APPLICATION DATA SHEET

COPPER • BRASS • BRONZE

copper-nickel piping for offshore platforms

■ Copper-nickel alloys are well known for their reliable performance in marine applications. Their seawater corrosion resistance, anti-biofouling properties and ability to withstand erosion-corrosion attack have been recognized and successfully exploited for most of this century.

There are a number of commercial copper-nickel alloys, each designed with particular properties and end uses in mind. Of these, Copper Alloy No. 706 (UNS C70600) offers the best combination of properties for marine applications, and has the broadest application in seawater service. Composition and relevant engineering data for Alloy 706 are given in Table 1.

Alloy 706 has been used aboard ships for decades, primarily as piping for seawater distribution and shipboard fire protection systems. It is used in many desalting plants and in sugar refineries located near the sea. Copper-nickel alloys, including 706, have also given exemplary service as condenser and heat exchanger tubes in coastal power stations and chemical plants where cooling waters are usually brackish or saline. With such a long and broad-based service history behind it, copper-nickel's compatibility with marine environments is firmly established. Based on this record of success, copper-nickel is being specified increasingly for seawater piping on offshore platforms, especially those designed for long-term service in deepwater locations. Repair and resupply of such platforms is difficult and costly, so design emphasis must favor materials reliability and place great stress on life-cycle cost savings. Copper-nickel helps fulfill these requirements.

The trend to larger platforms operating in deeper waters is relatively new to the U.S. offshore industry. In the North Sea, platforms have been larger and more complex, and deepwater operation has generally been the rule. Maintenance costs there are among the highest in the world, and consequently system reliability has received greater attention. It is principally for these reasons that seawater piping systems on North Sea platforms are now almost exclusively copper-nickel.

The uses of copper-nickel piping reflect the alloy's reliability. Typical applications include fire protection systems, sanitary plumbing services and process cooling lines, as well as seawater piping for flare booms, generator coolers and distillation plants. Copper-nickel is also successfully used for seawater feed lines to mud pumps and cement pumps, and for drill water supply. While most of the copper-nickel now used on offshore platforms is in the form of pipe (seamless below four inches in diameter; welded for larger sizes), newer platform designs will undoubtedly foster broader applications for copper-nickel sheet, plate and structural shapes. Potential applications under development include Alloy 706 linings for high-pressure well-injection pipes and sheathing on the seawater side of conductor pipes and platform support legs.

TABLE 1. COMPOSITION AND PROPERTIES FOR WROUGHT 90-10 COPPER-NICKEL (ALLOY C70600)

COMPOSITION, %

Copper	Nickel	Iron	Manganese	Zinc	Lead
Remainder	9.0–11.0	1.0–1.8	1.0 Max.	1.0 Max.	0.05 Max.

When product is for subsequent welding applications and so specified by the purchaser, Zinc shall be 0.50% max, Lead 0.02% max, Phosphorus 0.02% max, Sulfur 0.02% max, and Carbon 0.05% max.

PHYSICAL PROPERTIES

	English Units	Metric Units
Density (@ 68F)	0.323 lb/cu in.	8.94 gm/cm³ @ 20C
Melting Range	2010 - 2100F	1100 - 1150C
Thermal Conductivity (@ 68F)	26 Btu/ft/hr/ft²/°F	.11 cal/sq cm/cm/sec/°C @ 20C
Coefficient of Thermal Expansion	9.5 x 10^{-6}/°F (68-572F)	17.1 x 10^{-6}/°C (20-300C)
Specific Heat	.09 Btu/lb/°F	.09 cal/gm/°C @ 20C
Electrical Resistivity	115 ohm/cir mil/ft @ 68F	19.1 microhm-cm @ 20C
Modulus of Elasticity (Tension)	18 x 10^6 psi	124,000 MPa
Modulus of Rigidity	6.8 x 10^6 psi	46,900 MPa

MECHANICAL PROPERTIES*

Copper Alloy UNS No.	Outside Diameter, in. (mm)	Tensile Strength, min, ksi (MPa)	Yield Strength at 0.5% Extension Under Load, min, ksi (MPa)	Elongation in 2 in. (50.8 mm), min, %
C70600	up to 4½ (114), incl	40 (275)	15 (105)	25.0
	over 4½ (114)	38 (260)	13 (90)	25.0

*Requirements according to ASTM B467 for as-welded and fully-finished pipe when furnished in the annealed temper (WO61).

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Table 2 gives applicable standard specifications for Alloy 706 tubing, pipe, plate, sheet, strip, flanges and fittings.

ADVANTAGES OF COPPER-NICKEL

Designers of seawater piping systems have three principal material selection options: galvanized carbon steel, fiber-reinforced plastic and copper-nickel. Carbon steel's only advantage is its low first cost; plastics are light in weight and do not corrode, but they biofoul readily and lack a proven performance record. Copper-nickel offers firmly established technical advantages and is demonstrably the most economical material on the basis of platform life-cycle cost. The following list of copper-nickel's attributes is drawn from extensive shipboard experience and from the many platforms where the alloy has already given years of trouble-free service:

- *Ease of installation* of copper-nickel piping means straightforward practices and low direct labor cost. Copper-nickel, with its thinner wall schedule, is lighter and requires fewer workers and less time to position and install than equivalent carbon steel systems.
- *Corrosion resistance* of copper-nickel is far superior to steel, so much so that a properly designed system should last for the full life of the platform. The need for a piping cathodic protection system is completely eliminated with copper-nickel. This reduces capital costs and removes another source of recurring maintenance expenses.
- *No galvanic corrosion* when copper-nickel is used with other copper-based seawater distribution system components (brass or bronze pumps and valves, etc.) as Alloy 706 is galvanically compatible with these materials.
- *Biofouling resistance* of Alloy 706 is so high that maintenance costs associated with removal of marine growth are reduced to insignificance. Unlike galvanized steel or fiber-reinforced plastics, copper-nickel requires no diametral allowance for fouling buildup, meaning that smaller diameter piping can be specified, while maintaining a constant flow rate and pressure drop for the life of the system. Alloy 706 needs no additional antifouling protection. Since fouling cannot form, there will be no marine growth to dislodge and clog or damage fittings, screens, pumps or valves downstream. All such fouling-related considerations represent hidden costs which can be avoided through the use of copper-nickel piping.
- *Strength, ductility and damage resistance* of Alloy 706 piping are superior to fiber-reinforced plastic. Alloy 706 is safer for use in fire protection systems. In the unlikely event damage occurs, repair is faster, less costly and easier to inspect than with other piping materials.
- *High scrap value* of Alloy 706 means that initial materials costs are significantly offset. This economic advantage is unique to copper-nickel and should be taken into consideration when calculating system life-cycle cost.

TABLE 2. APPLICABLE STANDARD SPECIFICATIONS FOR 90-10 COPPER-NICKEL (ALLOY C70600)

Product	Specification
Pipe	ASTM-B466, B467, B608
	ASME—SB466, SB467
	MILITARY—MIL-T-16420K
Plate	ASTM—B122
	MILITARY—MIL-C-15726
Plate (Clad)	ASTM—B432
Plate (Condenser & Heat Exchanger)	ASTM—B171, B402
	ASME—SB171, SB402
	MILITARY—MIL-C-15726
Sheet	ASTM—B122, B402
	ASME—SB402
	MILITARY—MIL-C-15726
Strip	ASTM—B122
	MILITARY—MIL-C-15726
Flanges	ANSI—B16.5
Weld Fittings	ANSI—B16.11 (threaded, socket)
	B16.28 (elbows, return bends, reducers)
	B16.9 (elbows, tees, return bends, reducers)

Many alternative piping materials have been proposed and tried over the years. Besides galvanized steel and fiber-reinforced plastics, these have included steel pipe with epoxy resin coatings and with rubber, plastic or even cement linings. While each of these may offer limited advantages, all are subject to serious shortcomings: discontinuities ("holidays") and local damage to linings or internal coatings expose the unprotected steel substrate to severe localized attack. Repairs can be costly and unreliable; loose lining fragments can clog or damage downstream components; linings can be sensitive to handling conditions and may be damaged by external welding. None of the alternative piping materials provide protection against *both* corrosion and biofouling; only copper-nickel has this ability. It is an intrinsic, permanent characteristic of the alloy.

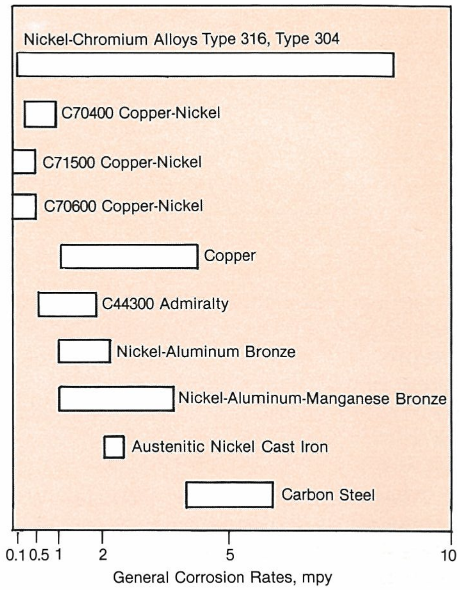


FIGURE 1. A GENERAL COMPARISON OF THE CORROSION RESISTANCE OF SEVERAL ALLOY FAMILIES IN QUIET SEAWATER.

CORROSION AND BIOFOULING

The seawater corrosion resistance of Alloy 706 compares very favorably with other materials (Figure 1), and its life expectancy in seawater piping service is correspondingly high (Table 3). Exposed to seawater, Alloy 706 forms a thin but tightly adhering oxide film on its surface. To the extent that this film forms, copper-nickel does in fact "corrode" in marine environments. However, there are two important differences between the corro-

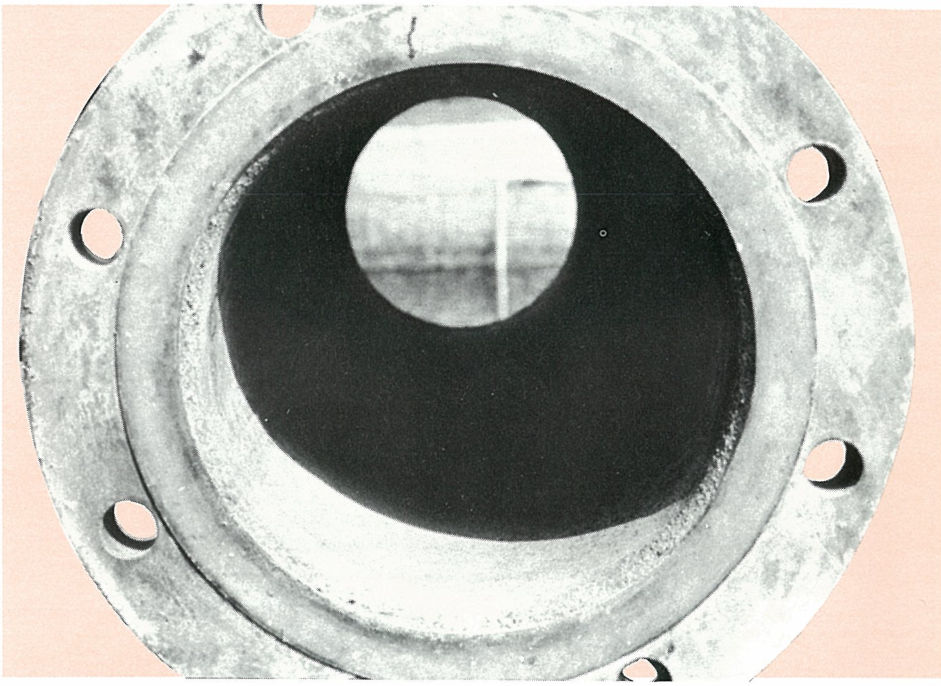
TABLE 3. AVERAGE LIFE EXPECTANCY FOR PIPE MATERIALS IN SEAWATER SERVICE	
Material	Years of Useful Service
Galvanized Steel	5.7
Copper (Copper C12200)	5.9
90-10 Copper-Nickel (Alloy C70600)	20+
70-30 Copper-Nickel (Alloy C71500)	20+ +

sion experienced by copper-nickel and that which develops on steel surfaces. The copper-nickel oxide film is firmly bonded to the underlying metal and is nearly insoluble in seawater. It therefore protects the alloy from further attack, once it has formed. Initial corrosion rates may be in the range from less than 1.0 to about 2.5 mils per year. In the absence of turbulence, as would be the case in a properly designed piping system, the copper-nickel's corrosion rate will decrease with time, eventually dropping to as low as 0.05 mils per year after several years' service. Rates as low as 0.02 mils per year have been observed on 15- to 20-year old shipboard piping.

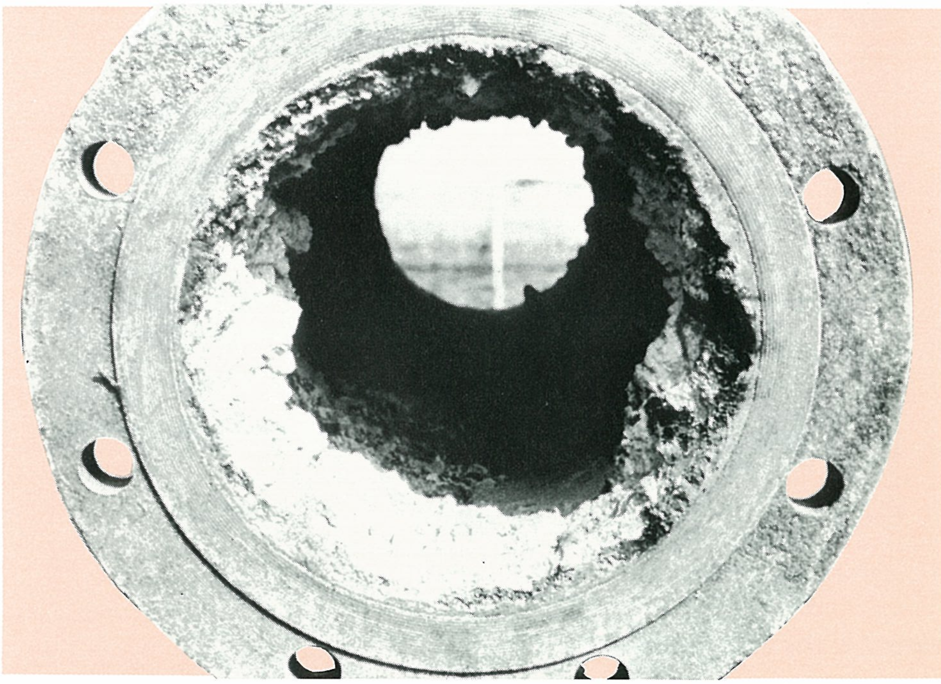
The second important advantage of the oxide film developed on Alloy 706 is that it is an extremely poor medium for the adherence and growth of marine life forms. Algae and barnacles, the two most common forms of marine biofouling, simply will not grow on Alloy 706, or on most of the other copper-based alloys. Alloy 706 piping therefore remains clean and smooth, neither corroding appreciably nor becoming encrusted with growth. Figure 2, which compares the internal surfaces of steel and Alloy 706 pipes after twenty-two months' service, clearly demonstrates copper-nickel's superiority.

DESIGN CONSIDERATIONS

Seawater piping systems are complex, consisting of numerous components fabricated from a variety of materials. Because these are all connected, in the electrical sense, by a conductive and potentially corrosive medium (seawater), careful consideration must be given to galvanic interaction among system components. Beyond this are the basic design



COPPER-NICKEL



CARBON STEEL

FIGURE 2. COPPER-NICKEL ALLOY NO. C70600 AND CARBON STEEL PIPING AFTER 22 MONTHS IN SEAWATER SERVICE.

The carbon steel has corroded and is severely biofouled: the copper-nickel piping remains clean and smooth.

considerations: pressure drop and friction loss, bulk velocity, the effect of turbulence and careful selection of fabrication and installation methods.

Materials Selection

In multi-component, multi-material systems such as marine piping, avoiding galvanic corrosion is a principal design consideration. Fortunately, galvanic corrosion is well understood and can be prevented through the proper selection of materials and intelligent system design.

The tendency for two metals to form a galvanic corrosion couple can be esti-

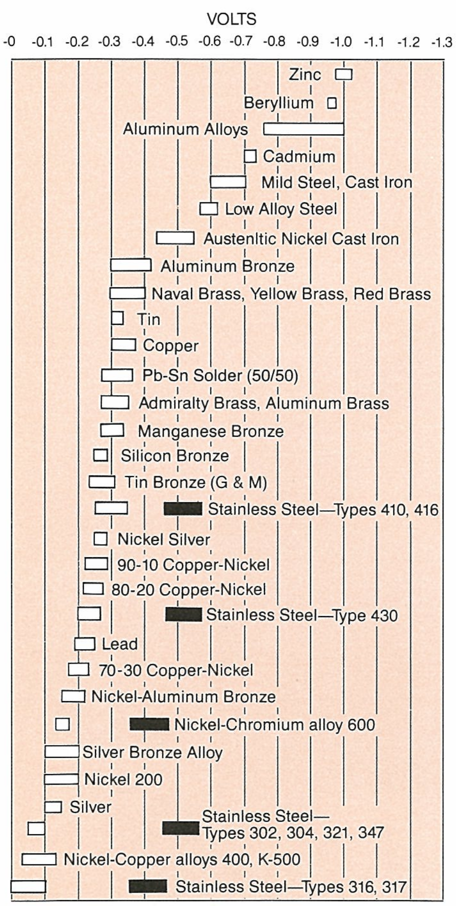


FIGURE 3. THE GALVANIC SERIES.

■ When active due to low velocity, poor aeration.

Alloys are listed in the order of the potential they exhibit in seawater. Alloys reasonably near each other in potential will have little tendency to form damaging galvanic corrosion couples.

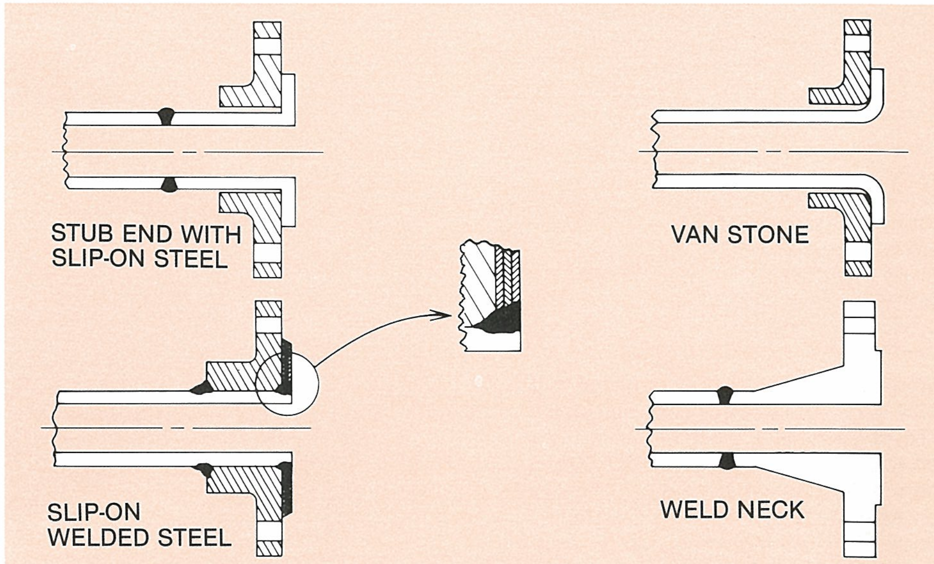


FIGURE 4. TYPICAL FLANGED CONNECTIONS FOR COPPER-NICKEL PIPING SYSTEMS.

Dissimilar metals, such as steel and copper-nickel, should be insulated from each other to avoid galvanic effects.

The inset indicates that a steel flange is overlayed with one pass nickel and two passes 70/30 copper-nickel and machined flush before welding to pipe.

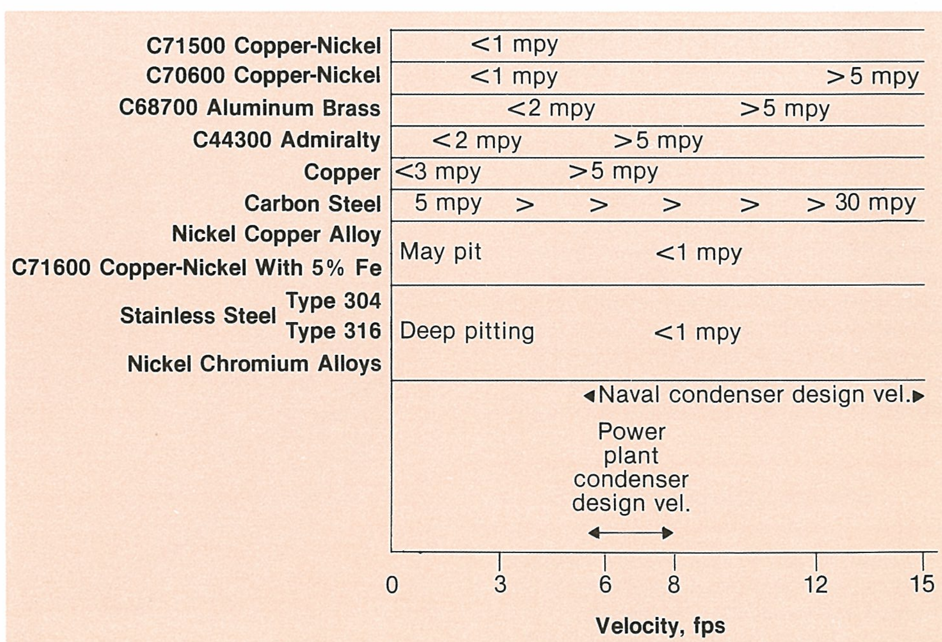


FIGURE 5. THE EFFECT OF SEAWATER VELOCITY ON THE GENERAL CORROSION RATES OF SEVERAL ENGINEERING MATERIALS.

Copper-nickel has excellent corrosion resistance at velocities normally encountered in seawater piping systems.

mated from their relative positions in the galvanic series, depicted graphically in Figure 3. Metals which lie close together in the series (i.e., whose potentials with respect to an arbitrary electrode are nearly the same) have less tendency to form a corrosion couple than those which are far apart. There are exceptions to the rule, but Alloy 706, for example, can usually be safely coupled (electrically connected in the presence of the electrolyte, seawater) to tin bronze, 70-30 copper-nickel or nickel aluminum bronze without fear of galvanic attack. For highest reliability, aluminum bronze pumps and valves should be specified in copper-nickel piping systems. To achieve similar good performance in seawater with less corrosion resistant copper alloys, such as naval brass or red brass, they should be independently protected by a less noble metal (steel, for example) and should not be used in 90-10 copper-nickel systems.

It is sometimes impossible to avoid couples between copper-nickel and anodic (less noble) metals in seawater piping systems. Non-critical components such as slip-on flanges may have to be accepted in steel for reasons of economy. In such cases, galvanic corrosion can be prevented by electrically insulating the more active (steel) component from the more noble (Alloy 706) pipe. This has two effects: first, it prevents galvanic corrosion attack on the steel; second, it allows the copper-nickel to form its normal protective corrosion film, as discussed earlier. With the film intact, the copper-nickel retains its anti-biofouling properties, something it could not do were it to become the cathode in a galvanic couple. Standard insulating kits are available to provide the required galvanic separation. It is also good practice to coat steel components externally with epoxy to guard against corrosion by the atmosphere, or from leakage. Figure 4 illustrates several types of flanged connection and demonstrates techniques to prevent galvanic attack. In summary, the aim is to avoid widely dissimilar metals as much as possible and when they must be used, to keep them electrically apart.

Flow velocities also play an important role in seawater corrosion. Materials which behave well in stagnant water may not endure long under conditions of rapid flow. Velocity-dependent erosion-corrosion is often associated with turbulence and entrained particulates. The general effect of velocity on corrosion resistance of a number of alloys in seawater is shown in Figure 5.

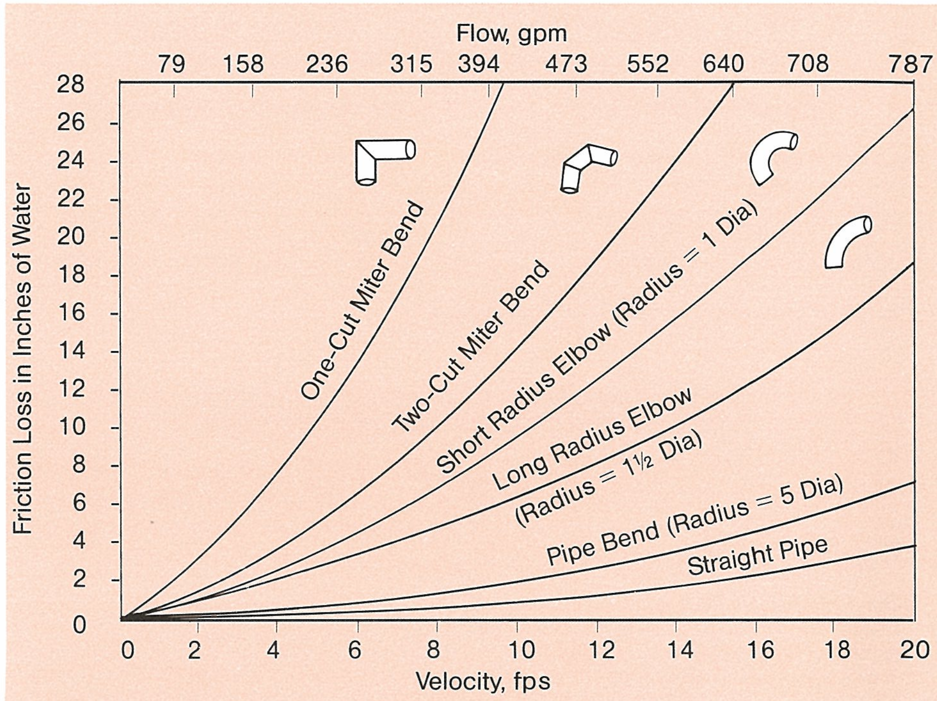


FIGURE 6. THE EFFECT OF STREAMLINED DESIGN ON FRICTION LOSS AND PUMP POWER REQUIREMENTS.

Using pipe bends or long-radius elbows is recommended.

Pressure Drop, Velocity, Turbulence

Flow-related failure mechanisms, such as those just described, are preventable through good design, which is usually employed anyway for the sake of system efficiency. Figure 6, for example, illustrates the importance of streamlined design in reducing friction loss and pumping power requirements. Adhering to the guidelines for reduced friction loss also helps avoid turbulence and any erosion-corrosion it can cause.

Corrosion considerations aside, the key to correct piping design is streamlining, which minimizes pressure drop and required pumping power. The general points to bear in mind are:

1) Run all piping as directly as possible with a minimum number of bends, fittings, valves and branches.
2) Design for bends, rather than fittings, wherever possible. Bend radii of five pipe diameters are preferred, with three diameters being the absolute minimum.
3) When fittings are used, specify long radius, full-formed types.
4) Choose square stub-end flanges, the gasket cut flush with the inside pipe diameter. If rolled-over type flanges are specified, design velocity should be reduced 1 to 2 fps. Under other circumstances, refer to the flow velocity data in Table 4.
5) Control flow with the least number of valves. Less expensive gate or butterfly valves can replace more costly globe valves for this purpose.

TABLE 4. VELOCITY GUIDELINES FOR 90-10 COPPER-NICKEL SEAWATER PIPING SYSTEMS (ALLOY C70600)

Pipe Size, in.	Velocity for Continuous Service, fps
3 and under	5
4 to 8 with short radius bends	6.5
4 and larger with long radius bends	11
8 and larger	11

TABLE 5. EQUIVALENT SIZE FOR EQUAL FLOW AND PRESSURE DROP — STEEL vs. 90-10 COPPER-NICKEL (ALLOY C70600)

Schedule 80 Steel Pipe				Equivalent 90-10 Copper-Nickel*		
Diameter, in.	Velocity, fps	Pipe Condition	Total Head Loss, ft	Diameter, in.	Velocity fps	Total Headloss, ft
24	6	New	1.02	20	7.1	1.25
24	6	Biofouled	1.71	18	8.82	1.97

*Head loss comparable to schedule 80 steel pipe.

TABLE 6. COMPARISON OF ROUGHNESS FACTORS– STEEL vs. 90-10 COPPER-NICKEL (ALLOY C70600)

	Roughness Factor, X	Friction Factor "C" of the Hazen and Williams Formula
90-10 Copper-Nickel:		
Throughout Service Life	0.9	140
Galvanized Steel: New	1.0	130
2nd Year Onward (Corroded)	1.6 to 2.5	100 to 80
Rubber-Lined Steel:		
2nd Year Onward (Biofouled)	2.5	80

A major benefit of using Alloy 706 is the fact that the piping can be smaller, and will have better flow characteristics, than equivalent carbon steel pipe. Tables 5 and 6 illustrate these differences. Note, in Table 6, that the roughness and friction factors for Alloy 706 remain constant throughout the material's service life, while those for galvanized or rubber-lined steel degrade appreciably.

FABRICATION

Alloy 706 pipe is available in standard sizes, as are Alloy 706 standard fittings and flanges. However, smooth long-radius bends should be specified rather than fittings, especially below 6 in., since these reduce man-hour requirements and provide a lower pressure drop (see Figure 6). Alloy 706 pipe, seamless or welded, is readily bent cold. Bends can be made in conventional equipment for steel pipe bending, since outside pipe diameters are identical. Since copper-nickel pipe is lighter wall than steel, inside diameters of copper-nickel pipe are larger, and mandrels must be larger to prevent wrinkling.

Copper-nickel pipes should be supported according to the guidelines suggested in Table 7. Copper-nickel components can be assembled by normal joining techniques. Brazing and welding are closely cost-competitive in diameters smaller than 3 in. In larger sizes, welding is less expensive.

Brazing

Two basic categories of brazing filler metal are used: types BAg and BCuP. Both are excellent for joining copper-nickel alloys. The choice of type depends on four main factors:

1) Dimensional tolerance at the joint,
2) Type and material of fitting (cast or forged),
3) Desired appearance, and
4) Cost.

In brazing copper-nickel alloys, the most commonly used fillers are the silver-based alloys (AWS A5.8) BAg-1, BAg-1a, BAg-2, BAg-5, BAg-18. Brazing alloys BCuP-3 and BCuP-5 are acceptable for use with copper-nickels of 10% or less nickel content. Because these two filler metals contain phosphorus, they should not be used with alloys having a high nickel content due to the possibility that embrittling nickel phosphides will be formed. Copper-phosphorus brazing alloys should not be selected for use in sulfurous atmospheres. These brazing alloys are recommended for use with standard bronze brazing fittings (C83600, C90300, C92200), commonly known as silbraze fittings.

TABLE 7. GENERAL GUIDELINES FOR PIPE SUPPORT SPANS

Nominal Pipe Size, in.	Maximum Distance Between Supports, ft
1	7
2	9
4	12
6	15
8	17
10 and above	20

For good brazed joints on pipe sizes of 3-in. diameter or less, annular clearance between pipe and fitting should be between 0.002 and 0.005 in. to ensure good filler metal penetration. When brazing, avoid temperature-indicating crayons containing sulfur which can cause local incipient cracking during torch heating.

Fluxes of the AWS Types 3 or 4 are

TABLE 8. COPPER-NICKEL WELDING FILLER METAL SPECIFICATIONS (Bare Wire: AWS A5.7, MIL-R-19631, QQ-R-575; Electrode: AWS A5.6, MIL-E-22200/4.)

	Composition, % Bare Wire	Composition, % Electrode*
Copper	Remainder	Remainder
Nickel	29.0-32.0	29.0-33.0
Iron	0.40-0.75	0.40-0.75
Manganese	1.00	1.0-2.50
Titanium	0.20-0.50	0.50
Silicon	0.15	0.50
Lead	0.02**	0.02**
Phosphorus	0.02	0.02
Sulfur	0.01	0.015
Zinc	**	**
Tin	**	**
Total Other Elements (TOE)	0.50	0.50

*Deposited weld metal.
**Included in calculating TOE.
Note: Single values are maximum percentages.

satisfactory for most applications. Joint surfaces must be coated completely to avoid oxidation, and oil and dirt should be removed with a solvent and/or emery cloth. A neutral flame should be used. After brazing, flux residues should be removed by brushing. Detailed information on brazing can be found in "Brazed Copper-Nickel Piping Systems," CDA Application Data Sheet 701/5.

Welding

Annealed pipe should be specified when welding is anticipated. If annealing is done on site, the pipe should be degreased first. Oil or grease will decompose and leave a carbon film on the pipe which, if not removed, can lead to pitting corrosion.

Copper-nickel alloys are readily welded by SMAW, GTAW and GMAW processes, using the filler metals listed in Table 8. The 70-30 copper-nickel filler metal is used for joining both 90-10 (Alloy 706) and 70-30 (Alloy 715) alloys. It is metallurgically compatible with both, and when both are used in a joint, ensures a proper galvanic relationship. Materials up to 1/8-in. thick can be welded with a square-butt joint having a 0.050-in. gap. Materials from 1/8 to 1/4 in. should be beveled to a 90° included angle, while thicker materials will normally require a V- or U-groove joint preparation, with a root gap, for optimum weld performance. Comprehensive welding data are given in CDA Application Data Sheet 145/1, but the following summaries may be helpful.

SMAW (Stick) Welding. Coated electrodes for copper-nickel piping will generally be one size smaller than those used for carbon steel. Current settings will also be lower than for an equivalent steel rod. Flux-covered electrode ECuNi is used with direct current, reverse polarity. Short arc lengths allow the weld pool to be controlled in all positions. The molten metal tends to be quite fluid, so small-diameter electrodes and low current settings are preferred. Too-high currents will produce excessive spattering and undercutting, especially when the base metal's melting point is significantly lower than that of the filler. Open root gaps and wide groove angles improve penetration and assure good fusion. Tack welds every six inches are usually required to maintain the gap. A square-butt edge preparation may be used for plate up to 1/4 in. thick when welding downhand, but beveled grooves are required for out-of-position welds. Both stringer and weaving techniques can be used.

TABLE 9. REPRESENTATIVE GAS TUNGSTEN-ARC WELDING PARAMETERS (RCuNi filler, direct current straight polarity)

Thickness, in.	Electrode Size, in.	Filler Wire, in.	Current, A	Argon Flow, cfh
1/16	1/8	1/16	100–140	15–20
1/8	1/8	1/8	140–200	15–20
1/4	1/8	1/8–3/16	180–260	20–30
3/8	1/8–3/16	1/8–3/16	260–320	20–30
1/2	3/16	1/8–3/16	320–400	20–30

GTAW (TIG) Welding. GTAW welding is performed with direct current, straight polarity, although high-frequency AC may also be used. Representative welding parameters are given in Table 9. Because of the relatively high conductivity of 90-10 copper-nickel, current settings should be toward the upper limit of the ranges listed. Argon shielding gas is preferred for better arc control and uniform weld appearance. A short arc, about 0.03-in. long, and a thoriated tungsten electrode are usually recommended. Vertical and overhead welding can be carried out by slightly reducing the settings suggested for downhand welding. The use of deoxidized filler wire is essential in order to prevent weld porosity.

GMAW (MIG) Welding. GMAW welding is less often used for copper-nickel pipe fabrication because its relatively high energy level makes it more suitable for section thicknesses greater than 1/4 in. Most Alloy 706 piping for seawater service is thinner than that, but the representative welding parameters given in Table 10 may be used as a reference.

Welding Dissimilar Metals. Filler metals for joining copper-nickel alloys to carbon steels are CuA1-A2, ENiCu-2, ERNiCu-7 and ERNi-3. They may be used as a barrier by buttering one of the edges to be welded, or the groove may be filled entirely with these compatible alloys. The welding technique should allow for longer arc contact with the higher-melting steel side of the weld in order to assure complete fusion. For welding copper-nickels to stainless steels, a barrier of ENi-1 or ERNi-3 nickel filler over the steel is suggested before welding with ECuNi or ENiCu-2. ERNi-3 is used for gas-shielded arc processes and ENi-1 is used as a covered electrode.

TABLE 10. REPRESENTATIVE GAS METAL-ARC WELDING PARAMETERS (1/16-in. ECuNi filler, direct current reverse polarity)

Thickness, in.	Edge Preparation	Gap, in.	Voltage, V	Current, A	Wire Feed, in. per min	Argon Flow, cfh
1/8	square butt	0	22-28	270-300	180-200	20-30
1/4	square butt or single V, 60°	1/16-1/8	22-28	270-330	180-220	20-30
3/8	single V, 60°	0	22-28	300-360	200-240	20-30
1/2	single or double V, 60°, 1/16-in. face	0	22-28	350-400	220-240	20-30
3/4	double V, 60° 1/16-1/8-in. face	0	24-28	350-400	220-240	30-50
1	double U 1/16-1/8-in. face	0	26-28	350-400	220-240	30-50
>1	double U 1/16-1/8-in. face	0	26-28	370-420	240-260	30-50

COST COMPARISON: COPPER-NICKEL VS. STEEL

Despite its higher initial cost, Alloy 706 piping will result in significantly lower total expenditure over the service life of a typical offshore platform. Major contributions to cost-saving stem from two factors:

- A properly designed copper-nickel piping system should last for the life of the platform, 20 years or more. A steel system will probably require replacement in less than six years.
- A copper-nickel system, properly designed, needs only minimum maintenance since it resists corrosion and biofouling. Steel piping requires periodic cleaning and refurbishing. Steel must also be protected from the buildup of marine growth by an expensive and maintenance-prone biofouling inhibition system, usually of the chlorination type.

Additional savings derive from the fact that, needing no allowance for corrosion or biofouling buildup, copper-nickel piping can be smaller in diameter and thinner wall than equivalent steel pipe. This can reduce both the initial cost and the cost of installation.

A detailed cost analysis conducted for a seawater piping system aboard a self-contained drilling rig atop an eight-pile, Gulf-based platform confirms this. Alloy 706 was compared, both on the basis of initial cost and expected maintenance expense over 20 years, with steel systems, with and without chlorination. The steel and copper-nickel systems were assumed to be of the same size (8-in. diameter); however, an additional calculation was made based on a smaller (6-in. diameter) Alloy 706 system, functionally equivalent to the 8-in. steel for the reasons explained above. The results of the comparison are summarized in Table 11.

Even when (unnecessarily) specified in the same size as steel pipe, Alloy 706 still provides a life-cycle saving of more than $37,000 over an unprotected steel system and more than $34,000 if the steel piping incorporates chlorination. If 6-in. copper-nickel piping is specified, as it should be, the savings — without taking any credit for increased production or reduced downtime — will be $45,000 or more over the 20-year life of the platform. The return on investment data given in Table 12 show that the choice of Alloy 706 is amply justified, on a cost basis.

TABLE 11. 20-YEAR LIFE-CYCLE COST SUMMARY

System	Net Present Value, dollars Capital Cost	Maintenance Cost	Salvage Value	Total Cost
8-in. Diameter 90-10 Copper-Nickel	92,250	12,221	3,898	100,573
6-in. Diameter 90-10 Copper-Nickel	80,425	12,221	2,920	89,726
8-in. Diameter Steel	75,610	62,751	—	138,361
8-in. Diameter Steel with Chlorination	86,060	48,919	—	134,979

TABLE 12. RETURN ON INVESTMENT (ROI) AND PAYBACK COMPARISON–COPPER-NICKEL vs. STEEL

	ROI, %	Payback, Yr
Alloy C70600 vs. 8-in. Carbon Steel		
8-in. Dia. 90-10 Copper-Nickel	11	8.8
6-in. Dia. 90-10 Copper-Nickel	51	2.0
Alloy C70600 vs. 8-in. Carbon Steel with Chlorination		
8-in. Dia. 90-10 Copper-Nickel	28	3.6
6-in. Dia. 90-10 Copper-Nickel	Lowest Capital Cost	

FURTHER INFORMATION

A thorough understanding of copper-nickel piping requires more information than could be included in this data sheet. Engineers and designers wishing to learn more about the subject may contact CDA at 203/625-8210 (Greenwich, CT) or 713/350-4283 (Houston, TX).

BIBLIOGRAPHY

1. Copper Development Association Inc., Wrought Mill Products, Standards Handbook, Alloy Data/2, 113/5, (1985).
2. Tuthill, A.H., Schillmoller, C.M., "Useful Guidelines in the Selection of Corrosion Resistant Materials for Marine Service," Marine Technology Transactions, Vol. 3.
3. LaQue, F.L., Tuthill, A.H., "Economic Considerations in the Selection of Materials for Marine Applications," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 69 (1962).
4. Albaugh, E.K., "Copper-Nickel for Offshore Seawater Piping Systems," *World Oil*. Vol. 197 (November 1984).
5. INCO, "Marine Materials," *Nickel Topics*, Vol. 23, No. 3, (1965).
6. INCO, "The Design and Installation of 90-10 Copper-Nickel Seawater Piping Systems," A-1107 (1972).
7. Tuthill, A.H., Fielding, S.A., "Shipboard Piping Systems — Costs and Reliability," *Nickel Topics*, Vol. 27 (1974).
8. Copper Development Association Inc., "Brazed Copper-Nickel Piping Systems," Application Data Sheet 701/5, (1985).
9. Copper Development Association Inc., "Joining Copper-Nickel Alloys," Application Data Sheet 145/1, (1971).

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