APPENDIX

Some Commonly Used Marine Materials

from Dexter, S.C. (1985), Handbook of Oceanographic Materials, Krieger Publishing, Malabar, FL.

Aluminum Alloys

Material	**Composition**	**Density, ρ (lb/in^3)**
Aluminum alloy 5052	97.25% Al, 2.5% Mg, 0.25% Cr	0.097
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
10×10^6	31 (H34)	38 (H34)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.92 to -1.1	Crevice and sometimes pitting attack.	Applications demanding good corrosion resistance and fatigue strength. These include fuel lines, tanks, and sheets.
Special Notes: Severe galvanic attack can occur when placed in contact with steel, stainless steel, copper alloys, nickel alloys, and titanium. Corrosion protection is desired for submerged applications.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Aluminum alloy 6061	97.95% Al, 1.0% Mg, 0.6% Si, 0.25% Cu, 0.20% Cr	0.098
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
10×10^6	40 (T6)	45 (T6)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.72 to -1.07	Crevice and pitting attack. May also undergo intergranular attack and SCC.	Applications demanding adequate corrosion resistance and good mechanical properties. The most versatile aluminum alloy for marine use.
Special Notes: Severe galvanic attack can occur when placed in contact with steel, stainless steel, copper alloys, nickel alloys, and titanium. Cathodic protection and coating is desired for submerged applications.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Aluminum alloy 7075	90% Al, 5.6% Zn, 2.5% Mg, 1.6% Cu, 0.3% Cr	0.101
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
10.4×10^6	73 (T6)	83 (T6)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.72 to -0.83	Severe crevice and pitting attack. Also susceptible to SCC and exfoliation.	Applications requiring high strength and low weight.
Special Notes: Severe galvanic attack can occur when placed in contact with steel, stainless steel, copper alloys, nickel alloys, and titanium. Must be anodized, coated, and cathodically protected for submerged applications.		

Copper and Copper alloys

Material	**Composition**	**Density, ρ (lb/in^3)**
Copper	99.9% Cu	0.322
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
17 x 10^6	50 (Fully hardened)	55 (Fully hardened)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.12 to -0.30	Uniform attack and sometimes localized attack as a result of metal ion concentration cells. Velocity effects can also be quite marked.	Electrical and architectural applications. Resists biofouling at corrosion rates > 1 mpy.
Special Notes: None		

Material	**Composition**	**Density, ρ (lb/in^3)**
Beryllium-Copper, CDA 172	97.9% Cu, 1.9% Be, 0.2% Co	0.298
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
18 x 10^6	150 - 190 (HT and 75% Cold Worked)	195 - 205 (HT and 75% Cold Worked)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.10 to -0.25	Uniform corrosion and slight crevice attack.	Applications requiring good corrosion resistance and high strength. These include springs, bearings, and bushings.
Special Notes: As in most copper alloys, metal ion concentration cells may form.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Red Brass, CDA 230	85% Cu, 15% Zn	0.316
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
17 x 10^6	49 (50% Work Hardened)	57 - 72 (50% Work Hardened)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.20 to -0.40	Uniform corrosion and slight dezincification.	Applications requiring good corrosion resistance.
Special Notes: As in most copper alloys, metal ion concentration cells may form.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Inhibited Admiralty Brass	71% Cu, 28% Zn, 1% Sn, 0.6% As, Sb, or Pb	0.308
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
16 x 10^6	72 (Fully Hardened)	88 - 97 (Fully Hardened)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.16 to -0.25	Uniform corrosion and crevice attack. Erosion corrosion at velocities > 6 fps.	Heat exchanger and condenser tubes and plates.
Special Notes: As in most copper alloys, metal ion concentration cells may form.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Naval Brass	60% Cu, 39% Zn, 1% Sn	0.304
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
15 x 10^6	66 (Hard-Drawn)	88 (Hard-Drawn)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.20 to -0.27	Uniform corrosion and dezincification (not completely eliminated with CP).	Condenser plates, prop shafts, fasteners.
Special Notes: Dezincification of this alloy may be severe, and, therefore, should be used with caution in submerged applications.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Aluminum Bronze D, CDA 614	91% Cu, 7% Al, 2% Fe	0.281
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
18 x 10^6	40 - 55 (Hardened)	75 - 85 (Hardened)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.09 to -0.26	Uniform corrosion and some dezincification and crevice corrosion	Corrosion resistant tubing, tanks, fasteners, and sheathing.
Special Notes: As in most copper alloys, metal ion concentration cells may form.		

Material	**Composition**	**Density, ρ (lb/in^3)**
High Silicon Bronze A, CDA 655	94.8% Cu, 3.3% Si, 1.5% Mn, < 1.5% Fe and Zn	0.308
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
15 x 10^6	45 - 57 (Half-Hard)	78 - 98 (Half-Hard)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.17 to -0.23	Uniform corrosion and crevice corrosion.	Marine hardware, fasteners, shafting, and heat exchanger tubing.
Special Notes: As in most copper alloys, metal ion concentration cells may form.		

Material	**Composition**	**Density, ρ (lb/in^3)**
90-10 Copper-Nickel	88.7% Cu, 10% Ni, 1.3% Fe	0.323
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
18 x 10^6	57 (Light Drawn)	60 (Light Drawn)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.15 to -0.30	Uniform corrosion and some surface attack.	Excellent resistance to marine fouling if allowed to freely corrode. Used for seawater tubing and boat hulls.
Special Notes: Susceptible to sulfide attack. Velocity effects at velocities > 10 fps.		

Material	**Composition**	**Density, ρ (lb/in^3)**
70-30 Copper-Nickel	68.9% Cu, 30% Ni, 0.5% Fe, 0.6% Mn	0.323
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
22 x 10^6	79 (Cold Drawn)	85 (Cold Drawn)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.17 to -0.23	Uniform corrosion and some surface attack.	Good strength. Used in heat exchangers with high water velocities.
Special Notes: Susceptible to sulfide attack. Velocity effects at velocities > 15 fps.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Cast Silicon Brass and Bronze	82 - 91% Cu, 5 - 14% Zn, 4% Si	0.302
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
15 x 10^6 - 18 x 10^6	22 - 35 (As Cast)	55 - 70 (As Cast)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
~ -0.27	Uniform corrosion.	Bearings, impellers, gears, props, pumps, fittings.
Special Notes: None		

Material	**Composition**	**Density, ρ (lb/in^3)**
Cast Aluminum Bronze	81 - 88% Cu, 9 - 13% Al, 1 - 5% Fe, others	0.272 - 0.281
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
14 x 10^6 - 20 x 10^6	40 - 80 (Heat Treated)	80 - 124 (Heat Treated)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.3 to -0.4	Uniform corrosion and dealloying.	Pump housings, bearings, impellers, gears, props, fittings.
Special Notes: None		

Nickel Alloys

Material	**Composition**	**Density, ρ (lb/in^3)**
Monel 400	66.25% Ni, 31.5% Cu, 1.35% Fe, 0.9% Mn	0.319
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
26 x 10^6	90 - 130 (Fully Hardened)	100 - 140 (Fully Hardened)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.04 to -0.14	Uniform corrosion, pitting, and crevice attack.	Valves, pumps, prop shafts, fixtures, fasteners.
Special Notes: Resists erosion corrosion to high velocities. May cause severe galvanic attack of less noble metals when coupled.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Inconel 625	65.3% Ni, 18.6% Cr, 9% Mo, 4% Cb, 3% Fe, 0.05% C	0.305
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
29.8 x 10^6	201 (70% Cold Worked)	219 (70% Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.04 to +0.10	Highly resistant to most forms of attack.	Wire rope, propeller blades, fittings, springs, fasteners. Parts where little to no corrosion can be accepted.
Special Notes: Resists erosion corrosion to high velocities.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Incoloy 825	41.8% Ni, 21.5% Cr, 30% Fe, 3% Mo, 1.8% Cu, 1% Ti, 0.03% C	0.294
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28 x 10^6	35 - 45 (Cold Drawn)	85 - 101 (Cold Drawn)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.03 to +0.05	Crevice corrosion and pitting.	Components in desalination plants and heat exchangers.
Special Notes: Resistant to chloride SCC.		

Iron and Steels

Material	**Composition**	**Density, ρ (lb/in^3)**
Ductile Cast Iron	3.3 - 4.0% C, 2 - 3% Si, 0.2 - 0.6% Mn, < 2.5% Ni, > 0.15% total P and Mg, remainder Fe	0.257
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
23 x 10^6 - 25 x 10^6	40 - 150	60 - 175
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.60 to -0.72	Mostly uniform with some shallow pitting.	General machinery parts, props, piping.
Special Notes: Cathodic protection is needed for longer term submerged exposure.		

Material	**Composition**	**Density, ρ (lb/in^3)**
AISI 1040 Steel	99.6% Fe, 0.4% C	0.283
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
30 x 10^6	86 (Heat Treated)	113 (Heat Treated)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.60 to -0.70	Mostly uniform with slight crevice corrosion.	Multiple structural and mechanical uses.
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Material	**Composition**	**Density, ρ (lb/in^3)**
AISI 1080 Steel	99.2% Fe, 0.8% C	0.283
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
30 x 10^6	142 (Heat Treated)	190 (Heat Treated)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.60 to -0.70	Mostly uniform with slight crevice corrosion. Also susceptible to SCC and hydrogen embrittlement.	Multiple structural and mechanical uses.
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Material	**Composition**	**Density, ρ (lb/in^3)**
HY-80 Steel	2 - 3.25% Ni, 1 - 1.8% Cr, 0.2% - 0.6% Mo, 0.15 - 0.35% Si, <0.25% P and S, 0.1 - 0.4% Mn, 0.18% C, remainder Fe	0.284
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
30 x 10^6	80 - 100 (Quenched and Tempered)	103 (Quenched and Tempered)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.63	Mostly uniform.	Hull plating, offshore platforms, tanks pressure vessels, cranes, booms
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Material	**Composition**	**Density, ρ (lb/in^3)**
HY-100 Steel	2.25 - 3.5% Ni, 1 - 1.8% Cr, 0.2% - 0.6% Mo, 0.15 - 0.35% Si, <0.25% P and S, 0.1 - 0.4% Mn, 0.2% C, remainder Fe	0.284
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
30 x 10^6	100 - 105 (Quenched and Tempered)	110 - 118 (Quenched and Tempered)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.63	Mostly uniform. Some tendency towards SCC and hydrogen embrittlement.	Hull plating, offshore platforms, tanks pressure vessels, cranes, booms
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Low Alloy-High Strength Steels (ASTM A-242 and A-441)	0.18 - 0.22% C, 0.5 - 1.5% (each) Mn, Ni, Cr, ~0.25% (each) P, Si, S, Cu, remainder Fe	0.283
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
30 x 10^6	40 - 60 (Annealed)	60 - 80 (Annealed)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.57 to -0.63	Mostly uniform with some crevice corrosion and pitting.	Structural sections and members.
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Maraging 300 Steel	18 - 19 % Ni, 8.5 - 9.5% Co, 4.7 - 5.2% Mo, 0.5 - 0.7% Ti, 0.05 - 0.15% Al, < 0.03% C, remainder Fe	0.290
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
29 x 10^6	295 - 303 (Heat Treated)	297 - 306 (Heat Treated)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.57 to -0.58	Uniform, SCC, and hydrogen embrittlement. SCC and embrittlement can be controlled with cathodic protection.	High strength weldable structural pieces.
Special Notes: Coatings and/or cathodic protection is needed for marine use. Galvanic attack may occur if this alloy is immersed in seawater and in contact with copper alloys, nickel alloys, stainless steels, or titanium alloys.		

Titanium and Titanium Alloys

Material	**Composition**	**Density, ρ (lb/in^3)**
Unalloyed Titanium	98.9 - 99.5% Ti	0.163
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
15 x 10^6	up to 90 (Cold Worked)	up to 100 (Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.05 to +0.06	None.	Structural members, marine parts requiring immunity, impressed current anodes.
Special Notes: SCC is possible if titanium contains higher levels of oxygen.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Titanium 6Al-4V	5.5 - 6.5% Al, 3.5 - 4.5% V, <0.25% Fe, remainder Ti	0.160
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
16.5 x 10^6	155 (Age Hardened)	165 - 170 (Age Hardened)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.05 to +0.06	None, except some tendency for SCC.	Pumps, impellers, structural members, marine hardware and parts requiring immunity.
Special Notes: None		

Stainless Steels

Material	**Composition**	**Density, ρ (lb/in^3)**
302 Stainless Steel	70.85 - 74.85% Fe, 17 - 19% Cr, 8 - 10% Ni, 0.15% C	0.290
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28 x 10^6	75 (Quarter Hard)	125 (Quarter Hard)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.05 to -0.10 (passive) -0.45 to -0.57 (active)	Crevice and pitting corrosion. Susceptible to local attack in areas covered by fouling	General purpose in non-submerged applications.
Special Notes: Local attack minimized in water velocities > 5 fps, but not generally recommended for submerged use due to pitting.		

Material	**Composition**	**Density, ρ (lb/in^3)**
303 Stainless Steel	17 - 19% Cr, 8 - 10% Ni, > 0.15% S or Se, 0.15% C, remainder Fe	0.290
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28 x 10^6	75 (Cold Worked)	110 (Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.05 to -0.10 (passive) -0.45 to -0.57 (active)	Severe crevice and pitting corrosion. Susceptible to local attack in areas covered by fouling	Generally not recommended for seawater application.
Special Notes: This grade may be substituted for others by suppliers with devastating consequences. Non-magnetic, austenitic alloy.		

Material	**Composition**	**Density, ρ (lb/in^3)**
304 Stainless Steel	67.92 - 72.92% Fe, 18 - 20% Cr, 9 - 12% Ni, 0.08% C	0.290
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28 x 10^6	75 (Cold Worked)	110 (Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.09 to -0.15 (passive) -0.20 to -0.57 (active)	Crevice and pitting corrosion. Susceptible to local attack in areas covered by fouling. Heat effected zones may be sensitized.	Topside wire rope and general purpose submerged use where velocities are > 5 fps.
Special Notes: Cathodic protection is necessary for submerged structural applications when exposure is greater than two months. Non-magnetic, austenitic alloy.		

Material	**Composition**	**Density, ρ (lb/in^3)**
316 Stainless Steel	64.92 - 71.92% Fe, 16 - 18% Cr, 10 - 14% Ni, 2 - 3% Mo, 0.08% C	0.290
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28 x 10^6	30 - 42 (Annealed)	80 - 90 (Annealed)
Potential in Seawater, ref. S.C.E. and Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.00 to -0.15 (passive) -0.35 to -0.60 (active)	Crevice and pitting corrosion. Susceptible to local attack especially in areas covered by fouling. Heat effected zones may be sensitized.	Topside wire rope and general purpose where velocities are > 5 fps.
Special Notes: Cathodic protection is necessary for submerged structural applications when exposure is greater than six months. This is the most corrosion resistant 300 series stainless. Non-magnetic, austenitic alloy.		

Material	**Composition**	**Density, ρ (lb/in^3)**
17-4 PH Stainless Steel	16.5% Cr, 4% Ni, 4% Cu, 0.3% Nb and Ta, 0.07% C, remainder Fe	0.280 - 0.282
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
28.5 x 10^6	178 - 185 (Hardened)	200 (Hardened)
Potential in Seawater, ref. Ag-AgCl (V)	**Corrosion Types Suffered**	**Uses**
-0.10 to -0.20 (passive) -0.20 to -0.40 (active)	Crevice and pitting corrosion. Weld bead attack.	Parts with moderate corrosion resistance and high strength to weight ratio.
Special Notes: Cathodic protection should be from impressed current or mild steel sacrificial anodes. Problems arise with aluminum, zinc, and magnesium anodes. Cathodic protection may lead to hydrogen embrittlement and cracking.		

Material	**Composition**	**Density, ρ (lb/in^3)**
410 Stainless Steel	85.35 - 87.35% Fe, 11.5 - 13.5% Cr, 1% Mn, 0.15% C	0.280
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
29 x 10^6	140 - 145 (Heat Treated)	180 - 190 (Heat Treated)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.24 to -0.35 (passive) -0.45 to -0.57 (active)	Severe crevice and pitting corrosion.	Applications where a high strength alloy is important. Submerged applications require cathodic protection to prevent localized attack.
Special Notes: Magnetic, martensitic alloy.		

Other Metals

Material	**Composition**	**Density, ρ (lb/in^3)**
Commercially Pure Magnesium	99.98% Mg	0.063
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
5.7×10^6 - 6.5×10^6	3 (As Cast)	13 (As Cast)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-1.60 to -1.63	Rapid uniform corrosion. Severe galvanic effects when coupled with all common marine metals.	Sacrificial anodes and corrosive links.
Special Notes: Not suitable for structural applications in seawater.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Zinc	99.92% Zn, 0.08% Pb	0.258
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
----	----	19 - 23 (Hot Rolled)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.98 to -1.03	Uniform corrosion with some pitting in anaerobic conditions.	Galvanizing, sacrificial anodes and corrosive links.
Special Notes: None.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Lead	----	0.410
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
2.0×10^6	----	2.0 (As Cast)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.19 to -0.25	Uniform corrosion.	Galvanizing, sacrificial anodes and corrosive links.
Special Notes: None.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Gold	99.5 - 99.99% Au	0.698
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
10.8×10^6 - 11.6×10^6	30 (60% Cold Worked)	32 (60% Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
----	Completely resistant to marine corrosion.	Specialty applications and electrical contacts.
Special Notes: None.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Platinum	99.85% Pt	0.775
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
21 x 10^6 - 25 x 10^6	27 (50% Cold Worked)	28 - 30 (50% Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
+0.20 to +0.35	Completely resistant to marine corrosion.	Impressed current anodes and electrical contacts.
Special Notes: None.		

Material	**Composition**	**Density, ρ (lb/in^3)**
Silver	99.9% Ag	0.379
Elastic Modulus, E (psi)	**Yield Strength, σ_y (ksi)**	**Tensile Strength, σ_u (ksi)**
10.3 x 10^6 - 11.3 x 10^6	44 (50% Cold Worked)	up to 54 (50% Cold Worked)
Potential in Seawater, ref. S.C.E. (V)	**Corrosion Types Suffered**	**Uses**
-0.09 to -0.14	Slight uniform corrosion. Increased tarnish with sulfur compounds present.	Electrical conductors and radar applications. Solder when alloyed.
Special Notes: None.		

Polymers, Rubbers, and Elastomers

Material	**Description**	**Specific Gravity**
ABS, Medium Impact	Thermoplastic (acrylonitrile butadiene styrene)	1.05 - 1.07
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
3.0×10^5 - 4.1×10^5	0.2 - 0.45% in 24 hrs.	5.9 - 8.0
Behavior in the Marine Environment		**Uses**
Slight yellowing and embrittlement in direct sunlight. No chemical degradation in seawater. Not attacked by borers unless in contact with wood.		Multiple structural uses. Pipe, tubing, instrument housings, bearings.

Material	**Description**	**Specific Gravity**
Acetal, Standard Homopolymer	Thermoplastic (tradenames - Delrin, Celcon)	1.43
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
5.2×10^5	0.25% in 24 hrs.	10.0
Behavior in the Marine Environment		**Uses**
Slight chalking in sunlight. No chemical degradation in seawater. Usually not attacked by borers unless in contact with wood or tape. It is attacked by strong acids and bases. Excellent resistance to many organic solvents.		Gears, bushings, levers, shafts, springs, hardware.

Material	**Description**	**Specific Gravity**
Cast Acrylics	Polymethyl methacrylate (tradenames - Lucite, Perspex, Plexiglas)	1.17 - 1.28
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
2.7×10^5 - 5.0×10^5	0.2 - 0.5% in 24 hrs.	5.5 - 8.0 (High Impact Sheet)
Behavior in the Marine Environment		**Uses**
Usually not affected by sunlight. No chemical degradation in seawater. Usually not attacked by borers unless in contact with wood or tape. Water absorption can lead to a 10% reduction in hardness and up to a 30% reduction in tensile strength. It is attacked by strong acids and bases. Soluble in ketones, esters, and aromatic and chlorinated hydrocarbons. Excellent resistance to many organic solvents.		Lenses, windows, housings and many general purpose applications.

Material	**Description**	**Specific Gravity**
Epoxy	Diglycidal ether of bisphenol A	1.1 - 2.0
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
5×10^5 - 15×10^5	0.1 - 1.0% in 24 hrs.	5 - 15
Behavior in the Marine Environment		**Uses**
Resistant to sunlight with UV inhibitors. Usually not attacked by borers unless in contact with wood or tape. May be attacked by sulfuric and acetic acid. Some attack by stong bases. Resistant to organic solvents and weak acids and bases.		Potting material for electical components, castings, marine coatings, adhesives, patching compounds.

Material	**Description**	**Specific Gravity**
Nylon, Type 6	Thermoplastic, polyamide	1.14
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
3.8×10^5	1.3 - 1.9% in 24 hrs.	9.5 - 12.5
Behavior in the Marine Environment		**Uses**
Embrittled by prolonged exposure to sunlight. Usually not attacked by borers unless in contact with wood. May be attacked by strong acids, phenols, and formic acid. Resistant to bases, weak acids, and most common solvents. Water absorption and swelling may alter dimensions and mechanical properties		Bearings, gears, bushings, housings, rods, ropes, coatings.

Material	**Description**	**Specific Gravity**
Polycarbonate (unfilled)	Tradenames - Lexan, Merlon	1.19 - 1.25
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
3.0×10^5 - 4.5×10^5	0.12 - 0.19% in 24 hrs.	9.0 - 10.5
Behavior in the Marine Environment		**Uses**
Sunlight may lead to a slight color change and some embrittlement. No chemical degradation in seawater. Usually not attacked by borers unless in contact with wood. Low water absorption leads to good dimensional stability and retention of properties. It is attacked by strong acids and bases, organic solvents, and fuels. Resistance to weak acids, oils, and greases.		Lenses, windows, housings, impellers and parts requiring high impact resistance.

Material	**Description**	**Specific Gravity**
Polyethylene, High Density	Thermoplastic (Tradenames - Marlex, Norchem, Rulan)	0.95 - 0.96
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
3.0×10^5 - 4.5×10^5	< 0.01% in 24 hrs.	4.4
Behavior in the Marine Environment		**Uses**
Greatly degraded by sunlight if inhibitors are not used. Usually not attacked by borers unless in contact with wood. Generally shows excellent resistance to the marine environment. Good chemical resistance. Slowly attacked by strong acids.		Wire and cable insulation, pipe, housings.

Material	**Description**	**Specific Gravity**
Polypropylene	General purpose and high impact thermoplastic	0.89 - 0.91
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
1.6×10^5 - 2.2×10^5	< 0.01 - 0.03% in 24 hrs.	4.3 - 5.5
Behavior in the Marine Environment		**Uses**
Greatly degraded by sunlight if inhibitors are not used. Usually not attacked by borers unless in contact with wood. Generally shows excellent resistance to the marine environment. Good chemical resistance. Slowly attacked by strong acids.		Wire and cable coatings, film, packaging, hinges housings.

Material	**Description**	**Specific Gravity**
Teflon, PTFE	Polytetrafluoroethylene (tradenames - Teflon, Fluon, Halon, Rulon)	2.1 - 2.3
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
0.38×10^5 - 0.65×10^5	0.01% in 24 hrs.	2.0 - 6.5
Behavior in the Marine Environment		**Uses**
Not degraded by sunlight. Usually not attacked by borers unless in contact with wood. Generally shows excellent resistance to the marine environment. Excellent chemical resistance. May be attacked by the alkali metals.		Pipes, valves, bearings, impellers, electrical insulators, non-stick coatings.

Material	**Description**	**Specific Gravity**
Polyvinyl Chloride, PVC	Polytetrafluoroethylene (tradenames - Teflon, Fluon, Halon, Rulon)	1.30 - 1.45
Elastic Modulus, E (psi)	**Water Absorption**	**Tensile Strength, σ_u (ksi)**
3.5×10^5 - 6.0×10^5	0.03 - 0.04% in 24 hrs.	5.5 - 9.0
Behavior in the Marine Environment		**Uses**
Sunlight produces minor effects. Generally shows good resistance to the marine environment. Attacked by strong acids, ketones, esters, and aromatic hydrocarbons. Resistant to alcohols, aliphatic hydrocarbons, oils, bases, and weak acids.		Pipes, tanks, molded and extruded parts, housings.

Material	**Description**	**Specific Gravity**
Butyl Rubber	Isobutylene-isoprene	0.90
Tear Resistance	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
Good	Good to Excellent	2.5 - 3.0
Behavior in the Marine Environment		**Uses**
Very good resistance to sunlight produces. Excellent resistance to swelling in water. Resistant to acids, oxidation and heat aging. Vulnerable to many solvents, oils, and fuels.		Flexible electrical insulation, hose, shock absorption, diaphragms.

Material	**Description**	**Specific Gravity**
Natural and Synthetic Rubber	Polyisoprene	0.93
Tear Resistance	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
Excellent	Excellent	2.5 - 4.5
Behavior in the Marine Environment		**Uses**
Fair to poor resistance to sunlight. Marine exposure may cause some swelling. Microorganisms and hydrogen sulfide may lead to severe cracking. Resistant to oxidation and heat aging. Vulnerable to many solvents, oils, and fuels. Shows fair to good resistance to organic acids.		Seals, gaskets, hose, chemical tank linings.

Material	**Description**	**Specific Gravity**
Neoprene Rubber	Chloroprene	1.25
Tear Resistance	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
Fair to Good	Good	3.0 - 4.0
Behavior in the Marine Environment		**Uses**
Very good resistance to sunlight. Marine exposure may cause some swelling. May be degraded by aromatic hydrocarbons. Good to excellent resistance to other organic solvents, oils, fuels, acids, and heat.		Seals, gaskets, chemical tank linings, wetsuits.

Material	**Description**	**Specific Gravity**
Fluorocarbon Elastomers	Trade names: Kel-F, Viton	1.40 - 1.95
Tear Resistance	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
Poor to Fair	Good	1.5 - 3.0
Behavior in the Marine Environment		**Uses**
Very good resistance to sunlight and swelling. May be degraded by alkalies, synthetic lubricants, hydraulic fluids containing phosphates. Excellent resistance to high temperature air and oils.		O-rings, seals, gaskets, hose, shaft seals.

Material	**Description**	**Specific Gravity**
Urethane Elastomers	Trade names: Adiprene, Cyanaprene, Elastothane, Roylar	1.07
Tear Resistance	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
Excellent	Superior	5.0 - 8.0
Behavior in the Marine Environment		**Uses**
Very good resistance to sunlight and swelling (except at high temperatures). May be degraded by acids, alkalies, oxygenated alcohols. Excellent resistance to hydrocarbon solvents, oils.		Components requiring superior abrasion resistance.

Concrete and Glass

Material	**Composition**	**Density, ρ (lb/ft^3)**
Concrete	Varied	140 - 150
Elastic Modulus, E (psi)	**Compressive Strength, (ksi)**	**Flexural Strength, (ksi)**
3 x 10^6 - 6 x 10^6	3.5 - 7.5	0.4 - 0.8
Porosity (% by volume)	**Marine Attack Suffered**	**Uses**
5 - 10	Water absorption up to 2.4% @ 550 ft head. Degraded by high sulfate waters, causing cracking and softening.	Large structural members (with and without steel reinforcement), ship hulls, moorings.
Special Notes: Deterioration of concrete can lead to lowering of pH at the rebar, causing corrosion and spalling of the concrete. For longer term durability concrete, it is desirable to use low permeability types with reduced alkalinity and low 3 CaO Al_2O_3 content.		

Material	**Composition**	**Specific Gravity**
Glass (Borosilicate and Soda Lime)	Trade names: Kimax, Pyrex	2.13 to 2.55
Elastic Modulus, E (psi)	**Abrasion Resistance**	**Tensile Strength, σ_u (ksi)**
7.4 x 10^6 - 10.0 x 10^6	Excellent	0.5 - 40.0
Refractive Index	**Behavior in Marine Environment**	**Uses**
1.468 - 1.525	Generally unaffected by weathering or marine exposure.	Containers, plates, buoyancy spheres, lenses, housings.
Special Notes: May be attacked by hydrofluoric acid and sodium hydroxide.		

Wood

Material	Moisture Content (%)	Specific Gravity
Hardwood, Seasoned Maple and Oak	12	0.63 to 0.68
Elastic Modulus in Bending (psi)	**Modulus of Rupture (ksi)**	**Behavior in Marine Environment**
1.8×10^6	15.8 (maple) 14.3 - 15.2 (oak)	Left untreated these woods can be severely damaged by marine borers in as little as six months exposure when placed within six feet of bottom sediments. The borer attack is generally most rapid in warm coastal and lower latitude waters.

Material	Moisture Content (%)	Specific Gravity
Teak and Mahogany	52 (teak)	0.50 (mahogany)
Elastic Modulus in Bending (psi)	**Modulus of Rupture (ksi)**	**Behavior in Marine Environment**
1.4×10^6 - 1.7×10^6	11.1 - 11.4	These woods are susceptible to borer attack.

Material	Moisture Content (%)	Specific Gravity
Softwood, Seasoned Cedar and Cypress	12	0.46 to 0.47
Elastic Modulus in Bending (psi)	**Modulus of Rupture (ksi)**	**Behavior in Marine Environment**
0.9×10^6 - 1.4×10^6	8.8 (cedar) 10.6 (cypress)	Left untreated these woods can be severely damaged by marine borers in as little as six months exposure when placed within six feet of bottom sediments. The borer attack is generally most rapid in warm coastal and lower latitude waters.

Material	Moisture Content (%)	Specific Gravity
Softwood, Seasoned Pine and Spruce	12	0.35 to 0.40
Elastic Modulus in Bending (psi)	**Modulus of Rupture (ksi)**	**Behavior in Marine Environment**
1.2×10^6 - 2.0×10^6	8.6 - 10.1 (pine) 10.2 (spruce)	Left untreated these woods can be severely damaged by marine borers in as little as six months exposure when placed within six feet of bottom sediments. The borer attack is generally most rapid in warm coastal and lower latitude waters.

Fiber Reinforced Plastics (FRP)

from Agarwal, B.D and L.J. Broutman (1990), Analysis and Performance of Fiber Composites, Wiley Publishing, New York.

Material	**Composition**	**Specific Gravity**
E-Glass Reinforced Epoxy	57% E-Glass, 43% Epoxy	1.97
Tensile Modulus, E (psi)	**Tensile Strength, σ_u (ksi)**	**Longitudinal Poisson's Ratio**
3.1×10^6	82.5	0.25
Uses:		
Applications demanding excellent corrosion resistance and high strength to weight ratio. These include structural members, boat hulls, tanks, specialty items.		
Special Notes: Can be degraded by sunlight if inhibitors or barrier coat protection is not used. May also be somewhat degraded by water absorption if not protected.		

Material	**Composition**	**Specific Gravity**
Kevlar 49 Reinforced Epoxy	60% Kevlar 49, 40% Epoxy	1.40
Tensile Modulus, E (psi)	**Tensile Strength, σ_u (ksi)**	**Longitudinal Poisson's Ratio**
5.8×10^6	94.3	0.34
Uses:		
Applications demanding excellent corrosion resistance and high strength to weight ratio. These include structural members, boat hulls, tanks, specialty items.		
Special Notes: Can be degraded by sunlight if inhibitors or barrier coat protection is not used. May also be somewhat degraded by water absorption if not protected.		

Material	**Composition**	**Specific Gravity**
Carbon Fiber Reinforced Epoxy	58% Carbon Fiber, 42% Epoxy	1.54
Tensile Modulus, E (psi)	**Tensile Strength, σ_u (ksi)**	**Longitudinal Poisson's Ratio**
12.0×10^6	55.1	0.38
Uses:		
Applications demanding excellent corrosion resistance and high strength to weight ratio. Excellent stiffness properties. Uses include structural members, boat hulls, tanks, specialty items.		
Special Notes: Can be degraded by sunlight if inhibitors or barrier coat protection is not used. May also be somewhat degraded by water absorption if not protected.		