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Standard Terminology Relating to Metallography[1]

This standard is issued under the fixed designation E7; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This standard covers the definition of terms, acronyms, and symbols used in ASTM documents related to the field of metallography and metallographic testing. Terms that are only relevant to a particular standard or that are adequately defined in a general dictionary are not defined in this terminology standard.

1.2 This standard includes terminology used in metallographic areas, such as, but not limited to: light microscopy, microindentation hardness testing, specimen preparation, x-ray and electron metallography, quantitative metallography, photomicrography, and determination of grain size and inclusion content.

1.3 This standard may be of use to individuals utilizing standards of Committee E04 as well as by those in need of a general reference source for terminology in the field of metallography.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E45 Test Methods for Determining the Inclusion Content of Steel

E80 Recommended Practice for Dilatometric Analysis of Metallic Materials; Replaced by E 228 (Withdrawn 1986)[3]

E112 Test Methods for Determining Average Grain Size

E175 Terminology of Microscopy (Withdrawn 2019)[3]

E1122 Practice for Obtaining JK Inclusion Ratings Using Automatic Image Analysis (Withdrawn 2006)[3]

3. Significance and Use

3.1 Standards of Committee E04 consist of test methods, practices, and guides developed to ensure proper and uniform testing in the field of metallography. In order for one to properly use and interpret these standards, the terminology used in these standards must be understood.

3.2 The terms used in the field of metallography have precise definitions. The terminology and its proper usage must be completely understood in order to adequately communicate in this field. In this respect, this standard is also a general source of terminology relating to the field of metallography facilitating the transfer of information within the field.

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[1] This terminology is under the jurisdiction of ASTM Committee E04 on Metallography and are the direct responsibility of Subcommittee E04.02 on Terminology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

4. Terminology

Abbe condenser—see **condenser, Abbe**. (E175)

aberration—any error that results in image degradation. Such errors may be chromatic, spherical, astigmatic, comatic, distortion, or curvature of field; and can result from design or execution, or both. (E175)

absorption—the decrease in intensity which radiation undergoes during its passage through matter when the ratio of transmitted or reflected luminous flux to incident is less than 1.

absorption coefficient—specific factor characteristic of a substance on which its absorption radiation depends. The rate of decrease of the natural logarithm of the intensity of a parallel beam per unit distance traversed in a substance. For X-rays, the linear absorption coefficient is the natural logarithm of the ratio of the incident intensity of an X-ray beam incident on unit thickness of an absorbing material to the intensity of the beam transmitted. If $I_e$is the incident intensity of a beam of X-rays, $I_t$the transmitted intensity, and X the thickness of the absorbing material, then:

$$I_t = I_e exp(-\mu X) \quad (1)$$

Here μ is the linear absorption coefficient. The mass absorption coefficient is given by μ/ρ where ρ is the density.

absorption edge—an abrupt change in absorption coefficient at a particular wavelength. The absorption coefficient is always larger on the short wavelength side of the absorption edge.

absorption limit—See **absorption edge**.

accelerating potential—a relatively high voltage applied between the cathode and anode of an electron gun to accelerate electrons.

achromatic—literally, color-free. A lens or prism is said to be achromatic when corrected for two colors. The remaining color seen in an image formed by such a lens is said to be secondary chromatic aberration. See **apochromatic objective**

achromatic objective—an objective that is corrected chromatically for two colors, and spherically for one, usually in the yellow-green part of the spectrum.

achromatic objective lens—an objective lens with longitudinal chromatic correction for green and blue, and spherical chromatic correction for green. Note—Lens should be used with a green filter.

acid extraction—See **extraction**.

air-lock—an intermediate enclosed chamber of a vacuum or pressure system through which an object may be passed without materially changing the vacuum or pressure of the system.

airy disk—the image of a bright point object, as focused by a lens system.

DISCUSSION—

With monochromatic light, it consists of a central point of maximum intensity surrounded by alternate circles of light and darkness caused by the reinforcement and interference of diffracted rays. The light areas are called maxima and the dark areas minima. The distribution of light from the center to the outer areas of the figure was investigated mathematically by Sir George Airy. The diffraction disk forms a basis for determining the resolving power of an ideal lens system. The diameter of the disk depends largely on the aperture of the lens. The diffraction of light causing the Airy disk is a factor limiting the resolution of a well corrected optical system. (E175)

alignment—a mechanical or electrical adjustment of the components of an optical device in such a way that the path of the radiating beam coincides with the optical axis or other predetermined path in the system. In electron optics there are three general types:

(*1*) *magnetic alignment*—an alignment of the electron optical axis of the electron microscope such that the image rotates about a point in the center of the viewing screen when the current flowing through a lens is varied.

(*2*) *mechanical alignment*—a method of aligning the geometrical axis of the electron microscope by relative physical movement of the components, usually as a step preceding either magnetic or voltage alignment.

(*3*) *voltage alignment*—a condition of alignment of an electron microscope such that the image expands or contracts symmetrically about the center of the viewing screen when the accelerating voltage is changed.

allotriomorphic crystal—a crystal whose lattice structure is normal, but whose outward shape is imperfect since it is determined to some extent by the surroundings; the grains in a metallic aggregate are allotriomorphic crystals.

alloy system—a complete series of compositions produced by mixing in all proportions any group of two, or more, components, at least one of which is a metal.

alpha brass—a solid solution phase of one or more alloying elements in copper and having the same crystal lattice as copper.

alpha iron (Fe)—solid phase of pure iron which is stable at temperatures below 910°C and possesses the body-centered cubic lattice. It is ferro-magnetic below 768°C.

amplifier—a negative lens, used in lieu of an eyepiece, to project under magnification the image formed by an objective. The amplifier is especially designed for flatness of field and should be used with an apochromatic objective.

ampliphan eyepiece— See **amplifier**.

analyzer—an optical device, capable of producing plane polarized light, used for detecting the state of polarization.

angle of reflection: (*1*)*reflection* —the angle between the reflected beam and the normal to the reflecting surface.
(*2*) *diffraction*—the angle between the diffracted beam and the diffracting planes.

Angstrom unit (abbreviation) = A,Å , or*A. U*—a unit of length equal to 10^{-8} cm. This is the standard unit of measurement in X-ray crystallography.

angular aperture—See **aperture, optical**.

anisotropic (replaces anisotropy)—having different values for a property, in different directions.

annealing-twin bands— See **twin bands**.

anode aperture—See **aperture**.

anvil—the base on which objects for hardness test are placed.

anvil effect—the effect caused by use of too high a load or when testing the hardness of too thin a specimen, resulting in a bulge or shiny spot on the under side of the specimen.

aperture, angular—the angle between the most divergent rays that can pass through a lens to form the image of an object **(E175)**

aperture, effective—the diameter of the entrance pupil; it is the apparent diameter of the limiting aperture measured from the front. **(E175)**

aperture, electron:—
anode aperture— the opening in the accelerating voltage anode shield of the electron gun through which the electrons must pass to illuminate or irradiate the specimen.

condenser aperture—an opening in the condenser lens controlling the number of electrons entering the lens and the angular aperture of the illuminating beam. The angular aperture can also be controlled by the condenser lens current.

physical objective aperture—a metal diaphragm, centrally pierced with a small hole, used to limit the cone of electrons accepted by the objective lens. This improves image contrast since highly scattered electrons are prevented from arriving at the Gaussian image plane and therefore can not contribute to background fog.

aperture, optical—the working diameter of a lens or a mirror.

angular aperture— the angle between the most divergent rays which can pass through a lens to form the image of an object.

aplanatic—corrected for spherical aberration and coma. **(E175)**

aperture diaphragm—a device to define the aperture.

apochromatic objective—an objective with longitudinal chromatic correction for red, green and blue, and spherical chromatic correction for green and blue. This is the best choice for high resolution or color photomicrography.

arcing—in electron diffraction, the production of segments of circular patterns, indicating a departure from completely random orientation of the crystals of the specimen.

arrest—that portion of a cooling curve in which temperature is invariant with time (for example, thermal or eutectic arrest).

artifact—a false microstructural feature that is not an actual characteristic of the specimen; it may be present as a result of improper or inadequate preparation, handling methods, or optical conditions for viewing.

ascending fork point—in a ternary phase diagram, the configuration at the convergence of the three bivariant curves upon each of the four phases associated in Class II univariant equilibrium; for example, the union of two ascending liquidus surface valleys to form one ascending liquidus surface valley.

aspect ratio—the length-to-width ratio of a microstructural feature in a two-dimensional plane.

asterism—a lengthening of diffraction spots usually in the radial direction.

astigmatism—a defect in a lens or optical system which causes rays in one plane parallel to the optical axis to focus at a distance different from those in the plane at right angles to it.

ASTM grain size number— See **grain size**.

athermal—not isothermal, with changing rather than constant temperature conditions.

atomic replica—See **replica**.

atomic scattering factor—the ratio of the amplitude of the wave scattered by an atom to that scattered by a single electron. Symbol = *f*.

austenite—a face-centered cubic solid solution of carbon or other elements in gamma iron.

austenite grain size—the grain size which exists or existed in austenite at a given temperature. See Test Methods E112.

autographic dilatometer—a dilatometer that automatically records instantaneous and continuous changes in dimensions and some other controlled variable such as temperature or time.

autographic pyrometer— See **pyrometer**.

automatic image analysis—the separation and quantitative evaluation of an image into its elements with or without operator interaction. It includes the enhancement, detection, and quantification of the features contained in an image through the use of optical, geometrical, and stereological parameters and a computer program. Image analysis data output can provide individual measurements on each separate feature (feature specific) or totals for all features of a particular type in the field (field specific).

automatic image analyzer—a device which can be programmed to detect and measure features of interest in an image. It may include accessories such as automatic focus and an automatic traversing stage to permit unattended operation.

average coefficient of cubical expansion— average change in unit volume of a substance per unit change in temperature over a specified range of temperature.

average coefficient of linear expansion— average change in unit length of a body per unit change in temperature over a specified range of temperature.

average coefficient of thermal expansion— general term. (See also **average coefficient of cubical expansion** and **average coefficient of linear expansion**.)

average grain diameter— See **grain size**.

axial ratio—the ratio of the length of one axis to that of another (for example, *c*/*a*) or the continued ratio of three axes (for example, *a:b:c*).

axis (crystal)—the edge of the unit cell of a space lattice. Any one axis of any one lattice is defined, in length and direction, with respect to the other axes of that lattice.

axis, optical—the line formed by the coinciding principal axes of a series of optical elements comprising an optical system. It is the line passing through the centers of curvature of the optical surfaces. **(E175)**

axis, optic—the direction, or directions in an anisotropic crystal along which light is not doubly refracted. **(E175)**

Babo's law—the vapor pressure over a liquid solvent is lowered approximately in proportion to the quantity of a nonvolatile solute dissolved in the liquid.

backing film—a film used as auxiliary support for the thin replica or specimen-supporting film.

back reflection—the diffraction of X-rays at a Bragg angle approaching 90°.

bainite—upper, lower, intermediate— metastable microstructure or microstructures resulting from the transformation of austenite at temperatures between those which produce pearlite and martensite. These structures may be formed on continuous (slow) cooling if the transformation rate of austenite to pearlite is much slower than that of austenite to bainite. Ordinarily, these structures may be formed isothermally at temperatures within the above range by quenching austenite to a desired temperature and holding for a period of time necessary for transformation to occur. If the transformation temperature is just below that at which the finest pearlite is formed, the bainite (upper bainite) has a feathery appearance. If the transformation temperature is just above that at which martensite is produced, the bainite (lower bainite) is acicular, resembling slightly tempered martensite. At the higher resolution of the electron microscope, upper bainite is observed to consist of plates of cementite in a matrix of ferrite. These discontinuous carbide plates tend to have parallel orientation in the direction of the longer dimension of the bainite areas. Lower bainite consists of ferrite needles containing carbide platelets in parallel array cross-striating each needle axis at an angle of about 60°. Intermediate bainite resembles upper bainite; however, the carbides are smaller and more randomly oriented.

balsam, Canada——a resin from the balsam fir *Abies balsamea*.

DISCUSSION—
Dissolved in xylene, toluene, or benzene it is used as a mountant for permanent microscopical preparations. Its refractive index may vary from 1.530 to 1.545 and its softening point from room temperature to 100°C, these properties varying with age and solvent content. If impure it discolors with age. **(E175)**

band—in electron diffraction, a broad intensity maximum with sharp edges.

banded structure (banding)—alternate bands parallel with the direction of working resulting from the elongation of segregated areas.

barrel distortion— See **distortion**.

basal plane—that plane of a hexagonal or tetragonal crystal which is perpendicular to the axis of highest symmetry. Its Miller indices are (0001) or (001), respectively.

bellows length—the distance from the eyepiece to the photosensitive material or viewing screen in a photomicrographic apparatus.

Bertrand lens—an auxiliary removable lens in the body of a microscope, used to examine images in the back focal plane of the objective, for example, interference figures with polarized light.

beta structure—structurally analogous body-centered cubic phases (similar to beta brass), or electron compounds, that have ratios of 3 valence electrons to 2 atoms.

biased gun—an electron gun in which there is a bias voltage on the cathode cap. (See also **self-biased gun**.)

bifilar eyepiece—a Filar eyepiece with motion in two mutually perpendicular directions.

bi-modal grain size distribution—a condition where the distribution of individual grain areas or intercept lengths, converted to ASTM grain size numbers (based on the area percent or length percent per G class) exhibits two peaks.

binary alloy—any specific composition in a binary system.

binary system—the complete series of compositions produced by mixing a pair of components in all proportions.

binodal curve—in a two-dimensional phase diagram, a continuous line consisting of both of the pair of conjugate boundaries of a two-phase equilibrium and which join, without inflection, at a critical point. See **miscibility gap**.

birefringent—having more than one refractive index. Such materials exhibit alternately bright and dark reflections at 45° intervals during a 360° rotation with plane-polarized light. (See also **anisotropic**.)

bivariant equilibrium—a stable state among a number of phases equal to the number of components in a system and in which any two of the external variables (temperature, pressure, or concentrations) may be varied, at will, without necessarily causing a change in the number of phases; sometimes called divariant equilibrium.

bisectrix, acute—in biaxial crystals, that principal axis of the ellipsoid of indexes which bisects the smaller angle between the optic axes. **(E175)**

bisectrix, obtuse—in biaxial crystals, that principal axis of the ellipsoid of indexes which bisects the larger angle between the optic axes. **(E175)**

blowholes—a hole produced in a casting by gas which was trapped during solidification.

body-centered—having an atom (or group of atoms) separated by a translation of ½, ½, ½ from a similar atom (or group of atoms). The number of atoms in a body-centered cell must be a multiple of two.

boiling pressure—at a specified temperature, the pressure at which a liquid and its vapor are in equilibrium.

boiling temperature—at a specified pressure, the temperature at which a liquid and its vapor are in equilibrium.

bonded abrasive disk—a rigid support surface with an abrasive, typically diamond, bonded to the surface by a ceramic, resin, or metal based material.

boundary grain—in the Jeffries' method for grain size measurement, a grain that is intersected by the boundary of the standard area and is, therefore, counted only as one-half grain. (See also **Jeffries' Method**.)

Bragg angle—the angle between the incident beam and the lattice planes considered.

Bragg equation:—

$$n\lambda = 2d\sin\theta \tag{2}$$

where:

n = order of reflection,
λ = wavelength of X-rays,
d = distance between lattice planes, and
θ = Bragg angle.

Bragg method—a method of X-ray diffraction in which a single crystal is mounted on a spectrometer with a crystal face parallel to the axis of the instrument.

Braun's law—the ratio of the solubility change with pressure, temperature being constant, $(\delta X/\delta P)T$, to the solubility change with temperature, pressure being constant, $(\delta X/\delta T)P$, is equal to the negative of the product of the absolute temperature, T, and the (fictitious) volume change (Δv) which accompanies the solution of 1 g·molecular weight of the solute in an infinitely large quantity of the saturated solution at T degrees, divided by the amount of heat, Q, developed in the process:

$$(\delta X/\delta P)T/(\delta X\,\delta T)P = -T\cdot\Delta v/Q \tag{3}$$

brightfield illumination— *for reflected light*, the illumination which causes specularly reflected surfaces normal to the axis of a microscope to appear bright. *For transmission electron microscopy*, the illumination of an object so that it appears on a bright background.

burning (burnt, burned)—a term applied to metal which has been permanently damaged by having been heated to a temperature close to or within the melting range. This results in a structure exhibiting incipient melting or intergranular oxidation.

calibration—1) the act or process of determining the relationship between a set of standard units of measure and the output of an instrument or test procedure,

2) the graphical or mathematical relationship relating the desired property (expressed in a standard unit of measure such as micrometers or Kg/mm^2) to the instrument output (instrument units such as filar divisions or pixels).

caliper diameter (Feret's diameter)—the length of a line normal to two parallel lines, tangent to opposite edges of a phase or object.

calcite—a doubly refracting mineral used in the manufacture of polarizing prisms.

DISCUSSION—

It is uniaxial negative and in the trigonal diversion of the hexagonal system of crystals. Its indexes are $\varepsilon = 1.486$, $\omega = 1.658$; its hardness is 3 on the Mohr scale and specific gravity 2.711. **(E175)**

Canada balsam——see **balsam, Canada**. **(E175)**

carbide—a compound of carbon with one or more elements, which, in customary formulation, are considered as being more positive than carbon.

case—*in a ferrous alloy*, the outer portion that has been made harder than the inner portion (see **core**) as a result of altered composition, or structure, or both, from treatments such as carburizing, nitriding, and induction hardening.

cassette—a light-tight film or plate holder.

*cast replica***—**See **replica**.

cast structure—the structure, on a macroscopic or microscopic scale, of a casting.

cathode lens—a lens field terminated on one side by a surface at zero potential (cathode) normal to the optic axis. A cathode lens occurs in any system in which a cathode is imaged by its own electron emission, be it thermionic, photoelectric, secondary, or field emission.

cementite—a very hard and brittle compound of iron and carbon corresponding to the empirical formula Fe_3C. It is commonly known as iron carbide and possesses an orthorhombic lattice. In "plain-carbon steels" some of the iron atoms in the cementite lattice are replaced by manganese, and in "alloy steels" by other elements such as chromium or tungsten. Cementite will often appear as distinct lamellae or as spheroids or globules of varying size in hypo-eutectoid steels. Cementite is in metastable equilibrium and has a tendency to decompose into iron and graphite, although the reaction rate is very slow.

central pencil—a bundle of rays originating in the axis with an angular aperture equal to the effective aperture of the lens. These rays pass through the lens aperture and contribute to the formation of the image.

certified reference material—a reference material, the composition or properties of which are certified by a recognized standardizing agency or group. Typically such a material is accompanied by documentation (certificate).

characteristic curve—the curve showing the relationship between exposure and resulting density in a photographic image. It is usually plotted as the density against the log exposure. Called also the "H and D curve" and the "sensitometric curve."

characteristic radiation—X-radiation of a particular set of wavelengths, produced by and characteristic of a particular element used as a target whenever its excitation potential is exceeded.

charge neutralizer gun—an electron gun used to dissipate the charges which tend to build up on specimen surfaces, within an electron-diffraction camera, which would introduce undesired electrostatic fields.

chemical potential—(μ_i or G^-_i) the partial molar free energy of component *i*, that is, the change in free energy of a solution upon adding one mole of component *i* to an infinite amount of solution of given composition,

$$(\delta G/\delta n_i)_{T,P,n_{1...}} = \bar{G}_i = \mu_i \quad (4)$$

where:

G = Gibbs free energy, and
n_i = number of moles of the i^{th}component.

Chinese script eutectic—a configuration of eutectic constituents, found particularly in some cast alloys of aluminum containing iron and silicon and in magnesium alloys containing silicon, which resembles in appearance the characters in Chinese script.

chlorine or volatile halide extraction—See **extraction**.

chromatic aberration—a defect in a lens or lens system as a result of which the lens possesses different focal lengths for radiation of different wavelengths.

Class I quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, one of which must disappear upon lowering the temperature or pressure; for example, the quaternary eutectic equilibrium, $L = \alpha + \beta + \gamma + \delta$.

Class I quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, one of which must disappear upon lowering the temperature or pressure; for example, the quinary eutectic equilibrium, $L = \alpha + \beta + \gamma + \sigma + \varepsilon$.

Class I ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, one of which must disappear upon lowering the temperature or pressure; for example, the ternary eutectic equilibrium, $L = \alpha + \beta + \delta$.

Class II quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, two of which appear in each of the three associated bivariant equilibria at temperatures and pressures above, while the other three phases all occur in both of the associated bivariant equilibria below; for example, $L + \alpha = \beta + \gamma + \delta$.

Class II quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, two of which appear in each of the four associated bivariant equilibria at temperatures and pressures above, while the other four phases occur in both of the associated bivariant equilibria below; for example, $L + \alpha = \beta + \gamma + \delta + \varepsilon$.

Class II ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, two of which appear in both of the associated bivariant equilibria at higher temperature and pressure, while the other two phases occur in both bivariant equilibria below; for example, $L + \alpha = \beta + \gamma$.

Class III quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, three of which appear in both of the associated bivariant equilibria at temperatures and pressures above, while the other two phases occur in all three of the associated bivariant equilibria below; for example, $L + \alpha + \beta = \gamma + \delta$.

Class III quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, three of which appear in all three of the associated bivariant equilibria at temperatures and pressures above, while the other three occur in all three of the associated bivariant equilibria below; for example, $L + \alpha + \beta = \gamma + \delta + \varepsilon$.

Class III ternary equilibrium—in a three-component system, the stable univariant coexistence of four phases, one of which must disappear at higher temperature or pressure; for example, the ternary peritectic equilibrium, $L + \alpha + \beta = \gamma$.

Class IV quaternary equilibrium—in a four-component system, the stable univariant coexistence of five phases, one of which must disappear at higher temperature or pressure; for example, the quaternary peritectic equilibrium, $L + \alpha + \beta + \gamma = \delta$.

Class IV quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, four of which appear in both associated bivariant equilibria at temperatures and pressures above, while the other two occur in all four associated bivariant equilibria below; for example, $L + \alpha + \beta + \gamma = \delta + \varepsilon$.

Class V quinary equilibrium—in a five-component system, the stable univariant coexistence of six phases, one of which must disappear upon increasing the temperature or pressure; for example, the quinary peritectic equilibrium, $L + \alpha + \beta + \gamma + \delta = \varepsilon$.

Clausius-Clapeyron equation—the rate of change of the pressure of a heterogeneous equilibrium with change of temperature dP/dT is equal to the heat of transformation from the low to the high temperature state ΔHv divided by the product of the absolute temperature of the equilibrium and the volume change of the transformation $T\Delta V$:

$$dP/dT = \Delta Hv/T\Delta V \tag{5}$$

or,

$$d\ln P/dT \approx Hv/RT \tag{6}$$

where R is the gas constant and the equilibrium is not near a critical point.

clear cross test—an experimental method for determining which of two conceivable two-phase equilibria is real; at that composition at which the two conceivable two-phase fields cross, an alloy is brought to equilibrium and the phases identified; the same principle may be applied to higher-order equilibria in higher-order systems.

clear glass focusing screen—a glass screen polished on both sides and mounted for use in a camera, in lieu of photo-sensitive material, for the purpose of establishing a plane on which to focus an image prior to recording it.

cleavage planes—that family of planes of a crystal along which the crystal is easily split.

close packed—a geometric arrangement whereby a collection of equally sized spheres (atoms) may be packed together in a minimum total volume.

coefficient of thermal expansion—change in unit of length (or volume) accompanying a unit change of temperature, at a specified temperature.

coalescence—growth of grains at the expense of the remainder by absorption or the growth of a phase or particle at the expense of the remainder by absorption or by reprecipitation.

coarse grains—grains either larger than normal for the particular wrought metal or alloy, or grains of such a size that a surface roughening, popularly known as “orange peel” or “alligator skin,” is produced.

coherent precipitate—a precipitated particle of a second phase, the lattice of which still maintains registry with the matrix lattice. Because the lattice spacings are usually different, strains usually exist at the interface.

coherent scattering—a kind of X-ray electron scattering in which the phase of the scattered beam has a definite (not random) relation to the phase of the incident beam. Also called unmodified scattering.

cold-cathode gun—an electron gun in which electrons produced in a gas discharge are accelerated through a small aperture in the anode.

cold junction—See **reference junction**.

cold junction correction— See **reference junction correction**.

cold worked structure—a microstructure resulting from plastic deformation of a metal or alloy below its recrystallization temperature.

collimation—the operation of controlling a beam of radiation so that its rays are as nearly parallel as possible.

collodion replica— See **replica**.

color film—a photographic film consisting of several emulsion layers, where the individual layers selectively record various wavelengths of light.

color temperature—the temperature of a blackbody in degrees Kelvin (K). In photography, the apparent temperature in K of a luminous source which may be measured by its emission ratio of blue to red light.

column, electron microscope—the assembly of gun, lenses, and specimen, viewing and plate chambers.

columnar structure—a macro- or microstructure characterized by elongated grains whose long axes are parallel, for example, to solidification direction, electroplated direction, etc.

coma—a lens aberration occurring in that part of the image field that is some distance from the principal axis of the system. It results from different magnification in the various lens zones.

DISCUSSION—

Extra-axial object points appear as short comet-like images with the brighter small head toward the center of the field (positive coma) or away from the center (negative coma). **(E175)**

comparison standard—a standard micrograph or a series of micrographs, usually taken at 75 or 100 diameters, or a suitable equivalent built into the eyepiece and used to determine grain size by direct comparison with the image.

compensating eyepiece—one designed for use with objectives such as apochromats, the lateral chromatic aberration of which is undercorrected.

compensating lead wires—wires leading from a thermocouple to the voltage-measuring instrument. These wires must be of such compositions that they will generate an *emf* equivalent to the *emf* generated by the reference junction of the couple.

complex silicate inclusions—a general term describing silicate inclusions containing visible constituents besides the silicate matrix. An example would be corundum or spinel crystals occurring in a silicate matrix in steel.

component—one of the independently variable substances by means of which the composition of each phase of a system of heterogeneous equilibrium may be described completely; usually an element, or a compound that remains undissociated throughout the range of temperature and pressure concerned.

composition—the quantity of each of the components of a mixture; usually expressed in terms of the weight percentage, or the atomic percentage of each of the components in the mixture.

Compton scattering—X-ray scattering by atoms in which the scattered beam has, relative to the incident beam, a longer wavelength and a random phase relationship. Also called incoherent or modified scattering.

condensed system—a pure substance, or mixture, at a pressure and temperature such that the vapor phase does not exist.

condenser—a term applied to lenses or mirrors designed to collect, control, and concentrate radiation in an illumination system.

condenser, Abbe—originally a two-lens substage condenser combination designed by Ernst Abbe.

DISCUSSION—

It lacks chromatic correction though designed for a minimum of spherical aberration and has only a very low-angle aplanatic cone. It may be rated with a numerical aperture as high as 1.3. **(E175)**

*condenser aperture***—** See **aperture**.

condenser, darkfield—a condenser forming a hollow cone of light with its apex (or focal point) in the plane of the specimen.

DISCUSSION—

When used with an objective having a numerical aperture lower than the minimum numerical aperture of the hollow cone, only light deviated by the specimen enters the objective. Objects are seen as bright images against a dark background. **(E175)**

condenser, darkfield, bispheric—a darkfield condenser consisting of a convex spherical reflector mounted concentric with a larger concave reflector.

DISCUSSION—

The rays are formed into a diverging cone by the convex reflector. The annular concave reflector then forms a hollow converging cone which is focused on the subject. See **condenser, darkfield**. **(E175)**

condenser lens—a device used to focus radiation in or near the plane of the object.

condenser, darkfield, paraboloid—a darkfield condenser consisting of a reflecting surface in the form of a segment of a paraboloid of revolution.

DISCUSSION—

Parallel rays entering the condenser around the periphery of the central stop are reflected from the curved surfaces and converge at the focus of the paraboloid. See **condenser, darkfield**. **(E175)**

condenser, variable-focus—essentially an Abbe condenser in which the upper lens element is fixed and the lower movable.

DISCUSSION—

The lower lens may be used to focus the illumination between the elements so that it emerges from the stationary lens as a large diameter parallel bundle. The field of low-power objectives may thus be filled without removing the top element. At the opposite extreme it can be adjusted to have a numerical aperture as high as 1.3. **(E175)**

congruent transformation—an isothermal, or isobaric, phase change in which both of the phases concerned have the same composition throughout the process; the order of a system becomes unary at a composition of congruency.

conjugate phases—those states of matter of unique composition which coexist at equilibrium at a single point in temperature and pressure; for example, the two coexisting phases of a two-phase equilibrium.

conjugate planes—two planes of an optical system such that one is the image of the other.

constituent—a phase, or combination of phases, which occurs in a characteristic configuration in an alloy micro-structure.

constitutional diagram—graphical representation of the compositions, temperatures, pressures or combinations thereof at which the heterogeneous equilibria of an alloy system occur; also called “phase diagram,” or “equilibrium diagram.”

continuous phase—the phase forming the matrix or background in which other phases may be dispersed as isolated units.

continuous spectrum (X-rays)—the polychromatic radiation given off by the target of an X-ray tube, containing all wavelengths above a certain minimum value called the short wave length limit.

contrast enhancement (electron optics)— an improvement in electron image contrast by the use of an objective aperture diaphragm, shadow casting, or other means.

contrast perception—the ability to differentiate various components of the object structure by different intensity levels in the image.

contrast, photographic—the word contrast has been used in many different senses in connection with various photographic characteristics; there are different types of photographic contrast and different methods of measuring it. It is frequently used to designate the magnitude of the density difference resulting from a given exposure difference. (For another use, see **gamma**.)

conversion, hardness—the exchange of a hardness number determined by one method for an equivalent hardness number of a different scale.

cooling curve—graphical representation of the course of temperature fall of a chemical mixture as a function of time commonly exhibiting more or less abrupt changes of rate at, or near, those temperatures at which phase changes begin; used in finding the temperatures at which phase changes occur. Occasionally, some property or function other than time may be used; for example, thermal expansion.

cooling rate—the average slope of the time-temperature curve taken over a specified time and temperature interval.

core—(*1*) *case hardening*—interior portion of unaltered composition, or microstructure, or both, of a case-hardened steel article. (*2*) *clad products*—the central portion of a multilayer composite metallic material.

coring—a variable composition between the center and outside of a unit of structure, (such as a dendrite, grain, carbide particle) resulting from non-equilibrium growth which occurs over a range of temperatures or compositions.

corona shield—a smooth, rounded metal covering placed around exposed high-voltage components to prevent electrical discharge.

counter—a device for the measurement of radiation intensity by means of an electrical triggering principle (Geiger-Müller).

coupler, color—a substance capable of reacting with the oxidation product of a color-forming developer to produce a colored dye image.

critical curve—in a binary, or higher order, phase diagram, a line along which the phases of a heterogeneous equilibrium become identical.

critical illumination—see **illumination, critical**. **(E175)**

critical point—in a phase diagram, that specific value of composition, temperature, pressure or combinations thereof at which the phases of a heterogeneous equilibrium become identical. (See also **transformation temperature**.)

critical pressure—that pressure above which the liquid and vapor states are no longer distinguishable.

critical surface—in a ternary, or higher order, phase diagram, the area upon which the phases in equilibrium become identical.

critical temperature—that temperature above which the vapor phase cannot be condensed to liquid by an increase in pressure.

cross direction—one of three mutually perpendicular directions used to define a worked material, specifically that direction in the plane of working which is at right angles to the direction of maximum elongation.

crystal—a solid composed of atoms, ions, or molecules arranged in a pattern which is periodic in three dimensions.

crystal, birefringent——a pertaining to the use of a microscope. **(E175)**

crystal analysis—a method for determining crystal structure, for example, the size and shape of the unit cell and the location of all atoms within the unit cell.

crystallite—a crystalline grain not bounded by habit planes.

crystal system—one of seven groups into which all crystals may be divided; triclinic, monoclinic, orthorhombic, hexagonal, rhombohedral, tetragonal, and cubic.

cube texture—a texture found in wrought metals in the cubic system, in which nearly all the crystal grains have a plane of the type (100) parallel or nearly parallel to the plane of working and a direction of the type [001] parallel or nearly parallel to the direction of elongation.

cubic—having three mutually perpendicular axes of equal length.

cupping—the condition sometimes occurring in heavily cold worked rods and wires, in which the outside fibers are still intact and the central zone has failed in a series of cup-and-cone fractures.

Curie point—that temperature above which a substance becomes paramagnetic.

curvature of field—a property of a lens that causes the image of a plane to be focused into a curved surface instead of a plane.

darkfield condenser—see **condenser, darkfield**. **(E175)**

darkfield illumination—the illumination of an object such that it appears illuminated with the surrounding field dark. This results from illuminating the object with rays of sufficient obliquity so that none can enter the objective directly. As applied to electron microscopy, the image is formed using only electrons scattered by the object.

dashpot—a hydraulic cylinder device with a controlled leak designed to eliminate impact loading of mechanisms. Hardness testers may employ a dashpot to bring an indenter into contact with a specimen without impact or other disturbance.

dead-weight loading—a method of loading in which a weight is supported solely by the specimen and has no other mechanical connection to the testing machine. In hardness testing, the weight is supported by the indenter.

Debye ring—a continuous circle, concentric about the undeviated beam, produced by monochromatic X-ray diffraction from a randomly oriented crystalline powder. An analogous effect is obtained with electron diffraction.

Debye-Scherrer method—a method of X-ray diffraction employing monochromatic radiation and a polycrystalline specimen mounted on the axis of a cylindrical strip of film. (See **powder method**.)

decarburization—loss of carbon from the surface of a carbon containing alloy due to a reaction with one or more chemical substances in a medium that contacts the surface. Decarburization may be either (*1*) *partial*, that is, where carbon content is less

than the unaffected interior but greater than the room temperature solubility limit of carbon in ferrite or (*2*) *complete*, that is, where carbon content is less than the solubility limit of carbon in ferrite so that only ferrite is present.

deep etching—macroetching; etching preliminary to macro-examination, intended to develop gross features such as segregation, grain flow, cracks or porosity.

define (X-rays)—limit a beam of X-rays by passage through apertures in order to obtain a parallel, divergent, or convergent beam.

definition—the clarity or sharpness of a microscopical image.

deformation bands—bands produced within individual grains during cold working which differ variably in orientation from the matrix.

deformation lines—thin bands or lines produced in grains of some metals, particularly those of face-centered cubic structure, by cold working; they are not removed by repolishing and re-etching.

degree of freedom—in heterogeneous equilibrium, an external variable that may be adjusted independently without causing a change of state; the external variables usually considered are: temperature, pressure, and concentration parameters numbering one less than the order of the system.

delta ferrite—designation commonly assigned to delta iron containing alloying elements in solid solution. Small amounts of carbon and large amounts of other alloying elements markedly affect the high-and-low-temperature limit of equilibrium.

delta iron (δ Fe)—solid phase of pure iron which is stable at temperatures between 1400 and 1539°C and possesses the body-centered cubic lattice. Strictly, there is no difference between delta and alpha iron.

denatured alcohol—ethyl alcohol containing an addition of a poisonous substance, making it unfit for human consumption.

dendrites—crystals, usually formed during solidification or sublimation, which are characterized by a tree-like pattern composed of many branches; pine-tree or fir-tree crystals.

densitometer—an instrument which measures the relationship between incident light and transmitted or reflected light and, using a logarithmic scale, gives a numerical measurement that corresponds to a material's opacity or a film's photographic density.

density (film)—transmission density is the common logarithm of the ratio of the radiant flux incident on the sample to the radiant flux transmitted by the sample, assuming no reflection.

density, optical—logarithm to the vase 10 of the reciprocal of transmittance. **(E175)**

deoxidation products—a term specifically applied to those non-metallic inclusions formed as a result of the addition of deoxidizing agents to molten metal.

depletion—selective removal of one component of an alloy, usually from the surface or preferentially from grain boundary regions.

depth of field—the depth or thickness of the object space that is simultaneously in acceptable focus.