

ASM Metals Reference Book

Second Edition

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Second Edition

Compiled by
The Editorial Staff
Reference Publications
American Society for Metals

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Preface to the Second Edition

The first edition of the *ASM Metals Reference Book* was designed as a first-stop source for metals data. It was developed in response to persistent demand for a book containing the basic information needed daily by metallurgists and engineers. Data were consolidated on the elements and on the compositions and properties of the major industrial alloys. Expanding on this core of information, additional data areas included crystal structure, frequently used phase diagrams, definitions of terms, and general engineering tables. The book was an immediate success and became one of the most popular titles in the ASM catalog of reference books.

Nevertheless, the first edition of the *ASM Metals Reference Book* was also found wanting in several respects. Although designed for frequent and easy use, the large size, 8½ x 11 inches, was awkward to handle. Therefore, the second edition is a smaller, more compact size that is handier to use.

Another shortcoming was the lack of information on processing. Thus, in the second edition, data on heat treating, forming, joining, and machining supplement the alloy sections. The utility of the book has also been improved through the addition of more data on the elements and conversion factors, plus a new section on testing and inspection containing a sub-

stantial amount of information on metallography.

A prime objective in compiling this reference book was to provide source listings to help the reader locate data not included within this volume. Therefore, the final section on organizations and engineering data sources has also been expanded to include information on alloy cross-referencing, automated literature searching, and standards-issuing organizations.

The improvements of the second edition and the quality of the first combine to make this new edition of the *ASM Metals Reference Book* a better and more complete first-stop source for metals engineering data.

Timothy L. Gall
Metals Park, Ohio
September, 1982

Preface

This volume is a helpful handbook of information about metals. The *ASM Metals Reference Book* brings together data from many sources, including major contributions from the Eighth and Ninth Editions of *Metals Handbook*.

The Editors make no claim for completeness; the vast amount of metallurgical data available makes that task difficult. The range of information selected should prove most useful and serves to provide an at-the-fingertips reference volume for engineers, designers, and metallurgists—a one-stop

source of engineering data about metals.

The first section of the *ASM Metals Reference Book* is a glossary of terms related to metals and metalworking compiled by the ASM Committee on Definitions of Metallurgical Terms. Metric conversions and hardness-number conversions appear in the second section. The third section contains formulas for length, area, volume and weight, and tables of functions of numbers.

The most extensive collection of in-

formation in the *ASM Metals Reference Book* is contained in Sections 4 through 15, which present compositions and properties of the major commercial metals and alloy systems. Mechanical and physical properties of most standard alloys, compositions, standard designations, and processing and fabrication characteristics are described in 175 tables of data.

Two sections contain crystal-structure information and phase diagrams of importance to the industrial metallurgist. A final section provides additional sources of metallurgical information.

The Editorial Staff
Reference Publications

William H. Cubberly
Director
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American Society for Metals

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Glossary of Metallurgical and Metalworking Terms

This glossary clarifies more than 3000 specialized technical terms encountered in metallurgical literature. The list includes terms from: materials science; physical metallurgy; heat treating; extractive metallurgy; casting, forging, machining, forming, welding and joining; metal cleaning and finishing; electrometallurgy; powder metallurgy; mechanical testing, inspection and quality control; and metallography, fractography and failure analysis. Terms whose meanings are the same for both technical and non-technical usage, as well as terms having universal scientific meanings, are largely excluded.

Many cross references to preferred terms, alternative terms and closely related terms have been included; these cross references are printed in italics. Also, terms that are obsolete or otherwise inappropriate for use in current writings are so indicated. Many terms can have more than one meaning in metallurgical literature; alternative meanings are identified by parenthetical numbers preceding each alternative. Whenever possible, a general or generic meaning is given before a specific or specialized meaning, but there is no special significance to the order in which alternative meanings are given.

The definitions in this glossary are

compatible with (although not necessarily identical to) definitions published by ANSI, ASQC, ASTM, AWS, SAE and other organizations.

A

A_{cm}, A₁, A₃, A₄. Same as **Ae_{cm}, Ae₁, Ae₃** and **Ae₄**.

abrasion. A roughening or scratching of a surface due to *abrasive wear*. On aluminum parts, also known as a rub mark or traffic mark.

abrasive. (1) A hard substance used for *grinding, honing, lapping, superfinishing, polishing*, pressure blasting or *barrel finishing*. It includes natural materials such as garnet, emery, corundum and diamond, and electric-furnace products like aluminum oxide, silicon carbide and boron carbide. (2) Hard particles, such as rocks, sand or fragments of certain hard metals, that wear away a surface when they move across it under pressure.

abrasive belt. A coated abrasive product, in the form of a belt, used in production grinding and polishing.

abrasive blasting. A process for cleaning or finishing by means of an abrasive directed at high velocity against the workpiece.

abrasive disk. (1) A grinding wheel that is mounted on a steel plate, with the exposed flat side being used for

grinding. (2) A disk-shaped, coated abrasive product.

abrasive wear. The removal of material from a surface when hard particles slide or roll across the surface under pressure. The particles may be loose or may be part of another surface in contact with the surface being worn. Contrast with *adhesive wear*.

Ac_{cm}, Ac₁, Ac₃, Ac₄. Defined under *transformation temperature*.

accuracy. The closeness of approach of a measurement to the true value of the quantity measured. Since the true value cannot actually be measured, the most probable value from the available data, critically considered for sources of error, is used as "the truth". Contrast with *precision*.

acicular ferrite. A highly substructured nonequiaxed ferrite that forms upon continuous cooling by a mixed diffusion and shear mode of transformation that begins at a temperature slightly higher than the temperature transformation range for upper bainite. It is distinguished from bainite in that it has a limited amount of carbon available; thus, there is only a small amount of carbide present.

acicular ferrite steels. Those steels having a microstructure consisting of either acicular ferrite or a mixture of acicular and equiaxed ferrite.

acid. A chemical substance that yields

The terms were compiled and collected by the ASM Committee on Definitions of Metallurgical Terms for an earlier publication, *Glossary of Metallurgical Terms and Engineering Tables*. Members of the Committee were: Howard E. Boyer, *Chairman*, Consultant; James W. Barr, *Aluminum Association*; F. W. Boulger, *Senior Technical Advisor*, Battelle-Columbus Laboratories; Price B. Burgess, *Plant Metallurgist*, Hayes-Albion Corp.; John R. Cuthill, *Assistant Chief*, Alloy Physics Section, National Bureau of Standards; Charles C. Dick, *Metallurgist*, Lindberg Heat Treating Co.; Jon L. Dossett, *Division Manager*, Lindberg Heat Treating Co.; F. L. Ewald, *Assistant Manager*, Production Laboratory, Budd Co.; Irving J. Feinberg, *Mechanical Properties Section*, National Bureau of Standards; Michael Field, *President and General Manager*, Metcut Research Associates, Inc.; Ronald Gibala, *Professor of Metallurgy and Materials Science*, Case Western Reserve University; W. C. Harmon, *Technical Advisor*, Research Center, Republic Steel Corp.; Thomas J. Hughes, *General Motors Technical Center*, General Motors Corp.; Kenneth J. Hummerstone, *Vice President*, American Tank & Fabricating Co.; Charles G. Interrante, *Metallurgist*, National Bureau of Standards; F. L. Jamieson, *Metallurgical Laboratory*, Steel Co. of Canada; Frank La Que, *Consultant*; Joseph B. Long, *Manager*, Tin Research Institute; Paul T. Lovejoy, *Senior Metallurgist*, Research Center, Allegheny Ludlum Steel Co.; W. Stuart Lyman, *Manager*, Technical and Market Services, Copper Development Association, Inc.; R. C. McMaster, *Regents Professor of Welding Engineering*, Ohio State University; Joseph T. Michalak, *Senior Scientist*, Physical Metallurgy, Research Laboratory, United States Steel Corp.; Thomas J. Moore, *Lewis Research Center*, National Aeronautics and Space Administration; Fielding Ogburn, *National Bureau of Standards*; Bernard R. Queneau, (retired), formerly *General Manager*, Product Metallurgy, United States Steel Corp.; Glenn O. Ratliff, *President*, Shore Metal Treating, Inc.; Kempton H. Roll, *Executive Director*, Metal Powder Industries Federation; M. T. Rowley, *Vice President*, Technology, American Foundrymen's Society; John A. Simmons, *Microstructure Characterization Section*, National Bureau of Standards; Frank Speight, *American Welding Society*; Harry Turner, *Chief*, Metallic Materials Branch, Material and Process Development, McDonnell Aircraft Co.; C. F. Walton, *Technical Director*, Iron Castings Society; William G. Wood, *Vice President of Research and Development*, Kolene Corp.; David Benjamin, *Secretary*, *Senior Editor*, *Metals Handbook*, American Society for Metals.

hydrogen ions (H^+) when dissolved in water. Compare with *base* (3).

acid bottom and lining. The inner bottom and lining of a melting furnace consisting of materials like sand, siliceous rock or silica brick that give an acid reaction at the operating temperature.

acid copper. (1) Copper electrodeposited from an acid solution of a copper salt, usually copper sulfate. (2) The solution referred to in (1).

acid embrittlement. A form of *hydrogen embrittlement* that may be induced in some metals by acid treatment.

acid steel. Steel melted in a furnace with an *acid bottom and lining* and under a slag containing an excess of an acid substance such as silica.

activation. The changing of a passive surface of a metal to a chemically active state. Contrast with *passivation*.

activation energy. The energy required for initiating a metallurgical reaction; for example, plastic flow, diffusion, chemical reaction. The activation energy may be calculated from the slope of the line obtained by plotting the natural log of the reaction rate versus the reciprocal of the absolute temperature.

activity. A measure of the chemical potential of a substance, where chemical potential is not equal to concentration, that allows mathematical relations equivalent to those for ideal systems to be used to correlate changes in an experimentally measured quantity to changes in chemical potential.

addition agent. A substance added to a solution for the purpose of altering or controlling a process. Examples: wetting agents in acid pickles; brighteners or antipitting agents in plating solutions; and inhibitors.

adhesion. Force of attraction between the molecules (or atoms) of two different phases. Contrast with *cohesion*.

adhesive bonding. A materials joining process in which an adhesive, placed between faying surfaces, solidifies to bond the surfaces together.

adhesive wear. The removal of material from a surface by the welding together and subsequent shearing of minute areas of two surfaces that slide across each other under pressure. In advanced stages, may lead to *galling* or *seizing*. Contrast with *abrasive wear*.

adjustable bed. Bed of a press de-

signed so that the die space height can be varied conveniently.

Ae_{cm}, Ae₁, Ae₂, Ae₃, Ae₄. Defined under *transformation temperature*.

age hardening. Hardening by aging, usually after rapid cooling or cold working. See *aging*.

age softening. Spontaneous decrease of strength and hardness that takes place at room temperature in certain strain hardened alloys, especially those of aluminum.

aging. A change in the properties of certain metals and alloys that occurs at ambient or moderately elevated temperatures after hot working or a heat treatment (quench aging in ferrous alloys, natural or artificial aging in ferrous and nonferrous alloys) or after a cold working operation (strain aging). The change in properties is often, but not always, due to a phase change (precipitation), but never involves a change in chemical composition of the metal or alloy. See also *age hardening*, *artificial aging*, *interrupted aging*, *natural aging*, *overaging*, *precipitation hardening*, *precipitation heat treatment*, *progressive aging*, *quench aging*, *step aging*, *strain aging*.

air bend die. Angle-forming dies in which the metal is formed without striking the bottom of the die. Metal contact is made at only three points in the cross section: the nose of the male die and the two edges of a V-shape die opening.

air bending. Bending in an *air bend die*.

air classification. The separation of metal powder into particle-size fractions by means of an air stream of controlled velocity; an application of the principle of *elutriation*.

air-hardening steel. A steel containing sufficient carbon and other alloying elements to harden fully during cooling in air or other gaseous mediums from a temperature above its transformation range. The term should be restricted to steels that are capable of being hardened by cooling in air in fairly large sections, about 2 in. or more in diameter. Same as *self-hardening steel*.

air-lift hammer. A type of gravity drop hammer where the ram is raised for each stroke by an air cylinder. Since length of stroke may be controlled, ram velocity and thus energy delivered to the workpiece may be varied.

alclad. Composite wrought product

comprised of an aluminum alloy core having on one or both surfaces a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the core and thus electrically protects the core against corrosion.

alkali metal. A metal in group IA of the periodic system—namely, lithium, sodium, potassium, rubidium, cesium and francium. They form strongly alkaline hydroxides; hence, the name.

alkaline cleaner. A material blended from alkali hydroxides and such alkaline salts as borates, carbonates, phosphates or silicates. The cleaning action may be enhanced by the addition of surface-active agents and special solvents.

alkaline earth metal. A metal in group IIA of the periodic system—namely, beryllium, magnesium, calcium, strontium, barium and radium—so called because the oxides or "earths" of calcium, strontium and barium were found by the early chemists to be alkaline in reaction.

alligatoring. The longitudinal splitting of flat slabs in a plane parallel to the rolled surface. Also called *fish-mouthing*.

allotriomorphic crystal. A crystal whose lattice structure is normal but whose external surfaces are not bounded by regular crystal faces; rather, the external surfaces are impressed by contact with other crystals or another surface such as a mold wall, or are irregularly shaped because of nonuniform growth. Compare with *idiomorphic crystal*.

allotropy. A near synonym for *polymorphism*. Allotropy is generally restricted to describing polymorphic behavior in elements, terminal phases, and alloys whose behavior closely parallels that of the predominant constituent element.

allowance. The specified difference in limiting sizes (minimum clearance or maximum interference) between mating parts, as computed arithmetically from the specified dimensions and tolerances of each part.

alloy. A substance having metallic properties and being composed of two or more chemical elements of which at least one is a *metal*.

alloying element. An element added to a metal to effect changes in properties and which remains within the metal.

alloy plating. The codeposition of two or more metallic elements.

alloy powder. A powdered metal in

which each particle is composed of the same alloy.

alloy steel. Steel containing specified quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, copper, silicon, sulfur and phosphorus) within the limits recognized for constructional alloy steels, added to effect changes in mechanical or physical properties.

all-position electrode. In arc welding, a filler-metal electrode for depositing weld metal in the flat, horizontal, overhead and vertical positions.

all-weld-metal test specimen. A test specimen wherein the portion being tested is composed wholly of weld metal.

alpha ferrite. See *ferrite*.

alpha iron. The body-centered cubic form of pure iron, stable below 910 °C (1670 °F).

alsifer. A deoxidizer (20 Al, 40 Si, 40 Fe) used for steel.

alternate-immersion test. A corrosion test in which the specimens are intermittently immersed in and removed from a liquid medium at definite time intervals.

Alumel. A nickel-base alloy containing about 2.5 Mn, 2 Al and 1 Si used chiefly as a component of pyrometric thermocouples.

aluminizing. Forming an aluminum or aluminum alloy coating on a metal by hot dipping, hot spraying or diffusion.

aluminum bomb. A bomb-shaped container used in determining the oxygen content in liquid steel.

amalgam. An alloy of mercury with one or more other metals.

amorphous. Not having a crystal structure; noncrystalline.

amphoteric. Possessing both acidic and basic properties.

anchorite. A zinc-iron phosphate coating for iron and steel.

anelasticity. The property of solids by virtue of which strain is not a single-valued function of stress in the low-stress range where no permanent set occurs.

angle of bite. In rolling metals where all the force is transmitted through the rolls, the maximum attainable angle between the roll radius at the first contact and the line of roll centers. Operating angles less than the angle of bite are called contact angles or rolling angles.

angle of nip. In rolling, the angle of bite. In roll, jaw or gyratory crushing,

the entrance angle formed by the tangents at the two points of contact between the working surfaces and the (assumed) spherical particle to be crushed.

angstrom (unit). A unit of linear measurement equal to 10^{-10} m, or 0.1 nm, sometimes used to express small distances such as interatomic distances and some wavelengths.

anion. A negatively charged ion; it flows to the anode in electrolysis.

anisotropy. The characteristic of exhibiting different values of a property in different directions with respect to a fixed reference system in the material.

annealing. A generic term denoting a treatment, consisting of heating to and holding at a suitable temperature followed by cooling at a suitable rate, used primarily to soften metallic materials, but also to simultaneously produce desired changes in other properties or in microstructure. The purpose of such changes may be, but is not confined to: improvement of machinability, facilitation of cold work, improvement of mechanical or electrical properties, and/or increase in stability of dimensions. When the term is used without qualification, full annealing is implied. When applied only for the relief of stress, the process is properly called stress relieving or stress-relief annealing.

In ferrous alloys, annealing usually is done above the upper critical temperature, but the time-temperature cycles vary widely in both maximum temperature attained and in cooling rate employed, depending on composition, material condition, and results desired. When applicable, the following commercial process names should be used: black annealing, blue annealing, box annealing, bright annealing, cycle annealing, flame annealing, full annealing, graphitizing, in-process annealing, isothermal annealing, malleablizing, orientation annealing, process annealing, quench annealing, spheroidizing, subcritical annealing.

In nonferrous alloys, annealing cycles are designed to: (a) remove part or all of the effects of cold working (recrystallization may or may not be involved); (b) cause substantially complete coalescence of precipitates from solid solution in relatively coarse form; or (c) both, depending on composition and material condition. Specific process names in commercial

use are final annealing, full annealing, intermediate annealing, partial annealing, recrystallization annealing, stress-relief annealing, anneal to temper.

annealing carbon. Fine, apparently amorphous carbon particles formed in white cast iron and certain steels during prolonged annealing. Also called temper carbon.

annealing twin. A twin formed in a crystal during recrystallization.

anneal to temper. A final partial anneal that softens a cold worked nonferrous alloy to a specified level of hardness or tensile strength.

anode. The electrode where electrons leave an operating system such as a battery, an electrolytic cell, an x-ray tube or a vacuum tube. In the first of these, it is negative; in the other three, positive. In a battery or electrolytic cell, it is the electrode where oxidation occurs. Contrast with *cathode*.

anode compartment. In an electrolytic cell, the enclosure formed by a diaphragm around the anodes.

anode copper. Special-shaped copper slabs, resulting from the refinement of *blister copper* in a reverberatory furnace, used as anodes in electrolytic refinement.

anode corrosion. The dissolution of a metal acting as an anode.

anode effect. The effect produced by polarization of the anode in electrolysis. It is characterized by a sudden increase in voltage and a corresponding decrease in amperage due to the anode becoming virtually separated from the electrolyte by a gas film.

anode efficiency. Current efficiency at the anode.

anode film. (1) The portion of solution in immediate contact with the anode, especially if the concentration gradient is steep. (2) The outer layer of the anode itself.

anode mud. Deposit of insoluble residue formed from the dissolution of the anode in commercial electrolysis. Sometimes called anode slime.

anode polarization. See *polarization*.

anodic cleaning. Electrolytic cleaning where the work is the anode. It is also called reverse-current cleaning.

anodic coating. A film on a metal surface resulting from an electrolytic treatment at the anode.

anodic pickling. Electrolytic pickling where the work is the anode.

anodic protection. Imposing an external electrical potential to protect a

metal from corrosive attack. (Applicable only to metals that show active-passive behavior.) Contrast with *cathodic protection*.

anodizing. Forming a *conversion coating* on a metal surface by anodic oxidation; most frequently applied to aluminum.

anolyte. The electrolyte adjacent to the anode in an electrolytic cell.

antiferromagnetic material. A material wherein interatomic forces hold the elementary atomic magnets (electron spins) of a solid in alignment, the state being similar to that of a *ferromagnetic material* but with the difference that equal numbers of elementary magnets (spins) face in opposite directions and are antiparallel, causing the solid to be weakly magnetic, that is, paramagnetic, instead of ferromagnetic.

antipitting agent. An *addition agent* for electroplating solutions to prevent the formation of pits or large pores in the electrodeposit.

anvil. (1) In drop forging, the base of the hammer into which the *sow block* and lower die part are set. (2) A block of steel upon which metal is forged.

anvil cap. Same as *sow block*.

apparent density. (1) The weight per unit volume of a metal powder, in contrast to the weight per unit volume of the individual particles. (2) The weight per unit volume of a porous solid, where the unit volume is determined from external dimensions of the mass. Apparent density is always less than the true density of the material itself.

approach distance. The linear distance, in the direction of feed, between the point of initial cutter contact and the point of full cutter contact.

Ar_{em}, Ar₁, Ar₂, Ar₃, Ar₄, Ar', Ar". Defined under *transformation temperature*.

arbitration bar. A test bar, cast with a heat of material, used to determine chemical composition, hardness, tensile strength, and deflection and strength under transverse loading in order to establish the state of acceptability of the casting.

arbor. (1) In machine grinding, the spindle on which the wheel is mounted. (2) In machine cutting, a shaft or bar for holding and driving the cutter. (3) In founding, a metal shape embedded in green sand or dry sand cores to support the sand or the applied load during casting.

arbor press. A machine used for forc-

ing arbors or mandrels into drilled or bored parts preparatory to turning or grinding. Also used for forcing bushings, shafts or pins into or out of holes.

arbor-type cutters. Cutters having a hole for mounting on an arbor and usually having a keyway for a driving key.

arc blow. The swerving of an electric arc from its normal path because of magnetic forces.

arc brazing. A brazing process in which the heat required is obtained from an electric arc.

arc cutting. A group of cutting processes that melt the metals to be cut with the heat of an arc between an electrode and the base metal. See *carbon-arc cutting, metal-arc cutting, gas tungsten-arc cutting, plasma arc cutting*.

arc furnace. A furnace in which material is heated either directly by an electric arc between an electrode and the work or indirectly by an arc between two electrodes adjacent to the material.

arc gouging. An arc cutting procedure used to form a bevel or groove.

arc melting. Melting metal in an electric arc furnace.

arc of contact. The portion of the circumference of a grinding wheel or cutter touching the work being processed.

arc time. The time the arc is maintained in making an arc weld. Also known as *weld time*.

arc voltage. The voltage across any electric arc—for example, across a welding arc.

arc welding. A group of welding processes that fuse metals together by heating them with an arc, with or without the application of pressure and with or without the use of filler metal.

artifact. A feature of artificial character (such as a scratch or a piece of dust on a metallographic specimen) that can be erroneously interpreted as a real feature. In inspection, an artifact often produces a *false indication*.

artificial aging. Aging above room temperature. See *aging*. Compare with *natural aging*.

athermal transformation. A reaction that proceeds without benefit of thermal fluctuations; that is, thermal activation is not required. Such reactions are diffusionless and can take place with great speed when the driving force is sufficiently high. For ex-

ample, many martensitic transformations occur athermally on cooling, even at relatively low temperatures, because of the progressively increasing driving force. In contrast, a reaction that occurs at constant temperature is an *isothermal transformation*; thermal activation is necessary in this case and the reaction proceeds as a function of time.

atmospheric riser. A riser that uses atmospheric pressure to aid feeding. Essentially a *blind riser* into which a small core or rod protrudes, the function of the core or rod being to provide an open passage so that the molten interior of the riser will not be under a partial vacuum when metal is withdrawn to feed the casting, but will always be under atmospheric pressure. Often called *Williams riser*.

atomic fission. The breakup of the nucleus of an atom in which the combined weight of the fragments is less than that of the original nucleus, the difference being converted to a very large energy release.

atomic hydrogen welding. An arc welding process that fuses metals together by heating them with an electric arc maintained between two metal electrodes enveloped in a stream of hydrogen. Shielding is provided by the hydrogen, which also carries heat by molecular dissociation and subsequent recombination. Pressure may or may not be used and filler metal may or may not be used. (This process is now of limited industrial significance.)

atomic number. The number of protons in an atomic nucleus; determines the individuality of the atom as a chemical element.

atomic percent. The number of atoms of an element in a total of 100 representative atoms of a substance.

atomization. The dispersion of a molten metal into small particles by a rapidly moving stream of gas or liquid.

attenuation. The fractional decrease of the intensity of an energy flux, including the reduction of intensity resulting from geometrical spreading, absorption and scattering.

attritious wear. Wear of abrasive grains in grinding such that the sharp edges gradually become rounded. A grinding wheel that has undergone such wear usually has a glazed appearance.

ausforming. Hot deformation of metastable austenite within controlled

ranges of temperature and time that avoids formation of nonmartensitic transformation products.

austempering. A heat treatment for ferrous alloys in which a part is quenched from the austenitizing temperature at a rate fast enough to avoid formation of ferrite or pearlite and then held at a temperature just above M_s until transformation to bainite is complete.

austenite. A solid solution of one or more elements in face-centered cubic iron. Unless otherwise designated (such as nickel austenite), the solute is generally assumed to be carbon.

austenitic grain size. The size attained by the grains of steel when heated to the austenitic region; may be revealed by appropriate etching of cross sections after cooling to room temperature.

austenitic steel. An alloy steel whose structure is normally austenitic at room temperature.

austenitizing. Forming austenite by heating a ferrous alloy into the transformation range (partial austenitizing) or above the transformation range (complete austenitizing). When used without qualification, the term implies complete austenitizing.

autofrettage. Prestressing a hollow metal cylinder by the use of momentary internal pressure exceeding the yield strength.

autogenous weld. A fusion weld made without the addition of filler metal.

automatic brazing. Brazing with equipment that performs the brazing operation without constant observation and adjustment by a brazing operator. The equipment may or may not perform the loading and unloading of the work.

automatic press. A press in which the work is fed mechanically through the press in synchronism with the press action. An automation press is an automatic press that, in addition, is provided with built-in electrical and pneumatic control equipment.

automatic welding. Welding with equipment that performs the welding operation without adjustment of the controls by an operator. The equipment may or may not load and unload the work. Compare with *machine welding*.

automation press. See *automatic press*.

autoradiography. An inspection technique in which radiation sponta-

neously emitted by a material is recorded photographically. The radiation is emitted by radioisotopes that are (a) produced in a metal by bombarding it with neutrons, (b) added to a metal such as by alloying, or (c) contained within a cavity in a metal part. The technique serves to locate the position of the radioactive element or compound.

auxiliary anode. In electroplating, a supplementary anode placed in a position to raise the current density on a certain area of the cathode to get better plate distribution.

Avogadro's number. The number of atoms (or molecules) in a mole of substance; equals 6.02252×10^{23} per mole.

axial rake. For angular (not helical) flutes, the angle between a plane containing the tooth face and the axial plane through the tooth point. See sketch accompanying *face mill*.

axial relief. The relief or clearance behind the end cutting edge of a milling cutter.

axial runout. For any rotating element, the total variation from a true plane of rotation, taken in a direction parallel to the axis of rotation. Compare with *radial runout*.

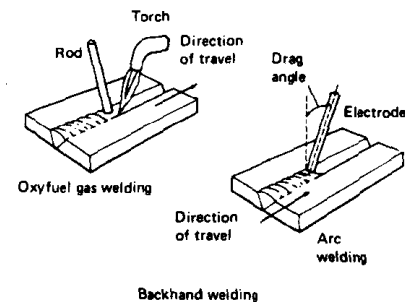
axis of weld. A line through the length of a weld perpendicular to the cross section at its geometric center.

back draft. A reverse taper on a casting pattern or a forging die that prevents the pattern or forged stock from being removed from the cavity.

back extrusion. See *backward extrusion*.

backfire. The recession of a flame into the tip of a torch followed by immediate reappearance or complete extinction of the flame. See *flashback*.

backhand welding. Welding in which the back of the principal hand (torch or electrode hand) of the welder faces



the direction of travel. It has special significance in oxyfuel gas welding in that the flame is directed backward toward the weld bead, which provides *postheating*. Compare with *forehand welding*.

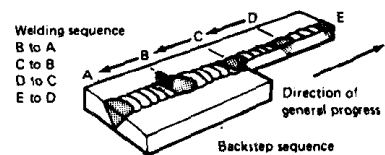
backing. (1) In grinding, the material (paper, cloth or fiber) that serves as the base for coated abrasives. (2) In welding, a material placed under or behind a joint to enhance the quality of the weld at the root. It may be a metal backing ring or strip; a pass of weld metal; or a nonmetal such as carbon, granular flux or a protective gas.

backlash. Lost motion, play or movement in moving parts such that the driving element (as a gear) can be reversed for some angle or distance before working contact is again made with a driven element.

backoff. A rapid withdrawal of a grinding wheel or cutting tool from contact with workpiece.

back rake. The angle on a single-point turning tool corresponding to axial rake in milling. It is the angle measured between the plane of the tool face and the reference plane and which lies in a plane perpendicular to the axis of the work material and the base of the tool. See sketch accompanying *single-point tool*.

backstep sequence. A longitudinal welding sequence in which the direction of general progress is opposite to that of welding the individual increments.



backward extrusion. Same as indirect extrusion. See *extrusion*.

back weld. A weld deposited at the back of a single-groove weld.

baghouse. A chamber containing bags for filtering solids out of gases.

bail. Hoop or arched connection between the crane hook and ladle or between crane hook and mold trunnions.

bainite. A metastable aggregate of ferrite and cementite resulting from the transformation of austenite at temperatures below the pearlite range but above M_s . Its appearance is feathery if formed in the upper part of the bainite transformation range; acicu-

lar, resembling tempered martensite, if formed in the lower part.

baking. (1) Heating to a low temperature in order to remove gases. (2) Curing or hardening surface coatings such as paints by exposure to heat. (3) Heating to drive off moisture, as in the baking of sand cores after molding.

balance. (1) (dynamic) Condition existing where the principal inertia axis of a body coincides with its rotational axis. (2) (static) Condition existing where the center of gravity of a body lies on its rotational axis.

ball burnishing. (1) Same as *ball sizing*. (2) Removing burrs and polishing small stampings and small machined parts by *tumbling* in the presence of metal balls.

ball mill. A machine consisting of a rotating hollow cylinder partly filled with metal balls (usually hardened steel or white cast iron) or sometimes pebbles; used to pulverize crushed ores or other substances such as pigments.

ball sizing. Sizing and finishing a hole by forcing a ball of suitable size, finish and hardness through the hole or by using a burnishing bar or broach consisting of a series of spherical lands of gradually increasing size coaxially arranged. Also called *ball burnishing*, and sometimes *ball broaching*.

banded structure. A segregated structure consisting of alternating nearly parallel bands of different composition, typically aligned in the direction of primary hot working.

band mark. An indentation in carbon steel sheet or strip caused by external pressure on the packaging band around cut lengths or coils; it may occur in handling, transit or storage.

bands. (1) Hot rolled steel strip, usually produced for rerolling into thinner sheet or strip. Also known as hot bands or band steel. (2) See *electron bands*.

bar. (1) An obsolete unit of pressure equal to 100 kPa. (2) An elongated rolled metal product that is relatively thick and narrow; most bars have simple, uniform cross sections such as rectangular, square, round, oval or hexagonal. Also known as *barstock*. Compare with *section* (3).

bare electrode. A filler-metal arc welding electrode, in the form of a wire or rod having no coating other than that incidental to the drawing of

the wire or to its preservation.

bar end. See *end loss*.

bar folder. A machine in which a folding bar or wing is used to bend a metal sheet whose edge is clamped between the upper folding leaf and the lower stationary jaw into a narrow, sharp, close and accurate fold along the edge. It is also capable of making rounded folds such as those used in wiring. A universal folder is more versatile in that it is limited to width only by the dimensions of the sheet.

bark. The decarburized layer just beneath the scale that results from heating steel in an oxidizing atmosphere.

Barkhausen effect. The sequence of abrupt changes in magnetic induction occurring when the magnetizing force acting on a ferromagnetic specimen is varied.

barrel cleaning. Mechanical or electrolytic cleaning of metal in rotating equipment.

barrel finishing. Improving the surface finish of metal objects or parts by processing them in rotating equipment along with abrasive particles that may be suspended in a liquid.

barreling. Convexity of the surfaces of cylindrical or conical bodies, often produced unintentionally during upsetting or as a natural consequence during compression testing.

barrel plating. Plating articles in a rotating container, usually a perforated cylinder that operates at least partially submerged in a solution.

barstock. Same as *bar*.

basal plane. A plane perpendicular to the principal axis (c axis) in a tetragonal or hexagonal structure.

base. (1) The surface on which a single-point tool rests when held in a tool post. Also known as *heel*. See sketch accompanying *single-point tool*. (2) In forging—see *anvil*. (3) A chemical substance that yields hydroxyl ions (OH^-) when dissolved in water.

base bullion. Crude lead containing recoverable silver, with or without gold.

base metal. (1) The metal present in the largest proportion in an alloy; brass, for example, is a copper-base alloy. (2) The metal to be brazed, cut, soldered or welded. (3) After welding, that part of the metal which was not melted. (4) A metal that readily oxidizes, or that dissolves to form ions. Contrast with *noble metal* (2).

basic bottom and lining. The inner bottom and lining of a melting fur-

nace, consisting of materials such as crushed burned dolomite, magnesite, magnesite bricks or basic slag that give a basic reaction at the operating temperature.

basic steel. Steel melted in a furnace with a *basic bottom and lining* and under a slag containing an excess of a basic substance such as magnesia or lime.

basin. Same as *pouring basin*.

basis metal. The original metal to which one or more coatings are applied.

batch. See *lot*.

Bauschinger effect. For both single-crystal and polycrystalline metals, any change in stress-strain characteristics that can be ascribed to changes in the microscopic stress distribution within the metal, as distinguished from changes caused by strain hardening. In the narrow sense, the process whereby plastic deformation in one direction causes a reduction in yield strength when stress is applied in the opposite direction.

Bayer process. A process for extracting alumina from bauxite ore before the electrolytic reduction. The bauxite is digested in a solution of sodium hydroxide, which converts the alumina to soluble aluminate. After the "red mud" residue has been filtered out, aluminum hydroxide is precipitated, filtered out and calcined to alumina.

beach marks. Progression marks on a fatigue fracture surface that indicate successive positions of the advancing crack front. The classic appearance is of irregular elliptical or semielliptical rings, radiating outward from one or more origins. Beach marks (also known as clamshell marks or tide marks) are typically found on service fractures where the part is loaded randomly, intermittently, or with periodic variations in mean stress or alternating stress.

beaded flange. A flange reinforced by a low ridge, used mostly around a hole.

beading. Raising a ridge or projection on sheet metal.

bead weld. See preferred term *surfacing weld*.

bearing stress. The shear load on a mechanical joint (such as a pinned or riveted joint) divided by the effective bearing area. The effective bearing area of a riveted joint, for example, is the sum of the diameters of all rivets

times the thickness of the loaded member.

bed. (1) The stationary portion of a press structure that usually rests on the floor or foundation, forming the support for the remaining parts of the press and the pressing load. The *bolster* and sometimes the lower die are mounted on the top surface of the bed. (2) For machine tools, the portion of the main frame that supports the tools, the work, or both.

Beilby layer. A layer of metal disturbed by mechanical working presumed to be without regular crystalline structure (amorphous); originally applied to grain boundaries.

bel. A unit denoting the ratio of power levels of signals or sound. The number of bels may be given as the common logarithm of the ratio of powers:

$$n = \log (p_1/p_2)$$

where p_1 and p_2 are the initial and final power levels.

belt grinding. Grinding with an *abrasive belt*.

bench press. Any small press that can be mounted on a bench or table.

bend allowance. The length of the arc of the neutral axis between the tangent points of a bend.

bend angle. The angle through which a bending operation is performed.

bender. Term denoting a die impression, tool or mechanical device designed to bend forging stock to conform to the general configuration of die impressions to be subsequently used.

bending brake. A *press brake* used for bending.

bending moment. The algebraic sum of the couples or the moments of the external forces, or both, to the left or right of any section on a member subjected to bending by couples or transverse forces, or both.

bending rolls. Two or three rolls with an adjustment for imparting a desired curvature in sheet or strip metal.

bend radius. (1) The inside radius of a bent section. (2) The radius of a tool around which metal is bent during fabrication.

bend tangent. A tangent point where a bending arc ceases or changes.

bend test. A test for determining relative ductility of metal that is to be formed (usually sheet, strip, plate or wire) for determining soundness and toughness of metal (after welding, for

example). The specimen is usually bent over a specified diameter through a specified angle for a specified number of cycles.

beneficiation. Concentration or other preparation of ore for smelting.

bentonite. A colloidal claylike substance derived from the decomposition of volcanic ash composed chiefly of the minerals of the montmorillonite family. Western bentonite is slightly alkaline; southern bentonite is usually slightly acidic.

bessemer process. A process for making steel by blowing air through molten pig iron contained in a refractory lined vessel so as to remove by oxidation most of the carbon, silicon and manganese. This process is essentially obsolete in the United States.

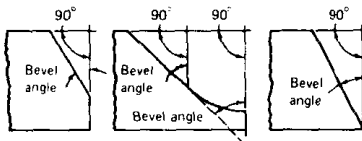
beta ray. A ray of electrons emitted during the spontaneous disintegration of certain atomic nuclei.

beta structure. A Hume-Rothery designation for structurally analogous body-centered cubic phases (similar to beta brass) or electron compounds that have ratios of three valence electrons to two atoms. Not to be confused with a beta phase on a constitution diagram.

Betts process. A process for the electrolytic refining of lead in which the electrolyte contains lead fluosilicate and fluosilicic acid.

bevel. See preferred term, *corner angle*, and also sketch accompanying *face mill*.

bevel angle. The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.



bevel flanging. Same as *flaring*.

biaxiality. In a *biaxial stress* state, the ratio of the smaller to the larger principal stress.

biaxial stress. A state of stress in which only one of the *principal stresses* is zero, the other two usually being in tension.

billet. (1) A solid semifinished round or square product that has been hot worked by forging, rolling or extrusion; usually smaller than a *bloom*. (2) A general term for wrought starting stock used in making forgings or extrusions.

billet mill. A primary rolling mill used to make steel billets.

binary alloy. An alloy containing only two component elements.

binder. (1) In founding, a material, other than water, added to foundry sand to bind the particles together, sometimes with the use of heat. (2) In powder metallurgy, a cementing medium; either a material added to the powder to increase the green strength of the compact and that is expelled during sintering, or a material (usually of relatively low melting point) added to a powder mixture for the specific purpose of cementing together powder particles that alone would not sinter into a strong body.

bipolar electrode. An *electrode* in an electrolytic cell that is not mechanically connected to the power supply, but is so placed in the electrolyte, between the anode and cathode, that the part nearer the anode becomes cathodic and the part nearer the cathode becomes anodic. Also called *intermediate electrode*.

bipolar field. A longitudinal magnetic field that creates two magnetic poles within a piece of material. Compare with *circular field*.

biscuit. (1) An upset blank for drop forging. (2) A small cake of primary metal (such as uranium made from uranium tetrafluoride and magnesium by bomb reduction). Compare with *derby* and *dingot*.

black annealing. Box annealing or pot annealing ferrous alloy sheet, strip or wire. See *box annealing*.

blackheart malleable. See *malleable cast iron*.

blackening. Carbonaceous materials such as plumbago, graphite or powdered carbon used in coating pouring ladles, molds, runners, pig beds.

black light. Electromagnetic radiation not visible to the human eye. The portion of the spectrum generally used in fluorescent inspection falls in the ultraviolet region between 330 and 400 nm, with the peak at 365 nm.

black oxide. A black finish on a metal produced by immersing it in hot oxidizing salts or salt solutions.

blade-setting angle. See preferred term, *cone angle*.

blank. (1) In forming, a piece of sheet material, produced in cutting dies, that is usually subjected to further press operations. (2) A pressed, presintered or fully sintered powder metallurgy compact, usually in the

unfinished condition and requiring cutting, machining or some other operation to produce the final shape. (3) A piece of stock from which a forging is made; often called a slug or multiple.

blank carburizing. Simulating the carburizing operation without introducing carbon. This is usually accomplished by using an inert material in place of the carburizing agent, or by applying a suitable protective coating to the ferrous alloy.

blank holder. The part of a drawing or forming die that holds the workpiece against the draw ring to control metal flow.

blanking. Producing desired shapes from metal to be used for forming or other operations, usually by punching.

blank nitriding. Simulating the nitriding operation without introducing nitrogen. This is usually accomplished by using an inert material in place of the nitriding agent or by applying a suitable protective coating to the ferrous alloy.

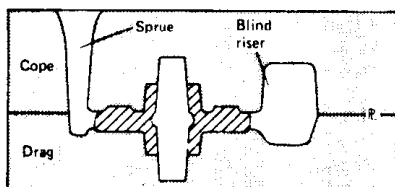
blast furnace. A shaft furnace in which solid fuel is burned with an air blast to smelt ore in a continuous operation. Where the temperature must be high, as in the production of pig iron, the air is preheated. Where the temperature can be lower, as in smelting copper, lead and tin ores, a smaller furnace is economical, and preheating of the blast is not required.

blasting. Cleaning or finishing metals by impingement with abrasive particles moving at high speed and usually carried by gas or liquid or thrown centrifugally from a wheel.

blemish. A nonspecific quality control term designating an imperfection that mars the appearance of a part but does not detract from its ability to perform its intended function.

blending. In powder metallurgy, the thorough intermingling of powders of the same nominal composition (not to be confused with *mixing*).

blind riser. A riser that does not extend through the top of the mold.



blister. A raised area, often dome shaped, resulting from (a) loss of adhesion between a coating or deposit and the basis metal or (b) delamination under the pressure of expanding gas trapped in a metal in a near subsurface zone. Very small blisters may be called pinheads or pepper blisters.

blister copper. An impure intermediate product in the refining of copper, produced by blowing copper *matte* in a converter, the name being derived from the large blisters on the cast surface that result from the liberation of SO_2 and other gases.

block brazing. An obsolete brazing process in which the joint was heated using hot blocks.

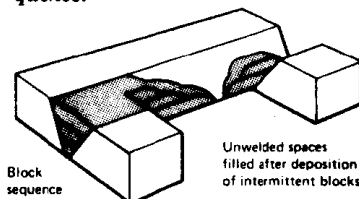
blocker. The impression in the dies (often one of a series of impressions in a single die set) that imparts to the forging an intermediate shape, preparatory to forging of the final shape. Also called blocking impression.

blocker-type forging. A forging that approximates the general shape of the final part with relatively generous finish allowance and radii. Such forgings are sometimes specified to reduce die costs where only a small number of forgings is desired and the cost of machining each part to its final shape is not excessive.

blocking. In forging, a preliminary operation performed in closed dies, usually hot, to position metal properly so that in the finish operation the dies will be filled correctly.

blocking impression. Same as *blocker*.

block sequence. A welding sequence in which separated lengths of a continuous multiple-pass weld are partly or completely built up in cross section before intervening lengths are deposited. Compare with *cascade sequence*.



bloom. (1) A semifinished hot rolled product, rectangular in cross section, produced on a blooming mill. See also *billet*. For steel, the width of a bloom is not more than twice the thickness, and the cross-sectional area is usually not less than about 230 cm^2 (36

in.²). Steel blooms are sometimes made by forging. (2) A visible exudation or efflorescence on the surface of an electroplating bath. (3) A bluish fluorescent cast to a painted surface caused by deposition of a thin film of smoke, dust or oil. (4) A loose, flower-like corrosion product that forms when certain metals are exposed to a moist environment.

bloomer. The mill or other equipment used in reducing steel ingots to blooms.

blooming mill. A primary rolling mill used to make blooms.

blotter. In grinding, a disk of compressible material, usually blotting-paper stock, used between the grinding wheel and its flanges to avoid concentrated stresses.

blowhole. A hole in a casting or a weld caused by gas entrapped during solidification.

blowpipe. A welding or cutting torch.

blue annealing. Heating hot rolled ferrous sheet in an open furnace to a temperature within the transformation range and then cooling in air, in order to soften the metal. The formation of a bluish oxide on the surface is incidental.

blue brittleness. Brittleness exhibited by some steels after being heated to some temperature within the range of about 200 to 370 °C (400 to 700 °F), particularly if the steel is worked at the elevated temperature. Killed steels are virtually free of this kind of brittleness.

blue dip. A solution containing a mercury compound, once widely used to deposit mercury on a metal by immersion, usually prior to silver plating.

bluing. Subjecting the scale-free surface of a ferrous alloy to the action of air, steam or other agents at a suitable temperature, thus forming a thin blue film of oxide and improving the appearance and resistance to corrosion. NOTE: This term is ordinarily applied to sheet, strip or finished parts. It is used also to denote the heating of springs after fabrication in order to improve their properties.

board hammer. A type of forging hammer in which the upper die and ram are attached to "boards" that are raised to the striking position by power-driven rollers and let fall by gravity. See *drop hammer*.

bolster. A plate to which dies may be fastened, the assembly being secured to the top surface of a press bed. In

mechanical forging, such a plate is also attached to the ram.

bond. (1) In grinding wheels and other relatively rigid abrasive products, the material that holds the abrasive grains together. (2) In welding, brazing or soldering, the junction of joined parts. Where filler metal is used, it is the junction of the fused metal and the heat-affected base metal. (3) In an adhesive bonded or diffusion bonded joint, the line along which the faying surfaces are joined together.

book mold. A split permanent mold hinged like a book.

bore. A hole or cylindrical cavity produced by a single-point or multipoint tool other than a drill.

boring. A machining method using single-point tools on internal surfaces of revolution.

bort. Industrial diamond.

bosh. (1) The section of a blast furnace extending upward from the tuyeres to the plane of maximum diameter. (2) A lining of quartz that builds up during the smelting of copper ores and that decreases the diameter of the furnace at the tuyeres. (3) A tank, often with sloping sides, used for washing metal parts or for holding cleaned parts.

boss. A relatively short protrusion or projection from the surface of a forging or casting, often cylindrical in shape.

bottom board. A flat base for holding the flask in making sand molds.

bottom drill. A flat-ended twist drill used to convert a cone at the bottom of a drilled hole into a cylinder.

bottoming tap. A tap with a *chamfer* of 1 to 1½ threads in length.

bottom pipe. An oxide-lined fold or cavity at the butt end of a slab, bloom or billet; formed by folding the end of an ingot over on itself during primary rolling. Bottom pipe is not pipe, in that it is not a shrinkage cavity, and in that sense, the term is a misnomer. Bottom pipe is similar to *extrusion pipe*. It is normally discarded when the slab, bloom or billet is cropped following primary reduction.

bowing. Deviation from flatness.

box annealing. Annealing a metal or alloy in a sealed container under conditions that minimize oxidation. In box annealing a ferrous alloy, the charge is usually heated slowly to a temperature below the transformation range, but sometimes above or within it, and is then cooled slowly; this process is also called close an-

nealing or pot annealing. See *black annealing*.

boxing. Continuing a fillet weld around a corner as an extension of the principal weld. Also called an end return.

brake. A device for bending sheet metal to a desired angle.

brale. A diamond penetrator of specified sphericoconical shape used with a Rockwell hardness tester. This penetrator is used for the A, C, D and N scales for testing hard metals.

brass. An alloy consisting mainly of copper (over 50%) and zinc, to which smaller amounts of other elements may be added.

brazing welding. A method of welding by using a filler metal having a liquidus above 450 °C (840 °F) and below the solidus of the base metals. Unlike *brazing*, in *brazing welding*, the filler metal is not distributed in the joint by capillary attraction.

brazing. A group of welding processes that join solid materials together by heating them to a suitable temperature and by using a filler metal having a liquidus above 450 °C (840 °F) and below the solidus of the base materials. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

brazing alloy. See preferred term *brazing filler metal*.

brazing filler metal. A nonferrous filler metal used in *brazing* and *brazing welding*.

brazing sheet. Brazing filler metal in sheet form or flat-rolled metal clad with brazing filler metal on one or both sides.

breakdown. (1) An initial rolling or drawing operation, or a series of such operations, for the purpose of reducing a casting or extruded shape prior to the finish reduction to desired size. (2) A preliminary press-forging operation.

breaking stress. Same as *fracture stress*, part (1).

breaks. Creases or ridges usually in "untempered" or in aged material where the yield point has been exceeded. Depending on the origin of the break, it may be termed a *cross break*, a *coil break*, an *edge break*, or a *sticker break*.

bridge die. A two-section extrusion die capable of producing tubing or intricate hollow shapes without the use of a separate mandrel. Metal separates into two streams as it is extruded past a bridge section, which is attached to

the main die section and holds a stub mandrel in the die opening; the metal then is rewelded by extrusion pressure before it enters the die opening. Compare with *porthole die*.

bridging. (1) Premature solidification of metal across a mold section before the metal below or beyond solidifies. (2) Solidification of slag within a cupola at or just above the tuyeres. (3) Welding or mechanical locking of the charge in a downfeed melting or smelting furnace. (4) In powder metallurgy, the formation of arched cavities in a powder mass. (5) In soldering, an unintended solder connection between two or more conductors, either securely or by mere contact. Also called a crossed joint or solder short.

bright annealing. Annealing in a protective medium to prevent discoloration of the bright surface.

bright dip. A solution that produces, through chemical action, a bright surface on an immersed metal.

brightener. An agent or combination of agents added to an electroplating bath to produce a lustrous deposit.

bright finish. A high-quality finish produced on ground and polished rolls. Suitable for electroplating.

bright plate. An electrodeposit that is lustrous in the as-plated condition.

bright range. The range of current densities, other conditions being constant, within which a given electroplating bath produces a bright plate.

Brillouin zones. See *electron bands*.

Brinell hardness test. A test for determining the hardness of a material by forcing a hard steel or carbide ball of specified diameter into it under a specified load. The result is expressed as the Brinell hardness number, which is the value obtained by dividing the applied load in kilograms by the surface area of the resulting impression in square millimetres.

brinelling. Evenly spaced dents in a raceway of a rolling-element bearing that occur when the bearing assembly is subjected to a force or impact load great enough to cause the rolling elements to indent the raceway surface. Also called *true brinelling*. Compare with *false brinelling*.

brittle crack propagation. A very sudden propagation of a crack with the absorption of no energy except that stored elastically in the body. Microscopic examination may reveal some deformation even though it is

not noticeable to the unaided eye.

brittle fracture. Separation of a solid accompanied by little or no macroscopic plastic deformation. Typically, brittle fracture occurs by rapid crack propagation with less expenditure of energy than for ductile fracture.

brittleness. The quality of a material that leads to crack propagation without appreciable plastic deformation.

broach. A bar-shaped cutting tool provided with a series of cutting edges or teeth that increase in size or change in shape from the starting to finishing end. The tool cuts in the axial direction when pushed or pulled and is used to shape either holes or outside surfaces.

bronze. A copper-rich copper-tin alloy with or without small proportions of other elements such as zinc and phosphorus. By extension, certain copper-base alloys containing considerably less tin than other alloying elements, such as manganese bronze (copper-zinc plus manganese, tin and iron) and leaded tin bronze (copper-lead plus tin and sometimes zinc). Also, certain other essentially binary copper-base alloys containing no tin, such as aluminum bronze (copper-aluminum), silicon bronze (copper-silicon) and beryllium bronze (copper-beryllium). Also, trade designations for certain specific copper-base alloys that are actually brasses, such as architectural bronze (57 Cu, 40 Zn, 3 Pb) and commercial bronze (90 Cu, 10 Zn).

bronzing. (1) Applying a chemical finish to copper or copper-alloy surfaces to alter the color. (2) Plating a copper-tin alloy on various materials.

brush anodizing. An anodizing process similar to *brush plating*.

brush plating. Plating with a concentrated solution or gel held in or fed to an absorbing medium, pad or brush carrying the anode (usually insoluble). The brush is moved back and forth over the area of the cathode to be plated.

brush polishing (electrolytic). A method of *electropolishing* in which the electrolyte is applied with a pad or brush in contact with the part to be polished.

buckle. (1) A local waviness in metal bar or sheet, usually transverse to the direction of rolling. (2) An indentation in a casting resulting from expansion of molding sand into the mold cavity.

buckling. Producing a bulge, bend,

bow, kink or other wavy condition by compressively stressing a beam, column, plate, bar or sheet.

Bucky diaphragm. An x-ray scatter-reducing device originally intended for medical radiography but also applicable to industrial radiography in some circumstances. Thin strips of lead, with their width held parallel to the primary radiation, are used to absorb scattered radiation preferentially; the array of strips is in motion during exposure, to prevent formation of a pattern on the film.

buffer. A substance whose purpose is to maintain a constant hydrogen ion concentration in water solutions, even where acid or alkalis are added. Each buffer has a characteristic limited range of pH over which it is effective.

buffing. Developing a lustrous surface by contacting the work with a rotating *buffing wheel*.

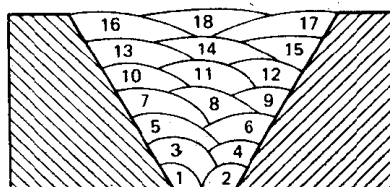
buffing wheel. Buff sections assembled to the required face width for use on a rotating shaft between flanges. Sometimes called buff.

buff section. A number of fabric, paper or leather disks with concentric center holes held together by various types of sewing to provide degrees of flexibility or hardness. These sections are assembled to make wheels for polishing.

builder. A material, such as an alkali, a buffer or a water softener, added to soap or synthetic surface-active agent to produce a mixture having enhanced detergency. Examples: (1) alkalis—caustic soda, soda ash and trisodium phosphate; (2) *buffers*—sodium metasilicate and borax; and (3) water softeners—sodium tripolyphosphate, sodium tetrakisphosphate, sodium hexametaphosphate and ethylene diamine tetraacetic acid.

buildup. Excessive electrodeposition that occurs on high-current-density areas, such as corners or edges.

buildup sequence. The order in which weld beads are deposited, generally designated in cross section as shown in the accompanying illustration.



Buildup sequence

built-up edge. Chip material adhering to the tool face adjacent to the cutting edge during cutting.

bulging. Expanding the walls of a cup, shell or tube with an internally expanded segmented punch or a punch composed of air, liquids or semiliquids such as waxes, rubber and other elastomers.

bull block. A machine with a power-driven revolving drum for cold drawing wire through a drawing die as the wire winds around the drum.

bulldozer. A horizontal machine, usually mechanical, having two bull gears with eccentric pins, two connecting links to a ram, and dies to perform bending, forming and punching of narrow plate and bars. Railroad car sills are formed with a bulldozer.

bullion. (1) A semirefined alloy containing sufficient precious metal to make recovery profitable. (2) Refined gold or silver, uncoined.

bull's-eye structure. The microstructure of malleable or ductile cast iron when graphite nodules are surrounded by a ferrite layer in a pearlitic matrix.

bumper. A machine used for packing molding sand in a flask by repeated jarring or jolting.

bumping. (1) Forming a dish in metal by means of many repeated blows. (2) Forming a head. (3) Setting the seams on sheet metal parts. (4) Ramming sand in a flask by repeated jarring and jolting.

burned deposit. A dull, nodular electrodeposit resulting from excessive current density.

burned-on sand. A mixture of sand and cast metal adhering to the surface of a casting. In some instances, may resemble *metal penetration*.

burning. (1) Permanently damaging a metal or alloy by heating to cause either incipient melting or intergranular oxidation. See *overheating*. (2) In grinding, getting the work hot enough to cause discoloration or to change the microstructure by tempering or hardening.

burnishing. Smoothing surfaces through frictional contact between the work and some hard pieces of material such as hardened metal balls.

burn-off. (1) Unintentional removal of an autocatalytic deposit from a non-conducting substrate, during subsequent electroplating operations, owing to the application of excessive

current or a poor contact area. (2) Removal of volatile lubricants such as metallic stearates from metal powder compacts by heating immediately prior to sintering. (3) See *melting rate*.

burr. (1) A turned-over edge on work resulting from cutting, punching or grinding. (2) A rotary tool having teeth similar to those on hand files.

burring. Same as *deburring*.

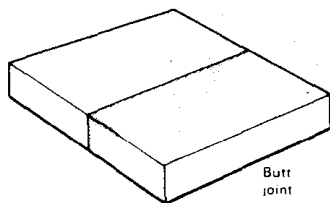
bushing. A bearing or guide.

buster. A pair of shaped dies used to combine preliminary forging operations such as edging and blocking, or to loosen the scale.

butler finish. A semilustrous metal finish composed of fine, uniformly distributed parallel lines, usually produced with a soft abrasive wheel; it is similar in appearance to the traditional hand-rubbed finish on silver.

buttering. A form of surfacing in which one or more layers of weld metal are deposited on the groove face of one member (for example, a high-alloy weld deposit on steel base metal that is to be welded to a dissimilar base metal). The buttering provides a suitable transition weld deposit for subsequent completion of the butt weld.

butt joint. A joint between two abutting members lying approximately in the same plane. A welded butt joint may contain a variety of grooves. See *groove weld*.



button. (1) A globule of metal remaining in an assaying crucible or cupel after fusion has been completed. (2) That part of a weld that tears out in the destructive testing of spot, seam or projection welded specimens.

butt seam welding. See *seam welding*.

butt welding. Welding a butt joint.

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cake. (1) A copper or copper alloy casting rectangular in cross section used for rolling into sheet or strip. (2) A coalesced mass of unpressed metal powder.

calcination. Heating ores, concentrates, precipitates or residues to decompose carbonates, hydrates or other compounds.

calomel electrode (calomel half cell). A secondary reference electrode of the composition: $\text{Pt}/\text{Hg}-\text{Hg}_2\text{Cl}_2/\text{KCl}$ solution. For 1.0N KCl solution, its potential versus a hydrogen electrode at 25 °C and one atmosphere is +0.281 V.

calorizing. Imparting resistance to oxidation to an iron or steel surface by heating in aluminum powder at 800 to 1000 °C (1472 to 1832 °F).

camber. (1) Deviation from edge straightness, usually referring to the greatest deviation of side edge from a straight line. (2) Sometimes used to denote crown in rolls where the center diameter has been increased to compensate for deflection caused by the rolling pressure.

cam press. A mechanical press in which one or more of the slides are operated by cams; usually a double-action press in which the blankholder slide is operated by cams through which the dwell is obtained.

canning. (1) A dished distortion in a flat or nearly flat surface, sometimes referred to as oil canning. (2) Enclosing a highly reactive metal within one relatively inert for the purpose of hot working without undue oxidation of the active metal.

capillary attraction. The combined force of adhesion and cohesion that causes liquids, including molten metals, to flow between very closely spaced solid surfaces, even against gravity.

capped steel. A type of steel similar to rimmed steel, usually cast in a bottle-top ingot mold, in which the application of a mechanical or a chemical cap renders the rimming action incomplete by causing the top metal to solidify. The surface condition of capped steel is much like that of rimmed steel, but certain other characteristics are intermediate between those of rimmed steel and those of semi-killed steel.

capping. The partial or complete separation of a powder metallurgy compact into two or more portions by cracks that originate near the edges of the punch faces and that proceed diagonally into the compact.

carbide. A compound of carbon with one or more metallic elements.

carbide tools. Cutting or forming

tools, usually made from tungsten, titanium, tantalum, or niobium carbides, or a combination of them, in a matrix of cobalt, nickel, or other metals. Carbide tools are characterized by high hardnesses and compressive strengths and may be coated to improve wear resistance.

carbon dioxide welding. *Gas metal-arc welding* using carbon dioxide as the shielding gas.

carbon edges. Carbonaceous deposits in a wavy pattern along the edges of a sheet or strip; also known as snaky edges.

carbon electrode. A carbon or graphite rod used in carbon-arc equipment, such as in carbon-arc welding or cutting torches.

carbon equivalent. (1) For cast iron, an empirical relationship of the total carbon, silicon and phosphorus contents expressed by the formula:

$$\text{CE} = \text{TC} + \frac{1}{3}(\text{Si} + \text{P})$$

(2) For rating of weldability:

$$\text{CE} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

carbonitriding. A case hardening process in which a suitable ferrous material is heated above the lower transformation temperature in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, create a concentration gradient. The process is completed by cooling at a rate that produces the desired properties in the workpiece.

carbonization. Conversion of an organic substance into elemental carbon. (Should not be confused with *carburization*).

carbon potential. A measure of the ability of an environment containing active carbon to alter or maintain, under prescribed conditions, the carbon level of the steel. NOTE: In any particular environment, the carbon level attained will depend on such factors as temperature, time and steel composition.

carbon restoration. Replacing the carbon lost in the surface layer from previous processing by carburizing this layer to substantially the original carbon level. Sometimes called *recarburizing*.

carbon steel. Steel having no specified minimum quantity for any alloying