CIM
August / août
17 - 20, 1986
Toronto, Ont.
ICM

25th ANNUAL CONFERENCE OF METALLURGISTS – 1986
25è CONFÉRENCE ANNUELLE DES MÉTALLURGISTES – 1986

Nickel-Containing Materials in Marine and Related Environments

Brian Todd
Consultant to the Nickel Development Institute
European Technical Information Centre
Edgbaston, Birmingham, England

ABSTRACT

The need for large volumes of water for cooling of process (desalination industry) purposes has resulted in the location of many major industries on the coast. The marine environment is recognized as the most corrosive natural environment, and designers have problems selecting materials that will give good performance at reasonable cost.

Nickel-containing materials such as copper-nickel alloys, stainless steels, and nickel-base alloys have been found to provide optimum techno-economic solutions in many cases.

The paper reviews factors such as corrosion resistance, fabric ability and cost . . . which determine the selection of marine materials.

INTRODUCTION

The use of materials in marine environments has traditionally been associated with ships. In recent years, however, important new industries with new materials problems have developed.

Notable among such industries are desalination (production of potable water from seawater) and offshore oil and gas production. Also, requirements for large volumes of cooling water by modern industry have often resulted in siting of plants by the ocean, particularly in arid areas such as the Middle East.

This has increased interest in the use of materials for handling seawater, particularly as the marine environment is accepted as the most corrosive natural environment; designers often find difficulty arises not simply from the corrosivity of seawater but because of the many factors such as marine fouling, velocity of flow and aeration which have to be considered in making the optimum technical/economic choice.

Nickel-containing materials such as cupronickels, austenitic stainless steels and nickel-base alloys have been used for marine applications for many years. Of note in recent years has been the rapid growth in usage of 90/10 cupronickel* which has proved to be a very versatile material in many applications such as heat exchanger tubing, seawater and steam piping, evaporator bodies, waterboxes, boat hulls and hydraulic piping.

A more recent development has been that of high-alloy stainless steels, resistant to pitting and crevice corrosion in seawater.

The opportunities for nickel-containing and nickel-base alloys are increasing, and this paper reviews factors influencing selection of marine materials and how these are satisfied by nickel-containing alloys in some major applications.

CORROSION OF MATERIALS IN SEAWATER

A General

Seawater is a complex mixture of inorganic salts (mainly sodium chloride), dissolved gases (notably oxygen), suspended solids, organic matter and organisms.

Tests in solutions of salts approximating seawater composition can give misleading results, and it is now realized that the living organisms have an influence on corrosion behavior. Thus a layer of marine growth can reduce corrosion on carbon steel or cause crevice corrosion on stainless steels. Meaningful data are best obtained in real seawater.

Oxygen content has a marked effect on corrosivity of seawater, and where this is reduced, as in desalination and oil-well injection systems, the seawater or brine is much less corrosive to most materials. This enables designers to use materials such as stainless steels which, in aerated seawater, could suffer serious pitting.

---

*See **Appendix** for compositions of materials.

B Alloys of Nickel and Copper

There are three important commercial alloys of copper and nickel containing nominally 10, 30 and 70% nickel. The two copper-base alloys have deliberate additions of iron to improve their corrosion resistance, particularly to flowing seawater. The nickel-base alloy also contains small amounts of iron and manganese.

Corrosion data on these alloys in seawater are given in *Table 1*.

TABLE 3

OVERALL FAILURE RATES* AND TUBE REPLACEMENT IN MULTISTAGE FLASH (MSF) PLANTS

Section of plant	Failure and replacement
Heat recovery (hot deaerated)	0.81
Heat reject (natural seawater)	2.46%

*% tubes plugged *replacement bundles

TABLE 1

CORROSION OF COPPER-NICKEL ALLOYS IN SEAWATER

Alloy	Corrosion rate – mm/yr Velocity 0-0.6 m/sec	Pitting mm	BNF Jet test 30 days 5.5 mm/s Depth of mm	Corrosion rate 30-40 m/sec mm/year
90/10 CuNi + 1.5% Fe	0.015	Slight	0.06	0.5-1.3
70/30 CuNi + 0.6% Fe	0.0065	0.12+	0.03	0.9-1.8
Monel+ Alloy 400 (70/30 NiCu) + 16-year test[1]	0.008+	0.85+	0	0.01

These data show that the copper-base alloys have high corrosion and pitting resistance in low and moderate velocity seawater and are not prone to pitting under stagnant conditions. At high velocities they corrode at high rates. The nickel-copper alloy is prone to pitting under stagnant conditions but becomes passive in flowing seawater and has high resistance even at 40 m/sec.

A modified 70/30 cupronickel, which contains 2% iron and 2% manganese, has now largely displaced the standard 70/30 alloy in markets outside North America. This alloy was originally developed in the United Kingdom for applications requiring resistance to cooling waters with high sand contents. The high iron content, however, does give high resistance to impingement attack in clean seawater and is often used because of this property.

Resistance to deaerated seawater is now of major interest with the growth of the desalination industry, which operates mainly under low oxygen brines, and where copper-base alloys are the usual choice for heat exchanger tubing.

Laboratory tests and service experience show that these deaerated environments are less corrosive than natural seawater to copper-base alloys, even though the temperature may be raised. *Table 2* gives data on some copper-base alloys in hot deaerated seawater:

TABLE 2

CORROSION IN HOT DEAERATED SEAWATER

Corrosion rate mm/year

Alloy	20 ppb oxygen	100 ppb oxygen	200 ppb oxygen
Aluminum brass	0.04	0.16	0.24
90/10 Cupronickel	0.02	0.020	0.020
70/30 Cupronickel	0.006	0.008	0.005

90-day test at 105°C. TDS 35 000 ppm. 8 ft/sec.

These data show that the cupronickels are less affected by variations in oxygen content than aluminum brass – a material that is sometimes used in the less aggressive sections of desalination plants.

Statistical data(2) from actual desalination plants confirm the mild corrosivity of hot deaerated seawater – *Table 3*.

The data in *Table 3* refer to a wide geographical spread of more than 120 plants of varying age, and the failure rate includes all tubes in replacement bundles as well as tubes that have failed by corrosion.

Data for individual alloys on the same basis is given in *Table 4*.

TABLE 4

FAILURE RATES AND TUBE REPLACEMENTS

Alloy	Heat recovery %	Heat reject %
Aluminium brass	1.07	6.8
90/10 Cupronickel	0.38	2.3
70/30 Cupronickel	0	1.6
70/30 Cupronickel + 2% Fe, 2% Mn	0.02	0.05

In summary, it can be said that the copper-nickel alloys show good resistance to seawater with a low general corrosion rate and high resistance to pitting under static conditions, good resistance at moderate flow rates, and rapid attack at high flow rates. The nickel-copper alloys have a tendency to pit under static conditions, but have excellent resistance at moderate and high flow rates.

C Nickel-Chromium Alloys and Stainless Steels

The behavior of austenitic stainless steels – which are essentially iron-base alloys containing chromium and nickel – is similar to the nickel-copper alloys, but their tendency to pit under static conditions, particularly in crevices, is greater.

The resistance of stainless steels to pitting and crevice corrosion is improved by adding molybdenum. In recent years the addition of nitrogen(3) has also been found beneficial in improving resistance to crevice attack.

As alloys resistant to crevice attack will resist pitting, it is usual to study only crevice corrosion resistance (CCR). There is no single, generally accepted test for measuring CCR but one widely used test is the Inco multicrevice assembly (MCA), *Figure 1*. This test has the advantage of providing many crevice sites on a single sample. *Table 5* shows the type of data that can be generated by this test and indicates the beneficial effects of molybdenum on crevice corrosion.

TABLE 5

POSSIBILITY OF CREVICE CORROSION INITIATION AND MAXIMUM DEPTH OF ATTACK OF VARIOUS STAINLESS STEELS EXPOSED FOR 30 DAYS TO SEAWATER AT 15°C.
MULTICREVICE ASSEMBLY – 120 CREVICES PER STEEL

Stainless steel	Probability of crevice corrosion initiation %	Maximum depth of attack (mm)
17% Cr (430)	52	1.17
18% Cr 10% Ni (304)	13	0.28
18% Cr 10% Ni 2-2.5% Mo (316)	2	0.03
18% Cr 12% Ni 3-3.5% Mo (317)	0	0

Nickel-base nickel-chromium alloys show a similar improvement in CCR when molybdenum is added(5) – *Table 6*.

TABLE 6

CREVICE CORROSION OF NICKEL-BASE ALLOYS
(MCA TESTS 120 CREVICE SITES)

		No of sites attacked	Depth of attack mm
Alloy 825	(2.7% Mo)	37	0.25 – 2.42
Alloy G	(5.8% Mo)	6	0.02 – 0.87
Alloy 625	(8.5% Mo)	0	0
Alloy C-276	(15.5% Mo)	0	0

A study(6) of the mechanism of crevice corrosion has resulted in the development of a mathematical model, which, from simple laboratory tests, is able to rank materials accurately in terms of their CCR in natural seawater. This model has revealed the influence of crevice dimensions – notably crevice gap – in crevice attack. *Figure 2*(7) shows the crevice gap needed to initiate crevice corrosion on various alloys.

Improved understanding of the crevice corrosion process has resulted in development of high-alloy stainless steels with CCR approaching that of the high molybdenum nickel-base alloys, but at less cost. *Table B*(8) in the *Appendix* lists some of the alloys now commercially available.

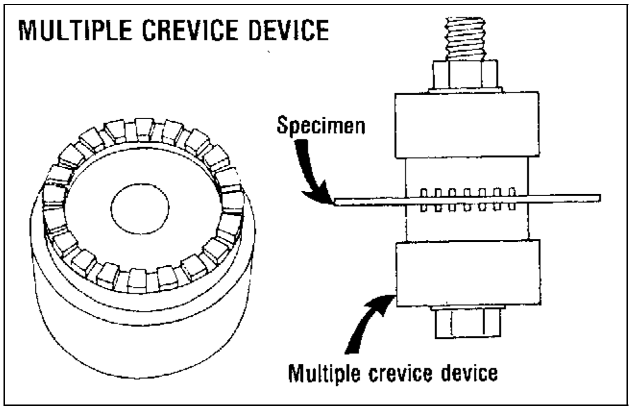

Figure 1: Multiple crevice assembly

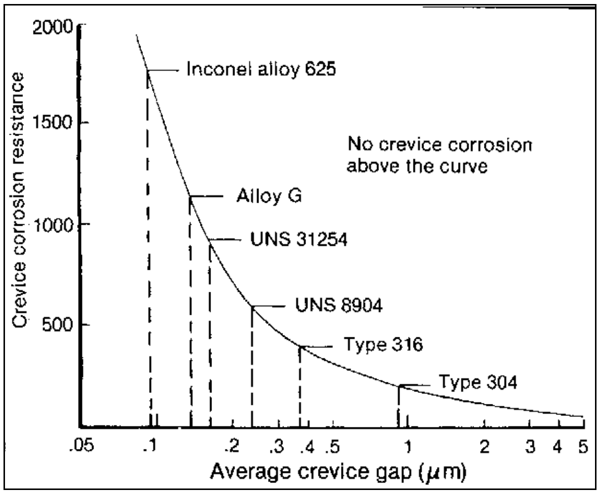

Figure 2: Effect of crevice gap

The PRE_N number in this list is a guide to CCR based on the empirical formula.

$$\text{PRE}_N = \text{Cr}\% + 3.3\text{Mo}\% + 16\text{N}\%$$

This formula indicates the marked influence of molybdenum and nitrogen on resistance to crevice corrosion.

In flowing seawater stainless steels and nickel-base alloys become passive, and above a velocity of about one m/sec pitting on exposed surfaces ceases; and, up to at least 40 m/sec, the general corrosion rate is negligible.

In deaerated seawater, laboratory tests and service experience show that resistance to pitting and crevice corrosion increases. This is because these phenomena depend on differential aeration effects, which are eliminated when the oxygen level is low. *Table 7* provides data in aerated and deaerated seawater on two stainless steels and a nickel base alloy. The marked reduction of attack in deaerated conditions is typical of that seen in this type of material.

TABLE 7

CORROSION OF STAINLESS STEEL AND A NICKEL-BASE ALLOY

Alloy	Environment	Exposure time (days)	Maximum depth of pitting mm
AISI 316	North Atlantic seawater	486	2.4
AISI 316	Deaerated seawater 105°C 25 ppb O_2	547	0.12
AISI 304	Deaerated seawater 105°C 25 ppb O_2	547	0.60
Incoloy* alloy 825	Deaerated seawater 93°C	90	0.05
Inconel* alloy 625	Flowing deaerated 107°C	124	0.00

*Trademark

In recent years great interest has developed in austenitic-ferritic-duplex stainless steels. These materials have a much higher strength than austenitic stainless steels, and their composition can be adjusted to provide high resistance to marine corrosion. One widely used alloy is UNS S31803 (22 Cr 5.5 Ni 3 Mo 0.12 N_2). *Table 8* gives some data on mechanical properties of this material and of Type 316.

TABLE 8

MECHANICAL PROPERTIES OF STAINLESS STEELS			
	0.2% Yield strength N/mm^2	Tensile strength N/mm^2	Elongation % 5 A
UNS S31803	450 min^m	680 – 900	25 min^m
Type 316	210 min^m	500 – 700	45 min^m

Table 9 gives crevice corrosion data in tests on the Swedish North Sea coast.

TABLE 9

CREVICE CORROSION RESISTANCE IN SEAWATER

Alloy	Number of samples attacked	Maximum depth of attack (mm)
316	19 out of 19	1.9
UNS N08904 (904L)	12 out of 16	0.7
UNS S31803 (2205)	7 out of 10	0.4

Test period one year

An additional attraction of these alloys is their high resistance to stress corrosion cracking. This is not normally a problem in most marine applications because service temperatures are normally below the widely accepted limit for cracking of 60°C. However, some applications in the oil and gas industry can result in exposures above this minimum limit and the duplex alloys are then often chosen.

APPLICATIONS OF MATERIALS IN SEAWATER

A Cupronickels

90/10 and 70/30 cupronickels have been used for heat exchanger tubing for many years. The need for high reliability in large modern plants has favored the use of cupronickels rather than the traditionally used brasses. *Figure 3* from an *Iron Age*(9) survey shows how market share for cupronickels in the United States has grown.

Of major importance has been the growth of the desalination market – *Figure 4* shows the expansion in capacity since 1970. About 75% of this capacity involves distillation processes – multistage flash distillation is the most common.

These plants are essentially large heat exchangers, and they provide a large market for tubing. As each cubic metre/day of output requires about 25 kg of tubing, the installed capacity in *Figure 2* represents about 200,000 tonnes of tubing, about 75% of which is cupronickel – mainly 90/10 but with significant amounts of the 2% iron, 2% manganese, 70/30 cupronickel.

The reasons for this trend to cupronickel are apparent from the data in *Tables 2* and *4*. In addition to the tubing applications, there has been strong growth in other applications where weldability and fabricability are required in addition to corrosion resistance. 90/10 cupronickel has good weldability and can be fabricated into complex shapes such as water-boxes and ship hulls. Strong growth has been seen in recent years in those applications where fabrication is involved, notably seawater piping. Large tonnages of 90/10 cupronickel piping have been supplied to the offshore oil industry – *Figure 5*.

Early platforms in the North Sea followed U.S. Gulf of Mexico practice and galvanized steel seawater systems were used. These proved unreliable, and in the severe environmental conditions in the North Sea maintenance costs were very high. Later platforms used 90/10 cupronickel seawater systems, and these have proved to be economic and reliable. The use of cupronickel has now spread beyond the North Sea to such areas as the Arabian Gulf and Brazil.

90/10 cupronickel is also available as clad plate, i.e., carbon steel clad with a layer of cupronickel. This product has been used in large tonnages in the desalination industry for water-boxes and large-diameter piping, and has overcome the corrosion problems encountered in early coated-steel water-boxes and piping.

More recently(11) in Italy, a series of fireboats with hulls built from 90/10 cupronickel-clad steel has been built. These vessels have fouling and corrosion resistance due to the copper-alloy hull. *Figure 6* shows an earlier example of this concept, which has operated for more than 10 years without fouling or corrosion problems.

The attractive properties of 90/10 cupronickel, together with its fabricability and weldability, will ensure that this versatile material is used increasingly in marine applications.

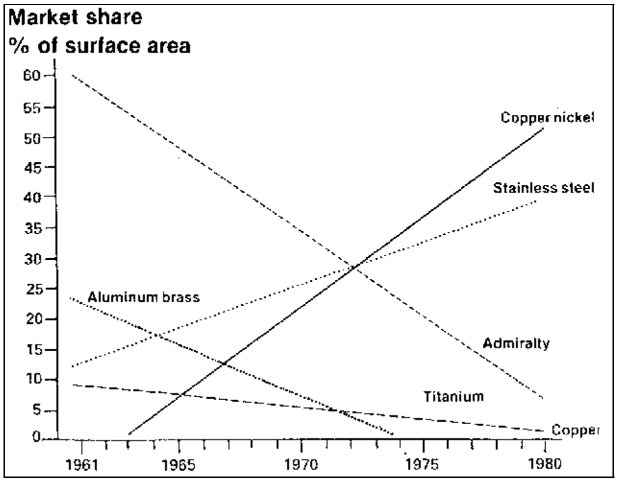

Figure 3: Fitted trend line of market share of specified condenser tube materials by surface area (new units only)

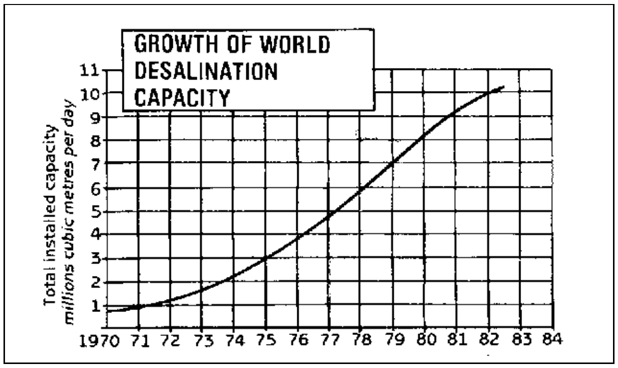

Figure 4: Growth of desalination plant capacity worldwide

Photo courtesy of IMI Yorkshire Alloys Ltd.

Figure 5: Cupronickel piping for a North Sea platform

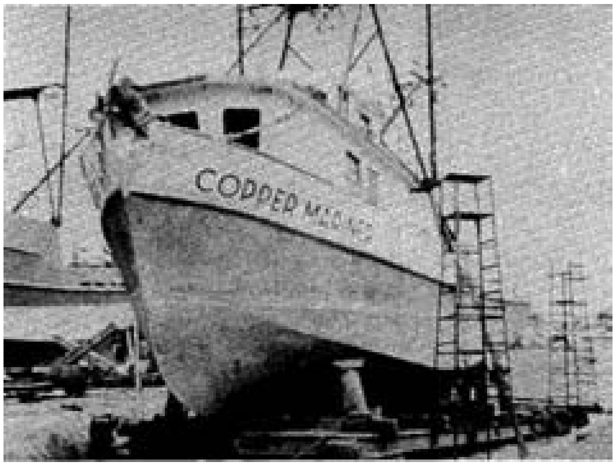

Figure 6: 90/10 cupronickel-hulled shrimp boat

B Nickel-Copper Alloys

Two wrought alloys based on 70/30 Ni/Cu have been extensively used in critical marine applications. The basic alloy contains 67% Ni 1% Fe 1 % Mn, RemCu, and is characterized by good strength and marine corrosion resistance, particularly under conditions of high water velocity.

It is used for fasteners, propeller and pump shafts, and valve trim. It is also available in cast form and is used for pump impellers where its high resistance to flowing seawater is used to advantage. In desalination plants, it has been widely used for demisters where high corrosion resistance to brine and incondensible gases is important.

Of particular interest has been the use of Monel* alloy 400 for sheathing offshore steel structures for corrosion protection in the splash zone. Installations using this alloy have been in service in the U.S. Gulf area for more than 20 years, and are extensively used in the Arabian Gulf where they are claimed to be the most cost-effective method of protection in the splash zone.(13)

An interesting offshore oil production problem involving splash zone corrosion occurred about 10 years ago when failure of cement covering on a pipe carrying hot oil focused attention on the high corrosion rates that could occur in the splash zone when cold oxygenated seawater splashed onto the hot surface. Perforation of the pipe wall several mm thick occurred in a few months. Sheathing the splash zone of these hot oil pipes with Monel alloy 400 again proved an effective method of protection, and this method is now extensively used in the North Sea oil industry and elsewhere.

The standard nickel-copper Alloy 400 can be rendered age-hardening by alloying with aluminum and titanium. With suitable heat treatment, this alloy (nickel-copper Alloy 500) can be strengthened and room-temperature tensile strength can readily be doubled compared with the standard alloy. Tensile strengths of 1100 Newtons/mm^2 can be achieved in hot-rolled and heat-treated bar and are advantageous in applications such as shafts and fasteners, particularly for marine applications.

C Stainless Steels

Problems of pitting and crevice corrosion have made some designers reluctant to use stainless steels in seawater. Advantage can be taken of its other properties, however, such as resistance to fast-flowing seawater, for excellent service in some applications. One such application is for pump impellers and shafts. Many pumps use Type 316 stainless steels for these components and, provided the pump is not left standing for long periods, problems with crevice corrosion are minimal.

Where static conditions are expected, advantage is often taken of the cathodic protection provided to austenitic stainless steels by Ni-Resist cast irons. These high-nickel cast irons have good corrosion resistance in marine environments, and are often used for pump casing parts such as inlet bell mouths, column pipes and discharge heads in large vertical pumps such as are used for circulating seawater in MSF and power plants. *Table 10*(12) gives some relevant data.

TABLE 10

EFFECT OF CARBON STEEL AND NI-RESIST TYPE II ON CREVICE CORROSION OF TYPE 316 STAINLESS STEEL IN SEAWATER AT A VELOCITY OF 0.5 M/SEC

	Crevice attack	
Area ratio (SS: Steel or Ni-Resist)	**N° of sites initiated**	**Max^{m} depth of attack MM**
1:0 (Control)	42	3.18
10:1 (Steel)	0	0
50:1 (Steel)	5	0.02
50:1 (Ni-Resist)	0	0

30-day test. M.C.A. – 120 crevice sites

Similar considerations apply to valve stems and valve trim where high resistance to turbulent seawater makes stainless steels attractive.

The growing use of stainless steels for heat exchanger tubing was evident from *Figure 3*. Large amounts of austenitic stainless steels such as AL-6X* and Avesta 254 SMO* have been used for power plant condenser tubing. These alloys are favored where pollution of seawater – particularly where it contains hydrogen sulphide – rules out the use of copper-base alloys.

Major uses of stainless steels in the offshore oil and gas industry are reviewed in *Reference 13*.

In the desalination industry, large quantities of stainless steel are used in applications such as vent piping (used to draw gases from the plant to maintain vacuum conditions), distillate trays and transfer troughs, evaporator vessel linings and demisters.

In modern plants the entire distillate system is normally in Type 316 stainless steel as experience has shown that this high purity water can be corrosive to carbon steel. The low oxygen levels in these plants enable stainless steels to be used to handle boiling seawater and brine as shown in *Table 7*. It also prevents stress corrosion cracking in these warm environments.

A recent application for stainless steels has been in reverse osmosis (RO), a membrane process that enables freshwater to be produced from seawater by pressure. In the RO process, natural aerated seawater is used, which means that Type 316 stainless steel suffers crevice corrosion at the numerous joints associated with the multiple modules used to build up these plants – *Figure 7*.

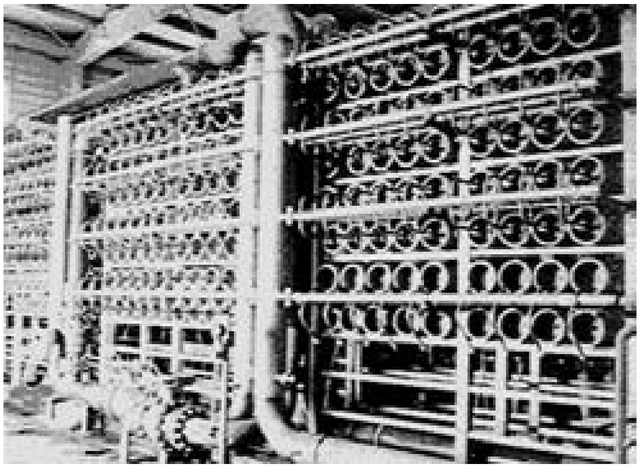

Figure 7: Ras Abu Jarbour osmosis plant

The piping material in these plants is being upgraded to high-alloy stainless steels such as Avesta 254 SMO as in the piping shown in *Figure 7*.

Other major marine markets are in ships' tanks (for carrying wine, chemicals and solvents), fittings for pleasure craft, and fasteners.

D Nickel-Base Alloys

Nickel-base alloys such as Hastelloy C*, Inconel alloy 625* and Incoloy alloy 825* are often used for critical components such as bellows expansion joints, fasteners, exhaust systems and shaft seals. Hastelloy C and Inconel alloy 625 have very high resistance to marine environments but are too expensive for some applications where this resistance could be used to advantage.

One method of overcoming this problem is to use the alloys as a weld overlay on less expensive base materials to provide critical areas, subject to attack, with a high crevice corrosion resistance. Such areas are shaft surfaces in way of seals and crevice areas on pipes and pump casings.

Figure 8 shows an Inconel alloy 625 overlay on a warship fin shaft boss. This boss had corroded severely in service and was repaired with Inconel alloy 625. After several years' service, the welded surface was in perfect condition.

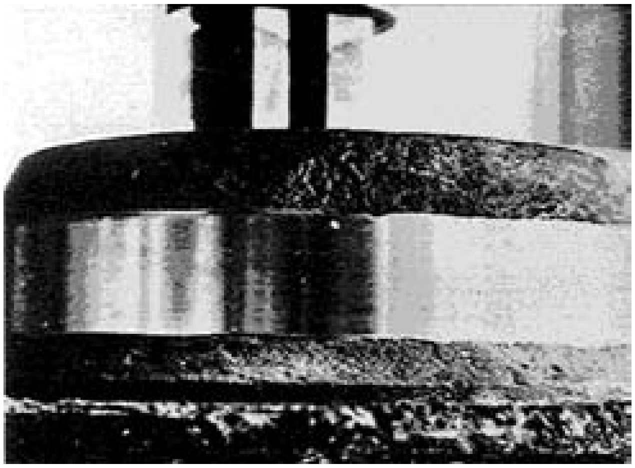

Figure 8: Fin shaft boss with Inconel alloy 625 weld overlay

This technique of weld overlaying of critical areas with a highly resistant material such as Alloy 625 is now widely used for marine and offshore applications.

SUMMARY AND CONCLUSIONS

Nickel-containing alloys such as cupronickels, stainless steels and nickel-base alloys have properties well suited to many marine applications. Modern requirements for high reliability and low life-cycle costs are likely to result in increased usage of these alloys in the marine field.

---

* *Trademark*

REFERENCES

1 C.R. Southwell, J.D. Bultman and A.L. Alexander – *Corrosion of Metals in Tropical Environments* – Final Report of 16-year exposures. *Materials Performance*, July, 1976.

2 *Survey of Materials in Large Desalination Plants Around the World* – March, 1972. E.H. Newton, J.D. Birkett and J.M. Ketteringham. A.D. Little – Report to the U.S. Office of Saline Water.

3 H.J. Dundas, A.P. Bond. *Effects of Delta Ferrite and Nitrogen Contents on Resistance of Austenitic Stainless Steels to Pitting Corrosion.* Pre-print 159. NACE 1975, Toronto.

4 A.J. Sedriks – *Corrosion of Stainless Steels* – Published by Wiley-Inter-Science.

5 H.P. Hack – *Crevice Corrosion Behavior of Molybdenum-Containing Stainless Steels in Seawater.* June, 1983, *Materials Performance.*

6 J.W. Oldfield and W. H. *Sutton – New Technique for Predicting the Performance of Stainless Steels in Seawater and other Chloride-Containing Environments.* British *Corrosion Journal* 15, p. 31, 1980.

7 J.W. Oldfield and B. Todd – *The Use of Stainless Steels and Related Alloys in Reverse Osmosis Desalination Plants.*

8 P. Lovland – *Advanced Corrosion-Resistant Steels and Alloys Offshore.* A summary of Alternatives and Research Needs. Corrosion 86. Paper No. 221, March, 1986, Houston, Texas.

9 R.R. Irving – *The Battle is On for the Tubing in Heat Exchangers. Iron Age*, January 13, 1982.

10 S. Sato and K. Nagata – 5th International Symposium on Fresh Water from The Sea. May, 1976.

11 H. Pitcher and B. Ruhland – *Use of Copper-Nickel Cladding on Ships and Boat Hulls.* CDA Conference, Birmingham, England, April, 1985.

12 T.S. Lee and A.H. Tuthill – *Use of Carbon Steel to Mitigate Crevice Corrosion of Stainless Steels in Seawater. Materials Performance Vol.* 22, No. 1.

13 B. Todd – CIM Conference, Toronto, August, 1986.

APPENDIX

TABLE A: NOMINAL COMPOSITION OF ALLOYS

A ALLOYS OF NICKEL AND COPPER

UNS number	Usual designation	Nominal composition			
		Cu%	Ni%	Fe%	Mn%
C 70600	90/10 Cupronickel	Balance	10	1.25	0.50
C 71500	70/30 Cupronickel	Balance	30	0.60	0.50
C 71640	70/30 Cupronickel 2% Fe 2% Mn	Balance	30	2.00	2.00
N 04400	Monel Alloy 400	31	Balance	1.00	1.25

B STAINLESS STEELS

		Cr%	Ni%	Mo%	Other %
S30403	304L	18	10	-	-
S 31603	316L	17	12	2.5	-
S 31703	317L	18	14	3.5	-
S 31803	2205 Duplex	22	5.5	3.0	0.15 N_2

C NICKEL-BASE ALLOYS

		Cr%	Mo%	Ni%	Fe%	Other %
NO 8904	904L	20	4.5	25	Balance	1.5
NO 8825	Incoloy Alloy 825	22	2.5	42	Balance	1.5
NO 6007	Hastelloy G	22	6.0	Balance		2.0 Cu 2.0 Nb
NO 6625	Inconel Alloy 625	22	8.5	Balance		3.5 Nb + Ta
NO 10002	Hastelloy C	15.5	16.0	Balance		4 W

D NI RESIST CAST IRONS

ISO grade	Usual designation	C% M	Ni%	Cr%	Other
L-Ni Cr 20.2	Type II – see **Table 10**	3.0	20	2	Balance Iron
S-Ni Cr 20.2	Type D-2	3.0	20	2	Balance Iron
GGG NiCr Nb 20.2	Type D-2W	3.0	20	2	Balance Iron

APPENDIX

TABLE B: HIGH ALLOY STAINLESS STEELS COMMERCIALLY AVAILABLE

Typical analysis of some highly alloyed stainless steels

Designation	Producer	Cr%	Ni%	Mo%	Cu%	N%	PRE_N
AL-6XN	Allegheny	20.8	25.0	6.5		0.20	45.4
Uranus SB 8	Creusot-Loire	25.0	25.0	5.0	1.5	0.15	43.9
254 SMO (UNS S31243)	Avesta	20.0	18.0	6.1	0.7	0.20	43.3
A 965 (UNS S31254)	VEW	20.0	18.0	6.1	0.7	0.20	43.3
HR 8N	Sumitomo	21.0	24.5	5.8	0.8	0.20	43.3
AL-6X (UNS N08366)	Allegheny	20.3	24.5	6.3			41.4
Cronifer 1925 HMO (UNS N08925)	VDM	21.0	25.0	5.9		0.14	42.7
Sanicro 28 (UNS N08028)	Sandvik	27.0	31.0	3.5	1.0		38.9
Alloy No. 20 Mod (UNS N08320)	Haynes	22.0	26.0	5.0			38.8