



# SURFACE VEHICLE RECOMMENDED PRACTICE



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Ship Systems and Equipment – Materials for Fluid Systems

## RATIONALE

J1781 has been reaffirmed to comply with the SAE five-year review policy.

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### 1. SCOPE

The scope of this Recommended Practice is to delineate groups of materials for which there is considerable fabrication and operating experience in the sea water environment. In addition, some of the more promising materials for possible future applications are covered.

#### 1.1 Purpose

The purpose of this Recommended Practice is to define materials for use in fluid systems of marine vehicles, including submersibles and advanced surface craft. This report is more particularly directed to the designer of fluid power and piping systems on board marine vehicles.

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## 2. REFERENCES

### 2.1 Applicable Publications

The following publications form a part of the specification to the extent specified herein. The latest issue of the documents shall be used except in those cases where an invitation for bid or procurement contract specifically identifies the issues in effect on a particular date.

#### 2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

- SAE AMS 2447 Coating, Thermal Spray High Velocity Oxygen/Fuel Process
- SAE J1777 General Environmental Considerations for Marine Vehicles
- SAE J1778 Ship Systems and Equipment—Recommended Practice for Hydraulic Fluid Selection
- SAE J1779 Ship Systems and Equipment—Hydraulic System Design Criteria for Marine Vehicles
- SAE J2280 Ship Systems and Equipment—Fasteners—Selection and Identification Requirements

#### 2.1.2 Department of Defense Publications

Available from U.S. Government, DODSSP, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-2179, <http://assist.daps.dla.mil/quicksearch/>.

- MIL-B-24480 Bronze, Nickel-Aluminum (UNS C95800) Castings for Seawater Service
- MIL-STD-438 Schedule of Piping, Valves, Fittings and Associated Piping Components for Submarine Service
- MIL-STD-777 Schedule of Piping, Valves, Fittings and Associated Piping Components for Naval Surface Ships

#### 2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, [www.astm.org](http://www.astm.org).

- ASTM B 150/B 150M Aluminum Bronze Rod, Bar and Shapes
- ASTM B 677 Standard Specification for UNS N08925, UNS N08354, AND UNS N08926 Seamless Pipe and Tube
- ASTM G 82 Standard Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance

## 2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

### 2.2.1 Industry Reports

DTIC No. ADA055609—Materials Study for High Pressure Sea Water Hydraulic Tool Motors; Mechanical Technology Inc., Latham, NY, April 1, 1978, available from DTIC (see 2.2.3)

Fink, F.W. & Boyd, "Corrosion of Metals in Marine Environments," MCIC-78-37/March 1978, Battelle's Columbus Laboratories, Columbus, OH, September 1977

### 2.2.2 Publications

Metal Boat Quarterly "Marine Metals Reference" Summer 1997, Box 991, Port Townsend, WA 98368, <http://www.kastenmarine.com/mbqMetRef.pdf>

### 2.2.3 U.S. Government Reports

Available from Defense Technical Information Center, ATTN: DTIC-BR, Suite 0944, 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218, Tel: 1-800-225-3842 (Assistance--selection 3, option 2), <http://stinet.dtic.mil/info/s-stinet.html>.

DTIC No. ADA020974—Mechanical Properties and Seawater Behavior of Nitronic 50 (22 Cr-13Ni-5Mn) by I.L. Caplan, David W. Taylor Naval Ship R&D Center, Bethesda, MD, Report 4554, January 1976

Handbook of Hydraulic Systems for Deep Ocean Applications, W. E. Schneider and J. A. Sasse, David W. Taylor Naval Ship R&D Center, Annapolis, MD 21402, February 1981

## 3. MARINE ENVIRONMENT

Exposure of fluid power system components to the marine environment on board marine vehicles varies in severity from application to application. While the working fluid, i.e., hydraulic oil or sea water is the prime consideration, the external environment is also critical. The environment may range in severity from slight moisture condensation in air conditioned cabins to severe salt water spray at air inlets; from occasional wetting down in bilges and on weather decks to continuous immersion in external locations below waterline. Wet/dry cycles are often more adverse than continuous wetting by seawater because of such factors as oxygen and lack of cathodic protection when dry. Corrosion rates double with every 10 °C increase in seawater temperature, and can be accelerated by stray electric currents, such as from welding. Mineral deposits, industrial wastes and marine life such as barnacles and micro-organisms may vary from place to place of operation. (See SAE J1777 for additional information.)

Table 1 identifies material properties to be considered in the selection of materials to be used in the marine environment.

TABLE 1 - MATERIAL PROPERTIES IN MARINE ENVIRONMENT

---

1. Mechanical Properties:
Ultimate tensile strength
Yield strength
Shear strength
Cyclic fatigue
Modulus of elasticity
Density
Ductility and fracture toughness
Bearing properties
Lubrication properties
Magnetic properties
2. Susceptibility to Environmental Degradation:
Uniform surface corrosion
Pitting and crevice corrosion
Galvanic corrosion
Stress corrosion cracking
Corrosion fatigue
Erosion and cavitation
Hydrogen embrittlement
Fretting fatigue
Galling and wear
Selective phase attack
Fluid compatibility
Biodeterioration
3. Acquisition and Maintenance Cost Factors:
Raw material cost and availability
Fabricability: forming
distortion under heat treatment
joining
machining
surface finishes
Inspectability
Repairability

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#### 4. CORROSION

Of major concern in selecting metals for use in seawater, is corrosion. It takes many forms: general, galvanic corrosion, pitting and crevice attack, selective phase attack, exfoliation and stress corrosion. Corrosion fatigue can be one of the most rapid modes of deterioration under the combined action of fatigue plus crevice attack. Table 2 illustrates the effect of saltwater immersion without protection on endurance limits. Endurance limits are not given for design, only for emphasis on corrosion protection. Seawater velocity effects such as mechanical or fluid impingement may accelerate corrosion or retard it in the case of crevice attack. Selective phase attack occurs in alloys with susceptible constituents. Cavitation attacks all metals and must be prevented by hydrodynamic design. Flow velocities in constantly running seawater and brine piping should be restricted to reduce the likelihood of erosion or accelerated corrosion due to the stripping of protective oxide layers on the pipe/component internal surfaces. The material used affects the limiting flow velocity. Table 3 provides guidance for pipe sizing.

Attention should also be given to fairness of mating passages, such as at the joint between a flange and valve. Vortices can form at sharp edges resulting in accelerated corrosion rates. As guidance, passages should be fair to within 0.080 inches (2 mm) between diameters.

TABLE 2 - STRENGTH OF METALS IN AIR AND IN SALT WATER

Metal and Alloy Grade	Yield Tensile Strength (ksi) <sup>(1)</sup>	Ultimate Tensile Strength (ksi) <sup>(1)</sup>	Percent Elongation in./in.	Percent Reduction in Area	Longitudinal Charpy Vee Notch (ft-lbs) <sup>(2)</sup>	Fatigue Strength <sup>(3)</sup> @ 10 <sup>8</sup> Cycles Smooth (ksi) <sup>(1)</sup> Air	Fatigue Strength <sup>(3)</sup> @ 10 <sup>8</sup> cycles Smooth (ksi) <sup>(1)</sup> Salt Water <sup>(4)</sup>	Fatigue Strength <sup>(3)</sup> @ 10 <sup>8</sup> cycles Notch (ksi) <sup>(1)</sup> Air	Fatigue Strength <sup>(3)</sup> @ 10 <sup>8</sup> cycles Notch (ksi) <sup>(1)</sup> Salt Water <sup>(4)</sup>
Steels									
High Yield Strength, HY80	88	103	27	70	100	42	9	20	4
HY100	100	120	22	65		66	12	16	4
Low Alloy HY130	140	150	21	65	50	67	9	43	4
Maraging 18% Nickel 17-4PH (H1100)	180	191	15	65	60	65	7	35	4
precipitation hardened	135	150	17	58	45	60	20	30	10
15-5PH (H1100) precipitation hardened	135	150	17	58	45	60	20	30	—
Titanium									
Ti-7Al-2Cb-1Ta-1Mo	110	125	12	30	40	38	40	20	20
Ti-6Al-4V	120	135	12	25	20	55	55	38	35
Nickel									
Inconel 718	147–175	160–200	12–24	15–30	50–75	84	25	25	20
Aluminum									
5456 H116	40	33	12	—	—	20	<5	16	<5

1. 1 ksi = 1000 psi = 6.9 MPa

2. At approximately 20 °C

1 ft-lb = 1.36 N·m

3. Rotating Cantilever Specimens, 1450 cpm

4. Salt water immersion without cathodic protection

TABLE 3 - RECOMMENDED MAXIMUM FLOW VELOCITIES TO MINIMIZE CORROSION

Pipe Size (NPS)	Velocity –ft/s (m/s)	
	90:10 CuNi	70:30 CuNi
½	4.2 (1.4)	6.2 (2.0)
¾	4.8 (1.6)	6.8 (2.2)
1	5.4 (1.8)	7.4 (2.4)
1-1/4	6.2 (2.0)	8.2 (2.7)
1-1/2	6.6 (2.2)	8.6 (2.8)
2	7.4 (2.4)	9.4 (3.1)
2-1/2	8.2 (2.7)	10.2 (3.3)
3	9.1 (3.0)	11.1 (3.6)
3-1/2	9.8 (3.2)	11.8 (3.9)
4	10.3 (3.4)	12.3 (4.0)
5	11.5 (3.8)	13.5 (4.4)
6 and larger	12 (3.9)	14 (4.6)

#### 4.1 Galvanic Attack

Because sea water is an excellent electrolyte, severe corrosion often occurs when two different metals are coupled together and immersed in sea water. One metal in the couple may be anodic to the other. The degree of attack depends partly on the relative position of the two metals in the galvanic series for seawater, see Table 4. Usually the greater the difference in potential the greater will be the attack on the anodic member of the couple. Polarization of the surfaces may tend to reduce intensity of the attack with time. Adverse ratio of small exposed anode area to large cathode area accelerates corrosion. A pin hole size flaw in the protective coating of the anode can lead to perforation in a relatively short time.

Metal ions form and electrons are released at the surface of the lower potential metal. The ions, which have a positive electrical charge, go into solution and migrate through the seawater. The electrons, which have a negative electrical charge, pass through the conducting metals to the higher potential.

The electrons are released at the surface of the higher potential metal into the sea water, where they reduce hydrogen ions to atomic hydrogen. The hydrogen is either passed off as gas or is diffused near the surface of the metal, which results in embrittlement, i.e., leading to future cracks.

The area that is corroding is, by definition, an anode; and the area where reduction is occurring, a cathode. A corrosion cell, then consists of four elements:

1. Anode, seat of corrosion (oxidation)
2. Cathode, seat of reduction
3. Metallic path for electrons from anode to cathode
4. Electrolytic path of current from anode to cathode

The following means may be employed for reducing corrosion rate: (a) isolate the anode from the cathode electrically along the metallic path; (b) isolate the surface of the cathode with nonconductive coating; (c) increase the resistance of the electrolytic path by means of nonconducting piping; (d) connect the anode to a sacrificial anode at a still lower potential; (e) impress a protective current from an external source flowing in the electrolyte to the anode.

Cathodic protection requires metallic and electrolytic conduction paths to all parts to be protected.

TABLE 4 - GALVANIC SERIES IN SEA WATER<sup>(1)</sup>

Material		Volts (Calomel Reference) Max.	Volts (Calomel Reference) Min.
Graphite	Cathodic	+0.30	+0.20
Platinum	↑	+0.25	+0.19
Ni-Cr-Mo Alloy C		+0.09	-0.04
Titanium		+0.07	-0.05
Ni-Cr-Mo-Cu-Si Alloy B		+0.05	+0.02
Ni-Fe-Cr Alloy 825		+0.05	-0.02
Alloy 20 Stainless Steels		+0.06	-0.04
316, 317 Stainless Steels, Passive		+0.00	-0.10
Ni-Cu Alloys 400, K-500		-0.03	-0.13
302, 304, 321, 347 Stainless Steels, Passive		-0.05	-0.10
Silver		-0.10	-0.15
Nickel 200		-0.10	-0.20
Silver Braze Alloys		-0.10	-0.20
Ni-Cr Alloy 600		-0.14	-0.18
Ni-Al Bronze		-0.15	-0.22
70-30 Copper Nickel		-0.18	-0.24
Lead		-0.19	-0.25
430 Stainless Steel, Passive		-0.20	-0.27
80-20 Copper-Nickel		-0.21	-0.27
90-10 Copper-Nickel		-0.22	-0.28
Nickel Silver		-0.25	-0.28
410, 416 Stainless Steels, Passive		-0.25	-0.35
Tin Bronzes (G&M)		-0.24	-0.32
Silicon Bronzes		-0.25	-0.29
Manganese Bronze		-0.25	-0.34
Admiralty Brass, Aluminum Brass		-0.26	-0.35
Pb-Sn Solder 50/50		-0.27	-0.36
Copper		-0.30	-0.37
Tin		-0.31	-0.34
Naval Brass, Yellow Brass, Red Brass		-0.30	-0.40
Aluminum Bronze		-0.31	-0.42
316, 317 Stainless Steel, Active, Chrome		-0.35	-0.46
Ni Cr Alloy 600, Active		-0.35	-0.46
Austenitic Nickel Cast Iron		-0.43	-0.54
410, 416, 430 Stainless Steels, Active		-0.45	-0.56
302, 304, 321, 347 Stainless Steel, Active		-0.46	-0.56
Low Alloy Steel		-0.57	-0.63
Mild Steel, Cast Iron		-0.60	-0.71
Cadmium		-0.70	-0.74
Aluminum Alloys		-0.75	-1.00
Beryllium		-0.96	-0.98
Zinc	↓	-0.98	-1.03
Magnesium	Anodic	-1.60	-1.63

1. More specific galvanic series information referring to the seawater conditions of flow/time/temperature is available in ASTM G 82.

4.2 Crevice and Pitting Corrosion

An O-ring gland in 300 series stainless steels in sea water is a typical example of a crevice, where exposed, and, confined sites of a metal form a corrosion cell. See Figure 1. The exposed sites are oxygenated by running water. The confined site under the O-ring is oxygen starved by stagnant seawater.

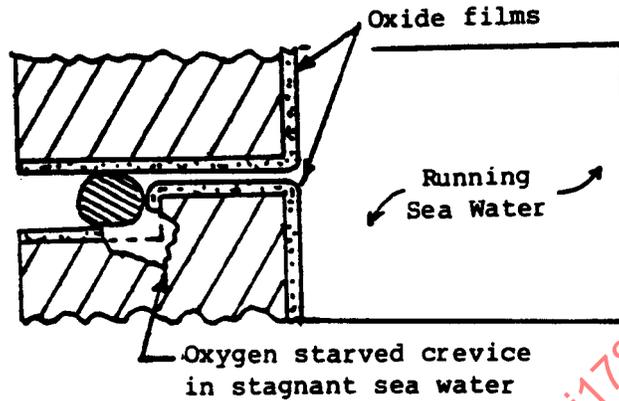


FIGURE 1 - CREVICE CORROSION OF STAINLESS STEEL AT AN O-RING SEAL IN SEA WATER

Stainless steel depends upon a thin "passive" oxide film for its corrosion resistance. When immersed in seawater, chloride ions in the water tend to deteriorate the oxide film of the stainless steel. So long as sufficient free oxygen is available, as in a high velocity stream, the oxygen repairs the threatened breaks in the oxide film. The stainless steel remains "passive" and does not corrode. The effect of seawater velocity on corrosion is shown in Figure 2.

Alloy	Flow Conditions			
	Stagnant	Quiescent	Moderate	High Speed
Aluminum				
2024, 2219 7178 7079 7075 3003	XXXXXX	XXXXXX	XXXXXX	XXXXXX
2014 6061 7002 5052 5154 1100	////	////	////	////
5456 5086 5052 5083	////	////	////	////
90/10 CuNi	////	////	////	////
70/30 CuNi	////	////	////	////
Monel, Ni	////	////	////	////
Stainless Steels	XXXXXX	XXXXXX	////	////
Hastelloy C, Ti	_____	_____	_____	_____

Key	No Attack	Attack Little or Nil	Attack Moderate	Attack Considerable
	_____	////	////	XXXXXX

FIGURE 2 – CREVICE CORROSION AND PITTING VERSUS SEA WATER FLOW CONDITIONS

In stagnant seawater, however, such as under an O-ring seal, the limited amount of oxygen cannot keep the oxide film repaired. The underlying stainless steel begins to corrode by forming an "active" site. Metal ions form and electrons are released to pass through the metal from the corroding site to another site where they become available for reduction of hydrogen ions to hydrogen atoms. The active site, where corrosion occurs is the anode, the passive site where reduction occurs is the cathode as in a galvanic corrosion cell.

These small sites are parts of the same piece of metal, and therefore the metallic conduction path cannot be interrupted. The use of sacrificial anodes is the preferred method of corrosion protection. An alternative is the use of stainless steels containing approximately 4% or more molybdenum which have more stable oxide films. Figure 3 shows the effect of molybdenum and chromium content on crevice corrosion.

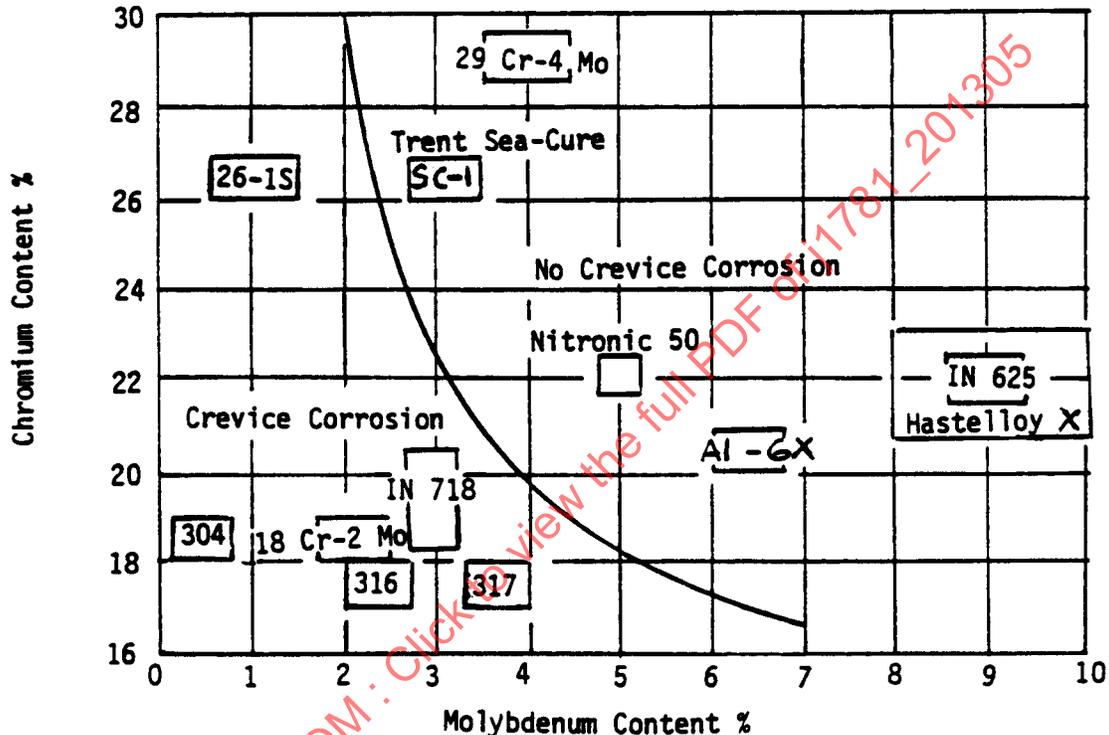


FIGURE 3 - EFFECT OF MOLYBDENUM CONTENT ON CREVICE CORROSION

#### 4.3 General Corrosion

Various points of the metal surface become alternatively anodes and cathodes at various times. Low alloy steels are an example. An increase in metal thickness, "corrosion allowance," is an effective though unsophisticated way to approach the problem of general surface corrosion. A complete nonconducting coating system may be adequate in the absence of severe erosion and cavitation. Plating with a sacrificial anode metal such as cadmium is not durable in immersion applications. Zinc flame spraying the hull of the hydrofoil DENNISON was reported very successful. Cathodic protection consisting of sacrificial anodes or impressed current is recommended.

#### 4.4 Selective Phase Attack

Anodic constituents may be removed selectively from an alloy. Brasses and bronzes are susceptible, particularly if they contain more than 15% zinc. Zinc is leached out leaving behind a sponge-like matrix of copper. Aluminum bronzes may experience selective removal of aluminum unless they contain at least 4% nickel.

#### 4.5 Exfoliation

Metal formed by rolling can be selectively corroded at boundaries of successive layers, which become separated by corrosion products. Exfoliation has been observed on aluminum alloys with more than 5% magnesium at sensitized areas due to heat or cold work.

#### 4.6 Stress Corrosion Cracking

Prolonged static stresses or internal strains resulting from cold work may cause some materials to crack and corrode by intergranular penetration in the presence of a corroding medium. Certain brasses, which normally withstand corrosive conditions in the annealed or stress-relieved state, fail in the cold-worked condition. The existence of a stress condition will tend to increase the rate of corrosion.

### 5. DESIGN GUIDELINES FOR METALS

From the guidance in Section 4 on corrosion, it can be seen that a structural or fluid systems designer must rely heavily on the expertise of materials and process engineers experienced in sea water applications. Specialists will be required to recommend protective coatings, the need for and the type of cathodic protection, and in many instances the desirability of changing alloys to maintain a certain level of corrosion resistance in a given system. A list of common alloys and their corrosion behavior in seawater is given in Table 5. For detailed information on properties, corrosion resistance and material availability, search the web by UNS number or alloy description.

TABLE 5 - CORROSION BEHAVIOR OF COMMON ALLOYS IN SEA WATER

Alloy Type UNS No.	Alloy Designation	Corrosion Resistance	Remarks <sup>(2)</sup>
<u>Titanium Base</u>			
R50250, R50400, R50550, R50700	Commercially Pure (CP)Titanium	Excellent	Offers best seawater corrosion resistance of any of the structural alloys. Severe galling problem.
R56401	Ti 6Al-4V	Excellent	Highest strength-to-weight ratio alloy.
R53620	Ti 3Al-2.5V	Excellent	Tradeoff in toughness of CP for strength of 6Al-4V.
R53622			
R55111	Ti-5-1-1-1	Excellent	Ideal for use in marine environments where toughness and corrosion resistance are essential.
<u>Cobalt Base</u>			
R31233	Co-Cr-Ni Ultimet <sup>(1)</sup>	Excellent	Available in wrought forms, castings, powder. Weldable, often used as an overlay material.
R30003	Elgiloy	Excellent	Wide use in oil industry, excellent spring material.
R30035	MP35N <sup>(1)</sup>	Excellent	For Fasteners.
R30159	MP159 <sup>(1)</sup>	Excellent	For Fasteners, Higher temperatures than MP35N.
<u>Nickel Base</u>			
N10276	Hastelloy C-276 <sup>(1)</sup>	Excellent	Difficult to fabricate. Excellent resistance to pitting and stress corrosion cracking.
N06200	Hastelloy C-2000 <sup>(1)</sup>	Excellent	Improved performance over C-276.
N06022	Hastelloy C-22 <sup>(1)</sup>	Excellent	More versatility for fabrication. Can be welded.
N06686	Inconel <sup>(1)</sup> 686	Excellent	Extraordinarily good pitting resistance, weldable. Mechanical properties better than Alloy C-276.
N06625	Inconel <sup>(1)</sup> 625	Excellent	More easily fabricated than Hastelloy C.
N07041	Rene 41	Excellent	High Temperature Resistance.
N07718/ N07719	Inconel <sup>(1)</sup> 718	Good	High strength level 900-1200 MPa (130-170 ksi) available. Some pitting attack.
N07725	Inconel 725	Excellent	Highly corrosion resistant, extremely high strength.
N04400	Ni-Cu Alloy 400	Good	Pits in stagnant sea water 0.13-0.38 mm per year.
N05500	Ni-Cu-Al Alloy 500	Good	Higher strength than Alloy 400.

TABLE 5 - CORROSION BEHAVIOR OF COMMON ALLOYS IN SEA WATER (CONTINUED)

Alloy Type UNS No.	Alloy Designation	Corrosion Resistance	Remarks <sup>(2)</sup>
<u>Stainless Steel</u>			
<u>6% Moly</u>			
S31254	20Cr-18Ni-6Mo	Good	Good resistance to pitting and crevice corrosion.
N08367	Al-6XN	Fair-Good	Better corrosion resistance than 316 and 50% stronger.
	AL-6XN Plus <sup>(1)</sup>	Good	More corrosion resistant than Al-6XN.
N08926	Inconel 25-6Mo <sup>(1)</sup>	Good	Excellent workability, weldability. See ASTM B 677.
<u>4% Moly</u>			
N08904	AL 904 <sup>(1)</sup> Alloy	Fair-Good	Piping material, see ASTM B 677.
<u>Duplex SS</u>			
S31803	Ferritic Austenitic	Good	A cost effective alternative to 316L. Elevated strength provides weight savings.
S32205			
<u>Super Duplex</u>			
S32750	Ferritic Austenitic	Good	Exceptionally high mechanical strength (over twice the yield strength of 300 series stainless steel. Low thermal expansion. Very high resistance to pitting, crevice, general corrosion and stress corrosion cracking. Good workability and formability.
S32760	Ferritic Austenitic	Good	
S32550	Ferrarium <sup>(1)</sup> 255		
<u>Stainless Steel</u>			
<u>Mo &lt;4%</u>			
S44660	Ferritic Sea-Cure <sup>(1)</sup>	Excellent	Heat exchanger material. Welding is a problem. Corrosion resistance similar to titanium.
N08020	Alloy 20	Good	Very good resistance to pitting for a stainless steel.
S20910	Nitronic <sup>(1)</sup> 50 (XM19)	Good	Greater corrosion resistance than 316 with twice the yield strength.
S21800	Nitronic <sup>(1)</sup> 60	Fair	Better corrosion resistance than 304 with twice the yield strength of 304 and 316.
S66286	A-286	Fair	Excellent in high velocity. High tensile strength.
S17400	17-4 PH	Fair	Susceptible to crevice attack. Excellent in high velocity. Cathodic protection required. Protection of more than -0.8 volt may cause hydrogen embrittlement.
S15500	15-5 PH	Fair	Similar to 17-4PH with better toughness.
S21900	21-6-9	Fair	Similar to 17-4PH.
S31600	316	Fair	May pit in excess of 1.3 mm (50 mils) per year in stagnant water. Should be provided with cathodic protection.
S31603	316L	Fair	Galling problems.
S30400	304	Poor	Weldable variant. Low carbon. Do not use for immersion.
<u>Low Alloy Steel</u>			
	HY 80, HY 100	Poor	Poor General surface corrosion must be controlled by organic coatings.
<u>Copper</u>			
C96400	Cu-Ni 70-30	Excellent	Excellent. Will suffer slight corrosion, but is one of the best general purpose alloys for seawater. Outstanding for piping up to 3.7 m/s (12 ft/sec) velocities. Susceptible to erosion corrosion above. Prevents biological fouling.
C96200	Cu-Ni 90-10	Excellent	Same corrosion resistance as CuNi 70-30 up to about 8 ft/sec; actually superior in stagnant water.
C95800	Alpha-nickel-aluminum bronze	Good	Use MIL-B-24480 and ASTM B150 Alloy C-63200 for wrought material Including propellers.
Various	Phosphor bronze	Good	Wide use as non-ferrous spring materials.

TABLE 5 - CORROSION BEHAVIOR OF COMMON ALLOYS IN SEA WATER (CONTINUED)

Alloy Type UNS No.	Alloy Designation	Corrosion Resistance	Remarks <sup>(2)</sup>
<u>Aluminum</u>			
A95083 A95086	5000 Series	Good	5086 is best. 5083 also good. Must be isolated from steel or other cathodic metals. Condensation drip from copper alloys may cause severe pitting even though the aluminum is electrically isolated.
A96061	6061-T6	Fair-Good	Same remarks as above. Responds well to cathodic protection.
A03560 A97xxx	Alloy 356 7000 Series	Fair-Good Very Poor	Same remarks as above. It is the preferred casting alloy. Do not use for new design. Encapsulate component with paint and seal, provide cathodic protection.
A92xxx	2000 Series	Very Poor	Do not use.
<u>Magnesium</u>			
		Very Poor	Do not use.

1. Trade Name.
2. For more detailed information on materials, their availability and test reports it is recommended that the web be searched by alloy designation and UNS number.

## 6. NON-METALLICS

Non-metallics cover a wide variety of materials including thermoplastics, composites, glass, elastomers and coatings.

### 6.1 Plastics

The term "plastics" covers a variety of organic materials ranging from soft to high strength. The number of plastic materials and their usage for view ports, buoyancy material, gaskets, packings, housings flexible hose and cable expanded at an accelerating rate in the 1970's and 1980's. Delrin<sup>1</sup>, epoxies, fluorocarbons, polyamids (Nylon<sup>1</sup>), and phenolics are listed to name a few.

The strength characteristics and other properties of plastics are specific to the type of resin, additives and curing used. Technical data may be obtained from manufacturer's literature, handbooks, and a multitude of reports generated from Government sponsored programs in various technical areas.

### 6.2 Composites

Fiber reinforced plastics provide strength characteristics in the direction of fibers equal to or better than metal. Transverse strength, shear strength and bearing strength, however, are no better than that of the matrix, and allowance must be made for in the design of mechanical or adhesive bonded joints. Water seepage at the ends of the fibers must be eliminated or the structural system may be destroyed.

Glass reinforced plastics (GRP) gained wide acceptance in the 1970's for secondary structures, such as fairings, sea water tanks and piping, because of low cost and corrosion resistance. Impact strength in compression and fatigue life are poor. Advanced composites such as carbon fiber reinforced plastics have been developed which exceed metals in mechanical properties including strength and stiffness in the direction of the fibers. Graphite-fiber reinforced Teflon<sup>1</sup> is cathodic when coupled to most metal alloys, and may accelerate their corrosion over the contact area.

Torlon 4275 is an example of a composite with a combination of ingredients for achieving desired results. It is a polyamide-imide with glass-fiber reinforcing and a Teflon<sup>1</sup> filler for lubrication. Torlon has relatively low swell and is used for vanes in a sea water motor. Vespel<sup>1</sup> is another example: it is used as a hydraulic motor spline adapter to eliminate fretting.

<sup>1</sup> Trade Name.