



Glossary of Terms
Aluminium

Ageing, Age Hardening, Precipitation Hardening The second stage in the process (solution treatment and ageing) for those aluminium alloys that respond to heat treatment as a means of increasing their mechanical properties. It entails the precipitation of a constituent from a supersaturated solid solution. The rate of precipitation, and hence ageing, is both temperature and time dependent, with some alloys ageing at room temperature. It is more usual to perform ageing at higher temperatures. It should be noted that routinely operating aged alloys at unusually high ambient temperatures will permit further ageing and even over ageing leading to loss of properties. *Related terms: Aluminium*

Alloy Classifications

Alloy A combination of two or more metals, or of metals and other elements. An alloy is formed by adding the 'alloying elements' to the 'parent' metal in the molten state. The parent metal usually accounts for more than 50% of the resultant mixture.

Alocroming, Chromating, Alocrom A family of proprietary chemical conversion coating processes based on chromate (hexavalent chromium) solutions that act as a surface pre-treatment before painting or insulation foaming. This also increases the corrosion resistance. More environmentally benign processes based on trivalent chromium are being introduced.

Alumina Aluminium Oxide – A white powder that is produced from the aluminium ore Bauxite and then smelted to produce aluminium metals.

Related terms: Hall Heroult Process

Aluminium Alloy Classifications Wrought aluminium alloys are specified in British, European and other National standards and are classified in an agreed 4 digit system.

They fall into 2 distinct sub groups:-

1xxx, 3xxx and 5xxx series that develop strength by cold working, the number will be followed by the digit H and other numbers referring to the degree of annealing or cold work, e.g. 3105H22.

2xxx, 6xxx, 7xxx and 8xxx alloys that develop properties by solution treatment and precipitation hardening. The number is usually followed by a T and a number, defining the heat treatment condition of the alloy, e.g. 6082T6.

Thus the 4 digits, the letter and following digits for a product clearly define the chemical composition and the mechanical properties of that material. *Related terms: Temper Designations*

Anodising An electrochemical method for artificially thickening the naturally occurring oxide surface film on Aluminium and Aluminium Alloy surfaces to improve appearance and/or corrosion resistance. Not all alloy grades are suitable for decorative anodising, with the general rule being the purer the aluminium, the better it will anodise. The thickness and other film characteristics can be controlled to meet varied requirements for improved corrosion resistance, improved abrasion resistance, electrical insulation or as a pre-treatment for subsequently applied coatings. Colour can also be applied using dyes. Anodising film thickness is typically 5 to 25 microns. *Related terms: Anodising*

Quality Material

Anodising Quality Material Material with characteristics that make it suitable for decorative anodising after a suitable preliminary treatment

Artificial Ageing, Precipitation Treatment The thermal treatment of an alloy that increases the hardness and strength by precipitation of constituents from the super-saturated solid solution at above room temperature. *Related terms: Ageing, Age Hardening, Precipitation Hardening*

As-Quenched Condition The condition of an alloy during the time immediately following the quench and before the mechanical properties have been significantly raised by precipitation hardening (ageing).

Back-End Defect A defect found in extruded products due to incorrect extrusion procedures at the mill.

Bauxite The main ore of aluminium, found in great abundance in the earth's crust, near the surface. It is mined using open cast mining.

Bayer Process A chemical process used to refine the aluminium ore bauxite into alumina (aluminium oxide) from which the aluminium metal can be extracted by smelting

Bend Radius The radius of curvature of the former around which a specimen is bent.

Bend Test The bending of a specimen to conform with a predetermined radius and angle, to assess bending characteristics and ductility.

Billet, Bloom Cast aluminium in the form of large round (or occasionally square) bars.

Blank A work-piece prepared for subsequent processing e.g. by forming, bending, cupping, drawing, impact extrusion, pressing, etc.

Bow The deviation of the edges from the true longitudinal axis of a product seen as an arc.

Buckle, Ripple The variation in flatness represented by alternate bulges and hollows along the length of a rolled product, the edges of which remain reasonably flat.

Busbars Bar or section for use as a common junction between electrical circuits.

Cast, Heat, Melt These terms are used interchangeably to refer to the product of a single melting furnace charge. Sometimes the furnace contents are tapped into two or more ladles when the product of each ladle may be called a separate cast.

It is always assumed that the chemical composition of an entire cast will be uniform. This is described as the "cast analysis" on a Certificate of Conformity etc.

Chemical Brightening A chemical treatment to improve the specular reflectivity of a surface.

Chemical Conversion Coating The treatment of material with chemical solutions by dipping or spraying to increase the thickness of the natural oxide film on the surface or to build up an oxide film bearing chromates or phosphates *Related terms: Alocrom*

Circumscribing Circle A circle that will just contain the cross section of an extrusion, usually designated by its diameter.

Clad Material Material that has a thin layer of Aluminium or Aluminium alloy metallurgically bonded to it usually by rolling, extruding or drawing. Most often it is used to provide a more corrosion resistant surface or to facilitate anodising.

Cold Working The permanent alteration of shape or dimensions by plastic deformation at room temperature by, e.g., cold rolling, cold reduction, drawing, pressing, forming, bending, swaging, etc.. Cold working increases strength and hardness but reduces ductility.

Colour Anodising Incorporation of colouring matter (dyes) into the film of anodised Aluminium during the anodising process.

Concentricity Strictly, this is the shift between the centres of the circles that are the Outside Diameter (OD) and Inside Diameter (ID/ Bore) of a round tube. Any such shift will cause a variation in wall thickness around the circumference of the tube, hence the tolerance on concentricity is determined by the wall thickness tolerance.

Container The key part of an extrusion press into which the billet is placed before extrusion. It is a hollow cylinder which is closed at one end by the die and at the other by the extrusion ram. It has to contain the substantial pressures generated during extrusion.

Controlled Stretching Stretching, under controlled tension, of plate and sheet products to a specified extension (percentage permanent set). It relieves internal stress and minimises distortion during machining as well as improving flatness and straightness.

Critical Quenching Rate The minimum mean cooling rate from the solution treatment temperature necessary to retain the alloying constituents in solid solution and thus permit the alloy to meet specified mechanical property requirements in the precipitation hardened (aged) condition.

Deep Drawing The forming of deeply recessed parts (such as beverage cans and hollow-ware) by means of plastic deformation of the material. As deep drawing does not uniformly cold work the blank there will be variations in the hardness and annealing response around the final part.

Deep Drawing Sheet Sheet produced with specific characteristics that permit deformation by deep drawing – such as softness, high ductility and low tensile strength.

Delayed Ageing, Delayed Age Hardening Retarding natural ageing by holding the alloy below room temperature. If the alloy is raised to room temperature then natural ageing will proceed at the expected rate. *Related terms: Ageing, Age Hardening, Precipitation Hardening*

Die Drawing A CAD Drawing of the extrusion die showing exact detail of the shape of the profile.

Die Lines Continuous longitudinal lines that are formed on extruded and drawn products by minor irregularities, or pick up, on the bearing surfaces of the die.

Die, Extrusion Die The hardened steel aperture through which a heated extrusion billet is pushed to form an extruded profile shape.

There are 3 types of die:

Flat Die – For extruding solid shapes

Porthole Die – For extruding hollow shapes – This leaves one or two 'weld' seams along the length of the extrusion so tube produced in this way is called Welded Tube.

Flat Die with Mandrel – For extruding seamless hollow shapes and seamless tube

Differential Annealing The localised heating of part of a blank so that only specific areas are annealed.

Diffusion (in clad material) The migration of alloying elements from the core into the cladding layer during thermal treatment. This can be detrimental to the properties and behaviour of both the core and cladding.

Diffusion Staining Patchy surface discolouration that can occur as a result of diffusion in clad material.

Direct Extrusion, Extrusion The extrusion process in which a preheated billet is placed in the container and is pushed by the ram through the stationary die to form the extruded section. *Related terms: Container*

Directional Properties Deformation by cold working causes changes to the grain structure and, sometimes, variations in mechanical properties across and along a work-piece. Properties measured along the direction of deformation are described as longitudinal, whilst those measured at a right angle to the direction of working are called transverse.

Drawing, Cold Drawing The pulling of a work-piece through a fixed die at room temperature. It can reduce the size, change the cross section or shape, improve surface finish, improve tolerances or work-harden the material.

Drawn Tube A hollow product of uniform wall thickness, produced by cold drawing. *Related terms: Drawing, Cold Drawing*

Drift Test, Flaring Test A test for the weld integrity of a welded tube, usually carried out to BS1139. All batches of Scaffolding Tube undergo this test. *Related terms: Scaffolding Tube*

Duplex Ageing A two stage age-hardening heat treatment conducted at different temperatures.

Dye Penetrant Test A non-destructive test for surface defects and flaws. A clean and degreased work-piece is dipped in, or otherwise coated by, a fluid containing a brightly coloured dye. This fluid is often called dye penetrant ink. After a predetermined time the ink is removed, usually by washing, and a, usually white, developer applied. The dye seeps out from any flaws and cracks, thereby making them easily visible.

Etching The production of a uniform matt, surface finish on a work-piece by controlled chemical or electrochemical attack. The etching agent can be either acid or alkali in nature.

Etching Test The use of a chemical reagent to reveal the macrostructure of a sample from a work-piece. The test is usually made on a cross section from the work-piece so is destructive.

Extrusion Ratio The ratio of the cross-sectional area of the extrusion container to that of the extruded product.

Finstock Narrow strip in the thickness range 0.2mm to 0.4mm used for finning of heat exchanger tubes in applications such as air conditioning.

Fixed Mandrel A device for producing hollow extrusions of regular cross section. The tapered mandrel is attached to the main extrusion ram and passes through the hollow billet. As the ram moves forward the mandrel passes, with the billet, through the die giving a product slightly tapering in wall thickness along its length. The mandrel is tapered to facilitate its removal when extrusion is complete.

Flash Annealing Annealing of a work-piece by rapid heating and a short dwell time at the appropriate temperature.

Flatness The property of having a horizontal surface without any slope, tilt, or curvature, i.e. that of a flat plane. In practice a perfectly flat surface is probably unobtainable so there will be a flatness tolerance. *Related terms: Flatness Tolerance*

Flatness Tolerance A three-dimensional geometric tolerance that controls how much a product surface can deviate from a flat plane. The permitted deviation will depend upon the thickness of the sheet or plate varying between 0.2% and 0.5% of its width and length, usually measured over a 1 metre length.

Floating Mandrel A tapered mandrel that is inserted into the hollow extrusion billet. It is not attached to the extrusion ram so is left free to centre itself in a hollow billet as it moves forward through the die as the ram advances and extrusion proceeds. The resulting product tapers slightly in wall thickness along the length. *Related terms: Fixed Mandrel*

Foil, Tin Foil, Kitchen Foil, Cooking Foil Cold rolled aluminium flat product less than 250 microns in thickness. Usage includes kitchen foil (cooking foil) and foil trays for food. Kitchen Foil is often incorrectly referred to as Tin Foil.

Forging Hot working using a forge with shaped tools that 'hammers' the work-piece into a predetermined shape.

Fracture Test, Impact Test, Charpy Test, Izod Test A test in which the test piece is notched and broken. The fracture surface examined to assess grain structure and freedom from defects. Also used to determine toughness, often at varying temperatures to establish at what reduced temperature the material becomes brittle.

Free Machining Alloy (FMA) An alloy designed to give, when machined, small broken chips, lower power consumption, better surface finish and/or longer tool life. Chemical composition and microstructure both influence this property.

Full Heat Treatment For alloys in the 2xxx, 6xxx, 7xxx and 8xxx series this is the heat treatment cycle consisting of solution treatment followed by artificial age hardening.

Gauge Length In a tensile test this is the prescribed part of the cylindrical or prismatic portion of the test piece on which elongation is measured at any moment during the test. In particular, a distinction should be made between the following:
~ The original gauge length, i.e. the gauge length before the test is started.
~ The final gauge length – The gauge length after the test is completed and the test piece has fractured. The broken pieces are carefully fitted together to lie in a straight line so that it can be measured.

Grain Flow Elongation of the grain structure in the direction of cold working.

Grain Growth Coarsening of the grain structure that occurs under certain conditions of heating. It is generally undesirable and is deleterious.

Grain Size A measure of the area or volume of grains in polycrystalline material. Grain size is reported in a number of ways
1. number of grains per unit of area or volume,
2. average diameter,
3. as a grain size number derived from area measurements and comparison with a standard chart.

Hall Heroult Process, Smelting The main process used for the production of Aluminium metal whereby Alumina is dissolved in a salt bath of molten cryolite and subject to an electrolysis process. Often referred to as Smelting, this process uses very large amounts of electricity. Named after two scientists who developed the process independently of each other at around the same time.

Hall-Heroult Process The main process used for the production of Aluminium metal whereby Alumina is dissolved in a salt bath of molten cryolite and subject to an electrolysis process. Often referred to as Smelting, this process uses very large amounts of electricity. Named after two scientists who developed the process independently of each other at around the same time – Hall, English and Heroult, French. *Related terms: Smelting*

Hardness Test A test conducted to measure Hardness. A load is applied to an indenter to press it into the surface of the test piece. The indenter can be either a ball of various standard diameters or a diamond of one of several specified geometric profiles. The result of the test is reported as a Hardness Number which is derived from either a measurement of the depth to which the indenter penetrates or from the surface area of the impression left by the indenter. *Related terms: Hardness*

Hardness, Vickers Hardness, Brinell Hardness, Rockwell Hardness The resistance of a metal to plastic deformation usually by indentation using a diamond or a hardened steel ball. There are various recognised hardness scales including Vickers (VPN), Brinell and Rockwell. N.B. The empirical, but robust, relationship between hardness and tensile properties that applies in steels does not apply, and the steel tables must not be used for aluminium and its alloys. A less rigorous relationship has been established for some aluminium alloys but it is not widely used.

Heat Treatable Alloy Any of the 2xxx, 6xxx, 7xxx and 8xxx series of wrought aluminium alloys whose mechanical properties can be increased by a solution treatment and age hardening heat treatment cycle.

Heat Treatment The thermal processing of a work-piece specifically to alter its mechanical properties. It includes:-
1. Annealing to soften and improve ductility.
2. Solution treatment and precipitation hardening to increase strength. It does not include heating before hot rolling, forging or extrusion etc.

Homogenisation The structure of as cast semi finished products e.g. slab, extrusion billet or forging blanks is invariably chemically segregated - that is the alloying elements are concentrated locally rather than uniformly distributed within the microstructure.

Homogenising is a way of mitigating this as the work-piece is held at a suitably high temperature for sufficient time to eliminate, or at least decrease, chemical segregation by diffusion of the alloying elements.

Hot Working Plastic deformation, e.g. hot rolling, extrusion or forging, of a work piece in a temperature range and at a rate such that strain hardening does not occur.

Indirect Extrusion, Backwards Extrusion The extrusion method in which there is no relative movement between the billet and the container.

This is accomplished by:-

Either pushing the die held on the end of a long, hollow, stem through the billet.

Or moving the billet and container together over the die, again held on the end of a long, hollow, stem.

As there is no movement between the billet and container the friction, and hence extrusion loads, are reduced by up to 30% compared to direct extrusion and grain structures can be improved. The process is limited by the size, length and strength of the stem which holds the die.

Related terms: Direct Extrusion

Ingot A cast product that may be various shapes including slab, billet, bloom or more complex shapes.

Produced by pouring liquid aluminium into a shaped mould and allowing it to cool.

Integral Colour Anodising Coloured surfaces developed either by anodising certain Aluminium alloys and/or by using special organic electrolytes that produce colours during anodising.

Internal Stress Stresses within a work-piece caused by previous treatments, e.g. casting, thermal treatment or fabrication.

Isothermal Quenching A procedure in which the work piece is quenched, and held for some time, in a fluid which is held at a constant temperature between the solution treatment temperature and room temperature. This permits precipitation hardening.

Lateral Curvature, Edge Curvature The lateral departure, in arc form, of an edge from linear straightness.

Lüders Lines Surface marks caused by localised flow that appears on some alloys after light straining. They run parallel to the direction of maximum shear stress i.e. at 45° to the direction of the deforming stress.

Mean Diameter The sum of any two diameters at right angles divided by two.

Mean Wall Thickness For a tube this is the sum of four wall thickness measurements, made at 90° intervals around the diameter, divided by four.

Multi-Hole Die An extrusion die, with more than one hole, allowing multiple extrusions to be made simultaneously from one billet.

Natural Ageing The process that can alter the hardness and strength in some alloys after a period of time at ambient (room) temperature. It is caused by the spontaneous precipitation of constituents from a super-saturated solid solution. Generally it increases mechanical properties but can also, in some circumstances, cause loss of

properties by over-ageing. *Related terms: Ageing, Age Hardening, Precipitation Hardening, Over-ageing*

Non-Heat Treatable Alloy An alloy, from the 1xxx, 3xxx and 5xxx series that are incapable of being strengthened by thermal treatment. These alloys gain their strength from cold-working.

Oil Staining Surface staining caused by the partial decomposition during thermal treatment of residual lubricant.

Orange Peel A roughening, on subsequent cold deformation, of the surface of sheet or strip when the grain size is too coarse. Has the appearance of an orange skin.

Ovality Any variation from a true circle of the cross section of a round tube, bar or wire.

Over-ageing Artificial ageing treatment at too high a temperature, or for too long a time, after the maximum hardening effect has been achieved. It causes some loss of properties.

In some cases it may be a deliberate act, e.g. to improve resistance to stress corrosion or to minimise any further loss of properties in alloys operating at higher temperatures.

Partial Annealing Thermal treatment, after cold working, of a work-piece to reduce its strength to a controlled, but not fully softened, level.

Percentage Elongation after Fracture (A) The gauge length elongation after fracture expressed as a percentage of the original gauge length.

Peripheral Coarse Grain, Peripheral Grain Band An effect shown in extruded products and also forgings made from extruded stock. It is an area of recrystallised grains at the periphery which has lower properties than the non-recrystallised core.

Pick-up Irregular surface roughness or damage caused by adhesion and subsequent fracture or tearing between the forming tools and the work piece.

Pips, Pip Lines, Pip Marks, Ident Pips A marking on an extrusion (on a non-visible surface) placed there by the extrusion mill's die to allow the mill to identify extrusions produced by that mill.

Pitting Corrosion Non uniform corrosion of the surface that causes small pits or craters to develop.

Plate A hot rolled flat product of rectangular section, typically over 10mm thick. Control of surface finish is less rigorous than for sheet.

Related terms: Sheet, Shate

Porthole Dies Dies that produce extruded hollow products from solid extrusion ingots.

They incorporate a mandrel as an integral part of the die assembly and leave one or two 'weld' seams along the extrusions.. Bridge, spider, duo and self-stripping dies are particular types of porthole die.

Powder Coating Application of an even layer of colour to aluminium extrusions by spraying powdered paint using an electrostatic process then baking on (stove enamelling).

Pre-Ageing A thermal treatment after quenching and before the end of the precipitation incubation period.

Precipitation Annealing The heating of a quenched and precipitation hardened work piece for some time at a temperature between the artificial ageing temperature and the solution treatment temperature. It produces significant softening by coalescing the hardening precipitates.

Pressure Test A hydraulic or pneumatic test for tubes to prove that they material can withstand a specified pressure for a specified time without leakage or rupture.

Proof Stress (Rp) The stress or applied load which produces a permanent elongation equal to a specific percentage of the original gauge length. In alloys that do not exhibit a yield point it is used as an equivalent to the elastic limit.

If a proof stress is specified, the non-proportional elongation must be stated. The most common values used in specifications is 0.2% or 1.0% and the RP symbol used for the stress will be supplemented by an index giving this prescribed percentage of the original gauge length, e.g. RP0.2 = 0.2% Proof Stress

Quenching The rapid cooling a metal or alloy from the solution treatment temperature by contact with a solid, a liquid or a gas to retain the hardening constituents in solid solution. Quenching is often carried out by immersion in cold water. Extrusions are quenched after extrusion by air blasts.

Recrystallisation Annealing A heat treatment that softens a cold worked metal or alloy by complete recrystallisation.

Rectification Work done to correct dimensional errors.

Residual Stress Any stress in a finished product after fabrication (mainly cold work) which exists without the presence of any service or external loads, even after stress relieving.

Roller Levelling, Tension Levelling Flattening of sheet, strip or coil metal by passing it through a roll train staggered rolls. Levelling is achieved by precisely bending metal strip back and forth as it's passed through a series of small-diameter offset rolls. The material is usually also under tension loading.

Roller Straightening The straightening of extrusions by passage through a series of small diameter, staggered, rolls.

Scaffolding Tube A 'welded' tube, size 1 29/32 inch O/D x 7 swg wall thickness (7swg = 0.176 inch / 4.47mm) used for scaffolding that has been Drift Tested

Scalping Mechanical removal of oxide and contamination from surface of a cast slab prior to hot rolling.

Sealing of Anodic Coatings A post anodising treatment to close layer porosity and reduce absorbency.

Segregation The non uniform distribution in the microstructure of alloying elements during the solidification of an ingot, billet or slab. Some non metallic impurities may also be segregated during solidification.

Self-Quenching Alloy An alloy whose critical quench rate from its solution treatment temperature is slower than the rate of cooling in still air. This means that the alloying elements will be held in solid solution even after cooling in still air.

Shate A term used for rolled material where the thickness lies between that of cold rolled sheet and hot rolled plate, typically 4 to 10 mm. the finish may be hot or cold rolled.

Shear Strength The maximum stress that a material can sustain when loaded in shear.

As a very rough guide for aluminium alloys the maximum shear strength is about 60 to 65% of the ultimate tensile strength and the yield strength in shear is 50 to 55% of the 0.2% Proof Stress.

Shear Test A test in which the test piece is progressively loaded to fracture in shear to measure its shear strength.

Sheet Usually defined as cold rolled flat product in the thickness range 0.25mm to 3.25mm.

Short Transverse Direction The minor axis at right angles to the major, longitudinal, axis.

Single-Hole Die An extrusion die with one hole, therefore capable of producing just one extrusion per cycle. *Related terms: Multi-Hole Die*

Slab, Rolling Slab A cast product that will be used for hot rolling. Size up to 300mm thick, 2000mm wide and 10/15 metres long with weight up to 15 tonnes.

Slitting The simultaneous cutting of a coil or wide strip into a number of narrower strips by means of rotary cutters.

Stop Mark A transverse peripheral ridge on a product arising from a stoppage during rolling, extrusion or drawing.

Strain Hardening, Work Hardening The increase in strength and hardness with a general loss of ductility that results from cold working of a work-piece. *Related terms: Cold Working*

Stretching, Stretcher Levelling A term used to describe both the levelling of rolled materials and the straightening of extruded and drawn materials by imparting sufficient permanent extension to remove distortion.

Stress Corrosion This is the frequently rapid, sudden, failure of normally ductile alloys when experiencing tensile stresses in certain and specific corrosive environments. These stresses may be residual internal stresses or from external loading.

Stretcher Grip Marks Transverse indentations left by the gripper jaws of the stretching machine on the ends of a product.

Stretcher Strain Markings These are permanent surface distortions that can occur on stretching. They can appear as either flamboyant patterns or Lüders lines. Their onset and extent depends on the type of material and the degree of stretching. *Related terms: Stretching, Lüders Lines*

Super Annealing An annealing cycle for heat treatable alloys that utilises a slow, controlled, cooling rate to produce a structure with maximum ductility and the minimum tendency to natural ageing.

Surface Bloom A general term for any surface discolouration caused by thermal treatment or from exposure to moist atmospheres.

Temper The characteristic structural and mechanical properties produced by mechanical working and/or thermal treatments. *Related terms: Temper Designations*

Temper Designations There are two systems of letters and digits used, after the alloy designation number, to define and describe the temper of an aluminium alloy.

The following is only an outline guide to these systems.

For the strain hardening alloys of 1xxx, 3xxx and 5xxx series the following is used:-

O = Annealed, soft

F = As Fabricated

H1x = Strain Hardened only

H2x = Strain Hardened and partly annealed.

H3x = Strain Hardened and stabilised

H4x = Strain Hardened and organically coated with an oven cure.

The second number shown as x above indicates the final degree of hardness or strength.

2 = quarter hard

4 = half hard

6 = three quarter hard

8 = fully hard.

For the heat treatable alloys of the 2xxx, 6xxx, 7xxx and 8xxx series the following applies.

T1 = cooled from a high temperature forming process and naturally aged.

T2 = cooled from a high temperature forming process cold worked and naturally aged.

T3 = solution treated, cold worked and naturally aged.

T4 = solution treated and naturally aged.

T5 = cooled from a high temperature forming process and age hardened by heat treatment.

T6 = solution treated and age hardened.

T7 = solution treated and deliberately overaged

T8 = solution treated, cold worked and age hardened

T9 = solution treated, age hardened then cold worked.

Additional numbers may also appear to indicate variations in treatment that can significantly influence the condition of the alloy.

Temper Rolling A controlled cold rolling procedure performed to develop specific mechanical properties in a work piece.

Tensile Strength, Ultimate Tensile Strength (UTS) The maximum load, in tension, that a material can withstand before breaking. It is calculated as a breaking load for a standard cross section area.

Tensile Test A procedure to measure the mechanical properties of a representative test piece in tension. The test piece is progressively loaded in tension and its gauge length plotted against the applied load generally to the point of fracture. The Proof Stress (Rp) and Tensile Strength (Rm) values are then determined.

Tolerance The permissible limit, or limits, of variation to a specified parameter such as a dimension or weight, usually expressed as 'plus' or 'minus' value or percentage on that quantity.

Torsion Test A test in which a sample is twisted axially for a given number of revolutions. It may be conducted to destruction or to demonstrate that the material can withstand a specific amount of twisting.

Traffic Marks, Fretting Abrasions, usually dark in colour, resulting from relative movement, or rubbing, between contacting metal surfaces during transit.

Transition Joint, Triplate An explosively bonded bimetal flat bar that comprises a layer each of steel and marine-grade aluminium (alloy 5083) usually with an interlayer of pure aluminium. It is used for the on site welding of aluminium to steel, especially in shipyards and for offshore structures.

Ultrasonic Test A non-destructive test method using ultra high frequency sound waves to locate and assess the size of internal material defects.

Under-Ageing An artificial ageing treatment that fails to achieve maximum or optimum increase in mechanical properties/hardening. It is caused either by processing for an insufficient time or at too low a temperature.

Upper Critical Strain The minimum amount of cold work needed prior to annealing or solution treatment to produce a fine recrystallized equiaxed grain structure by eliminating the cold worked structure of elongated grains.

Water Staining A residue left on aluminium that has been wet and allowed to dry naturally. This is very difficult to remove and cannot be improved by polishing or anodising.

Wrought Product A product made by hot, or hot and cold, plastic deformation by the rolling, extruding or forging of a cast product.



Glossary of Terms

Copper

Admiralty Brass A nominal 70% Copper / 30% Zinc Brass with 1% Tin added to improve corrosion resistance.

Alloy A combination of two or more metals, or of metals and other elements. An alloy is formed by adding the 'alloying elements' to the 'parent' metal in the molten state. The parent metal usually accounts for more than 50% of the resultant mixture. Brass is an alloy of Copper and Zinc whilst Bronze is an alloy of Copper and Tin.

Alpha Brass A Brass whose microstructure consists only of the 'alpha phase' in which the Zinc is in solid solution within the Copper matrix. This occurs in the range from pure Copper to about 64% Copper - 36% Zinc. Alpha Brasses have good cold-working properties.

Alpha-Beta Brass A Brass containing over 36% Zinc, or with other additions, that has both alpha and beta phases present in its microstructure. *Related terms: Duplex Brass*

Aluminium Bronze Not true Bronzes as they contain no Tin, Aluminium Bronzes are alloys of Copper with 5 - 12% Aluminium, some having additions of Iron, Nickel, Manganese and Silicon. They are available in cast and wrought form with designations such as CA104, Defence Standard (NES) 83. Aluminium Bronzes combine high strength with excellent corrosion and shock resistance. Widely used for stressed components in corrosive environments they are, in particular applications, frequently technically sound, cost effective, alternatives to Stainless Steels and Nickel Alloys.

Annealing Full Annealing is a heat treatment process for fully softening Copper and Copper Alloys. It involves heating to 500-550°C and holding for an appropriate time. Partial annealing is used to leave some residual temper such as quarter hard or half hard.

Architectural Bronze A confusing, loose, but widely used term used to describe a number of brasses.

- Those, whose colour mimics that of Bronzes, that are used in architectural applications, such as decorative shop fittings, window frames, etc,
- The Manganese containing brass CZ136, which is also incorrectly called Manganese Bronze, is a High Tensile Duplex Brass which extrudes well and has a warm 'chocolate' colour.
- The term is also applied to Gilding Metals which have been chemically toned to give a 'bronze' finish. *Related terms: Manganese Bronze*

Arsenical Brass A 70% Copper/30% Zinc alpha brass that contains Arsenic, and frequently Aluminium. It has better corrosion resistance than cartridge brass, but similarly excellent forming properties.

ASTM The American Society for Testing and Materials. ASTM produces Standards for materials and test methods that are widely used other than in the USA.

Beryllium Copper Copper alloys with 1.5 to 2% Beryllium additions that have the highest strengths of all Copper Alloys by both heat treatment (solution treatment and age hardening) and cold working.

Beta Brass A brass with very high Zinc content. It will have a predominantly beta phase microstructure, be brittle and used only as a brazing filler alloy.

Beta Phase A phase in the microstructure of brasses that contain more than about 36% Zinc. Beta phase adversely affects the cold formability of brasses and hot working processes, such as hot stamping, are preferred. *Related terms: Alpha-Beta Brass, Duplex Brass*

Blister Copper Copper of about 98% purity obtained by 'converting' copper matte. *Related terms: Copper Matte, Converting Process*

Brass Any alloy of Copper and Zinc. *Related terms: Alpha Brass, Alpha-Beta Brass, Architectural Bronze, Cartridge Brass, Dezincification Resistant Brass, Duplex Brass*

Bronze Any alloy of Copper and Tin.

Cartridge Brass A 'straight' 70% Copper / 30% Zinc brass with excellent cold forming and deep-drawing properties. So called because it was originally used deep-draw cartridge cases it now has a wide range of industrial applications, particularly if severe deformation, such as spinning or flanging, is involved. Arsenical Brass may be preferred because of its superior corrosion resistance.

Casting, Ingot Casting The pouring of molten metal into a mould or die where it is allowed to solidify. When solidified, the resultant 'casting' takes on the shape and approximate dimensions of the mould.

Examples

- Ingot for forging or other hot working
- Intermediate uses include extrusion billets, slabs for rolling, forging blanks.
- End use: valve body.

Cathode Copper, Copper Cathode The Copper, of at least 99.9% purity, produced by electrolytic refining. It is the feedstock for melting most Copper alloys and their subsequent manufacturing processes.

CEN Comité Européen de Normalisation, aka European Committee for Standardisation. The body responsible for developing European Standards, often referred to as 'Euro-Norms or EN for short.

Chalcocite A Sulphide ore of Copper with the chemical formula Cu_2S . It is a highly valued ore since it approaches 80% Copper by weight.

Chalcopyrite An important ore of Copper. It is a Copper Iron Sulphite with the chemical formula $CuFeS_2$.

Common Brass A very widely used brass containing 63% Copper plus 37% Zinc. It is also known as CZ108, Basis Brass and 63/37 Yellow Brass. It can be hot or cold worked, has good ductility permitting cold heading of wire and rods and cold presswork but not deep drawing.

Converting Process The process which transforms Copper Matte into Blister Copper. By reacting the Matte with Oxygen enriched air and silica slags both the Iron and Sulphur are removed leaving Copper metal of 98% purity known as Blister Copper. *Related terms: Chalcopyrite*

Copper Matte The mixture of Copper and Iron Sulphides which is the feedstock to the Converting Process that turns Chalcopyrite ore into Blister Copper. *Related terms: Chalcopyrite, Converting Process, Matte*

Copper-Nickel, Cupro-Nickel Alloys of Copper and Nickel, with between 10% - 45% Nickel, and usually small quantities of Iron and Manganese. Copper Nickels have outstanding resistance to sea-water corrosion.

Creep The tendency of a metal to flow or deform permanently at under an applied load that is lower than its yield point. It is time and temperature dependent, the rate always increases with temperature.

Deep Drawing A cold deformation process that uses a punch and die to produce hollow cylindrical components with a high length to diameter ratio (such as cartridge cases). It imparts significant cold work to the work piece.

DEFSTAN, DSTAN Defence Standards

Deoxidised Copper Copper with a deoxidiser added to reduce Oxygen. Phosphorus is usually added but other elements such as boron or magnesium may be used. Welding and brazing properties are improved, but conductivity is somewhat impaired.

Dezincification The selective corrosion of the beta phase of Duplex Brass. The result is a Copper residue with a porous layer of Zinc Oxide.

Dezincification Resistant Brass, DZR Duplex Brass (CW602N, CZ132) that has an Arsenic addition and a special heat treatment to prevent dezincification by soft, acidic, domestic water supplies. Sometimes the term is applied to Arsenical, Aluminium or Admiralty Brasses that also have Arsenic additions. These alloys need no special heat treatment as no beta phase is present.

DGS Director General Ships. An obsolete prefix for British Naval material standards, in turn became NES (Naval Engineering Standards), in turn replaced by DSTAN or DEFSTAN (Defence Standards).

DIN The prefix for German National Standards, also the German National Standards Organisation.

Drawing A process carried out at room temperature where extrusion is pulled through a die to improve tolerances, surface finish and mechanical properties.

DTD Director of Technical Development. The prefix for material standards used by the British Army, RAF and other defence applications.

Ductility The ability of a metal or alloy to deform without cracking or failing under tensile loads. Materials with low ductility exhibit brittle behaviour and fail at more modest loads. *Related terms: Malleability*

Duplex Brass Brasses with composition ranging from 58% to 62% Copper with 38% to 42% Zinc that have both alpha and beta phases present in their microstructure. Duplex Brasses are superior to Alpha Brasses for hot working, but inferior for cold working.

Element A pure chemical substance that consists of just one type of atom as defined by its atomic number (the number of protons in its nucleus). Elements combine to make compounds, e.g. Copper Sulphate which contains Copper, Sulphur and Oxygen. An Alloy, e.g. Brass, is a solid solution of two or more elements.

EN Euro Norm, European Standard.

Engraving Brass CW612N / CZ120 Brass formulated to be best suited for engraving - For example of nameplates and pet's collar identity discs.

ETP Electrolytic Tough Pitch, high conductivity, Copper, CW004A (C101).

Extrusion The process in which a preheated billet is constrained within a strong container in a press and then pushed by a ram through a shaped die.

The product, also called an extrusion, has the shape of the die along its whole length. Angles, rectangles, rounds and hexagons are common shapes of extruded bar, whilst tubes are frequently hollow extrusions.

With Copper Alloys, extrusion is very often followed by cold drawing to improve tolerances, surface finish and mechanical properties.

Feedstock A semi-finished material that is used to 'feed' the next process. For example continuously cast billet is the feedstock for extrusion and continuously cast rod or bar may be the feedstock for wire making.

Flotation A mineral beneficiation technique used to concentrate ore by blowing air through a tank in which ore particles are suspended in water that contains additions that make the ore more hydrophilic. The ore clings to the bubbles and is scraped off as 'froth'.

Free Machining, Free Cutting, High Speed Machining Terms that are used interchangeably to describe materials that can be turned, drilled or otherwise machined using high cutting speeds and feeds to leave a good surface finish with low tool wear and no appreciable build-up of swarf around the cutting tool.

The addition of Lead to Copper alloys usually improves machinability. The brass CW614N (CZ121 Pb3) has one of the fastest rates of metal removal, but ductility is compromised. This brass sets the machinability standard against which the machinability of all other alloys are measured.

Gliding Metals Alpha Brasses with 80% to 90% Copper content and no other alloying constituents apart from Zinc.

They have good ductility and are easily brazed or enamelled. They are used for decorative purposes such as jewellery and architectural hardware.

Gunmetal A Casting Bronze alloy of Copper with Tin (10%) and Zinc (2%). Historically it was used to cast cannons so it is sometimes called Admiralty Gun Metal.

It has excellent corrosion resistance in seawater and steam. Leaded Gunmetal containing slightly less Tin, more Zinc and up to 7% Lead is a very useful plain bearing metal.

Heat Treatable Alloy The description applied specifically to a Copper Alloy whose mechanical properties can be increased by heat treatment, typically solution treatment and age hardening e.g. for Beryllium Copper. *Related terms: Beryllium Copper, Heat Treatment of Copper and its Alloys*

Heat Treatment of Copper and its Alloys A range of heat treatment processes are applied to copper and its alloys including

- Homogenising
- Annealing

- Stress Relieving
- Solution Treatment and Ageing
- Quench and Temper Hardening

It is important to recognise that not all processes are appropriate for all alloys.

Homogenising in which prolonged soaking at elevated temperature is used to reduce solidification chemical segregation in castings particularly in Phosphor Bronzes, Copper Nickels and Silicon Bronzes that have long freezing ranges.

Annealing is used to soften and increase ductility and toughness in wrought alloys.

Stress relieving is used to relieve internal stresses without significantly affecting mechanical properties.

Solution Treatment and Ageing is used on Beryllium Copper, Copper/Chromium, Copper /Zirconium and Copper/Nickel/Silicon/Chromium alloys to increase mechanical properties.

Quench and Temper Hardening is applied to certain Aluminium Bronzes, Nickel Aluminium Bronzes and some cast Manganese Bronzes to increase their mechanical properties.

High Tensile Brasses An important group of brasses whose strength has been increased by modifications to their chemical composition by additions of Iron, Nickel, Manganese and/or Aluminium. Aluminium or Tin additions also improve corrosion resistance, Silicon additions are beneficial to wear properties.

IACS International Annealed Copper Standard - a measure of electrical conductivity agreed in 1913 with "pure" Copper set as 100%. Advances in copper refining mean that now the pure Copper can attain 103% IACS. The minimum requirement for High Conductivity Copper now is 101% IACS.

ISO The International Standards Organisation responsible for the ISO range of standards.

Machinability An important, but difficult to quantify, property of a material.

It relates to the ease by which material can be removed from a work-piece by a cutting tool, in turning, drilling, shaping or milling, etc., to leave a satisfactory surface finish. Materials with good machinability permit fast cutting speeds, high feeds with low tool wear and produce a bright, smooth surface. Free Machining Brass CW614N (CZ121 Pb3) has one of the fastest rates of metal removal and sets the machinability standard against which the machinability of all other alloys are measured.

Malleability The ability of a metal to deform into a useful shape, without breaking or cracking, under a compressive load. It is therefore the analogue of ductility which measures these effects in tension. A ductile material is invariably malleable and, hence, ductility and malleability are, incorrectly, often used interchangeably. Malleability is improved by annealing.

Manganese Bronze A frequently, but incorrectly, used term to describe the duplex, high tensile, Brasses (e.g. CW721R / CZ114) that contain Manganese.

Matte The mixture of Copper and Iron Sulphides produced by smelting the concentrated ore

Mega Pascals The SI unit for measuring the strength of a material and is abbreviated to MPa. Numerically it is exactly equivalent to Newtons/square millimetre (N/mm² or Nmm⁻²).

An approximate, rule of thumb, conversion to the Imperial measure of ton/in² is: 1 ton/in² = 15 MPa.

MIL The prefix given to U.S. military specifications.

Naval Brass A nominal 62% Copper / 37% Zinc Brass that has a 1% Tin addition to improve its corrosion resistance in marine environments.

NES The prefix for the, now obsolete, Naval Engineering Standards. It replaced DGS and in turn was replaced by Defence Standards. *Related terms: DGS*

Nickel Silver Copper, Nickel and Zinc alloys. Their Copper content is similar to that of Brasses but up to 20% of the Zinc is replaced by Nickel.

Silvery white in colour they have good corrosion resistance and remain "springy" at moderate temperatures.

Noble A term used to indicate the corrosion resistance, or the lack of it, of a material.

If metals are listed in order of their general corrosion resistance, most resistant at the top and going down to the least at the bottom, the higher a metal is in the list the more "noble" it is said to be.

When two different metals are connected in a corrosive environment then the least "noble" will be attacked preferentially. This effect can be used to protect structures from corrosion by using a "sacrificial anode" of a less noble metal.

Ore A mineral that contains a metal, in combination with other elements, which is mined as a source of that metal. *Related terms: Chalcocite, Chalcopyrite*

Patina The greenish layer that naturally develops on Copper exposed to the atmosphere. Chemically it is a complex mixture of Chlorides, Carbonates and Sulphides.

Pre-patinated sheet is used for roofing applications.

Phosphor Bronze, Leaded Phosphor Bronze Hard and strong cast and wrought Copper/Tin alloys with small, deliberate, Phosphorus additions.

Wrought alloys such as PB102 contain 4% to 8% Tin, whilst cast alloys contain 9% to 12% Tin.

Leaded Phosphor Bronzes, with Lead contents up to 20%, are usually available only as castings – Examples are PB1 and SAE660.

Refining The further purification of Blister Copper by removal of its Oxygen content and recovery of any rare or precious metals that were present in the ore by either:

- a) fire refining in a furnace
- b) electrolytic refining, in which the blister Copper is cast into anodes, suspended in an acid solution and deposited on to plates at the cathode by electrolysis.

Riveting Brass CW606N / CZ131 Brass formulated to be most suitable for riveting.

SAE, SAE600 The US Society of Automobile Engineers -the body that develops standards and specifications for the U.S. motor industry.

The value and applicability of SAE standards is widely appreciated and they are now used in other industries and countries. For example, Cast Leaded Gunmetal to specification SAE660 is popular in the UK.

Season Cracking So called because it was first observed, in the rainy season in India, on deep drawn 70/30 brass cartridge cases that had been stored in horse stables where the atmosphere contained Ammonia. *Related terms: Stress Corrosion*

Smelting A stage in the extraction of Copper from its ores. The ore concentrate is melted, with a flux, in a reverberatory furnace to produce Copper Matte, a mixture of Copper and Iron Sulphides that contains 30% to 40% Copper. *Related terms: Copper Matte, Matte*

Solid Solution If alloying elements are retained in the lattice of the parent metal instead of forming a different phase they are said to be in solid solution.

Alloys which that are multi-phase at room temperature can usually be made single phase by heating to a suitable temperature below the melting point, by holding at this temperature, then quenching in water, oil or cold air. The alloying element(s) have been taken into solid solution by the heating and retained there by the rapid cooling. They can be precipitated out by heating again, to a lower temperature, a process called ageing. The two stages are a useful heat treatment cycle for many alloys including Beryllium Copper.

Stamping Brass, Hot Stamping Brass CW617N / CZ122 Brass formulated to be most suitable for hot stamping.

Stress Corrosion Stress Corrosion is the rapid and often abrupt failure of a normally ductile metal or alloy caused by residual or other stresses in the work-piece and in the presence of specific corroding agents. It is temperature dependent.

Alpha Brasses are susceptible in atmospheres that contain Ammonia. The effect can be mitigated to some extent by a stress relieving heat treatment but, if the service conditions pose any risk of stress corrosion, an alternative alloy such as Aluminium Bronze is preferred.

Temper A term used to describe the degree of work hardening in a cold worked, usually rolled, material. The range is from "fully annealed" to "fully hard".

For Alpha Brasses the intermediate quarter hard or half hard tempers are usually achieved by temper annealing fully hard material. Copper sheet and strip can be given the correct temper by temper rolling, starting with fully annealed material. *Related terms: Annealing*

Tough Pitch Copper An obsolete term for Copper that has been cast with a deliberate Oxygen addition (typically 0.01 % - 0.05%) to improve electrical conductivity.

The metal may have first been either the electrolytically or fire refined.

Work Hardening The process of increasing the strength and hardness of a metal or alloy by cold deformation e.g. cold rolling, deep drawing, cold forging, hammering or cold extrusion.

Work-hardening is sometimes referred to as 'cold work'.

Wrought Product A product that has shaped, after casting, by either hot or cold deformation by rolling, forging or extrusion.

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Glossary of Terms
Stainless Steel

Alloy A combination of two or more metals, or of metals and other elements. An alloy is formed by adding the 'alloying elements' to the 'parent' metal in the molten state. The parent metal usually accounts for more than 50% of the resultant mixture.

Stainless Steel is an alloy of Iron plus Chromium (minimum 10.5%) with a small amount of Carbon plus various other elements (such as Nickel, Molybdenum, Titanium, Manganese) depending upon the grade.

Anneal, Annealing A heat treatment cycle used to soften and restore ductility after cold working and to relieve internal stresses in a work piece. *Related terms: Solution Treatment, Stress Relieving*

Anode The electrode in an electrochemical, or corrosion, cell from which a current flows into the cell. In corrosion processes material is dissolved at the anode.

Anodic Protection Electrochemical corrosion protection, achieved by increasing the electrode potential of the steel.

As-welded Tubular products made by continuously welding formed strip that were not subject to a heat treatment such as annealing after welding.

Austenite A face centred cubic (FCC) phase found in all steels. In most carbon and low alloy steels it is present only above 760°C. In austenitic stainless steels their chemical composition stabilises austenite to room temperature and even cryogenic temperatures. Austenite is non-magnetic.

Austenitic Stainless Steel Stainless Steels that contain a minimum of 18% Chromium and sufficient Nickel, or a combination of Nickel, Manganese and Nitrogen, to stabilise the face centred cubic (FCC) phase austenite down to cryogenic temperatures – This phase is normally present only above 760°C in most steels, These steels are, except in very particular circumstances, non-magnetic and have good ductility but relatively high work hardening rates. They have excellent corrosion resistance to most environments, although susceptible to stress corrosion cracking (SCC) above 60°C. Pitting and crevice corrosion can occur in chloride environments except with Type/Grade 316 where the Molybdenum content inhibits, but cannot always fully prevent, these problems. They cannot be hardened by heat treatment - The mechanical properties can only be increased by cold working.

Billet, Bloom A rolled or forged semi-finished product intended for further working by re-rolling or forging. Billets are usually square with chamfered or radiused corners. *Related terms: Slab*

Bright Annealing Annealing performed in a furnace with an inert atmosphere so that no scale is formed and the resulting surface has a bright finish. *Related terms: Annealing*

BSP, BSP Thread, Whitworth Thread British Standard Pipe Thread, also called Whitworth Thread, with 14 threads per inch.

Carbide A compound formed when an element, usually a metal, combines with Carbon. The carbides of metals are usually very hard. Both Iron and Chromium readily form carbides – Chromium has the greater affinity so will form its carbide in preference to Iron. This is a significant disadvantage in stainless steels as any carbide formation depletes the amount of chromium available to form the protective oxide layer. This is one reason why stainless steels have very low Carbon

content (maximum 0.03% in low Carbon grades). *Related terms: Carbide, Inter-granular Corrosion, Sensitisation, Stabilised Grades*

Carbide Precipitation This occurs in an alloy when the thermal conditions and processing allow one or more of the constituents react with any available Carbon to form discrete particles within the microstructure. Usually this is undesirable in austenitic and ferritic stainless steels as chromium carbide is formed preferentially and compromises the corrosion resistance.

Cast, Heat, Melt These terms are used interchangeably for the product of a single melting or refining furnace charge. Occasionally, if the furnace contents are cast into a number of different forms, these may be called separate casts.

Cathode The electrode in an electrochemical cell, through which positive electric current leaves an electrolyte. The electrode reaction at a cathode is a reduction of ions or molecules in the electrolyte by electrons emitted from the cathode. In corrosion processes, reduction of dissolved oxygen and emission of hydrogen are two common reactions. The current flow causes positive ions to migrate towards the cathode.

Cathodic Protection Electrochemical corrosion protection achieved by lowering the electrode potential.

Cold Drawing Drawing hollow or solid products through a hardened steel or tungsten carbide die at room temperature. Cold drawing reduces the O.D. or wall thickness, or both. It produces smooth surface finishes and develops closer tolerances. Cold drawing increases hardness and mechanical properties. In welded hollow products it promotes weld area recrystallisation during subsequent annealing. Cold drawing of hollow sections is usually done with a mandrel in the bore (drawn over mandrel).

Cold Rolling Passing sheet or strip at room temperature between a pair of rotating rolls. The reduction in thickness may be very light, as in the finishing process applied to hot rolled sheets, or heavy as in the cold rolling of narrow strip. Cold rolling improves surface finish, increases hardness and mechanical properties and develops tighter dimensional tolerances.

Cold Working Changing the shape, dimensions, mechanical properties and surface finish of a work-piece by mechanical deformation at room temperature. It may be accomplished by rolling, forging drawing, pressing, forming, bending, swaging, etc.

Concentricity In tubular products this describes how closely the centres of the two circles that respectively describe the outside diameter and bore coincide. The separation of these two centres causes variation in wall thickness around the tube and eccentricity. *Related terms: Eccentricity*

Corrosion Degradation of a material by chemical or electrochemical reaction with its immediate environment.

Corrosion Fatigue Cracking, possibly initiated and certainly accelerated, in a work-piece subjected to alternating or cyclic stresses in the presence of a corrosive medium. It will cause premature, often unexpected, failure. *Related terms: Fatigue*

Corrosion Product The residue, or product, that is formed when a corrosion reaction occurs.

Creep The tendency of a metal to flow or deform permanently under an applied load that is lower than its yield point. It is time and temperature dependent, the rate always increases with temperature.

Crevice Corrosion Localised corrosion that occurs in narrow crevices where stagnant, non-aerated, liquid can accumulate. It is a particular problem with alloys, such as stainless steels, that rely on a passive film to protect them as these films are unstable in the presence of high concentrations of Chloride Cl⁻ and Hydrogen H⁺ ions. The lack of aeration prevents the passive film from regenerating so attack can proceed. Good design is the key to preventing crevice corrosion.

Deformation The change in dimensions and/or shape of a material or work-piece due to applied forces. Deformation can be elastic or permanent. Elastic deformation happens when the work-piece returns to its previous dimensions or shape when an applied load below the yield point is removed. Loads above the yield point cause permanent deformation when the change in shape or dimension is not reversed when the load is removed. *Related terms: Yield Point*

Descaling The removal of surface scale from hot worked or heat treated products by acid pickling or mechanical means such as grit or shot blasting. Caution is advised if stainless steels are mechanically descaled as blasting media can be embedded in the surface and act as corrosion initiation sites.

It can also refer to the removal of scale formed during hot working processes by the application of water, coal dust, brushwood, oil, etc.

Ductility The ability of a metal or alloy to deform without cracking or failing under tensile loads. Materials with low ductility exhibit brittle behaviour and fail at more modest loads. Ductility typically decreases at lower temperatures and most materials will become brittle below a certain temperature called the Ductile-Brittle Transition.

Duplex Stainless Steels Duplex stainless steels have a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. The proportions are approximately 50% of each phase.

Duplex stainless steels:

- are stronger, by a factor of up to 2, than the austenitic and ferritic grades
- are tougher and more ductile than the ferritic grades
- have better stress corrosion resistance than the austenitic grades.

Related terms: Ferritic Stainless Steels, Austenite, Ferrite, Austenitic Stainless Steel

Eccentricity This occurs in tubular products when the centres of the circles that describe the outside diameter and the bore do not coincide. It manifests itself as a variation in wall thickness around the tube. *Related terms: Concentricity*

Electrochemical Corrosion Corrosion, or metal dissolution, caused by the reaction $M \rightarrow M^{+} + e^{-}$ at the anode.

Electrochemical Protection The prevention of corrosion in an electrolyte by manipulation of the electrode potential of steel.

Electrode There are two electrodes in an electrochemical or corrosion cell, the anode and cathode. They are the electron conductors, through which electrons can enter and leave an electrolyte permitting reactions such as dissolution at the anode and deposition at the cathode to occur.

Electrode Potential The potential difference in a solution between the test electrode and a reference electrode, e.g. a saturated calomel electrode.

Electrode Reaction A chemical half or partial reaction that occurs at an electrode surface. It is called a half or partial reaction as only either the oxidation or the reduction part of the overall cell reaction occurs at any one electrode.

Electrolyte An electrically conducting medium, such as a salt solution or a molten salt through which an electric current is transported by ions.

Electrolytic Polishing An electrochemical method of imparting brilliance to the surface of a metal. The work-piece is made the anode and by careful selection of electrolyte and processing parameters a thin, uniform, surface layer is removed. It may be regarded as the opposite of electro plating.

Extrusion The process in which a preheated billet is constrained within a strong container in a press and then pushed by a ram through a shaped die. The product, or extrusion, has the shape of the die along its whole length. Although some simple shapes are extruded in Stainless Steel, this process is most commonly used for Aluminium.

Fatigue The localised, progressive and permanent damage or structural change that occurs to a material subjected to repeated, fluctuating, loads that are lower, often much lower, than the static yield strength of the material. Good design is the key to minimising or mitigating fatigue problems.

Ferrite A body centred cubic (BCC) phase found in most carbon and low alloy steels. It is magnetic and is why most steels themselves are magnetic. It transforms above 760°C into the non-magnetic, face centred cubic (FCC) phase austenite.

Ferritic Stainless Steels Ferritic stainless steels are iron chromium alloys that contain a minimum of around 10.5% Chromium. They have a body centred cubic (BCC) ferrite microstructure. They contain little or no Nickel and hence are less expensive than austenitic stainless steels. They generally have somewhat better mechanical properties than the austenitic grades but have inferior corrosion resistance except, importantly, they do have superior stress corrosion cracking resistance.

Free Machining Stainless Steels Many standard compositions of stainless also have a “free machining” variant with enhanced machinability. This is achieved by adding small amounts of certain alloying elements to the steel during melting. These added elements produce inclusions in the microstructure that act as chip breakers and can also lubricate the cutting action, increasing cutting speeds by approximately 75% on stainless steel. Sulphur is particularly good for heavy machining because of the large and fairly continuous inclusions. Selenium additions have also been used, especially in the USA, but are not available from European suppliers.

General Corrosion Corrosion in which the whole exposed surface is attacked by the corrosive medium at a broadly uniform rate. All corrosion is deleterious but general corrosion is more predictable and may be readily monitored and so managed. This is in contrast to the localised forms of attack such as pitting corrosion, crevice corrosion, inter-granular corrosion and stress corrosion cracking where the attack is very localised and can be

intense causing unexpected, premature, failure. *Related terms: Pitting Corrosion, Crevice Corrosion, Inter-granular Corrosion, Stress Corrosion Cracking*

Grain Size A measure of the area or volume of grains (crystals) in polycrystalline material.

Grain size is reported in a number of ways:-

- Number of grains per unit of area or volume,
- Average diameter,
- As a grain size number derived from area measurements and comparison with a standard chart.

Grain Structure The shape, size, distribution and disposition of metal crystals and their crystal structure within a solid metal or alloy.

Guillotining The cutting of plate, sheet or strip to size or length using guillotine shears. For the guillotining of stainless steels, as compared to mild/carbon steels, the shearing blades need to be sharper and have a reduced clearance.

Heat Exchanger A device that facilitates the efficient transfer of heat energy from one fluid to another.

The fluids are often kept apart by solid barriers, either the walls of tubes, or the formed sheets of clam shell type heat exchangers. Typically a heat exchanger will have many tubes or clam shells assembled in either bundles or stacks connected by manifolds. One fluid flows outside the assembly whilst the other flows inside.

Hollow, Tube Hollow Interchangeable terms for a hot finished semi-finished product from either an extrusion or piercing process. They are the feedstock for cold drawing or cold reduced tube production.

Huey Test A corrosion test for evaluating the inter-granular corrosion resistance of stainless steels by boiling in refluxed 65% nitric acid for five consecutive 48-hour periods, each period starting with fresh acid.

Immunity In corrosion terms a thermodynamically stable condition. In other words there is no corrosion attack.

Inclusion Non-metallic particles within the microstructure. Some, sulphides and selenides, are deliberately formed in the metal during its manufacture, others are an inevitable result of melting and casting. Good practice dictates that the second type be kept to minimal levels as they are deleterious. *Related terms: Free Machining Stainless Steels*

Inter-granular Corrosion Preferential, concentrated, corrosion attack at the grain boundaries. It is highly deleterious and usually caused by the precipitation of carbide particles in the grain boundaries after welding or incorrect thermal processing. *Related terms: Sensitisation, Sensitised, Weld Decay*

Localised Corrosion A general term for, often high rate, corrosion attack affecting restricted, specific, parts of the surface. *Related terms: Pitting Corrosion, Crevice Corrosion, Stress Corrosion Cracking*

Manipulation Tests Tests performed on full section or sector specimens to evaluate the ability of the work-piece to withstand possibly severe manipulation.

Crush, flare, bend, flare and flange, flatten, reverse flatten, reverse bend and Van Stone flange tests may be used.

Martensite A non-equilibrium, hard, phase that can exist in some steels. It is formed if a steel with sufficient Carbon content, usually above 0.35 to 0.4%, is heated into the austenite temperature range above 760°C, held at that temperature for a period and then quenched rapidly to room temperature. The Carbon, which is present in the lower temperature ferrite phase as carbides, dissolves in the austenite and, on quenching is trapped in, and strains, the lattice increasing the hardness. This reaction is the mechanism by which all Carbon and most alloy steels are hardened.

Martensitic Stainless Steels Martensitic grades of stainless steel are corrosion resistant, although less so than the austenitic grades, but can be hardened by heat treatment.

They are straight Chromium steels containing little or no Nickel. They are magnetic and are mainly used where hardness, strength, and wear resistance along with corrosion resistance are required. Typical applications include cutlery, surgical instruments, fasteners, valves, pumps, springs and components for food processing.

Mechanical Properties The properties of a material that reveal its elastic or plastic behaviour under an applied load. They govern its suitability for any mechanical application. The usual properties considered are modulus of elasticity, yield or 0.2%/1.0% proof strength, ultimate tensile strength, elongation and fatigue limit. *Related terms: Tensile Strength*

Mill Coil The hot rolled strip product of a single cast billet or slab.

Mill Edge The edge produced when sheet or strip is rolled on the flat surfaces only.

Moneypenny-Strauss Test A corrosion test that uses copper sulphate solution containing sulphuric acid to determine the susceptibility to inter-granular corrosion of stainless steel.

Non-Destructive Test Any test method, including eddy current, ultrasonic and dye-penetrant, used to detect surface and subsurface defects without damaging or destroying the product.

Orange Peel The surface roughening of sheet or strip that develops on subsequent cold deformation if the grain size is too coarse. The appearance is similar to the skin of an orange.

Ovality Any difference between the maximum and minimum outside diameters of a tube.

Oxide Film, Passive Film Generally it is the oxide layer spontaneously formed on the surface of a metal or alloy by its reaction with the oxygen in the atmosphere.

Specifically in stainless steels it is the protective chromium oxide film that forms on alloys containing more than 10.5% chromium that is impervious to many corroding media. It is why stainless steels are "stainless".

Passivation Treatment in oxidising acids to remove light surface contamination by iron based materials left by machining or wire brushing and to enhance the naturally occurring chromium oxide film. Any residual contaminants can act as sites for corrosion cells. Heavy contamination or other contaminants (mill scale, etc.) should be removed by acid pickling before passivation.

Phase Any constituent part of an alloy, e.g. elemental metal, solid solution, or inter-metallic compound, that is physically and chemically homogeneous and distinct within the microstructure.

Physical Properties The intrinsic properties of a material, e.g. density, electrical conductivity, thermal conductivity, thermal expansion that govern its behaviour and potential for use in an application.

Pickling, Acid Pickling The removal, by immersion in a solution containing nitric and hydrofluoric acids, of the scale left after hot working or annealing. It leaves a matt grey finish. *Related terms: Passivation*

Pinch Passing, Skin Passing A cold rolling pass, with minimal reduction of thickness, of annealed sheet or strip. It reduces the tendency to kinks, flats and stretcher strains on subsequent manipulation. Flat material so treated is described as 'skin passed', 'pinch passed', 'non-kinking', 'non-flattening' or 'killed'. The material will also be brighter and have closer tolerances.

Pipe, Pipes Tubular products made to Nominal Bore and Schedule Wall Thickness dimensions specified by ANSI/ASTM standards. Sizes specifically for Stainless Steel Pipe are to ANSI B36.19 where the Schedule Wall Thickness has an S after the number to denote Stainless – e.g. Schedule 40S. Stainless Steel Pipe can also be made to the ANSAI B36.10 sizes intended for carbon/mild/alloy steels where the schedule has no S after it.

Pit A corroded hollow in a metal surface, caused by localised corrosion (pitting).

Pitting Corrosion Concentrated, localised, corrosion attack that can reach considerable depths and cause premature failure.

Precipitation Hardening Stainless Steels Precipitation hardening stainless steels are Iron, Nickel, Chromium alloys that also contain precipitation hardening additions such as Aluminium, Titanium, Copper, Niobium and Molybdenum. They offer higher mechanical properties than the austenitic grades, with lower toughness and do have comparable corrosion resistance.

Pressure Test A hydraulic or pneumatic test for tubes to prove that the material can withstand a specified pressure for a specified time without leakage or rupture.

Proof Strength The tensile load required to extend a sample of material by 0.2% (RP0.2) or 1% (RP1.0). Measured in Newtons per square mm (Nmm²) or Mega-Pascals (MPa).

Recrystallisation The change in crystal structure of a cold worked metal that occurs when heated through a specific temperature range.

Roll Marks Periodic surface marks on a work-piece caused by imperfections on the surface of a roll.

Rolled-in Scale A surface defect caused by patches of scale that were pressed into the surface of the work-piece during rolling.

Roller Levelling The process of flattening sheet metal by passing it through a roll train of staggered rolls. Levelling is achieved by precisely bending metal strip back and forth as it is passed through a the series of small-diameter offset rolls.

Sensitisation Sensitisation occurs because Chromium has a higher affinity for Carbon than does Iron. Welding and some heating cycles provide the thermal energy for chromium carbides form in preference and these precipitate within the microstructure. This process causes the steel to become susceptible to corrosion as the matrix areas around the carbide are depleted in Chromium and cannot form the protective oxide film. *Related terms: Carbide, Inter-granular Corrosion, Sensitised, Stabilised Grades*

Sensitised This describes the condition of a stainless steel that, having been welded or otherwise thermally processed, now has chromium carbide particles present in the grain boundaries. In this condition the steel becomes susceptible to corrosion as the matrix areas around the carbide are depleted in chromium and cannot form the protective oxide film. *Related terms: Carbide, Stabilised Grades, Inter-granular Corrosion, Sensitisation*

Sheared Edges The cut edges that are produced when a wide sheet or coil is sheared or slit, by rotary cutters or a guillotine, into narrower widths/lengths.

Shearing The operation of cutting sheet or strip to the required size with a guillotine.

Sinking, Sink Drawing The cold drawing of a tube without a mandrel in the bore to control bore dimensions. It enables closer tolerances to be achieved on the outside diameter and increases mechanical properties. *Related terms: Cold Drawing*

Slab A hot rolled or forged primary feedstock for rolling or forging. The cross-section is rectangular, typically with a width more than twice the thickness.

Slitting The operation of continuously cutting a wide coil of strip into a narrower strips by rotary cutters. The narrower strips are usually re-coiled after slitting.

Solid Solution The name given to an alloy, e.g. Iron Chromium, phase which appears, in the microstructure, to be one material. In Iron Chromium solid solutions the Iron is the major constituent and the Chromium, the "alloying element", atoms occupy places within the iron lattice and modify its properties. Solid solutions are fundamental in metallurgy. Pure metals have definite melting and freezing points, solid solutions have a melting and freezing range.

Solution Treatment, Solution Annealing A heat treatment process to dissolve precipitated carbides followed by quenching or rapid cooling to retain the carbon into solid solution. This restores the chromium content of the matrix and hence the corrosion resistance. *Related terms: Sensitisation, Inter-granular Corrosion*

Springback, Spring Back The tendency of a metal work-piece that has been deformed to not stay exactly in the shape to which is has been manipulated, but instead to spring back a little. Stainless steels spring back more than mild/carbon/alloy steels and thus need to be over-bent to a greater degree.

Stabilised Grades Stainless Steels whose composition has been modified by additions of Titanium or Niobium to overcome sensitisation and its consequent problems. The mechanism is that these elements have a higher affinity for Carbon than does Chromium so their Carbides form in preference. The Chromium content of the matrix is

therefore not reduced so its corrosion resistance is retained.

Stainless Steel Stainless Steel is the term used to describe an extremely versatile family of engineering materials, which are used primarily for their corrosion and heat resistant properties.

All Stainless Steels are alloys of Iron and Chromium, with a minimum Chromium content of about 10.5%, and with varying Carbon content. This Chromium content develops a self-repairing Chromium Oxide surface film which prevents the surface rusting typical of many other types of steel.

Higher Chromium content will further enhance corrosion resistance and some stainless grades also contain other alloying elements including Nickel and Molybdenum.

Most commonly you will see reference to "austenitic stainless steel", "ferritic stainless steel", "martensitic stainless steel", "duplex stainless steel" and "precipitation hardening stainless steel".

Stainless Steel Designations Stainless steels are governed by a wide range of Proprietary, National, European and International standards. This range of standards has led over time to the use of a number of designation systems.

Many people are familiar, and comfortable with, the 3-digit system that originated in the USA and was adopted into former British Standards in which

2xx and 3xx designations were applied to austenitic grades (e.g. 201, 304, 304L)

4xx designations were applied to ferritic and martensitic grades (e.g. 410, 430)

In Europe these have now been replaced by BSEN numbers of the type 1.4xxx (e.g. 1.4301) although the American 3-digit system is still widely used.

Straightness Tolerance, Camber The permitted deviation from a true straight line, or bow, within a specified length of a product.

The usual methods to determine such a deviation are with a straight edge and dial gauge or a flat plate and feeler gauges.

Stress Stress is the measure of the forces acting within a deformable body or work-piece when it is under load. These forces will seek to resist any permanent change in shape of the body or work-piece until the yield point strength of the material has been exceeded.

Stress Corrosion Cracking Stress Corrosion Cracking (SCC) is the rapid and often abrupt failure of a normally ductile metal or alloy caused by residual or other stresses in the work-piece and in the presence of specific corroding agents. It is temperature dependent. Austenitic stainless steels are susceptible in chloride environments temperatures above 60°C.

Ferritic grades are immune to this form of attack.

Stress Relieving An annealing heat treatment used to reduce internal stresses in steel after fabrication. *Related terms: Annealing*

Swaging A cold forging process in which the dimensions of a tube are altered by blows delivered rapidly against its outside diameter. An internal mandrel is usually used.

Tolerance The permissible limit, or limits, of variation to a specified parameter such as a dimension or weight per unit length usually expressed as 'plus' or 'minus' value on that quantity.

Ultimate Tensile Strength, Tensile Strength The maximum load, in tension, that a material can withstand before breaking. It is calculated as a breaking load for a standard cross section area

and measured in Newtons per square mm (Nmm²) or Mega-Pascals (MPa).

Weld Decay This describes the condition of a stainless steel that, having been welded or otherwise thermally processed, now has chromium carbide particles present in the grain boundaries. In this condition the steel becomes susceptible to corrosion as the matrix areas around the carbide are depleted in chromium and cannot form the protective oxide film.

Yield Point, Yield Strength The tensile load above which a material ceases to behave elastically and will undergo permanent deformation. Measured in Newtons per square mm (Nmm²) or Mega-Pascals (MPa).

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