrodes, including copper, silver, iron, and arc welding electrodes with and without coatings. The time for an arc to establish the cathode drop voltage measured from the time the last contact causes an appreciable voltage drop is found to be less than 40 microseconds. The cathode drop for copper is found to decrease with air pressure from 13 v. at atmospheric pressure to 8 v. at 0.1 mm. of mercury pressure. (*Science Abstracts*)

No. 781. W. M. Bauer and J. D. Cobine, "Gap Recovery Strength of A-C Arcs at High Pressures," *G. E. Rev.*, Vol. 44, No. 6, June, 1941, p. 315.

An investigation into the rate of recovery with time after the extinction of short a-c. arcs. Extinction times were from 50 microseconds to 10 microseconds. Pressures ranged from 1 to 32 atmospheres of nitrogen. Currents were between 0.25 and 7.85 amp. Two methods were used, a direct oscillograph method and an arc-quenching method with a thyratron shunting the arc. (*Science Abstracts*)

No. 782. G. Windred, "Electrical Contact Resistance," *J.*, Frank. Inst., Vol. 231, No. 6, June, 1941, p. 547.

A general review of the phenomena of contact resistance is followed by a theoretical treatment based on the assumption of the constriction of the lines of current flow through point contacts between the two metals in question. The effects of surface films and coherer action are discussed and a general theory is presented. A short account of experimental work on coherer action and the effect of contact pressure is given and contact voltage characteristics are described. (*Science Abstracts*)

No. 783. R. Seeliger, "Observation on the Theory of Arc Discharge," *Phys. Z.*, Vol. 42, March, 1941, p. 63. (In German.)

This concerns the two theories of the arc discharge with metals of low boiling points, such as copper and mercury; the Langmuir "field" arc theory and the Slepian theory of a thermal ionization of the gas or vapor next to the cathode. The formulas of an earlier article are extended by combining them with the field emission formula in view of the recent work by Haefer. The two models of the earlier work are taken. In Model I the electrons and ions are assumed free to traverse the region of the cathode fall. In Model II the electrons are free to traverse this region, but the ions, on the other hand, lose their entire energy with each gas-kinetic collision. The conclusion is reached that the mechanism of the cathode fall cannot be interpreted by the "field" arc theory and that the correct way of dealing with the Slepian theory is that proposed previously. (*Science Abstracts*)

No. 784. L. B. Loeb and J. M. Meek, "The Mechanism of the Electric Spark," Stanford University Press, Stanford University, California (1941).

In this analysis of the present status of the theory of the mechanism of the electric spark in air the authors developed a new streamer theory of spark discharge. A general unified theory applicable to various gaps and configurations of electrodes is set forth, from which the methods of computation given enable one to predict in advance the breakdown potential of any spark gap for direct current in the absence of space-charge distortion, and where field distribution in the gap can be calculated. (*Electrical Engineering*)

No. 785. J. Zeleny, "Electrical Discharges from Pointed Conductors," *J.*, Frank. Inst., Vol. 231, July, 1941, p. 23.

The general properties of and the current-voltage relationship in electrical discharges from points are discussed. The current-voltage relationship is often erratic at the beginning of the discharge. This is particularly so in the case of negative discharges. The nature of the negative and positive discharges is described. The discharge from points in Geiger-Müller counters is discussed. The abrupt change in the current-voltage curve for positive discharges near the onset of the discharge, which was formerly observed, was due to the type of galvanometer used and was therefore spurious. The effect of external ionization of the space before the passage of the discharge is described. In the case of a positively charged point, when a strong radioactive source is brought up, a large current flows at voltages just below the minimum starting potential, but ceases when the source is removed. When,

however, the minimum starting potential is exceeded, the current continues to flow even though the radioactive source is removed, but it drops to the value it would have had in the absence of the source. In the case of a negatively charged point, the saturation current due to the ions produced by the radioactive source remains practically the same as the potential of the point is raised until this reaches a certain value, at which there is a sudden, considerable increase in current. An explanation of the different behaviors of the two points is given. (*Science Abstracts*)

No. 786. W. Rogowski, "Characteristic of Irradiated Spark-Gap," *Zeits. f. Phys.*, Vol. 117, Nos. 3 and 4, January 20, 1941, p. 265.

The results of the recent breakdown investigations are brought together. The basis of these results is simplified and made more general.

No. 787. E. W. Boehne, "The Geometry of Arc Interruption," *G. E. Rev.*, Vol. 44, No. 4, April, 1941, p. 207.

A "back current," calculated by considering the arc voltage applied to the circuit constants, is superposed on the original short circuit current prior to interruption to obtain the resultant arc current. When this reaches zero, the arc voltage changes suddenly to the generator value and sets up a corresponding recovery voltage oscillation, the change being doubled to give the initial peak. It is shown that by shifting the phase of the current from 90 deg. lag to an appreciable lead, which can be done in such circuit breakers as the magne-blast, the recovery voltage can be reduced to very small values. The computation is conveniently semigraphical and yields other data, including arc energy. A number of diagrams are given for single-phase interruption and extended to take circuit resistance and various starting phase relations into account. Good agreement is obtained with oscillograph checks. The method is also suited to polyphase applications. (*Science Abstracts*)

No. 788. E. H. Laister, "Rhodium Contacts," *Electronic Engg.*, November, 1941. Abstract in *Electronics*, Vol. 15, No. 1, p. 88 (1942).

Physical properties of rhodium and its characteristics in various types of contact applications are discussed. It is particularly useful where there is no arcing but where it must remain absolutely reliable as far as electrical contact is concerned.

No. 789. G. Wehner and H. Meinhardt, "Electrostatic Extinction of the Arc by the Starving (De-Ion) Principle," *Arch. f. Elektr.*, Vol. 35, December 15, 1941, pp. 692–694.

Some critical remarks concerning Meinhardt's paper (*Sci. Abst.*, 516 (1942)) and the author's reply. (*Science Abstracts*)

No. 790. W. R. Rankin and R. M. Bennett, "Conserved-Pressure Air-Blast Circuit Breaker for H. V. Service," *Trans.*, A.I.E.E., Vol. 60, May, 1941, pp. 193–196.

The paper describes the design and construction of a 139-kv., 1,500,000-kva. air-blast circuit breaker. A new interrupting device is used which utilizes the axial blast nozzle together with a conserved-pressure chamber. The chamber receives the exhaust from the interrupting nozzle and contains the movable contact of the circuit breaker in its open position. By means of a spring-loaded relief valve the pressure and dielectric strength of the air in the chamber are maintained at a high level. The pressure in the chamber is at the same time less than 50 per cent of the pressure above the nozzle restriction so that the air flow through the interrupting nozzle is unimpaired, being the same as through the same nozzle discharging to atmospheric pressure. The three-phase circuit breaker consists of two interrupting units in series per pole with a disconnecting device included. Operation is entirely pneumatic, opening and closing being performed by energizing the electrically operated valve. (*Science Abstracts*)

No. 791. R. C. Dickinson and R. H. Nau, "New Air Circuit-Breaker with 250,000 KVA. Interrupting Capacity," *Trans.*, A.I.E.E., Vol. 60, May, 1941, pp. 197–201.

The interrupter consists essentially of an arc chamber of laterially spaced refractory plates embodying V-shaped slots and a magnetic circuit which imposes an intense magnetic field transverse to the slotted plates during the arcing period. The theory of arc interrupting by this new circuit breaker is considered. Design details are described and illustrated. Complete sets of test results are given, with representative oscillograms. The test results are discussed, and it is demonstrated that the new circuit breaker is applicable to modern metalclad switchgear. (*Science Abstracts*)

No. 792. T. B. Holliday, "Applications of Electric Power in Aircraft," *Elec. Engg.*, Vol. 60, May, 1941, pp. 218–225.

Attention is drawn to the scope for increased interest on the part of the electrical industry in the development of accessories for aircraft. Hitherto equipment of this type has been supplied by makers who are not necessarily the best designers of electrical apparatus, and other forms of power have often been used for duties to which electricity is applicable. Data are given concerning operating conditions and requirements. Needs already recognized include: engine-driven generators of greater output per

pound; a constant-speed drive for alternators with variable-speed prime movers; lighter storage batteries; motors with the smoothness and ease of control of hydraulic equipment; light and accurate motors for remote control; simplified avoidance of radio interference; smaller sizes of cable; improved circuit-protection devices; and electrically operated substitutes for certain hydraulic and pneumatic equipments. (*Science Abstracts*)

No. 793. L. R. Ludwig and B. P. Baker, "Vertical-Flow Outdoor Compressed-Air Breaker," *Trans.*, A.I.E.E., Vol. 60, May, 1941, pp. 217–222.

The interrupting device consists of horizontally disposed fiber disks having central orifices through which the vertical arc is drawn and through which a vertical flow of air passes to effect the interruption; one or more elements can be placed in series. A 139-kv. design is described with a diagram and photograph. The interrupting contact consists of a simple rod sliding within two tulip-type contacts supported from the mechanism box and the top of the breaker, respectively, both extending toward the central interrupting element. The arc is drawn from the upper stationary contact downward through the interrupter. Test results and oscillograms are given. (*Science Abstracts*)

No. 794. J. Slepian, "Displacement and Diffusion in Fluid-Flow Arc Extinction," *Trans.*, A.I.E.E., Vol. 60, April, 1941, pp. 162–167.

The displacement and diffusion theories of arc extinction in flowing fluids are defined and contrasted. Consideration of the flow of an ideal fluid indicates that pure streaming, without diffusive defects, will thin the arc but will not change its dielectric strength per unit length. The fluid motion can, however, greatly increase the interrupting effect of already diffusive forces. A discussion of turbulence indicates that the effective diffusion coefficient may be enormously increased so that ionic diffusion and cooling may be increased as much as 100-fold. Photographs are reproduced which support the diffusion theory as against the displacement theory. (*Science Abstracts*)

No. 795. G. W. Edgeley, "Simple Functions of Circuit Breakers," *BTH, Act.*, Vol. 17, July, 1941, pp. 80–85.

The author explains the requirements and action of circuit breakers in terms of the atomic structure of matter and the change of resistance and arc effect between the circuit breaker terminals. This treatment facilitates explanation of the characteristic features of knife switches, fuses, and circuit breakers as means of interrupting current flow. The requirements of d-c. and a-c. circuit breakers are examined, the constructional means of meeting them are explained, and typical performance data are presented. (*Science Abstracts*)

No. 796. R. C. van Sickle, "Power Circuit-Breaker Ratings," *Trans.*, A.I.E.E., Vol. 60, September, 1941, pp. 882–884.

A report has been published by an A.I.E.E. subcommittee on a simplified procedure for calculating short circuit currents. The present article discusses the correlation of short circuit ratings so that a breaker selected for adequate interrupting current by the new method will automatically have ratings adequate for the other short circuit currents. (*Science Abstracts*)

No. 797. E. A. Crellin, "Circuit-Breaker Analyser Diagnoses Hidden Maladies," *Elec. World*, Vol. 116, November 29, 1941, pp. 44–45.

Briefly describes and gives a circuit diagram of an electromechanical apparatus for observing the mechanical performance of a circuit breaker. The equipment records on a chart the contact travel to a time base and indicates the instants of contact opening and closing. (*Science Abstracts*)

No. 798. R. T. Lythall, "Lower-Voltage Circuit-Breakers," *Elec. Rev.*, London, Vol. 128, February 21, 1941, pp. 387–388.

B.S.S. 936/1940 is issued as a War Emergency Standard, but in view of its importance it will no doubt be amended and issued for general use. It refers to industrial switchgear up to 660 kv., eight ratings of breaking capacity up to 30 mva. being recognized. In this article comparisons are made with B.S.S. 116/1937. Chief among the changes under definitions is that which introduces a force trip release, a safeguard against damage due to closing on to a fault. There is an easement with regard to rated making current, which is warranted by a reduction in the asymmetry factor appropriate to the p. f. of l. v. circuits under fault conditions. The duty cycle on rupturing-capacity tests is B-MB. Appendix K contains useful information on the calculation of short-circuit currents. (*Science Abstracts*)

No. 799. Anonymous. "Electrical Contacts," *Elec. Rev.*, London, Vol. 128, March 14, 1941, p. 459.

Heating tests on an oil circuit breaker fitted with contacts of various kinds are briefly described. A current sufficient to give a 30 deg. rise with 40 C. ambient air temperature was passed through the contacts, which were opened once a day. Copper contacts reached a high temperature after a few weeks, whereas silver contacts showed only a moderate increase at the beginning and then became constant. Silver contacts are being increasingly used on isolators both for indoor and outdoor use. (*Science Abstracts*)

No. 800. B. P. Baker, "The Vertical-Flow Interrupter and Its Application to Oil-Poor Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 60, pp. 440–445 (1941). Discussion, pp. 635–638.

A description of the interrupter and its theory of operation is given. The application of two of these interrupters to a 138-kv., $1^1/_2$ million kva. oil-poor, porcelain-clad circuit breaker is shown, together with laboratory test results. A review is given of important field tests on a 138-kv. single-pole unit, tested line to earth on a large 220-kv. operating system up to approximately $2^1/_2$ million three-phase kva. Magnetic and cathode-ray oscillograms of these tests are shown. (*Science Abstracts*)

No. 801. R. M. Bennett and B. W. Wyman, "Medium-Capacity Air-Blast Circuit-Breakers for Metal-Clad Switchgear," *Trans.*, A.I.E.E., Vol. 60, pp. 383–388 (1941). Discussion, pp. 627–631.

The cross-blast principle of arc interruption provides maximum air economy and is well suited for use in an air-blast breaker that must conform to the rigid space requirements and small phase spacings in medium-capacity metal-clad equipment. Proper coordination of the operating mechanism, air supply, interrupting chamber and resistor, make possible a design to meet these requirements. The principle of operation is discussed and it is shown how a resistance is utilized to provide further air economy. (*Science Abstracts*)

No. 802. F. Kesselring, "The Problem of High Voltage Switching," *Arch. f. Elektr.*, Vol. 35, March 25, 1941, pp. 155–184.

In this part (IV) of the survey, circuit breakers with a liquid medium for the extinction of the arc are dealt with, that is, oil and water circuit breakers, the common feature of which is that the extinguishing vapor is generated by the current. The quenching is partly due to the hydrogen effect and partly to the expansion effect. The interaction between the arc and the liquid surface is discussed. Both effects are critically investigated in connection with the open oil circuit breaker and breakers with enforced extinction by rigid or elastic explosion chambers, deion grids, etc. For either type of circuit breakers impedance, current, and voltage characteristics serve for explaining their behavior in the range of the expansion effect. Finally switchgear with solid extinction medium is dealt with, for example, explosion fuses, hard-gas circuit breakers (*Sci. Abst.*, 290 (1942)) and fuses with granular extinction medium. (*Science Abstracts*)

No. 803. J. D. Cobine, "Gaseous Conductors. Theory and Applications," McGraw-Hill, New York, N. Y. (1941).

This book is an excellent discussion which gives the theoretical results of most of the effects of the conduction of electricity in gases. Sufficient of the theoretical background and derivations are given in each case considered to make the book a valuable source of basic information. The chapter headings are as follows: I. Introduction to the Kinetic Theory of Gases. II. Motion of Ions and Electrons. III. Atomic Structure and Radiation. IV. Ionization and Deionization. V. Emission of Electrons and Ions by Solids. VI. Space Charge and Plasma. VII. Field-Intensified Ionization and Breakdown of Gases. VIII. Glow Discharges. IX. Electric Arc. X. Circuit Interruption. XI. Gas-Discharge Rectifiers. XII. Rectifier Circuit Theory. XIII. Gas-Discharge Light Sources. XIV. Cathode-Ray Oscillographs.

No. 804. J. D. Cobine and E. C. Easton, "A Timer for Spark Breakdown Studies," *Rev. Sci. Inst.*, Vol. 12, June, 1941, pp. 301–305.

As an aid in the study of the time lag of spark breakdown, devices have been constructed to apply a rectangular voltage wave and to measure its length which is from 1 to 5000 microseconds in duration. It is possible to apply an essentially rectangular voltage by (1) maintaining the spark which closes the circuit through the applying switch before the contacts meet mechanically, and (2) by making the test-gap circuit aperiodic. The length of the applied voltage wave is determined by a valve circuit designed to pass a constant current output as long as the bias to the first valve exceeds a predetermined value. The output current is passed through a ballistic galvanometer whose reading is a measure of the time during which the gap voltage remains above the datum level. A thyratron circuit has been arranged to supply the timer with rectangular waves for the purpose of calibration. Cathode-ray oscillograms showing errors of 5 per cent to 10 per cent indicate that the accuracy of the apparatus is sufficient for most breakdown studies. (*Science Abstracts*)

No. 805. F. R. Hensel, E. I. Larsen, and E. F. Swazy, "Tungsten Copper for Electrical Contacts" *Metals and Alloys*, Vol. 13 pp. 577–583 (1941).

Methods of powder metallurgy have been applied to the manufacturing of copper tungsten materials for electrical contacts. Various physical properties including density, expansion characteristics, hardness, tensile properties, and applications to contact devices are considered. Important applications for contact materials include arcing tips for circuit breakers, flash and spot welding surfaces and heavy duty bearings.

No. 806. E. W. Foster, "Production, Properties and Applications to Micro-Analysis for Arcs Possessing Large-Area Anode

Spots, *Proc.*, Phys. Soc., London, Vol. 53, September 1, 1941, pp. 594–612.

Factors influencing the area of hot spots are briefly discussed. Experiments are described in which an arc is struck in air at atmospheric pressure between a graphite cathode and a graphite anode in the form of a cup at the end of a thin pillar. The cup is filled with powdered graphite which has been impregnated with a small amount of one of several suitable alkali and alkaline earth salts. At first a localized spot appears at each electrode, but after a short time, t_s, the anode spot rapidly extends until it covers the surface of the powder. This new and stable condition is maintained for a period t_b, usually $> t_s$, until the supply of salt becomes exhausted (wholly by evaporation through the arc under suitable conditions), when the anodic spot again becomes localized. The anode cup is then usually at a temperature between 800 and 2000 C. t_s and t_b depend on the amount and nature of the salt, on the anode dimensions, and on the arc current. The relation between t_s and t_b and the other variables has been studied experimentally. Results are shown graphically and a theory to account for some of these and other observations is proposed. Conditions permitting a satisfactory general spectrographic system of quantitative microchemical analysis for mineral matter are discussed in the light of recently acquired knowledge of the arc and the new observations. A new method of analysis is suggested. Reasons for believing that the necessary conditions could be satisfied are given. Results obtained with a crude (and for rough work useful) approximation to this method are satisfactory. The limiting sensitivity for silver is in the neighborhood of 10^{-9} g. (*Science Abstracts*)

No. 807. L. S. Palatnik, "On the Composition and Structure of Alloys for the Contacts of Electro-Technical Apparatus," *Elektrichestvo*, No. 4. Translation listed in Library Service of G. E. Co. for September 15, 1941.

No. 807a. R. Holm, "Technical Physics of Electrical Contacts," Julius Springer, Berlin 337 pp., 160 illustrations (1941).

This book is probably the most complete discussion of electrical contacts which has ever appeared in book form. The large part of the work is the result of Dr. Holm's work on the subject of electrical contacts, although it is not limited to this field.

The book is divided into three general sections which are as follows:

1. Stationary contacts in which the effects to be observed in contacts which are in the closed position are discussed. This discussion includes the contact resistance, contact temperatures due to current through the contacts, variation of contact resistance with contact drop and elasticity hardness and contact resistance surface films and welding or sticking of contacts.

2. The second section covers the subject of sliding contacts. In this section there is also a complete discussion of friction together with the various effects which take place between brushes and rings on commutators. The latter effects include the electrical conductivity of contacts, wear, sparking, etc.

3. The third section discusses the cooperating contacts and particularly the effects of opening and closing of a circuit. The effects of arcing on the contacts and characteristics of the arcs from various materials. The effects of various effects on contact materials are considered in detail.

This book is a very valuable contribution to the science of electrical contacts.

No. 807b. E. A. Bryan, "Some Recent Developments in the Telephone Relay," *Siemens-Zeits.*, No. 199, December, 1941.

The importance of the relay in telephone work is already well known, and the duties which it is called upon to fulfill cover an extensive range. Many thousands of different combinations of the standard variable items have already been produced to meet particular circuit conditions, and this number is constantly being increased as fresh requirements arise. While many of these relays can be employed for purposes outside regular telephone practice, some of the special adaptations open up a much wider field of application. The usefulness of the relay can thus be materially increased by modifications or additions, frequently of quite a simple nature.

The apparatus in a large modern automatic telephone exchange frequently operates under conditions approaching the ideal, with purified air maintained at a uniform temperature and humidity. In many other applications met with in practice the atmospheric conditions are far from ideal. A comparatively short time ago tropical conditions and high humidity and high temperature with a daily cyclic change were considered to be very severe, but these are by no means so arduous as those which some present day relays may be called upon to meet. The temperature range has been more than doubled—the minimum being extended far below zero centigrade—and this is often coupled with very low atmospheric pressure. By far the most severe test, however, is a rapid change from low pressures with several degrees of frost, to normal pressure and temperature with 100 per cent humidity. In addition to these conditions, the electrical requirements are much more stringent, because relays are now being applied to an increasing extent on radio apparatus where high voltages and very high frequencies demand special insulation with low loss inductance in the contact switching arrangements.

No. 807c. J. C. Chaston, "Materials for Electrical Contacts," *J.*, I.E.E., pp. 276–289 (1941).

The principal types of failure in light- and medium-duty electrical contacts are analyzed in detail and an account is given of the characteristics of the commonly used contact materials.

The effects on contact resistance of the size, shape, surface finish, and closing pressure of light-duty contacts are discussed; an account is given of the resistance of contact materials to the formation of tarnish films; and attention is directed to the effects of dust and grease films in causing failure.

In medium-duty contacts, when arcing occurs, the most serious cause of failure is the action known as "material transfer" which takes place when direct currents are interrupted. As a result of transfer the contact gap may close and the contacts finally interlock. The factors which influence material transfer are discussed, and curves are reproduced to show the limiting current and the rate of build-up for a number of common contact materials under given test conditions.

A second cause of failure is the welding together of the contacts by the current surge at make. The inherent tendency of a number of contact materials to weld together has been measured.

In sliding contacts, excessive wear is a frequent cause of troubles. A method of testing the wear of unlubricated surfaces is described, and the results of measurements on a number of combinations are tabulated. (George Durst)

No. 807d. S. Keilien, "Velocity Measurement of Transient Mechanical Motions," *J. App. Phys.*, Vol. 12, No. 8, August, 1941, pp. 634–637.

Measurement of velocity of rapid nonrecurrent mechanical motions by means of an oscillograph is described. Two methods of measurement are given: One by modifying the optical system of the oscillograph, and the other by employing a slotted disk mounted on mechanism under test. These methods offer practical means of time-distance relation measurements of small devices, such as spring-actuated levers, cam mechanisms, triggers, etc., whose performance would be affected due to the additional load required to operate auxiliary measuring instruments. (Author's abstract)

No. 807e. R. F. Tylecote, "Spot Welding, Contact Resistance," Supplement, to *J.*, Am. Welding Soc., Vol. 6, No. 12, December, 1941, pp. 591–602.

This investigation was made on the assumption that the wide variation of interfacial contact resistance was responsible for the "spread" met with in testing spot welds made under exactly identical conditions. It now appears evident that this was an entirely erroneous assumption and that interfacial contact resistance has little connection with the strength of the weld. The results show that the variation of this contact resistance is even greater than was imagined. Also that it is probably unnecessary to have a consistent interfacial contact resistance.

As regards the electrode-to-sheet contact, there is no doubt that this must be as good as possible, and some form of preparation is essential. At the moment it looks as though the paste etch preparation gives the lowest contact resistance. Unfortunately, the adverse effect on the fatigue strength is worse than with the R.A.E. pickle.

Intimately connected with the electrode to-sheet resistance are the contour and deformation of the electrodes. No research has been done on this here. All that is known is that elastic deformation does occur and that permament deformation leads to the electrodes being scrapped after about 40 welds. The question remains, however, as to what is the effect of this deformation on the strength of the weld. (Author's abstract)

No. 807f. T. W. Schroeder and J. C. Aydelott, "The 'Black Band' Method of Commutation Observation," *Trans.*, A.I.E.E. Vol. 60, pp. 446–451 (1941). Discussion, pp. 659–660.

By shunting the commutating windings with a rheostat, ammeter and v.v. exciter, the commutating excitation may be bucked or boosted until visible sparking appears. The extent to which this may be done, measured in amperes and plotted against the load current, gives two limiting curves between which lies the black band. The correlation of the black band with various commutating conditions is discussed. (*Science Abstracts*)

No. 807g. H. Thommen, "An Alternating-Very High Service Voltage and Breaking Capacity," *Brown Boveri Rev.*, Vol. 28, October, 1941, pp. 292–294.

For service voltage up to 500 kv. and breaking capacities of several million kva., an air blast high speed circuit breaker with potential-controlled multiple breaks has been developed, which can be tested in the high capacity test plants available at present. It is suited for clearing arcing short circuits, whereby a maximum of safety against interruption of service is obtained by built-in earthing switches which, during one-phase openings, momentarily earth the affected line. (*Science Abstracts*)

No. 807h. B. Storsand, "Extra-High-Speed Circuit-Breakers," *E. Bull. Oerlikon*, No. 233, p. 1460 (1941). (*Science Abstracts*)

No. 807i. H. Schulze, "On the Use of Silver Alloys as Resistance Materials, II,"

Phys. Z., Vol. 42, December, 1941, pp. 385–389. (*Science Abstracts*)

No. 807j. H. Thommen. "The Latest Development of the Air-Blast High-Speed Circuit-Breaker," *Brown Boveri Rev.*, Vol. 28, June, 1941, pp. 137–143.

Two developments are reported: (1) Application of the principle of "dual arc extinction" to design of medium voltage circuit breakers for breaking currents > 50,000 amp. This uses a damping resistance in series with a spark gap inserted in the circuit to reduce rate of rise of restriking voltage. (2) Application of potential-controlled multibreaks to design of breakers up to 500 kv. (*Science Abstracts*)

No. 807k. J. C. Chaston, "Metals and Alloys for Electrical Contacts," *Metal Treatment*, Vol. 6 (Winter, 1940–1941), pp. 143–146.

The special conditions and contact materials for instrument contacts, medium-duty contacts, and heavy-duty air- and oil-break switchgear contacts are discussed. Although nearly every branch of metallurgical practice has contributed to the development of contact materials, the most important alloys for instrument make and break contacts are: platinum-iridium platinum-ruthenium, gold-silver, palladium-silver, and palladium-copper. Some product of powder metallurgy is likely to be developed for medium-duty contacts. (*Chemical Abstracts*)

No. 807l. J. C. Chaston, "Materials for Electrical Contacts," *J.*, I.E.E., Vol. 88, August, 1941, p. 276.

The principal types of failure in light- and medium-duty electrical contacts are analyzed in detail and an account is given of the characteristics of the commonly used contact materials. The effects on contact resistance of the size, shape, surface finish, and closing pressure of light-duty contacts are discussed; an account is given of the resistance of contact materials to the formation of tarnish films; and attention is directed to the effects of dust and grease films in causing failure. In medium-duty contacts, when arcing occurs, the most serious cause of failure is the action known as material transfer which takes place when direct currents are interrupted. As a result of transfer the contact gap may close and the contacts finally interlock. The factors which influence material transfer are discussed, and curves are reproduced to show the limiting current and the rate of build-up for a number of common contact materials under given test conditions. A second cause of failure is the welding together of the contacts by the current surge at make. The inherent tendency of a number of contact materials to weld together has been measured. In sliding contacts excessive wear is a frequent cause of troubles. A method of testing the wear of unlubricated surfaces is described, and the results of measurements on a number of combinations are tabulated. (*Science Abstracts*)

No. 807m. R. Holm. "Technical Physics of Electrical Contacts," *ETZ*, Vol. 62, July 17, 1941, pp. 633–637. (In German.)

Absolutely clean metallic surfaces can only be established and maintained in a vacuum, and when such surfaces are pressed together, effective contact is limited to isolated spots. In air, metallic surfaces are covered with a film of oxides, chlorides, etc. and usually lubricated. The effects of these phenomena on contact resistance, the narrowing of the current path and the breakdown of the surface film, are discussed. Reference is made to the breakdown of thicker films (coherer resistance), and contact pressure, deformation of surface, heating effects, and sliding contact are discussed. (*Science Abstracts*)

No. 807n. W. Burstyn, "New Observations on Silver Contacts," *ETZ*, Vol. 62, February 13, 1941, pp. 149–150. (In German.)

When a noninductive circuit (220 v.) is broken between silver contacts, the limiting current for arc-free interruption is 0.45 Å. It is possible, by repeated rupture with gradually increasing current, to raise this limit to 0.95 Å, but if at any intermediate value the current is reversed, arcing occurs. This points to a "forming" of electrodes, and interchange shows that the cathode is formed. With an inductive circuit the limiting current is 0.06 Å, on exceeding this limit a brush discharge occurs from the anode, but by gradually increasing the current the limit may be raised to 0.2 Å. By repeated rupture at 0.2 Å the discharge vanishes. The reason is unknown. (*Science Abstracts*)

No. 807o. G. Poppovic, "Heat Conduction Near a Contact," *ETZ*, Vo.. 62, July 17, 1941, pp. 637–639. (In German.)

Temperature distribution in the vicinity of the end-to-end joint of two infinitely long wires carrying electric current is discussed. The assumption of complete heat insulation of the contact simplifies the problem, but the more general problem, dropping this assumption, can be solved by substituting for the constant current an exponentially increasing current. Graphical integration is applied to some numerical examples and it is shown that the temperature at the contact approaches a limit for which the formula is given (*Science Abstracts*)

No. 807p. D. Müller-Hillebrand, "Surface Contacts Under High Pressure," *Wiss. Veröff. Siemens-Werk.*, Vol. 20, No. 1, pp. 83–103 (1941). (In German.)

The contact resistance of oxidized metals

under high contact pressure is investigated. The resistance is proportional to the radius of the current conducting spot and inversely proportional to the applied pressure. Cu, Al, and Mg contacts show a further rapid increase of resistance after heat treatment; Ag, Zn, and Sn contacts do not change. The contact surface can be 99.9 per cent oxidized without noticeable resistance increase, so long as there is a sufficient number of fine fissures in the oxide layer to provide current paths. The behavior of carbon contacts is also investigated. (*Science Abstracts*)

No. 807q. F. Lucan, "Centralized Remote Switching of Lighting Installations with Automatic Interlocking of the Local Switch Positions," *ETZ*, Vol. 62, March 20, 1941, pp. 311–313. (In German.)

The switching of the corridor and staircase lighting of an extensive building block is described in illustration of the centralized remote control of heavy current circuits by a weak current source, in this case a small transformer and rectifier, for operating the remote change-over switches (*Science Abstracts* No. 1566 (1938)), interlocking devices, and auxiliary relays. The individual corridor and staircase lighting circuits can be switched, on and off by local push-button switches, which are in the weak current system. The circuits can be switched on centrally in definite groups irrespective of the local switching. When switched on centrally, the local switches are automatically interlocked and can then not be opened. When switched off centrally the interlock of the switched-in groups is automatically released. The switching of the corridor and staircase lighting is shown on an indicator at the central control post. By means of a single-push button switch at the central control post, all the corridor and staircase lighting can be switched on and interlocked. They are also all switched on automatically and interlocked in the case of a fire alarm. (*Science Abstracts*)

No. 807r. H. Thommen, "Arc Extinction in a Compressed-Air High-Speed Breaker with Single and Multi-Breaks," *Nachr.*, Brown Boveri Co., Vol. 30, October–December, 1941, pp. 68–70. (In German.)

The hollow contacts of compressed-air circuit breakers have a definite optimum arc distance for a max. arc interruption effect. The distance is relatively small and usually insufficient to withstand main voltage after the air flow stops. A single-break compressed-air circuit breaker with a dwell period at this optimum distance and subsequent quick draw-out is difficult to construct. The difficulty is overcome by a 2-break design, the first break having this optimum distance while the second break ensures subsequent isolation. A multi-break reclosing circuit breaker for 220 Kv. is described and oscillograms of its action included. (*Science Abstracts*)

1942

No. 808. J. Wulff, "Powder Metallurgy," Am. Soc. Metals, Cleveland, Ohio (1942).

This book is a collection of papers presented at the 1940 and 1941 conferences on Powder Metallurgy held at the Massachusetts Institute of Technology. The titles and authors are as follows:

"Glossary of Powder Metallurgy," J. Wulff.
"The Early Development of Powder Metallurgy," C. R. Smith.
"Developments in Metal Powders and Products," H. E. Hall.
"Sintering," P. E. Wretblad and J. Wulff.
"Effect of Time, Temperature, and Pressure Upon the Density of Sintered Metal Powders," F. E. Kelley.
"Homogenization of Copper-Nickel Powder Alloys," F. N. Rhines and R. A. Colton.
"Plastic Deformation in Powder Metallurgy," C. G. Goetzel.
"Powder Production and Classification," D. O. Noel.
"Comminuted Forms of Aluminum," J. D. Edwards.
"Bronze Pigments," H. H. Mandle.
"Stainless Steel," J. Wulff.
"Hydride Process and Its Products," P. P. Alexander.
"Metallic Catalysts," P. H. Emmett.
"Magnetic Powders and Production of Cores for Inductance Coils," E. E. Schumacher.
"Particle Size Determination for Control of Tungsten Products," M. F. Rogers.
"Effect of Particle Size on Microstructure of Cemented Tungsten Carbide," M. F. Rogers.
"Laboratory Sizing," R. Schuhmann, Jr.
"Microscopic Particle Size Determination," C. R. Rogers.
"Determination of the Surface Area and the Average Particle Size of Finely Divided Metals by Use of Low Temperature Adsorption Isotherms," P. H. Emmett.
"The Electron Microscope as a Metallurgical Tool," G. G. Harvey.
"Molding of Metal Powders," J. Wulff.
"Dies for the Fabrication of Porous Bearings," A. J. Langhammer and M. F. Smith.
"Molding Some Dense Machine Parts," R. P. Seelig.
"Machinery for Compressing Powdered Metals," L. H. Bailey.
"Sintering Atmospheres for Production Purposes," R. P. Koehring.
"Sintering Furnaces," H. M. Webber.
"Some Experiments on Hot Forging of Iron Powder Briquettes," R. P. Koehring.
"Alloy Steel from Powders," J. Wulff.
"Properties of Compressed and Heated Aluminum Alloy Powder Mixtures," L. W. Kempf.
"The Coalescence Process for Producing

Semi-Fabricated Oxygen-Free Copper," J. Tyssowski.
"Sintering Characteristics of Various Copper Powders," J. E. Drapeau, Jr.
"The Sintering of Powdered Copper-Tin Mixtures," J. E. Drapeau, Jr.
"Hot Pressed and Sintered Copper Powder Compacts," C. G. Goetzel.
"Sintered and Hot Pressed Compacts of Copper-Zinc Powder," C. G. Goetzel.
"The Sintering of Iron Powder," J. Libsch, R. Volterra, and J. Wulff.
"Hot Pressing Experiments with Iron Powders," C. G. Goetzel.
"Refractory Metals," H. W. Highriter.
"Manufacture of Tungsten Metals," P. E. Wretblad.
"Cemented Carbides," E. W. Engle.
"Tool Materials (Cemented Carbides)," P. McKenna.
"Compound Contact Metals," H. H. Hausner and P. W. Blackburn.
"Physical Properties of Metal Compositions with a Refractory Metal Base," F. R. Hensel, E. I. Larsen, and E. F. Swazy.
"Tungsten Carbides in Electrical Contacts," F. H. Clark.
"Molybdenum-Iron Alloys," J. Kurtz.
"Oil Pump Gears. An Example of Iron Powder Metallurgy," F. V. Lenel.
"Steam Treatment of Porous Iron," F. V. Lenel.
"Copper-Nickel-Lead Bearings," A. L. Boegehold.
"Sintered Alnico," G. H. Howe.
"Aluminum-Nickel-Iron Alloys," P. R. Kalischer.
"Hazards in the Production and Use of Metal Powders," E. Pletsch and T. Edwardsen.
'Patent Survey of Powder Metallurgy," A. W. Deller.

No. 809. D. I. Bohn and O. Jensen, "A Fast Circuit-Breaker," *Trans.*, A.I.E.E., Vol. 61, March, 1942, pp. 165–168.

The paper describes a six-pole anode breaker primarily designed for quick reverse current operation in order to reduce the effects of back-fires in mercury arc rectifiers. The breaker uses a holding magnet and armature specially designed for a high pull-weight ratio. An oscillogram indicates contact separation at 0.154 cycle, peak current occurring at about $^1/_4$ cycle. (*Science Abstracts*)

No. 810. H. Hausner, "Contact Problems," *Bull.*, Assoc., Suisse des Elec., Vol. 33, January 28, 1942, pp. 29–34.

The transference of contact material due to electric arcs is discussed and the limiting currents at which arcs between various metal electrodes can be maintained at various voltages are tabulated. Equations are given for the relationships between electrical and thermal conductivity and for the various parameters which determine transference of contact material, that is, the loss in weight, the electric charge and the arc current. It is shown that a good contact material should have good conductivity and great hardness and that a combination of these properties in simple metals or metal alloys is impossible. New compound materials, that is tungsten-silver, tungsten-copper, and molybdenum-copper, which were produced to overcome this difficulty, are described and their physical properties discussed. (*Science Abstracts*)

No. 811. W. Kaufmann, "Metal Vaporization by High-Power Arcs," *ETZ.*, Vol. 63, April 9, 1942, p. 162.

Comparative tests were made of the flash-over strength of insulators which had been metallized by the vaporization of copper or aluminum wires fused by a high-power arc. Only insulators in the immediate neighborhood of the arc are more damaged by the aluminum than by the copper spray. With long duration of the arc or very high currents, the flash-over voltage may drop below the service voltage. Insulators further distant than about 30 cm. or protected by cell walls are damaged neither by the aluminum nor by the copper arc. (*Science Abstracts*)

No. 812. C. Thumim, "99.44 Per Cent Dry Air for Circuit-Breakers," *Power*, Vol. 86, April, 1942, pp. 74–76.

The air required for the operation of h. v. air-blast breakers can be dried by chemical absorption, by refrigeration, and precipitation, or by compression and expansion. A brief account is given of the three methods and of combined arrangements. (*Science Abstracts*)

No. 813. K. J. R. Wilkinson and J. R. Mortlock, "Synthetic Testing of Circuit-Breakers," *J.*, I.E.E., Vol. 89, Part II, April, 1942, pp. 137–142.

An investigation was carried out to determine whether synthetic testing as a general means of extending the range of a test plant was economically preferable to a straight extension of the plant. This embraced a study of the requirements of the case and an estimate of the cost of the plant to meet these requirements. A circuit suitable for use with all types of breaker was devised. The restriking voltage was considered as of (1 − cosine) form, rising to its peak value in times of 20 to 100 microseconds. The results show that there is little difference in capital cost as between synthetic injection testing and the use of full plant kva. Moreover, it is by no means certain that the synthetic method is fully equivalent to the direct test and, as clearing up this important question would entail the comparative application of both methods, it is concluded that synthetic methods cannot generally be justified economically. (*Science Abstracts*)

No. 814. J. Zeleny, "The Mechanism of the Electric Spark," *J. App. Phys.*, Vol. 13, July, 1942, pp. 444–450.

Meek's criterion (*Sci. Abst.*, 1792 (1940)) is criticized. The importance attached to the radial field is misplaced; a criterion based solely on the total number of ions produced in an avalanche gives results for sparking potentials for different spark lengths and for a gas at different pressures in agreement with those obtained by Meek's method. The dominant exponential term in each formula is based on the incorrect assumption that the field is not affected by the space charges in the avalanche. That a large amount of ionization is produced by a h. v. wave through the channel as soon as the positive streamer reaches the cathode is questioned. (*Science Abstracts*)

No. 815. C. W. Marshall, "Circuit-Controlling Devices on Power Supply Systems," *J.*, I.E.E., Vol. 89, Part I, April, 1942, pp. 175–190.

After outlining the general principles underlying the progress of circuit control—current limitation, voltage limitation, making and breaking of circuits—the author indicates some of the trends in British switchgear development, by describing, with illustrations, a number of individual installations. Important constructional developments have been the reduction of oil content, and the emergence of the air-blast breaker as a serious rival of the oil breaker. (*Science Abstracts*)

No. 816. W. J. McLachlan and D. L. Beeman, "Fundamental Consideration in Selecting Metal-Enclosed Switches for Unit Substations and Secondary-Network Transformers," *G. E. Rev.*, Vol. 45, May, 1942, pp. 293–298.

No. 817. K. Kirsch, "Automatic Reclosing of L. V. Automatic Circuit-Breaker," *ETZ.*, Vol. 63, June 4, 1942, pp. 255–257.

An illustrated description of automatic reclosing gear for reducing as far as possible the time of interruption of supply in automatically controlled traction, transformer, or distributing networks. The reclosing is effected immediately after the interruption of the circuit and, if necessary, repeated once or several times under the control of time relays. The appliance works with or without preliminary automatic testing of the current, voltage, and phase conditions. (*Science Abstracts*)

No. 818. L. R. Ludwig, H. M. Wilcox, and B. P. Baker, "A 2,500,000 KVA. Compressed-Air Powerhouse Breaker," *Trans.*, A.I.E.E., Vol. 61, May, 1942, pp. 235–241.

After describing the principle of operation of this type of compressed-air breaker, the authors give details of its construction, and the arrangement of the air supply system. Particulars are then given of two series of tests, the first consisting of 31 successive three-phase tests at 13.2-kv. opening and closing-opening, and with currents varying from 6 to 105 ka.; the maximum current closed was 248 ka. peak. The maximum arcing time did not exceed 0.9 cycle. Oscillograms are given, and photographs are given, showing the condition of the splitters, coolers, and contacts after test; the first, two splitters showed erosion, the coolers were slightly blackened, and the arcing contacts were pitted, but the breaker was capable of further interrupting duty. The other series of tests was carried out at widely differing rates of recovering voltage, from 300 v. per millisecond up to 13,600 v. per millisecond; interruption was satisfactory in all cases. (*Science Abstracts*)

No. 819. J. M. Meek, "The Electric Spark in Air," *J.*, I.E.E., Vol., 89, Part I, August, 1942, pp. 335–351. Discussion, pp. 352–356.

The inadequacy of the classical theory of spark discharge when applied to long gaps at atmospheric pressure is discussed. A brief description is given of the streamer theory of the spark. This theory incorporates a criterion, based on atom-physical consideration, which facilitates the calculation of the b. d. potentials of different gaps in which the field distribution is known. The results of such calculations for various types of gaps are described, with particular reference to the sphere-sphere gap. Various features of point-plane breakdown are also mentioned, and an explanation is given for the occurrence of the upward-growing positive streamer from the earthed plane when the h. v. point is of negative polarity. The subject of irradiation and statistical time-lag is dealt with in some detail. Certain criticisms are given of the published standard tables for voltage measurement by sphere-gaps. The lowering of sparkover voltage for uniform and nonuniform gaps by the intense light radiated from a nearby spark source was also investigated. An explanation of the various results obtained is given in terms of the new theory of the spark. (*Science Abstracts*)

No. 820. J. Slepian, W. E. Berkey, and M. J. Kofoid, "Arc Cathodes of Low Current Density at High Amperage," *J. App. Phys.*, Vol. 13, February, 1942, pp. 113–116.

From photographs and from the marking on the electrodes, it was found (*Sci. Abst.*, 1629A (1929)) that short-duration arcs of 25 amp. in gases at a pressure of a few centimeters had apparent current densities at the cathode of less than 100 amp. per sq. cm. This is in contradiction to the density required by accepted theories of the cold-cathode arc. Similar results have been found up to currents of 5000 amp., burning for $^1/_{120}$ sec. with electrodes of various metals in air

at less than 10 cm. pressure. Cathode current densities calculated from observed marking on the electrodes were less than 1000 amp. per sq. cm. The markings on the electrodes were apparently produced by oxidation only, the energy density developed at the electrodes being insufficient to bring the electrode surface to the melting point in the $^1/_{120}$ sec. duration of the arc. The circuit interrupting capacity of these short, low current density arcs is found to be not less than that of short arcs at atmospheric pressure. (*Science Abstracts*)

No. 821. H. G. MacPherson, "Radiation from Carbon Arcs," *J. App. Phys.*, Vol. 13, February, 1942, pp. 97–102.

After a description of the low-intensity arc, the flame arc, and the modern high-intensity arc, the author discusses the reason why brightness from 350 to 1200 c. per sq. mm. can be obtained with a continuous spectrum. The explanation is that the apparent continuity is due to transmission broadening of the spectrum lines, combined with the continuous spectrum from the incandescent carbon. (*Science Abstracts*)

No. 822. J. B. MacNeil and W. B. Batten, "High-Capacity Circuit-Breaker Testing Station," *Trans.* A.I.E.E., Vol. 61, February, 1942, pp. 49–53.

Particulars are given of additions to the equipment of the Westinghouse Elect. and Mfg. Co.'s circuit breaker testing station. Limitations in the testing capacity hitherto available have made it desirable in some instances to design circuit breakers with multiple interrupters arranged for adequate distribution of voltage between them and capable of demonstration singly or in groups for the maximum duty required. The increased testing capacity will permit of simplification of circuit breaker design. A second 60,000-kva. generator has been installed and a second bank of 33,333-kva. transformers; also high-current l. v. testing equipment and a low-temperature test room (−20 F.). Two 60,000-kva. generators in parallel produce 2,000,000-kva. initial 3-ph. symmetrical short circuit at the 13.2 test cells. The transformers provide for 3-ph. tests at 345 kv. and single-phase tests at 396 kv.; and for 5-sec. tests at 200 ka. 3-ph. or 345 ka. 1-ph. Details are given of the circuits and controls. (*Science Abstracts*)

No. 823. H. R. Brooker, "Relay Contacts," *Elec. Rev.*, London, Vol. 130, May 22, 1942, pp. 651–652.

Deals with contact materials for G.P.O.-type relays for heavy duty, with particular reference to a new powder-metallurgy product known as silver-nickel "Elkonite." This material is stated to offer the required compromise between ability to withstand the destructive effects of arcing and the liability to material transfer on the one hand, and reasonably constructed contact resistance under fairly light spring pressures on the other hand. Data are given on the properties of this material on comparison with those of other contact materials. (*Science Abstracts*)

No. 824. Charles R. Underhill, "What Metals for Electrical Contacts?" *Elec. Mfg.*, Vol. 29, February, 1942, pp. 52–54, 76–78, and 102–108.

A general discussion is given of the requirements of electrical contacts in various types of circuits and applications. An interesting table is given showing the factors governing the selection of solid electrical contacts and the reasons for the selections. Problems are considered with respect to substitution of critical materials.

No. 825. H. Y. Fan, "Theory of Electrical Contact Between Solids," *Phys. Rev.*, Vol. 61, 2d Series, Nos. 5 and 6, March 1 and 15, 1942, pp. 365–371.

The phenomena of electrical contact are examined in detail. The difference between the behaviors of metals and semiconductors is pointed out. It is shown that the density of conduction electrons in a semiconductor can be expected to change appreciably from its normal value which may be important for the explanation of certain phenomena. (Author's abstract)

No. 826. J. C. Chaston, "Electrical Contacts for Instruments," *J. Sci. Inst.*, London, Vol. 19, April, 1942, pp. 50–53.

The problem of contacts for instruments differs essentially from that in heavy engineering and may again be differentiated into light- and medium-duty contacts. Light-duty contacts are those with no wear at all. Factors involved include shape and size, closing force, surface finish, dust and other matter, and inherent tarnish resistance. Point contact is impracticable and the best shape, etc., varies from different cases. No one design and material is best for all purposes. Lists of materials with different properties are given, with information on their choice. (*Science Abstracts*)

No. 827. Alfred M. Suggs, "Brightness Rating of Metal Surfaces Measured by Reflected Light," *Prod. Eng.*, Vol. 13, No. 5, May, 1942, p. 253.

The method is discussed of measuring the brightness rating of metallic surfaces. The results of experiments are given in which the brightness is measured as a function of the time on silver surfaces, and coin silver surfaces, as the brightness changes by exposure to air. Different types of surface polishes are also considered. The method uses a standard light source and photoelectric cell to measure the brightness by reflected light.

No. 828. E. F. Holt and H. C. Graves, Jr., "Electrical Surge Tests on Contact Materials," A.S.T.M. Standards on Electrical-Heating and Resistance Alloys, October, 1942, pp. 119–128.

A setup was made to determine the relative welding characteristics of various materials under heavy surge currents. Tests were run on silver and copper using a special contact holding device which minimized the electromagnetic forces involved. Currents were taken from a large welder and the contacts tested in the closed position under certain pressures. Results for copper and silver are given.

No. 829. A. M. Suggs, "An Electrical Contact Testing Machine," ASTM BULLETIN, No. 119, December, 1942, pp. 25–30; also A.S.T.M. Standards on Electrical-Heating and Resistance Alloys, October, 1942, pp. 108–118.

A mechanical make-and-break arrangement is used and three sets of contacts can be tested at the same time. The forces acting at each set of contacts are provided by two adjustable coil springs and details are given of the spring system and of a special spring scale used to measure the contact force. The method of indicating contact welding is described. Oscillograph investigations on bouncing characteristics are reported and evidence is obtained of a fairly high resistant surface film. (*Science Abstracts*)

No. 830. W. E. Campbell, "The Use of Statistical Control in Corrosion and Contact Resistance Studies," Electrochem. Soc., *Preprint 81-26*, pp. 391–404 (1942).

It is pointed out that valid predictions from experimental data cannot be made unless the data are in statistical control. This fact is a serious handicap in studies of certain corrosion processes where the magnitude of the effect being studied is of the same order as that of the variance. Contact resistance data are used as illustrative examples. Statistical criteria are described which can be used to aid in detecting and eliminating causes of lack of statistical control, and it is demonstrated how an experimental error in the contact resistance measuring apparatus was eliminated using these criteria. The apparatus is then used to study the effect of oxidation of brass on its contact resistance behavior. (Author's abstract)

No. 831. H. E. Strang and W. F. Skeats, "Field Tests on High-Capacity Air-Blast Station-Type Circuit-Breakers," *Elec. Engg.*, Vol. 61, February, 1942, pp. 100–104.

The breaker described in a previous article (*Sci. Abst.*, 2098 (1940)) was submitted to seven tests up to approximately its full rating of 1.5 million kva. On two tests the breaker failed to clear, although the damage was limited to the arc chute and the glass of some insulators. As a result of these tests, modifications were made and the present article describes the modified breaker, a series of factory tests which were made on it by means of a synthetic circuit, and a second series of field tests up to 111,000 amp. which proved completely successful. The field test results agreed closely with those of the synthetic tests. (*Science Abstracts*)

No. 832. F. H. Clark, "Tungsten Carbide in Electrical Contacts," Chapter 43, pp. 493–496, Powder Metallurgy, Edited by J. Wulff, Am. Soc. Metals, Cleveland, Ohio (1942).

Contacts on polar relays used for telegraphic communication are one of the most vulnerable parts of the assembly. The failure of a single contact can tie up a transcontinental circuit. Because of the reliability required, a great deal of work has been done on various types of materials to find the most reliable. Tungsten carbide bonded with cobalt, osmium, platinum, rhodium, or iridium was satisfactory. Tungsten carbide bonded with nickel was unsatisfactory. Tungsten borides bonded with noble metals are similar in operation to the tungsten carbide.

No. 833. F. R. Hensel, E. I. Larsen, and E. F. Swazy, "Physical Properties of Metal Compositions with a Refractory Metal Base," Chapter 42, pp. 483–492, Powder Metallurgy, Edited by J. Wulff, Am. Soc. Metals, Cleveland, Ohio (1942).

Alloys of copper and tungsten cannot be produced by ordinary metallurgical means because the two elements are not soluble in each other and do not alloy. Powder metallurgical methods have therefore been developed to produce these materials for electrical purposes such as welding electrodes and electrical contacts. The physical properties of various combinations of these materials are given. A discussion is also given of various types of switching, welding, and bearing applications.

No. 834. H. H. Hausner and P. R. Blackburn, "Compound Contact Metals," Chapter 41, pp. 470–484, Powder Metallurgy, Edited by J. Wulff, Am. Soc. Metals, Cleveland, Ohio (1942).

A brief discussion is given of the characteristics required for various types of contact materials. The metallurgy of various types of materials such as silver molybdenum, silver tungsten, and copper tungsten is considered. The effects of various processes on the physical characteristics of the materials are measured. Results of tests under operating conditions are given for silver molybdenum, silver tungsten, and other materials.

No. 835. W. Weizel and R. Rompe, "Formation of Arc Burn Traces," *Zeits. f. Phys.*, Vol. 119, Nos. 5 and 6, pp. 366 and 373 (1942).

By taking into consideration the radial extent of the arc root and the nonuniform thermal and electrical characteristics appertaining through the cross-section, the contraction of the arc root, and thereby the reduction of the required voltage to the value of the cathode drop, can be explained. (*Science Abstracts*)

No. 836. B. Thommen, "The Extinction of the Arc in Single and Multiple Break Air-Blast High Speed Circuit Breakers," *Brown Boveri Rev.*, Vol. 29, Nos. 11 and 12, November and December, 1942, pp. 336–338.

One of the most striking features of air-blast breakers with hollow contacts is that the capacity of the hollow contacts not only depends on the nozzle diameter and the air pressure, but also on the travel of the contacts. The capacity, however, does not rise uniformly with increasing contact travel, but approaches an optimum value and then diminishes rapidly if the distance between the contacts becomes still greater.

But this most favorable extinction distance is too small to give sufficient electric strength between the contacts when the stream of air ceases. Therefore, a continuous opening movement of the contacts, as is usual with other types of circuit breakers, is quite unsuitable here. These difficulties are avoided if the contact is moved rapidly into the extinction zone, made to remain there for several half-cycles, and then moved on. But the design becomes complicated.

Another simpler and successful solution consists in subdividing the rupturing operation in two separate movements, that of the arcing contacts and that of the disconnecting contacts. The travel of the arcing contact is limited so that the most effective extinction zone is utilized, and the very small mass of the contacts allows a high speed and extremely short arcing time. The opened disconnecting contact forms a reliable insulating gap.

This system proved particularly valuable for extra high voltages, whereby using a potential controlled multiple break mass the travel of the arcing contacts could be further reduced. The connection of several breaks in series gives the arcing contacts a high electric strength. The characteristic feature of circuit breakers with potential-controlled multiple break is that each individual break interrupts a definite, predetermined power. For this reason, by dealing with one break at a time, circuit breakers of the highest rupturing capacity can be tested in the existing test bays.

An interesting fact disclosed by a large number of tests is that the efficiency of a certain cross-section is greatest at a quite definite voltage range. This can also be proved theoretically.

The air blast high speed circuit breaker is particularly adapted to high speed reclosing, due to the blast of air rapidly evacuating the gas generated between the contacts.

No. 837. W. Luchsinger, "The Rupturing of Low Currents with Air-Blast High-Speed Circuit-Breakers," *Brown Boveri Rev.*, Vol. 29, August, 1942, pp. 196–198.

The overvoltage caused by switching out a transformer on no-load is usually harmless. A resistor in the circuit breaker affords reliable protection only when air-blast high-speed circuit breakers are used. (*Science Abstracts*)

No. 838. K. W. Frohlich, "Highly Efficient Contact Materials of Platinum-Free Gold Alloys," *Elektrotechn. Zeitschr.*, Vol. 63, p. 443 (1942).

An alloy approximately 97 gold, 3 zirconium is described. Its hardness is 220–240 Brinell. It has no welding tendency and it does not show tarnish or oxidation at 400 C.

No. 839. H. Raabe, "The Application of Cupal in Telephone Service," *Zeits. f. Fernmeldetechnik*, Vol. 23, 1942 (Berlin-Wannsee).

The paper deals mostly with the substitution of copper and the saving of weight in coils, condensers, etc., by the use of Cupal (copper clad aluminum). There is only one mention of a contact problem: The electrical contact between Cupal contacts is better than between copper contacts because the soft aluminum base makes for better nestling of the contact surfaces. (George Durst)

No. 840. W. E. Campbell, "The Use of Statistical Control in Corrosion and Contact-Resistance Studies," *Trans.*, Electrochem. Soc., Vol. 81, pp. 377–390 (1942).

Valid predictions from experimental data cannot be made unless the data are in statistical control. Contact-resistance data are used as illustrative examples. Statistical criteria are described which can be used to aid in detecting and eliminating causes of lack of statistical control, and it is demonstrated how an experimental error in the contact-resistance measuring apparatus was eliminated. (*Science Abstracts*)

No. 841. L. B. Hunt, "Circuit-Breaker Castings," *Elec. Rev.*, Vol. 131, December 4, 1942, pp. 713–715.

The mechanical and electrical properties of the current carrying parts of circuit breakers are described. It is claimed that these requirements are satisfied by a heat-treated chromium-copper alloy known as "Mallory 3" in preference to the usual high-conductivity copper or Admiralty gunmetal. The tensile and elastic properties of Mallory 3 are comparable with those of steel while its conductivity is of the order of that of the best copper.

Examples of its use are given. (*Science Abstracts*)

No. 842. E. H. Alexander, "How to Select, Install and Maintain Control Equipment," *G. E. Rev.*, Vol. 45, July, 1942, pp. 387–391.

Control equipment can be quite simple or very complex, and the job of the maintenance man is easier if he has available instruction books and wiring diagrams covering every piece of control and every circuit for which he has responsibility. Extra coils and contact tips should be kept on hand as well as a complete list of spare parts. Maintenance is simplified considerably if the maintenance man makes a practice of becoming thoroughly familiar with the circuits and operation of each new controller as it is installed in the plant.

No. 843. A. E. Norris, "Oil Circuit-Breaker Maintenance," *Elec. Rev.*, Vol. 131, September 18, 1942, pp. 361–363.

Some notes on the care of l.v. types, including the checking of the oil, the contacts, and the mechanism. (*Science Abstracts*)

No. 844. W. Laig-Hörstebrock, "Calculation of the End Heating of Electric Switchgear," *Arch. f. Elektr.*, Vol. 36, March 31, 1942, pp. 131–152.

An analytical article presenting methods of calculation for the end-point temperatures of conducting systems consisting of several elements. (*Science Abstracts*)

No. 845. E. F. Guest, "Fluxes Used in Soft Soldering," *Engg. Suppl., Siemens-Zeits.*, No. 206 (6 pp.), August-September, 1942.

Soft soldering is considered from the viewpoint of the connecting up of telephone apparatus, and it is emphasized that many fluxes are unsuitable for such a purpose since they are acidic in nature and cause corrosion of the soldered joint. The main purpose of a flux is to prepare the surfaces by lifting or removing any oxides or other impurities. With $ZnCl_2$ such a cleansing action cannot occur until the salts have fused, and this takes place at a much higher temperature than the m.p. of the solder alloy. Rosin is inactive in the pure state and, when heated, forms a viscous and sticky fluid which does not spread easily over the surfaces to be joined. Processes have been developed for rendering resin active, either by making it mildly acidic until a certain temperature is reached, or by rendering the active agent ineffective until a certain temperature is attained. Rosin-cored solder in which precautions have been taken to avoid air voids, provide the most suitable fluxes for use in electrical work. (*Science Abstracts*)

No. 846. "Soldering Electrical Joints," *Elec. Rev.*, Vol. 131, August 28, 1942, pp. 263–266.

Characteristics of various solder alloys are described and tabulated with specific reference to the various applications in electrical engineering. Mention is made of the Chapman commutator soldering machine. Methods of reducing consumption of tin are discussed. (*Science Abstracts*)

No. 847. "Electrical Contact Problems," *Engineer*, Vol. 174, August, 1942, pp. 146–149.

A short summary of the arcing characteristics of electrical contact materials, with data on critical currents for formation of an arc, characteristic arc voltage, and material transfer during arcing. The production of compound contact materials formed by powder metallurgy is described. These materials consist of silver or copper, providing high conductivity, compounded with molybdenum or tungsten, providing great hardness and density. (*Science Abstracts*)

No. 848. M. C. Hunter, "Pneumatic Operating Systems," *BTH Act.*, Vol. 17, October, 1942, pp. 177–181.

By pneumatic operation the closing time of circuit breakers can be reduced to one half that required for the conventional solenoid operation. This article describes the general features of pneumatic operation, including the components used and their testing, and the distinctive requirements when applying this system to circuit breakers having draw-out isolation and circuit breakers fixed in location, respectively. The question of air leakage and its reduction is considered. (*Science Abstracts*)

No. 849. R. C. Cunningham and A. W. Hill "A Compressed-Air Operating Mechanism for Oil Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 61, September, 1942, pp. 695–698.

Advantages of the use of compressed air as a source of power to close circuit breakers include flexibility in design and compactness of the unit, avoidance of heavy closing currents, and an increase in breaker speeds, especially in reclosing. (*Science Abstracts*)

No. 850. H. E. Linkh and K. Krapf, "A New Arrangement for Testing the Welding Behaviour of Contacts," *ETZ*, Vol. 63, September 10, 1942, pp. 405–409.

A method was developed for measuring the tendency of various contact materials to weld and for determining the effect on this tendency of different influences, for example, electrical conditions, surface treatment, shape of surface, frequency of switching, etc. The current in the contacts is produced by capacitor discharge. Charging (d.c.) and discharging are automatically controlled by two thyratrons. The force required for separating the contacts after they are welded together is furnished by an adjustable chain balance. The welding force varies considerably even within one

series of tests, but average values increase with increasing current. By introducing five different qualifying numbers depending on the welding force a sharp quantitative distinction could be made between the various contact materials. (*Science Abstracts*)

No. 851. H. P. St. Clair and J. A. Adams, "Transient Recovery-Voltage Characteristics of Electric Power Systems," *Trans.*, A.I.E.E., Vol. 61, September, 1942, pp. 666–669.

A field survey of representative electric power systems discloses that transient recovery-voltage conditions in connection with the interruption of short circuits are more severe than was suspected. (*Science Abstracts*)

No. 852. "Flame-Proof Switchgear," *BTH Act.*, Vol. 17, October, 1942, p. 182.

A new development in flame-proof switchgear involves the incorporation of a one-phase two-kva. air-cooled lighting transformer connected in the run of the busbars in such a way as to permit of further extensions without disturbing the position of the transformer. An illustration shows a three-panel switchboard for 3300-v., 50 c./s., three-phase circuits, with the flame-proof transformer lighting unit connected to the busbars by a flame-proof extention chamber. Similar combinations of switchgear and lighting transformer can be supplied for medium voltages up to 650/110 v. (*Science Abstracts*)

No. 853. E. E. Tugby, "A New Single-Pole Service Restorer," *Elec. Eng.* (New York), Vol. 61, December, 1942, pp. 889–892.

The device utilizes a new application for the restoring of the operating energy and the restoration of the utilized operating energy after transient fault conditions. The operating energy is contained in a motor-rewound flat spiral spring where enough energy is stored to provide four opening operations and three reclosing operations on a sustained fault without rewinding, and an infinite number of operations on transient faults. (*Science Abstracts*)

No. 854. A. K. Leuthold, "Design and Operation of High-Voltage Axial Air-Blast Circuit-Breakers," *Elec. Eng.* (New York), Vol. 61, December, 1942, pp. 869–875.

The principles of design and operation are explained and the construction of 2 h.v. air blast circuit breakers rated at 150 kv. and 220 kv. is described and supplemented by a discussion of performance tests and oscillograms. The construction of a circuit breaker with axial blast, designed for e.h.v. and high i.c., is explained, and test results discussed. (*Science Abstracts*)

No. 855. H. W. Haberl and R. A. Moore, "Some Air-Blast Circuit-Breaker Installations in Canada," *Elec. Eng.*, (New York), Vol. 61, December, 1942, pp. 859–863.

A brief report on certain installations including results of interrupting tests and operating experience. (*Science Abstracts*)

No. 856. T. W. Schroeder, E. W. Boehne, and J. W. Butler, "Tests and Analysis of Circuit-Breaker Performance when Switching Large Capacitor Banks," *Trans.*, A.I.E.E., Vol. 61, November, 1942, pp. 821–831.

The performance of power circuit breakers when switching large capacitor banks is investigated. The problem is analyzed and results are given for tests on full scale and miniature capacitor banks. The oil blast and Magne-blast types of circuit breakers were used and conclusions are drawn with respect to the correct selection of breakers. (*Science Abstracts*)

No. 857. J. W. Seaman and L. W. Morton, "A New Multiple High-Speed Air Circuit-Breaker for Mercury-Arc-Rectifier Anode Circuits and Its Relation to the Arc-Back Problem," *Trans.*, A.I.E.E., Vol. 61, November, 1942, pp. 788–796.

An analysis of the arc-back problem and various means of protection from its effects. High-speed anode switching is an improved type of arc-back protection. The requirements which the multipole high-speed air circuit breaker must meet are discussed, and the electrical and mechanical features described. Performance was checked in field tests. (*Science Abstracts*)

No. 858. J. B. MacNeil, "Switchgear Practice in Europe and America," *Elec. Eng.* (New York), Vol. 61, December, 1942, pp. 609–613.

The history of switchgear apparatus in Europe and America and the present trends in development of switchgear on both continents have been analyzed in the light of current needs and facilities. The requirements of each of three major classes of switchgear are considered individually. (*Science Abstracts*)

No. 859. R. C. Van Sickel, "Transient Recovery Voltage and Circuit-Breaker Performance," *Trans.*, A.I.E.E., Vol. 61, November, 1942, pp. 804–813.

Recent tests on the response of h.v. breakers to both single and double frequency transient recovery voltages having natural frequencies up to 200 kc./s. showed similarities in the performance of different types of breakers; difficulty of interruption did not increase indefinitely with increasing natural frequency, and the maximum arcing time at a given voltage and current was obtainable in a high-power circuit breaker testing laboratory. (*Science Abstracts*)

No. 860. K. W. Fröhlich, "Platinum-Free High-Duty Contact Materials on Gold Basis," *ETZ*, Vol. 63, September 24, 1942, pp. 443–445.

Gold-silver compounds have proved ac-

ceptable substitutes for platinum-containing contact materials where mechanical stresses are not excessive and no tendency exists for transfer of the material in the switching process. The minimum gold content required is 66 per cent, or, if tarnishing must be avoided, 80 per cent. For higher resistance against abrasive forces gold-nickel compounds are used if the higher contact resistance is not prohibitive. Gold-zirconium compounds have not the disadvantages of these compounds and most of the advantages of platinum-iridium compounds. Comparative tables are given. (*Science Abstracts*)

No. 861. "Silver-Plating Switch Contacts," *Elec. News Engg.*, Vol. 51, November 15, 1942, p. 34.

Note on the experiences of a Canadian company. (*Science Abstracts*)

No. 862. T. Siegfried, "Automatic Circuit-Breaker and Its Use for Motor and Circuit Protection," *Bull.*, Assoc. Suisse des Elec., Vol. 33, pp. 721–725 (Sec. 2, 1942).

The conditions imposed by the necessity of protecting l.v. urban and industrial networks against overload are discussed and two types of circuit breakers are described of nominal rating 250 and 400 amp. 500 v.a.c. One of the models operates independently of the magnitude of the overload current. The second operates on a thermal principle and hence the release time decreases rapidly as the overload current increases. Constructional details are given. (*Science Abstracts*)

No. 863. H. Kroemer, "The Arc at Fusing Conductors in Sand," *Arch. f. Elektr.*, Vol. 36, August, 1942, pp. 455–470.

By means of a probe method and a moving coil oscillograph, the laws governing the fusing of conductors with locally reduced cross-section and surrounded by sand were investigated. Current densities of 50,000-100,000 amp./cm.^{2} were applied. At the arc head a voltage gradient of 300 v./cm. was observed. this gradient decreasing with longer duration of the arc. The arc voltage depends neither on the material of the conductor nor—for a certain range—on its cross-section. But the nature of the extinguishing material has a great influence on it, for example, the arc voltage with sand has about three times the value of that with sintered corundum. The arc characteristic was positive. The electrode consumption is compared with that of open arcs. An extinction constant is proposed, allowing of predicting the course of extinguishing the arc by certain arrangements under s.c. conditions. (*Science Abstracts*)

No. 864. A. M. Suggs, "An Electrical Contact Testing Machine," *Bull.*, Am. Soc. Testing Mats., No. 119, December, 1942, pp. 25–30.

A mechanical make and break arrangement is used and three sets of contacts can be tested at the same time. The forces acting at each set of contacts are provided by two adjustable coil springs and details are given of the spring system and of a special spring scale used to measure the contact force. The method of indicating contact welding is described. Oscillograph investigations on bouncing characteristics are reported and evidence is obtained of a fairly high-resistance surface film. (*Science Abstracts*)

No. 865. "Junctions in Aluminum Cable," *Light Metals*, Vol. 5, October, 1942, pp. 388–395.

Illustrated description and test results of various types of mechanical jointing devices for aluminum conductors, based on recent German publications. (*Science Abstracts*)

No. 866. H. Y. Fan, "Contacts Between Metals and Between a Metal and a Semiconductor," *Phys. Rev.*, Vol. 62, October 1 and 15, 1942, pp. 388–394.

The problem is treated classically with the help of the results of wave-mechanical theory of electron energy states in solids. The potential and electron-density distributions in two bodies near the contact are discussed. The bodies are assumed to be in immediate contact. The problem of a body in vacuum and the problem of two bodies separated by a gap are discussed qualitatively. (*Science Abstracts*)

No. 867. W. O. Schumann, "The Stabilization of the Controlled Vacuum Arc and the Arc Constants," *Arch. f. Elektr.*, Vol. 36, June, 1942, pp. 362–377.

An analytical investigation of the stable and labile conditions for various connections. (*Science Abstracts*)

No. 868. H. Raabe, "The Application of Copper Plated Aluminum Sheets in Communication Techniques," *Zeits. f. Fernmeldetechnik*, Vol. 23, 1942 (Berlin-Wannsee).

The paper deals mostly with the substitution of copper and the saving of weight in coils, condensers, etc., by the use of Cupal (copper clad aluminum). There is only one mention of a contact problem: The electrical contact between Cupal contacts is better than copper contacts because the soft aluminum base makes for better nestling of the contact surfaces.

Note.—Comment by George Durst: I have known these facts and I know that a similar observation has been made for silver clad aluminum contacts. The differences in voltage drop are, however, only small and vary, of course, with the contact pressure and the thickness of the contact metal layer. (George Durst)

No. 869. E. G. Ratz, "Some Canadian Developments in Relays and Relay Applica-

tions," *Elec. News Engg.*, Vol. 151, November 15, 1942, pp. 31–33, and December 1, 1942, pp. 20–22.

Nov. 15: Generator protection covered; overcurrent and overvoltage protection; generator field protection. *Dec. 1:* Transformer and transmission line protection; use of coupling capacitors for distance relays; impedance relays supplemented by current balance; coordination of impedance and directional elements; use of impedance relays for phase-to-ground protection. (Before Am. Inst. Elec. Engrs.) (*Engineering Index*)

No. 869a. H. Y. Fan, "Contacts Between Metals and Between a Metal and a Semi-Conductor," *Phys. Rev.* (II), Vol. 62, (7/8) pp. 288–294 (1942).

No. 869b. B. Fernier, "Opening 380 kv. Lines," *Bull. Soc. Franc. Elect.*, Vol. 2, April, 1942, pp. 181–198. (In French.)

Gives details of a 1-pole 2-break oil-blast circuit breaker with isolating switch; three synchronized units provide 3-phase interruption. Operating time is 0.06 sec. (mechanism) + 0.05 sec. (arcing), rigid mechanical transmission being used throughout. The porcelain operating chamber with oil on both sides and capillary communication between them; the break is at the bottom of the chamber and arc is first drawn into an explosion pot for heavy currents and further into a second chamber with a servo-oil-blast actuated by spring compression to deal with light currents (this reduces the arcing time at the critical current of 80 Å. from 0.12 to 0.06 sec.). The pressure chamber is cushioned by a spring which reduces external reactions on the porcelain to 5 per cent of their (rigid) value. Tests on a single break up to 250 kv. are satisfactory; division of voltage between breaks is between 60/40 and 55/45. Two breaks are preferred to a 40-break design of 1937. Oscillograms of heavy and light current tests are given; the latter include opening of charging currents to an artificial line. (*Science Abstracts*)

No. 809c. T. Buchhold, "On the Controlling Effect of Small a.c. Arcs and Its Application to the Spark-Free Operation of a.c. Contactors and Circuit Breakers," *ETZ*, Vol. 63, December 31, 1942, pp. 601–608.

If the switch controlling the magnet coil of a relay, contactor, or the like is opened the arc formed at its contacts causes the relay coil current to reach its zero-value slightly in advance of the time taken if no arc were formed. This behavior is investigated and it is shown how it may be used for controlling the spark-free operation of a-c. contactors. The influence of the contact material is discussed and the part played by its evaporation temperature is explained. Synchronous current impulses, preferably of rectangular shape obtained by distorted voltage curves, are used for feeding the relay coil. Examples show the application of the method on single-phase and 3-phase contactors and circuit breakers. On single-phase contactors the spark-free operation may be controlled by a simple additional set-screw. Spark-free operation may also be obtained with varying power factor, (*Science Abstracts*)

No. 869d. P. Aubry, "Factory Transformer Station Using Oil-Less Circuit-Breakers," *R.G.E.*, Vol. 51, February, 1942, pp. 96–101. (In French.)

This 4000 kva. substation is protected on the 12 kv. side by two manually operated 4-pole air blast breakers with a rupturing capacity of 125 mva. Each of four transformer groups is Scott connected, distributing at 200–115 v., 4-wire. The arrangement is illustrated and the protective gear described. (*Science Abstracts*)

No. 869e. K. Kesl, "New Scheme of Connection for Current Limiters, Contactors, Protective Gear and Especially for Small Automatic Breakers," *R.G.E.*, Vol. 51, February, 1942, pp. 85–96. (In French.)

Small distribution connections close to a transformer station may be subject to short-circuit currents sufficient to damage the individual protective arrangements. The present proposal is to protect a group of small connections by a main current limiter comprising a very rapid circuit breaker of special design which interposes a resistance sufficient to limit the current to a value within the capacity of the small protective gear. The design is fully described with oscillograms and test data; it is spring closed, opening electromagnetically. Extinction times are 1.5 to 2 ms at 1.5 to 2 ka., 220 v.; and 4 to 5 ms at 5 to 10 ka., 500 v. (*Science Abstracts*)

No. 869f. A Windmüller, "Switching Diagrams for Electric Industrial Plants and Their Practical Use," *Nachr.*, Brown Boveri Co., Vol. 29, April-September, 1942, pp. 41–47. (In German.)

Standardized symbols representing electrical and mechanical switching elements are proposed. Complicated switching diagrams can be simplified by the proposed methods to aid design and understanding. Examples of the method are shown applied to a lathe, a circuit breaker, and other a-c. and d-c. drives A method of design for complicated switching requirements is given using the simplified system and explained by means of a remote-controlled motor example. (*Science Abstracts*)

No. 869g. G. Scarpa, "Small Size Metal-Clad Switchgear for High Voltages," *Elettrotecnica*, Vol. 29, October 10, 1942, pp. 405–408. (In Italian.)

A new design of metal-clad switchgear of the air-insulated type and for voltage ratings in the range 10–30 kv. is described. Either low-oil content or air-blast breakers can be used, and they are interchangeable. Busbars and connections are covered with thick synthetic resin, laminated, extruded, or molded insulation which, in addition to deep spout bushings, allow a reduction of clearances to a minimum: 30- and 15-kv. models have phase centers at 70 and 50 cm., respectively. It is claimed that the cost of the equipment is equal to that of equivalent gear of the open type and a considerable saving in building costs can be achieved. Layout drawings are given. (*Science Abstracts*)

No. 869h. G. Someda, "Further Developments in the Study of a Circuit-Breaker Testing Plant Which Employs an Oscillatory Circuit," *Elettrotecnica*, Vol. 29, November 25, 1942, pp. 477–483. (In Italian.)

The theory and practical implications of the method suggested in *Science Abstracts* No. 2991 (1947) are amplified. Data supplied by Siemens show that with the exception of plain-break oil types, the energy available is sufficient for testing all modern 10-kv. breakers, and it is claimed that this limitation does not hold for ratings of 100 kv. and above. The validity of single-pole testing and the absence of asymmetrical components are discussed. Short-circuit test cycles to I.E.C. rules can be carried out as well as high-speed B.M.B. tests, since only fast breakers are suitable for this duty. Apart from cost, the advantages of the method are listed. Details of a plant under consideration are described which, by series-parallel connection of four sections, will give 400 mva. at 7.5–120 kv. (*Science Abstracts*)

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No. 870. C. B. Gwyn, Jr. "Things You Should Know About Contact Assembly Methods," *Elec. Mfg.*, Vol. 31, February, 1943, pp. 89–92 and 162–164.

Various methods for attaching contact materials to the supporting arm are discussed. These include the methods of riveting, spot welding, electric brazing, and furnace brazing. The methods are discussed in detail with respect to the ease of attaching and the economics of the operations.

No. 871. W. Richter and W. H. Elliot, "An Instrument for the Determination of Contact Making and Breaking Time," *Elec. Eng.*, (New York), Vol. 62, January, 1943, p. 14.

This paper describes an electronic instrument for the measurement of the arcing time of a contact closing or opening a circuit. This measurement is accomplished by permitting a current of constant value to flow into a capacitor during the time that an arc exists across the contacts under observation; the charge accumulated on the capacitor is therefore a measure of the arcing time. The instrument also contains electronic means of measuring the charge on the capacitor, by determining the voltage existing across it at the end of the measurement. The circuit serving this purpose is a Wheatstone bridge with a tube in one arm, to whose grid the capacitor is connected, and a microammeter in the diagonal which indicates directly the amount of unbalance produced by the capacitor voltage. The application of the instrument to the investigation of a three-pole contactor is described. (Authors' synopsis)

No. 872. K. W. Frolich, "Platinum-Free Heavy Duty Contact Materials on a Gold Basis," Communication from the Research Lab. Degussa-Siebert, Hanau (1943).

The field of electrical contact materials has become strongly fluid within the past few years. Recently gold alloys have, to an increasing amount, been introduced in electrical engineering practice. The properties of the three most important representatives of these gold alloys, *viz.*, one alloy each of gold with silver, nickel, and zirconium, respectively, are discussed. (*Science Abstracts*)

No. 873. M. Pirani, "Conditions Favouring the Start of an Arc Discharge Between Cold Activated Electrodes at 50 c./s.," *Trans.*, Electrochem. Soc., Vol. 83, Preprint No. 20, 1943.

The start of an a-c. arc discharge between two activated electrodes in a rare gas filling takes place in two stages: (1) h.v. glow discharge of low current, and (2) a change-over to the l.v. high-current arc discharge. The change-over is favored by electrodes comprising a pellet of special physical structure and chemical composition producing small amounts of active barium. (*Science Abstracts*)

No. 874. P. L. Taylor and H. W. Martin, "An Improved Axial-Air Blast Interrupter for Severe Operating Duty," *Trans.*, A.I.E.E., Vol. 62, June, 1943, pp. 323–333.

Describes the development of a small axial-air-blast circuit breaker for use in standard metal-clad installations to meet the requirements of severe repetitive duty cycles. The unit is of rating 2000 amp., 5 kv., 150,000 kva. Design details are given, with particular attention to the contacts; also the results of interrupting tests carried out on an experimental unit. Circuit breaker operating sequence, and transient recovery voltage control with axial-air-blast breakers, are dealt with. (*Science Abstracts*)

No. 875. "A Low-Voltage Air-Break Circuit-Breaker," *Elec. Ind.*, Vol. 43, November, 1943, pp. 328–329.

Describes the new air circuit breaker developed by Metropolitan-Vickers for systems up to 660 v., three-phase with current ranges of 600, 1200, 2000, and 4000 amp. (*Science Abstracts*)

No. 876. M. S. Coover and E. E. Jones, "Some Measures of Electrical-Brush Disintegration," *Trans.*, A.I.E.E., Vol. 62, December, 1943, pp. 750–754.

The concepts of wear resistance, wear resistivity,wear susceptance,and wear susceptivity of brushes, are significant and useful tools that may further an understanding of the basic problems of sliding electrical contacts. The conditions responsible for producing wear and those responsible for resisting wear can be distinguished. Effects of current density, ring speed, brush pressure, and relative humidity are considered. (*Science Abstracts*)

No. 877. K. Goldschmidt, "Time Control of Trip Actuation in A.C. Circuits," Rep. Brit. Elect. Allied Industr. Res. Ass. Ref. G-T161a (5 pp.), 1944; *J. Beama.*, Vol. 50, December, 1943, pp. 377–379.

A device developed for controlling the initiation of s.c. currents in a switchgear testing plant is described. It consists of a three-phase transformer with fixed tappings from which a voltage of constant amplitude is obtained, with phase variable within ±180 deg. with reference to any voltage in the three-phase system, which is fed into a one-phase peaked-wave transformer, a secondary voltage impulse of which can be shifted by 360 deg. with reference to any vector in the three-phase system. This impulse can be used to trip a contactor at a predetermined phase or time delay from a reference vector. (*Science Abstracts*)

No. 878. A. R. Blandford, "Air-Blast Circuit Breakers," *J.*, I.E.E., Vol. 90, Part II, December, 1943, pp. 411–452. *English Elec. J.*, Vol. 10, June, 1943, pp. 150–155, and December, 1943, pp. 165–172.

Improvements in design are discussed. The principal characteristics of air blast circuit breakers are reviewed and comparisons between oil and oilless circuit breakers are made. The cross blast breaker is referred to, but the paper deals mainly with the axial blast type developed by Brown Boveri and A.E.G. A description of 11 kv. and 66 kv. air blast designs by the English Electric Co. is given and the applications of these designs to service equipments are reviewed. (*Science Abstracts*)

No. 879. A. M. Suggs, "An Electrical Contact-Testing Machine," *Metal Ind.*, July 23, 1943, pp. 55–57.

A cam-and-lever movement is used for operating the three sets of contacts under test, the forces acting at each set of contacts being provided by two adjustable coil springs. The bounce characteristics of the actuating mechanism and contacts are studied with the aid of an oscilloscope. (*Science Abstracts*)

No. 880. A. C. Gibson, "The Use of Silver As a Contact Metal in Switchgear," *BTH Act.*, Vol. 18, July, 1943, pp. 55–61.

Switchgear contacts are divided into: (1) fixed bolted connections; (2) isolating contacts; required to carry current but not to make or break; and (3) switching contacts for current making or breaking. Each group is considered separately and subdivided into surface and line types. The surface preparation and the thickness of silver to be deposited are discussed and methods of deposition are noted. (*Science Abstracts*)

No. 881. "Interim Report on Application and Operation of Circuit-Breakers and Switchgear," *Trans.*, A.I.E.E., Vol. 62, July, 1943, pp. 481–482. A.I.E.E., Committee on Protective Devices, Subcommittee on Circuit Breakers, Switches and Fuses.

This is a report designed to recommend the best operating practices so that the maximum use may be made of existing equipment and that a minimum amount of material be used for new equipment. This report covers recommendations for the following types of equipment:

1. A-C power circuit breakers above 600 v., both indoor and outdoor.
2. Air disconnecting switches, and
3. Switch gear assemblies.

The factors which are considered are: Basis of Design of Apparatus, Effect of Ambient Temperature, Artificial Cooling, Emergency Loading, Modification of Existing Equipment, and Simplification of New Installations.

No. 882. A. F. Puchstein, "Commutation in A.C. Motors," *Elec. Eng.*, (New York), Vol. 62, July, 1943, pp. 325–326.

Analysis is given covering the solution of the differential equation of commutation where the brush covers one bar in the case of a-c. commutator machines. The solution is limited as most of these problems concerning brushes are in the fact that certain factors which are sometimes important must be neglected to give the problem an expression which can be solved. However, expressions for the current density, wattage per brush, are developed for both a.c. and d.c. The case where the brush covers more than one segment is discussed briefly. (*Science Abstracts*)

No. 883. V. Easton, "Some Factors Affecting the Design of Alternators for Switchgear Testing," *J.*, I.E.E., Vol. 90, Part II, August, 1943, pp. 202–216.

The mechanical and electrical factors are subdivided as follows: (*a*) electrical design, (1) reactance, (2) time constants and damping circuits, (3) recovery voltage, (4) speed of

plant, and (5) losses; (*b*) mechanical design, (1) slot conductors, (2) end windings, (3) foundations, and (4) couplings. Methods of increasing the output of this type of alternator are reviewed and involve the use of external reactance, increased initial voltage, shorter duration of test, super-excitation, or parallel operation of plant. (*Science Abstracts*)

No. 884. A. E. Anderson, "Short-Circuit Currents. I, II." *G. E. Rev.*, Vol. 46, June, 1943, pp. 316–319, and July, 1943, pp. 399–401.

Part I gives a comparison between calculated and measured currents on a l.v. a.-c. testing circuit in which rms. values over 100 ka. were measured, and whence it is concluded that good agreement can be achieved if the circuit constants are known. In Part II the effect of power transformers, l.v. generators, induction- and synchronous-motor loads are discussed, as well as the contributions of the d.-c. component. (*Science Abstracts*)

No. 885. F. R. Hensel and J. W. Wiggs, "Special Metals in the Electrical Industry," *Elec. Eng.* (New York), Vol. 62, July, 1943, pp. 296–302.

A survey of metals according to type of application, such as resistor materials, bimetals, contact alloys, resistance-welding electrodes, special magnetic alloys, materials used in electronics and special alloys for meters. (*Science Abstracts*)

No. 886. U. R. Evans, "Laws Governing the Growth of Films on Metals," *Trans., Electrochem. Soc.*, Vol. 83, Preprint, No. 10 1943.

Three laws have been established, expressing the thickness y of a film of oxide, sulfide, or iodide formed on metal exposed to a nonmetal for time t: $y = K_1 t$, $y^2 = k_2 t + k_3$, $y = k_4 \log (k_5 t + k_6)$. The paper discusses the theoretical basis of these laws and other mechanisms of film growth. (*Science Abstracts*)

No. 887. T. W. Wilcox, "Air-Blast Circuit-Breakers," *Elec. Times*, Vol. 104, July 8, 1943, pp. 32–35.

Axial-flow, radial-flow, and cross-blast arc interruption are described. The conditions existing during arcing are discussed and the use of resistors and probe gaps considered. On 132-kv. breakers the resistor current cannot be interrupted on a probe gap on the l.p. side of the nozzle and it is necessary to provide a separate pair of contact nozzles operating at full pressure. (*Science Abstracts*)

No. 888. R. C. H. Richardson, "Function, Characteristics and Installation of Circuit-Breakers," *Min. Elec. and Mech. Eng.*, Vol. 23, June, 1943, pp. 48–59.

Deals primarily with the oil circuit breaker, the nature of the current during short circuit, and the demands on the breaker; methods of arc extinction by oil-blast and cross-jet explosion pots; installation in substations and industrial plants. (*Science Abstracts*)

No. 889. H. A. P. Langstaff and B. P. Baker. "A Vertical-Flow Compressed-Air Circuit-Breaker and Its Application on a 132 kv. Power System," *Trans.*, A.I.E.E., Vol. 62, April, 1943, pp. 188–192.

Details are given of the construction and operation of a 138-kv., 1,500,000-kva. 3-pole breaker. Before installation at the Kittanning substation of the West Penn Power Co. its interrupting ability was checked and the mechanical operation was tested with the breaker in heavily iced conditions at −14 F. The air-supply system was tested at −4 F. and the breaker was found to operate satisfactorily. A description of these tests is given. A brief outline of its performance during three months of operation is presented. (*Science Abstracts*)

No. 890. R. C. Dickinson and B. I. Hayford, "A New 50,000 kva. Oilless Circuit-Breaker and Metalclad Switchgear Unit," *Trans.*, A.I.E.E., Vol. 62, June, 1943, pp. 302–306.

The design specifications for the breaker unit and metalclad structure are given. A general description of the unit as a whole is presented and illustrated. The steel housing consists of a welded steel frame with sheet steel barriers dividing it into three compartments. The breaker itself is of the magnetic deion type using spaced insulating plates of nongasforming material having tapered slots into which the arc is moved by a magnetic field. Details of tests on the unit itself as well as of supplementary tests on assembled switchgear are given. (*Science Abstracts*)

No. 891. E. A. Williams and W. G. Harlow, "The Auto-Blast Interrupter Switch," *Trans.*, A.I.E.E., Vol. 62, April, 1943, pp. 176–181.

An air interrupter switch in a nonautomatic air switch which combines the function of a disconnecting switch with the ability to interrupt current up to a predetermined magnitude. General specifications are proposed. The auto-blast type has each pole equipped with an arc chute into which the arc is driven by a blast of air generated automatically when the switch is opened. Interruption occurs within the chute by elongating and cooling the arc. The construction and operation are described and test data presented. (*Science Abstracts*)

No. 892. P. H. Estes, "Contact Bounce," *G. E. Rev.*, Vol. 46, June, 1943, pp. 321–323.

A recorder is described in which the relay under test is operated automatically at between 1 and 20 operating cycles per second. Contact at back of front controls the grid of a

valve amplifier which produces a potential between 200 and 600 v. between a stylus and a rotating drum carrying Teledeltos paper (which turns black when voltage is supplied to the stylus). Time intervals of 0.2 ms. can be read to an accuracy of 0.1 ms.; at low speed intervals up to 0.5 s. can be measured. (*Science Abstracts*)

No. 893. E. E. Hutchings, "Methods for Improving Electrical Continuity of Joints in Screwed Steel Conduit Joints," Rep. Brit. Elect. Allied Industr. Res. Ass. Ref. F/T157 (8 pp.) 1943.

Certain general trends on the purely electrical aspect of the problem are summarized. Various protective coatings and jointing methods are examined. (*Science Abstracts*)

No. 894. L. Kallir and E. E. Hutchings, "Electrical Continuity of Steel Conduit Joints," Rep. Brit. Elect. Allied Industr. Res. Ass. Ref. F/T152a (11 pp.) 1943.

Describes an investigation on screwed- and gripped-type steel-conduit joints to determine under what conditions higher resistances may occur. Tests were made to study the effects of exposure to abnormal humidity, contact with wet concrete and mechanical stresses. Measurements were made on existing installations in buildings. (*Science Abstracts*)

No. 895. "Outdoor Switchgear," *Elec. Rev.*, Vol. 133, December 4, 1943, pp. 731–734; see also *J., Beama*, Vol. 50, December, 1943, pp. 380–382.

Outdoor switchgear of the small-oil-volume type is described, including types from 33 kv. to 132 kv. and having breaking capacities of from 500 to 1500 mva. Pneumatic operating mechanism with electromagnetically operated control valves is employed. The air-control device is a rectangular turbulator. Circuit breakers can be operated manually. (*Science Abstracts*)

No. 896. C. W. Kuhn, "Aircraft Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 62, October, 1943, pp. 642–645.

The design of circuit breakers for aircraft purposes can be combined with switching and contactor functions. The principal function of both manual and telecontrol circuit breakers is to provide s.c. protection. Typical examples are surveyed with the aid of diagrams. Provision must be made for holding the circuit closed in an emergency. (*Science Abstracts*)

No. 897. R. A. Millermaster, "Manual Switches for Aircraft," *Trans.*, A.I.E.E., Vol. 62, September, 1943, pp. 596–598.

A brief discussion of performance characteristics of a switch on various types of circuit and under various conditions. (*Science Abstracts*)

No. 898. F. J. Russell and A. P. Charbonneau, "Aircraft Contactors," *Trans.*, A.I.E.E., Vol. 62, September, 1943, pp. 563–566.

Special design features are discussed, especially contacts, magnet and mounting, with regard to service (atmospheric) conditions and the accessories and equipment with which contactors are used. (*Science Abstracts*)

No. 899. R. B. Anderson, "Auto-Reclose Switchgear," *Elec. Rev.*, Vol. 133, December 10, 1943, pp. 770–773.

The author discusses rapid re-establishment of supply in rural areas in the event of interruptions. Construction and operation of automatic-reclose switchgear and periodic-reclose relays are described. A fully automatic substation switching arrangement is shown in diagrammatic form. Improvements in design should reduce the amount of maintenance necessary for h.v. switchgear in oil circuit breakers and on auxiliary components. (*Science Abstracts*)

No. 900. J. W. Donaldson, "The Hardness Testing of Metals and Alloys," *Metallurgia*, May, 1943, pp. 3–9.

Methods of testing and measuring the hardness of metals and alloys in modern use are described. (*Science Abstracts*)

No. 901. L. R. Ludwig and W. M. Leeds, "A Multi-Orifice Interrupter for High-Voltage Oil Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 62, March, 1943, pp. 119–125.

A description is given of the development and design of a multiorifice oil-flow interrupting unit which makes possible three-cycle breaks on 230 kv. with only two interrupting units per pole. Results of laboratory tests are presented and illustrated with oscillograms. Exceptional results are claimed on low magnetizing and charging currents as well as on short circuit current. (*Science Abstracts*)

No. 902. A. Roth, "A New Oil-Blast Circuit-Breaker for Medium Voltages," *Bull.*, Assoc. Suisse Elec., Vol. 34, May 19, 1943, pp. 291–294.

A new design of the oil-blast chamber which results in reduced over-all dimensions and oil content of breakers below 45 kv. is described and illustrated. An oscillogram shows the interruption of 5800 amp. under 23 kv. in less than 0.03 sec. A special design of the contacts is discussed. (*Science Abstracts*)

No. 903. John D. Kleis, "Design of Electrical Contacts for Trouble-Free Service," *Prod. Engg.*, November, 1943, pp. 733–737.

Nature of both mechanical and electrical failures in contacts used on electrical devices is described, analyzed, and classified. For each condition, design rules and solutions or remedies are given to obtain correct performance. Also methods of testing to facilitate selection

of contact materials, properties, and types. (*Product Engineering*)

No. 904. R. G. Lockette, "The Air Circuit-Breaker in the Steel Industry," *Iron and Steel Engr.*, February, 1943, pp. 54–60.

The general application of switchgear to the steel industry is discussed. The ordinary ironclad oil-immersed breaker is widely used, but there are certain protective schemes to which air circuit breakers adapt themselves. Examples are given and the use of the air circuit breaker is discussed. One of the most interesting developments is for checking a d.-c. short circuit when there is a back-fire on a mercury-arc rectifier anode. (*Science Abstracts*)

No. 905. R. A. Evans, "The Performance of Circuit-Breakers Under Short-Circuit," *Min. Elec. and Mech. Eng.*, Vol. 23, April, 1943, pp. 121–123.

A straightforward account of the phenomena which occur during an a.-c. short circuit. Diagrams illustrate the nature of the s.c. current, the form of which is discussed for the transient period only. The factors which affect the success of arc extinction are set out with reference to asymmetry and restriking voltage. (*Science Abstracts*)

No. 906. N. B. Priestnall, "Air-Break Circuit-Breakers, High Breaking-Capacity, for Medium-Voltage A.C. Systems," *M. V. Gazette*, Vol. 20, April, 1943, pp. 160–166.

The essential features of design are given. The Metrovick type air circuit breaker is described. Contact is made by means of rolling butt contacts for ratings below 600 amp. and by main contacts and rolling butt contacts with higher ratings. The arc chute is quite small, metal bars being inserted to facilitate cooling. Oscillograms of tests are shown, together with a series of tables giving a complete test duty cycle. (*Science Abstracts*)

No. 907. "Automatic Transfer Switch," *R. Sci. Inst.*, Vol. 14, March, 1943, p. 80.

All contacts are carried on one shaft and operate in the same direction. At all times the contacts are either in the normal or in the emergency position. One magnet frame with the coil connected to the normal supply line holds the normal contacts closed and the emergency contacts open during normal operation. On failure of the normal service the normal contacts open by gravity, and the emergency contacts close by means of individual compression springs on each contact, (Zenith Electric Co., Chicago, Ill.). (*Science Abstracts*)

No. 908. H. C. Hoban, "Oscillographic Study of Pre-arcing Energy in Fusible Cut-Outs," *Distrib. Elect.*, Vol. 15, January, 1943, pp. 63–67.

To forecast accurately the discriminating properties under s.c. conditions, it is necessary to have reliable information relating to the pre-arcing energy expended in the fuse. Tests involving a record of the change of voltage across a fuse when subject to a heavy current were made and the results are described. (*Science Abstracts*)

No. 909. W. Spraragen and B. A. Lengyel, "The Physics of the Arc," *Welding J.*, January, 1943, pp. 2-s–42-s.

The literature on new facts and theories on the physics of the arc up to February, 1942, is comprehensively reviewed. The characteristics of the arc, the theory of arc formation, the forces acting on the electrodes, the transfer of material across the arc and the a.-c. arc are described. Welding arcs are considered. Magnetic arc blow is discussed. (Bibliography.) (*Science Abstracts*)

No. 910. L. F. Hunt, E. W. Boehne, and H. A. Peterson, "Switching Over-Voltage Hazard Eliminated in High-Voltage Oil Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 62, February, 1943, pp. 98–106.

A specific problem of high transient switching voltage on the 220-kv. lines of the Southern California Edison Co. is discussed. A complete analysis is made using the transient analyzer to determine the possible magnitudes of switching overvoltages under various possible operating conditions. Power laboratory test results are presented and a large portion of the paper is devoted to the field testing at Boulder power plant and the interpretation of the results obtained. (*Science Abstracts*)

No. 911. R. W. Todd, "Mining-Switchgear Design, I-II," *Min. Elec. and Mech. Eng.*, Vol. 23, January, 1943, pp. 82–84, and February, 1943, pp. 87–90.

The special requirements of mining switchgear arising from the conditions under which it operates are pointed out and it is observed that voltages up to 600 v. and currents up to 150 amp. are usually employed. Circuit breaker contacts are discussed and preference is expressed for a contactor-type oil circuit breaker contact such that heavy through-currents increase the contact pressure. Hand-closing mechanisms are mentioned. Three types of release catch for automatic mechanisms are described. Earth-leakage protection and tripping conditions are discussed. Insulating materials and the metals used are considered and the conditions under which an oil circuit breaker should operate are outlined. (*Science Abstracts*)

No. 912. J. R. Taylor and C. E. Randall, "Voltage Surges Caused by Contactor Coils," *J.*, I.E.E., Vol. 90, Part II, April, 1943, pp. 90–100.

Discusses the phenomena associated with the switching of contactor coils and the like, particularly with reference to the effects of

"switching peak" voltages on insulation and switch contacts. The effect of circuit layout on the switching peaks and the arcing of contacts is described, together with methods of reducing the severity of these effects. (*Science Abstracts*)

No. 913. L. E. Fisher and R. L. Frank, "Paired-Phase Busbars for Large Polyphase Currents," *Trans.*, A.I.E.E., Vol. 62, February, 1943, pp. 71–77.

The arrangement is applicable to currents of 1000 amp. and above, at 600 v. or less, and is claimed to give very small voltage drop, considerable reduction in skin effect and proximity effect, and to be readily adaptable to metallic enclosure. The three-phase version has three separate pairs of conductors, the conductors in one pair being connected to different phases so that each of the three-phase currents is carried by two conductors in parallel. Currents in each close-spaced pair of bars are nearly equal and opposite. A mathematical analysis of a simplified arrangement is given and curves compare with behavior of this system with laminated and interlaced busbars. Wide flat bars face to face have proved the most satisfactory shape. (*Science Abstracts*)

No. 914. W. Deans, "What Shape Conductors for Electrical Busbars?," *Power*, Vol. 87, February, 1943, pp. 75–78.

A brief account of the relative merits of flat bars and sections (in various dispositions), concentric tubes and interleaved and split-phase bars. (*Science Abstracts*)

No. 915. C. J. O. Garrard and A. H. Worlock, "Developments in the Design of Heavy-Duty Metalclad Switchgear," *G. E. Rev.*, Vol. 12, February, 1943, pp. 161–172.

Describes a new line of switchgear, which is available in units for voltages of 6.6-33 kv. with breaking capacities of 500–1500 mva. The principal developments underlying the new gear are the production of an oil-poor type of double-break circuit breaker, the contacts of which may be inspected without removing the oil from the tank or breaking oil-tight joints; the extension of the use of capacitor bushings for the main connections; the substitution of fabricated steel for cast metal chambers in the busbar structure; and the complete enclosure of the gear in serviceable steel covers with roller shutters. The article is copiously illustrated with photographs and diagrams. (*Science Abstracts*)

No. 916. Same as **871**.

No. 917. G. Cluley. "Fuses *versus* Oil Circuit-Breakers," *Elec. Rev.*, Vol. 132, January 29, 1943, pp. 143–146.

General discussion of applications in medium-voltage a-c. industrial installations. (*Science Abstracts*)

No. 918. "New Air Circuit Breaker," *Electrician*, Vol. 130, March 12, 1943, pp. 271–272.

Describes tests on a new l.t. break, 200-amp., three-phase, 600-v. circuit breaker, which has successfully cleared 38,000 amp. at 400 v., 50 c/s. The breaker, after undergoing the test, remained in a usable condition. (*Science Abstracts*)

No. 919. "Air-Blast Switchgear in London," *Elec. Times*, Vol. 103, February 18, 1943, pp. 176–178.

Deals with the London Electric Supply Corp. installation. The 11-kv. switchgear (English Electric) is described, together with the methods of interlocking. Notes are given on the expected performance. (*Science Abstracts*)

No. 920. "Switchgear Dispersal," *Elec. Rev.*, Vol. 132, February, 1943, pp. 241–246.

Describes the precautionary measures taken at a distribution center to conform to the recommendations of the Electricity Commissioners. Sectionalizing and dispersal arrangements add materially to the reliability of switchgear and the continuity of supply. (*Science Abstracts*)

No. 921. H. W. Breeze, "Low-Voltage Joints," *Elec. Rev.*, Vol. 132, March 5, 1943, pp. 317–318.

To conserve lead and tin, cast-iron joint and service boxes are increasingly used. Principal requirements are ample jointing space, liberal compound-filling holes, compound expansion space, efficient banding and watertight construction. Bond resistance is some 0.002 ohm to lead and 0.005 ohm to armour, increasing 8 and 17 per cent, respectively, after 100 hr. vibration. Heating cycles in a quoted case resulted in a 50 per cent reduction in band resistance after 20 daily operations. With due regard to clearances and joint insulation the construction may be used up to 11 kv. (*Science Abstracts*)

No. 922. T. W. Wilcox, "Air-Blast Circuit-Breakers," *BTH Act.*, Vol. 18, October, 1943, pp. 75–79.

Axial-flow, radial-flow and cross-blast arc interruption are described. The conditions existing during arcing are discussed and the use of resistors and probe gaps considered. On 132-kv. breakers the resistor current cannot be interrupted on a probe gap on the l.p. side of the nozzle and it is necessary to provide a separate pair of contact nozzles operating at full pressure. (*Science Abstracts*)

No. 923. W. O. Schumann, "Plasma Phenomena Set Up by Sudden Pulses," *Ann. Phys., Lpz.*, Vol. 43, No. 5, October, 1943, pp. 369–382.

The space between anode and cathode contains equal concentrations of electrons and

positive ions. A sudden negative potential is applied to the anode or an electrode in the plasma so that the electrons move toward the cathode while the positive ions remain stationary. The resulting phenomena are described and a mathematical analysis (involving the use of elliptic functions) is given, with application to mercury arcs. Periodic oscillations are considered, the details being given for plane electrodes (*see Abstract 643 (1942)*). These oscillations are set up when the negative bias, applied to the plasma-electrode, is accompanied by a small a-c. ripple. Parallel resonance (minimum current) or series resonance (maximum current) may occur and the two preferred wave lengths, for the normal plasma, are 30-50 cm. and 3–5 cm. (*Science Abstracts*)

No. 924. F. Beldi and E. Uhlig, "Arc-Over Voltage of Multi-Part Insulators with Metallic Intermediate Flanges," *Brown Boveri Rev.*, Vol. 30, September-October, 1943, pp. 255–258.

In order to investigate the effect of the metal fittings of insulators on the flashover voltage of multi-unit h.v. insulators of the pedestal type, their normal frequency and impulse flashover voltages are compared with that of a corresponding single insulator, Conclusions are drawn for the equivalent flashover distance of multi-unit insulators (*Science Abstracts*)

No. 925. R. Holm, "The Physics of Sinter-Metal Contacts," *Kolloid-Z.*, Vol. 104, pp. 231–233 (1943).

No. 926. L. F. Hunt and F. H. Cole, "Dethermalizing Arc Quenchers," *Trans.*, A.I.E.E., Vol. 62, November, 1943, pp. 720–724.

Describes arc quenchers used in connection with normal-type oil circuit breakers, which cause the arc and its associated space to be cooled by the controlled flow of oil through and around the arc. The action has been proved effective by field tests, and an account is given of tests on the 16-kv. and 220-kv. systems of the Cal. Edison Co. (*Science Abstracts*)

No. 927. H. Mataré, "The Co-ordination of Air-Blast High-speed Circuit-breakers and Isolating Switches," *Brown Boveri Rev.*, Vol. 30, September–October, 1943, pp. 267–271.

Impulse flashover voltages are determined for the bushings with their protective gaps of air blast circuit-breakers and of isolating switches. The co-ordination of component parts of the breakers with one another and with the isolating switches is discussed with a view to reducing the required dimensions to a safe minimum. With the aid of statistical considerations, the probability of faulty flashovers at the selected co-ordination values is determined. (*Science Abstracts*)

No. 928. O. Mayr, "On the Theory of the Electric Arc and Its Extinction," *ETZ.*, (*Elektrotechn. Z.*), Vol. 64, December 16, 1943, pp. 645–652.

For the static arc, stabilized in the axis of a cylindrical enclosure, the relations between current density, electric conductivity, and the dimensions of the enclosure are given. The dynamic arc is discussed and a thermic time constant is defined which plays an important part in the extinction of the arc. The effect of shunting a d-c. or a-c. arc with a capacitor is investigated. The influence of local temperature on the electric strength of the arc path is discussed and illustrated by graphs. The considerations apply to the stabilized arc, and vertical and horizontal free-burning arc, the horn gap arrester, the quenched arc, the fuse with sand filling, the oil circuit breaker, various designs of gas-blast circuit breakers with axial and cross blast, including the hard-gas type, and the oil circuit breaker with explosion chamber, (*Science Abstracts*)

No. 929. E. Tochtermann, "Air Blast High-Speed Stator Reversing Switches for 3-Phase Winders," *Brown Boveri Rev.*, Vol. 30, November–December, 1943, pp. 306–308.

These switches are pneumatically operated and the arc is extinguished by air blast. The extinction time is 0.003 to 0.015 sec. After arc extinction the contacts are disconnected by isolating contacts in series, thereupon they reclose. The switches are built for voltages up to 10 kv. and currents up to 400 amp. An illustration of a complete switch is given (*Science Abstracts*)

No. 930. W. Weigel, "Systematic Formulation of Arc Types," *Z. techn. Phys.*, Vol. 24, No. 4, pp. 90–92 (1943).

Six equations are given which apply to the plasma of any form of gas discharge. Arc conditions may be considered as being (1) that the plasma is quasi-neutral, and (2) that the carrier concentration is in equilibrium with the temperature. A discussion of the boundary conditions tends to the formation of 2 types of arc discharge. (*Science Abstracts*)

No. 930a. F. Henker, "New Contact Types for Switchgear," *ETZ*, Vol. 64, No. 25–26, July 1, 1943, pp. 347–349.

The advantages of some of the new types of contact materials, such as silver tungsten, in comparison with silver and copper are described.

No. 930b. E. Doring, "Platinum-Tungsten, a Robust Noble Metal Contact for Light Current Practice," *ETZ*, Vol. 64, March 11, 1943, pp. 125–127. (In German.)

The properties of a Pt-W alloy containing 5 per cent tungsten are described. Electrically it compares favorably with a Pt-Ir alloy of 20 to 30 per cent Ir content, and

is much more easily worked than the latter. A table shows its chief physical properties and six micrographs show the state of Pt-W and Pt-Ir contacts after 5,000,000 switching operations. (*Science Abstracts*)

No. 930c. H. Manzinger, "Modern h.v. Isolating Switches for Indoor Installations," *ETZ*, Vol. 64, January 14, 1943, pp. 7–12. (In German.)

The basic requirements of isolating switches are formulated and discussed, and the construction and operation described in detail of a new design which embodies them. The new type, of which multipoint contact, one-piece insulator arm without metal fittings for the supports of the blade contacts, small dimensions and weight, high short-circuit strength are amongst its distinctive features, is built for 1 to 30 kv. and currents up to 1000 amp. in five single-pole and eleven triple-pole sizes. (*Science Abstracts*)

No. 930d. M. Lavet, "Time-Switches (Les horloges de commutation)," *R.G.E.*, Vol. 52, October, 1943, pp. 291–304. (In French.)

A general discussion of clock movements for operating triggering and switching devices comparing spring and gravity mechanical clocks with electric clocks of the synchronous type; the latter have special application to power networks. Causes of error in mechanical clocks are examined and theories given, with particular regard to temperature and magnetic fields. Synchronous clocks of the permanent magnet shaded-pole type and a compensated impulse-type originally due to Fèry are described; the latter is made by A.T.O. of Paris in a precision form which is fully detailed. (*Science Abstracts*)

No. 930e. F. Mertens, "Short-Circuit Protection and Disconnection in Grid-Controlled Rectifier Plants," *Nachr.*, Brown Boveri Co., Vol. 30, January–March, 1943, pp. 1–13. (In German.)

Various methods of interrupting short circuit by grid control are described. The case of short circuits on the d-c. bus with resistive inductive and capacitive load, and of backfires and flash-backs with rectifiers and inverters is discussed with oscillograms. Automatic reclosure after short-circuit and inverter protection are discussed. A comparison of switching with grid control and oil circuit breaker on a 25-kv. rectifier was made, and the results are shown. (*Science Abstracts*)

No. 930f. Fritz Kesselring, "Theoretical Boundaries for the Calculation of Switch Gear," *Sammlung Goschen*, p. 711 (1943). (In German.)

This book discusses the engineering and physical effects which take place in the operation of switchgear of practically all types. It is primarily concerned however with heavy-current, high-voltage equipment. The various chapters include the switching phenomena, electrical stress, dielectric losses, thermal stresses, electrodynamic stresses, electromagnets, and stresses concerned in opening and closing circuits, with particular reference to the quenching of the arc. This small and well-written book has a considerable amount of reference material which is useful to the designer.

1944

No. 931. "Turbulator Air-Blast Breaker," *Elec. Times*, Vol. 105, April 6, 1944, pp. 396–398.

Constructional and design details of the 66-kv., single air-blast turbulator, which includes current-carrying contacts, arc-initiating contacts, fixed arcing-electrodes and a metal nozzle, and the duplex air-blast turbulator, which incorporates an additional electrode between the two nozzles, are described. Breaking capacity, circuit breaking, and circuit making are discussed. (*Science Abstracts*)

No. 932. G. W. Heumann, "Electro-Pneumatic Control Speeds Heavy Contractor Operation," *Power*, Vol. 88, March, 1944, pp. 76–77.

The construction and mode of operation of electropneumatic contactors, as used for rheostatic control of large motors, is described, and comparisons are given of the operating times of the electropneumatic and electromagnetic types. (*Science Abstracts*)

No. 933. "Pneumatic Control Switch for Air Compressor," *Engineering*, Vol. 157, March 16, 1944, p. 217.

The switch utilizes for the throwing-gear mechanism the traverse of a piston subjected to the receiver air pressure; it is adjustable for receiver pressures up to 160 psi., and the starting and stopping points can be adjusted for any range within the maximum and the minimum. The instrument is suitable for d.c. or a.c. up to 550 v. (*Science Abstracts*)

No. 934. A. W. Hill and W. M. Leeds, "High-Voltage Oil Circuit-Breakers for Rapid Reclosing Duty," *Trans.*, A.I.E.E., Vol. 63, March, 1944, pp. 113–118.

Describes a new line of outdoor oil circuit breakers and the special design features which make them suitable for 20 and 35 c./s. reclosing duty at 230 kv., multiflow deion grid type of contacts and auxiliary oil-flushing piston. Data are included showing high-power, s.c. tests on these duty cycles at 139 kv. and 230 kv. at currents corresponding to three-phase duty of more than 2,500,000 kva. Detail drawings and oscillograms showing operation are given. (*Science Abstracts*)

No. 935. L. J. Linde and B. W. Wyman, "A Magnetic-Type Air Circuit-Breaker for 15,000 Volt Services," *Trans.*, A.I.E.E., Vol. 63, March, 1944, pp. 140–144.

A magne-blast circuit breaker for 15-kv. services with an interrupting rating of 250,000 kva. is described. The higher electrical resistance of the arc necessary because of the higher voltage has been made possible by an increase in the thermal efficiency of the interleaving arc chute which is discussed in some detail. The design of the breaker is described briefly, as well as its application to metal-clad switchgear. Test data and representative oscillograms are submitted. (*Science Abstracts*)

No. 936. R. T. Lythall, "Fused Switchgear," *Elec. Rev.*, Vol. 134, April 7, 1944, pp. 481–484.

Typical test results show that cartridge fuses are good for much more than listed breaking capacities. Examples of application are given, h.v. fuse gear is discussed, and a simplified circuit in which the tripping fuse is used on circuits up to 11 kv. with load-breaking switches is shown. Comparisons are drawn between fuse switchgear and circuit breakers. (*Science Abstracts*)

No. 937. J. R. Mortlock, "Restriking Voltages, I–II," *Elec. Times*, Vol. 105, March 2, 1944, pp. 248–250, and March 9, 1944, pp. 280–282.

The characteristics of restriking and recovery voltages under ideal conditions are traced and illustrated. Two characteristic interrupting conditions, the ideal and current-suppression conditions, are explained and typical cases given. Conditions where the current to be interrupted is asymmetrical are considered. This effect assists interruption. Current suppression and arc voltage are discussed; the former increases materially the magnitude and rate of rise of the restriking voltage. Post-arc conductivity and system considerations are briefly examined. (*Science Abstracts*)

No. 938. C. P. Harrison, "Fuses and Circuit-Breakers for Circuit Control and Protection in Marine Installations," *Trans.*, Inst., Mar. Engrs., Vol. 56, March, 1944, pp. 11–17.

The paper collects some of the latest information on the working principles of different types of fuses, particularly the h.r.c. cartridge fuse, compares the functions of fuses and circuit breakers, and considers the desirable features of switchboard layout in order to give the simplest type of installation combined with adequate protection of machinery, control gear, and wiring in service. (*Science Abstracts*)

No. 939. "Air-Blast Switchgear," *Elec. Power Engr.*, January, 1944, pp. 37–39.

An axial air-blast type of circuit breaker is described. The air flow is in the same direction as the arc, and full use is made of the mobility and low inertia of an arc to transfer it immediately to arcing contacts and to suppress it at the first current zero. The breaker can be employed for indoor or outdoor service, and is suitable from 3.3 to 132 kv. and for breaking capacities up to 1500 mva. Constructional and operational data are given. (*Science Abstracts*)

No. 940. R. A. Callacott, "Silver for Electrical Purposes," *Elec. Times*, Vol. 105, January, 1944, pp. 42–44.

Bearing in mind the data compiled on the mechanical and electrical properties of silver, the author discusses the application to current-carrying contacts, commutators, and sliprings. The addition of 0.05 per cent of silver reduces the corrosion of alloys containing 4 to 12 per cent antimony used in antimony-lead accumulators. The use of silver in the electroplating industry is discussed. (*Science Abstracts*)

No. 941. F. Henker, "New Contact Types for Switchgear," *ETZ*, Vol. 64, Nos. 25 and 26, July, 1943, pp. 347–349. Reviewed in *Engineer's Digest*, January, 1944, pp. 104–105.

A comparison was made on a contact testing machine between copper, silver, silver tungsten and several silver copper alloys. The physical properties of the contacts are also compared with the test results.

No. 942. M. N. Russell and S. Keilien, "The Vibration of Electrical Contacts," *Trans.*, A.I.E.E., Vol. 63, No. 4, April, 1944, p. 153.

The effects of bounce or vibration on electrical contacts are discussed with respect to the operation of the contacts in ordinary electrical switches. The effect of contact bounce is particularly bad in the case of switches operating tungsten filament lamps since the bounce means that the contacts must open and close up to eight times their normal current on the make. Oscillograms show the effects of bounce on the arc energy and several pictures show the appearance of contacts after test. It is necessary to design the contacts so that the energy causing vibration is absorbed at the instant of impact. This may be accomplished by the mutual preloading of contact blades. Under such conditions the vibration may be eliminated completely thus increasing the life of the contact considerably.

No. 943. M. J. DeLerno, "Potential Breakdown of Small Gaps Under Simulated High-Altitude Conditions," *Trans.*, A.I.E.E., Vol. 63, No. 3, March, 1944, p. 109.

To determine the effects of altitude conditions on the potential breakdown of small gaps a series of tests was set up duplicating some

of the flight results and the following conclusions were drawn:

1. Air-gap and creepage breakdown characteristics are substantially the same for 60- and 400-cycle supply for short gaps.

2. The effect of a very humid atmosphere on air-gap and creepage breakdown potentials is inappreciable, provided there is no moisture condensation on the electrodes or the dielectric.

No. 944. "Reyrolle Air-Blast Open-Type Circuit-Breakers," *J., Beama*, Vol. 51, May, 1944, pp. 154–156.

The main features of several designs, especially the turbulator unit, are described and a summary is given of the requirements. (*Science Abstracts*)

No. 945. "Flameproof Oil-Immersed Switchgear," *Mech. World*, May, 1944, p. 557. See also *Colliery Guard*, April, 1944, pp. 419–421, and *J., Beama*, Vol. 51, May, 1944, pp. 176–177.

The salient features of the design are that it renders impossible the exposure of live metal to the atmosphere and is robust for the space it occupies. The breaking capacity is 25 mva. at 3.3 kv. and 10 mva. at 400 kv. A brief description of the apparatus is given together with details of its operation, control, and protective arrangements. (*Science Abstracts*)

No. 946. "Rotary Timing Switch for Process Work," *Engineering*, Vol. 158, July 28, 1944, p. 66.

In the production of high-octane petrol, butadiene for synthetic rubber and toluene for explosives, consecutive processes require accurate timing. The timing can be set on the dials of the instrument by plug-and-socket connections to the segments of a segment ring over which a wiper arm travels. Although the contacts themselves can carry 10 amp. at 125 v., the processes are generally controlled by relays. (*Science Abstracts*)

No. 947. E. A. Coulson and R. J. Warne, "Automatic Pressure Regulation in Vacuum Distillation," *J. Sci. Inst.*, Vol. 21, July, 1944, pp. 122–123.

No. 948. "66 Kv. Built-in Circuit-breaker Switchgear," *Engineering*, Vol. 158, July 21, 1944, pp. 46–47.

A side view of one of the switch houses is shown, together with a simplified diagram of connections showing the ring busbar arrangement. Details of the general layout of the installation are given, followed by a more detailed description of the switchgear itself. The circuit-breaker is oil-immersed. Special provision is made for testing purpose and each switch house is equipped with its own oil-conditioning equipment. (*Science Abstracts*)

No. 949. "Air-Blast Switchgear," *Electrician*, Vol. 133, November 17, 1944, pp. 441–442. See also *Engineering*, Vol. 158, November 24, 1944, p. 406; *Engineer Lond.* Vol. 178, November 17, 1944, p. 400.

Briefly describes an air compressor delivering 13.5 ft.^{3}/min. at 300 lb./in.^{2} for operating air-blast switchgear. It comprises two units, each driven by a 3-hp., 400-v. motor, one unit acting as stand-by for the other. The air layout of a typical 132-kv. substation using air-blast beakers is given. (*Science Abstracts*)

No. 950. W. L. Berry and J. P. Dallas, "Higher-voltage d-c. Aircraft Electric Systems," *Trans.*, A.I.E.E., Vol. 63, November, 1944, pp. 843–849.

Advantages of 115-v. d-c. power are compared with 24-v. d-c. and 208/120-v. 400 c/s, 3-phase systems reliability is emphasized. Weight comparisons favorable to 155-v. d-c. are shown for power generation, distribution, and load components. Problems concerning the use of the 2 h. v. systems are discussed and compared. It is concluded that 115-v. d.-c. is the lightest and most practical system. (*Science Abstracts*)

No. 951. H. E. Cox and T. W. Wilcox, "The Influence of Resistance Switching on the Design of High-Voltage Air-Blast Circuit-breakers," *J.*, Inst. Elec. Engrs., Vol. 91, Part II, December, 1944, pp. 483–511.

It is shown that a circuit-breaker must not only break its rated breaking current but must also limit the value of surge voltage which it causes while it is opening the circuit. This can be brought about by limiting the electric strength of the breaker contact gaps. An experimental method of determining the electric strength of the nozzles under air-flow conditions is explained, followed by discussion of the means by which resistance switching enables the designer to control the breaking capacity and the electric strength of the nozzles independently. A 132-kv. breaker designed in conformity with the conclusions is described, and the results of a full-scale test set-up are given. An analysis of the validity of unit testing applied to multi-break breakers with resistance switching, as compared with two-part testing (B.S. 116, Part 2), is given. Proposals are made for a series of type-test duties to be applied to air-blast circuit-breakers. (*Science Abstracts*)

No. 952. E. M. Dakin and W. A. McNeill, "High-Voltage Circuit-Breaking," *Elec. Rev.*, London, Vol. 135, September 15, 1944, pp. 364–366.

Describes a new air-blast design for 132-kv. service which incorporates a duo-blast principle. The arc is blown both ways from its center, which avoids the generation of metallic vapor present in the central zone when two single nozzle breaks in series are used. Tests include 1-ph. breaking of 4 ka. at 115 kv. recovery voltage and 16 ka. at lower voltages, 1500 MVA 3-ph. breaking, and 20 to 400 a.

at 132 kv. to provide for transformer magnetizing currents. (*Science Abstracts*)

No. 953. R. C. Dickinson, "A 500 MVA, 7.5 kv.-Air Circuit-Breaker for Steel-Mill Service," *Trans.*, A.I.E.E., Vol. 63, May, 1944, pp. 242–245.

Completing a line of similar units from 50 MVA at 2.5 kv. designed for frequent operation at min. maintenance, this magnetic deion 3-pole breaker, with solid copper silver-inlaid contacts and silver-tungsten arcing contacts, forces the arc, by means of 2 blowout coils, into a slotted refractory, liberally vented to cool and expel the arc gases. The arcing time averages 0.02 sec. and the total interrupting time about twice this, and the performance is equally good at 25 and 50 c/s. (*Science Abstracts*)

No. 954. P. B. Garrett and M. E. Reagan, "Supervisory Control for the World's Most Modern Steel Mill," *Trans.*, A.I.E.E., Vol. 63, May, 1944, pp. 259–264.

This plant, the largest west of the Mississippi River, will produce about 700,000 tons of ship plates and 200,000 tons of structural steel annually, and is claimed to be the first steel mill in which the whole electric power supply and distribution system is under the supervision and control of a centrally located power dispatcher. All apparatus in the mill motor rooms is also telecontrolled and unattended. The supervisory control system uses telephone-type relays which send and receive code signals at about 14 impulses per sec. No polarized relays or selector switches are used. Each selection is checked automatically, individual lamp indications are given showing the position of each remote apparatus unit, and the whole equipment is normally at rest. The plant occupies an area about $2^1/_2$ by 1 mile, and each unit (open hearth, sintering, blast furnace, coke ovens) has independent supervisory control from the dispatching center. Individual controls are described and operating advantages discussed. (*Science Abstracts*)

No. 955. A. C. Gibson, "Class AG 2 Air-Break Switchgear," *BTH Act.*, Vol. 18, October, 1944, pp. 170–177.

The gear incorporates contactors or circuit breakers in series with h. r. c. fuses where required. The latter interrupt short-circuit currents more quickly than the circuit breaker so that the latter only has to be designed for interrupting overload currents, the tripping being effected by thermal relays, the characteristics of which are given. For currents up to 60 amp., contactor-type circuit breakers are used, and for 100- and 200-amp. units, air circuit breakers are employed, with fuses in each case. For 400 amp. an air circuit breaker with insulator and no fuse is adequate since the breaker is capable of interrupting the full prospective current corresponding to 25 MVA at 400 v. (*Science Abstracts*)

No. 956. J. M. Goodall, "Progress in the Design of High-rupturing-capacity Air-break Switchgear," *BTH Act.*, Vol. 18, July, 1944, pp. 135–142.

Describes developments in medium-voltage high-rupturing-capacity air-break switchgear since 1938, when first introduced by this company. Designs up to 600 v. and for 200/3 300 v. are illustrated, and test results given. (*Science Abstracts*)

No. 957. F. Grünewald, "Continental and American Air-Blast Breaker Developments," *Elec. Times*, Vol. 106, July 13, 1944, pp. 32–36.

The latest form of A. E. G. breaker and the theory of the Ruppel nozzle are described. The application of parallel resistance and multi-break contacts to the Brown Boveri breakers is discussed. American types of G. E. and Westinghouse manufacture, with reference to cross-jet arc extinction methods, are dealt with. (*Science Abstracts*)

No. 958. J. A. Harle and R. W. Wild, "Restriking Voltage as a Factor in the Performance, Rating and Selection of Circuit-Breakers," *J.*, A.I.E.E., Vol. 91, Part II, December, 1944, pp. 469–482 and 495–511.

Deals with the restriking-voltage transient and the rate of rise of restriking voltage. The effect on the performance of plain-break oil circuit-breakers, oil circuit-breakers fitted with arc-control devices, and air-blast circuit-breakers is discussed. Compared with the small effect that rate of rise has on plain-break and arc-control oil breakers, the importance of the effect of rate of rise on the performance of air-blast breakers is emphasized, and recommendations are made for the utilization of this factor in the rating, testing, and selection of these breakers. A method is proposed for testing h. v. air-blast breakers whose breaking capacities are above those for which testing stations are normally equipped. (*Science Abstracts*)

No. 959. A. P. Harvey, "Design and Testing of Circuit-breakers for Inflammable Atmospheres, with Particular Reference to Collieries," Min. Elec. Mech. Eng., Vol. 25, July, 1944, pp. 18–24, and August, 1944, pp. 45–47.

A review of the testing, specification, and construction of apparatus in this and other countries, including a number of sketches showing mechanical details. (*Science Abstracts*)

No. 960. C. J. Herman, "The Testing of Brushes for Life and Performance Under Various Altitude Conditions," *Trans.*, A.I.E.E., Vol. 63, December, 1944, pp. 929–933.

Owing to the large number of variables involved, brush tests must be very carefully conducted under strictly specified conditions in order to obtain true comparisons. A testing procedure is described which has been found useful in obtaining definite and reasonably consistent results in the measuring of brush performance. An outline is given of "Brush-qualification Test Procedures" to determine brush life, commutator life, as well as constancy and suitability characteristics as affected by the brushes. (*Science Abstracts*)

No. 961. F. G. B. Hill, "Direct-On-Line Contactor Starting of A-C. Squirrel-Cage Motors," *BTH Act.*, Vol. 18, October, 1944, pp. 181–185.

Types of contactor starters, with overcurrent relays, reversing and nonreversing, including flameproof apparatus, are illustrated. (*Science Abstracts*)

No. 962. J. E. Housley and O. Jensen, "Protection of Large D-C. Machines by Means of High-Speed Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 63, September, 1944, pp. 637–640.

In comparing a-c. and d-c. short-circuit conditions, it is shown that although it is an advantage to delay the action of an a-c. breaker for 3 to 5 cycles, a d-c. breaker must open as quickly as possible to obtain minimum breaking current. A complete description is given of the new FB high-speed circuit-breakers and oscillograms give the time to peak current as 0.403 to 0.667 cycles (based on 60 cycles) according to conditions. Sectional drawings, diagrams, and illustrations are given for a breaker rated at 7500 amp. A brief description is given of a rotary-converter station where these breakers are being installed on account of the troubles experienced with standard breakers. (*Science Abstracts*)

No. 963. J. Kurtz, "Electrical Contacts Based on Many Alloys," *Elec. Mfg.*, Vol. 34, December, 1944, pp. 111 *et seq.*

The properties of various metals and alloys in their relation to use as electric contacts.

No. 964. W. Laid-Hörsterbrock, "The Opening Motion in Low-Voltage Switchgear," *ETZ*, Vol. 65, January 13, 1944, pp. 1–4.

To determine the speed and switching time of a l. v. circuit-breaker, all forces and masses must be considered with reference to a selected point. By graphical integration, the speed and switching time may be determined. The contact forces at rest and in motion are different, owing to the inertia of the contact fingers. During motion the forces are determined by the distribution of the mass of the contact fingers and the instantaneous acceleration. (*Science Abstracts*)

No. 965. H. G. MacPherson, "The Energy Balance at the Positive Crater of the Carbon Arc," *Am. Phys. Soc.*, Cleveland, Ohio, September 11–12, 1944. Abstr. in *Phys. Rev.*, Vol. 66, December 1 and 15, 1944, p. 357.

Measurements were made of the electrical energy input to the crater of a low current carbon arc between solid electrodes and of the losses by radiation from the crater surface, by conduction through the electrode, and by evaporation of carbon. The relationships between the anode voltage drop, the temperature and area of the anode spot, and the physical characteristics of the anode material are discussed in the light of these results. (*Science Abstracts*)

No. 966. V. E. Phillips and W. P. Mitchel, "Peak Voltages with D-C. Arc Interruption for Aircraft," *Trans.*, A.I.E.E., Vol. 63, December, 1944, pp. 944–949.

Experimental data on the magnitude and variations of voltage peaks set up by d-c. arc interruptions of inductive circuits are given. The voltages were measured on systems of 30, 60, 125, and 250 v. with currents from 0.1 to 220 amp. and simulated altitudes from sea level to 50,000 ft. The loads included are motor fields and contactor coils. (*Science Abstracts*)

No. 967. J. S. Quill and L. T. Rader, "D-C. Arc Interruption for Aircraft," *Trans.*, A.I.E.E., Vol. 63, December, 1944, pp. 883–888.

Presents data on d-c. arc interruption up to 250 v. at pressures from sea level to 50,000 ft. altitude. Both resistive and inductive loads are investigated. The load range includes small currents corresponding to relay or auxiliary-contact values, and higher currents associated with power circuits. Two general types of devices were used: single- and double-break switches and a blowout-type contactor. The results are presented in the form of max. amperes which can be interrupted and arcing time in msec. The effect of inductive loads on arc interruption is discussed. The effect of a magnetic field on an arc, which at altitude tends to produce an arc movement in a direction opposite to that at sea level, is investigated. (*Science Abstracts*)

No. 968. D. Ramadanoff and S. W. Glass, "High-Altitude Brush Problem," *Trans.*, A.I.E.E., Vol. 63, November, 1944, pp. 825–830.

Ordinary carbon-copper brushes were found to wear very rapidly at very high altitudes, chiefly owing to lack of moisture in the atmosphere. Treatment of the brushes with two organic substances was found to give satisfactory operation. This article describes the results of exhaustive tests in a vacuum chamber both of carbon-copper and graphi-

tized carbon brushes at reduced pressures in various atmospheres and at various temperatures. Curves were obtained for the variation with altitude of brush wear and coefficient of friction. The results are thoroughly discussed. (*Science Abstracts*)

No. 969. C. P. West, "Improved Selective Tripping of Low-Voltage Air Circuit-Breakers," *Trans.*, A.I.E.E., Vol. 63, August, 1944, pp. 608–610.

After showing that full selectivity can be obtained with breakers having full interrupting ability and adequate short-time ratings in all steps, and tripped by time discriminating relays, the author considers the merits and demerits of cascaded breakers. New tripping devices are being developed for standard breakers combining instantaneous and time-delay tripping. (*Science Abstracts*)

No. 970. F. J. Russell and A. P. Charbonenau, "A-C. Contactors for Aircraft," *Trans.*, A.I.E.E., Vol. 63, September, 1944, pp. 613–616.

Contactors for aircraft must be of small size and weight, must not be affected by vibration or shock, must be able to operate under a wide range of temperature, humidity and pressure and under normal and emergency load conditions. They should also be enclosed to exclude dust and to confine any arcs. Specially designed contactors are described which meet these requirements. They include S.P. single- and double-throw contactors rated at 25 amp., 3-pole, single- and double-throw contactors, for 5, 25, 50, and 100 amp., and a 120 amp., 3-pole latched contactor or circuit breaker. (*Science Abstracts*)

No. 971. A. C. Schwager, "Tests of 230 Kv. High-Speed Reclosing Oil Circuit-Breaker," *Trans.*, A.I.E.E., Vol. 63, November, 1944, pp. 784–788.

Describes a 230-kv. oil circuit-breaker suitable for 3-pole or single-pole reclosing with a reclosing time of less than 20 cycles. The performance of the breaker is established by field tests for high-speed reclosing operation as well as for interruption of charging currents. (*Science Abstracts*)

No. 972. J. Solomon, "Starting Switchgear for Synchronous Motors," *M. V. Gazette*, Vol. 20, July, 1944, pp. 319–323.

A description of the M.-V. practice in the starting of synchronous motors of 500 hp. and over, and up to 11 kv. The general problems in starting and protecting these motors are considered and the following classifications are discussed. (1) Starting as induction motor on full voltage with solid poles, or laminated poles with squirrel-cage dampers, or with polyphase damper windings. (2) Starting as induction motor on reduced voltage with reactors or with two methods of "Korndorfer" auto-transformer starting (*a*) with a two-handle change-over switch or (*b*) with separate "start" and "run" switches. (3) Star-delta starting, tap starting from step-down transformer and the use of a starting motor are also mentioned. (*Science Abstracts*)

No. 973. J. H. M. Sykes, "Modern e. h. t. Circuit-Breakers," *Elec. Times*, Vol. 106, August 31, 1944, pp. 228–230.

Some maintenance consideration affecting the design of oil and air breakers. (*Science Abstracts*)

No. 974. F. G. W. Tree, "Brushes and Rotary Collectors," *Electrician*, Vol. 133, August 25, 1944, pp. 160–162.

A general statement of the fundamental conditions which govern faulty commutation, excessive brush wear, etc. These conditions are stated to be (*a*) the nature of the contact materials, (*b*) specific resistances, (*c*) temperature coefficients and friction, (*d*) current density, and (*e*) electrolytic action. Each of these items is briefly discussed. (*Science Abstracts*)

No. 975. C. Van Brunt, "Carbon-brush Contact Films," *Gen. Elec. Rev.*, Vol. 47, August, 1944, pp. 28–35.

Additional experiments [see Abstr. 1793 (1944)] on the contact characteristics of a carbon-copper system operating under l. v. are described and the results show that oxygen has a dual effect upon film resistance. Fluid impregnation of brushes, adjuvant reservoirs and solid adjuvants, each offer a probable substitute for the atmospheric moisture lacking at high altitudes. The carbon-brush sliding-contact problem is more complex than hitherto assumed. (*Science Abstracts*)

No. 976. C. Van Brunt and R. H. Savage, "Carbon-brush Contact Films. I." *Gen. Elec. Rev.*, Vol. 47, July, 1944, pp. 16–19.

The dark oxide film developed on a commutator when running with carbon brushes was investigated. Complete quantitative analyses of several films were made by microchemical methods. The low friction and wear of graphite is due not to any inherent lubricant quality but to adsorption upon its surface of substances derived from the atmosphere. Satisfactory brush operation is dependent upon the presence of O_2 or water vapor. (*Science Abstracts*)

* **No. 977.** W. N. Gittings and A. W. Bateman, "Switchgear and Control for an Electronic Power Convertor," *Trans.*, Am. Inst. Electrical Engrs., Vol. 63, August, 1944, pp. 585–589.

The switching of this 60/25 cycles per second, 69/44 kv. convertor (Abstr. 2474 (1945)) consists of closing the two power transformer breakers and energizing the

* Old 977 through 981 changed to 988 through 992.

auxiliary and ignition bus, interlocks ensuring that the ignition control is in the invertor position. Control may be by hand, by watt regulator, or by load regulator, the latter adjusting load flow to take the best advantage of the tariff. Protection is also discussed. (*Science Abstracts*)

No. 978. C. Bresson, "Airblast Breaker of High Interrupting Capacity for Medium Voltage," *R.G.E.*, Vol. 53, October, 1944, pp. 203–217. (In French.)

Essential factors in the process of interruption of airblast breakers are discussed, namely the current handled, the recovery voltage, and the rate of rise of voltage, the discussion being mainly confined to breakers for powers up to 15,000 mva. at 10 to 20 kv. It is suggested that the rate of rise of voltage can never be known with any certainty, and that this is an advantage for the airblast breaker incorporating resistance switching which is independent of rate of voltage rise. The advantages claimed for the use of resistance switching are that it considerably reduces the pressure required for arc interruption, and that it permits the testing of circuit breakers by separate tests at full current and reduced voltage, and at full voltage and reduced current. The latter advantage lies in the fact that small currents are interrupted without excessive overvoltage. The design and operation of breakers of this type are described. (*Science Abstracts*)

No. 979. E. W. Boehne, "The Geometry of Arc-Interruption. II. Current Zero-Phenomena," *Trans.*, Am. Inst. Electrical Engrs., Vol. 63, June, 1944, Supplement, pp. 375–386.

While voltage across a circuit breaker near the region of current zero can be conveniently recorded and studied, this is not the case for the current through the breaker. Current-voltage relations are studied in the following manner: the voltages consequent on the injection of linearly increasing and rectangular fronted "cancellation" currents into given networks are calculated and the total currents are deduced by considering that, in addition to the normal current, such cancellation currents flow as are necessary to produce the observed arc voltages. The total current is then the resultant of the normal and cancellation currents. Non-linear approach of the current to zero is also treated. The results are used in a discussion of the interruption of both d.c. and a.c. by circuit breakers of different types. (*Science Abstracts*)

No. 980. K. Berger and R. Pichard, "Calculation of the Overvoltages Caused by the Disconnection of Open-Circuited Transformers, in Particular by Means of High-Speed Breakers," *Bull. Ass. Suisse Elect.*, Vol. 35, October 4, 1944, pp. 560–570

A mathematical treatment of the so-called current-chopping phenomenon. It is shown that for a high-speed breaker and assuming a negative arc characteristic the voltages across the switch contacts can be calculated. For oil circuit breakers a similar mathematical treatment is not feasible. The current which flows into the transformer is calculated both before and after the first current zero and the conditions are determined under which restriking occurs, particular attention being paid to the instant of interruption with respect to the supply voltage. Assuming, as an example, a linear increase of the breakdown strength between the breaker contacts and, in a second case, a constant breakdown strength the highest possible overvoltages are calculated which may occur across the switch. To reduce the overvoltages two protective measures are briefly discussed: a protective gap with series resistance parallel to the breaker or a surge diverter at the transformer terminal. (*Science Abstracts*)

No. 981. A. Van Itterbreek and L. De Greve, "Measurement of the Electrical Resistance of Thin Films of Copper, Silver and Lead," *Physicas.' Grav.*, Vol. 11, February, 1944, pp. 78–90. (In French.)

Measurements were made by a Wheatstone bridge method on films 10 to 100 mfl thick obtained from a cathode discharge at temperatures between the b.p. of H, and room temperature. The temperature coefficient of Cu and Ag films was found to be much less than that of the standard metal and became negative for 3 mμ Cu and 4.5 mμ Ag films. The temperature coefficient of Pb films is approximately that of the normal metal and does not vary greatly with thickness. The specific resistance of Cu and Ag films is given by a formula due to Hamburger; $\log \rho = A \log D + B$ where $A = -0.6$, -1.0 and $B + -4.1$, -3.3 for Ag and Cu, respectively. (*Science Abstracts*)

No. 982. J. J. Trainor and H. N. Muller, "H.v. Interconnection Made Reliable by Single Pole Switching," *Pwr. Plant* (Engng.), Vol. 48, June, 1944, pp. 77–79, 138, and 140.

The single-pole reclosing breaker has the advantage that considerable power is transmitted over the unfaulted phases while the faulted phase is isolated. The history of the single-pole breaker is reviewed and it is claimed that its application in transmission line circuits has made h.v. interconnections between substations more reliable. Several 132-kv. circuits are described using high-speed single-pole breakers, and a table shows the comparative transient power limits calculated for a high-voltage line with different types of reclosing. Eight-cycle breakers and carrier-current relaying. (*Science Abstracts*)

No. 983. E. R. Summers and J. F. Settle, "New Test Chambers for Aircraft Electric Apparatus with Particular Reference to Carbon Brushes," *Trans.*, Am. Inst. Elect. Engrs., Vol. 63, December, 1944 Supplement, pp. 1205–1212.

Carbon brushes are shown to be subjected to greatly increased wear under atmospheric conditions prevailing at great flying heights. In order to test brush materials and those used for commutator and collector rings, various test chambers are developed which enable atmospheric flight conditions to be simulated and permit testing of a wide range of equipment, including a complete pressure-ventilated 40-kw. alternator. The construction of such chambers is described in detail and several illustrations are given. The ideal brush is shown to require formation and maintenance of a wear-resistant film on a freshly machined commutator at any altitude. (*Science Abstracts*)

No. 984. L. Perrin, "Effect of Rapid Re-closing on the Stability of Large Grid Systems," *R.G.E.*, Vol. 53, August, 1944, pp. 151–157.

A study is made of the particular case of a group of four identical zones consuming altogether 600 mw. at 0.9 power factor. All alternators, compensators, transformers, etc., have values commonly found in practice. The zones are fed at 220 kv. by a double line 400 m. long. It is further assumed that two 220-kv. transformers at the generating station and two more at the receiving center have their neutrals connected to earth. Calculation is then made of the gain or loss due to reclosing, as a function of (*a*) the time required to eliminate the fault and the time of reclosing, (*b*) the surge due to the fault, and (*c*) the surge due to the elimination of the fault. The results are given diagrammatically. It would appear that in order to obtain the best results from rapid reclosing, the breakers imagined to effect the reclosing should cut out very quickly and allow reclosing as soon as the arc due to the fault is deionized. (*Science Abstracts*)

No. 985. H. Morf, "New Developments in the Construction of Control Switches for Electrical Switch Installations," *E. Bull. Oerlikon*, No. 250, pp. 1607–1614 (1944).

Control switches on modern control panels are built so that the switch handle forms part of the mimic diagram and gives a direct indication, usually luminous, of the state of the circuit. A standard type of switch is described with accessories and connection diagrams illustrating its application in various types of control circuit. (*Science Abstracts*)

No. 986. E. Maury, "Arc Extinction in the Ultra-Rapid Single-Phase Reclosure of 220 kv. lines," *R.G.E.*, Vol. 53, May, 1944, pp. 79–90. (In French.)

The minimum permissible duration of circuit interruption and the technique of fault clearance on overhead lines by opening and rapid reclosure of the line is determined by the need for securing complete ionization of the fault path. In single-phase switching the minimum time is lengthed by the fact that after the faulted line has been completely disconnected the dielectric recovery is retarded by capacitance current induced from the two phases remaining alive. The factors affecting the duration of this secondary arc are studied: for example, magnitude and duration of the principal arc, atmospheric conditions, nature of overhead line, and length of line. It is concluded that for 220-kv. lines in sections not longer than 200 km., conditions are such that single-phase switching remains attractive. For longer lines further investigation is regarded as necessary. Experimental work was carried out under laboratory conditions, and the results are checked against field data. (*Science Abstracts*)

No. 987. J. Labouret, "Airblast Breakers: Their Evolution from Single-Break to Multiple-Break Technique and Automatic Reclosure after Short-Circuit," *R.G.E.*, Vol. 53, November, 1944, pp. 235–242. (In French.)

Advantages of the airblast breaker over the oil breaker are explained, and a brief account is given of the theoretical basis on which the interrupting elements of such breakers may be designed, in relation to current and voltage handled, and to the natural frequency of the network in which they are used. The limitations of single-interrupting elements for very high voltages are explained, and the advantages of using them in series are illustrated. Arrangements for achieving this in practice are described. The application of the air blast breaker to the rapid reclosure technique of line protection is noted, and an account is given of practical experience with airblast circuit breakers in France. (*Science Abstracts*)

No. 987a. Yu. V. Baimakoff, "Resistance of Contact Between Metals, and Between Metals and Carbon Materials," 3rd Technical-Scientific Conference of the Kalinin Polytechnic Institute, Leningrad, September, 1944, p. 50. Also *Engineer's Digest* (American Edition), Vol. 4, April, 1947, p. 164.

An investigation was made on the contact resistance between pure metals and between metal and carbon under ordinary temperatures and after heating at temperatures up to 300 C. It is noted that the contact resistance was lower for the metals which were more plastic and that the resistance in most cases increased in the higher temperatures. The increase in resistance was found to be due to the penetration of oxygen to the contact surface.

No. 987b. H. Dorsch, "Approximate Determination of the Sustained Short-Circuit Current at Network Short-Circuits," *ETZ*, Vol. 65, May 4, 1944, pp. 167–170. (In German.)

The sustained short-circuit current is determined as a multiple of the rated current of the generator or in relation to the peak value of the short-circuit current assuming a constant stray voltage of 20 per cent, equal reluctances in the direct and quadrature axes, exciting current for full load, and a p. f. of 0.8. The standard no-load and short-circuit characteristics of the VDE regulations are taken as a basis. Curves are derived for determining the sustained current for a purely inductive and an ohmic-inductive short circuit. Numerical examples of their use are given for salient pole machines with and without damper winding and for a turbo-generator. (*Science Abstracts*)

No. 987c. J. Frenkel, "On the Kinetics of the Formation of Oxide Films on the Surface of Metals," *J. Exp. and Theor. Physics (U.S.S.R.)*, Vol. 8, No. 4, pp. 225–229 (1944).

The formation of a film begins with the dissociation of adsorbed oxygen molecules into atoms, which then gradually penetrate the metal. A study is made of this process and of the diffusion of oxygen atoms through the crystal lattice. The classical diffusion equation is unsuitable; if n_k is the number of atoms in the $_k$th layer at a given time, a differential-difference equation is set up to determine n_k. This is solved and an expression is obtained for the total number of atoms that have penetrated the metal after a given time. (*Science Abstracts*)

No. 987d. A. M. Krutthof and J. A. Smit, "The Applicability of Saha's Formula to the Electric Arc," *Physica's Grav.*, Vol. 11, March, 1944, pp. 129–143. (In Dutch.)

The extent of applicability of Saha's equation (giving the degree of ionization of a gas in thermal equilibrium) to arc discharges is discussed. The required data, i.e. (*a*) electron, (*b*) ion, (*c*) atom concentrations, and (*d*) discharge temp. were obtained, respectively, by measurements of current, field strength, electron mobility, and "arc diameter" (*a*), by standard spectroscopic methods (*b* and *c*), and by observations of intensity ratios in the CN bands (*d*). Tests were made with d-c. and a-c. arcs in air at 1 atmos. containing Sr and Ba vapor. The conclusion was that Saha's equation is applicable to this case with an error of about ±20 per cent in the value of the amount of ionization. (*Science Abstracts*)

No. 987e. F. Metzger, "On the Appropriate Selection of Low-Voltage Circuit-Breakers," *ETZ*, Vol. 65, Spetember 28, 1944, pp. 285–90. (In German.)

The construction and operation of the three principal types of l.v. breaker are described, namely, the automatic type with latch mechanism, the oil and the air break types. Their application is discussed, based on the number of operations per hour which the circuit breaker must perform for various motor drives. For the appropriate selection a table is given containing the kind of circuit breaker, the highest permissible current, the average life (number of total operations), the highest permissible number of operations per day or hour, respectively, and the different services for which the circuit breakers are suitable. (*Science Abstracts*)

No. 987f. A. M. Schmidt, "Development of the Screwed-Plug Automatic Switch," *ETZ*, Vol. 65, December 21, 1944, pp. 449–453. (In German.)

The automatic installation switch for replacing screw-plugged fuses has been improved in design, material used in its construction and technical performance. Rupturing capacity has been raised to 1400 amp. at 220 v. d.c. by using the magnetic field of the overload switching coil also for arc blasting. The ceramic casing was replaced by one of plastic. The arc chamber and the opening path of the contacts have been increased and the over-all dimensions reduced. (*Science Abstracts*)

No. 987g. R. Holm, "On the Calculation of Switching Arc Times and the Effect of Capacitive Breaking Circuit, "*Siemens-Zeits.*, Vol. 24, January–June, 1944, pp. 1–5. (In German.)

Gives a universal nomogram for determining the arc length for extinction and arcing time of a switch, given the circuit voltage and current. By shifting coordinates, the chart is applicable to C, Fe, Ni, Cu, Zn, Cd, W, Pt, Au, and bronze contacts in air and Cu and Ag in oil. Two examples illustrate the method. The effect of an RC shunt across the contacts with a view to reducing arc time is investigated. The two cases of rupturing small and large d-c. currents are considered. R is most effective in series with C. (*Science Abstracts*)

No. 987h. R. Edler, "From the Required Switching Operation to the Circuit Diagram," *E. u. M.*, 62, January 21, 1944, pp. 30–52. (In German.)

Develops a quick, ingenious method for designing switch combinations for complex switching sequences or operations. The method is illustrated by numerous examples. (*Science Abstracts*)

No. 987i. B. Fleck, "Automatic Change-Over Switches for H. V. Lines," *E. u. M.*, Vol. 62, February 18, 1944, pp. 91–95. (In German.)

Change-over switch and relay schemes for 2 h.v. lines in the case of disturbances on one line are described. Special mechanically inter-

locked or standard circuit breakers can be used. The relay scheme usually has under-voltage relays with fixed or varying time delay depending on the amount of under-voltage. Before switch-over, the relay scheme tests whether the reserve line is actually carrying voltage and connected to the mains. Switching-back may be hand-operated or automatic when the fault is cleared. Discriminating relays prevent switch-over on over-current when the line is healthy. (*Science Abstracts*)

No. 987j. A. Horst, "Circuit Breakers and Motor Starters," E. u. M., Vol. 62, June, 1944, pp. 283–289. (In German.)

Gives the history of development, theory, and construction of the latest German small-size circuit breakers with overloads. Motor starter with thermal and magnetic overload releases are also discussed. Correlation between circuit breakers and any preceding mains fuses is necessary. (*Science Abstracts*)

No. 987k. R. Rompe, W. Thouret, and W. Weizel," The question of Stabilizing Free-Burning Arcs," *Zeits. f. Phys.*, Vol. 122, Nos. 1–4, pp. 1–22 (1944). (In German.)

The arc stability theory of Elenbaas (*Science Abstracts* No. 3845 (1934)) is applicable only to arcs in cylindrical tubes in close proximity to the walls. The paper investigates the theory of electric arc discharge for free-burning arcs remote from the walls as in high-pressure Hg-arc lamps with spherical bulbs. The case of a free-burning arc with finite electrode distance is mathematically treated by elliptic functions. The arc-stability, according to the pressure, rating, and electrode dimensions of the lamp, is determined either by: (*a*) convection currents; (*b*) contraction of the discharge at the electrodes due to the mechanism of charge transfer; (*c*) limitation in axial direction due to electrode spacing and dimensions. Experiments and photos of the various types of arcs with vertical, horizontal, and rotating electrode systems are included. (*Science Abstracts*)

No. 987l. H. Schmellenemier, "Meausurements of the Positive Column Gradient of Low-Pressure Rare Gas Discharges," *Zeits. f. Phys.*, Vol. 122, Nos. 5–8, pp. 269–284 (1944). (In German.)

The positive column of a low-pressure gas discharge usually has a negative resistance characteristic, and lamps of this type require series ballast. Experiments were carried out with tubes 60 cm. long of varying diameters and degrees of vacuum containing Ne, He, A, and Kr. A positive-voltage characteristic could be obtained with a certain range of pressures and diameters. Small tube diameter and high vacuum are conducive to positive characteristic. The characteristic becomes negative, however, beyond a certain current. Positive characteristic lamps can be mains-operated without ballast. The phenomenon is thought to be due to the observed difference in pressure at the anode and cathode end of long tubes, due to the discharge. (*Science Abstracts*)

No. 987m. R. Seeliger, "Remarks on the Theory of Cathode Potential Drop," *Zeits. f. Phys.*, Vol. 122, Nos. 1–4, pp. 209–215 (1944). (In German.)

The form of mathematical relation between electron-impact ionization and field strength required to correlate cathode p.d. characteristics with experimental results is discussed. A simple mathematical relation is desired to give a clear physical picture, and the simplified theory of v. Engel and Steenbeck is further simplified to a convenient area-relation. The relation is quantitatively in accordance with the physical limits. (*Science Abstracts*)

No. 987n. H. Schluge and W. Finkelnburg, "The Singing of Homogeneous Carbon Arcs," *Zeits. f. Phys.*, Vol. 122, Nos. 9–12, pp. 714–739 (1944). (In German.)

The "singing" arc was investigated by means of oscilloscopes and photographs. The relation between current, voltage, phase angle, note emitted, brightness, and type of carbons was studied. An apparatus for taking high-speed photographs of the arc is described, and results are shown. "Singing" threshold and tendency are investigated, and the mechanism underlying the "singing" arc is discussed. (*Science Abstracts*)

No. 987o. R. Rompe and W. Weizel, "On Toepler's Spark Law," *Zeits. f. Phys.*, Vol. 122 Nos. 9–12, pp. 636–639 (1944). (In German.)

Investigates the variation in resistance of a gas discharge during the initial period of voltage breakdown and ionization between the electrodes. According to Toepler, the conductances α the current integral. The authors develop another theory from fundamental considerations and find (conductance)^2 α (integral of current)^2. Experimental evidence seems to corroborate the theory. (*Science Abstracts*)

1945

No. 988. "Am Improved Air-Break Starter Design," *M. V. Gazette*, Vol. 21, January, 1945, pp. 20–21.

Describes a hand-operated, air-break, auto-transformer starter for polyphase squirrel-cage motors up to 25 hp., 600 v. The auto-transformer is of the air-cooled two-limb pattern and is mounted behind the switch mechanism. The starting switch is designed for a max. continuous current of 40 amp. (*Science Abstracts*)

No. 989. T. T. Hambleton, "Commutator, Collector-Ring and Brush Performance,"

Gen. Elec. Rev., Vol. 48, April, 1945, pp. 24–32.

Mechanical, chemical, and electrical factors affecting the adjustment and maintenance of commutators and current-collecting gear are discussed. Causes of faulty operation and remedial measures are given, illustrated by examples relating to discontinuity of brush contact, brush chatter, atmospheric humidity, and active chemical gases. Characteristic curves showing the influence of the commutating pole on the commutating neutral are given. (*Science Abstracts*)

No. 990. L. B. Hunt and H. G. Taylor "Electrical Contact Springs," *J.*, Inst. Elec. Engrs., Vol. 92, Part III, March, 1945, pp. 38–44.

Materials for springs of the type under discussion should possess a high ratio of max. safe stress/elastic modulus resulting in a high deflection for a given load within the elastic range (0.1 per cent proof stress). Non-ferrous metals and alloys are more suitable than steel, and comparative data of their relevant physical properties are given. Light-duty contacts are designed for low and constant contact resistance and high reliability. This requires adequate contact pressure, and the combination of one domed and one flat contact is the most useful.

Noble metals (Ag, Au, Rh, Pt, Pd), and some of their alloys, are widely used. Pt and Ir-Pt are highly tarnish-resistant, and have proved most reliable under service conditions. Ag should not be used adjacent to ebonite or vulcanized rubber if very low contact resistance is required. A number of contact materials can be electro-deposited successfully (Ag, Au, Pt, Rh) and 0.000015 in. of Rh on Ag will increase the tarnish resistance, but heavier deposits may be necessary according to service requirements. (*Science Abstracts*)

No. 991. W. B. Pieńtenpol and F. C. Walz, "Resistance of Carbon to Carbon Contact," *Proc.*, Am. Phys. Soc., New York, January, 1945. Abstr. in *Phys. Rev.*, Vol. 67, March 1 and 15, 1945, p. 201.

The contact resistance of plane C surfaces was measured at constant temperature over a pressure range of 78.88 to 31,803.6 g./cm.^{2} A potentiometer method was used with current approximately 0.1 amp. Corrections were made for the resistance of solid C, and resistances were measured to 4 significant figures with pressure determined to 0.1 g./cm.^{2} After pressures are increased, the contact resistances decrease with time and at one value do not reach equilibrium until after 24 hr. When pressures are decreased, contact resistances increase with smaller time lags. The equilibrium resistance/pressure curves agree with theory. [Abstr. 1201 (1941).] (*Science Abstracts*)

No. 992. C. B. Gwyn, Jr., "Electrical Contacts, Part I—Possible and Actual Materials," *Metals and Alloys*, Vol. 21, May, 1945, pp. 1318–1323.

Subsequent installments are to treat performance and applications. Lists 40 elements as possible contact materials, their advantages and disadvantages, concluding that field is narrowed to the following in the order of their importance: (1) W, (2) Ag, (3) Pt group, (4) Mo, (5) C impregnated materials, (6) Cu alloys and admixtures.

No. 993. C. A. C. Hillyer, "New Flameproof Switchgear," *BTH Act.*, Vol. 18, October, 1945, pp. 273–277.

Illustrated description of a new switchgear unit designed to meet B.S.S. 229–1940. Incorporating visible isolating links in a separate chamber, the unit includes overcurrent and undervoltage releases, earth fault trip, voltage and current transformers, voltmeter, and ammeter. The removable oil circuit breaker is 3-pole single break, with contacts of simple design to facilitate maintenance. Busbars and other items are Ag-plated to minimize corrosion; the busbar chamber is separated from the isolating chamber by a flame-proof diaphragm. (*Science Abstracts*)

No. 994. H. H. Hausner, "Pressed-Powder Electrical Contacts Using Graded Multiple-Layers," *Prod. Engg.*, Vol. 16, September, 1945, pp. 618–620.

Some of the difficulties in the construction of electrical contacts can be overcome by forming the contact points in multiple layers, thereby grading the electrical and mechanical properties. Tungsten powder and crystalline Ag may be used in the contact. The layers, made up of different proportions of the two constituents, are pressed one on top of the other. This is followed by heat treatment and a final pressing process. The contact may be brazed without difficulty on to Cu or other materials. (*Science Abstracts*)

No. 995. J. A. Harle and R. W. Wild, "Restriking Voltage as a Factor in the Performance, Rating and Selection of Circuit Breakers," Inst. Elec. Engrs., Vol. 92, December, 1945, pp. 529–536, 547–549. Discussion (see Abstr. 713 (1945)).

No. 996. H. W. Graybill and J. S. Ferguson, "A New Outdoor Air Switch and the Principles Involved in Its Design," *Trans.*, Am. Inst. Elec. Engrs., Vol. 64, August, 1945, pp. 583–586.

A new switch of the rotating insulator, vertical break type is described and design problems discussed. Blade mechanism and switch contacts are considered with reference to current carrying capacity, interruption capacity, and ease of operation. A typical switch for 69 kv., 600 amp. operation

is described and diagrams are given. The tests used to check its performance under normal and extreme conditions are described. The uses of Cr-Cu, Be-Co-Cu, and other alloys for the switch mechanism are discussed and their merits indicated. (*Science Abstracts*)

No. 997. J. Frenkel, "On the Theory of Electric Contacts Between Metallic Bodies," *Journal of Physics* (*USSR*), Vol. IX, No. 6, pp. 489–495 (1945).

An electric contact between two metals is treated as a gap through which the electrons penetrate from one metal into the other by the mechanism of thermoelectric emission, which is increased by the lowering of the corresponding potential barrier, under the influence of the image forces, by an ambient inversely proportional to the width of the gap. This enables one to understand the fact that the electrical conductivity of fine metallic powders and thin layers, constituted by very small grains, increases with a rise of temperature according to a law similar to that which refers to the electrical conductivity of semiconductors.

No. 998. C. H. Flurscheim and J. A. Nott, "Aircraft Circuit-Breakers," *Journal of Research*, Aeronautical Soc., Vol. 49, November, 1945, pp. 663–679.

The advantages of using circuit breakers rather than switches and fuses are summarized with reference to the particular conditions obtaining in airframes. Design factors are considered and typical examples of aircraft circuit breakers are shown and their operating characteristics illustrated by oscillograms. (*Science Abstracts*)

No. 999. H. M. Elsey, "Iodide-Treated Brushes Maintain the Essential Commutator Film," *Westinghouse Engr.*, Vol. 5, September, 1945, pp. 144–147.

For all d-c. machines, a thin film on the commutator is essential and is thought to be composed of Cu_2O. When normal brushes are used, the film cannot be maintained in a rarefied dry atmosphere. Experiments were made with brushes treated with metallic halides of I, Br, etc., and lead iodide proved the most satisfactory. It is thought that an unstable form of cuprous iodide is produced, and this being readily oxidized to Cu_2O even under adverse conditions of atmosphere, it is considered that these treated brushes may be of use in cases of difficult commutation at ground level. (*Science Abstracts*)

No. 1000. H. M. Elsey, "Treatment of High-Altitude Brushes by Application of Metallic Halides," *Trans.*, Am. Inst. Electrical Engrs., Vol. 64, August, 1945, pp. 576–579.

It was found that the rapid wear of brushes under high altitude conditions can be prevented by the treatment of the brushes with a suitable metallic halide. Carbon electrographitic, and metal-graphite brushes all respond to the treatment which has also been applied with success to earth surface machines operating under severe commutating conditions. The applications of the treatment and its advantages are discussed and a mechanism by which this type of chemical compound may react to maintain a satisfactory low friction film on a commutator is proposed. (*Science Abstracts*)

No. 1001. M. Dormont, "H.v. Circuit-Breakers," *Alsthom Bull. Tech.*, October, 1945, pp. 1–20.

Present ideas concerning arc quenching are discussed. Certain special arrangements are considered, such as the incorporation of and auxiliary isolating switch, multiple breaking and inserted resistance. Auto-quenching and forced quenching, both singly and combined, using oil jet circuit breakers are discussed. Air jet circuit breakers using compressed air are described. Reference is also made to circuit breakers in which gas is produced at the time of breaking. (*Science Abstracts*)

No. 1002. J. Dispaux, "Large Turbo-Alternators in Air and Hydrogen," *Mem. Soc. R. Ingen. Industr. B.* (No. 2), pp. 15–16 (1945). (In French.)

A statement that the A.C.E.C. have designed a turbo-alternator for 125 mva; 100mw; 10,500v; 3000 rpm. both in air and in H_2. Losses, weights, and over-all dimensions are given for both types. (*Science Abstracts*)

No. 1003. H. E. Cox and T. W. Wilcox, "The Influence of Resistance Switching on the Design of High-Voltage Air-Blast Circuit-Breakers," *J.*, Inst. Elec. Engrs. Pt H, Vol. 92, December, 1945, pp. 536–546, 547–549. Discussion (*Science Abstracts* No. 714 (1945)).

No. 1004. A. Bronstein, "A Gas-Generating ("hard-gas") Circuit Breaker," *Elektrichestvo* (No. 7), July, 1945, pp. 35–39. (In Russian.)

On the basis of investigation into the arc-quenching capacity of cylindrical gas-generating canals, optimum values of arc-quenching parameters were determined. An original circuit-breaker design has been developed and put into production. Principle and design are presented for the 6–10 kv., 200 amp. circuit breaker. (*Science Abstracts*)

No. 1005. H. S. Booth and D. R. Martin, "A Rugged Current Interrupter," *Industr. Engng. Chem.* (Anal. Ed.), Vol. 17, August, 1945, pp. 528–538.

No. 1006. M. Bernard, with G. Paillet, J. Schreder, and H. Van Der Elst, "Progress in h.v. Circuit Breakers," *Mem. Soc. R.*

Belge Ingen. Industr. B (No. 2), pp. 106–116 (1945). (In French.)

An illustrated review of h.v. circuit breakers of Belgian manufacture, including oil, water, minimum-oil, and air-blast types for high powers, and smaller ironclad units. Rupturing capacities range from 100 mva. at 6 kv. to 2500 mva. at 150 kv. (*Science Abstracts*)

No. 1007. J. Andrè, "Theory and Description of the Delle 'Inveruptair' or 'Symphaseur' circuit breaker for 1,500,000 kva.," *Bull.* Soc. Belg. Elect., Vol. 61, July–September, 1945, pp. 95–105. (In French.)

This paper describes the conception, construction, and test of the "Inveruptair" circuit breaker for powers up to 1500 mva. at 18 kv. The reasons leading to the choice of air-blast circuit breakers for the interruption of very heavy currents are explained, and the manner in which the design is made possible by the use of resistance switching is discussed. The principles on which the optimum value of shunt resistance is determined are set out, account being taken of difficulties arising when the breaker is called upon to interrupt small currents at lagging power factor. Some account is given of a process for testing the performance of such breakers, with testing plant inadequate for a normal test of full scale. An "Inveruptair" circuit breaker, capable of clearing 60 ka. at 15 kv. and closing on 150 ka. peak is described. (*Science Abstracts*)

No. 1008. "Air-Blast Switchgear," *Elec. Rev.*, London, Vol. 137, November 9, 1945, pp. 653–656. See also *Elec. Times*, Vol. 108, November 8, 1945, pp. 589–592.

Constructional details and test results of a new design made by Reyrolle and Co. Circuit breakers rated at 132 kv. and 2500 mva. are now being produced and designs are available for 220 and 264 kv. Each of the two interchangeable units which comprise the 3-phase breaker incorporates a duplex air-blast turbulator, a pneumatically operated series air-break isolator and porcelain post-insulator mounted on a bed-plate. In opening the circuit the isolator operates after the main contacts have opened and on reclosing it is used as a high-speed making switch. (*Science Abstracts*)

No. 1009. "Works Distribution, Switchgear Arrangements in a Propeller Factory," *Elec. Rev.*, London, Vol. 137, November 9, 1945, pp. 677–678.

Resistance furnaces provide the greater part of the electrical load which amounts to 0.75 kw. per sq. ft. of production area with a maximum demand of 1800 kw. The 750-kva., 11,000/400-v. transformer units are controlled by 150-mva. round-tank circuit breaker which have direct-acting over-current and earth-leakage protection with time-limit fuses across the over-current operating coils. Transformer secondaries are connected to a "Klad" medium-voltage switchboard incorporating 25 mva. circuit breakers. A 560-hp. autosynchronous motor driving a 250-rpm. air compressor is connected to each busbar section for power factor correction. (*Science Abstracts*)

No. 1010. "Oil Circuit-Breaker Demonstration Tests," *Pwr. Plant* (Engng.), Vol. 49, November, 1945, pp. 87–89.

The "Exotherm" principle of arc extinction was recently demonstrated by the Roller-Smith Co. at its "on the line" test station, to show the operating efficiency of breakers rated at 100 mva. and 150 mva. interrupting capacity. A substation of the Pennsylvania Power and Light Co. provided 250,000 kva. for the largest breakers. The test station facilities are enumerated and the results of tests are given with oscillograms. (*Science Abstracts*)

No. 1011. "Carbon Pile Contactor-Controller for Storage Battery Resistance Welding," *Mach. Shop Mag.*, Vol. 6, September, 1945, pp. 84–86.

The controller permits the rapid interruption without arcing of welding currents of up to 30 ka. The contactor consists of three large C plates which may be compressed by a pneumatic cylinder. The current passes from the two outer disks to the inner one. No sparking occurs between the C disks when the current is broken. (*Science Abstracts*)

No. 1012. S. Whitehead, "Symposium on the Corrosion of Metals," *J. Sci. Inst.*, Vol. 22, December, 1945, pp. 225–238.

No. 1013. M. H. Wells, "Progress in Switchgear Engineering," Iron and Steel Engr., Vol. 22, August, 1945, pp. 62–68.

A new type of oil circuit breaker has been developed for 115 to 230 kv. working and with interrupting capacities from 1×10^6 to 3.5×10^6 kva. within a time of 5 cycles on a 60-cycle basis. The use in this breaker of a new type of explosion pot, known as the multiflow type, has made possible an appreciable reduction in tank size. Other developments discussed are: a high-speed compressed-air circuit breaker, medium capacity switchgear, low voltage air breakers, power capacitors, and generator voltage regulators.

No. 1014. W. Wanger, "Systematic Tests of Rapid Re-closing in the System of the Gösgen and Laufenburg Power Stations," *Bull.*, Ass. Suisse Elect., Vol. 36, October 17, 1945, pp. 697–715. (In German.)

Two 50-kv 3-ph. lines, 24.4 km. long and 50 sq. mm. in cross-section, connected a 7050-kva. 83.3-rpm. machine at one end

with a 7850-kva. 107-rpm. machine at the other; a water resistance absorbed up to 12 mw. load. Arc faults were applied by fusing 0.3-mm. iron wires. The results are fully reported, with oscillograms. A pause of 0.25 sec. proved necessary and sufficient for complete deionization of the fault, and complicated arrangements to vary the length of the pause with the relative phase-speed of the two systems were felt to be superfluous. Fault duration in the tests was 0.10 to 0.12 sec. (*Science Abstracts*)

No. 1015. C. Volff, "Application of the Theory of Probability to Distribution Networks of Electric or Fluid Energy" (Feeding several electric arc-welding stations), *R.G.E.*, Vol. 54, April, 1945, pp. 122–124. (In French.)

A calculation is made of the probability that several stations will operate simultaneously and this leads to the chance that a given station shall be disturbed by the operation of a number of neighboring stations. The results are used to deduce requirements which must be satisfied by a generating station supplying the arc-welding stations. (*Science Abstracts*)

No. 1016. W. H. J. Vernon, "Controlling Factors in Atmospheric and Immersed Corrosion," *J. Sci. Inst.*, Vol. 22, December, 1945, pp. 226–230.

The principle of the controlling factor is extremely important in corrosion problems, and is now approached by way of corrosion under immersed conditions, of which there are two main types, H_2 evolution and O_2 adsorption. The former is normally associated with the more acid electrolytes, the latter with neutral salt solutions. Atmospheric corrosion is considered in two categories, according to whether the reactions involved are of the metal-liquid or the metal-gas type. Examples discussed include the effect of depth of immersion on rate of corrosion and of O_2 pressure on corrosion of mild steel, breakdown of air-formed films on iron, and promotion of rusting at critical humidity, and growth of air-forced oxide films. (*Science Abstracts*)

No. 1017. C. Varichon, "Circuit-Breaking Apparatus in l.v. Installations," *R.G.E.*, Vol. 54, August, 1945, pp. 227–236.

The different service conditions of circuit breakers (few operations at high current values) and contactors (few operations at high current values) and contactors (many operations at normal current) are discussed with special regard to contact design. Silver alloys of high melting point have high wear resistance, high conductivity, and are less likely to solder. Magnetic blowout which is considered of advantage in a-c. circuits only, should be carefully designed with due regard to circuit conditions, and must reduce to a minimum the time lag between separation of contacts and extension of the arc. The wear of contacts is proportional to the energy dissipated in the arc before extension. Graphs illustrate the change in the energy dissipated for various current intensities and magnetic field strengths. Oscillograms of arc rupture are given. The action of circuit breakers is considered for both a-c. and d-c. circuits. In the latter, it is mainly the magnetically stored energy which is released in the arc, and with a time constant of 0.02 sec., which is considered normal except for traction circuits, magnetic blowout is not required. The limits of application of circuit breakers, contactors, and fusible cut-outs are discussed and combinations of these are considered. (*Science Abstracts*)

No. 1018. C. H. Titus and P. J. Reischneider, "A 208Y/129-Volt, 120-Ampere, Three-Pole, 400-Cycle Electrically Operated Aircraft Circuit-Breaker," *Trans.*, Am. Inst. Electrical Engrs., Vol. 64, August, 1945, pp. 551–555.

It is designed for use as a busbar sectionalizing or generator breaker on a 400 cycles per second grounded neutral system. The interrupting rating is 3800 A and the closing solenoid and shunt trip coils are designed to operate over a wide range of ambient temperature and control voltage. The operating mechanism, control circuit, and operating characteristics are discussed with the aid of diagrams, and graphs show the short circuit and opening and closing characteristics. (*Science Abstracts*)

No. 1019. P. Sporn and H. P. St. Clair, "Field Tests and Performance of Heavy-Duty High-Speed 138-kv. Circuit Breakers," *Trans.*, Am. Inst. Electrical Engrs., Vol. 64, Supplement, pp. 401–410. (June, 1945.)

The test setup of a large interconnected 138-kv. system is described for testing under practical conditions, the performance of air-blast and an oil circuit breaker designed to interrupt a system load of 3500 mva. The test results are presented, characteristic oscillograms reproduced, and photographs are shown of the contacts after the tests. Each breaker was subjected to 20 interruptions ranging from 260 to 3200 mva. for the oil breaker and from 240 to 3500 mva. for the air-blast breaker. During these tests no mishap occurred and no serious operating disturbances were experienced. While the oil breaker exceeded the prescribed 3-cycle interrupting time slightly on one pole; the air-blast breaker succeeded in interrupting within 3 cycles on all tests and it was also shown capable of reclosing within 12 cycles. It is concluded that interruption with both types of breakers of 5000 mva. should be feasible. The importance of 3-phase full-

capacity field tests is emphasized and no other type of test is regarded as fully convincing. (*Science Abstracts*)

No. 1020. P. F. Soper, "A Review of a.c. Network Analysers," *Beama*, Vol. 52, September, 1945, pp. 303–329; October, 1945 pp. 341–348.

The essential features are described to enable a critical estimate to be made of the relative merits. Present applications to engineering problems are discussed with possible future uses. (*Science Abstracts*)

No. 1021. R. H. Savage, "Carbon-Brush Contact Films," *G. E. Rev.*, Vol. 48, October, 1945, pp. 13–20.

Describes investigations into the effect of water vapor on the friction between a C brush and a Cu surface under high altitude conditions. The results indicate that typical treated brushes require, for stable running, a v.p. of 100 to 200 microns which is higher than the v.p. at high altitudes. The ability of adjuvant brushes to operate for relatively short periods at high altitude is probably due to the stability of the films formed at low altitudes supplemented by the partial lubricant effect of the traces of water and O_2 in the stratosphere. (*Science Abstracts*)

No. 1022. C. J. Sarjeant, "New Design of a.c. Air-Break High Voltage Contactor," *BTH Act.* (Birt. Thomson-Houston), Vol. 18, October, 1945, pp. 289–291.

The increased use of high voltage low hp. motors led to the development by the B.T.H. of a new design of a-c. air-break contactor for operation at 6.6 kv. The arc-chutes are of the lift-off type and are easily removed for examination of the contacts. Provision was made for the magnet gap and contact gap of each pole to be adjusted to their proper values separately and individually. The contactor is suitable for direct-on-line starting of squirrel-cage motors, or for controlling the stators of slipping motors. For reversing motors two mechanically interlocked contactors are required, one for forward and the other for reverse operation. (*Science Abstracts*)

No. 1023. J. Saint-Germain, "Manufacturers' Views on Medium-Voltage Distribution Circuit-Breakers," *Bull.*, Soc. Franc. Elect., Vol. 5, December, 1945, pp. 379–391. (In French.)

Tabulates the ratings of circuit breakers for voltages between 3.75 and 70 kv. used in France and the number of each sold between the years 1934–1942. Nine methods of arc extinction, five methods of operation, and twelve methods of trippings are enumerated, and its is suggested that manufacturers should propose some standardization. The effect of circuit capacitance on breaking capacity is discussed and various suggestions for its inclusion in a standard form of testing are reviewed. (*Science Abstracts*)

No. 1024. A. Roth and E. Scherb, "New Breaking-Capacity Tests on an Oil-Blast Circuit-Breaker for Medium Voltages," *Bull.*, Ass. Suisse Elect., Vol. 36, February 21, 1945, pp. 115–118. (In German.)

A report of 28 breaking-capacity tests on a 30-kv., 600-amp., 200-mva. circuit breaker of the type with restricted oil content (*Science Abstracts* No. 2206 (1943)) comprising short-circuit tests of pure break and then of break-closure-break, the closure in the latter series following 22 per 100 sec. after the first break and the second break after a further 6 per 100 sec. Tests are also described on the effect of the formation of soot in the small quantity of oil in the breaker. (*Science Abstracts*)

No. 1025. R. Rambaut, "Effect of Circuit Arrangement on Restriking Voltage After a Current Interruption," *Bull.*, Soc. Belge Elect., Vol. 61, April–June, 1945, pp. 62–77. (In French.)

Gives results of an analytical and experimental investigation of the restriking voltage produced when d.c. is interrupted. The d.c. is passed through the a-c. network in the path followed by an a-c. fault current. The use of d.c. simplifies the experimental work and the results can be applied to a-c. conditions. (*Science Abstracts*)

No. 1026. W. G. Radley, "Some Practical Instances of the Corrosion of Non-Ferrous Metals in Telecommunications Plant," *J. Sci. Inst.*, Vol. 22, December, 1945, pp. 237–238.

No. 1027. G. Paillet, "Modern High Power Switchgear," *Bull.*, Soc. Belge Elect., Vol. 61, July–September, 1945, pp. 105–120. (In French.)

This paper describes in popular terms the three principles by means of which arc extinction in switchgear can be secured, namely, by extension of the arc in a suitable medium; by action in the arc of forces derived from the arc's own energy; and by action on the arc of forces derived from an external source. Utilization of these principles is illustrated by reference to the one particular type of circuit breaker, and the effect of the various characteristics on design is noted. Note is made of the peculiar difficulties arising in the design of high power switchgear for voltages in the range 10 to 20 kv, and the factors limiting the rupturing capacity of each type of breaker are discussed. (*Science Abstracts*)

No. 1028. J. R. Mortlock, "The Evaluation of Restriking Voltages," *J.*, Inst. Elect. Engrs., Vol. 92, Part *II*, December, 1945, pp. 562–579.

Considerable prominence has recently been given to the effects of restriking voltages on

the performance of circuit breakers, but little guidance has been given to the determination of these voltages. The approximate evaluation of restriking voltages is discussed using equivalent circuits for transformers, generators, etc., and their combination and reduction to a number of standard circuits, the solutions for which are tabulated. The mathematical work involved in any case has been reduced to routine evaluations. In particular, consideration has been confined to the interruption of 3-phase faults, but the principles can be applied to other types of faults, although these will not give higher voltages. (*Science Abstracts*)

No. 1029. S. Margoulies, M. Poma, and A. Blareau, "High Voltage Circuit Breakers," *Mem. Soc. R. Belge Ingen. Industr. B.*, No. 2, pp. 123–125 (1945). (In French.) (*Science Abstracts*)

No. 1030. S Margoulies with E. H. Hubert, "The Problem of Ultra-Rapid Reclosing," *Mem. Soc. R. Belge Ingen. Industr. B.*, No. 2, pp. 117–122 (1945). (In French.)

The time required for most transient 3-phase faults to clear varies from 0.1 sec. at 10 kv. to 0.24 sec. at 150 kv.; 1-phase faults may last 0.6 sec. Of total faults occurring, 90 per cent are transient (on high voltage lines) and in 80 per cent of these, reclosing may be effected without loss of synchronism, using air-blast switchgear. Tests made in Belgium confirm favorable opinions based on American experience, but it is not thought likely, on economic grounds, that ultra-rapid reclosing will for the present be used on other than important high voltage lines, nor on lines where a parallel interconnector prevents complete interruption. (*Science Abstracts*)

No. 1031. J. Labouret, "Pneumatic Breaking of the Electric Arc," *RGE*, Vol. 54, July, 1945, pp. 220–224.

Analogies are shown to exist between the supposed arc-breaking mechanism and the breaking-up of a liquid jet into independent drops. Assuming that the analogy would be more apt if gas jets were used, tests were carried out in which a thread of hydrogen was photographed on its introduction into the air jet of a supersonic blower. (*Science Abstracts*)

No. 1032. J. Labouret, "Medium-Voltage Air-Blast Circuit-Breakers for Electric Power Stations," *R.G.E.*, Vol. 54, December, 1945, pp. 355–361. (In French.)

Medium-voltage circuit breakers are those at the generator voltage. The duty on them is more severe than on others as there are no transformers between the source and the breaker and the fault current may therefore be severely asymmetric. The air-blast breakers in use are described together with various schemes for subdividing the high- and medium-voltage busbars to limit the short-circuit currents. (*Science Abstracts*)

No. 1033. J. C. Jaeger, "Switching Problems and Instantaneous Impulses," *Phil. Mag.*, Vol. 36, September, 1945, pp. 644–651.

Problems on transients in electric circuits involve a system started at time $t = 0$ with arbitrarily given initial conditions, which may or may not be compatible with the equations to be satisfied by the currents and charges when $t > 0$. The Laplace transform method, applied formally to such problems, needs justification. The point of view taken here is that when the initial conditions are incompatible, there is a rapid readjustment of conditions in a very short time following $t = 0$, and that under sufficiently general conditions the solution obtained by the formal Laplace transform method tends to the readjusted conditions as $t \to 0$. The theory of impulsive currents and emf.'s is involved and it is shown that the use of these, regarded as purely symbolical, leads to correct results. (*Science Abstracts*)

No. 1034. J. C. Hudson, "The Corrosion of Iron and Steel," *J. Sci. Inst.*, Vol. 22, December, 1945, pp. 231–235.

The work of the Corrosion Committee of the Iron and Steel Inst. and the British Iron and Steel Federation is reviewed on the subjects of protective coatings, atmospheric corrosion, marine corrosion, industrial waters, and buried metals; corrosion of unprotected iron or steel from the standpoint of environment and composition; protection of iron or steel against corrosion by paints and metallic coatings. (*Science Abstracts*)

No. 1034a. P. Chevalley, E. Eichenberger, and C. Ehrensperger, "High-Voltage Direct-Current Circuit-Breakers," *Brown Boveri Rev.*, Vol. 32, September, 1945, pp. 298–306.

Preliminary steps to provide d-c. circuit-breakers for h.sv., d-c. transmission are described. Oscillograms of tests on a small scale model line supplied from a.c. through a transformer and a mutator indicate the conditions arising in four cases. The effects of using d-c. units in series with or without insertion of resistance, and also of mutator/capacitor arrangements and the combined action of circuit breaker and mutator is discussed. (*Science Abstracts*)

No. 1034b. J. P. de la Gorce, "Influence of Surface Conditions on the Conductivity of Contacts," *Journies des États de Surface* (Paris), pp. 223–226 (1945).

Effects of oxide coatings, absorbed gases, and rough surfaces are considered; also pressure.

No. 1034c. J. Frenkel, "On the Theory of Electric Contacts Between Metallic Bodies,"

J. Exp. and Theor. Physics (*U.S.S.R.*), Vol. 9, p. 489 (1945).

Electrons penetrate the gap between two bodies by thermo-electric emission; image forces lower the potential barriers by an amount inversely proportional to the width of the gap. Thus the electrical conductivity of fine metallic powders and granular films rises with temperature in a way similar to semiconductors. (*Science Abstracts*)

No. 1034d. W. Wagner, "Systematic Tests with Automatic High-Speed Reclosing in the Goesgen and Laufenburg Power Systems," *Brown Boveri Rev.*, Vol. 32, December, 1945, pp. 415–435.

Tests were carried out to ascertain the limits of application of rapid reclosing on tie-lines between power stations or whole networks. Stable parallel operation can be maintained in the majority of cases. (*Science Abstracts*)

1946

No. 1035. F. Heaton and A. R. Heaton, "Air-Break Switchgear for Mines and Other Dangerous Situations," *Elect. Rev.*, London, Vol. 138, March 15, 1946, pp. 405–407.

A scheme suggested for improving the rupturing capacity and safety factor of totally enclosed switchgear for installation in dangerous atmospheres implies that opening and closing shall, in all circumstances, take place in fresh air. Air or inert gas is supplied under pressure and released on movement of a switch so as to direct a blast of air across the contacts. The operation of such a breaker and the compressed air supply are described. It is proposed to supply the air along ducts in the supply cables, branching off at junction and cable boxes. (*Science Abstracts*)

No. 1036. G. G. Grissinger and F. D. Johnson, "A New Submersible Network Protector of Higher Rating," *Trans., Am. Inst. Electrical Engrs.*, Vol. 65, February, 1946, pp. 41–46.

This protector unit consists of a 3-pole motor-operated air circuit breaker, three fuses, master network, phasing and desensitizing relays. Developments in distribution networks and the need for protectors of this rating are given in a general description of the apparatus which is a 3000 A submersible network protector for 120 to 208 v. 3-phase 60 cycles per second service. The interrupting rating is given as 40,000 A. Reduction of Cu and Fe losses is discussed together with heat dissipation and mechanical features. The measurement of a-c. resistance at low frequency in heavy conductors is considered. (*Science Abstracts*)

No. 1037. J. M. Goodall, "Oilless Circuit Breakers," *Electrician*, Vol. 136, March 8, 1946, pp. 589–592.

A description of an Aeroblast circuit breaker made by B.T.H. for ratings up to 750 mva. at 6.6/11 kv. and 1000 mva. at 33 kv., the basic design having been tested to the requirements of B.S.S. 116/1937. The interrupting elements and the air components are separately described. Attention is drawn to the nature and values of switching voltages which have to be provided for. These include the restriking voltage transient governed by the natural frequency of the system, steep wave front voltage transients generated by pre-zero current suppression; and transients resulting from discharge of circuit capacitance when the restriking voltage breaks down the gap between the opening breaker contacts at a current zero. (*Science Abstracts*)

No. 1038. W. J. Gibbons and W. W. Martin, "Switchgear for Voltages of 33 kv. and Above," *Trans.*, S. Afr. Inst. Elect. Engrs., Vol. 37, March, 1946, pp. 58–93.

A comprehensive review of current British practice. (*Science Abstracts*)

No. 1039. M. A. Garrett, "Air-Blast Breakers at Barrow," *Elec. Rev.*, London, Vol. 138, April 19, 1946, pp. 619–621.

A 132-kv. installation is described, the first to be installed and commissioned in this country. "Duo-Blast" air circuit breakers and their current transformers are located on concrete rafts at ground level, the complete arrangement being housed in the equivalent space of a bulk oil circuit breaker. The breaker design, the current transformers, and pneumatic installation are described. The latter incorporates duplicate air compressors charging automatically the main air storage system.; The apparatus is made by Ferguson Pailin. (*Science Abstracts*)

No. 1040. K. Fiechter, "Experience with Carbon Collector Strips on the S. E. Switzerland Railway." *Bull.*, Assn. Suisse Elect., Vol. 37, June 29, 1946, pp. 360–361. (In German.)

Experience shows that carbon current-collecting strips have a life of 150,000 to 200,000 km. as compared to 25,000 to 30,000 km. for Al or Cu, and the wear on the contact wire is also reduced in similar proportions. (*Science Abstracts*)

No. 1041. R. C. Dickinson and R. Frink, "Size Reduction and Rating Extension of Magnetic Air Circuit Breakers up to 500,000 kva, 15 kv.," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, June, 1946, pp. 220–223.

The principle of magnetic deionization has been extended to air circuit breakers of the 15-kv. class with interrupting ratings up to 500 mva. The interrupter has been improved so that the increase in kva. ratings of up to 500 per cent has not resulted in undue increase in space requirements. The short arc chute, 19 inches long for a 500-mva.,

15-kv. unit, has made possible compact horizontal drawout construction with all its inherent advantages. (*Science Abstracts*)

No. 1042. J. Christie, "Air Blast Switchgear and Its Application," *Elec. Power Engr.*, Vol. 28, May, 1946, pp. 321–327.

A 66-kv. outdoor air-blast circuit breaker is described and the advantages of multibreaks discussed. The use of breaks in series, instead of increased air pressure, is preferred and, if the voltage across each break is controlled by some form of voltage grading and the breaks are aerodynamically similar, each break takes a fair share of the work. Compressor and air-storage equipment, maintenance, and installation are also reviewed in addition to applications of the various types. At the present stage of development the air-blast circuit breaker is not expected to supersede the oil-immersed circuit breaker except in installations where breaking capacity and operating voltage are high, and operation frequent enough to involve maintenance problems in oil circuit breakers. (*Science Abstracts*)

No. 1043. I. V. Butkevich and A. M. Bronstein. "Switch with Solid Gas-Generating Dielectric for 6–10 kv., 200–300x10^3 kva.," *Elektrichestvo*, No. 5, pp. 35–43 (1946). (In Russian.)

A novel type of switch has been developed to replace oil-filled switchgear, particularly suitable for frequent operation (electric furnaces). The dielectric is polymethylmethacrylate. Its advantages are: high quenching qualities, low specific gas generation per kw. per second, good electrical and mechanical properties. Weak points are: low thermal stability, large amount of nitrogen liberated. It is possible to use the gas generated in the chamber walls for improved operation of the switch, blowing it across the chamber by means of buffer reservoirs. Transient effects are investigated, and self-resonances, critical capacitance, and the "residual resistance" of the arc calculated. Several cross-sectional drawings, oscillograms, and curves are presented. (*Science Abstracts*)

No. 1044. A. I. Builov, "Basic Types of Modern High Voltage Switches," *Elektrichestvo*, No. 5, pp. 16–23 (1946). (In Russian.)

While oil-filled switchgear is most suitable for lower power requirements, in large equipment where breaking currents up to 100,000 A are involved, co npressed air is the best dielectric. The relative amplitude of the transient peak after switch operation is shown to increase with current and with the rate of increase of the arc resistance and to drop with the working voltage of the line. Actual designs of switchgear with tandem arcs and compressed air quench chambers are described and schematic drawings and curves presented, showing relations between switched power, shunt resistance voltage recovery time, self-resonant frequency, and arc currents. (*Science Abstracts*)

No. 1045. W. B. Buchanan and G. D Floyd, "Field Tests of Interrupting Capacity of 138-kv. Oil Circuit Breakers," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, April, 1946, pp. 199–204.

By means of the network calculator the interconnection of a large 25 cycles per second supply system is determined so as to produce short circuit interrupting capacities of 1500 and 2500 mva., respectively. The measuring equipment used and the test procedure adopted are described. Typical short-circuit diagrams are reproduced and arcing times, fault durations, recovery voltages, and interrupting capacities tabulated. A comparison is made between test results and the currents calculated with the network calculator. The margin between rated and maximum interrupting capacity appears to be reduced for faults in a 25 as against a 60 cycle per second network. (*Science Abstracts*)

No. 1046. T. E. Browne, Jr., "Dielectric Recovery by an a-c. Arc in an Air Blast," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, March, 1946, pp. 169–176.

Gives results of a large number of tests carried out at 60 cycles per second, mainly at pressures of 5 to 40 psi. gage and currents from 50 to 4200 amp. on experimental air-blast contacts of various designs, at 13.8 kv. There is considerable spread in the results, but the general tendencies show: (1) an initial time delay at the higher currents, varying from 40 microseconds at 4200 amp. and 5 psi., to 5 microseconds at 1200 amp. and 40 psi., during which the restriking voltage remains fairly constant at a low value; (2) following this, a rapid rise of restriking voltage with time, lasting from 50 to 100 microseconds; (3) a third phase in which the restriking voltage is fairly constant at a value 5 or more times that reached in phase (1). Most of the tests were made on contacts of inferior design; a considerably improved performance was obtained especially on moderately low currents, by (*a*) rounding edges of orifice and contact rings to minimize electric stress concentration; (*b*) forming a crown on the upstream (moving) contact face and venting its center to atmosphere through a small auxiliary orifice; (*C*) insulating the metal orifice ring from the down stream (fixed) contact and spacing the contacts suitably with respect to the orifice. (*Science Abstracts*)

No. 1047. "State and Properties of Metallic Surfaces," *Nature*, London, Vol. 157, March 2, 1946, pp. 271–272.

A report of the Paris conference, October 23–26, 1945. (*Science Abstracts*)

No. 1048. "33 kv. Low Oil Volume Switchgear," *Engineer*, London, Vol. 181, April 19, 1946, pp. 355–356.

Details are given of the 33-kv. low oil volume metal-clad units made by Ferguson Pailin for installation in major power stations. The advantages of double-break design are retained by employing two small-diameter tanks per phase, joined together and externally braced at the waist. Testing has shown no marked deterioration of oil due to carbonization. An improved design F.P. cross-jet arc control device combined with quick-acting operating mechanism brings the breaker well within the high-speed category. (*Science Abstracts*)

No. 1049. "British Standard Specification for Tumbler Switches, Part 1, 5-ampere Flush-Type," Brit. Stand., No. 1299, 10 pp. (1946).

Covers flush-type one way single-pole tumbler-switches rated at 5 amp. 250 v., complete with switch boxes and switch plates. (*Science Abstracts*)

No. 1050. "33 kv. Low Oil Content Circuit Breaker," *Engineering*, Vol. 161, March 22, 1946, p. 282.

No. 1051. "Room Switches," *Colliery Guard*, Vol. 173, July 26, 1946, pp. 119–120.

The room-drill-switch described is intended for the control of drills. It is rated at 1.75 kva, 615/125 v., 3 phase, 50 cycles per second, and is suitable for separate use or for forming part of a room-switch multipanel switchboard. The switch is arranged so that within the main enclosure there are two separate flameproof compartments, the upper one accommodating three 300-amp. air-insulated Cu busbars, and the lower a 3-phase main transformer having an output of 1.75 kva. at 50 cycles per second. A circuit diagram is given of the complete control system. (*Science Abstracts*)

No. 1052. "Report on High Voltage Switch Gear," *FIAT Rep.*, No. 514, H. M. Station. Off.; U. S. Dep. Comm., 36 pp. (1946).

This account of personal observations on the high-voltage switchgear position in Germany contains interesting comments on the activities of the chief firms, especially Voigt and Haeffner and Siemens Schuckertwerke, with a brief outline of the different types of gear favored and notes on the position in other countries and on war damage sustained. Attention is drawn to new features such as "Expansin" (a nonignitible insulant) and a tripping device used with success for welding machine control and possibly suitable for developing a synchronous, high-voltage circuit breakers. (*Science Abstracts*)

No. 1053. L. M. Voronel, M. G. Koblenz, and E. V. Dudarenko, "New Series of Power Contractors for Direct Current," *Vestn. Elektroprom*, Vol. 17, No. 3, pp. 3–9 (1946). (In Russian.)

New proposals for the standardization of d-c. power contactors are presented: the current ranges should be 100, 150, 300, 600 amp.; limiting voltage 600 v.; contactors should be able to withstand 10,000,000 on-off operations. Present-time Russian and American contactors are described, and their salient points illustrated. The following design features are discussed: spark suppression method of anchor pivoting, magnetic systems, and contact assembly. A Russian 300-amp. contactor developed on these lines is described, and its test report quoted. (*Science Abstracts*)

No. 1054. E. M. Tsierov, "Spark Quench Chamber of an Air-Dielectric Switch for 110 kv.," *Elektrichestvo*, No. 5, pp. 24–30 (1946). (In Russian.)

The design of a spark quench chamber of compressed air type for a switch of 110 kv. and 2500 mva. is described in detail. Cross-sectional drawings of several types are shown, also an oscillogram and a curve of air pressure *vs* arcing time. The pneumatic contactor is described, the advantages of its novel hollow cylindrical contacts being particularly stressed. (*Science Abstracts*)

No. 1055. H. Thommen, "A Further Stage in the Development of the Indoor Air-Blast High-Speed Circuit-Breaker," *Brown Boveri Rev.*, Vol. 31, April, 1946, pp. 141–150.

Describes 30-kv., 400- and 600-mva. breakers employing resistance switching; the resistor is connected between one pole of the breaker and an auxiliary contact in the arc stream. The effect of the resistor on making the operation of the breaker independent of the system natural frequency is explained. Improved air flow conditions were examined by means of water which gives a good approximation if the velocity is adjusted. The breaker is built for wall, floor, or truck mounting and can be fitted with auto-reclose devices. (*Science Abstracts*)

No. 1056. D. T. J. Ter Horst and M. D. Dalebout, *Electro-techniek*, Vol. 24, June 20, 1946, pp. 143–144. (In Dutch.)

The device consists in principle of two sphere gaps in series, 1–2 and 2–3. Sphere 1 is connected through a 50 μF capacitor, charged to -3kv., to one terminal of the operating coil of the circuit breaker, two is connected through a switch to the 1-kv. a-c. generator, three to the other coil terminal. The gap 1 to 2 breaks down at $\sqrt{2}$kv., but 2 to 3 just does not. As soon as 1 to 2 breaks down, however, the potential of 2 rises from $\sqrt{2}$kv. to -3kv. less the arc voltage, whereby 2 to 3 breaks down and the capacitor dis-

charges through the coil. Operation is thus established at maximum voltage value. Description of the complete circuit is given, with diagram. (*Science Abstracts*)

No. 1057. A. P. Strom, "Long 60-Cycle Arcs in Air," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, March, 1946, pp. 113–117.

Volt-ampere characteristics of 60 cycles per second arcs in still air, with lengths and currents such as occur in power systems, were investigated under laboratory conditions. These arcs varied in peak current from 68 to 21,750 amp. and in length from 1/4 to 48 in. Typical oscillograms and volt-ampere curves of these tests are presented. The voltage gradient in the arc is affected very little by current magnitude. Throughout the entire range all gradients remained between 21.5 and 50 v. per inch with 35 per cent of all values in a 5 v. per inch interval having an average value of 34 v. per inch. The increase in apparent gradient due to voltage drop at the electrodes was found to be negligible where the arc length exceeds several feet. The decrease in short-circuit current of a power system through a series arc as compared with that for the same system with a metallic short circuit was investigated. Data show the actual reduction observed for various conditions of circuit voltage and impedance. (*Science Abstracts*)

No. 1058. P. F. Soper, "A Review of Carbon Brush Contact Phenomena," *Beama*, Vol. 53, April, 1946, pp. 132–137; May, 1946, pp. 189–193; June, 1946, 228–232.

No. 1059. W. F. Skeats and E. B. Rietz, "A New Line of High-Voltage Outdoor Tank-type Oil Circuit Breakers," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, June, 1946, pp. 224–231.

Further improvements are described of earlier breakers (*Science Abstracts* No. 1539 (1945)) of the 155 to 161 kv. range with interrupting capacities up to 3500 mva. within 3 cycles and reclosure within 20 cycles. As a result of a large number of tests the modified interrupter is shown to give even shorter arc durations and lower pressures at currents beyond the standard rating than the previous design. The results of similar tests on a 220-kv. breaker of the same fundamental construction are given. In such short-circuit tests it is now claimed to be possible to control both the displacement of the short-circuit current wave and the point at which the contacts separate. A completely sealed oil-filled bushing which is interchangeable with the old design is stated to be stronger both electrically and mechanically. The improvements effected produce a reduction in over-all dimensions and total weight. The operating mechanism of the pneumatic type with tripping arrangements for 3-cycle and 5-cycle breakers is described. (*Science Abstracts*)

No. 1060. L. J. Linde and B. W. Wyman, "The Development, Design, and Performance of Magnetic-Type Power Circuit Breakers," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, June, 1946, pp. 386–393.

Magnetic air circuit breakers establish a high resistance arc prior to circuit interruptions which modifies the circuit constants before recovery voltage is established. The treatment of the arc in this breaker to obtain a high arc resistance is explained in detail. Also, design practices and operating characteristics of the final magnetic type breaker are reviewed. (*Science Abstracts*)

No. 1061. A. Latour, "The High Power Air-Blast Circuit Breaker and Methods of Test," *R.G.E.*, Vol. 55, June, 1946, pp. 219–233. (In French.)

A brief outline of the principles of a-c. arc rupture is given. The twin problems of construction and testing of air-blast circuit breakers for high powers are discussed with reference to assumptions made in using multiple units and on tests other than full-scale. Observations are made on the speed of recovery of dielectric strength, deionization by turbulence, residual emission from the contact, ionization, the design of the arcing chamber and their interaction and relative importance. Details are given of the nature and arrangement of resistance put in parallel, a course advocated for achieving the highest breaking capacities. An indirect (composite) method of testing is described which it is suggested should prove in the future to be a satisfactory substitute for full-scale testing. (*Science Abstracts*)

No. 1062. C. H. Kreger, "Metal-Clad Unit-Type Switchgear for 33 kv. Service," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, June, 1946, pp. 360–368.

Gives experience gained over 13 to 16 yr. by the Public Service Co. of N. Illinois on seven outdoor metal-clad 3-kv. switchgear installations. Comparison is made with open-type gear of similar size. The metal-clad gear is safer, there having been no accidents, and more reliable, especially in dirty situations. Some electrical and mechanical troubles were experienced and cured. The cost is about 30 per cent more than that of the open-type gear. (*Science Abstracts*)

No. 1063. R. Koller, "Fundamental Properties of the Vacuum Switch," *Trans.*, Am. Inst. Electrical Engrs., Vol. 65, September, 1946, pp. 597–608.

The main result of a study of the various phenomena which take place during the interruption of currents in high vacuum are given. The experimental results obtained lead to a theory of the basic mechanism affecting switching in high vacuum. With a proper design of the switch, a constant working pressure can be obtained which represents

an equilibrium between gases and vapors evolving from the electrodes and a pumping action based on the sputtering of cathode material. A detailed study is made of the factors determining the loss of electrode material because of switching. The most essential design features of a vacuum switch are discussed briefly.

No. 1064. E. W. Andersson, "Fuses or Circuit-Breakers on h.v.," *Tekn. Tidskr.*," Vol. 76, September 7, 1946, pp. 859–863. (In Swedish.)

Discusses the use of fuses instead of, or as well as, circuit breakers for installations of 20 to 40 kv. A typical layout is given with the time current curves of fuses of different manufacturers and of inverse-time relays. These are compared with the heating-time curves of transformers on short circuit and it is concluded that fuses can often be used with advantage. (*Science Abstracts*)

No. 1065. G. Balachowsky, "H.v. Air-Blast Circuit-Breaker," *Bull. Soc. Franc. Elect.*, Vol. 6, May, 1946, pp. 231–233. (In French.)

Describes the Alsthom breaker for 220 kv. and 3500 mva. Three main breaks are used which are normally closed and which have permanently connected resistors across them to give proper voltage distribution. Isolation is by separate air blast units housed in a porcelain insulator. The total operating time is 2.5 cycles of which 0.2 cycles is for energizing the trip coil, 1.3 for operation of valves, etc., 0.5 for opening the contacts and 0.5 cycle for arc extinction. (*Science Abstracts*)

No. 1066. G. Balachowsky, "Circuit-Breakers with Self-Generated Gas Blast. Auto Gas-Blast Breakers," *Bull. Soc. Franc. Elect.*, Vol. 6, June-July, 1946, pp. 300–302. (In French.)

A description is given of the chief features of the "hard gas" type of circuit breaker, which derives the necessary blast of gas from the action of the arc on a substance such as fiber, often in the form of a tube and in close proximity to the arc. The cases of high breaking capacity and breaking on relatively low currents (weak range) are briefly considered. A 3-pole breaker for 17.5 kv. and full load current of 320 amp. is illustrated and desirable characteristics for the materials emitting the gas are listed. The evolution of the gas protects the material from rapid disintegration under the action of the arc. (*Science Abstracts*)

No. 1067. G. Balachowsky, "The General Problem of Circuit-Breaker Testing. Circuit-Breakers Used in Rapid Reclosing Tests at the Soleil Station at St. Étienne," *Bull. Soc. Franç. Elect.*, Vol. 6, August-September, 1946, pp. 389–394. (In French.)

The principle of reclosing on a fault to avoid, as is frequently possible, interruption of supply, is briefly outlined. The supply must be interrupted for a time long enough to clear a fault and short enough to avoid dangerous transients. The case of closing and reopening on a short circuit is discussed, and the importance of rapid and uniform breaking of the current independent of the magnitude of the short circuit is emphasized, with reference to the Alsthom "central impulse" breaker. The pneumatic control system is described and details given of a test on a 150-kv. network on which artificial faults were produced. (*Science Abstracts*)

No. 1068. A. Bally, "The New Oil-Poor High-Speed Circuit-Breaker, Type V, For Voltage Ratings of 10–30 kv.," *Bull. Oerlikon*, Vol. 26, February, 1946, pp. 1695–1700.

No. 1069. H. V. Benns, "A-C. Air-Break High Voltage Contactor Equipments," *BTH Act.*, Vol. 19, October-December, 1946, pp. 121–123.

Construction details of a range of a-c. air-break h.v. contactors, for use on supplies up to 6600 v., are discussed. Such equipment is suitable for the control of motors for power station auxiliaries; certain mill drives; rubber processing machinery; pumps; and other applications where h.v. motors are employed. When used on 6600 v. the contactor ratings are 300 hp. for direct on-line starting of squirrel-cage motors, and 700 hp. for starting slip-ring motors. (*Science Abstracts*)

No. 1070. F. Bertholet, "Some Technical Considerations Regarding Contactors," *Bull. Ass. Ing. Elect. Montefiore*, Vol. 59, August, 1946, pp. 353–375. (In French.)

Arc rupture, and causes and processes of extinction are discussed with particular attention to the shape of the arcing chamber and arc chute. The effects of current intensity (d.c. and a.c.) and of the type of network on the contactor operation are studied. The effects of self-inductance energy, energy from the network, and the inter-relation of growth of dielectric strength and restriking voltage, and increase of the arc-gap resistance are dealt with. The influence of the closing and opening coil arrangements on the performance of the main contactor is discussed and notes are given on oil-immersed contactors and on such difficulties as the "freezing" of contacts. (*Science Abstracts*)

No. 1071. F. Bertholet, "Some Technical Considerations Regarding Contactors," *Bull. Ass. Ing. Elect. Montefiore*, Vol. 59, June, pp. 271–277; July, 1946, pp. 317–341. (In French.)

The exacting demands of modern industry on contactor gear are discussed, and a general description is given of the elements of an electromagnetic contactor and of the magnetic circuit, respectively. In the latter, the sup-

ply of a.c. and d.c. to the operating coils is considered, with notes of measurement of flux, vibration on a.c., and the use of Cu_2O rectifiers. The design is treated dynamically and geometrically. Current density and resistance in small elements of the contact, oxidation, and deformation effects under pressure and temperature are considered. The problems of closing and tripping contactors are reviewed, with reference to the forces to be overcome, speed of closing, variation of current in the coils, and voltage drops at each contact and in the arc, and a more detailed study is made of temperature, space charge, and other conditions in the arc stream. (*Science Abstracts*)

No. 1072. F. V. Bezroukov, "Improved Properties of Tubular Circuit-Breakers Made of Organic Glass," *Elektrichestvo*, No. 9, pp. 54–56 (1946). (In Russian.)

Modern Russian developments in circuit breakers made of synthetic glass of up to 35 kv. and 5000 amp. capacity are described. The main features are: long life without the need for annual dismantling and overhaul, accessibility and ease of cleaning, and the novel method of artificial aging of the arc-quenching chamber by means of a semiconducting paint layer. Volt-second characteristics, plotted for new and used breakers, for positive, and negative pulses, are given, with constructional data. (*Science Abstracts*)

No. 1073. J. Bosle, "The Construction of Deion-Air Circuit-Breakers," *Bull. Soc. Franç. Élect.*, Vol. 6, June-July, 1946, pp. 294–299. (In French.)

The mechanism and mode of operation of the Deion-air breaker is described in some detail, the basic principle being that of a contactor with magnetic blow-out plus the special deionizing chamber. Illustrations of the radial field windings and the various shapes of the slotted Cu and insulator plates are included with photographs of completely assembled 4- and 3-pole types. Test data and oscillograms of an opening and of a closing test at high power are given. (*Science Abstracts*)

No. 1074. Bourdon, "Statement of Results of Improving Two Types of Water Vapor Circuit-Breaker," *Bull. Soc. Franç. Élect.*, Vol. 6, August-September, 1946, pp. 383–385. (In French.)

An account is given of various defects in early development and construction of some 108 single and 3-phase water vapor breakers in service on 10-kv. and 15-kv. overhead and buried cable networks for about 12 years. Notes are included on possible causes of breakdown and their remedies—choice and maintenance of the liquid used being important. (*Science Abstracts*)

No. 1075. C. Bresson, "Resistance-Switching Air Circuit-Breaker," *Bull. Soc. Franç. Élect.*, Vol. 6, May, 1946, pp. 212–216. (In French.)

Resistance switching, in which the interruption is carried out in two stages with a resistance of several ohms inserted in the first stage, allows the use of a smaller air pressure (only about 14 psi.) and renders the breaker independent of circuit characteristics. For medium-sized breakers, for example, 200 mva., sufficient air pressure can be obtained from spring-operated pistons charged during the closing operation. (*Science Abstracts*)

No. 1076. C. Bresson, "Low Oil Content Circuit-Breakers. The Circuit-Breaker with Small Oil Volume for Medium Voltages," *Bull. Soc. Franç. Élect.*, Vol. 6, June-July, 1946, pp. 259–263. (In French.)

The main characteristics of the ordinary oil circuit breaker are recapitulated and compared with those of the low oil-content type, mention being made of corresponding features in gas-blast and auto-gas blast circuit breakers. Attention is drawn to advantages of the low oil-content breaker such as the reduction of fire risk (in contrast to oil breakers) and noiselessness and flexibility in generating the means for extinguishing the arc in proportion to the current to be broken (as compared with the gas-blast type). It is concluded that the low oil-content variety is unsurpassed for operations on medium voltage and medium power circuits. (*Science Abstracts*)

No. 1077. W. H. Clagett and W. M. Leeds, "Four 370,000-kva. Short-Circuit Tests on Grand Coulee 230-kv Bus," *Trans. Am. Inst. Elect. Engrs.*, Vol. 65, November, 1946, pp. 729–734.

The unusually large concentration of generating capacity at Coulee Dam makes possible short-circuit power on the 230-kv. bus considerably in excess of the rupturing capacity of circuit breakers now available at that voltage. Methods of sectionalizing the bus and segregating the transmission lines to limit the maximum short circuit to less than 3500 mva. are described. A group of fault tests on one of the 230-kv., 3-cycle, 3500-mva. steel tank oil circuit breakers was made with a maximum of six generators connected. Three-phase faults close to the breaker rating and single phase-to-earth short-circuit currents equivalent to 4 370 mva. 3-phase were cleared with no apparent effort by the breaker. These are believed to be the heaviest short circuits ever interrupted on a power system. (*Science Abstracts*)

No. 1078. R. W. J. Cockram, "Circuit Interruption," *Elect. Rev.*, London, Vol. 139, September, 1946, pp. 385–388.

The micro-break switch for low power circuits is cited as an example of the application of knowledge of the rates of rise of restriking voltage and of restoration of dielectric

strength appropriate to the circuit conditions to be dealt with. Subsidiary benefits are reduction in arc energy released and in contact wear, burning, and pitting. The electrostatic aspect of switching is also discussed and a surge suppressor and various forms of mercury switches are described. (*Science Abstracts*)

No. 1079. R. David, "Deion Circuit-Breakers. The Rupture of Short a-c. Arcs and the Deion-Air Circuit-Breaker," *Bull. Soc. Franç. Élect.*, Vol. 6, June-July, 1946, pp. 289–293. (In French.)

In the Deion-air breaker the arc starting between the main contacts is tranferred by arcing horns to a deionizing chamber built of a number of Cu discs interleaved with insulation providing air pockets. The arc is divided into a number of short arcs in a magnetic field causing rapid rotation. A theory based on Slepian's work is developed, and questions of restoration of dielectric strength, ionization, space charges, and potential gradients are discussed. The important distinctions between glow discharge and arcing are dealt with, and it is concluded that, with the Deion-air type, the circuit will always be broken not more than one-half cycle after the arc has entered the deionizing chamber provided that (as is arranged for normal service) the recovery-voltage across each small gap <250 v. critical (sparkover) voltage. In these circumstances the operation is said to be independent of the circuit frequency. (*Science Abstracts*)

No. 1080. A. M. De Bellis, "Fuses Replace Circuit-Breakers on Station Feeders," *Elect. World*, N. Y., Vol. 126, November 9, 1946, pp. 99–100.

The fuses, known as Z-fuses, installed in the Sherman Creek station of Consolidated Edison Co., N. Y., are of flat Cu, H-shaped, the central fusible section being of special form to give the current-time features, and are fitted with moulded cement-asbestos covers. Their use in lieu of automatic circuit breakers on the feeders for the station auxiliaries and lighting, their mounting and characteristics are dealt with and illustrated. A lower maintenance cost than circuit breakers is obtained. (*Science Abstracts*)

No. 1081. R. Di Guiseppe, "Apparatus for the Determination of Rupturing-Time of Circuit-Breakers," *Energia Elett.*, Vol. 23, May, 1946, pp. 205–206. (In Italian.)

The distribution network of Rome is briefly described, and reasons for adjusting the operating times of the circuit breakers, operated by over-current relays, are given. Circuit diagram and some details are given of an installation incorporating a chronometer started by the primary relay-operating current and stopped by the completed rupture of the circuit breaker. The operation is described in detail. (*Science Abstracts*)

No. 1082. J. Dormont, "Interruption of Arcs by Compressed Air," *Bull. Soc. Franç. Élect.*, Vol. 6, May, 1946, pp. 205–211. (In French.)

Reviews briefly the axial, radial, and cross-blast principles, the use of multiple breaks, inherent or separate isolation, and the arrangement of the compressed air equipment. (*Science Abstracts*)

No. 1083. J. Dormont, "Notes on Arc Extinction by Jets of Oil," *Bull. Soc. Franç. Élect.*, Vol. 6, June-July, 1946, pp. 264–278. (In French.)

The growth of the oil jet concept for arc rupture is traced from the earliest idea of rendering turbulent the oil in an ordinary oil breaker to the later forms such as the explosion pot. Developments with multiple areing, cross-jets, and multi-jet arrangements are also described. The theory of arc extinction by use of oil jets is outlined, and the parts played by turbulence, recovery voltage, rise of dielectric strength, and the introduction of clean oil into the arc stream are discussed. Notes are included on the method of determining the correct dimensions of oil channels and outlets for various arrangements. Rapid reclosing problems and the modes of operation of modern types of oil-jet breaker are discussed. (*Science Abstracts*)

No. 1084. W. Elenbaas, "The Hypothesis of Minimum Voltage in the Theory of the Arc," *Physica's Grav.*, Vol. 12, October, 1946, pp. 491–498.

The author does not agree with the explanation of the contraction of the high-pressure discharge in the vicinity of the cathode, as given by Weizel and Rompe (Science Abstr. 1124 (1944), making use of the hypothesis of minimum voltage. It is shown, with the aid of Seeliger's consideration (Science Abstr. 1088 (1942)) regarding arcs in which the loss of energy is mainly due to thermal conduction, that the diameter, as given by the hypothesis of minimum voltage, is far too small at normal current intensities. This discrepancy being a function of temperature, it is considered that the relative behavior of the arc characteristics is not rightly described by the theory of minimum voltage. At very high current densities, at which ionization is almost complete, the principle of minimum voltage gives good results. (*Science Abstracts*)

No. 1085. C. J. O. Garrard, "Low-Oil-Content Outdoor Circuit-Breakers," *Gen. Elect. Co. Journal*, Vol. 14, August, 1946, pp. 83–89.

Particulars are given of a new range of outdoor circuit breakers for voltages from 6.6 to 66 kv. developed from the original heavy duty metal-clad gear previously described

(Science Abstr. 1476 (1943)), with illustrations of various types and of the contact arrangements. Information on mechanisms, methods, and materials employed is included. (*Science Abstracts*)

No. 1086. H. O. Gmelig-Meijling, "Design of h.v. Switchgear," *Electrotechniek*, Vol. 24, November 21, 1946, pp. 278–280. (In Dutch.)

An illustrated description of the grouping of cells, each cell containing circuit breaker, isolator, current transformer, instruments, and relays, in blocks of 4, facilitating supervision and busbar arrangement. (*Science Abstracts*)

No. 1087. A. Guillaume, "Indirect Tests at Reduced Voltage," *Bull. Soc. Franç. Élect.*, Vol. 6, August-September, 1946, pp. 410–414. (In French.)

The importance of being able to rely on proving station tests being strictly comparable to field tests is stressed, mention being made of the tendency to test single-phase units as prototypes and apply the results to the 3-phase case in practice without proper correlation. The definition of conditions for adequate proving tests at reduced voltage is discussed with reference to mechanical strength, energy released, and rate of rise of restriking voltage. It is concluded that the reduced voltage test envisaged is only applicable to auto-blast circuit breakers and that the use of c.r. oscillograms is necessary. (*Science Abstracts*)

No. 1088. A. Guillaume, "Water Circuit-Breakers. Medium Voltage Switch-Gear (Indoor Type)," *Bull. Soc. Franç. Élect.*, Vol. 6, August-September, 1946, pp. 371–382. (In French.)

The water-break circuit breaker can cope with short circuits up to 400,000 kva. in <0.06 sec. Features and advantages of water circuit breakers are described and illustrated, and particular attention drawn to performance at weak currents by use of glycol and water, which progressively inserts resistance as the contacts separate further apart. Precautions to observed are noted. (*Science Abstracts*)

No. 1089. M. C. I. Hunter, "Oil Circuit-Breakers and Their Operating Mechanisms," *BTH Act.*, Vol. 19, October–December, 1946, pp. 106–111.

Fundamental principles of the design of modern oil circuit breakers are discussed, with particular reference to the operating and auxiliary mechanisms. The design of a typical power-operated oil circuit breaker, of 3000 amp. capacity, is considered. A detailed account is given of the construction and operation of the breaker, and of the solenoid closing mechanisms. (*Science Abstracts*)

No. 1090. A. V. Jofee, "Electrical Resistance of the Contact Between a Semi-Conductor and a Metal," *J. Exp. and Theor. Physics* (*U.S.S R.*), Vol. 10, No. 1 pp. 49–60 (1946).

No. 1091. A. B. Krikunchik, "Simplified Method of Calculation of Short-Circuit Currents for the Selection of Switchgear," *Elektrichestvo*, No. 12, pp. 23–27 (1946). (In Russian.)

Russian standardized methods of short-circuit current determination are compared critically with corresponding methods abroad, particularly in the U.S.A., and the adoption of the latter is strongly recommended. (*Science Abstracts*)

No. 1092. J. Labouret, "Precautions to Be Taken on Installation and for the Maintenance of Air Circuit-Breakers," *Bull. Soc. Franç. Élect.*, Vol. 6, May, 1946, pp. 227–230. (In French.)

Condensation is the chief difficulty and is avoided, partly, by compressing the air to about 300 psi. for the storage cylinders and reducing to about 200 for operation. A trickle of dried air through the equipment and the use of electric heaters in the various chambers is also desirable. (*Science Abstracts*)

No. 1093. J. Labouret, "The Phenomenon of 'Forcing-Back' with the Electric Arc and the Thermo-Dynamic Limit of Breaking Capacity of Air Blast Circuit-Breakers," *CIGRE*, Rep. No. 128, 20 pp. (1946). (In French.)

The intense heat of the arc in the throat of a gas blast breaker may produce a back pressure which can momentarily check or even reverse the applied blast. A simple expression is given for the breaking capacity based on thermo-dynamical considerations suggested by jet propulsion studies. The argument is supported by calculations, experiments, and photographs of the arc. (*Science Abstracts*)

No. 1094. E. O. Larsen, "Making Electrical Contacts with Metal Powder," *Steel*, pp. 118, 119, 161, 162, 165 (1946).

No. 1095. A. Latour, "Development of the Radial-Blast Air Circuit-Breaker," *Bull. Soc. Franç. Elect.*, Vol. 6, May, 1946, pp. 217–262. (In French.)

Discusses the development of the diffusion theory of arc extinction. To secure rapid extinction there must be maximum turbulence and minimum electronic emission at the contacts, combined with resistance switching to reduce the rate of rise of restriking voltage. Attention to these details had led to the development of a 17.5-kv., 2 500-mva. breaker which is illustrated. (*Science Abstracts*)

No. 1096. A. Latour, "Power Testing of Circuit-Breakers Using Amplified Restriking Voltage," *Annales Univ. Grenoble*, Vol. 22, pp. 47–64 (1946). (In French.)

Means of increasing the testing range of proving stations such as those put forward by Biermanns and by Skeets are discussed and a modification of the latter's scheme is outlined. (*Science Abstracts*)

No. 1097. L. W. Long and J. F. Chipman, "Arc Furnace Switching," *Iron Steel Engr.*, Vol. 23, November, 1946, pp. 53–61.

Factors affecting the selection and maintenance of arc switching devices are discussed. Standard oil circuit breaker designed primarily for short-circuit protection and for infrequent switching are not suited to the large number of switching operations involved in arc furnace duty. Since a considerable volume of oil and frequent maintenance are likely to be required for the efficient operation of oil circuit breakers for furnace duties, it is suggested that it would be preferable to employ air-blast breakers. An experimental type of breaker rated at 23 kv., 600 amp. normal and 1500 max. interrupting capacity, and using an axial air blast is described. Test results are given. (*Science Abstracts*)

No. 1098. S. Margoulies and E. H. Hubert, "High Speed Reclosing of Circuit-breakers. Theoretical Considerations. Tests. Practical Experience on the System of Linalux (Belgium)," *C.I.G.R.E.*, Rep. No. 105, 15 pp. (1946.)

High-speed reclosing is shown to be justified in certain cases. Problems of fault elimination are studied theoretically. Tests show that the principle can be satisfactorily applied to large h.v. systems for protection against faults and lightning surges. (*Science Abstracts*)

No. 1099. L. A. Nettleton and F. E. Dole, "Contact Materials for Potentiometers," *R. Sci. Inst.*, Vol. 17, p. 356 (1946). *Met. Abst.*, Vol. 15, p. 76 (1947).

Contact material which gives long life when used against nickel-chromium slide wire on rheostats is an alloy containing platinum, palladium, gold, silver, copper, zinc and is called Patinoy No. 7.

No. 1100. O. Plechl, "Determination of Electric Switching Circuits," *Elektrotech. u. Maschinenbau*, Vol. 63, January-February, 1946, pp. 34–38. (In German.)

Multiple switching circuits can be treated mathematically by regarding a switch as an item of infinite or zero impedance. Work done on this subject in the war years is reviewed. (*Science Abstracts*)

No. 1101. A. H. Pollard, "Use of Resistance Switching in the Interruption of High Voltage Circuits," *C.I.G.R.E.*, Rep. No. 136, 16 pp. (1946).

Discusses the advantages of resistance switching for h.v. currents and the characteristics of suitable resistors. By this method, duty can be equalized in multi-break gear, the shape of the restriking transient can be controlled; the circuit breaker can be rendered insensitive to the rate of rise of restriking voltage transient, and unit tests become valid. (*Science Abstracts*)

No. 1102. M. Progent, "Contact-Wire Wear on Trolley-Bus Lines," *Rev. Gen. Élect.*, Vol. 55, July, 1946, pp. 281–287. (In French.)

Contact-wire wear for trolley buses is greater than for tramways chiefly because of the side pull if the vehicle is not running immediately below the wire, and because of the use of a sliding instead of a rolling contact. The path of a contact shoe in contact with a flexible wire is examined mathematically together with the effect of side pull. It is concluded that a light, highly tensioned wire with articulated supports, and with short spans of equal length is most desirable. (*Science Abstracts*)

No. 1103. K. Schiller, "Force Characteristics of Circuit-Breakers," *Engineering*, Vol. 162, October 25, 1946, pp. 385–387.

An analysis is presented of the closing and opening-force curves of circuit breakers, which gives an indication of no-load opening speed and, provided characteristics of the closing mechanism are available, of contact-making speed. Experimental procedure suggested for measuring closing and opening forces, consists in closing the breaker hydraulically and measuring the pressure on a hydraulic cylinder. An engine indicator is used to record the force cycle. The margin error of the method is approx. $\pm 10\%$, but representative figures for operating speeds can be obtained at an early stage in breaker assembly. (*Science Abstracts*)

No. 1104. E. I. Shobert, II, "Welding or Sticking of Electrical Contacts," Am. Soc. Testing Mats. Preprint 96 (1946).

After much effort, a method for evaluating the welding and sticking characteristics of contacts was developed. Consistent results were obtained in six different laboratories. The theory of this phenomenon is discussed at some length and a formula developed for the relationship between current on the testing machine and physical properties of the contact materials.

No. 1105. P. Sporn and J. H. Kinghern, "Ultra-High Speed Reclosing Demonstrates Its Value," *C.I.G.R.E.*, Rep. No. 106, 11 pp. (1946).

Modern developments in high-speed reclosing mechanisms for oil circuit breakers and

the results of nine years of operating experience are given. This operating experience covers 91 ultra-high-speed reclosing breaker installations mainly on a large interconnected and integrated h.v. system. Out of 635 cases of flash over, 89.8 per cent resulted in successful reclosure. Double circuit lines show a record of unsuccessful reclosure of double the average, but even in this case, 80 per cent of the apparently unsuccessful reclosures resulted in successful reclosure of one circuit. Conclusions are that ultra-rapid reclosure has been of major importance in improving line reliability; that its use can and should be extended to lower voltage lines; and that further improvement in performance can be expected when new circuit breakers with faster opening and reclosing time are employed. (*Science Abstracts*)

No. 1106. S. Teszner, "The Stresses on Circuit-Breakers in Operation on Networks and in Tests at Laboratories," *Bull. Soc. Franç. Élect.*, Vol. 6, August-September, 1946, pp. 395–409. (In French.)

The behavior of various breaker types is considered and restriking voltage phenomena and reignition are discussed in an attempt to assess the combined results of all factors involved. The cases of single and 3-phase generator breakers, breakers opening on line short circuit, and clearing short circuits or magnetizing currents on transformers are analyzed. Direct and indirect laboratory tests are described and general conclusions drawn. (*Science Abstracts*)

No. 1107. S. Teszner, "The Physical Mechanism of the Spark," *Bulletin de la Société des Electriciens*, Vol. 56, February, 1946, pp. 61–80. (English translation in the *Engineer's Digest*, Vol. 7, No. 11, November, 1946.)

This paper describes the distinct phases that can be observed during the formative and during the established conditions of sparking. The author touches on recent theories on phenomena involved and presents an entirely new theory which takes account of factors older theories have not considered but, as is shown, may assume considerable importance. The paper is mathematical to a great extent but also contains various experimental data. A special chapter is devoted to the influence of high and very high frequencies on the "established state" of sparks. This paper is of considerable interest to the student of electrical discharge phenomena.

No. 1108. A. Thibaudat, "A New Circuit-Breaker for 220 kv., 3500 mva.," *Bull. Soc. Franç. Élect.*, Vol. 6, June-July, 1946, pp. 279–284. (In French.)

A newly developed breaker with low oil content is described; in each unit there is an upper and a lower arc-gap, the arc gases at the latter forcing oil upwards to provide jets acting on the arc situated near the vents. The contacts rotate and circular canals guide both arcs (without constraint) so that they stay in the path of the moving contacts, and in the case of reopening the breaker after closing it on a short circuit the arrangements ensure that clean oil is available. The importance of reducing the weight of moving parts to allow rapid reclosing and to attain a high speed of operation is emphasized. A pneumatic damping device controls and reduces the gas pressure, particularly at the peak. Arrangements adopted in high power tests are outlined, attention being drawn to the dividing of the voltage equally over several breaks in series, and to methods of testing the breakers for duty on powers higher than available at the proving station. (*Science Abstracts*)

No. 1109. H. Thommen, "Problems Connected with the Rupturing of a-c. Currents at Very High Voltages up to 400 kv.," *C.I.G.-R.E.*, Rep. No. 109, 17 pp. (1946).

The report is concerned with multi-break gas blast circuit breakers for 400 kv. a.c. and above and for d.c. Attention is drawn to the importance of scavenging the arc chamber. Sectionalizing of long lines or use of high-speed earthing contacts is recommended. The sensitivity of various types of breakers to the inherent frequency of the system is discussed; the use of multi-breaks (and voltage distribution across them) and the special condition arising where small inductive currents have to be broken are considered. (*Science Abstracts*)

No. 1110. F. Tschumi, "The Planning of High-Voltage Indoor Switchgear Installations," *Brown Boveri Rev.*, Vol. 33, April-May, 1946, pp. 83–94.

Several feeder systems are discussed and the advantages of each method are considered. Various simple modern indoor installations are described with the aid of digrams. They are intended for use at 20 kv., but alteration in dimensions alone would render the layouts suitable for operation at 10 or 30 kv. if required. (*Science Abstracts*)

No. 1111. E. M. Tsierov, "Some Problems of Gas Dynamics in Compressed Air Switchgear," *Elecktrichestvo*, No. 12, pp. 14–22 (1946). (In Russian.)

The general principles and characteristics of compressed air switches based on Russian designs are treated in detail. The air duct feeding the compressed air and the valves operated by the switch are described. The volume and speed of airflow and the timing under 3 conditions are discussed: initial period of compression, 2nd period of counter-pressure mounting, 3rd period of actual switching. All the mechanisms of the air-quenching chamber, special differential valves,

and auxiliary valves are described with the aid of diagrams, based mainly on a switch for 110 kv., 2.5 mva. operation. (*Science Abstracts*)

No. 1112. O. B. Vikoren, "Application Ratings of Indoor Power Circuit-Breakers," *Trans.*, Am. Inst. Elec. Engrs., Vol. 54, November, 1946, pp. 768–773.

A discussion of the effect of overloads on circuit breakers, distinguishing between the oil and gas blast cases. General formulae are given for temperature rise and final temperature with numerical examples and supporting test data. For ambient temperature an average figure for "summer" and for "winter" is used. For a circuit breaker in an unventilated compartment, the ambient temperature was some 5 C. higher than when some ventilation was provided. The effects of contact resistance are very important. (*Science Abstracts*)

No. 1113. E. Vogelsanger, "Researches on Arc Quencing in Low-Oil-Content Circuit-Breakers," *C.I.G.R.E.*, Rep. No. 121, 26 pp. (1946).

Deals with the performance on 1-phase inductive circuits at 10–220 kv. of low-oil-content circuit breakers, in particular, the "Invertex" type. Conclusions based on arc voltage records are developed to indicate operating features and an expression is derived for energy liberated with a view to establishing breaking capacity. Observations are made on the quantity and pressure of the oil gas evolved, double break, and high-speed reclosing. (*Science Abstracts*)

No. 1114. A. T. Vrethem, "Operation of High-Voltage Systems up to 220 kv. equipped Arc-Suppression Coils," *C.I.G.R.E.*, Rep. No. 231, 29 pp. (1946).

A 3-year statistical investigation on Swedish 22 and 44-kv. systems shows that a combination of arc-suppression coils and high-speed auto-reclosure breakers can prevent a high proportion of system interruptions. On extensive h.v. transmissions systems the satisfactory operation of arc-suppression coils is determined by several factors, such as the number and location coils and the length of line to be protected, the accuracy of the tuning of the coils, and the design of protective relays. These factors are discussed and test and field results are reported. The magnitudes of overvoltages in the sound phases of a system with arc-suppression coils in the case of an earth fault are plotted as a function of the degree of compensation; and with a view to the operation of lightning arresters and circuit breakers the max. permissible lengths of uncompensated line are determined which produce a voltage rise of 20 per cent above the normal line-to-line voltage. Lightning fault statistics are presented for the extensive 77, 132, and 220-kv. lines the greater lengths of which are installed on wood poles. The protection afforded by arc-suppression coils is compared with that of other protective arrangements. (*Science Abstracts*)

No. 1115. "Contact-Face (Silver-Molybdenum) Alloy Resists Pitting, Welding under Heavy Current," *Scientific American*, Vol. 84, August, 1946. *Metal Abstracts*, Vol. 14, p. 414 (1947).

No. 1116. "Survey of Low Voltage, Air Circuit-Breaker Practice: Germany," *FIAT Rep.*, No. 512, H.M. Station. Off.; U. S. Dep Comm., 30 pp. (1946).

Attention is drawn to differences in construction and in application between American and German l.v. gear. Reference is made to design features and materials and methods used by the leading German firms with illustrations of breakers and panel and control-board installations. (*Science Abstracts*)

No. 1117. "Survey of the Carbon Brush Industry for Electrical Equipment of Germany," *FIAT Rep.*, No. 115, H.M. Station Off.; U. S. Dep. Comm., 22 pp. (1946).

The materials used in the industry are essentially the same as those used in the U.S.A., but prevailing production methods are less efficient. The composition of some carbon brushes is quoted, and some aspects of their manufacture are described. (*Science Abstracts*)

No. 1118. R. Holm, "Electric Contacts," *Hugo Gebers Forlag*, Stockholm, p. 396 (1946).

The work Dr. Holm has done in the field of electrical contacts is monumental. Unquestionably, he is one of the leaders in the study of the physical and engineering problems found in this field. Therefore, it is with pleasure and confidence that I recommend this book to anyone interested in the subject of electrical contacts.

The book is divided into four main parts. The first part discusses the problems concerned with stationary contacts, or contacts which are in the closed position. In this section he discusses such important points as contact resistance, the apparent and real contact surface, temperatures in contacts, electrodynamic and electrostatic forces in contacts, elasticity, hardness, properties of thin and thick surface films and other special features. Each of these items is considered in detail with enough test data or practical information to furnish direct use to be made of the results.

The second part of the book considers sliding contacts such as those on electrical machines. This section is opened with a detailed consideration of hydrodynamic and boundary layer friction. The effect of passing current through the sliding contact sur-

face is considered and contact resistance, arcing, wear, and commutation are discussed. The section on commutation is brief, but the background for further consideration of this problem is given.

The third section presents the electric phenomena in switching contacts. The theory of the electric arc and its application to contact problems is considered in detail. The characteristics of different types of circuits with respect to circuit interruption are presented. The physical basis of transfer of material is described and illustrated.

Part four gives a brief history of development of the physics of electrical contacts. The investigators who contributed to the progress made in this field are mentioned.

This brief résumé of Dr. Holm's book will give one a general idea of its scope. However it does not point out the magnitude of his work. The book must be read and studied carefully by anyone interested in taking full advantage of the results of extensive original work and able reporting. Only then is it possible to realize the full value of this book to the field of electrical contacts.

There is a great deal of confusion and contradiction in the practical application of electrical contacts, particularly in the field of sliding contacts. This book will not clear this up immediately, however it does shed considerable light on most of the details of these problems. In this way it will help those who use it to arrive at satisfactory solutions to their problems more easily and quickly.

There will undoubedly be many points and details with which many people will disagree, particularly when it comes to some of the practical applications of various contact materials. These points of difference will probably be caused by physical factors not under the same control in different tests. As much as anything, this book points out how much more work still must be done before complete solutions can be reached for many of the contact problems. (Review by E. I. Shobert in ASTM BULLETIN.)

No. 1118a. K. Oehler, "An Example in Switching Technique," *Bull. Ass. Suisse Élect.*, Vol. 37, June 1, 1946, pp. 298–302. (In German.)

A preferred alternative method to that of *Science Abstracts* No. 1371 (1948), *Contact Bibliography* No. 992h, is given. (*Science Abstracts*)

No. 1118b. "Increasing Safety of Plant by Using Odia Multiple Switches," *Technik*, Vol. 1, November, 1946, pp. 210–11. (In German.)

This multiple switch allows of making and breaking connections in a pre-determined manner. Push buttons are arranged in rows corresponding to the number of conductors and current consumers to be controlled, and columns corresponding to the number of combinations required. These push buttons are operated beforehand and show diagrammatically the possible combinations. Final connections are made by pressing a further push button (one for each column). The operation may be by hand (stage lighting) or automatically. The switch is also used for controlling motors or electrolytic plant, where simultaneous operation must be prevented. (*Science Abstracts*)

No. 1118c. Ernst Raub, "Plated Noble-Metal Contacts" (Forschungsinst. Probieramt Edelmetalle, Schwäb, Gmund, Germany), *Metallforschung*, Vol. 1, pp. 71–75 (1946).

The diffusion between basis metal and deposit, the material migration in the functioning of the contact and the changes in the surface produced thereby, and influence of local wear of the noble-metal deposit on the behavior of the contact must be considered in studying the elec. performance of plated noble-metal contacts. The contacts investigated had platings of Ag, Au, and 2 Au alloys containing in the one case 7 per cent Pt, and, in the other, 5 per cent Ni. Ag was plated directly on Cu; Au and the Au-Ni alloy were plated directly on Cu and also on an intermediate Ni layer soldered on Cu or bronze. The Au-Pt alloy was plated on an intermediate Ni layer soldered on bronze. The plated contacts were provided with platings of various thicknesses between 0.1 and 1 mm. Elec. performance was studied at a load of 3 amp. at 8 v. for 30 to 150 or 213 hr., or at 0.1, or 0.4 amp. and 60 v. for 1000 or 2000 hr., respectively. The make-and-break frequency was 100 per sec. With arc-free make and break, the heating of the contacts was slight. Micro-hardness determinations were made on polished sections to determine diffusion between plating and base metal. The investigation shows that the basis metal protects itself against local wear of the deposit by formation of an oxide skin. As a result of the diffusion zone normally formed in plated contacts between basis metal and deposit, destruction of the deposit does not lead to direct contact with the basis metal; this is limited instead to the diffusion zone. To avoid surface defects during operation, the noble-metal deposit should not be more than 0.2 mm. thick. If the hardness of the flaws produced on the cathode by material migration is higher than that of the basis metal, on continued operation the contact pressure leads to mechanical deformation of the basis metal itself; this can lead to attack on the basis metal by elec. loading of the contact. In the case of the gross migration occurring in elec.-arc operation, the attack on the basis metal proceeds unhindered. (*Chemical Abstracts*)

No. 1118d. P. de La Gorce, "Influence of

the State of Surface the Conductivity of Electrical Contacts," *Journées des États de Surface*, TA407 P21j pp. 223–226 (1946). (In French.)

Theoretically analyzes the above problem. Data for Ni, Cu, and Al are charted and interpreted for different surface conditions. (*Battelle Library Review*)

No. 1118e. Ernst Raub, "Precious-Metal-Plates Electrical Contacts," *Metallforschung*, Vol. 1, September, 1946, pp. 71–75. (In German.)

Describes and illustrates the mutual diffusion of the plating and the plates metal and the effect of particle transfer by electrolytic action on the plates surface and on the behavior of the contacts. The experiments were conducted on contacts plated with Au, Ag, and two gold alloys, containing 7 per cent Pt and 5 per cent Ni, respectively. (*Battelle Library Review*)

No. 1118f. L. B. Hunt, "Electrical Contacts," Johnson Mathey and Co. Ltd., May, 1946.

This book discusses primarily the engineering aspects of the contact problem. It does not go into the physical theory of the operation of contacts under various conditions, but does give a very excellent summary of most of the practical applications of contacts and what materials have been found suitable and are required for these various applications.

The book is divided into three major parts. The first section discusses the design and selection of contacts under various electrical and mechanical operating conditions. Limited duty contacts, medium duty contacts, contactor contacts and circuit-breaker contacts are considered. The second section discusses the properties of contact materials. In this section various metals and alloys of general classifications are considered. In addition, the special proprietary contact alloys are also discussed. Electro deposited contact materials are included in this section. The third section discusses the main problems involved in contact engineering. Various shapes, methods of attaching, special types and contact sub-assemblies are considered.

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No. 1119. A. Allan and D. F. Amer, "The Extinction of Arcs in Air Blast Circuit-Breakers," *Journal*, Instn. Elect. Engrs., Part II, Vol. 94, August, 1947, pp. 333–350.

A general survey is given of problems arising from the design of high-power air-blast circuit breakers, supported by data obtained on commercial and experimental breakers mainly of the turbulator type. The breaking performance criterion selected is rate of rise of restriking voltage × ka. broken; the importance of aerodynamic principles in designing the nozzle and air supply system is stressed. Other questions discussed are: characteristics of resistance switching, current chopping phenomena, and the effect of multi-break operation. An account is given of the design and test performance of 66-kv. (750-mva.) and 132-kv. (2500-mva.) turbulator breakers. Good design of the air supply system is an important factor for successful operation. (*Science Abstracts*)

No. 1120. H. W. Baxter, "The Influence of Design and Circuit Constants on Arc Energy and Pressure in Cartridge Fuses, Rep. Brit. Electrical Allied Ind. Res. Assoc. (Ref. G/T191), 10 pp. (1947).

The energy liberated in a cartridge fuse during the arcing period was studied, taking into account the effect of length and diameter of fuse wire, current and voltage, and grain size of filler. Measurements of pressures set up were also made. For a given fuse the arc energy increases with the current, the circuit inductance, and the circuit voltage. In a given circuit the arc energy increases with the diameter of the fuse wire but decreases with increasing length and is found substantially independent of the size of the filler grain. The pressure on the wall of the cartridge is materially influenced by the size of the filler grain and also by the internal diameter of the cartridge. There appears to be an optimum size of grain for minimum pressure. (*Science Abstracts*)

No. 1121. H. E. Cox and T. W. Wilcox, "The Performance of High-Voltage Oil Circuit-Breakers Incorporating Resistance Switching," *Journal*, Instn. Elect. Engrs., Pt. II, Vol. 94, August, 1947, pp. 351–361.

Reviews the improvement obtained in the performance of side-vented explosion pots when they are shunted by resistors. The rating of the pots is determined by two critical regions, one determining the maximum voltage, and the other the maximum breaking-current rating. The effect of resistors on these critical regions is described and illustrated by actual test results. The resistors shunting the pots can also be used to give even voltage distribution over several pots in series. The practical application of resistors is illustrated by a 132-kv., 2500-mva. oil circuit breaker. The effect of the resistors when breaking small currents in inductive and capacitive circuits is discussed in detail. A discussion follows on the validity of testing separately one pole of a 3-ph. separate-tank breaker, having two breaks per pole, by applying the full 3-ph. output of the test plant, the third terminal being obtained by bringing out through the tank wall a connection from the moving cross-bar. Test results obtained on one pole of a 3-ph. 132-kv., 2500-mva. breaker are given. (*Science Abstracts*)

No. 1122. E. Holm and R. Holm. "Electrode Erosion in Light Arcs," *Arkiv. f. Mat.-Astr. och. Fysik*, Vol. 34A (No. 1), Paper 8, 13 pp. (1947). (In German.)

Experiments with arcing contacts breaking 3 amp. currents show that matter transfer across gap = matter evaporated less deposit of atoms and ions, assuming evaporation is proportional to quantity of electricity passed. (*Science Abstracts*)

No. 1123. R. Holm, "Initial Current Densities," *Arkivf. Mat.-Astr. och. Fysik*, Vol. 34B (No. 1), Paper 8, 7 pp. (1947). (In German.)

The mechanism of high initial current densities in arcs is discussed. (*Science Abstracts*)

No. 1124. R. B. Immel, "Some Design Considerations for Electrical Contact Operation," *Product Engineering*, February, 1947, p. 107.

Causes of arcing of contacts are discussed and proper mechanical design is shown to be essential for best contact operation and life. Methods of reducing bounce of contacts, characteristics of contact materials, loss and transfer of material in contacts, and an engineering comparison of three different mechanical designs of a d-c. accelerating contactor are included. (*Product Engineering*)

No. 1125. S. Keilien, "Incandescent Lamps as Electrical Load for Testing," *Journal of Applied Physics*, Vol. 18, No. 8, August, 1947, pp. 769–773.

Because of the positive coefficient of resistivity of tungsten, incandescent lamps permit a current considerably greater than the normal lamp current to flow for a short initial period. When lamps are used as load for testing electrical apparatus, the factors affecting this inrush must be considered. Size of power source, its distance from the load (lamps), and frequency of switching the lamps (employing repetitive operations for endurance testing) are evaluated. From the given curve the necessary cooling time for the desired current inrush may be determined, and thus the frequency with which the lamps could be switched "on" and "off" may be calculated. Practical means for obtaining the required cooling time are described.

No. 1126. W. M. Leeds and R. C. Van Sickle, "The Interruption of Charging Current at High Voltage," *Trans.*, Am. Inst. Elect. Engrs. (Preprint 47–59) 16 pp. (1947).

The problem of breaking charging currents of large capacitor banks for h.v. and on long transmission lines is discussed, with a reference to the relevant characteristics of oil breakers with plain breaks, oil blast, baffle, air blast, and other types. It is concluded that with solidly earthed systems, a single restrike will not produce dangerous overvoltages, and though certain sequences of repeated restrikes can produce over 4 × line-to-earth peak voltage they seldom happen in practice. The use of resistance in parallel with the breaker contacts should be considered and more field tests should be done to establish and check results and provide adequate design data for h.v. switching equipments. (*Science Abstracts*)

No. 1127. I. Lindström, "Three-Phase Circuit-Breakers for over 200 kv.," *Tekn. Tidskr.*, Vol. 77, March 29, 1947, pp. 301–302. (In Swedish.)

Some data concerning insulation, current, and voltage-rupturing capacity for compressed-air circuit breakers for 300-kv. and 380-kv. networks are given. Rapid reclosing is briefly discussed. (*Science Abstracts*)

No. 1128. I. Lindström, "Present Features of Compressed-Air Breakers," *Tekn. Tidskr.*, Vol. 77, August 2, 1947, pp. 561–570. (In Swedish.)

Discusses the various forms of contact for, and the use of resistance switching with, compressed-air breakers. Diagrams and photographs of 1000 and 2500 amp. units at 10 kv. are given, and also of a multi-break 200-kv. unit together with oscillograms showing the behavior. (*Science Abstracts*)

No. 1129. A. J. Maddock, "A Design of Heavy-Current Contact, Particularly for Radio-Frequency Use," *Journal* Inst. Elect. Engrs., Pt. III, Vol. 94, January, 1947, pp. 52–54.

The contact device described is of a spring-loaded cam type with operating pressure and c.d. of $1^1/_2$–$2t$/in.^{2} and 35–40 ka./in.^{2}, respectively (as calculated from an estimate of the contact area). The contact material used is Be-Cu, Ag-plated with a flash of Rh. Currents of 75 amp. (20 Mc/s) and 150 amp. (50 c/s) can be dealt with and the contact has been used as a h.v. switch rated at 30 kv. A mechanical wear test indicates a life of $> 1/4 + 10^6$ operations. (*Science Abstracts*)

No. 1130. J. R. Mortlock, "Network Analysers," *Elect. Times*, Vol. 111, June 5, 1947, pp. 635–639.

A brief comparison of a-c. and d-c. types. (*Science Abstracts*)

No. 1131. J. R. Mortlock and G. Lyon, "Surges in Power Systems. The Study of Their Behaviour by Models," *BTH Act.*, Vol. 19, July, 1947, pp. 200–204.

Model circuits are used to simulate the 3 main types of surge (lightning, switching, and fault). Equivalent representations for cable and overhead line circuits and for generators and transformers are briefly described, and examples of transient analysis are given with some explanatory oscillograms. (*Science Abstracts*)

No. 1132. J. M. Wallace, "An Improved Automatic Circuit Recloser," *Trans.*, Am.

Inst. Elec. Engrs. (Prepr. 47–50), 6 pp. (1947).

Improvements in design of recloser which has operated for over 6 years are described. In conjunction with fuses on the load side, the recloser operates on fault before the fuse is damaged. If the fault is temporary, service is restored, if not, the fuse clears the faulty line on the second or third reclosure. Improved coordination of reclosers and of reclosers and fuses calls for a combination of instantaneous tripping, high-speed reclosure, time lag tripping, and line delay reclosure, covering 5 operations. The reasons for the selection made are reviewed and the improved model described, an interesting feature being the integrator for controlling the sequence of operations. A cross-sectional diagram, typical oscillograms, and time/current curves for a 5 amp. recloser are given. (*Science Abstracts*)

No. 1133. "A Mercury-Switch Flameproof Drill Panel," *Colliery Engineering*, Vol. 24, June, 1947, pp. 201–202.

A single-unit compact 50 c/s drill panel is described. By the use of Hg switches maintenance time is reduced, faster switching times give improved rupturing capacity, and increased protection is provided against explosion. Earth leakage, overload, and undervoltage protection facilities are incorporated. (*Science Abstracts*)

No. 1134. "Low Temperature Operation of the Aeri Jet Circuit-Breaker," *BTH Act.*, Vol. 19, July, 1947, pp. 196–199.

Results of tests on 1-ph unit at temperature down to −37 C. on no load, using the minimum (lock-out) air pressure of 220 psi., are given in the form of curves for making and breaking tests. The object was to check operation of the pneumatic and mechanical devices and general behavior when moving parts were coated with ice. For the lower temperatures, special low temperature fluid in place of standard insulating oil in the dashpots is advocated. (*Science Abstracts*)

No. 1135. "Contact Alloys," *Scientific American*, Vol. 107, March, 1947. *Metal Abstracts*, Vol. 14, p. 414 (1947).

Discusses gold-zirconium, platinum-beryllium, and platinum-tungsten alloys used by the German contact industry.

No. 1136. "Electrical Contacts," *FIAT Rep.*, No. 785, H.M. Station Off.; U. S. Dept. Comm., 24 pp. (1947).

The report gives an account of the manufacture of contact materials by 8 German firms. A table of electrical properties and copies of German industrial specifications are appended. Among the materials discussed are pure and alloyed forms of Ag, Au, Cu, W Ta, and Ti carbide, Ti, Pt-Ir, Pt-Ni, etc. The manufacturing methods for small contact rivets are also described. (*Science Abstracts*)

No. 1137. V. Savagnone, "Earthing of the Neutral and Automatic Reclosing of Circuit Breakers," *Electtrotecnica*, Vol. 34, March 1947, pp. 74–79. (In Italian.)

The action of the arc-suppression coil is discussed, and the Brown Boveri design of continuous regulation is described. American practice of solid earthing is compared with German and Swiss suppression-coil schemes on the basis of statistics of supply interruptions. Rapid reclosing of circuit breakers is considered with regard to the time required for de-ionization of the arc and the question of stability in interconnected systems. McEachron's observations on multiple lightning strokes are reviewed, and adequate protection of two interconnected systems is discussed. (*Science Abstracts*)

No. 1138. Yu. V. Baimakoff, "Resistance of Contact Between Metals, and Between Metals and Carbon Materials," *Engineer's Digest*, April, 1947.

In two tables is given the effect of temperature and pressure on the contact resistance. Heating for 120 hours to 300 C. caused as much as 40 times increase for the pair steel-aluminum but a drop of resistance to $^1/_{44}$ for brass-brass, and to $^1/_5$ for brass-carbon and steel-carbon, to give a few examples. The tests were done at pressures of 150 and 600 kg. per sq. cm.

No. 1139. I. N. Stranski and R. Suhrmann, "Electron Emission from Crystalline Metal Surfaces and Its Relation to the Crystal Structure; I. Pure Metal Surfaces," *Ann. der Phys.*, Series 6, Vol. 1, Nos. 4–5, May, 1947, pp. 153–168. (In German.) For Pt. II, see A.S.T.M. Abstract No. 1140 (1948).

The relation between the emission from the faces of metal crystals is discussed in relation to the crystal constants, using W as an example. The relationship between work function and the specific surface energy appears to be worth further study. Low surface energy goes with high work function, which explains the phenomenon in which the work function of a surface can be lowered by deposition of a partial layer of the same substance. (*Science Abstracts*)

No. 1140. I. N. Stranski and R. Suhrmann, "Electron Emission from Crystalline Metal Surfaces and Its Relation to the Crystal Structure; II. Single Crystal Surfaces with Adsorbed Impurity Atoms," *Ann. der Phys.*, Series 6, Vol. 1, Nos. 4–5, May, 1947, pp. 169–80. (In German.) For Pt. I, see A.S.T.M. Abstract No. 1139 (1948).

The mechanism of the adsorption of Cs and Ba atoms on crystalline W is considered. Cs is first adsorbed on the 112-face and next on the 011-face. The covered spots spread and

emission increases when the adsorbed film is thick enough, again first on the 112-face. The formation of layers is shown to depend on the lattice constant, the atomic diameter of the impurity, and on the work function of the crystal face. Thus, on the 001 face of W only atoms of diameters 3.1, 4.5, 63., 8.9, etc., Å can form films. On the 111-face the values are 4.5, 8.9, etc., Å. The adsorption and migration energies are discussed, as is the formation of layers more than one atom thick. (*Science Abstracts*)

No. 1141. L. Labbaye and R. Chambrillon, "Calculation of 3-Phase Busbar Sets," *Merger Mag.*, No. 37, June, 1947, pp. 15–24.

The effect of short-circuit over-voltages on the design of busbars is considered, with due regard to the temp. rise and the electrodynamic stresses. The article is based on four nomographs whose titles are: "Determination of Over-voltages of Short Duration in Sets of Busbars as a Function of the Admissible Temperature Rise"; "Calculation of Supports"; "Relation between the Maximum Admissible Current and the Installation Characteristics" (distances between supports, distances between phases); "Resonance Conditions." (*Science Abstracts*)

No. 1142. W. Elenbaas, "Influence of Cooling Conditions on High-Pressure Discharges," *Philips Res. Rep.*, Vol. 2, June, 1947, pp. 161–170.

Experiments on the variation of voltage gradient along a high-pressure Hg vapor due to changes in tube wall temperature are described. Theoretical derivations of the gradient for the cases of a constant pressure and constant density are given. For the latter case, and the particular discharge described, 100 C. rise in wall temp., experiment gives 1.7–2 per cent increase in gradient while the theory gives 1.8 per cent. The case of convection-stabilized discharges is also discussed. (*Science Abstracts*)

No. 1143. F. Burlando, "Consideration on the Behaviour of Modern Distribution Networks Protected by Reclosing Circuit Breakers," *Energia Elett.*, Vol. 24, June, 1947, pp. 208–215. (In Italian.)

A very detailed discussion of the transients following the opening of a circuit breaker on a fault on 1, 2, or all 3 phases of a 3-phase network and their effects on the dynamic stability of the system, with special regard to motors, leads to consideration of speed of opening duration of interruption before reclosing, deionization, and the action of compressed-air circuit breakers. Generation of oscillations and resonance frequencies of the network are dealt with, the effects of arc-suppression coils are discussed, and numerical examples are given and illustrated by oscillograms. Bibliography. (*Science Abstracts*)

No. 1144. J. E. Carlsson, "The Relation Between the Mechanics of Contacts in Contactors and the Amount of Contact Wear," *ASEA Journal*, Vol. 20, July-August, 1947, pp. 110–114.

Maintenance requirements of automatic motor control gear are greatly reduced by appropriate design of contacts based on a study of contact motion. Tests on oil-break contactors confirm that the amount of contact wear varies with the amount of energy dissipated at the initial point-contact. A rational approximate formula is developed showing the importance of rapid contact making. The closing speed should be the highest that can be used without causing the contacts to rebound. The design of a type of contact satisfactory in this respect is discussed, and a formula is developed for the radius of a fixed cylindrical contact on which rolls a plane moving contact. (*Science Abstracts*)

No. 1145. S. Keilien, "Incandescent Lamps as Electrical Load for Testing," *J. App. Phys.*, Vol. 18, August, 1947, pp. 768–773.

Because of the positive coefficient of resistivity of tungsten, incandescent lamps permit a current considerably greater than the normal lamp current to flow for a short initial period. When lamps are used as load for testing electrical apparatus, the factors affecting this inrush must be considered. Size of power source, its distance from the load (lamps), and frequency of switching the lamps (employing repetitive operations for endurance testing) are evaluated. From the given curve the necessary cooling time for the desired current inrush may be determined, and thus the frequency with which the lamps could be switched on and off may be calculated. Practical means for obtaining the required cooling time are described. (*Science Abstracts*)

No. 1146. A. P. Harvey, "The Calculation and Control of Fault-Currents in Electric Supply Systems," *Min. Elec. Mech. Eng.* Vol. 28, August, 1947, pp. 48–59.

Gives formulae and figures for reactance of power system plant and works out the short-circuit current for a fault on a typical colliery supply system. Formulae for heating and electromagnetic effects of the short-circuit currents, and curves showing the arc duration with different types of circuit-breaker contacts for various breaking currents are given. A further numerical example illustrates the effect of reactors in controlling the fault current. (*Science Abstracts*)

No. 1147. W. Weizel and R. Rompe, "Theory of the Electric Spark," *Ann. der Phys.*, Series 6, Vol. 1, No. 6, August, 1947, pp. 285–300. (In German.)

Four distinct stages of spark breakdown are considered: (*a*) ignition stage, when spark channel is formed and little energy taken from the emf. sources; (*b*) spark plasma stage, when channel is heated by an aperiodic discharge and not all the energy is taken from source; (*c*) stage of damped current oscillations when all energy of source—e.g., spark condenser—is used up; and (*d*) after-glow stage when radiation is emitted after previous electrical processes are completed. In all four stages electron energy is the predominant factor. Estimates are made of the relaxation time required to attain equilibrium in various ionizing processes after application of emf. The influence of inductance, capacitance, and resistance of the spark circuit on the four stages is discussed. A time-constant parameter is introduced which determines spark duration, and which increases with gas pressure and spark length. A perturbation of the normal Maxwellian distribution of electrons is smoothed out in 10^{-13} sec. at atmospheric pressure, but attainment of equilibrium between atoms and electrons is slow, taking 10^{-5} of 10^{-6} sec. The main discussion in the paper covers complete breakdown phases and not ignition of sparks. (*Science Abstracts*)

No. 1148. S. C. Killian, "Aluminum Busbar Laps and Joints Need Not Be Larger Than Copper," *Elect. World*, Vol. 128, September 13, 1947, pp. 118–119.

The commonly accepted theory that Al must have larger laps and joints in busbars than Cu is disproved by the results of laboratory heat-runs. With Al, care is required in making the joint, and the best results are obtained if a protective compound is used. In one case this is a greasy substances (No-ox-id) which is spread on the joint and then wire-brushed or scraped; another substance (Alcoa) can be painted on the joint before bolting. Data on the temperature rise of Cu-Cu, Al-Al and Cu-Al, joints and values of contact potentials, which have a bearing on corrosion hazards, are tabulated. (*Science Abstracts*)

No. 1149. M. Langer, "Influence of the Fritting Current on the Contact Resistance of Selector Systems," *Elektrotechnik* Vol. 1, September, 1947, pp. 93–94. (In German.)

For avoiding fading effects due to sudden increases of the contact resistance of current-free selector contacts, a small current of 1 ma. is sent continuously through the contact unless the microphone current of 25–50 ma. is used as such a "fritting current." Graphs show test results relating to the dependence of the contact resistance on contact voltage and fritting current, respectively, and the reduction of the noise voltage with reduced contact resistance for lift-slew and motor selectors. A marked improvement is obtainable by replacing one-sided by double-sided (gripping) contacts. The influence of relative humidity is discussed. (*Science Abstracts*)

No. 1150. William Deans, "Selective Tripping of Low-Voltage Air Circuit Breakers," *Trans.*, A.I.E.E., October, 1947.

Selective or sequential tripping of low-voltage air circuit-breaker application provides for removal from the system of a faulted part only, leaving the rest of the system in operation. Present standard circuit breakers generally are not suitable. Solution of the problem is through direct-acting series tripping means with distinct current-time characteristics in ranges of overcurrent and fault current, with minimum time to complete interruption being the objective. This subjects the circuit breaker to the very severe duty of having to carry short-circuit currents for appreciable times, whereas standard circuit breakers have been designed to open instantaneously. Modified standard circuit breakers may be applied to selective tripping, with limitations of application based upon: (1) rated interrupting capacity; and (2) series trip coil rating. As tests show that modified standard circuit breakers will carry short-circuit current for necessary times, they also may be applied with relay schemes requiring delayed tripping. In systems using cascade or back-up arrangements of circuit breakers, little is gained by selective tripping. It is recommended that for a particular installation choice be made between selective tripping and cascade arrangements, according to relative importance of advantages of each.

No. 1151. A. Roxburgh, "Unit Testing of High-Voltage Circuit Breakers," *BTH Act.*, Vol. 19, October, 1947, pp. 235–241.

The three most useful methods of testing are cited. Three-phase tests on a triple-pole breaker with breaks on each phase short circuited, and three-phase tests on one pole of a triple-pole breaker, are described with reference to tests actually carried out in both air-blast and oil circuit breakers. Specimen test results are tabulated. (*Science Abstracts*)

No. 1152. C. Eyraud, "Discharge mechanisms in High-Frequency Arcs," *Compt. rend.*, Vol. 225, November 17, 1947, pp. 939–940. (In French.)

Certain peculiarities, i.e., successive maxima and minima of activity, were noticed in chemical reactions involving an oxide of nitrogen (NO) in h-f. discharges. They are, it is claimed, explicable if there is a nonuniform distribution of N_2^- ions in the discharges and if certain other, generally allowed assumptions are made. The argument is briefly developed. (*Science Abstracts*)

No. 1153. J. Dormont, "The Possibilities of Refitting Oil-Immersed Circuit Breakers," *Bull. Soc. Franç Élect.*, Series 6, Vol. 7, December, 1947, pp. 648–652. (In French.)

A brief summary is given of the history of large oil volume circuit breakers and, in particular, of their development in France and America, with reference to various types of explosion pots and enclosures leading to designs with low oil content. The modernization of a 220-kv. breaker is described, and it is concluded that the improvement can be general, i.e., increased breaking capacity and reduction in arcing time and closing time, allowing rapid reclosure. (*Science Abstracts*)

No. 1154. D. I. Azarjiev, "Model of Electrical Systems," *Elektrichestvo*, No. 5, pp. 17–23 (1947). (In Russian.)

A new, versatile a-c. model for investigations of electric power networks is described. The equipment is 50 c./s. operated throughout, with vastly improved components (thus all reactors have constant inductance with varying current), and care has been taken to construct the control panel to enable a single operator to supervise several generators and their changing loads. The principles of operation and the representation of units such as synchronous generators, loads with changing reactance, etc., by their corresponding models are explained in detail. (*Science Abstracts*)

No. 1155. Some Aspects of Electrical Contacting Materials and Phenomena Associated with the Design of Electro-Mechanical Devices Used in German Telecommunications Equipment," *BIOS Rep.*, No. 1276, H.M. Station. Off.; U. S. Dept. Comm., 45 pp. (1947).

A brief description is given of German wartime activities in connection with substitute materials for contacts, life tests, spark quenching, lubrication, powder metallurgy, hermetically sealed relays, maintenance procedure, glass-metal seals, and a number of other technological fields. (*Science Abstracts*)

No. 1156. P. Schulz, "The Influence of Positive Ions on Electron Mobility: 1. The Electron mobility in a High-Pressure Plasma," *Ann. der Phys.*, Series 6, Vol. 1, Nos. 7–8, pp. 318–332 (1947). (In German.)

Measurements were made on ion densities, by observing spectral line widths in high-pressure (30–40 atmos.) discharges in Hg, Kr, and Xe for a current range of approximately 10–30 A. Electrical measurements of current densities used in conjunction with the electron and ion concentrations (assumed practically equal in the plasma) enabled total cross-sections (O+Q+) to be calculated. The ambi-polar mobility gives a mean free path $\lambda = 1/(NQ + Q+Q+)$ which was determinable from the experimental data. The ion concentrations $\simeq 10^{16}$ per cu. cm., and $di+ = 2.2–3.7 \times 10^{-13}$ sq. cm., depending on experimental conditions ($Q \simeq 0.9–1.18 \times 10^{-16}$ sq. cm. (*Science Abstracts*)

No. 1157. "German Switchgear Practice," Rep. Brit. Elect. Applied Indus. Res. Ass., Ref. G/T 205, 40 pp. (1947).

Replies to questionnaire submitted to German experts. (*Science Abstracts*)

No. 1158. C. J. Herman, "Dynamic Brush Characteristics by the Dynamotor Method," *Trans.*, A.I.E.E., Vol. 66, pp. 759–763 (1947).

A description of tests taken on brushes riding on the commutator of a dynamotor to give dynamic characteristics under commutating conditions. The tests are particularly applicable to small machines. It was found that the suitability of a brush depends largely on temperature. Curves of friction coefficient and contact drop are given for various grades of brush, both at constant current density with varying ventilation and constant ventilation with varying density. (*Science Abstracts*)

No. 1159. J. F. Heuberger, "Iron-Graphite Contact," U. S. Patent No. 2,416,830 (1947).

A sintered mixture, graphite oriented substantially perpendicular to wearing surface. Oil impregnation to reduce friction of sliding contacts; also to prevent rust.

No. 1160. G. Durst, "Electrical Contact," U. S. Patent No. 2,433,687 (1947).

Structural design of contacts that permits the use of extremely small precious metal contacts by etching-off method.

No. 1161. F. R. Hensel, "Electrical Contact and Brush," U. S. Patent No. 2,418,710 (1947).

Pt and/or Pd with 1–40 per cent Pb, produced by either melting and casting or sintering.

No. 1162. H. Mol, "Inverse Circuits with Relay Contacts," *PTT-Bedrijf*, Vol. 1, No. 3, pp. 84–91 (1947–1948). (In Dutch.)

When switching apparatus is being designed, the "inversion theorem" relating to relay contacts can be used. An endeavor to apply this theorem on a wider scale leads to the conclusion that the inversion theorem is a special case of the theory of duality. (*Science Abstracts*)

No. 1162a. Karl Wilhelm Frohlich, "Silver-Base Electrical-Contact Materials," *Metallforschung*, Vol. 2, January, 1947, pp. 29–32.

Enumerates factors limiting pure silver as a satisfactory contact metal, and discusses methods for its improvement. The following substitutes are discussed: Ag + 1.5 per cent Si; Ag + 0.15 per cent Ni; sintered Ag-W alloys; sintered Ag alloys containing 20–30 per cent Ni or Fe; and Ag + 30 per cent Zn. (*Battelle Library Review*)

No. 1162b. Gerhard Schrag, "Observations on Liquid 'Bridges' Between Electrical

Contacts," I. *Metallforschung*, Vol. 2, January, 1947, pp. 25–28. (In German.)

At 24 v. and 10 amp., a liquid bridge was observed between metallic electrical contacts. For iron contacts, the bridge consisted of molten metal; for copper, cobalt, and nickel, it was a molten oxide. The amount of current carried by ions was calculated; and the temperature of the bridge of the contact, and the temperature difference between the two contacts are discussed. (*Battelle Library Review*)

No. 1162c. Ernst Raub, "Migration of the Contact Area as a Result of the Opening and Closing of Gold-Alloy Contacts Alloyed with Base Metals," *Metallforschung*, Vol. 2, September, 1947, pp. 281–288. (In German.)

The contact area migrates as a result of build up of metal transferred from one contact to the other by means of the spark which bridges the gap during making and breaking the contact. This effect was studied for numerous binary and several ternary alloys. Results graphed and illustrated by photomicrographs. (*Battelle Library Review*)

No. 1162d. J. Kohler, "The New Oerlikon Direct-Current High-Speed Circuit Breaker," *Bull. Oerlikon*, No. 269, October, 1947, pp. 1819–1822.

The d.c. breaker is for current ratings up to 1000 amp. and voltages up to 1500 v. It is used in traction substations as a main breaker for rectifiers and convertors. Also, it is specially suitable as a feeder high speed breaker of substations for outgoing feeder mains. The feature of the double electromagnet which operates the breaker is a magnetic device which entirely excludes oscillation. The operation is described with a diagram of the mechanism. Oscillographs of rupture are given, also connections diagrams for its automatic control with s.c. testing and reclosure, and with hand control. (*Science Abstracts*)

No. 1162e. P. Hammalund, "Transient Recovery Voltage, Subsequent to Short-Circuit Interruption with Special Reference to Swedish Power Systems," *Acta Polytech.*, No. 4 (1947), *Elec. Eng.*, Series 1, Vol. 1; *Ingen-Vetensk Akad. Handl.*, No. 189, 264 pp. (1946). (In English.)

Gives an extensive and critical review of research work started in Sweden in 1938. Transient oscillation of different network parts and apparatus is treated analytically. Practical methods for calculation are given; values for capacitances and inductances of the network component have been compiled. Measurements confirm that the proposed methods give good practical results. A systematic and thorough investigation of the Swedish networks has been made. Work on the behavior of circuit breakers with respect to transient recovery voltage is also considered. A survey of the same kind is recommended for other countries, aiming at a universal standard for circuit breaker testing. (*Science Abstracts*)

No. 1162f. E. W. Boehne and M. J. Jang, "Performance Criteria of D-C. Interrupters," *Trans.*, A.I.E.E., Vol. 66, pp. 1172–1180 (1947).

Initially based on empirical knowledge, the successful d-c. interrupter was gradually developed. Fundamental principles of operation are analyzed. The mechanical problems are outlined, followed by sections on circuit parameters, time constants, stored energy, and arc energy, with a table of performance criteria and numerical evaluations in a practical case. Three typical arc voltage wave shapes are discussed and the conclusions contain a brief statement of features influencing performance of d.-c. interrupters, the arc voltage being the most important. (*Science Abstracts*)

No. 1162g. E. A. Hoxie, "The Application of Storage Batteries to the Control of Switchgear," *Trans.*, A.I.E.E., Vol. 66, pp. 1561–1570 (1947).

After review of U. S. standards for control voltages for closing and tripping devices, a method for finding the required battery capacity is given, with notes on the choice of battery type and on its operation. Tests are described for determining voltage decline under various conditions, and battery performance when discharging at high rates, having regard also to the charging means used and whether the battery is floating. It is suggested that since the battery tested had Planté plates, check tests might be made on a battery with pasted plates. (*Science Abstracts*)

No. 1162h. F. A. Lane and B. W. Wyman, "Switchgear Equipment for Tidd High-Voltage Test Lines," *Trans.*, A.I.E.E., Vol. 66, pp. 1619–1623 (1947).

Performance required in new h.v. switchgear is outlined, covering high speed operation and reclosing, also insulation levels needed for co-ordination with lightning arresters. The low oil content impulse type as originally developed for 287 kv. is favored because of good service record. An experimental breaker for 360 kv. 3-ph. and breaking capacity 10,000 mva. is described and illustrated. Oil and air-blast breakers and the type chosen by the authors are compared. (*Science Abstracts*)

No. 1162i. L. J. Lewis, "Circuit-Breaker Current Measurements during Reignitions and Recovery," *Trans.*, A.I.E.E., Vol. 66, pp. 1253–1257 (1947).

In circuit-breaker operations in hp. a-c.

circuits, the current values at critical periods may be measures of the arc conductivity or may indicate breaker performance closely as well as assist in the fundamental study of arc behavior. This paper describes techniques used and results gained (on 1340 v., 780 amp.) in an effort to obtain legible and accurate records of arc current by use of a special shunt and amplifier. Attention is drawn to noticeable differences in recovery voltage waveforms in tests made in almost identical conditions, also variations in current during final recovery. Other questions of interest are discussed, e.g., whether arc current and arc voltage across the arc space both pass through zero at the same instant. It is concluded that measurements of current at higher test values are possible and might provide useful means for judging whether a circuit breaker is nearing the limit of its breaking capacity. (*Science Abstracts*)

1948

No. 1163. C. G. Miller and L. B. Loeb, "Spark Breakdown at Atmospheric Pressure and Above in Relation to Paschen's Law," *Phys. Rev.*, Vol. 73, January 1, 1948, pp. 84–85.

Calculations on sparking potentials at high pressures for three given pressures show: (*a*) that Paschen's law does not hold in air at high pressures; (*b*) that the departure is what would be expected from the streamer mechanism; and (*c*) that the Meek-Raether criterion (*Science Abstracts* No. 5024 (1938)) requires amplification to include photoelectric absorption. (*Science Abstracts*)

No. 1164. A. Borup, "A Sensitive Circuit Breaker for Instrument Protection," *Elec. Eng.*, Vol. 20, January, 1948, pp. 26–27.

A protective device was developed for low-range microammeters, incorporating a gas-filled triode feeding an electromagnetic relay to open a circuit breaker. For the valve used, it was found that an anode voltage of 80 v. was required, needing about 6 v. on the grid. A transformer supplies a.c. for anode, grid, and cathode, and resistor adjustments may be made for various current ranges as required. A suggested refinement includes a diode as a stabilizer for mains-voltage variations. (*Science Abstracts*)

No. 1165. F. Burlando, "The Function of a Resistance in Parallel with the Arc in Air-Blast Circuit-Breakers," *Energia Elett.*, Vol. 25, January-February, 1948, pp. 27–34. (In Italian.)

The performance of air-blast circuit breakers with and without resistance in parallel with the arc is analyzed. It is shown that, when a resistance of sufficiently small value is used (≤ 20–25Ω), the energy required to extinguish the arc is greatly reduced, i.e., lower pressure, smaller reservoir and compressor are required. In breakers fitted with silencers counter-pressure phenomena are eliminated. Switching over-voltages are of lower amplitude and are made independent of other circuit constants. Resistance materials are considered, and it is claimed that ceramic valve-type resistances are highly suitable because of their high thermal capacity, stability, and desirable electrical characteristics. The use of a spark gap in series with the resistance is discussed. (*Science Abstracts*)

No. 1166. R. M. Schahfer and W. H. Knutz, "Short-Circuit Tests Predict Performance of Corroded Connectors," *Elect. World*, Vol. 129, February 14, 1948, pp. 80–82.

The method used for producing corrosion artificially, and the preparation, treatment, and testing of the joints for determining the effect of corrosion on the joint resistance and the ability of a corroded joint to carry short-circuit currents are explained. Table I gives the connector types tested and the critical condition of the conductors. Table II summarizes the results of the corrosion tests, both on new clean and weathered unclean conductors. The tests show that the joint resistance of many bolted connectors is increased by corrosive atmospheres beyond the safety value. Inhibitors slow down the resistance increase, but lose their effectiveness with time. Compression connectors withstand corrosion best. (*Science Abstracts*)

No. 1167. W. A. Prowse and B. Cooper, "Gas Discharges at Centimeter Wave Lengths," *Nature*, Vol. 61, February 28, 1948, pp. 310–311.

The breakdown voltage between electrodes forming part of a resonant cavity was investigated at 2800 and 9800 mc./s., both for individual pulses and pulses repeated at 400 per sec. The behavior and appearance of the discharge, and the effect of irradiation with ultraviolet light and Ra, are described. (*Science Abstracts*)

No. 1168. J. J. Payne, "Cleaning Switch Contacts," *Wireless World*, Vol. 54, February, 1948, pp. 51–52.

The application of CCl_4 to wafer-switch contacts for the removal of dirt is shown to be harmful, owing to the simultaneous removal of the surface lubricant. Instead, the use of a grease dissolved in the cleaning fluid is advocated, as a lubricating film will be left on the contact after the solvent has evaporated, but care is needed to avoid deposition of the film on the switch insulation. A recommended solution is 10 per cent lanolin in white spirit or C_2HCl_3. (*Science Abstracts*)

No. 1169. P. T. Thornhill, "Medium-Voltage Air-Break Switchgear," *Metrop.-Vick. Gaz.*, Vol. 22, March, 1948, pp. 243–247.

A range of cubicle-type, air-break circuit

breakers for 600 v. in four current ratings up to 3 ka. is described with particulars of automatic controls fitted, and of contact, arc chute, and installation arrangements. Attention has been paid to ease of maintenance. The results of heavy tests for an ASTA certificate are discussed. (*Science Abstracts*)

No. 1170. S. B. Toniolo, "Over-Voltages produced by the Opening of Circuit Breakers," *Energia Elett.*, Vol. 25, March, 1948, pp. 99–102. (In Italian.)

The nature of over-voltages produced in circuit breaking are examined with particular reference to the max. values that can be obtained. Forcing of current to zero, even when the load is not highly inductive, can cause overstressing of the system, and designers should take care to avoid it. On this assumption the worst conditions are obtained if there is a preponderance of rotating machinery in the circuit. In such a case, crest voltages up to 4.3 × the phase voltage can be reached. (*Science Abstracts*)

No. 1171. S. B. Toniolo, "Performance Tests on Small Circuit Breakers with Over-Current Releases," *Elettrotecnica*, Vol. 35, April 10, 1948, pp. 130–135. (In Italian.)

A discussion of the various items to be considered for performance tests, put forward as a basis for the preparation of a standard. In order to compare different types it is necessary that the tests should always be performed under the same conditions. For this purpose, a test plant has been built which synchronizes the action of the switch with the phase of the supply voltage. This plant is described and oscillograms given. (*Science Abstracts*)

No. 1172. R. Holm, "Calculation of the Temperature Development in a Contact Heated in the Contact Surface, and Application to the Problem of the Temperature Rise in a Sliding Contact," *J. App. Phys.*, Vol. 19, April, 1948, pp. 361–366.

The temperature is calculated in two cases: (I) A circular area on a semi-infinite body heated at a constant rate from the time $t = 0$. (II) A sliding contact, the heat, which is generated by friction, being limited at every point to the time of contact. Observations on the temperatures in bimetallic sliding contacts, indicating the contact temperature rise by means of a thermoelectric current, are compared with the calculations. A fairly good agreement is found. (*Science Abstracts*)

No. 1173. C. C. Dilworth, "The Influence of Surface films on the Electrical Behavior of Contacts," *Proc.*, Phys. Soc., Vol. 60, April, 1948, pp. 315–325.

The variation of current with voltage at an idealized contact between two crystals of a semiconductor is calculated on the assumption that electrons penetrate the surface barrier by tunnel effect. Comparison with experimental curves for silicon carbide powders leads to the conclusion that these crystals are covered by an insulating surface film, which affects the rectifying properties of the crystal when it is in contact with a metal. It is shown that this can account for the discrepancies observed between experimental curves and those deduced from the simple Schottky theory of rectification. (*Science Abstracts*)

No. 1174. E. Aubert, "Expansion Circuit Breakers and Their Treatment," *Elektrotek. Tidsskr.*, Vol. 61, April, 1948, pp. 128–130. (In Norwegian.)

Damage of some 60-kv. and 10-kv. generator circuit breakers led to careful examination, results of which are discussed. Recommendations for inspection of details of the circuit breakers are given. (*Science Abstracts*)

No. 1175. F. R. Hensel, "Electrical Contacts," Joint Intelligence Objectives Agency, PB 32586, Pamphlet, 25 pp., Reproduced by Mapleton House, Brooklyn, N. Y., May, 1948.

Reproduction of a report based on survey of German contact materials and manufacturing methods.

The composition, properties, and production of contact alloys and the companies which produce them are discussed. Alloys of gold and zirconium; beryllium and platinum; tungsten and platinum have been developed to replace iridium alloys. Methods used for bonding inlays and overlays to inexpensive basic metals are given.

No. 1176. H. Franken, "The Rating of Low-Voltage Switchgear," *Elektrotechnik*, Vol. 2, May, 1948, pp. 135–136. (In German.)

The nominal current rating of 1-v. switchgear merely determines the heating limit for infrequent operation. To apply switchgear correctly, however, the working cycle, heating, rupturing and making capacity, apparatus and contact life, dynamic and thermal current limit must be considered. For this purpose a "rating diagram," showing the number of operations per hour, the switchgear life, and the corresponding rating is proposed. The rating diagram is bounded by 3 lines, representing the rating limit for: (1) apparatus life; (2) contact burning; (3) rupturing capacity, starting transients, thermal and dynamical limiting current. The nature of the application is taken into account by classifying typical cases into light, normal, and heavy loading. (*Science Abstracts*)

No. 1177. K. T. Sutton, "Quality Tests of Mercury Buttons Made Automatically," *G.E. Rev.*, Vol. 51, May, 1948, pp. 39–41.

Describes a 10-amp. mercury switch comprising partly a rotary button formed by sealing two $^7/_8$-in. diameter metal cups with glass to an interposed ceramic barrier. The cups, containing Hg and an inert gas, form the poles

of the switch, and, on rotation, a hole in the ceramic barrier dips into the Hg, thereby completing the circuit. Buttons are mounted in insulated housing with terminal contacts rubbing the metal cups; springs maintain any angle of rotation. Single and 3-way buttons are made up to four buttons per switch, and all forms fit standard wiring boxes and wall plates. Production tests described are electrically controlled to assess angle of operation and arc duration from one equipment, with a similar machine to assess button resistance. The former machine tests angle of movement five times followed by five arc duration tests based on capacitor charging time variations caused by delayed voltage recovery. Stepping relays energize rejection solenoids in each case for a single failure and segregate rejects according to the fault. (*Science Abstracts*)

No. 1178. R. N. Wagner, "A New A.C. Bus Design," *Elec Engg.*, Vol. 67, May, 1948, pp. 448–450.

An Al busbar design for 600 v. and up to 5000 amp. 3-ph. is described, special attention being paid to simplicity, reduction in cost, and low reactance. The conductors resemble shallow channel strips arranged in triangular formation, and carry fins for stiffening and cooling. Insulators with precautions against tracking, special types of bolts and washers used, provision for enclosing the busbar, and allowances for expansion are considered. (*Science Abstracts*)

No. 1179. H. Böhm, "The Development of the Contact Rectifier, "*Elektrotechnik*, Vol. 2, June, 1948, pp. 176–179. (In German.)

After describing the early types of small rectifiers, those with fluid electrolyte, and especially those employing reactances, are discussed fully. They have been developed up to about 400 v. and 8000 amp. (*Science Abstracts*)

No. 1180. B. W. Wyman and R. B. Shores, "A New Insolated-Phase, Metal-Enclosed Busbar," *Elect. Eng.*, Vol. 67, June, 1948, p. 564.

A photograph and cross-sectional drawing are given of a 1-ph., fully enclosed busbar system for a 4-ka. d-c. rating and a short-circuit current of 130 ka. The aluminum housing is designed for quick sectional erection and provides ready access for inspection and maintenance. The busbars are kept in position by post-type porcelain insulators, provision being made for thermal expansion and contraction. (*Science Abstracts*)

No. 1181. I. Lundström, "Swedish Standard Specifications for High-Voltage Circuit Breakers," SEN 31—1945, *A.S.E.A. J.*, Vol. 21, June–August, 1948, pp. 63–71.

Clauses in this specification are reviewed and compared with corresponding passages in BS 116, *VDE-Foch berichte* 0670, and I.E.C. Publication 56. Values such as standard voltage, current, and breaking capacity ratings are compared in tabular form. Definitions, tests, and recovery clauses are also dealt with, and though SEN 31 does not include a standard for defining restriking voltage, methods used by A.S.E.A. are outlined, with notes on the difficulties encountered in coordinating the rate of rise with breaking capacity, having regard to the different reactions of various types of breakers. (*Science Abstracts*)

No. 1182. J. E. Carlsson, "Under-Voltage Tripping in Low-Voltage Networks," *A.S.E.A. J.*, Vol. 21, June–August, 1948, pp. 73–77.

The question of ensuring that rapid reclosing on h-v. network faults produces no undesired effects in under-voltage tripping devices is discussed, and the importance of studying the operational characteristics of units so protected is stressed. Various means for avoiding instantaneous tripping are described, e.g., for hand-operated starters, contactor starters, and circuit breakers, with notes on interlocking and use of an independent d-c. supply. (*Science Abstracts*)

No. 1183. "Heavy Current Busbars," *Elec. Times*, Vol. 114, July 1, 1948, pp. 3–5.

A unique installation for electrotinning steel strip requiring busbars to carry 20–30 ka. d.c. is described. Reasons for choosing Cu and not Al are given. Heat dissipation, jointing, allowance for expansion, flexible connections, etc., are also dealt with. (*Science Abstracts*)

No. 1184. W. H. Brattain and J. Bardeen," "Nature of the Forward Current in Germanium Point Contacts," Letter in *Phys. Rev.*, Vol. 74, July 15, 1948, pp. 231–232.

The forward resistance of Ge rectifiers is considerably lower than the spreading resistance calculated from the dimensions of the point contact and the known properties of bulk Ge. Potential probe measurements in the neighborhood of a rectifying contact are thought to indicate the existence of a thin surface layer of deficit semiconductors. Such a layer could arise from the electronic equilibrium condition at a contact, if the width of the forbidden energy band is comparable with the diffusion potential. (*Science Abstracts*)

No. 1185. H. Puppikofer, "Report on the Activities of the International Committee for the Study of Circuit Breakers from 1st July, 1946, to 1st July, 1948," *C.I.G.R.E., Rep. No.* 138, 26 pp. (1948).

Summarizes discussions at two meetings of the committee, mainly on indirect tests for circuit breakers; natural frequency of network; revision of the concept of recovery voltage and rapid reclosing. (See also *Science*

Abstracts No. 2430 (1948).) International cooperation is advocated. The natural frequency of networks is becoming of increased importance. New rules concerning circuit breakers drafted by national committees of several countries covering various aspects are discussed. A table of natural frequencies to be used in tests according to new English, French, and Swiss proposals is given. Suggestions are made for revision of definitions in the I.E.C. rules for a-c. breakers, No. 56, 1937, and a note on rapid reclosing is added. Calculations are given on which curves for natural frequencies as a function of normal voltage and for various network layouts are based. (*Science Abstracts*)

No. 1186. D. E. Lambert and J. Christie, "Standardization of Switchgear," *J.* I.E.E., Pt. I, Vol. 95, July, 1948, pp. 296–321.

Standardization of switchgear for a-c. systems is dealt with. Supply-system requirements, performance requirements for rating, types and design, components and auxiliary equipment are reviewed. Rationalization and the need for quantity production are discussed in relation to standardization and the benefits accruing therefrom. Suggestions are made for a reduction in the number of British Standard circuit breakers. General suggestions are made from standardization or for rationalization; detailed design standardization appears feasible only for some of the smaller switchgear, components, and auxiliary equipment. (*Science Abstracts*)

No. 1187. C. F. Wagner and L. L. Fountain, "Low-Voltage, Arcing-Fault Currents," *Elec. Eng.*, Vol. 67, August, 1948, pp. 769–771. Essential substance of A.I.E.E. Paper 48-26.

Since the recommended A.I.E.E. method of calculating l.v. short-circuit currents is based on the assumption of a "bolted" fault (i.e., a clamped or bolted connection making a rigid and solid fault path), and as results appeared higher than those met in practice, the following tests were accordingly made. Standard 3-ph., 125-, 250-, and 500-v. busbars were short circuited by means of wires and groups of wires of various sizes, or by copper or steel rods lying on the busbars, for comparison at each nominal current setting with the result for a "bolted" fault. The conclusions indicate that arcing faults (e.g., as initiated by wires) are often unstable and extinguish themselves in two cycles or less; that the values of the first half cycle of current are affected by the means used to start the fault; and that sustained currents may be $<0.8 \times$ the bolted symmetrical current. (*Science Abstracts*)

No. 1188. B. Feldbauer, "The Design of Contactors with Regard to Their Industrial Application," *J.* I.E.E., Pt. II, Vol. 95, August, 1948, pp. 439–451.

Contactor principles, types, and duties are discussed, including problems such as current transients, contact bounce, arc-control devices, and contact materials. Other features covered are oil-immersed and h-v. contactors special designs, e.g., latched-in, and resistance furnace control and auxiliary switches. There appears a need for revising British Standards 587 and 775. (*Science Abstracts*)

No. 1189. F. Kurth, "Study of Problems in Circuit Interruption with Air-Blast Breakers," C.I.G.R.E., *Rep. No. 128*, 26 pp. (1948).

Outlines the principles of air-blast switching, e.g., opening on no load or small load and interrupting short circuits with a plain air-blast breaker or with those having one or two resistance steps. Diagrams and many oscillograms are shown. The two-step resistance type is advocated for suppression of switching-off over-voltages and switching-in surges; the breaking capacity is stated to be large. (*Science Abstracts*)

No. 1190. M. Poma, "Considerations on the Technique of Air-Blast Circuit Breakers, C.I.G.R.E., *Rep. No.* **108**, 10 pp. (1948).

A brief review of important factors in air-blast breaker operation in practice, outlining main characteristics, design details, mechanical construction, ancillary air supply, and special precautions required for outdoor operation. It is concluded that this type of breaker is superior to others for indoor installations but that the outdoor type is still of the nature of a prototype requiring further development. (*Science Abstracts*)

No. 1191. K. I. Lundström, "Air-Blast Circuit Breakers for 220-kv. and Higher Voltages for Swedish Networks," C.I.G.R.E., *Rep. No. 105*, 22 pp. (1948).

Design details of A.S.E.A. air-blast breakers as installed in the past four years on the 220-kv. network are given, with particulars of requirement, insulation, breaking capacity, and control systems, for proposed air-blast breakers for 350/385 kv. (*Science Abstracts*)

No. 1192. W. A. NcNeill, "Pneumatic Operation of Air-Blast Circuit Breakers," C.I.G.R.E., *Rep. No. 104*, 17 pp. (1948).

In air-blast breaker installations the reliability of the ancillary compressed air equipment is essential; design features and compressor, storage and supply details, including control valves, are discussed. Service experience on a 132-kv. substation on the British grid system is referred to, the importance of moisture extraction being emphasized. (*Science Abstracts*)

No. 1193. A. A. Akopyran, "Opening of No-Load High-Voltage Lines by an Oil Circuit Breaker with Arc Control Chamber," *Elektrichestvo*, No. 2, pp. 49–57 (1948). (In Russian.)

Conditions likely to damage switchgear when operating on low inductive currents or breaking capacitative circuits are investigated by study of tests in working conditions and of laboratory checks. Methods suggested for reducing or eliminating such stresses are: (1) Shunting of the arc control chambers by resistors, (2) maintenance of the necessary insulation levels from line to earth and of the discharge voltage for surge protective gear such as expulsion tube gaps; (3) use of special discharging apparatus to reduce the amplitude of surge voltage along the line, without increasing the prospective short-circuit current. (*Science Abstracts*)

No. 1194. A. Blaha, "Contribution to indirect Tests of Circuit Breakers," C.I.G.R.E., *Rep. No.* 132, 24 pp. (1948).

An analysis of synthetic tests made on a-c. breakers with a.c. and with d.c. classified according to: (1) Voltage source, e.g., impulse generator or power transformer; (2) filter used, e.g, a reactance or an auxiliary circuit breaker; (3) synchronization of application of test voltage. The importance of the restriking voltage, especially in air-breaker tests and of arcing voltage in other cases is discussed, followed by description of methods used in tests carried out and including some 350 check tests on the prague tramway system and others on the 6-kv. ZMF network, Brno. (*Science Abstracts*)

No. 1195. S. Teszner, A. Thibaudat, and F. Descans, "Direct and Indirect Tests on Circuit Breakers," C.I.G.R.E., *Rep. No. 129*, 23 pp. (1948).

Methods of direct and indirect testing in proving stations are compared. Indirect tests are divided into two classes: (1) In which the period of interruption is submitted at the same instant (current-zero) to a source of current and a source of voltage; (2) in which the period of interruption is, at this instant, only connected to the source of voltage. Among the conclusions reached are that while 1-ph. direct tests can give useful results, only direct 3-ph. tests at full voltage can reproduce the actual stresses in service, and, even then, rate of rise of restriking voltage is important and should be clearly defined. In many ways indirect tests, however, can increase the range of a proving station and give useful data. (*Science Abstracts*)

No. 1196. E. Vogelsanger, "Indirect Circuit-Breaker Tests," C.I.G.R.E., *Rep. No. 122*, 28 pp. (1948).

The report draws attention to the fact that existing proving stations are not now powerful enough to test the largest modern circuit breakers to their full rated breaking capacity, and, therefore, indirect testing methods are of great interest, though not yet adequate for acceptance tests. Methods of indirect testing are classed in four groups: (1) Tests of separate components; (2) separate tests with specified current and voltage; (3) synthetic tests; (4) other indirect tests. (See also *Science Abstracts* No. 2429 (1948).) Conclusions suggest that one of the test methods faithfully reproduce the stresses of the direct test, though it is hoped that they eventually will. A bibliography is given. (*Science Abstracts*)

No. 1197. C. Bresson, "Indirect Tests on Circuit Breakers," C.I.G.R.E., *Rep. No. 10*, 19 pp. (1948).

General principles of indirect testing to extend the range of proving stations are discussed, with particular reference to the two main methods employed in practice, namely, using groups of individual tests and making simultaneous tests. The limitations of such methods and how they may be applied for testing special types of circuit breakers are described. (*Science Abstracts*)

No. 1198. N. Linnichenko, "Gas Dynamics in Air-Blast Switchgear," *Vestn. Elektroprom.* No. 3, pp. 22–24 (1948). (In Russian.)

A general analysis of the dynamic gas processes during the operation of h.v. switchgear. Formulae for inflow, outflow, and rate of change of air pressure in the switch chamber are derived. (*Science Abstracts*)

No. 1199. V. V. Usov, "Metallo-Ceramic Contacts with Cadmium Oxide," *Elektrichestvo*, No. 1, pp. 60–62 (1948). (In Russian.)

CdO contacts can be applied where the current is too heavy for Ag or W, but where no special arc extinction methods are necessary. Dissociation of the oxide occurs at 1000 C. (arc temperature >2000 C.); hence gases are formed which tend to de-ionize the arc when the contacts part. An apparatus for measuring the tendency for contacts to weld together is described and curves give the results, with the region of usefulness of this type of contact. (*Science Abstracts*)

No. 1200. I. S. Bruk, S. S. Chugunov, and M. S. Libkind, "A.C. Network Analyzer," *Elektrichestvo*, No. 1, pp. 37–44 (1948). (In Russian.)

The analyzer is supplied from a 3-ph., 400 c./s., 220-v. generator, the frequency and emf. of which are stabilized electronically to an accuracy of 0.1 per cent. There are 14 generator units, each consisting of an induction-type phase and a similar voltage regulator. The normal output of 50 v. and 50 ma. is taken as base load. The 300 R, L, and C units are arranged as decade boxes with 1000 Ω at 400 c./s. taken as the base. There is a system of telephone-type plug sockets and bus wires, making possible the connection in series or parallel of as many of the various units as may be required to give a picture of the system under investigation. The dy-

namometer-type voltmeter, ammeter and wattmeter, operated by electronic amplifiers, may be switched into any of the units by means of relays and interlocking push buttons. (*Science Abstracts*)

No. 1201. N. A. Babakov, "Construction of Contacts for Low-Voltage Switchgear," *Vestn. Elektroprom.*, No. 2, pp. 23–24 (1948). (In Russian.)

Forces deflecting the contact arc and ultimately burning ceramic walls are plotted against contact dimensions. It is shown that it is desirable to make the contacts as thick and narrow as possible. Big improvements are obtained by providing contacts with single or double slits. (*Science Abstracts*)

No. 1202. I. Dietrich and E. Rüchardt, "Fine Grain Migration at Pressure Contacts," *Z. angew. Phys.*, Vol. 1, January, 1948, pp. 1–8. (In German.)

Fine grain migration is observed for contact voltages below the minimum arcing voltage. It is due to the existence of a liquid metallic bridge between the two current-carrying conductors during separation. The temperature distribution across this bridge is asymmetrical, as is demonstrated by a series of photomicrographs and the corresponding photoelectric evaluations. The temperatures are estimated from the brightness of the metal parts. The temperature distribution causes the bridge to rupture asymmetrically and thus results in the transfer of contact material. The detailed characteristics of the phenomena depend on the magnitude and polarity of the currents and voltages, on the contact materials and on the facilities for heat dissipation (i.e., on contact design). Theory accounts well for the behavior of Pt contacts, but contacts of Au, Ag, and Au-Ag alloys have properties which are not yet fully understood. (*Science Abstracts*)

No. 1203. T. J. Higgins and H. P. Messinger, "Proximity Effect Factors for 3-Phase Coaxial Busses Comprised of Square Tubular Conductors," *Trans., A.I.E.E.*, Vol. 67, pp. 1538–1543 (1948). Digest in *Elec. Eng.*, Vol. 68, March, 1949, p. 244.

These are essentially equal to those for circular conductors of the same thickness and with diameter equal to the side of the square. The factors can therefore be calculated by Dwight's curves for circular conductors. A family of curves is given for factor against thickness. (*Science Abstracts*)

No. 1204. J. H. Michael and T. G. Bank, "Arc Furnace Air-operated Interrupter Switch," *Elec. Eng.*, Vol. 68, April, 1948, p. 294. Digest of A.I.E.E. Paper, pp. 48–288.

Describes a design successfully applied to arc furnace automatic switching based on an air-blast device pneumatically operated and rated to interrupt 600 amp. a. c. up to 15 kv. This is intended for use as a switch capable of withstanding severe duty. One conventional circuit breaker can be used to protect several furnaces each equipped with this device. (*Science Abstracts*)

No. 1205. W. Rochester, "Selection of Switchgear and Associated Equipment for Colliery Electrification," *Trans.*, Inst. Mining Engrs., Vol. 107, May, 1948, pp. 441–451.

The breaking-capacity requirements of switchgear are first studied, and it is shown how a colliery ring-main system can be utilized to ensure continuity of supply. Devices for the protection of feeders and transformers are considered. A survey is made of factors affecting the selection of h.v. and m.v. switchgear on the surface and underground. The choice of transformers is briefly discussed. (*Science Abstracts*)

No. 1206. I. M. Shmushkevich, "Dependence of Contact Resistance of Semiconductors on Frequency of Field," *Zhurnal Eksperimental* No. 1. *I. Teoreticheskoi Fiziki* (*J. Exp. and Theor. Physics*), Vol. 18, May, 1948, pp. 462–474. (In Russian.)

Changes in the distribution and concentration of electrons in chemically homogeneous semiconductors, in contact with metal during passage of an alternating current of small amplitude, were investigated. (*Battelle Library Review*)

No. 1207. H. Bossi, "Compressed Air in Modern Indoor Switchgear Installations," *Brown Boveri Rev.*, Vol. 35, May–June, 1948, pp. 135–143.

The introduction of air-blast breakers brought with it pneumatic control as a simple means of securing high speed mechanical operation. Illustrations of various equipments, including compressed-air-insulated voltage transformers, are given. Particulars of automatic compressor mechanisms, layout, operating pressures, and distribution, including means to secure air dryness, are included for indoor gear. (*Science Abstracts*)

No. 1208. N. A. Babakov, "Speed of Motion of Short Electric Arcs," *Elektrichestvo*, No. 7, July, 1948, pp. 74–76. (In Russian.)

The speed of motion of short electric arcs in the narrow air-gap between plane parallel electrodes is an important factor in the design of contacts and magnetic blow-out devices in l.v. switchgear. The experiments of O. B. Bron have shown that the arc occurs at break when the contacts have separated between 2–3 mm., and at make, when the distance is ~1 mm.; the wear on switchgear details is largely determined by the speed of the arc travelling over their surfaces. The present aims to complete Bron's investiga-

tion by measuring the speed for electrode spacing between 3 and 0.1 mm. with arc currents between 100 and 400 amp. and for blow-out fields from 100 to 1000 oersted; the arc velocity ranges from a few m./sec. to 100 m./sec. The method adopted consists of a correlation between oscillograms and multiple high speed photographs, using a special camera taking up to 10,000 exposures/sec. Families of curves display the velocity of the arc as a function of electrode separation for various field strengths and constant currents. Three regions of the phenomena are recognized, in the middle one of which the velocity reaches a max. for spacings between 1 and 2 mm.; the max. occurs at shorter gap lengths for higher/higher field strengths and is more marked for large arc currents. A second set of curves shows that for constant current and gap length the velocity is only slightly dependent on the electrode width. The paper concludes with a discussion of the physical conditions relating to each region, the effect of the ionized air, of metallic vapor and of the cooling influence of the electrodes. There is a brief description of the apparatus employed. (*Science Abstracts*)

No. 1209. M. F. Karasev, "Experimental Investigation on a Model of the Commutation Process of D-C. Machines," *Elektrichestvo*, No. 7, July, 1948, pp. 37–42.

Investigation on a special model enabled the different phases of the process to be studied separately, furthermore, in the absence of a commutating field, and of mutual induction between the sections. The tests show that the influence of the conductance of the sections, load current and collector speed at c.d.'s on the brushes of >5–6 Å does not at all agree with the classical theory of the commutation process, owing to ionic processes in the contact layer of the brushes. (*Science Abstracts*)

No. 1210. A. Amstutz, "Residual Currents and Voltages with Single-Pole Rapid Reclosing," *Brown Boveri Rev.*, Vol. 35, July-August, 1948, pp. 220–226. (In English.)

The problems arising with single-pole rapid reclosing on systems with solid earthing and with earthing through arc-suppression coils are discussed with reference to events during the interval between disconnecting and reconnecting. The importance of the magnitudes of residual current and the voltage in the disconnected conductor are stressed. Rapid reclosing with solid earthing presents no basic problems but application with resonant earthing is not so easy and calls for special measures, although there is the advantage of protection against 2-ph. faults. Nonetheless, 3-ph. reclosing is preferable in this case. (*Science Abstracts*)

No. 1211. W. J. Wilson, "New Design of Class QA and Class QF Switch-Gear," *BTH Act.*, Vol. 19, July-August, 1948, pp. 363–366.

Switchgear in the ranges 2.2–11 kv., 400–1000 amp., and breaking capacity 75–250 mva. is described, with notes on the reasons for, and results of, redesign. Operating means and arrangement of ancillary gear, e.g., transformers and cable boxes, are dealt with, also such questions as duplicate busbars, earthing, and testing. Brief particulars of a new explosion chamber type of oil circuit breaker are given, including illustrations of three different types of plugging contacts. (*Science Abstracts*)

No. 1212. P. Pelissier, "Protection of D-C. Networks by Circuit-Breakers with High Speed Breaking," *Rev. Alsthom*, No. 74, July-September, 1948, pp. 25–30. (In French.)

Two new types (DR, 800 amp., 600 v.; JRT, 2000 amp., 1800 v.) are described, and details are given of tests on them. (*Science Abstracts*)

No. 1213. H. Thommen, "Circuit-Breakers and Neutral-Point Earthing," *Brown Boveri Rev.*, Vol. 35, July-August, 1948, pp. 227–230. (In English.)

To aid designers in considering worst case of duty required of a circuit breaker a list of the most important types of fault is given and discussed, especially with regard to the type of earthing used on a system and factors of safety of insulation. The relative values of recovery voltage in various cases given show that the extreme values are much lower with a solid earthed system than with one having Petersen or arc-suppression coils. It is concluded that the reduction in effectiveness of such coils in e.h.v. systems owing to corona losses should be taken into account. Solid earthing with 400 kv. is advocated. (*Science Abstracts*)

No. 1214. E. A. Frowein and C. E. M. De Kuyper, "New Tap Changing Switches, 10 KV-200A," *Smit Med.*, Vol. 3, July–September, 1948, pp. 58–65. (In Dutch.)

Describes an oil-immersed switch for 10 tappings of max. 2 per cent of the phase-voltage, for full load of 200 amp. The contact rollers can carry the 6000 amp. s.-c. current for 3 sec. Instantaneous switching is obtained by great force from a spring, which is wound up by a motor. In addition, a time delay between switching impulse and operation, an overload locking relay prevents the switch operating on s.c. The life of the contacts is approx. 50,000 operations under full load. The switch is operated off the 380 v. supply. Oscillograms of switching tests are shown. (*Science Abstracts*)

No. 1215. D. S. Krivozub, "Various Aspects in Calculation of Short Circuit Cur-

rents," *Elektrichestvo*, No. 8, August, 1948, pp. 66–68. (In Russian.)

The author outlines a method for power systems introducing a new quantity, P_k in mva., expressed by $P_k = U_H^2/X = P_H X^*$, where U_H = nominal voltage in kv.; P_H = nominal power in mva.; X = resistance in Ω; X^* = resistance expressed as a fraction. The method is claimed to have a more direct approach than that of the standard methods. (*Science Abstracts*)

No. 1216. S. B. Toniolo, "Large Current High-Voltage A.C. Breaking Tests," *Elettrotecnica*, Vol. 35, August, 1948, pp. 334–342. (In Italian.)

The factors tending to oppose the extinction of the arc in circuit breaking, namely, arc energy and restriking voltage, can be produced from two distinct sources. It is proposed that the basic circuit already used by Skeats (Abstr. 2212 (1936)) be altered to include a bank of ignitions as the device for short-circuiting the "voltage" source during the arcing period. Scale model tests, made using thyratrons for the same purpose, confirmed the possibilities of the method. It is suggested that by this means the range of existing test plant can be extended and that power sufficient for most tests can be obtained from an ordinary distribution network. (*Science Abstracts*)

No. 1217. "Tropicalization of Switchgear," *Petrol Times*, Vol. 52, August 13, 1948, pp. 800–806.

Special h.v. and l.v. oil circuit breakers suitable for oil industry use and capable of withstanding tropical climates have been produced. A climatic laboratory has been built and equipped in order to determine whether the switchgear can withstand the following extreme tropical conditions: (1) temp. cycles of 10–50 C. with 90–100 per cent relative humidity; (2) temp. variations of 30 C. in <1 hr.; (3) tropical storms, dust, floods, and vermin; (4) mold growth and the resultant corrosive effects; (5) direct sunray producing a surface temp. of 70 C.; and (6) polluted atmospheres. (*Science Abstracts*)

No. 1218. L. Albert, "The Wear of Contact Wires of Tramway or Trolley-Bus Lines," *G. E. Rev.*, Vol. 57, September, 1948, pp. 365–375. (In French.)

Previous investigations, mainly with trolley collectors or tram lines, are reviewed and results discussed. Considering the modern trolleybus lines with bow collectors, the influence of the rigidity, span, and horizontal tension of contact wires and of the trajectory of the bow is discussed, special attention being paid to the shock on entering and leaving the supports, and to curves on the line. The optimum span is determined and the effect of current intensity on the wear is discussed. (*Science Abstracts*)

No. 1219. G. Flodman and B. Strender, "Contact Deterioration in Telephone Relays," *Tekn. Medd. K. Telegr Styr., Stockholm*, No. 3, September 30, 1948, pp. 131–162. (In Swedish.)

The use of ohmic and non-ohmic (varistor, evilit-resistor) resistance for limiting voltage on contact-breaking is discussed and voltage and current transients in circuits with shunt resistance, shunt varistor, shunt capacitor – resistance, and long lines where capacitance between conductors renders the circuit oscillatory, are evaluated mathematically. Spark and arc phenomena are considered in detail and a number of oscillograms are given. Bridge erosion is discussed and results of a series of experiments at the Swedish telegraph works are given. Data on design of spark-quenching circuits, varistors, and capacitor circuits are added. (*Science Abstracts*)

No. 1220. P. R. H. Trencham, "Mechanical Improvements in Modern High-Voltage Oil Circuit-Breakers," *BTH Act.*, Vol. 19, September–October, 1948, pp. 406–411.

A survey of the mechanics involved in operating oil circuit breakers of high breaking capacity, with particular reference to improvement of the "total break time." In considering toggles, springs, mass, and various types of buffers, functions and limitations are outlined, with remarks on the minimum speed required to avoid contact burning on closing. The conclusion is that mechanical technique is unlikely to improve total breaking time for h.v. oil breakers beyond $2^1/_2$ cycles. (*Science Abstracts*)

No. 1221. C. Trettin, "Short-Circuit Currents and Voltages with Brushes Covering More Than One Segment," *Z. Elektrotech.*, Vol. 1, September, 1948, pp. 45–52; October, 1948, pp. 74–80; November, 1948, pp. 106–116. (In German.)

A rigid solution of the theory of commutation has only been obtained on the basis of brush being the same width as the segment. The condition of the brush covering more than one segment is treated by means of differential equations, taking into account the mutual inductance between adjacent conductors. Curves of s.c. currents and voltages are obtained for different types of winding and numerical examples are given. The theory shows that the wider brush gives better commutation and allows a more accurate calculation of the interpole strength. (*Science Abstracts*)

No. 1222. "Air-Blast Switchgear in South Wales," *Engineer* (London), Vol. 186, September 17, 1948, pp. 289–292.

In an important 66 kv. network some 16 outdoor and 24 indoor type air-blast circuit breakers have been installed, since 1942, as a

result of satisfactory experience with the first units used. A general description of Swansea valley substation is given, followed by particulars of design, operation and maintenance of the air-blast breakers and of the types of protection employed. There is a brief account of the compressed air equipment which supplies not only the air-blast breakers, but pneumatically operates the oil breakers. Fire risk is considerably reduced and although the station is in an open exposed position no trouble due to climatic conditions has been experienced in air-blast or pneumatic control operation. (*Science Abstracts*)

No. 1223. G. E. Dana, "Experience with High Speed Reclosing," *Elec. Eng.* Vol. 67, October, 1948, pp. 942–944.

Gives the results of $2^1/_2$ years' experience with high speed reclosing on two 114-kv. lines in wooden H-frames, the longer line (82 miles) having no earth wires. High speed reclosing with only a steam generating plant having a small local load at the end of a radial line and with the reclosing of a tie line between two parts of a system held in synchronism by other lines are compared. The question of overstressing the turbine generator is discussed and some relaying difficulties are mentioned. (*Science Abstracts*)

No. 1224. C. H. Flurscheim and E. L. L'Estrange, "Factors Influencing the Design of High-Voltage Air-Blast Circuit-Breakers," *I.E.E.*, Paper 775, October, 1948, 14 pp.

Air-blast circuit-breaker design is studied, more especially in the range 110–264 kv. and 1500–5000 mva. The influence of air-pressure range on excess breaking capacity at normal pressure, and methods of achieving economy in air consumption are described. Limitations and advantages of multibreak interruption are discussed with reference to constructional, voltage grading, and airflow problems. Design limits of shunts for voltage control and the advantages of nonlinear resistors (n.l.r.) for this purpose are given. Methods of short-circuit testing are examined, and the severity of test-plant restriking rate, both for tests made on complete and subdivided breakers, is compared with that for actual systems. The performance of a double-break, 3500-mva. 132-kv. circuit breaker, incorporating parallel air flow and n.l.r. voltage control, is presented in graphical form, showing the effects of voltage, current, and restriking rate in terms of air pressure, and the behavior of n.l.r. shunting. An account is given of the facilities offered by air-blast breakers for high speed reclosure and service maintenance, and of the manner in which these requirements are executed. (*Science Abstracts*)

No. 1225. M. F. Karasev, "Nature of Brush Contact in Direct-Current Machines," *Elektrichestvo*, No. 10, October, 1948, pp. 36–42. (In Russian.)

See Abstr. 1256 (1949) dealing with experimental work on commutation. Commutation processes are analyzed, and among the conclusions derived is a deviation from the classical theory, in that the commutating poles in d.-c. machines do not compensate for the reactance voltage, but displace its peaks from trailing to leading edges of the brush. (*Science Abstracts*)

No. 1226. J. J. Lander and L. H. Germer, "The Bridge Erosion of Electrical Contacts," *J. App. Phys.*, Pt. I, Vol. 19, October, 1948, pp. 910–928.

Bridge erosion is the transfer of metal from one electrode to the other which occurs when an electric current is broken in a purely resistive l.v. circuit. It is associated with the bridge of molten metal formed between the electrodes as they are pulled apart, and more specifically with the ultimate boiling of some of the metal of this bridge before the contact is finally broken. This paper is concerned with fundamental studies of this molten bridge and with empirical measurements of the transfer of metal. From known physical constants one calculates that, when the melting point is reached at a current I, the diameter of the area of contact of two electrodes $\sim 1{\cdot}5 \times 10^{-5} I$ cm. for Ag, Cu, or Au, and $\sim 7{\cdot}5 \times 10^{-5} I$ for Pt or Pd. When the max. temperature of the molten bridge reaches the boiling point the mean bridge diameters are $\sim 4 \times 10^{-5} I$ and $20 \times 10^{-5} I$, respectively. These calculations were checked experimentally. On breaking a contact, $\sim 6 \times 10^{-14} I^3$ cm.^{3} of metal is transferred from the positive to the negative electrode. This represents about 100 per cent of the volume of the molten bridge for Ag, Cu, or Au, and about 0.5 per cent for Pt or Pd. The amount of transfer can be decreased, and even its direction reversed, by heating the negative electrode, and by other means. Temperature distributions in the neighborhood of a contact were calculated and a theory developed to account for the reversal of direction of transfer. (*Science Abstracts*)

No. 1227. G. R. Langley, "Oil, Air-Blast and Magnetic-Blast Circuit Breakers," *Engng. J.* (Montreal), Vol. 31, October, 1948, pp. 522–530, 544–545.

Rating and recovery voltage features are treated and the importance of sound mechanical design of items such as tanks, tank linings, contacts, and cross-bar speed is stressed. Notes are given on selection of suitable oil, use of arc splitters with a description of various mechanisms, e.g., solenoids, with observations on features of pneumatic and motor drives and on maintenance. (*Science Abstracts*)

No. 1228. E. Maury and J. Renaud, "Synthetic Testing of Circuit Breakers," G. E., Rev., Vol. 57, October, 1948, pp. 389–401; November, 1948, pp. 447–461. (In French.)

The general principles and limitations of methods developed for indirect testing are recalled, with a description of a synthetic test arrangement more suitable for testing all types of breakers. This is based on the use of extra fast relays combined with thermal ionization taking the place of the auxiliary breaker used in some previous systems. The validity of composite or indirect testing methods is examined for several cases and for different types of test breaker; comparisons are made with results gained on direct tests. (*Science Abstracts*)

No. 1229. P. F. Soper, "A Three-Phase Trunking System for Experimental Work," *Beama J.*, Vol. 55, October, 1948, pp. 339–345.

Describes a 3-ph., l.v. heavy current metal-clad busbar system, wherein bare conductors are supported on porcelain saddles, with provision for bends, Tee-pieces, and plug and fuse boxes. Asbestos tubes or packing may be used and the system can be arranged for vertical mounting. The influence of unsymmetrical conductor arrangements and the result of modification of the magnetic field by the steel casing are dealt with theoretically, followed by a general description of a full-scale model of a commercial type suitable for laboratory use. (*Science Abstracts*)

No. 1230. B. O. Austin and H. H. C. Richards, "Carbon-Pile Voltage Regulator Improvements," *Elec. Eng.*, Vol. 67, November, 1948, pp. 1083. (Digest of A.I.E.E. Paper 48-214, to be published in *Trans.*, p. 67 (1948).)

A brief description of improvements made recently in regulators for U. S. aircraft. Among the desired features are improved performance, lower weight, and easier maintenance. (*Science Abstracts*)

No. 1231. B. V. Malevinski, "Calculation of Pressure in Arc-Quenching Circuit Breakers," *Elektrichestvo*, No. 11, November, 1948, pp. 44–48. (In Russian.)

After a short description of methods used for calculating the volume and average temperature of gases generated by the arc, the basic equations for determining the pressure/time characteristic are established analytically. The data obtained are compared with those derived by a graphical integration method and with experimental results supplied by oscillographic observation. Several plotted curves show good agreement between these methods. (*Science Abstracts*)

No. 1232. J. Marsden and R. H. Savage, "Effects of Silicone Vapor on Brush Wear," *Elec. Eng.* Vol. 67, November, 1948, p. 1084. (Digest of A.I.E.E. Paper 48–211, to be published in *Trans.*, Vol. 67 (1948).)

It has been observed that brush wear is very rapid in totally enclosed machines having silicone insulation. This is not improved by curing the insulation for long periods even up to 250 C. A theory is advanced and experiments are being made with impregnated brushes. (*Science Abstracts*)

No. 1233. J. M. Marzolf, "Aircraft Reverse Current Cutout," *Elec. Eng.*, Vol. 67, November, 1948, p. 1183.

A proposed arrangement uses two relay elements, each having a differential, residual, and reverse winding and a pivoted unconstrained permanent magnet armature. The first relay fires a thyratron which operates the main contactor; this mechanically trips the second relay and locks the first. It is intended especially for aircraft use on 20–30 v. and designed to be free from shock and vibration troubles. Experimental models have been made and found satisfactory. (*Science Abstracts*)

No. 1234. F. P. Phillips, "Lift Safety-Improved Ultimate Limit Switch," *Elec. Rev.* (London), Vol. 143, November 12, 1948, pp. 733–736.

Design requirements for complete overrun protection are stated and available methods discussed. A control feature is introduced which facilitates power resetting after overrun, with reduced accident risk due to electrician leaving resetting work partly completed. Diagrams show two alternative arrangements of striker and limit switch and the principle is claimed to be applicable to the mechanical limiting of other than electrically powered machinery. (*Science Abstracts*)

No. 1235. J. L. Barker, "Large Capacity Service Bus Design," *Elec. World*, Vol. 139, December 4, 1948, pp. 90–94.

Because of the high capacity ratings now required in l.v. busbar systems, proximity and skin effects, inductive heating, ventilating and conductor arrangements have an added importance. These are discussed with illustrations. Information is given on current carrying capacity for various Cu and Al bars, for different shapes of bar, and a monogram shows lateral stresses on short circuit. The figures are based on 60 cps. frequency, so that some corrections will be required if they are applied to British practice. (*Science Abstracts*)

No. 1236. W. F. Bonwitt, "Bolted Aluminum-To-Copper Connections," *Elec. Eng.* Vol. 67, December, 1948, p. 1190. Digest of A.E.E. Paper 48-216, to be published in *Trans.*, Vol. 67 (1948).

Connections with various platings and different compounds between contact sur-

faces were subjected to 200 C. in a corrosive atmosphere of a 20 per cent NaCl solution atomized by pre-heated air. The criterion of performance was contact resistance. Properly made bolted connections are satisfactory although tinning or the use of a compound such as Penetrox A helps. (*Science Abstracts*)

No. 1237. K. Brouwer, "A New Type of Distribution Fuseboard for Low Voltage Circuits," *Electrotechiek*, Vol. 26, December 2, 1948, pp. 411–413. (In Dutch.)

Describes a fuseboard fed by two 3-ph. transformer stations in which the fuse bases each have three contacts in line, the center contacts being connected to the outgoing cables and the top and bottom contacts to two busbars. Two of the fuse bases on the busbars feed each busbar from a transformer station, the incoming supply being connected to the center contact. By inserting the fuse between center and top or center and bottom contact either busbar may be fed from either station. Similarly any outgoing cable may be fed from either busbar by inserting its fuse between center and top or bottom contact. This arrangement enables the load sharing between the two stations to be adjusted with ease. On the same principle the load on a distribution board fed by a winter station can be shared out between two permanent stations in the summer. Fuse bases of this type are in use for 350 amp. and 200 amp. fuses. (*Science Abstracts*)

No. 1238. O. Dunkel, "The Odu Contact," *Arch. Tech. Messen* (Issue 158), Ref. J 04-3, F 1. December, 1948. (In German.)

This is a specially designed banana pin or banana jack in which the contact wires arranged around the central pin or inside the socket are so shaped that they make contact over their whole length. This entails a small contact resistance, small skin resistance, high current-carrying capacity, easy connecting and loosening, small wear, constant contact resistance, no additional inductance at h.f., low cost, small expenditure of material, long life, and safe working. Various designs are illustrated and graphs show the contact resistance, its percentage scattering, and the permissible load for various diameters. A comparison of the Odu contact with other connectors is made on the basis of life tests of up to 10^5 make and break operations. (*Science Abstracts*)

No. 1239. G. J. Himler and G. O. Cohn, "The Reverse Blowout Effect," *Elec. Eng.*, Vol. 67, December, 1948, pp. 1148–1152.

At high altitudes a d.-c. arc may move under the influence of an external magnetic field in a direction opposite to that found at sea level. Experiments with various forms of apparatus showed the reverse blowout to be very critical and not easily reproduced. The velocity and direction of movement of the arc channel is a function of the properties of the cathode and the arc current, etc. A discussion of the effect of magnetic fields on cathode phenomena and on the suggested formation of a localized negative space charge near the cathode is given. (*Science Abstracts*)

No. 1240. F. Koppelmann, "A New Contact Rectifier Connection," *Elektrotechnik* (Berlin 2), December, 1948, pp. 829–832. (In German.)

It is shown that by using a 6-ph bridge connection (6 reactors), no-load and load safety factors and contact life are increased, load on reactors is decreased, the power factor is increased, voltages of 800 v. and currents of 8000 amp. per unit become feasible and the connection is more economical. Reactive volt drop is increased by about 50 per cent and more contacts are required. (*Science Abstracts*)

No. 1241. J. R. Mortlock, "A Computer for Use in Power-System Transient Stability Studies," *J. Inst. Elect. Engrs.*, Part II, Vol. 95, December, 1948, pp. 751–755.

The angular swing of a machine during successive intervals in a step-by-step stability computation can be determined by balancing a sequence of a.-c. potential dividers. A form of the device designed for use with a network analyzer is described in detail, and it is claimed that results of comparable accuracy can be obtained in one-tenth the time required for the usual tabular method which is also described. (*Science Abstracts*)

No. 1242. W. J. Oosterkamp, "Calculation of the Temperature Development in a Contact Heated in the Contact Surface, and Application to the Problem of the Temperature in a Sliding Contact," Letter in *J. App. Phys.*, Vol. 19, December, 1948, pp. 1180–1181.

The similarity between the problem of heat dissipation treated by Holm (Abstr. 3295 A (1948)) and that of the heat dissipation in an X-ray tube anode is pointed out. The anode focal spot corresponds to the contact area, a stationary anode to a stationary contact, and a rotating anode to a sliding contact. The formulae previously obtained (W. J. Oosterkamp, and L. Philips, Philips Res. Rep., 3, 49–59; 161–173; 303 (1948)) are applied to the contact problem and the results, shown graphically, are compared with Holm's. (*Science Abstracts*)

No. 1243. D. M. Quick, "Welded Aluminum Bus in Outdoor Transformer Yard of Sewaren Generating Station," Edison Elect. Inst., *Bull.*, Vol. 16, December, 1948, pp. 415–418.

Heliarc welding has provided a means of overcoming the difficulties previously encountered in the use of Al busbars. Out-

standing features in the design of the Sewaren station, Newark, N. J., included: (1) adequate bus cross-section; (2) the method of making Al-to-Al connections; (3) the method of making Al-to-Cu connections; and (4) cost of the busbars including material and labor. A number of test welds were made and the results are discussed. A detailed explanation of the construction of the 13-kv. and 132-kv. bus is included. (*Science Abstracts*)

No. 1244. R. W. Wild, "The Electrical Measurement of Pressure and Strain, with Particular Reference to the Testing of Circuit Breakers," *J. Instn. Elec. Engrs.*, Part II, Vol. 95, December, 1948, pp. 733–749.

Pressure-recorders of the electromagnetic and carbon-pile types are detailed, the former being used successfully for circuit-breaker research. Small transformers with variable air gaps are connected with secondaries, tuned for 1 kc. per sec., in opposition for balance at zero pressure. The pressure to be recorded is applied to a suitable diaphragm controlling the air gap. An amplifier with a gain up to 50,000 is followed by a Duddell oscillograph as the recorder. The carbon-pile type is used in a bridge and is also satisfactory. Pressures up to 3000 psi. were recorded and application details are given. The resistance strain-gage is also mentioned. (*Science Abstracts*)

No. 1245. P. O. Bobo, H. A. Travers, and E. E. George, "Use of A.C. Network Calculator in Planning and Operating Electric Power Systems," *Conf. Int. Gr. Res. Elect. C.I.G.R.E.* (Rep. No. 328), 15 pp. (1948). (In English.)

The general principles and arrangements of a network calculator are described with particulars of twenty in use in the U. S. A., followed by notes on new features now added and a list of types of problems which can be solved. Care is needed in selecting a standard order of procedure and in checking the assumptions made before operating the calculator. (*Science Abstracts*)

No. 1246. H. F. Brown, H. A. Travers, and C. A. Woods, Jr, "Circuit Breaker Modernization and Faster Fault Clearing on Single-Phase Electrified Railroad," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 705–712 (1948), Paper 48–170.

The circuit breakers designed in 1913 for sectionalizing the 11/22 kv., 3-wire trolley and feeder circuits on the New Haven Railroad electrification had become inadequate by 1936 because of limited interrupting capacity to clear line faults fast enough to ensure system stability and reliability. The application of modern interrupters to the original breakers, together with the redesign of tanks, operating mechanism, and supporting frames (with spring supports), produced a circuit breaker of approximately the same over-all dimensions and weight which high power tests proved to be adequate for interrupting the entire fault current (instantaneous rms. symmetrical) as determined by a.-c. network calculator studies of the system. These studies were also the basis of application of instantaneous over current relays for fault clearing by the line circuit breakers, of which there are over 500. An analysis of the network calculator studies, the tests of the redesigned circuit breaker, and operating results are reported. (*Science Abstracts*)

No. 1247. T. E. Brown, Jr., "A Study of A-C. Arc Behavior near Current Zero by Means of Mathematical Models," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 141–153 (1948), Paper 48-23.

The differential equations of two idealized models of the arc column proposed by previous writers have been combined into a composite model whose behavior approximates that of actual a.-c. power arcs in circuit breakers and fuses near a critical current zero for arc extinction. An extensive series of curves are presented showing, for this model, the variation with time just before and after current zero of arc resistance, arc current, arc power, and dielectric strength of the arc space under certain simplifying assumptions for three different forms of circuit recovery voltage. These quantities are expressed in terms of prior arc current and voltage and of a characteristic "time constant" which depends upon the physical conditions imposed upon the arc. The model curves are compared with oscillographic measurements. Such models help in the understanding of arc behavior in circuit interrupters and in correlating and making extrapolations from interrupting data. (*Science Abstracts*)

No. 1248. J. W. Dalton, "German High Voltage Circuit-Breaker Design," Summary of dimensional data from *BIOS Rep.* and other sources. *Rep.*, Brit. Elect. Allied Indus. Res. Assoc. (Ref. G/T223), 8 pp. (1948). (*Science Abstracts*)

No. 1249. A. Dovjikov and C. C. Diemond, "Performance Test of the Allgemeine Elektrizitäts Gesellschaft Free-Jet Air-Blast 220-kv. 2500 Megavolt-Ampere Reclosing Circuit Breaker," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 295–306 (1948), Paper 48–43.

Contains detailed particulars of the circuit breaker and describes tests made in February, 1947, with it, on a large network to study favorable features with a view to developing gear for handling very high power. Ease of inspection of contacts and of maintenance and replacement, together with elimination of the use of oil, attracted favorable comment; fault currents were broken in 6 cycles (as compared with three for the

fast U. S. A. oil breakers), but interruption of line charging current, though successful, was accompanied by many restrikes. Possible modifications to improve performance are suggested. (*Science Abstracts*)

No. 1250. A. A. Hudson, "Gas Blast Circuit Breakers," Preliminary Study of Aero-Dynamic Conditions Near the Nozzle Contact. *Rep.*, Brit. Elect. Allied Indus. Res. Assoc. (Ref. G/T220), 9 pp. (1948).

Gives the results obtained in the first stage of an aerodynamical investigation into the conditions existing in the vicinity of the nozzle contact of a gas-blast breaker, both under no load and when arcing is present. The tests described were carried out on an E.R.A. experimental switch, fitted with an interrupter head used in previous heavy testing. Two types of nozzle contact were used, namely, a parallel bore contact of $1^1/_4$ in. diameter, and a convergent-divergent contact of 1 in. diameter throat section. Measurements were first made of the variation of total pressure and static pressure, along the axis of the nozzle, with no arc present, and from these results the velocity variation along the axis was deduced in the case of the convergent-divergent throat. A number of photographs were obtained showing the shock-wave formations in the jet issuing from the two types of nozzle. (*Science Abstracts*)

No. 1251. G. Jancke, "Experience in Operation with Automatic Reclosing of Breakers after Line Faults," *Conf. Int. Gr. Res. Elect., C.I.G.R.E.* (Rep. No. 306), 13 pp. (1948). (In English.)

In Sweden rapid reclosing was formerly not thought advisable because of risks of accidents, damage to rotating machines, etc., but after tests made in 1933 on 44 kv. and on 220 and 132 kv. in 1944, all new circuit breakers (77–380 kv.) are of the high speed reclosing type. Results of tests and applications to various systems, e.g., radial and loop and tie lines, are discussed, with observations on performance of relays, breakers, and types of load involved. The conditions favor high speed reclosing, and on a number of 11-44 kv. networks with neutral earthed through Petersen coils, about 82 per cent of line faults were eliminated by rapid reclosing. Maintenance includes check operation on no-load once a month. (*Science Abstracts*)

No. 1252. G. E. Jansson, "Large Indoor Power Air-Blast Circuit Breakers," *Trans.*, A.I.E.E., Vol. 67, pp. 1675–1679 (1948). Digest in *Elec. Eng.*, pp. 68, 439 (May, 1949).

Performances of axial and of cross-blast designs are briefly compared and five arrangements containing the best features were tested, two of which gave good performance. The tests also indicated the inherent difference in air flow in the two designs, and the effect of a suitable resistance in parallel with part of the arc in operation is mentioned. (*Science Abstracts*)

No. 1253. C. L. Killgore and W. H. Clagett, "Field Tests for Development of Ultra-High Interrupting Capacity 230-KV. Oil Circuit Breakers," *Conf. Int. Gr. Res. Elect., C.I.G.R.E.* (Rep. No. 130), 32 pp. (1948). (In English.)

Discusses the field tests made on Grand Coulee power plant, U. S. A., on four types of 230-kv., 3-cycle oil circuit breakers to determine the max. interrupting capacity breakers which can be developed for 230-kv. systems and also to determine their reaction towards restrikes and possible overvoltages during interruption of line-charging currents. More than 7 million kva. on the 230-kv. system was successfully interrupted during these tests. Reclosing tests with speeds of 12 cycles were made on both solid and arcing faults. Interruption of line-charging current was effected up to 382 miles of 230-kv. line. As a result, it was concluded that 10 million kva. interrupting capacity, 230-kv. circuit breakers could be developed at this time and that no de-rating factor would be required for one 20-cycle reclosure. (*Science Abstracts*)

No. 1254. C. L. Killgore and W. H. Clagett, "Field Tests for Development of 10,000,000 Kva. 230-KV. Oil Circuit Breakers for Grand Coulee Power Plant," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 271–287 (1948), Paper 48-42.

Presents much data obtained on field tests at Coulee Dam with four types of oil circuit breaker at 230-kv. handling faults equivalent to 7000 mva., 3 ph. The objects included supplementing and extrapolating laboratory results, determination of mechanical distress and other operating data on extra heavy fault, and finding the maximum breaking capacity of the gear tested. Line switching tests on the equivalent of up to 380 miles of line are mentioned The tests conclusively show that field tests up to 7500 mva. short-circuit value can be safely made on a large interconnected system without undue disturbance and that such tests are essential to permit combined development of h.v. systems and equipment. (*Science Abstracts*)

No. 1255. W. M. Leeds and G. B. Cushing, "A 230-KV. 3-Cycle Oil Circuit Breaker for Extra-Heavy Arc Rupturing Duty," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 236–242 (1948), Paper 48–40.

Describes a multiflow circuit breaker designed for a breaking capacity of 7500 to 10,000 mva. Particulars of laboratory and field tests at 60 cps. are given and the correlation between them is discussed. There are notes on the design of the arc control

principle used, the operating mechanism, rapid reclosing features, and other details. The steep rise in breaking capacities now required is indicated by reference to the Grand Coulee Dam location where an ultimate short-circuit capacity of some 15,000 mva. may have to be met. (*Science Abstracts*)

No. 1256. N. A. Mesentsev, "Three-Phase Sequential or Repeated One Way Switching of Two Power Systems," *Elekt. St.*, No. 7, pp. 40–44 (1948). (In Russian.)

Russian experiments on rapid repeated switching of two 110-kv. grid systems by automatic processes are described. Automatic frequency control and subsequent automatic determination of the correct 2nd switching (phase coincidence) are discussed. Successful operation was also achieved with one system having a single-phase short-circuit to earth. (*Science Abstracts*)

No. 1257. O. Naef and J. Wild, "Staged Tests and Operating Results on an 8-KV. Overhead Line System Using High Speed Automatic Reclosing," *Conf. Int. Gr. Res. Elect., C.I.G.R.E.* (Rep. No. 331), 26 pp. (1948). (In English.)

Describes special tests with rapid reclosing on the 8-kv. Zurich E.K.Z. System to collect service data and to study the effect on connected machines. After outlining features of the system, including the protective gear used, operating experience is dealt with and fault statistics tabulated, with an account of laboratory tests to establish the time delay needed to deionize the arc path in the range 6–10 kv., and to check motor behavior on brief interruption of supply. The conclusions contain recommendation on protection in this latter case and show that rapid reclosing was successful in an average of some 75 per cent of the cases, and that this figure can be improved. (*Science Abstracts*)

No. 1258. S. Rambaut, "Determination of the Voltage Across the Terminals of a Circuit Breaker as a Function of the Current Interrupted, by Means of Rupturing Tests with Small Currents," *Conf. Int. Gr. Res. Elect., C.I.G.R.E.* (Rep. No. 111), 25 pp. (1948). (In English.)

The results of tests on existing networks and transformers using alternating and direct currents of <1 A are applied to determining the voltage across the terminals of a circuit breaker and its relation to current broken. For a. c. the concept of "forced" current is used, which is defined as the current in magnitude and sign to be superposed on the real current to obtain the undisturbed working current. Results are applied to the standard diagram for a.-c. breaking and conclusions are reached concerning the voltages resulting from sudden and from progressive interruption. These voltages have no relation to the service voltage but depend on the value of the current broken, the circuit characteristics, and the wave form of the forced current. (*Science Abstracts*)

No. 1259. E. B. Rietz, "Unusual Performance of Standard 230-KV. Impulse and Tank-Type Oil Circuit Breakers on Field Tests," *Trans.*, A.I.E.E. Vol. 67, Part I, pp. 267–270 (1948), Paper 48–41.

A short review of existing circuit-breaker designs and arrangements made and tests done to ascertain whether breakers can be designed for breaking capacity rating of 7500–10,000 mva. required for the Grand Coulee Power Plant. (See Abstr. 1639 (1949).) It is concluded that slight changes in design will meet the requirements and that field tests are necessary for development and proving in the range above 3500 mva. (*Science Abstracts*)

No. 1260. L. H. Sperow and J. A. Favre, "An Improved Design of Low-Voltage Panel-Mounted Air Circuit Breaker," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 695–698 (1948), pp. 48–166 (1948).

Describes an air break circuit breaker rated at 600 v. a.c. or 250 v. d.c. in 225- and 600-amp. sizes handling 15-ka. and 25-ka. s.-c. current. Features mentioned include the use of hinges with silver-plated pins in place of braided connectors, the design and operation of special tripping devices, and materials used. (*Science Abstracts*)

No. 1261. H. Thommen, "On the Question of the Electro-Dynamic Oscillations Stressing High-Power Circuit Breakers," *Conf. Int. Gr. Res. Elect. C.I.G.R.E* (Rep. No. 125), 19 pp. (1948). (In English.)

A study based mainly on calculations of the rates of rise of restriking voltage, to which modern circuit breakers may be subjected in typical networks and in combinations of circuit units such as generators and transformers. The influence of such factors on breaking capacity is explored and the results of field tests on short-circuit, switching out transformers, and on no-load with an air-blast breaker and a B.B. breaker of low oil content are compared with calculated values. Proposals for required performance of circuit breakers are made based on curves for high and for low frequencies. (*Science Abstracts*)

No. 1262. H. M. Wilcox and B. P. Baker, "A Compressed Air Circuit Breaker for 23-KV. Arc Furnace Duty," *Trans.*, A.I.E.E., Vol. 67, Part I, pp. 154–158 (1948), Paper 48–24.

Outlines requirement for the duty and gives details of a circuit breaker rated for 600 amp. breaking 3000 amp. and provided with 345-kv. class insulation. Test results include life test over 110,000 operations—

30,500 of which were on load—and representative oscillograms. Reference is made to the operating mechanism, arc chute design, arc splitters, and use of an arc suppressor. The breaker is suitable for severe duty, i.e., frequent operation. (*Science Abstracts*)

No. 1263. I. L. Zhdanov, "Stacked On-Off and Change-Over Switches," *Vestn. Elektroprom.*, No. 9, pp. 11–13 (1948). (In Russian.)

Russian rotary switches up to 380 v. and 60 amp. capacity are surveyed. Up to five stacked switches can be assembled and ganged for single manual rotary control. (*Science Abstracts*)

No. 1264. "Fuses, Electric Protection. Fine-Sensitive and Surge-Resisting Types, Below 5 Amperes, Produced in Germany," *BIOS Rep.* (No. 1771) (H. M. Station Off.), 11 pp. (1948).

Lists German manufacturers of this class of fuse with notes on methods, material used, and production rates. Single wire fuses with wires <0.01 mm. are not made and the chief differences between British and German or continental construction for sensitive delay action fuses for radio equipment and the like is that the former uses a single straight wire down to 0.0004 in diameter while the other technique employs wires, springs, etc., joined by special solders. (*Science Abstracts*)

No. 1265. "German Switchgear Developments by the Siemens Schuckert Concern," *Rep.*, Brit. Elect. Allied Indus. Res. Assoc. (Ref. G/T206), 10 pp. (1948)

The main items discussed are: flameproof expansion breakers up to 6-kv. arc control devices for water circuit-breakers, and improvement in 100 kv. breakers. There are notes on developments in the 220-kv. breaker field; designs for 400 kv., general operating principles, and a few remarks on isolators. (*Science Abstracts*)

No. 1265a. G. E. Rudashevskii, "Electrical Contacts of the Strainometer in Operation," *Isvestiya Akademii Nauk S.S.S.R., Otdelenie Technicheskikh Nauk* (Bulletin of the Academy of Sciences of the U.S.S.R., Section of Technical Sciences), January, 1948, pp. 19–22. (In Russian.)

Factors responsible for errors in the above were investigated. It was found that the main factors were defective contacts between the moving-shaft and the brushes. A series of practical remedies is proposed. (*Battelle Library Review*)

No. 1265b. Isolde Dietrich, "Thermoelectric Currents on Contact With Monomolecular Films of Impurities in Monometallic Circuits," *Z. angew. Phys.*," Vol. 1, (May, 1948, pp. 377–382. (In German.)

This proves experimentally that the thermoelectric voltage, which appears when two crossed gold rods are heated on one side only, is caused by a thin film of foreign matter at the points of contact. The magnitude of the voltage agrees with Kohler's work, and the film resistance follows the Wiedemann-Franz law. Includes diagrams and graphs. 14 references. (*Battelle Library Review*)

No. 1265c. A. B. Chernin, "Calculation of Currents and Voltages for a Complete Analysis of Relay Protection with Short Circuit and With Simultaneous Open Circuit of One Phase," *Elektrichestvo*, No. 6, June, 1948, pp. 20–25. (In Russian.)

Using symmetrical component theory, equivalent circuits are deduced and equations for the current and voltage are tabulated for (*a*) open-circuit and simultaneous short-circuit to earth of phase A; (*b*) short-circuit to earth on phases A and B open-circuit phase A; (*c*) short-circuit between phases A and B with open-circuit phase A; (*d*) short-circuit phase A to B to C with open-circuit phase A; (*e*) 3-ph. short-circuit to earth with open-circuit in phase A. An example is taken of case (*b*) to demonstrate the calculation of the s.-c. currents and voltages using the equations derived. The paper is entirely mathematical and is confined chiefly to faults on interconnecting lines with a possible two-way feed of power into a fault. (*Science Abstracts*)

No. 1265d. U. R. Evans, "Electrical Contacts; the Effect of Atmospheric Corrosion," *Met. Ind.*, Vol. 73, July 2, 1948, pp. 10–13.

Investigations reviewed suggest that two entirely different types of corrosion product can be produced by atmospheric attack and that these two types affect electrical-contact problems in different ways. 31 references. (*Battelle Library Review*)

No. 1265e. N. N. Linnichenko, "The Effects of Eddy Currents on the Recovery Voltage at the Switching-On of a Short-Circuited Transformer," *Elektrichestvo*, No. 11, November, 1948, pp. 63–66. (In Russian.) (*Science Abstracts*)

No. 1265f. A. I. Rutskiĭ, "Heating of Steel Busbars Under Short Circuit," *Elektrichestvo*, No. 11, November, 1948, pp. 58–60. (In Russian.)

Rectangular section steel busbars operating at 50 cps. and designed for a current density of 1.61 amp. per sq. mm. have a temperature rating of 75 C. Calculation of temperature attained under s.-c. conditions is difficult as the effective resistance changes. This is because the large current causes the permeability to fall, owing to magnetic saturation, and hence the skin effect is reduced. Experimental results show the influence on a.-c. apparent resistance of s.-c. currents and of thickness of the bar. With s.-c. current 5–10 ×

normal current, skin effect is pronounced in bars from 3–12 mm. thickness. With s.-c. current 10–20× normal, skin effect is important only in thicker bars (4–12 mm.). With s.-c. currents >20× normal and thickness ≤12 mm., skin effect is negligible. Curves are given enabling heating to be calculated in each of these cases. (*Science Abstracts*)

No. 1265g. A. Bardócz, "Synchronous Switches for Electric Spark Generators Used in Spectrochemical Analysis," *Publ. Univ. Tech. Sci.*, No. 3, pp. 140–157 (1948). (In English.)

This is a review of the principles of design of the switches. The possibility of using such switches in apparatus for generating a pulsating arc discharge is pointed out. Different methods of phase adjustment are discussed, also the special problems introduced by using h.v. A special description is given of a remote phase-adjusted and voltage-controlled rotary switch for 40-kv. peak voltage. (*Science Abstracts*)

No. 1265h. J. Brandmüller and H. Heumann, "Investigations on Contact Noise and Contact Vibration," *Z. angew. Phys.*, Vol. 1, No. 3, pp. 139–142 (1948). (In German.)

The investigations showed that with careful installation the contact noise remains an order of magnitude below the noise level of the closed amplifier. If the contact resistance is very large, the noise may be larger. (*Science Abstracts*)

No. 1265i. K. R. Schade, "Physical Problems in Electrical Contacts. Critical Résumé," *Rep. Brit. Elect. Res. Ass.* (Ref. U/T107), 47 pp. (1948).

A review of present knowledge on electrical contacts with particular attention to the material wear. The influence of chemical and metallurgical properties of the contact material in determining the circuit conditions to be observed to reduce arc formation, material migration, and welding of the contacts. (*Science Abstracts*)

No. 1265j. ASTM Standards on Electrical-Heating, Resistance, and Related Alloys," Am. Soc. Testing Mats., 170 pp. (1948).

This review includes standards for the above, as well as thermostat metals, contact materials, materials for lamps and radio tubes, and structural and electrical-resistor materials for furnaces. (*Battelle Library Review*)

No. 1265k. "Report of Committee B-4 on Electrical Heating, Resistance, and Related Alloys," *Proceedings, Am. Soc. Testing Mats.*, Vol. 48, p. 176 (1948).

This review includes proposed methods for modulus of elasticity of thermostat metals (Cantilever Beam method), for resistivity of metallically conducting resistance and contact materials, and for testing sleeves and tubing for radio-tube cathodes. (*Battelle Library Review*)

1949

No. 1266. F. Dahlgren, "Line Model for the 200-KV Network," *Tekn. Tidskr.*, Vol. 79, January 1, 1949, pp. 13–15. (In Swedish.)

Description and circuit diagrams are given of a 3-ph., 50 cps. model of the Swedish 200-kv. network, built for investigation of the relay protection. Line reactances are represented by solenoids with movable iron core for adjustment. A model showing interference between two and three lines is also given. (*Science Abstracts*)

No. 1267. S. C. Killian, "New Outdoor Air Switch," *Elec. Eng.*, Vol. 68, January, 1949, p. 47. Digest of A.I.E.E. Paper 48–248, to be published in *Trans.*, Vol. 67 (1948).

The switch described dispenses with contact cleaning devices by using high-pressure Cu-Ag contacts for capacities of 400–5000 A at 7.5 to 230 kv. Reasons advanced for a use of a combination of contact materials include the applicability of Wiedemann and Franz' law to the conduction of heat from a point of contact under fault conditions, the abrasion-free characteristics of the combination and a new contact theory involving ionic migration through the contact film forming fine conducting paths at a given "coherer voltage." The value of "coherer" voltage is related to the melting point of the metal and film thickness. A brief outline of preliminary work is reported and further tests may be expected. (*Science Abstracts*)

No. 1268. S. Lalander, "Network-Analyzer Investigations on the Swedish Trunkline System," *Tekn. Tidskr.*, Vol. 79, January 1 1949, pp. 7–11. (In Swedish.)

A detailed report on the measurements carried out to date on the London (BTH) analyzer concerning load distribution and stability of the Swedish system. Adjustments of the analyzer and special connections made to accommodate an adequate model of the system are discussed and scale calculations are given. Graphs show phase rotation and s. c. effects and load distribution on s. c. investigations continue. (*Science Abstracts*)

No. 1269. R. Lundholm, "CTH (Chalmers Technical High School) Network Model of the Swedish Trunkline System," *Tekn. Tidskr.*, Vol. 79, January 1, 1949, pp. 12–13. (In Swedish.)

The model includes all 26 generating stations, the impedance elements being fixed. An inductive reactance is represented by a noninductive resistance, a resistance by a capacitive reactance and a capacitive reac-

tance by a negative resistance. The supply is 50 cps. Compensation for instrument impedance is provided by measurement of the error when an equal impedance is coupled in series on opening the s.-c. switch. The model is described, including special arrangements for phase regulation of generator elements. (*Science Abstracts*)

No. 1270. B. G. Rathsman, "Network Analyzers-Design and Application," *Tekn. Tidskr.*, Vol. 79, January 1, 1949, pp. 1–7. (In Swedish.)

Description of a small d.-c. analyzer for s. c. determination and relay adjustment, and of the modern a.-c. (440–448 cps.) analyzer with up to 400 elements for determining load distribution, steady-state and transient stability of large interconnected networks. A table shows the number of each type of element, and the range of adjustment. The supply is 50 v. 0.05 amp., or 100 v, 1 amp. One analyzer (Iowa) uses 10 kc. per sec. Possible measurements and accuracy are discussed and the procedure is described. (*Science Abstracts*)

No. 1271. H. Manzinger, "What Requirements Must Pneumatic Operating Gear for Isolating Switches Fulfill?" *Electrotech. u. Maschinenb.* (*EuM*), Vol. 66, February, 1949, pp. 39–43. (In German.)

Unsatisfactory experience has led to some dislike of pneumatic operation, but the troubles, when understood, can be overcome. The main difficulty is the wide range of torque which is greatly increased by dirt and the effects of heavy short circuits. On the other hand, damage may be caused by excess of power when air pressure is at a maximum and friction lowest. A study of torque curves, of which examples are given, is a valuable aid to design. The simplest drive consists of a single cylinder and piston, but the use of two coupled pistons for closing and opening is common as sealing against loss of air is simplified. A satisfactory rotary drive is described. (*Science Abstracts*)

No. 1272. P. W. Swenson, "Contacts," *Bell Laboratories Record*, Vol. 27, p. 50 (1949).

Use of Pt, Pd, Au, Ag, Pt alloy and Ag in relays in telephone circuits. Pt or Pd preferred where low contact resistance, i.e. low noise, is required. Base metal used for sliding type contacts.

Locking of the contacts, due to snapping of the build-up of the one contact in the cavity of the other, is the most frequent cause of trouble. Contacts are protected against this by adding an additional capacitance and resistance to ground.

No. 1273. A. Hamilton and R. W. Sillars, "Spark Quenching at Relay Contacts Interrupting D.C. Circuits," *Proc.*, I. E. E., Part I, Vol. 96, March, 1949, pp. 64–76. (In English.)

An account is given of experiments on discharge-quenching at silver contacts interrupting in air currents up to 20 A in circuits containing sufficient inductance to produce discharges ($10^{-1} > L/R > 10^{-3}$ sec). The influence of the following factors on the value of the parallel capacitance required for discharge quenching was examined: current, contact material, resistance in series or parallel with the capacitance, speed of separation of contacts, circuit inductance, and supply voltage. Measurements were not strictly reproducible, but it was found that, apart from the current, the above factors had little influence. Resistors were only effective with currents of <0.1 A: higher currents needed a capacitance for arc quenching, the necessary capacitance being α the current. Increasing the initial speed of separation of the contacts reduced the value of the necessary capacitance. The capacitances normally used for quenching purposes are too low, but they do shorten the discharge life. It is concluded that the necessary conditions for discharge quenching at contacts can be completely found from the voltage/current/time characteristic curves of arcs; the parameters of the circuit being interrupted are largely irrelevant except insofar as they determine the current to be interrupted. (*Science Abstracts*)

No. 1274. N. N. Linnichenko, "The Break in the Arc of a Circuit-Breaker," *Vestn. Elektroprom.*, Vol. 20, March, 1949, pp. 21–23. (In Russian.)

The breaking of a purely inductive circuit is considered in conjunction with the problem of a rupture of an arc prior to the passage through zero of the current and the corresponding danger of considerable overvoltages. It is claimed that the fundamental relations applying to this process are derived for the first time. (*Science Abstracts*)

No. 1275. H. Manzinger, "What Requirements Must Pneumatic Operating Gear for Isolating Switches Fulfill?" Part II, *Elektrotech. u. Maschinenb.* (*EuM*), Vol. 66, March, 1949, pp. 58–63. (In German.)

Practical requirements and design data are considered in detail. Points for attention include suitable torque, space requirements, easy method of connection, latching devices, emergency hand operation, dependence on temperature, and lubrication. (*Science Abstracts*)

No. 1276. W. G. Pfann, "Contact Bridge Erosion and Its Prevention," *Elec. Eng.* Vol. 68, March, 1949, p. 197. Digest of A.I.E.E. Paper 48–274, to be published in *Trans.*, Vol. 67 (1948).

The diameters of resultant craters are considered to be those of the molten metallic

bridge formed on the separation of electrical contacts and are found to vary for different contact materials. Crater diameters are equal for some materials, but others give asymmetric conditions. Bridge erosion tests suggest that contact material is transferred in the direction of the smaller crater. Artificial asymmetry, set up by pairing, in one contact, two metals of different "natural" bridge diameters, is advanced as a means of reducing transfer, minimum transfer occurring on asymmetry. A diagrammatic example of Au + to Pt − shows a thin layer of Pt facing on Au contact for equilibrium. (*Science Abstracts*)

No. 1277. E. Schwaiger, "The Bow Current Collector," *Maschinenb. u. Wärmewirtsch (MuW)*, Vol. 4, March, 1949, pp. 41–47. (In German.)

The conditions are investigated for ensuring a satisfactory contact and avoiding harmful sparking between an overhead line and a bow current collector for electric locomotives or motor coaches. The three static characteristics are first discussed showing the functional relations between weight of the bow, its mass to be accelerated and the force pressing it upwards on the one hand and its height above the ground on the other. The dynamic characteristic of the bow collector indicates the speed and the path of the collector if with the locomotive stationary the bow is suddenly released from its lowest position. If this test is repeated with the locomotive running a curve is obtained which may be plotted against the path of travel. In order to prevent contact being lost between bow and overhead line the latter must coincide with this curve whenever its height above ground is altered. The use of the dynamic characteristic in erecting the overhead line is shown by an example. (*Science Abstracts*)

No. 1278. P. E. Gaze, "Truck Type Air-Break Switchgear," *BTH Act.*, Vol. 20, March–April, 1949, pp. 54–57.

Gives main particulars of a range of air-break switch gear, covering breaking capacities of 100–150 mva. at 3.3 kv. with current ratings of 400–2400 amp. Some short-circuit test results for various duties are included. (*Science Abstracts*)

No. 1279. G. Ohman, "Air-Blast Circuit-Breakers," *A.S.E.A. J.*, Vol. 22, March–April, 1949, pp 42–51. (In English.)

Gives particulars of the construction and mode of operation of a range of air-blast circuit breakers, designed for controlling long transmission h.v. systems (11–220 kv. and ultimately 380 kv.) in Sweden. Each pole comprises a power break which extinguishes the arc and is followed by a series break which isolates the circuit. On heavy currents at lower voltages (up to 22 kv.) two-stage interruption utilizing resistance switching is employed and on the higher voltage, nonlinear resistor to damp switching overvoltages are fitted. Several ingenious air supply and operating devices are briefly mentioned and provision is made for rapid reclosing on 3- or on 1-phase. (*Science Abstracts*)

No. 1280. "Lightning Protection of Metalclad Switchgear and Unit Substations Connected to Overhead Lines," *G. E. Rev.*, Vol. 52, March, 1949, pp. 19–23.

Discusses the impulse coordination of lightning arresters and of different types of indoor and outdoor substations with and without a length of cable between overhead line and substation. Numerical values are given for the voltage range from 2400 to 13,800 v. and for interrupting ratings of 50–500 mva. Typical examples of insulation coordination are described with particular reference to the best point or points of installation of lightning arresters. A maximum length of cable between overhead line and substation is derived which is stated to require no arrester at the substation end of the cable. (*Science Abstracts*)

No. 1281. A. M. Bronstein, "The Resistance of an Arc Gap During the Process of Voltage Recovery," *Elektrichestvo, No. 4*, April, 1949, pp. 39–45. (In Russian.)

Measurements of the residual currents at arc extinction were made on gas-generating tubes of various shapes. The resistance of the column in a gas-generating tube on breaking of currents of 25–500 amp. immediately after the current to be broken had passed through its last zero was several kΩ for large current values, and >10 kΩ for small currents. The resistance of the arc gap immediately after the beginning of the voltage recovery rose slowly, especially at high rupturing currents. Often there was an initial decline in the residual resistance. The oscillograms show that the discharge characteristic is not a falling one. It must be assumed that during the recovery an arc discharge with strongly contracted arc column takes place, comparable to the arc discharge in a very narrow channel. The value and duration of the residual current depends also on the geometry of the arc-quenching tube. The residual resistance up to the first amplitude of the recovery voltage is relatively low and influences the form of the recovery voltage curve. (*Science Abstracts*)

No. 1282. A. W. Brunot and Florence F. Buckland, "Thermal Contact Resistance of Laminated and Machined Joints," *Trans.*, Am. Soc. Mech. Engrs., Vol. 71, April, 1949, pp. 253–256; discussion, p. 257.

Values are reported for two types of joints: between two blocks of laminated steel, either in direct contact or separated by cement

or shims of steel, aluminum, or aluminum foil; and between two blocks of cold-rolled steel with various surface finishes. The resistance measured amounts to 0.3 to 8 in. of additional material, depending upon configuration. Results are also given in terms of contact resistance. (*Battelle Library Review*)

No. 1283. Else Holm, Ragnar Holm, and Erle I. Shobert II, "Theory of Hardness and Measurements Applicable to Contact Problems," *J. App. Phys.*, Vol. 20, April, 1949, pp. 319–327.

The ball indentation method is recommended for the determination of real contact area. Hardness is defined as the ratio between the contact load and the mouth area of indentation. Variation of hardness with geometric and metallurgical conditions and the relation between hardness and yield point are discussed. Data are tabulated and plotted. 10 references. (*Battelle Library Review*)

No. 1284. M. Morgan, "Limit Switch Circuits for Electric Motor Drives," *Prod. Eng.*, Vol. 20, April, 1949, pp. 124–128.

Limit switches are included in the motor control circuits of industrial equipment to keep the travel of the operating members within safe limits, to stop machine motion at pre-selected points, or automatically to stop and reverse the direction of travel. An analysis is given of some of the conditions that govern the relationship between the machine motor, its control, and the driver member, and hence the type of limit-switch circuit that is to be selected. Methods of controlling the displacement and reversal of machines and the circuit operation and application are described. (*Science Abstracts*)

No. 1285. R. Roeper, "Thermal Stresses Due to Varying Short-Circuit Currents," *Elektrotech. Z.* (*ETZ*), Vol. 70, April, 1949, pp. 131–135. (In German.)

The theory is developed of a practical method of determining exactly the thermal stresses due to varying s.-c. currents, such as exist in circuits of low reactance, e.g., close to generator terminals. The time constants are derived from the ratios of the known s.-c. currents under steady, alternating, and sudden s.-c. conditions. Tabulated curves render the method rapid and simple. Comparison is made with the results obtained by other methods. (*Science Abstracts*)

No. 1286. P. V. Sakharov and I. I. Pekker, "Comparison of the Electromagnetic Systems of A.C. Contactors with Linear Movement," *Vestnik Elektroprom.*, Vol. 20, No. 4, April, 1949, pp. 18–24. (In Russian.)

Linear contactors are being increasingly used in starters of motors of up to 4 kw. and 380 v., in switchboards and cubicles of substations, etc. Ten different designs are compared, considering traction characteristics, energy consumption, weight and clearances, effect of voltage on traction characteristics, and price. (*Science Abstracts*)

No. 1287. N. D. Weills and E. A. Ryder, "Thermal Resistance Measurements of Joints Formed Between Stationary Metal Surfaces," *Trans.*, Am. Soc. Mech. Engrs., Vol. 71, April, 1949, pp. 259–266; discussion, pp. 266–267.

Gives the results of measurements on dry and oil-filled joints between two flat surfaces of various metals. Thermal resistance is decreased by increasing temperature and pressure, by inclusion of oil, or by plating the surfaces with a soft metal. (*Battelle Library Review*)

No. 1288. "Corrosion of Base Metal Contact Surfaces in the Telephone System," *Corrosion*, Vol. 5, April, 1949, p. 134.

Describes method for minimizing above corrosion by use of a special lubricant composition. Comparative results with and without treatment are illustrated. (*Battelle Library Review*)

No. 1289. S. S. Chugunov, "The Non-Linear Element of an A.C. Calculating Board," *Elektrichestvo*, No. 5, May, 1949, pp. 24–28. (In Russian.)

A non-linear element (as self-regulating load) is described, designed for use in an a.-c. calculating board. This element may be substituted for circuits possessing nonlinear volt-ampere characteristics. In particular it may replace a negative active resistance, an ideal inductance (loss-less and independent of current), a generator or load of constant current and of an active or reactive character. (*Science Abstracts*)

No. 1290. V. V. Kaplan and V. M. Nashatyr, "Method of Simultaneously Switching Several High-Voltage (D.C. Operated) Circuits," *J. Tech. Phys.*, U.S.S.R., Vol. 19, May, 1949, 567–569. (In Russian.)

Two circuits to be switched on simultaneously are joined by a small capacitance in parallel with a high resistance: a spark gap is included in the second circuit. The capacitance is initially charged by means of the operating voltage of the first circuit acting through both circuits and the resistance in series; this arrangement is claimed to be novel and simple. The first circuit may then be switched on and the voltage across the spark gap immediately becomes the operating voltage of the second circuit plus the capacitor voltage; the gap breaks down and switches on the second circuit. The method may be extended to switching several circuits and, by a slight modification, the action on oscillatory circuits may be improved. Choice

of values of C and R is considered qualitatively. (*Science Abstracts*)

No. 1291. "Metal-Clad Single-Break Switchgear," *Engineer* (London), Vol. 187, May 27, 1949, pp. 591–592.

Describes a new metal-clad circuit breaker developed by Cooke and Ferguson for rating up to 1000 mva., on 33 kv. which incorporates several novel features. The construction, which includes use of single break, is aimed to secure economy in bushing lengths, strength and rigidity at the contacts, and reduction in arc energy and amount of oil required. Other features of interest are accessibility of current transformers, interlocks, lowering mechanism, and use of light alloy castings. A table of short-circuit performance is given. (*Science Abstracts*)

No. 1292. R. D. Knott and J. W. P. Hudson, "Starter Switches for Fluorescent Lamps," *Elec. Times*, Vol. 115, June 9, 1949, pp. 763–766.

Switches for the glow discharge and heater coil types are described and the required operational characteristics indicated. Curves included related changes of ambient temperature with striking and extinction voltages and closing time of contacts, and also relate variation of closing time with applied voltage. Starter switch life values of 5000 lamp-starting operations are normal, but 25,000 are often achieved. D-C. glow starters are possible, if required, and 130 v., a.-c. models have been developed to meet coal face installation regulations and the operational requirements of the new 2 ft. and $1^1/_2$-ft. lamps recently introduced. (*Science Abstracts*)

No. 1293. T. Persson, "Supervision of H.V. Circuit-Breakers in the Plant," *Tekn. Tidskr.*, Vol. 79, June 4, 1949, pp. 441–443. (In Swedish.)

Experience with unsatisfactory operation of circuit breakers installed led to framing of a scheme of routine testing, including resistance measurements, operating voltage, opening and reclosing time, air pressure, and lubrication. A recording instrument is described, with circuit diagram, and a specimen report form is given. Some results obtained in tests at various power stations are discussed. (*Science Abstracts*)

No. 1294. Yu. Ya Yurov, "Influence of Gas Films on Contact Resistance," *Electrichestvo*, No. 6, June, 1949, pp. 47–50. (In Russian.)

Theoretical and experimental investigations show increase of contact resistance due to gas films covering these contacts. Removal of gas films by increasing contact pressure, operation in vacuum, external heating, or heating by electrical current cause fall of contact resistance. Theoretical estimates and test results on a 30 Ω carbon pile show close agreement. (*Science Abstracts*)

No. 1295. S. Gerszonowicz, "Quantitative Characteristics of High Voltage A.C. Circuit-Breakers," *Bull. Soc. Franç. Élect.*, Séries 6, Vol. 9, July, 1949, pp. 319–327. (In French.)

Restriking voltage, the d.-c. component, and recovery voltage of circuit breakers are briefly reviewed and the definitions of breaking capacity and making capacity as used in U. S. A. and in Europe are discussed. The main quantities (referring to rating) are critically examined and a definition of breaking capacity is proposed. The influences of p.f., nature of the fault to be dealt with, and type of circuit-breaker used are outlined. (*Science Abstracts*)

No. 1296. R. Holm, "The Vaporization of the Cathode in the Electric Arc," *J. App. Phys.*, Vol. 20, July, 1949, pp. 715–716.

Calculations are carried out which show that, because of the smallness of the cathode spot, the cathode is not able to dissipate the heat generated with heavy currents by conduction. Therefore, a much higher vaporization of cathode material per coulomb occurs for heavy currents than for low currents. (*Science Abstracts*)

No. 1297. H. Paetow, "Bridge Formation by Contact Fusion and Migration of Particles," *Elektrotech. Z.* (*ETZ*), Vol. 70, July 1, 1949, pp. 227–232. (In German.)

The voltage/time curve by the opening of a switch was recorded on an oscillogram, and the bridge formation when a small drop (some hundredths mm.) is drawn from the anode and adheres to the cathode was investigated by microscope. The electrode distance by rupture of the bridge $/_A$ was $\alpha/^1/_2$ for 0.3 amp. $< 1 <$ 4000 amp.; the diameter was $\alpha/^3/_4$. The factor of proportionality was the same and is apparently a material constant. Temperature measurements were made with thermo-element and the bridge formation is explained on the basis of Thomson effect and surface tension, the laws of the phenomenon being deduced theoretically. Measurement of temperature differences between the solid electrodes gives a means for determining Thomson and Peltier effects at high temperatures. (*Science Abstracts*)

No. 1298. T. P. Musatov, "Testing of the Operating Voltage of the Tripping Coils of a Circuit-Breaker," *Elekt. St.*, Vol. 20, July, 1949, pp. 33–34. (In Russian.)

Failure to trip of an imported 35-kv. circuit breaker on a 110-kv. substation led to an investigation and to revision of circuit-breaker testing regulations. It is suggested that the "testing voltage" should be 65 per cent of the rated operation voltage, to allow for deterioration during service. This "testing

voltage" of the tripping coils is defined as the minimum voltage at which the mechanism completes its operation, though at a reduced speed of the movement of the armature of the relay. It represents a measure of the power reserve available at the rated operating voltage and at the lower limit of the operating voltage. (*Science Abstracts*)

No. 1299. H. Viehmann, "Abnormal Wear of Carbon Brushes on Electric Machines," *Elektrotech. Z. (ETZ)*, Vol. 70, July 15, 1949, pp. 263–267. (In German.)

A discussion of the researches which have taken place in Germany and America to investigate brush wear in high flying aircraft. (*Science Abstracts*)

No. 1300. A. Roxburgh, "Compressed Air Systems for Air-Blast Circuit Breakers," *BTH Act.*, Vol. 20, July–August, 1949, pp. 111–115.

Discusses problems of design, layout, pumping capacity, and conditioning of the air supplied to the circuit breaker. Air drying is considered at some length and refrigeration is suggested as an effective method. (*Science Abstracts*)

No. 1301. C. H. Flurscheim and E. L. L'Estrange, "Factors Influencing the Design of High-Voltage Air-Blast Circuit-Breakers," *Proc.*, I.E.E., Part II, Vol. 96, August, 1949, pp. 557–586.

Air-blast circuit breaker design is studied, more especially in the range 110–264 kv. and 1500–5000 mva. The influence of air-pressure range on excess breaking capacity at normal pressure and methods of achieving economy in air consumption are described. Limitations and advantages of multibreak interruption are discussed with reference to constructional, voltage grading, and air-flow problems. Design limits of shunts for voltage control and the advantages of nonlinear resistors (n.l.r.) for this purpose are given. Methods of short-circuit testing are examined, and the severity of test-plant restriking rate, both for tests made on complete and subdivided breakers, is compared with that for actual systems. The performance of a double-break, 3500-mva. 132-kv. circuit breaker incorporating parallel air flow and n.l.r. voltage control is presented in graphical form, showing the effects of voltage, current, and restriking rate in terms of air pressure, and the behavior of n.l.r. shunting. An account is given of the facilities offered by air-blast breakers for high speed reclosure and service maintenance, and of the manner in which these requirements are executed. (*Science Abstracts*)

No. 1302. P. F. Soper, "Carbon-Brush Contact Phenomena in Electrical Machinery," *Proc.*, I.E.E., Part II, Vol. 96, August, 1949, pp. 645–654.

A theoretical investigation into the change in contact resistance when sliding occurs. It is assumed that the current is conducted by a series of points on the surface which are continually changing and the problem is considered on the basis of electron emission. The effects of brush quality, polarity, pressure, surface film, etc., are discussed. Test results are given. (*Science Abstracts*)

No. 1303. "A New Calculating Table for Alternating Current," *Tech. Mod.*, Vol. 41, August 1–15, 1949, pp. 270–272. (In French.)

Gives particulars of an extensive model apparatus for determining s.-c. current, voltage rise, or reactive power in a.-c. networks. The equipment includes 16 generators, 33 autotransformers, and several hundreds of elements calibrated to represent line resistances, reactances, and capacitances. It is supplied at 220 v., 3 ph., 500 cps. (*Science Abstracts*)

No. 1304. F. Llewellyn Jones, "Arcing Phenomena at Electrical Contacts as Used in Communication Engineering," *Proc.*, I.E.E., Part I, Vol. 96, November, 1949, pp. 305–311.

The arc phase of electrical contacts of the type used in low-power communication engineering is discussed from the point of view of the fundamental processes which occur both in the arc column and at the electrode surfaces. A theory of electrode erosion due to spark discharges is applied to the case of contacts, and the results of recent experiments on discharge initiation and arc transfer are discussed. Attention is drawn to the practical consequences of the short time in which an arc can be established. It is shown that the state of the surface of the electrodes themselves is important in arc quenching; restriking of the spark or arc as the contacts separate can be effected by electron emission from thin oxide films or from dust on the surfaces. The influence of the various disposable parameters on the wear of the electrode is examined; conclusions are drawn concerning the desirable physical properties of the electrode material and the conditions of operation, in order that the wear shall be least. Recent experiments confirm that dust can be extremely effective in spark initiation, and it is suggested that the maintenance of the electrode surfaces clean and dust free would reduce the tendency for the striking of the spark or arc with separating contacts, and so reduce the value of the parallel capacitance required for discharge suppression. The use of preferred gas atmospheres and the treatment of the electrode surfaces can assist in arc quenching; and the presence of even very slight self-inductance ($\sim 10^{-8}$) in the local contact circuit can lead to arcing under certain conditions. (*Science Abstracts*)

No. 1305. Billy M. Horton, "Sliding Contacts to Transmit Small Signals," *Rev. Sci. Instruments*, Vol. 20, No. 12, December, 1949, pp. 930–932.

Measurements have been made of root-mean-square noise voltage in the frequency range 0.5 to 200 cps. generated by contacts sliding at low speeds using four arrangements of contacting bodies and various materials. Mercury with amalgamated probes gave the lowest noise levels. Some solid contacts operating with low friction on clean metal surfaces yielded values of generated noise below 1 microvolt at a sliding speed of 35 cm./sec. when two contacts were in parallel.

The noise increases with speed and varies with normal force. The r.m.s. generated noise voltage of a large number of independently mounted contacts in parallel is inversely proportional to the square root of the number of contacts.

No. 1306. Emil Alm, "Physical Properties of Arcs in Circuit Breakers," *Trans.* Roy Inst. Tech., No. 25 (T4 R81t), 248 pp. (1949.)

Consists of a comprehensive fundamental and practical treatise on the above. Surveys those divisions of the theory of gas discharge which deal primarily with arc phenomena. Continuous arcs are treated at length in spite of differences between them and the short-interval arcs occurring during switching, because of the larger amount of material available on them, and also because the two types have much in common. Some of the more outstanding quantitative theories on circuit breakers are reviewed. Numerous diagrams, graphs, and illustrations. (*Battelle Library Review*)

No. 1307. G. A. Chetchuev, "Substation High Speed (Oil) Circuit-Breakers Type MKP 35," *Vestnik Elektroprom.*, No. 6, Vol. 20, pp. 1–6 (1949). (In Russian.)

A new outdoor type made in 600 amp. and 1000 amp. sizes (differing only in the construction of the explosion pots and contacts) for 20 and 35 kv. with rupturing capacities of 430 and 750 mva. The three separate phase tanks hold a total weight of 0.8 metric ton of oil; each is fitted with two 600-v. heaters. With two cross-jet pots per phase the circuit is interrupted in 0.08 sec. after the operating coil is energized; on heavy load the arc burns for 3 half-cycles. Condenser bushings are used; 12 current transformers can be fitted. Constructional details and performance figures are given. (*Science Abstracts*)

No. 1308. A. Johansson, "The Laminated Contact—A New Type of Contact and Its Application to Certain Important Forms of Switching Devices," *Ericsson Rev.*, No. 1, pp. 28–32 (1949). (In English.)

Describes in detail a flat pin-type laminated contact for which constant contact resistance characteristics are claimed. Up to 40 or more cable terminations can be arranged in a single plug. A similar lamination is used as a spring contact member located in a slotted circular plug pin. A coaxial form of plug and socket and a valve holder are also described. By using the ends of the laminations, arranging these in pairs on two pitch circle diameters and mounting a roller to traverse the projecting ends, a new form of rotary switch is produced capable of controlling 200 switching points. (*Science Abstracts*)

No. 1309. W. B. Boast and J. D. Ryder, "A Network Analyser Operating at 10,000 Cycles," *Proc.*, Midwest Pwr. Conf., Vol. 11, April, 1949, pp. 72–78.

This review gives particulars of the design and application of an analyzer made as a development model with only 4 generators. The enlarged unit contemplated will have 14 to 16 generators, 100 line units, and 50 load units. An advantage of the frequency chosen is that standard radio units for capacitances and reactances may be used. Examples, comparing analyzer results and calculated results, are included to indicate the accuracy obtainable. (*Science Abstracts*)

No. 1310. H. Puppikoffer, A. Gantenbein, E. Vogelsanger and Kurth, "Minimum Oil Circuit Breakers," *Bull. Oerlikon*, No. 277 February, 1949, pp. 1903–1923; No. 278, April, 1949, pp. 1925–1938.

A review of the development of this type from the earliest forms of oil circuit breaker with a note on the field of application of the three main types now used, *viz.*, oil, minimum oil, and air-blast breakers. The mechanism of breaking an arc in oil is outlined, graphs and oscillograms being given to illustrate performance in networks having varied characteristics. Indirect testing for high power gear is discussed at some length, followed by a review of constructional features of Oerlikon circuit breakers, how they are installed, the types of drive used, and service experience. (*Science Abstracts*)

No. 1311. P. de Nicola and E. Binell, "Automatic Protective Section Switches for 3 kv. d.-c. Contact Lines," *Ing. Ferroviaria*, Vol. 4, June, 1949, pp. 431–435. (In Italian.)

It is shown that a short-circuit in a section generally causes the trip-out of the breaker at the nearest substation, while the current from the farther substation, which is limited by the resistance of the contact line, will continue to feed the s.c. with serious danger to the equipment. A new voltage-sensitive cut-out has been designed for installation at intermediate points of sections. It operates when the voltage falls below a value which is ad-

justable between 1 and 2 kv. When normal conditions are reestablished, the device resets itself automatically through the operation of a clock mechanism with a delay adjustable between 0 and 300 sec. A warning bell to traffic control personnel is provided. The supply to the auxiliaries of the device is taken from the a.-c. mains but provision is made for operation from a battery. Experiments carried out during the last 3 yr. on the Orte-Falconara and Chiusi-Florence lines have shown promising results. (*Science Abstracts*)

No. 1312. S. Rudeforth, "Contact Resistance and its Variation with Current," *P. O. Elec. Eng. J.*, Vol. 42, July, 1949, pp. 65–69.

Multiple tests on contacts of Uniselector were conducted over a current range of 0.22 to 4.5 amp. using a 12-v. supply. For "static" tests, a peak-millivoltmeter was used to obtain maximum values of resistance persisting for short periods after switching on the current. Multiple results are plotted in a combined graphical and statistical manner. The metallic contact condition is concluded to require a maximum of 2 v. For "dynamic" tests, a stepping rate of 10 per sec. was used, and oscillograph records showed peaks of contact resistance on vibration either from stepping magnet or from external sources. Although make-before-break switching was used, higher values were recorded than for "static" test conditions and these again increased after 250–500 switch operations. (*Science Abstracts*)

No. 1313. M. F. Karasev, "On the Problem of D.-C. Machine Commutation Calculations," *Elektrichestvo*, No. 7, July, 1949, pp. 30–36. (In Russian.)

A continuation of previous papers (Abstr. 1956, 2356 (1949)). The classical commutation theory is recalled as obtaining the commutation emf. curve by superimposing on that of the armature reaction the line of the reactance voltage. The maximum value of reaction emf. by Schenfer's formula includes a coefficient for the mutual inductance between sections in different slots and for the commutator bars per brush width not being a whole number. When this is so, the coefficient becomes unity and Pichelmeyer's formula results which ignores effect of brush width. By experiment the author proves this method incorrect because contact ionization produces very unequal current distribution in brush width; peak values of reaction emf. all occur next to each other and thus do not depend on brush width. Interpole emf. (e_k) does not compensate the reaction emf. but moves the current collecting point in the contact to achieve optimum current distribution between trailing and leading edges. The classical theory, based on constant contact resistance, is therefore rejected and Wegner's based on constant contact volt-drop, is analyzed. It is proposed that commutation calculations should be based on experimentally obtained curves of contact ionization for different brush grades, and it is found that one type of brush sparking depends on mechanical factors (e.g., vibration) and the other on the commutated section's parameters. Both types also depend on current density. It is proved, using c.r. oscillograms, that with no commutation zone field or mutual inductance between sections, ampere-turns IT of commutated section = constant, which differs with brush grade. Thus contact ionization is determined by the section's magnetic flux energy. When corrected for specific magnetic slot conductance and armature length the expression becomes $I^2T^2, \lambda I = K$, $K = 15$ for Cu graphite, 30 for hard, and 60 for graphite brushes. Slot damping is checked by obtaining values of IT at which ionization begins for various numbers of short-circuited turns in slots adjacent to the commutated section. A brush-width coefficient should be introduced in the above formula and I should be the current in the trailing edge. The expression is evaluated for different brush grades with the more common ratios of brush-width: segment-width and for optimum current distribution between trailing and leading edges. It can then be applied to commutation calculations. (*Science Abstracts*)

No. 1314. Joseph Brandmuller and Heinz Heumann, "Research on Contact Noise and Contact Vibration, Part II," *Z. angew. Phys.*, Vol. 1, August, 1949, pp. 454–462. (In German.)

The existence of characteristic contact vibration is proved by measurements with the Hemholtz pendulum and with the cathode-ray oscillograph. Results show that vibration rate decreases as elasticity modulus of the contact increases. Other factors affecting contact vibration are investigated and explained. Diagrams, graphs, and tables are included. (*Battelle Library Review*)

No. 1315. J. Hlávka, "The Basic Principles of the Synthetic Testing of Extra-High-Voltage Circuit Breakers," *Elektrotech. Obz.*, Vol. 38, September 25, 1949, pp. 469–477. (In Czech.)

The basic principles of the synthetic testing of circuit breakers are analyzed, and the differences between the results obtained by real and synthetic tests, respectively, are shown to be both inherent in the synthetic method and functional resulting from its practical application. During the arcing phase, the electrical conditions of the real test can be simulated with comparatively good accuracy, provided the arc voltage is not relatively large, a condition which precludes any breaker with a long arc path. The phase of the test following the extinction of the arc is much more critical, as, although the arc has ceased

to exist, the space between the electrodes does not immediately become nonconducting. It is, therefore, essential for the voltage generator not only to produce the required voltage, but also a certain output. The difference between the amount of energy fed into the discharge during this second phase in the real and in the synthetic test, respectively, can therefore be taken as a measure for the accuracy of the synthetic test. The economy of synthetic tests being based on the use of h.-v. generators of small capacity, the available machines are not as a rule sufficient to produce results which would allow a correct evaluation of the rupturing capacity of the breaker. The problem is treated in detail mathematically in general terms, so that the results obtained can be applied to any type of circuit breaker, and the parameters developed can be used for more detailed studies of individual types. (*Science Abstracts*)

No. 1316. C. Bellomi and R. Righi, "Automatic Switches in Signalling Equipment," *Ing. Ferroviaria*, Vol. 4, September, 1949, pp. 563–574. (In Italian.)

The use of automatic switches in place of fuses is one of the measures adopted by the Italian State Railways to make signalling circuits safe from double faults. Two important advantages result: (1) After operation the protected circuit is completely isolated from the supply and can be earthed, thus making it safe from accidental contacts; (2) the control circuit can be operated from an independent supply. Types designed for the various duties and now in general use have basic interchangeable elements. The switches are insensitive to vibrations, have contacts designed to interrupt large currents, have sensitivity and robust construction. The construction and operation are described, characteristics given, and an example worked out for a particular application. (*Science Abstracts*)

No. 1317. R. Dubey, "High Voltage Metal-clad Swithgear," *Rev. Alsthom.*, July–September, 1949, pp. 11–25.

Essential characteristics and methods of insulation of conductors such as oil, compound and treated paper are outlined. The dimensions of metal-clad switchgear are compared with other types, and vertical or horizontal layout, systems of connection, mounting of voltage transformer, isolating and coupling cubicles, and current transformers are discussed. Brief details are given of "monobloc" installations made up, for example, of 3 metal-clad cubicles, 1 transformer, and a distribution board. (*Science Abstracts*)

No. 1318. H. Franken, "Silver in the Construction of Switchgear," *Elektrotechniker*, Vol. 1, September, 1949, pp. 73–77. (In German.)

The great advantages are stressed of using Ag or Ag-tipped contacts in the construction of switchgear, using both for high-current carrying capacity and infrequent operation and for very frequent switching of low currents. Graphs show comparative values of the contact resistance for Ag/Ag, Cu/Ag, Cu/Cu and Ag-plated contacts. Questions of wear are discussed and some examples of present-day constructions are illustrated. On an average the life of Ag contacts working in air is about 10 × that of Cu contacts, and the work necessary for maintenance in good working order is considerably reduced. (*Science Abstracts*)

No. 1319. F. E. Martin and H. E. Stauss, "Contact Transients in Simple Electrical Circuits," Washington, Naval Research Laboratory, No. Pb-99613, Nat. Bureau Standards publication (Office of Technical Services, U. S. Dept. of Commerce, Washington, D.C.), September 30, 1949.

An oscilloscopic study has been made of transient types occurring over a range of inductance and capacity values in direct-current circuits. This work is an extension of that of Curtis and his associates, who worked with circuits containing a relay and a line of variable length. The results reported here are similar to those obtained by the earlier experimenters, but they amplify them and broaden their validity.

No. 1320. M. Hensel, "Switchgear Control Diagrams and their Efficient Design for Installation Purposes," *Elektrotechn. Zeitschr.*, Vol. 70, October 15, 1949, pp. 408–410. (In German.)

To save time and work and eliminate wiring faults in the installation of complicated control gear associated with switchgear installations, and to facilitate maintenance and fault detection, a method representing the installation in the form of a schematic diagram, detail diagram, and wiring instruction table is suggested and examples shown. (*Science Abstracts*)

No. 1321. M. Paavola, "On Systematic Wiring Diagrams for Electrical Installations," *Kraft o. Ljus.*, Vol. 22, October, 1949, pp. 208–214. (In Swedish.)

Diagrams for design of electric plant should include a clear plan of main current-circuits, of external connections to switches, meters, and other apparatus, wiring of instrument boards, control, and meter cables, with indications of the type of apparatus, and systematic numbering of terminals and connections. Examples are given. (*Science Abstracts*).

No. 1322. R. Marenesi, "Influence of Line Characteristics on A.-C. Circuit Breaking," *Energia Elett.*, Vol. 26, October, 1949. 605–632. (In Italian.)

Opening of a short circuit in one phase by an ideal circuit breaker is considered and the relevant equations are established and solved, giving the recovery voltage. Next, the effect of the arc on the phenomena at circuit breaking is examined, restriking is discussed, and the influence of capacitance of the line is considered. Damping by resistance, whether line leakage or shunt on the breaker, is accounted for, and the rate of recovery is discussed. Arc energy and the various ionizing and de-ionizing factors are dealt with in detail, and the theoretical considerations are applied to some special types of circuit breaker: with small oil volume, with large oil volume, with compressed air, with special reference to the recovery of electric strength of the gap. Some experimental results on arcing time, rupturing capacity, restriking of arc, and effects of line constants are discussed. 77 references and 64 diagrams are given. (*Science Abstracts*)

No. 1323. A. Sperti, "A Modern Type of Circuit Breaker Suitable for High-Speed Reclosing," *Ind. Ital. Elettrotic.*, Vol. 2, October, 1949, pp. 31–34. (In Italian.)

A brief description with illustrations of a low oil content breaker for voltages up to 275 kv. is given. The moving contact is operated with a pantograph multiplier of small mass. This has allowed a single-break construction. The extinction chamber consists of a pre-chamber with diaphragm acting as arc guide and an extinction chamber proper of the multiple labyrinth type. Arcing time is 3 half-periods. When fitted for high-speed reclosing, each pole is operated independently. Details of the relay circuit are given. (*Science Abstracts*)

No. 1324. I. Dietrich and E. Rüchardt, "Thermal Potentials in Platinum Contacts," *Z. Naturforsch.*, Vol. 4a, October, 1949, pp. 482–486. (In German.)

It is shown experimentally that the thermal potential observed when crossed Pt wires are unsymmetrically heated is due to a thin film of impurity between them. The thermal potential and the thermal resistance of the unimolecular impurity film were determined. The measurements were in good agreement with values calculated from the theory of Kohler (*Ann. Phys.*, Vol. 38, p. 542 (1940), and *Naturwissenschaften*, Vol. 29, p. 164 (1941)). (*Science Abstracts*)

No. 1325. "Guide for Applying Low-Voltage Air Circuit Breakers," *Elec. Engg.*, Vol. 68, October, 1949, pp. 852–854.

An A.I.E.E. Committee report briefly describes how circuit breakers of adequate breaking capacity for the duty required may be selected having regard to the A.I.E.E. standard. Methods of determining symmetrical and asymmetrical s.-c. currents (1- and 3-ph.) are outlined. Requirements for circuit breakers in cascade and in selective tripping arrangements are discussed. For d.-c. faults of 100 kva. and over, consideration should be given to the rate of rise of currents as compared with the interrupting speed and rating of the breaker. (*Science Abstracts*)

No. 1326. I. G. Nekrashevich and T. Z. Fisher, "Dependence on Frequency of the Uni-Polar Conductivity of Contacts," *J. Tech. Phys.*, U.S.S.R., Vol. 19, November, 1949, pp. 1312–1320. (In Russian.)

Investigation of a crystal rectifier (PbS) in a wide frequency interval is recorded. Curves of rectified current *versus* amplitude of applied voltage and frequency were obtained for electronic and "hole" conductivity. Inversion of the rectification effect occurs at definite relations between frequency and amplitude of the applied voltage. An equivalent valve circuit is presented, demonstrating the behavior of the detector considered. (*Science Abstracts*).

No. 1327. P. M. Davidson, "The Theory of the Thomson Effect in Electrical Contacts," *Proc.*, A.I.E.E., Vol. 96, Part I, November, 1949, pp. 293–295.

A general theorem is given concerning the influence of the Thomson effect on the location of the maximum temperature in an electrical contact. Its application to the theory of fine transfer in electrical contacts is discussed. (*Science Abstracts*)

No. 1328. L. H. Germer and F. E. Haworth, "Erosion of Electrical Contacts on Make," with appendix; D. P. Ling, "Effect of Steady Value Current Upon Erosion," *J. App. Phys.*, Vol. 20, November, 1949, pp. 1085–1109.

When an electric current is set up by bringing two contacts together, they necessarily discharge a capacitance. If the discharge takes place through an arc before the metallic circuit is established, erosion of the electrodes results. In an l.-v. circuit the occurrence of an arc depends upon the condition of the electrode surfaces and upon the circuit inductance. For "inactive" surfaces, and a voltage of the order of 50, an arc does not occur if the inductance is $>3\mu$H. Surfaces of various metals can be "activated" by vapors of certain unsaturated organic compounds, and in the active condition they give arcs even when the circuit inductance exceeds the limiting value by a factor of $>10^3$. When an arc occurs at the make of inactive metal surfaces, its energy, of practical interest in l.-v. circuits, is drawn entirely from a charged condenser, is dissipated almost entirely upon the positive electrode, and melts out a crater intermediate in volume between the volume of metal which can be melted by the energy and that which can be vaporized. Some of the

melted metal lands on the negative electrode and, with repeated operation, results in a mound of metal transferred from anode to cathode. This transfer is about 4×10^{-14} cm.^{2} of metal per erg. The arc voltage is of the order of 15 v. If the initial circuit potential is > about 50 v. there may be more than one arc discharge, successive discharges being in opposite directions and resulting in the transfer of metal in opposite directions, always to the negative electrode. (*Science Abstracts*)

No. 1329. T. J. ter Horst, "Synthetic Methods of Testing Circuit Breakers," *Electrotechiek*, Vol. 27, October 13, 1949, pp. 379–389; November 10, 1949, pp. 429–431. (In Dutch.)

This is a review of suggested methods for testing circuit breakers beyond the power limits of the testing plant. A full list of references is given. It is doubted whether unit testing of multiple-break, 1-ph. breakers as applied to oil breakers simulates the natural condition with sufficient accuracy when applied to air-blast breakers, since the air quantity passing through one contact when being tested alone will be either smaller or greater than when all contacts operate together, according to whether the air circuit is in parallel or series respectively. In connection with the method in which a large current is applied to the breaker followed by a high recovery voltage from a separate source across the open contacts, it is shown that it is essential that the voltage in the circuit to be interrupted should be high in relation to the expected arc voltage, so as to avoid deformation of the current wave-form. The argument that this deformation imposes a more severe test condition of arc extinguishing is disproved. Various methods of applying a synthetic recovery voltage resembling the natural condition are described in detail. An example of calculating the voltage distribution in a multiple-break, 1-ph. breaker is given. (*Science Abstracts*)

No. 1330. E. M. Tseĭrov, "Influence of the Arc on the Air Flow in the Quenching Chamber of an Air-blast Circuit Breaker," *Elektrichestvo*, No. 11, November, 1949, pp. 50–58. (In Russian.)

A theoretical and experimental investigation is given. It is concluded that the air flow in the quenching chamber is essentially different from that through pipes. The arc has a heavily retarding effect and restricts the volume of air passing through the chamber. Within certain limits this effect is α energy dissipated in arc. The average values of the flow constants can be determined from initial conditions of air, dimensions of the chamber, and power of arc. With a knowledge of the limiting temperature of positive arc column, the arc-quenching properties of chambers may be expressed analytically. It is proportional to the cross-section of escape opening of chamber and air pressure in the chamber. Where chamber cross-section varies smoothly, quenching effect will be satisfactory only if the arc is maintained near its critical cross-section. (*Science Abstracts*)

No. 1331. E. Maass, "Community Isolators for Outdoor Switching Stations," *Elektrizitaeswirtschaft*, Vol. 48, November, 1949, pp. 258–263. (In German.)

Four firms have collaborated to produce a range of isolators in which all main parts are either standard or interchangeable. Each phase unit has two rotating post insulators with horizontally moving arms. The three mechanically coupled units may be operated by hand or compressed air. The 110-kv. type was designed first and is described in detail. The experience obtained was used to produce 220- and 60-kv. types, the latter having some parts similar to the 110-kv. model. (*Science Abstracts*)

No. 1332. H. Mackh, "Contacts in Electrical Measuring Technique," *Arch. Tech. Messen*, No. 166 (Ref. JO4-1) T102–4, November, 1949. (In German)

A review of the most important contact properties and their relation to physical and chemical contact structure, with special reference to errors of measurement which may arise from faulty contacts. The main characteristics of Ag, Pt, Au, W, Al, various alloys, and graphite as contact materials are briefly discussed and tables of constants for a wider range of substances are given. (*Science Abstracts*)

No. 1333. L. R. Bergström, "Switching-Overvoltages in Large Power Circuits," *Tekn. Tidskr.*, Vol. 79, December 3, 1949, pp. 915–922. (In Swedish.)

The building-up of the voltage across a switch on opening a capacitive circuit is explained. The following cases are studied in detail: (1) A compressed-air circuit breaker separating an open-circuit line in a direct-earthed network. The first half-period is critical. A short line may cause greater difficulties of rupture than a long line, but if a station becomes isolated through line breakdown, the long line is more troublesome. (2) A Network earthed through arc-suppression coils. The circuit-breaker voltage is higher than for direct earthing, and restriking of the arc is more dangerous. (3) Inductive load; experimental transformer on no-load. In all cases the effects of inductance and capacitance of generating station and line are examined, oscillograms of tests are given and discussed, and the maximum overvoltage is given. (*Science Abstracts*)

No. 1334. R. Chambrillon, "Study of the Equivalence of Short-Circuit Tests on Circuit Breakers at Low Frequency, Low Volt-

age A-C. and on D-C.," (Rev. Gen. Elect.), Vol. 58, December, 1949, pp. 521–531. (In French.)

A mathematical study of the principles involved in the short-circuit testing of circuit breakers by means of a high power alternator run at low speed. The results are compared with those of a similar study for d-c. tests and the different values arising in the formulae given are discussed to demonstrate their validity. Test figures indicate that the low-frequency, low-voltage method gives results which are sufficiently accurate to permit its use in extending the range of a d-c. test plant. (*Science Abstracts*)

No. 1335. B. M. Norton, "Sliding Contacts to Transmit Small Signals," *R. Sci. Inst.*, Vol. 20, December, 1949, pp. 930–932.

Measurements have been made of rms. noise voltage in the frequency range 0.5 to 200 cps. generated by contacts sliding at low speeds using 4 arrangements of contacting bodies and various materials. Hg with amalgamated probes gave the lowest noise levels. Some solid contacts operating with low friction on clean metal surfaces yielded values of generated noise $<1\mu v.$ at sliding speed of 35 cm. per sec. when two contacts were in parallel. The noise increases with speed and varie with normal force. The rms. generated noise voltage of a large number of independently mounted contacts in parallel is α (number of contacts) $-1/2$. (*Science Abstracts*)

No. 1336. E. A. Frowein, "The New Smit Regulating Switchgear," *Smit. Med.*, Vol. 4, October–December, 1949, pp. 80–87. (In Dutch.)

Equipment for transformer voltage stabilization by tap-changing on load is described. (*Science Abstracts*)

No. 1337. M. Varichon, "*Electrical Equipment*," *Bull. Soc. Belge Elect.*, Vol. 65, October–December, 1949, pp. 177–195. (In French.)

Description of a unit-block design for h-v. and l-v. transformer stations using prefabricated metal-encased basic units. The metal plate casings, busbar, and other (protection, metering, condenser, etc.) units can be mass-produced at the works, which considerably reduces their cost. The space required for the installation of such substations is much smaller than that occupied by corresponding plants of conventional design, and this appreciably reduces the cost of ground and buildings. A detailed analysis of the economic and technical merits of this system is given and numerous diagrams, sketches, and actual photographs of such "normablock" installations for h.v. and l.v. are shown. (*Science Abstracts*)

No. 1338. F. O. Mason, L. H. Orton, and A. M Cassie, "Gas Blast Circuit Breakers: Behavior of Experimental Models at Reduced Pressures," *Engineer*, Vol. 188, December 2, 1949, pp. 630–633. Also *Rep. Brit. Elect. Res. Ass.* (Ref. G/XT129), 11 pp. (1949).

This describes experimental work to identify the cause of variation in performance of an experimental breaker when deliberately operated at a blast pressure well below normal. Several possible causes, such as variation in the shape of the electrodes, turbulence, or the effect of the arc, are considered. (*Science Abstracts*)

No. 1339. F. C. Prior, "German War-Time Patents Relating to High Voltage Circuit Breaking, 1939–1945, with Translations of Main Claims of Interest," Rep. Brit. Elect. Allied Indus. Res. Ass., (Ref. G/T229), 60 pp. (1949). (*Science Abstracts*)

No. 1340. L. Gosland and D. G. White, "Rates of Rise of Restriking Voltage at Circuit Breaker Positions on 66-kv. Systems (System A)," Rep. Brit. Elect. Allied Indus. Res. Ass., (Ref. G/T227), 7 pp. (1949).

The review gives results of calculations for most of the circuit breakers on one 66-kv. system. These calculations are intended to cover the most severe conditions which arise at each installation, but frequently the highest rates of voltage do not occur under the conditions giving the highest short-circuit mva., and in such cases alternative calculations have been made. In all cases the calculations relate to the interruption of fault current when all feeders on the system other than those constituting a link between the fault and generating plant have been disconnected. The condition considered is that at the clearance of the first phase of a 3-ph. short circuit, not to earth. (*Science Abstracts*)

No. 1341. B. W. Wyman and E. J. Casey, "A Manually-Operated Spring Mechanism for Medium Voltage Oilless Circuit Breakers," *Trans.*, A.I.E.E., Vol. 68, Part I, 357–363 (1949).

A method is described of closing circuit breakers by a mechanism consisting of compression springs manually compressed by a jacking motion. Tests indicate that sufficient energy is available to close and latch magne-blast breakers rated at 2.3–15 kv. on momentary currents of 60 ka. On lighter duty, excess energy is returned to the springs, and no dashpots or buffets are required to absorb excess energy on no-load operations. (*Science Abstracts*)

No. 1342. B. P. Baker and E. Frisch. "A New 69-kv., Compressed-Air Circuit Breaker," *Trans.*, A. I. E. E., Vol. 68, Part I, pp. 363–372 (1949).

A brief description is given of an outdoor metal-clad, 3-ph. circuit breaker with rating of 2 kva. and 3500 mva. breaking capacity.

Each pole is a self-contained unit comprising 2 breaks (one being shunted by a resistor) and an isolator. The air-blast pressure used is 200–250 psi. and clearing time from energizing the trip coil in $3^1/_2$ cycles. A few test results are mentioned. (*Science Abstracts*)

No. 1343. E. A. Ricker, "Automatic Grounding and Air-Break Switches for Protection of Transformer Stations," *Trans.*, A.I.E.E., Vol., 68, Part II, pp. 851–857 (1949).

A means for protecting small transformer stations is described whereby an automatic earthing switch puts a solid earth on the h.-v. transmission line when the transformer relays have detected any fault. After the circuit breaker at a distant station has cleared this fault, an automatic 3-ph., air-break switch is opened on the h.-v. side of the faulty transformer, disconnecting the bank and the earthing switch from the line. Thus the cost of an expensive h.-v. circuit breaker in the transformer station is avoided. System conditions suitable for this arrangement are described and a list of stations using it is given, with notes on typical cases. (*Science Abstracts*)

No. 1344. A. C. Boisseau, B. W. Wyman, and W. F. Skeats, "Insulator Flashover Deionization Times as a Factor in Applying High-Speed Reclosing Circuit Breakers," *Trans.*, A.I.E.E., Vol., 68, Part II, pp. 1058–1067 (1949).

As the result of the great reduction in reclosing time made possible by modern circuit breakers, flash-over de-ionization times are shown to determine the lower limit of permissible reclosure times. Laboratory tests are made to determine the variation of deionization time with several of the most important parameters. The test procedure involving arcs of 1000 to 20,000 amp., and 120 to 10,000 mva. is described. Single- and 3-pole reclosures on s.-c. and d-c. lines are examined oscillographically and with the aid of cine-camera records of the test arcs across insulator strings. The results obtained are presented in several curves from which the minimum permissible reclosure times can be directly obtained for various system conditions. In view of the disturbing effect of capacitive coupling, 3-pole switching is found to be superior to 1-pole. On most types of line, reclosure times might be decreased well below the present American standard of 20 cycles. (*Science Abstracts*)

No. 1345. W. A. Morgan, F. S. Rothe, and J. J. Wisness, "An Improved A-C. Network Analyzer," *Trans.*, A.I.E.E., Vol. 68, Part II, 891–897 (1949).

The new analyzer of the bureau of Reclamation has a base voltage of 50, a base current of 50 ma., and a frequency of 480 cps.; there is a total of 272 units. Improvements on previous models relate to details of measurement. (*Science Abstracts*)

No. 1346. C. E. Winegartner and H. E. Bonheimer, "A-C., Tripping and Reclosing of Line Sectionalizing Circuit Breakers," *Trans.*, A.I.E.E., Vol. 68, Part II, pp. 1357–1359 (1949).

This describes application of automatic switching, sectionalizing, and reclosing without the use of a control battery in a system supplied by a large transmission station. The station feeds two 18 mva., 34.5 kv. underground cables tapped to supply one or more distribution stations. Details of operation on o.h. line or cable faults are given with notes on tripping and reclosing features. (*Science Abstracts*)

No. 1347. F. J. Harrington and E. C. Starr, "Deionization Time of High-Voltage, Fault-Arc Paths," *Trans.*, A.I.E.E., Vol. 68, Part II, pp. 997–1004 (1949).

Recording circuits, designed to have negligible effects on the problem under investigation, and the procedure adopted for 13.8 and 115 kv. tests are described. Relations between de-ionization time and fault duration are given, and oscillograms illustrate features for various circuit conditions to show minimum times of reclosure in practice. The deionization time is mainly a function of fault duration; variation of fault mva. from 750 to 1500 hardly affects the maximum values of the former although faults of 2000 to 3000 mva. increase them somewhat. Speed of reclosure may be limited by multiple lightning stroke phenomena. (*Science Abstracts*)

No. 1348. M. J. Baldwin, "Oscillographing Commutation," *Trans.*, A.I.E.E., Vol. 68, Part I, pp. 100–105 (1949).

Search coils were fitted along the centers of of the conductors of a 3-section armature coil of a traction motor. One end of each search coil was connected to the main conductor at the commutator end, and the other ends were brought out to sliprings at the back end. The current and voltages were measured by oscillograph and the effect of under-, over-, and correct-compensation indicated. Details of the technique are carefully explained. (*Science Abstracts*)

No. 1349. D. P. Motter, "Commutation on D-C. Machines and its Effects on Radio Influence Voltage Generation," *Trans.*, A.I.E.E., Vol. 68, Part I, pp. 491–496 (1949).

An investigation on a dynamotor used in U. S. military aircraft is described, this particular machine being chosen because the radio influence voltage across the brushes of the h.-t. winding so greatly exceeded that experienced when the same brushes passed the same current through sliprings. Oscillograms show the transients across the brushes while

by the provision of 3 sliprings and special connections, the instantaneous voltage across, and current through, one armature coil over one armature revolution are similarly presented. The main transient is produced at the end of the commutating period when the current rate of change is highest, but there is evidence of others arising during the commutation of an adjacent coil. Because the crossface resistance of the normal brush is too low to limit appreciably the circulating current, special laminated brushes were introduced where: (1) the thickness $\leq$ the insulation thickness between commutating bars; (2) each lamination is insulated from all others except at the pig-tail end; and (3) the resistivity of the brush material increases from the leading to the trailing segment of the brush. Here, no transients on either voltage or current curves are observed. Furthermore, curves of radio noise v. frequency, 0.15–20 mc. per sec. show much lower figures, amounting to ~26 db. at 0.35 mc. per sec. for the laminated than for the normal brushes. Also, over a 20-deg. range of brush position, the laminated brushes show a fairly constant noise level 20–30 db. below that of the normal brushes. Details of design of the special brushes are given. (*Science Abstracts*)

No. 1349a. Edward Justi and Herman Schultz, "Recent Experiments Made to Explain the Bridge Transfer in Electric Breaking Contacts," *Abhandlungen der Braunschweigischen Wissenschaftlichen Gessellschaft*, Vol. 1, No. 1, pp. 89–100 (1949).

Previous theories and experimental work are reviewed, and the above described. Results showed that Holm's thermoelectric explanation fails to explain the almost consistently "positive" direction of material transfer. The second Benedicks homogeneity effect was applied. This thermoelectric effect between identical electrodes is caused by absorbed gas layers. Thus, electron tunnelling through the potential wall of the contact space preheats the anode by its kinetic energy and supports positive bridge transfer. Experiments to avoid bridge transfer by use of higher melting anode failed to be 100 per cent successful; but reduction of the work function of the cathode by oxidation diminished the kinetic energy of the tunnelling electrons, 10 references. (*Battelle Library Review*)

No. 1350. J. M. Richardson, "The Linear Theory of Fluctuations Arising From Diffusional Mechanisms: an Attempt at Theory of Contact Noise," *Bell System Technical Journal*, Vol. 29, January, 1950, pp. 117–141. 17 references. (*Battelle Library Review*)

No. 1351. A. Schliephake, "Experiments on the Influence of the Ambient Atmosphere on the Brush Contact Voltage," *Elektrotech. Z.*, Vol. 71, January 15, 1950, pp. 32–34. (In German.)

The curves showing the functional relation between brush-contact voltage and current density with a-c. have the steepest trend with low currents. This cannot be attributed solely to the negative temperature coefficient of the brush carbon. The influence of the surrounding atmosphere was therefore investigated, and curves are given for the brush-contact voltage and resistance measured with a. c., d. c. and mixed currents at various air pressures and with atmospheres of CO_2, O, NH_3, N, H, and water vapor, and on commutators as well as on copper and carbon sliprings. Except for H there is a marked difference for different gas pressures and different humidities. (*Science Abstracts*)

No. 1352. G. Silvatici, "A Very Fast, Automatic, Electro-Pneumatic, Overload Line Contactor for 3 kv. d-c., "*Ind. Ital Elettrotic.*, Vol. 3, January, 1950, pp. 9–12. (In Italian.)

It has 3 breaks ganged together and connected in series. The closing is initiated by 3 compressed air-operated pistons and completed by powerful springs which ensure both quick make and break. The locking device is controlled by a retaining electromagnet and release is obtained either by interrupting the current in its coil or by field compensation obtained with a few turns wound in opposition and carrying the load current. Arc chutes and cross-magnetic fields are provided for arc quenching. Tests with highly inductive loads showed arc durations of 0.04–0.07 sec. for currents of 80–380 amp., and with lightly inductive loads showed arc durations of 0.03-0.04 sec. for currents of 600–1200 amp. Overall size: approximately $17\frac{1}{2} \times 21 \times 30\frac{1}{2}$ in., weight: 250 lb. It is easily fitted on existing rolling stock. (*Science Abstracts*)

No. 1353. K. Töfflinger, "Commutation Disturbances in 1-Phase Traction Motors," *Elekt. Bahnen*, January, 1950, pp. 13–17. (In German.)

Comparison of the designs of motors over the past 20 yr. shows that commutation has improved although the commutating voltage is unaltered. This is due to the greater knowledge of the additional voltages from various causes. The number of armature slots has been increased, the gap and ampere turns of the interpoles increased, and saturation in the interpoles and main magnetic circuit reduced. These points have generally increased the weight and size of the motors. Some oscillographic tests of commutation are included. (*Science Abstracts*)

No. 1354. Y. Baron, "A New Oscillograph for the Study of the Action of Switchgear," *R.G.E.* (*Rev. Gen. Elect.*), Vol. 59, February, 1950, pp. 91–96. (In French.)

The replacement by the c.r.o. of an elec-

tromagnetic oscillograph is discussed, with an example of a simple 5-valve amplifier. It is shown that at make and break very high transient frequencies arise which can only be shown by a c.r.o. Both electromagnetic and electrostatic methods of deflection are considered, the former being preferred. For current measurements the resistance and inductance of the shunt and leads are critical; the use of mumetal transformers is also discussed. The instrument quoted uses a photographic paper film 30 m. long and 60–240 mm. wide; the speed can vary between 3 mm. per sec. and 3 m. per sec. Typical oscillograms on 132 and 220 kv. circuits are reproduced, with an outline circuit diagram. (*Science Abstracts*)

No. 1355. Yu. V. Butkevich, "Quenching of an Open A-C. Arc on High-Voltage Installations," *Elektrichestvo*, No. 3, March, 1950, pp. 3–9. (In Russian.)

The literature on this important subject is comparatively poor, which is all the more surprising when the enormous number of papers on arcing in circuit breakers is remembered. The author treats the self-quenching of open arcs across protective gaps and between parallel conductors without supply interruption, breaking, and rapid reclosing in 3-ph. svstems, and 1-ph. breaking and reclosing. The theory of the 3 basically different cases can be fairly simply stated by extending the criterion of stability of the d-c. arc to the a-c. case, leading to the result that the critical condition of the a-c. arc is reached when the operating voltage cannot cover the voltage drops in the system and arc at the current maximum. Arcs between horizontal and vertical parallel conductors differ in that the former may reach about 20 times the length of the conductor spacing, the latter a maximum of 5 times before being quenched. The 3 cases differ in the conditions of de-ionization, energy input (absent in the second case), and therefore in the values of the critical parameters, but the analysis is equally successful in all of them. (*Science Abstracts*)

No. 1356. P. Chapoulié, "Formula and Abac for Determining Permissible Currents in Busbars of Tubular and Other Shapes of Aluminum and its Alloys," *R.G.E.* (*Rev. Gen. Élect.*), Vol. 59, March, 1950, pp. 114–116. (In French.)

An extension of Melsom and Booth's formula for the current rating (I) of Al busbars: $I = 5KS^{0.5}p^{0.39}$, where K is a general coefficient; S the cross-section (sq. mm.); p, the perimeter (mm.). The general coefficient, K, is split into 10 parts to take into account the following: shape of the cross-section, number of bars in parallel, conductivity, state of surface (bare or painted), ambient temperature, a.c. or d.c., ventilation. Tables of values of these coefficients are given covering all cases and conditions met with in practice. The abac provides a simple solution to the formula, and the method of using it is shown by a numerical example. (*Science Abstracts*)

No. 1357. Isolde Dietrich, "Peltier Effect on Monometallic Contacts," *Z. angew. Phys.*, Vol. 2, March 1, 1950, pp. 128–131. (In German.)

It was experimentally established that the inverse effect (which is analogous to the Peltier effect) of the thermal potential at the contact cannot be observed when the contact is coated with a thin film of foreign matter. Effect of temperature of the contact on Peltier effect and Thomson effect as well as Peltier coefficient for Au and Pt were determined. Diagrams and graphs are included. (*Battelle Library Review*)

No. 1358. V. Palva, "Determination of Short-Circuit Effects in Finland's Trunk-Line Network," *Kraft o. Ljus*, Vol. 23, March, 1950, pp. 69–72. (In Swedish.)

All illustrated description is given of a reactance analyzer representing Finland's network. The results of some short-circuit determinations are briefly discussed. (*Science Abstracts*)

No. 1359 W. J. Wilson, "Modern Cellular Switchgear for 33-kv. Power Station Service," *BTH Act.*, Vol. 21, March–April, 1950, pp. 41–49.

Cellular-type switchgear installed at North Wilford and Kearsley Power Stations is described. For operation with cellular-type switchgear, type OH small oil volume circuit breakers are used. The construction of these units are discussed as well as of busbars, isolating switches, and instrument transformers. Because of complete phase isolation, the possibility of a fault is reduced to negligible proportions. (*Science Abstracts*)

No. 1360. "Type OLX Air-Insulated, Metal-Clad Switchgear," *English Elec. J.*, Vol. 11, March, 1950, pp. 82–89.

This switchgear, designed by the English Electric Co., is of simple and compact design and is available for ratings up to 800 Å., 250 mva., at 6.6 and 11 kv. An oil-immersed ring main isolator has been developed for the use with this pillar. The circuit breaker is of the cylindrical tank type, on the top plate of which is mounted the operating handle and box-like member containing the l.-v. isolating contacts. The circuit breaker is fitted with de-ion grid contacts. (*Science Abstracts*)

No. 1361. D. L. Beeman, D. E. Craig, and E. M. Hunter, "Application of Interrupter Switches to Load-Center Unit Substations," *G.E. Rev.*, Vol. 53, April, 1950, pp. 9–13.

Ideally a circuit breaker would be installed as the incoming line, interrupting device in each unit substation, but in practice interrupter switches with or without fuses are often

used. Various types of such switches, the duty required of them, and method of use are described. The importance of interlocks is stressed. (*Science Abstracts*)

No. 1362. N. M. Chernyshev, "Synchronizing System, for the Testing of High Voltage Circuit Breakers Under Artificial Conditions," *Elektrichestvo*, No. 4, April, 1950, pp. 36–42. (In Russian.)

The importance of synthetic methods of circuit-breaker testing is explained, and the details of suitable setups are discussed. One of the most important factors in the simulation of service conditions is the strict synchronization of the voltage pulse producing the simulated recovery voltage; it must have a certain lead on the current zero. All the solutions hitherto suggested, however, worked with a log up to 100 μsec. Theoretical analysis of the conditions led the author to a new design of synchronizing system, of which the principle and a special form of execution are described. Oscillograms prove the satisfactory response of the new mechanism. (*Science Abstracts*)

No. 1363. H. Ehrensperger, "Oil Stream Breakers for Reducing Short Circuit Damages and Service Disturbances on A-C. Electrified Railways," *Bull. Ass. Suisse Elect.*, Vol. 41, April 29, 1950, pp. 346–350. (In German.)

The Swiss Federal Railways have installed in the feeders to their 16 kv. $16^2/_3$ cps. overhead networks, circuit breakers with an arc-quenching device having a double opening in series. The auxiliary arc creates a preliminary oil pressure to help in quenching the main arc which occurs slightly later. Laboratory experiments and s.-c. tests on traction networks revealed the breaker's good qualities. (*Science Abstracts*)

No. 1364. G. W. Heumann, "High-Voltage, High Interrupting Capacity A-C. Motor Controllers," *G.E. Rev.*, Vol. 53, April, 1950, pp. 15–20.

The heavy duty imposed on motor controllers in modern systems is discussed with reference to N.E.M.A. class E controllers, oil-immersed and air-break contactors, and available short-circuit capacities. The basis of controller interrupting rating is outlined with an example of under-voltage protection which may be used. (*Science Abstracts*)

No. 1365. H. Mazinger, "Load Switching with Isolating Switches," *Öst Z. Elektrizitätswirtsch.*, Vol. 3, April, 1950, pp. 118–123. (In German.)

This review discusses the use of air-break isolating switches for load switching on 5–25 kv. networks. Currents that can be interrupted are: load currents at < 0.7 p.f. of 3.5 Å. at 5 kv. and 1.7 Å at 25 kv.; transformer magnetizing currents of 2.0 Å. at 5 kv. and 1.0 Å. at 25 kv. (200 and 315 kva. transformers respectively); cable charging currents corresponding to 4.0 km. of cable at 5 kv. and 0.4 km. at 25 kv. and o.h. line charging currents corresponding to 60 km. at 5 kv. and 10 km. at 25 kv. (*Science Abstracts*)

No. 1366. R. H. Nau, "Modern Type, High Power Circuit Breakers," *Proc.*, Midwest Pwr. Conf., Vol. 12, April, 1950, pp. 53–60.

A review of progress with 39 references to A.I.E.E. papers only. (*Science Abstracts*)

No. 1367. R. Bresson, "Two-Power Circuit-Breaker for Reducing Power Demand by Domestic Consumers at Network Peak Load." *R.G.E.* (*Rev. Gen. Elect.*), Vol. 59, May, 1950, pp. 201–208, (In French.)

The circuit breaker replaces the ordinary main switch in domestic installations and serves partly as a power limiting circuit breaker operated by bimetal relay and partly as a remote operated control reducing the available power at certain times. The design of the circuit breaker is described in detail, with diagrams and photographs. (*Science Abstracts*)

No. 1368. R. R. Bush, "Investigation of Lubricants for Power Circuit Breakers, *Trans., Am. Soc. Mech. Eng.*, Vol. 72, May, 1950, pp. 415–420.

The problems involved in the lubrication of power circuit breakers are discussed. Greases are preferred to oils; the desirable properties of such greases are considered and a tentative specification is presented. Some 30 different products were investigated, the tests including oxidation, friction, corrosion, oxygen bomb, and finally evaporation in certain cases. The results of the tests are discussed. It is concluded that a grease can be found which fulfills all requirements for a particular application. Life tests on the apparatus itself are always advisable as a final check for satisfactory performance. The investigation was conducted to find a suitable lubricant for sleeve-type bearings, primarily textolite. (*Science Abstracts*)

No. 1369. M. G. Diehl, "Mechanical Wear on Contacts," *Electrotechiek*, Vol. 28, May, 1950, pp. 218–221. (In Dutch.)

Both mechanical and electrical wear contribute to the loss of contact material. Mechanical wear due to friction depends on the nature of the material, the form of the contacts, their movement, and the pressure between them. A simple experiment shows the increased wear between two metals due to sliding action without lubrication. On frequently operating contacts, mechanical wear can be reduced by a rolling motion instead of a wiping movement. A calculation of sliding and rolling of contacts is given. (*Science Abstracts*)

No. 1370. H. E. Hollman, "Semiconductive Colloidal Suspensions with Nonlinear Properties," *J. App. Phys.*, Vol. 21, May, 1950, pp. 402–413.

Semiconductive particles in a colloidal suspension, when subjected to an electric polarizing field, form semiconductive chains. Once the suspension is polarized, its conductivity increases with increasing fields, because the forces of electrostatic attraction press the individual particles together, thus strengthening the transition contacts along the chains. Both effects result in an over-all electric nonlinearity that is the subject of extensive investigation. The nonlinear characteristics of such colloidal resistors are oscillographed and described in relation to the polarizing field strength by means of simple formulae, based on field coefficients of the first and second order. In addition to a true rectification, resulting from the curved characteristics, a "pseudo-rectification" occurs which corresponds to an average pre-polarization by stronger alternating fields. The alternating forces of electrostatic attraction assure an h.-f. response, so that nonlinear Lissajous figures and harmonics, up to r.f., are produced. (*Science Abstracts*)

No. 1371. H. Kalpers, "Bimetallic Contacts," *Metallforschung*, Vol. 4, May, 1950, pp. 193–195. (In German.)

The above consists of base metals plated with nobler metals by mechanical means (as rolling) at elevated temperatures. Different types of bimetals, the effect of rolling on their hardness, and their economic and technical advantages are discussed, as well as special problems such as bending, embossing, drawing, and riveting. (*Battelle Library Review*)

No. 1372. B. Warsinski, "The Standardization of Open indoor Type Switchgear, Series 10 to 30," *Elektrotech. Zeitschr.*, Vol. 71, May, 1950, pp. 239–241. (In German).

Further suggestions are made regarding universal standards for cubicle-type switchgear up to 30 kv. Measurements for phase spacing, cell height, and depth are given, together with the space required for cable isolators and access passages; these sizes depend on voltage and interrupting capacity, but not on current. Since the switches themselves appear incapable of standardization, it is recommended to use connections of rectangular section throughout in order to render interchange easier. Further work is required on the method of operation, i.e., pressure and pipe size for compressed air mechanism, and torque and angle of rotation for lever operation. (*Science Abstracts*)

No. 1373. W. Laig-Hörstebrock, "The Contact Force in Opening Low Voltage, Electrical Switchgear," *Elektrotechnik*, Vol. 14, June, 1950, pp. 226–228. (In German.)

The relations between operating forces and masses of l.-v. circuit breakers are investigated. Graphical solutions of differential equations are given in curves showing the relations between opening force, reduced masses, contact pressure, switching time, and length of travel. The correct distribution of the masses is of special importance. An increase of the masses of the contact arm, the toggle, and the switch lever increases the contact pressure without unduly lengthening the switching time. This latter is much more influenced by the free-release mechanism. (*Science Abstracts*)

No. 1374. N. N. Linnichenko, "Standardization of Recovery Voltage," *Elektrichestvo*, No. 6, June, 1950, pp. 53–57. (In Russian.)

The author discusses basic research in this field in Britain, the U. S. A., and Sweden, before presenting his own analysis of the operation of circuit breakers. This is given in a convenient tabulated form showing the conditions for successful operation, with equivalent circuits enabling the recovery voltage to be determined for circuit breakers of any rating. A diagram given shows the characteristics of all possible recovery voltages, including amplitude and frequency of the recovery voltage, and the corresponding powers on short circuit. (*Science Abstracts*)

No. 1375. L. H. Fisher, "Mechanism of the Spark Breakdown," *Elec. Eng.*, Vol. 69, July, 1950, pp. 613–619.

Experimental data on d-c. spark discharge in air in a uniform field are reviewed, and criteria for establishing the reliability of sparking potential measurements are suggested. Implications of recent measurements of the formative time lag of spark breakdown are discussed in detail. 34 references. (*Battelle Library Review*)

No. 1376. J. A. Fitzpatrick, "The Protection of Busbars and Switchgear," *G.E.C.J.*, Vol. 17, July, 1950, pp. 141–154.

Modern busbar protection schemes are discussed, and recommendations for various types of installation are made. Two loadbias schemes are described in detail. By the use of current transformers together with a summation transformer, a bias coil is energized in proportion to the sum of the currents through the various switchboard units, while the operating coil current is as usual proportional to their difference. By means of a suitable setting of the bias, it is possible to prevent operation due to "spill" or spurious currents induced during through-faults, and thus avoid the need for close matching of the current transformers. The relay itself is polarized; its setting is controlled by a small permanent magnet which also provides for positive operation. Schematic diagrams for phase-to-earth protection only or together

with phase-to-phase protection are given, and testing facilities and back-up protection are discussed. Brief reference is made to frame-earth fault protection. (*Science Abstracts*)

No. 1377. H. Jacobs and J. Martin, "The Role of Cathode Temperature in the Glow Discharge," *J. App. Phys.*, Vol. 21, July, 1950, pp. 681–685.

Experiments were conducted to study the role of the temperature of oxide-coated cathodes in the glow discharge of argon, neon, and mixtures of neon and argon, and mercury vapor and argon. It was found that for tubes without mercury present, in the region of cathode temperature between 300 K. and 750 K: (1) The sparking potential falls with increasing cathode temperature. (2) The regulation voltage rises with increasing cathode temperature. For argon and mercury vapor, the regulation voltage falls with increasing cathode temperature. The action here is attributed to metastable states of inert gas. (3) The current density in the glow discharge decreases with increasing cathode temperature. This, too, is attributed to the action of metastable states. (4) The minimum sustaining current in a glow discharge is found to decrease with increasing cathode temperature and rise with increasing pressure. (5) The current density in the glow discharge varies roughly linearly with pressure, or at a slightly higher rate, in contrast with the space-charge derivations which claim a variation with pressure squared. (6) The regulation voltage tends to rise very slightly at lower pressures. (*Battelle Library Review*)

No. 1378. S. Rambaut, "Calculation of the Voltage Caused by the Rapid or Gradual Current Interruption of the Components of a Network, "*R.G.E. Rev. Gen. Élect.*, Vol. 59, July, 1950, pp. 297–309. (In French.)

An analytical and oscillographic investigation is presented of the amplitudes and wave shapes of restriking voltages caused by the disconnection of a transformer in a system comprising o.h. lines and cables. In the case of rapid current interruption, the resulting voltages are shown to be readily calculable from a knowledge of the surge impedances of the system components involved. The resulting free oscillations are determined. In the case of an interruption with ensuing arcing, the term "forced current" is introduced which enables a relation to be established between the variation of the rupture current with time and the resulting voltages. (*Science Abstracts*)

No. 1379. I. S. Stekol'nikov, "Investigation of Initial Stages of Discharge Across Very Small Electrode Gaps," *Izvestiya Akademii Nauk S.S.S.R.*, (Bulletin of the Academy of Sciences of the USSR), Section of Technical Sciences, July, 1950, 985–994. (In Russian.)

The above was experimentally investigated in air and in oil. Oscillograph records indicate that the beginning of discharge may be caused by conducting filaments (bridges) in the presence of conditions for "bridge" formation (contamination of the air or liquid between the electrodes). Effect of varying the voltage was studied. Experimental data are charted and tabulated. (*Battelle Library Review*)

No. 1380. R. Holm, "Electrical Contacts in Measuring Instruments," *Arch. Tech. Messen.*, August, 1950, pp. T95–T96. (In German.)

The effects of various factors on electrical conductivity and resistance of mono- and bimetallic contacts are described. Data for a series of bimetal combinations are tabulated and graphed. 12 references. (*Battelle Library Review*)

No. 1381. Eugen Kappler, "Variation of Contact Resistance with Contact Pressure," *Z. angew. Phys.*, Vol. 2, August 15, 1950, pp. 313–319. (In German.)

Effects of various factors on the above variation for "crossed-wire" contacts of precious metals and their alloys were investigated. These included effects of applied load resulting in plastic deformation, of monomolecular and thicker foreign films, of surface condition, elastic after-effect and hysteresis. The review includes diagrams, graphs, tables, and photomicrographs. (*Battelle Library Review*)

No. 1382. F. E. Haworth, "Experiments on the Initiation of Electric Arcs," *Phys. Rev.*, Vol. 80, No. 2, October 15, 1950, pp. 223–226.

Arcs have been struck in vacuum between widely spaced electrodes by positive ion charging of an insulating film on the cathode, at separations from 0.5 to 5 mm. and at potentials from 34 to 2000 v. The arc current must be allowed to grow initially at the rate of at least 10^6 amp. per sec. for the arc to occur. These experiments constitute a test of one of the fundamental steps postulated to account for the initiation of an arc between electrodes coming together at low voltages. (*Battelle Library Review*)

No. 1383. W. B. Kouwenhoven and W. T. Sackett, "The Spreading Resistance of Contacts," *Welding Journal*, Vol. 29, October, 1950, pp. 512s–520s.

The authors present a study of electrical resistance of contacts resulting from a constricting effect of the contact subareas which produces nonuniform current flows in them. Application of the information to resistance welding is discussed. (*Battelle Library Review*)

No. 1384. G. G. MacFarlane, "A Theory of Contact Noise in Semi-Conductors," *Proc., Phys. Soc.*, Vol. 63, Sec. B, October 1, 1950, pp. 807–814.

The above theory is described in which low-frequency noise is attributed to random movement of adsorbed ions on the surface of a semiconductor from which an electron current is being drawn. Emission of electrons is assumed to take place only at localized patches on the surfaces, and the adsorbed ions are assumed to give rise to a Schittky barrier layer, in which the potential maximum is linearly related to the concentration of ions. Diffusion of ions over the surface causes random fluctuations in the concentration of ions in a patch, which results in random fluctuations in the height of potential barrier and emission current. 12 references. (*Battelle Library Review*)

No. 1385. William Dubilier, "Latest Developments in Cold Pressure Welding Widen Its Field of Application," *Materials & Methods*, Vol. 32, No. 5, November, 1950, pp. 78–80.

The review contains one section on the application of cold pressure welding in the fabrication of electrical contacts.

No. 1386. H. K. Henisch and J. Ewels, "A Study of Electrical Forming Phenomena at Selenium Contacts," *Proc. Phys., Soc.*, Vol. 63, Sec. B, November 1, 1950, pp. 861–876.

When a reverse voltage is applied to a rectifying contact between a selenium surface and a metal electrode, the resulting current is not constant but is generally a function of time. An increase of current with time is called positive creep, and a decrease at constant voltage is referred to as negative creep. The review describes experiments at various temperatures on Se specimens of different impurity content. Dependence of above phenomena on electrical and thermal history and on nature of the counterelectrode was investigated. It is shown that two opposing "creep" mechanisms are, in general, active simultaneously: one due to power dissipation within the barrier layer, and the other to structural changes which take place under influence of the applied field. A theory of "current creep" is proposed on the basis of the observations. (*Battelle Library Review*)

No. 1387. J. G. Trump, R. W. Cloud, J. G. Mann, and E. P. Hanson, "Influence of Electrodes on D-C. Breakdown in Gases at High Pressure," *Elec. Engg.*, Vol. 69, No. 11, November, 1950, pp. 961–964.

Direct-current breakdown measurements up to 900 kv. between metallic electrodes producing a uniform field and immersed in compressed gases show markedly higher values for stainless steel after conditioning by sparkover than for aluminum electrode systems. Sparkover voltage measurements were made in air, in carbon dioxide, in equal mixtures of carbon dioxide and nitrogen, and in nitrogen. The relative insulating strength of these gases diminished in the order listed, and a similar electrode dependence on higher pressure was shown in all of them.

No. 1388. J. P. Molnar, "Conduction Phenomena in Gases," *Elec. Eng.*, Vol. 69, No. 12, December, 1950, pp. 1071–1076.

A review is made of the processes involved in the breakdown of a gas, in which a body of neutral gas particles that acts as an insulator is changed to one containing a great many charged particles that acts as a conductor. Factors which must be taken into account in discussing these mechanisms include the gas pressure and the nature of the applied field.

No. 1389. G. C. Akerlof and E. Wills, "A Bibliography of Chemical Reactions in Electric Discharges," *Mellon Institute of Industrial Research*, 240 pp. (1950).

Reference with abstracts are listed alphabetically by author, It includes patent list and author and subject indexes. (*Battelle Library Review*)

No. 1390. P. Baltensperger, "Overvoltages Due to the Interruption of Small Inductive Currents," *C.I.G.R.E.*, Paper 116, 26 pp. (1950).

A discussion of the physical phenomena resulting from the interruption of small inductive currents, the terms of restriking and recovery voltage being defined. It is shown that the maximum overvoltages which may be caused by the interruption of such currents have to be determined by statistical means; typical test results obtained on gas-blast breakers are examined. The problems investigated include: the effect on the overvoltages produced of a parallel resistance to the arcing chamber; the effect of overvoltage protection devices; the disconnection of an unloaded transformer; and the effect on the operation of a gas blast breaker of an auxiliary spark gap subjected to slight blast. The operation of gas-blast breakers and of breakers with a small oil volume is compared. (*Science Abstracts*)

No. 1391. R. Belot, "Inherent Frequencies of the Transmission Networks of the Unions de Centrales Electriques du Hainaut," *C.I.G.R.E.*, Paper 317, 24 pp. (1950).

The results are given of a series of measurements on the restriking voltage of a large number of circuit breakers installed on the networks in the province of Hainaut (Belgium). The networks are interconnected between themselves by an overhead network at 70 kv. The measurements were carried out by c.r.o. on 35 links differing in nature: underground cables, overhead lines, transformers; in voltage: from 6 to 30 kv.; and

in their circuit breakers. Some tests were carried out on the 70-kv. network with small oil-volume circuit breakers. The results give a general indication of the order or the frequencies which these circuit breakers have to withstand. (*Science Abstracts*)

No. 1392. A. C. Boisseau, B. W. Wyman, and W. F. Skeats, "Insulator Flashover Deionization Times as a Factor in Applying High Speed Reclosing Circuit Breakers," *C.I.G.R.E.*, Paper 135, 12 pp. (1950).

Describes a high power laboratory investigation of the time required for an insulator string to recover its dielectric strength sufficiently to permit reenergization of the circuit after subjection to a power arc. Tests were made by supplying the desired current for the proper duration in the initial flashover from one source while reclosure was made from a second source, so that complete control could be exercised over the interval between clearing and reclosure. Tests were made at currents up to 25,000 amp. and at voltages up to 132 kv. corresponding to the leg of a 230-kv. system. Tests were also made on the effect of follow currents such as might be permitted by the shunting resistors used in some circuit breakers or by induced effects from neighboring conductors. Also data were obtained on the duration of induced effects arising from adjacent transmission lines or from the other two conductors of a 3-phase line when one conductor has been disconnected. It is shown that de-energized times of the order of 0.20 sec. are satisfactory except at the highest values of short-circuit power, that the effect of resistance current depends upon circuit voltage, and that the effect of neighboring transmission lines is unimportant but that of the other two conductors of the same line is possibly so serious as to render single-pole reclosing feasible at 230 kv. (*Science Abstracts*)

No. 1393. B. F. Borgel, "Power Station Centralized Control. Design and Operation of Central Control Rooms," *Trans., A.I.E.E.*, Vol. 69, Part 1, pp. 598–603(1950).

The layout and design of central control rooms are discussed on the basis of the experience in the operation of the Warren station (2×30 mv.) of the Pennsylvania Electric Co. placed in service in August, 1948. Sudden shedding of nearly the whole load due to electric storms followed by rapid pickup after reclosing and sudden demands in urban areas are characteristics of the region served. Centralization of the controls has reduced the time taken for resynchronization and return to full load after complete shedding from 11 min. to < 5 min. with a record performance of 90 sec. The panels were designed to present all operations in their correct sequence, different types of handles being used to distinguish various types of control, and full use has been made of vertical segregation to ensure ease of supervision and operation. Suggested changes in design include: transfer of recorders from central control panel to other positions to clear valuable space for indicators, and full use of miniature-type instruments eventually leading to adoption of desk-type panel. Diagrams given show a schematic section through the plant and the general layout of the control room and of individual panels. (*Science Abstracts*)

No. 1394. C. Bresson, "Particular Stresses on Circuit Breakers in Networks," *C.I.G.R.E.*, Paper 104, 17 pp. (1950).

This paper discusses circuit-breaker duties other than opening or closing on full load or s.c., e.g., breaking the magnetizing current of a transformer. Results of tests on transformers illustrate surges and other phenomena arising in various cases such as when the neutral is earthed or isolated. There are brief references to opening lines on no load, and operation of a breaker connecting two networks which may be in opposition. (*Science Abstracts*)

No. 1395. Cabanes, Raimbault, Revol, Dietsch, Devilaine, Lanoe, Regent, and Roche, "Practical Results with New Equipment for Locating Transient Faults and Some Results of Slow Reclosure and Automatic Tie Line Reconnection," *C.I.G.R.E.*, Paper 341, 26 pp. (1950).

Gives an analysis of operating and fault conditions for the whole of the French power systems during 1947 and 1948, tabulating causes of faults, types, and whether transient or not. Fault location is dealt with in some detail, and the results obtained with slow reclosing (duration of cycle > 1.5 sec.) are recorded for several important lines with a large number of interconnections. Judicious use of rapid single-pole reclosing or slow automatic reclosing on 1 or 3 phase is advocated as a means of reducing serious faults and their effects and improving restoration of supply. (*Science Abstracts*)

No. 1396. Chambrillon, "A Study of Controlled Trip Indirect Tests on Gas Blast and Oil Circuit Breakers," *C.I.G.R.E.*, Paper 140, 17 pp. (1950).

The results of tests on various types of circuit breakers in order to verify rupturing capacity, using an indirect method, show that this method is valid, in particular, for controlled trip gas-blast and oil circuit breakers. The importance of the various factors occurring during rupture is underlined. These factors may be modified as a result of an indirect method of testing. The tests were concentrated on the determination of the value of post arc resistance after rupture in the various types of circuit breakers and its influence in indirect tests. (*Science Abstracts*)

No. 1397. J. S. Cliff, "Testing Station Restriking Voltage Characteristics and Circuit

Breaker Proving," *C.I.G.R.E.*, Paper 109, 18 pp. (1950).

In order to assign a breaking capacity rating to some forms of circuit breaker, it is necessary to consider the restriking voltage severity of the test circuit. The results are described of an investigation into the restriking voltage characteristics of the testing stations of the Association of short Circuit Testing Authorities (A.S.T.A.), made to collect data which can be related to system conditions in order to reach a standard of restriking voltage severity for proving circuit breakers. To deal with the multifrequency wave forms which are obtained from some of the circuits, an empirical method of evaluating the equivalent severity for such waves was evolved, and details of the method are given. The characteristics of the test plants are given for the circuits corresponding to standard voltage and mva. ratings, and brief recommendations are made for the rating and testing of circuit breakers. A list of definitions used is included. (*Science Abstracts*)

No. 1398. C. H. Flurscheim, K. J. Saulez, and R. W. Sillars, "Resistance Shunts for High Voltage Circuit Breakers," *C.I.G.R.E.*, Paper 103, 16 pp. (1950).

Discusses the applications of linear and non-linear resistance shunts to oil and air blast circuit breakers. It summarizes the requirements for reduction in rate of rise of restriking voltage and in restriking voltage peak, for distribution of voltage across multi-break circuit breakers, for suppression of overvoltage when switching small inductive currents, and for prevention of restriking when switching capacitance currents. The limitations and advantages of linear and non-linear resistors are assessed in relation to these duties, having regard to the problems of voltage transfer from one gap to another, and of final interruption of the shunt current. (*Science Abstracts*)

No. 1399. C. H. Flurscheim, K. L. Saulez, and R. W. Sillars, Supplement to Paper No. 103, "Resistance Shunts for High Voltage Circuit Breakers," *C.I.G.R.E.*, Paper 103 bis., 2 pp., (1950). (*Science Abstracts*)

No. 1400. A. A. Johnson and H. A. Thompson, "Bus Transfer Tests on 2300-v. Station Auxiliary System," *Trans., A.I.E.E.*, Vol. 69, Part I, pp. 386–394. (1950).

The Phillips Plant of the Duquesne Light Company has one 75-mva. turbo-generator. Auxiliaries are connected to two buses supplied during start-up from a 75-mva. station service transformer. After the main unit is synchronized to the system, one of the auxiliary buses is transferred by open transition to an auxiliary 7500-kva. generator on the same shaft as the main unit. Tests have been carried out to determine the optimum time interval of such transfer, the results of which are outlined, together with oscillographic records. The authors conclude that for this system the optimum time interval is about 50 cycles. Abnormally high motor currents flow for transfer time intervals of 10 to 15 cycles. Coal pulverizers operated satisfactorily for all transfer intervals up to 150 cycles, and there was no noticeable effect on the normal operation of station boilers up to this limit. (*Science Abstracts*)

No. 1401. E. Juillard, "Report of the Activities of the International Study Committee No. 3 on Circuit Breakers," *C.I.G.R.E.*, Paper 147, 22 pp. (1950). (*Science Abstracts*)

No. 1402. H. L. Knudsen, "Solution of a System of Linear Equations with a Slightly Unsymmetrical Matrix by Using a Network Analyzer," *Trans., Danish Acad. Tech. Sci.*, No. 2, 16 pp. (1950).

A related symmetrical matrix is derived and set up on an analyzer, and an iteration process used to obtain the solution. The convergence of this process is discussed. (*Science Abstracts*)

No. 1403. M. Laborde and Y. Baron, "Recent Developments in High Voltage, Circuit-Breaker Testing in France," *C.I.G.R.E.*, Paper 139, 37 pp. (1950).

A survey describing research work in progress and the Fontenay testing station. (*Science Abstracts*)

No. 1404. W. M. Leeds and R. E. Friedrich, "High Voltage Oil Circuit Breakers for 5,000,000 to 10,000,000 kva. Interrupting Capacity," *Trans., A.I.E.E.*, Vol. 69, Part I, pp. 70–78, (1950).

Lists a number of h.-v. high-rupturing capacity circuit breakers installed at various locations and classifies 3 main types, air blast, low oil content, and steel tank, the last being most favored in U. S. A. Design features of a heavy-duty, multiflow de-ion grid type are outlined, the more conventional features being described in an earlier paper (Abstr. 1986 (1945)). Operating speeds and breaking capacities are illustrated by high power laboratory test results with notes on such features as rapid reclosing. (*Science Abstracts*)

No. 1405. H. A. H. Nijland, "Some Principles Leading to the Construction of Metal-Clad Switchgear," *C.I.G.R.E.*, Paper 131, 7 pp. (1950).

The article recalls the difficulties of adopting metal-clad construction for use with voltages of about 30 kv. and upwards and outlines a method of overcoming them by considering insulation problems and making and breaking problems separately, as was possible in "pillar type" design. The design of a commercial circuit-breaker installation for 150 kv. on this principle is described. (*Science Abstracts*)

No. 1406. C. E. Parks and W. R. Brownlee, "Consideration of Requirements and Limitations of Relaying and High Speed Reclosing on Long and Heavily Loaded Transmission Lines," *Trans., A.I.E.E.*, Vol. 69, Part I, pp. 103–109, (1950).

This gives economics now desirable in transmission of power call for protection allowing higher normal and emergency loading of lines nearly up to the limit of what they can withstand. Relaying requirements for a hypothetical system representative of networks occurring in practice are discussed for various fault and reclosing conditions, with notes on selection of the type of protection most suitable. (*Science Abstracts*)

No. 1407. M. Perolini, "Circuit Breakers for Very High Tie Lines," *C.I.G.R.E.*, Paper 130, 19 pp. (1950).

Deals with features required in the operation of circuit breakers of large breaking capacity on voltages of the order of 250 kv. The breakers concerned are of the air-blast type with several breaks in series. The distribution of voltage between the breaks is considered. Opening times, overvoltages, breaking of small inductive currents, automatic reclosure, and operation at overvoltage are discussed. It is concluded that air-blast, multibreak operation with judicious use of the resistance switching principle will meet all requirements. (*Science Abstracts*)

No. 1408. R. Sinave, "Flameproof Electrical Plant," *A.C.E.C.*, No. 2, pp. 37–46, (1950). (In French.)

Describes the latest A.C.E.C. power and lighting flameproof control boxes, each with busbar chamber above, and protection gear and control panel below. Some can be linked laterally into a group. Others are on skids. Internal parts are readily accessible and standard with ordinary practice. Illustrations show outside and inside views with wiring diagrams of the 2-speed reversible motors, cable entries, remote control pushes, limit switches, and meters. All comply fully with British and continental mining regulations. (*Science Abstracts*)

No. 1409. H. R. Strickler. "The Voltage Distribution in Circuit Breakers with Two Break Points in Series, in the Open State and on Closing," *C.I.G.R.E.*, Paper 122, 17 pp. (1950).

The author discusses conditions arising in a single-pole, 400-kv, low oil content circuit breaker having 2 breaks in series. Means for improving the voltage distribution and their relative merits are described with reference to effects of discharge current, flashover, and breakdown when closing. (*Science Abstracts*)

No. 1410. B. Thorén, "Synthetic Short Circuit Testing of Circuit Breakers," *C.I.G.R.E.*, Paper 121, 18 pp. (1950).

The problem of synthetic testing is studied from a theoretical point of view. General conditions are formulated for the equivalence between direct and synthetic tests, and it is shown that it is theoretically impossible to obtain full equivalence between a synthetic and a direct test, if a test installation is to be used which produces a short-circuit power lower than the breaking capacity of the breaker to be tested. Some divergence from the conditions in a direct test must, therefore, be tolerated, if synthetic testing shall be possible. Different synthetic methods are discussed. The ability of the current-producing circuit to reproduce the energy conditions in the arc of the breaker is examined. Examples are given of the energy conditions for different types of circuit breakers. It is shown that the a-c. generator circuit is the most favorable type, and that a ratio of $1/3$ between the generator capacity and the breaking capacity is acceptable, at least for circuit breakers with voltage ratings of 30 kv. and above. At lower voltage ratings the acceptable ratio is smaller. The voltage-producing circuit is examined with regard to its ability to produce correct transient recovery voltage also in the case of residual current in the test breaker. The transformer circuit is shown to give correct results only if the residual current is very small. This was verified by tests. Even the common surge generator circuit is shown to give correct results only if the residual current is very small, but it has been improved to give correct results even in the case of moderate values of the residual current. (*Science Abstracts*)

No. 1411. H. Thommen, "The Characteristic Properties of Simplified Air-Blast Circuit Breakers for Service Voltages up to 380 KV.," *C.I.G.R.E.*, Paper 113, 19 pp. (1950).

Simplification in the construction of h.-v. air-blast circuit-breaker construction being desirable, extensive tests were made with the object of eliminating the ancillary isolator, perfecting the principle of multiple breaks across which the voltage is equally divided. The use of compressed air as a dielectric during contact separation was studied, and the testing of mechanisms in locations and under working conditions of more than usual severity was considered. The result was the creation of a range of air-blast circuit breakers for nominal voltages up to 380 kv., simple in construction and withstanding the most severe service conditions (especially phase opposition). Tests made on the network of Electricité de France showed the satisfactory behavior of this gear in service. (*Science Abstracts*)

No. 1412. H. C. Basak and L. H. Seshu, "Automatic Switching of a Large Number of Circuits to a Common Circuit," *Electrotechnics*, No. 22, March, 1950, pp. 80–87.

An arrangement, based on the switching principles of automatic telephony, has been devised, by which it is possible to connect automatically a large number of circuits to a common circuit in a selective manner. The decade system of numbering has been adopted. For selection a uniselector is positioned by means of a set of plunger-type keys, but without any dialing impulses. Ten keys are arranged in a row, the number of rows depending on the number of digits to be "dialed." Each individual circuit can be switched through by bringing the uniselector to a given unique position. The arrangement has been described for one common circuit and a hundred individual circuits. (*Science Abstracts*)

No. 1413. S. C. Killian, "High Voltage Circuit Interruption by Means of Air Switches with Gas-Blast Device," *Proc.*, Midwest Pwr. Conf., Vol. 12, April, 1950, pp. 98–100.

Describes a switch developed for dealing with small power loads, e.g., charging current of lines or exciting current of transformers. It is based on a standard horn-gap air switch with addition of an air-blast device fed through valves from compressed air storage tanks (110 lbs. per sq. in.). The blast tube is of porcelain and to avoid flashover the orifice is not close to the arc as in usual practice, but several feet away. The design problems arising are briefly discussed with some particulars of tests made. (*Science Abstracts*)

No. 1414. A. Amstutz and H. Meyer, "Field Tests on High Voltage Air-Blast Circuit Breakers," *Brown Boveri Rev.*, Vol. 37, April–May, 1950, pp. 136–143.

This describes short-circuit tests made at Fontenay using the whole available power of the French 220-kv. network to prove two variants of a new type of circuit breaker and give comparative results for an earlier design. Particulars of the various tests are given with a table of results recording no overvoltages when disconnecting unloaded lines, breaking times of the order of 60 msec. and 3-phase interrupted power of 2000–3600 mva. The latter was at 398 kv. when interrupting phase to phase s.c. with one unit. (*Science Abstracts*)

No. 1415. H. Thommen, "Modernized Indoor, Air-Blast, High Speed Circuit Breakers," *Brown Boveri Rev.*, Vol. 37, April–May, 1950, pp. 143–153.

The author outlines characteristics, design, and performance of an extension of a range of indoor, air-blast circuit breakers made in view of the success achieved by switchgear of this type in service. New ratings extend to 60 kv., 1500 a., 1500 mva. Advantages claimed include short break time, very slight contact erosion, and excellent performance in high-speed reclosure, also safety from explosion and fire. (*Science Abstracts*)

No. 1416. W. Luchsinger, "The Effect of High Speed, Circuit Reclosure on Asynchronous Motor Performance, *Brown Boveri Rev.*, Vol. 37, April–May, 1950, pp. 154–158.

An investigation into the conditions when a load center, consisting chiefly of induction motors, is supplied through a radial feeder, a reclosing circuit breaker being installed at the supply end. The performance is explained by means of oscillograms, and it is concluded that the motors will usually recover speed without difficulty. An unfavorable case is the fully loaded slip-ring motor having a braking torque independent of the speed. This case is discussed in detail and limiting values given for the m. and i. of the driven machine. (*Science Abstracts*)

No. 1417. H. Meyer, "The Fundamental Problems of High-Voltage Circuit Breakers," *Brown Boveri Rev.*, Vol. 37, April–May, 1950, pp. 108–122.

Problems of an electrical nature which are of importance in the design of h.-v. switchgear are discussed. These include short-circuit interruption, restriking voltage, circuit breaking with interconnected systems 180° out of phase, high-speed reclosing, verification of breaking capacity, switching of low inductive currents, isolation of unloaded lines, and circuit-breaker resistors. It is concluded that the air-blast breaker meets all requirements of supply systems. (*Science Abstracts*)

No. 1418. S. Gerszonowicz, "Effect of the Dimensions of the Salient Poles of the Alternator on the Choice of Rupturing-Capacity of Circuit-Breakers for 3-ph. Networks," *Bol. Fac. Ing. Montevideo*, Vol. 4, May, 1950, pp. 23–35. (In Spanish.)

Present definitions of rupturing-capacity are discussed and considered inadequate insofar as they do not take recovery voltage into account. Three parameters are defined, dependent on the design of the alternator (ratios between reactances), and a series of diagrams for various values of these parameters show the zones within which the several faults, 3-ph. between 2 phases, and 1-ph. to earth, become the most serious. (*Science Abstracts*)

No. 1419. J. Blase, "The Influence of the Restriking Voltage on Circuit Breaker Performance," *Bull. Sci. Ass. Ing. Elect. Montefiore*, Vol. 63, June, 1950, pp. 221–238. (In French).

The mechanism of extinction of an a-c. arc is discussed, as is the influence of features such as arc voltage, residual conductance, deionization, resistance shunting, post arc current, on the process of circuit breaking. The difficulty of assessing the natural frequency of complicated networks and the relation of such figures to those for test stations are mentioned. The performances of the main types

of circuit breakers are outlined with interesting notes on the different techniques used for the air-blast type in Europe and in America. The chief emphasis is laid on explaining why some types of circuit breaker are insensitive to the natural frequency of the circuit and how to make the others less sensitive. (*Science Abstracts*)

No. 1420. B. Pavlovsky, "Combined Application of Automatic Reclosing, a New Protective Relay, and an Arc Suppression Coil," *Elektrotech. Obz.*, Vol. 39, July, 1950, pp. 310–318. (In Czech.)

A detailed account is given of experiments carried out in a 22-kv. distribution system—fed from a 110-kv. transmission system and a small water-power station generating at 6 kv.—on the combined use of a new type of line protection relay, 22-kv. circuit breakers with automatic reclosing and arc-suppression coils. The new protective relay consists of five elements and has a stepped characteristic. It is concluded that the performance of the new relay represents an improvement on the types used so far, and that it is of advantage to install both automatic reclosing switches and arc-suppression coils in the 22-kv. system described. Numerous graphs, oscillograms, and circuit diagrams are shown. (*Science Abstracts*)

No. 1421. E. Kappler, E. Rüchardt, and R. Schläfer, "Contact Resistance as a Function of the Contact Load," *Z. angew. Phys.*, Vol. 2, August, 1950, pp. 313–319. (In German.)

The contact resistance between crossed cylindrical wires was measured by a voltmeter and ammeter method for Ag, Au, Pt, AgPt 70/30, AgPt 90/10, and Ni. The load was applied by an electromagnet with the aid of a machine which permitted the load to be weighed. The theory of the ideal case leads to a variation of resistance with $P^{-1/3}$ for the elastic, and with $P^{-1/2}$ for the plastic region. Departures from the theory are caused by imperfections of the surface and the adsorbed layer, which adds a resistance proportional to the contact area. The effect of several cleaning and polishing methods was investigated. The results obtained with intermittent but regularly increasing load agree well with the theory until the plastic deformation is so great that the approximation (contact radius $\ll$ wire radius) breaks down. Subsequent measurements with falling load show hysteresis which depends on the surface finish; welding sometimes occurs. An oil film protects the surface. (*Science Abstracts*)

No. 1422. H. J. Lurk, "A Voltage-Independent, Time Switch Arrangement for Communication Equipment," *Frequenz.*, Vol. 4, August, 1950, pp. 196–203. (In German.)

Circuits are described composed of relays, resistors, and capacitors, which can be arranged to give a series of pulses with a fixed time interval. It is shown how variations of pulse rate with supply voltage fluctuations can be kept to a minimum by the use of a differential circuit arrangement and by a suitable choice of component values. (*Science Abstracts*)

No. 1423. J. Nevrala, "The Loading of Aluminum and Copper Busbars," *Elektrotech. Obz.*, Vol. 39, Nos. 17–18, September, 1950, pp. 393–401. (In Czech.)

A formula and nomogram for the loading of busbars in power developed by P. Chapoulie is amplified, and the various coefficients characterizing various designs of busbars are examined in detail. On the basis of these, the standards for busbar loading of Czechoslovakia, France, and the U.S.S.R. are compared, and it is concluded that the Czechoslovak standards are too rigorous and that it would be economical and safe to adopt a higher loading. (*Science Abstracts*)

No. 1424. R. Mayeur, "Commutation with Two-Layer Brushes in D-C. Machines," *R.G.E.*, (Rev. Gen. Elect.), Vol. 59, September, 1950, pp. 400–405. (In French.)

In a previous article (Abstr. 1263 (1925)), the relation between the current in the short-circuited coil and the amount of commutation segment in contact with the brush was developed by means of curves for a homogeneous brush. The method is explained again and extended to brushes composed of two layers of different grades, stuck together. It is concluded that in certain conditions the current can be increased by 13 per cent before sparking occurs. (*Science Abstracts*)

No. 1425. R. Edler, "A New Versatile Multi-Disk Switch," *Elektrotech. u. Maschinenbau.*, Vol. 67, September, 1950, pp. 275–280. (In German.)

The article describes a flush-mounting switch consisting of handle with indicating lamps, position control mechanism, and up to 16 four-contact discs staggered 45 deg.; the unit is held together by through bolts. The rotating contact is an 8-sided star punching any of whose points may be broken off to give different contact arrangements. The switch has performed satisfactorily during repeated operation on a 380-v., 60-a., 0.6 p.f. circuit. The author then describes two applications, a charging switch for a battery floating across a supply main which splits it into three parts, and a star-delta starting switch. A method to determine rapidly the most suitable switch connections is explained in detail. (*Science Abstracts*)

No. 1426. R. Proia, "The Calibration at Working Current of the Ultra-High-Speed Circuit Breakers Installed in 3000 v., D-C. Substations," *Ing. Ferroviaria*, Vol. 5, September, 1950, pp. 571–575. (In Italian.)

A brief description is given of the three models of circuit breaker used by the Italian State Railways and of the means of protection used in their substations. The calibration of breakers and overload relays must be carried out at full working current, and equipment was built for this purpose. It consists of 20 Fe, Cd, Ni, accumulator cells connected in parallel and is capable of delivering 2000 a. continuously for 45 min. Simple rheostats are used for current adjustments. Accumulators, charging equipment, and instruments are built into an easily transportable unit. The switchgear of 40 substations has already been checked and standardized. (*Science Abstracts*)

No. 1427. P. O. Bobo, "Handling Power System Problems on an A-C. Network Calculator," *Elec. Engg.*, Vol. 69, October, 1950, pp. 867–869.

A note of certain improvements in technique, including developments in the recording table itself. By the use of generator reactance behind the generator terminals, approximate self-regulation of board generator output has been achieved in load flow studies. (*Science Abstracts*)

No. 1428. C. J. O. Garrard, "11-kv. Distribution Switchgear," *G.E.C.J.*, Vol. 17, October, 1950, pp. 193–198.

A forecast is made of the way in which networks may develop having regard to the B.E.A. decision to use a 275-kv. grid. Theoretical and actual short-circuit levels for the 132-kv. grid suggest that 3600 mva. is the maximum economic rating for 132-kv. circuit breakers, and short-circuit level for the 275-kv. grid may be of the order of 7500 mva. Based on this and bearing in mind supply areas represented by existing divisions of the B.E.A. and that new generating plants will usually feed the higher voltage networks, it is suggested that, for economy and convenience, the 150-mva. range is the most suitable for 11-kv. gear. The rating of associated transformers is then discussed and particulars are given of appropriate switchgear units, followed by an outline of some of the chief features of their design, manufacture, and performance on tests. (*Science Abstracts*)

No. 1429. T. C. N'Guyen, "Electric Contacts and Powder Metallurgy," *Ann. Radioélectricité.*, Vol. 5, October, 1950, pp. 339–353. (In French.)

The application of powder metallurgy to electric contacts is discussed, especially with reference to the pseudo-alloys: W (or Mo) Cu (or Ag), Ag CdO (or Ni, or graphite, or Pb). Each constituent of the psuedo-alloy retains its individual properties, thereby enabling the realization of ranges of properties such as density, hardness, malleability, resistance, etc. Recent data of the above pseudo-alloys, especially of ductility and malleability, and the resulting convenience for industrial design, are cited. There are 12 sets of microphotographs and 4 references. (*Science Abstracts*)

No. 1430. E. M. Tseĭrov, "Quenching of the Electric Arc by an Air-Blast, *Elektrichestvo*, No. 10, October, 1950, pp. 27–34. (In Russian.)

The previous investigations (Abstr. 646 (1950)) are extended, particularly those dealing with the influence of the air pressure on the recovery of the dielectric strength of the air. The gas-dynamical investigations of the processes in the quenching chamber at current-zero or during voltage recovery shows that there is an incomplete rupture in the air flow. The latter obeys laws of unsteady flow. The most important fact revealed is that in the particular conditions of a quenching chamber, the air pressure at rupture is considerably lower than in a normal flow. As the rupture occurs in the circuit-breaker breach, the parameters of the latter are of the greatest importance. The air volume in the chamber is divided into two fractions under very different conditions, a cold and a hot zone (heated by the arc). The conditions in the usual quenching chamber are unfavorable to the quenching of the arc, despite the high dielectric strength of the compressed air and its high velocity of flow, so that the rate of rise of the dielectric strength in the breach is comparatively low. The good properties of the compressed air are insufficiently utilized, and an improvement can only be obtained by careful pressure control. The dielectric strength, after reaching its maximum at a certain pressure, becomes independent of pressure, so that the limit of the quenching capacity of any individual chamber, or of its possible increase by pressure variation, is quickly reached. (*Science Abstracts*)

No. 1431. N'Guyen-Chi, "Les Contacts Electriques et la Metallurgie des Poudres," *Annales de Radioelectricite*, Vol. 5, No. 22, October 1950, pp. 339–353.

Possibilities of powder metallurgical techniques in fabrication of materials for electric contacts; pseudo-alloys of W-Cu, Mo-Cu, W-Ag, Mo-Ag, Ag-CdO, and others; properties of such pseudo-alloys embody those of individual constituents permitting range of properties never attained by classical metallurgy methods; discussion of convenience of such powder alloys for design of industrial contacts. (*Engineering Index Service*)

No. 1432. W. Erbacher, "Construction and Operation of Austrian Network Analyzer," *Ost. Z. Elektrizitätswirtsch.*, Vol. 3, November, 1950, pp. 357–361. (In German.)

This reviews types and applications of analyzers and describes a unit fed from a 220-v., 50-cps., 30-kva. frequency controlled gen-

erator. The generator panel of the analyzer comprises 10 generator units, each consisting of a phase shifter and a voltage regulator. The main panel comprises a number of boxes into which can be placed impedance (R, L, or C) units giving a maximum of 126 junction points. Facilities are provided at each junction for inserting measuring instruments located on a central measuring desk. (*Science Abstract*)

No. 1433. V. L. Fiks, "Investigation of Fusion of Relay Contacts," *Electrichestvo*, November, 1950, pp. 71–74. (In Russian.)

The above phenomenon was investigated by high-speed, motion picture photography. Results show quite completely the cause of fusion of contacts. Individual stages of the process lasting 0.005 sec. were investigated. Test circuit is diagrammed. (*Battelle Library Review*)

No. 1434. T. Rosskopf, "Temperature Rise of Conductors Under Overload Conditions of Short Duration," *Electrotechiek*, Vol. 28, November 23, 1950, pp. 469–473. (In Dutch.)

Formulae and rules which determine the relation between temperature rise, s.-c. current density, and duration have been adopted as standard in different countries, but these are generally based on approximations. Precise formulae for this relation are derived, taking into account that the ratio of a-c. losses to d-c. losses (factor k) varies according to type and arrangement of the conductor. The formulae are put in a simple form and tables are derived from which results can be readily obtained. (*Science Abstracts*)

No. 1435. H. W. Baxter, "An Experimental Synchronous Contactor for Repeated Automatic Operation," *J. Sci. Inst.*, Vol. 27, November, 1950, pp. 299–300.

A description is given of the design and operation of a small contactor which enables any of the following to be independently varied: contact pressure; velocity of contact separation; "point of wave" at which contacts separate; and relative sliding between contacts. (*Science Abstracts*)

No. 1436. A Brownell, and D. D. Hinman, "For Measuring Fluorescent Lamp Starter Transients," *G.E., Rev.*, Vol. 11, November, 1950, pp. 17–19.

The transient voltage and energy set up by lamp starter switches is assessed against an equivalent circuit incorporating a neon lamp in place of a c.r.o. or grid-controlled valve. The unreliable results obtained with the latter units are attributed to inconsistencies between measured transient voltage and lamp starting ability. Testing against actual lamps also gives variable results depending on lamp manufacturing variations, past use of the lamp, ambient conditions, and the presence of conducting material near the lamp. In the circuit employed, the starter switch is connected in series with a choke across an a-c. supply. The starter is shunted by a variable 0.2 MΩ and a 0.4 MΩ fixed resistor connected in series. The former controls the neon lamp voltage and the common point of this resistor; the supply and the neon lamp are earthed through a small condenser. Tests may be carried out at a low level of room illumination, and transient tester readings may be arranged to determine the maximum voltage produced by the starter or to select starters which exceed a given voltage. The use of krypton in place of argon as a filling gas has increased the required starting voltage values. (*Science Abstracts*)

No. 1437. E. Kündiger, "The Switching off of Squirrel-Cage Motors," *Elektrotechn., Zeitschr.*, Vol. 71, November 15, 1950, pp. 609–611. (In German.)

One of the tests laid down for switches in the V.D.E. Rules is that they must be able to switch off an induction motor when at rest. It is permitted to use resistance and inductance in series instead of an actual motor. This arrangement does not take the distribution of magnetic energy into account correctly, and it is proposed to connect a resistance across series-connected resistance and inductance. Curves are given showing that with the proposed arrangement, the results are nearer to those that would be obtained with an actual motor. (*Science Abstracts*)

No. 1438. G. H. Buffery, "A Contribution to the Algebra of Relay and Switch Contacts," *Proc.*, Part I, Vol. 97, November, 1950, pp. 357–362. (Reprint No. 1037).

The paper is complementary to one by Montgomerie (Abstr. 2091 (1948)) whose method of algebraic manipulation it is suggested may be considerably improved. In Montgomerie's paper, a closed contact is alloted the symbol unity, and an open contact the symbol zero. Contacts in series are then treated as if additive, while contacts in parallel are treated as if multiplicative. The present paper shows that, if contacts in series are treated as multiplicative and contacts in parallel as additive, a considerable simplification of algebra results, with a concomitant gain in elegance. This usage avoids the necessity for rules such as $1 + 0 = 0, 1 \times 0 = 1$. Also, many results which according to the original proposal would be obtained only after considerable manipulation, are obtainable at sight using the methods now proposed. (*Science Abstracts*)

No. 1439. J. R. Mortlock, "High Speed Reclosure of Circuit Breakers," *BTH Act.*, Vol. 21, November–December, 1950, pp. 188–192.

The factors governing the required "deionization" time to be allowed in the applica-

tion of high-speed reclosure to a system are discussed, and some examples showing the effect of single- and triple-pole reclosing on stability given. It is concluded that a "dead" time of about 0.2 sec. should ensure successful reclosure on transitory faults, that a system analysis is desirable before reclosure is used, and that single pole reclosure can be applied generally up to 139 kv. but that the associated control circuits are complicated. (*Science Abstracts*)

No. 1440. T. R. Stuelpnagel, "An Environment-Free 120-v., D-C. Limit Switch," *Elec. Engg.*, Vol. 69, December, 1950, p. 1070. (Digest of A.I.E.E., Paper 50–203 to be published in Trans. 69 (1950).)

Concerns a new hermetically sealed aircraft limit switch to carry $3\frac{1}{2}$ kw. and interrupt a 1.8-kw. motor load 15 times per sec. for duty cycles of 15 sec. each. The control pressure is eight ounces to eliminate vibration, contact bounce, and oxidation problems; the insulation used is fused mica and glass. Other features are briefly described. (*Science Abstracts*)

No. 1441. R. Meliarca and F. Sbaraccani, "Comparison Tests on Low Voltage, Electro-Magnetic Circuit Breakers," *Ing. Ferroviaria*, Vol. 5, December, 1950, pp. 855–859. (In Italian.)

Small automatic switches are increasingly used to replace fuses in the 220-v. distribution networks of the Italian State Railways. In many locations the prospective fault current is very high, and since standards for this type of switch are still under discussion, a study of their performance under strictly controlled conditions was undertaken with the dual purpose of determining this behavior in the field and of contributing to the setting up of the standards. The selected test conditions are described. Prominent is the provision in the test circuit of a synchronizing switch which closes at predetermined points on the voltage wave. The construction and operation of this switch is described. The results obtained from the tests on 3 A, 1-ph.(s.-c.c. 800 A); 12 A; 3-ph. (s.-c.c. 1200 A); 30 A, 3-ph. (s.-c.c. 1200 A); 10 A, 3-ph. (s.-c.c. 1200 A) are described and illustrated with oscillograms. (*Science Abstracts*)

No. 1442. J. F. McKenney, "High-Voltage Load-Ratio-Control Contactors," *G.E. Rev.*, Vol. 53, December, 1950, pp. 36–38.

The basic elements for on-load tap-changing of transformers are discussed, followed by suggestions for the design of the contactor assembly for 15–69 kv. and for 92 kv. and over. A bushing-mounted contactor is also described. (*Science Abstracts*)

No. 1443. H. V. Henk, "Oil Circuit Breakers for 150 kv.," *Ingenioren*, Vol. 59, December 23, 1950, pp. 1031–1038. (In Danish.)

Cross-sections, action diagrams, and oscillograms of operation and tests on inductive and capacitive circuits illustrate a detailed description of the design of an oil-poor (mini-oil) circuit breaker. The oil in the turbulator is kept separated from oil in other parts of the breaker, which is thus not contaminated by soot; insulation properties, rupturing capacity, and reclosing are discussed. Maintenance is claimed reduced to a minimum. (*Science Abstracts*)

No. 1444. I. B. Johnson and J. Berdy, "Magnification of Switching Over-Voltages in Coupled Oscillatory Circuits," *G.E. Rev.*, Vol. 53, December, 1950, pp. 22–24.

A short paper confirming by use of a transient analyzer that magnification of transient voltages set up in one part of a system may occur in another part of it, possibly at a different voltage level. Some particulars are given of the results obtained in switching capacitors and of precautions to be observed. (*Science Abstracts*)

No. 1445. E. B. Rietz and C. J. Balentine, "A New 69-kv., Oil-Blast Circuit Breaker," *Trans.*, A.I.E.E., Vol. 69, Part I, pp. 416–423 (1950).

A description is given of the mechanical features and field test performance of a new design of oil-blast circuit breaker of 1500- and 2500-mva. rating which are smaller, require less oil, and clear and reclose at higher speed, than the designs now superseded. Other advantages claimed are increased reliability, greater interchangeability of parts, and reduced oil and contact deterioration. Field test results are given. (*Science Abstracts*)

No. 1446. E. B. Rietz, "Development and Testing of an Improved High Voltage, High-Capacity Impulse Circuit Breaker," *Trans.*, A.I.E.E., Vol. 69, Part I, pp. 15–26 (1950).

Describes development of a low oil content, impulse-type breaker based on equipment developed for the Tidd. h.-v. test line (see Abstr. 384 (1949)). Modifications in design have made the mechanism frame size for 360-kv. operation smaller than that formerly used on 230 kv. This paper contains accounts of research with summarized results of laboratory and field tests. This type of circuit breaker is considered to embody all the requirements for protection of the high power systems envisaged, tests having been already made on 10,000-mva. designs for use on 230 and 360 kv. (*Science Abstracts*)

No. 1447. G. D. McCann, J. E. Conner, and H. M. Ellis, "Dielectric Recovery Characteristics of Power Arcs in Large Gaps," *Trans.*, A.I.E.E., Vol. 69, Part I, pp. 616–625 (1950).

Circuits and techniques used in studying

rates of recovery of electric strength are given. A surge generator is used to break down the gap, and after the fault current has flowed for a given time a second surge generator is used to determine the electric strength over selected ranges of times. The results include oscillograms and high-speed photographs. The subject is complex, and many more tests are required before some of the important conclusions can be drawn. (*Science Abstracts*)

No. 1448. H. Krida and E. T. McCurry, "A New Grounding and Testing Device for Metal-Clad Switchgear," *Trans.*, A.I.E.E., Vol. 69, Part I, pp. 407–415 (1950).

The unit is mechanically interchangeable with switchgear for 4.16 and 13.8 kv, and current ratings of 0.6, 1.2 and 2.0 ka. With it all the required testing functions can be performed, e.g., voltage phase sequence, insulation, fault resistance, measurements, and also earthing. The device is convenient and safe in operation. (*Science Abstracts*)

No. 1449. R. T. Horsfall, K. N. Thompson, R. W. Mills, and P. O. Bobo, "Automatic Control of Metal-Clad Switchgear Serving Oil Refinery Motors During Power System Disturbances," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1600–1605 (1950).

Discusses working conditions, costs, and service problems for electrical gear in refineries. Reliability must compare favorably with steam plants where one failure in 20 years is a normal figure, and therefore a duplex design from the 132-kv. source to the 480-v. supply at the motors has been adopted. The largest motor units are two 3600-hp., synchronous-motor driving blowers. Particulars are given of means used to resynchronize them after system voltage disturbances on the power supply system. (*Science Abstracts*)

No. 1450. B. S. Beal, III, and P. J. Reifschneider, "Aircraft D-C. Circuit Breakers for 28 and 120 Volts." *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1283–1288 (1950).

New circuit breakers have been developed with ratings of 300 and 600 A at 28 v. and 250 A. at 120 v. The interrupting ratings, over a range of altitude from sea level to 50,000 ft. are 12 ka. and 5 ka. for the 28- and 120-kv circuit breakers respectively. A compact and efficient interrupter makes the 120-v. rating possible. For generator circuit applications, an inverse time-delay, reverse-current trip device has been designed for the circuit breakers. For other applications, nondirectional time delay and directional and nondirectional instantaneous trip derives have been designed. Tri-free mechanisms for both the manually and electrically closed circuit breakers and antipump control for the closing solenoid add to the protection provided by these circuit breakers. The operation of these circuit breakers is satisfactory under conditions of vibration, shock, sand, and dust, and extremes of temperature and humidity, incident to aircraft. (*Science Abstracts*)

No. 1451. B. G. Trembloy and M. E. Horn, "An Air-Delayed, Selective Overcurrent, Tripping Device for Low-Voltage Air Circuit Breakers, "*Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1649–1653 (1950).

A tripping mechanism is described with wide range of adjustment and resettable, even when, in course of tripping on overload, the overload is removed. It comprises a series coil attached to a moving core which has a spring-loaded stem carrying a valve which operates on a diaphragm, time control being effected by rate of admission of air through various valves. Various adjusting means of wide range are incorporated. (*Science Abstracts*)

No. 1452. F. E. Andrews, L. R. Janes, and M. A. Andersson, "Interrupting Ability of Horn-Gap Switches," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1016–1027 (1950).

A description is given of the results of some 400 tests made to ascertain: (1) arc behavior with horn-gap switches under various system conditions; (2) what currents can be broken on existing switches under prevailing system conditions; (3) basic switch design factors for successful operation under specified conditions. The three main types of test made at 60 cps. were: (1) opening one side of a 33-kv. line and transferring its load to parallel lines; (2) breaking transformer excitation currents at voltages from 12–49 kv.; (3) breaking 132-kv. line charging currents with and without gas-blast using air or nitrogen. The chief features studied were total arc length over its irregular path, and "reach" defined as distance from a point midway between the arc length. Oscillographic records are compared with pairs of cine-camera records taken at right angles to each other. The influence of wind velocity, 1- and 3-phase, and power factor are discussed briefly. (*Science Abstracts*)

No. 1453. J. B. Owens, "Ice Testing of Outdoor Disconnecting Switches to Simulate Field Conditions," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1488–1492 (1950).

Describes artificial means for producing clear icing, which is the most tenacious encountered in service, and outlines arrangements made to ensure that tests are practical and of the correct order of severity. In course of the work, some desirable features of the design of air-break switches for operating in icy conditions were noted and are briefly discussed, the chief being provision of a mechanism to twist the blade and break the ice before the blade rises. This mechanism

should be entirely enclosed, with the contact protected at the hinge end. A flat surface requiring movement with respect to an adjacent parallel stationary surface should be avoided. (*Science Abstracts*)

No. 1454. T. R. Stuelpnagel, "An Environment-Free 120-v. D-C. High-Performance Limit Switch," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1289–1293 (1950).

This article concerns the new hermetically sealed aircraft limit switch to carry 3 1/2 kw. and interrupt a 1.8-kw. motor load 15 times per sec. for duty cycles of 15 sec. each. The control pressure is 8 oz. to eliminate vibration, contact bounce, and oxidation problems; the insulation used is fused mica and glass. Other features are briefly described. (*Science Abstracts*)

No. 1455. S. C. Killian, "Induced Currents in High-Capacity Bus Enclosures," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1388–1395 (1950).

Tests and theory show that induced circulating currents in bus enclosures are proportional to the main current, reduce the resistance of the main conductors, and do not increase with the lengthening of the busbar beyond 20 ft. Enclosures reduce field strengths outside to about 10 per cent of that without enclosure. Decrease in phase separation also reduces the circulating current. (*Science Abstracts*)

No. 1456. P. Duffing, "Development of a New Arc-Free Synchronous Contractor," *VDE-Fachberichte*, Vol. 14, pp. 41–44 (1950). (In German.)

A new contactor has been designed for the contact convertor (Abstr. 1770 (1946)). It consists of three elements, an impulse-controlled contactor switch, an impulse generator, and a choke. The impulse generator consists of a d-c. saturated current transformer. The contactor switch has for its excitation a permanent magnet, and the holding force is at the proper moment reduced to zero but can not be reversed by counter excitation from the impulse generator. This is accomplished by a special design of magnet system which is described in detail and illustrated. (*Science Abstracts*)

No. 1457. H. Franken, "Contact Materials for Motor Switchgear with Special Consideration of Fine Silver and Cadmium Silver," *VDE-Fachberichte*, Vol. 14, pp. 63–68 (1950). (In German.)

The essential properties of a contact material for motor switchgear are constancy of contact resistance, good conductivity, small tendency to oxidation, long life, and high permissible initial current. Graphs and tables show the behavior of fine Ag and Cf-Ag contacts, particularly with regard to their tendency to burning off. Except for special cases, the use of fine Ag is advocated. (*Science Abstracts*)

No. 1458. J. Heinze, "High-Voltage Cellular-Type Switchgear for Indoor and Outdoor Installation," *VDE-Fachberichte*, Vol. 14, pp. 15–21 (1950). (In German.)

An illustrated description of cellular-type switchgear and experiences gained in its erection and operation. A comparison is made with American "package substations." The main advantages of the cellular or package type are that they are pre-fabricated and therefore easily and quickly erected and that they are easily accessible and space-saving. (*Science Abstracts*)

No. 1459. H. Johann, "Trends in the Development of Automatic Switches for Domestic Installation and Their Justification," *VDE-Fachberichte*, Vol. 14, pp. 68–73 (1950). (In German.)

The historical development of automatic switches for replacing domestic fuses is described. The main features of modern types are the switching-on by press-button with free release, magnetic release without delay in cases of short circuit, and delayed thermal release for sustained overloads and magnetic spark extinction. Switches with rectangular base and with screw fitting have been developed. Questions of standardizing testing conditions are discussed. The use of modern manufacturing methods and of plastics as constructional material and the reduction of dimensions are the main characteristics of recent development. (*Science Abstracts*)

No. 1460. Earle E. Schumacher, "Communications Metallurgy," *Journal of the Institute of Metals*, Vol. 78, p. 1 (1950).

No. 1461. W. H. Brattain and G. L. Pearson, "Changes in Conductivity of Germaniun Induced by Alpha-Particle Bombardment," *Phys. Rev.*, Vol. 80, No. 5, pp. 846–850 (1950).

No. 1462. "Proposed Test Code for Aircraft Circuit Interrupting Devices (12-, 24-, and 120-v. Direct Current Systems)," *A.I.E.E., Stand.*, No. 801, 8 pp. (1950).

No. 1463. "Electrical Control and Indication for Switchgear," *Reyrolle Rev. Repr.*, Nos. 136, 138, 139–147, 67 pp. (1950).

Outlines with notes and diagrams of the main control features of circuit breakers, namely, tripping, closing, interlocking, metering, and indicator and alarm devices. There are also sections on synchronizing, automatic voltage regulation, and protection; the latter covers directional over-current protection. Merz-Price (for feeder and transformers) Solkor, and means for protecting reactors, generators, and generator fields. (*Science Abstracts*).

No. 1464. Schrag, Gerhard, and Horst Steinert, "Observations on Liquid Contact Bridges," *Zeits. f. Metallkunde*, Vol. 42, January, 1951, pp. 24–26. (In German.)

Describes experiments made to study further the formation of molten metal or metal-oxide bridges upon the opening of contacts. Data for Ni contacts are tabulated, charted, and discussed. (*Battelle Library Review*)

No. 1465. R. A. Branflick, "Hold Closed—a New Function for Automatic Reclosers," *Elec. World*, Vol. 135, January 15, 1951, pp. 49–52.

This describes the use, in conjunction with fuses, of a recloser which performs 1 or 2 "instantaneous" openings for clearing transient faults before the fuses concerned suffer damage. If the fault is eliminated, the recloser resets for normal operation, but if the fault persists, it stays closed and the appropriate fuse isolates the fault, the recloser thereafter automatically resetting for a complete new cycle of operation. The principal advantages of the system are discussed, and curves and a table show how coordination between recloser and a 9FIC series of fast-blowing fuse links may be obtained. (*Science Abstracts*)

No. 1466. Schultheiss, "Comparison and Development of Space- and Material-Saving Designs in the Construction of E.H.V. Switchgear Installations with Due Regard to Service Requirements," *Elektrotechnik*, Vol. 5, January, 1951, pp. 4–8. (In German.)

Four different designs of e.h.v. installations are critically compared; they are distinguished by arrangement of the disconnectors, the busbars, and the main circuit breaker. While the "series-lengthwise" arrangement requires the least amount of constructional material, the "parallel-crosswise" arrangement is preferable from the point of view of accessibility of its parts for inspection and repair and the avoidance of service interruptions. (*Science Abstracts*)

No. 1467. F. Metzger, "Present-Day Problems in Low Voltage Switch- and Control-Gear, *Elektrotechnik*, Vol. 5, January, 1951, pp. 8–13. (In German.)

Increased activity in research, standardization, simplification, and specialization in this field are advocated for achieving these ends. (*Science Abstracts*)

No. 1468. E. Jönsson, "Pneumatic Interlocking System for H.V. Switchgear," *Tekn. Tidskr.*, Vol. 81, January 6, 1951, pp. 11–12. (In Swedish.)

An experiment is shown, and a diagram gives the electric current paths and the air paths in a control system for operating isolating switches on a double busbar with transmission lines. The operations are described and the protection against faulty switching, opening a line on load, coupling errors, and arcing accidents is discussed. (*Science Abstracts*)

No. 1469. B. G. Tremblay and M. E. Horn, "Air-Delayed, Selective Overcurrent, Tripping Device," *Elec. Engg.*, Vol. 70, January, 1951, p. 39. (Digest of A.I.E.E., Paper 50–271 to be published in Trans. 69 (1950).)

A tripping mechanism is described with wide range of adjustment and resettable, even when, in course of tripping on overload, the overload is removed. It comprises a series coil attached to a moving core which has a spring-loaded stem carrying a valve which operates on a diaphragm, time control being affected by rate of admission of air through various valves. Various adjusting means of wide range are incorporated. (*Science Abstracts*)

No. 1470. W. R. Smith, D. R. Stemler, and W. H. Cutting, "Oil Switch and Voltage Control Give Low-Cost Capacitor Switching," *Elec. World*, Vol. 135, January 1, 1951, pp. 57–60.

Describes the automatic capacitor switching arrangements for the Pennsylvania Power and Light Company and outlines the factors leading to the design of switch selected, the method of voltage control, and the necessary control adjustments. A short account of routine maintenance is included with photographs of equipment. (*Science Abstracts*)

No. 1471. E. B. Gebert and T. F. Cofer, "Contact Materials in Telegraph Apparatus," *Western Union Technical Review.*, Vol. 5, January, 1951, pp. 32–40.

Discusses requirements, properties of the various types, design, and applicabilities. (*Battelle Library Review*)

No. 1472. L. H. Fisher and B. Bederson, "Formative Time Lags of Spark Breakdown in Air in Uniform Fields of Low Overvoltages," *Phys. Rev.*, Ser. 2, Vol. 81, January 1, 1951, pp. 109–114.

An attempt was made to establish the region of validity of the streamer and Townsend mechanisms of spark breakdown in air by measurements of the formative time lag of the breakdown process. These lags were measured in a uniform field for overvoltages of a few per cent down to as close to threshold as possible. Such measurements were carried out as a function of pressure and plate separation. 26 references. (*Battelle Library Review*)

No. 1473. G. Meiners, "Problems in Modern Switchgear Design," *AEG-Mitt.*, Vol. 41, January–February, 1951, pp. 3–14. (In German.)

After some references to recent trends in the U. S. A. and Britain, the author describes a system of standard components developed by

the AEG in which individual drawings can be combined rapidly to produce any station layout. The article covers low-level 110-kv. outdoor switching as well as indoor 10-kv., cellular and metal-clad, air-insulated gear. Air-blast circuit breakers are used at 110 kv. and compressed-air breakers or switch-fuses at 10 kv. A scissor-type isolator designed up to 220 kv. occupies very little space when extended. This method of assembling typical component drawings goes as far as schematic station drawings and wiring diagrams. (*Science Abstracts*)

No. 1474. L. R. Bergström and U. Sandström, "The Field Testing of 220-kv. Air-Blast Circuit Breakers," *Elec. Engg.*, Vol. 70, February, 1951, pp. 118–124.

The article describes extensive field tests, using a 40-mva. generator and a standard 220-kv. breaker, made to study problems to be settled before putting into operation a 380-kv. line 593 miles long in Sweden, e.g., fixing of the insulation level by determining what switching over-voltages can arise. The various types of test are discussed in some detail with diagrams, specimen oscillograms, and tables of results for different lengths of lines both directly earthed and using arc-suppression coils with and without non-linear resistors. The case of interrupting a shunt reactor load is also dealt with. Reference is made to other details of the system described earlier. (Abstr. 997 (1949)) (*Science Abstracts*)

No. 1475. G. Musso, "Tests on Ultra-Rapid Circuit Breakers for 3-kv. D-C. Traction," *Ing. Ferroviaria*, Vol. 6, February, 1951, pp. 121–132. (In Italian.)

The ultra-rapid circuit breaker reduces arc duration to some tenths of a msec. and opens a few msec. after starting of a short circuit. The characteristics of short circuits on a traction network with mutator substations are discussed, the opening of the circuit breaker is discussed theoretically, the testing arrangement is described, and test results are given, illustrated by numerous oscillograms, and discussed. Some hints on improvements in design are given. (*Science Abstracts*)

No. 1476. M. E. Horn and J. J. Mikos, "New Low-Voltage Air Circuit Breaker," *Elec. Engg.*, Vol. 70, February, 1951, p. 104. (Digest of A.I.E.E., Paper 50–272 to be published in Trans. 69 (1950).)

The design of a 3-pole, 1.5-ka., 600-v. air circuit breaker is outlined. It is electrically operated, has direct-acting series over-current trips, and the breaking capacity is 30 ka. (presumably at 600-v.). Tests have shown that the total closing time is 7 cycles (at 60 cps.) and the total shunt tripping time 3.4 cycles. Other features are ability to close and latch on 50 ka. (which permits delayed tripping through the whole range of fault current, thus improving selective tripping performance); economy in space occupied; and a novel contact arrangement. (*Science Abstracts*)

No. 1477. J. B. Owens, "Ice Testing of Outdoor Disconnecting Switches to Simulate Field Conditions," *Elec. Engg.*, Vol. 70, February, 1951, pp. 139–142.

Describes artificial means for producing clear icing, which is the most tenacious encountered in service, and outlines arrangements made to ensure that tests are practical and of the correct order of severity. In the course of the work some desirable features of the design of air-break switches for operating in icy conditions were noted and are briefly discussed, the chief being provision of a mechanism to twist the blade and break the ice before the blade rises. This mechanism should be entirely enclosed, with the contact protected at the hinge end. A flat surface requiring movement with respect to an adjacent parallel stationary surface should be avoided. (*Science Abstracts*)

No. 1478. V. V. Gusev, "Calculation of Transient Processes in Power Systems During Single-Phase Rapid-Reclosing," *Elektrichestvo*, No. 2, February, 1951, pp. 3–8. (In Russian.)

Expressions are given for the resistance operators for determining current and voltage on closing and tripping a single-pole circuit breaker at any point of a 3-ph. system during parallel and series faults. These formulae for the transient resistances, together with equivalent circuits of the system connections for the various phase sequences in the form of generalized circuits with multipoles and with the resulting systems of reduced equations, enable transient problems on 1-ph. rapid reclosing to be solved. These are, in particular, closing and tripping of a single-pole circuit breaker when the circuit breakers of the other phases are in arbitrary positions and when faults exist at one or two points of the system. (*Science Abstracts*)

No. 1479. S. C. Killian, "Induced Currents in High-Capacity Bus Enclosures, *Elec. Engg.*, Vol. 70, February, 1951, p. 116. (Digest of A.I.E.E. Paper 50–222 to be published in Trans. 69 (1950).)

Tests and theory show that induced circulating currents in bus enclosures are proportional to the main current, reduce the reactance of the main conductors, and do not increase with the lengthening of the busbar beyond 20 ft. Enclosures reduce field strengths outside to about 10 per cent of that without enclosure. Decrease in phase separation also reduces the circulating current. (*Science Abstracts*)

No. 1480. F. E. Andrews, L. R. Janes, and M. A. Anderson, "Interrupting Ability of

Horn-Gap Switches," *Elec. Engg.*, Vol. 70, February, 1951, p. 136. (Digest of A.I.E.E. Paper 50–161 to be published in Trans. 69 (1950).)

This describes the results of some 400 tests made to ascertain: (1) arc behavior with horn-gap switches under various system conditions; (2) what currents can be broken on existing switches under prevailing system conditions; (3) basic switch design factors for successful operation under specified conditions. The three main types of test made at 60 cps. were: (1) opening one side of a 33-kv. line and transferring its load to parallel lines; (2) breaking transformer excitation currents at voltages from 12 to 49 kv.; (3) breaking 132-kv. line charging currents with and without gas-blast using air or nitrogen. The chief features studied were total arc length over its irregular path, and "reach" defined as distance from a point mid-way between the arc roots to the most remote point of the arc at the time of its maximum length. Oscillographic records are compared with pairs of cine-camera records taken at right angles to each other. The influence of wind velocity, 1- and 3-phase and power factor, are discussed briefly. (*Science Abstracts*)

No. 1481. H. E. Linckh, "Investigation of Migration of Material at Electrical Contacts," *Elektrotech. Zeitschr.*, Vol. 72, February 1, 1951, pp. 79–83. (In German.)

The search for substitutes for noble metals of the Pt group in fine contacts is described. Tests showed the fundamental behavior of various metals and alloys in relation to the electrical stresses. The chief factor is the so-called arc limit: Above this limit there is a high loss of metal by burning and vaporization; below it transfer takes place only from anode to cathode. Some examples of detrimental point formation and more favorable shapes of surface are given. Au-Ni (5 per cent) and Au-Ag-Ni alloys have favorable properties. The transfer of metal is explained by the Thomson effect associated with the liquid metal bridge. Measurements of the transfer for a number of metals and photographs of contacts are presented. (*Science Abstracts*)

No. 1482. V. E. James, "Telephone Type Relays—Arc Suppression and Contacts," Product Engg., Vol. 22, No. 2, February, 1951, pp. 136–140.

Capacitor-resistor arrangement schemes for suppressing sparks and arcs across relay contacts. Characteristics, ratings, and applications of contacts made of different materials and alloys. Protective inclosures for telephone-type relays.

No. 1483. F. Grieb, "Some Special Problems of Modern H.V. Circuit Breakers," *Elektrotech. u. Maschinen-bau.*, Vol. 68, March 1, 1951, pp. 98–107. (In German.)

A qualitative comparison is made of the performance of small oil-volume and gas-blast breakers when interrupting s.-c. currents and disconnecting a transformer under no-load conditions. The particular advantages of gas-blast breakers for rapid reclosure are outlined. Problems connected with the testing of circuit breakers are examined. Several examples of 220-kv. gas-blast breakers are described, and test results are given of a series of staged line tests with both gas-blast breakers and breakers with small oil volume. (*Science Abstracts*)

No. 1484. D. R. Davies, "33-kv. Metal-Clad Switchgear for Substations," *Metrop.-Vick. Gaz.*, Vol. 23, March, 1951, pp. 332–336.

Type SB 14 single-break, metal-clad switchgear is described. It has a rated breaking capacity of 750 mva. at 33 kv. The following features are discussed: floor area occupied; insulation; circuit breaker; circuit-breaker maintenance; isolation; interlocks; earthing and testing of cables; instrument and protective transformers; busbars; and voltage transformers. (*Science Abstracts*)

No. 1485. J. H. C. Peters, "High-Voltage Switching Stations Incorporating Air-Blast Circuit-Breakers in Blockhouses," *Engl. Elec. J.*, Vol. 12, March, 1951, pp. 37–47.

Describes a compromise design of substation for networks operating at voltages of the order of 33 and 66 kv. Each in-door air-blast circuit breaker is housed in a simple brick building, and the rest of the h.-v. gear with the exception of current transformers is out-of-doors. Details of the layout are well illustrated, and particulars of two suitable types of air-blast circuit breakers and of air supply arrangements are given with brief reference to relative costs. (*Science Abstracts*)

No. 1486. P. A. Raine, "Jointing Aluminum Cable—Methods of Wiping and Soldering," *Elec. Rev.*, Vol. 148, March 16, 1951, pp. 529–531.

Aluminum sheath is degreased with trichlorethylene and the oxide film removed by filing. A tinning solder (90 per cent Sn; 10 per cent Zn) then adheres to the Al surface at 200 C., without the use of flux. The tinned surface is then used as the base for a wiped joint, using a low Sb content (max. 0.3 per cent) wiping solder. Severe mechanical tests prove the strength of the Al solder bond. Conductor joints are similarly affected using Cu ferrules. (*Science Abstracts*)

No. 1487. O. E. Berg and H. E. Stauss, "Use of Photo-Tube to Correlate Contact Separation with Electrical Transients," *Rev. Sci. Instrum.*, Vol. 22, March, 1951, pp. 153–155.

A method is described which permits correlation between the separation of electrical

contact points and the transient voltages occurring across the electrical contacts when a current is interrupted. The current from a phototube, energized by light passing through an aperture-slit system mounted on the same relay as the contact points, exhibits on a single-triggered oscilloscope sweep the extent of contact separation on a time axis. This trace is superimposed on the same film frame as a subsequent transient voltage trace when the current is interrupted. The double exposure gives an accurate correlation between aperture and transient characteristic, inasmuch as the same sweep speed and sweep trigger are used for both traces. The sweep organ is extremely stable. (*Science Abstracts*)

No. 1488. R. Edler, "Change-Over Switch for Telephone Batteries," *Öst. Z. Telegr.-Teleph.-Funk-Fernsehtech.*, Vol. 5, March–April, 1951, pp. 51–55. (In German.)

A switch designed to avoid interrupting the supply during changeover. Extra contacts and resistors are used to minimize current surges. (*Science Abstracts*)

No. 1489. G. Jolles, "Recent Developments in Air-Blast Circuit Breakers," *Elettrotecnica.*, Vol. 38, April 25, 1951, pp. 179–190. (In Italian.)

The modes of operation of air-blast breakers under normal and abnormal circuit conditions are reviewed, and illustrations are given of breakers of Brown-Boveri design. In the m.v. range, 3 to 30 kv., standard designs for ratings up to 600 and 1000 mva. and special designs for high nominal current (4000 A). or high breaking capacity (1500 and 2000 mva.) are shown. These models are of classical design, with single- or double-break, incorporating resistance-switching and with series isolator. In the h.-v. range, a new design has been developed. It consists of a large number of breaks in series, and isolation is obtained with the interruption chamber contacts remaining open under the action of air at 15 atm. Graphs show that the "internal" dielectric strength of the chambers at power frequency and at impulse voltages exceeds the external flash-over voltage at all pressures above 5 atm. Voltage grading is usually obtained with shunt capacitors and, for the highest breaking capacities, with the further addition of nonlinear resistors. Results of tests on this type of breaker, carried out in the laboratory and at the Fontenay station of the Electricite de France, are given and models of ratings up to 380 kv. and 8500 mva. are illustrated. (*Science Abstracts*)

No. 1490. R. J. Hopkins and N. R. Schultz, "Switching of Distribution Capacitors by Manual and Automatic Devices," *G.E. Rev.*, Vol. 54, April, 1951, pp. 36–42.

Various capacitor switching operations arising in distribution system practice and associated deenergizing and energizing problems are outlined. Suggestions as to selecting switches complying with the requirements are given with notes on coordinating them with associated fuses (enclosed-type expulsion or open-type expulsion). Examples are included of various practical cases, with tables comparing oil-switch characteristics and allowable size of capacitor banks; also particulars of some suitable types of gear. (*Science Abstracts*)

No. 1491. S. V. Avakyan, "Calculation of the Gas-Dynamical Processes in Arc-Quenching Devices Using an Oil Cross-Jet," *Elektrichestvo*, No. 4, April, 1951, pp. 19–27. (In Russian.)

Full experimental and mathematical analysis of the quenching process in an explosion-pot type circuit breaker with an oil cross-jet shows that the individual stages of the processes are quite distinct and, despite their complex character, can be satisfactorily represented mathematically. The theory is verified by photographs and oscillograms, and by detailed energy balances supported by power measurements. The treatment is based on the consideration of the gas bubble produced by the arc and which fills up the space liberated by the contact piston. The following simplifying assumptions furnish results in agreement with experiments. The jet duct is filled with a gas-vapor mixture and this jet, when leaving the outlet of the duct and the oil layer covering it, assumes the form corresponding to a speed maximum near that of sound. At the oil-gas-vapor separation there is a strong eddying effect. It results in an increase of the hydraulic resistance to the propagation of the jet. A simple relation between cross-section of the issuing jet and that of the duct, involving the initial pressure of the gas bubble and a constant coefficient, leads to satisfactory agreement with empirical data. (*Science Abstracts*)

No. 1492. F. L. Musselman, "Coordination of Parts in Switchgear Assemblies," *G.E. Rev.*, Vol. 54, April, 1951, pp. 22–25.

The author outlines steps taken to ensure that in a metal-clad circuit-breaking unit the components such as the circuit breaker proper, instrument transformers, and associated fuses are all designed to withstand their particular duties. The electrical rating of the circuit breaker is discussed, and the mechanical ratings of components (the mechanical and thermal effects they have to withstand) are discussed with general notes on insulation and on the selection of fuses for voltage-transformers. (*Science Abstracts*)

No. 1493. H. L. Lowe and R. L. Hodgkins, "Centralized Control Board for Steam-Electric Generating Plants," *Elec. Engg.*, Vol. 70, April, 1951, pp. 304–307.

Centralized control of boilers, turbines, and

generators is usually accomplished by grouping their several control boards in a specific area. An improved arrangement, using specially designed control panels, is installed at Morgan Creek power station, and enables all important operations to be controlled by one man. Only essential indications are provided, and a 50 per cent saving of control space is claimed. Low-pressure compressed air is used as the transmitting medium from full-sized meters on the plant to miniature indicators on the control panel. Morgan Creek comprises two 20-mw. units. Each 13.2-kv., hydrogen-cooled, 3600-rpm. turbogenerator is supplied at 850 lb. per sq. in., 900 F., by a 220,000 lb. per hr., gas- or oil-fired boiler. (*Science Abstracts*)

No. 1494. B. J. Dalton, "New Control for High-Voltage Industrial Motors," *G.E. Rev.*, Vol. 54, May, 1951, pp. 49–55.

A description is given of current-limiting fuses and air-break contactors for the 2300 to 4160-v. range. The construction is described in detail, and performance curves included. (*Science Abstracts*)

No. 1495. M. R. Swinehart, "Instrumentation for Analysis of Contact Wear," *Elec. Engg.*, Vol. 70, May, 1951, p. 414.

A condensation that describes the above. The ultimate goal is to be able to use the instruments to determine contact life of a specific design in a few hours, instead of the usual weeks or months required for the life-testing methods now used. Some of the factors affecting contact wear are reviewed. (*Battelle Library Review*)

No. 1496. R. C. Dickinson and J. D. Findley, "Mechanism for Hand Closing of Circuit Breakers," *Elec. Engg.*, Vol. 70, May, 1951, p. 394. (Digest of A.I.E.E. Paper 51–25 to be published in Trans. 70 (1951).)

Describes and illustrates a spring-operated mechanism designed to close air circuit breakers without use of electric power for operation and for which manual operation is unsatisfactory. The energy required for obtaining the proper speed and power is stored in a large coil spring compressed by means of a hand-lever ratched mechanism. The apparatus was designed for gear ranging from 150 to 250 mva. at 4.16 kv. and 150, 250, and 500 mva. at 13.8 kv. It has closed successfully on 65 kv. at 4.2 kv. (*Science Abstracts*)

No. 1497. H. Hohm and E. Maass, "The Arc Chamber and Its Application in Low-Oil-Content Switchgear," *Elektrotechn. Zeitschr.*, Vol. 72, May 1, 1951, pp. 263–266. (In German.)

The article deals with recent developments of an arc chamber in which a differential piston operated by the pressure inside the pot forces oil radially through an annular orifice into the arc. For low arc currents, the oil flow is increased by an additional piston driven from the main operating shaft. Interrupting capacities of 2500 mva. at 110 kv. and 1000 mva. at 33 kv. have been obtained. (*Science Abstracts*)

No. 1498. M. R. Swinehart, "Instrumentation for Analysis of Contact Wear," *Elec. Engg.*, Vol. 70, May, 1951, p. 414. (Digest of A.I.E.E., Paper 51–52 to be published in Trans. 70 (1951).)

An accelerated life test method for determination of the life of contacts based on the empirical formula ($M/N = I^2(C_1 + C_2K^2t^2)$, where N is contact tip life, M is mass available for wear on double-break contacts, I is arc current at break, K is ratio of arc current during make to that at break, t is arcing time in msec. and C_1, C_2 are constants. A polar coordinate-type oscilloscope is used to measure the arc characteristics which include contact bounce, vibration, and shock characteristics. A spot is deflected in proportion to the voltage across the contacts, while sweeping circumferentially at constant speeds of either 900, 1800 or 3600 rpm. A circular oscillogram is illustrated and analyzed. Contact bounce is considered to be established as a major factor controlling contact life. (*Science Abstracts*)

No. 1499. I. A. D. Lewis, "A Symbolic Method for the Solution of Some Switching and Relay-Circuit Problems," *Proc.*, A.I.E.E., Part II, Vol. 98, May, 1951, pp. 181–191. (Reprint No. 1107).

A symbolic method, using ordinary algebra throughout, is developed for the solution of some switching and relay-circuit problems. It is applied initially to 2-terminal networks consisting of switch contacts only. Each element is identified by a letter, and expressions representing the networks are derived. The values 0 and 1 indicate an open circuit and a closed circuit, respectively, as applied to both a network as a whole and to individual elements; for the latter these same values also indicate whether the associated relay is unoperated or operated. A simple notation is used to distinguish between make contacts and break contacts. The method is extended to include symbols representing relay coils, and expressions are derived which represent a complete 2-terminal circuit, consisting of contacts and coils, connected to the supply battery. Problems of circuit analysis, simplification, and synthesis are treated both for reflex and nonreflex types of circuit. (*Science Abstracts*)

No. 1500. S. B. Toniolo, "Considerations on the Synthetic Method of A-C. Circuit-Breaking Test," *Elettrotecnica*, Vol. 38, June, 1951, pp. 258–265. (In Italian.)

The four phases which characterize the arc during interruption as described by Cassie (see disc. on: A-C. Arc Behavior Near Current Zero, Abstr. 1529 (1949)) are examined

with a view to establishing the characteristics required of a synthetic test plant. The power required by the voltage and current sources is considered in relation to the characteristics of the breaker under test and to the power required for normal test. A direct comparison between the two methods of tests is advocated. (*Science Abstracts*)

No. 1501. A. Keil and C. L. Meyer, "The Influence of the Direction of Crystal Fibres on the Resistance to Electrical Wear of Tungsten Contacts," *Elektrotech. Zeitschr.*, Vol. 72, June 1, 1951, pp. 343–346. (In German.)

A tungsten contact wears more rapidly if the crystal fibers of the metal are parallel to the surface of the contact. More even wear is achieved if the fibers are perpendicular to the surface. Electrical wear is primarily responsible for the deterioration of the contacts; mechanical wear is not evident, even after 5×10^7 operations. On dc. the life of the cathode contact is influenced by the direction of the crystal fibers, but not that of the anode contact. Generally, tungsten contacts should be loaded with < 20 g. and p.d. across should be > 6 v. (*Science Abstracts*)

No. 1502. R. B. Shores and J. W. Beatty, "A New 69-kv. Air-Blast Circuit Breaker," *Elec. Engg.*, Vol. 70, June, 1951, p. 480. (Digest of A.I.E.E. Paper 51–27 to be published in Trans. 70 (1951).)

Gives main design features of a unit for outdoor metal-enclosed switchgear capable of handling the maximum "voltage recovery rate" (6 kv. per μ sec.) encountered in practice at 3500-mva. duty. This involved use of a shunting resistor and a double-flow exhaust system. The unit is housed in a dust- and weight-tight outdoor metal enclosure, and means for avoiding condensation are described. Particulars are given of operation on test with a description of the sequence of events, and it is concluded that the performance could be increased to 5000 mva. if desired and that the enclosed isolator is a feature which should allow acceptance of the circuit breaker as an outdoor porcelain-clad unit. (*Science Abstracts*)

No. 1503. A. Hochrainer, "The Present State of Knowledge of the Stresses on Switchgear in H. V. Networks," *Elin-Z.*, Vol. 3, June, 1951, pp. 56–64. (In German.)

Rated rupturing capacity is a somewhat crude criterion of the suitability of a circuit breaker to deal with all conditions which may arise on the system. Particularly onerous are those involving h.-f. oscillations, e.g., high rate of rise of recovery voltage, switching small currents in highly inductive circuits and capacitors. Considerable use is now made of models and system analyzers in studying such phenomena. The increasing use of earthed systems and automatic reclosing has set new problems, particularly with m.v. switchgear. Development of large circuit breakers is handicapped by limitations of test plant so that reliance has to be placed on synthetic tests, the validity of which is questionable. Performance in service is therefore the only reliable guide. (*Science Abstracts*)

No. 1504. H. Edels, "A Technique for Arc Initiation," *Brit. J. Appl Phys.*, Vol. 2, June, 1951, pp. 171–174.

A method for initiating an arc discharge between fixed electrodes by an auxiliary spark discharge is discussed. Theoretical limiting values for the parameters of the initiation are obtained, and these are compared with the experimental values found to be satisfactory in a circuit used for initiating an arc. (*Science Abstracts*)

No. 1505. D. L. Pettit, "An Electronic Power Source for Large D-C. Contact Testing," *Elec. Engg.*, Vol. 70, June, 1951, pp. 530–532.

Describes an electronic equipment providing d-c. power values suitable for testing contacts at up to 10^4 A at 250 v. and adjustable for 250- to 750-v. range. Large water-cooled welder ignitrons are used for rectification. The load current, obtained from a 13.2-kv. supply through a 3-ph. transformer, is used to fire the ignitors. Cycling of contacts is manually controlled by start and stop push-buttons. The rectifier characteristics give a faster recovery voltage than that of a generator, and this usually leads to earlier breakdown of the equipment under test. Current and voltage readings are taken with a meter equipped with mechanical stops; these may be preset just below anticipated values, thereby minimizing errors due to inertia of the instrument movement. (*Science Abstracts*)

No. 1506. D. B. Corbyn, "Economical Interlock and Indication Circuits, *Electronic Engg.*, Vol. 23, June, 1951, p. 225.

Describes control of interconnected electrical equipments by double-pole switches such that supply is cut off if the switches of each individual equipment are not all set in a given way. A method of achieving the same end by use of 2-way, single-pole switches is given, and extension of the principle to interlock 4 positions with a single-pole, 4-way switch is illustrated, as is the interlocking of 3 positions using rectifiers. (*Science Abstracts*)

No. 1507. A. A. Gorev, V. V. Kaplan, and V. M. Nashatyr, "Dual-Frequency Oscillation Circuit for Testing High-capacity H. V. Circuit Breakers for Breaking Capacity," *Elektrichestvo*, No. 6, June, 1951, pp. 5–12, (In Russian.)

Development work over 15 years in the Leningrad Polytechnical Institute resulted in the design of a dual-frequency oscillation circuit which uses a powerful capacitor bank, charged by a rectifier of comparatively low

rating over a long time, instead of an impulse generator. The discharge current is sinusoidal and has a flow decrement which makes it suitable for testing purposes. After arc-quenching, the recovery voltage across the circuit-breaker contacts is simulated by the recharging process of the capacitor battery through one part of the dual-frequency circuit. (*Science Abstracts*)

No. 1508. A. L. Riche, "Your Next Switch Selection Problem," *Prod. Engg.*, Vol. 22, No. 6, June, 1951, pp. 162–167.

No. 1509. H. Manzinger, "The Position of the Development and Behavior in Operation of On-Load Tapping Switches in Regulating Transformers," *Elin-Z.*, Vol. 3, June, 1951, pp. 65–79. (In German.)

A general description of the construction of the apparatus made by the Elin Company, with many illustrations and diagrams. Operating conditions are discussed, with special references to the methods of improving the life of the contacts. (*Science Abstracts*)

No. 1510. D. L. Pettit, "An Electronic Power Source for Large D-C. Contact Testing," *Elec. Engg.*, Vol. 70, No. 6, June, 1951, pp. 530–532.

A scheme for providing power electronically for large d-c. contact testing has been devised. This power source provides characteristics which are quite acceptable for testing up to 10,000 amp. at 250 v. It is less expensive than rotating equipment, has a voltage range from 250 to 750 v., and takes less space than rotating equipment. (*Battelle Library Review*)

No. 1511. R. C. Van Sickle and A. W. Funkhouser, "Tests Show Restrikes in Capacitor Switching," *Elec. World*, Vol. 136, July 2, 1951, pp. 74–77.

Oscillographic tests on a 34.5-kv., 3-phase, 7.29-mva. capacitor bank controlled by a standard 34.5-kv. circuit breaker are described. On deenergizing, the arc restruck (reestablishing current after about $1/4$ cycle current pause) in some cases with dangerous overvoltages on the system. The de-ion grid circuit breaker was modified by adding a spring-controlled piston to force oil into the arc space, thus giving satisfactory interruption at low currents. Further tests and subsequent operating experience showed the device to be effective. (*Science Abstracts*)

No. 1512. "The Suitability of Reyrolle Open-Type Circuit-Breakers for Three-Phase, High-Speed Auto-Reclosing," *Reyrolle Rev. Repr.*, No. 54, 12 pp. (Received July 5, 1951.)

Outlines practical requirements both for oil-break and air-blast circuit breakers. Two distinct types of auto-reclosing are involved, namely, with a definite time-lag and a mechanical time delay. The question of reclosing more than once is also dealt with. At the present time there is little demand for it, and it is only applicable to pneumatically operated gear. (*Science Abstracts*)

No. 1513. L. H. Germer, "Arcing at Electrical Contacts on Closure. I. Dependence upon Surface Conditions and Circuit Parameters," *J. App. Phys.*, Vol. 22, July, 1951, pp. 955–964.

In a l-v. circuit the occurrence of an arc between approaching electrodes is dependent upon the nature of the surfaces and upon the circuit inductance. For C surfaces, or noble metal surfaces which have been "activated" by operation in various organic vapors resulting in a carbonaceous layer, the limiting circuit inductance is somewhat above 10^{-8} H which is much higher than the limiting inductance for clean, noble metal surfaces. This activation by organic vapors occurs for noble metals only and for certain vapors, for example, benzene derivatives. In the case of Ag and benzene vapor, it has been shown that the activation is due to adsorption of benzene onto a greasy-surface layer and its decomposition there by the heat of subsequent closures. A metal surface, which has been activated by organic vapor, remains active indefinitely if there is no arcing at the surfaces; but with continued operation and accompanying arcing, the activating material is burned away, and the surface returns to the inactive condition if no activating vapor is supplied. Arc voltages, which are independent of current and of ambient gas, as far as tested, have been measured for a number of metals and for C; the arc voltage for C is quite erratic in the range between 20 and 30 v., but for each of a number of metals the arc voltage is steady. Arcing at noble metal surfaces, similar to that induced by carbonaceous material from organic vapors, can be produced also by insulating particles or insulating films. The active condition gradually disappears with continued arcing; there is a steady supply of insulating material to the surface. The minimum arc current has been measured to be 0.6 A for active Ag and for C, and 0.03 A for inactive Ag. These are the currents at which an established arc is extinguished. (*Science Abstracts*)

No. 1514. A. W. Funkhouser, R. C. Van Sickle, and D. F. Shankle," Switching High-Voltage Shunt Capacitor Banks," *Elec. Engg.*, Vol. 70, July, 1951, p. 596. (Digest of A.I.E.E. Paper 51–18 to be published in Trans. 70 (1951).)

Constructional details are given of a 34.5-kv., 7290-kva. capacitor and the results of switching tests on associated circuit breakers. From analysis of the oscillograms reproduced, it is concluded that such banks can be switched without exceeding 2.5 × normal

phase earth voltage on the busbar. In special cases circuit breakers can be equipped with special interrupters which reduce the overvoltage. (*Science Abstracts*)

No. 1515. H. W. Kretsch and F. J. Walker, "Speed-Controlled Switch," *Electronics*, Vol. 24, July, 1951, pp. 112–113.

A standard type of a-c. tachometer can make and break contacts when a predetermined speed has been reached without materially affecting the tachometer load. The tachometer output is taken to a transformer with two secondary windings. One feeds the grid circuit of a thyratron through a Wien bridge tuned to the selected frequency, and the other the thyratron anode circuit through a relay. From a mains transformer, heater current and negative d-c. bias are supplied to the thyratron, the bias preventing the thyratron from firing unless voltages of the correct amplitude and phase from the bridge are superimposed. An increase in speed increases the grid voltage and advances its phase, so firing the thyratron. Decreased speed also causes the grid voltage to rise, but now the phase is retarded and the thyratron does not fire. Line-voltage variations do not affect the operating point and by making one resistance in the bridge of copper, the influence of temperature changes are eliminated. A 10 per cent fluctuation in tachometer voltages causes a 1.2 per cent shift in the operating point. The whole unit is hermetically sealed for use in aircraft. (*Science Abstracts*)

No. 1516. N. N. Krachkovskil, "Some Problems of the Switching Circuit of H. V. Systems," *Elektrichestvo*, No. 7, July, 1951, pp. 25–28. (In Russian.)

The switching circuit of the step-down substations connected to single and interconnected transmission lines fed at either end are treated. Possible circuit variants are briefly analyzed with regard to reliability of operation of the substations, of the relay protection, and rapid-reclosing systems; the possibility of automatic control and telecontrol is also considered. Existing methods are criticized and more reliable and economical solutions are suggested. (*Science Abstracts*)

No. 1517. K. K. Schiller, "No-Load Pneumatic Transients in Air-Blast Circuit Breakers," *Engineer*, Vol. 192, August 17, 1951, pp. 200–203.

Theoretical aspects of the processes involved in air flow from the reservoir to the nozzles at the contacts are considered and compared with results of tests on a 1-ph. experimental breaker. The transients include expansion, compression, shock, and reflected waves, and theories developed by Riemann (1860) and later writers such as Rankine are discussed. Applications to practical circuit-breaking conditions are outlined with numerical examples. Some interesting conclusions are drawn. (*Science Abstracts*)

No. 1518. A. E. Anderson, "The Switchgear Divisions Laboratory," *G.E. Rev.*, Vol. 54, August, 1951, pp. 23–28.

This outlines the main sections of this G. E. Company Laboratory which is one of the 25 main laboratories attached to various departments. The nature of switchgear design is such that more than half of the personnel has been educated in nonelectrical fields such as mechanics, physics, chemistry, and metallurgy. The purposes, facilities, and functions of each section are discussed with examples of coordination through committees with other lahoratories. Attention is paid to product improvement, research on basic principles, field test equipment, and checking of raw material and manufacturing processes. (*Science Abstracts*)

No. 1519. L. H. Germer, "Arcing at Electrical Contacts on Closure. II. The Initiation of an Arc," *J. App. Phys.*, Vol. 22 September, 1951, pp. 1133–1139.

For Pt. I, see Abstr. 3290 (1951). The capacitance of the plates of an oscilloscope charged to 35 or 40 v. is discharged repeatedly by approaching electrodes of carbon, active silver, and inactive silver. Facts about the discharges, which are arcs of very short duration, are inferred from resulting open-circuit potentials and calculated electrode separations. The separation at the first arc varies in different experiments but corresponds on the average to a nominal electric field of 0.6×10^6 v. per cm. for carbon or active silver and to 2×10^6 v. per cm. for inactive silver. Each arc is initiated by a very small number of field emission electrons. The hypothesis that a single electron may perhaps be sufficient is consistent with observations at later stages of each closure when the electrodes are closer and the field much higher. The earlier observation, that the potential across a short arc is constant and independent of current, is not true if the arc time is sufficiently short. For active silver a time comparable with 2×10^{-8} sec. is required to establish the steady arc voltage characteristic of later stages of arcs which last longer than this. The initial time during which the potential is decreasing toward its final steady value is 100 × the transit time of a silver ion across the gap. (*Science Abstracts*)

No. 1520. G. Schrag and H. Steinert, "Observations on Liquid Contact Bridges. Part II," *Zeits. f. Metallkunde*, Vol. 42, p. 24 (1951).

No. 1521. G. Schrag and Rudolf Toberer, "Observations on liquid contact bridges. Part III," *Zeits. f. Metallkunde*, Vol. 42, No. 8, pp. 243–245 (1951).

No. 1522. V. E. James, "Telephone Type Relays, Arc Suppression, and Contacts," *Prod. Engg.*, Vol. 22, No. 2. p. 136 (1951).

No. 1523. F. E. Haworth, "Electrode Reactions in the Glow Discharge," *J. App. Phys.*, Vol. 22, p. 606 (1951).

No. 1524. L. Gosland and J. S. Vosper, "Rates of Rise of Restriking Voltage at Circuit-Breaker Positions on 66-kv. Systems, (Systems D, E, F, G, H, and K)," Rep. Brit. Elect. Allied Indus. Res. Ass., Ref. G/T252, 14 pp. (1951).

See Abstr. 3294–5 (1951). The present report gives details of the restriking voltage characteristics of the six remaining systems in the restriking voltage survey on 66-kv. systems in Great Britain. Each system is treated separately to conform with the earlier reports in the series, and the descriptions and circuit diagrams of the systems are included. (*Science Abstracts*)

No. 1525. L. Gosland and J. S. Vosper, "Rates of Rise of Restriking Voltage at Circuit-Breaker Positions on 66-kv. Systems (System C)," Rep. Brit. Elec. Allied Indus. Res. Ass., Ref. G/T236, 8 pp. (1951).

See previous Abstract. The results were obtained experimentally on a model network arranged to represent the most severe conditions which can arise at each circuit-breaker location. They relate to the interruption of fault current when all feeders on the system other than those constituting a link between the fault and generating plant have been disconnected. The condition considered is that of the first phase to clear of a 3-ph. fault not to earth on the assumption that the power frequency peak recovery voltage is 1.5 ($\sqrt{2}$ line voltage)/$\sqrt{3}$. (*Science Abstracts*)

No. 1526. L. Gosland and H. Goldenberg, "Rates of Rise of Restriking Voltage at Circuit-Breaker Positions on 66-kv. Systems (System B)," Rep. Brit. Elec. Allied Indus. Res. Ass., Ref. G/T235, 5 pp. (1951).

Report G/T227 (Abstr. 644 (1950)) gave the results of calculations of rate of rise of restriking voltage for most of the circuit breakers on a 66-kv. system. The present report gives similar data for a second 66-kv. system. (*Science Abstracts*)

No. 1527. H. Goldenberg, "The Maximum Energy Dissipated During First Current Loops of Different Asymmetry on Closing an A-C. Series Circuit," Rep. Brit. Elec. Allied Indus. Res. Ass., Ref. G/T250, 9 pp. (1951).

It is required to find the maximum energy dissipated in a resistance, in the first current loop, in a series circuit containing any values of fixed resistance and inductance, in which the point of commencement of current flow can be varied anywhere within a half cycle of the applied sinusoidal voltage, the source of which is assumed to have negligible impedance. A useful picture of the phenomena involved is obtained from the initial consideration of the envelope of the instantaneous power in the resistance for varying circuit parameters and varying instants of closure of the circuit. (*Science Abstracts*)

No. 1528. R. K. Beggs, "Powder Metals in Electrical Contacts," *J. of Metals*, Vol. 3, p. 860 (1951).

Various Pt metals mentioned. Special mention of Pt-W for spark-plug electrodes.

No. 1529. T. H. Bloodworth, "Designing an Air Break Contactor for High-Voltage Service," *Elec. Mfg.*, Vol. 46, No. 1, pp. 92–97, 194–196 (1951).

No. 1530. W. B. Kouwenhoven and W. T. Sackett, Jr, "Contact Resistance—the Contribution of Nonuniform Current Flow," *Trans.*, A.I.E.E., Vol. 70, 5 pp. (1951). (Preprint.)

No. 1531. Frank E. Reeves, "Making Electrical Contacts Stand Up in Control Service," *Elec. Mfg.*, Vol. 47, No. 1, p. 102 (1951).

No. 1532. Frank E. Martin and Henry E. Stauss, "Contact Transients in Simple Electric Circuits," *Trans.*, A.I.E.E., Vol. 70, 4 pp. + 2 pp. Disc. (1951). (Preprint.)

The proper functioning of electric contacts is of great importance. Much work has been done on contacts, but comparatively little has been done on types of transient phenomena occurring at circuit break in inductive d-c. circuits and their relation to contact erosion. Some work was done on transient types occurring at circuit break in telephone relay circuits by A. M. Curtis and his associates at the Bell Telephone Laboratories. This study dealt with transients in d-c. circuits, including the fixed inductance of a relay winding and the small distributed capacity of a line wire, and embodied a study of the effect on the transient phenomena of changing the length of the line wire. The present investigation covered the variation of transients occurring for a fixed contact pair over a range of lumped inductance and lumped capacity values in a contact circuit; in addition, effects of the transients of varying the steady-state current (by steady-state current is meant the current immediately preceding circuit break), the voltage impressed on the circuit, and the circuit resistance were studied. (*Battelle Library Review*)

No. 1533. A. H. Baguhn and G. W. Lengnick, "A Million Breaks," Allis Chalmers Review, Vol. 16, No. 3, Third Quarter, pp. 14–16 (1951).

Design considerations involved in the use of silver tungsten contacts are presented in the

application of these materials to circuit breakers, tap-changers, and other high-voltage, high-power uses.

No. 1534. A. M. Cassie and A. A. Hudson, "Gas-Blast Circuit Breakers. Aerodynamic Conditions in Nozzle as Affected by Arcing and Nozzle Diameter," Rep. Brit. Elect. Allied Indus. Res. Ass., Ref. G/T234, 19 pp. (1951).

The influence of the arc upon the mass of air flowing through the nozzle has been examined for a range of currents from 1500–7500 A rms. and of nozzle diameters from 1.0 to 2.5 cm. It is found that, for the above ranges of current (I) and nozzle diameter (d), the ratio of apparent mass-flow during the whole arcing period to the mass-flow during the same period with no arc present is a function of $I/d^{1.4}$. (*Science Abstracts*)

No. 1535. J. D. Cobine and C. J. Gallagher, "New Electrodes for Stabilizing Inert-Gas Welding Arcs," *Trans.*, A.I.E.E., Vol. 70, 3 pp. (1951). (Preprint.)

No. 1536. Wolfgang Finkelnburg, "The Physical Mechanism of Low- and High-Current Arcs, and Their Relation to the Welding Arc," *Trans.*, A.I.E.E., Vol. 70; 4 pp. (1951). (Preprint.)

No. 1537. G. Schmitz and W. Hecker, "Concerning the Numerical Calculation of Temperature Distributions in Wall-Stabilized Arc Discharges," *Zeits. f. Phys.*, Vol. 129, No. 1, pp. 104–107 (1951) (In German.)

Describes a new treatment of the Elenbaas-Heller differential equation describing the equilibrium condition of an arc column. The graphical integration of the equation is simplified, and the value of the new method is illustrated with an example. (*Science Abstracts*)

No. 1538. A. Stern, "On the Theory of A-C. Circuits for Arc Lamps," *Z. angew. Math. Phys.*, Vol. 2, No. 1, pp. 43–49, (1951) (In German.)

The paper describes a theoretical treatment, more complete than those previously published, of the behavior of p.f.-corrected lamp circuits, including such studies as the variation of circuit current with time. (*Science Abstracts*)

No. 1539. G. Schmitz and O. Koch, "Final Remarks on the Paper of G. Schmitz—On the Breadth of the Wall Stabilized Arc Discharge—and on the Discussion Following It," *Z. Phys.*, Vol. 129, No. 1, p. 33 (1951). (In German.)

See Abstract 6524 (1950). A short note referring to various papers (9 in number) on the structure of arc columns and the views expressed therein. (*Science Abstracts*)

No. 1540. H. Leyburn and C.H.W. Lackey, "The Protection of Electrical Power Systems: a Critical Review of Present Day Practice and Recent Progress," A.I.E.E., Paper 1135, 13 pp. (early proof issue.)

The paper deals with the protection of generators, power transformers, feeders, and busbars, and with the characteristics of protective transformers. Some new important developments are described, namely, an instantaneous differential protective system for power transformers, a high resistance pilot wire scheme, a starting scheme for carrier protection, and a biased differential system of busbar zone protection. The performance requirements of protective transformers are briefly examined. (*Science Abstracts*)

No. 1541. H. L. Lowe and R. L. Hodgkins, "Centralized Control Board for Steam-Electric Generating Plants," *Trans.*, A.I.E.E., Vol. 69, Part II, pp. 1296–1400 (1951).

Centralized control of boilers, turbines, and generators is usually accomplished by grouping their several control boards in a specific area. An improved arrangement, using specially designed control panels, is installed at Morgan Creek power station and enables all important operations to be controlled by one man. Only essential indications are provided, and a 50 per cent saving of control space is claimed. Low-pressure compressed air is used as the transmitting medium from full-sized meters on the plant to miniature indicators on the control panel. Morgan Creek comprises two 20-mw. units. Each 13.2-kv., hydrogen-cooled, 3600-rpm turbo-generator is supplied at 850 lb. per sq. in., 900 F. by a 220,000 lb. per hr. gas- or oil-fired boiler. (*Science Abstracts*)

No. 1542. "132- to 400-kv., Outdoor, Air-Blast Circuit Breakers," *Engineering*, Vol. 171, January 26, 1951, pp. 89–90.

The range of circuit breakers described covers breaking capacities from 2500 to 10,000 mva. and was developed by the English Electric Co. from a design used for 66 kv., 1500 mva. The main features are tabulated and illustrated. Particulars of power make and break tests on one pole of a 7500-mva, 275-kv. circuit breaker are also given. A general account of the means for operating the gear and of compressed air arrangements is included. (*Science Abstracts*)