

Table Of Contents

Heat Requirement Calculations.....	16-2	Electrical Formulas/Diagrams	16-9
Properties of Materials.....	16-4	Sheath Material Selection Guide.....	16-12
Wattage Estimation Tables.....	16-5	Conversion Factors.....	16-21
Formulas for Liquids and Gases	16-6	Area and Volume Formulas	16-22
Temperature Conversion Table	16-8	Decimal/Millimeter Equivalents	16-23

16

section

Heat Requirement Calculations

Heat Requirement Calculations

There are two basic heat energy requirements to be considered in the sizing of heaters for a particular application:

1. Start-Up Heat is the heat energy required to bring a process up to operating temperature. Start-up heat requirement calculations which include a material change of state should be calculated in three parts:

- 1) Heat requirement from ambient temperature to change of state temperature
- 2) Heat requirement during change of state (latent heat)
- 3) Heat requirement from change of state temperature to operating temperature

2. Operating Heat is the heat energy required to maintain the desired operating temperature through normal work cycles. The larger of these two heat energy values will be the wattage required for the application.

A safety factor is usually added to allow for unknown or unexpected operating conditions. The safety factor is dependent on the accuracy of the wattage calculation. A figure of 10% is adequate for small systems closely calculated, while 20% additional wattage is more common, and figures of 25% to 35% should be considered for larger systems with many unknown conditions existing.

Start-Up Heat requirements will include one or more of the following calculations, depending on the application:

1. Wattage required to heat material:

$$\frac{\text{Weight of material (lbs)} \times \text{Specific Heat (Btu/lb } ^\circ\text{F)} \times \text{Temperature rise (} ^\circ\text{F)}}{3.412 \text{ btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$



See page 16-4 for
Properties of Materials

2. Wattage required to heat container or tank:

$$\frac{\text{Weight of container (lbs)} \times \text{Specific Heat (Btu/lb } ^\circ\text{F)} \times \text{Temperature rise (} ^\circ\text{F)}}{3.412 \text{ btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

3. Wattage required to heat hardware in container:

$$\frac{\text{Weight of hardware (lbs)} \times \text{Specific Heat (Btu/lb } ^\circ\text{F)} \times \text{Temperature rise (} ^\circ\text{F)}}{3.412 \text{ btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

4. Wattage required to melt a solid to a liquid at constant temperature:

$$\frac{\text{Heat of fusion (Btu/lb)} \times \text{Weight of material to be melted (lb/hr)}}{3.412 \text{ btu/watt hr.}} = \text{Watts}$$

Heat of Fusion (Latent Heat): The amount of heat required to change one pound of a given substance from solid to liquid state without change in temperature is termed the heat of fusion. It requires 144 Btu to change one pound of ice at 32°F to one

pound of water at 32°F, thus the heat of fusion of ice is 144 Btu per pound.

A change of state is usually accompanied by a change of specific heat. The specific heat of ice is 0.5; while that of water is 1.0.

5. Wattage required to change a liquid to a vapor state at constant temperature:

$$\frac{\text{Heat of vaporization (Btu/lb)} \times \text{Weight of material to be vaporized (lb/hr)}}{3.412 \text{ btu/watt hr.}} = \text{Watts}$$

Heat of Vaporization (Latent Heat): The amount of heat required to change one pound of a given substance from liquid to vapor state without change in temperature is termed the heat of vaporization.

It requires 965 Btu to change one pound of water at 212°F to one pound of steam at 212°F.

6. Wattage to counteract liquid surface losses: See Graph 3 on opposite page for loss rates of water and oils.

$$\frac{\text{Total liquid surface area (sq. ft.)} \times \text{Loss rate at final temperature (watts/sq. ft.)}}{2} = \text{Watts}$$

7. Wattage to counteract surface losses from container walls, platen surfaces, etc.: See Graph 2 on opposite page for losses from metal surfaces. See Graph 1 for losses from insulated surfaces.

$$\frac{\text{Total surface area (sq. ft.)} \times \text{Loss rate at final temperature (watts/sq. ft.)}}{2} = \text{Watts}$$

Heat Requirement Calculations

Operating heat requirements will include one or more of the following calculations. Any additional losses particular to the application should also be estimated and included.

1. Wattage to counteract losses from open liquid surfaces: See Graph 3 for loss rates of water and oils.

$$\text{Total liquid surface area (sq. ft.)} \times \text{Loss rate at operating temperature (watts/sq. ft.)} = \text{Watts}$$

2. Wattage to counteract container or platen surface losses, either insulated (See Graph 1) or uninsulated (See Graph 2).

$$\text{Total surface area (sq. ft.)} \times \text{Loss rate at operating temperature (watts/sq. ft.)} = \text{Watts}$$

3. Wattage required to heat material transferred in and out of the system.

(Metal dipped in heated tanks, air flows, make-up liquids, etc.)

$$\frac{\text{Weight of material to be heated (lbs)} \times \text{Specific Heat (Btu/lb } ^\circ\text{F)} \times \text{Temperature rise (} ^\circ\text{F)}}{3.412 \text{ btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

4. Heat-up of racks of containers, etc. transferred in and out of the system:

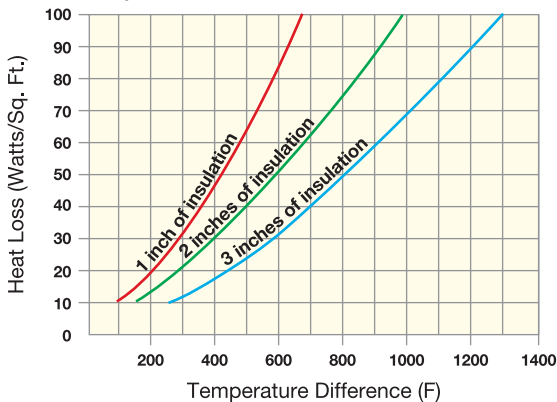
$$\frac{\text{Weight of items to be heated (lbs)} \times \text{Specific Heat (Btu/lb } ^\circ\text{F)} \times \text{Temperature rise (} ^\circ\text{F)}}{3.412 \text{ btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

Specific Heat: The heat necessary to increase the temperature of all other substances has been referred to water as a standard. The ratio of the amount of heat required to increase the temperature of

one pound of any substance by one degree to the amount necessary to increase one pound of water is known as the specific heat of that substance.

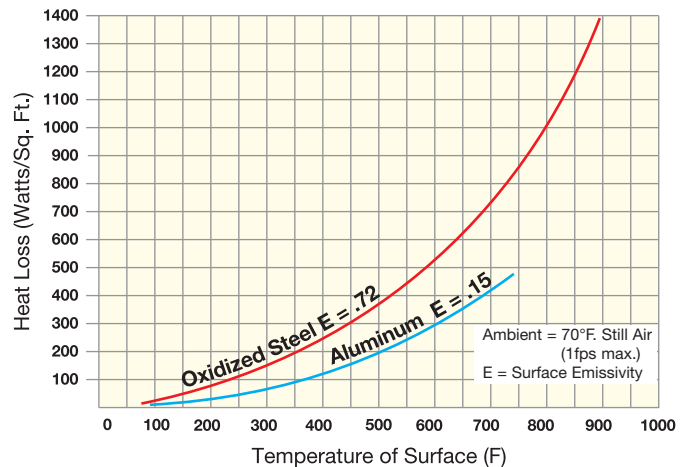
Heat Loss Information

Graph 1 Heat Losses through Insulated Walls (based on standard thermal insulations)

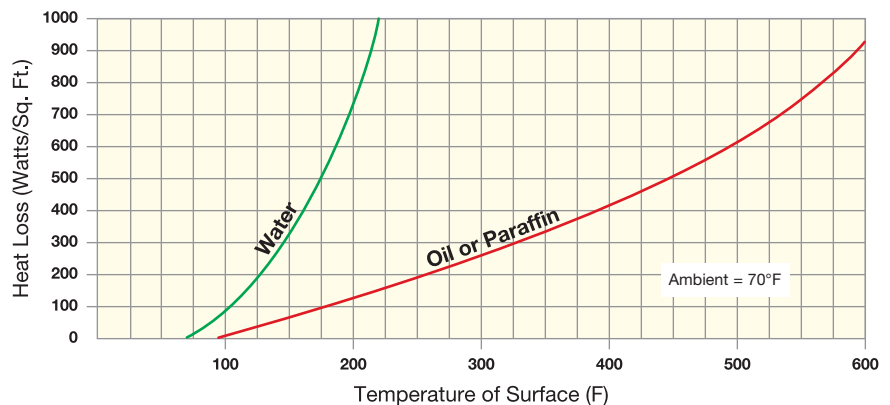


Figures are for vertical surfaces. Multiply by 120% for a horizontal top surface and by 60% for a horizontal bottom surface.

Graph 2 Heat Losses from Uninsulated Metal Surfaces



Graph 3 Heat Losses from the Surface of Water and Oil



Properties of Materials

Properties of Metals

Material	*Density lb./in ³	Specific Heat Btu (lb) (°F)	*Thermal Conductivity (Btu) (in.) (hr.) (ft ²) (°F)	Melting Point °F (Lowest)	Latent Heat of Fusion Btu/lb.	*Thermal Expansion in/in/°F × 10 ⁻⁶
Aluminum 1100-0	.098	.24	1540	1190	169.0	13.1
Brass, Yellow	.306	.096	816	1710		11.3
Copper	.324	.095	2736	1981	91.1	9.2
Gold	.698	.032	2064	1945	29.0	7.9
Incoloy® 800	.290	.13	80	2500		7.9
Inconel® 600	.304	.13	103	2500		5.8
Invar 36% Ni	.289	.12	76	2600		0.6
Iron, Malleable Cast	.260	.11	320	2250		6.0
Lead, Solid	.410	.032	241	621	11.3	16.3
Lead, Liquid	.372	.037	107			
Magnesium	.063	.25	1068	1202	160.0	14.0
Molybdenum	.369	.071	980	4750	126.0	2.94
Monel 400	.319	.11	151	2400		6.4
Nickel 200	.321	.12	520	2615	133.0	5.8
Nichrome (80% Ni-20% Cr)	.302	.11	104	2550		7.3
Palladium 99.5%	.432	.06	490	2830	69.5	6.5
Platinum	.775	.035	480	3217	49.0	4.9
Silver	.379	.057	2904	1761	38.0	11.4
Solder (50% Pb-50% Sn)	.321	.051	323	421	17	13.0
Steel, Mild	.284	.12	460	2760		6.7
Steel, Stainless 304	.290	.12	113	2550		9.6
Steel, Stainless 430	.280	.11	181	2600		5.8
Tantalum	.600	.035	372	5425		3.57
Tin, Solid	.264	.065	468	449	26.1	12.8
Tin, Liquid	.246	.052	228			
Titanium 99.0%	.163	.13	112	3020	187	4.8
Tungsten	.697	.03	1140	6170	79.0	2.45
Type Metal (85% Pb-15% Sb)	.387	.04		500	14	
Zinc	.258	.096	785	787	43.3	22.0
Zirconium	.234	.067	145	3350	108	3.22

Properties of Non-Metallic Solids

Asphalt	.076	.22	5.16	250	40	
Boron Nitride (Compacted)	.082	.33	125.00	5430		1-4
Brick, Hard	.072	.24	9.00			3-6
Carbon	.080	.20	165.00	6700		0.3-2.4
Cellulose Acetate	.048	.40	1.20-2.30			61-83
Delrin	.050	.35	1.56			45
Glass, Crown	.101	.16	7.50			5
Ice	.033	.49	15.60	32	144	28.3
Mica	.098	.12	4.80			18
MgO (Compacted)	.110	.21	14.40			7.7
Nylon	.042	.45	1.70			61-63
Paper	.033	.33	0.84			
Paraffin	.033	.69	1.60	133	63	
Phenolic (Cast Resin)	.047	.35	1.1			44-61
Polyethylene (High Density)	.035	.55	3.36			94
Polystyrene	.038	.32	0.70-1.00			33-44
Rubber, Hard	.043	.48	1.12			340
Steatite	.073	.20	20.40			4.5-5.5
Sulfur	.072	.20	1.80	230	17	36
Teflon	.078	.25	1.70			55
Vinylidene	.062	.32	2.00			28-100
Wood, Oak	.027	.57	1.22			

Properties of Liquids

Liquid	*Density lb./Gal.	Specific Heat Btu (lb) (°F)	*Thermal Conductivity (Btu) (in.) (hr.) (ft ²) (°F)	Boiling Point °F	Heat of Vaporization Btu/lb.
Acetic Acid, 20%**	8.60	.91	3.70	214±	810±
Alcohol (ethyl)	6.74	.60	1.30	173	367
Brine (25% NaCl)**	9.91	.79	2.88	220±	730±
Caustic Soda (18% NaOH)**	10.00	.84	3.90	221±	795±
Dowtherm A	8.80	.44	0.96	496	42.2
Ethylene Glycol	9.36	.56		387	
Freon 12	10.94	.23	0.49	-21.6	62
Glycerine	10.52	.58	1.97	556	
Hydrochloric Acid 10%**	8.89	.93	3.90	221	
Nitric Acid, 7%**	8.65	.92	3.80	220±	918±
Oils (Petroleum)	7.35	.45			
Paraffin (melted)	7.49	.69±	1.68	572	70
Potassium (K)***	5.96	.18	253.20	1400	893
Sodium (Na)***	6.84	.30	446.40	1638	1810
Sulfuric Acid 10%**	9.90	.92	4.00	216	
Therminol FR-2	12.10	.30	0.70	648±	
Turpentine	7.22	.42	0.90	319	133
Vegetable Oil	7.75	.43±	1.10		
Water	8.34	1.00	4.08	212	965



* At or near room temperature
** Percent concentration by weight in H₂O solution
*** At 1000°F
± Approximate

Properties of Gases

Gas	*Density lb./ft ³	Specific Heat Btu/(lb) (°F)	*Thermal Conductivity (Btu) (in.)/(hr.) (ft ²) (°F)
Air at 80°F	.073	.240	.18
at 400°F	.046	.247	.27
Ammonia	.044	.523	.16
Argon	.102	.125	.12
Carbon Dioxide	.113	.199	.12
Carbon Monoxide	.072	.248	.18
Chlorine	.184	.115	.06
Helium	.011	1.250	1.10
Hydrogen	.0052	3.390	.13
Methane	.0447	.590	.21
Nitrogen	.072	.248	.19
Oxygen	.082	.218	.18
Sulphur Dioxide	.172	.152	.07

Air Density Table (lb./cu. ft.)

Temp °F	Specific Heat	Gauge Pressure						
		0	10	50	100	200	250	300
0	.240	.086	.145	.380	.674	1.261	1.555	1.848
10	.240	.085	.142	.372	.659	1.234	1.522	1.808
20	.240	.083	.139	.364	.646	1.208	1.490	1.771
30	.240	.081	.136	.357	.632	1.184	1.459	1.735
40	.240	.079	.133	.350	.620	1.160	1.430	1.700
50	.240	.078	.131	.343	.608	1.137	1.402	1.667
60	.240	.076	.128	.336	.596	1.115	1.375	1.635
70	.240	.075	.126	.330	.585	1.094	1.349	1.600
80	.240	.074	.124	.324	.574	1.074	1.324	1.574
90	.240	.072	.121	.318	.563	1.055	1.300	1.546
100	.240	.071	.119	.312	.553	1.036	1.277	1.518
120	.240	.068	.115	.301	.534	1.000	1.233	1.466
140	.240	.066	.111	.291	.516	.967	1.192	1.417
160	.241	.064	.108	.282	.500	.936	1.153	1.371
180	.241	.062	.104	.273	.484	.906	1.117	1.328
200	.242	.060	.101	.265	.470	.879	1.084	1.288
220	.242	.058	.098	.257	.456	.853	1.052	1.250
240	.242	.057	.095	.250	.443	.829	1.022	1.215
260	.243	.055	.093	.243	.430	.806	.993	1.181
280	.243	.054	.090	.236	.419	.784	.966	1.149
300	.244	.052	.088	.230	.408	.763	.941	1.119
320	.244	.051	.086	.224	.397	.744	.917	1.090
340	.244	.050	.083	.219	.387	.725	.894	1.063
360	.246	.048	.081	.213	.378	.707	.872	1.037
380	.246	.047	.079	.208	.369	.691	.851	1.012
400	.247	.046	.078	.203	.360	.674	.832	.989
420	.247	.045	.076	.199	.352	.659	.813	.966
440	.247	.044	.074	.194	.344	.644	.795	.945
460	.248	.043	.073	.190	.337	.630	.777	.924
480	.248	.042	.071	.186	.330	.617	.761	.905
500	.249	.041	.070	.182	.323	.604	.745	.886
520	.249	.041	.068	.178	.316	.592	.730	.868
540	.249	.040	.067	.175	.310	.580	.715	.850
560	.250	.039	.065	.171	.304	.569	.701	.834
580	.251	.038	.064	.168	.298	.558	.688	.818
600	.252	.037	.063	.165	.292	.547	.675	.802
620	.252	.037	.062	.162	.287	.537	.662	.787
640	.252	.036	.061	.159	.281	.527	.650	.773
660	.253	.035	.060	.156	.277	.518	.639	.759
680	.253	.035	.059	.153	.272	.509	.627	.746
700	.254	.034	.058	.151	.267	.500	.616	.733
720	.254	.034	.057	.148	.263	.492	.606	.721
740	.255	.033	.056	.146	.258	.483	.596	.709
760	.256	.033	.055	.143	.254	.475	.586	.697
780	.256	.032	.054	.141	.250	.468	.577	.686
800	.257	.032	.053	.139	.246	.460	.568	.675
820	.257	.031	.052	.137	.242	.453	.559	.664
840	.257	.031	.051	.134	.238	.446	.550	.654
860	.258	.030	.051	.132	.235	.439	.542	.644
880	.259	.030	.050	.130	.231	.433	.534	.634
900	.260	.029	.049	.129	.228	.427	.526	.625
920	.260	.029	.048	.127	.225	.420	.518	.616
940	.260	.028	.048	.125	.221	.414	.511	.607
960	.261	.028	.047	.123	.218	.408	.504	.599
980	.261	.028	.046	.121	.215	.403	.497	.590
1000	.262	.027	.046	.120	.212	.397	.490	.582
1020	.262	.027	.045	.118	.209	.392	.483	.574
1040	.263	.026	.044	.117	.207	.387	.477	.567
1060	.264	.026	.044	.115	.204	.382	.470	.559
1080	.264	.026	.043	.114	.201	.377	.464	.552
1100	.265	.025	.043	.112	.199	.372	.458	.545
1120	.265	.025	.042	.111	.196	.367	.453	.538
1140	.265	.025	.042	.108	.194	.363	.447	.531
1160	.266	.025	.041	.108	.191	.358	.441	.525
1180	.266	.024	.041	.107	.189	.354	.436	.518
1200	.267	.024	.040	.105	.187	.349	.431	.512

Wattage Estimation Tables

Kilowatt Hours to Heat Water

Amount of Water		Temperature Rise (°F)						
Cubic Feet	Gallons	20	40	60	80	100	120	140
		Kilowatts to heat in one hour						
0.67	5	0.3	0.5	0.8	1.1	1.3	1.6	1.9
1.3	10	0.5	1.1	1.6	2.2	2.7	3.2	3.8
2.0	15	0.8	1.6	2.4	3.2	4.0	4.8	5.6
2.7	20	1.1	2.2	3.2	4.3	5.4	6.5	7.5
3.3	25	1.3	2.7	4	5.4	6.7	8.1	9.4
4.0	30	1.6	3.2	4.8	6.5	8.1	9.7	11.3
5.3	40	2.2	4.3	6.5	8.6	10.8	12.9	15.1
6.7	50	2.7	5.4	8.1	10.8	13.5	16.1	18.8
8.0	60	3.2	6.5	9.7	12.9	16.1	19.4	22.6
9.4	70	3.8	7.5	11.3	15.1	18.8	22.6	26.4
10.7	80	4.3	8.6	12.9	17.2	21.5	25.8	30.1
12.0	90	4.8	9.7	14.5	19.4	24.2	29.1	33.9
13.4	100	5.4	10.8	16.1	21.5	26.9	32.3	37.7
16.7	125	6.7	13.5	20.2	26.9	33.6	40.4	47.1
20.1	150	8.1	16.1	24.2	32.3	40.4	48.4	56.5
23.4	175	9.4	18.8	28.2	37.7	47.1	56.5	65.9
26.7	200	10.8	21.5	32.3	43	53.8	64.6	75.3
33.4	250	13.5	26.9	40.4	53.8	67.3	80.7	94.2
40.1	300	16.1	32.3	48.4	64.6	80.7	96.9	113.0
53.5	400	21.5	43.0	64.6	86.1	107.6	129.1	150.7
66.8	500	26.9	53.8	80.7	107.6	134.5	161.4	188.3

For Water:

Use Equation 1 for heating flowing water.

Use Equation 2 or the table for heating water in tanks.

Equation 1

$$KW = GPM \times \text{Temperature Rise } (^\circ F) \times .16$$

Equation 2

$$KW = \frac{\text{Gallons} \times \text{Temperature Rise } (^\circ F)}{372 \times \text{Heat-up time (hrs.)}}$$

NOTE: 10% safety factor is included.

Kilowatt Hours to Heat Oil

Amount of Oil		Temperature Rise (°F)					
Cubic Feet	Gallons	50	100	200	300	400	500
		Kilowatts to Heat in One Hour					
0.67	5	0.3	0.7	1.4	2.09	2.79	3.49
1.3	10	0.7	1.4	2.8	4.19	5.58	6.98
2.0	15	1	2.1	4.2	6.28	8.37	10.5
2.7	20	1.4	2.8	5.6	8.37	11.2	14
3.3	25	1.7	3.5	7	10.5	14	17.4
4.0	30	2.1	4.2	8.4	12.6	16.7	20.9
5.3	40	2.8	5.6	11	16.7	22.3	27.9
6.7	50	3.5	7	14	20.9	27.9	34.9
8.0	60	4.2	8.4	17	25.1	33.5	41.9
9.4	70	4.9	9.8	20	29.3	39.1	48.8
10.7	80	5.6	11	22	33.5	44.7	55.8
12.0	90	6.3	13	25	37.7	50.2	62.8
13.4	100	7	14	28	41.9	55.8	69.8
16.7	125	8.7	17	35	52.3	69.8	87.2
20.1	150	10	21	42	62.8	83.7	105
23.4	175	12	24	49	73.3	97.7	122
26.7	200	14	28	56	83.7	112	140
33.4	250	17	35	70	105	140	174
40.1	300	21	42	84	126	167	209
53.5	400	28	56	112	167	223	279
66.8	500	35	70	140	209	279	349

For Oil:

Use equation or table

$$KW = \frac{\text{Gallons} \times \text{Temperature Rise } (^\circ F)}{860 \times \text{Heat-up time (hrs.)}}$$

NOTE: The above KW values are based on an average specific heat of 0.45 (btu/lb/°F) and a Density of 7.35 lb/gallon plus a 20% safety factor. This table should be used only as a guide; exact wattage requirements can be calculated using the formulas on pages 16-2 and 16-6.

Kilowatts to Heat Air

For free air:

Use equation or table

$$KW = \frac{\text{SCFM} \times \text{Temperature Rise } (^\circ F)}{3000}$$

Use the maximum anticipated airflow. This equation assumes insulated duct (negligible heat loss) and 70°F inlet air at 14.7 PSIA.

For compressed air:

$$KW = \frac{\text{CFM}^* \times \text{Density}^*(\text{lbs/cu. ft.}) \times \text{Temperature rise } (^\circ F)}{228}$$

*At heater inlet temperature and pressure

Amt. of Air SCFM	Temperature Rise (°F)										
	50	100	150	200	250	300	350	400	450	500	600
100	1.7	3.3	5	6.7	8.3	10	11.7	13.3	15	16.7	20
200	3.3	6.7	10	13.3	16.7	20	23.3	26.7	30	33.3	40
300	5	10	15	20	25	30	35	40	45	50	60
400	6.7	13.3	20	26.7	33.3	40	46.7	53.3	60	66.7	80
500	8.3	16.7	25	33.3	41.7	50	58.3	66.7	75	83.3	100
600	10	20	30	40	50	60	70	80	90	100	120
700	11.7	23.3	35	46.7	58.3	70	81.7	93.3	105	116.7	140
800	13.3	26.7	40	53.3	66.7	80	93.3	106.7	120	133.3	160
900	15	30	45	60	75	90	105	120	135	150	180
1000	16.7	33.3	50	66.7	83.3	100	116.7	133.3	150	166.7	200
1100	18.3	36.7	55	73.3	91.7	110	128.3	146.7	165	183.3	220
1200	20	40	60	80	100	120	140	160	180	200	240

NOTE: If air flow is given in CFM at operating temperature and pressure it can be converted to SCFM (Standard Cubic Feet per Minute) with the following formula:

$$\text{SCFM} = \text{CFM} \times \frac{\text{PSIG} + 14.7}{T + 460} \times 35.37$$

PSIG = operating pressure (gauge pressure in lbs/sq.in.)

T = operating temperature in °F

SCFM = flow rate in CFM at standard conditions of 60°F and 14.7 PSIA.



KW Calculations

Calculating KW Requirements for Heating Liquids and Gases

When calculating the required KW, always use the maximum flow of the medium to be heated, the minimum temperature at the heater inlet, and the maximum desired outlet temperature. Also include a 20% Safety Factor to allow for heat losses to jacket and piping, voltage variation and wattage tolerance.

For specific heat and density values see Properties of Materials Tables on page 16-4.

Safe element watt density and sheath material charts are located on pages 16-12 through 16-20.

Formula for Heating Liquids

$$KW = \frac{\text{Flow} \times 60 \text{ minute/hour} \times \text{Density} \times \text{Specific heat} \times \Delta T \times \text{Safety factor}}{3412 \text{ BTU/KWH}}$$

Flow = Flow in gallons/minute

Density = Density of liquid in pounds/gallon

Specific Heat = Specific heat of liquid in BTU/pound °F

ΔT = Temperature rise in °F

Sample problem for heating water:

Calculate KW required to heat 5 gallons/minute of water from 50 to 100°F.

$$KW = \frac{5 \text{ gal/min} \times 60 \text{ min/hr} \times 8.34 \text{ lb/gal} \times 1.0 \text{ BTU/lb}^\circ\text{F} \times 50^\circ\text{F} \times 1.2}{3412 \text{ BTU/KWH}}$$

Total KW required = 44

Water Flow Chart for Tempco 3" and 5" Flanged Circulation Heaters

Maximum water flow per hour through selected heaters at specified temperature rise.

Part Number	KW	20°F	30°F	40°F	50°F	60°F	70°F	80°F	90°F	100°F	110°F	120°F	130°F
CHF01891	6	123	82	61	49	41	35	31	27	25	22	20	19
CHF01895	9	184	123	92	74	61	53	46	41	37	33	31	28
CHF01898	12	245	164	123	98	82	70	61	55	49	45	41	38
CHF01901	15	307	205	153	123	102	88	77	68	61	56	51	47
CHF01904	18	368	245	184	147	123	105	92	82	74	67	61	57
CHF01928	24	491	327	245	196	164	140	123	109	98	89	82	76
CHF01931	30	614	409	307	245	205	175	153	136	123	112	102	94
CHF01934	36	736	491	368	295	245	210	184	164	147	134	123	113
CHF01935	50	1023	682	511	409	341	292	256	227	205	186	170	157
CHF01936	60	1227	818	614	491	409	351	307	273	245	223	205	189

$$(\text{Gallons}) \text{ HR} = \frac{(\text{KW}) (3412)}{(8.34) (\Delta T)}$$

NOTE: Safety factor not included. Add to suit application.

Formula for Heating Gases

$$KW = \frac{\text{Flow} \times 60 \text{ minute/hour} \times \text{Density} \times \text{Specific heat} \times \Delta T \times \text{Safety factor}}{3412 \text{ BTU/KWH}}$$

Flow = Flow in SCFM (standard cubic feet per minute measured at 14.7 PSIA and 70°F)

Density = Density of gas in pounds/cubic foot at standard conditions.

Specific Heat = Specific heat of gas in BTU/pound °F at standard conditions.

ΔT = Temperature rise in °F

NOTE: If air flow is given in CFM at operating temperature and pressure it can be converted to SCFM (Standard Cubic Feet per Minute) with the following formula:

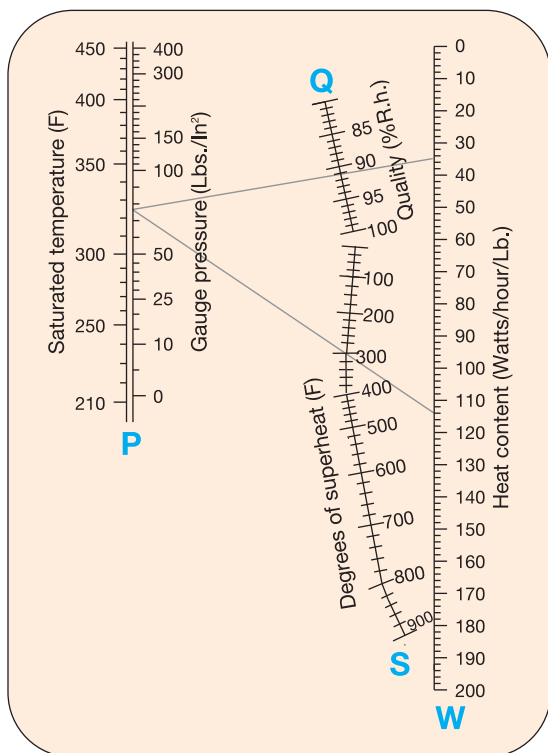
$$\text{SCFM} = \text{CFM} \times \frac{\text{PSIG} + 14.7}{T + 460} \times 35.37$$

PSIG = operating pressure (gauge pressure in lbs/sq.in.)

T = operating temperature in °F

SCFM = flow rate in CFM at standard conditions of 60°F and 14.7 PSIA.

Calculating KW Requirements to Superheat Steam



Superheated Steam Graph

Problem: Heat 420 lbs/hr of 90% quality steam to 620°F @ 75PSIG

1. Plot the pressure on graph **P** and the steam quality on graph **Q**. Draw a straight line from **P** through **Q** and read **W1**.
2. Plot the degrees of superheat on graph **S**. The degrees of superheat equals operating temperature minus saturated temperature. Saturated temperature is read beside gauge pressure on graph **P**.
620°F - 320°F = 300°F
Draw a straight line from **P** through **S** and read **W2**.
3. Determine the required KW using the following equation:

$$KW = \text{LBS/HR} \times (\text{W2} - \text{W1}) / 1000 \times \text{Safety factor}$$

$$= 420 \times (114 - 36) / 1000 \times 1.2 = 39.3 \text{ KW}$$



Note: Element watt density is critical in choosing the correct circulation heater and is dependent upon maximum operating temperature and steam velocity.

Standard Pipe Data

Nominal Pipe Size	Threads Per Inch	Inside Diameter (inches)	Outside Diameter (inches)	Weight Pipe (lbs/ft)	Length in Feet Containing One Cubic Foot	Gallons in One Linear Foot	Weight Water (lbs/ft of Pipe)
1/8	27	0.269	0.405	0.244	2526.000	0.0030	0.025
1/4	18	0.364	0.540	0.424	1383.800	0.0054	0.045
3/8	18	0.493	0.675	0.567	754.360	0.0099	0.083
1/2	14	0.622	0.840	0.850	473.910	0.0158	0.132
3/4	14	0.824	1.050	1.130	270.030	0.0277	0.231
1	11 1/2	1.049	1.315	1.678	166.620	0.0449	0.374
1 1/4	11 1/2	1.380	1.660	2.272	96.275	0.0777	0.648
1 1/2	11 1/2	1.610	1.900	2.717	70.733	0.1058	0.882
2	11 1/2	2.067	2.375	3.652	49.913	0.1743	1.453
2 1/2	8	2.469	2.875	5.793	30.077	0.2487	2.073
3	8	3.068	3.500	7.575	19.479	0.3840	3.200
3 1/2	8	3.548	4.000	9.109	14.565	0.5136	4.280
4	8	4.026	4.500	10.790	11.312	0.6613	5.510
5	8	5.047	5.563	14.617	7.198	1.0393	8.660
6	8	6.065	6.625	18.974	4.984	1.5008	12.510
8	8	7.981	8.625	28.551	2.878	2.5988	21.680
10	8	10.020	10.750	40.483	1.826	4.0963	34.100
12	8	12.000	12.750	49.560	1.274	5.9036	49.000
14	8	13.250	14.000	54.570	1.046	7.1928	59.700
16	8	15.250	16.000	62.580	0.789	9.5301	79.100
18	8	17.250	18.000	70.590	0.617	12.1928	101.200

Barlow's Formula

Pressure ratings of fluid vessels depend mainly on the tensile strength of the material being used at the process temperature, and the wall thickness of the vessel. Normally, the safety factor ratio should be at least 4 to 1 in determining the maximum pressure a vessel may see.

$$\text{Minimum wall thickness (in)} = \frac{\text{Maximum Pressure (PSI)} \times \text{OD of vessel (in)}}{2 \times \text{Tensile Strength (PSI) at process temperature}}$$



Temperature Conversion

Temperature Conversion Table

Locate temperature value for conversion in the light blue area.
 Corresponding temperature in degrees Fahrenheit will be found in column to the right.
 Corresponding temperature in degrees Celsius will be found in column to the left.
 (For temperatures between values in chart use Interpolation Factors below)

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-17.8	0	32.0	8.89	48	118.4	36.1	97	206.6	288	550	1022	560	1040	1904	832	1530	2786
-17.2	1	33.8	9.44	49	120.2	36.7	98	208.4	293	560	1040	566	1050	1922	838	1540	2804
-16.7	2	35.6	10.0	50	122.0	37.2	99	210.2	299	570	1058	571	1060	1940	843	1550	2822
-16.1	3	37.4	10.6	51	123.8	38	100	212	304	580	1076	577	1070	1958	849	1560	2840
-15.6	4	39.2	11.1	52	125.6	43	110	230	310	590	1094	582	1080	1976	854	1570	2858
-15.0	5	41.0	11.7	53	127.4	49	120	248	316	600	1112	588	1090	1994	860	1580	2876
-14.4	6	42.8	12.2	54	129.2	54	130	266	321	610	1130	593	1100	2012	866	1590	2894
-13.9	7	44.6	12.8	55	131.0	60	140	284	327	620	1148	599	1110	2030	871	1600	2912
-13.3	8	46.4	13.3	56	132.8	66	150	302	332	630	1166	604	1120	2048	877	1610	2930
-12.8	9	48.2	13.9	57	134.6	71	160	320	338	640	1184	610	1130	2066	882	1620	2948
-12.2	10	50.0	14.4	58	136.4	77	170	338	343	650	1202	616	1140	2084	888	1630	2966
-11.7	11	51.8	15.0	59	138.2	82	180	356	349	660	1220	621	1150	2102	893	1640	2984
-11.1	12	53.6	15.6	60	140.0	88	190	374	354	670	1238	627	1160	2120	899	1650	3002
-10.6	13	55.4	16.1	61	141.8	93	200	392	360	680	1256	632	1170	2138	904	1660	3020
-10.0	14	57.2	16.7	62	143.6	99	210	410	366	690	1274	638	1180	2156	910	1670	3038
-9.44	15	59.0	17.2	63	145.4	100	212	413.6	371	700	1292	643	1190	2174	916	1680	3056
-8.89	16	60.8	17.8	64	147.2	104	220	428	377	710	1310	649	1200	2192	921	1690	3074
-8.33	17	62.6	18.3	65	149.0	110	230	446	382	720	1328	654	1210	2210	927	1700	3092
-7.78	18	64.4	18.9	66	150.8	116	240	464	388	730	1346	660	1220	2228	932	1710	3110
-7.22	19	66.2	19.4	67	152.6	121	250	482	393	740	1364	666	1230	2246	938	1720	3128
-6.67	20	68.0	20.0	68	154.4	127	260	500	399	750	1382	671	1240	2264	943	1730	3146
-6.11	21	69.8	20.6	69	156.2	132	270	518	404	760	1400	677	1250	2282	949	1740	3164
-5.56	22	71.6	21.1	70	158.0	138	280	536	410	770	1418	682	1260	2300	954	1750	3182
-5.00	23	73.4	21.7	71	159.8	143	290	554	416	780	1436	688	1270	2318	960	1760	3200
-4.45	24	75.2	22.2	72	161.6	149	300	572	421	790	1454	693	1280	2336	966	1770	3218
-3.89	25	77.0	22.8	73	163.4	154	310	590	427	800	1472	699	1290	2354	971	1780	3236
-3.34	26	78.8	23.3	74	165.2	160	320	608	432	810	1490	704	1300	2372	977	1790	3254
-2.78	27	80.6	23.9	75	167.0	166	330	626	438	820	1508	710	1310	2390	982	1800	3272
-2.23	28	82.4	24.4	76	168.8	171	340	644	443	830	1526	716	1320	2408	988	1810	3290
-1.67	29	84.2	25.0	77	170.6	177	350	662	449	840	1544	721	1330	2426	993	1820	3308
-1.11	30	86.0	25.6	78	172.4	182	360	680	454	850	1562	727	1340	2444	999	1830	3326
-0.56	31	87.8	26.1	79	174.2	188	370	698	460	860	1580	732	1350	2462	1004	1840	3344
0.00	32	89.6	26.7	80	176.0	193	380	716	466	870	1598	738	1360	2480	1010	1850	3362
0.56	33	91.4	27.2	81	177.8	199	390	734	471	880	1616	743	1370	2498	1016	1860	3380
1.11	34	93.2	27.8	82	179.6	204	400	752	477	890	1634	749	1380	2516	1021	1870	3398
1.67	35	95.0	28.3	83	181.4	210	410	770	482	900	1652	754	1390	2534	1027	1880	3416
2.22	36	96.8	28.9	84	183.2	216	420	788	488	910	1670	760	1400	2552	1032	1890	3434
2.78	37	98.6	29.4	85	185.0	221	430	806	493	920	1688	766	1410	2570	1038	1900	3452
3.33	38	100.4	29.9	86	186.8	227	440	824	499	930	1706	771	1420	2588	1043	1910	3470
3.89	39	102.2	30.6	87	188.6	232	450	842	504	940	1724	777	1430	2606	1049	1920	3488
4.44	40	104.0	31.1	88	190.4	238	460	860	510	950	1742	782	1440	2624	1054	1930	3506
5.00	41	105.8	31.7	89	192.2	243	470	878	516	960	1760	788	1450	2642	1060	1940	3524
5.56	42	107.6	32.2	90	194.0	249	480	896	521	970	1778	793	1460	2660	1066	1950	3542
6.11	43	109.4	32.8	91	195.8	254	490	914	527	980	1796	799	1470	2678	1071	1960	3560
6.67	44	111.2	33.3	92	197.6	260	500	932	532	990	1814	804	1480	2696	1077	1970	3578
7.22	45	113.0	33.9	93	199.4	266	510	950	538	1000	1832	810	1490	2714	1082	1980	3596
7.78	46	114.8	34.4	94	201.2	271	520	968	543	1010	1850	816	1500	2732	1088	1990	3614
8.33	47	116.6	35.0	95	203.0	277	530	986	549	1020	1868	821	1510	2750	1093	2000	3632
8.89	48	118.4	35.6	96	204.8	282	540	1004	554	1030	1886	827	1520	2768	1099	2010	3650
9.44	49	120.2	36.1	97	206.6	288	550	1022	560	1040	1904	832	1530	2786	1104	2020	3668
10.0	50	122.0	36.7	98	208.4	293	560	1040	566	1050	1922	838	1540	2804	1110	2030	3686
10.56	51	123.8	37.2	99	210.2	299	570	1058	571	1060	1940	843	1550	2822	1116	2040	3704
11.11	52	125.6	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
11.67	53	127.4	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
12.22	54	129.2	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
12.78	55	131.0	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
13.33	56	132.8	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
13.89	57	134.6	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
14.44	58	136.4	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
15.00	59	138.2	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
15.56	60	140.0	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
16.11	61	141.8	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
16.67	62	143.6	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
17.22	63	145.4	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
17.78	64	147.2	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
18.33	65	149.0	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
18.89	66	150.8	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
19.44	67	152.6	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
20.00	68	154.4	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
20.56	69	156.2	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
21.11	70	158.0	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
21.67	71	160.0	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
22.22	72	161.6	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
22.78	73	163.4	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
23.33	74	165.2	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3

Percent of Rated Wattage for Various Applied Voltages

Applied Voltage	Rated Voltage														Applied Voltage
	110	115	120	208	220	230	240	277	380	415	440	460	480	550	
110	100%	91%	84%	28%	25%	23%	21%	16%	8.4%	7%	6.3%	5.7%	5.3%	4%	110
115	109%	100%	92%	31%	27%	25%	23%	17%	9.2%	7.7%	6.8%	6.3%	5.7%	4.4%	115
120	119%	109%	100%	33%	30%	27%	25%	19%	10%	8.4%	7.4%	6.8%	6.3%	4.8%	120
208			300%	100%	89%	82%	75%	56%	30%	25%	22%	20%	19%	14%	208
220				112%	100%	91%	84%	63%	34%	28%	25%	23%	21%	16%	220
230				122%	109%	100%	92%	69%	37%	31%	27%	25%	23%	17%	230
240				133%	119%	109%	100%	75%	40%	33%	30%	27%	25%	19%	240
277							133%	100%	53%	45%	40%	36%	33%	25%	277
380								188%	100%	84%	75%	68%	63%	48%	380
415									119%	100%	89%	81%	75%	57%	415
440										112%	100%	91%	84%	64%	440
460										123%	109%	100%	92%	70%	460
480											119%	109%	100%	76%	480
550											156%	143%	131%	100%	550

To determine the resultant wattage on a voltage not shown in the chart above, use the following formula:

$$\text{Actual Wattage} = \frac{\text{Rated Wattage} \times (\text{Applied Voltage})^2}{(\text{Rated Voltage})^2}$$



Applying higher than the actual rated voltage to heating elements will increase the watt density (watts/in.sq.), which can lead to premature heater failure and/or damage the material being heated.

Watt Density Calculations

Band Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{(\text{Diameter} \times 3.1416 \times \text{Width}) - (\text{Cold Area})}$$

Cartridge and Tubular Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Diameter} \times 3.1416 \times \text{Heated Length}}$$

Mica Strip Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Heated Length} \times \text{Width}}$$

Channel Strip Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Heated Length} \times 3.625}$$

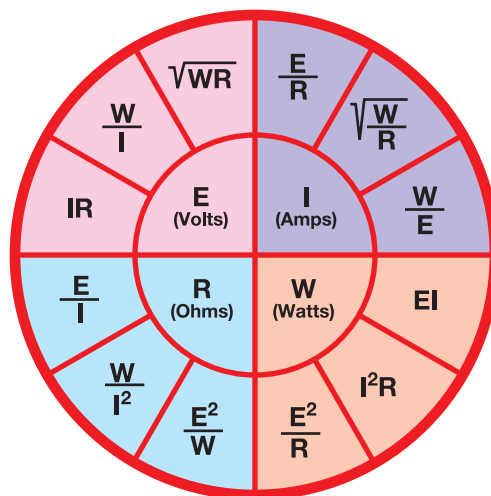
Ohm's Law

Volts

$$\begin{aligned} \text{Volts} &= \sqrt{\text{Watts} \times \text{Ohms}} \\ \text{Volts} &= \frac{\text{Watts}}{\text{Amperes}} \\ \text{Volts} &= \text{Amperes} \times \text{Ohms} \end{aligned}$$

Ohms

$$\begin{aligned} \text{Ohms} &= \frac{\text{Volts}}{\text{Amperes}} \\ \text{Ohms} &= \frac{\text{Watts}}{\text{Amperes}^2} \\ \text{Ohms} &= \frac{\text{Volts}^2}{\text{Watts}} \end{aligned}$$



Amperes

$$\begin{aligned} \text{Amperes} &= \frac{\text{Volts}}{\text{Ohms}} \\ \text{Amperes} &= \sqrt{\frac{\text{Watts}}{\text{Ohms}}} \\ \text{Amperes} &= \frac{\text{Watts}}{\text{Volts}} \end{aligned}$$

Watts

$$\begin{aligned} \text{Watts} &= \text{Volts} \times \text{Amperes} \\ \text{Watts} &= \text{Amps}^2 \times \text{Ohms} \\ \text{Watts} &= \frac{\text{Volts}^2}{\text{Ohms}} \end{aligned}$$

Wiring Information

Amperage Conversion Table

Watts	Volts Single Phase			Volts 3 Phase Balanced Load		Watts
	120	240	480	240	480	
100	0.83	0.42	0.21	0.24	0.12	100
150	1.3	0.63	0.31	0.36	0.18	150
200	1.7	0.83	0.42	0.48	0.24	200
250	2.1	1.0	0.52	0.60	0.30	250
300	2.5	1.3	0.63	0.72	0.36	300
350	2.9	1.5	0.73	0.84	0.42	350
400	3.3	1.7	0.83	1.0	0.48	400
450	3.8	1.9	0.94	1.1	0.54	450
500	4.2	2.1	1.0	1.2	0.60	500
600	5.0	2.5	1.3	1.4	0.72	600
700	5.8	2.9	1.5	1.7	0.84	700
750	6.3	3.1	1.6	1.8	0.90	750
800	6.7	3.3	1.7	1.9	1.0	800
900	7.5	3.8	1.9	2.2	1.1	900
1000	8.3	4.2	2.1	2.4	1.2	1000
1100	9.2	4.6	2.3	2.6	1.3	1100
1200	10.0	5.0	2.5	2.9	1.4	1200
1250	10.4	5.2	2.6	3.0	1.5	1250
1300	10.8	5.4	2.7	3.1	1.6	1300
1400	11.7	5.8	2.9	3.4	1.7	1400
1500	12.5	6.3	3.1	3.6	1.8	1500
1600	13.3	6.7	3.3	3.8	1.9	1600
1700	14.2	7.1	3.5	4.1	2.0	1700
1750	14.6	7.3	3.6	4.2	2.1	1750
1800	15.0	7.5	3.8	4.3	2.2	1800
1900	15.8	7.9	4.0	4.6	2.3	1900
2000	16.7	8.3	4.2	4.8	2.4	2000
2200	18.3	9.2	4.6	5.3	2.6	2200
2500	20.8	10.4	5.2	6.0	3.0	2500
2750	22.9	11.5	5.7	6.6	3.3	2750
3000	25.0	12.5	6.3	7.2	3.6	3000
3500	29.2	14.6	7.3	8.4	4.2	3500
4000	33.3	16.7	8.3	9.6	4.8	4000
4500	37.5	18.8	9.4	10.8	5.4	4500
5000	41.7	20.8	10.4	12.0	6.0	5000
6000	50.0	25.0	12.5	14.4	7.2	6000
7000	58.3	29.2	14.6	16.8	8.4	7000
8000	66.7	33.3	16.7	19.2	9.6	8000
9000	75.0	37.5	18.8	21.7	10.8	9000
10000	83.3	41.7	20.8	24.1	12.0	10000

Wiring Hints

1. Wire gauge, conductor material, and wire insulation choice depend upon current draw, electric service voltage and operating temperature. In high temperature environments, high temperature insulation and/or nickel coated copper or nickel conductors may be required.
2. Heater terminal connections should be tightened with maximum torque consistent with terminal strength. When possible, a wrench or pliers should be used to support the heater terminal to prevent it from twisting when tightening connections.
3. It is good wiring practice to run thermocouple circuit wiring in a separate conduit.
4. Thermostat capillary tubing must be kept away from heater terminals.

Selection of Hook-Up Lead Wire Gauge

Approximate Current Carrying Capacities of High Temperature insulated Nickel (Grade "A") and Nickel Plated Copper wire based on ambient temperature of 40°C (104°F).

This table should only be used as a starting point when establishing ratings for any given situation. It is recommended that design engineers desiring accurate ampacity data refer to the current National Electric Code Handbook, Article 310-15-310-84.

Current Carrying Capacity Table Ambient Temperature at 40°C (104°F)

Conductor Size AWG	Conductor Type and Temperature Rating			
	250°C (482°F) "A" Nickel	250°C (482°F) NPC 2%-10%	450°C (842°F) "A" Nickel	450°C (842°F) NCC 27%
24	4	8	4.3	9
22	5	10.8	5.6	12
20	7	15	8	18
18	9.4	20	11	23
16	12	26	14	30
14	18	39	21	45
12	25	54	26	56
10	34	73	35	75

For ambient temperatures other than 40°C (104°F), multiply the ampacities shown above by the appropriate factor shown below.

Ambient Temperature Correction Factors

Ambient Temperature °C	Wire Temperature Rating		Ambient Temperature °F
	250°C (482°F)	450°C (842°F)	
41-50	0.98	0.99	106-122
51-60	0.95	0.99	124-140
61-70	0.93	0.96	142-158
71-80	0.9	0.95	160-176
81-90	0.87	0.93	177-194
91-100	0.85	0.92	195-212
101-120	0.79	0.89	213-248
121-140	0.71	0.86	249-284
141-160	0.65	0.84	285-320
161-180	0.58	0.81	321-356
181-200	0.49	0.78	357-392
201-225	0.35	0.74	393-437
226-250	—	0.69	439-482
251-275	—	0.65	483-527
276-300	—	0.6	528-572
301-325	—	0.55	573-617
326-350	—	0.49	618-662
351-375	—	0.42	663-707
376-400	—	0.34	708-752

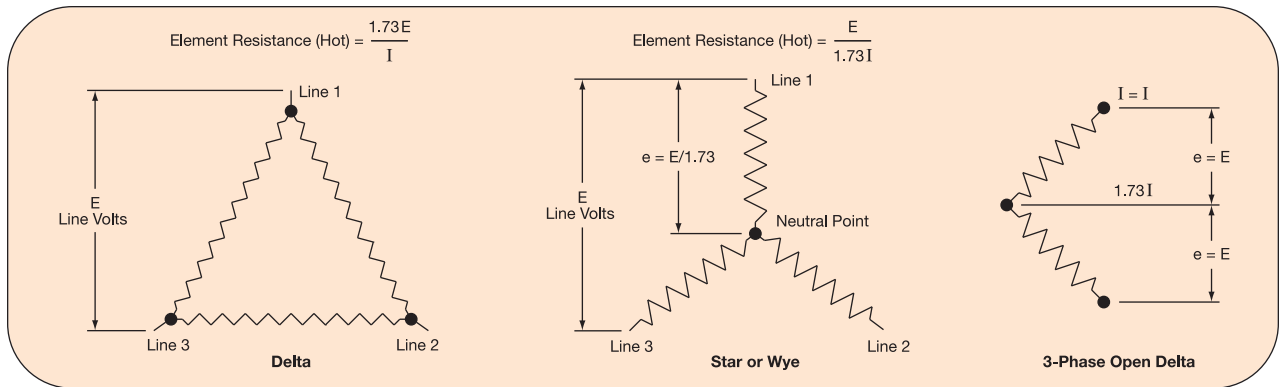
5. Safe operation of heaters equipped with NEMA 4 and NEMA 7 terminal housings depends on electrical wiring meeting the national electrical code for these locations and limiting maximum operation temperatures. Approved pressure and/or temperatures limiting controls must be used to assure safe operation in the event of system malfunctions.
6. An integral thermostat functions as a temperature control only and is not a fail-safe device. An approved pressure and/or temperature limit control should be used in the event of system malfunctions.

7. Never perform any type of service on heaters prior to disconnecting all electrical power.



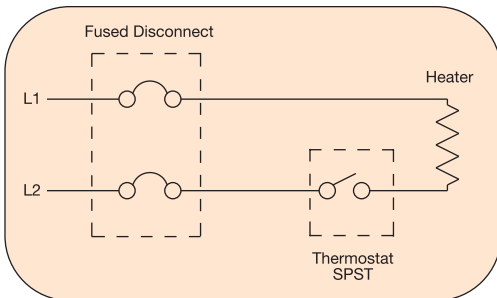
All wiring should be done in accordance with the National Electrical Code and applicable local codes.

Wiring Diagrams

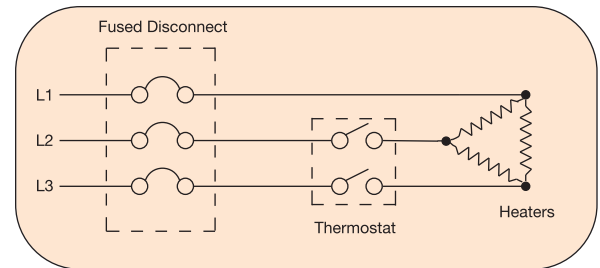


For current in 3 phase circuits: $I = \frac{W}{1.73E}$

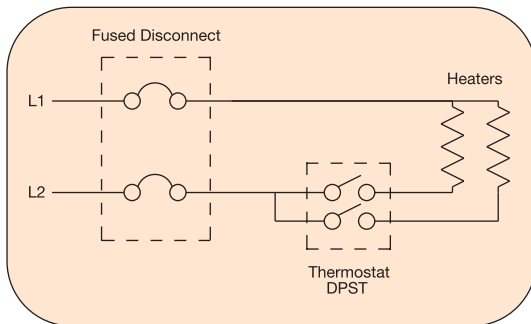
Note: If elements are designed for 3-phase delta connection wattage output may be reduced to 1/3 by rewiring to 3-phase WYE.



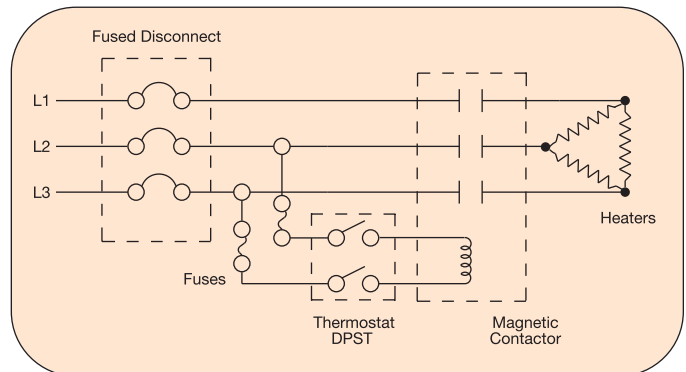
Single-phase circuit with SPST thermostat.



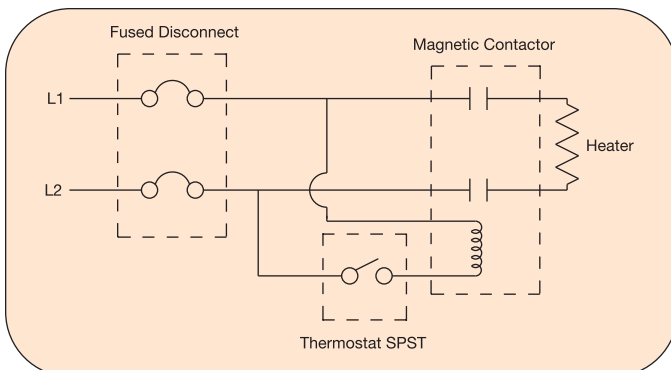
Three-phase circuit with DPST thermostat.



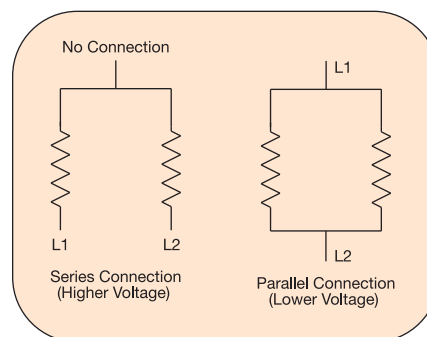
Single-phase circuit with thermostat connected for half current load across each contact.



Three-phase circuit when line current exceeds thermostat rating.



Single-phase circuit when line current exceeds thermostat rating.



Dual Voltage

Example: Two 120V heaters wired in parallel for 120V operation or wired in series for 240V operation.

NOTE: To reduce wattage in a system, two heaters rated at 240 volts wired in series to a 240 volt power supply will generate 1/4 of their rated wattage.

Sheath Material Selection Guide

CORROSION POLICY

TEMPCO cannot warrant any electric immersion heater against failure by sheath corrosion if such failure is the result of operating conditions beyond the control of the heater manufacturer. The facts and recommendations appearing in the TEMPCO catalog or any other literature published by TEMPCO are based on our own research and the research of others, and are believed to be accurate. We cannot anticipate all conditions under which this information and our products, or the products of other manufacturers in combination with our products, may be used.

We accept NO responsibility for results obtained by the application of this information or the safety and suitability of our products, either alone or in combination with other products. It is the responsibility of the Purchaser to make the ultimate choice of sheath material based on his/her knowledge of the chemical composition of the corrosive solution, character of materials entering the solution, and controls, which he/she maintains, on the process.

Examples of process variables that can affect heater sheath selection

- * Solution chemistry
- * Solution contamination
- * Temperature
- * Flow rate (velocity) past heater
- * Heater watt density
- * Heating cycle (time-on, time-off)
- * Galvanic behavior
- * Degree of aeration

Key to Notes in Sheath Material Selection Guide:

1. This solution contains a mixture of various chemical compounds whose identity and proportions are unknown or subject to change. Check with chemical supplier to confirm suitability of sheath material chosen.
2. Caution—flammable material.
3. Chemical composition varies widely. Check supplier for specific recommendations.
4. Direct immersion heaters not practical. Use clamp-on heaters on outside surface of cast iron pot.
5. Element surface loading should not exceed 20 watts per square inch.
6. For concentrations greater than 15%, element surface loading should not exceed 20 watts per square inch.
7. See suggested watt density chart.
8. Remove crusts at liquid level.
9. Clean often.
10. Passivate stainless steel, Inconel® and Incoloy®.



Maximum Recommended Watt Densities for Various Materials

Material Being Heated	Maximum Operating Temperature °F	Maximum Watt Density W/in ²
Acid Solutions	180	40
Alkaline Solutions, Oakite	212	40
Ammonia Pltg. Solution	50	25
Asphalt, Tar or Heavy Compounds	200-500	4-10
Caustic Soda 2%	210	45
10%	210	25
75%	180	25
Degreasing Solution Vapor	275	20
Electroplating Solution	180	40
Ethylene Glycol	300	30
Fatty Acids	150	20
Fuel Oils		25-30 circ.
Light Grade	180	8
Heavy (Bunker C)	160	23
Gasoline	300	10
Glycerine	500	

Material Being Heated	Maximum Operating Temperature °F	Maximum Watt Density W/in ²
Machine Oil SAE 30	250	15-20 non-circ.
Metal Melting Pot	500-900	20-27
Mineral Oil	400	16
Molasses	100	4-5
Molten Tin	600	20
Oil Draw Bath	600	20
Paraffin or Wax	150	16
Potassium Hydroxide	160	25
Propylene Glycol	150	20
Steel Tubing Cast Into Aluminum	500-750	50
Steel Tubing Cast Into Iron	750-1000	55
Trichlorethylene	150	20
Water (Process)	35-150	100-125 circ. 75-100 non-circ. 75 circ. 50 non-circ.
	212	

Media Being Heated	Element Sheath Material															*Notes			
	Iron & Steel	Gray Cast Iron	Cast Iron Ni-Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Str. Stl.	316 Str. Stl.	Type 20 Str. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B		Quartz	Graphite	Teflon®
Acetaldehyde					A				A	A									Note 2
Acetic Acid, Crude	X		C	F	F	X	F	F	F	F		C	C						
Pure			X	A	F	F	A	F				C	C						
Vapors			X	C	F	X	F	F				C	C	F					
150 PSI; 400°F				C	F	X	F	F				C	C						
Aerated	X	X	X	C	X	X	X	X	X	F	F		X	A					
No Air		X	X	C	F	X	A	F	C	F	F		X	A					
Acetone	C	X	F	F	A	A	A	A	A	A	A	A	A	A	A	A	A		Note 2
Actane™ 70																	A	A	Note 1
Actane™ 80																	A	A	Note 1
Actane™ Salt																	A		Note 1
Alboloy Process	A																		
Alcoa™ R5 Bright Dip																A		A	Note 1
Alcohol	F	F		F	A	A	A	A	F	A	A	A	A	A	A	A	A		Note 2
Allyl Alcohol		A	A	F	A	F	A	A	A	A	A	A	A						
Alcorite™															A				Note 1
Alkaline Cleaners									A										Note 1
Alkaline Soaking Cleaners	A																		Note 1
Alodine™										A									Note 1
Aluminum (Molten)	CONSULT TEMPCO																		
Aluminum Acetate	X	X			F	A	F	F	F	A	A		F	A	A				
Aluminum Bright Dip																A		A	Note 1
Aluminum Chloride	X	X		X	X	X	X	X	X	X	X	X	X	X	A	A	A	A	Note 1
Aluminum Cleaners	C	C		X	X	X	A	A	A	A	F	A	A	F		X	X		Notes 1, 9
Aluminum Potassium Sulfate (Alum)		X	X	X	A	F	F	F	X	C	F		F	F					
Aluminum Sulfate	X	X	X	X	X	F	X	X	F	F	F	X	X	A		A	A		Note 1
Ammonia	X	X		C	X	C	X	X	X	X	C	F	A	A	A	A			
Ammonia (Anhydrous) (Gas)	F				X				A	A									
Cold	C		A	A	A	F	A	A	A	A		A	A						
Hot	C		C		A	X	A	A	C	C	A		A						
Ammonia and Oil	A																		
Ammonium Acetate	A	F	F	A	X	X	A	A	A	A	A	A							
Ammonium Chloride	X	X	F	X	X	X	F	F	X	C	C	C	C		A	A	A	A	
Ammonium Hydroxide	F	F	F	C	X	F	X	A	A	A	A	A	A		X	A			
Ammonium Nitrate	F	X	C	F	X	X	X	X	A	A	A	X	X	X		A	A		
Ammonium Persulfate	X	X		X	X	C	X	X	F	F	F		X			A	A	A	
Ammonium Sulfate	X	X	F	X	X	F	F	F	C	F	F	F	F	A		A	A		
Amyl Acetate	F				A		A	A	A	A	A		A						
Amyl Alcohol	A	F	F	C	A		A	F	A304	A	A	A	A	A		A			Note 2
Aniline	F	A		F	X	F	F	F	A304	A	A	F	F	A		A	A		
Aniline, Oil	A			X	X				A	A									
Aniline, Dyes							A		A	A									

Corrosion Resistance Ratings:

- A** = Good
- F** = Fair
- C** = Depends on Conditions
- X** = Unsuitable

Blank = Data Not Available

* See Key to Notes in Material Selection Guide on Page 16-12.



Recommended Sheath Materials

Media Being Heated	Element Sheath Material																*Notes		
	Iron & Steel	Gray Cast Iron	Cast Iron Ni-Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz		Graphite	Teflon®
Anodizing Solutions (10%)																			
Chromic Acid 96°F	C								A	A			A						
Nickel Acetate						C	A	F											
Nigrosine Black Dye							F	F											
Sodium Hydroxide Alkaline	A				A			A		A	A	A	A						
Sulfuric Acid 70°F						A					A								
ARP™ 28																	A	A	Note 1
ARP™ 80 Blackening Salt																	A		Note 1
Arsenic Acid	X	X		X	X	X	X	X	C	F	F	X	X	X		A	A	A	
Asphalt	A	A		X	X	X	X	A	A	A	A	A	A	A		A	A		
Barium Chloride				X				A	F	F									
Barium Hydroxide	F	F		X	X	X	F	A	F	A	A	F	F	X		A	A		
Barium Sulfate	F	F	F		F	F	F	F	F	F	F	F	F	A		A	A		
Barium Sulfite									F										
Black Nickel																A		A	Note 5
Black Oxide									A										Note 5
Bleaching Solution 1½ lb. Oxalic Acid per Gallon of H ₂ O at 212°F							A		F										
Bonderizing™ (Zinc Phosphate)	C		F						A	A									
Boric Acid	X	X		X	C	C	C	C	C	C	C	C	C	A	A	A	A	A	
Brass Cyanide									A										Note 1
Bright Nickel													A		A				Notes 1, 5
Brine (Salt Water)							A					F							
Bronze Plating	A								A										Note 1
Butanol	A	A		F	A	A	A	A	A	A	A	A	A		A	A	A		Note 2
Cadmium Black															A				Note 1
Cadmium Fluoborate																	A	A	Note 1
Cadmium Plating									A			A	A						Note 1
Calcium Chlorate	F	F		F	C	C	F	F	F	F	F	F			A				
Calcium Chloride	F	F		C	F	X	F	F	F	F	F	F	A	A	A	A	A		
Carbon Dioxide—Dry Gas	X	X	A	A	A	F	A	A	A	A	A	A	X		A	X	X		
Carbon Dioxide—Wet Gas	X	X	C	A	X	F	A	A	A	A	A	A	X		A	X	X		
Carbon Tetrachloride	X	X	C	X	C	A	A	A	C	F	F	A	A	A		A			
Carbonic Acid	C	C		C	C	X	C	C	A	F	A	F	A	A		A	A	A	
Castor Oil	A	A		A	A	A	A	A	A	A	A	A	A		A	A	A		
Caustic Etch	A	A		X	X		A	A	A	A	X	X	X	A		X	A	X	
Caustic Soda (Lye) (Sodium Hydroxide) 2%	F	F	F	X	F	X	A	A	X	F	A	A	A	A					
10–30%, 210°F	F	F	A	X	F	X	A	A	A	A	A	A	A	A					
76%, 180°F	X	X	X	X	X	X	F	A	F	F	F	A	A	F					
Chlorine Gas: Dry	X	X	F	X	X	X	F	C	C	C	F	C	F	X		A	F	F	Note 2
Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	F		A	X	X	Note 2
Chloroacetic Acid	X	X		X	X	X	F	F	X	X		C	C	A		A	A	A	
Chromic Acetate																A			Note 1

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* See Key to Notes in Material Selection Guide on Page 16-12.

Media Being Heated	Element Sheath Material																*Notes		
	Iron & Steel	Gray Cast Iron	Cast Iron Ni-Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Strn. Stl.	316 Strn. Stl.	Type 20 Strn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz		Graphite	Teflon®
Chrome Plating	X	X		X	X	F	X	X	X	X	X	X	A		A	A	X		
Chromic Acid	X	C	X	X	X	F	X	X	X	X	X	X	A		A	A	X		
Chromylite																		Note 1	
Citric Acid	X	X	C	C	C	X	F	F	C	C	F	F	A	A	A	A	A		
Clear Chromate										A								Note 1	
Cobalt Acetate at 130°F							F	F	A	A		F	F						
Cobalt Nickel															A			Notes 1, 6	
Cobalt Plating									A						A			Note 1	
Coconut Oil						F	A												
Cod Liver Oil				A			A	A	A	A	A	A							
Copper Acid													A		A			Note 1	
Copper Bright									A	A								Note 1	
Copper Bright Acid															A				
Copper Chloride	X	X		C	X	C	X	X	X	X	X	X	A		A	A	A		
Copper Cyanide	A	A		X	X		C	X	F	F	F	X	X		A	A	A		
Copper Fluoborate							F	F	F	F	F	F				A	A		
Copper Nitrate	X	X	X	X	X	X	X	X	F	F	F	X	X		A	A	A		
Copper Plating	A																		
Copper Pyrophosphate									A									Note 1	
Copper Strike	A	A							A									Note 1	
Copper Sulfate	X	X	F	X	C	A	X	X	F	A	C	X	A		A	A	A		
Creosote	A	F	F	C	F	X	F	F	F	F	F	F			A			Note 2	
Cresylic Acid	C	C		C	C	X	F	F	F	A	A	C	F	F	A	A	A	Note 2	
Deoxidine™									A										
Deoxlyte™									A										
Deoxidizer (Etching)															A			Note 1	
Deoxidizer (3AL-13)									A	A								Note 1, Non-Chromate	
Dichromic Seal	X	X																	
Diethylene Glycol	F	A		F	F	A	F	F	A	A	A	F	F	A		A	A		
Diphenyl 300° - 350°F	A	A	A	A	A	A	A	A	A			A							
Disodium Phosphate	A																		
Diversey™ DS9333															A			Note 1	
Diversey™ 99	A																		
Diversey™ 511															A			Notes 1, 5	
Diversey™ 514																A	A	Note 1	
Dowtherm™ A	A																		
Electro-Polishing																		Note 1	
Electroless Nickel													A		A			Note 1	
Electroless Tin (Acid)															A			Note 1	
(Alkaline)										A			A					Note 1	
Enthone Acid-80																	A	A	Note 1
Ether	F	F		F	F	F	F	F	F	F	A	F	F	A		A		Note 2	
Ethyl Chloride	F	F		F	A	F	F	A	F	F	A	F	A	A		A	A	A	Note 2



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Recommended Sheath Materials

Media Being Heated	Element Sheath Material																	*Notes
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Ethylene Glycol	A	F		A	F	X	F	F	F	F	F	F	A		A	A	A	Note 5
Fatty Acids	X	X		A	X	X	F	F	F	A	A	F	F	A	A	A		
Ferric Chloride	X	X	X	X	X	X	X	X	X	X	X	X	A		A	A	A	
Ferric Nitrate	X	X		X	X		X	X	F	F	A	X	X		A	A		
Ferric Sulfate	X	X	X	X	X	A	X	C	F	F	F	C	C	A	A	A		
Fluorine Gas, Dry	C	X		X	X	X	A	A	C	C	C	C	A	A	C	X		
Formaldehyde	X	X	F	F	F	X	F	F	A	A	A	F	F	A	A	A		
Formic Acid	X	X		X	F	X	C	C	X	X	A	F	C	X	A	A		
Freon	A	A	A	A	A	A	A	A	A	A	A	A	A					
Fuel Oil	A	A		A	A	A	F	F	A	A	A	F	F	A				Notes 2, 3, 7
Fuel Oil - Acid	X	X		X	X	A	C	C	C	F	A	C	C	A				Notes 2, 3, 7
Gasoline - Refined	A	A	A	A	A	A	F	F	A	A	A	F	F		A	A		Notes 2, 5
Gasoline - Sour	C	C		C	C	A	X	X	F	F	A	X	X		A	A		Notes 2, 3, 5
Glycerine, Glycerol	F	C	F	A	F	F	A	A	A	A	A	A	A		A	A		
Gold Acid	A												A	A				Note 1
Gold Cyanide									A	A								Note 1
Grey Nickel													A	A		A		Notes 1, 5
Holdens 310A Tempering Bath								A										
Hot Seal Sodium Dichromate										A								Note 1
Houghtone Mar Tempering Salt	C							C										
Hydrocarbons - Aliphatic	A	A		A	A		A	A	A	A	A	A	A		A	A		Note 2
Hydrocarbons - Aromatic	A	A		A	A		A	A	A	A	A	A	A		A	A		Note 2
Hydrochloric Acid < 150°F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	A	A		
> 150°F	X	X		X	X	X	X	X	X	X	X	X	X	X	A	A	A	
Hydrocyanic Acid	X	X		F	X	X	F	F	F	F	F	F	F		A	A		
Hydrofluoric Acid, Cold < 65%	X	X	X	X	X	X	C	X	X	X	X	X	X	X	X	A	A	Note 5
> 65%	F	X	X	X	X	X	C	X	X	X		X	X	X				
Hydrofluoric Acid, Hot < 65%	X			X	X	X	C	X	X									
> 65%	X			X	X	X	C	X	X	X		X	X	X				
Hydrogen Peroxide	X	X	X	A	X	X	C	F	F	F	F	F	F	A	A	X		
Indium															A		A	Note 1
Iridite™ #4-75, #4-73, #14, #14-2, #14-9, #18-P										A								Note 1
Iridite™ #1, #2, #3, #4-C, #4PC&S, #4P-4, #4-80, #4L-1, #4-2, #4-2A, #4-2P, #5P-1, #7-P, #8, #8-P, #8-2, #12-P, #15, #17P, #18P															A			Note 1
Iridite™ Dyes #12L-2, #40, #80															A		A	Note 1
Irillac™															A		A	Note 1
Iron Fluoborate																A	A	Note 1
Iron Phosphate (Parkerizing)	C		F						A	A								
Isoprep™ Deoxidizer #187, #188										A								Note 1
Isoprep™ #191 Acid Salts																A	A	Note 1

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Blank = Data Not Available

* See Key to Notes in Material Selection Guide on Page 16-12.

Media Being Heated	Element Sheath Material																*Notes		
	Iron & Steel	Gray Cast Iron	Cast Iron Ni-Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Strn. Stl.	316 Strn. Stl.	Type 20 Strn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz		Graphite	Teflon®
Isoprep™ Acid Aluminum Cleaner #186									A										Note 1
Isopropanol	C				A		A	A	A	A		A							
Jetal™									A										Note 1
Kerosene	A			A	A		A	A	A	A	A	A					A		Note 2
Kolene									A										
Lacquer Solvent	F	A	A	A	F	A	F	F	A	A	A	F	F	A		A			Note 2
Lead Acetate	X	X		X	X	X	A	A	A	A	A	A	A		A	A			
Lead Acid Salts									A										Note 1
Lime Saturated Water	F	F		X	F	X	F	F	F	A	F	F	F			X	A		
Linseed Oil	X	A		F	F	X	F	F	A	A	A	F	F			A	X		Note 2
Magnesium Chloride	X	C	F	X	F	X	F	A	F	F	A	F	A	A		A	A		
Magnesium Hydroxide	A	A	A	F	A	A	F	A	A	A	A	A	A			A	A		
Magnesium Nitrate	F	F		F	F	C	F	F	F	F	F	F	X	F		A	A		
Magnesium Sulfate	F	F	F	F	F	A	A	A	F	F	A	F	A	A		A	A		
MacDermid™ M629																	A	A	Note 1
Mercuric Chloride	X	X	X	X	X	X	X	X	X	X	X	X	X	F		A	A		
Mercury	A	A	A	X	X	X	F	F	F	A	A	A	F	X		A			
Methyl Alcohol (Methanol)	F	F		C	F	F	A	A	F	A	A	F	A	A		A	A		Note 2
Methyl Bromide	C	C		X	F	F	F	F	A	A	A	F	F	A		A			
Methyl Chloride	C	C		X	A	C	C	C	C	C	C	C	C	A		A	A		
Methylene Chloride	X	C		C	C	F	C	F	C	F	A	C	F	A		A	A		
Mineral Oil	A	A		A	A	A	A	A	A	A	A	A	A	A		A	A		
Muriato																	A	A	Note 1
Naptha	A	F	F	A	A	A	A	A	A	A	A	A	A	A		A	A	A	Note 2
Napthalene	A	A	A	F	F	A	F	F	A	A	A	F	F	A					Note 2
Nickel Acetate Seal										A									Note 1
Nickel Chloride	X	X	X	X	X	C	C	X	X	C	C	C	F	F		A	A	A	Notes 1, 5
Nickel Copper Strike (Cyanide Free)									A	A									Note 1
Nickel Plate - Bright						A								A		A		A	Notes 1, 5
Nickel Plate - Dull						A										A		A	Notes 1, 5
Nickel Plate - Watts Solution														A		A		A	Notes 1, 5
Nickel Sulfate	X	X	X	X	F	F	C	F	F	F	F	C	F			A	A	A	
Nitric Acid, Crude	X				X	X	X	X	C	C		X	X			A		A	
Concentrated	X				X	X	X	X	F	F		X	X			A		A	
Diluted	X				X	X	X	X	A	A		X	X			A		A	
Nitric Hydrochloric Acid	X	X		X	X	X	X	X	X	X	X	X	X	X		A	A	A	
Nitric 6% Phosphoric Acid										C						A		A	Note 1
Nitric Sodium Chromate										A						A		A	Note 1
Nitrobenzene	A	A	A	A	F	X	A	A	A	A	A	A	A	A		A			Note 2
Oakite™ #67									A										Note 1
Oakite™ #20, 23, 24, 30, 51, 90	A																		
Oleic Acid	C	C	C	C	C	X	F	F	C	F	A	F	A	F		A	A	A	



CORROSION POLICY

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We accept NO responsibility for results obtained by the application of this information or the safety and suitability of our products, either alone or in combination with other products. It is the responsibility of the Purchaser to make the ultimate choice of sheath material based on his/her knowledge of the chemical composition of the corrosive solution, character of materials entering the solution, and controls, which he/she maintains, on the process.



Recommended Sheath Materials

Media Being Heated	Element Sheath Material																	*Notes	
	Iron & Steel	Gray Cast Iron	Cast Iron Ni-Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite		Teflon®
Oxalic Acid	X	X	X	F	F	X	C	F	X	X	F	X	F	X		A	A	A	
Paint Stripper (High Alkaline Type)	A																		Note 1
Paint Stripper (Solvent Type)										A									Notes 1, 2
Paraffin	A	A		A	A		F		A	A	A								Notes 2, 7
Parkerizing™ (See Iron Phosphate)																			
Perchloroethylene	F	F		C	F	F	A	A	F	F	F	F	A	A		A			
Perm-A-Clor™									A										
Petroleum - Crude < 500°F	F	F	A	A	C	C	A	C	A	A	A					A	A		Notes 2, 3, 7
> 500°F	A		A	A	X	X	X	X	A										
> 1000°F	X			X	X	X	X	X	A347										
Phenol	F	F		F		X	F		C	F	F	F	F	A	A				
Phosphate										A								X	Notes 1, 5, 9
Phosphate Cleaner									A									X	Notes 1, 5, 9
Phosphatizing										A								X	Notes 1, 5, 9
Phosphoric Acid, Crude	C			X	X	C	X	X	C										
Pure < 45%	X	X	X	C	C	C	F	C	C	C	F	A	A	X					
> 45% Cold	X	X	X	X	F	C	F	C	A	F	F	A		X					
> 45% Hot	X	X	X	X	C	X	C	X	X	X	F	A	F	X					
Photo Fixing Bath									C	A									
Picric Acid	X	X		X	X	X	X	X	F	F	F	C	C			A	A	A	
Potassium Acid Sulfate																A		A	Note 1
Potassium Bichromate	C	F	F	F		F	F	F	A347	A	A	F		F	A	A		A	
Potassium Chloride	C	X	F	X	C	C	F	F	C	F	A	C	F	A		A	A		
Potassium Cyanide	C	X	F	X	X	X	C	F	F	F	F	F	F	X		A	C	A	
Potassium Dichromate									A347										
Potassium Hydrochloric																A		A	Note 1
Potassium Hydroxide	X	X		X	C	X	F	A	C	C	C	C	F	X		X	A	A	
Potassium Nitrate	F	F	F	A	F	F	F	F	F	F	F	F	F	A		A	A		
Potassium Sulfate	C	C	C	A	F	A	A	F	A	A	A	F	F	A		A	A	A	
Prestone™ 350°F	A						A												
R5 Bright Dip For Copper Polish at 180°F										A									
Reynolds Brightener																A		A	Note 1
Rhodium Hydroxide																A		A	
Rochelle Salt Cyanide	A								A										Note 1
Ruthenium Plating																A		A	Note 1
Silver Bromide	X	X		X	X		C	C	X	X	C			A		A	A	A	
Silver Cyanide	C	C		X	X		F		A	A	A	A				A			
Silver Lume									A										Note 1
Silver Nitrate	X	X		X	X	X	X	X	C	C	F	C	C	A		A	A		
Soap Solutions	A	A	A	X	C		A		A	A	A								Note 3
Sodium - Liquid Metal	C	X		X	X	X	F	A	A			A	A			X	X		

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Sodium Bisulfate	X	X	X	C	F	C	C	F	X	X	A	F							
Sodium Bromide	F	C		X	F	F	F	F	C	F	F	F				A	A	A	
Sodium Carbonate	C	C		X	A	X	F	F	F	F	A	F	F	A		C	A	A	
Sodium Chlorate	X	X		F	A	F	A	A	F	F	F	F	A	A		A	A	A	
Sodium Chloride	C	X	F	X	F	F	A	F	X	X	C	F	A	C		A	A		
Sodium Citrate	X	X		X	X	X			F	F	F					A	A	A	
Sodium Cyanide	C	F	C	X	X	X	C	C	A	A	A	A	C		A	C			
Sodium Dichromate (Sodium Bichromate)	F	F	F	C	X				F	F	F		C		A				
Sodium Hydroxide (See Caustic Soda)																			
Sodium Hypochlorite	X	X	X	X	X	X	X	X	X	X	F	X	X	A	A	A	A	A	
Sodium Nitrate	F	F	A	C	C	C	F	F	A	A	A	A	A		A	A			
Sodium Peroxide	F	A	F	C	X	X	F	F	F	F	F	F							
Sodium Phosphate	C	C	F	X	F	F	A	C	F	A	F	F	A	A		A	A	A	
Sodium Salicylate	F	C	F		F		F	F	F	F	F	F	F		A	A	A		
Sodium Silicate	A	F	A	X	F	X	A	A	A	A	A	A	A	A		A	A	A	Note 4
Sodium Stannate	C	C	C				F	F	F	F	F	F	F		A		A		
Sodium Sulfate	F	C		F	F	F	F	F	X	F	F	F	F	C		A	A	A	
Sodium Sulfide	C	X	C	C	X	A	F	F	X	C	C	C	C	C		C	A	A	
Solder Bath	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	Note 4
Soybean Oil									A										
Sannostar™																A		A	Note 1
Steam < 500°F	A			A	A	C	A	A	A			A	A						
500° - 1000°F	C			C	C	X	C	C	A			A	A						
> 1000°F	X			X	X		X	X	A			A	A						
Stearic Acid	C	C	C	C	X	X	F	F	C	A	A	F	F	F		A	A		
Sugar Solution	A	A		A	A	A	A	A	A	A	A	A	A	A		A	A	A	Note 7
Sulfamate Nickel														A		A		A	Note 1
Sulfamic Acid	X	X		X					X	X						A		A	
Sulfur	C	X	C	A	X	X	F	C	C	F	F	A	A	A		A	A		
Sulfur Chloride	X	X	C	X	X	F	X	C	C	X	C	C	F			A	X	A	
Sulfur Dioxide	C	C		C	C	F	X	C	C	F	F	C	C	A		A	A		
Sulfuric Acid < 10% Cold	X		X	C	A	F	F	C	X	C	F		X						
Hot	X	X	X	C	X	X	X	X	X	X	X		F						
10 - 75% Cold	X			X	F	F	C	C	X	X	F		X	X					
Hot	X			X	X	F	C	X	X	X	C		X	X					
75 - 95% Cold	F	F	F	X	F	F	X	X	F	F	F			X					
Hot	X	X	X	X	X	C	X	X	X	X	X			X					
Fuming	C	X	C	X	X	X	X	X	F	C	C	C	C						
Sulfurous Acid	X	X		C	X	A	X	X	X	C	F		C	A					
Tannic Acid	C	C		C	C	X	C	C	C	A	A		A	A		A			
Tar	A			A					A			A	A						
Tartaric Acid		X	F	C		C	F	C	C	A	F		F	F					



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Tetrachlorethylene	F	F		C	F	F	A	A	F	F	F	F	A	A		A			
Therminol™ FR1 8-12 W/Sq. In. 640°F	A																		
Thermoil Granodine™	F																		
Tin (Molten)	F	F		X	X	X	X	X	F	F	X		X	A			X	X	Note 4
Tin - Nickel Plating																A		A	Note 1
Tin Plating - Acid																	A	A	Note 1
Tin Plating - Alkaline	A								A										Note 1
Toluene	A	A	A	A	C	A	A	A	A	A	A	A	A	A					
Triad Solvent	C																		
Trichloroethane	A	C	C	F	F	F	F	F	A	F	F	F	F	A		A	A		
Trichloroethylene	F	C	C	F	C	X	C	C	F	F	F	F	A	A		A	A		
Triethylene Glycol	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A			
Trioxide (Pickle)																A		A	Note 1
Trisodium Phosphate	A	A		X	C	X	C	C	C	C	C					X	F	X	
Turco™ 2623	A																		
Turco™ 4008, 4181, 4338										A									Note 1
Turco™ Ultrasonic Solution										A									Note 1
Turpentine	C	C	C	A	F	A	A	A	A	A		A							
Ubac™																A			Note 1
Udylite #66													A		A		A		Notes 1, 5
Unichrome™ CR-110															A		A		Note 1
Unichrome™ 5RHS															A		A		Note 1
Urea Ammonia Liquor 48°F	A																		
Vegetable Oil	C		C	F	X	X	A	A	A	A	A	A							
Vinegar	C			C			A		F	A									
Water, Acid Mine Containing Oxidizing Salts	X		C	C	C	C	X	C	A										
No Oxidizing Salts	C		A	A			A		X										
Water, Deionized	X	X		X	X		A	A	A	A	A	A	A						Note 10
Deminerlized	X	X		X	X		A	A	A	A	A	A	A						Note 10
Distilled	X	X			X	X	C	A				A	A						Note 10
Potable	X	C	A	A	A	X	A	A	C	F	A	A	A	A		A			
Return Condensate	A		A	A	A	A			A	A	A	A							
Sea	X	X	A	X	X	A	A		C	C	A	F	F	A		A	A		
Watt's Nickel Strike																A			Note 1
Whiskey and Wines	X		C				A	A	A	A	A	A							Note 2
Wood's Nickel Strike																A			Note 1
Yellow Dichromate										A						A			Note 1
X-Ray Solution									A										
Zinc (Molten)				X	X	X	X	X	X	X	X	X	X	X				X	
Zinc Chloride	C	C	C	X	X		F	F	X	X	F	X	F	C		A	A	A	
Zinc Phosphate										A								X	Notes 1, 5
Zinc Plating Acid																A			Note 1
Zinc Plating Cyanide	A								A										Note 1
Zinc Sulphate	C	X	A	C	F	A	F	C	C	C	C		F	A					
Zincate™	A								A										Note 1

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Frequently Used Conversion Factors

U.S. Customary
1 cu. ft. = 1728 cu. in. = 0.03704 cu. yd.
1 cu. ft. = 7.481 gal.
1 gal. = 231 cu. in. = 0.1337 cu. ft.
1 gal. water = 8.3 lbs.
1 cu. ft. Water = 62.43 lbs.
1 KWH. will evaporate 3.5 lb. of water at 212°F
1 KWH. will raise 22.75 lb. of water from 62°F to 212°F
3412 BTU = 1 KWH = 1.34 HP Hour
1 HP = 745.7 Watts
1 BTU = 252 calories = 0.293 Watt Hours

Metric
1 in. = 2.54 cm = 25.4 mm
1 ft. = 0.3048 m
1 m = 39.37 in.
1 sq. in. = 6.4516 sq. cm.
1 sq. ft. = 0.0929 sq. m.
1 cu. in. = 16.39 cu. cm
1 cu. ft. = 0.02832 cu. m. = 28.32 liters
1 lb. = 453.6 grams
1 gal. (U.S.) = 3.785 liters
1 liter = 61.024 cu. in.

TO CONVERT	INTO	MULTIPLY BY
Atmospheres	Cms of Mercury	76
Atmospheres	Feet of Water (at 4°C)	33.9
Atmospheres	Inches of Mercury (at 0°C)	29.92
Atmospheres	Kgs/Square Cm	1.0333
Atmospheres	Kgs/Square Meter	10.332
Atmospheres	Pounds/Square Inch	14.7
BTU/Hour	Watts	0.2931
BTU/Minute	Horsepower	0.02356
BTU/Minute	Kilowatts	0.01757
BTU/Minute	Watts	17.57
Centiliters	Ounces Fluid (U.S.)	0.3382
Centimeters	Feet	3.281 × 10 ⁻²
Centimeters	Inches	0.3937
Cubic Centimeters	Cubic Feet	3.531 × 10 ⁻⁵
Cubic Centimeters	Cubic Inches	0.06102
Cubic Centimeters	Gallons (U.S. Liquid)	2.642 × 10 ⁻⁴
Cubic Feet	Cubic Cms	28.320
Cubic Feet	Cubic Inches	1,728
Cubic Feet	Cubic Yards	0.03704
Cubic Feet	Gallons (U.S. Liquid)	7.48052
Cubic Inches	Cubic Cms	16.39
Cubic Inches	Cubic Feet	5.787 × 10 ⁻⁴
Cubic Inches	Gallons	4.329 × 10 ⁻³
Cubic Inches	Cubic Feet	35.31
Cubic Meters	Cubic Yards	1.308
Cubic Meters	Gallons (U.S. Liquid)	264.2
Feet	Centimeters	30.48
Feet	Kilometers	3.048 × 10 ⁻⁴
Feet	Millimeters	304.8
Feet of Water	Atmospheres	0.0295
Feet of Water	Inches of Mercury	0.8826
Feet of Water	Pounds/Square Foot	62.43
Feet of Water	Pounds/Square Inch	0.4335
Gallons	Cubic Cms	3,785
Gallons	Cubic Feet	0.1337
Gallons	Cubic Inches	231
Gallons	Cubic Meters	3.785 × 10 ⁻³
Gallons	Cubic Yards	4.951 × 10 ⁻³
Gallons (Liquid Br. Imp.)	Gallons (U.S. Liquid)	1.20095
Gallons of Water	Pounds of Water	8.3453
Gallons/Minute	Cubic Feet/Hour	8.0208

TO CONVERT	INTO	MULTIPLY BY
Grams	Pounds	2.205 × 10 ⁻³
Horsepower	Kilowatts	0.7457
Horsepower (Boiler)	BTU/Hour	33479
Horsepower (Boiler)	Kilowatts	9.803
Inches	Meters	2.540 × 10 ⁻²
Inches of Mercury	Atmospheres	0.03342
Inches of Mercury	Feet of Water	1.133
Inches of Mercury	Pounds/Square Inch	0.4912
Kilograms	Pounds	2.205
Kilograms/Cubic Meter	Pounds/Cubic Feet	0.06243
Kilowatt Hours	BTU	3412
Liters	Cubic Feet	0.03531
Meters	Feet	3.281
Meters	Yards	1.094
Microns	Meters	1 × 10 ⁻⁶
Millimeters	Feet	3.281 × 10 ⁻³
Millimeters	Inches	0.03937
Ounces	Pounds	0.0625
Radians	Degrees	57.3
Radians	Minutes	3,438
Square Feet	Square Inches	144
Square Feet	Square Yards	0.1111
Square Inches	Square Cms	6.452
Square Inches	Square Feet	6.944 × 10 ⁻³
Square Meters	Square Feet	10.76
Square Meters	Square Yards	1.196
Square Yards	Square Feet	9
Square Yards	Square Inches	1,296
Square Yards	Square Meters	0.8361
Watts	BTU/Hour	3.4129
Watts	Foot-Pounds/Minute	44.27
Yards	Kilometers	9.144 × 10 ⁻⁴
Yards	Meters	0.9144

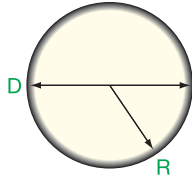
Area and Volume Formulas

Circle

$$D = 2R$$

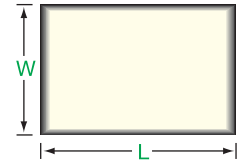
$$C = 2\pi R = \pi D$$

$$A = \pi R^2 = \frac{\pi D^2}{4}$$



Rectangle

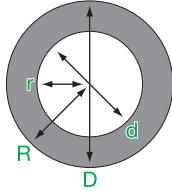
$$A = L \times W$$



Circular Ring

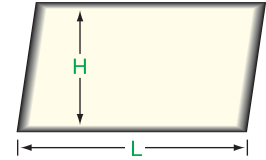
$$A = \pi (R^2 - r^2)$$

$$= 0.7854 (D^2 - d^2)$$



Parallelogram

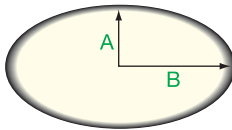
$$A = L \times H$$



Ellipse

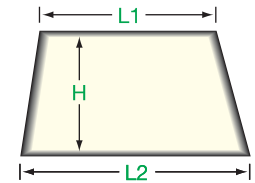
$$A = \pi \times A \times B$$

$$C = \pi \sqrt{2(A^2 + B^2)}$$



Trapezoid

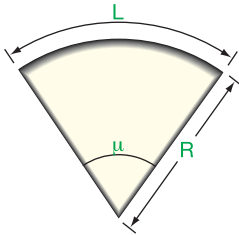
$$A = \frac{(L1 + L2) H}{2}$$



Sector

$$A = \frac{\pi R^2 \alpha}{360} = \frac{RL}{2}$$

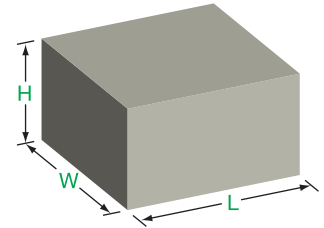
$$L = \frac{\pi R \alpha}{180} = \frac{2A}{R}$$



Rectangular Solid

$$A = 2(WL + LH + HW)$$

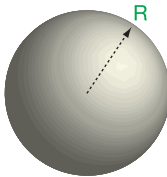
$$V = W \times L \times H$$



Sphere

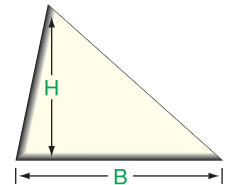
$$A = 4\pi R^2$$

$$V = \frac{4\pi R^3}{3}$$



Triangle

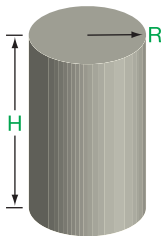
$$A = \frac{B \times H}{2}$$



Cylinder

$$A = 2\pi R (R + H)$$

$$V = \pi R^2 H$$

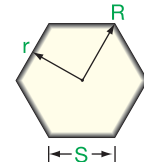


Hexagon

$$S = R = 1.155r$$

$$A = 2.598 S^2$$

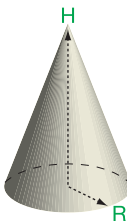
$$= 3.464 r^2$$



Cone

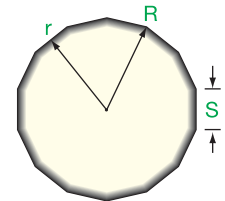
$$A = \pi R \sqrt{R^2 + H^2}$$

$$V = \frac{\pi R^2 H}{3}$$



Regular Polygon

$$A = \frac{NSr}{2} = \frac{NS}{2} \sqrt{\frac{R^2}{4} - \frac{S^2}{4}}$$



A = Area
V = Volume
 π = 3.1416

C = Circumference
R = Radius

D = Diameter
S = Length of side

N = Number of sides
 α = Angle

Fractional, Decimal and Millimeter Equivalents

	Decimals	Millimeters		Decimals	Millimeters	mm	inches	mm	inches		
	$\frac{1}{64}$	.015625	0.397	$\frac{33}{64}$	.515625	13.097		0.1	.0039	46	1.8110
	$\frac{1}{32}$	.03125	0.794	$\frac{17}{32}$	.53125	13.494		0.2	.0079	47	1.8504
	$\frac{3}{64}$	.046875	1.191	$\frac{35}{64}$	.546875	13.891		0.3	.0118	48	1.8898
$\frac{1}{16}$	$\frac{5}{64}$	.078125	1.984	$\frac{9}{16}$	.5625	14.288		0.4	.0157	49	1.9291
	$\frac{3}{32}$	.09375	2.381	$\frac{19}{32}$	.59375	15.081		0.5	.0197	50	1.9685
$\frac{1}{8}$	$\frac{7}{64}$	.109375	2.778	$\frac{39}{64}$	.609375	15.478		0.6	.0236	51	2.0079
	$\frac{9}{64}$	.140625	3.572	$\frac{41}{64}$	.640625	16.272		0.7	.0276	52	2.0472
	$\frac{5}{32}$	.15625	3.969	$\frac{21}{32}$	.65625	16.669		0.8	.0315	53	2.0866
$\frac{3}{16}$	$\frac{11}{64}$	.171875	4.366	$\frac{43}{64}$	.671875	17.066		0.9	.0354	54	2.1260
	$\frac{13}{64}$	.203125	5.159	$\frac{11}{16}$	.6875	17.463		1	.0394	55	2.1654
	$\frac{7}{32}$	.21875	5.556	$\frac{23}{32}$	.71875	18.256		2	.0787	56	2.2047
$\frac{1}{4}$	$\frac{15}{64}$	.234375	5.953	$\frac{47}{64}$	.734375	18.653		3	.1181	57	2.2441
	$\frac{17}{64}$	.265625	6.747	$\frac{49}{64}$	.765625	19.447		4	.1575	58	2.2835
	$\frac{9}{32}$	.28125	7.144	$\frac{25}{32}$	.78125	19.844		5	.1969	59	2.3228
$\frac{5}{16}$	$\frac{19}{64}$	.296875	7.541	$\frac{51}{64}$	.796875	20.241		6	.2362	60	2.3622
	$\frac{21}{64}$	.328125	8.334	$\frac{13}{16}$	.8125	20.638		7	.2756	61	2.4016
	$\frac{11}{32}$	.34375	8.731	$\frac{27}{32}$	.84375	21.431		8	.3150	62	2.4409
$\frac{3}{8}$	$\frac{23}{64}$	.359375	9.128	$\frac{55}{64}$	.859375	21.828		9	.3543	63	2.4803
	$\frac{25}{64}$	.390625	9.922	$\frac{7}{8}$	.8750	22.225		10	.3937	64	2.5197
	$\frac{13}{32}$	.40625	10.319	$\frac{29}{32}$	.90625	23.019		11	.4331	65	2.5591
$\frac{7}{16}$	$\frac{27}{64}$	.421875	10.716	$\frac{59}{64}$	.921875	23.416		12	.4724	66	2.5984
	$\frac{29}{64}$	.453125	11.509	$\frac{15}{16}$	.9375	23.813		13	.5118	67	2.6378
	$\frac{15}{32}$	.46875	11.906	$\frac{31}{32}$	.96875	24.606		14	.5512	68	2.6772
$\frac{1}{2}$	$\frac{31}{64}$	.484375	12.303	$\frac{63}{64}$	.984375	25.003		15	.5906	69	2.7165
	$\frac{1}{2}$	.5000	12.700	$\frac{1}{1}$	1.000	25.400		16	.6299	70	2.7559
		1 mm = .03937"				.001" = .0254 mm		17	.6693	71	2.7953
								18	.7087	72	2.8346
								19	.7480	73	2.8740
								20	.7874	74	2.9134
								21	.8268	75	2.9528
								22	.8661	76	2.9921
								23	.9055	77	3.0315
								24	.9449	78	3.0709
								25	.9843	79	3.1102
								26	1.0236	80	3.1496
								27	1.0630	81	3.1890
								28	1.1024	82	3.2283
								29	1.1417	83	3.2677
								30	1.1811	84	3.3071
								31	1.2205	85	3.3465
								32	1.2598	86	3.3858
								33	1.2992	87	3.4252
								34	1.3386	88	3.4646
								35	1.3780	89	3.5039
								36	1.4173	90	3.5433
								37	1.4567	91	3.5827
								38	1.4961	92	3.6220
								39	1.5354	93	3.6614
								40	1.5748	94	3.7008
								41	1.6142	95	3.7402
								42	1.6535	96	3.7795
								43	1.6929	97	3.8189
								44	1.7323	98	3.8583
								45	1.7717	99	3.8976
								100	1.8110	100	3.9370

When You Know	Multiply by	To Find
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	30.48	Centimeters (cm)
Yards (yds)	0.9	Meters (m)
Miles (mi)	1.6	Kilometers (km)