PANEL DISCUSSION ON PYROMETRIC PRACTICE IN ELEVATED-TEMPERATURE TESTING

INTRODUCTION

By J. W. Freeman[1]

The American Society for Testing Materials offers three recommended practices for conducting tension tests at elevated temperatures:

The Recommended Practice for Short-Time Elevated-Temperature Tension Tests of Metallic Materials (E 21 – 43)[2] presents approved testing conditions for short-time tension tests where the specimen is heated and the tension test carried out in the same manner as the familiar tension test at room temperature. The data obtained are tensile strength, elongation, and reduction of area; and, if desired, stress-strain data are recorded from which can be obtained offset-yield strengths, proportional limit, and modulus values.

The Recommended Practice for Conducting Long-Time High-Temperature Tension Tests of Metallic Materials (E 22 – 41)[3] describes conditions of testing for obtaining creep data at elevated temperatures. It was written to cover test conditions for measuring the continued plastic deformation with time arising from creep. Time periods of the order of 1000 hr for the tests were a controlling factor in the way the practice was written. In general, it can be considered to cover prolonged tests in which fracture does not occur and the total strains during the tests are relatively small, frequently being 1 per cent or less. It is the test used to establish the familiar "creep strengths" for rates of 0.0001 per cent per hr (0.1 per cent per 1000 hr) and 0.00001 per cent per hr (0.01 per cent per 1000 hr). These are the two creep strengths often referred to as the stresses for 1 per cent creep in 10,000 hr and 1 per cent creep in 100,000 hr, respectively.

The Tentative Recommended Practice for Conducting Time-for-Rupture Tension Tests of Metallic Materials (E 85 – 50 T)[4] covers the familiar stress-rupture test in which the primary measurement is the time for rupture by creep during constant load tests at elevated temperatures. Creep data are often taken during rupture tests, although the creep rates are almost inherently made faster due to the use of higher stresses than those of the E 22 – 41 creep tests in order to obtain fracture.

These recommended practices are under the jurisdiction of the Joint ASTM-ASME Committee on the Effect of Temperature on the Properties of Metals. At the time the recommended practice for rupture tests, E 85 – 50 T, was prepared, considerable disagreement arose over the permissible variation in

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[2] 1955 Book of ASTM Standards, Part 1, p. 1605.

[3] *Ibid.*, p. 1612.

[4] *Ibid.*, p. 1685.

temperature of test specimens in the test. In order to obtain sufficient agreement for the acceptance of E 85 – 50 T, it was necessary to recommend temperature limits which have been widely interpreted as wider than those of E 22 – 41. An examination of the three recommended practices indicates that two features of specimen temperature are covered:

1. Temperature variation along the gage length of the specimen.
2. Variation from the nominal test temperature during the test.

These can be summarized as follows:

Recommended Practice	Permissible Temperature Variation Along Gage Length	Variation in Nominal Test Temperature During Tests
E 21 – 43 (Tension Tests)[a]	±10 F up to and including 1600 F ±20 F above 1600 F	Keep less than ±10 F during test
E 22 – 41 (Creep Tests)	±3 F up to and including 1200 F ±5 F from 1200 to 1600 F ±10 F above 1600 F	Keep as small as possible and report the variation
E 85 – 50 T (Rupture Tests)	±5 F up to 1200 F ±10 F at 1200 F and higher temperatures (Both apply initially and during the test)	±5 F up to 1200 F ±10 F at 1200 F and higher temperatures (Adjust no more often than every 24 hr)

[a] Also specifies equipment for measuring temperatures which is accurate to within the following permissible variations for the temperatures shown: ±3 F up to and including 1200 F; ±5 F from 1200 to 1600 F; and ±10 F over 1600 F.

The limits specified in E 85 – 50 T could be considered considerably more strict than those in E 22 – 41 in that specific requirements are placed on the variation from the nominal test temperature.

At the time E 85 – 50 T was submitted, there was considerable disagreement regarding the limits of temperature variation. One group favored extending the limits of E 22 – 41 for variation along the gage length and using the same limits for variation from the nominal test temperature. The predominant group felt that these limits were impractically strict so long as the nominal temperatures were considered to be the true temperatures of the specimens. In fact, it appeared that adoption of temperature limits on that basis would render obsolete a large percentage of the rupture-testing equipment in this country.

In general, the disagreement over temperature limits was not based on "indicated" temperatures. There was, however, disagreement over pyrometry practices and inherent ability to measure true metal temperatures within the limits of E 22 – 41. The errors introduced by thermocouple calibrations, methods of using thermocouples to measure temperatures, maintenance of calibration of thermocouples during tests, kinds of thermocouples, and instrument errors certainly raised serious questions regarding practicality of the limits of E 22 – 41. The subgroup which had charge of writing E 85 – 50 T investigated possible errors and had to concur that the usual practices in laboratories conducting rupture and creep tests would probably not assure true metal temperatures as close as those required for variation along the gage length of specimens under E 22 – 41. For this reason, a strong recommendation was made to have the pyrometry of elevated temperature testing reviewed and definite procedures outlined to minimize errors as well as to make clear the uncertainties of temperature measurements in the tests. The author has felt that a good deal of the criticisms of E 85 - 50 T temperature limits was due to misunderstanding of whether actual true temperatures, or indicated temperatures, were involved. The temperatures specified in E 85 - 50 T are "true metal temperatures." It is suspected that when E 21 - 43 and E 22 - 41 were written "indicated temperatures" obtained with good pyrometric practices were those set forth.

The continuing criticism of E 85 - 50 T was referred to the Test Methods Panel of the Joint ASTM-ASME Committee on the Effect of Temperature on the Properties of Metals. This Panel Session is a step in the direction of resolving the matter to everyone's satisfaction. It is hoped that information will be provided which will clarify the issues and provide a working basis for bringing the recommended practices in this field into agreement.

Speaking as an individual who acted as chairman of the group which prepared E 85 - 50 T, the following comments are offered:

1. There has been no deterioration of pyrometry practices in creep and rupture testing since E 21 - 43 and E 22 - 41 were written. If anything the contrary is true.

2. If tests are conducted under E 85 - 50 T to wider temperature control limits than under E 22 - 41, it is because individuals have chosen to apply the limits to indicated temperatures. It seems self evident that, to maintain "true temperature" limits as close as those indicated in E 85 - 50 T, indicated temperatures would have to be at least as close as those of E 22 - 41.

3. There is no technical reason why the temperature limits should differ in E 21 - 43, E 22 - 41, or E 85 - 50 T.

4. Pyrometry practice would have to be clearly understood, well established, and rigidly applied to meet E 22 - 41 limits applied both to temperature variation along the gage length and variation from the nominal test temperature. Before such limits can be placed in the recommended practices, a suitable pyrometric practice will probably have to be written.

The reasons for this concern over the temperature limits should be understood. Properties of metallic materials are highly temperature dependent. As long as properties are evaluated in terms of a specific constant temperature, it will be highly desirable to keep the temperatures at the specific values. It becomes acute where such extremely sensitive values as time-for-rupture, creep rate, or time for a specific total deformation under a specific stress are involved. This has been an increasing problem as acceptance testing based on such values has become more and more a part of materials specifications. Most such materials specifications prefer to specify the ASTM recommended practices for test procedure requirements. There are materials for which such specifications have been written where a total possible range from 10 F below to 10 F above the nominal temperature certainly raises questions. The research man likes to have the temperature limits closely controlled so that published data can be relied upon for his purposes. This is very commendable since the accumulation of such data is so slow and expensive. It should be emphasized that all of those conducting tests should use every effort to keep data as free from temperature uncertainties as possible.

Two sets of stress-rupture - time curves were reviewed for possible effects of temperature variation under the temperature limits under discussion. The following data are offered for consideration:

Alloy	Temperature, deg Fahr	Stress, psi	Rupture Time, hr	Stress for Rupture in 100 hr, psi
A 286	1190	60 000	200	63 000
	1195	60 000	120	...
	1200	60 000	100	60 000
	1205	60 000	85	...
	1210	60 000	75	58 000
S816	1490	24 500	225	25 700
	1495	24 500	130	...
	1500	24 500	100	24 500
	1505	24 500	82	...
	1510	24 500	70	23 250

These variations indicate the magnitude of the effects of temperature variation for two alloys. There are other alloys, as well as other conditions of testing temperature, stress, and time, where the ranges may be more or less.

Such effects of temperature probably are within the reproducibility between heats for high-temperature properties of alloys. Our experience at the University of Michigan indicates no difficulty in keeping reproducibility in rupture times within 90 to 120 hr under the nominal stress for rupture in 100 hr for uniform material. It is, however, difficult to obtain material this uniform from specimen to specimen. Considerable care has to be taken to prepare material with this degree of reproducibility. It seems safe to observe that metallurgical variables are generally more influential than temperature variations when an attempt is made to measure and keep true temperatures within the limits of E 85 – 50 T.