ELECTRICAL EQUATIONS

Single phase relationships:

$$V = \sqrt{WR} = W/I = IR$$

$$RW/I^2 = V^2/W = V/I$$

$$I = V/R = W/V = \sqrt{W/R}$$

$$W = V^2/R = I^2R = VI$$

KEY:
V = Volts
W = Watts
R = Resistance (ohms)
C = Current (amps)

For current in electrically balanced three phase A.C. circuits:

$$I = \frac{W}{V(\sqrt{3})}$$

NOTE: For circuits wired in 3 phase delta, wattage may be reduced to 1/3 by rewiring to a 3 phase wye connection.

FIG. 1 - THREE PHASE DELTA CONNECTION

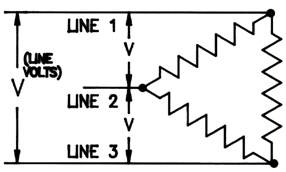


FIG. 2 - THREE PHASE WYE OR STAR CONNECTION

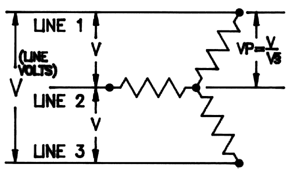


FIG. 3 - SPECIAL USE OF TWO POLE THERMOSTAT

Single phase circuit split with half of the current load across each thermostat contact.

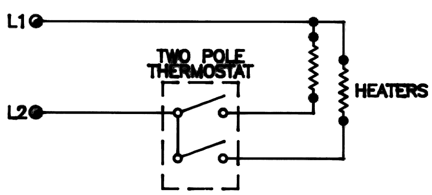


FIG. 4 - USE OF CONTACTOR (SINGLE PHASE)

Single phase circuit for conditions where the line current exceeds the thermostat rating and a contactor is added.

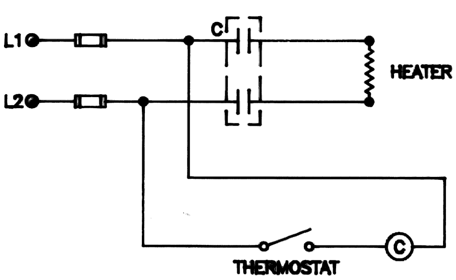


FIG. 5 - USE OF CONTACTOR (THREE PHASE)

Three phase circuit for conditions where the line current exceeds the thermostat rating and a contactor is added.

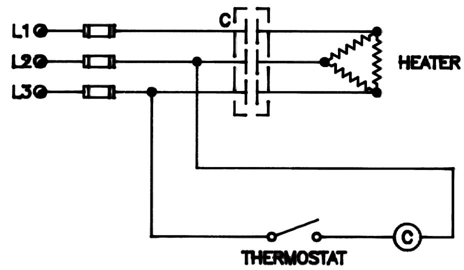


FIG. 6 - SERIES TO PARALLEL DELTA TRANSFORMATION

Special circuit with two thermostats and two contactors. When both contactors are closed, elements are wired in 3 phase parallel delta and circuit operates at full power. When only one of the contactors is closed, elements are wired in 3 phase series delta and the circuit operates at 1/4 power.

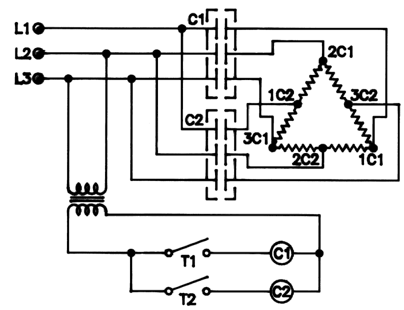
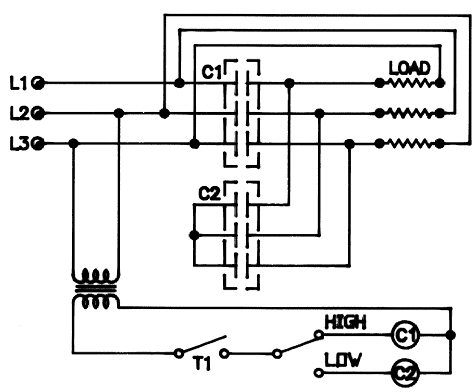


FIG. 7 - WYE TO DELTA TRANSFORMATION

Special circuit with two contactors, thermostat and two position switch.

When contactor 1 (C1) is closed, elements are wired in 3 phase delta and circuit operates at full power. When contactor 2 (C2) is closed, contactor 1 (C1) is opened, elements are wired in 3 phase wye and the circuit operates at 1/3 power. **CAUTION:** Contactors C1 and C2 must be mechanically interlocked in this configuration.



A. POWER REQUIREMENT FOR INITIAL HEAT-UP

1. Heat absorbed by all materials:

$$\frac{\underset{\text{(lb)}}{\text{Weight of material}} \times \underset{\text{(Btu/lb-°F)}}{\text{Specific heat}} \times \underset{\text{(°F)}}{\text{Temperature difference (final - initial)}}}{\text{3412(Btu/kwh)}} = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: The above step must be repeated for each material heated. See Tables 1, 2, 3, and 4 on pages 46 and 47 for specific heats and weights.

2. Heat required for fusion or vaporization:

$$\frac{\underset{\text{(lb)}}{\text{Weight of material}} \times \underset{\text{(Btu/lb)}}{\text{Heat of fusion or vaporization}}}{\text{3412 (Btu/kwh)}} = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: When the specific heat of a material changes at some temperature during the heat-up, due to melting (fusion) or evaporation (vaporization), perform Step 1 for the heat absorbed from the initial temperature up to the temperature at the point of change, add Step 2, then repeat Step 1 for heat absorbed from the point of change to the final operation temperature. See Tables 1, 2, 3, and 4 on pages 46 and 47 for heats of fusion and vaporization and temperatures at which these changes in state occur.

3. Heat required to replace average heat losses:

$$\frac{\underset{\text{(sq. ft.)}}{\text{Exposed surface area}} \times \underset{\text{(W/sq. ft.)}}{\text{Heat loss at final operating temperature}} \times \underset{\text{(hrs)}}{\text{Time allowed for heat-up}}}{\text{1000 (W/kW)}} \times \frac{1}{2}\left(\begin{array}{l}\text{to obtain an}\\ \text{average loss}\end{array}\right) = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: See Figures 1 - 4 on pages 48 and 49 for normal heat losses

4. Heat to provide for contingencies, Safety Factor: 20% [Step 1 (kwh) + Step 2 (kwh) + Step 3 (kwh)] = ________kwh

Total Heat Requirement for Initial Heat-up: = ________kwh

Total Power Requirement for Initial Heat-up:

$$\frac{\text{Step 1 (kwh) + Step 2 (kwh) + Step 3 (kwh) + Step 4 (kwh)}}{\text{Time allowed for heat-up (hrs)}} = \text{\_\_\_\_\_\_\_\_kw}$$

B. POWER REQUIREMENT FOR OPERATING HEAT

1. Heat absorbed by all materials added to the process:

$$\frac{\underset{\text{(lb)}}{\text{Weight of material added}} \times \underset{\text{(Btu/lb-°F)}}{\text{Specific heat}} \times \underset{\text{(°F)}}{\text{Temperature difference (final - initial)}}}{\text{3412(Btu/kwh)}} = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: The above step must be repeated for each material heated. See Tables 1, 2, 3, and 4 on pages 46 and 47 for specific heats and weights.

2. Heat required for fusion or vaporization during process:

$$\frac{\underset{\text{(lb)}}{\text{Weight of material}} \times \underset{\text{(Btu/lb)}}{\text{Heat of fusion or vaporization}}}{\text{3412 (Btu/kwh)}} = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: When the specific heat of a material changes at some temperature during the heat-up, due to melting (fusion) or evaporation (vaporization), perform Step 1 for the heat absorbed from the initial temperature up to the temperature at the point of change, add Step 2, then repeat Step 1 for heat absorbed from the point of change to the final operation temperature. See Tables 1, 2, 3, and 4 on pages 46 and 47 for heats of fusion and vaporization and temperatures at which these changes in state occur.

3. Heat required to replace heat losses:

$$\frac{\underset{\text{(sq. ft.)}}{\text{Exposed surface area}} \times \underset{\text{(W/sq. ft.)}}{\text{Heat loss at final operating temperature}} \times \underset{\text{(hrs)}}{\text{Working cycle time}}}{\text{1000 (W/kW)}} = \text{\_\_\_\_\_\_\_\_kwh}$$

Note: See Figures 1 - 4 on pages 48 and 49 for normal heat losses

4. Heat to provide for contingencies, Safety Factor: 20% [Step 1 (kwh) + Step 2 (kwh) + Step 3 (kwh)] = ________kwh

Total Heat Requirement per Working Cycle: = ________kwh

Total Power Requirement for Operating Heat:

$$\frac{\text{Step 1 (kwh) + Step 2 (kwh) + Step 3 (kwh) + Step 4 (kwh)}}{\text{Working cycle time (hrs)}} = \text{\_\_\_\_\_\_\_\_kw}$$

HEATING LIQUIDS (WATER)

An open steel tank, 2 ft. wide, 3 ft. long, 2 ft. deep and weighing 270 lbs., is filled with water to within 6 inches of the top. Bottom and sides have 3 inches of insulation. Water is to be heated from 50°F to 150°F within 2 hours and, from then on, approximately 4 gallons per hour will be drawn off and replaced.

From Table 1 on page 46, Specific Heat of steel:
0.12 Btu/lb.-°F
From Table 3 on page 47, Specific Heat of water:
1.0 Btu/lb.-°F
From Table 3 on page 47, Weight of water:
62.5 lb./cu. ft. (8.3 lb./gal.)
Water in tank:
(2 x 3 x 1.5)cu. ft. x 62.5 lb./cu. ft. = 563 lb.
From Fig. 3 on page 49, Water surface loss at 150°F:
270 W/sq. ft.
From Fig. 4 on page 49, Insulated wall loss at 100°F rise:
7 W/sq. ft.

A. INITIAL HEAT-UP REQUIREMENT

1a. To heat water:

$$\frac{563 \text{ lb.} \times 1.0 \text{ Btu/lb.-°F} \times (150 - 50)\text{°F}}{3412 \text{ Btu/kwh}} = 16.5 \text{ kwh}$$

1b. To heat tank:

$$\frac{270 \text{ lb.} \times 0.12 \text{ Btu/lb.-°F} \times (150 - 50)\text{°F}}{3412 \text{ Btu/kwh}} = 0.95 \text{ kwh}$$

2. Heat of fusion or vaporization: None

3a. Average water surface loss:

$$\frac{6 \text{ sq. ft.} \times 270 \text{ W/sq. ft.} \times 2 \text{ hrs.}}{1000 \text{ W/kW} \times 2} = 1.62 \text{ kwh}$$

3b. Average tank surface loss:

$$\frac{26 \text{ sq. ft.} \times 7 \text{ W/sq. ft.} \times 2 \text{ hrs.}}{1000 \text{ W/kW} \times 2} = 0.18 \text{ kwh}$$

4. Safety factor:
20% (16.5 + 0.95 + 1.62 + 0.18) = 3.85 kwh

Total Heat Requirement = 23.10 kwh

Power Required for Initial Heat-up:
23.10 kwh / 2 hrs. = 11.55 kw

B. OPERATING REQUIREMENT

1. To heat additional water

$$\frac{4 \text{ gal./hr.} \times 8.3 \text{ lb./gal.} \times 1.0 \text{ Btu/lb.-°F} \times (150 - 50)\text{°F}}{3412 \text{ Btu/kwh}} = 0.97 \text{ kw}$$

2. Heat of fusion or vaporization: None

3a. Water surface loss:

$$\frac{6 \text{ sq. ft.} \times 270 \text{ W/sq. ft.}}{1000 \text{ W/kW}} = 1.62 \text{ kw}$$

3b. Tank surface loss:

$$\frac{26 \text{ sq. ft.} \times 7 \text{ W/sq. ft.}}{1000 \text{ W/kW}} = 0.18 \text{ kw}$$

4. Safety factor:
20% (0.97 + 1.62 + 0.18) kw = 0.55 kw

Power Required for Operation = 3.32 kw

MELTING SOLIDS (PARAFFIN)

An open top uninsulated steel tank, $1\frac{1}{2}$ ft. wide, 2 ft. long, $1\frac{1}{2}$ ft. deep, and weighing 140 lb., contains 168 lb. of paraffin to be heated from 70°F to 150°F in 2 hours. Steel drills, each weighing 0.157 lb. are to be placed in a 60 lb. rack and dip coated in the melted paraffin. 1500 drills can be processed per hour with 20 lb. of paraffin.

From Table 1 pg. 46, Specific Heat of steel: 0.12 Btu/lb.-°F
From Table 2 pg. 46, Specific Heat of solid paraffin: 0.70 Btu/lb.-°F
From Table 2 pg. 46, Melting Point of paraffin: 133°F
From Table 2 pg. 46, Heat of Fusion of paraffin: 63 Btu/lb.
From Table 3 pg. 47, Specific Heat of melted paraffin: 0.71 Btu/lb.-°F
From Fig. 3 pg. 49, Paraffin surface loss at 150°F: 70 W/ft.^{2}
From Figs. 1 & 2 pg. 48, Steel surf. loss at 150°F: 55 W/ft.^{2}

A. INITIAL HEAT-UP REQUIREMENT

1a. To heat tank:

$$\frac{140 \text{ lb.} \times 0.12 \text{ Btu/lb.-°F} \times (150 - 70)\text{°F}}{3412 \text{ Btu/kwh}} = 0.39 \text{ kwh}$$

1b. To heat solid paraffin:

$$\frac{168 \text{ lb.} \times 0.70 \text{ Btu/lb.-°F} \times (133 - 70)\text{°F}}{3412 \text{ Btu/kwh}} = 2.17 \text{ kwh}$$

Fusion occurs at this point

1c. To heat melted paraffin:

$$\frac{168 \text{ lb.} \times 0.71 \text{ Btu/lb.-°F} \times (150 - 133)\text{°F}}{3412 \text{ Btu/kwh}} = 0.59 \text{ kwh}$$

2. Heat of fusion, to melt paraffin

$$\frac{168 \text{ lb.} \times 63 \text{ Btu/lb.}}{3412 \text{ Btu/kwh}} = 3.10 \text{ kwh}$$

3a. Average paraffin surface loss:

$$\frac{3 \text{ sq. ft.} \times 70 \text{ W/sq. ft.} \times 2 \text{ hrs.}}{1000 \text{ W/kW} \times 2} = 0.21 \text{ kwh}$$

3b. Average tank surface loss:

$$\frac{13.5 \text{ sq. ft.} \times 55 \text{ W/sq. ft.} \times 2 \text{ hrs.}}{1000 \text{ W/kW} \times 2} = 0.74 \text{ kwh}$$

4. Safety factor:
20% (0.39 + 2.17 + 0.59 + 3.10 + 0.21 + 0.74) = 1.44 kwh

Total Heat Requirement = 8.64 kwh

Power Required for Initial Heat-up:
8.64 kwh / 2 hrs. = 4.32 kw

B. OPERATING REQUIREMENT

1a. To heat drills and rack:

$$\frac{(1500 \times 0.157 + 60)\text{lb./hr.} \times 0.12 \text{ Btu/lb.-°F} \times (150 - 70)\text{°F}}{3412 \text{ Btu/kwh}} = 0.83 \text{ kw}$$

1b. To heat additional solid paraffin:

$$\frac{20 \text{ lb./hr.} \times 0.70 \text{ Btu/lb.-°F} \times (133 - 70)\text{°F}}{3412 \text{ Btu/kwh}} = 0.26 \text{ kw}$$

Fusion occurs at this point

1c. To heat additional melted paraffin:

$$\frac{20 \text{ lb./hr.} \times 0.71 \text{ Btu/lb.-°F} \times (150 - 133)\text{°F}}{3412 \text{ Btu/kwh}} = 0.07 \text{ kw}$$

2. Heat of fusion, to melt additional paraffin:

$$\frac{20 \text{ lb./hr.} \times 63 \text{ Btu/lb.}}{3412 \text{ Btu/kwh}} = 0.37 \text{ kw}$$

3a. Paraffin surface loss:

$$\frac{3 \text{ sq. ft.} \times 70 \text{ W/sq. ft.}}{1000 \text{ W/kW}} = 0.21 \text{ kw}$$

3b. Tank surface loss:

$$\frac{13.5 \text{ sq. ft.} \times 55 \text{ W/sq. ft.}}{1000 \text{ W/kW}} = 0.74 \text{ kw}$$

4. Safety factor:
20% (0.83 + 0.26 + 0.07 + 0.37 + 0.21 + 0.74) kw = 0.50 kw

Power Required for Operation = 2.98 kw

TABLE 1 - PROPERTIES OF METALS

Material	Average specific heat, Btu/(lb.)(°F)	Latent heat of fusion, Btu/lb.	Density lbs./in.^{3}	Melting point, °F (lowest)	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)	Thermal expansion in./in./°F x10^{-6}
Aluminum	.24	169	.098	1190	1540	13.1
Antimony	.049	69	.239	1166	131	
Babbit - lead base	.039		.370	470	165.6	
Babbit - tin base	.071		.267	465	278.4	
Barium	.068		.130	1562		
Beryllium	.052		.066	2345	1121.0	
Bismuth	.031	22.4	.353	520	59	
Boron	.309		.083	4172		
Brass (80-20)	.091		.310	1700	82	
Brass (70-30)	.10		.304	1700	672	
Brass (yellow)	.096		.306	1710	830	11.2
Bronze (75/25)	.082	75	.313	1832	180	
Cadmium	.055	23.8	.313	610	660	
Calcium	.149	140	.056	1564	912	
Carbon	.165		.080	6422	173	
Chromium	.11		.260	2822	484	
Cobalt	.099	115.2	.321	2696	499	
Constantan	.098		.321			
Copper	.095	91.1	.322	1981	2680	9.8
German silver	.109		.311	1761	168	
Gold	.032	29.0	.698	1945	2030	7.9
Incoloy 800	.13		.290	2500	80	7.9
Incoloy 600	.126		.304	2500	103	5.8
Inconel 600	.11		.304	2470	109	5.8
Iron, cast	.12		.260	2150	346	6.0
Iron, wrought	.12		.278	2800	432	
Lead, solid	.032	11.3	.410	620	240	16.4
Lead, liquid	.037		.387		108	
Linotype	.04		.363	480		
Lithium	.79	59	.212	367	516	
Magnesium	.27	160	.063	1202	1106	14
Manganese	.115	116	.268	2268	80.6	
Mercury	.033	5.0	.488	-38	60.8	
Molybdenum	.071	126	.369	4750	980	2.94
Monel 400	.11		.319	2400	151	6.4
Nickel 200	.12	133	.321	2615	520	5.8
Nichrome	.11		.302	2550	104	7.3
Platinum	.035	49	.775	3225	480	4.9
Potassium	.058	26.2	.434	146	720	
Rhodium	.059		.449	3570	636	
Silicon	.162		.008	2570	600	
Silver	.057	38	.379	1760	2900	10.8
Sodium	.295	49.5	.035	207	972	
Solder	.051	17	.323	361	310	13.1
Steel, mild	.122		.284	2760	460	6.7
Stn. Stl. 304	.12		.286	2550	105	9.6
Stn. Stl. 430	.11		.275	2650	155	6.0
Tantalum	.035		.60	5425	375	3.57
Tin, liquid	.052		.253		218	
Tin, solid	.065	26.1	.263	450	455	13
Titanium 99.0 %	.13		.164	3035	112	4.7
Tungsten	.040	79	.697	6170	1130	2.45
Type Metal	.040	14	.388	500	180	
Uranium	.028		.677	3075	193.2	
Zinc	.096	43.3	.258	787	740	22.1
Zirconium	.067	108	.234	3350	145	3.22

TABLE 2 - PROPERTIES OF NON-METALLIC SOLIDS

Material	Average specific heat, Btu/(lb.)(°F)	Latent heat of fusion, Btu/lb.	Average Density lbs./in.^{3}	Melting point, °F (lowest)	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)	Thermal expansion in./in./°F x10^{-6}
ABS Plastic	.35		.042		1.32	
					2.28	
Acrylic	.34		.041		1.0	
Alumina			.087			
Aluminum Silicate	.2		.086	3690	9.1	
Asbestos	.25		.021		.44	
Ashes	.2		.025		.49	
Asphalt	.40		.046		5.3	
Bakelight, Pure Resin	.3 - .4		.045			
Barium Chloride	.10		.139	1697		
Beeswax		75	.035	144	1.67	
Boron Nitride	.33		.082	5430	125	1 - 4

TABLE 2 - PROPERTIES OF NON-METALLIC SOLIDS (cont)

Material	Average specific heat, Btu/(lb.)(°F)	Latent heat of fusion, Btu/lb.	Average Density lbs./in.^{3}	Melting point, °F (lowest)	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)	Thermal expansion in./in./°F x10^{-6}
Brickwork	.22		.076		3 - 7	3 - 6
Calcium Chloride	.17	72	.091	1422		
Carbon	.28		.080	6700	165	0.3 - 2.4
Canauba Wax	.8		.036			
Cellulose Acetate	.3 - .5		.047		1.2 - 2.3	61 - 83
Cement	.19		.054		2.04	
Ceramic Fiber	.27		.007			
Chalk	.215		.083		5.76	
Clay	.224		.052	3160	9	
Coal (Coarse Anthercite)	.32		.046		11	
Coal Tars	.35 - .45		.045			
Coke	.265		.043			
Concrete (Cinder)	.16		.058		5.3	
Concrete (Stone)	.156		.083		9.5	
Cork	.5		.008		.36	
Cotton (Flax, Hemp)	.31		.053		.41	
Delrin	.35		.051		1.6	45
Diamond	.147		.127		13872	
Earth, Dry & Packed	.44		.054		.9	
Epoxy	.25 - .3		.045		1.2 - 2.4	
Ethyl Cellulose	.32 - .46		.041			
Fiberglass			.0004		.28	
Firebrick, Fireclay	.243		.083	2900	6.6	
Firebrick, Silica	.258		.089	3000	7.2	
Flourspar	.21					
Fluoroplastics	.28		.081		1.68	
Glass, crown	.161		.101		7.5	5
Granite	.192		.097		13 - 28	
Graphite	.20		.075		1.25	
Ice	.53	144	.0324	32	11	28.3
Isoprene	.48		.034		1.0	
Limestone	.217		.088		3.6-9	
Magnesia	.234		.130	5070	.48	
Magnesite Brick	.222		.092		10.8 - 30	
Magnesium Silicate			.101		15.6	
Marble	.21		.097		14.4	
Marinite I @ 400°F	.29		.027		.89	
Mica	.21		.102		3.0	18
MgO (Before Compacted)	.21		.085		3.6	
MgO (Compacted)	.209		.112		20	7.7
Nylon	.4		.040		1.5	61 - 63
Paper	.45		.034		.82	
Paraffin	.70	63	.032	133	1.6	
Phenolic Plastic	.35		.060		1.02	
Phenolic Resin, Cast	.3 - .4		.049		1.1	
Phenolic, Sheet or Tube Laminated	.3 - .5		.045		2.4	
Pitch, Hard			.048	300		
Polycarbonate	.3		.044		1.38	
Polyester	.2 - .35		.046		3.96 - 5	
Polyethylene	.55		.035		2.3	94
Polypropylene	.46		.032		1.72	
Polystyrene	.32		.038		.7 - 1.0	33 - 44
Polyvinyl Chloride Acetate	.2 - .3		.049		.84 - 1.2	
Porcelain	.26		.087		6 - 10	
Potassium Chloride	.17		.072	1454		
Potassium Nitrate	.26		.076	633		
Quartz	.26		.080		9.6	
Rock Salt	.219			1495		
Rubber	.44		.044		1.1	340

TABLE 2 - PROPERTIES OF NON-METALLIC SOLIDS (cont)

Material	Average specific heat, Btu/ (lb.)(°F)	Latent heat of fusion, Btu/lb.	Average Density lbs./in.^{3}	Melting point, °F (lowest)	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)	Thermal expansion in./in./°F x10^{-6}
Sand, Dry	.191		.054		2.26	
Sandstone	.22		.081			
Silica (fused)	.316				10.0	
Silicon Carbide	.20 - .23		.069		105	
Silicone Rubber	.45		.045		1.5	
Soapstone	.22		.097		11.3	
Sodium Carbonate	.30		.078	520		
Sodium Chloride	.22		.078	1474		
Sodium Cyanide	.30		.054	1047		
Sodium Nitrate	.29		.082	584		
Sodium Nitrite	.30		.078	520		
Soil, Dry						
Steatite	.20		.094		17.5 - 23	4.5 - 5.5
Stone	.20					
Sugar	.30		.061	320		
Sulfur	.175	17	.075	246	1.9	36
Tallow			.035	90		
Teflon	.25		.078		1.7	55
Urea, Form-aldehyde	.4		.056			
Vinyl	.3 - .5		.046		.8 - 2.0	28 - 100
Wood, Oak	.57		.029		1.1	

TABLE 3 - PROPERTIES OF LIQUIDS

Material	Average specific heat, Btu/ (lb.)(°F)	Heat of vapor-ization, Btu/lb.	Density lbs./ U.S. Gal.	Boiling point, °F	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)
Acetic acid, 20%	.91	810	8.6	214	3.7
Acetic acid, 100%	.48	175	8.7	245	1.14
Acetone, 100%	.514	225	6.5	133	1.15
Alcohol (allyl)	.665	293	7.4	207	
Alcohol (amyl)	.65	216	7.4	280	
Alcohol (butyl)	.687	254	6.1	244	
Alcohol (ethyl)	.60	367	6.6	173	1.3
Alcohol (propyl)	.57	295.2	6.7	208	
Ammonia, 100%	1.1	589	6.4	-27	3.48
Asphalt	.42		8.3		5.04
Benzene	.42	170	7.5	175	1.04
Brine (25% CaCl)	.689		10.2		3.36
Brine (25% NaCl)	.786	730	9.9	220	2.88
Brine (25% NiCi)	.81	728	9.9	221	4.0
Carbon Tetrachloride	.21		13.2	170	
Caustic soda (18%)	.84	795	10.0	221	3.9
Corn Syrup, Dextrose	.65		11.7	231	
Cottonseed Oil	.47		7.9		1.2
Dowtherm A	.44	42.2	8.8	496	.96
Ether	.503	160	6.1	95	.95
Ethyl Acetate	.475	183.5	6.9	180	
Ethyl Bromide	.215	108	12.1	101	
Ethyl Chloride	.367	166.5	7.6	54	
Ethyl Iodide	.161	81.3	15.1	160	
Ethylene Bromide	.172	83	16.0	270	
Ethylene Chloride	.299	139	9.6	240	
Ethylene Glycol	.555		9.4	387	
Formic Acid	.525	216	9.3	213	
Freon 11	.208		12.3	74.9	.600
Freon 12	.232	62	10.9	-21.6	.492
Freon 22	.300		10.0	-41.36	.624
Fuel Oil #1	.47	86	6.8	440	1.008
Fuel Oil #2	.44		7.2		.96
Fuel Oil #3, #4	.425	67	7.4	580	.918
Fuel Oil #5, #6	.41		7.9		.852
Gasoline	.53	116	5.5 - 5.7	280	.936
Glycerine	.61		10.5	556	2.0
Heptane	.49	137.1	5.1	210	
Hexane	.6	142.5	5.1	155	
Hydrochloric 10%	.93		8.9	221	3.9
Ice	.5		7.5		3.96
Lard	.64		7.7		
Linseed Oil	.44		7.7	552	
Mercury	.033	117	113.0	675	59.64
Methyl Acetate	.47	176.5	7.3	133	
Methyl Chloroform	.26	95	11.1	165	

TABLE 3 - PROPERTIES OF LIQUIDS (continued)

Material	Average specific heat, Btu/ (lb.)(°F)	Heat of vapor-ization, Btu/lb.	Density lbs./ U.S. Gal.	Boiling point, °F	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)
Methylene Chloride	.288	142	11.0	104	
Molasses	.60		11.7	220	
NaK (78% K)	.21		6.2	1446	167.0
Napthalene	.396	103	7.2	424	
Nitric acid, 7%	.92	918	8.6	220	3.8
Nitric acid, 95%	.5	207	12.5	187	
Nitrobenzene	.35	142.2		412	
Oil (SAE10-30)	.43		7.4		
Oil (SAE40-50)	.43		7.4		
Olive Oil	.47		7.8	570	
Paraffin (melted)	.71		6.3		1.0
Perchlorethylene	.21	90	13.5	250	
Phenol	.56		8.9	346	
Phosphoric 10%	.93		8.7		
Phosphoric 20%	.85		9.2		
Potassium (K)	.18	893	6.0	1400	320.0
Propane (Comp)	.576		0.02	-48.1	1.81
Sea Water	.94		8.6		
Sodium (Na)	.30	1810	6.8	1621	580.0
Sodium Hydroxide					
30% Solution	.84		11.1		
50% Solution	.78		12.8		
Soybean Oil	.24-.33		7.7		
Starch			12.8		
Sucrose, 40% Sugar	.66		9.8	214	
Sucrose, 60% Sugar	.74		10.7	218	
Sulfur, Melted 500°F	.24	120	15.0	832	
Sulfuric acid, 10%	.92		9.9	216	4.0
Sulfuric acid, 20%	.84		9.5	218	
Sulfuric acid, 60%	.52		12.5	282	2.88
Sulfuric acid, 98%	.35	219	15.3	625	1.8
Therminol FR-2	.30		12.1	648	.70
Toluene	.42		7.2		1.032
Trichloroethylene	.23	103	12.2	188	.84
Transformer Oils	.42		7.5		.9
Turpentine	.41	123	7.3	318	.90
Vegetable oil	.43		7.7		1.1
Water	1.0	970	8.3	212	4.2
Xylene	.411	149.2	7.2	288	

TABLE 4 - PROPERTIES OF GASES

Gas	Specific heat, Btu/lb./°F	Density lbs./ft.^{3}	Thermal Conductivity K (Btu)(in.)/(hr.)(sq.ft.)(°F)
Acetylene	.35	.073	.129
Air at 80°F	.240	.073	.18
at 400°F	.245	.046	.27
Alcohol, Ethyl (Vapor)	.4534		
Alcohol, Methyl (Vapor)	.4580		
Ammonia	.523	.044	.16
Argon	.125	.102	.12
Butane		.1623	.0876
Butylene		.148	
Carbon dioxide	.199	.113	.12
Carbon monoxide	.248	.072	.18
Chlorine	.115	.184	.06
Chloroform	.1441		.046
Chloromethane	.24	.1309	.0636
Ethyl Chloride		.1703	.066
Ethyl Ether	.4380		.0924
Ethylene	.40	.0728	.1212
Helium	1.25	.011	1.10
Hydrochloric Acid	.191	.0946	
Hydrogen	3.39	.0052	.13
Hydrogen Sulfide	.2451	.096	.091
Methane	.528	.041	.25
Nitric Oxide	.231	.0779	.1656
Nitrogen	.248	.072	.19
Nitrous Oxide	.221	.1143	.1056
Oxygen	.218	.082	.18
Sulphur dioxide	.152	.172	.07
Water Vapor (212°F)	.482	.0372	.16

TABLE 1 - PROPERTIES OF AIR

Temp. (°F)	Specific Heat (BTU/lb.°F)	Density (lb./ft.^{3})
0	.240	.086
50	.240	.078
100	.240	.071
150	.241	.065
200	.242	.060
250	.243	.056
300	.244	.052
350	.245	.049
400	.247	.046
500	.249	.041
600	.252	.037
700	.254	.034
800	.257	.032
900	.260	.029
1000	.262	.027
1100	.265	.025
1200	.267	.024

TABLE 2 - THERMAL CONDUCTIVITY OF INDUSTRIAL INSULATION

Type of Insulation	Maximum Service Temp. (°F)	Typical K Values BTU/hr./sq.ft./°F/in. — Mean Temp. (°F) Between Inner and Outer Insulation Surface: 100	200	300	500	700	900
Mineral Wool Blanket flexible felt	450	.26	.34	.45			
Mineral Wool Block and Board resin binder	600	.28	.35	.43			
85% Magnesia Block and Board	600	.35	.38	.42	.46		
Foam Glass Block and Board	800	.41	.48	.55			
Calcium Silicate low density	1200	.38	.41	.44	.52	.62	.72
Mineral Wool Blanket metal reinforced	1200	.29	.35	.42	.56		
Silica Lime Block and Board	1200	.33	.38	.43	.53	.64	.75
Mineral Wool Block and Board inorganic binder	1600	.34	.39	.44	.54	.64	
Calcium Silicate high density	1800				.63	.74	.95

TABLE 3 - VISCOSITIES

Material	SSU 4.4°C 40°F	SSU 26.7°C 80°F	SSU 49°C 120°F	CENTIPOISE 4.4°C 40°F	CENTIPOISE 26.7°C 80°F	CENTIPOISE 49°C 120°F
Asphalt RS-1 MS-1 SS-1	400	160			86	34
Asphalt RC-0 MC-0 SC-0	950	340				
Asphalt RC-3 MC-3 SC-3	40000	7000				
Asphalt RC-5 MC-5 SC-5	500000	45000				
Asphalt 100-120 penetration	3500 at 250°F					
Asphalt 40-50 penetration	8000 at 250°F					
Benzene				.8	.62	.46
Gasoline				.7	.55	.44
No.1 Fuel Oil (Kerosene)	40	36		3.3	2.1	1.4
No.2 Fuel Oil - PS100	43	36	33	4.6	2.6	1.6
No.3 Fuel Oil - PS200	84	52	41	15.0	7.0	4.0
No.4 Fuel Oil	480	125	62	92.0	24.0	9.6
No.5 Fuel Oil - PS300		1600	370		390.0	75.0
No.6 Fuel Oil. Bunker C		4500	650		1000.0	155.0
Transformer Oil. Light	170	72	49	34.2	12.1	6.3
Transformer Oil. Medium	460	145	70	89.0	28.2	11.9
34°API Mid-continent crude	88	51	37	15	6.5	3.0
28°API gas oil	135	59	48	25	9.0	6.0
Quench and tempering Oil						
SAE-5W	550	160	74			
SAE-10W	1500	265	120	170	50	22
SAE-20	2900	500	170			
SAE-30	5000	870	260	1200	200	60
SAE-40	8500	1400	380			
SAE-50	23000	3600	720		400	100

Figure 1 - Heat losses from uninsulated smooth solid surfaces (60 - 180°F). Assumed external ambient temperature of 70°F.

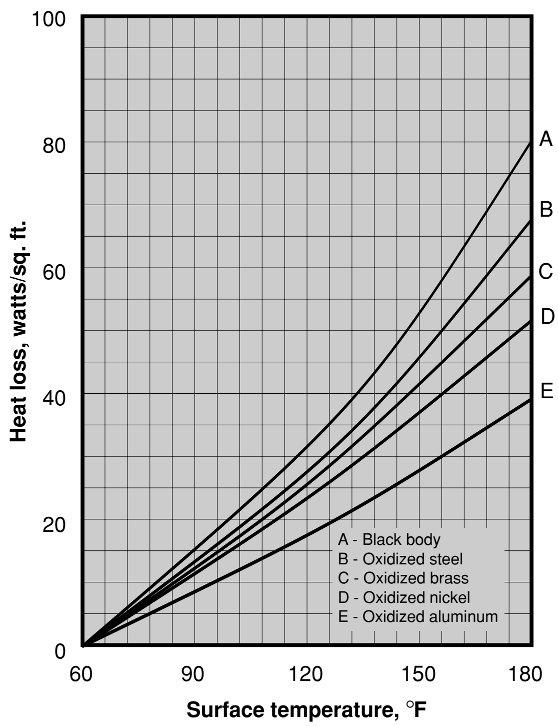


Figure 2 - Heat losses from uninsulated smooth solid surfaces (150 - 1000°F). Assumed external ambient temperature of 70°F.

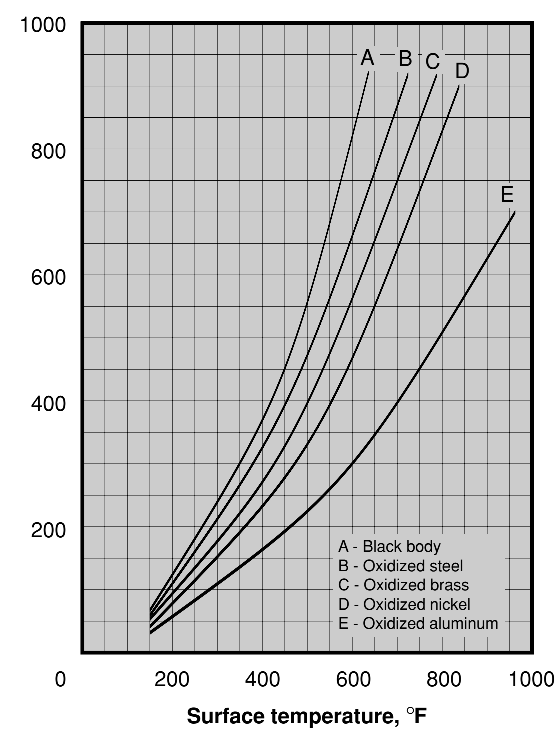


Figure 3 - Heat losses from liquid surfaces. Assumed external ambient temperature of 70°F.

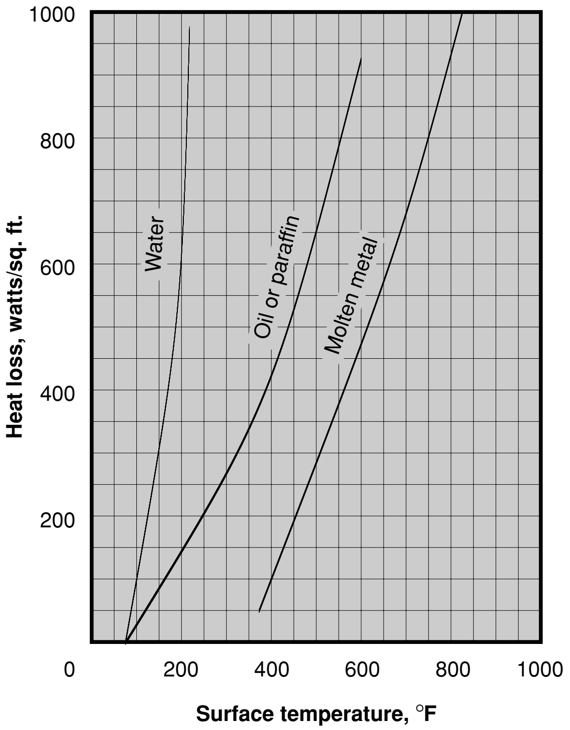
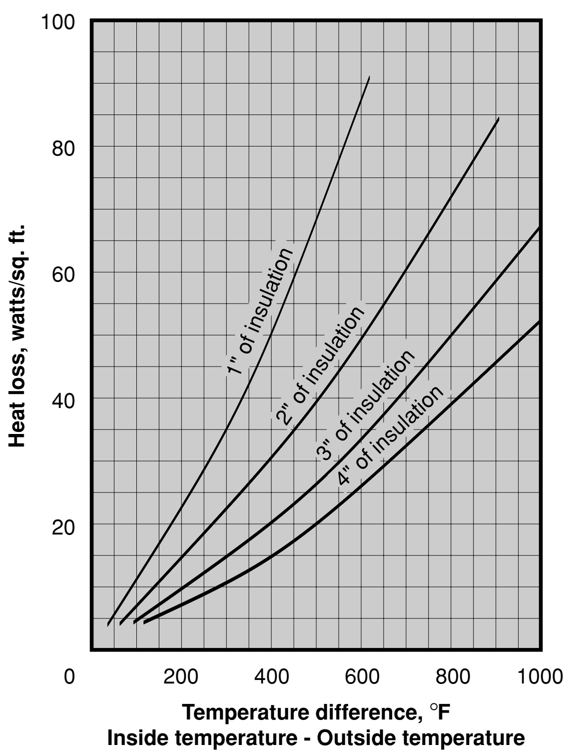


Figure 4 - Heat losses from insulated walls. Curves are for standard high-grade material, such as 85% magnesia, Rockwool, etc.



WIND VELOCITY AND HEAT LOSS

Wind velocity will increase surface heat losses. Table 1 can be used as a guide for estimating the factors to be applied to the still air heat losses from Figs. 1, 2 and 4.

TABLE 1 - WIND VELOCITY FACTORS

WIND VELOCITY	WELL SEALED INSULATED SURFACE			UNINSULATED SURFACE (TEMP. °F)		
(MPH)	1"	2"	3"	200	600	1000
5	-	-	-	1.7	1.5	1.3
10	-	-	-	2.1	1.7	1.4
15	1.1	-	-	2.4	2.0	1.6
20	1.2	1.1	-	2.7	2.3	1.7
25	1.3	1.2	1.1	3.0	2.6	1.8
30	1.4	1.3	1.2	3.3	3.0	1.9

HEAT LOSSES FROM INSULATED PIPES

To find the heat loss from the insulated pipes, in watts/ft. multiply the appropriate factor from Table 2 by the °F difference between the pipe holding temperature and the minimum ambient temperature.

If the pipe holding temperature is above 200°F, multiply the above answer by 1.2.

TABLE 2 - HEAT LOSS FACTORS FOR PIPE

PIPE SIZE	INSULATION THICKNESS AND FACTORS						
	1/2"	1"	1 1/2"	2"	2 1/2"	3"	4"
1/2	0.086	0.054	0.043	0.037			
1/4	0.102	0.062	0.048	0.041			
1	0.123	0.073	0.056	0.047			
1 1/4	0.142	0.083	0.063	0.052			
1 1/2	0.164	0.094	0.070	0.058			
2	0.192	0.109	0.081	0.066			
2 1/2	0.229	0.128	0.093	0.076			
3	0.259	0.142	0.107	0.083			
3 1/2	0.287	0.157	0.113	0.091			
4	0.316	0.172	0.123	0.098	0.083	0.073	0.060
4 1/2	0.347	0.189	0.134	0.107	0.090	0.079	0.065
5	0.417	0.219	0.155	0.121	0.103	0.089	0.073
6	0.472	0.250	0.174	0.136	0.114	0.099	0.080
7	0.526	0.275	0.192	0.151	0.126	0.109	0.088
8	0.571	0.305	0.212	0.166	0.137	0.119	0.095
9	0.634	0.338	0.234	0.183	0.151	0.130	0.104
10	0.634	0.338	0.234	0.183	0.151	0.130	0.104
12	0.776	0.397	0.275	0.212	0.175	0.149	0.119
14	0.834	0.431	0.298	0.230	0.190	0.162	0.128
16	0.961	0.498	0.334	0.258	0.212	0.181	0.142
18	1.088	0.555	0.379	0.289	0.236	0.200	0.156
20	1.190	0.598	0.416	0.319	0.260	0.219	0.171
24	1.430	0.731	0.490	0.374	0.305	0.259	0.200

PRACTICAL FLOW VELOCITIES IN PIPE

FLOW/SERVICE	P.S.I.G.	VELOCITY
Saturated Steam	0-25	4000-6000 ft./min.
	25 and up	6000-10000 ft./min.
Superheated Steam	200 and up	7000-20000 ft./min.
Water/Boiler Feed	-	8 - 15 ft./sec.
Water/Pump Suction	-	4 - 7 ft./sec.
Water/Drain	-	4 - 7 ft./sec.
Water/General Service	-	4 - 10 ft./sec.

ALLOWABLE PRESSURE RATINGS FOR PIPES AND FLANGES

The information included on this page is to be used as a guide only in the pre-selection of pipe and flange sizes for various temperatures and pressures.

When calculating thickness requirements in accordance with the ASME code for safe pressure vessel design, stress values may often be less than shown in Table 1.

TABLE 1 - APPROXIMATE ALLOWABLE STRESS FOR PIPE IN P.S.I.G.

	PIPE MATERIAL AND TYPE			
TEMP. °F	A53B WELDED STEEL	A106B SEAMLESS STEEL	304 S.S. WELDED	316 S.S. WELDED
100	12,800	15,000	16,000	16,000
300	12,800	15,000	12,000	13,300
500	12,800	15,000	10,400	11,300
650	12,800	15,000	-	-
700	12,200	14,400	9,400	10,300
900	5,500	6,500	8,700	9,800
1100	-	-	7,500	9,400
1300	-	-	3,200	3,500

DETERMINATION OF APPROXIMATE PIPE WALL THICKNESS (t_N) FOR VARIOUS PRESSURES AND TEMPERATURES

$$t_N = \frac{.5PD}{SE - .6P} \quad (1.143)$$

t_N = Nominal pipe wall thickness (page 208) not including corrosion allowance

P = Max. pressure (P.S.I.G.)

D = Inside pipe diameter (in.)

S = Allowable stress from Table 1

E = Joint efficiency (assume a value of 1.0 for seamless pipe or welded pipe where full radiography is done).

FLANGE PRESSURE - TEMPERATURE RATINGS

		MAX. ALLOWABLE PRESSURE (PSIG)					
METAL	TEMP. °F	150 LB.	300 LB.	400 LB.	600 LB.	900 LB.	1500 LB.
CARBON STEEL	100	285	740	990	1480	2220	3705
	200	260	675	900	1350	2025	3375
	300	230	655	875	1315	1970	3280
	400	200	635	845	1270	1900	3170
	500	170	600	800	1200	1795	2995
	600	140	550	730	1095	1640	2735
	650	125	535	715	1075	1610	2685
	700	110	535	710	1065	1600	2665
	750	95	505	670	1010	1510	2520
	800	80	410	550	825	1235	2060
	850	65	270	355	535	805	1340
	900	50	170	230	345	515	860
	950	35	105	140	205	310	515
	1000	20	50	70	105	155	260
304 S.S.	100	275	720	960	1440	2160	3600
	200	235	600	800	1200	1800	3000
	300	205	530	705	1055	1585	2640
	400	180	470	630	940	1410	2350
	500	170	435	585	875	1310	2185
	600	140	415	555	830	1245	2075
	700	110	405	540	805	1210	2015
	800	80	395	525	790	1180	1970
	900	50	385	510	770	1150	1920
	1000	20	325	430	645	965	1610
	1100	-	260	345	515	770	1285
	1200	-	155	205	310	465	770
	1300	-	85	110	165	245	410
	1400	-	50	65	90	145	240
	1500	-	25	30	50	70	120
316 S.S.	100	275	720	960	1440	2160	3600
	200	240	620	825	1240	1860	3095
	300	215	560	745	1120	1680	2795
	400	195	515	685	1030	1540	2570
	500	170	480	635	955	1435	2390
	600	140	450	600	905	1355	2255
	700	110	430	575	865	1295	2160
	800	80	415	555	830	1245	2075
	900	50	395	525	790	1180	1970
	1000	20	365	485	725	1090	1820
	1100	-	325	430	645	965	1610
	1200	-	205	275	410	620	1030
	1300	-	140	185	275	410	685
	1400	-	75	100	150	225	380
	1500	-	40	65	85	125	205
304L 316L S.S.	100	230	600	800	1200	1800	3000
	200	195	505	675	1015	1520	2530
	300	175	455	605	910	1360	2270
	400	160	415	550	825	1240	2065
	500	145	380	510	765	1145	1910
	600	140	360	480	720	1080	1800
	700	110	345	460	685	1030	1715
	800	80	330	440	660	985	1645

REFERENCE ASME/ANSI B16.5 - 1988

ATMOSPHERIC CONDITIONS AND TEMPERATURE CODES

The information listed on this page is to be used only as a general guide. Consult the latest edition of the Code to check the suitability of the heater to your needs.

For detailed information concerning the installation of electrical equipment in hazardous locations, refer to either the Canadian Electrical Code Part 1 Section 18, available from the Canadian Standards Association, or the National Electrical Code Chapter 5 Articles 500 through 503, available from the National Fire Protection Association.

Where electrical equipment is required by Section 18 or Chapter 5 to be approved for the class of location, it shall also be approved for the specific gas, vapour, or dust that will be present. Such approval may be indicated by one or more atmospheric group designations which have been established for the purpose of testing and approval.

Note that the maximum external temperature of the equipment shall not exceed the minimum ignition temperature of the atmosphere as listed in Table 2.

TABLE 1 - Equipment Maximum Temperature

Temperature Code	Maximum External Temperature
T1	450°C / 842°F
T2	300°C / 572°F
T2A	280°C / 536°F
T2B	260°C / 500°F
T2C	230°C / 446°F
T2D	215°C / 419°F
T3	200°C / 392°F
T3A	180°C / 356°F
T3B	165°C / 329°F
T3C	160°C / 320°F
T4	135°C / 275°F
T4A	120°C / 248°F
T5	100°C / 212°F
T6	85°C / 185°F

TABLE 2 - Atmospheric Conditions

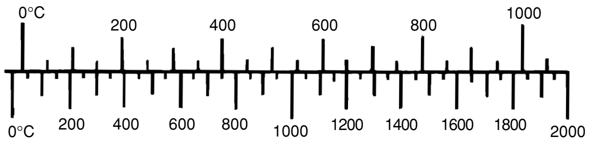
ATMOSPHERE	MIN. IGNITION TEMP. LIMIT
GROUP A CONTAINING	
acetylene	305°C / 581°F
GROUP B CONTAINING	
butadiene	420°C / 788°F
ethylene oxide	429°C / 804°F
hydrogen	500°C / 932°F
manufactured gases containing more than 30% hydrogen (by volume)	500°C / 932°F
propylene oxide	499°C / 930°F
GROUP C CONTAINING	
acetaldehyde	175°C / 347°F
cyclopropane	498°C / 928°F
diethyl ether	160°C / 320°F
ethylene	450°C / 842°F
unsymmetrical dimethyl hydrazine (UDMH 1, 1-dimethyl hydrazine)	249°C / 480°F
GROUP D CONTAINING	
acetone	465°C / 869°F
acrylonitrile	481°C / 898°F
alcohol (see ethyl alcohol)	
ammonia	651°C / 1204°F
benzene	498°C / 928°F
benzine (see petroleum naphtha)	
benzol (see benzene)	
butane	287°C / 549°F
1-butanol (butyl alcohol)	343°C / 649°F
2-butanol (secondary butyl alcohol)	405°C / 761°F
butyl acetate	425°C / 797°F
isobutyl acetate	421°C / 790°F
ethane	472°C / 882°F
ethanol (ethyl alcohol)	363°C / 685°F
ethyl acetate	426°C / 799°F
ethylene dichloride	413°C / 775°F
gasoline	280°C / 536°F
heptanes	204°C / 399°F
hexanes	223°C / 433°F
isoprene	395°C / 743°F
methane	537°C / 999°F
methanol (methyl alcohol)	385°C / 725°F
3-methyl-1-butanol (isoamyl alcohol)	350°C / 662°F
methyl ethyl ketone	404°C / 759°F
methyl isobutyl ketone	448°C / 838°F
2-methyl-1-propanol (isobutyl alcohol)	415°C / 779°F
2-methyl-2-propanol (tertiary butyl alcohol)	478°C / 892°F
naphtha (see petroleum naphtha)	
natural gas	482°C / 900°F
octanes	206°C / 403°F
pentanes	260°C / 500°F
1-pentanol (amyl alcohol)	300°C / 572°F
petroleum naphtha	288°C / 550°F
propane	432°C / 810°F
1-propanol (propyl alcohol)	412°C / 774°F
2-propanol (isopropyl alcohol)	399°C / 750°F
propylene	455°C / 851°F
styrene	490°C / 914°F
toluene	480°C / 896°F
vinyl acetate	402°C / 756°F
vinyl chloride	472°C / 882°F
xylenes	463°C / 865°F
GROUP E COMPRISING atmospheres containing metal dust, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics	
GROUP F COMPRISING atmospheres containing carbon black, coal, or coke dust	
GROUP G COMPRISING atmospheres containing flour, starch, or grain dust, and other dusts of similarly hazardous characteristics	

TEMPERATURE CONVERSION

°F = 9/5°C + 32   °R = °F + 460
°C = 5/9 (°F - 32)   °K = °C + 273

KEY: F = Fahrenheit C = Centigrade R = Rankine K = Kelvin

Degrees Centigrade



Degrees Fahrenheit

COMMON CONVERSION FACTORS

To Convert From	To	Multiply By
Atmospheres	mm Mercury (32°F)	760.
Atmospheres	Newtons / sq. meter	101,325.
Atmospheres	Ft. water (39.1°F)	33.90
Atmospheres	Ins. mercury (32°F)	29.921
Atmospheres	Pounds / sq. in.	14.696
Bars	Pounds / sq. in.	14.504
Boiler H.P.	Kilowatts	9.803
B.t.u.	Calories (gram)	252.
B.t.u. / hour	Watts	0.29307
B.t.u. / sec.	Watts	1,054.4
B.t.u. / sq. ft. / min.	Kilowatts / sq. ft.	0.1758
Circular mills	Square inches	7.854×10^{-7}
Cubic feet water	Pounds	62.37
Cubic feet / minute	Cubic cm / sec.	472.0
Cubic feet / minute	U.S. gallons / sec.	0.1247
Cubic feet / second	U.S. gallons / min.	448.8
Feet / min.	Miles / hour	0.011364
Gallons (U.S.)	Gallons (Imperial)	0.8327
H.P. (British)	Watts	745.7
Pounds	Grains	7,000.

SPECIAL CONVERSION FACTORS

To Convert From	To	Multiply By
Heat transfer		
p.c.u. / (hr.)(ft.^{2})(°C)	B.t.u. / (hr.)(ft.^{2})(°F)	1.
kg-cal. / (hr.)(m^2)(°C)	B.t.u. / (hr.)(ft.^{2})(°F)	0.2048
g-cal. / (sec.)(cm^2)(°C)	B.t.u. / (hr.)(ft.^{2})(°F)	7,380.
watts / (cm^2)(°C)	B.t.u. / (hr.)(ft.^{2})(°F)	1,760.
watts / (in^2)(°F)	B.t.u. / (hr.)(ft.^{2})(°F)	490.
B.t.u. / (hr.)(ft.^{2})(°F)	p.c.u. / (hr.)(ft.^{2})(°C)	1.
B.t.u. / (hr.)(ft.^{2})(°F)	kg-cal. / (hr.)(m^2)(°C)	4.88
B.t.u. / (hr.)(ft.^{2})(°F)	g-cal. / (sec.)(cm^2)(°C)	0.0001355
B.t.u. / (hr.)(ft.^{2})(°F)	watts / (cm^2)(°C)	0.000568
B.t.u. / (hr.)(ft.^{2})(°F)	watts / (in^2)(°F)	0.00204
B.t.u. / (hr.)(ft.^{2})(°F)	hp / (ft.^{2})(°F)	0.000394
B.t.u. / (hr.)(ft.^{2})(°F)	joules / (sec.)(m^2)(°C)	5.678
kg-cal. / (hr.)(m^2)(°C)	joules / (sec.)(m^2)(°C)	1.163
watts / (m^2)(°C)	joules / (sec.)(m^2)(°C)	1.0
Viscosity		
centipoises	g / (sec.)(cm) or poise	0.01
centipoises	lb. / (sec.)(ft.)	0.000672
centipoises	lb. / (hr.)(ft.)	2.42
centipoises	kg / (hr.)(m)	3.60
centipoises	(newton)(sec.) / m^2	0.001
lb. / (sec.)(ft.)	(newton)(sec.) / m^2	1.488
Thermal Conductivity		
g-cal. / (sec.)(cm^2)(°C / cm)	B.t.u. / (hr.)(ft.^{2})(°F / in.)	2903.0
watts / (cm^2)(°C / cm)	B.t.u. / (hr.)(ft.^{2})(°F / in.)	694.0
g-cal. / (hr.)(cm^2)(°C / cm)	B.t.u. / (hr.)(ft.^{2})(°F / in.)	0.8064
B.t.u. / (hr.)(ft.^{2})(°F / ft.)	joules / (sec.)(m^2)(°C)	1.731
B.t.u. / (hr.)(ft.^{2})(°F / in.)	joules / (sec.)(m^2)(°C)	0.1442

S. I. CONVERSIONS

BASIC CONVERSION FACTORS

Velocity			**Power**		
1 fps	=	0.3048 m/s	1 Btu/h(int.)	=	0.29307 W
1 fpm	=	0.00508 m/s	1 Btu/s(int.)	=	1.05506 kW
1 mph	=	0.44704 m/s	1 HP mech. (UK)	=	0.74570 kW
1 mph	=	1.60934 km/h	1 HP boiler	=	9.8095 kW
Length			**Density**		
1 inch	=	25.4 mm	1 lb./ft^3	=	16.01846 kg/m^3
1 foot	=	0.3048 m	1 lb./gal (imp.)	=	99.77633 kg/m^3
1 mile	=	1.60934 km	1 lb./gal (US)	=	119.82640 kg/m^3
Area			**Thermal Conductivity**		
1 sq. inch	=	6.4516 cm^2	1 Btu.ft/ft^{2}h.°F	=	1.73073 W/m°C
1 sq. foot	=	0.09290 m^2	1 Btu.in/ft^{2}h.°F	=	0.14423 W/m°C
Volume			**Volumetric Flow**		
1 inch^3	=	16.38706 cm^3	1 ft^3/s	=	0.028317 m^3/s
1 foot^3	=	0.02832 m^3	1 ft^3/s	=	101.9406 m^3/h
Capacity Imp. Measure			**Kinematic Viscosity**		
1 fluid oz.	=	28.41306 ml	1 ft^2/s	=	0.092903 m^2/s
1 gallon	=	4.54609 l	1 centistoke (cSt)	=	1.0×10^{-6} m^2/s
Weight or Mass			**Dynamic Viscosity**		
1 oz.	=	28.34952 g	1 centipoise (cP)	=	0.001 Pa-s
1 lb.	=	0.45359 kg	1 lb./ft.s	=	1.488164 Pa-s
Pressure			**Heat Transfer**		
1 psi	=	6.89476 kPa	1 Btu/ft^{2}h.°F	=	5.67826 W/m^2°C
1 bar	=	10^5 Pa	1 kcal/m^{2}h.°F	=	1.163 W/m^2°C
Energy			**Specific Energy**		
1 kWh	=	3.6 MJ	1 Btu/lb.	=	2.326 kJ/kg
1 watt-hour	=	3.6 kJ	1 cal/g	=	4.1868 kJ/kg
Frequency			**Specific Heat**		
1 cps	=	1 Hz	1 Btu/lb.°F	=	4.1868 kJ/kg°C

DERIVED UNITS WITH SPECIAL NAMES

Measurement	Unit	Symbol	Derivation
Frequency	hertz	Hz	s-1
Force	newton	N	kg•m/s^2
Pressure	pascal	Pa	N/m^2
Energy	joule	J	N•m
Power	watt	W	J/s
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Electric conductance	siemens	S	1/Ω
Electric charge	coulomb	C	A•s
Capacitance	farad	F	C/V
Magnetic flux	weber	Wb	V•s
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd•sr
Illumination	lux	lx	lm/m^2
Temperature	Celsius degree	°C	K - 273.15
Pressure	bar	bar	10^5 Pa
Volume	liter	l	dm^3

THE PREFERRED PREFIXES

Prefix	Symbol	Meaning	Prefix	Symbol	Meaning
tera-	T	10^{12}	milli-	m	10^{-3}
giga-	G	10^{9}	micro-	µ	10^{-6}
mega-	M	10^{6}	nano-	n	10^{-9}
kilo-	k	10^{3}	pico-	p	10^{-12}
deci-	d	10^{-1}	femto-	f	10^{-15}
centi-	c	10^{-2}	atto-	a	10^{-18}