Definitions of Heat Treating Terms — SAE J415e

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(These definitions were prepared by the Joint Committee on Definitions of Terms Relating to Heat Treatment appointed by the American Society of Testing and Materials, The American Society for Metals, the American Foundrymen's Association, and the SAE.)

This glossary is not intended to be a specification, and it should not be interpreted as such. Since this is intended to be strictly a set of definitions, temperatures have been omitted purposely.

Ac_{cm}, Ac_1, Ac_3, Ac_4-Defined under Transformation Temperature.

Ae_{cm}, Ae_1, Ae_3, Ae_4-Defined under Transformation Temperature.

AGE HARDENING-Hardening by aging, usually after rapid cooling or cold working. See Aging.

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 alloys. See also Age Hardening, Artificial Aging, Natural Aging, Overaging, Precipitation Hardening, Precipitation Heat Treatment, Progressive Aging, Quench Aging, Strain Aging.

ANNEALING-Heating to and holding at a suitable temperature and then cooling at a suitable rate, for such purposes as reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties. When applicable, the following more specific terms should be used: Black Annealing, Blue Annealing, Box Annealing, Bright Annealing, Flame Annealing, Full Annealing, Graphitizing, Intermediate Annealing, Isothermal Annealing, Malleablizing, Process Annealing, Quench Annealing, Recrystallization Annealing and Spheroidizing.

Definitions of the above terms are given in their alphabetic positions in this glossary.

When applied to ferrous alloys, the term "annealing" without qualification, implies full annealing.

When applied to nonferrous alloys, the term "annealing" implies a heat treatment designed to soften a cold worked structure by recrystallization or subsequent grain growth or to soften an age hardened alloy by causing a nearly complete precipitation of the second phase in relatively coarse form.

Any process of annealing will usually reduce stresses, but if the treatment is applied for the sole purpose of such relief it should be designated Stress Relieving.

Ar_{cm}, Ar_1, Ar_3, Ar_4-Defined under Transformation Temperature.

ARTIFICIAL AGING-Aging above room temperature.See Aging and Precipitation Heat Treatment. Compare with Natural Aging.

AUSTEMPERING-Quenching a ferrous alloy from a temperature above the transformation range, in a medium having a rate of heat abstraction high enough to prevent the formation of high temperature transformation products, and then holding the alloy, until transformation is complete, at a temperature below that of pearlite formation and above that of martensite formation.

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 austentizing.

BAKING-Heating to a low temperature in order to remove gases.

BLACK ANNEALING-Box annealing or pot annealing ferrous alloy sheet, strip or wire. See Box Annealing.

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 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.

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.

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.

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 annealing: or "pot annealing." See Black Annealing.

BRIGHT ANNEALING-Annealing in a protective medium to prevent discoloration of the bright surface.

BURNING-Permanently damaging a metal or alloy by heating to cause either incipient melting or intergranular oxidation. See Overheating.

CARBON POTENTIAL-A measure of the ability of an environment containing active carbon to alter or maintain, under prescribed conditions, the carbon content of the steel exposed to it. *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.

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 which produces the desired properties in the workpiece.

CARBURIZING-A process in which an austenitized ferrous material is brough into contact with a carbonaceous atmosphere of sufficient carbon potential to cause absorption of carbon at the surface and, by diffusion, create a concentration gradient.

CASE-In a ferrous alloy, the outer portion that has been made harder than the inner portion or Core by Case Hardening.

CASE HARDENING-A generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two and, by diffusion, create a concentration gradient. The processes commonly used are: carburizing and and quench hardening, cyaniding, nitriding, carbonitriding. The use of the applicable specific process name is preferred.

CEMENTATION-The introduction of one or more elements into the outer portion of a metal object by means of diffusion at high temperature.

CLOSE ANNEALING-See Box Annealing.

COLD TREATMENT-Exposing to suitable subzero temperatures for the purpose of obtaining desired conditions or properties, such as dimensional or microstructural stability. When the treatment involves the transformation of retained austenite, it is usually followed by a tempering treatment.

CONDITIONING HEAT TREATMENT-A preliminary heat treatment used to prepare a material for a desired reaction to a subsequent heat treatment. For the term to be meaningful, the treatment used must be specified.

CONTROLLED COOLING-Cooling from an elevated temperature in a predetermined manner, to avoid hardening, cracking, or internal damage, or to produce a desired microstructure or mechanical properties. The term applies to cooling following hot working.

CORE-In a case hardened or surface hardened ferrous alloy, the inner portion that is softer than the outer portion or Case.

CRITICAL COOLING RATE- The minimum rate of continuous cooling to prevent undesirable transformation. For steel it is the minimum rate at which austenite must be continuously cooled to suppress transformations above the ^{m}s temperature.

CRITICAL TEMPERATURE RANGE-Synonymous with Transformation range which is pre-

ferred.

CYANIDING- Introducing carbon and nitrogen into a solid ferrous alloy by holding above Ac_1-in contact with molten cyanide of suitable composition. The cyanided alloy is usually quench hardened.

CYCLE ANNEALING-An annealing process employing a predetermined and closely controlled time-temperature cycle to produce specific properties or microstructure.

DECARBURIZATION-The loss of carbon from the surface of a ferrous alloy as a result of heating in a medium that reacts with the carbon.

DIFFERENTIAL HEATING-Heating that intentionally produces a temperature gradient within an object such that, after cooling, a desired stress distribution or variation in properties is present within the object.

DIFFUSION COATING-Any process whereby a basis metal or alloy is either: (1) coated with another metal or alloy and heated to a sufficient temperature in a suitable environment or (2) exposed to a gaseous or liquid medium containing the other metal or alloy, thus causing diffusion of the coating or of the other metal or alloy into the basis metal with resultant change in the composition and properties of its surface.

DIRECT QUENCHING-Quenching carburized parts directly from the carburizing operation.

DOUBLE AGING-Employment of two different aging treatments to control the type of precipitate formed from a super-saturated alloy matrix in order to obtain the desired properties. The first aging treatment, sometimes referred to as intermediate or stablizing, is usually carried out at a higher termperature than the second.

DOUBLE TEMPERING-A treatment in which quench hardened steel is given two complete tempering cycles at substantially the same termperature for the purpose of assuring completion of the tempering reaction and promoting stability of the resulting microstructure.

DRAWING-A misnomer of Tempering.

FERRITIZING ANNEAL-A treatment given as-cast gray or ductile (nodular) iron to produce an essentially ferritic matrix. For the term to be meaningful, the final microstructure desired or the time-temperature cycle used must be specified.

FLAME ANNEALING-Annealing in which the heat is applied directly by a flame.

FLAME HARDENING-A surface hardening process in which only the surface layer of a suitable workpiece is heated by a suitably intense flame to above the upper transformation temperature and immediately quenched.

FOG QUENCHING-Quenching in a mist.

FULL ANNEALING-Annealing a ferrous alloy by austenitizing and then cooling slowly through the transformation range. The austenitizing temperature by hypoeutectoid steel is usually above Ac_3 and for hypereutectoid steel usually between Ac_1 and Ac_{cm}.

GAS CYANIDING-A misnomer for Carbonitriding.

GRAIN GROWTH-An increase in the average size of the grains (see Notes 1 and 2) in polycrystalline metal, usually as a result of heating at elevated temperature.

NOTES: (1) A grain is an individual crystal in a polycrystalline metal and includes twined regions and subgrains when present.

(2) Grain size is a measure of the mean diameter, area, or volume of all individual grains observed in a polycrystalline metal. In metals containing two or more phases, the grain size refers to that of the matrix unless otherwise specified. For further information on grain size and its measurement, see ASTM E 112, Methods for Estimating the Average Grain Size of Metals.

GRAPHITIZING-Annealing a ferrous alloy in such a way that some or all of the carbon is precipitated as graphite.

HARDENABILITY-In a ferrous alloy, the property that determines the depth and distribution of hardness induced by quenching.

HARDENING-Increasing the hardness by suitable treatment, usually involving heating and cooling. When applicable, the following more specific terms should be used: Age Hardening, Case Hardening, Flame Hardening, Induction Hardening, Precipitation Hardening, and Quench Hardening.

HEAT TREATMENT-Heating and cooling a solid metal or alloy in such a way as to produce desired conditions or properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition.

HOMOGENEOUS CARBURIZING-A process that converts a low carbon ferrous alloy to one of substantially uniform and higher carbon content throughout the section, so that a specific response to hardening may be obtained.

HOMOGENIZING-Holding at high temperature to reduce or eliminate chemical segrega-

tion by diffusion.

HOT-COLD WORKING-Mechanical deformation of austenitic and precipitation hardening alloys at a temperature just below the recrystallization range to increase the yield strength and hardness by either plastic deformation or precipitation hardening effects induced by plastic deformation or both.

HOT QUENCHING-An imprecise term used to cover a variety of quenching procedures in which a quenching medium is maintained at a prescribed temperture above 160° F (71° C).

INDUCTION HARDENING-A surface hardening process in which only the surface layer of a suitable ferrous workpiece is heated by electrical induction to above the upper transformation temperature and immediately quenched.

INDUCTION HEATING-Heating by electrical induction.

INTERMEDIATE ANNEALING-Annealing wrought metals at one or more stages during manufacture and before final thermal treatment.

INTERRUPTED AGING-Aging at two or more temperatures, by steps, and cooling to room temperature after each step. See Aging and compare with Progressive Aging.

INTERRUPTED QUENCHING-Quenching in which the metal object being quenched is removed from the quenching medium while the object is at a temperature substantially higher than that of the quenching medium. See also Time Quenching.

ISOTHERMAL ANNEALING-Austenitizing a ferrous alloy and then cooling to and holding at a temperature at which austenite transforms to a relatively soft ferrite-carbide aggregate.

ISOTHERMAL TRANSFORMATION-A change in phase at constant temperature.

MALLEABLIZING-A process in which the as-cast malleable-type (white) iron is thermally treated for the purpose of converting most of all of the carbon in Fe_3C to graphite (temper carbon) to produce a family of products with improved ductility.

MARAGING-A precipitation hardening treatment applied to a special group of iron base alloys to precipitate one or more intermetallic compounds in a matrix of essentially carbon-free martensite.

NOTE: The first developed series of maraging steels contained, in addition to iron, more than 10% nickel and one or more supplemental hardening elements. In this series, the aging is done at about 900° F.

MARTEMPERING-Quenching an austenitized ferrous alloy in a medium at a temperature in the upper part of the martensite range, or slightly above that range and holding in the medium until the temperature throughout the alloy is substantially uniform. The alloy is then allowed to cool in air through the martensite range.

MARTENSITE RANGE-The temperature interval between M_s and M_f.

M_f-Defined under Transformation Temperature.

M_s-Defined under Transformation Temperature.

NATURAL AGING-Spontaneous aging of a supersaturated solid solution at room temperature. See Aging and compare with Artificial Aging.

NITRIDING-Introducing nitrogen into a solid ferrous alloy by holding at a suitable temperature (below Ac_1 for ferritic steels) in contact with a nitrogenous material, usually ammonia or molten cyanide of appropriate composition. Quenching is not required to produce a hard case.

NORMALIZING-Heating a ferrous alloy to a suitable temperature above the transformation range and then cooling in air to a temperature substantially below the transformation range.

OVERAGING-Aging under conditions of time and temperature greater than those required to obtain maximum change in a certain property, so that the property is altered in the direction of the initial value. See Aging.

OVERHEATING-Heating a metal or alloy to such a high temperature that its properties are impaired. When the original properties cannot be restored by further heat treating, by mechanical working, or by a combination of working and heat treating, the overheating is known as Burning.

PATENTING-In wire making, a heat treatment applied to medium carbon or high carbon steel before the drawing of wire or between drafts. This process consists of heating to a temperature above the transformation range and then cooling to a temperature below Ae_1, in air or in a bath of molten lead or salt.

POSTHEATING-Heating weldments immediately after welding, for tempering, for stress relieving, or for providing a controlled rate of cooling to prevent formation of a hard or brittle structure.

POT ANNEALING-See Box Annealing.

PRECIPITATION HARDENING-Hardening caused by the precipitation of a constituent from a supersaturated solid solution. See also Age Hardening and Aging.

PRECIPITATION HEAT TREATMENT-Artificial aging in which a constituent precipitates from a supersaturated solid solution. See Artificial Aging, Interrupted Aging, and Progressive Aging.

PREHEATING-Heating before some further thermal or mechanical treatment. For tool steel, heating to an intermediate temperature immediately before final austenitizing. For some nonferrous alloys, heating to a high temperature for a long time in order to homogenize the structure before working.

PROCESS ANNEALING-In the sheet and wire industries, heating a ferrous alloy to a temperature close to, but below, the lower limit of the transformation range and then cooling, in order to soften the alloy for further cold working.

PROGRESSIVE AGING-Aging by increasing the temperature in steps or continuously during the aging cycle. See Aging and compare with Interrupted Aging and Step Aging.

PSEUDOCARBURIZING-See Blank Carburizing.

PSEUDONITRIDING-See Blank Nitriding.

QUENCH AGING-Aging induced by rapid cooling after Solution Heat Treatment.

QUENCH ANNEALING-Annealing an austenitic ferrous alloy by Solution Heat Treatment.

QUENCH HARDENING-Hardening a ferrous alloy by austenitizing and then cooling rapidly enough so that some or all of the austenite transforms to martensite. The austenitizing temperature for hypoeutectoid steels is usually above Ac_3 and for hypereutectoid steels usually between Ac_1 and Ac_{cm}.

QUENCHING-Rapid cooling. When applicable, the following more specific terms should be used: Direct Quenching, Fog Quenching, Hot Quenching, Interrupted Quenching, Selective Quenching, Spray Quenching, and Time Quenching.

RECRYSTALLIZATION-(1) The change from one crystal structure to another, as occurs on heating or cooling through a transformation termperature. (2) The formation of a new, strain-free grain structure from that existing in cold worked metal, usually accomplished by heating.

RECRYSTALLIZATION ANNEALING-Annealing cold worked metal to produce a new grain structure without phase change.

RECRYSTALLIZATION TEMPERATURE-The approximate minimum temperature at which complete recrystallization of a cold worked metal occurs within a specified time.

SECONDARY HARDENING-The hardening phenomenon that occurs during high temperature tempering of certain steels containing one or more carbide forming alloying elements. Up to an optimum combination of tempering time and temperature, the reaction results either in the retention of hardness or an actual increase in hardness.

SELECTIVE HEATING-Intentional heating of only certain portions of a workpiece.

SELECTIVE QUENCHING-Quenching only certain portions of a workpiece.

SHELL HARDENING-A surface hardening process in which a suitable steel workpiece, when heated through and quench hardened, develops a martensitic layer or shell that closely follows the contour of the piece and surrounds a core of essentially pearlitic transformation product. This result is accomplished by a proper balance between section size, steel hardenability, and severity of quench.

SLACK QUENCHING-The incomplete hardening of steel due to quenching from the austenitizing temperature at a rate slower than the critical cooling rate for the particular steel, resulting in the formation of one or more transformation products in addition to martensite.

SNAP TEMPER-A precautionary interim stress-relieving treatment applied to high hardenability steels immediately after quenching to prevent cracking because of delay in tempering them at the prescribed higher temperature.

SOAKING-Prolonged holding at a selected temperature.

SOLUTION HEAT TREATMENT-Heating an alloy to a suitable temperature, holding at that temperature long enough to cause one or more constituents to enter into solid solution, and then cooling rapidly enough to hold these constituents in solution.

SPHEROIDIZING-Heating and cooling to produce a spheroidal or globular form of carbide in steel. Spheroidizing methods frequently used are:

1. Prolonged holding at a temperature just below Ae_1.
2. Heating and cooling alternately between temperatures that are just above and just below Ae_1.
3. Heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace or holding at a temperature just below Ae_1.
4. Cooling at a suitable rate from the minumum temperature at which all carbide is dissolved, to prevent the re-formation of a carbide network and then reheating in accordance with Method 1 or 2 above. (Applicable to hypereutectoid steel con-