ELGILOY®

THE COBALT CHROMIUM-NICKEL ALLOY

CHEMISTRY

Cobalt	39.0 % / 41.0 %	Molybdenum	6.0 % / 8.0 %	Beryllium	0.10 % max
Chromium	19.0 % / 21.0 %	Manganese	1.5 % / 2.5 %	Iron	Balance
Nickel	14.0 % / 16.0 %	Carbon	0.15 % max		

DESCRIPTION

- High strength, ductility and good mechanical properties:
  - Ultimate Tensile Strength - 250,000 to 350,000 psi (1,700 to 2,000 MPa)
  - Hardness (HRC) - 45 to 60
  - Elastic Modulus - Up to 30,000,000 psi (270 GPa)
- Excellent Fatigue Life
- Corrosion Resistant in numerous Environments
- Non-Magnetic
- Stable for most applications
- Performs in temperatures ranging between minus 184˚C (-300˚F) to 454˚C (850˚F)

PHYSICAL PROPERTIES

Density	8.30 g/cm^3 (0.30 lbs. / cu. in)
Linear Expansion	12.7 x 10^{-6} per ˚C (range 0˚C to 50˚C)
Thermal Conductivity	0.0298 Cal/sec/cm/cm^2/˚C
Electrical Resistivity	99.6 micro ohm cm
Thermoelasticity	39.6 x 10^{-5} per ˚C (range 0˚C to 500˚C)
Mean Coefficient of Thermal Expansion	15.17 x 10^{-6} per ˚C (range 0˚C to 500˚C)
Melting Temperature	1427˚C (2600˚F)
Specific Heat	0.103 Cal/gm/˚C (25˚C)
Magnetic Permeability*	1.0004 at room temperature

* For all practical purposes, Elgiloy® is non-magnetic through all temperature ranges. If this is important to your application, consult Elgiloy® engineers.

AVAILABLE FORMS

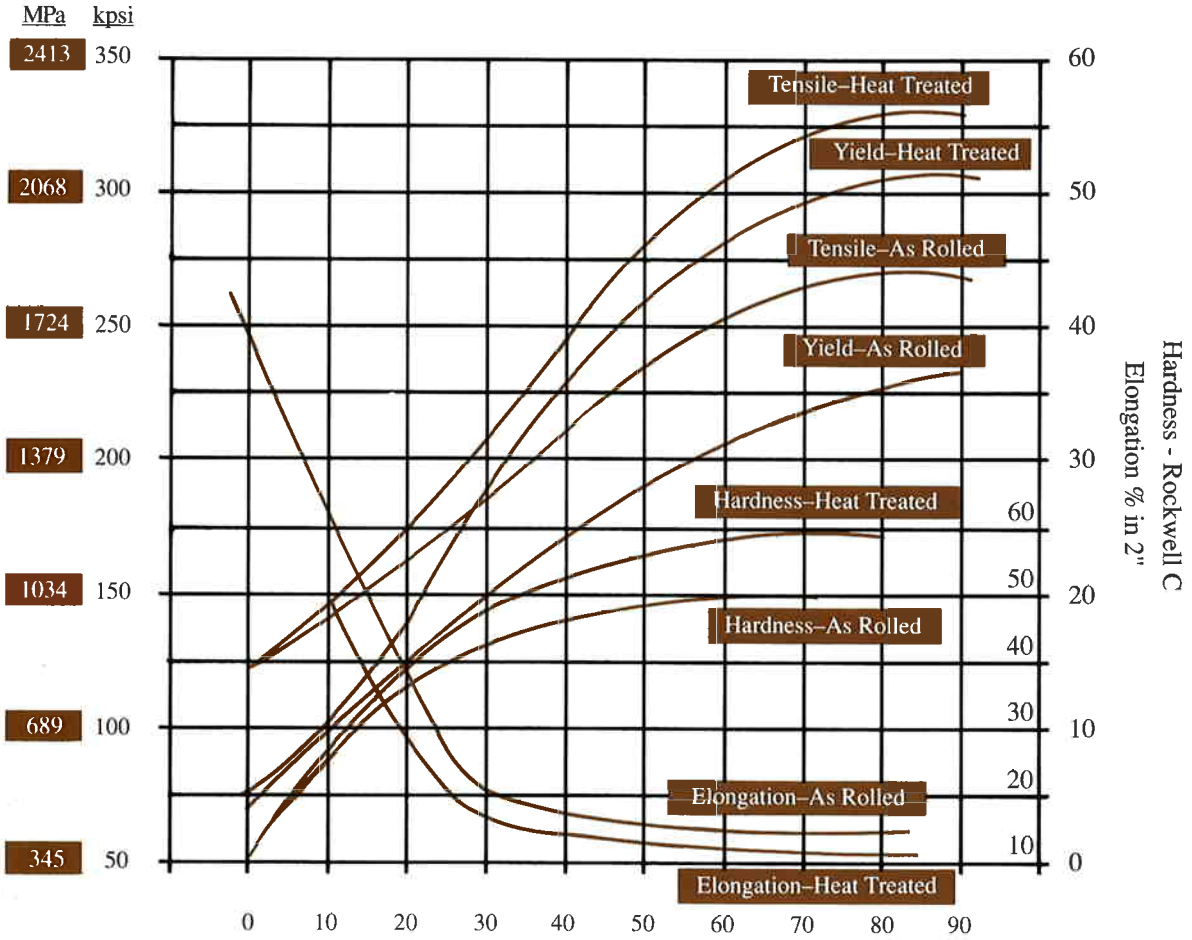
Strip	Sheet	Wire	Cable
Ribbon		Rod	Some Fabricated Parts

STANDARD MATERIAL SPECIFICATIONS

AMS 5833	AMS 5875	UNSR 30003
AMS 5834	AMS 5876	NOL-WS 13822
ASTM F-1058	Listed in NACE MR0175	

MECHANICAL PROPERTIES OF ELGILOY® STRIP

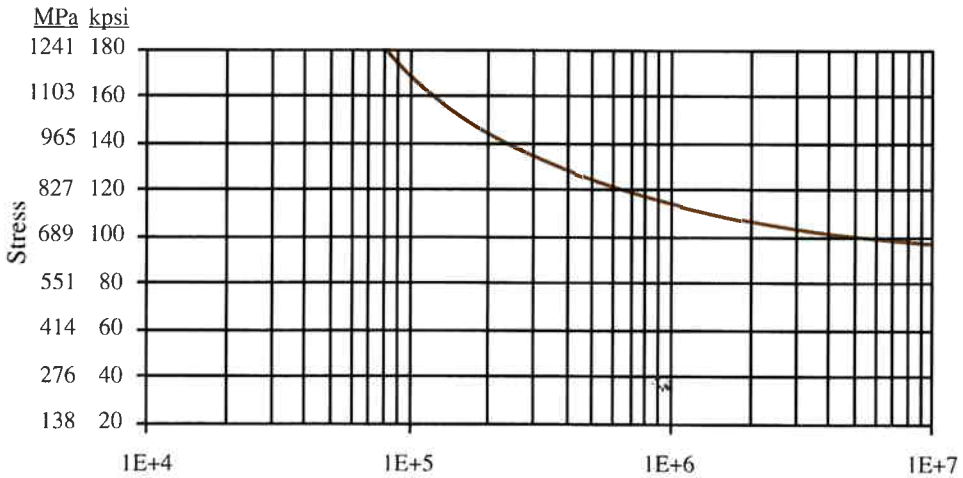
EFFECT OF COLD REDUCTION ON MECHANICAL PROPERTIES OF TYPICAL THIN STRIP ELGILOY®



Heat Treated 5 hours at 482°C (900°F)

The amount of cold reduction also has a direct effect on the hardness of Elgiloy strip and in cases where it is required, hardness can be adjusted by varying the percent of cold work. The chart is based on studies of thin sections of Elgiloy strip since the material is most often used in thicknesses below 0.020". Present equipment will allow an 85 % cold reduction in thickness up to 0.025". Above this, the amount of cold reduction and the maximum strength properties decrease as the thickness increases.

S-N CURVE FOR 0.005" THICK ELGILOY® STRIP (85% REDUCTION, HEAT TREATED)

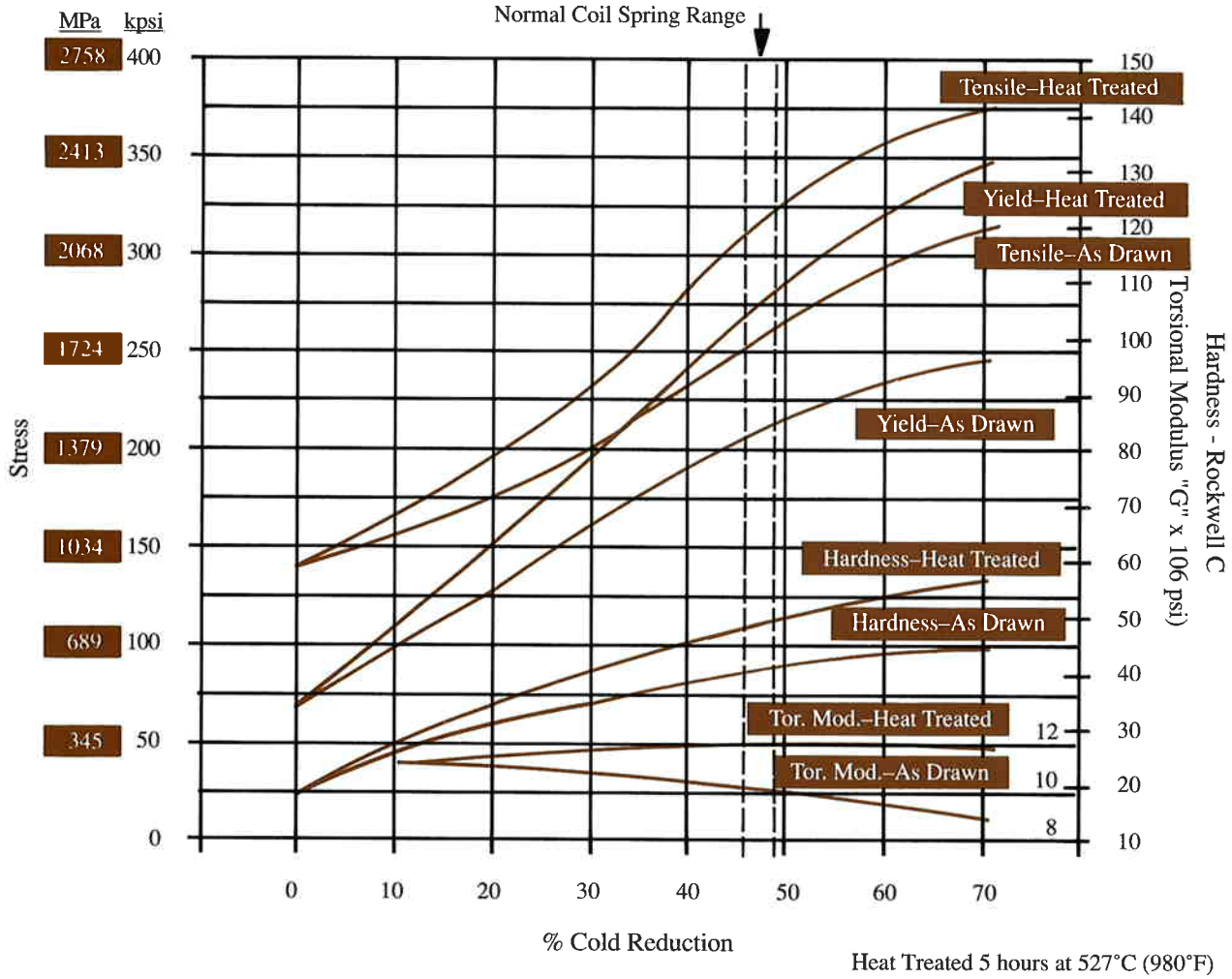


Number of Cycles to Failure

Reverse Bending Fatigue Elgiloy® Strip

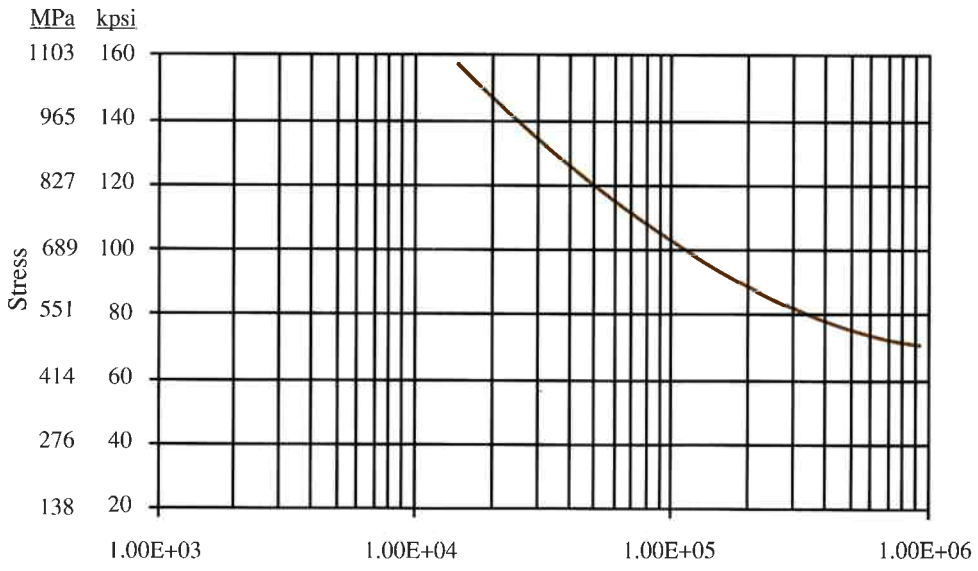
MECHANICAL PROPERTIES OF ELGILOY® WIRE

EFFECT OF COLD REDUCTION ON MECHANICAL PROPERTIES OF 0.050" DIAMETER ELGILOY® WIRE



Heat Treated 5 hours at 527°C (980°F)

S-N CURVE FOR 0.060" DIAMETER ELGILOY® WIRE (45%-48% REDUCTION, HEAT TREATED)



Number of Cycles to Failure

Zero-to-Torsion Fatigue Elgiloy® Wire

FORMING

Information concerning the forming of Elgiloy® must necessarily be of a general nature since the material thickness and cold reduction directly affect its formability. However, the following rules should generally be observed:

A. Forming should be done prior to heat treatment since the heat-treat process strengthens the material and makes it more difficult to form.

B. STRIP
   1. Bending should take place perpendicular to the direction of rolling so that it will be across the elongated grain structure rather than parallel to it.
   2. In forming a 90° bend, the radius should be at least 8 times the material thickness; in a 360° bend, a diameter of 18 to 25 times the material thickness is usually acceptable.

C. WIRE
   1. Wire should not be formed beyond a mean diameter of 4 times the wire size.

HEAT TREATMENT

A. AGING

Elgiloy's® mechanical properties are derived from a combination of cold work and subsequent heat treatment. The amount of reduction in cross-sectional area necessary for each application should be determined individually based on factors of strength, fatigue, and hardness. For maximum mechanical properties the following temperatures, time cycles, and cold reductions are recommended.

TYPE	TEMPERATURE	TIME CYCLE	COLD REDUCTION
Round Wire	980°F ± 10 (527°C ± 5.5)	5 hours	-
Coil Spring	-	-	45% - 48%
Max. Hard.	-	-	75%
Flat Strip	900°F ± 10 (482°C ± 5.5)	5 hours	-
Max. Hard.	-	-	85%

   1. Cooling rate after the aging of Elgiloy is not critical, but air cool or faster is preferred.
   2. Atmosphere for aging can be open air, argon, or vacuum.
   3. To prevent oxidation, a vacuum atmosphere of approximately $10E^{-7}$ torr or better is required.
   4. Stress relieving can be performed at 360°F for sufficient time to produce desired results.

B. ANNEALING

Annealing is not recommended to allow ease of forming since Elgiloy® will thereby lose its cold work, and maximum properties cannot be regained by heat treatment. Nevertheless, where sections not subjected to high stresses are involved, annealing can be performed, and a temperature of 1177 °C (2150 °F) is r ecommended. As noted previously, Elgiloy® has a tendency to embrittle between 593 °C-760 °C (1100 °F-1400 °F) so that when a section is annealed, some portion along the strip may be embrittle. However, if this area is not highly stresses and chill blocks are used to minimize the affected area, satisfactory results can often be obtained.

C. CLEANING
   1. Wire must be cleaned in an alkaline bath (pH > 11) at 145 / 165°F prior to heat treatment.
   2. If oxidation is produced by heat treatment, an acid treatment of 12% HNO_3 and 4% HF must be used at 145 / 165°F for sufficient time to remove oxidation.

JOINING

Whenever possible, it is best to use some mechanical method to join Elgiloy® to itself or any other material since this procedure has been proven superior in fatigue and strength. However, when this method cannot be employed, one of the following means is acceptable:

A. SPOT WELDING

Excellent results have been obtained in spot welding Elgiloy®, and due to its control, precision and cleanliness, it is to be preferred over soldering and brazing where a choice can be made. Any commercial spot-welding equipment can be used with the setup determined by the particular application.

B. SOLDERING AND BRAZING

Elgiloy® can be soldered or brazed by using ordinary techniques; however, the following points should be noted:
   1. A very active flux should be employs and allowed to remain on the material for a minute or two.
   2. When brazing, caution should be exercised to keep temperatures below 593°C-760°C (1100°F-1400°F). Because of this, furnace brazing should be employed whenever possible.

C. LASER AND ELECTRON BEAM WELDING

Best results may be achieved with laser and electron beam welding. Users have had success in obtaining 90,000 psi (620 MPa) endurance limits.

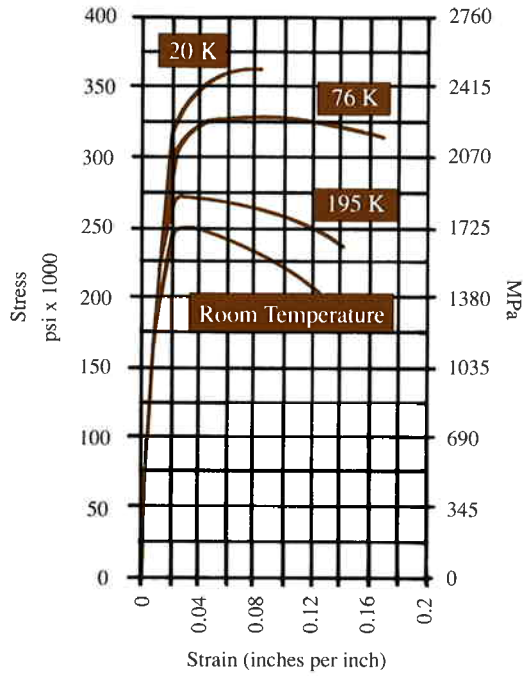
PLATING

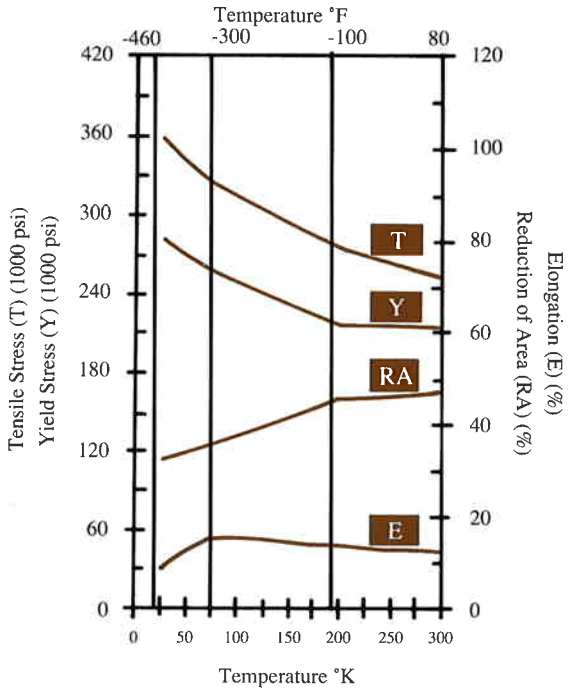
Although Elgiloy® is relatively poor conductor of electricity, it is often used in the contact field when its properties are necessary in the particular application by plating with copper, gold, silver, and other such materials.

EFFECT OF TEMPERATURE ON MECHANICAL PROPERTIES

EFEECT OF SIZE AND TEMPERATURE ON MECHANICAL PROPERTIES OF ELGILOY® WIRE					
Wire Diameter inches	Test Temperature °F	Tensile Strength 1000 psi	Proportional Limit 1000 psi	Yield Strength 0.02% Offset - 1000 psi	Modulus of Elasticity 10^6 psi
0.040	-85	334	226	255	29.5
0.040	Room	332	204	238	30.7
0.040	400	301	196	238	26.6
0.040	600	270	176	205	26.2
0.040	800	269	157	192	25.1
0.040	1000	252	150	182	21.9
0.060	-85	342	220	252	28.8
0.060	Room	308	174	209	30.6
0.060	400	285	179	205	27.3
0.060	600	271	168	195	26.7
0.060	800	265	167	192	25.2
0.060	1000	248	151	178	21.8
0.080	-85	318	196	230	28.5
0.080	Room	299	191	221	29.6
0.080	400	272	163	198	25.8
0.080	600	259	147	176	25.6
0.080	800	250	146	178	24.4
0.080	1000	234	136	164	21.7
0.100	-85	336	204	245	29.9
0.100	Room	312	180	214	29.4
0.100	400	282	167	199	25.7
0.100	600	271	161	193	25.1
0.100	800	261	155	187	24.4
0.100	1000	246	151	172	22.1
0.120	-85	319	191	225	28.7
0.120	Room	305	171	199	30.9
0.120	400	275	170	199	25.7
0.120	600	261	164	186	25.0
0.120	800	252	152	186	24.9
0.120	1000	241	144	170	21.5

TENSILE PROPERTIES VS. TEMPERATURE FOR 45% COLD REDUCED ELGILOY®





EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY				
Temperature T (°C)	Temperature T (°F)	Modulus of Elasticity E (10^6 psi)	Modulus of Rigidity G (10^6 psi)	Poisson's Ratio $\mu = (E/2G) - 1$
24 °C	75 °F	27.500	11.219	0.226
-18 °C	0 °F	28.125	11.415	0.232
-73 °C	-100 °F	28.750	11.669	0.232
-129 °C	-200 °F	29.375	11.900	0.234
-184 °C	-300 °F	29.844	12.106	0.233

CORROSION COMPARISON TABLE

CORROSIVE MEDIA	CONCENTRATION PERCENT	TEMPERATURE °C	TEMPERATURE °F	ELGILOY®	ALLOY HASTELLOY C-276	316 SS
Acetic Acid	50%	106	223	E	G	S
Acetic Acid	10%	99-104	210-220	E	-	E
Ammonium Chloride	50%	113	235	E	S	-
Ammonium Chloride	10% - 15%	104	220	E	E	E
Ammonium Sulfate	10%	99-104	210-220	E	E	-
Calcium Chloride	10%	103	218	E	E	E
Chromic Acid	10%	107	224	U	U	-
Citric Acid	10%	106	222	E	E	E
Cupric Chloride	10%	102	215	U	-	U
De-ionized Water	-	27	80	E	E	-
Ferric Chloride	10%	102	216	U	-	U
Ferric Chloride	10%	24	75	E	E	E
Ferric Sulfate Acid	50%	Boiling Temperature		S	S	-
Hydrochloric Acid	Concentrated	24	75	F	-	-
Hydrochloric Acid	50%	24	75	G	-	-
Hydrochloric Acid	10%	24	75	G	G	U
Hydrochloric Acid	Concentrated	66	150	U	-	-
Hydrochloric Acid	50%	66	150	U	-	-
Hydrochloric Acid	10%	66	150	U	-	U
Hydrochloric Acid	Concentrated	110	230	U	-	U
Hydrochloric Acid	50%	110	230	U	-	U
Hydrochloric Acid	10%	102	216	U	U	U
Lactic Acid	10%	104	219	E	G	-
Mercuric Acid	10%	101	214	E	-	U
Nitric Acid	Concentrated	110	230	F	-	S
Nitric Acid	50%	110	230	G	-	G
Nitric Acid	10%	102	216	E	G	-
Oxalic Acid	10%	102	216	G	G	U
Phenol	10%	104	219	E	-	E
Phosphoric Acid	Concentrated	166	330	U	-	U
Phosphoric Acid	50% - 55%	116-121	240-250	S	G	U
Phosphoric Acid	10%	107	225	E	-	G
Sea Water	-	Room Temperature-Boiling Point		E	E	-
Sodium Chloride	10%	103	218	E	E	E
Sodium Cyanide	10%	103	218	E	-	E
Sodium Hydroxide	Any Concentration	Room Temperature-Boiling Point		E	F	-
Sodium Sulfide	10%	104	220	E	-	E
Sodium Sulfite	10%	104	220	E	-	E
Stannous Chloride	10%	102	216	E	-	E
Sulfuric Acid	Concentrated	259	498	U	-	U
Sulfuric Acid	50%	150	302	U	-	U
Sulfuric Acid	10%	105	221	U	S	U
Tartanic Acid	10%	104	219	E	-	E
Zinc Chloride	10%	103	217	E	E	E

KEY

E	Excellent.....	Less than 2 mpy (0.05 mm/y)
G	Good.....	2 mpy to 10 mpy (0.05 mm/y to 0.25 mm/y)
S	Satisfactory.....	10 mpy to 20 mpy (0.25 mm/y to 0.51 mm/y)
F	Fair.....	20 mpy to 50 mpy (0.51 mm/y to 1.27 mm/y)
U	Unsatisfactory.....	Over 50 mpy (1.27 mm/y)

These charts are intended only as a guide and should not be construed as exact data. The *only* reliable method is to sample material under actual conditions.

SPECIFICATION QUALIFICATIONS

Specification		Environment	Condition
National Association of Corrosion Engineers (NACE)	MR-01-75	Resistant to Sulfate Stress Cracking as specified is standard	Spring Temper
Marshall Space Flight Center			
"Material Selection List for Space Hardware Systems"	MSFC-HDBK-527	Corrosion Resistance and Stress Corrosion Cracking Susceptibility Rating "A"	Spring Temper
"Material Selection List for Space Hardware Systems"	MSFC-HDBK-527	Compatible with Gaseous and Liquid Oxygen, Nitrogen Tetroxide, and Low and High Pressure Hydrogen Rating "A"	Spring Temper

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