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Copper-nickel alloys, properties and applications

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Introduction

Copper, the most noble of the metals in common use, has excellent resistance to corrosion in the atmosphere and in fresh water. In seawater, the copper-nickel alloys have superior resistance to corrosion coupled with excellent anti-fouling properties.

Copper cladding of wooden hulled warships, introduced by the Royal Navy in the 18th Century to prevent damage by wood-boring insects and worms such as the teredo, was discovered to prevent biofouling by weed and molluscs. This meant that ships could stay at sea for long periods without cleaning. Nelson's successful blockade tactics and subsequent victory at Trafalgar were partly due to the superior speed of his clean-hulled ships.

The addition of nickel to copper improves its strength and durability and also the resistance to corrosion, erosion and cavitation in all natural waters including seawater and brackish, treated or polluted waters. The alloys also show excellent resistance to stress corrosion cracking and corrosion fatigue. The added advantage of resistance to biofouling gives a material ideal for application in marine and chemical environments for ship and boat hulls, desalination plants, heat exchange equipment, seawater and hydraulic pipelines, oil rigs and platforms, fish farming cages, seawater intake screens, etc.

The purpose of this publication is to discuss typical applications for copper-nickel alloys and the reasons for their selection. The two main alloys contain either 10 or 30% nickel, with iron and manganese additions as shown in Table 12, which lists typical international and national standards to which the materials may be ordered in wrought and cast forms.

Specifications, properties and availability

The copper-nickel alloys are single phased throughout the full range of compositions and many standard alloys exist within this range, usually with small additions of other elements for special purposes. The two most popular of the copper-rich alloys contain 10 or 30% of nickel. Some manganese is invariably present in the commercial alloys as a deoxidant and desulphurizer; it improves working characteristics and additionally contributes to corrosion resistance in seawater. Other elements which may be present singly or in combination are:

Iron, added (up to about 2%) to the alloys required for marine applications. It confers resistance to impingement attack by flowing seawater. The initial development of the optimum compositions of the copper-nickel-iron alloys in the 1930s has been described by G. L. Bailey (see bibliography). This work was to meet naval requirements for improved corrosion-resistant materials for tubes, condensers and other applications involving contact with seawater. Throughout the publication the term "copper-nickel" refers in fact to copper-nickel-iron alloys.

Chromium can be used to replace some of the iron content and at one per cent or more provides higher strength. It is used in a newly-developed 30% nickel casting alloy (IN-768).* A low-chromium 16% nickel wrought alloy (C72200)[†] has been developed in the USA.

Niobium can be used as a hardening element in cast versions of both the 10% and 30% nickel alloys (in place of chromium). It also improves weldability of the cast alloys.

Silicon improves the casting characteristics of the copper-nickel alloys and is used in conjunction with either chromium or niobium.

Tin confers an improved resistance to atmospheric tarnishing and at the 2% level is used with 9% nickel to produce the alloy C72500.[†] This has useful spring properties and is used in the electronics industry. It is not recommended for marine applications.

Impurities

Impurity elements such as lead, sulphur, carbon, phosphorus, etc. in the amounts to be found in commercial material have little or no effect on corrosion performance, but because of their influence on hot ductility may impair weldability and hot workability and are, therefore, carefully controlled.

Variations in the common national and international specifications for the 90/10 and 70/30 alloys are shown in Table 12. From this the extent to which various standard materials overlap may be compared. In some standards the impurities are more closely controlled than others but in all cases the material supplied will be fit for its designated purpose. However, the limits for some impurities (such as lead) in the specifications do not guarantee weldability by all techniques. In cases of doubt the supplier's advice should be obtained.

The forms in which the various standard compositions are available are shown in Table 1, which shows the common international (ISO), British (BS), Ministry of Defence, Navy (DGS), American (ASTM) and German (DIN) standards for wrought and cast forms. Future references in this publication to 90/10 and 70/30 copper-nickel alloys refer to the alloys normally containing iron and manganese as used in marine applications. When the 70/30 alloy is mentioned it should be borne in mind that in some circumstances it is preferable to use the alloy with 2% iron, 2% manganese (BS designation CN 108) rather than the alloy with lower iron and manganese (CN 107).

For information, Table 2 shows the common production limits on the sizes of these materials. This is a guide only. Material in these sizes will not always be in available stock. It may also be possible to make material outside these sizes by arrangement.

Provided foundry practice is good, satisfactory complex

*INCO designation.
[†]American Society for Testing & Materials (ASTM) Unified Numbering System designation.

Table 1 Applicable Standards for various Wrought and Cast Products

Standards	Applicable Standard Numbers								
	Composition	Plate	Sheet	Strip	Tube	Rod	Wire	Forgings	Castings
ISO	429	1634	1634	1634	1635 1636.2	1637 1639	1638	1640	
BS		2875	2870	2870	2871		2901*		1400[†]
DGS		8541C[‡]	8541C[‡]		8562F 271A	320A[‡]		320A[‡]	229
ASTM		122 171 402	122 402	122	111 359 466 467 469 552 543 608	122 151			369 505
DIN	17664	17670	17670	17670	17671 1755[§] 1785 86018[§]	17672		17673	17658

*Filler Wire for Welding. [†]To be included at next revision. [‡]70/30 alloy only. [§]90/10 alloy only.

castings can be made in these types of alloy. The 90/10 composition has a lower melting and pouring temperature than the 70/30 alloy. Normally for small castings, additions of some extra alloying elements are made for improved properties. The only official British specification is the Ministry of Defence DGS 229 covering a complex alloy containing additions of manganese, iron and aluminium (Trade name Hiduron 501).* The introduction of electric furnace melting in foundries has led to a greater interest in 70/30 alloys, in particular a chromium-containing INCO proprietary alloy (IN 768) which has exceptional resistance to impingement corrosion, making it ideal for heavy-duty pump and piping applications. Electric melting practice is desirable for attaining the correct melting temperature in reasonable time and to give a cleaner furnace atmosphere to avoid contamination and gas pick-up.

For security and other reasons the copper-nickel alloys used for a large percentage of the world's coinage requirements do not necessarily conform to any of the common specifications quoted. Generally, they do not include the iron, manganese or other significant additions. Since this is a very specialized application, the coinage alloys are not included in this publication.

*Langley Alloys Ltd designation.

A selection of cast 90/10 copper-nickel pipe fittings and flanges. (David Flanagan Ltd)

Table 2 Availability of Wrought Copper-Nickel Alloys.

The sizes below represent typical manufacturing capabilities. They are not necessarily available from stock, nor in every alloy. Larger sizes may be available on special order.

Form	Sizes
Plate	up to 3000 mm wide, 10 to 150 mm thick
Clad steel plate	to order only
Sheet & Strip	up to 1000 mm wide, 0.2 to 10 mm thick
Tubes - seamless	
Pipeline	8 to 420 mm OD 0.8 to 5.0 mm wall thickness
Condenser	8 to 35 mm OD 0.75 to 2.0 mm wall thickness
Coiled	6 to 22 mm OD 0.5 to 3 mm wall thickness
Tubes – longitudinally welded	270 to 1600 mm OD 2.0 to 10 mm wall thickness
Fabrications	by arrangement
Wire	all common wire and wire mesh sizes
Rod & Section	all common sections up to 180 mm diameter
Welding Consumables	all common sizes

A complex casting in the proprietary 70/30 type copper-nickel-chromium alloy IN 768 produced for the Ministry of Defence by the BNF Metals Technology Centre.

Table 3 90-10 copper-nickel-iron alloy. Mechanical properties. Typical values and ranges. Exact values vary with compositon, size and heat treatment.

Form	Condition	0.1 per cent proof stress		Tensile strength		Elongation on 5.65 $\sqrt{S_o}$ per cent	Hardness	Shear strength*	
		N/mm^2	$tonf/in^2$	N/mm^2	$tonf/in^2$		HV10	N/mm^2	$tonf/in^2$
Tube	Annealed	140	9	320	21	40	85	250	16
	Cold drawn (hard)	460	30	540	35	13	165	360	23
	Temper annealed	190-320	12-21	360-430	23-28	38-30	115-140	280-320	18-21
Plate	Annealed	120	8	320	21	42	85	250	16
	Hot rolled	140-190	9-12	340-360	22-23	40	95-105	260	17
Sheet	Annealed	120	8	320	21	42	85	250	16
	Hot rolled	180	12	360	23	40	105	260	17
	Cold rolled	380	25	420	27	12	125	290	19

*Double shear test

Table 4 70-30 copper-nickel-iron alloy. Mechanical properties. Typical values and ranges. Exact values vary with composition, size and heat treatment.

Form	Condition	0.1 per cent proof stress		Tensile strength		Elongation on $5.65 \sqrt{S_o}$	Hardness	Shear strength	
		N/mm^2	tonf/in^2	N/mm^2	tonf/in^2	per cent	HV 10	N/mm^2	tonf/in^2
Tube	Annealed	170	11	420	27	42	105	310	20
	Cold drawn (hard)	370-570	24-37	510-660	33-43	20-7	150-190	320-370	21-24
	Temper annealed	200-340	13-22	430-490	28-32	35-25	120-140	320--370	21-24
Plate	Annealed	150	10	390	25	42	95	290	19
	Hot rolled	170-200	11-13	400-430	26-28	40	105-120	310-320	20-21
Sheet	Annealed	150	10	390	25	42	95	290	19
	Hot rolled	200	13	430	28	40	120	320	21
	Cold rolled	430	28	500	32	16	140	350	23

The typical mechanical properties for the 90/10 and 70/30 alloys given in Tables 3 and 4 are taken from “The Copper-Nickel Alloys — Engineering Properties and Applications”, published by INCO Europe Ltd. Further data are included in that publication and also the appropriate CIDEC Data Sheets (see Bibliography). Material should normally be ordered to the appropriate minimum properties quoted in the ISO or national specification used.

Resistance to corrosion and biofouling

The 90/10 and 70/30 alloys have excellent resistance to seawater corrosion and biofouling with some variations in the performance of the alloys under different conditions as shown in Table 5 and Table 6, for instance, the 90/10 alloy has the better biofouling resistance. In Table 5 the corrosion resistance of the 90/10 and 70/30 alloys in heat exchangers and condensers is compared and in Table 6 the relative resistance of various alloys to fouling in quiet seawater. If water velocity is accelerated above 1 m/sec, any slight biofouling on metal with good fouling resistance will be easily detached and swept away. On a material that does not have this good fouling resistance, strongly adherent, marine organisms would continue to thrive and multiply.

The effect of water velocity on fouling and corrosion rates of various metals is shown in Fig. 1 which also shows the typical service design speeds for certain items of common equipment in contact with seawater. The excellent corrosion resistance of 70/30 and 90/10 copper nickel alloys and their suitability for many applications can be seen. Some materials with apparently better corrosion resistance may have disadvantages such as lack of resistance to biofouling, lack of availability in the forms required, or susceptibility to crevice corrosion. They may also be more expensive and therefore less cost-effective over the required service lifetime.

Crevice corrosion can occur in components in seawater when they are locally starved of oxygen at a joint or under attached biofouling. Table 7 shows the good tolerance of the copper-nickel alloys to this type of attack, giving these alloys advantages over other materials of equal corrosion resistance.

The copper-nickel alloys have good corrosion resistance in the quiescent or stagnant conditions which may occur during the commissioning or overhaul of plant. Where plant is not being used at design speeds some other materials may fail.

The corrosion resistance of the alloys is due to the protective surface film formed when in contact with water. On initial immersion cuprous oxide is formed but complex changes occur in seawater which research work is only now beginning to elucidate. At a flow rate of 0.6 m/s the equilibrium corrosion rate is an almost negligible 0.002 mm/year. Normally, design flow rates of up to 3.5 m/s give a satisfactory safety factor for use in pipework systems. This figure makes allowance for the fact that local speeds may be higher at changes of direction, points of divergence, etc. If water velocity is excessive, it can cause vortices leading to impingement attack which can cause premature failure. Where surfaces in contact with water allow smooth flow, as in ships’ hulls, different design criteria apply.

As mentioned, the fouling resistance is due to the copper ions at the surface, making it inhospitable to most marine organisms in slowly moving water. In static conditions there may be some deposition of chemical salts and biological slimes, possibly leading to some weakly adherent fouling, but such residues are easily detached from the metal's corrosion resistant surface, exposing a fresh, biocidally active surface.

When first brought into use, care must be taken to allow copper-nickel alloys to form their protective corrosion resistant surface freely. Normally, this protective film will develop in six to eight weeks. Contact with other less noble metals or with cathodic protection systems must be avoided to ensure development of the corrosion resistant surface film and the non-fouling properties.

Copper-nickel alloys do not suffer the stress-corrosion problems associated with some other materials.

Table 5 Comparison of corrosion behaviour of CuNi10Fe and CuNi30Fe in seawater (in heat exchanger service)

Environmental conditions	Type of corrosion	Service experience	
		CuNi10Fe	CuNi30Fe
(Waterside conditions)			
Clean seawater at velocities up to 1 m/s Clean seawater at velocities up to 3.5 m/s*	Uniform, general Impingement attack	0.0025-0.025 mm/a Satisfactory	0.0025-0.025 mm/a Satisfactory
Polluted seawater	Accelerated general and pitting	Less resistant	Preferred but not immune
Entrained sand in seawater	Accelerated general and erosion	Unsuitable, except in mild conditions	Use CuNi30Fe2Mn2
Accumulated deposits on surface	Local attack	Generally good	Tendency to pit
Hot spots due to local overheating	Local attack by denickelification	Good	Good but some failures in extreme conditions
Corrosion plus stress	Stress corrosion	Very resistant	Very resistant
(Vapour side conditions)			
Feedwater heaters working under cyclic conditions	Exfoliation attack	Resistant	Susceptible
Non-condensable gases†	Local attack and general thinning	Highly resistant	Most resistant
Hydrogen sulphide in desalination plant	General attack	Less resistant	Resistant‡

*Local velocities caused by obstructions can be very high.
†If concentration of CO_2 is extremely high, stainless steel may be a better choice. (INCO)
‡Attack may will increase in concentration or temperature.

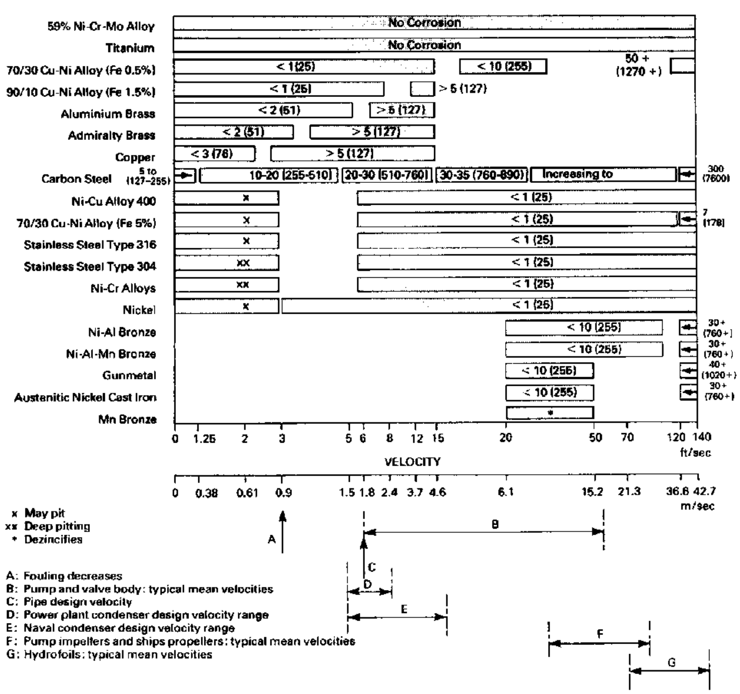


Figure 1 Corrosion rates of materials in flowing seawater. Approximate corrosion rates are given by the figures on the bars and expressed in units/hr (microns/yr). (INCO)

Table 6 Fouling resistance of various alloys in quiet seawater

Arbitrary Rating Scale of Fouling Resistance		Materials
90-100	Best	Copper 90/10 copper-nickel alloy
70-90	Good	Brass and bronze
50	Fair	70/30 copper-nickel alloy, aluminium bronzes, zinc
10	Very Slight	Nickel-copper alloy 400
0	Least	Carbon and low alloy steels, stainless steels, nickel-chromium-high molybdenum alloys Titanium

Above 1 m/s (about 3 ft/sec or 1.8 knots) most fouling organisms have increasing difficulty in attaching themselves and clinging to the surface unless already securely attached. (INCO)

Table 7 Tolerance for pitting under fouling and crevice corrosion conditions in seawater

Crevices can normally be tolerated in designs using these materials	Titanium Alloy C Alloy 625	These metals foul but rarely pit. Titanium will pit at temperatures above 120°C. Alloy 625 after 2-3 years show signs of incipient pitting in some tests in quiet seawater.
	90/10 copper-nickel (1.5 Fe) Admiralty Brass	Shallow to no pitting. 90/10 copper-nickel is standard seawater piping alloy.
	70/30 copper-nickel Copper Tin and aluminium bronzes Austenitic nickel cast iron	Good resistance to pitting. Useful in piping applications.
Useful although Cathodic protection required on critical surfaces	Nickel-copper alloy 400	Pits tend to be self-limiting in depth at about 1-6 mm. No protection required for heavy sections. Cathodic protection from steel or copper base alloys will prevent pitting on O Ring, valve seats, and similar critical surfaces.
	CN7M (Alloy 20) Alloy 825	Occasional deep pits will develop. Protection not normally required for all alloy 20 pumps. Cathodic protection from less noble alloys may be necessary for O Ring and similar critical surfaces.
	Type 316 Stainless Steel	Cathodic protection from zinc, aluminium, or steel is required except when part is frequently removed from seawater and thoroughly cleaned.
Crevices cannot be tolerated in designs (Excellent, however, in above-the-waterline marine applications)	Nickel	Many deep pits develop. Cathodic protection from less noble alloys required.
	Type 304 Stainless Steel	Many deep pits develop. Cathodic protection from steel may not be fully effective.
	Precipitation Hardening Grades of Stainless Steel	Many deep pits develop. Cathodic protection with zinc or aluminium may induce cracking from hydrogen.
Severe crevice corrosion limits usefulness	Type 303 Stainless Steel	Severe pitting. Cathodic protection may not be effective.
	Series 400 Stainless Steel	Severe pitting. Cathodic protection with zinc or aluminium may induce cracking from hydrogen.

(INCO)

Fabrication

Hot and cold working techniques may be used for the forming of wrought materials to required shapes though cold working is normally be to preferred. For the 90/10 alloy the hot working temperature range is from 900 down to about 800°C while for the 70/30 material it is from 950 down to about 850°C. If substantial working is required, it is always useful to consult the supplier for recommendations.

The maximum amount of cold work possible before an anneal is required may be up to 50% dependent on the material form and deformation process used. Tubes may be bent by the usual methods, with care being taken to produce smooth bends to assist non-turbulent liquid flow in service.

Stress corrosion is not a problem normally encountered with copper-nickel alloys but if after excessive cold work a stress relief heat treatment is required, a temperature of 300-400°C will suffice. For full annealing 700-800°C is needed for the 90/10 alloy and 750-850°C for the 70/30 alloy with time and temperature dependent on the extent of cold work in the alloy, the section thickness and annealed temper and grain size required. Oily residues must be removed before annealing in order to prevent the possible formation of carbonaceous films which can lead to pitting corrosion and enhance susceptibility to impingement attack in some service conditions, as is also the case with copper and other copper alloys. Most producers of the alloys are able to advise on their fabrication and use.

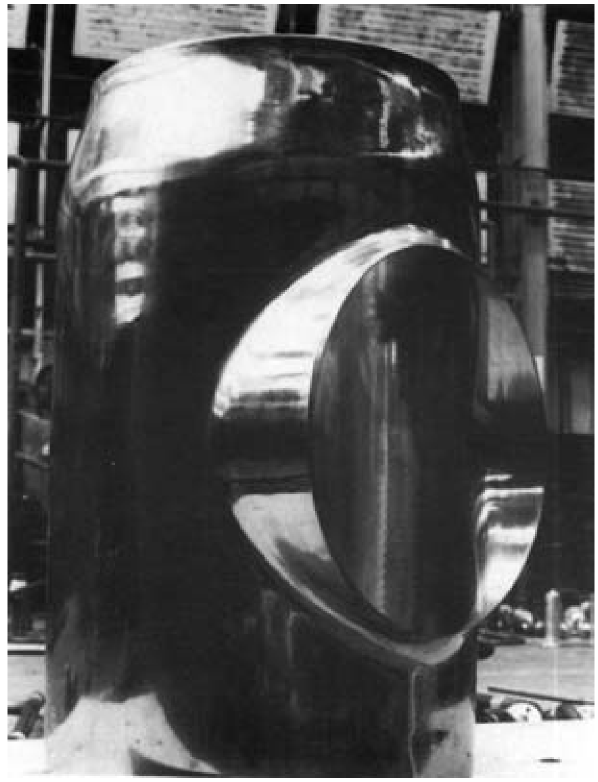
Machining

The machining properties of the copper-nickel alloys are similar to many other high-strength copper base alloys such as the aluminium bronzes, phosphor bronzes, nickel silvers and others without special free machining properties.

Recommendations are contained in CDA Technical Note 3; see the Bibliography.

Typical forged and machined components in 70/30 copper-nickel for use in seawater systems. Flange diameters are over 300 mm and piece-weights as forged from 28 to 184 kg.
(Doncaster Special Alloys Products Ltd)

A large forging weighing 6,550 kg in 70/30 copper nickel.
(N. C. Ashton Ltd)



An individual “T” piece for a piping system 500 × 406 × 406 mm fabricated from welded tubing by swaging.
(Vickers Shipbuilding & Engineering Ltd)

Illustrating the use of a variety of fabrication procedures. This 90/10 copper-nickel prefabricated pipework assembly shows swaged reducers, small radius bends and butt welds. Pipe sizes are from 75 to 200 mm nominal bore.
(Vickers Shipbuilding & Engineering Ltd)

90/10 and 70/30 materials in either wrought or cast form can generally be satisfactorily joined by conventional welding techniques for the assembly of fabricated components and structures (see Table 8). These materials can also be welded to a number of dissimilar metals when appropriate filler materials are used. In all such work, due attention should be paid to recommended techniques of joint preparation and welding in order to obtain best results (see references to appropriate literature).

Because of the susceptibility of the copper-nickel alloys to hot cracking in the presence of deleterious impurities (e.g., bismuth, lead, phosphorus, selenium, silicon and sulphur), commercial materials from reputable suppliers are supplied with the requisite low impurity levels. The alloys are also particularly susceptible to oxygen and hydrogen contamination from the atmosphere during welding. This can lead to weld metal porosity and precautions should be taken to avoid the problem by the use of adequate fluxing or gas shielding. When using the gas-shielded arc welding process it is, in all cases, necessary to use filler metals which have been developed for the applications, usually with a titanium addition as the major deoxidant. Recommended filler metals for the most used welding processes are shown in Tables 9 and 10.

In welding copper-nickel alloys to steel it is essential to avoid local changes in composition of weld metal which are “hot short” as depicted in Fig. 2. Careful control of the welding process is necessary. The higher the nickel content, the less is the iron penetration problem and it may be useful to vary the composition of the filler metal progressively with successive passes, i.e., to use high-nickel filler metal for the first deposition and to finish with the normal copper-nickel composition.

Choice of filler metals can also be influenced by corrosion potential considerations, with 70/30 type alloys being slightly more noble than 90/10. Further information and recommendations can be obtained from some of the references in the bibliography or by consultation with manufacturers of the materials or welding consumables.

The alloys can be soft soldered readily. This technique is not however normally employed because of the inadequacy of the joint strength in service conditions for which copper-nickel alloys are specified and problems of bimetallic corrosion which may arise in aggressive environments. Of the conventional brazing methods available, the use of high silver filler alloys is strongly recommended to minimize selective corrosion risks. Copper-phosphorus and copper-silver-phosphorus brazing alloys should not be used due to the possibility of intergranular penetration and consequent embrittlement. Heavily cold-worked material should be annealed before brazing to avoid excessive penetration and cracking of the parent metal by the brazing alloy.

Table 8 Suitability of Joining Processes for Copper-Nickel Alloys

Joining Process	90/10 & 70/30 alloys
Soldering	excellent
Capillary Brazing	excellent
Bronze welding	not recommended
Oxyacetylene welding	good
Gas shielded arc welding	excellent
Manual metal arc welding	good
Resistance welding	good
Cold Pressure Welding	fair
Friction welding	good
Induction welding	good
Electron beam welding	good

Producers of the alloys or welding materials should be consulted for detailed recommendations for good welding practice.

Table 9 Welding products and processes for copper-nickel alloys

Process	Welding product	
	Alloy to itself	Alloy to steel
Oxyacetylene	70/30 CuNi filler metal	Not recommended
Inert-gas shielded (TIG and MIG)	70/30 CuNi filler metal	65/35 NiCu for root 70/30 CuNi for cover
Metal-arc	70/30 CuNi flux coated welding electrode	65/30 CuNi flux coated welding electrode
Submerged-arc	70/30 CuNi filler metal with suitable flux	65/30 CuNi filler metal with suitable flux

Table 10 Typical composition ranges of weld metals for copper-nickel alloys

Filler metal type	BS Ref	Main alloying elements, weight per cent						
		Cu	Ni	Mn	Fe	Si max.	Ti	Al max.
90/10 CuNi bare filler wire	C 16*	Balance	10.0-12.0	0.5-1.0	1.5-1.8	0.1	0.20-0.50	0.03
70/30 CuNi flux-coated electrode	-	Balance	29 min.	1.0-2.5	0.4-0.75	0.5	0.5 max.	-
70/30 CuNi bare filler wire	C 18*	Balance	30-32	0.5-1.5	0.4-1.0	0.1	0.20-0.50	-
65/30 NiCu flux-coated electrode	-	Balance	60-68	4.0 max.	2.5 max.	1.0 max.	1.0 max.	0.75 max.
65/30 NiCu bare filler wire	NA 33†	Balance	62-69	3.0-4.0	2.5 max.	1.25 max.	1.5-3.0	1.25 max.

*BS 2901 Part 3
†BS 2901 Part 5

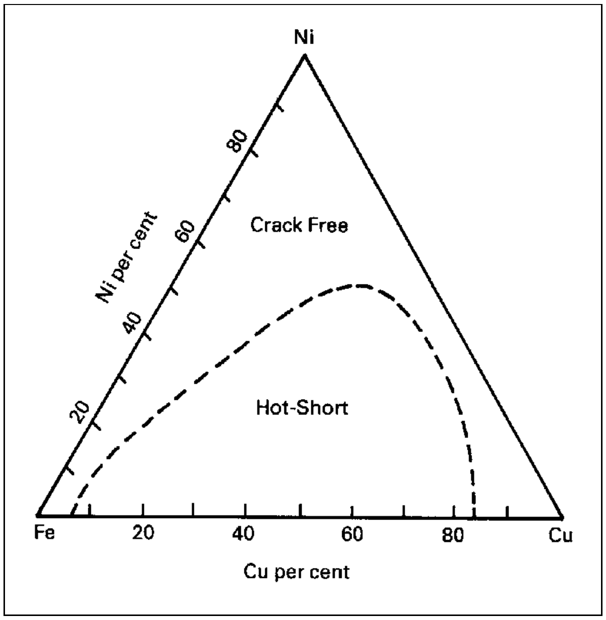


Figure 2 Cu-Ni-Fe diagram showing hot short areas

A welded 90/10 copper-nickel pipe 1420 mm outside diameter for use in the Dubai desalination plant brine recirculation system.
(Yorkshire Imperial Alloys)

Copper-nickel clad steel

For applications where for economic or engineering considerations solid copper-nickel is unsuitable, the use of copper-nickel clad steel should be considered. Loose lining, MIG spot welded linings and adhesive bonding have all been used successfully but for some applications a clad steel with a continuous metallurgical bond is the preferred product.

Clad plate can be produced either by hot roll bonding, explosive bonding or weld overlaying. The economic breakpoint for section thickness using these three routes is a matter for some conjecture but, as a rule of thumb, one would use solid plate up to 10 mm, above this roll bonded material up to 35 mm total thickness. Explosive bonding is common above 35 mm and weld overlay is the preferred method at thicknesses greater than 100 mm. Normally, the cladding thickness is 1.5 mm minimum, 2-3 mm is most common; heavier deposits are rarely encountered except as explosively bonded tube plates or weld overlayed components.

Irrespective of any economic factors, the use of clad plate, taking advantage of the higher strength of the steel base, can be a decisive factor in design if the fabricated components have to withstand heavy loads or high pressures.

Clad plate is available commercially in thickness from 6 mm upwards from several sources in Europe and suppliers should be contacted for precise details of available sizes. Large plates 13 m long by 3.5 m wide are available.

The bond strength of copper-nickel to the steel in roll bonded plate is good and if the material is supplied to ASTM B 162, a minimum shear stress of 137 N/mm^2 will be guaranteed.

A water box used to collect and distribute water from and to bundles of tubes in one stage of a desalination plant. Because of the turbulent water flow expected, the steel casing has been lined with copper-nickel sheet by spot welding.
(Portobello Fabricators Ltd)

Copper-nickel clad plate can be readily welded and, depending upon access from the steel or clad side, welding procedures are well established. Normally, to avoid embrittlement caused by copper penetration in to the steel, root runs are made with a 65% nickel-copper alloy which has a higher tolerance to iron dilution than copper-nickel alloys before cracking.

If copper-nickel has been selected because of its anti-fouling properties, then the capping layer on the weld should be 70/30 or 90/10 copper-nickel, as the 65% nickel-copper alloy is not resistant to biofouling.

Copper-nickel clad plate is a recently developed product and currently its main application is in water boxes and flash chambers in multistage flash desalination plants. It has, however, been used to construct a ship's hull, with no serious problems being encountered in fabricating this material under shipyard conditions. The overland section of seawater intake for a desalination plant in the Middle East has also utilized significant quantities of copper-nickel clad plate. The current and potential applications for copper-nickel clad plate in marine environments have been well reviewed by Moreton (see Bibliography).

For the use of linings in vessels and equipment for chemical processes, BS 5624: 1978 gives the appropriate code of practice.

Pipelines for handling seawater

All ships and most offshore structures need supplies of seawater for cooling purposes and many industrial installations such as power generation and desalination plants are situated adjacent to the sea for access to water for cooling purposes. Seawater piping systems are also installed for conveying ballast, tank cleaning water and steam and for emergency fire-fighting purposes.

Seawater is a complex mixture, containing any dissolved salts, suspended abrasive solids, gases both dissolved and as bubbles and organic matter and organisms, and its composition may vary widely depending on location and state of tidal flow. In estuarine locations the water may be brackish or polluted and will vary in composition according to the tide and season.

The types of problems encountered in pipeline materials include general corrosion in fresh seawater, impingement attack due to turbulent flow-round bends or obstacles, pitting corrosion caused by interaction with other material, crevice corrosion, in locations starved of oxygen and erosion caused by suspended solids. Piping systems should therefore be designed to be efficient and cost-effective throughout the projected life of the installation rather than simply for the cheapest first cost. Copper-nickel alloys are frequently the most economic to use due to their good resistance to corrosion and fouling over a range of flowing and static conditions.

Commonly regarded as one of the cheapest materials for pipelines in first cost, carbon steel may show a total life cost many times that of copper-nickel if it has to be replaced one or more times during equipment lifetime. Even on a comparison of initial installed costs, it may be more expensive if, due to the allowance for corrosion wastage, it has to be significantly thicker and hence heavier than copper-nickel.

Welding costs for the thin-gauge copper-nickel tube can be lower than for similar steel. Since the water-flow resistance of copper-nickel is initially lower than for steel (see Fig. 3), it is frequently possible for designs to use a smaller internal diameter with no need to allow for increases in surface roughness in service.

The use of inert materials for pipelines or organic linings inside pipelines may cause problems elsewhere in the system. While fouling may be limited at operating speeds, quiescent conditions may result in the attachment of organisms which will then continue to grow during subsequent operating seawater flow. Detachment of molluscs or other debris will then give the dangerous possibility of blockage of heat exchanger tubing or physical damage to pumps and valves.

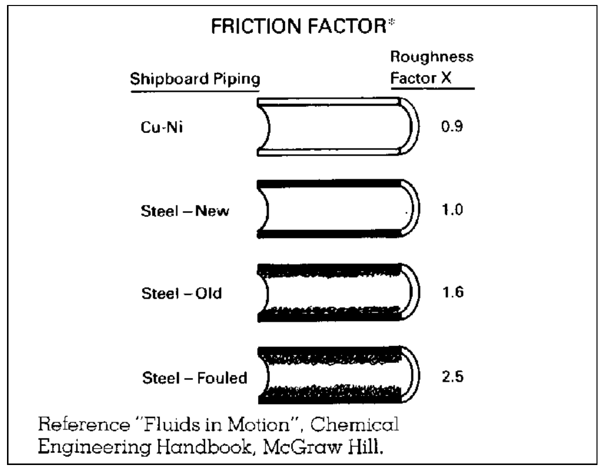
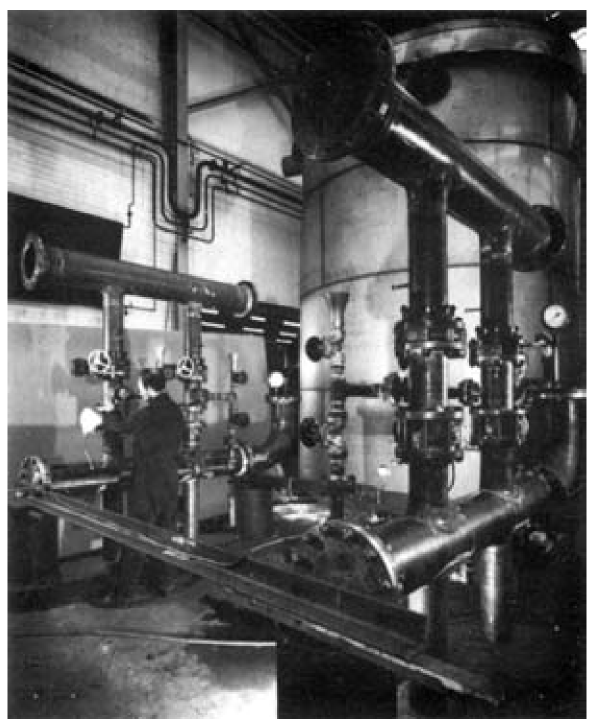
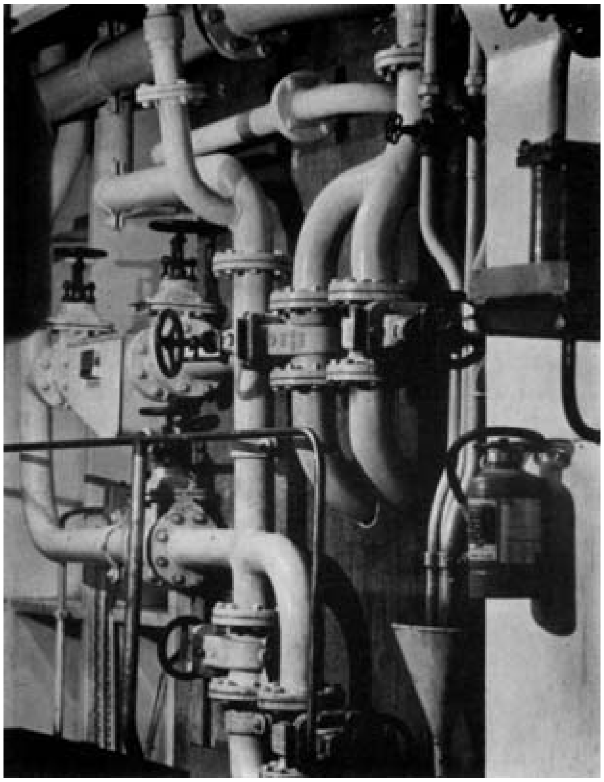


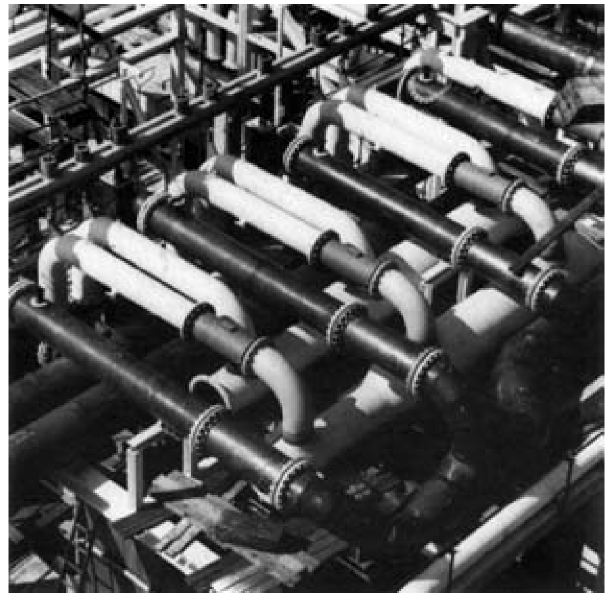
Figure 3 Roughness factors for copper-nickel alloys and steel.



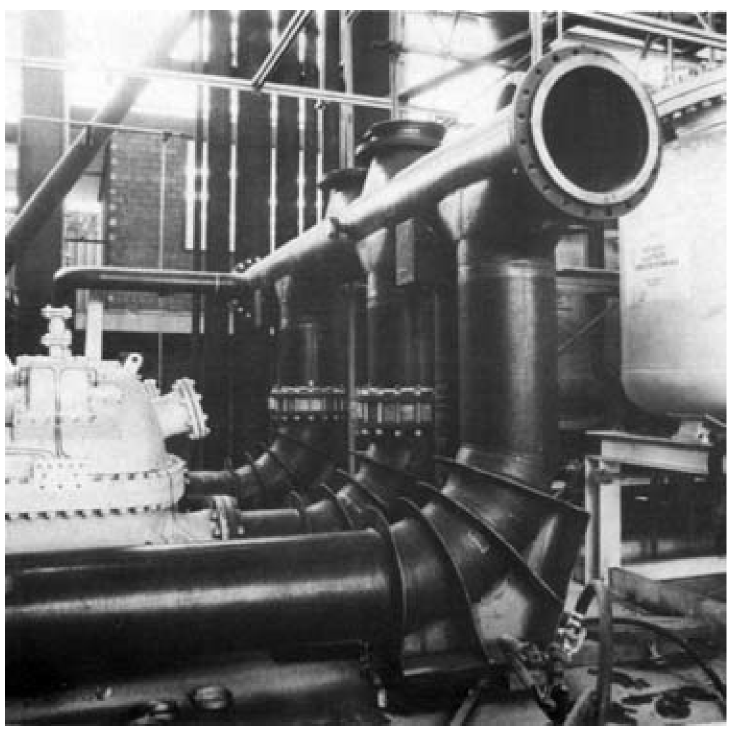
For the offshore oil industry this 90/10 copper-nickel emergency seawater deluge fire extinguishing system is fabricated from solid drawn tube and flanges cut from plate.
(G. Clark & Sons (Hull) Ltd)



90/10 copper-nickel seawater pipework in the engine room of the s.s. “Moreton Bay”, a 29,000 ton d.w.t. container ship built by Blom & Voss, Hamburg, and operated by Overseas Containers Ltd, London.
(INCO (Europe) Ltd.)



On the Elf TCP 2 offshore gas compression platform all seawater piping is in 90/10 copper-nickel.
(Yorkshire Imperial Alloys & Kvaerner Engineering, Norway)



Part of the fire-extinguishing water distribution system for a North Sea oil platform, all pipework and other components being made in 90/10 copper-nickel.
(Vereinigte Deutsche Metallwerke A.G.)

Condensers and heat exchangers

A variety of heat exchangers under construction. Tubes, tube plates and outer shells may be of copper-nickel alloy dependent on expected service condition.
(Motherwell Bridge Thermal Ltd)

Usually a heat exchanger consists of a set of tubes mounted between tube plates, with the whole assembly fitted into a shell which has provision for entry and exit of the gas or liquid to be heated or cooled. Where the tubes are internally cooled by water, then water boxes are needed outside each tube plate to act as distribution manifolds. The materials from which heat exchangers are constructed vary according to the service conditions expected. Where seawater cooling is to be used, then copper-nickel alloys may be the most suitable, especially for the most critical components, the tube.

The most important properties required from a material for condenser and heat exchanger tubing are:

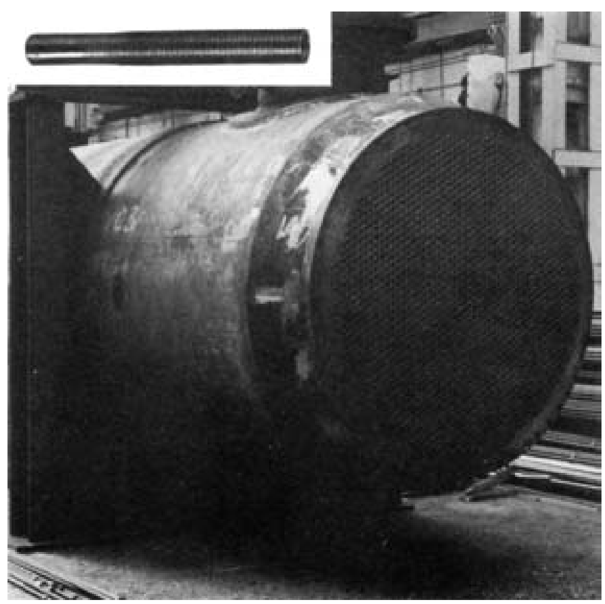
- Resistance to erosion and impingement attack in flowing seawater.
- Resistance to pitting in static seawater.
- Resistance to product-side corrosion, e.g., ammoniated condensate.
- Resistance to stress corrosion.
- Ease of production as tube.
- Reasonable strength and ductility.
- Good thermal conductivity.
- Resistance to marine biofouling.
- Galvanic compatibility with tube plate and water box materials.
- Resistance to crevice corrosion at tube plate joints.
- A total-life reliability and cost-effectiveness.

Of the materials in such service, many are copper-based alloys which meet most of the above criteria. One of the most common is aluminium brass which is widely used in moderate seawater cooling conditions.

Where even better corrosion resistance is required, 90/10 copper-nickel shows a greater margin of safety against various forms of corrosion such as impingement attack caused by the locally high water-flow rates around obstructive debris; it is also resistant to stress corrosion caused by ammonia. For many purposes it is preferred to the more expensive 70/30 copper-nickel alloy, although the latter may be preferable in polluted seawater despite slightly lower tolerances to pitting corrosion under deposits. The high iron, high manganese alloy CN 108 has a higher resistance to impingement attack and to some other harmful conditions existing in condensers and may be preferred to the conventional 70/30 copper nickel alloy CN 107.

For tube plates several copper-based alloys are used, including rolled 60/40 brass (Muntz metal) or Naval Brass, aluminium brass, aluminium bronze or copper-nickel alloys. Because of the strength required to support the tube bundle, these plates are comparatively thick and slight wastage due to corrosion can be tolerated. In very severe conditions the use of copper-nickel plate will be required. Similar conditions apply to the water boxes and outer shells. For some of these applications the use of clad plate may prove the most effective choice.

Where rates of heat transfer higher than normal are required, it is some times appropriate to use finned tubes which have a larger heat exchange surface per unit length than plain tubes. Tubing can be made with a variety of types and sizes of fin, both external and internal. In other circumstances, improved cost-efficiency may be achieved by the use of spirally corrugated (roped) or longitudinally fluted tubes.



Refrigerant condenser for liquified natural gas plant at Skikla, Algeria. For high heat transfer rates this was tubed with 90/10 copper nickel “Integron” low fin tubing (with insert close-up of Integron tube).
(Yorkshire Imperial Alloys)

Desalination plant

The simple distillation process for the production of pure water has been in use for many years. By evaporation of steam from heated water and collection of condensate under controlled conditions, a very pure product can be achieved. Modern plants have improved efficiency due to the employment of feedwater preheated by waste heat from other processes and by recovering some of the latent heat of evaporation of the steam.

Significant quantities of pure or potable water are needed in marine situations such as on board ships and oil rigs. For these, self contained packaged units are often installed with the ability to maintain output over long periods without the need for supervision and maintenance.

The “Movak” unit shown is a self-contained single-stage unit in a vertical shell. Hot fresh water from the diesel engine jacket is passed into a heater tube nest made of copper-nickel tubes designed to heat seawater with maximum heat transfer and minimum pressure drop. The generated vapour passes through a system of deflector plates and a demister baffle to prevent carry-over. In the evaporator the vessel, water boxes, tubes and pipework are all 90/10 copper-nickel, the tubeplates being naval brass. In the cooler the shell, end plates and tubes are all of 90/10 copper-nickel.

Two single-stage Movak Mk II water distillation plants for offshore oil rig “Maureen”.
(Caird & Rayner Ltd)

Multistage flash distillation plants

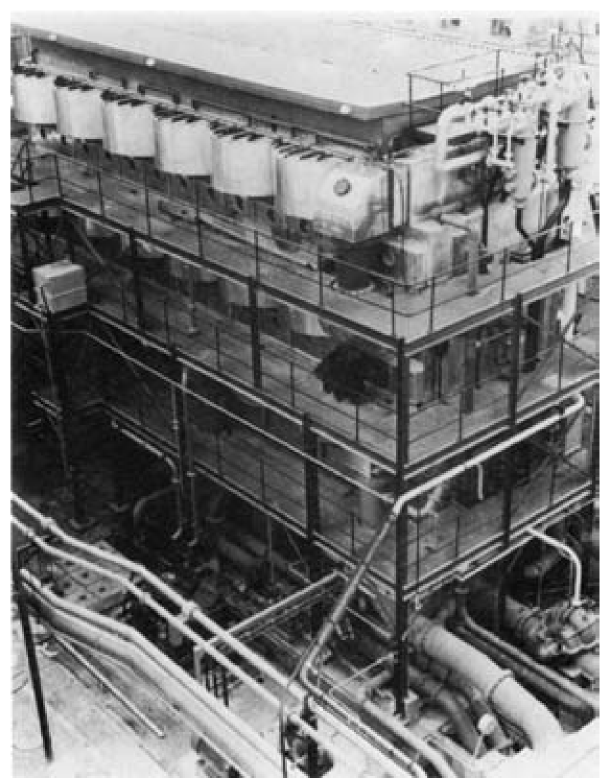
In larger distillation plants it is economic to design to recover a significant proportion of the latent heat of evaporation in multistage flash distillation plants, which were developed in 1957 by a team led by Dr R. Silver of the Weir Group of Glasgow.

Principles of flash distillation

Water can be made to boil just as effectively by reducing the pressure as by raising the temperature. In fact, if water and steam are together in a closed vessel, their temperature and pressure are so interrelated that any reduction in pressure will cause instantaneous boiling of some of the water, with the characteristic “flashing” effect.

A multistage flash distillation plant consists of a series of chambers, usually 20 or more, each operating at a lower pressure than the last. As heated brine flows from one chamber to the next, some of it flashes off into water vapour. This passes through moisture separators which remove any entrained droplets of brine, condenses on colder condenser tubes and drops as distillate into trays from which it is led away to storage.

The brine, in passing from chamber to chamber, becomes progressively cooler. Some of this brine is mixed with sea-water from the heat rejection stages and is then pumped back through the condenser tubes to act as the coolant in the condenser section of each chamber, becoming progressively hotter as it picks up the latent heat of condensation. Consequently, when it reaches the heat input section, and before reentering the first flash chamber, it needs to be raised in temperature only by the



One of the seawater distillation plants installed to use waste heat from the Malta Electricity Board Marsh “B” power station. Each plant can produce 1.22 million gallons of fresh water per day and is tubed with 90/10 copper-nickel in the brine heater and heat rejection sections.
(Yorkshire Imperial Alloys & Weir Westgarth Ltd)

few degrees necessary to allow the vapour released in the flash chamber to condense on the condenser tubes. The heat is normally supplied by low-pressure steam.

By this process purified water can be produced very economically, especially if the steam is supplied from the final stages of an integrated electric power generation plant.

Materials for flash distillation plants

Individual plants of 7.5 million gallons per day capacity are now feasible and several plants can be installed on one site if required. The impurity content of the water produced can be considerably lower than one part per million if so specified and controlled. Naturally, the selection of materials in the design of such plant is critical to its economic construction and efficient operation. The principal properties required are, of course, structural strength and corrosion resistance at the operating temperatures in steam, aerated and deaerated seawater and concentrated brine in the presence of any chemicals such as acids or polyphosphates added to reduce scaling. Aluminium brass, 90/10 and 70/30 copper-nickel alloys are satisfactorily and extensively used for this purpose. A typical large plant may contain 500 tons of these alloys compared with 650 tons of steel used for structural and non-critical applications and 75 tons of stainless steels.

The large numbers of components used in this type of installation can be seen from Fig. 4, which shows a schematic view of the distiller chamber and the external view and section of a typical single-deck multistage flash desalination plant. The wide variety of fabricated shapes needed for these assemblies can be appreciated. Besides the very large quantities of condenser tubing needed in the heat-exchanger sections, the tube plates themselves may also be made of copper-nickel as also are many other components. For the large water boxes and elbows, fabrications are made from copper-nickel or 90/10 clad steel plate. The chamber walls themselves are normally made of clad plate. For pumps and similar components cast copper-nickel components may be suitable.

Tube materials vary depending on location. In the heat reject section the preferred alloy is a 70/30 copper-nickel containing 2% iron and 2% manganese for best corrosion resistance with standard 70/30 or 90/10 alloys as alternatives. In the heat recovery section 90/10 copper-nickel and aluminium brass have both been used successfully. In the brine heater where periodic descaling is required, the 90/10 alloy may be used, though the 70/30 alloys (CN 107 or CN 108) may be better.

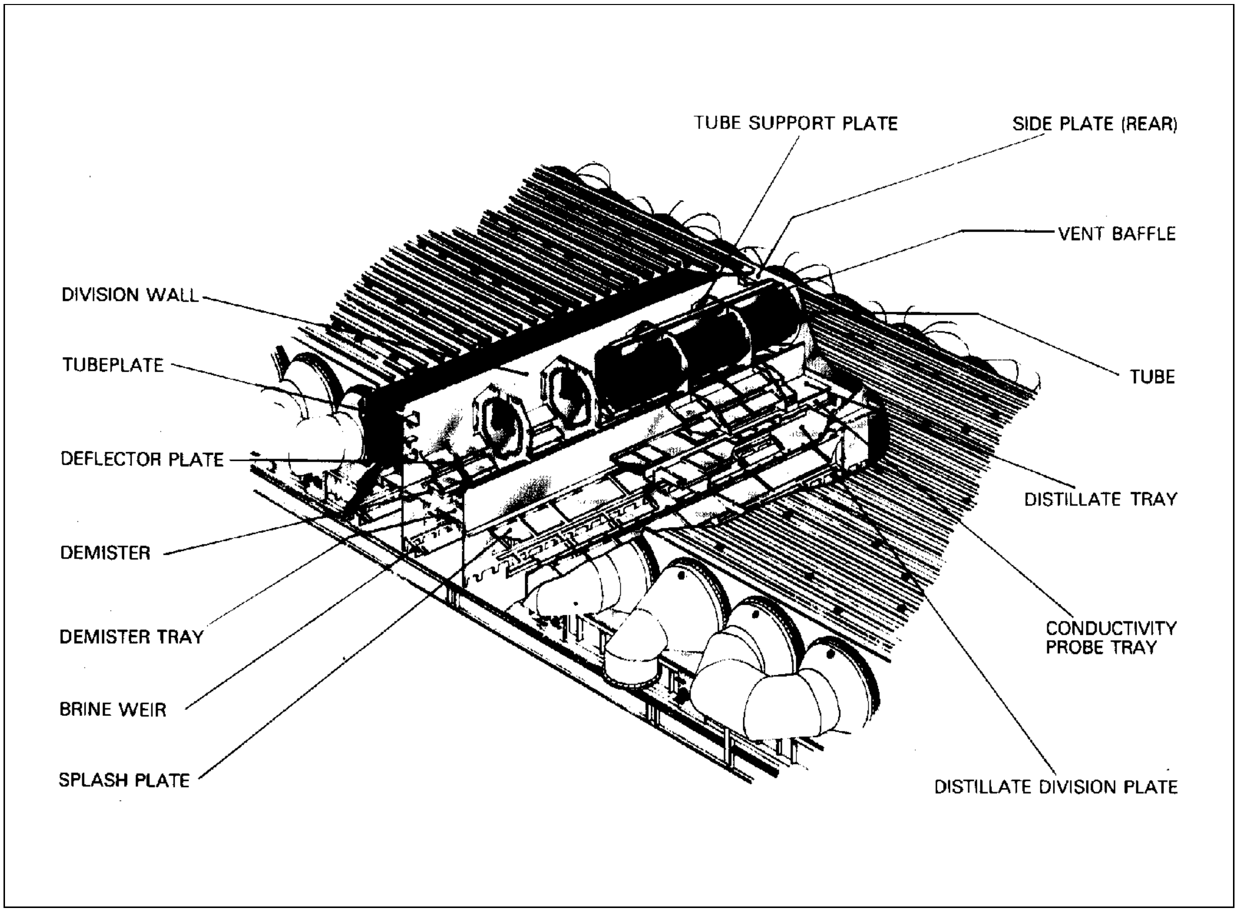
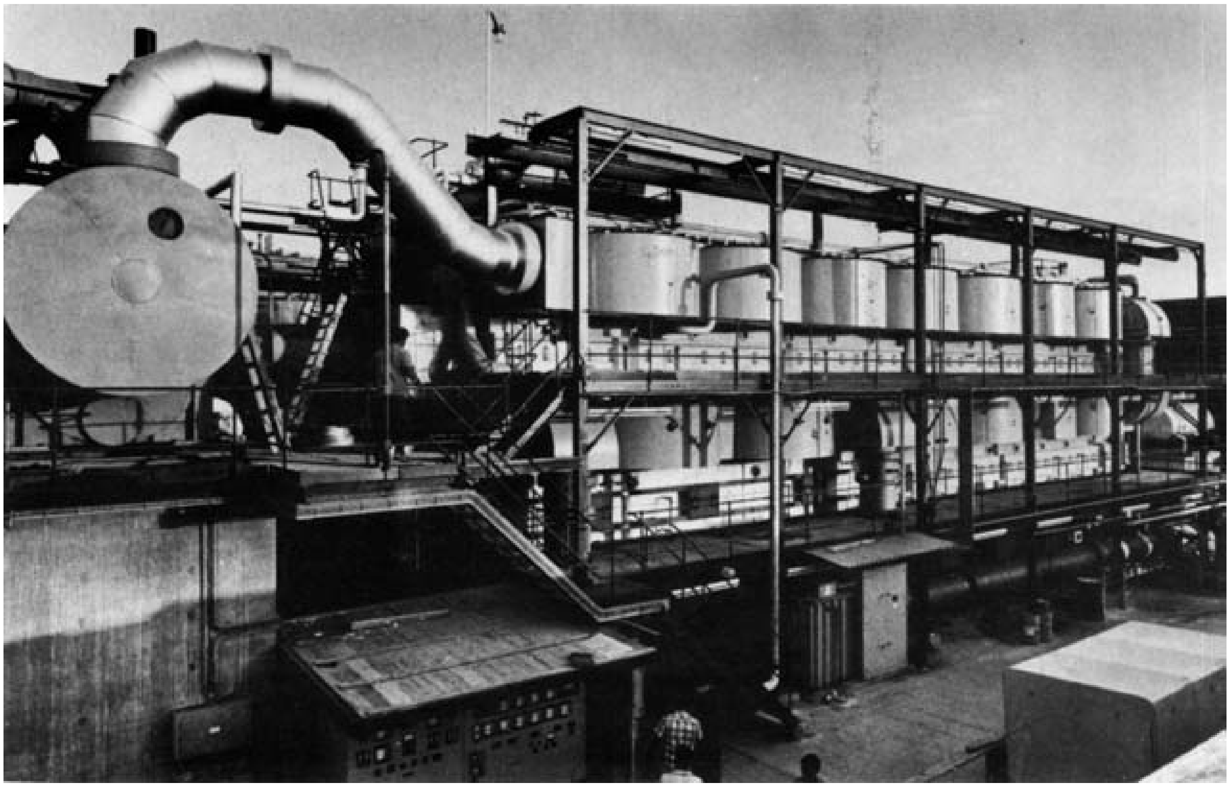
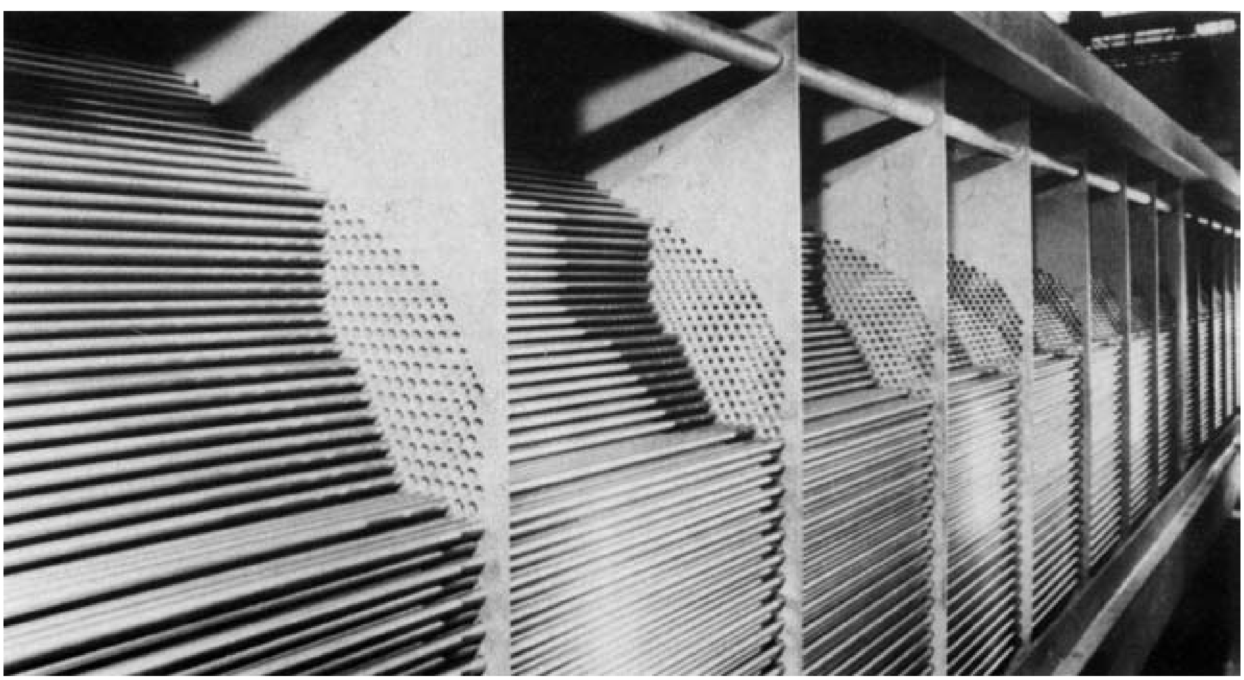


Figure 4 Section of single deck multistage flash desalination plant
(Weir Westgarth Ltd.)



One of six seawater distillation plants supplied to the Government of Abu Dhabi. Each can produce 2 million gallons of fresh water per day and is tubed with 90/10 copper nickel in the brine heater and heat rejection sections.
(Yorkshire Imperial Alloys & Weir Westgarth Ltd)



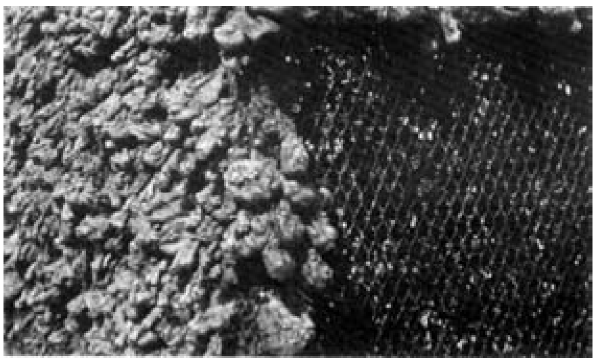
Section of a multistage flash evaporator of a 4 million gallons/day seawater desalination plant. Tube, sheet and plate all of 90/10 copper-nickel.
(Vereinigte Deutsche Metallwerke A. G.)

Seawater intakes

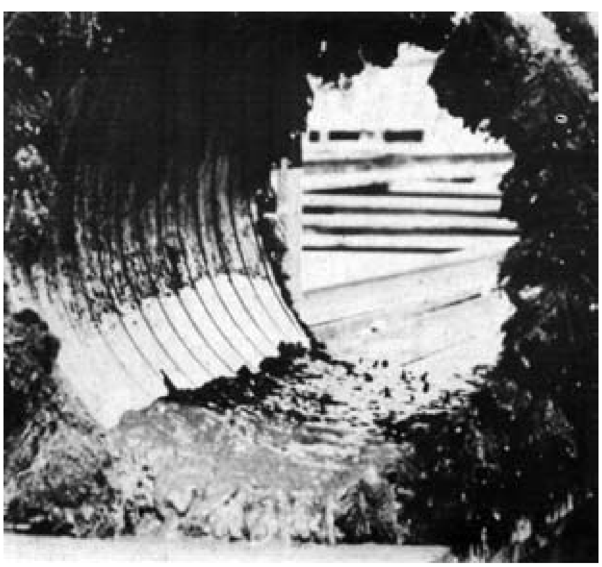
Seawater is frequently required in large quantities for cooling purposes. One of the problems associated with seawater intake in marine- or land-based installations is the occurrence of gross marine fouling of the entry. This may be of soft growth, barnacles or bivalves. Not only can this restrict the water flow but the marine fouling may be detached from time to time and cause blockages in heat exchangers or severe mechanical damage to pumps and valves.

Injection of chemicals such as chlorine can be effective against marine fouling organisms. However, additions must be closely controlled to be effective and even so, may have a detrimental effect on the installation and the environment near the outflow. Storage of bulk chlorine can also be hazardous. Adequate control is possible during steady-state running conditions, but this becomes difficult during downtime when flow ceases.

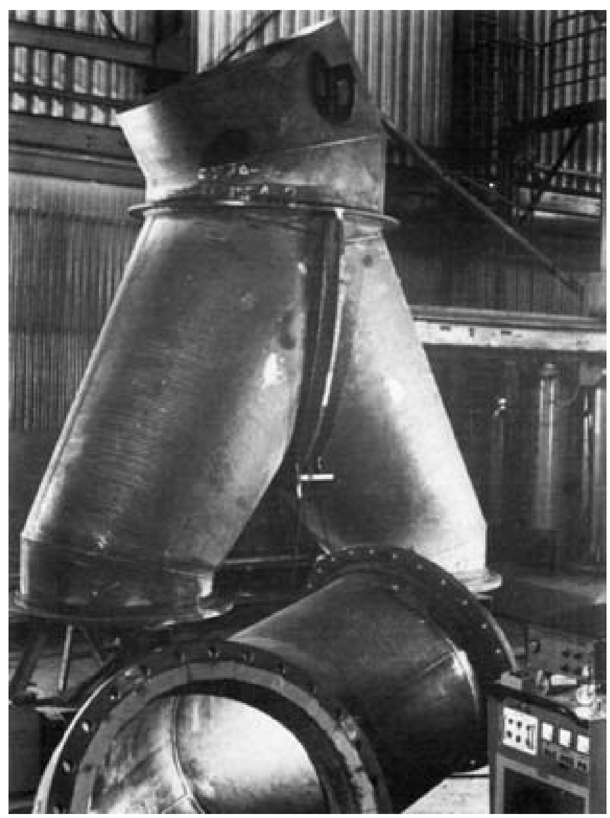
An alternative is to make intakes and intake screens of 90/10 copper-nickel which is resistant to fouling. The intake pipes themselves may be of copper-nickel, or large concrete piping may be internally lined either by casting the concrete round a formed pipe or by attaching sheet inside pipes by rivets or adhesive.



Comparison of zinc anode protected steel and 90/10 copper-nickel expanded metal pump intake screen material after 162 days' exposure (149 days' operation).
(INCO (Europe) Ltd)



Large diameter concrete intake pipe lined with copper-nickel. The outer concrete has fouled heavily while the inside has no growth attached, merely a slime which slips to the pipe bottom.
(INCO (Europe) Ltd)



For the overland section of a seawater intake pipe 10 mm thick, mild steel is intemally clad with 2 mm thick 90/10 copper-nickel. This illustration shows a Y junction prior to installation. The main tube is 1400 mm O.D. and each of the branches 1000 mm O.D.
(Vereinigte Deutsche Metallwerke A.G. & Carl Canzler Apparate—und Maschinebau)

Boat and ship hulls

As mentioned previously, copper sheet was in use for many years to protect the bottoms of wooden-hulled ships. Initially this was to prevent attack by boring organisms such as the Teredo worm. The lack of fouling by sea weeds and barnacles was a side effect very soon appreciated. However, once iron or steel was in use it became impossible to use copper sheathing because of the lack of technology to prevent accelerated corrosion of the steel in the vicinity of the more noble metal.

With steel hulls it has been accepted that, after the deterioration of anti-fouling paint coatings, fouling will occur at a rate dependent on the conditions to which the hull is exposed both at sea and in harbour. The build-up of fouling causes higher drag, resulting in a lower speed through the water and higher fuel consumption. When this becomes economically unacceptable the ship is taken out of service for expensive cleaning and repainting.

During the mechanical cleaning the fouling is detached, leaving the surface of the steel hull corroded and roughened by pitting. Even though the surface is repainted it will not be possible to regain the initial smoothness and there remains some penalty in the economics of propulsion. After repeated treatments the steel surface may be so rough as to prevent the economic running of the ship and may materially affect the decision to scrap the vessel before the hull thickness is reduced to a safety-critical value.

Many anti-fouling treatments are available including paints, the best of which all include a proportion of copper which is slowly released as a biocide. Naturally, such coatings have a finite life and can only extend the periods between dry docking rather than avoid the need for them. While the fouling resistance of the copper-nickel alloys has been known for years, their use has been restricted by their initial cost which is higher than that of steel. Now that the cost of all forms of energy has risen, the total-life economics of the use of fouling-resistant alloys has become more attractive. Fuel savings and elimination of the loss of revenue during dry docking can now give payback periods as short as 32 years.

During the construction and operation of various types of hulls, the best techniques of construction have been evaluated as well as the operating costs. With the techniques of joining these alloys autogenously and to other metals such as steel now well established, the expansion of this market is continuing.

A classic comparison of the economics of copper-nickel and steel hulls was started in 1971 with the construction of the shrimping boat “Copper Mariner” alongside sister ships built in steel. Without the need for a great change in fabrication technology or the rules of construction, 90/10 copper nickel plates were built on to conventional steel framing.

Close monitoring of the operation of these vessels has shown that the steel hulled boats need to be taken out of the water for cleaning every six months, whilst fouling of the copper-nickel hull is minimal. Initial fuel savings were about 15%. This figure grew to nearly 50% when compared with a fouled steel hulled boat due for cleaning. After four years the steel hulls were so far corroded as to need significant replacement of plating.

Some other applications are shown in Table 11, where it can be seen that the majority of applications have been for relatively small vessels. These never exceed a speed of about 8 knots, about 4 m/sec, which happens to be close to the limiting water speed recommended for tubular heat exchangers.

Comparison of fouling of copper-nickel hull of “Copper Mariner” with steel hull of sister ship “Jinotega”.
(INCO (Europe) Ltd)

However, the water flow conditions around a ship’s hull are clearly quite different from those in heat-exchanger tubing. It was believed that for the conditions under which ships’ hulls operate, far higher water speeds could be tolerated. To assess this under severe conditions, the rudder of a very large container ship (VLCC) “Great Land” was covered with 90/10 sheet spot welded to the steel substrate. Operating at speeds of 24 knots the ship operates regularly in waters with a high propensity to fouling and also with the abrasion caused by ice in Alaskan seas. The rudder is also subject to severe turbulence caused by the ship’s propeller. Trials showed that fouling and corrosion resistance was maintained under these conditions.

For hulls built with 90/10 copper-nickel plate it is essential to give some protection against corrosion to the dissimilar-metal joint made to the framing within the hull. Whilst these techniques are established and effective, the need for them is eliminated with the use of 90/10 copper-nickel clad steel plate. As described previously, techniques for joining these bimetal plates have been developed and have been approved by insurers. They are described in some of the references given in the Bibliography.

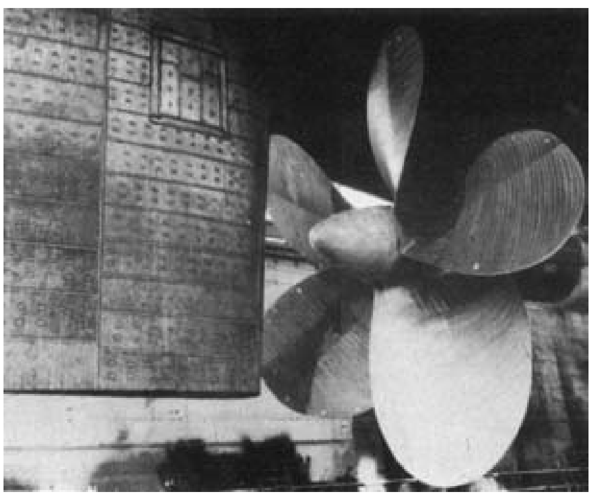
Fouling problems are of course also encountered in yachts, pleasure craft and workboats built of fibreglass. Normally these have to be repainted at intervals with antifouling paint at and below the waterline. Not only is this expensive but it can also be detrimental to the life of the fibreglass if the etch-primer used softens the gel coat sufficiently to permit water entry by osmosis. If an initial gel coat loaded with copper-nickel powder (Scott Bader Crystic Copper-clad) is used in the construction of the hull, the need for other anti-fouling treatments is eliminated.

A retrofit option being developed for existing or new boats is that of copper-nickel foil adhesively bonded to the hull. Using a modern adhesive the bond is good and the narrow width of strip used ensures easy conformity to hull curvatures.

Table 11 Some applications of copper-nickel alloys for ships' hulls

Vessel	Date launched	Built	Hull thickness (mm)	Operating area	Length (m)	Remarks
"Asperida II" ketch	1968	Holland	4	USA	16	Corrosion rate less than 0.01 mm/yr
"Copper Mariner" - shrimping boat	1971	Mexico	6	Nicaragua	22	Steel-built sister boat requires hull repaint every 6-8 months. Payback period 6½ yrs. (not inflation-adjusted)
"Pink" class fishing boats (4)	1975	Mexico	4	Sri Lanka	17	Satisfactory
"Copper Mariner II" shrimping boat	1977	Mexico	6 steel +2 Cu/Ni clad plate	Nicaragua	25	Satisfactory
"Sieglinde Marie" sailing/motor cruiser	1978	UK	6	UK & Caribbean	21	Satisfactory
"Great Land" VLCC		US		Pacific to Alaska	240	Trial rudder sheathing only – satisfactory at high speed.

(This list represents only a sample of the craft constructed.)



The rudder of the VLCC "Great Land" successfully clad with 90/10 copper-nickel.
(INCO (Europe) Ltd)

Offshore structures

Oil drilling platforms are extremely expensive structures which require a great deal of inspection and maintenance if they are to remain in a safe condition. Initially it was not thought that fouling would be a great problem and few precautions were taken against it. However, two problems have become apparent. Although the rigs are normally stationary there can be a considerable tidal flow of water past them and this can be greatly increased under storm conditions. In some waters fouling has been found to be very extensive, especially around the tidal splash zone and this can increase the drag sufficiently to affect rig stability.

The pounding of wind and sea on these rigs causes high alternating stresses which can initiate failures in structural members and it is therefore essential to maintain a regular program of inspection on legs, bracing struts and the nodes that join them. Only after fouling has been removed can inspection for excessive corrosion or cracks be undertaken.

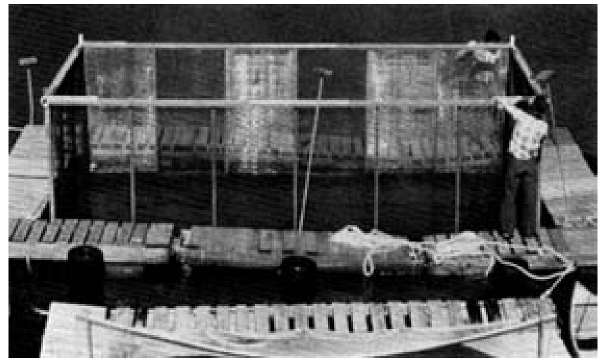
Conventional anti-fouling paints may be applied during rig construction but they have a limited life, which can be as short as 18 months. After this they cannot be renewed by conventional dry-docking procedures.

Periodic repainting of the accessible splash zone may preserve the upper parts of the rig legs but this is an extremely expensive undertaking which is not always successful. The lower part of the splash zone is not usually accessible for repainting due to very infrequent calm low tides. Current practice is to add 12 to 16 mm extra to the plate thickness as a corrosion allowance for a reasonable life.

An offshore oil rig weighing 18,000 tons being towed out for service in the severe marine environment of seawater corrosion and biofouling. To achieve a 20-year life, the steel plate thickness is increased by a 12 mm corrosion allowance. Cleaning and repainting of the splash zone can cost £1 million each time and be required at one- to three-year intervals. Initial construction using steel plate clad with 90/10 copper-nickel alleviates these problems considerably.

Very high corrosion rates have been encountered with steel riser pipes, due to the higher operating temperature caused by hot oil. Cladding of these with 70/30 nickel-copper alloy has been proved successful, but there has so far been only limited experience with this material for cladding of jacket legs, where it would suffer pitting under marine fouling that would become attached at ambient temperatures.

Given the known corrosion and biofouling resistance of 90/10 copper-nickel alloy, it is to be expected that this will be an ideal material for leg cladding, particularly if suitable precautions can be taken to avoid the loss of fouling resistance caused by cathodic protection due to contact with adjacent steel or sacrificial anodes.



Used as expanded mesh made from 0.8 mm thick 90/10 sheet, 90/10 copper-nickel is an ideal material for fish cages.
(INCRA)

Fish farming

With the steady depletion of natural resources of finned- and shell-fish, it is becoming more economic to rear many commercial species of fish in cages suspended in seawater. These cages have open mesh sides to allow free flow of water through them, bringing nutrient and oxygen and assisting the removal of feces and other detritus.

Most cages are made of net and nylon mesh, which despite anti-fouling coatings, becomes restricted by growths of molluscs and weed and this requires frequent cleaning and maintenance.

Following extensive trials, it has been shown that the use of mesh made from 90/10 copper-nickel completely overcomes the fouling problem. Not only does the use of this metal obviate the need for frequent maintenance, but it is more resistant to storm and predator damage which can result in the disastrous loss of fish from the cage. Other advantages of copper-nickel mesh for the fish farmer are improved growth rates and higher stocking densities as well as a cage suitable for use at more exposed sites.

While woven wire mesh can be used, the mesh is also made from expanded sheet metal. The mesh opening is chosen to suit the fish size and water conditions. As an example, for salmon a 9 mm mesh is used with a 76% open area to allow easy water flow.

While the biocidal properties of the 90/10 copper-nickel alloy surface help to prevent fouling, there is no extra uptake or accumulation of copper by the fish. They are as palatable as those grown naturally and appear to grow more rapidly than fish reared in cages of other material. Further details of these advantages are found in the literature quoted.

The excellent biofouling and corrosion resistance of 90/10 copper-nickel mesh coupled with its mechanical strength and low resistance to water flow make it an ideal material for the large-scale development of underwater pens and enclosures, thus adding a new dimension to fish farming.

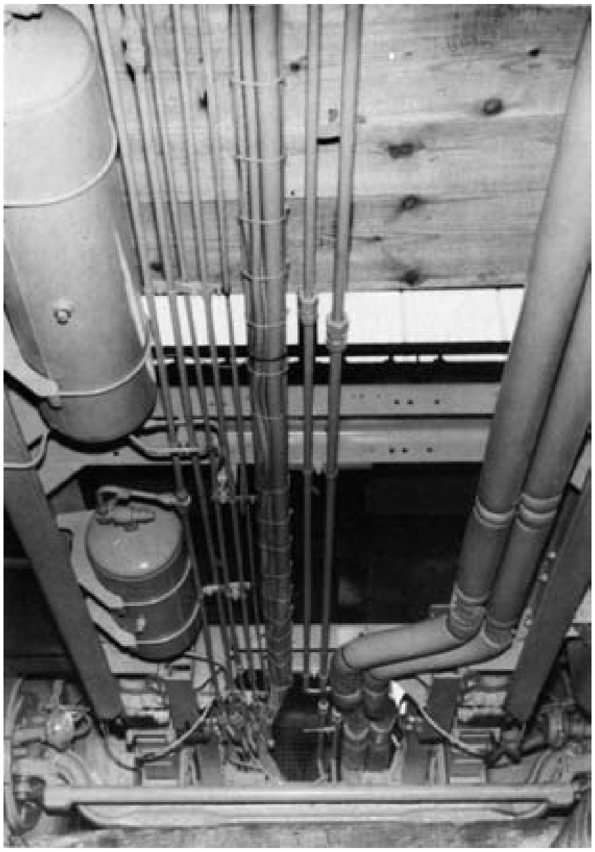
Hydraulic brake tubing for vehicles

One of the most safety-critical items in a road vehicle is its braking system. Of the many components involved, the tubing from the central master cylinder to each of the slave cylinders at the wheels is perhaps the most vulnerable to damage and to corrosion from salt thrown up from the road surface.

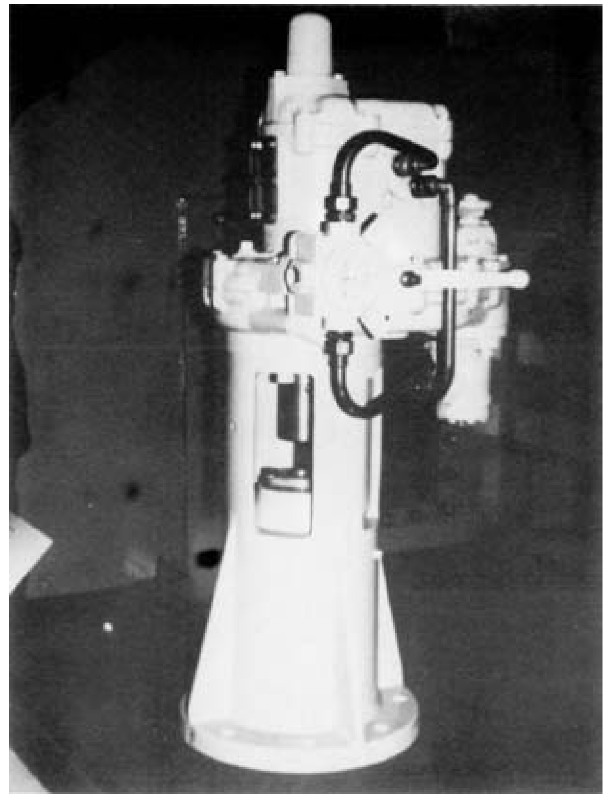
Conventionally, mild steel tubing has been used, protected by a tin/lead coating. This is initially relatively cheap but has been shown to have a limited life expectancy especially in severe conditions. An alternative, galvanizing is a sacrificial coating on steel, only effective for a limited period of time. Once the zinc protection has gone the steel will corrode.

Internal corrosion will result in the formation of debris causing premature failure of hydraulic cylinders. External corrosion causes wastage which may eventually result in the tube bursting in use. It also causes connecting nuts to seize to cylinders which may result in severe damage to brake tubing during cylinder servicing.

Tubing of 90/10 copper-nickel has for some years been widely used for the replacement of failed steel tubing and is increasingly being used as original equipment by manufacturers of cars and commercial vehicles wishing to keep reputations for safety and reliability.



The underside of a Hestair Dennis “Dominator” bus chassis, showing the 90/10 copper-nickel air brake tubes. Over 200 feet of four sizes of tube are used per vehicle. (Photographed at East Lancashire Coachbuilders Ltd., Blackburn.) The wooden floor-boards are used to mount the batteries etc. for the transit journey from Guildford to the Blackburn body building factory.
(Yorkshire Imperial Alloys)



A marine rotary hydraulic actuator fitted throughout with 90/10 copper-nickel tubing for reliability.
(Yorkshire Imperial Alloys)

A multi-tube installation in 90/10 copper-nickel alloy for hydraulically operated controls for ESV “Iolair".
(Yorkshire Imperial Alloys)

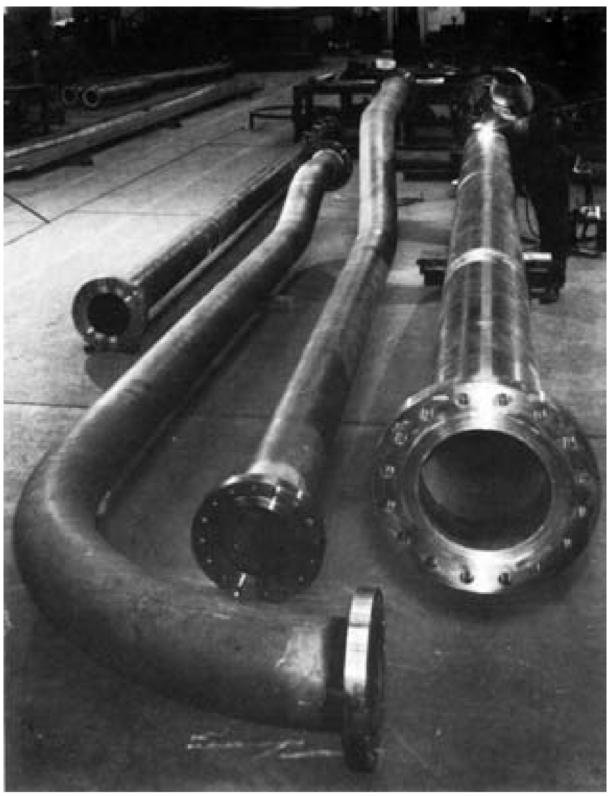
Hydraulic and instrumentation tubing for marine and offshore use

In recent years, the use of copper-nickel tubing has been extended to hydraulic and instrumentation systems which have become increasingly important in the operation of ship and offshore platform control and monitoring systems.

The copper-nickels offer excellent resistance to saltwater corrosion which ensures a highly reliable system. Costly repairs during the life of the installation are eliminated and, perhaps more important, so too are the large revenue losses and safety hazards associated with system breakdowns.

Use of copper-nickel tubing can also provide savings on the costs and time required for installation. Its ductility facilitates easy, smooth-contoured bending and its availability in long-length coils minimizes the number of expensive joints which are required.

90/10 copper-nickel normally has adequate strength to withstand the pressures in most marine hydraulic and instrumentation systems but where a stonger material is required, 70/30 copper-nickel can be used.

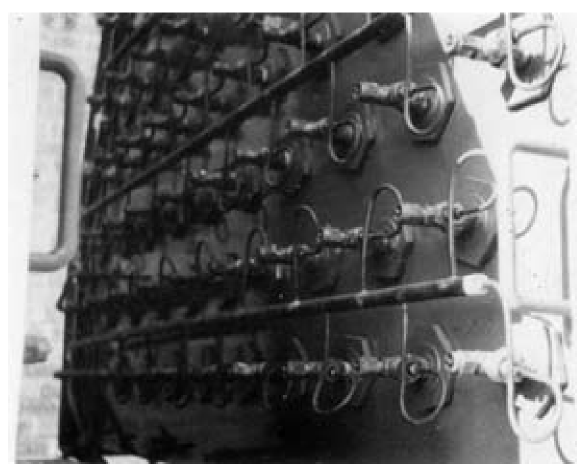


Copper pipes fitted with 90/10 copper-nickel flanges for use in oxygen-blown steelmaking. Because these are to convey oxygen at 600 psi, all welds are subjected to 100% X-ray inspection for integrity and a final pneumatic test at 750 psi.
(G. Clark & Sons (Hull) Ltd)

Gas pipelines

For certain specialized applications copper-nickel alloys prove the ideal material. For use with high-pressure oxygen there is no danger of rapid oxidation of the metal. As shown, it is used for the flanges connecting conventional copper pipes for use in oxygen-blown steelmaking.

For use with mobile hydrogen supplies, 90/10 copper-nickel is also ideal as it is not permeable to hydrogen (as is steel) and has a greater fatigue strength than conventional copper.



Small diameter 90/10 copper-nickel tubes used for fatigue resistant connections to trailer-mounted hydrogen cylinders.
(Hydrogen Supplies Ltd)

Table 12 Comparison between various specifications for 90/10 and 70/30 copper-nickel alloys

90/10 ALLOYS

Standard	ISO		BS	DGS	ASTM				DIN
Designation	CuNi9Sn2	CuNi10Fe1Mn	Cn102						CuNi10Fe
Ref. No.				Class 1	C70600	C70610	C72500	C96200	2.0872
Plate		√	√	√	√		√		√
Sheet/strip	√	√	√	√	√		√		√
Tube		√	√	√	√	√			√
Rod		√	√	√	√		√		
Wire	√								
Forgings				√					√
Castings								√	
Copper									
min	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	84.5	Rem.
max								87.0	
Nickel									
min	8.5	9.0	10.0	10.0	9.0	10.0	8.5	9.0	9.0
max	10.5	11.0	11.0	11.0	11.0	11.0	10.5	11.0	11.0
Iron									
min	-	1.2	1.0	1.5	1.0	-	-	1.0	1.0
max	0.3	2.0	2.0	2.0	1.8	0.6	0.6	1.8	1.8
Maganese									
min	-	0.5	0.5	0.5	-	-	-	-	0.5
max	0.3	1.0	1.0	1.0	1.0	0.2	0.2	1.5	1.0
Tin									
min	1.8	-	-	-	-	-	1.8	-	-
max	2.8	0.02	-	-	-	-	2.8	-	-
Bismuth	-	-	-	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-	-	-	-
Boron	-	-	-	-	-	-	-	-	-
Carbon	-	0.05	0.05	-	0.05†	0.05	-	0.15	0.05
Chromium	-	-							
Cobalt	-	-							-
Lead	0.05	0.03	0.01	-	0.02†	0.01	0.05	-	0.03
Niobium	-	-	-	-	-	-	-	1.0	-
Phosphorus	-	-	-	-	0.2†	-	-	-	-
Silicon									
min	-			-	-	-	-	0.30	-
max	-	-	-	-	-	-	-	-	-
Zinc	-	0.5	-	1.0	0.50†	-	0.50	-	0.5
Zirconium	-	-	-	-	-	-	-	-	-
Total other impurities	-	0.1	-	-	-	-	-	-	0.1
Total impurities	-	-	0.30	0.30	-	-	-	-	-

Maxima except where range given.

70/30 ALLOYS

Standard	ISO		BS				DGS	ASTM				DIN
Designation	CuNi30Mn1Fe	CuNi30Fe2Mn2	CN107	CN108	CNl ø	CN2 ø						CuNi30Fe
Ref. No.							Classes 2-5*	C71500	C7164	C96400	C96600	2.0882
Plate	√		√				√	√				√
Sheet/Strip	√						√	√				√
Tube	√	√	√				√	√	√			√
Rod	√						√	√				√
Wire												
Forgings												
Castings					√	√						
Copper												
min	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	65.0	Rem.	Rem.
max										69 .0		
Nickel												
min	29.0	29.0	30.0	29.0	29.0	28.0	30.0	29.0	29.0	28.0	29.0	30.0
max	32.0	32.0	32.0	32.0	33.0	32.0	32.0	33.0	32.0	32.0	33.0	32.0
Iron												
min	0.4	1.5	0.4	1.7	0.4	1.0	0.4	0.4	1.7	0.25	0.8	0.4
max	1.0	2.5	1.0	2.3	1.0	1.4	1.0	1.0	2.3	1.5	1.1	1.0
Maganese												
min	0.5	1.5	0.5	1.5	0.5	1.1	0.5	-	1.5	-	-	0.5
max	1.5	2.5	1.5	2.5	1.2	1.6	1.5	1.0	2.5	1.5	1.0	1.5
Tin												
min	-	-	-	-	-	-	-	-	-	-	-	-
max	0.02	0.02										
Bismuth	-	-	-	-	0.002	0.002	0.002	-	-	-	-	-
Berylium	-	-	-	-	-	-	-	-	-	-	0.40-0 .7	-
Boron	-	-	_	-	-	-	0.02	-	-	-		-
Carbon	0.06	0.06	0.06	0.05	0.03	0.03	0.06	0.05t	0.06	0.15	-	0.06
Chromium	-	-	-	-	1.6-2.0	-	-	-	-	-	-	-
Cobalt	-	-	-	-	0.05	0.05	-	-	-	-	--	-
Lead	0.03	0.03	0.01	-	-	-	0.01	0.021	-	0.03	0.01	0.03
Niobium	-	-	-	-	-	Nb+Ta 1.2-1.4	-	-	-	- 0.50-1.5	-	
Phosphorus	-	-	-	-	-	-	0.01	0.02t	-	-		
Silicon												
min	-	-	-	-	0.2	0.2						
max	-	-	-	-	0.3	0.3	0.03	-	-	0.50	0.15	-
Sulphur	0.06	0.06	0.08	-	0.01	0.01	0.02	0.021	0.03	-	-	0.05
Zinc	0.5	0.5		1.0	-	-	-	0.501	-	-	-	0.5
Zirconium	-	-	-	-	0.1-0.2	-	-	-	-	-	-	-
Total other impurities	0.1	0.1	-	-	-	-	-	-	-	-	-	0.1
Total Impurities	-	-	0.3	0.3	0.2	0.3	0.3	-	-	-	-	-

Maxima except where range given.

† When required for welding *Composition requirements vary for different product forms.

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Contact information

Where organizations are identified, publications can be obtained from the addresses below:

Abbreviation	
CDA	Copper Development Association, Orchard House, Mutton Lane, Potters Bar, Herts EN6 3AP
INCRA	International Copper Research Association, Brosnan House, Darkes Lane, Potters Bar, Herts EN6 1BW
INCO	(International Nickel Company), INCO Europe Ltd, Thames House, Millbank, London SWIP 4QF
CDA Inc.	Copper Development Association Inc., 405 Lexington Avenue, New York, NY 10017, USA
DKI	Deutsches Kupfer Institut, Knesebeckstrasse 96, 1000 Berlin 12, Germany

Abbreviation	
YIA	IMI Yorkshire Imperial Alloys Ltd, PO Box No. 166, Leeds LS1 1 RD
	Henry Wiggin & Company Ltd, Holmer Road, Hereford HR4 9SL
VDM	Vereinigte Deutsche Metallwerke AG, Postfach 100167, Worthstrasse 171, D-4100 Duisburg, Germany
	Columbia Metals Limited, Wingfield Mews, Wingfield Street, Peckham, London SE15 4LH
	Weir Westgarth Limited, Cathcart, Glasgow G44 4EX
	Motherwell Bridge Engineering Ltd, PO Box 4, Motherwell ML1 3NP

Other publications can be obtained through reference libraries.

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