Design for Manufacture in Cost-effective & Recyclable Brass

(Copper Development Association)

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A Presentation to Design and Engineering Undergraduates

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Introduction to and the structure of the presentation

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Copper Development Association is a non-trading organisation sponsored by the copper producers and fabricators to encourage the use of copper and copper alloys and to promote their correct and efficient application. Its services, which include the provision of technical advice and information, are available to those interested in the utilisation of copper in all its aspects. The Association also provides a link between research and user industries and maintains close contact with other copper development organisations throughout the world.

Over 70 publications, datadisks, wallcharts and videos are currently in print, of which a considerable number have information relating to Brass. Three, the Brasses Design Compendium, Design in Brass and Architectural Brass, are specific to Brass. The majority of these publications and datadisks are on the CD ROM Megabytes on Coppers and Copper Alloys II, which also contains many out of print publications.

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There is a large demand for brass throughout the world. Consumption in Europe alone of wrought material exceeded 1,000,000 tonnes in 1999 and, if foundry ingots (castings) are taken into account, the figure exceeds 1,500,000.

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The demand for brass is not static in Europe as might be expected but has grown at over 2½% per annum over the last 20 years.

The market for brass in Italy, Europe's greatest user, has grown by a fifth in the last 5 years demonstrating that there are significant opportunities for designing in brass.

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Brass is a metal alloy of Copper and Zinc, with copper content ranging from 58% to 95%.

In addition to Zinc, the major alloying element, small additions (less than 5%) of other alloying elements are added to modify the properties so that the resulting material is fit for a given purpose.

There are over 40 standard compositions of Brass

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Brasses containing a minimum of 63% copper are termed alpha brasses or cold working brasses and are highly ductile at room temperature, and are readily deformed by cold rolling, deep drawing, bending, spinning cold heading, thread rolling etc. The best known of these alloys is 70/30 or cartridge brass, so called because it is easily deep drawn and used for making cartridge cases. Alloys with a higher copper content (80%-90%) and which are gold in colour are used extensively for decorative metalwork, costume jewellery, badges and buttons as well as rolled formed architectural applications because of their high level of cold ductility.

Brasses containing 35%-45% zinc are known as alpha-beta or duplex brasses because they contain a mixture of the original solid solution (alpha phase) and a new solid solution of higher zinc content (beta phase). Their ability to be deformed at room temperature (cold worked) is limited, but they are far more workable at elevated temperatures and are ideal for extruding into complex solid and hollow shapes and hot forging.

NB Copper alloys containing 5% zinc, tin and lead are known in the USA as “red brass” but in the UK are classified as leaded gunmetal.

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Table of alloying elements added to brass and the property they improve.

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Brass has **excellent machinability** and is the material by which all other materials are judged, however this can be improved even further by the addition of 3% lead to give free cutting high speed machining brasses. The addition of lead however gives a slight reduction in ductility.

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Table comparing the machinability of brass with other common metals.

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Brasses are **medium strength** engineering materials, comparable to high strength structural steels and some stainless steels and aluminium alloys. In the softened or annealed condition brasses are ductile and strong but, when hardened by cold working, their strength increases markedly. The addition of small quantities of Manganese, Aluminium, Tin, Silicon, Iron and Nickel in cast brasses produces a family of High Tensile Brasses that can have tensile strengths in excess of 700N/mm^2.

For general purposes the **corrosion resistance** of standard free machining alloys is excellent. The addition of 1% tin in Naval and Admiralty Brasses (as the names infer these brasses were originally developed for sea water service) improves corrosion especially in sea water. The addition of a small amount of Arsenic (typically 0.1%) to alpha brass alloys brass produces a heat treatable dezincification resistant brass frequently used for water fittings.

A small amount of aluminium added to duplex brasses gives an attractive yellow coloured Architectural Brass with excellent hot workability.

In the occasional instances when it is necessary to plate brass, because most plated coatings are porous to a certain extent, its inherently good corrosion resistance prevents the early onset of cracks, blisters, or eruptions of rust through the plating that can occur when the substrate is steel.

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Brasses have good electrical and thermal conductivity and are markedly superior to ferrous alloys, nickel based alloys and titanium. Their high conductivity combined with good corrosion resistance makes them ideal for the manufacture of electrical equipment. Condenser and heat exchanger tubing also makes use of the good thermal conductivity of copper alloys.

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Radiators and Heat Exchangers
For many years, car radiators were made from copper finstock of excellent **thermal conductivity**, brass tubes and brass header and bottom tanks, all soldered together to give a long-lasting product with the advantage that it could be repaired if ever damaged.

With the development of the use of other materials to make some radiators, there was a need to review and improve the design to meet the competition. This has now been achieved with the use of copper finstock rolled to much thinner gauge in modern mills, tubing made from precision strip by either high-frequency welding or laser welding, and the use of either a zinc-based solder or a new brazing system that will permit operation at much higher temperatures. Special lacquers, electrophoretically applied, protect the finstock from corrosion caused by salted roads.

A new sealing method is used to join the heat exchanger to the header and bottom tanks. This has reduced initial cost and weight, while retaining the high heat-exchange efficiency of copper to permit the use of a smaller total heat exchange surface and smaller content of cooling water. The finished radiator is lighter than those made of other materials, both as made and when full of coolant.

13 Amp Plug
For economic production of these safety-critical items, brass is used to make the pins to ensure a long, trouble-free life. Brass does not corrode in service, has good strength, **electrical conductivity** and resistance to wear as well as being easy to extrude.

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Brasses do not spark when struck by other materials and are approved for use in hazardous environments e.g. mines and quarries

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Conflow Ltd of Nottingham design and manufacture specialist water systems for dust suppression, fire suppression and hydraulics for underground coalmining. The major hazard in a coalmine is fire and therefore materials used in mining products must not support combustion, which usually eliminates plastics and aluminium. Two metals that are readily available and meet this criterion are brass and steel. Conflow chooses to specify brass because of its corrosion resistance to water, its machinability and castability.

An additional property of brass that makes it ideal for underground applications is its **non-sparking property**. The company's products are unlikely to come into contact with items that will generate sparks in their normal operating environment, but it is reassuring to know that if the products are accidentally struck by another metallic item no sparks will be generated.

A typical example of a product that benefits from the above properties of brass is the company's Emulsion Mixer, which mixes and supplies a constant and accurate percentage mix of soluble oil and water. The resulting mixture is used as fire resistant hydraulic fluid to power the coal face roof supports. The mixer operates without electrical power, an additional safety feature, driven purely by its inlet water supply. The head, which is 150mm diameter is readily and speedily turned and machined at high speeds from free cutting brass bar, while the base is efficiently machined from a brass casting produced in the company's own copper alloy foundry.

The benefits of machining large brass items, in addition to the timesaving, are reduced tool wear and lower power consumption i.e. less powerful machines tools required. The corrosion resistance of brass eliminates the need for protective coatings, allowing all parts to be immediately assembled after machining, reducing manufacturing time and buffer stocks. The swarf produced during machining is readily recycled and commands a premium price.

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Copper and gold are the only two metals with any distinctive colour.

In consequence, brasses are extensively used for durable decorative applications and for the manufacture of functional items where aesthetic appeal is a requirement in addition to a long service life. Aluminium brasses have a distinctive silvery sheen and the addition of manganese to certain brasses gives them an attractive bronze colour when extruded. High tensile brasses, some of which are otherwise known as "manganese brasses" or previously "manganese bronzes" are particularly suitable for architectural applications since they can also be patinated to a range of durable brown and bronze finishes.

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In brasses, the red of copper is toned to a range of attractive yellow hues by the addition of varying amounts of zinc, ranging from the gold-like colours of the 95/5, 90/10, 85/15 and 80/20 alloys (appropriately called "gilding metals") through the more subtle variations in the 70/30, 2/1 and 64/36 series of brasses to the stronger yellow colour of the 60/40 alloy, formerly known as "yellow metal".

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The brasses are very suitable for use at cryogenic temperatures since the properties are retained or slightly improved.

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The presence of lead in brass has a lubricating effect that gives good low friction and wear properties that are utilised in pinions and instrumentation and clock gears. The addition of silicon in special brasses make them ideal for use in heavy duty bearings.

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The "Perkomatic" is tested to 500,000 operations to ensure it meets current and proposed legislation. To achieve this number of cycles has meant the design has become highly refined and the choice of materials has been critical. An example of this is the end and anchor plates which secure the "Perkomatic" to the door and the door frame respectively. The twin chains which connect the hydraulic cylinder mechanism in the door to the anchor in the frame pass through the end plate rubbing against it every time the door opens and closes.

Brass stampings were chosen for the end and anchor plates because it was discovered during testing that steel end plates wore more quickly. Steel was found not to have the self lubricating and low friction properties of brass and only had a life of 10,000 operations before failure, 2% of that required and easily achieved by brass.

The life of forged steel end anchor plates may have been extended by surface treatments required to prevent corrosion and give an aesthetic appeal. There was concern however that the chains would abrade any decorative finish exposing bare untreated metal leaving it susceptible to corrosion and high mechanical wear. These concerns combined with the strong possibility that particles from a degrading finish could enter the hydraulic system causing premature failure and the fact that steel forgings were marginally dearer without a protective finish than brass stampings, which needed no finish, eliminated steel from further investigations.

In conclusion brass which is an apparently expensive material is in component form very cost-effective as a machined stamping, because of its excellent formability, machinability and corrosion resistance. These features combined with its bearing and mechanical properties make it an ideal material for architectural building products as Perkins and Powell have demonstrated with their Perkomatic concealed door closer.

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The recycling of brass by melting is a basic essential of the industry. All of the feedstock for the manufacture of billets for extrusion of rod comes from scrap, including

- process scrap such as offcuts from within the mill
- process scrap such as turnings from machine shops
- scrap from brass components being recycled after a long and useful life.

Brass scrap and swarf command high prices because it is easily remelted back to its original state without loss of properties and, when costing a brass product, the high value of any swarf or scrap produced during manufacture should be taken into account. Likewise when calculating the lifetime cost of a product, the ease with which a brass component is recycled at the end of its useful life needs to be taken into account.

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The recycling of brass scrap is a basic essential of the economics of the industry. Brass for extrusion and hot stamping is normally made from a basic melt of scrap of similar composition adjusted by the addition of virgin copper or zinc as required to meet the specification before pouring. The use of brass scrap bought at a significantly lower price than the metal mixture price means that the cost of the fabricated brass is considerably less than it might otherwise be.

The presence in brass of some other elements such as lead is often required to improve machinability so such scrap is frequently acceptable. Besides the common free-machining brasses, there are many others made for special purposes with properties modified to give extra strength, hardness, corrosion resistance or other attributes, so strict segregation of scrap is essential.

Brass swarf arising from machining operations can be economically remelted but should be substantially free from excess lubricant, especially those including organic compounds that cause unacceptable fumes during remelting.

When brass is remelted, there is usually some evolution of the more volatile zinc. This is made up in the melt to bring it back within specification. The zinc is evolved as oxide that is drawn off and trapped in a baghouse and recycled for the manufacture of other products.

Brass to be made into sheet, strip or wire form must be free of harmful impurities in order to retain ductility when cold. It can then be rolled, drawn, deep drawn, swaged, riveted, spun or otherwise cold formed. It is normal therefore to make it substantially from virgin copper and zinc, together with process scrap arising from processing that has been kept clean, carefully segregated and identified.

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In addition to its primary properties brass has a number of less obvious properties.

Copper is a well-known as a biocide and the copper content of the brasses has the beneficial effect of restricting the the growth of micro-organisms. Tests on door furniture such as knobs and finger plates have shown that those made of clean brass are far less likely to encourage the growth of the organisms causing nosocomal infections than other materials. Brass fittings, free from further protective finishes, should therefore be used in sensitive environments such as hospitals.

Its strength is maintained up to 200°C and reduces by only about 30% at 300°C which compares favourably with other materials.

Brasses have good impact resistance (toughness) and do not shatter or crack when subject to a high impact load.

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Brass components can be produced by a wide variety of techniques. Besides the effects of composition, processing history will have a significant effect on properties.

Hot working is commonly carried out either by hot rolling of cakes or slabs or by extrusion or forging of billets. The basic effect of hot working on the brasses is to break up the original cast structure which improves physical properties and modifies directionality. The properties will then correspond to the annealed (O) state. If, however, the final working temperature is below that needed for full recrystallisation, then some cold working occurs. Material in the "as manufactured" (M) condition is therefore generally stronger than in the annealed (O) condition.

The strength of most of the commercially available brasses cannot be improved by heat treatment. Any improvement in properties over the soft, annealed condition is obtained by cold working. In the case of extruded products such as rods, bars, sections, tubes and wire, the cold reduction is applied by drawing through dies, while in the case of sheet and strip it is applied by cold rolling.

Progressive amounts of cold working increase the tensile strength, proof strength and hardness of the alloy, with a consequent reduction in ductility, as measured by elongation. Material available from manufacturers has been subjected to various amounts of cold reduction; temper grades covered by British Standards for sheet, strip and wire are 1/4 hard, 1/2 hard, hard, extra hard, spring hard and extra spring hard. Not all brasses or forms are available in all temper conditions. Hard rolled brasses have better ductility longitudinally in line with the rolling direction rather than in the transverse direction. Advantage of this can be taken when designing springs or other flexible parts.

The temper grade specified when ordering material must be based on the degree of forming necessary to produce the finished component. With experience, alpha brasses can be temper-annealed within a wide variety of combinations of properties such as hardness and grain-size suitable for differing end-uses.

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Casting not only produces the the billet and cake for all the other manufacturing processes, but is used to produce components.
There are a variety of casting processes but essentially molten liquid metal is poured into a shaped mould.

Sand cast moulds as inferred are made from sand bonded with clays and silicates. Shell moulds are made from sand coated with thermosetting resin which is allowed to fall on to heated metal pattern plates. After a short time these are inverted and the excess sand falls away leaving a shell of sand adhering to the pattern. The shell is baked to harden the resin, resulting in a easily handled strong biscuit from which moulds are assembled. The molten metal is then poured into the mould and allowed to solidify before the sand is broken away to reveal a finished casting replicating the cavity in the sand moulds.

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Gravity and pressure die casting is also known as permanent mould die casting. In gravity die casting the dies are usually cast iron , the molten metal is poured into these moulds by gravity. The rapid rate of cooling given by chill gives good properties. It is used for the manufacture of plumbing fittings and taps. The dies for pressure die casting are made from machined tool steel and the metal is injected into mould under high pressure. The process gives good properties with a level of details and is ideal for long runs.

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An example of sophisticated pressure die casting tooling.

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Schematic of a Cold Chamber Diecasting Machine

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Investment casting also known as the lost wax process has been used for centuries. The process uses a wax pattern which is invested with refractory slurry to build up a shell. The shell is then fired to strengthen and remove moisture, this melts the wax which runs out the shell, molten metal is then poured in the refractory shell. An ideal process for producing accurate complex components that might otherwise have to be assembled from many parts.

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Centrifugal casting, the process consists of pouring molten metal into mould or die usually of steel that rotate at a fairly high speed. Rings or discs are produced with the die spinning on a vertical axis and tubes while it rotates on a horizontal axis. It is an ideal method of producing symmetrical shapes.

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In the **continuous casting** process metal flows from a holding furnace through a die as it solidifies. It is withdrawn by rollers and then cut into convenient lengths for handling. It produces products with close tolerances and good surface finish with high and consistent soundness. It is the usual method by which billets are produced for extrusion and rolling.

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Typical cast products

From left to right top row
Sand Cast Breather Valve Guard
An elaborately cored shell moulded valve

From left to right bottom row
Pressure Die Cast Components, ideal for longs runs, this process gives excellent products with good properties and accurate reproduction. Closer tolerances can be obtained than with gravity die casting.
Investment Cast Clarinet Keys, eliminated the need for assembly by silver soldering from several components.

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Extrusion is a hot working technique where billets, cut from continuously cast logs, preheated to between 600°C and 800°C are forced through a die that is shaped in the form of the finished product. This gives round rod, square, hexagonal or special profiles as required. The use of a mandrel allows hollow extrusions to be produced. Duplex materials that have good ductility at hot working temperatures are usually used for extrusion. The resulting structure of the material is uniform with a fine grain structure.

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In **direct extrusion** a ram forces the preheated brass billet through the die. This can be likened to squeezing toothpaste out of a tube. Using this method it is possible to extrude up to six lengths from one die.

Direct extrusion is usually used for the manufacture of profiled sections and hollow bar products.

Indirect extrusion is the reverse of direct extrusion, the die being forced on to the billet rather than the billet being forced through the die.

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Typical Extruded Profiles

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Hot Stamping
A near-net shape forming process involving hot forging between shaped, closed dies. Products are typically up to 1 kg in weight but can be up to 30 kg. Die costs depend on whether it is a simple two-die shape or if the opportunity is taken to include provision for third dies to help produce a more complex shape. This can be a very cost-effective production method for relatively long runs of product. Typical materials are the hot stamping brasses but others are possible.

Hot stampings are made by forming hot slugs between shaped dies that are designed and made to give components that need a minimum of finishing. The dies can give accurate and consistent reproduction of the component in batches of from 500 to 50,000 units at rapid production rates.

Compared with castings, hot stampings are sound, have good properties and are free from internal entrapped dross or surface moulding sand. They are easy to jig for accurate finish machining of faces, holes and threads. It is easy to stamp leaded brasses that are free-machining and other brasses such as dezincification-resistant brasses.

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Production of Hot Stampings

Pre heated brass billets are placed between two metal dies whose internal cavity is the component shape required. The die is powered down, forcing the the billet to flow and fill the cavity when the two die halves meet. Die tooling configurations are discussed below.

Open Die Stamping

The least complex die arrangement whereby when the die halves are forced together, metal flow is initiated before the die halves meet, and completed once the die halves are in face to face contact or a pre-set register position.

Closed Die Stamping

In this configuration the two die halves initially close face to face face around the hot billet and are then forced down onto a third die part or core pin which causes the metal to fill the cavity.

Hot Brass Stampings, have high strength, are free from porosity, are near-net-shape, give close consistent component tolerances, have a superior surface finish and give optimum metal usage.

NB Stamping dies have considerably longer life than die casting dies due to the lower temperatures involved. Generally stamping dies will produce up to 50,000 components compared with a maximum of 15,000 shots for die castings.

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Hot brass stampings are used by most industries and the major ones are listed below:-

Plumbing, heating and gas transmission

Taps, control valves, pressure valves, pipe unions and fittings, nuts, bath and basin wastes, strainers, shower heads, pump parts and electrical immersion heater element bosses.

Builders hardware

Door knockers, handles and face plates, lock bodies and barrels, window handles and fittings, eyebolts, wing nuts, brass bed and handrail fittings.

Transportation

Piston guide bushings and valve plugs, air brake servo-pistons, automotive gear rings, control equipment linkages and and hydraulic fluid line fittings.

Gas welding equipment

Torch components, jets, “Y” fitting assemblies, control valves, regulator bodies and associated components.

Refrigeration equipment

Manifolds, filter parts, liquid indicators and all types of valves: shut off, regulator, thermostatic, pressure control and relief valves.

Fluid handling equipment

Impellers, gas and oil couplings, part for fuel pumps etc.

Electrical equipment

Selector contacts and switchgear accessories and the blades, washers and retaining caps for fuses.

Fire protection fittings

Fire house couplings, water control valves and fog nozzles. Also line and outlet fittings in fixed fire sprinkler systems.

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The strength of most of the commercially available brasses cannot be improved by heat treatment. Any improvement in properties over the soft, annealed condition is obtained by cold working.

Cold working usually leads to improved surface finish and dimensionally accuracy.

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The cold work in the case of extruded products such as rods, bars, sections, tubes and wire, is applied by drawing through reducing dies.
Progressive amounts of cold working increase the tensile strength, proof strength and hardness of the alloy, with a consequent reduction in ductility, as measured by elongation. Material available from manufacturers will have been subjected to various amounts of cold reduction; temper grades covered by British Standards for sheet, strip and wire are 1/4 hard, 1/2 hard, hard, extra hard, spring hard and extra spring hard. Not all brasses or forms are available in all temper conditions.

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Brass is frequently specified for the tubes of heat exchangers because it is relatively cheap, strong, corrosion resistant and easily soldered. It is also used elsewhere when similar properties are required. Precision brass tube is also used for the concentric thin walled tubes to make collapsible aerials and pointers.

Drawing normally makes tubes to size from hollow ‘tubeshells’ produced by extrusion. They are then cold drawn to size by a succession of passes, with interstage anneals as required and supplied either in straight lengths or coil. A selection of brasses is available with properties to suit applications from telescopic aerials to marine condensers.

Normally brass tubes are thought of as being circular, with tolerances on inside and outside diameters that make them easy to join with standard fittings. However, tubes can in fact be made by many different techniques to bespoke shapes and sizes. They can be square, circular, or hexagonal. They can be made twisted or indented. They can be fluted, fined, decoratively patterned or grooved. The inside shapes can be different from the outside and can have specified wall thicknesses, uniform or uneven. For example a round hole inside a square tube is often needed to ensure correct flow of coolant. Another frequent need is for an oblong tube with the corners either square or typically radiused to half the wall thickness. Often, one side must be significantly thicker than the other. For tubular heat exchangers such as oil coolers there are concentric tubes, the flow of coolant can be made turbulent by helical grooves or raised ridges.

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Typical brass wire products and tube sections

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The single-phase alloys can be readily riveted-over and are used to manufacture cold-formed parts. Rivets, pins, screws and similar items are mass-produced from wire by cold heading, up to 30,000 items an hour being possible. Small screws may be produced by cold heading wire blanks followed by thread rolling. Wire may also be used for the production of circlips and zip fasteners.

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The TIMco Top Brass Wood Screw, a patented design, is a modern example of a product that is both cold headed and thread rolled.

NB: The sabre point self starting point is machined because of the machinability of brass.

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Slabs of metal are passed through a series of rolls, each pass reduces the thickness of the material increasing its strength, but reducing its ductility.
NB: Only a limited number of passes can be made before the material has to be annealed.

Hard rolled brasses have better ductility longitudinally in line with the rolling direction rather than in the transverse direction. Advantage should be taken of this when designing springs or other flexible parts.

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In stamping/pressing a sheet of metal is deformed between two suitably shaped dies usually to produce a cap or dish shaped component.
Alpha brasses in sheet and strip have good cold deformation properties and are therefore readily formed and shaped by cold stamping or pressing and production rates can be very high.
Cold stamping and pressing is typically used to produce the following types of components: connectors, precision mechanics, key blanks, contact elements, decorative ware, jewellery, clock making items etc.

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Deep drawing differs from stamping/pressing in that the starting sheet of flat brass is larger than the area of the punch and the outer parts of the sheet are drawn in towards the die as the operation proceeds. A pressure plate fixed to the power press prevents wrinkling of the edges during “drawing in”.

A deep drawn component may show regions near the edges that are thicker than the original sheet (the thickening being caused by the drawing in process) and regions which are thinner than the original sheet due to local elongation. The process is limited by the possibility of fracture occurring during drawing, however cups may be redrawn to a deeper depth after an interstage anneal.

For deep drawing operations the quality of strip required should be non-directional and of the correct combination of hardness and grain size for the tooling. Directionality leads to 'earring' of drawn cups, a large grain size leads to 'orange peel' surface effects and too high a hardness can limit drawability. Wrinkling, tearing and similar problems can often be caused by incorrect tooling, so tooling geometry and clearances, clamping and drawing forces and lubricant supply also need to be reproducibly controlled.

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Examples of Deep Drawn Components

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For making dished ends of hollow vessels flanges for water vessels, ball floats, electrical switchgear products and similar items, spinning can be a useful production technique. The spinning lathe and the former needed for simple jobs are relatively cheap but the process is labour intensive and needs significant skills.

With the introduction of hydraulic spinning machines, the scope for metal spinning has increased dramatically. Diameters up to 4,000 mm and thicknesses up to 25 mm can now be spun to close tolerances, maintained through short or long production runs. Tooling costs are much lower than press tools and there is a further advantage that differing material thicknesses can be tried on the same tool during product development.

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A typical metal spun component.

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Machining is a cold-working operation in which the cutting tool forms chips or shavings by producing a continual series of fractures of the metal being cut. The ease of machining depends on the design of the cutting tool, the cutting lubricant and the micro- structure and properties of the material being cut.

Whilst all brasses are intrinsically easy to machine, the addition of small amounts of lead to brasses further improves this property and the well-known "free machining brass" is universally accepted as setting the standard by which other materials are judged when machinability is being assessed. Higher machining speeds and lower rates of tool wear mean that overall production costs are minimised, tolerances are held during long production runs and surface finish is excellent.

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Free-machining brass produces fine chips of swarf.

Brass swarf is valuable (worth 40% of virgin material), is easily to handle and compact.

The swarf from **non-free machining metals** is slow to clear from the tool, giving higher tool wear, long tangles of swarf and the need for expensive cutting lubricants.

Ferrous swarf has little value.

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Typical components machined from free-machining brass.

NB: The above were originally machined from leaded free machining steel and converting to free-machining brass showed savings of between £0.58-£33.58 per 1,000 components.

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Brasses can be readily joined to other copper alloys and most other metals by commercial joining processes.

Brasses can be bolted or riveted, but care must be taken in selecting an appropriate material for the bolts and rivets to ensure no galvanic corrosion takes place in service.

Modern adhesives can be used to join brasses but because, like all copper alloys, brass quickly forms a surface oxide pre cleaning is essential to ensure a good bond. The adhesive suppliers advice on joint design and surface preparation techniques should always be sought.

Soldering is a low cost and simple method of joining brass using low melting point alloys. Traditional solders have tended to be lead/tin alloys but modern lead free solders are now becoming available. Fluxes used in soldering should always be washed away after soldering to prevent staining and tarnishing.

All brasses other than those containing more than 1.5% lead (under controlled conditions 3%Pb may be possible) and less than 10% aluminium are readily brazed. Brazing is a high temperature joining process where the filler metal (which melts below the melting point of the metals to be joined) penetrates between the close fitting metals to be joined by capillary attraction.

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Illustration of the stages in Brazing.

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Most brasses can be successfully welded with the correct choice of filler alloy and modern MIG and TIG welding processes. However care must be taken because of the evolution of zinc fumes due to the zinc boiling off in the weld pool.

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Brass case studies follow that illustrate the numerous properties of brass particularly its cost-effectiveness and recyclability.

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The requirement is to produce a reliable, robust and safe valve chest for the operation of mine roof support hydraulic jacks. When made from steel the amount of pre-machining from bar stock is extensive, the finish machining time extended and there is also a need to send out the components for protective plating. High tensile brass is supplied to the required shape, is relatively easy to machine and requires no plating in order to be safe for this application.

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First Costs = Material plus production costs.

Cheapest material costs may involve higher production costs. It is frequently possible to reduce total costs by buying free machining material or components made near net shape before finish machining and assembly.

A simple example of comparison of first costs for heavy duty valve chests is shown in the slide.

The advantages can be clearly seen from this example of how MECO International used an extruded high tensile brass profile to replace the steel previously used in the manufacture of a typical valve body.

A saving of £7.34 per component was achieved over steel giving an annual saving in the order of £20,000. (Comparison costs supplied courtesy of MECO International).

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Vickers Systems Division have 50 years experience in the design and manufacture of the Lang range of pneumatic products, which include cylinders, directional control valves and ancillary products. The company pride themselves on developing and manufacturing innovative and creative products at competitive prices.

To achieve this material selection is critical, selecting a material not only for its properties, but its cost-ffectiveness. One example of this is the 4-Way Semi-Rotary Slide Valve which is required to have a long life (20 plus years) when fitted to heavy duty products e.g. Railway Wagons, Brewery Handling Equipment and Keg Cleaning Systems, Military Vehicles, Quarrying and Mining Equipment, which operate in harsh and rugged environments. In these instances the valve needs to be manufactured from a corrosion resistant, low friction, self lubricating and easily machined material. The natural choice of material would be a free machining brass in extruded bar form, however the raw material price of brass would appear to rule it out. A possible alternative choice of material might be extruded aluminium, the raw material cost being half that of brass. (see cost analysis).
To have the same wear properties as brass in this application aluminium needs to be hard anodised after machining. This accounts for over a quarter of the cost of manufacture, whereas brass requires no finish.
Additionally brass machines faster than aluminium and the value of the scrap produced during the machining operations has a higher value, therefore resulting in further cost savings in favour of brass.

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The final cost analysis shows the body is 15% cheaper to manufacture in brass than aluminium, because of the savings demonstrated above, which offset the higher raw material cost.

There being no need for surface finishing, the requirement for the components to go outside the company is eliminated, thus enabling the company to control their manufacture at all times and operate a JIT system. A further benefit to the company and their customers.

Furthermore because no expensive tooling (moulds or dies) with long deliveries is required, machined brass components are therefore ideal for medium batch runs and the manufacture of specials required at short notice.

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Linic Plastics Secateurs Brass Case History

Brass has been chosen for the pivot pin in Linic Plastics new range of anvil secateurs because it is 5p cheaper than mild steel. The reason is that brass machines much faster than steel; the swarf produced is readily recycled and therefore commands a premium price. In addition the brass pivot pin does not require plating to prevent corrosion and is self-lubricating.

The 5p saving at component level represents a 25p-30p saving on the final selling price and Nic Burdett, the company’s Managing Director says, “This puts our secateurs in a lower price band making them an impulse buy and increasing our sales volumes.” Richard Smout, responsible for the design of the company’s new range of garden tools was quoted as saying, “The use of brass gives the product a touch of class and an added perceived value in a competitive market”.

Linic Plastics, based in Fleckney Leicestershire is a leading UK designer, manufacturer and supplier of injection moulded plastic DIY, model making and garden hand tools.

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KeyMed Series 5 Rigid Borescope

KeyMed, a division of Olympus Optical Company Limited, have made the internal chassis and focusing mechanism of the company's Series 5 Rigid Borescope in an all brass construction, giving a significant cost and performance advantage, helping them to produce an improved product at a competitive price.

Borescopes give visual access to remote areas and are used for inspecting all manner of plant and equipment, including amongst many others, jet engine turbine blades, heat exchanger tubes, printed circuit boards and pressure vessels.

Brass was initially chosen for the Series 5 because of its machinability, corrosion resistance and strength, but it has been found to have many other advantages. Brass machines considerably faster than stainless steel, the other major contender, giving cost savings of over two thirds on larger more complex component parts, such as the main chassis housing. The majority of components used in the Series 5 control mechanism are complex machined parts, but because brass causes minimal tool wear, the company can maintain the high degree of accuracy and repeatability required to produce a precision optical instrument.

The Series 5 has a number of bearing surfaces. Due to its inherent lubricity, brass on brass is used with only a minimal amount of grease. Previously aluminium was used, but this required a separate "oilite" bearing which added to the cost.

Thin walled brass tube is also used to separate the optical components. These ‘spacers’ having a formed surface, reduce reflections which would otherwise degrade the image quality. Brass sheet is also chemically milled to form precision optical apertures.

In summarising the benefits of using brass in this application, Ian Ross, Head of Research & Development at KeyMed, commented: "The use of brass has given us a strong precision chassis, good optical alignment and helped the ergonomics of the Series 5, giving it a very good balance in the hand. Even though machined components are now more complex, our costs have not increased".

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Tungum Hydraulics Ltd Tube and Fittings

The Tungum alloy tube is expected to serve for twenty years marine exposure on a Shell semi-submersible support vessel. The stainless steel section, from a southern North Sea gas platform in the Lima field, shows both crevice corrosion and chloride pitting after barely 5 years in the same environment.

Failure of stainless steel instruments and hydraulic tubing in these aggressive environments has necessitated replacements after only five years on platforms with a life expectancy of 20 years. This has had serious cost implications, not only in replacement materials, but in the higher labour costs involved in working offshore. An alternative material was sought and Tungum, BS designation CZ127, a high copper brass containing aluminium, nickel and silicon, was found to be the most cost-effective. Tungum has a high strength-to-weight ratio, good ductility, excellent corrosion resistance (especially to seawater in the 'splash zone'), excellent fatigue properties and is non-magnetic and non-sparking. In tube form it exhibits clean bore features making it ideal for hydraulic and pneumatic applications. Shell's Southern Business Unit Lowestoft now specify Tungum tubing on all new platforms and is replacing existing stainless steel during platform refits. Despite Tungum being initially more expensive to buy, life time costing shows it to be the most cost-effective material for tubing in the oil/gas/petrochemical industry.

Lifetime Cost
First costs plus servicing cost and costs of failure during component life.
Well-designed and specified components can be cheaper if they last their full-expected life than if designed only for lowest first cost.

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S & P Coil Products Ltd

Included in their extensive product range is a series of heat exchanger coils for cooling exhaust gases or for heat recovery in a "run around system". The product comprises of a bank of finned copper tubes through which flow a suitable refrigerant or coolant, while the gas to be cooled passes over their surface. The copper tubes are held in position by end plates 1.6mm thick which have holes of pre-determined pitch punched in them. The tubes are finally secured by locally expanding them to fill the end plate holes. The complete assembly is then electro-tinned to provide sacrificial corrosion protection.

For conventional applications the end plates are pre-galvanised mild steel strip and the tube fins are aluminium. However in harsh environments, typically with contaminated industrial air flows and swimming pool systems the electro-tinning soon flakes off, exposing the galvanising which breaks down causing the mild steel to corrode rapidly. In addition, the surface take-up of electro-tinning on galvanised steel is poor giving a blistered orange peel effect, and spoiling the general aesthetics of the product. Similarly the electro-tinning does not adhere to the aluminium tube fins and chlorine laden atmospheres typically found in swimming pools rapidly corrode the unprotected aluminium.

The company's engineers' solution to this problem was to replace the pre-galvanised mild steel with brass end plates, and when necessary the aluminium tube fins with copper. The whole assembly is then electro-tinned as normal giving a better bonded and much smoother surface finish on both the end plates and tube fins.

Although the brass end plates are 60% dearer, the final price of the assembly is typically only fractionally more expensive (4%) and the following benefits have been achieved. Firstly brass is well adapted to electro-tinning and although the tinning still flakes off it takes longer. Secondly the material exposed is brass which resists corrosion for longer than the galvanised mild steel. These combined give the product a life expectancy of three times the original thus saving on replacement and installation costs, which compensate for the small increase in the cost of the original unit many times over.

The better quality product, both technically and aesthetically has also led to increased sales.

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ERA Security Products Concealed Security Bolt

J E Reynolds & Co Ltd of Short Heath Willenhall West Midlands are well known manufacturers of quality security products marketed under the ERA brand name. Products, many of which conform to relevant British Standards and are frequently Which Magazine Best Buys include Mortice, Rim and Window Locks and Security Bolts. The company are continually striving for improved product performance without increased manufacturing costs. This was achieved recently by replacing the welded tubular steel housing of their concealed security bolts with brass.

A concealed security bolt is simply a round sliding bolt housed in a tube, the bolt is driven backwards and forwards by a splined key inserted in the tube which mates with a rack on it. The assembly is fitted into the edge of a door or window and is intended to replace or supplement existing locks and handles.

The original design called for a steel tube fixed to a end plate by firstly peening over the tube and brazing. The tube was machined and then finally painted. A number of problems were discovered: firstly the tube and end plate assembly had to go off site for brazing and this disrupted the flow within the manufacturing cell which had been set up for the product. Secondly the machining required a drilling operation on the tube and the break out of the drill was never clean leaving a "flap" on the bore. A number of techniques were tried to remove this but the usual effect was to force the flap back into the hole.

Consideration was given to replacing the steel tube with brass to overcome the manufacturing problems but brass tube was five times the price of the steel. Would it be cost effective? Trials confirmed the greater degree of formability of brass allowing the painted end plate to be secured without the need for brazing. Secondly the brass machined quicker which was expected, but an additional bonus was a clean break through on drilling, enabling all internal machining burrs to be simply removed by the reaming operation required to finally size the bore. External burrs on the key entry holes are removed by counter sinking which also provides a natural lead in for the key.

The above benefits meant the product lent itself to effective cell manufacture eliminating buffer stocks of assemblies which were being brazed off site. Production rates increased by over 300% (130 to 450 completed assemblies an hour) paying for the increased price of brass tube.

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Brass is Cost-effective

The close tolerance manufacturing processes of extrusion, drawing,cold rolling, hot and cold stamping, and casting ensure that near-net component preforms are readily available.

Brasses particularly leaded brasses are capable of being machined at very high speeds and feeds with very little tool wear.

A premium price is paid for brass swarf or scrap (clippings from stampings, sprues from castings etc.).

In normal atmospheres plating and painting is not required to prevent corrosion. However, if wear resistance or a decorative finish is required such as chromium plating, brass provides the ideal substrate. Most plated finishes are porous and the corrosion resistance of brass prevents the early onset of cracks, blisters, or eruptions of rust through the plating which can occur if steel is the substrate.

Brass is Recyclable

When brass is resmelted for recycling there is no loss of mechanical, electrical properties.

The infrastructure to collect and recycle brass has been in place for many years and is known to everyone and everyone is aware of the value of scrap brass. The majority of extruded brass is made from recycled material.