

CHEMICAL AND PHYSICAL PROPERTIES OF MATERIALS

	THERMAL CONDUCTIVITY (32 - 212o F.) BTU / SQ. FT. HR. o F. IN.	APPROXIMATE MELTING POINT °F	TENSILE STRENGTH (PSI)	YIELD STRENGTH (0.2% OFFSET, PSI)	CHROMIUM	NICKEL	CARBON	COPPER	IRON	LEAD	ALUMINUM	TANTALUM	MANGANESE	MOLYBDENUM	PHOSPHORUS	SULFUR	SILICON	ZINC	OTHER
					Cr	Ni	C	Cu	Fe	Pb	Al	Ta	Mn	Mo	P	S	Si	Zn	
ALUMINUM 6061-T6	1110	1080	45,000	40,000	0.25	---	---	0.25	0.25	---	---	---	---	---	---	---	0.6	---	Mg 1.0
STEEL (C-1018)	460	2760	70,000	40,000	---	---	0.2	---	Bal.	---	---	---	0.75	---	0.04	0.05	---	---	
ALUMINUM (1100)	1070	1200	39,000	33,000	---	---	---	---	---	---	99	---	---	---	---	---	---	---	1% Imp. ¹
CR. MOLY. A182 F11	---	2750	70,000	40,000	1.25	---	0.15	---	---	---	---	---	0.5	0.5	0.04	0.04	0.75	---	
CR. MOLY. A182 F22	---	2750	70,000	40,000	2.25	---	0.15	---	---	---	---	---	0.45	1	0.04	0.04	0.5	---	
HARDWARE BRONZE	1100	1850	70,000	65,000	---	---	---	85	---	1.75	---	---	---	---	---	---	---	---	
EVERDUR (1010) *	---	1920	67,000	30,000	---	---	---	95.8	---	---	---	---	1.1	---	---	---	3.1	13.25	
DEOXIDIZED COPPER	2680	1980	45,000	30,000	---	---	---	99.9	---	---	---	---	---	0.02	---	---	---	---	
TYPE 303 STAINLESS	105	2550	85,000	40,000	18	8	0.15	---	---	---	---	---	2	0.6	---	---	---	---	2
TYPE 304 STAINLESS	105	2600	87,000	40,000	18	8	0.08	---	---	---	---	---	2	---	---	---	1	---	
TYPE 309 STAINLESS	110	2550	95,000	45,000	23	12	0.2	---	---	---	---	---	2	---	---	---	1	---	
TYPE 310 STAINLESS	105	2550	100,000	50,000	25	20	0.25	---	---	---	---	---	2	---	---	---	1.5	---	
TYPE 316 STAINLESS	105	2525	85,000	40,000	18	12	0.1	---	---	---	---	---	2	2.5	---	---	1	---	
TYPE 317 STAINLESS	110	2525	85,000	40,000	18	12	0.1	---	---	---	---	---	2	3.5	---	---	1	---	
TYPE 321 STAINLESS	105	2575	85,000	40,000	18	9	0.1	---	---	---	---	---	2	---	---	---	1	---	Ti 4x C
TYPE 347 STAINLESS	105	2575	85,000	40,000	18	10	0.1	---	---	---	---	---	2	---	---	---	1	---	Nb 10x C
TYPE 410 STAINLESS	160	2775	65,000	35,000	12	---	0.15	---	---	---	---	---	1	---	---	---	1	---	
TYPE 416 STAINLESS	180	2425	77,000	50,000	13	---	0.15	---	---	---	---	---	1.25	0.6	---	---	1	---	2
TYPE 430 STAINLESS	155	2725	75,000	45,000	16	---	0.12	---	---	---	---	---	1	---	---	---	1	---	
TYPE 446 STAINLESS	140	2725	80,000	50,000	27	---	0.35	---	---	---	---	---	1.5	---	---	---	1	---	
MONEL 400 *	160	2450	100,000	80,000	---	67	---	30	1.4	---	---	---	1	---	---	---	0.1	---	
MONEL K-500 *	130	2430	115,000	85,000	---	65	0.15	29	0.9	---	2.75	---	0.085	---	---	0.01	0.15	---	Ti 0.50
INCONEL 600 *	104	2575	135,000	110,000	16	76.5	0.04	0.1	7.2	---	---	---	0.2	---	---	0.005	0.2	---	
NICKEL 200	420	2625	95,000	70,000	---	99.4	0.1	0.1	0.15	---	---	---	0.2	---	---	0.007	0.05	---	
NICHROME	94	2460	110,000	60,000	15	61	---	---	Bal.	---	---	---	---	---	---	0.005	---	---	
NICHROME V *	104	2550	110,000	60,000	20	80	---	---	Bal.	---	---	---	---	---	---	---	---	---	
INCOLOY 800*	82	2475	87,500	45,000	20.5	32	0.04	0.3	46	---	0.3	---	0.75	---	---	---	0.35	---	Ti 0.30
TANTALUM	375	5425	110,000	---	---	---	---	---	---	---	---	99.9+	---	---	---	0.007	---	---	
TITANIUM	105	3150	90,000	70,000	---	---	0.1	---	---	---	---	---	---	---	---	---	---	---	
HASTELLOY B *	78	2430	135,000	62,000	---	61+	---	---	6	---	---	---	Trace	32	---	---	Trace	---	
HASTELLOY C *	87	2350	122,000	60,000	17	52+	---	---	6	---	---	---	Trace	19	---	---	Trace	---	W 5
HASTELLOY D *	145	2040	38,000	38,000	---	86+	---	3	---	---	Trace	---	Trace	---	---	---	10	---	
ZIRCONIUM	612	3375	64,000	53,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
ALLOY 20	---	2650	70,000	30,000	20	29	0.07	3.25	Bal.	---	---	---	---	2.5	---	---	1	---	Nb 10x C

*Note: See Registry Of Trademarks in Table of Contents.

¹Impurities

²S or Se 0.07 minimum



CORROSIVE SERVICE GUIDE TO MATERIALS

CORRODENT	TEMP °F.	CONC. %	RECOM. MATERIAL	CORRODENT	TEMP °F.	CONC. %	RECOM. MATERIAL	CORRODENT	TEMP °F.	CONC. %	RECOM. MATERIAL
Acetic Acid	212	ALL	Monel	Copper Plating Solution (Cyanide)	180		304 SS	Oleic Acid			SEE FATTY ACIDS
Acetic Anhydride	300		Nickel	Copper Plating Solution (Acid)	75		304 SS	Oxalic Acid	212	ALL	Monel
Acetone	212	ALL	304 SS	Corn Oil	200		304 SS	Photographic Bleaching	100	ALL	304 SS
Acetylene	400		304 SS	Creosote	200	ALL	304 SS	Palmitic Acid			SEE FATTY ACIDS
Alcohols	212	ALL	304 SS	Crude Oil	300		Monel	Phosphoric Acid	212	ALL	316 SS
Alum (Potassium or Sodium)	300	ALL	Hast. C	Ethyl Acetate			SEE LACQUERS AND THINNERS	Phenol	212	ALL	316 SS
Aluminum Chloride	212	ALL	Hast. B	Ethyl Chloride, Dry	500		Steel	Potassium Compounds			SEE SODIUM COMPOUNDS
Aluminum Sulfate	212	ALL	316 SS	Ethanol			SEE ALCOHOLS	Propane	300		Steel
Ammonia, Dry	212	ALL	304, 316 SS	Ethylene Glycol (Uninhibited)	212	ALL	304 SS	Rosin	700	100%	316 SS
Ammonium Hydroxide (Ammonia, Aqua)	212	ALL	304, 316 SS	Ethylene Oxide	75		Steel	Sea Water	75		Monel
Ammonium Chloride	300	50%	Monel	Fatty Acids	500	ALL	316 SS	Soap and Detergents	212	ALL	304 SS
Ammonium Nitrate	300	ALL	304 SS	Ferric Chloride	75	ALL	Hast. C	Sodium Bicarbonate	212	20%	316 SS
Ammonium Sulfate	212	ALL	316 SS	Ferric Sulfate	300	ALL	304 SS	Sodium Bisulphite	212	20%	304 SS
Amyl Acetate	300	ALL	304 SS	Formaldehyde	212	40%	316 SS	Sodium Bisulphate	212	20%	304 SS
Aniline	75		Monel	Formic Acid	300	ALL	316 SS	Sodium Carbinatate	212	40%	316 SS
Asphalt	250		304 SS	Freon	300		Steel	Sodium Chloride	300	30%	Monel
Atmosphere (Industrial and Marine)			304 SS	Flourine, Anhydrous	100		304 SS	Sodium Chromate	212	ALL	316 SS
Barium Compounds		SEE CALCIUM		Furfural	450		316 SS	Salt or Brine			SEE SODIUM CHLORIDE
Beer	70		304 SS	Gasoline	300		Steel	Sodium Cyanide	212	ALL	304 SS
Benzene (Benzol)	212		Steel	Glucose	300		304 SS	Sodium Hydroxide	212	30%	316 SS
Benzoic Acid	212	ALL	316 SS	Glue ph 6-8	300	ALL	304 SS	Sodium Hypochlorite	75	10%	Hast. C
Bleaching Powder	70	15%	Monel	Glycerine	212	ALL	Brass	Sodium Nitrate	212	40%	304 SS
Borax	212	ALL	Brass	Hydrobromic Acid	212	ALL	Hast. C	Sodium Nitrite	75	20%	316 SS
Bordeaux Mixture	200		304 SS	Hydrochloric Acid (37-38%)	225	ALL	Hast. B	Sodium Phosphate	212	10%	Steel
Boric Acid	400	ALL	316 SS	Hydrogen Chloride, Dry	500		304 SS	Sodium Silcate	212	10%	Steel
Bromine	125	DRY	Monel	Hydrocyanic Acid	212	ALL	304 SS	Sodium Sulfate	212	30%	316 SS
Butane	400	ALL	Steel	Hydrofluoric Acid	212	60%	Monel	Sodium Sulfide	212	10%	316 SS
Butyl Alcohol		SEE ALCOHOLS		Hydrogen Flouride, Dry	175		Steel	Sodium Sulfite	212	30%	304 SS
Butyric Acid	212		Hast. C	Hydrofluogilicic Acid	212	40%	Monel	Sodium Thiosulfate	212	ALL	304 SS
Calcium Bisulphite	75	ALL	Hast. C	Hydrogen Peroxide	125	10-100%	304 SS	Steam			304 SS
Calcium Chloride	212	ALL	Hast. C	Kerosene	300	ALL	Steel	Stearic Acid			SEE FATTY ACIDS
Calcium Hydroxide	300	20%	Hast. C	Lacquers and Thinners	300	ALL	304 SS	Sugar Solutions			SEE GLUCOSE
Calcium Hypochlorite		SEE BLEACHING POWDER		Lactic Acid	300	ALL	316 SS	Sulfur	500		304 SS
Carbolic Acid		SEE PHENOL		Lime	212	ALL	316 SS	Sulfur Chloride	75	DRY	316 SS
Carbon Dioxide, Dry	800	ALL	Brass	Linseed Oil	75		Steel	Sulfur Dioxide	500	DRY	316 SS
Carbonated Water	212	ALL	304 SS	Magnesium Chloride	212	50%	Nickel	Sulfur Trioxide	500	DRY	316 SS
Carbonated Beverages	212		304 SS	Magnesium Hydroxide (or Oxide)	75	ALL	304 SS	Sulfuric Acid	212	10%	316 SS
Carbon Disulfide	200		304 SS	Magnesium Sulfate	212	40%	304 SS	Sulfuric Acid	212	10-90%	Hast. B
Carbon Tetrachloride	125	ALL	Monel	Meccuric Chloride	75	10%	Hast. C	Sulfuric Acid, Fuming	175		Alloy 20
Chlorine, Dry	100		Monel	Mercury	700	100%	Steel	Sulfurous Acid	75	20%	316 SS
Chlorine, Moist	100	ALL	Monel	Methylene Chloride	212	ALL	304 SS	Titanium Tetrachloride	75	ALL	316 SS
Chloracetic Acid	212	ALL	Monel	Methyl Chloride, Dry	75		Steel	Tannic Acid	75	40%	Hast. B
Chloroform, Dry	212		Monel	Milk, fresh or sour	180		304 SS	Toluene	75		Steel
Chromic Acid	300	ALL	Hast. C	Molasses			SEE GLUCOSE	Trichloracetic Acid	75	ALL	Hast. B
Cider	300	ALL	304 SS	Natural Gas	70		304 SS	Trichlorethylene	300	DRY	Monel
Citric Acid	212	ALL	Hast. C	Nitric Acid	75	ALL	304 SS	Turpentine	75		316 SS
Copper (10) Chloride	212	ALL	Hast. C	Nitric Acid	110	ALL	316 SS	Varnish	150		Steel
Copper (10) Nitrate	300	ALL	316 SS	Oxygen	75	ALL	Steel	Zinc Chloride	212	ALL	Hast. B
Copper (10) Sulfate	300	ALL	316 SS					Zinc Sulfate	212	ALL	316 SS

TEMP-PRO Inc. • 200 Industrial Drive • Northampton, MA 01060
 Telephone: (413) 584-3165 • Toll Free: (800) 991-9093 • Fax: (413) 586-3625
 E-Mail: sales@temp-pro.com • Web Site: www.temp-pro.com



POWER TEST CODE CALCULATIONS

(For limitations of this method see ASME Power Test Code Supplement, Part 3)

To insure that a thermowell is designed adequately to withstand operating conditions (temperature, pressure, velocity and vibrations generated by steam or water) the following evaluations should be made.

1. VIBRATION

Liquids, flowing transverse to a thermowell, generate a vibration at the thermowell with a so-called "wake frequency". Any thermowell itself has a so-called "natural frequency". A sufficient lifetime of the thermowell can only be expected if the thermowell is not working in resonance. To verify frequencies for tapered thermowells the following calculations should be made:

1.1. Natural Frequency

$$f_n = \frac{K_f}{A^2} \sqrt{\frac{E}{d}}$$

f_n ...Natural frequency of thermowell (Hz)

K_f ...A constant according to Table I

A ...Insertion length of well (Inches)

E ...Modulus of elasticity of well material at use temperature (PSI)

d ...Specific weight of well material at use temperature (Lb/cu inch)

1.2. Wake Frequency

$$f_w = \frac{2.64 V}{B}$$

f_w ...Wake frequency (Hz)

V ...Fluid velocity (Ft/second)

B ...Tip diameter (Inches)

MODULUS OF ELASTICITY (TENSION), PSI x 10⁶

MAT'L	302	304	309	310	316	321	347	ALLOY 400	ALLOY 600	A105	ALUM 1100	ALUM 6061-T	NICKEL 200	410	446	COPPER	BRASS	INC 800	HAST B
200	27.9	27.9		28.2	28.1	28.0	28.2	26.8	31.0	29.5	10.0	10.0	29.1	29.0	29.0	14.0	9.0	28.0	30.0
300	27.3	27.1		27.5	27.5	27.3	27.5			29.0				28.3					
400	26.7	26.6		26.8	26.9	26.5	26.8			28.3			28.3	27.7				26.6	29.7
500	26.0	26.0		26.2	26.3	25.8	26.1			27.4				27.0					
600	25.4	25.6		25.5	25.6	25.3	25.4	25.6	29.5	26.7			27.4	26.0					
700	24.8	24.7		24.9	24.9	24.5	24.8			25.4				24.8					
800	24.2	24.1	23.1	24.2	24.2	23.8	24.1	24.8	28.0	23.8			26.4	23.1				24.4	27.9
900	23.6	23.2		23.6	23.5	23.2	23.1							21.4					
1000	23.0	22.5	22.6	23.0	22.8	22.5	22.8	23.7	26.8				25.2	19.7					26.9
1100	22.3	21.8		22.4	22.2	21.9	22.0												
1200	21.8	21.1	21.8	21.8	21.5	21.2	21.4	22.6	25.5									22.3	26.0
1300	21.2	20.4	21.2	21.2	20.8	20.4	20.7												
1400	20.6	19.4		20.5	20.0	19.7	20.0	21.3	24.0									21.1	24.7
1500	20.0	18.1	19.8	19.0	19.1	19.1	19.4												
1600			19.2	19.2			18.7	18.3	22.5									20.0	23.3
1700																			
1800								21.0										18.7	21.6

SPECIFIC WEIGHT (POUNDS PER CUBIC INCH)

MAT'L	302	304	309	310	316	321	347	ALLOY 400	ALLOY 600	A105	ALUM 1100	ALUM 6061-T	NICKEL 200	410	446	COPPER	NAVAL BRASS	INC 800	HAST B
d	.290	.290	.290	.290	.290	.290	.290	.319	.304	.283	.098	.098	.321	.28	.270	.323	.304	.290	.334



1.3. Relationship wake/natural frequency

(r) shall not exceed the value of 0.8, in formula:

$$r = \frac{f_w}{f_n} \leq 0.8$$

2. MAX OPERATING PRESSURE

The maximum pressure that a thermowell can withstand for a given material at a given temperature shall be computed from the following:

$$P = K_1 S$$

- P Maximum allowable static gage pressure (PSI)
 S Allowable stress for material at operating temperature (See Table II)
 K₁ See Table III

3. MAXIMUM INSERTION LENGTH

One limitation is given by vibratory considerations, as considered in section 1. The other limitation on maximum insertion length is one of steady state stress considerations as given by the following formula:

$$A_{max} = \frac{K_2}{V} \sqrt{\frac{v(S - K_3 P_o)}{1 + F_m}}$$

- A_{max} Max. Insert Length (Inches)
 V Fluid Velocity (FPS)
 K₂, K₃ Constants, see Table III
 v Specific volume of fluid (Ft³ / lbs)
 S Allowable stress, see Table II (PSI)
 P_o Operating press (PSI)
 F_m Magnification factor: F_m = r² / (1 - r²)
 r Frequency ratio (See section 1.3 - Vibration)

TABLE I: VALUES OF K₁

INSERTION LENGTH A, INCHES	NOMINAL WELL BORE DIAMETER				
	1/4	3/8	9/16	11/16	7/8
2-1/2	2.06	2.42	2.97	3.32	3.84
4-1/2	2.07	2.45	3.01	3.39	3.96
7-1/2	2.08	2.46	3.05	3.44	4.03
10-1/2	2.09	2.47	3.06	3.46	4.06
16	2.09	2.47	3.07	3.47	4.08
24	2.09	2.47	3.07	3.48	4.09

TABLE II: ALLOWABLE STRESS VALUES - PSI¹

MATERIAL	TEMPERATURE° F						
	0	300	500	700	900	1100	1300
Aluminum (1100)	2350	1850	---	---	---	---	---
Aluminum (6061-T6)	6000	5000	---	---	---	---	---
Nickel	10,000	10,000	9500	---	---	---	---
Steel (2)	11,250	11,000	10,250	9000	7750	6500	---
304 S. Stl.	18,750	13,750	11,400	10,500	10,000	8250	3400
310 S. Stl.	18,750	16,400	15,500	15,100	11,650	8500	3500
316 S. Stl.	18,750	14,600	12,600	11,300	10,300	9450	4000
321-347 S. Stl.	18,750	15,300	13,500	12,200	11,300	9100	2200
410 S. Stl.	15,000	13,800	12,850	12,050	9650	2900	---
446 S. Stl.	17,500	16,100	15,000	---	---	---	---
A182-F11	16,150	16,150	16,150	16,150	13,100	4000	---
A182-F22	17,500	17,500	17,500	17,500	14,000	4200	---
Copper	6000	5000	---	---	---	---	---
Admiralty Brass	10,000	10,000	---	---	---	---	---
Monel 400 *	16,600	13,600	13,100	13,100	8000	---	---
Inconel 600 *	20,000	18,800	18,500	18,500	16,000	3000	---
Incoloy 800 * (3)	15,600	12,100	10,400	9600	9100	8800	4150
Hastelloy B * (4)	25,000	24,750	21,450	---	---	---	---
Hastelloy X * (5)	23,350	18,850	16,000	15,500	15,500	15,500	9500

- ...Values from ASME Boiler and Pressure Vessel Code Section VIII - Unfired Pressure Vessels, 1965.
- ...ASME Spec. Min. Tensile = 45,000 PSI
- ...ASME Code (See Note 1), Case 1325 (special ruling)
- ...ASME Code (See Note 1), Case 1323 (special ruling)
- ...ASME Code (See Note 1), Case 1321 (special ruling)

TABLE III

CONSTANT	NOMINAL WELL BORE DIAMETER				
	1/4	3/8	9/16	11/16	7/8
K1	0.412	0.334	0.223	0.202	0.155
K2	37.5	42.3	46.8	48.7	50.1
K3	0.116	0.205	0.389	0.548	0.864

