Section 2 – WHY MAKE IT IN BRASS ?

Brass is the best material from which to manufacture many components because of its unique combinations of properties. Good strength and ductility are combined with excellent corrosion resistance and superb machinability. Brasses set the standard by which the machinability of other materials is judged and are also available in a very wide variety of product forms and sizes to allow minimum machining to finished dimensions.

As rod or bar, brasses are readily available from manufacturers and stockists. For longer runs it is frequently worth considering the purchase of special sizes or extruded shapes designed to minimise subsequent production costs. Brass rod manufacturers are able to produce a very wide variety of shapes and sizes of product with minimum order quantities that are very low compared with many other materials.

Die costs for special extrusions can be inexpensive when spread over a long production run and hollow extrusions can save excessive boring operations.

The die costs for hot stampings are much less than for the die casting or injection moulding techniques used for some alternative materials. For special shapes, hot stampings can provide very economical feedstock. Manufacturers welcome discussions regarding optimum alloy, sizes and tolerances at an early stage in the design of components.

Brasses, having various combinations of strength and ductility, corrosion resistance, machinability, conductivity and many other attributes, are very widely used in the manufacture of components and finished goods. Alternative materials can be considered but it must be remembered that the main criteria to be assessed are those that affect the overall lifetime cost-effectiveness rather than first cost or raw material cost.

The basic price of brass may sometimes be higher than other alternatives, but that is only part of the overall cost picture. The availability of the brasses in precise preformed shapes such as extrusions, hot stampings and die castings, eliminates much of the machining costs required to produce finished components. This fact, combined with the considerable value of recycled offcuts and swarf, often results in items made from brass being cheaper than those in other apparently lower cost materials. Brasses also frequently offer better and longer service performance, avoiding consequential service and guarantee claims.

LIFETIME COSTING

For any product, the first cost is of importance but not necessarily paramount when fitness for purpose must be assured. Lifetime costing can be used within parameters set up in an organisation to monitor cost-effectiveness.

The costing of component production depends on many factors. Some to be considered are:

First Cost

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 ***Table 2***.

Lifetime Cost

First costs plus servicing costs 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.

Material Cost

Cost of metal mixture plus casting and fabrication costs, less the value of reclaimed process scrap.

COST-EFFECTIVENESS

There are many factors, sometimes overlooked, that contribute to the low costs of brass components:

- *Close tolerance manufacturing techniques can be employed so that finishing costs are minimal.*
- *Tooling costs may be significantly lower than for other materials or processes.*
- *Ease of machining means that production costs can be minimised.*
- *The good corrosion resistance of the brasses means that the cost of protective finishing is lower than for many other materials.*
- *In addition to these benefits, the high value of any process scrap can be used to reduce production costs significantly.*
- *The long service life normally expected of well-designed brass components means that the costs of service failures are minimal.*

This is only a part of the production cost of components. Careful consideration of material costs can reduce total costs. Rather than buy stock material, it is frequently worth paying more for special preforms that give more significant savings on production costs.

Economic Order Size

For wrought material stock, large orders can be placed with material manufacturers who are pleased to supply directly, and frequently make material that is specially designed to suit non-standard requirements agreed with the customer. Minimum order quantities depend on production considerations including optimum batch sizes and the programming requirements needed to meet any special orders.

Small quantities of materials are bought from stockists rather than materials manufacturers. This is because it is economical for manufacturers to make material in long runs of large quantities and distribute these to a variety of stockists in different areas. Stockists themselves have different specialities, many being able to offer cutting to size or other services as required.

The properties which lead to lifetime cost-effectiveness are:-

Availability in a wide range of forms

The hot and cold ductility of the brasses make them amenable to all the normal metalforming processes. They are also easily cast. From the range of compositions, standardised alloys can be selected for:

- *Extruded rods and sections (solid and hollow)*
- *Hot stampings and forgings*
- *Rolled plate, sheet, strip and cut circles*
- *Drawn tubes - round and shaped*
- *Drawn wire - round and shaped*
- *Castings - sand, shell, investment, gravity and pressure-die*

Strength

In the softened or annealed condition, the brasses are ductile and strong but, when hardened by cold working techniques such as rolling or drawing, their strength increases markedly. Strong, stiff structures can be assembled from sections which have been extruded and drawn. Bars, rolled sheet and plate can be fabricated into containers and other items of plant which operate under pressure.

The strength of brasses is substantially retained at temperatures up to around 200ºC and reduces by only about 30% at 300ºC, which compares favourably with many alternative materials.

The brasses are very suitable for use at cryogenic temperatures, since the mechanical properties are retained or slightly improved under these operating conditions. ***(see Figure 1).***

FIGURE 1 – Effect of temperature on properties of free-machining brass CW614N (CZ121)

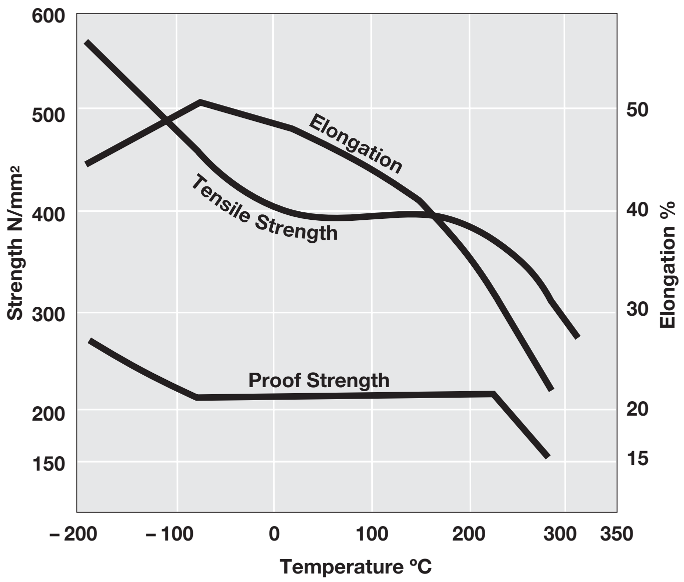


TABLE 2 – Comparison of first costs for heavy duty valve chests *(courtesy Meco International)*			
	High Tensile Brass	**Steel**	*The requirement is to produce a reliable, robust and safe valve chest for the operation of mine roof support hydraulic jacks. When made from steel the amount of pre-machining 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.* ***(See page 14)***
Design requirements sought			
Working pressure (bar)	350	350	
Non sparking for mining application	Yes	No	
Cost per component (£)			
Raw material	6.22	2.35	
Pre-machining	–	3.50	
Milling	–	2.50	
Finish machining	7.90	11.70	
Plating	–	1.41	
Total cost per component	**14.12**	**21.46**	

For applications demanding higher strengths the high tensile brasses are available. These contain additional alloying elements which further improve the properties.

Ductility and formability

Brasses with a copper content greater than 63% can be extensively deformed at room temperature, and are widely used for the manufacture of complex components by pressing, deep drawing, spinning and other cold forming processes. If the copper content is below 63% and no other alloying elements are present, the room temperature ductility is reduced, but such alloys can be extensively hot worked by rolling, extrusion, forging and stamping.

Machinability – the standard by which others are judged

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.

Corrosion resistance

Brasses have excellent resistance to corrosion that makes them a natural, economic first choice for many applications.

Atmospheric exposure of the brasses results in the development of a superficial tarnish film. Outdoor exposure will ultimately result in the formation of a thin protective green 'patina' which is frequently seen as a visually attractive feature in buildings, but the brass will remain essentially unaffected for an unlimited period of time, i.e. it will not rust away like iron and steel. Seawater can be handled successfully providing the correct alloy is chosen, and there is a long history of the use of brass tube and tube fittings, valves, etc. in domestic plumbing, central heating, seawater lines, steam condensers and desalination plant. High tensile brasses containing manganese have excellent resistance to atmospheric corrosion, continual exposure resulting in a gradual darkening of the bronze colour.

Conductivity

Brasses have good electrical and thermal conductivities and are markedly superior in this respect to ferrous alloys, nickel-based alloys and titanium. Their relatively high conductivity, combined with corrosion resistance, makes them an ideal choice for the manufacture of electrical equipment, both domestic and industrial. Condenser and heat exchanger tubing also require the good thermal conductivity of copper and its alloys *(see Table 26 on page 58)*.

Wear resistance

The presence of lead in brass has a lubricating effect that gives good low friction and low wear properties utilised in the plates, pinions and gears used in instruments and clocks. Special brasses are available with additions of manganese and silicon that make the material ideal for use in heavy duty bearings. The wear resistance arises due to the presence of manganese silicide particles.

Spark resistance

Brasses do not spark when struck and are approved for use in hazardous environments.

Attractive colour

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

Decorative or protective finishing is easily applied

Brasses may be polished to a high surface finish which can then be either easily repolished when required or lacquered to preserve the natural colour, enamelled or plated with chromium, nickel, tin, silver, gold, etc. as required. Alternatively, the surface can be toned to a range of colours, from 'bronze' through various shades of brown, to blue-black and black, using commercially available toning chemicals. These coloured finishes are frequently used for decorative and architectural metalwork.

All types of common plating processes may be used. For many other metals it is usual to use a copper plate underlayer. This is not required on brass because it is easily polished and does not need the expense of an initial copper strike. Cadmium plating of steel was traditionally used to give it corrosion protection when used against brass but, since cadmium is toxic, this has now been replaced by zinc.

Ease of joining

Brasses may readily be joined to other copper alloys or to other metals by most of the commercial joining processes such as riveting, soft soldering, silver brazing and friction welding. Modern adhesive joining practice can also be used.

Hygiene - control of MRSA contamination

Copper is well-known for its anti-bacterial properties and the copper content of the brasses has the beneficial effect of restricting the growth of micro-organisms. Tests at Southampton University have shown the superiority of copper alloys such as brasses compared to stainless steels in controlling harmful micro-organisms. These tests strongly indicate that the use of copper alloys in applications, including door knobs, push plates, fittings, fixtures and work surfaces, would considerably mitigate MRSA in hospitals and reduce the risk of cross-contamination between staff and patients in critical care areas. It has also been shown that copper alloys are effective in controlling *E.Coli* OH 157 and *Listeria monocytogenes*, both of which cause serious food poisoning.

LOW COST MANUFACTURING

Machining operations

To take greatest advantage of the excellent machinability of brasses, production techniques are optimised to give lowest component costs. There are some useful machining parameters such as tool geometry, speed, feed and depth of cut that give good guidance *(see Figure 2)*. These can be modified in the light of experience with equipment.

A good introduction to the principal recommendations for the machining of coppers and copper based alloys, including the brasses, is given in CDA TN44. Materials are divided into groups depending on ease of machinability. Group 1 includes the traditional free-machining brasses, whilst Group 2 mainly covers the lead-free alloys. None of the brasses considered falls into Group 3, which includes other copper alloys not so easily machined as brass.

The ease with which free-machining brass swarf clears from the tools means that a 0º back rake is used on turning tools and form tools. Tool wear is minimal for these materials and, when regrinding is eventually needed, the absence of back rake means that one less operation is required, giving a reduction of 20% in tooling costs.

The cutting speeds used for the improved free-machining brass may be up to double those established at present, that is up to 200 surface metres per minute (650ft/min). With older equipment it may not be possible to take advantage of this, but the benefits of improvement in tool life and reduction in failures are achieved.

The good corrosion resistance of brass allows the use of water-soluble cutting oils. The neat oils required for many alternative materials are not necessary. This can result in a saving of up to 70% in lubricant costs, giving improved cooling of both the bar stock and cutting tools, and also avoiding the problem of the noxious fumes from overheated mineral oils.

Free-machining brass gives a swarf consisting of small chips which clear from the tool very easily *(see page 14)*. This means that continual attention to swarf removal is not required and machine manning levels can be reduced, often by a factor of four. The fine swarf is also easy to collect and recycle.

Brass prices

The price of zinc is normally about half that of copper, although the relationship varies. Therefore the alloys containing the most zinc have the lowest basic metal cost. The higher zinc brasses also lend themselves to relatively cheap production routes compared with the higher copper alloys. As a result the 60/40 hot working brasses are the most frequently ordered for general purposes, while the 70/30 and 64/36 brasses tend to dominate the brass sheet, strip, tube and wire markets. The higher copper materials tend to be used only if there is a particular advantage.

Swarf value - recyclability

Careful consideration of design and feedstock can reduce swarf production but it is sometimes inevitable that large quantities of swarf are produced, up to 70% of the original weight on occasions. The brass industry is well organised and equipped to recycle this. Because of the ease with which clean swarf and offcuts can be recycled, it retains a high proportion of its initial value. It is possible for large users to be offered a firm buy-back price for swarf and other process scrap at the time stock is ordered, so facilitating accurate economical budgeting for lowest possible production costs.

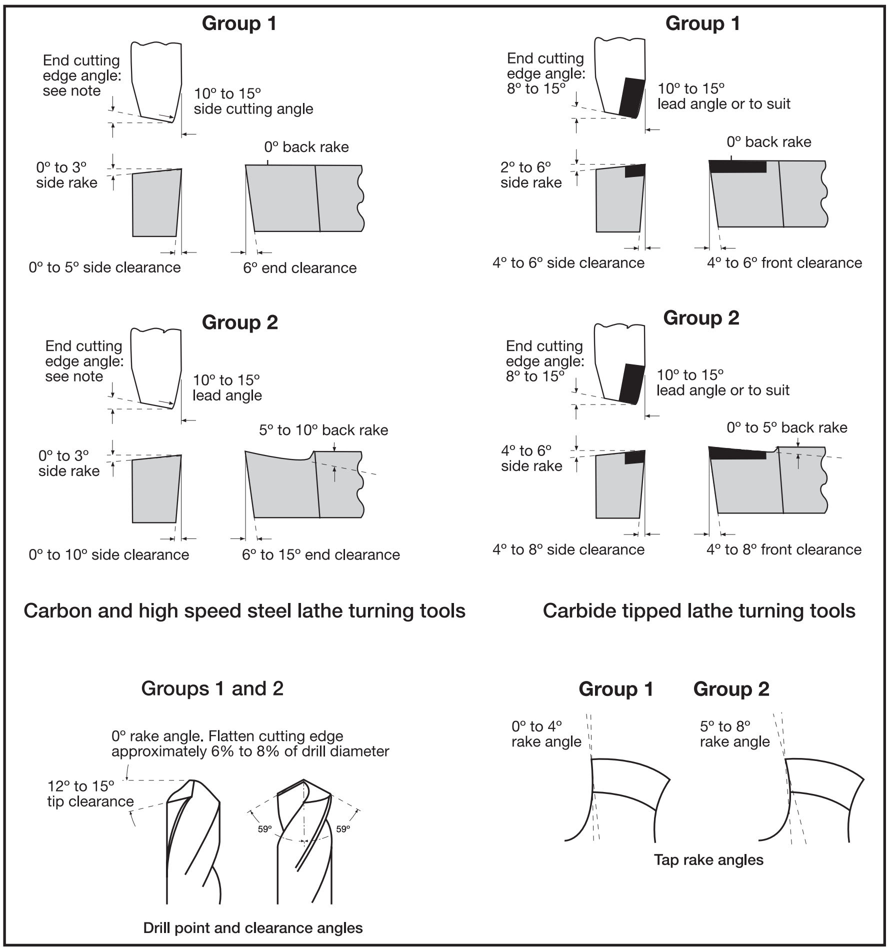
Use of profiles and hollow extrusions

As well as round rod, special shapes can be extruded to give a two-dimensional near-net-shape feedstock needing little further machining. Design of these profiles can be improved if there is good liaison between customer and fabricator regarding the most suitable geometry to suit both the end use requirement and the extrusion process. Hollow sections may also be specified in order to reduce the mass of metal to be removed in the manufacture of hollow components. Since the manufacture of hollow sections is more complicated than for solid material, there is an extra cost involved to be offset against the savings in machining costs.

Brass may be extruded over a mandrel to produce a hollow section. This is possible because of the lower friction of brass when compared with other materials which gall and wear the mandrel very quickly. For many other materials, hollows are produced by extrusion over a bridge die which splits the metal and then rewelds it at the die exit. By examination of the etched cross-section of extruded hollows it is normally possible to detect the joins in bridge-die extruded metal and this type of process is not recommended in specifications for materials requiring good integrity.

Although hollow extrusions cost more per unit weight than solid sections, this is frequently offset by the saving in drilling and reduction of swarf. Very small hollows may be uneconomic to produce and it must also be borne in mind that large, thin-walled hollows can be easily damaged. Broadly speaking, however, for the majority of sizes the advantages can be considerable. Using modern production techniques the eccentricity of hollows is minimal.

FIGURE 2 – Tool geometry for the machining of brasses in machinability groups 1 & 2



(Group 1 includes all the free-machining brasses, the others are in Group 2. For further details of recommended machining practice see CDA TN 44 'Machining of copper and its alloys').

Use of stampings

Where it is required to produce irregular shapes such as elbows, tees or more complex items, then the use of stampings (also known as hot forgings) as feedstock is an obvious economy in reducing both machining time and metal wastage. Stampings have the advantage of a strong, uniform wrought structure, similar in properties to extrusions.

The use of stampings is also economical for uniaxial products where it is possible to show cost savings over machining from solid. As a general rule, if the largest outside diameter is more than 25% greater than the smallest internal diameter the economics of using hollow stampings are likely to be favourable. Close liaison with the manufacturers of hot stampings can ensure that the blank design is suitable for both ease of forging and subsequent machining. Forging techniques, as with most other production methods, are improving with time and die costs are not as high as for many other processes.

Castings

Near-net-shape preforms can also be made by casting processes including sand, shell moulding, diecasting, continuous casting or precision casting depending on size of component, number required and accuracy requirements.

High-speed machining – the facts

Until recently there was no way in which the machinability of metals could be accurately compared. A standard ASTM test gives results for a given combination of typical machining operations. Tests carried out give the values in ***Table 3*** relative to high-speed machining brass having a nominal 100% machinability, whilst ***Table 5*** gives typical mechanical properties of a number of brasses and low alloy and stainless steels.

CORROSION RESISTANCE

One of the many virtues of the brasses is their general resistance to corrosion, required in combination with other properties for many applications. For terminations of all sorts, from electric cables to hydraulic pipelines, brass fittings are ideal because of their good performance in air and also in many working and process fluids. For aggressive environments, especially marine, there are special brasses listed in ***Tables 19 and 20*** such as the naval brasses, high tensile brasses and dezincification-resistant brass. For general purposes, however, the standard free-machining alloys are excellent.

In common with the other copper based alloys, the brasses have excellent resistance to normal atmospheric corrosion and this is one of the key properties vital in materials selection decisions. For this reason brass is the first choice material to give many years of satisfactory service for many common but critical applications such as electrical components, scientific and other accurate instruments, clocks, hose and pipe fittings, etc.

Protective oxide films

When exposed to a dry atmosphere, brasses gradually darken over a period of time, due to the slow formation of a tarnish film on their exposed surfaces. This film is mainly oxide, but in locations where sulphur pollution is present, a proportion will be sulphide.

This film eventually becomes stable and protective and no further oxidation occurs. It is very thin and smooth and does not normally interfere with the operation of moving parts, as does for instance rust on ferrous parts. For electrical applications it is also useful that the oxide film formed does not have the disadvantages of the non-conducting refractory oxide formed on aluminium.

If the atmosphere is damp, or if exposed to the weather, the familiar green patina consisting of basic oxides, hydroxides and carbonates will eventually form. Again, this is thin and protective, but is rougher and more powdery than the tarnish film formed in dry atmospheres. In a marine environment, a green patina of similar appearance develops but, in this case, also contains basic chlorides.

In contact with most potable waters, a protective oxide film develops, in which is normally incorporated some of the constituents of the water such as salts of calcium, magnesium and iron.

MACHINABILITY

TABLE 3 – Relative machinability ratings of various metals					
Material Description	**Designation**		**US Designation**	**Hardness**	**Machinability Rating**
	Old BS	**EN**		**HB**	**%**
Free-cutting mild steel	En1A	220M07	B1112	160	33
Plain low carbon steel	En3	070M26	C1025	143	22
Plain medium carbon steel	En8	080A40	C1040	205	20
High strength low alloy steel 1.5% NiCrMo	En24	817M40	A4340	210	17
High strength low alloy steel 2.5% NiCrMo	En25	826M31	6407	180	17
1% carbon, 1% Cr ballbearing steel	En31	535A99	E52100	206	10
Low carbon case hardening steel	En32	080M15	C1015	131	20
18/8 stainless steel	En58J	316	316	195	12
K-Monel	–	–	K500	240	12
Titanium alloy	–	–	A-70	188	10
Titanium alloy	–	–	C-130	255	6
Aluminium alloy	–	AA2017	2017-T	95	50
Free-cutting aluminium alloy	–	AA2011	2011	95	66
Aluminium bronze	CA104	CW307G	C63000	200	20
Aluminium silicon bronze	CA107	CW301G	C64400	180	60
Copper-chromium	CC101	CW105C	C18200	140	20
Copper-nickel	CN102	CW352H	C70600	90	20
Copper	C101	CW004A	C11000	50	20
Free-machining copper	C109 C111	CW118C CW114C	C14500 C14700	50 50	80 80
Forging brass	CZ122	CW617N	C37710	70	90
Free-cutting brass	CZ121	CW614N	C38500	70	100

Note: Machinability ratings (after Carboloy Systems Div) with high-speed machining brass rated at 100%. The higher the rating, the better the machinability.

A major machine shop with a wide experience of many materials has compiled a tabulation of actual metal removal rates under production conditions. Comparison is made with two aluminium alloys, one with a reasonable corrosion resistance (a), the other with better machinability (b), but with corrosion resistance inadequate for many applications ***(see Table 4).***

Following a series of in-depth comparisons of production techniques, a series of case histories has been established showing conclusively that, for the components considered, the finished cost is significantly less when they are made of brass than when machined from steel, even though the initial cost of the steel stock is lower than that of brass (***see pages 27 and 28).***

Figure 3 shows typical retail costs for brass and low alloy steel screwed rod (studding) for sizes from 6mm down to 2mm diameter. For the larger sizes, where the predominant cost is that of the material, then the steel is cheaper. Below 3mm diameter the low cost of machining brass to good tolerances and surface finish means that it gives a cheaper product, as well as having other advantages.

Stainless steel is more difficult to machine and can result in components being two to five times the cost of similar items made in brass.

TABLE 4 – Practical metal removal rates *(courtesy Hawke Cable Glands Ltd)*	
Alloy	**Metal Removal Rate cm³/min**
Brass CW609N (CZ121 Pb4)	133
Aluminium (a)	44
Aluminium (b)	80
Mild steel	36
Stainless steel (304)	6

FIGURE 3 – Comparison of costs of low alloy steel and brass studding

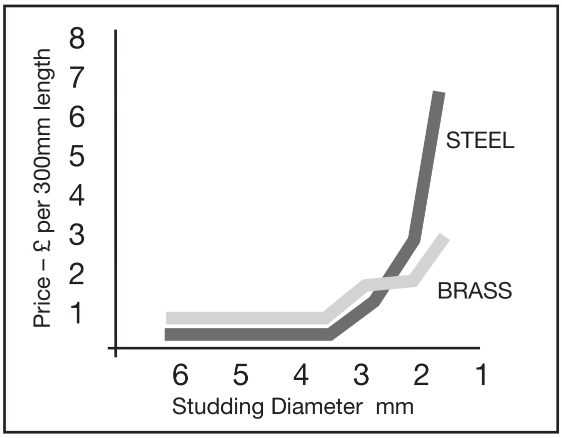
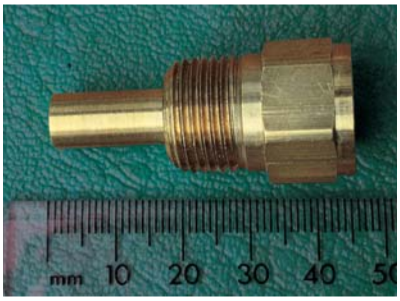


TABLE 5 – Comparison of typical mechanical properties of brasses, free-cutting mild steels and stainless steels					
Material	**Tensile Strength (N/mm²)**	**Yield Strength or 0.2% Proof Strength (N/mm²)**	**Elongation (%)**	**Hardness**	**Machinability Index %**
EN 12164 (BS 2874)					
CW614N (CZ121Pb3)	380-520	150-400	30-10	90-150 HV	100
CW617N (CZ122)	380-520	150-400	30-15	90-150 HV	90
CW603N (CZ124)	340-500	130-350	40-15	85-140 HV	97
CW608N (CZ128)	350-510	150-380	40-15	85-140 HV	80
BS 970					
220M07(EN 1A) Low Carbon, Unleaded, Free-Cutting					
Hot Rolled	360 Min	215 Min	22	–	–
Cold Drawn	355-465	355-465	10-7	–	33
230M07 Low Carbon, Unleaded, Free-Cutting					
Hot Rolled	360 Min	215 Min	22	103 HB	35
Cold Drawn	570-680	420-530	10-6	–	–
BS 4360 (Structural Steels)					
Grade 43C	430-580	275	22	–	–
BS 970 Austenitic Stainless Steels (Softened)					
304S11	480 Min	180 Min	40	183 HB Max	–
304S15	480 Min	195 Min	40	183 HB Max	–
204S31	490 Min	195 Min	40	183 HB Max	–
316S11	490 Min	190 Min	40	183 HB Max	12
316S13	490 Min	190 Min	40	183 HB Max	12
316S31	510 Min	205 Min	40	183 HB Max	12
316S33	510 Min	205 Min	40	183 HB Max	12
321S31	510 Min	200 Min	40	183 HB Max	–
303S31 (Free-machining grade)	510 Min	190 Min	40	183 HB Max	16
BS 970 Stainless Steels					
All Grades Cold Drawn (up to 45mm section)					
	650-865	310-695	18-12	–	–



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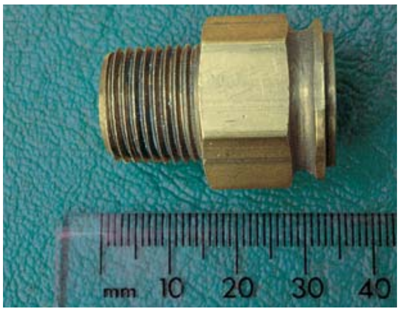
Brass is cheaper than steel

(see examples 1 – 5 below)



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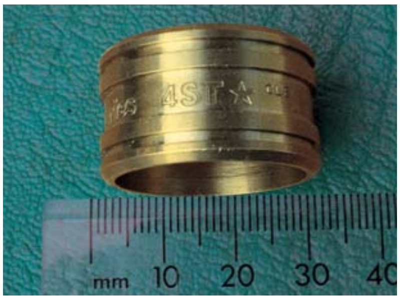
Component	**Fitting body**	**Manifold adapter**	**Air brake hose fitting**	**Actuating sleeve**	**Pneumatic hose fitting**	**Knob insert (knurled)**
Photograph	No 1	Not shown	No 2	No 3	No 4	No 5
Application	Underwater pump assembly	Automotive	Automotive	Pneumatic power	Aircraft	Garden equipment
Special features	Teflon coated	Better quality, cheaper	Safety-related	Deep hole	Productivity savings	
Part weight (g)	49	33	41	36	26	5.4
Brass premium (a)	23	30	36	17	42	32
Cycle time - brass (sec)	4.5	3.2	5.6	4.75	3.7	3.75
Cycle time - steel (sec)	8.0	5.9	9.1	8.4	8.3	5.5
Productivity gain using brass (%)	102	110	86	102	157	68
Cost saving gain using brass (£/1,000)	**3.92**	**0.58**	**33.98** (b)	**40.60** (c)	**25.08** (d)	**2.62**



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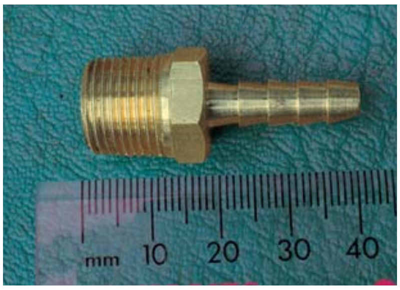

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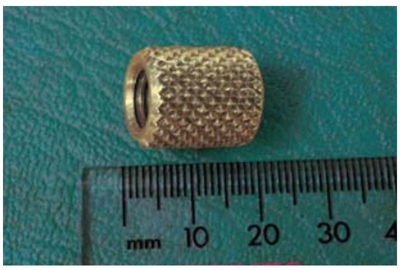

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Notes: Comparisons are between CW603N (CZ124) free-machining brass and leaded free-machining steel 12L14 and are based on multi-spindle auto production.

(a) Brass material cost premium includes scrap allowance.

(b) Brass v plated steel. For bare steel the saving is £26.26 per 1,000 parts.

(c) Brass v plated steel. For bare steel the saving is £33.58 per 1,000 parts.

(d) Brass v plated steel. For bare steel the saving is £20.09 per 1,000 parts.

Free-machining brass
This gives fine chips of swarf which minimise tool wear and the need for lubrication.

Cable glands for offshore platforms
These close-tolerance cable glands made from brass are 33% cheaper than those made from aluminium.

Brass is easier to machine, has a higher metal removal rate and causes less tool wear than the aluminium alloy needed to give adequate corrosion resistance for this application. One operator can supervise the machining of brass on six lathes at a time whereas aluminium gives a constant build up of swarf when machining and needs the supervision of one operator per machine.

Valve chests for mining equipment
Valve chests made from brass are 34% cheaper than those made from steel.

Good strength, ductility, corrosion resistance and spark-resistant properties, combined with ease of manufacture, make brass the ideal choice for use as the material for heavy duty valve chests used for controlling complex hydraulic roof-supporting equipment. The chests are made from a large, near-net-shape extrusion in high tensile brass which is relatively easy to machine and requires no protective plating. Previously, chests were made from steel which required extensive pre-machining from bar stock as well as plating for protection. The costings are shown on ***page 7***.

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