A Glossary of metallurgical terms and terms relating to materials testing

CONTACT

Address: Unit 8, Petre Court
Clayton Le Moors
Accrington
Lancashire
BB5 5HY
Tel: +44 (0)1254 775133
Web: https://www.stainlessmetricstock.com/

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ABNORMAL STEELS
(a) Carbon steels showing relatively poor low deformation creep behaviour usually as indicated by abnormally high creep rates. This usually occurs when high aluminium additions are made and is thought to be associated with removal of nitrogen from solid solution as AIN.
(b) A name given by McQuaid and Ehn to carburizing steels which tended to show soft spots on quenching after carburizing. The cause is low hardenability associated with fine grain size.

ACID STEEL
A steel melted in a furnace with an acid lining, i.e., consisting of a siliceous refractory such as ganister or sand, and under a siliceous slag. Neither sulphur nor phosphorus is removed to any appreciable extent during the process and for this reason a higher grade of raw material is required than in the basic process. Acid steel may be produced either by the open hearth, Bessemer or electric processes.

ALLOTROPY
The property possessed by some elements of existing in two or more states (allotropes), differing widely in properties and each stable within certain limiting conditions of temperature and pressure, e.g., carbon has three allotropic varieties, diamond, graphite and amorphous carbon. The allotropy of iron modifies the solubility of carbon, and it is due to this fact that steel can be hardened. Pure alpha iron (ferrite) exists up to 910^{o} C. and pure gamma iron (austenite) from 900^{o} C.-1405^{o} C. Above 1405^{o} C. and up to the melting point of 1537^{o} C. it exists as delta iron. These temperatures are modified by alloy additions so that in certain steels, e.g., Staybrite and 14% manganese steel, the austenitic condition is stable at room temperature. The lattice of the alpha and delta iron is body centred cubic whilst that of gamma iron is face centred cubic.

ALPHA IRON
The allotropic form of iron, which in pure iron is stable below 910^{o} C., the atoms being arranged in a body centred cubic space lattice. It is magnetic below the magnetic change point, which, in pure iron, occurs at 770^{o} C. Above the magnetic change point, it was formerly known as beta iron.

ANNEALING
A heat treating operation wherein the metal is heated to a temperature above its critical range, held at that temperature long enough to allow full recrystallization, then slowly cooled through the critical range. Annealing removes working strains , reduces hardness, and increases ductility.

AUSTEMPERING
An interrupted quenching process which consists essentially of heating steel to an appropriate temperature above the critical range to render it austenitic and then, instead of cooling it to room temperature in one of the conventional cooling media, transferring the steel to a hot quenching bath maintained at a predetermined, constant temperature below the critical range, but above the martensitic change point (Ms point) usually between 260^{o} and 370^{o} C.; the steel is held at this temperature for a certain time to ensure the complete direct transformation of the austenite in the final products (e.g., pearlite and/or bainite), after which the material may be cooled to atmospheric temperature in any convenient manner. (See also Critical Cooling Rate).

AUSTENITE
The allotropic form of iron (gamma iron) which has a face centred cubic lattice, the parameter of which increases with increasing carbon content. Austenite, containing only carbide of iron in solution, is not stable at ordinary temperatures, nor can it be completely retained in solution by quenching, but its stability is greatly increased by the addition of certain alloying elements.

AUSTENITIC STEELS
Steels consisting of austenite, which, owing to the presence of high percentages of certain alloying elements such as manganese and nickel, are stable, for most practical purposes, at normal temperatures. Typical examples of austenitic steels include 14% manganese steel, and the corrosion-resistant type containing about 18% chromium and 8% nickel, e.g., Staybrite.

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BAINITE
An acicular aggregate of ferrite and carbide particles formed when austenite is transformed at temperatures in the intermediate range, i.e., above the martensite range and below the pearlite range. The structure of bainite varies with the composition of the austenite from which it is formed and with the temperature of its formation. (See Austempering).

BALANCED STEEL
Steel in which the deoxidation is so controlled that the evolution of gas during solidification approximately balances the shrinkage normally occurring. Thus no pipe cavity is produced and a high yield of usable metal can be obtained on rolling the ingot.

BANDED STRUCTURES

Light and dark parallel bands revealed by etching and formed by the elongation of segregated areas during rolling or forging.

BASE METAL
(a) A metal which becomes oxidized when heated in air, e.g., copper, lead, zinc, and tin, as distinct from a noble metal such as gold and platinum.
(b) In electro-metallurgy, a metal at the lower end of the electro-chemical series.
(c) The preponderant metal in an alloy.
(d) The metal to be welded or cut.

BASIC STEEL
Steel produced in an open hearth or Bessemer or electric furnace in which the hearth consists of a basic refractory such as rammed magnesite or dolomite. A slag, rich in lime, is produced and the sulphur and phosphorus pass into the slag during the working of the charge. The charge of the basic open hearth furnace consists of pig iron and scrap. In the hot-metal process, iron from the blast furnace goes through the mixer to the open hearth furnace, and constitutes 75% or more of the charge, the rest being scrap. In the scrap process, the basis of the charge is scrap steel. This may be up to 85% of the charge, the remaining 15% being pig iron. In either case, however, the refining of the metal consists of the removal of some of the carbon and the partial elimination of sulphur and phosphorus, the manganese changes which occur being incidental to the process.

BAUSCHINGER EFFECT
The decrease in compressive yield strength and increase in tensile yield strength obtained when a metal is plastically strained in tension beyond its yield point.

BEND TEST
A test in which a standard specimen is bent through a specified arc to determine the degree of ductility and the soundness of internal structure.

B/H LOOP
(Magnetic hysteresis and hysteresis curve). A closed figure formed by plotting magnetizing force against flux density for a magnetic material when the magnetizing force is taken through a complete cycle of increasing and decreasing values. The area of the figure is proportional to the magnetic hysteresis loss.

BLUE BRITTLENESS
The loss of ductility found on testing steel in the blue heat range which varies between about 200^{o} C. and 400^{o} C. according to the composition of the steel. This embrittlement is shown by the increase in maximum strength and decrease in the elongation, reduction of area and impact value. If steel is deformed at room temperatures, heated in the blue heat range and then tested at normal temperatures, the loss of ductility is revealed by the impact test rather than by elongation. The term blue brittleness is derived from the fact that blue oxide films are formed on polished steel within the range of temperature in question.

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BODY CENTRED CUBIC LATTICE
A lattice in which atoms are present at the corners of each cube or rectangular prism, with one atom in the centre of such cube or prism. The unit cell contains two atoms, because each corner atom is shared by seven other cubes

BRINNEL HARDNESS
The measurement of a metal hardness (or the ability to resist penetration). A steel ball is forced into the surface of the material tested under a specific load. The diameter of the depression is measured, and the hardness is the ratio of the load to the spherical area of the impression.

BURNT STEEL
The term is usually applied to a condition in which visible oxide films are formed at the crystal boundaries of the steel. This denotes that the steel has been heated almost to the solidus temperature and is, therefore, permanently damaged.

CARBIDE
A chemical combination of carbon with iron or any other elements, e.g., Fe C (cementite). Metallic carbides are hard and brittle; certain of them, of which the principal are tungsten carbide and titanium carbide, are the chief constituents of the hard metals used for cutting tools.

CARBON STEEL
A steel whose properties are determined primarily by the percentage of carbon present. Besides iron and carbon, such steels may contain a maximum of manganese up to 1.5%, silicon up to 0.5%, sulphur and phosphorus up to 0.1%, nickel up to 0.40%, chromium up to 0.30%, molybdenum up to 0.15%, copper up to 0.25%, tungsten, cobalt, aluminium up to 0.10% and niobium, tantalum, titanium, vanadium, zirconium up to 0.05%. These alloying elements in such quantities are regarded as residual elements, but their deliberate addition in substantial amounts will put the steel in the alloy steel category.

CARBONITRIDING
A case hardening process in which steel is heated in an atmosphere containing both carbon and nitrogen. Steels of the case hardening type are normally used, and since the absorption of nitrogen depresses Ac and increases hardenability the temperature and alloy content need not be so high as those used in case carburizing. A typical treatment would be: heat at 825^{o} C. for two hours in a carburizing gas to which about 10% anhydrous ammonia has been added, and quench in oil: but many variations of these conditions can be employed to give the required depth and hardness of case.

CARBURIZING
The introduction of carbon into the surface layer of a steel having a low carbon content (case hardening steel). It may be effected by heating in a solid, liquid or gaseous carbon-containing medium, which at high temperatures provides a supply of carbon for absorption by the material being carburized. By controlling the temperature and time of treatment, the concentration of carbon in the surface of the steel and the depth of penetration may be varied over wide limits. In the original process of box- or pack-carburizing, the steel is heated to the necessary temperature in a solid carburizing compound, usually a mixture of hardwood charcoal and an oxide or carbonate of the alkalies or alkaline earths. Gas carburizing is finding increasing use because it gives better control over the carbon content of the case.

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CAST IRON
Iron with a total carbon content varying between about 1.8 and 4.5%, the carbon being present in excess of the amount which can be retained in solid solution in austenite at the eutectic temperature. In addition to carbon, there are also present, varying amounts of silicon, manganese, sulphur and phosphorus. These irons can normally be divided into the following types:- Grey cast iron, in which all or part of the carbon content is in the form of graphite distributed through the metal as flakes which are responsible for the inherently poor shock-resistance and relatively low mechanical properties of the material; White cast iron, in which practically the whole of the carbon is retained in chemical combination with the iron as carbide of iron, Fe C. This compound has a silver-white colour and the fractures of the cast iron are white. White iron is very hard and brittle and practically unmachinable, and is used chiefly as an intermediate product in the production of malleable iron castings or a thin hard layer on the surface of a softer iron casting; Malleable cast iron is cast white and then annealed at about 850^{o} C. to remove carbon (White-heart process) or to convert the cementite to rosettes of graphite (Black-heart Process). It is distinguished from grey and white cast iron by exhibiting some elongation and reduction of area in a tensile test; Spheroidal Graphite cast iron, in which, as the name implies, the graphite is in spheroidal form instead of flakes, as found in grey cast iron. The production of this iron involves the addition of an appropriate amount of either magnesium or cerium to the molten iron shortly before casting. The mechanical strength is doubled and such castings show measurable ductility and greatly increased shock resistance. Alloy Cast Iron contains a specially added element or elements in amounts sufficient to produce a measurable modification of the physical properties.

CAST STEEL
(a) A term, originally applied to crucible steel to distinguish it from shear steel, and still used for high carbon tool steel;
(b) The term also covers steel which has solidified from the molten condition in a mould and hence undergoes no further change of shape, e.g, by forging or rolling, except for such minor modifications as may be involved in machining.

CAUSTIC EMBRITTLEMENT
A type of intercrystalline stress corrosion cracking produced below the liquid level in mild steel and low-alloy steel boilers. Failure is at riveted joints or crevices where concentration of caustic can occur associated with a high internal or external stress. Welded boilers are normally free from this type of attack.

CEMENTATION
(a) The process of introducing elements into the outer layer of metal objects by means of high temperature diffusion.
(b) (Converting process). In this process, best quality Swedish wrought iron bars were packed in layers separated and surrounded by charcoal in pots, which were slowly heated to a temperature of about 1100^{o} C. and maintained at that temperature for a period of 7 to 10 days according to the desired carbon content, and then allowed to cool slowly, the whole process occupying about three weeks. During this operation, carbon provided by the charcoal, diffused into the iron, and some of it, reacting with the slag content of the wrought iron, liberated carbon monoxide which formed blisters on the surface of the bar, hence the name blister bar, and blister steel; or converted or cemented bar, or cemented steel, or plated bar. Some six of these were then piled together, placed in a clip, raised to a white heat, and hammered into a faggot or small bloom. This was known as single shear steel. For the production of double shear steel, the faggot was nicked, bent back on itself, reheated and hammered down again to its original size. The process is now obsolete; the last cementation furnace in the country is now preserved at the Sheffield laboratories of BISRA.

CEMENTITE
The iron carbide (Fe C) constituent of steel and cast iron. It is hard, brittle and crystalline and contains 6.67% of carbon by weight.

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CHARPY TEST
A notched-bar impact test in which a beam usually 10 mm. x 10 mm. in section supported at both ends, and having a notch in the middle of its length, is struck behind the notch by a striker carried on a pendulum. The energy absorbed in fracture is obtained from the height to which the pendulum rises. A notch with a depth of 2 mm. and rounded at the bottom to a diameter of 2 mm. is known as a Mesnager notch. A notch produced by drilling a hole usually 2 mm diameter and centre 4 mm. below one face with a saw cut from that face to the hole, is known as a keyhole notch. Other notches may be used, such as the Izod V-notch.

CHROMIZING/CHROMATING
The production of a corrosion- and heat-resisting surface layer by the high temperature diffusion of chromium into iron or steel.

CLAD STEELS
Two dissimilar types of sheets or plates bonded together. The covering metal usually possesses greater corrosion resistance, as when mild steel is clad with stainless steel.

CLEAVAGE PLANES
Planes of easy fracture where cleavage usually occurs when the crystal is subjected to stress parallel to one or more of the faces of the system to which the crystal belongs. They are not necessarily related to the boundaries of the crystal, and are found in both minerals and metals.

CLINK
A large crack in a block of metal caused by uneven contraction or expansion during cooling or heating.

CLOSE PACKED HEXAGONAL
An arrangement of atoms in crystals. (See Space Lattice).

CONTRACTION CAVITIES
Voids formed when the supply of molten metal fails at certain points. In well designed castings, the bulk of the contraction that accompanies the solidification is concentrated in the feeder heads and risers, from which molten metal flows to compensate for contraction in the casting proper. In steel ingots the contraction may result in the formation of pipe if feeding is inadequate.

COOLING AND HEATING CURVES
Graphs obtained by plotting time against temperature for a metal cooling or heating under constant conditions. Changes of rate resulting from the absorption or evolution of heat indicate phase changes.

CORING
The microscopic segregation developed by the progressive freezing of zones successively richer in one metal when a liquid solution of two metals is solidifying to form a solid solution.

CORROSION FATIGUE
Corrosion combined with alternating or repeated stress accelerates the fatigue. The severity of the action depends upon the range and frequency of the stress, the intensity of the corroding conditions, and the time. The fracture is akin to a fatigue fracture, but may exhibit a characteristic discolouration, dark at the origin and grading away to a lighter shade with increasing distance from it.

CREEP TEST
A method of determining the plastic deformation of metals under a definite load at a definite temperature. Various criteria are used for assessing the behaviour of materials in a creep test, namely
(i) as a definite creep rate, e.g., between x and z hours (e.g., 24-72 or 25-35) or creep rate at 1000 hours.
(ii) total deformation in a certain period of time.
Owing to the lengthy nature of such testing where the service may extend to 10 years, or longer, considerable use is made of the extrapolation of creep test results obtained for relatively short times.

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CREVICE CORROSION
(Shielding). This type of attack occurs in crevices as formed by washers, sleeves or bearings, etc., or at the edge of a protective coating. It is due to a concentration of corrosive media or by a depletion in oxygen resulting in an aeration cell.

CRITICAL COOLING RATE
The term , as applied to steel, represents the slowest rate of cooling which allows the formation of martensite. In many cases this amounts to the rate of cooling which will just suppress the austenite/pearlite transformation. (See also Transformation Range).

CRITICAL POINTS
The points of temperature at which changes of phase occur in steel. They are marked by the liberation of heat, recalescence, during cooling, and by absorption of heat, decalescence, on heating, thus resulting in halts or arrests on the cooling or heating curves. In steel there are several such points, the temperature for which depends largely on the composition of the steel. (See also Transformation Range).

CRITICAL TEMPERATURE
(a) The temperature at which some change occurs in a metal or alloy during heating or cooling, i.e., the temperature at which an arrest or critical point is shown on heating or cooling curves.
(b) The temperature at which alpha iron loses its magnetic properties, i.e., about 770^{o} C.
(c) The temperature above which a given gas cannot be liquefied.

CRYSTAL BOUNDARIES
The surfaces of contact between adjacent crystals in a metal. Anything not soluble in the crystals tends to be situated at the crystal boundaries, but in the absence of such a phase, the boundary between two similar metals is simply the region where the orientation changes.

CUP AND CONE
A type of fracture occurring in tensile test pieces from steels possessing reasonable ductility, and containing no local abnormality where the necking occurs after maximum stress. The fracture gives one surface with a cup-like contour, and the other in the form of a cone, fitting the cup. This is accepted as evidence of toughness and uniformity of structure.

CUPPINESS
An internal defect in wire-drawing which leads to fracture of the cup and cone type. It may be caused by excessive cold work (overdrawing) without adequate intermediate annealing or by segregation where the hard centre, being less ductile than the surface, tears and starts the fracture.

DAMPING CAPACITY
This has been described as "elastic hysteresis" and "internal friction", but the word damping more suitably indicates the effect obtained when a material having the property in question is subjected to vibrations which are not maintained by external energy, e.g., if a steel bar supported at one end is struck with a hammer it will vibrate for varying lengths of time depending upon the stress imposed and the composition and condition of the steel, but at a uniformly decreasing rate owing to the internal friction of the material which dissipates the energy as heat and sound.

DELTA FERRITE
The allotropic form of iron which in the pure metal exists between 1405^{o} C. and the melting point, 1535^{o} C. It is non-magnetic,and the atoms are arranged in the body centred cubic structure as in alpha iron. It is often present in high chromium stainless steels at room temperature as a separate phase.

DENDRITE
A tree-like crystal formation. Metal crystals grow by branches developing in certain directions from the nuclei. Secondary branches are later thrown out at periodic intervals by the primary ones and in this way a skeleton crystal, or dendrite, is formed. The interstices between the branches are finally filled with solid which in a pure metal is indistinguishable from the skeleton. In many alloys, however, the final structure consists of skeletons of one composition in a matrix of another, giving what is called a cored structure. (See Coring).

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DEOXIDATION
The final operation in the production of "killed" steel, when elements such as silicon or aluminium are added to stabilize the dissolved oxygen. This prevents it reacting with the carbon to form carbon monoxide which would form blowholes during subsequent solidification.

DIAMOND PYRAMID HARDNESS TEST
An indentation hardness test in which the indenter, a square diamond pyramid with an angle between opposite faces of 136^{o} , is forced under a standard load into the surface of the specimen under test. The hardness is determined by measuring the diagonal of the indentation produced. The diamond pyramid hardness number is the number obtained by dividing the applied load in kilogrammes by the surface area of the impression in square millimetres computed from the measured diagonal of the impression. It is assumed that the impression is an imprint of the undeformed penetrator.

DIFFUSION
The process whereby the molecules in a solution move from regions of high concentration until complete homogeneity is attained. This process is rapid in gases, and moderate in liquids. The migration of atoms within a solid is brought about by thermal activation. Examples of this include nitriding, carbon case hardening and cementation which involve diffusion into the surface of a solid whilst decarburization involves diffusion from the surface.

DISLOCATION
A discontinuity in the crystal lattice of a metal. The movement of such discontinuities under stress may be used to explain slip, creep, plastic yielding, etc.

DUCTILITY
The property of metals which permits deformation to occur without fracture. Ductile metals show considerable elongation under tensile stress and ultimately fail by necking, with consequent rapid increase in stress locally.

DYE PENETRANT INSPECTION
Used for detecting surface porosity or cracks, more particularly in non-magnetic substances. The part to be examined is cleaned and coated with a dye which penetrates any small cracks or openings. The surface is then wiped clean and coated with a white powder. The dry powder soaks up the dye which is still held in the defects and thereby indicates their position.

DYNAMIC STRENGTH
Resistance to loads suddenly applied or to pulsating loads.

ELASTIC LIMIT
The highest stress that can be applied to a metal without producing a measurable amount of plastic (i.e., permanent) deformation. Usually assumed to coincide with the limit of proportionality.

ELASTICITY
The tendency of a body to return to its original size and shape, after having been stretched, compressed or deformed. The ratio of the stress called into play in the body by the action of the deforming forces to the strain or change in dimensions or shape is called the coefficient or modulus of elasticity.

ELECTRIC STEEL
Steel made by one of the electric processes where the heat required for melting the steel is provided either by an electric arc usually made to pass between the metal itself and a carbon electrode, i.e., the arc process, or by eddy currents induced by a high frequency current. In each process the furnace lining may be either acid or basic.

ELECTRICAL CONDUCTIVITY
Rate at which electrons move through atoms causing current to flow.

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ELECTRON MICROSCOPE
An instrument for the examination of structures, the details of which are too fine to be resolved by the use of either visible or ultra-violet light. In it a stream of electrons and an electromagnetic field replace the light rays and optical lenses of the ordinary microscope.

ELONGATION
(a) The total extension produced in a tensile test are determined after fracture by holding the pieces of a fractured tensile test piece together and measuring between pop marks applied before starting the test. It is expressed as a percentage of the original gauge length, which should also be given, and in this country is usually 4 A, where A is the cross-sectional area of the test piece. It is a measure of the ductility of the steel.
(b) The extension produced, for example, in rolling.

ENDURANCE LIMIT
In fatigue testing, the value of the applied alternating stress which will produce fracture after a given number of reversals. (Cf. Fatigue Limit).

ENERGISER
A substance added to carburizing mixtures to accelerate the carbon case hardening process. The energisers most generally used are barium or sodium carbonates whose action is similar to a catalyst. It is believed that the energiser provides carbon dioxide, which in turn reacts with incandescent carbon to form an additional supply of carbon monoxide.

EQUILIBRIUM DIAGRAM
(Constitutional Diagram). A diagram constructed from thermal and other data showing the limits of temperature and composition within which the different constituents and phases of the alloy system in question are stable. From this, the changes of structure and the composition of the constituents in equilibrium at any specified temperature can be determined.

ERICHSEN TEST
The standard cupping test, using a tool with a spherical end of 20mm. diameter to deform the test piece, which is held between annular jaws of 27mm. internal diameter. The test sheet, which is 3.1/2 in. square, is first clamped between the jaws to measure the thickness; the jaws are then moved apart by 0.05mm. and clamped in that position, to allow the metal to be drawn into the cup as the test progresses. The tool is pressed into the metal until a crack appears in the cup, and the depth of cup at this instant is taken as a measure of the ductility of the metal.

ETCHING
A process of revealing the structure of metal by selective chemical attack of the structure. This is rendered possible by the fact that the differently orientated crystals have different rates of solution in the etching reagents.

ETCHING PITS
Small cavities formed on the surface of metals during etching.

EUTECTIC
A mixture of definite composition, consisting of two or more constituents, which solidifies simultaneously out of the liquid at a minimum freezing point. This point occurs at the intersection of two descending liquidus curves in a binary system or three descending liquidus curves in a ternary system.

EUTECTIC CHANGE
The transformation from the liquid to the solid state in a eutectic alloy. It involves the simultaneous crystallization of two constituents in a binary system and of three in a ternary system.

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EUTECTIC POINT
The point in the binary or ternary constitutional diagram indicating the composition of the eutectic alloy, or mixture of minerals, and the temperature at which it solidifies.

EUTECTIC STRUCTURE
The characteristic arrangement of the constituents in a eutectic resulting from their simultaneous crystallization from the melt.

EUTECTOID
A mixture of two or more constituents which forms simultaneously on cooling from a solid solution and transforms again on heating, e.g., pearlite. The essential difference between a eutectic and a eutectoid is that the eutectic is formed from the melt whereas the eutectoid is formed from a solid.

EUTECTOID STEEL
Steel having the same composition as the eutectoid point in the iron-carbon system (0.83% carbon), and which, therefore, with suitable cooling conditions, consists entirely of pearlite at temperatures below 710^{o} C.

EXTENSOMETER
An instrument for measuring minute extensions of the test piece during a tensile test. This is necessary when determining the Limit of Proportionality or Proof Stress.

FACE CENTRED CUBIC LATTICE
An arrangement of atoms in crystals in which the atomic centres are disposed in space in such a way that they may be supposed to be situated at the corners and the middle of the faces of a set of cubic cells, i.e., the lattice possesses half an atom in the middle of each face of the cubic lattice, the corners each sharing one atom with seven other cubes. Thus, each unit cell contains four atoms.

FATIGUE
The effect on a metal of repeated cycles of stress. Fracture results from the development of a crack which progresses across the section, with repeated stress. (See also Fatigue Limit and Corrosion Fatigue.)

FATIGUE LIMIT
The maximum value of the applied alternating stress which a test piece can withstand indefinitely. (Cf. Endurance Limit).

FATIGUE RANGE
The maximum range of stress which a metal will withstand indefinitely. When the maximum stress in tension equals that in compression, the fatigue range is twice the fatigue limit. The mean stress, i.e., half the range, must be stated to define the fatigue conditions

FATIGUE RESISTANCE
The ability of a metal to withstand repeated and varying loads.

FERRITE
A term once restricted to pure alpha iron but now extended to include any solid solutions of which alpha or delta iron, as distinct from gamma iron, is the solvent. Alpha ferrite forms from the gamma, austenitic phase, in slowly cooled hypo-eutectoid steels, and unless hardened by cold work it is soft and ductile. It may contain, in solid solution, many of the special elements, e.g., up to 30% chromium, or 15% silicon, but very little carbon, i.e., less than 0.03%. Pure iron consists of 100% ferrite and ferrite is the principal constituent in low carbon steels. When etched with nital, the grain boundaries appear as dark lines surrounding the white ferrite.

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FERRO ALLOYS
A term used for alloys of iron with another metal such as chromium, manganese, silicon, tungsten, molybdenum or vanadium. These alloys are used as a means of introducing the alloying element into steel or cast iron, or as deoxidisers. Ferro alloys are produced by electric smelting or by reduction with aluminium, an exception being high carbon ferro manganese which is normally produced in blast furnaces.

FERRO MANGANESE
The form in which manganese is generally used in the steel industry. The ordinary qualities contain 70 to 80% manganese and about 7% carbon. Spiegeleisen may contain from 12 to 30% manganese and about 5% carbon. These alloys are produced in small blast furnaces of standard type except that they are often fitted with special cooling devices, owing to the high temperatures involved in the reduction of manganese oxides. Low carbon ferro manganese is an electric furnace product and is available in several grades, of which the highest quality may contain as much as 90% manganese with a maximum carbon content of 0.07%.

FIRECRACKS
(a) Cracks found, for example, on the surface of rolls of hot rolling mills, or metallic bodies which have been subjected to repeated heating and cooling.
(b) (Chill Cracks). Marks on the surface of a hot rolled product which appear periodically, having been produced by a crack or cracks on the surface of the roll.

FLAKES
(Hair Line Cracks, Snow Flakes). Fine internal fissures which may be found lying in various directions in the interior of steel. They occur most frequently in large alloy steel sections but may also be found in carbon steels. Flakes in the heads of rails are known as Shatter Cracks. They are caused by hydrogen in the steel and may be prevented by appropriate heat treatment or by casting in a vacuum.

FLOW LINES (Fibre).
(a) The fibrous appearance of hot-worked steel caused by local differences in composition and the presence of inclusions which are drawn out in the direction of working. Flow lines are important in many stamped parts since the fibre habit results in directional properties.
(b) Striations visible on etching cold-worked steels. They are caused by local electrolytic differences of potential produced by the varying degrees of local distortion, and indicate the principal directions in which movement of the metal has taken place.

GRAIN SIZE CONTROL
A special deoxidation technique producing steel having an austenitic grain size within a specified range in accordance with the McQuaid Ehn grain size scale. It is achieved by the addition of aluminium to the liquid steel.

HARDENABILITY
The property that determines the depth and distribution of hardness induced by quenching, i.e., it represents the resistance to transformation. It is generally expressed in relative terms and is related to the critical cooling rate, i.e., the rate at, or above which wholly martensitic structures are formed. This critical cooling rate, or hardenability, is largely a function of composition, although steels of apparently similar composition can have different hardenabilities and the same cast of steel may show fairly wide variations. There is a limit to the section size which can be completely hardened upon quenching. Plain carbon steels are shallow hardening, and alloy additions increase the depth of hardening. The Jominy Test is a method of assessing hardenability.

HARDNESS
Signifies, in general, resistance to deformation. It is usually measured by determining the resistance to indentation, as in the Brinell, Diamond Indenter, Rockwell and Shore tests. The values of hardness obtained by the different methods are to some extent related to each other, and to the ultimate tensile stress of non-brittle metals. In Moh's scale comparative hardness is determined by testing against ten standard minerals: (1) talc, (2) gypsum, (3) calcite, (4) fluorite, (5) apatite, (6) orthoclase, (7) quartz, (8) topaz, (9) corundum, (10) diamond. Thus, a mineral with "hardness 5" will scratch or abrade fluorite, but will be scratched by orthoclase.

HARDOMETER
The principle embodied in this instrument is similar to that of the Brinell machine in which a hard steel ball is pressed, by means of a known load, into the specimen to be tested, the hardness being determined by measurement of the impression. Owing to the limitations of the hardened steel ball, for testing harder materials a pyramid diamond indenter is used. The hardness numbers are obtained by dividing the load in kilograms by the area of the impression in square millimetres; this applies both to the steel ball and to the diamond indenter. In the latter case, the hardness numbers obtained should be referred to as the diamond hardness numbers. The scale of ball impression diameters and Brinell hardness numbers corresponds exactly to that used with the 10mm. ball Brinell machine, provided both machines are used with the same ratio of load to square of ball diameter.

HATFIELD TIME YIELD
A short time creep test criterion. The specimen placed under the time-yield stress should not show an extension exceeding 0.50% of the gauge length in the first 24 hours, and during the next 48 hours should show no further extension, within a sensitivity of measurement of 1/10,000th inch on a 2 inch gauge length, which is approximately equivalent to a rate of creep of a millionth of an inch per inch per hour during this period.

HEYN'S REAGENT
An etching reagent containing 10% copper ammonium chloride in water.

HIGH SPEED STEEL
A high alloy steel, capable of intense hardening, used for metal-cutting tools. It retains its hardness at a low red heat, and hence the tools can be used in lathes, etc., operated at high speeds. It usually contains 12-22% tungsten, up to 5% chromium, up to 1% carbon, and varying amounts of other elements (vanadium, cobalt, etc.) Part or all of the tungsten may be replaced by half its weight of molybdenum.

HOMOGENIZING
A process of heat treatment at high temperature intended, by means of diffusion, to eliminate or decrease segregation.

HOOKE'S LAW
This law states that "within the limits of elasticity the strain produced by a stress of any one kind is proportional to the stress producing it". The value of the stress at which a material ceases to obey Hooke's Law is known as the limit of proportionality.

HOT SHORTNESS
Brittleness in metal at certain ranges above normal room temperature. It is manifested by loss in ductility and a liability to crack under stress at that particular temperature.

HYSTERESIS CURVE
A curve showing the relation between the magnetizing force and flux density in a sample of iron or steel, the curve being taken with ascending and descending values of magnetizing force, in order to illustrate the magnetic hysteresis loop.

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IMPACT TEST
A test to determine the resistance of a material to a suddenly applied stress, i.e., shock. A notched test piece is normally employed and the testing machines in general use are the Izod and Charpy. The resistance is usually reported as the energy in ft.-lb. or kg. m. required to fracture or bend the test piece, or as kg. m. per square centimetre of section behind the notch.

INTERCRYSTALLINE CORROSION
(Intergranular Corrosion). (Weld Decay). A defect occurring in chromium-nickel austenitic steels when submitted to chemical attack after heating within the range 500° -800° C. At this temperature the carbon is precipitated at the grain boundaries as chromium carbide, thus impoverishing the chromium content of the austenite adjacent to the boundaries and rendering them susceptible to corrosion. In welding, the material near the weld is heated in this range of temperature. For such zones, or in steel otherwise heated in this range, corrosion may produce complete disintegration of the steel at the crystal boundaries. The defect may be prevented by adding to the steel a carbide-forming element such as titanium or niobium which acts as a stabilizer. It is added in an amount sufficient to form a stable carbide and thus prevent the carbon from combining with the chromium. The alternative to adding the carbide-forming element is to maintain the carbon content of the steel at a very low level, e.g., <0.03%.

INTERCRYSTALLINE CORROSION TESTS
Of various methods for determining susceptibility of stainless steels to intercrystalline corrosion, the two most commonly used are the sulphuric acid-copper sulphate test (Hatfield or Strauss test), and the boiling 65% nitric acid test (Huey test).

INVERSE SEGREGATION
(Negative Segregation). A concentration of certain alloy constituents that have lower melting points in the region corresponding to that first solidifying; caused by interdendritic flow of enriched liquid through channels where the pressure drops with contraction of dendrites. The internal evolution of hydrogen may also give a positive pressure, aiding this flow and causing a liquated surface.

IZOD IMPACT TEST
A test piece of 10mm. square in section is notched transversely by a V-cutter, to a depth of 2mm. and an angle of 45° . The radius at the bottom of the notch is 1/4mm. The piece is fixed vertically in the vice of the machine by the lower end with the notch at the level of the face of the vice. When the pendulum of the machine is released it swings freely, and a knife edge carried in the tup of the machine strikes the piece at a distance of 22mm. above the notch, on the same side as the notch. The angle of swing of the pendulum beyond the vertical after breaking the test piece is indicated by a pointer which should have been previously set to zero. From the amount by which the angle falls short of the angle to which the pendulum would have swung if there had been no test piece, the amount of energy absorbed in breaking the test piece is known, and is indicated by the pointer in ft.-lb. The height of fall of the centre of mass of the pendulum is 2.1/2 ft., and the capacity of the machine 150 ft.-lb., or 120 ft.-lb., the distance from the pivot to the striking edge being 4 feet. The striking velocity, when using the full capacity of the machine, is 13.6 ft. second.

JOMINY TEST
A hardenability test in which a standard test piece, 1 inch diameter x 4 inches long, is heated to a predetermined temperature, rapidly transferred to a jig fixture and quenched, under standard conditions, by a jet of water impinging on one end. When the specimen is sufficiently cool, hardness determinations are made along the specimen from the quenched end; the diagram relating hardness to distance from the quenched end of the specimen is known as a hardenability curve.

KILLED STEEL
Steel that has been completely deoxidized by the addition of manganese, silicon, and sometimes aluminium, before casting, so that there is practically no evolution of gas during solidification, and sound ingots are obtained. The shrinkage cavity or pipe is limited to the upper portion of the ingot or in the feeder-head with which such ingots are usually provided.

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Unit 8, Petre Court, Clayton Le Moors, Accrington, Lancashire, BB5 5HY

LATENT HEAT
Thermal energy expended in changing the state of a body without raising its temperature, e.g., ice to water at 0 C., or water to steam at 100° C., or alpha to gamma iron at the A point.

LEDEBURITE
The eutectic of the iron/iron carbide system. It freezes at about 1130° C. and is composed of austenite and cementite containing about 4.3% carbon. During cooling, the austenite may transform to ferrite and cementite. It is typically found in cast iron.

LIMIT OF PROPORTIONALITY
The stress (load divided by original area of cross-section of the test piece) at which the strain (elongation per unit of gauge length) ceases to be proportional to the corresponding stress. In practice it is determined by inspection of a load-elongation diagram, obtained by plotting extensometer readings, and is the stress at which the load-elongation line ceases to be straight.

LIMITING CREEP STRESS
A term used somewhat loosely to denote the maximum stress at which a material will not creep by more than a certain amount within the working life of the part. It is also used in some of the short-time creep tests, as, for example, the Hatfield Time Yield.

LIMITING RANGE OF STRESS
The greatest range of stress that a metal can withstand for an indefinite number of cycles without failure. If exceeded, the metal fractures after a certain number of cycles which decrease as the range of stress increases. When the mean stress is zero, half this range is the fatigue limit.

LIQUIDUS
A line in a binary phase diagram or a surface on a ternary phase diagram, representing the temperatures under equilibrium conditions at which freezing begins during cooling, or melting is completed on heating, i.e., the line or surface above which all the alloys in the system are completely molten.

LOAD-EXTENSION CURVE
A line plotted from the results of a tensile test, with loads as ordinates and elongations of the gauge length as abscissae, thus relating the extension of the material under test to the applied load. (See also Stress-Strain Curve).

McQUAID EHN GRAIN SIZE TEST
A method of assessing austenitic grain size which was first developed to determine the cause of soft spots on case hardened steels. A specimen of steel from which all scale has been removed is carburized in a solid medium for 8 hours at 925° C. The size of the pearlite crystals, which indicates the size of the original austenite grain, is easily seen by the surrounding membranes of excess Fe C (cementite). The grain size is measured at 100 diameters and compared with standard charts. The figures range from No.1, very coarse, to No.8, very fine.

MACROGRAPH
A low power reproduction, usually by photography, of the coarse structure of, for example, a metal as shown by a polished and, as a rule, etched section or surface.

MACROSTRUCTURE
The general crystalline structure of a metal or alloy and the distribution of impurities as seen on polished and etched surfaces, either by the naked eye or under magnifications of less than 10 diameters.

MAGNETIC CHANGE POINT

The temperature at which iron becomes non-magnetic on heating (Ac) and conversely that at which it becomes magnetic on cooling Ar). This temperature, also known as the Curie or magnetic transformation point, in pure iron is 770° C.

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MAGNETIC CRACK DETECTION
The part to be examined is magnetized either by passing a heavy current through it or by making it the core of a coil through which a heavy current is passed. Small cracks, or non-magnetic phases such as inclusions, cause the magnetic flux to break the surface thus forming small magnets. When the part is sprayed with a suspension of iron oxide particles in paraffin, the particles cling to the small magnets and thus show the presence of defects.

MAGNETIC ETCHING
A method in which a polished surface is covered with a thin colloidal suspension of magnetic particles and a magnetic field applied. A visible concentration of the colloid results wherever there are free poles, e.g. at cracks and non-metallic inclusions.

MAGNETIC FLUX
A term used to denote the amount of magnetism induced in a piece of magnetic material when it is placed in a magnetizing field.

MAGNETIC FLUX DENSITY (B).
(Magnetic Induction). The normal magnetic flux induced by a magnetizing force H, measured in lines or gauss per sq. cm.

MAGNETIC HYSTERESIS LOOP
A closed figure formed by plotting the magnetizing force (H) against the magnetic flux density (B) when the former is taken through a complete cycle after initial magnetization, the magnetic hysteresis loss being proportional to the area of this loop.

MAGNETOSTRICTION
The change in dimensions of magnetic materials brought about by magnetization or conversely the changes in magnetic properties brought about by strain.

MALLEABILITY
The property which enables a metal to be mechanically deformed under compression, as in hammering or rolling into thin sheets without cracking. (See Ductility).

MARTEMPERING
In this method of heat-treatment, the ideal is to quench the part at such a rate that it reaches the Ms temperature in the fully austenitic condition. After equalization of temperature, the part is cooled slowly, so that the temperature gradients are negligible and the resulting thermal stresses are at a minimum. In practice, this ideal is only approached in so far as it is necessary to prevent cracking, reduce distortion and to obtain a given hardness. As the Ms point is usually in the region of 250^{o} C., the quenching must be done in salt or metal bath. The quenching and time available for the equalization of temperature limits the section size that can be successfully martempered to somewhat less than that permissible with conventional quenching. Similarly, the minimum carbon or alloy content for a given section is higher. The outstanding advantages of martempering are the prevention of cracking and the minimizing of distortion, these both resulting from the reduction of thermal stresses.

MARTENSITE

A microconstituent of steel characterized by its acicular structure. Essentially a non-equilibrium condition of alpha iron formed directly from undercooled austenite. It is produced typically when steel is cooled from the hardening temperature at a speed greater than its critical cooling rate so that the transformation of austenite occurs at 400^{o} C. or below. It is the hardest of the decomposition products of austenite and is brittle but when tempered becomes softer and tough.

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MATRIX
As used in metallography the term applies to the principal constituent in which the other constituents are embedded.

MEEHANITE
A trade name applied to certain pearlitic cast irons in which the molten metal has been treated with calcium silicide resulting, it is claimed, in increased tensile strength.

MELTING POINT
(Fusion Point). The temperature at which a solid begins to liquefy. Pure metals, eutectics and some intermetallic constituents melt at a constant temperature. Alloys generally melt over a range.

METTALLOGRAPHIC EXAMINATION
The study of the microscopic features of material surfaces that have been specially prepared by cutting, grinding, polishing, and etching.

METALLURGICAL
Science of metals and alloys devoted to the study of engineering materials.

MICROHARDNESS
Hardness as measured with an indenter under the application of a low load, usually between 1 gram and 200 grams. Owing to the small size of the impression, the hardness of an individual phase in a microstructure can be determined.

MICRON
A unit of length equal to a millionth of a metre (0.001 mm.) 0.000039 in. It is used for expressing minute distances of wave-lengths of light, and is denoted by the Greek letter μ.

MODULUS OF RIGIDITY
In a torsion test, the ratio of the unit shear stress to the displacement caused by it per unit length in the elastic range. This modulus corresponds to the modulus of elasticity in the tension test.

NEUMANN BANDS
Narrow bands differently oriented within a grain of ferrite. Ordinarily these bands are formed only on deformation by impact, but in some alloys (silicon ferrite, for example), and particularly at low temperatures, the bands are formed more readily, as in ordinary cold-working processes. It is suggested that the Neumann band is primarily a shearing or faulting movement operating along the pre-existent planar disjunctions of the mosaic structure, and as a secondary operation, twinning may be completed, as is known to be possible in ferrite.

NON-AGEING STEEL
Low carbon steel to which is added an element (usually aluminium, less commonly titanium or vanadium) which stabilizes the active nitrogen or carbon to prevent strain ageing.

NON-DESTRUCTIVE TESTING
Any form of testing which does not result in permanent damage or deformation to the part being tested. Examples are ultrasonic inspection, X-ray inspection, gamma radiography, magnetic crack detection and dye penetrant inspection

NON-FERROUS
Metals that do not contain iron as the major alloying element.

NON-MAGNETIC STEELS
Austenitic steels, such as 14% manganese-, 25% nickel-, and 18/8 chromium-nickel steels, under normal conditions

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NORMALIZING
Commonly used heat treatment that decreases the pearlite interlamellar spacing and refines grain size. The process consists of hearting steels above the transformation temperature range, holding at temperature, and then cooling in air.

PEARLITE
The lamellar conglomerate of ferrite and cementite which constitutes the eutectoid in the iron-carbon equilibrium system. It results from the transformation of austenite at or below Ar , and is so called from the mother-of-pearl lustre given by an etched surface when viewed under the microscope. This pearly appearance is due to the fine and regular alternation of the two constituents. The lamellar arrangement of ferrite and cementite produces a tough structure and is responsible for the mechanical properties of the unhardened steels. Pearlite is present in small quantities in low carbon steels and increases in quantity as the carbon increases, until in a plain carbon steel, containing about 0.83 per cent of carbon, the structure consists entirely of pearlite.

PEELED BAR
A round bar that has been centreless machined to remove its outer surface. The peeling process takes less than one fourth the time of conventional lathe turning operations.

PERMANENT SET
(a) An extension remaining after the load has been removed from a test piece when the elastic limit has been exceeded (see Elastic Limit).
(b) Permanent deflection of any structure after being subjected to a load.

PERMEABILITY
(a) The ratio B/H for a magnetized material, where B is the flux density produced and H is the magnetizing force.
(b) In sand, a measure of that physical property which permits gas to pass through the moulded mass of sand.

pH VALUE
A method of expressing differences in the acidity or alkalinity of solutions. It is the logarithm to the base 10 of the reciprocal of the concentration of the hydrogen ions in gram molecules per litre in an aqueous solution. Thus, water has a pH value of 7, acidic solutions are less than 7, and basic solutions are higher than 7.

PHASE DIAGRAM
(Thermal Equilibrium Diagram). A graph showing the limits of composition and temperature of the various phases present in an alloy system under equilibrium conditions. A phase is the name given to a constituent which can be distinguished from the remainder of an alloy by physical and chemical methods such as etching, and in the solid may be a solid solution, an element or an intermetallic compound.

PHOTOELASTICITY
A property of transparent substances which enables the presence of strain to be detected by examination in polarized light. If models of engineering structures are made of such a substance, the stress distribution in the structures may be deduced.

PHOTOMICROGRAPH
A photographic reproduction of a microstructure.

PITTING CORROSION
Passive metals are resistant to a wide variety of corrosive media but under certain conditions breakdown of the passive film may occur at various points. Depending on the conditions, this may lead to a complete breakdown of the passive film or the attack may concentrate at these initial areas, leading to rapid failure by pitting.

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PLASTIC FLOW
The deformation of metals by the mechanism of slip along definite geometric planes within the crystals.

POLING
Stirring molten metal, either in a furnace or in a ladle, with a pole of green wood, the heat distilling off the volatile products which stir up the metal, and, together with the charcoal formed, help to reduce any oxide present.

POWDER METALLURGY
The art of producing metal powders and forming them into coherent objects. Individual, mixed, or alloyed metal powders, with or without the inclusion of non-metallic constituents, are pressed or moulded into objects which may be simultaneously or subsequently heated to produce a coherent mass, either without fusion or with the fusion of a low melting constituent only.

PROOF STRESS
The stress which is just sufficient to produce a permanent elongation equal to a specified percentage of the original gauge length. It can be determined :-

(a) By direct measurement of the gauge length after various loads have been applied to the test piece and removed; Or

(b) From the load-elongation curve by drawing a line parallel to the straight portion of the curve and distant from it by an amount representing the required permanent elongation, thus determining the load at which the line cuts the curve.

QUENCHING
Rapid cooling of a heated metal generally by immersion in liquids, to increase strength and hardness. Quenching is always followed by a temper to increase ductility.

QUENCHING CRACK
(Hardening Crack). A fracture resulting from thermal and/or transformation stresses, induced during rapid cooling.

RADIOGRAPHY
A non-destructive method for internal examination of a metallic body exposed to a beam of X-ray or gamma radiation. Differences in thickness, density or absorption caused by internal defects or inclusions are apparent in the shadow image, either on a fluorescent screen or on a photographic film placed behind the object.

RED SHORTNESS
Brittleness in a metal when red hot, causing it to crack when under the hammer or during rolling. It may be caused by the presence of a high sulphur content which exists in the form of sulphide.

REDUCTION OF AREA
(a) The percentage decrease in the cross-sectional area of a tensile test piece caused by the waisting or necking of the specimen. It is expressed as a percentage of the original area of the test piece and is a measure of ductility.
(b) The percentage decrease in cross-sectional area of bar or wire after rolling or drawing.

RESILIENCE
A general term for the power of an elastically strained body of spring back on removal of the load. Strictly it is the potential energy stored up by an elastically strained body and given out when the load is removed. It is expressed in energy units such as foot pounds per cubic inch. The proof resilience is the greatest amount of energy that can be stored up by a body strained only elastically.

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ROCKWELL HARDNESS TESTER
Rockwell hardness numbers are based on the additional depth to which an indenter is driven into a metal by heavy load beyond the depth to which the same indenter has been driven by a light load, the conditions under which this happens being arbitrary but definite. For the inspection of hard steel parts the sphero-conical diamond Brale penetrator is used with a major load of 150 kg. The number indicated on the black scale of the dial is observed and is prefixed invariably by the letter C, as C-62. For the testing of rolled, drawn, extruded and cast metal, with the exception of very soft metals or very thin pieces, the penetrator employed is the 1/16 in. diameter steel ball with the other standard load, 100 kg. The readings are then taken from the red calibration on the dial and the prefix is the letter B, as B-68. Tests can also be made with other load penetrator combinations than are required for the standard "B" and "C" scales, for example, a 60 kg. major load with a Brale penetrator is used for the "A" scale.

SEASON CRACKING
Cracking resulting from combined corrosion and internal stress. It occurs in severely cold-worked materials. The term is usually applied to the stress corrosion cracking of brass.

SEGREGATION
The non-uniform distribution of impurities or alloying elements. The phenomenon depends not only on the chemical composition of the alloy, but also on the rate of cooling, both of the ingot as a whole, and of each individual point within the mass. For example, and referring more particularly to piped ingots, near the walls, where the rate of cooling is rapid, the segregated impurities are trapped in the rapidly growing crystals. Further inside the ingot, where the cooling is slower, the segregates will collect together and produce the so-called ghosts, or they may tend to rise to the surface and collect in the scrapped ingot head. In normal segregation, the constituents with the lowest melting points concentrate in the last portions to solidify, but in inverse segregation this is reversed. The segregation tends to form in bands sloping inwards to the top of the ingot (A segregate) and at the same time, due to shrinkage, it takes a V shape (V segregate) along the upper part of the ingot axis.

SHORE SCLEROSCOPE
An instrument which consists essentially of a small diamond-tipped hammer which falls freely down a graduated glass tube from a constant height on to the surface of the sample under test. The hardness, or the elastic quality, is measured by the height of the rebound. In one form of the instrument the rebounding hammer actuates the pointer of a scale so that the height of the rebound is recorded.

SIGMA PHASE
Originally a phase in iron chromium alloys containing essentially the compound FeCr, but the term has subsequently been extended to include similar related phases in other systems. It is stable at temperatures of the order of 900 C. and may occur in stainless steels where, because of its hard brittle nature, it is undesirable.

SLIP
The mechanism of cold deformation wherein one part of a crystal glides over another part along certain planes known as slip planes.

SLIP BANDS
A series of parallel lines showing across the individual crystals of a deformed polished surface.

SOLID SOLUBILITY
The extent to which one metal is capable of forming solid solutions with another. This capacity varies considerably: some metals are almost insoluble in each other, whilst others are mutually soluble in all proportions.

SOLID SOLUTIONS
A homogeneous solution of two or more crystallized bodies in the solid state.

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SOLIDUS
A line or surface in a constitutional diagram indicating the temperatures at which solidification is completed or melting begins in alloys and other melts of different composition, i.e. the line or surface below which the alloys are in a solid condition (Cf. Liquidus).

SOLUTION HEAT TREATMENT
A treatment in which an alloy is heated to a suitable temperature and held at this temperature for a sufficient length of time to allow a desired constituent to enter into solid solution, followed by rapid cooling to hold the constituent in solution. The material is then in a supersaturated, unstable state and may subsequently exhibit age hardening.

SPACE LATTICE
The dimensional geometric pattern in which the atoms of a metal arrange themselves, and upon which a crystal is built. There are several known lattice configurations, but most metals crystallize in one of three types:
(1) Face centred cubic;
(2) Body centred cubic; and
(3) Close packed hexagonal.

SPARK TESTING
A method of determining the approximate composition of steel by holding a sample on a grinding wheel and producing sparks. An experienced operator can detect differences in the carbon content of steels of 0.05% in the range up to 0.35% and 0.10% in the range from 0.35 to 0.60%. The effects of alloying elements such as tungsten molybdenum, chromium, nickel, silicon and manganese are also recognizable.

STRESS CORROSION
The term implies a greater deterioration in mechanical properties of material through the simultaneous action of static stress and exposure to corrosion than could occur by the separate but additive action of those agencies. It is often accompanied by cracking.

STRESS STRAIN CURVE
A graph similar to a load extension curve except that stress (load divided by the original cross-sectional area of the test piece) is plotted against strain (the extension divided by the length over which it is measured).

STRETCHER STRAINS
(Lüders Lines). Irregular lines appearing on the surface of some materials, particularly mild annealed steel sheet or strip, on cold working. The markings can be prevented by temper rolling the sheet after annealing.

SULPHUR PRINT
A macrographic method of examination for the distribution of impurities in which a sheet of bromide paper, after being soaked in dilute sulphuric acid, is placed upon the plane polished surface to be examined. The sulphides in the steel react with the acid, liberating hydrogen sulphide which again reacts with the silver salt in the paper, leaving a dark brown stain, thus indicating the distribution of the sulphur.

TENSILE STRENGTH
(Maximum Stress). (Ultimate Tensile Stress). The highest load applied in breaking a tensile test piece divided by the original cross-sectional area of the test piece

TEMPER
Heat treatment process performed after quenching or normalizing. The forging is heated to a temperature below the critical range and cooled at a suitable rate. Tempering steel after hardening to relieve quenching stresses ensures dimensional stability and obtains specified mechanical properties

TENSILE TEST
A test in which specimens are subjected to an increasing tensile pull, until they fracture. A stress-strain curve may be plotted and the limit of proportionality, proof stress, yield point, tensile strength, elongation and reduction of area determined.

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TOUGHNESS TESTING
Test used to assess the resistance of metals to brittle fracture propagation in the presence of stress raisers.

TRANSFORMATION RANGE
(Transformation Temperature Range). The temperature interval within which austenite forms while ferrous alloys are being heated. Also the temperature interval within which the austenite transforms while ferrous alloys are being cooled. The range on cooling is lower than the corresponding range on heating: this phenomenon is known as thermal hysteresis. The limiting temperature of the ranges depends on the composition of the alloy and on the rate of change of temperature, particularly during cooling. If the transformation temperatures under conditions of equilibrium are plotted against carbon content of the steel, a diagram similar to the one shown in Figure 1 is obtained. On progressively heating hypo-eutectoid steels through the transformation range, ferrite dissolves in the austenite and on reaching the A point, solution is complete. In hyper-eutectoid steels, cementite progressively dissolves in the austenite. Eutectoid steels transform completely to austenite at a fixed temperature. The addition of alloying elements may profoundly modify the transformation ranges. The limits of the transformation range may be determined by measuring the temperatures at which evolution of heat (on cooling) or absorption (on heating) occurs. Other methods of determination include the measurement of the change in length with temperature or the rapid quenching from various temperatures in order to inhibit transformation with subsequent examination of the specimens, for example, either metallographically, by X-ray crystallography, or by hardness measurements. (See also Transformation Temperature).

TRANSFORMATION TEMPERATURE
The temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a transformation range. In order to distinguish between the critical points on heating and on cooling, those on heating are known as the Ac points (c chauffage or heating) and those on cooling as the Ar points (r refroidissement or cooling). The following symbols are used for iron and steel:

Ac *cm*.	In hyper-eutectoid steel, the temperature at which the solution of cementite in austenite is completed during heating.
Ac*1*.	The temperature at which austenite begins to form during heating.
Ac*3*.	The temperature at which transformation of ferrite to austenite is completed during heating.
Ac*4*.	The temperature at which austenite transforms to delta ferrite during heating.
Ae*1*, Ae*3*, Ae *cm*, Ae*4*.	The temperature of phase changes at equilibrium.
Ar *cm*.	In hyper-eutectoid steel, the temperature at which precipitation of cementite starts during cooling.
Ar*1*.	The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.
Ar*3*.	The temperature at which austenite begins to transform to ferrite during cooling.
Ar*4*.	The temperature at which delta ferrite transforms to austenite during cooling.
M*s*. (or Ar' '.)	The temperature at which transformation of austenite to martensite starts during cooling.
M*f*.	The temperature at which martensite formation finishes during cooling.

All these changes, except the martensite transformation, occur at lower temperatures during cooling than during heating, and depend on the rate of change of temperature. The martensite change is not reversible and is not affected by the rate of cooling.

TRANSITION TEMPERATURE
The temperature at which, in steel, a transition from ductile to brittle fracture takes place. It is commonly determined by making a series of Charpy impact tests at various temperatures; the transition temperature is usually taken as the point where 50% of the fracture surface shows cleavage. There are other methods of assessing the transition temperature, e.g., by bend tests, and each method gives a different value.

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TRANSVERSE TEST
A test usually applied to cast iron in which a bar is supported at its ends and loaded in the centre of the span until fracture occurs.

TWINNING
Well-defined bands in crystals in which the orientation of the atoms in the crystal lattice is the mirror image of that of the remainder of the crystals. It may be a result of heat treatment following cold-work, as in the austenitic 18/8 stainless steels.

ULTRASONIC INSPECTION
Owing to the piezo-electric effect certain crystals can be made to vibrate when influenced by an oscillating electric current. For ultrasonic inspection the crystal is made to vibrate at frequencies between 1/2 and 10 megacycles per second and when held against a piece of steel causes the vibrations to travel through the steel and be reflected back from the opposite side or from any intervening defects. The echoes are made visible on a cathode ray tube.

VACANCY
An empty atomic site within the crystal lattice. Vacancies can move about within the crystal under the application of stress.

VICKERS' DIAMOND HARDNESS TESTER
A small impression machine, suitable for testing metals of a high degree of hardness, finished parts and very thin sheets. The diamond impression is square. Angularity of pyramid 136 . The duration of the application of the load is controlled automatically and is always applied and removed in exactly the same manner. The machine may also be used with a ball indenter and thus give regular Brinell impressions. (See also Diamond Pyramid Hardness Test).

X-RAY CRYSTALLOGRAPHY
Max von Laue in 1921 showed that the planes of atoms in crystals act as a diffraction grating to X-rays, which are scattered by them and provide an accurate means of determining the details of the internal atomic structure. X-ray photographs of metals provide information which in many cases cannot be obtained by ordinary microscopic methods. The lines produced by each element, or phase, are characteristic, and their general pattern enables the crystalline structure to be identified. The scale of the pattern can be used to determine accurately the size of the unit cell and, therefore, the distance apart of the individual atoms; and from the relative intensity of the lines can be deduced the distribution throughout the unit cell of the various types of atoms in an alloy, or the degree of preferred orientation in the material. In addition, the sharpness of the lines provides information on both the state of strain and the grain size of the material.

YIELD POINT
The stress in a material at which there occurs a marked increase in strain without an increase in stress.

YIELD STRESS
The lowest stress at which extension of the tensile test piece increases without increase in load. Practically it is determined by observing a fall of the testing lever and checked by a pair of dividers on the original gauge length. Many materials do not indicate a defined yield stress and in such cases the proof stress is used.

YOUNG'S MODULUS
(Modulus of Elasticity). The ratio within the limits of elasticity of the stress to the corresponding strain, i.e., the stress divided by the resulting strain. Assuming a material to be perfectly elastic, the modulus of elasticity would be the stress applied to extend the test piece to double its length. For steel, Young's Modulus is of the order of 13,000 tons per square inch, and is only very slightly affected by composition and heat treatment.