Appendix

Acronyms for Organizations and the Terms Related to Lubricants, Lubrication, and Tribology [667]

AAM—Alliance of Automobile Manufacturers.

AAMA—American Automobile Manufacturer Association.

ACC—American Chemistry Council.

Abrasion (Abrasive Wear)—A process in which hard particles or surface roughness (protuberances) are forced against and moving along a solid surface causing displacement of material. Also, see Abrasive Erosion.

Abrasive Erosion—Erosive wear caused by the relative motion of solid particles which are entrained in a fluid, moving nearly parallel to a solid surface.

ACEA—Association des Constructeurs Européens de l'Automobile (Association of European Automotive Manufacturers.

Acidity—The amount of free acid in any substance.

Acid Number—A measure of the amount of potassium hydroxide (KOH) needed to neutralize all or part of the acidity in a petroleum product.

ACS—American Chemical Society.

Additive—In lubrication, a material added to a base stock for the purpose of imparting new properties or of enhancing its existing properties. Major classes of additives include dispersants, detergents, oxidation inhibitors, viscosity modifiers, and antiwear/extreme pressure agents.

Additive Treat Level—The total percentage of all additives in a lubricating oil or grease.

Adherence—Physical attachment, either by adhesion or by other means, of a material to a surface.

Adhesion—Attraction or joining of two materials. The strength of adhesion is reflected by the force or forces necessary to separate them. In frictional contacts, adhesion is the attractive force between adjacent surfaces. In physical chemistry, it is the attraction between a solid surface, such as metal and a second liquid or solid phase, such as lubricating grease. In some instances, adhesion is reversible but in others, it is irreversible. When adhesion is solely due to interlocking of the asperities, it is called mechanical adhesion.

Adhesive Wear—Wear caused by the transfer of material from one surface to another during movement (tearing) of the solid-phase welded surfaces. Welding occurs due to frictional heat resulting from metal-to-metal contact. The particles removed from one surface are either permanently or temporarily attached to the other surface.

AF,AFR—Air/Fuel Ratio.

AFNOR—Association Française de Normalisation.

AFV—Alternative Fuel Vehicle.

Age Hardening—An increase in consistency (hardening) of greases over time. Also see Thixotropy.

AGELFI—Co-operative Research Organisation of the oil companies AGIP, ELF and FINA.

AGMA—American Gear Manufacturers' Association.

AGO—Automotive Gas Oil.

AHEM—Association of Hydraulic Equipment Manufacturers.

Air Entrainment—Incorporation of air in the form of bubbles as a dispersed phase in the bulk liquid. Air entrainment may be because of the mechanics of the system or by the release of the dissolved air due to a sudden change in environment, or both. Appearance of a liquid, such as being bubbly, opaque, etc., is an indication of air entrainment. It is important to note that the dissolved air can only be determined by analysis.

Alkali—While chemically any substance with basic properties (alkaline) is considered an alkali, the term usually implies hydroxides of ammonium, lithium, potassium, and sodium. The last three are members of the class of alkali metals. These substances are water soluble and have the ability to neutralize acids. The term is also extended to the hydroxides of the alkaline earth metals, such as magnesium, calcium, barium, and strontium.

Alkylaromatics (Alkylbenzene and Alkylnaphthalene)—These additives, made by the alkylation of benzene and naphthalene, are used as base fluids as well as sulfonated to sulfonic acids to make detergent additives.

Alkylbenzenesulfonic and Alkylnaphthalenesulfonic Acids—These are used to make detergent additives by their reaction with an alkali metal or an alkaline earth metal base, with or without carbon dioxide.

Alkylphenol—Product of alkylation of phenol. Some alkylphenols, such as 2,6-di-*t*-butylphenol and its derivatives are used as oxidation inhibitors in lubricants. Others, such as dodecylphenol, are converted into metal salts, called phenates, for use as detergent additives.

Alkylsalicylic Acid—Made from alkylphenol by base catalyzed carbonation. Used as a starting material for making alkaline earth metal salicylate detergents for use in engine oils.

Almen EP Lubricant Tester—A journal bearing machine used for determining load-carrying capacity or extreme pressure properties of the gear lubricants, or both.

ALTENER—Alternative Energy Programme of the European Commission.

AMT—Automated Manual Transmission.

ANFAVEA—Auto Manufacturers Association (Brazil).

Anhydrous—Free of water. Term is often used to describe lubricating grease.

Aniline Point—The lowest temperature at which equal volumes of aniline and a hydrocarbon liquid (fuel or lubricant base stock) are completely miscible. A lower aniline point is a measure of high aromatic content of the liquid. Aniline point is used to assess solvency of a base stock or the cetane number of distillate diesel fuel. A product of high aniline point will be low in aromatics and naphthenes and, therefore, high in paraffins. In conjunction with API gravity, the aniline point may also be used to calculate the net heat of combustion of aviation fuels.

ANSI—American National Standards Institute.

Anticorrosion Additive—See Corrosion Inhibitor.

Antifoam Agent/Additive—See Foam Inhibitor.

Antifriction Bearing—A type of bearing that employs

rollers or balls. They are also called rolling element bearings. These may or may not contain a solid lubricant.

Antifriction Material—Material that exhibits low-friction or self-lubricating properties.

Antiknock—Resistance to detonation or pinging in spark-ignition engines.

Antioxidant—See Oxidation Inhibitor.

Antiscuffing Lubricant—Lubricant that is formulated to avoid scuffing, a type of wear damage. A more descriptive name is extreme-pressure lubricant.

Antiseizure Property—Ability of a bearing material to resist seizure during momentary lubrication failure.

Antistatic Additive—Additive that increases the conductivity of a hydrocarbon fuel to quickly dissipate electrostatic charge during fast dispensing, thereby reducing the fire/explosion hazard.

Antiwear Additive—Lubricant additive used to reduce wear. Additives or their reaction products form thin, tenacious chemical films on highly loaded parts to separate the potentially contacting surfaces.

Antiwear Agents—See Antiwear Additive.

Antiwear Number (AWN)—A variant of the wear coefficient (k). $AWN = -\log_{10} k$

Anti-weld Characteristic—See Antiseizure Property.

APE—Association of Petroleum Engineers (USA).

API—American Petroleum Institute.

API Engine Service Classification System—Classifications and designations for automotive engine oils developed by API in conjunction with SAE and ASTM.

API Gravity (API Degree)—Measure of density used in the U.S. petroleum industry where: API° =[(141.5/Specific Gravity at 60 °F)] – 131.5.

API Oil Group—Classification of base fluids, both petroleum-derived and synthetic, based on VI and sulfur content, for use in formulating lubricants.

Apparent Area of Contact—Area of contact between two solid surfaces defined by the boundaries of their macroscopic interface.

Apparent Viscosity—Ratio of shear stress to shear rate of a non-Newtonian fluid, for example, thickened lubricants, such as viscosity modified oils and greases. In greases, the apparent viscosity depends on shear rate and temperature. Hence, both these parameters must be specified while reporting apparent viscosity.

Appearance/Bulk Appearance—General term relating to characteristics that are observable by visual inspection. It is usually reported for greases as bloom, color, luster, and texture. Bulk appearance determination involves an examination of the grease surface in an undisturbed state and is expressed as *bleeding, cracked, grainy, rough, smooth, bright, dull, etc*.

1. Bleeding, if there is free oil on the surface.
2. Cracked, if there are surface cracks.
3. Grainy, if the surface contains granules or lumps.
4. Rough, if the surface shows irregularities.
5. Smooth, if surface is free of irregularities.
6. Bright, if it reflects light with a relatively strong intensity.
7. Dull, if it reflects light with a relatively weak intensity. A high water content or certain thickeners and fillers may impart lubricating grease dull luster.

Aromatic—Derived from, or characterized by, the presence of a benzene ring.

Arylsulfonic Acid—Also see Alkylbenzenesulfonic Acid and Alkylnaphthalenesulfonic Acid. Alkylbenzene sulfonic acids can be natural or synthetic in origin. Natural sulfonic acids are obtained as by-products during base oil manufacture. Synthetic sulfonic acids are obtained from alkylation of benzene.

ASEAN—Association of South-East Asian Nations.

Ash—Metal-derived deposits formed in the combustion chamber and other engine parts during high-temperature operation.

Ash Content—Residue in weight percent left after combustion of a sample of a petroleum product.

ASLE—American Society of Lubrication Engineers, Now called Society of Tribologist and Lubrication Engineers (STLE).

ASM—American Society of Metals.

ASME—American Society of Mechanical Engineers.

Asperities—Small irregularities on a solid surface. Shape, size, and mechanical properties of asperities are the basis for developing many theoretical models for friction, lubrication, and wear.

Asphalt—Black to dark-brown solid or semi-solid material left during petroleum refining after removal of fuels and lubricant base stocks. Bitumens are the primary constituents of asphalt.

Asphaltic—Materials that are largely composed of or are similar to asphalt. Term is often used to describe lubricating oils derived from crude oils which contain asphalt.

ASTM—International (formerly American Society for Testing and Materials), whose D2 Committee deals with Petroleum Products and Lubricants.

ASTM Colorimeter—Apparatus widely used for determining the color of lubricating oil (ASTM Method D1500). The color so determined is known as ASTM Color.

ASTM Viscosity-Temperature Equation—Relates kinematic viscosity (v) with temperature.

ATC—Technical Committee of Petroleum Additives Manufacturers (Europe).

ATEIL—Association Technique de l'Industrie Européennes des Lubrifiants.

ATF—Automatic Transmission Fluid.

Auto-ignition—Spontaneous ignition and the resulting rapid reaction of a portion or all of the fuel-air mixture in an engine. The flame speed is many times greater than that of normal spark ignition. The noise associated with it is called knock.

Automatic Transmission Fluid (ATF)—Lubricant/hydraulic fluid used in automotive transmissions.

Bactericide—See Biocide.

Base—Compound that reacts with acids to form salts and water. Alkalis are water-soluble bases that are used in petroleum refining to remove acidic impurities. Oil soluble bases are used as lubricant additives to neutralize acids formed during the combustion and oxidation of the lubricant.

Base Number—Amount of acid (perchloric or hydrochloric) needed to neutralize part or all of a lubricant's basicity. When the acid in a sample is completely neutralized, the base number is called the total base number (TBN). Base

number is usually expressed as mg KOH/g of sample, the same as the acid number.

Base Stock—Base fluid, usually a refined petroleum fraction or a selected synthetic material, into which additives are blended to produce finished lubricants. Base stock comprises major portion of the lubricant.

Basic Sulfonate—See Overbased Sulfonate.

Batch—Quantity of material handled or considered as a unit in processing.

Bath Lubrication—See flood lubrication.

Bentonite—Mineral montmorillonite, a magnesium-aluminum silicate, which is used as a component of drilling mud and a thickener in greases.

BHRA—British Hydromechanics Research Association.

Bingham Solid—An idealized solid that begins to flow appreciably only when the amount of applied stress exceeds its yield stress. After which the flow rate is proportional to the difference between the applied stress and the yield stress. Many lubricating greases can be considered as Bingham solids.

Biocide—Additive used to inhibit bacterial growth in the water-based hydraulic and metalworking fluids.

Biodegradation—Process of biochemical breakdown or transformation of a substance caused by microorganisms and their enzymes.

BIS—Bureau of Indian Standards.

Bitumen—Also called asphalt or tar, bitumen is the brown or black viscous residue left after the vacuum distillation of crude petroleum. It consists of high molecular weight hydrocarbons and minor amounts of sulfur and nitrogen compounds.

Black Oils—Lubricants that contain asphaltic materials, which improve adhesion and hence they are used to lubricate open gear systems and steel cables.

Bleeding—Oil released on the surface of a lubricating grease when it is not in service.

Blending—Process of mixing various lubricant base stocks to obtain base oils/fluids of desired physical properties.

BLF—British Lubricants Federation.

Block Grease—Lubricating grease that is sufficiently hard to maintain its shape in block or stick form.

Bloom—Typical blue or green surface color of a grease when viewed by reflected daylight. The color is associated with the absorption of the ultraviolet light in the oil and is not always visible when the sample is viewed by artificial light.

Bloom Fluorescence—Different color of an oil in reflected light than in transmitted light. For some applications, oils with yellowish-green bloom are preferred over those with bluish-green bloom. This demand is met either by special processing or by the use of fluorescent additives.

Blow-by—Unburned and partially burned fuel and combustion gases that travel past the piston rings into the internal combustion engines. This not only results in fuel dilution of the lubricant and its contamination, but also results in extensive oxidation of the oil by the chemically reactive species and free radicals that are present in the blow-by.

Blown Oil—Fatty oil artificially thickened by blown air.

BNP—Bureau de Normalisation des Petroles.

BOCLE—Ball on Cylinder Lubricity Evaluator.

Body—Nonscientific term used to designate viscosity or consistency.

BOI—Base Oil Interchanger.

Boiling Point—Temperature at which a substance experiences a phase change from being liquid to vapor. Boiling point is directly affected by pressure: It increases with an increase in pressure and decreases with a decrease in pressure.

Bonded Film Lubricant—See Bonded Solid Lubricant.

Bonded Solid Lubricant—Solid lubricant dispersed in a continuous matrix of a binder, or attached to a surface by the use of an adhesive material.

Boundary Lubricant—Lubricant that protects metal surfaces against wear under boundary conditions. This type of lubricating environment occurs when the loads are high and speeds are low. Boundary lubricants contain sulfur and phosphorus containing antiwear or extreme pressure (EP) additives that prevent surface wear damage by making resilient chemical surface films. Boundary conditions exist in bearings, gears, and some metalworking operations. Also see Elasto-hydrodynamic Lubrication, Extreme-pressure Lubrication, and Thin-film Lubrication.

Boundary Lubrication—Lubrication environment in which the lubricant film is too thin to effectively separate mutually rubbing surfaces and as a result, contact of surface asperities occurs. Consequently, friction and wear protection are determined by the chemical nature of the lubricant rather than its bulk properties.

Break-in—See running-in.

Break In—Operate a newly installed bearing, seal, or other tribo-component to condition its surface(s) for improved functional operation. The term run in is also used to describe this process.

Bright Stock—Refined, high viscosity lubricating base stock obtained from residual stocks by the use of processes such as acid treatment, solvent extraction, dewaxing, and or clay finishing. These stocks have low pour points, excellent solvency, and superb viscosity-pressure relationship.

Brookfield Viscosity—Apparent viscosity of a non-Newtonian fluid at controlled temperature and shear rate as measured by Brookfield viscometer.

BRT—Ball Rust Test.

BSI—British Standards Institution.

BSN—Bacharah Smoke Number.

BTC—British Technical Council of the Motor & Petroleum Industries (UK National Body in CEC).

BTU—British Thermal Units.

Built-up Edge—Material collected from the machining of a work piece that is collected at the edge of the cutting tool. Also see wedge formation.

Burning—Oxidation of a surface due to local heating in an oxidizing environment that commonly occurs in sliding contacts.

Burnish—Alteration of an originally machined surface to a more polished condition as a consequence of sliding or rolling action.

CAFE—Corporate Average Fuel Economy.

Cam—Eccentric shaft that is used in most internal combustion engines to coordinate opening and closing of the valves.

CARB—California Air Resources Board.

Carbon Residue—Coked material remaining after an oil has been exposed to high temperatures under controlled conditions.

Carboxylate Esters—See Diesters and Polyol Esters.

Catalytic Converter—An integral part of a vehicle's emissions control system. Oxidizing converters remove hydrocarbons and carbon monoxide (CO) from exhaust gases by oxidizing them to carbon dioxide (CO_2) and water, and reducing converters remove nitrogen oxide (NOx) emissions by chemically converting it into nitrogen (N_2) and water. Both use noble metal (platinum, palladium or rhodium) catalysts that can be "poisoned" by the phosphorus compounds present in the lubricant.

Catastrophic Wear—Sudden surface damage, deterioration, or a change of shape caused by wear, to an extent that the life of the part is appreciably shortened or its function is impaired.

Cavitation—Formation of vapor cavities within a liquid and their subsequent collapse caused by movement or vibration within the liquid film. Commonly occurs in greases and hydraulic fluids.

Cavitation Cloud—A collection of a large number of small cavitation bubbles.

Cavitation Damage—See Cavitation Erosion.

Cavitation Erosion—Progressive loss of material from a solid surface due to continuous exposure to cavitation; it is the collapse of the vapor bubbles that lead to high temperatures and local high-impact pressures which cause erosion.

CCD—Combustion Chamber Deposit.

CCMC—Comite des Constructeurs d'Autonobile de Marche Commun (Common Market Automobile Manufactures Association.

CCS—Cold Cranking Simulator.

CEC—Conseil Européens de Coordination pour les Développements des Essais de Performance des Lubrifiants et des Combustibles pour Moteurs (Coordinating European Council), whose test method CEC L-33-A93 (formerly CEC L-33-T82) is widely used to determine primary biodegradation of lubricants.

CEC-EFTC-CEC—Engine Fuels Technical Committee.

CEC-ELTC-CEC—Engine Lubricants Technical Committee.

CEC-TLTC-CEC—Transmission Lubricants Technical Committee.

CEFIC—European Chemical Indusrty Council.

CEN—Conseil Européens de Normalisation.

CentiStoke or centistokes(cSt)—Unit of kinematic viscosity. 1 cSt = 1 mm^2/s.

Cetane Index—Approximate cetane value of a diesel fuel calculated from physical properties, such as API gravity and mid-boiling point.

Cetane Number—Measure of ignition quality of a diesel fuel, as determined in a standard single cylinder test engine which measures ignition delay relative to primary reference fuels. High Cetane Number is associated with easy starting of a high-speed, direct-injection diesel engine and the less "white smoking" and the less "diesel knock" after the start-up. Cetane Number is determined by comparing the candidate diesel performance in the test engine with that of the various composition blends of normal cetane (*n*-cetane) and heptamethylnonane (HMN). Percentage by volume of *n*-cetane in a blend with HMN, which matches ignition quality of the test fuel, is the cetane number. See ASTM Method D613. For reference, normal cetane, a high-ignition fuel, has been assigned an arbitrary number of 100.

Cetane Number Improver—Substance which, when added to a diesel fuel, has the effect of increasing its cetane number. Common types of cetane improvers include nitroalkanes, nitrates, nitrocarbonates, and peroxides. 2-Ethylhexyl nitrate is one of the most often used cetane improver.

CFPP—Cold Filter Pugging Point.

CFR—Coordinating Fuel and Equipment Research Committee, composed of engine manufacturers, petroleum-refiners, petroleum-consumers, universities, government, and other technical people who supervise cooperative testing and study engine fuels for the Coordinating Research Council, Inc.

CGO—Cracked Gas Oil.

Chafing—Repeated rubbing of two solid bodies that can result in surface damage or wear, or both.

Channeling—Term is used in a variety of contexts.

1. Tendency of a grease or viscous oil to form air channels in a bearing or gear system, resulting in an intermittent lubricant film.
2. Grooves in a lubricating grease formed by passing rolling elements. Some gear lubricants and greases when they thicken, due to cold weather or other causes, form a groove or a channel through which the part to be lubricated moves without actually coming in full contact with the lubricant.
3. Low-temperature thickening of a flow-type lubricating grease to prevent uniform flow due to gravity.
4. In percolation filtration, channeling is when flow predominantly occurs only through certain portions of the clay bed.

Chatter—Elastic vibrations resulting from frictional or other instability.

Chemical Conversion Coating—Coating produced by a chemical or an electrochemical treatment of a metallic surface resulting in a superficial layer of compounds of the metal. Such coatings are usually pretreatments onto which fluid or solid lubricants may be applied. However, the coatings may themselves have lubricating properties.

Chemical Wear—See Corrosive Wear.

Chlorinated Lubricant—Lubricant containing a chlorine compound that reacts with the rubbing surfaces at elevated temperatures to form a protective chemical film; thereby preventing wear damage to the surface due to sliding. Also see extreme-pressure lubricant, sulfochlorinated lubricant, and sulfurized lubricant.

CIMAC—International Council on Combustion Engines.

Cloud Point—Temperature at which petroleum oil separates paraffin wax or other solid substances as crystals, imparting a cloudy appearance to the oil when it is chilled under prescribed conditions. Cloud point indicates the tendency of a material to plug filters or small orifices under cold weather conditions.

CIS—Commonwealth of Independent States.

CL (Cleanliness level)—A measure of relative freedom from contaminates.

CLR—Cooperative Lubrication Research.

CMA—Chemical Manufacturers Association.

CNG—Compressed Natural Gas.

CO—Carbon Monoxide.

CO_2—Carbon Dioxide.

Cocoa—Powdery debris resulting from fretting wear, primarily consisting of iron oxides, that is expelled from a ferrous metal joint near the location where fretting wear is occurring.

Coefficient of Adhesion—Ratio of the *normal force* required to separate two bodies to the *normal load* with which they were previously placed together.

Coefficient of Friction—Coefficient of *static* friction is the ratio of the tangential force initiating sliding motion to the load perpendicular to that motion. Coefficient of *kinetic friction* (usually called coefficient of friction) is the ratio of the tangential force sustaining sliding motion at constant velocity to the load perpendicular to that motion. In tribology, the dimensionless ratio of the friction force (F) between two bodies to the normal force (N) pressing these bodies together (Ref. 2): μ or $f = (F/N)$.

Cohesion—Molecular attraction causing particles of a substance to attract each other and stick together. Cohesion contributes to the resistance of a lubricating grease to flow.

Cold Cranking Simulator (CCS)—Intermediate shear rate viscometer that predicts the ability of an oil to assure satisfactory cranking speed in a cold engine.

Colloid—Substances of particle size larger than molecules, but small enough to possess reasonable dispersion stability in two phase systems. For example, lubricating grease is a colloidal system. See also Thickener.

Color—Predominant hue of lubricating grease, could be natural or due to an added dye. Some lubricants are color coded to facilitate identification or recommended use. Examples include transmission fluids, brake fluids, and two-stroke cycle engine oils. Color rating of dye-free oils is carried out by the use of many methods, including the ASTM D1500 procedure, under specified conditions and using specialized equipment. Some oils that are too dark for direct rating are diluted to report color.

Compatibility (Frictional)—Materials that exhibit good sliding behavior, including resistance to adhesive wear. Some materials that are considered metallurgically incompatible, for example, silver and iron, may be frictionally very compatible.

Compatibility (Lubricant)—Measure of the degree to which lubricants or lubricant components can be mixed without phase separation or deterioration in performance.

Compatibility (Metallurgical)—Measure of the extent to which materials are mutually soluble in the solid state.

Complex Grease or Complex Soap Grease—Lubricating grease thickened by a complex soap consisting of a normal soap and a complexing agent. The use of soap complexes yields products which have higher softening points than greases made from normal soaps.

Complex Soap—Soap formed by co-crystallization of two or more compounds. Complex soaps are mixtures of two or more components with structure or structures that improve their oil-retaining ability. More specifically, the dropping point of the resulting greases is effectively increased. Complexing agent used in such soaps is a low molecular weight carboxylic acid, such as acetic acid or lactic acid, or inorganic salts, such as metal carbonate or metal chloride.

Compounding—Process of mixing various additives in base oils/fluids to develop a finished lubricant of desired performance. Certain industrial oils, called compounded oils, contain fatty oils and similar materials which impart these lubricants special properties. While compounding is different from blending, it is important to note that most formulators do not recognize the subtle distinction and use the terms compounding and blending interchangeably.

Compression Ratio—In an internal combustion engine, the ratio of the volume of combustion space at bottom dead center to that at top dead center.

CONCAWE—Conservation of Clean Air and Water (Europe).

Cone Resistance Value (CRY)—A measure of the yield stress of a grease, obtained by static indentation with a cone. Also see Penetration.

Conformability—Quality of plain bearing material to adjust itself to shaft deflections and minor misalignments by deformation or by wearing away, without creating operating difficulties.

Consistency—Imprecise measure of the degree of a plastic material, such as a lubricating grease, to resist deformation under applied force (load).

Contact Lubrication (Obsolete Term)—Lubrication obtained when solid lubricant powders get rubbed into a surface.

Conversion Coating—See Chemical Conversion Coating.

Copper Strip Corrosion—Measure of the tendency of a petroleum product to corrode pure copper (ASTM D130).

Corrosion—Chemical-related surface damage of the metal. Corrosion involves the attack of the metals by oxygen, sulfur, and acidic and basic chemicals. Chemically, corrosion is the oxidation of the metal to its oxides or salts. Rusting is the air-mediated formation of iron oxide and yellow metal corrosion is sulfur-mediated formation of copper sulfides.

Corrosion Inhibitor—An additive used to reduce corrosion. Metals whose corrosion is of primary concern in lubricant-related applications are iron, a copper, and lead.

Corrosive Wear—Wear caused by a chemical or an electrochemical reaction. See also Oxidative Wear.

cP—centiPoise, the unit of dynamic viscosity.

CR—Common Rail (Diesel Injection).

Cracking—Process of converting unwanted long-chain hydrocarbons into short-chain molecules by thermal or catalytic action. The latter is called catalytic cracking.

Crater Wear—Wear that occurs on the rake face of a cutting tool due to the contact with the material in the chip that is sliding along that face.

CRC—Coordinating Research Council. Organization supported by American Petroleum Institute and Society of Automotive Engineers, which administers the work of various committees pertaining to test work on fuels, lubricants, engines, etc.

Crown—Top of the piston in an internal combustion en-

gine above the fire ring, which is exposed to direct flame impingement.

CRTV—Commercial Road Transport Vehicle.

cSt—CentiStoke, the unit of kinematic viscosity.

CSTCC—Continuously Slipping Torque Converter Clutch.

CUNA—Commissione Tecnica de Unificazione dell' Autoveicolo.

Cut—Product or fraction obtained by distillation within a specified temperature range.

Cutting Wear—See Abrasive Wear.

CVT—Continuosly Variable Transmission.

Cyclohexane Derivatives—These fluids were developed for use in automotive transmission applications requiring high traction.

DAP—Detroit Advisory Panel.

DASMIN—Deutsche Akkreditierungsstelle Mineralöl (Germany).

Debris—See Wear Debris.

Deformability—See Conformability.

Deformation Wear—Sliding wear involving plastic deformation of the wearing surface.

Delamination Wear—Wear process in which thin layers of material are removed from the wear surface.

Demulsibility—Measure of an organic water-immiscible fluid's ability to separate from water.

Density—Mass per unit volume. Useful in formulating lubricants with additives by volume and to calculate the amount of energy required to pump a fluid.

DEO—Diesel Engine Oil.

DEOP—Diesel Engine Oil Advisory Panel (API/EMA).

Detergent—Substance added to fuel or lubricant to keep engine parts clean. In engine oil formulations, the most commonly used detergents are basic metal sulfonates that have reserve basicity to neutralize acids formed from combustion and lubricant oxidation. They also possess the ability to suspend ordinarily oil-insoluble materials in the bulk lubricant.

Detergent/Dispersant—Additive package that combines a detergent with a dispersant. Both in combination are extremely effective in keeping harmful lubricant decomposition products away from surfaces.

Detergent Oil—Lubricating oil possessing sludge-dispersing properties for use in internal-combustion engines. Such oils hold sludge particles in suspension and thus promote engine cleanliness.

Detonation—Uncontrolled burning of the last portion (end gas) of the air-fuel mixture in the cylinder of a spark-ignition engine. Also known as "knock" or "ping."

DGMK—Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie (Germany).

DI—Detergent Inhibitor.

DI—Direct Injection.

Dicarboxylic Acid Ester—Made from a dicarboxylic acid and an alcohol. Such esters are used as synthetic base fluids.

Dielectric Strength—Measure of the adequacy of electrical insulating oils of petroleum origin to be used in electrical devices, such as cables, transformers, oil circuit breakers, and similar apparatus.

Diester—See Dicarboxylic Acid Ester

Dilatant—Reversible increase in viscosity with an increase in shear stress.

Dilution of Engine Oil (Oil Dilution)—Contamination of the crankcase oil by the unburned fuel, leading to reduced viscosity and flash point. Reduced oil viscosity may lead to poor lubrication; hence increased wear.

DIN—Deutsches Institut für Normung.

Dirt Content—Measure of the size and concentration of foreign particles present in a lubricant. Lubricant decomposition products are also sometimes referred to as dirt.

Dispensability—Property of a grease which reflects the ease of a grease being dispensed from a container. Dispensability is related to pumpability and feedability.

Dispersant—Additive that is capable of dispersing oil-insoluble lubricant decomposition products, such as varnish, lacquer and sludge precursors.

Dispersant Oil—Heavy-duty oil that contains dispersant additive.

Distillate—Any of a wide range of products produced by distillation of crude petroleum.

Distillation—Process involving converting a volatile liquid into its vapor and then collecting it as a liquid. Distillation is also used to characterize volatility of a gasoline or distillate fuel.

***DN* Value**—Product of bearing bore diameter in millimetres and speed in revolutions per minute. *DN* value is used to select proper grease for bearings used in high speed applications.

DOHC—Double Overhead Cam (Twin Cam).

DOT—Department of Transportation.

Drawing Compound—Extreme-pressure lubricant used for such metalworking operations as wire drawing.

Drip Feed (Drop Feed) Lubrication—Lubrication system in which the lubricant is supplied to a device in the form of drops at regular intervals.

Drop (Dropping) Point—Temperature at which a drop falls from a grease through a specified orifice. It indicates grease transition from being a semisolid to a liquid state. In view of the test being a static test, dropping point does not necessarily coincide with maximum operating temperature of a grease.

Dry Film Lubricant—Solid material placed between two moving surfaces to prevent metal-to-metal contact, thus reducing friction and wear. Lubricating properties arise from sliding of the crystal lattice layers under low shear. Materials that are often used as lubricants include graphite and molybdenum disulfide. They are especially useful in mixed film lubrication regimes. They may be applied in the form of a paste, dispersion, or by spraying, dipping, and brushing in an air-drying carrier, which evaporates leaving a dry film.

Dry Sliding Wear—Sliding wear in which there is no intentional lubricant or moisture introduced into the contact area. Adsorbed species or oxides and other metal films that are either present or form during sliding may act as a lubricant. The proper term is unlubricated since solid lubricants, when used, will also form dry films.

Durometer Reading—Durometer is a device that is used to test the hardness of elastomers. Durometer reading is an index used to rank relative hardness of these materials.

Dynamic Viscosity—See Viscosity.

Elasto-hydrodynamic Lubrication (EHD)—

Lubrication regime which is characterized by high loads and high speeds in rolling elements where the mating parts deform elastically due to the incompressibility of the lubricant film under very high pressure.

ECCC—Electronically Controlled Converter Clutch.

EEB—European Environmental Bureau.

EELQMS—European Engine Lubricants Quality Management System.

EEV—Enhanced Environmental Friendly Vehicles and Engines.

EFI—Electronic Fuel Injection.

EFTC—Engine Fuels Technical Committee (of CEC).

EGR—Exhaust Gas Recycling.

EHD—Elastohdrodynamic Lubrication.

EKS—Electronic Knock Sensor.

ELTC—Engine Lubricants Technical Committee (of CEC).

EMA—Engine Manufacturer's Association.

EMD—General Motors Electromotive Division.

Emissions (Mobile Sources)—While emissions from an internal combustion engine include water, CO_2, CO, NOx and hydrocarbons (HC), only the last three are subject to stringent legislative control. Diesel engines in addition emit particulates (PM) which are also controlled. Efforts are being made to decrease the amount of the greenhouse gases, such as CO_2, in the environment due to a concern for global warming.

Emissions (Stationary Sources)—Emissions from stationary sources are hydrocarbons from evaporation of fuel and sulfur-derived emissions. These are in addition to CO and PM. Since fuel composition can influence emission of some of these pollutants, efforts are on the way to control sulfur content of heavy fuel oils used in such facilities.

Emulsifier—Additive that promotes the formation of a stable oil-water systems, called emulsions. Emulsifiers are bipolar additives with solubility in both phases. They are nonionic, if none of the atoms in their structure contain any electrical charges; anionic, if the charge on the organic portion is negative; and cationic, if the charge on the organic portion is positive.

Emulsion—Dispersion of fine droplets of one liquid (dispersed phase) in another liquid (continuous phase). Emulsions used as lubricants are oil-water systems that maintain their integrity with the help of a chemical compound called the emulsifier. Oil-in-water emulsions are called normal emulsions and water-in-oil emulsions are called invert emulsions.

ENGVA—European Natural Gas Association.

Engine Deposits—These include sludge, varnish, lacquer, and carbonaceous residues. They are derived both from the fuel combustion and the lubricant oxidation. Fuel combustion products contain unburned and partially burned fuel fragments which enter the crankcase as blow-by and cause break down of the lubricant. Water from the condensation of the combustion products, carbon, residues from fuel and lubricating oil additives, dust, and metal particles also contribute towards deposits.

Engine Oil—Oil used to lubricate internal combustion engine.

EOLCS—Engine Oil Lubricant Classification System (of API).

EP—Abbreviation for extreme pressure.

EPA—Environmental Protection Agency.

EPA Complex Model Gasoline—Gasoline designed to improve emissions quality. Limits were implemented on Reid Vapor Pressure (RVP), T-50 and T-90 (50 % and 90 % evaporated gasoline temperatures), oxygen content, aromatics content, and amounts of olefins, benzene, and sulfur. Effective date January 1, 1997.

EPA Simple Model Gasoline—Gasoline that was formulated to minimize volatile organic compound (VOC) emissions. Parameters manipulated included RVP and oxygen content and limits were placed on oxygen, benzene, sulfur, olefins, and T-90 content at levels equal to or lower than those of a refiner's 1990 baseline. Effective date January 1, 1995.

EP (Extreme Pressure) Agent—Additive used in a lubricant to impart or improve load-carrying capacity or anti-weld quality. It prevents sliding metal surfaces from adhering to each other under extreme pressure conditions.

EPEFE—European Programme on Emissions, Fuels & Engine Technologies.

EP Lubricant—See Extreme-pressure Lubricant.

Erosion—Surface wear of a solid due to the motion of a fluid in contact that contains solid particles.

ESCS—Engine Service Classification System (API).

ESI—Extended Service Interval.

ETC—European Transient Test Cycle.

ETLP—Engine Test of Lubricants Panel (IP).

EU—European Union.

EUC—European Union Commission.

EUI—Electronic Unit Injector.

Evaporation Loss—Lubricant loss due to volatilization during use or storage.

Exhaust Gas Recirculation (EGR)—Process involving recycling of the exhaust gases into the carburetor or intake manifold to dilute the combustion mixture and reduce peak combustion temperatures. The result is the lowering of the amount of NOx formation.

Extreme Pressure Lubricant—Lubricating oil or grease which is supplemented with an EP agent to prevent metal-to-metal contact in operations involving high loads. Such lubricants are typically used in gear and bearing applications. These lubricants usually contain sulfur, halogens, or phosphorus. Another name for extreme pressure lubricant is anti-scuffing lubricant.

FA,FAR—Fuel Air Ratio.

Fat—Naturally-occurring ester which is a reaction product of fatty acid and glycerol. It is also called a triglyceride.

Fatigue—Cracking, flaking or spalling of a surface due to stresses beyond the endurance limit of the material.

Fatigue Wear—Removal of particles as a consequence of fatigue resulting from repeated localized stress. Fatigue wear in a part is usually indicated in the form of fracture or spall.

Fatty Acid—Organic acid derived from fats and natural oils.

Fatty (Natural) Oil—Fat (glycerol ester) that is liquid at room temperature.

FEO—Fuel Economy Oil.

Feedability—Ease with which a lubricating grease flows through a dispensing pump.

Ferrograph/Ferrography—An instrument used to determine the size distribution of the wear particles in lubricating oils used in mechanical systems. Ferrography, also called Magnetic Particle Analysis, is the technique used to analyze debris that is attracted to a magnet in the ferrograph.

Fiber—Grease soap thickeners occur in fibrous form. If fibers are very small (microscopic), grease appears smooth. If they are large or exist in bundles, the grease appears fibrous. Sodium soap thickened greases are usually fibrous, other soap greases are normally smooth.

Fiber Grease—Grease with a pronounced fibrous structure.

Fibril—Tiny fiber, barely visible even with an electron microscope. Fibers may be made of bundles of fibrils.

Filler—Materials, such as talc, pigments, and carbon black, that increase a lubricant's bulk or density. Fillers, commonly used in lubricating greases, may have no effects on the lubricating properties of a grease, except to increase its apparent viscosity.

Film Strength—Durability of the lubricant film against the effects of load, speed, and temperature without breaking down or rupturing. Rupture of such films occurs due to rubbing of the film by the asperities during sliding or rolling. High film strength implies high load-carrying capacity, which may or may not be true until proven through measuring due to a lubricating film.

Film Thickness—Distance between two surfaces due to a lubricant film that otherwise will be in contact.

Fire Point—Lowest temperature at which a petroleum product vaporizes to form air-vapor mixture above the liquid surface that burns continuously, when ignited by a small flame.

Flaking—Removal of material from a surface in the form of flakes or scale-like particles (pitting) as a result of fatigue.

Flash Point—Lowest temperature at which a fluid will support instantaneous combustion (a flash). Flash point is an important indicator of fire and explosion hazards associated with a petroleum product. It is determined by the use of Cleveland Open-cup (COC) Tester, Penskey-Martens Tester, and Tag Closed-cup Tester.

Flash Temperature—Maximum local temperature generated at some point in a sliding contact.

Flocculation (Floc) Point—Temperature at which wax or solids separate in an oil.

Flood Lubrication—System of lubrication in which a lubricant is supplied in a continuous stream at low pressure and subsequently drains away. Also known as bath lubrication.

Fluid Friction—Friction between the molecules of a gas or liquid in motion, expressed as shear stress. Unlike solid friction, fluid friction varies with speed and area.

Fluidity—Reciprocal of viscosity.

Fluoroester Fluids—These are the reaction products of perflluorocarboxylic acids with fluorinated alcohols. These are used as base fluids in specialty lubricants.

Foam—Collection of gas bubbles separated from one another by a thin liquid film.

Foaming—Process of formation of gas bubbles.

Foam Inhibitor—An additive used either to suppress foam formation of the petroleum products in service or to collapse it quickly, if it forms. Common foam inhibitors include silicone oil or polymers. These are used in extremely small quantities.

Four-Ball Tester—Of two types: Four-Ball Wear Tester and the Four-Ball EP Tester. These machines are used to evaluate a lubricant's antiwear qualities, frictional characteristics or the load-carrying capability. Its name is derived from four 1/2 in. steel balls used as test elements.

Fretting—Wear resulting from small amplitude (vibratory or oscillatory) motion between two surfaces; may produce red or black oxide. Also see False Brinelling.

Friction—Resistance to motion of one object over another. Friction depends on the degree of smoothness of the contacting surfaces, as well as the force (load) with which they are pressed together.

Friction Coefficient—See Coefficient of Friction.

Friction Force—Resisting force when one body moves or tends to move relative to the other under the action of an external force.

Friction Polymer—Amorphous, organic deposit that is produced when certain metals are rubbed together in the presence of certain liquids or gases.

Frosting—A form of ball bearing groove damage, appearing as a frosted area, which suggests that surface distress has occurred.

FTP—Federal Test Procedure (USA).

Full-film Lubrication—Type of lubrication where the solid surfaces are separated completely by a hydrodynamic fluid film.

FZG—Foschungstelle für Zhanräder und Getriebau: Technische Hochnische München.

FZG Test—A German gear test for evaluating the EP properties.

Galling—Severe form of scuffing associated with gross damage to the surfaces or failure. Also see adhesive wear.

Gaseous Fuels—Liquefied or compressed hydrocarbon gases (propane, butane or natural gas), which are being used in motor vehicles as replacements for gasoline and diesel fuel.

Gasket—A device that is usually made of a deformable material, which is used between two relatively static surfaces to prevent leakage.

Gasohol—Fuel mixture of 90 % gasoline and 10 % ethyl alcohol (ethanol).

Gasoline—Volatile mixture of liquid hydrocarbons, containing small amounts of additives and suitable for use as a fuel in spark-ignition, internal combustion engines.

GATT—General Agreement on Tariffs and Trade.

GDI—Gasoline (Engine) Direct Injection.

GE—General Electric Company.

Gel—An elastic mixture of a colloid and a liquid possessing a yield point and a jelly-like texture.

Gelling Agent—See Thickener.

GEPE—Groupe des Experts pour la et l'Engergie (Group of Experts for Pollution & Energy).

GM—General Motors Corporation.

Gravity—Expressed as mass per unit volume at a specified temperature, usually 60 °F (15 °C). Also see API Gravity.

Grease—See Lubricating Grease.

Grease Texture—Texture of a grease is determined by pressing a small portion of a grease together and then by slowly drawn apart. Texture is described as:

1. *Brittle,* if it ruptures or crumbles when compressed.
2. *Buttery,* if it separates in short peaks with no visible fibers.
3. *Long Fibers,* if it stretches or strings out into a single bundle of fibers.

GTL (Gas-to-Liquid) Base Stocks—Made by the conversion of the natural gas, primarily methane, into a synthetic hydrocarbon base fluid.

Gum—Rubber-like, sticky deposit, black or dark brown in color, which results from the oxidation and polymerization of the fuels and lubricating oils, or both. Harder deposits are described as lacquers or varnishes.

Hardness—Property of a solid material that indicates its resistance to penetration or abrasion by other bodies. Hardness of a solid depends on the method of its measurement.

HC—Hydrocarbons.

HD—Heavy Duty (vehicle or lubricant).

HDDO,HDDEO—Heavy-duty Diesel Engine Oil.

Heat Transfer Oil—Medium used to transfer heat away from a part or the equipment. Such oils are usually based on high-boiling petroleum fractions.

Heavy-duty Oils—Lubricants used in gasoline and diesel engines. These oils are stable against oxidation, protect bearings from corrosion, and have detergency and dispersancy.

Hershey Number—Dimensionless number used to evaluate performance of bearings. It is normally written as ZN/P, where Z denotes viscosity, N the frequency of rotation, and P the pressure. Often used in Stribeck curve to indicate various lubrication regimes.

HFO—Heavy Fuel Oil.

HFRR—High Frequency Reciprocating Rig.

Homogenization—Intimate mixing of a grease to produce a uniform dispersion of components.

HSDI—High Speed Direct Injection (diesel engine).

HT/HS—High Temperature/High Shear (viscosity).

Humidity Cabinet Test—Test used to evaluate the rust-preventing properties of metal protecting oils (metal preservatives) under conditions of high humidity.

Hydrated Soap—Soap with water associated with its structure, for example, that present in water-stabilized calcium soap grease.

Hydraulic Fluid—Fluids used as a medium to transfer hydraulic pressure to operate devices. They may or may not possess lubricant properties and may be water-based, mineral oil-based, or synthetic fluid-based.

Hydrocarbon—Compound that is made of carbon and hydrogen atoms only. The simplest hydrocarbons are gases at ordinary temperatures, but as their molecular weight increases, they become liquid, and ultimately solids (waxes). Hydrocarbons are the major constituents of petroleum.

Hydrodynamic Lubrication—Formation of a continuous lubricating fluid film of appropriate thickness between surfaces to prevent them from touching each other, thereby minimizing friction and wear. High lubricant viscosity, high equipment speed, and low load promote this type of lubrication. It is also called fluid film lubrication.

Hydrofinishing (Hydrogen Finishing)—Process for treating extracted base stocks with hydrogen to remove unsaturation; hence improve stability.

Hydrogenation—Chemical reaction between hydrogen and a material that has unsaturation or aromatic rings.

Hydrolytic Stability—Resistance of additives and certain synthetic lubricants against decomposition in the presence of water.

Hydrophilic—Affinity of a substance towards water.

Hydrophobic—Lack of affinity towards water. Related term is lipophilic—an affinity for organic materials. Usually hydrophobic materials are lipophilic.

Hydroprocessing (Hydrogen Processing)—Treating petroleum fractions with hydrogen, typically in the presence of a noble metal catalyst. Simple addition of hydrogen simply removes unsaturation. Hydrogenation under more severe conditions leads to bond breaking and bond forming, thereby altering chemical structures of the original hydrocarbons. When bond breaking is the primary outcome, the process is called hydrocracking, and when hydrocracking is followed by bond formation, it is called hydroisomerization.

Hydrostatic Lubrication—Lubrication in which the lubricant is supplied to a plain bearing under sufficient external pressure to separate the opposing surfaces by a continuous lubricant film.

Hypoid Gear Lubricant (Hypoid Oil)—Lubricant with extreme-pressure characteristics suitable for use in hypoid gears, which are often used in automobiles.

IChemE—Institute of Chemical Engineers (UK).

ICOMIA—International Council of Marine Industries Associations.

IDI—Indirect Injection.

IEA—International Energy Agency.

IFP—Institut Français de Pétrole.

ILSAC—International Lubricant Standardization Committee.

Impingement Corrosion—Form of erosion/corrosion generally associated with the impingement of a high-velocity flowing liquid containing air bubbles against a solid surface.

ILMA—Independent Lubricant Manufacturers Association.

Incompatibility—Fluids that do not mix well. Incompatibility may be reflected by phase separation, or loss of activity and or performance. This commonly occurs in lubricating greases and synthetic fluids.

Induction Period—Time during which oxidation of a material proceeds at a constant but a relatively slow rate. This period ends at the point where the oxidation rate increases sharply.

Inhibitor—Chemical whose presence in a petroleum product prevents or retards undesirable chemical changes from taking place, or in the condition of the equipment in which the product is being used. Common inhibitors include oxidation inhibitors and rust and corrosion inhbitors. These retard the rate of oxidation or corrosion.

Inorganic Thickener—See Nonsoap Thickener.

Insolubles—Contaminants in used oils that include dust, dirt, wear particles, and or oxidation products. In oils, their amount is often measured as pentane or benzene in-

solubles. In greases, they are measured by the use of prescribed reagents according to special analytical procedures, such as ASTM D128. Additional identifying analytical tests are required to determine the nature and composition of the isolated materials that comprise fillers, additives, and certain types of thickeners.

Insulating Oil—Oil used in circuit breakers, switches, transformers, and other electrical apparatus for insulating, cooling, or both. In general, such oils are highly-refined petroleum distillates of low volatility, with high resistance to oxidation and sludging.

IP—Institute of Petroleum, now called Energy Institute

ISO—International Standards Organization.

Iso-dewaxing—Hydroisomerization of the linear hydrocarbons (waxes) into branched hydrocarbons to improve low-temperature properties, such as pour point of the mineral base stocks. Also see Hydroprocessing.

IVD—Inlet Valve Deposit.

JALOS—Japanese Lubricating Oil Society.

JAMA—Japan Automobile Manufacturers Association.

JARI—Japan Automobile Research Institute.

JAST—Japan Society of Tribologists.

JASO—Japan Automobile Standards Organization.

JIS—Japan Industrial Standards.

JSAE—Society of Automotive Engineers, Japan.

Kinematic Viscosity—Measure of a fluid's resistance to flow under gravity at a specific temperature, usually 40 °C and 100 °C. Kinematic viscosity is easier to measure than dynamic viscosity. Kinematic viscosity can be converted into dynamic viscosity by dividing its value by fluid density, and vice versa. The units of kinematic viscosity are Stoke (St) and centiStoke (cSt), which correspond to cm^2/s and mm^2/s in Metric System. The units for dynamic or absolute viscosity are Poise (P) and centipoise (cP), which correspond to 0.1 and 0.001 Pa·s, respectively.

Kinetic Coefficient of Friction—Coefficient of friction under conditions of macroscopic relative motion between two bodies.

Knock—Audible hammering noise resulting from violent, explosive combustion of air-fuel mixture in a spark ignition engine.

KV—Kinematic Viscosity.

Lands—Circumferential areas between the grooves of a piston.

Lard Oil—Animal oil prepared from the fat of pig. Such oils are compounded with mineral oils to yield lubricants with special properties, especially cutting oils.

LCV—Light Commercial Vehicle.

LEV—Low Emissions Vehicles.

Liquefied Natural Gas (LNG)—Similar to LPG but consisting of lighter hydrocarbons, such as methane and ethane.

Liquefied Petroleum Gas (LPG)—Light hydrocarbon material, gaseous at atmospheric temperature and pressure, held in the liquid state by pressure to facilitate storage, transport and handling. Commercial liquefied gas consists essentially of propane, butane, or their mixture.

LMAO—Locomotive Maintenance Officer's Association.

Load—Force applied normal to the surface of one body by another contacting body or bodies. The term normal force is more precise and therefore preferred; however, the term normal load is also used. If applied vertically, the load can be expressed in mass units, but it is preferable to express force in as Newton units (N).

Load-carrying Capacity—Maximum load that a sliding or rolling system can support without failure; or maximum load or pressure that can be sustained by a lubricant, when used in a system under specific conditions, without failure.

Load Wear Index (LWI)—Measure of the relative ability of a lubricant to prevent wear under applied loads. See Four-Ball Test. It is calculated from the loads applied and corrected for elastic deformation of the balls under static loading and for the size of the wear scar. Formerly, it was called Mean Hertz Load.

LRI—Lubricants Review Institute (USA).

LSADO—Low Sulfer Automotive Diesel Oil.

Lubricant—Any substance interposed between two surfaces in relative motion for the purpose of reducing friction or wear that may occur. The term implies externally added substance. However, species such as oxide layers and tarnishes on certain metals can also prevent friction and wear.

Lubricant Compatibility—See Compatibility (Lubricant).

Lubricating Grease—A lubricant in which a lubricating fluid is thickened with soap or another material to a solid or semisolid consistency. Common soaps include calcium soap, sodium soap, barium soap, lithium soap, and aluminum soaps, both simple and complex. The liquid phase may be mineral oil or a synthetic base fluid.

Lubrication—Control of friction and wear by introducing a friction-reducing film between moving surfaces in contact. Such a film may be due to the presence of a fluid, solid, or a plastic substance. See Lubrication Regimes.

Lubrication Regimes—Lubrication environments defined on the basis of operating conditions, such as speed, load, etc., in lubricated tribo-systems. Different regimes have different amount of separation of surfaces and surface interaction; hence different frictional characteristics. Also see Boundary Lubrication, Elasto-hydrodynamic Lubrication, Full-film Lubrication, Hydrodynamic Lubrication, and Quasi-hydrodynamic Lubrication.

Lubricious—Relating to a substance or surface condition that tends to produce relatively low friction.

Lubricity—Ability of a lubricant to reduce friction and wear other than by its viscosity.

Luster—Reflected light intensity from a grease, its sheen or brilliance. See Appearance/Bulk Appearance.

Main Bearing—Bearing supporting the main power-transmitting shaft.

MDCL—Medium Diesel Cylinder Lubricant.

MDO—Marine Diesel Oil.

MGO—Marine Gas Oil.

Mechanical Activation—Acceleration or initiation of a chemical reaction by mechanical exposure of a nascent solid surface, for example obtained by a metal cutting operation.

Mechanical Stability (Grease)—Shear stability as tested in a standard rolling tester.

Mechanical Wear—Removal of material due to mechanical processes involving sliding, rolling, or repeated impact. Mechanical wear includes adhesive wear, abrasive

wear, and fatigue wear, but not corrosive wear and thermal wear.

Melt Lubrication—Lubrication provided by steady melting of a lubricating species.

Metal Deactivator—Fuel or lubricant additive, usually a chelating agent, which through complexation deactivates metal surfaces and metal ions that will ordinarily catalyze fuel and lubricant breakdown; thereby inhibiting the formation of resin and other oxidation products. Copper in fuel lines and iron are of concern both in metallic form and in oxidized form (ions).

Metallic Wear—Wear due to rubbing or sliding contact between metallic materials. Its cause is cold welding of asperities, followed by separation and inter-surface metal transfer. Also see Adhesive Wear and Severe Wear.

Metallurgical Burn—Modification of the microstructure near the contact zone due to frictional temperature increase.

Metallurgical Compatibility—See Compatibility (Metallurgical).

Methylene-bridged Alkylphenol—Obtained by the reaction of alkylphenol with formaldehyde. Used as starting materials to make detergent additives for heavy-duty diesel engine oils.

Mineral Oil—Refined hydrocarbon oil obtained directly from petroleum refining.

MIRA—Motor Industry Research Association.

Mist Lubrication—Lubrication by an oil mist produced by injecting oil into a gas stream.

MITI—Ministry of International Trade and Industry (Japan).

MON—Motor Octane Number.

Morphology—Pertaining to structure and form.

MRV—Mini Rotary Viscometer.

MTAC—Multiple Test Acceptance Criteria.

MTBE—Methyl Tertiary Butyl Ether.

MTF—Manual Transmission Fluid.

Multi-grade Oil—Engine or gear oil that meets the requirements of more than one SAE viscosity grade, for example 10W-30, which meets the requirements of both SAE 10W and SAE 30. Such multi-viscosity oils provide broad-temperature performance and are usually made by adding a viscosity modifier to a low viscosity oil. In some case, such as narrow viscosity range gear oils (80W-90), multi-grades are made by blending base oils of two different viscosities.

Multiply-alkylated cyclopentanes, or MACs—These are made by the reaction of cyclopentadiene with an alcohol or an alkyl halide. They are used as base fluids in formulating high-temperature lubricants.

Multi-purpose Grease—Lubricating grease that meets the requirements of various applications. For example, it is suitable for use as a chassis lubricant, bearing lubricant, joint lubricant, water-pump lubricant, and cup grease.

MVEG—Motor Vehicle Emmisions Group (of the European Commision).

MVMA—Motor Vehicle Manufactures Association.

Naphthene—A group of cyclic hydrocarbons, which is also termed cycloparaffins or cycloalkanes. Polycyclic members are also found in the higher boiling fractions. The general formula for naphthenes is C_nH_{2n}, where n is a whole number.

Naphthenic—Petroleum-derived fluid, usually obtained from naphthenic crude oil, containing a high proportion of saturated cyclic structures.

Natural Sulfonate—Metal salt of the petroleum-derived (natural) sulfonic acid.

NEMA—National Electrical Manufacturers Association.

Neutral Oil—Petroleum-derived lubricant base stock that is devoid of acidity or alkalinity. Neutral oils are the basis of most commonly used automotive and diesel lubricants. They are light overhead cuts from vacuum distillation.

Neutralization Number—Measure of acidity or alkalinity of an oil. Neutralization number is the amount of milligrams of acid (HCI) or base (KOH) required to neutralize one gram of oil. It is expressed as mg of KOH/g of oil. Also see Acid Number and Base Number.

Newtonian Behavior—Lubricant exhibits Newtonian behavior if its shear rate is directly proportional to the shear stress. This constant proportion is the viscosity of the liquid.

Newtonian Flow—Fluid exhibits Newtonian flow if its viscosity is independent of the shear stress.

Newtonian Fluid—Fluid that exhibits Newtonian viscosity, that is, shear stress is proportional to the rate of shear.

Nitration—Process where nitrogen oxides react with hydrocarbon (petroleum) fluids at high temperatures, resulting in oxidation products that cause viscosity increase and deposit formation.

NLGI—National Lubricating Grease Institute.

NLGI Consistency Number—Scale comparing consistency (hardness) of greases. Scale range is from 000 to 6; higher consistency numbers indicate firmer (harder) greases. Greases both softer and harder than indicated by these consistency numbers are well known in the industry. However, such greases do not have an NLGI Number.

NMMA—National Marine Manufacturers Association.

NMOG—Non-Methane Organic Gases.

NOx—Nitrogen Oxides, primarily Nitrous Oxides.

Non-Newtonian Behavior—Fluids exhibit this type of behavior if they have variable relationship between shear stress and shear rate. This implies that they do not possess real viscosity but apparent viscosity. Such fluids, exemplified by greases and polymeric additive-containing lubricants, are called **Non-Newtonian fluids**.

Nonsoap Thickener—Lubricating grease thickener that is not derived from metal carboxylates (soaps). Such thickeners can be organic or inorganic. Former type includes polyurea and cellulosic materials and the latter type includes silica and modified clays.

NPRA—National Petroleum Refiners Association.

NVMA—National Vehicle Manufacturers Association.

OBD—On-board diagnostics.

OCP—Olefin Co-polymer.

Octane Number—Measure of a fuel's ability to prevent detonation in a spark ignition engine. Measured in a standard single cylinder, variable-compression-ratio engine by comparison with primary reference fuels which are blends of *iso*-octane (Octane Number 100) and *n*-heptane (Octane Number 0). Under mild conditions, the engine measures Research Octane Number (RON); under severe conditions it measure Motor Octane Number (MON). Posted Octane

Number of commercial gasolines, called Antiknock Index (AK), is the average of the two values.

Octane Requirement (OR) or Octane Number Requirement (ONR)—Lowest octane number reference fuel that will allow an engine to run knock-free under standard conditions of service.

Octane Requirement Increase (ORI)—As deposits in automobiles combustion system increase, the ORI of the engine increases. That is, higher octane number fuel is required for trouble-free operation. Addition of deposit control/cleanliness additives to gasoline help prevent this from happening.

ODI—Oil Drain Interval.

OECD—Organization Economic Cooperation and Development.

OEM—Original Equipment Manufacturer.

OICA—Organisation Internationale des Constructeurs d'Automobiles.

Oil—A liquid of vegetable, animal, mineral, or synthetic origin that feels slippery to the touch.

Oil Fog Lubrication—See Mist Lubrication.

Oil Groove—A channel or interconnected channels cut in a part to improve oil flow. When applied to a bearing, this strategy facilitates distribution of oil over the shaft as well.

Oiliness—Capability of a fluid to orient itself on metal surfaces and lower friction. Also see lubricity.

Oiliness Agent—Chemical with the ability to form an adsorbed film on metal that reduces friction.

Oil Pocket—A depression designed to retain oil on a sliding surface.

Oil Ring—A mobile ring whose inner surface rides a shaft or journal, causing the ring to rotate and pick up lubricant by dipping into the lubricant reservoir and delivering it to the top of the shaft for distribution to a bearing. An internal-combustion engine piston also contains an oil ring which controls the lubrication of the piston and cylinder walls.

Oil Ring Lubrication—See Oil Ring.

Oil Starvation—Situation in which a bearing, or another tribo-component, receives an inadequate supply of lubricant.

OPEST—Oil Protection and Emission System Test.

Organic Thickener—See Nonsoap Thickener.

ORI—Octane Requirement Increase.

Overbasing—Technique to impart base reserve in additives, called detergents. Such base exists in the additive in a colloidal form. Addition of overbased additives to a lubricant imparts ability to neutralize acidic oxidation products.

Oxidation—Reaction of oxygen with organic and inorganic materials. Hydrocarbon (petroleum) fluids oxidize to yield highly polar oxygenated materials of polymeric structure and carboxylic acids. These species lead to lubricant viscosity increase, deposit formation, and metal corrosion. Oxidation rate is accelerated by heat, light, metal catalysts and the presence of water, acids, or solid contaminants.

Oxidation Inhibitor—Additive used for the purpose of reducing the rate of oxidation and subsequent deterioration of oil or grease.

Oxidation Stability—Resistance of a petroleum product to oxidation and, therefore, it is a measure of a product's potential service or storage life.

Oxidative Wear—Corrosive wear in which a chemical reaction with oxygen or oxidizing environment predominates. This type of wear is usually a mild form of wear, but it can be severe in highly oxidative environment, such as those involving liquid oxygen or liquid fluorine.

Oxygenate—Oxygen-containing, metal-free organic compound, such as alcohol or ether, that can be used as a fuel or fuel supplement.

Oxygenated Fuels—Fuels for internal combustion engines that contain oxygenates, such as alcohol and methyl-*t*-butyl ether (MTBE), which increase gasoline's octane value.

Oxygenated Gasoline—Required annually from September 15 to March 15 for use in carbon monoxide (CO) nonattainment areas. Oxygenated gasoline contains a minimum of 2.0 % mass oxygen and a maximum of 1.0 % volume benzene.

Ozone and CO Nonattainment Areas—Any area in the continental United States that does not meet the 1990 Clean Air Act requirements for carbon monoxide or ground-level ozone pollutants.

PAG—See Poly(alkylene glycol).

PAH—Polyaromatic Hydrocarbon.

PAJ—Petroleum Association of Japan.

Pale Oil—Petroleum lubricating oil or process oil refined until its color by transmitted light is straw to pale yellow. Typically, it is a naphthenic oil.

Paraffinic—Type of petroleum fluid derived from paraffinic crude oil and containing a high proportion of straight chain saturated hydrocarbons, because of which it suffers from cold flow problems.

PCB,PCBs—Polychlorinated Biphenyls.

PCD—Passenger Car Diesel.

PCMO—Passenger Car Motor Oil.

PCV—Passenger Car Vehicle.

Penetration—Measure of consistency (hardness) based on an inverse penetration measurement (the softer the consistency, the higher the penetration number). Penetration is measured as the distance in millimetres that a standard needle or cone penetrates vertically into a sample of the material, under known conditions of loading, time, and temperature. Penetration may be measured without disturbing the grease (Undisturbed penetration), with minimum disturbance (Unworked penetration), and with substantial disturbance (Worked Penetration).

Pentane Insolubles—See Insolubles.

Percent Permanent Viscosity Loss (PPVL)—Measure of the PVL related to the viscosities of the fresh oil—equals PVL divided by fresh oil viscosity, multiplied by 100.

Percent Temporary Viscosity Loss (PTVL)—Difference between the viscosity of an oil measured at low and high shear stresses, divided by viscosity measured at low shear stress, multiplied by 100.

Perfluoropolyethers (PFPEs)—These are poly(alkylene glycol) analogues, where all hydrogen atoms in their structure are replaced by fluorine atoms. They are used in specialty applications due to unique properties.

Permanent Viscosity Loss (PVL)—Difference between the viscosity of fresh oil and that of the same oil after engine operation or special test conditions to determine polymer degradation.

Petroleum Oil—See Mineral Oil.

PFI—Port Fuel Injection.

Phosphate Esters—Made from phosphorus oxychloride and a hydroxy compound, such as an alcohol or a phenol. Phenol and alkylphenol esters are used as base fluids for fire-resistant lubricants and hydraulic fluids.

PIB—See Polyisobutylene.

Pitting—Surface damage in the form of cavities, which may be related to fatigue, overload, or corrosion.

Plastic Flow—Surface deformation of metal as a result of yielding under heavy load.

Plowing (ploughing)—Formation of grooves by plastic deformation of the softer of the two surfaces in relative motion.

PM—Particulate Matter.

PM2.5—Particulate matter of the diameter 2.5 μ or less.

PM10—Particulate matter with particle size below 10 microns.

Poise (P)—Metric unit of dynamic viscosity. Also see Kinematic Viscosity.

Polishing—A surface-finishing process utilizing successive grades of abrasive.

Polishing (Bore)—Excessive smoothening of the surface finish of the cylinder bore or cylinder liner in an engine to a mirror-like appearance, resulting in depreciation of ring sealing and oil consumption performance.

Polishing Wear—Mild form of wear that may involve fine-scale abrasion, plastic smearing of micro-asperities, tribochemical material removal, or a combination thereof.

Poly(alkylene glycol)—Made by acid or base-catalyzed polymerization of alkylene oxides, such as ethylene oxide and propylene oxide. Used as synthetic base fluids.

Polyisobutylene—Made by the polymerization of isobutene (isobutylene). Used as a starting material for making additives, such as dispersants, and after hydrogenation used as a viscosity modifier in lubricants.

Polyol Esters—These are the reaction products of polyhydric alcohols (polyols) and carboxylic acids. These are used as base fluids to design high temperature lubricants.

Poly(phenyl Ether)s, Polyphenyl Ethers, or PPEs—These materials are obtained by the reaction of an alkali metal phenate with a halogenated benzene. These are used in lubricants for high-temperature and radiation environments.

Positive Crankcase Ventilation (PCV)—System involves recycling the blow-by gases, which contain unburned hydrocarbons, from the crankcase through the carburetor intake manifold into the combustion chamber to burn them. The objective is to reduce hydrocarbon emissions.

Pour Point—The lowest temperature at which the fluid will flow when cooled under prescribed conditions. Pour point is an indicator of the ability of an oil or the distillate fuel to flow at cold operating temperatures.

Pour Point Depressant, PPD—Additive which lowers the pour point of a paraffinic oil which contains wax.

Pour Stability—Ability of a pour point depressant-treated oil to maintain its original ASTM pour point when subjected to storage at low temperature approximating winter conditions.

Precipitation Number—Number of millimetres (mL) of precipitate formed when 10 mL of lubricating oil is mixed with 90 mL of petroleum naphtha of defined quality and centrifuged under prescribed conditions. Precipitation number indicates the amount of asphaltic components in the lubricating oil, although a certain amount of paraffinic components may also separate.

Preignition—Ignition of the fuel-air mixture in a gasoline engine before the spark plug fires. Often caused by incandescent fuel- or lubricant-derived deposits in the combustion chamber, it wastes power and may damage the engine.

Pressure Lubrication—System of lubrication in which the lubricant is supplied under pressure to various parts of the equipment or the device.

Pressure-Viscosity Coefficient—Slope of a graph that shows variation of viscosity with pressure on a logarithmic scale. The term pressure-viscosity coefficient assumes a linear relationship between these two parameters.

Process Oil—Oil used as a component in another material or as a carrier for other products.

Protuberances—See Asperities.

PTF—Power Transmission Fluid.

Pumpability—Flow properties of a grease that permits proper delivery through lines, nozzles, and fittings of the grease dispensing systems and subsequent lubrication of the moving components. Also see Dispensability and Feedability.

Quasi-hydrodynamic Lubrication—A loosely defined regime of lubrication, especially in metalworking, where thin-film lubrication predominates.

Quenching Oil—Oil used for quenching metals during a heat-treating operation.

R&O Oil—Rust and oxidation inhibited oil. Such oils are highly-refined lubricating oils, which are formulated for long service in circulating systems, compressors, hydraulic systems, bearing housings, gear cases, etc.

REACH—Acronym for European environmental legislation pertaining to chemical contamination of the environment—**R**egistration, **E**valuation, and **A**uthorization of **CH**emicals.

Reclaimed Oil—Lubricating oil which, after undergoing a period of service, is collected, reprocessed, and sold for reuse.

Refining—Series of processes to convert crude oil and its fractions into finished petroleum products. Processes include thermal cracking, catalytic cracking, polymerization, alkylation, reforming, hydrocracking, hydroforming, hydrogenation, hydrogen treating, Hydrofining®, solvent extraction, dewaxing, de-oiling, acid treating, clay filtration, and de-asphalting.

Re-refining—Process of reclaiming used lubricant oils and restoring them to a condition similar to that of virgin stocks by filtration, clay adsorption, or more elaborate refining methods.

Reversibility—Ability of a grease to return to its normal grease-like consistency after temporary exposure to temperatures near or above its dropping point. Only a few types of greases possess this property.

Reynold's Equation—A basic equation of hydrodynamic lubrication.

Rheology—Deformation or flow characteristics, or both, of grease in terms of stress, strain, temperature, and

time—commonly measured by Penetration and Apparent Viscosity.

Rheopectic Material—A material that shows an increase in viscosity with time under constant shear stress. After the removal of the shear stress, the viscosity slowly returns to the original level.

Rheopectic Grease—Lubricating grease which increases its consistency number (hardens) upon being subjected to shear.

Ridging—Form of plastic flow on the surface of the gear teeth that is characterized by a rippled appearance. Damage appears in the form of deep scratches that run as parallel ridges and is a consequence of plastic flow of the subsurface layer.

Rings—Circular metallic elements that ride in the grooves of a piston and provide compression sealing during combustion and to spread oil for lubrication.

Ring Sticking—Freezing of a piston ring in its groove in a piston engine or reciprocating compressor due to heavy deposits in the piston ring zone.

Ripple Formation (rippling)—Formation of periodic ridges and valleys transverse to the direction of motion.

Roller Bearing—See Anti-friction Bearing.

Rolling—Motion of two moving bodies of opposite curvature whose surface velocities in the common contact area are identical in magnitude and direction.

Rolling and Peening—Forms of plastic flow on the surface of the gear teeth that gives the appearance of being hammered. Metal may even be rolled over the teeth tips.

Rolling-contact Fatigue—Repeated stressing of a solid surface due to rolling contact between it and another solid surface or surfaces.

Rolling-contact Wear—Wear to a solid surface that results from rolling contact between that surface and another solid surface or surfaces.

Rolling-element Bearing—Bearing in which the moving parts are separated by balls, rollers, or needles.

RON—Research Octane Number.

RPM—Revolutions Per Minute.

Run In—Applying specified initial operating conditions to a tribological system to improve its long-term frictional or wear behavior, or both. It may involve conditions either more severe or less severe than the normal operating conditions and may also involve the use of special lubricants or surface chemical treatments, or both. Also see Break-in.

Running-in—Process by which machine parts improve in conformity, surface topography, and frictional compatibility during the initial stage of use. Chemical processes include formation of surface an oxide film and metallurgical processes include strain hardening.

Rust Preventative—Compound used to coat metal surfaces with a film that protects against rust, primarily in stored equipment.

RVP—Reid Vapor Pressure.

SAE—Society of Automotive Engineers.

SAE Viscosity Grade—An arbitrary number used for classifying engine oils, automotive transmission fluids, and gear oils, according to their viscosities, established by the Society of Automotive Engineers. SAE Grades are selected on the basis of the operating temperature and tribological requirements of the equipment.

Saponification—Making of a metal salt (soap) from a carboxylic acid ester, such as natural oils and fats, by the reaction of an alkali metal base, such as sodium hydroxide and potassium hydroxide.

Saponification Number—Measure of the amount of material in petroleum products that will saponify under test conditions. Saponification number, like the acid and base numbers, are expressed as number of milligrams of base, in this case sodium hydroxide, consumed by 1 g of oil. Saponifiable (fatty) material is not naturally present in petroleum products but is added to improve their lubricity.

Saybolt Color—Color standard for petroleum products (ASTM Method D156).

Saybolt Universal Viscosity (SUS or SSU)—It is based on time, in seconds, taken for 60 mL of fluid to flow through a capillary tube in a Saybolt Universal Viscometer at a given temperature (ASTM Method D88).

Scoring—Formation of significant scratches in the direction of sliding. Scoring may be due to local solid-phase welding or to abrasion. In the United States, the term scuffing is sometimes used as a synonym for scoring. It can be prevented by the use of antiwear, extreme pressure, and friction reducing additives.

SCR—Selective Catalyst Reduction.

Scratching—Fine abrasive furrows in the direction of sliding, which are produced by the cutting or plowing action, or both, of a sharp particle or protuberance moving along that surface.

Scuffing—See Scoring.

Seal—Device used to prevent leakage between moving parts, movement of the fluid from one chamber to another, or to exclude contaminants.

Seizure—Stopping of relative motion due to interfacial friction. Seizure may be accompanied by gross surface welding.

Selective Transfer—Process involving transfer and attachment of a specific species from one contacting surface to the other contacting surface during sliding.

Self-lubricating Bearing—See Anti-friction Bearing.

Self-lubricating Material—Solid material that shows low friction without the application of a lubricant. Examples include graphite, molybdenum disulfide, and polytetrafluoroethylene, and even composite materials with inherently low friction. Also see Solid Lubricant.

SEM—Scanning electron microscope/microscopy.

Separation Test—Test to determine the tendency of the oil to separate from a lubricating grease under conditions prescribed in ASTM Method D1742.

SHC—See Synthetic Hydrocarbons.

Shearing—Relative slipping or sliding between one part of a substance and an adjacent part. In solids, shearing involves breaking or altering of the crystal structure; in a fluid or plastic, shearing may or may not destroy the continuous nature of the substance.

Shear Rate—Rate of sliding within a flowing substance. See ASTM D1092.

Shear Stability—Resistance of a grease to changes in consistency (hardness) during mechanical working. In a lubricant, it is the ability of a lubricant to withstand the shearing action without degradation.

Shear Stability Index (SSI)—Measure of a viscosity

modifier's contribution towards percent loss in viscosity of an oil when subjected to engine operation or in specialized tests.

Shear Stress—Stress (force per unit area) that can cause shearing. Ratio of shear stress to shear rate in a fluid is its viscosity.

Shear-thickening—Increase in viscosity with an increase in shear rate or time.

Shear-thinning—Decrease in viscosity with an increase in shear stress or time. Decrease in viscosity may be temporary or permanent. The latter happens when the shear stress is sufficiently high to cause structural breakdown of the polymeric additives. Permanently sheared fluid has a lower viscosity than it had prior to shearing.

SHPD—Super High Performance Diesel (oil).

Silicate Esters—These are organic esters of orthosilicic acid, H_4SiO_4, which are made by the hydrolysis of alkoxysilicon chlorides with an alcohol. Used in lubricants for specialty application.

Silicones/Polysiloxanes—Made by water-catalyzed polymerization of dialkyl/diaryl silicon halides. Used as base fluids for specialty lubricants and as foam-inhibiting additives.

SIP—Styrene Isoprene Copolymers.

Slide-roll Ratio—Ratio of sliding velocity to rolling velocity, for example, in gear sets.

Sliding—Motion of two relatively moving bodies, in which their surface velocities in the common contact area are different with regard to magnitude or direction, or both.

Sliding Velocity—Difference between the velocities of each of the two surfaces relative to the point of contact.

Sludge—Semisolid to solid thick, dark residue containing oil, oxidation products, carbon, and water, which results from the low temperature operation of a combustion engine. Sludge is normally of mayonnaise consistency that accumulates on nonmoving interior surfaces of the engine and is usually removable by wiping, unless baked to a carbonaceous consistency.

Slumpability—Flow of a grease in a container under gravity, thereby allowing it to be fed into a pump or can. Also see Feedability.

Slurry—Mixture of solid particles in a liquid, of a consistency that is capable of being pumped as a liquid.

Slushing Oil—Mineral oil containing additives that enable it to protect the parts of a machine against rusting.

Soap—Alkali or alkaline metal salt of a carboxylic acid, especially a fatty acid. Also see Thickener, Complex Soap, and Saponification. While soaps are of importance as thickeners in greases, metal soaps formed in boundary lubrication regime by the in situ reaction of fatty additives and metal play an important role in reducing friction and wear.

Solid-film Lubrication—Lubrication by the application of solid lubricants.

Solid Lubricant—Solid used as a powder or a thin film on a surface to provide reduced friction and wear protection during the relative movement of the surfaces in contact. These lubricants have a layered (lamellar) structure, for example, graphite and molybdenum disulfide. Certain solids, such as glass, lubricate only in the melted state at the interface. These are not considered solid lubricants.

Soluble Oil—Mineral oil containing additives that enable it to form a stable emulsion with water.

Solvent Extraction—Refining process used to separate reactive components (unsaturated hydrocarbons) from the lubricant distillates in order to improve their oxidation stability, viscosity index, and additive response.

Solvent Refining—Process of extracting lubricant base stocks from heavy gas oil or another heavy, stripped crude stream by the use of selective solvents such as furfural or phenol.

Spalling—Separation of particles from a surface in the form of flakes, leaving behind a surface that consists of large pits, cavities, and related cracks. The term spalling is commonly associated with rolling-element bearings and with gear teeth. Spalling is usually a result of subsurface fatigue due to overloading and is more extensive than pitting.

Specific Gravity—Ratio of the weight (in air) of a given volume of a material to the weight (in air) of an equal volume of water at the stated temperature.

Spindle Oil—Oil of low viscosity used to lubricate light spindles operating at high speeds.

Splash Lubrication—System of lubrication in which the lubricant is splashed onto the moving parts.

Squeeze Film Lubrication—Development of fluid pressure sufficient to support a load between surfaces thickly coated or flooded with lubricant and rapidly moving toward each other. Because of viscosity (or apparent viscosity), the lubricant cannot immediately flow away from the area of contact. Squeeze-film lubrication occurs between gear teeth.

SSI—Shear Stability Index.

SSU (or SUS)—Saybolt Seconds Universal (or Saybolt Universal Seconds) a unit of vicosity. Also see Saybolt Universal Viscosity.

Starting Torque—Torque required for initiating rotary motion.

Static Coefficient of Friction—Coefficient of friction corresponding to the maximum frictional force that must be overcome to initiate motion of the two bodies in contact.

Stick-Slip—Transition from high coefficient of friction (stick) to low coefficient of friction (slip), as the relative velocity increases. This phenomenon can be explained in terms of the formation of the interfacial junctions on a microscopic scale first and then their destruction. Time duration between stick and slip will depend upon the velocity and the elastic characteristics of the system. Stick-slip in a system is indicated by a jerky motion.

Stoke (St)—Nonmetric unit of Kinematic viscosity.

STLE (Formerly ASLE)—Society of Tribologists and Lubrication Engineers.

Storage Stability—Measure of the ability of a lubricant to undergo prolonged periods of storage without showing any adverse conditions due to oxidation, oil separation, contamination, or any type of deterioration. Storage stability tests are often run on lubricants to determine their shelf life.

STOU—Super Tractor oil Universal.

Stribeck Curve—Graph showing the relationship between coefficient of friction and the dimensionless number (ZN/P), where Z is the dynamic viscosity, N is the equipment speed (revolutions per minute), and P is the load per unit of projected area.

Strong Acid Number—Quantity of base, expressed in terms of the equivalent number of mg of KOH, which is required to titrate the strong acid constituents present in 1 g of sample (ASTM Method D664 or D974).

Strong Base Number—Quantity of acid, expressed in terms of the equivalent number of mg of KOH, which is required to titrate the strong base constituents present in 1 g of sample (ASTM Method D664 or D974).

Structure—Physical arrangement of the thickener particles of the lubricating grease, additives, if any, and liquid lubricant. It is the nature and stability of this arrangement which determine the appearance, texture, and physical properties of the grease.

Sulfated Ash—Ash content (expressed as wt %) of oil determined by burning the oil, treating the residue with sulfuric acid, and evaporating to dryness.

Sulfochlorinated Lubricant—Lubricant containing chlorine and sulfur compounds, which react with the rubbing surfaces at elevated temperatures to form chemical protective films.

Sulfur-bridged Alkylphenol—Obtained by the reaction of an alkylphenol with elemental sulfur or sulfur chlorides. Such phenols are used as starting materials to make detergent additives for heavy-duty diesel engine oils.

Sulfurized Lubricant—Lubricant containing sulfur or a sulfur compound that reacts with the rubbing surfaces at elevated temperatures to form chemical protective films.

Surface Damage—Damage to a solid surface resulting from the mechanical contact with another substance, surface, or surfaces moving relative to it. Damage involves displacement or removal of the material. Wear is a form of surface damage in which the material is progressively removed. In another context, surface damage involves deterioration of function although no material loss from the surface has occurred.

Surface Distress—Distress occurs to the contacting surfaces in bearings and gears through intermittent contact as a consequence of sliding or surface fatigue, or both.

Surfactant—Chemical substance characterized by a strong tendency to form adsorbed interfacial films when in solution, emulsion, or suspension, thus producing effects such as low surface tension, penetration, boundary lubrication, wetting, and dispersing (Ref 1).

Syneresis (grease)—See Bleeding.

Synthetic Grease—A grease that contains a liquid lubricant that is not a mineral oil, but is synthetic.

Synthetic Hydrocarbons/Hydrocarbon Polymers—Base fluids and starting materials that contain carbon and hydrogen atoms only. See Polyolefins (PAOs, PIOs, and PIBs) and Alkylaromatics.

Synthetic Lubricant—See Lubricating Oil.

Synthetic Lubricating Oil—Lubricating fluid made by chemically reacting materials of a specific chemical composition to produce compound/s with desired and predictable properties. Also see Synthetic Oil/Fluid.

Synthetic Oil/Fluid—Oil produced from petroleum-derived raw materials by chemical synthesis, instead of obtaining it from petroleum refining. Examples include esters, ethers, silicones, glycols, and halogenated hydrocarbons.

Synthetic Sulfonate–A metal salt of a synthetic sulfonic acid.

Synthetic Thickener—See Nonsoap Thickener.

Tackiness—Grease description indicating its stickiness or adhesion capability.

Tag Closed-cup Tester—Instrument used to determine the flash point of flammable volatile materials flashing below 175 °F (80 °C), as described in ASTM Method D56.

TAN—Total Acid Number. See Acid Number.

TBN—Total Base Number. See Base Number.

Temporary Shear Stability Index (TSSI)—Measure of the viscosity modifier's contribution to an oil's temporary viscosity loss under high shear conditions. Temporary shear loss results from reversible deformation of the shape of the viscosity modifier in high shear regions of the engine.

Temporary Viscosity Loss (TVL)—Measure of decrease in dynamic viscosity under high shear rates compared to dynamic viscosity under low shear.

Texture—Texture of a grease, observed when a small portion of it is pressed together and then slowly separated. Also see Grease Texture.

Thermal Wear—Removal of material due to softening, melting, or evaporation during sliding or rolling.

Thickener—Solid material that is dispersed in a liquid lubricant to produce a grease. Common thickeners include soaps (metal carboxylates), silica, clays, and polyurea.

Thick-film Lubrication—State of lubrication in which the lubricant film thickness is much greater than the size of the surface asperities.

Thin-film Lubrication—Lubrication state where the lubricant film thickness is such that the friction and wear between the surfaces is determined by the properties of the surfaces as well as the viscosity of the lubricant.

Thixotropy—Property of a material to recover its consistency after a decrease due to shear. Lubricating grease exhibits this property in that the shear forces cause a decrease in consistency (softening), which reverts when the shear forces are removed.

Timken EP Test—This test is used in determine the load carrying capacity of an oil or a grease.

TISI—Thai Industrial Standards Institute

TLEV—Transitional Low Emissions Vehicle.

TPEO—Trunk Piston Engine Lubricant.

Transfer—Process in tribology by which material from one sliding surface becomes attached to another surface, possibly as the result of interfacial adhesion. Material may also back transfer to the surface from which it came. Also see Selective Transfer.

Transmission Oil—Oil used for transmission of hydraulic power and or to lubricate automobile transmission systems.

Tribo-—Prefix indicating a relationship to interacting surfaces in relative motion.

Tribo-chemistry—Chemistry dealing with the interacting surfaces in relative motion.

Tribo-element—Solid body that resides within a tribo-system and is bound by one or more tribo-surfaces.

Tribology—Science and technology of interacting surfaces in relative motion and the practices related to them. Tribology includes the study of friction, lubrication, and wear by erosion or by cavitation.

Tribometer—Instrument or test rig used to measure normal and frictional forces of moving surfaces and lubrica-

tion and wear behavior of materials or components.

Tribosystem—Functional combination of tribo-elements, including thermal and chemical surroundings.

Tribotechnology—Aspect of tribology that involves engineering applications of tribo-science and the design, development, analysis, and repair of the components for tribological applications.

U.S. Military Specification—Guide in determining the quality requirements of products used by the military services, published by the U.S. Department of Defense.

UEIL—European Union of Independent Lubricant Manufacturers.

UFIP—Union Française des Industries Pétrolières.

UHC—Unburned Hydrocarbon.

UK-PIA—United Kingdom Petroleum Industry Association.

ULEV—Ultra-low Emissions Vehicle.

UTAC—Union Technique de l'Automobile, du Motocycle et du Cycle.

UTTO—Universal Tractor Transmission Oil.

Vacuum Residue—Residue from vacuum distillation of crude oil.

Vapor-phase Lubrication—Type of lubrication in which one or more gaseous reactants are supplied to the vicinity of the surface to be lubricated and which subsequently react with the surface to form a chemical lubricating film.

Vapor Pressure Reid (RVP)—Pressure of the vapor accumulated above a sample of gasoline or other volatile fuel in a standard closed vessel (bomb) at 100 °F (37.8 °C). RVP is used to predict the vapor locking tendencies of the fuel in a vehicle's fuel system.

Varnish—Thin, insoluble, nonwipeable film occurring on some interior engine parts. It can cause sticking and malfunction of the moving parts with close clearances. Such film in a diesel engine is called lacquer. Varnish and lacquer deposits result from the oxidation or polymerization, or both, of fuels and lubricants, or both.

VI (Viscosity Index) Improver—Also called viscosity improver. It is usually a polymeric additive which is added to an oil to increase its viscosity index, that is, to reduce variation in oil viscosity with temperature. VI improvers are the additives that are used to make multi-grades.

Viscoelasticity—Combined property where the fluid is both viscous and elastic. Viscoelastic fluid deformation is dependent both upon temperature and strain rate.

Viscosity—Measure of a fluid's resistance to flow, which is due to friction that exists between fluid layers, called internal friction. Also see Kinematic Viscosity.

Viscosity Conversion Table—Table or chart which is used to convert kinematic viscosity, in centistokes, into Saybolt viscosity in seconds at the same temperature. Conversion into Saybolt Universal viscosities may be carried out by the procedures and tables described in ASTM Method D446, and into Saybolt Furol viscosities by those described in ASTM Method D666. Augmented tables are published in ASTM Special Technical Publication 43B.

Viscosity Index (VI)—Relationship of viscosity of a fluid to temperature in 40° and 100 °C range. High VI fluids lose viscosity with temperature at a slower rate than the low VI oils.

Viscosity Modifier—High molecular weight polymer that is used to maintain the viscosity of an oil in the desired viscosity range. Also see VI Improver.

VOC—Volatile Organic Compound.

Water Resistance—Resistance of an oil or the lubricating grease to be adversely effected by water. Water can cause hydrolysis of the additives or the base fluids such as carboxylate esters, phosphate esters, and poly(alkylene glycol)s, thereby diminishing lubricant performance. Some greases can experience soap washout, depending on the amount of water.

Water Spray Resistance—Ability of a grease to resist displacement from a surface by the impact of water spray.

Wear Debris—Particles that become detached in the wear process.

Wear Resistance—Resistance of a body against wear-related material removal.

Wear Scar—Portion of a solid surface that indicates removal of material due to wear.

Wear Scar Diameter—Dimensions of the wear scar.

White Oil—Highly refined lubricant stock used for specialty applications such as cosmetics and medicines.

Wick Lubrication—System in which the lubricant is delivered to the metal surface by means of a wick.

Wiping—Spreading or removal of material from one point and deposition at another point on the surface of the two bodies in sliding contact. Smeared metal is usually in a softened or a melted form.

Working—Subjecting the lubricating grease to intentional agitating or shearing action.

Worked Penetration—Penetration of a sample of lubricating grease immediately after it has been worked 60 strokes at 77 °F in a standard grease worker.

Yield Point (Yield Value or Yield Stress)—Minimum shear stress that produces flow in a plastic material.

ZDDP—Zinc Dialkyl Dithiophosphates.

ZEV—Zero Emissions Vehicle.

The Systeme International (SI) Units and Conversion Factors

This section of the Appendix provides a summary of the units of measurement that apply to the material included in this book, together with the appropriate conversion factors needed to change them into a "standard" unit of the SI. (See Tables A.1 and A.2.)

The SI is founded on seven SI base *units* for seven *base quantities* assumed to be mutually independent, as given in Table A.3. In addition, there are quantities, called *derived quantities,* which are defined in terms of the seven base quantities via a system of quantity equations [844]. Examples of the SI derived units are given in Tables A.4–A.6. SI also employs 20 prefixes to form decimal multiples and submultiples of SI unit, which are provided in Table A.7. Certain units are not part of the International System of Units per se, but are important and widely used. These units are accepted for use with the SI and are given in Table A.8. Table A.9 lists some of the commonly used Metric System units and symbols and Table A.10 provides the conversion factors.

TABLE A.1—European Lubricants Coding—ISO 6743.

LUBRICANT FAMILY	ISO STANDARD	SYMBOLS
Total loss system	**(ISO 6743/1)**	**A**
Open gears, wire ropes		AB
Undemanding applications		
Refined mineral oils		AN
Unrefined mineral oils		AY
Mold release		**B**
Gears	**(ISO 6743/6)**	**C**
Enclosed		
Mineral oils, R&O		CKB
EP/AW		CKC
EP/AW thermally stable		CKD
R&O with low friction		CKE
Splash lubrication (EP,AW)		CKG
Extreme temperature lubricants (very low or high temperatures)		CKS
CKS lubricants under high load		CKT
Open gears		
Asphaltic, R&O		CKH
Asphaltic, EP		CKJ
Grease		CKL
Intermittent application		CKM
Compressors	**(ISO 6743/3)**	**D**
Air compressors		
Reciprocating (oil lubricated compression chambers)		
Light duty (stage pressure ration < 3:1, discharge temp <160 C)		DAA
Medium duty		DAB
Heavy duty (where coke formation may occur with DAB)		DAC
Rotary vane or screw compressors		
Light duty (Discharge <800 Kpa , air temp <90 C)		DAG
Medium duty		DAH
Heavy duty (Discharge pressure >1500 Kpa or air > 110 C)		DAJ
Vacuum pumps		
Reciprocating, rotary drip-feed, rotary oil flooded (vane/screw)		
Low vacuum for non-aggressive gas (1000 to 1 mbar)		DVA
Low vacuum for aggressive gas (1000 to 1 mbar)		DVB
Oil sealed vacuum pumps (sliding, rotary vane or plunger)		
Medium vacuum for non-aggressive gas (1 to 0.001 m bar)		DVC
Medium vacuum for aggressive gas (1 to 0.001 m bar)		DVD
High vacuum for non-aggressive gas (.001 to .0000001 mbar)		DVE
High vacuum for aggressive gas (0.001 to 0.0000001 mbar)		DVF
Gas compressors		
Non-reactive gas (use oil)		
Gases which do not contain condensable materials		DGA
DGA gases containing moisture or condensable materials		DGB
Reactive gases (use synthetics)		
Gases with high solubility in mineral oil that reduce viscosity		DGC
Gases that chemically react with mineral oil		DGD
Very dry inert or reducing gases with dew point –40 C		DGE
Refrigeration compressors		
Ammonia evaporator above –40 C		DRA
Ammonia evaporator below –40 C (synthetic hydrocarbon)		DRB
Halocarbon refrigerant		DRC
Hydrocarbon refrigerant		DRD
Internal combustion engines	**(ISO 6743/15)**	**E**
Two-stroke engines		EG
Mineral base stocks-lubricity and detergency		EGB
Synthetic fluid to reduce smoke and exhaust deposits		EGC
With Synthetic fluid and added detergency, severe service		EGD
Spindle bearings, clutches	**(ISO 6743/2)**	**F**
Clutches, spindle bearings, bearings		FC
Spindle bearings, bearings		FD
Slide ways	**(ISO 6743/13)**	**G**
Hydraulic systems	**(ISO 6743/4)**	**H**
Automatic transmissions		HA
Fire resistant fluids		HF
Oil in water emulsions (soluble oils)		HFAE
Chemical solutions in water		HFAS
Water in oil emulsions (invert emulsions)		HFB
Water polymer solutions (water glycol)		HFC

TABLE A.1— (*Continued.*)

LUBRICANT FAMILY	ISO STANDARD	SYMBOLS
Synthetic fluids containing no water		HFD
Phosphate ester		HFDR
Chlorinated hydrocarbons		HFDS
Mixtures of HFDR and HFDS fluids		HFDT
Other compositions		HFDU
Hydraulic-slide way		HG
Refined mineral oil		HH
R&O		HL
Anti-wear		HM
Couplers & converters		HN
High VI R&O		HR
High VI AW		HV
Synthetic w/o fire resist		HS
Metal working	**(ISO 6743/7)**	**M**
Operations needing lubrication (oil)		
Fluid with antirust		MHA
Fluid with fat (friction reducing)		MHB
Fluid with inactive S, EP without fat		MHC
Fluid with active S, EP without fat		MHD
Fluid with inactive S with fat		MHE
Fluid with active S with fat		MHF
Greases, pastes, wax diluted with MHA		MHG
Soaps, powders, solids and blends thereof		MHH
Operations needing cooling (water)		
Soluble oils with rust prevention		MAA
Solubles with friction reduction		MAB
Solubles with EP		MAC
Solubles with friction reduction & EP		MAD
Semi-synthetics with rust prevention		MAE
Semi-synthetics with rust, AW &/or EP		MAF
Synthetics with rust preventions		MAG
Synthetics with friction and/or EP		MAH
Greases and pastes applied blended with water		MAI
Electrical insulation		**N**
Pneumatic tools	**(ISO 6743/11)**	**P**
Percussive pneumatic tools		
Non-inhibited straight mineral oil		PAA
Mineral oil with AW or corrosion prevention (CP)		PAB
Mineral oil with AW, CP, emulsifying and foam inhibition		PAC
Synthetic base fluid lubricants		PAD
Greasing (semi-fluid grease)		PAE
Rotary pneumatic tools		
Non-inhibited straight mineral oil		PBA
Mineral oil with CP		PBB
Mineral oil with AW, CP, emulsifying and foam inhibition		PBC
Synthetic base fluid lubricants		PBD
Heat transfer	**(ISO 6743/12)**	**Q**
Corrosion preventives	**(ISO 6743/8)**	**R**
Light duty		
Water-displacing fluid leaving a thin film		RA
Water-based fluid leaving an oily film		RB
RB products having water-displacing properties		RCC
More severe duty		
Undiluted fluid		RD
RD products having water-displacing properties		RDD
Solvent-based fluid leaving oily or greasy film		RE
RE products having water-displacing properties		REE
Solvent-based fluid leaving a waxy to dry film		RF
RF products having water-displacing properties		RFF
Solvent-based fluid leaving a bituminous film		RG
Water-based fluid leaving a waxy to greasy film		RH
Soft or thick grease		RK
Undiluted fluid (for protection coated materials)		RL
Fluid leaving waxy to dry film (to protect coated materials)		RM
Solvent-or water-based fluid leaving peelable film		RP
Plastic compound applied when melted		RT
Turbines	**(ISO 6743/5)**	**T**
Aircraft turbines		TA
Hydraulic		TH
Steam turbine		
Normal service, R&O		TSA
Synthetic fluids w/o fire-resistant properties		TSC

TABLE A.1— *(Continued.)*

LUBRICANT FAMILY	ISO STANDARD	SYMBOLS
Turbines	**(ISO 6743/5)**	**T**
Fire resistant phosphate		TSD
High load-carrying ability		TSE
Gas turbine		
Normal service with R&O		TGA
High temperature service with R&O		TGB
Synthetic fluids w/o fire-resistant properties		TGC
Fire-resistant (phosphate ester) for control system		TGD
High load-carrying ability		TGE
Control system (phosphate)		TCD
Heat treatment	**(ISO 6743/14)**	**U**
Grease applications	**(ISO 6743/9)**	**X**
Use 5 symbols after X		
Lower temperature (0 to <-40 C)		A through G
Upper temperature (+60 to >180 C)		A through G
Rust protection (A = bad through I = best)		A through I
Load (A = no EP, B = with EP)		A or B
NLGI Consistency		000 to 6
Example X-A-A-G-B-2 (is a EP, rust inhibited #2 EP grease, 0 to +60 C range)		
(**Note differences from DIN 51512 are base fluid code, EP code and code order**)		
Other applications	**(ISO 6743/10)**	**Y**
Process oils (dust, ink, etc)		
Benzene and naphthalene removal from coal gas		YA
Batching of fibers		YB
Caking prevention		YC
Dust suppression		YD
Extending rubber or plasticizing plastics (aromatic extracts)		YEA
Extending rubber or plasticizing plastics (naphthenics)		YEB
Extending rubber or plasticizing plastics (paraffinic)		YEC
Extending rubber or plasticizing plastics (white oil)		YED
Air filters for air conditioning systems		YF
Impregnation		YG
Cleaning and household		YH
Conditioning of leather		YL
Plant spraying		YM
Printing inks (heavy inks/absorption type printing)		YPA
Printing inks (light oils-heat-set drying or radiation set ink)		YPB
Crack detection (non-fluorescent mineral oils)		YR
Foam suppression		YS
Cosmetics (white oils)		YT
Pharmaceuticals (white oil)		YW
Electrolysis and metal plating		YX
Testing (calibration and standardizing)		YZ
Steam cylinders		**Z**

TABLE A.2—Viscosity conversion table—cSt versus SSU (SUS).

Viscosity (cSt)	Viscosity (SSU)	Viscosity (cSt)	Viscosity (SSU)	Viscosity (cSt)	Viscosity (SSU)
2	32.6	46	214	240	1112
3	36.0	50	233	250	1159
4	39.1	55	256	260	1205
5	42.5	60	279	270	1251
6	45.7	65	302	280	1297
7	49.0	70	325	290	1344
8	52.0	75	349	300	1390
9	55.7	80	372	315	1460
10	59.0	85	395	330	1529
11	62.5	90	418	350	1622
12	66.2	95	442	370	1715
13	70.0	100	465	390	1807
15	77.5	110	511	410	1900
17	85.5	120	558	430	1990
19	94	130	605	450	2090
21	100	140	649	470	2180
23	111	150	695	490	2270
25	120	160	742	500	2320
28	133	170	788	550	2540
30	142	180	834	600	2780
33	155	190	881	650	3010
35	164	200	927	700	3240
38	178	210	973	750	3470
40	187	220	1020	800	3700
43	200	230	1058		

TABLE A.3—SI base units [844].

	SI Base Unit	
Base Quantity	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	Kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

TABLE A.4—Examples of SI derived units [844].

	SI Derived Unit	
Derived Quantity	Name	Symbol
area	square metre	m^2
volume	cubic metre	m^3
speed, velocity	metre per second	m/s
acceleration	metre per second squared	m/s^2
wave number	reciprocal metre	m^{-1}
mass density	kilogram per cubic metre	kg/m^3
specific volume	cubic metre per kilogram	m^3/kg
current density	ampere per square metre	A/m^2
magnetic field strength	ampere per metre	A/m
amount-of-substance concentration	mole per cubic metre	mol/m^3
luminance	candela per square metre	cd/m^2
mass fraction	kilogram per kilogram, which may be represented by the number 1	kg/kg=1

TABLE A.5—SI derived units with special names and symbols [844].

Derived Quantity	Name	Symbol	Expression in Terms of Other SI Units	Expression in Terms of SI Base Units
plane angle	radian	rad	⋯	$m \cdot m^{-1} = 1$ [(b)]
frequency	hertz	Hz	⋯	s^{-1}
force	Newton	N	⋯	$m \cdot kg \cdot s^{-2}$
pressure, stress	Pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	Joule	J	N·m	$m^2 \cdot kg \cdot s^{-2}$

TABLE A.6—Examples of SI derived units whose names and symbols include SI derived units with special names and symbols [844].

Derived Quantity	Name	Symbol
dynamic viscosity	Pascal second	Pa·s
moment of force	Newton metre	N·m
surface tension	Newton per metre	N/m
angular velocity	radian per second	rad/s
heat capacity, entropy	Joule per Kelvin	J/K
specific heat capacity, specific entropy	Joule per kilogram Kelvin	J/(kg·K)
specific energy	Joule per kilogram	J/kg
thermal conductivity	watt per metre Kelvin	W/(m·K)
permittivity	farad per metre	F/m
molar entropy, molar heat capacity	Joule per mole Kelvin	J/(mol·K)
exposure (x and γ rays)	coulomb per kilogram	C/kg
absorbed dose rate	gray per second	Gy/s

TABLE A.7—SI Prefixes [844].

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

TABLE A.8—Non-SI units accepted for use with the SI units [844].

Name	Symbol	Value in SI units
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3600 s
litre	L	1 L = 1 $dm^3 = 10^{-3}$ m^3
metric ton or tonne	t	1 t = 10^3 kg
bar	bar	1 bar = 0.1 MPa = 100 kPa = 1000 hPa = 10^5 Pa
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
rad	rad	1 rad = 1 cGy = 10^{-2} Gy

TABLE A.9—Commonly used metric system units and symbols [845].

Quantity Measured	Unit	Symbol	Relationship
Length, width,	millimetre	mm	10 mm = 1 cm
distance, thickness,	centimetre	cm	100 cm = 1 m
girth, etc.	metre	m	
	kilometre	km	1 km = 1000 m
Mass	milligram	mg	1000 mg = 1 g
("weight")*	gram	g	
	kilogram	kg	1 kg = 1000 g
	metric ton	t	1 t = 1000 kg
Time	second	s	
Temperature	degree Celsius	°C	
Area	square metre	m^2	
	hectare	ha	1 ha = 10 000 m^2
	square kilometre	km^2	1 km^2 = 100 ha
Volume	millilitre	mL	1000 mL = 1 L
	cubic centimetre	cm^3	1 cm^3 = 1 mL
	litre	L	1000 L = 1 m^3
	cubic metre	m^3	
Speed, velocity	metre per second	m/s	
	kilometre per hour	km/h	1 km/h = 0.278 m/s
Density	kilogram per cubic metre	kg/m^3	
Force	Newton	N	
Pressure, stress	kiloPascal	kPa	
Power	Watt	W	
	kilowatt	kW	1 kW = 1000 W
Energy	kiloJoule	kJ	
	MegaJoule	MJ	1 MJ = 1000 kJ
	kiloWatt hour	kW·h	1 kW·h = 3.6 MJ
Electric current	ampere	A	

TABLE A.10—Unit conversion factors [846].

Units	Multiplied by Factor	Converted Units
ampere-hours	3600	Coulombs (C)
ampere-hours	0.03731	Faradays
amps	amp × volt	Watts
angstrom unit	3.94E – 06	inch
angstrom unit	0.0001	micron
atmospheres	76	cm of mercury
atmospheres	101.325	kilo Pascal
atmospheres	14.7	pounds/sq in.
barrels (oil)	158.9873	litre (L or l)
barrels (oil)	42	gallons (oil)
bars	0.9869	atmospheres
bars	100	kiloPascals (kPa)
bars	14.5	pounds/sq in.
Btu	1.06E + 10	ergs
Btu (39 °F)	1059.67	Joules (J)
Btu/hr	0.2930711	Watts
calorie, gram (mean)	0.00396832	Btu (mean)
calorie	1.56E – 06	horsepower-hour
calorie (mean)	4.19002	Joule
calorie	1.16E – 06	kiloWatt-hour (kWh)
Celsius (degree C)	1.8 + 32	degree Fahrenheit
centimetres (cm)	0.3937	inches
centimetres	393.7	mils
centimetres of mercury (0 °C)	1333.2239	Pascal
centimetres of mercury	0.01316	atmospheres
centimetres of mercury	0.1934	pounds/sq in. (psi)
centiPoise	1.00E – 03	Pascal second (Pa-s)
centiStokes	1.00E – 06	metre sq per second
Coulombs	1.04E – 05	Faradays
cubic centimetre	0.06102374	cu. inch
cubic centimetre	0.002113	pint (US liq.)
cubic centimetre	0.001057	quart (US liq.)
cycle per second (cps)	1	hertz
degrees Fahrenheit	–32 × 0.55555	degrees Celsius
degrees (angle)	0.01745329	radians
degrees/sec	0.1667	revolutions/min
dyne/sq cm	9.87E – 07	atmospheres
dyne/sq cm	2.95E – 05	inch of mercury at 0 °C
dynes	0.00102	grams
dynes	0.0000001	Joules/cm
dynes	0.00001	Joules/metre (Newton)
dynes	1.02E – 06	kilograms
dynes	2.25E – 06	pounds
dyne cm	1.00E – 07	Newton metre
dyne per sq cm	0.1	Pascal (Pa)
dynes/sq cm	0.000001	bars
ergs	9.48E – 11	Btu
ergs	7.37E – 08	foot-pounds
ergs	2.78E – 14	kiloWatt-h
ergs	2.78E – 11	Watt-h
ergs/s	5.69E – 06	Btu/min
ergs/s	4.43E – 06	ft-lb/min
ergs/s	7.38E – 08	ft-lb/s
ergs/s	1.34E – 10	horsepower
ergs/s	1.43E – 09	kg-calories/min
ergs/s	1.00E – 07	Watts
Fahrenheit (°F)	–32 × 0.55555	Celsius (°C)
Faradays	26.8	ampere-hours
Faraday (chemical)	96495.7	coulomb per mole
Faraday (physical)	96521.9	coulomb per mole
Feet (ft)	30.48	centimetres

TABLE A.10— (*Continued.*)

Units	Multiplied by Factor	Converted Units
foot-pounds	0.001286	Btu
foot-pounds	1.36E + 07	ergs
foot-pounds	0.3238	gram-calories
foot-pounds	5.05E – 07	hp-h
foot-pounds	1.355818	Joules
foot-pounds	0.000324	kg-calories
foot-pounds	3.77E – 07	kiloWatt-h
foot-pounds/min	0.001286	Btu/min
foot-pounds/min	0.01667	foot-pounds/s
foot-pounds/min	0.0000303	horsepower
foot-pounds/min	0.000324	kg-calories/min
foot-pounds/min	0.0226	Watts
foot-pounds/s	4.6263	Btu/h
foot-pounds/s	0.07717	Btu/min
foot-pounds/s	8.18E – 04	horsepower
foot-pounds/s	1.01945	kg-calories/min
foot-pounds/s	1.355818	watts
gallons (Imperial)	4.54609	litres
gallons (US)	3785.412	cubic cm (cc)
gallons (US)	3.785412	litres
gallons (liq. British imp.)	1.20094	gallons (US liq.)
gallons (US)	0.83267	gallons (imp.)
gauss	1.00E – 04	Tesla
grams	0.001	kilograms
grams	1000	milligrams
grams	0.035273962	ounces(avoirdupois)
grams	0.002204623	pounds
grams/cm	0.0056	pounds/inch
grams/cu. cm	0.03613	pounds/cu in
grams/litre	1000	parts/million
grams/sq cm	2.0481	pounds/sq ft
grams force/sq cm	98.0665	Pascal
gram-calories	0.0039683	Btu
gram-calories	4.19E – 07	ergs
gram-calories	3.088	foot-pounds
gram-calories	1.56E – 06	horsepower-h
gram-calories	0.001163	watt-h
gram-calories/s	14.286	Btu/h
gram-calories	9.30E – 08	Btu
gram-centimetres	980.7	ergs
gram-centimetres	980700	Joules
horsepower	42.44	Btu/min
horsepower	33000	foot-lb/min
horsepower	550	foot-lb/s
horsepower (metric)	0.9863	horsepower
horsepower	10.68	kg-calories/min
horsepower	0.7457	kilowatts
horsepower (metric)	735.4988	watts
horsepower-h	2547	Btu
horsepower-h	2.68E + 13	ergs
horsepower-h	1980000	foot-lb
horsepower-h	2684000	Joules
horsepower-h	641.1	kg-calories
horsepower-h	273700	kg-metres
horsepower-h	0.7457	kilowatt-h
inches	2.54	centimetres
inches	0.0254	metres
inches	25.4	millimetres
inches	1000	mils
inches of mercury (at 32 °F)	3386.389	Pascal
inches of mercury	0.03342	atmospheres

TABLE A.10— (*Continued.*)

Units	Multiplied by Factor	Converted Units
inches of mercury	0.03453	kgs/sq cm
inches of mercury	345.3	kgs/sq metre
inches of mercury	70.73	pounds/sq ft
inches of mercury	0.4912	pounds/sq in.
Joules	9.48E–04	Btu
Joules	10000000	ergs
Joules	0.7376	foot-pounds
Joules	0.0002389	kg-calories
Joules	0.102	kg-metres
Joules	0.0002778	watt-h
Joules/cm	10200	grams
Joules/cm	10000000	dynes
Joules/cm	100	Joules/metre (Newton)
Joules	22.48	pounds
Kelvin	t/°C=T/K –273.15	degree Celsius
kilos (slang)		kilograms
kilograms (kg)	980665	dynes
kilograms	1000	grams
kilograms	0.09807	Joules/cm
kilograms	9.807	Joules/metre (Newton)
kilograms	2.2046	pounds
kilograms	9.84E–04	tons (long)
kilograms	1.10E–03	tons (short)
kilograms/cu metre	0.001	grams/cu cm
kilograms/cu metre	0.06243	pound/cu ft
kilograms/cu metre	3.61E–05	pounds/cu in
kilograms/cu metre	3.41E–10	pounds/mil-foot
kilograms/metre	0.672	pounds/ft
kilograms/sq cm	980665	dynes
kilograms/sq cm	0.9678	atmospheres
kilograms/sq cm	28.96	inches of mercury
kilograms/sq cm	2048	pounds/sq ft
kilograms/sq cm	14.22	pounds/sq in.
kilograms/sq metre	9.68E–05	atmospheres
kilograms/sq metre	9.81E–05	bars
kilograms/cu metre	2.90E–03	inches of mercury
kilograms/cu metre	0.2048	pounds/sq ft
kilograms/cu metre	1.42E–03	pounds/sq in.
kilograms/sq mm	1.00E+06	kgs/sq metre
kilogram-calories	3.968	Btu
kilogram-calories	3088	foot-pounds
kilogram-calories	1.56E–03	hp-h
kilogram-calories	4186	Joules
kilogram-calories	426.9	kg-metres
kilogram-calories	4.186	kiloJoules
kilogram-calories	1.16E–03	kilowatt-h
kilogram-metres	9.29E–03	Btu
kilogram-metres	9.80E+07	ergs
kilogram-metres	7.233	foot-pounds
kilogram-metres	9.804	Joules
kilogram-metres	2.34E–03	kg-calories
kilogram-metres	2.72E–06	kilowatt-h
kilogram-force metres	9.80665	Newton metres
kilolitres	1000	litres
kilometres	3280.84	feet
kilometres	1000	metres
kilometres	0.6214	miles
kilometres	1094	yards
kilometres/h	0.6214	miles/h

TABLE A.10— (*Continued.*)

Units	Multiplied by Factor	Converted Units
kilowatts	56.92	Btu/min
kilowatts	737.6	foot-lb/s
kilowatts	1.341	horsepower
kilowatts	14.34	kg-calories/min
kilowatts	1000	watts
kilowatt-h	3413	Btu
kilowatt-h	3.60E+13	ergs
kilowatt-h	2.66E+06	foot-lb
kilowatt-h	1.341	horsepower-h
kilowatt-h	3.60059E +06	Joules
kilowatt-h	860.5	kg-calories
kilowatt-h	3.67E+05	kg-metres
kilowatt-h	4448.222	Newton
knots	1.8532	kilometres/h
knots	1	nautical miles/h
knots	1.151	statute miles/h (mph)
lb (short for 'pounds')	0.4536	kilograms
litres	1000	cu cm
litres	0.2642	gallons (U.S. liq.)
litres	2.113	pints (U.S. liq.)
litres	1.057	quarts (U.S. liq.)
litres/min	5.89E–04	cu ft/s
litres/min	4.40E–03	gals/s
metres	100	centimetres
metres	3.281	feet
metres	39.37	inches
metres	0.001	kilometres
metres	5.40E–04	miles (nautical)
metres	6.21E–04	miles (statute)
metres	1000	millimetres
metres	1.094	yards
metres/s	196.8	feet/min
metres/s	3.281	feet/s
metres/s	2.237	miles/h
micrograms	1.00E–06	grams
microns	1.00E–06	metres
miles (nautical)	1.852	kilometres
miles/h	1.609344	kms/h
miles/h	0.8684	knots
millibars	100	Pascals
millibars	0.0295299	inches of mercury
milligrams	0.001	grams
milligrams/litre	1	parts/million
millilitres	0.001	litres
millimetres	0.1	centimetres
millimetres	3.28E–03	feet
millimetres	0.03937	inches
millimetres	1.00E–06	kilometres
millimetres	0.001	metres
millimetres	39.37	mils
mils	2.54E–03	centimetres
mils	0.001	inches
mils	2.54E–02	millimetres
Newton	1.00E+05	dynes
Newton	0.2248	pound force (lbf)
ounces	28.349523	grams
ounces	0.0625	pounds
ounces (fluid)	0.02957	litres
oz or ozs (short for ounce)	28.349523	grams
pints (US liquid)	473.1765	cu cm

TABLE A.10— (*Continued.*)

Units	Multiplied by Factor	Converted Units
pints (US liquid)	0.125	gallons (US)
pints (US liquid)	0.4731765	litres
pints (US liquid)	473.1765	millilitres
pints (US liquid)	16	ounce (US fluid)
pints (US liquid)	0.5	quarts (liquid)
Poise (P)	0.1	Pascal s
Poiseuille	1	Pascal s
pounds	453.5924	grams
pounds	0.04448	Joules/cm
pounds	4.448	Joules/metre (Newton)
pound (lb)	0.4536	kilograms
pounds	16	ounces
pounds	0.0005	tons (short)
pound force (lbf)	4.448	Newton
pounds/ft	1.488	kgs/metre
pounds/in.	178.6	gms/cm
pounds/sq in.	0.06804	atmospheres
pounds/sq in.	2.036	inches of mercury
pounds/sq in.	6894.757	Pascal (Pa)
psi (pounds-force/sq in.)	6.894757	kiloPascal (kPa)
quarts (liquid)	946.4	cu cms
quarts (liquid)	0.25	gallons
quarts (liquid)	0.9463	litres
rad (ionizing radiation)	0.01	gray (Gy)(Joule/kg)
revolutions/min (r/min)	6	degrees/s
revolutions/min	0.1047198	radians/s
square centimetres	0.155	square inches
stokes	1.00E−04	metre sq per s
quarts (liquid)	0.25	gallons
quarts (liquid)	0.9463	litres
rad (ionizing radiation)	0.01	gray (Gy)(Joule/kg)
revolutions/s	60	revs/min
square centimetres	0.155	square inches
square inches	6.452	sq cm
square millimetres	1.55E−03	sq inches
stokes	1.00E−04	metre sq per s
tons (long)	1016.047	kilograms
tons (tonne)(metric)	1000	kilograms
tons (metric)	2205	pounds
tons (short)	2000	pounds
tons (short)	0.9071847	tonnes (metric)
torr	133.32237	pascal
watts	3.4129	Btu/h
watts	44.27	foot-lb/min
watts	1.34E−03	horsepower
watts	1.36E−03	horsepower (metric)
watts	0.01433	kg-calories/min
watt hour	3600	Joule
watt-hours	3.413	Btu