ENGINEERING DATA

Energy savings and initial cost reduction will be realized when the basic physical science rules as presented in this section are followed. The formulas and tables are proven. Proper use of this information will result in longer heater life and more satisfactory results in heater applications.

TO CALCULATE HEAT REQUIREMENT

Two basic steps are required to properly size a heater to an application:

1. Determine start up power required.
2. Establish operating (maintaining) power.

In the majority of applications, the start up power requirement will be the larger of the two.

A safety factor of 20% for contingencies should be added to the results of your calculation.

1. Power Required For Initial Heat-Up

A. Btu absorbed by material and container

$$\frac{\left[\left(\text{Weight of Material} \times \text{Specific Heat}\right) + \left(\text{Weight of Container} \times \text{Specific Heat}\right)\right] \times \text{Temperature Rise}}{3412} = \_\_\_\text{KWh}$$

B. Btu required for fusion or vaporization

$$\frac{\text{Weight of Material} \times \text{Heat of Fusion or Vaporization}}{3412} = \_\_\_\text{KWh}$$

NOTE: *Step B will be required only if the specific heat of a material changes, at some temperature during the process, due to melting or evaporation. Calculate the Btu absorbed from the initial temperature at the point of change (Step A), and Step B, then repeat Step A for Btu absorbed from the point of change to the final operating temperature.*

C. Btu required to replace average losses

$$\frac{\text{Exposed Surface Area (sq. ft.)} \times \text{Watts per sq. ft. Loss at Final Temperature}}{2000} \times \text{Hours allowed for heating} = \_\_\_\text{KWh}$$

Total Power Required for Heat-up (KW) $= \dfrac{\text{Step A + Step B + Step C}}{\text{Hrs. allowed for heat-up}} \times 1.2 \left(\text{Safety Factor}\right)$

2. Power Required To Maintain Operating Temperature

A. Btu absorbed by material per hour

$$\frac{\text{Weight of Material added per hour} \times \text{Specific Heat} \times \text{Temperature Rise}}{3412} = \_\_\_\text{KW}$$

B. Btu required for fusion or vaporization

REFER TO 1. STEP B IF APPLICABLE

C. Btu required to replace losses

$$\frac{\text{Exposed Surface Area} \times \text{Watts per sq. ft. Loss at Operating Temperature}}{1000} = \_\_\_\text{KW}$$

Total Power Required to Maintain Operating Temperature KW = (Step A + Step B + Step C) × 1.2

EXAMPLE FOR HEATING LIQUIDS

An uninsulated steel tank weighing 100 lbs. is 2.5 feet in diameter x 4 feet high and contains 80 gallons of water at 70°F. Calculations to heat this water to 150°F in two hours and to heat additional 100 gallons of water per hour from 70 to 150 thereafter.

Specific heat of steel	= 0.12 Btu/lb./°F
Specific heat of water	= 1.0 Btu/lb./°F
Surface losses from tank (curve HL5)	= 56 Watts/sq. ft.

1. Power Required for Initial Heat-Up

A. $\dfrac{[(80 \times 8.34 \times 1) + (100 \times .12)] \times (150 - 70)}{3412} = 15.9 \text{ KWh}$

B. Not Required

C. $\dfrac{56\,(2.5\,\pi \times 4 + 2\,\pi(1.25)^2)}{2000} \times 2.0 = 2.3 \text{ KWh}$

Total Power Required For Initial Heating, Safety Factor of 20% Added $\dfrac{15.9 + 2.3}{2} \times 1.20 = 10.9 \text{ KW}$

2. Power Required to Maintain Operating Temperature With Additional Liquid

A. $\dfrac{100 \times 8.34 \times 1 \times (150 - 70)}{3412} = 19.6 \text{ KW}$

B. Not Required

C. $\dfrac{56\,(2.5\,\pi \times 4 + 2\,\pi(1.25)^2)}{1000} = 2.3 \text{ KW}$

Total Power Required to Maintain Operating Temperature = (19.6 + 2.3) x 1.20 = 26.3 KW

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AIR DUCT HEATING

To calculate the wattage required to heat forced air in a duct work system, use the formula:

$$KW = \frac{CFM \times \Delta T}{3000}$$

CFM = Blower rating in cubic feet per minute

ΔT = Temperature rise required in Deg. F.

Note: A 10% safety factor is generally added to the calculation to allow for voltage fluctuations and manufacturing tolerances.

Refer to graph DH-3, for a quick estimate of your kilowatt requirement.

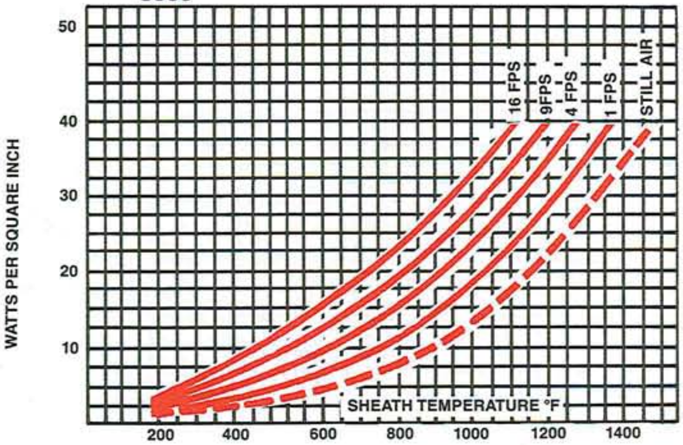

FIG. DH-1 SHEATH TEMPERATURE OF TUBULAR UNITS at various watt densities in free or forced air at 80°F.

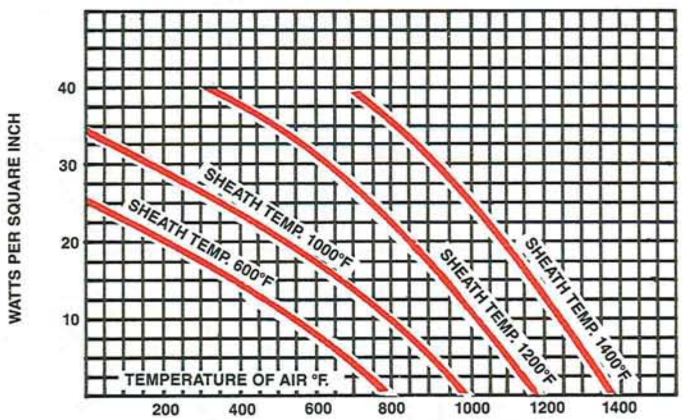

FIG. DH-2 ALLOWABLE WATT DENSITY ON TUBULAR UNITS OPERATING AT 800°F. to 1400°F. Sheath temperature for various temperatures in distributed air velocity of 16 fps.

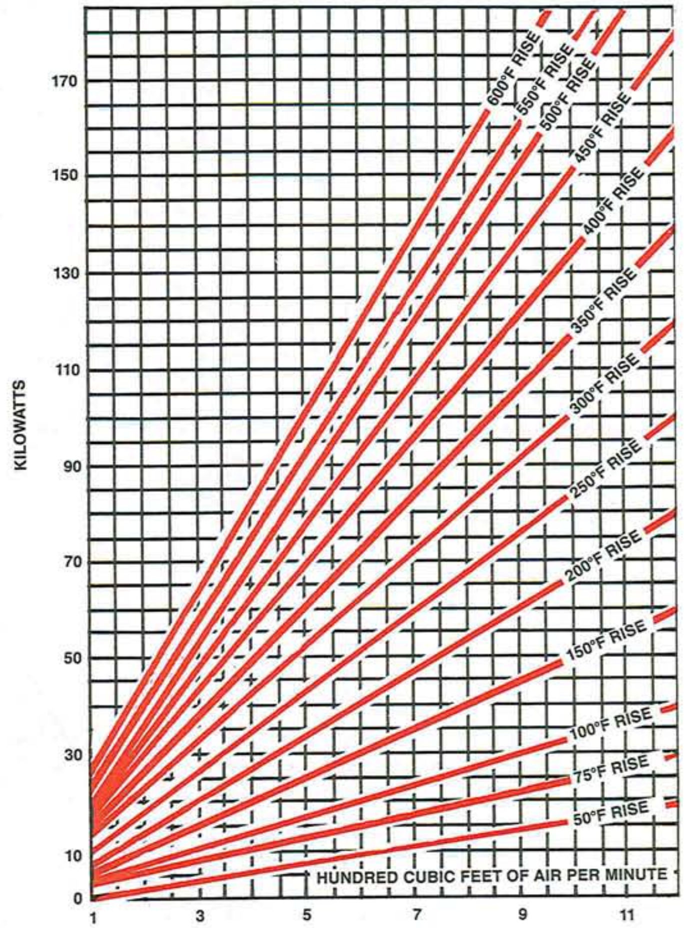

FIG. DH-3 HEAT REQUIREMENTS FOR AIR

Maximum Water Flow Per Hour through Delta Liquid Circulation Heaters for Temperature Rise. (Gallons per hour at specified temperature rise.)

Model #	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
CH33-60	6	122	81	61	49	40	35	30	27	24	22	20	18
CH33-90	9	184	122	92	73	61	52	46	40	36	33	30	28
CH33-120	12	245	163	122	98	81	70	61	54	49	44	40	37
CH33-150	15	306	204	153	122	102	87	76	68	61	55	51	47
CH33-180	18	368	245	184	147	122	105	92	81	73	66	61	56
CH56-240	24	490	327	245	196	163	140	122	109	98	89	81	75
CH56-300	30	613	409	306	245	204	175	153	136	122	111	102	94

Based on equation: $\text{Gal/hr} = \frac{(KW)\ (3412)}{(8.34)\ (\Delta T)}$

NOTE: *Safety factor not included in above figures, apply as suitable for the specific application.*

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HEAT LOSS INFORMATION

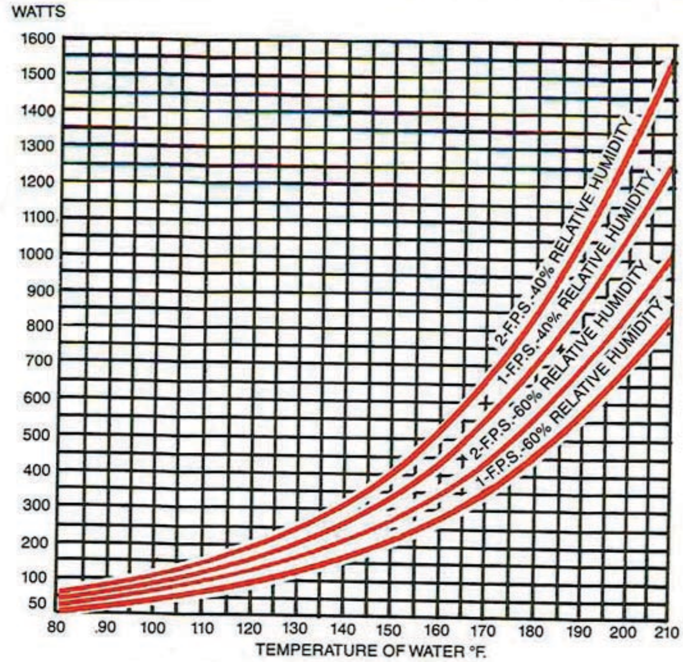

FIG. HL-1 HEAT LOSSES FROM WATER SURFACE IN WATTS PER SQUARE FOOT OF SURFACE AREA

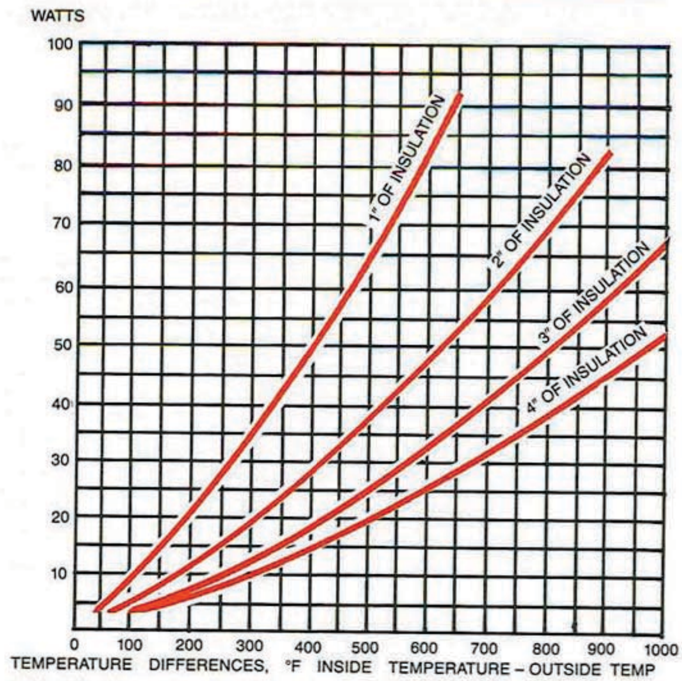

FIG. HL-3 HEAT LOSSES FROM INSULATED WALLS, PER SQUARE FOOT

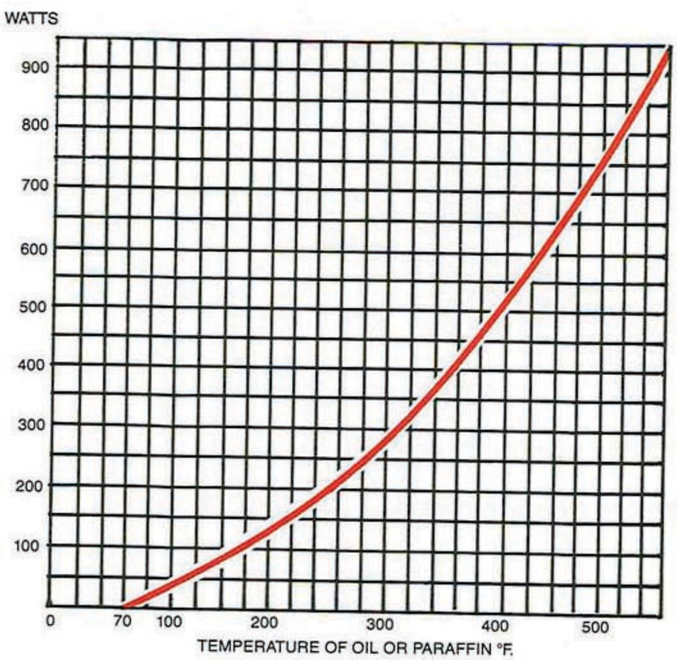

FIG. HL-2 HEAT LOSSES FROM OIL AND PARAFFIN SURFACES IN WATTS PER SQUARE FOOT ON SURFACE AREA

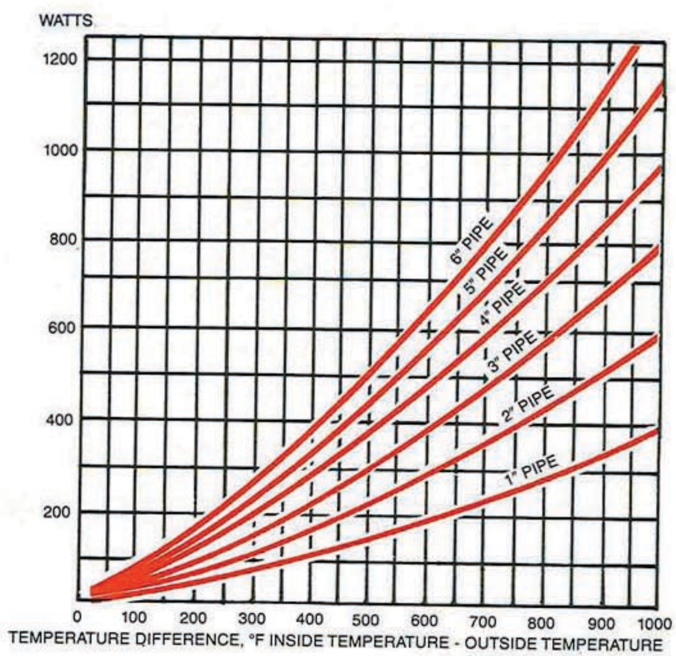

FIG. HL-4 HEAT LOSSES FROM INSULATED PIPE LINES, PER LINEAR FT.

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HEAT LOSS INFORMATION

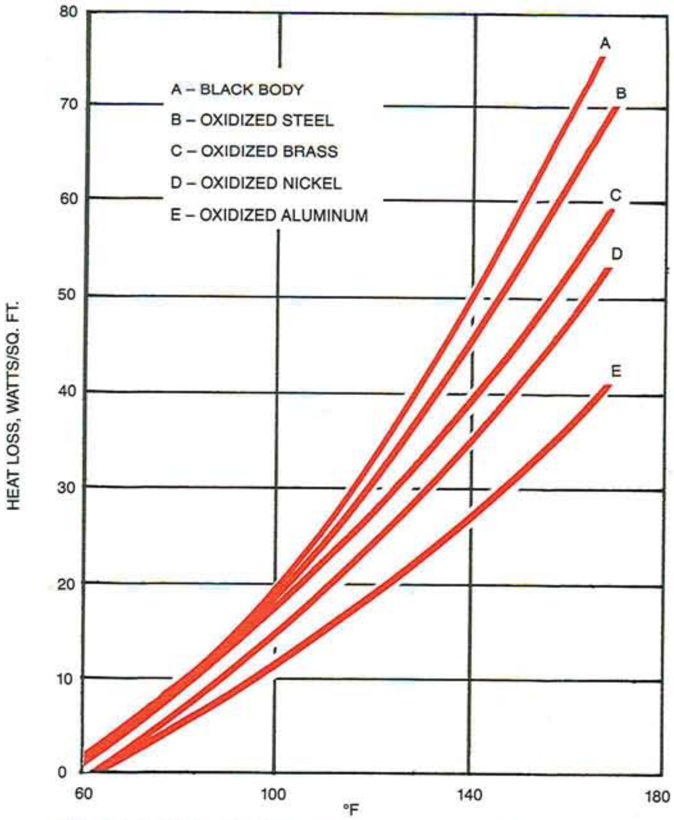
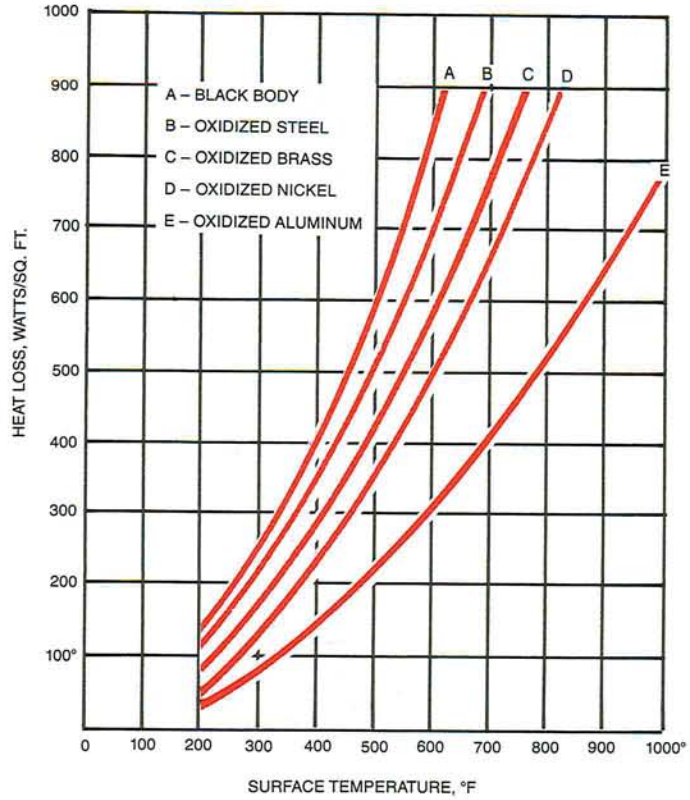
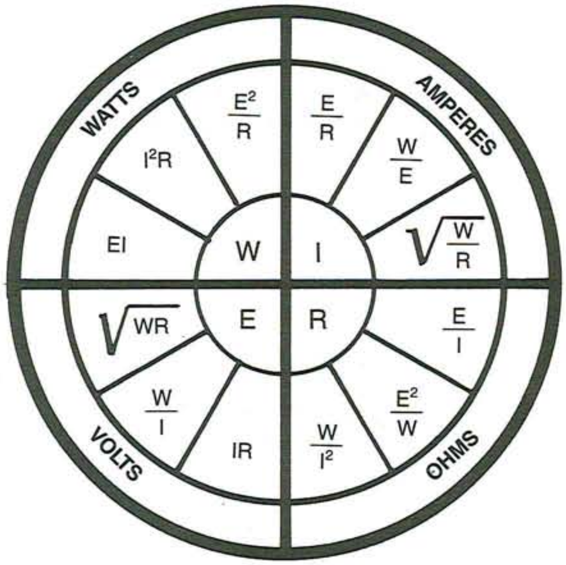


FIG. HL-5 HEAT LOSSES FROM UNINSULATED METAL SURFACES. WATTS PER SQUARE FOOT OF SURFACE AREA AMBIENT TEMPERATURE = 70°F

CURVE HL-6
HEAT LOSSES FROM UNINSULATED METAL SURFACES



OHMS LAW



ENGINEERING CONSTANTS

1728 Cu. In. = 1 Cu. Ft. = 7.48 Gal.
1″ = 2.54 Cm.
3412 Btu = 1 Kwh = 1.34 Hp Hour
491 Btu/Ft.^{2} = $1\ \frac{\text{Watt Hour}}{\text{In.}^2}$ = Heat Density
1 Btu/Lb. °F = 1 Gram-Cal./Gram °C = Specific Heat
231 Cu. In. = 1 Gal.
1 Ampere = 1000 Milliamperes
1 Btu = 252 Calories = .293 Watt-Hours
1 Btu/Lb. = 1.8 Calories/Gram
1 Hp = 745.2 Watts
1 Kw = 1000 Watts
1 Megohm = 1,000,000 Ohms
1 Gal. Water = 8.3 Lb.
1 Kw-Hr. will evaporate 3.5 lb. of water from and at 212 °F
1 Kw-Hr. will raise 22.75 lb of water from 62°F to 212°F
1 Gal. = 231 Cu. In. = 3.785 Liters = .1337 Cu. Ft.
1 Cu. Ft. = 1728 Cu. In. = .03704 Cu. Yd. = 7.481 Gal.

WIRING DATA

TYPICAL 3 PHASE WIRING DIAGRAMS AND EQUATIONS FOR RESISTIVE HEATERS

DEFINITIONS

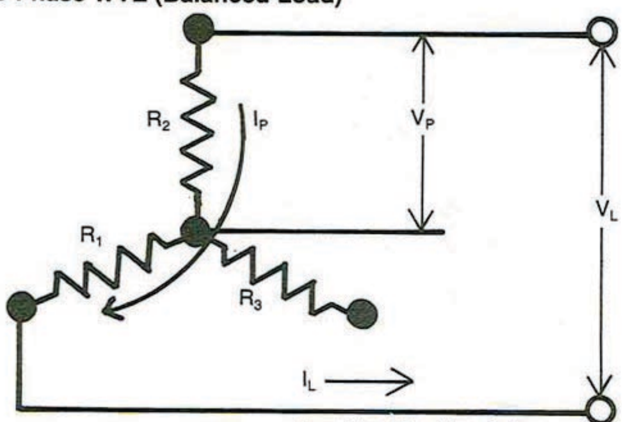
For Both Wye and Delta (Balanced Loads)

V_P = Phase Voltage
V_L = Line Voltage
I_P = Phase Current
I_L = Line Current
$R = R_1 = R_2 = R_3$ = Resistance of each branch
W = Wattage

Wye and Delta Equivalents

$W_{DELTA} = 3\ W_{WYE}$
$W_{ODELTA} = ⅔\ W_{DELTA}$
$W_{OWYE} = ½\ W_{WYE}$

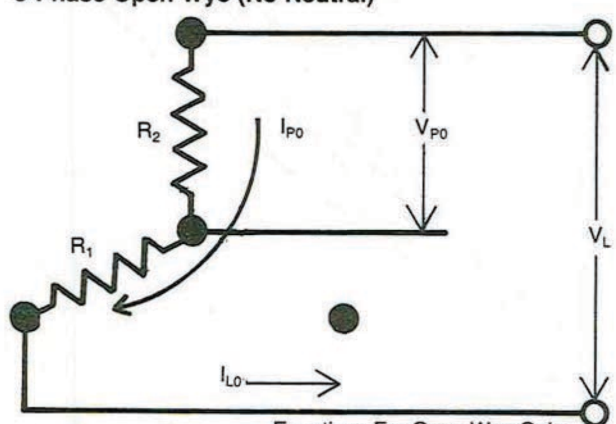
3-Phase WYE (Balanced Load)



Equations For Wye Only

$I_P = I_L$
$V_P = V_L/1.73$
$W_{WYE} = V_L^2/R = 3\ (V_P^2)/R$
$W_{WYE} = 1.73\ V_L I_L$

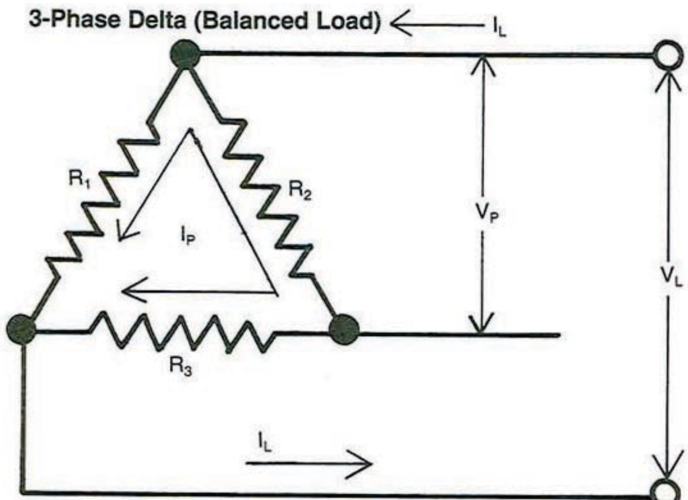
3-Phase Open Wye (No Neutral)



Equations For Open Wye Only
(No Neutral)

$I_{PO} = I_{LO}$
$V_{PO} = V_L/2$
$W_{OWYE} = ½\ (V_L^2/R)$
$W_{OWYE} = 2\ (V_{PO}^2/R)$

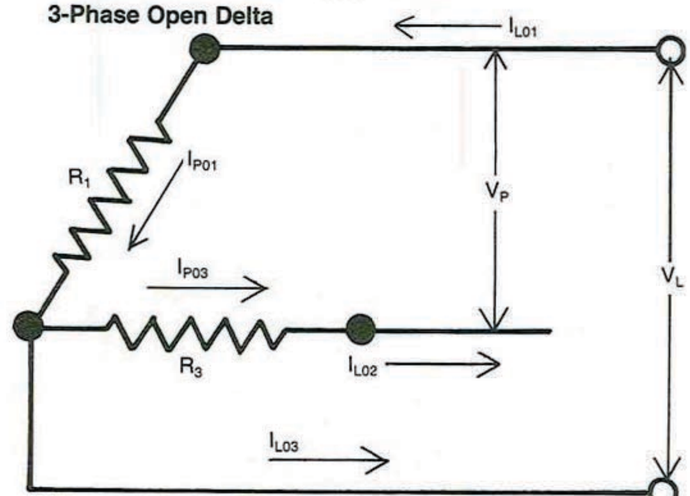
3-Phase Delta (Balanced Load)



Equations For Delta Only

$I_P = I_L/1.73$
$V_P = V_L$
$W_{DELTA} = 3(V_L^2)/R$
$W_{DELTA} = 1.73\ V_L I_L$

3-Phase Open Delta

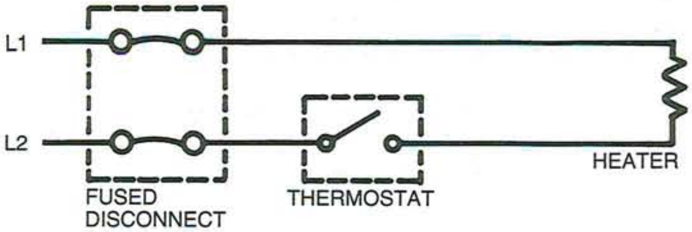


Equations For Open Delta Only

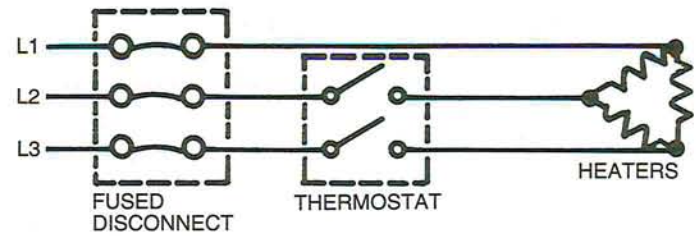
$V_P = V_L$
$I_{P01} = I_{P03} = I_{L02}$
$I_{L03} = 1.73\ I_{P01}$
$W_{0DELTA} = 2\ (V_L^2/R)$

WIRING DATA

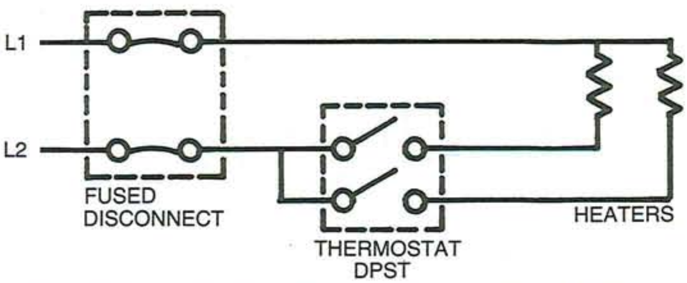
SINGLE PHASE CIRCUIT WITH SPST THERMOSTAT.



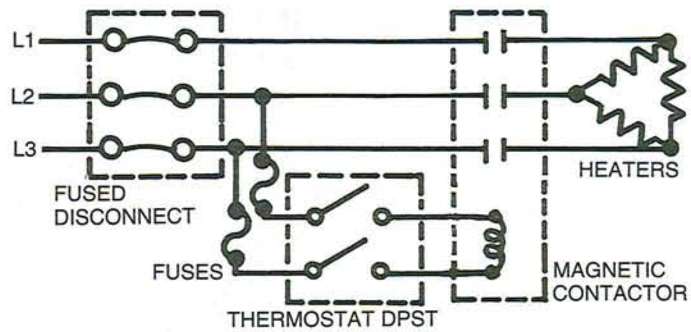
THREE PHASE CIRCUIT WITH DPST THERMOSTAT.



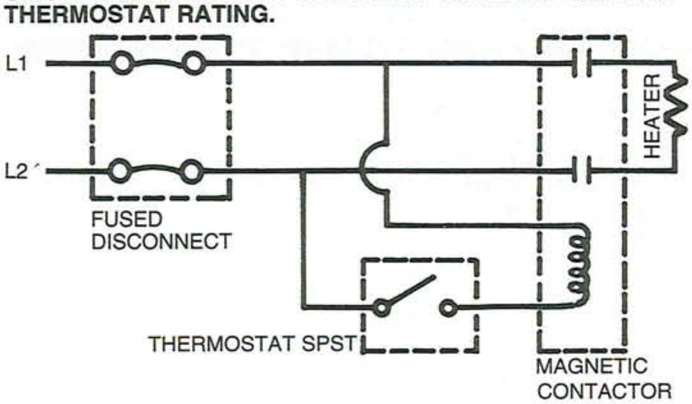
SINGLE PHASE CIRCUIT WITH THERMOSTAT CONNECTED FOR HALF CURRENT LOAD ACROSS EACH CONTACT.



THREE PHASE CIRCUIT WHEN LINE CURRENT EXCEEDS THERMOSTAT RATING.



SINGLE PHASE CIRCUIT WHEN LINE CURRENT EXCEEDS THERMOSTAT RATING.



RATINGS OF LISTED HEATER VOLTAGES OPERATED ON OTHER VOLTAGES

Kw Rating of Heater	120 Volts		240 Volts			480 Volts	
	Output Kw of Heater When Operated On:						
	110 Volts	115 Volts	208 Volts	220 Volts	230 Volts	440 Volts	460 Volts
1.0	0.84	0.92	0.75	0.84	0.92	0.84	0.92
2.0	1.69	1.84	1.50	1.69	1.84	1.69	1.84
3.0	2.53	2.76	2.25	2.53	2.76	2.53	2.76
4.0	3.36	3.67	3.00	3.36	3.68	3.36	3.68
4.5	3.78	4.13	3.38	3.78	4.14	3.78	4.14
5.0	4.20	4.59	3.5	4.2	4.6	4.2	4.6
7.5	6.30	6.89	5.6	6.3	6.9	6.3	6.9
10.0			7.5	8.4	9.2	8.4	9.2
12.5			9.4	10.5	11.5	10.5	11.5
15.0			11.3	12.6	13.8	12.6	13.8
20.0			15.0	16.9	18.4	16.9	18.4
25.0			18.8	21.0	23.0	21.0	23.0
50.0			37.6	42.0	46.0	42.0	46.0
75.0			56.3	63.0	69.0	63.0	69.0
100.0			75.1	84.0	92.0	84.0	92.0

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	2-5
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		
Light Grade	180	25-30 circ.
Heavy (Bunker C)	160	8
Gasoline	300	2-5
Glycerine	50	40
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	500-750	50
Steel Tubing Cast	750-1000	55
Trichlorethylene	150	20
Water (Process)	35-150	100-125 circ. 75-100 non-circ
	212	75 circ. 50 non-circ.

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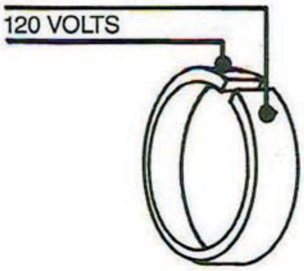
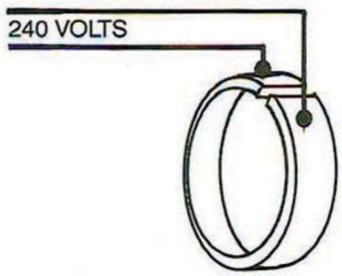
ENGINEERING DATA

HEATER BAND WIRING
1 PIECE HEATER BANDS

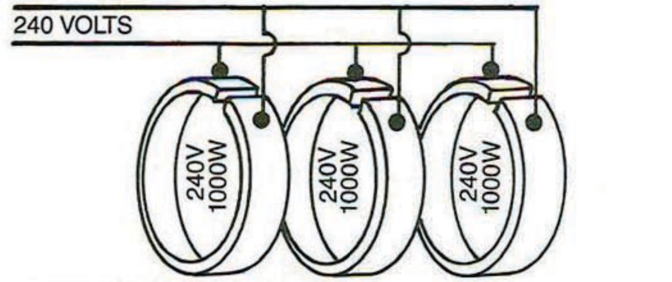
**1 PIECE BAND
RATED 120 VOLT
1,000 WATTS**



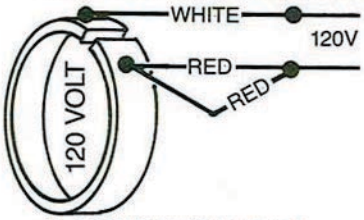
**1 PIECE BAND
RATED 240 VOLT
1,000 WATTS**



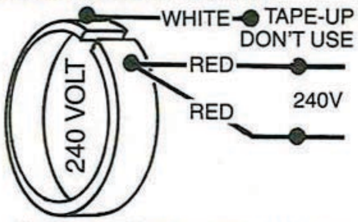
PARALLEL WIRING:
HEATER BANDS ARE NORMALLY WIRED IN PARALLEL BY ZONES



HOW TO WIRE DUAL VOLTAGE BANDS 120/240

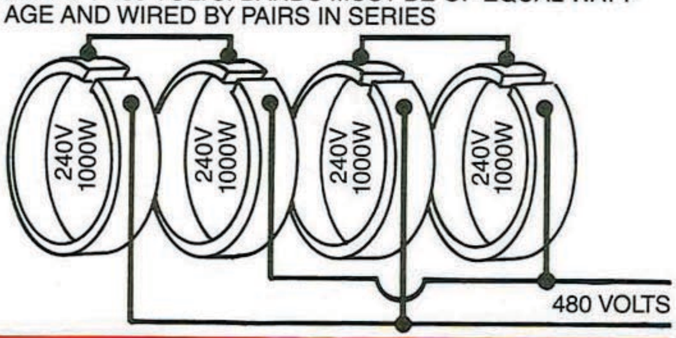


1) CONNECT WHITE TO COMMON
2) JOIN TWO REDS TO OTHER LINE



1) TAPE WHITE WIRE AND DO NOT USE
2) CONNECT ONE RED TO EACH SIDE OF LINE

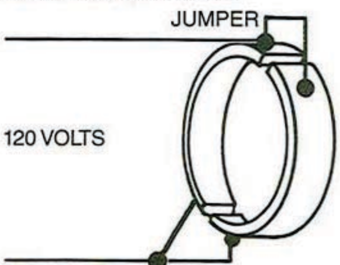
SERIES WIRING:
ILLUSTRATION SHOWS 240 VOLT BANDS WIRED TO ACCEPT 480 VOLTS. BANDS MUST BE OF EQUAL WATTAGE AND WIRED BY PAIRS IN SERIES



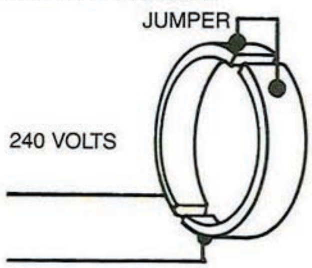
HEATER BAND WIRING
2 PIECE HEATER BANDS

120 VOLTS PER HALF

2 PIECE BAND RATED 240 VOLTS 1,000 WATTS. EACH HALF IS 120 VOLTS 500 WATTS. WIRE EACH HALF PARALLEL.



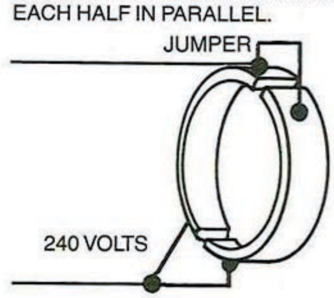
2 PIECE BAND RATED 240 VOLTS 1,000 WATTS. EACH HALF IS 120 VOLTS 500 WATTS. WIRE EACH HALF IN SERIES



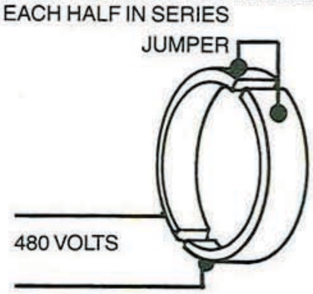
EACH HALF IS 120 VOLTS 500 WATTS

240 VOLTS PER HALF

2 PIECE BAND RATED 240 VOLTS 1,000 WATTS. EACH HALF IS 240 VOLTS 500 WATTS. WIRE EACH HALF IN PARALLEL.



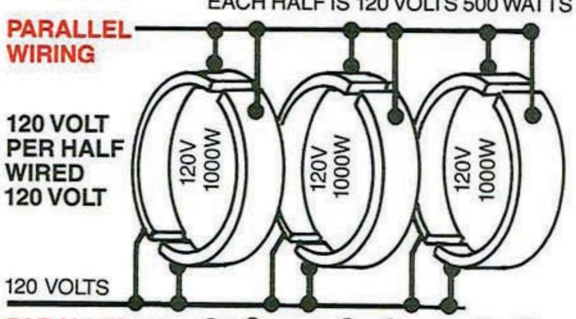
2 PIECE BAND RATED 480 VOLTS 1,000 WATTS. EACH HALF IS 240 VOLTS 500 WATTS. WIRE EACH HALF IN SERIES



EACH HALF IS 240 VOLTS 500 WATTS

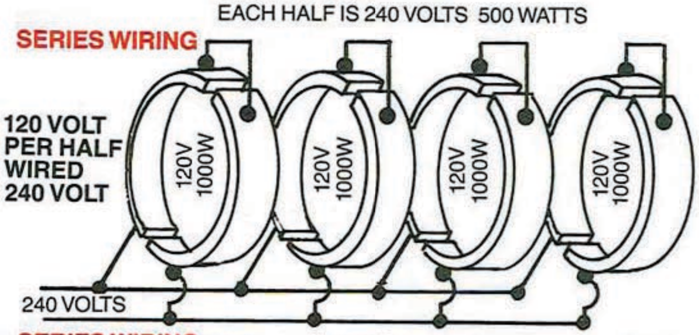
PARALLEL WIRING

120 VOLT PER HALF WIRED 120 VOLT



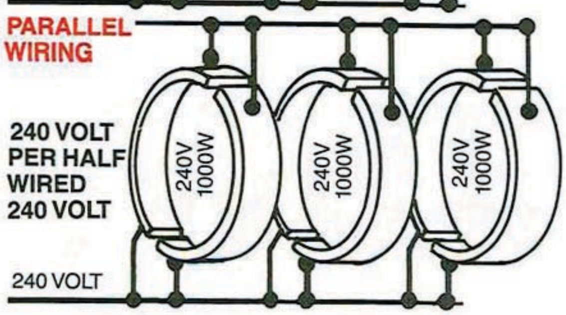
SERIES WIRING

120 VOLT PER HALF WIRED 240 VOLT



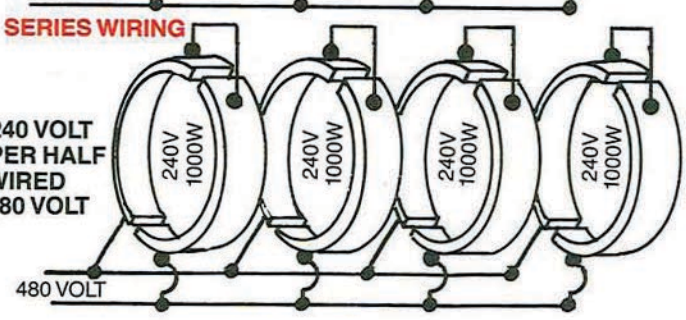
PARALLEL WIRING

240 VOLT PER HALF WIRED 240 VOLT



SERIES WIRING

240 VOLT PER HALF WIRED 480 VOLT



PHYSICAL PROPERTIES OF SOLIDS

Metals

Substance	Density †† g/cm³	Melt. pt. °C	Latent ht. fusion** g-cal/g	Boil pt. °C	Latent ht. vaporization g-cal/g**	Spec. ht. g-cal/g or Btu/lb
Aluminum	2.70	659.8	93.0	1800	1950-2000	0.226
Antimony	6.618	630.5	39.0	1380	373	0.0504
Arsenic	5.73	Volatilizes	—	615*	74	0.078
Barium	3.5	850	—	1140	628	0.068
Beryllium	1.8	1350	318	1500	—	0.425
Bismuth	9.781	271.3	12.5	1450	221	0.0294
Brass	—	1700	—	—	—	0.092
Cadmium	8.648	320.9	12.8	766	227.5	0.0552
Calcium	1.55	810	78	1170	—	0.149
Cerium	6.90	640	—	1400	—	0.0511
Cesium	1.873	26.0	3.78	670	131.4	0.0482
Chromium	6.93	1765	70	2200	14.71	0.111
Cobalt	8.71	1480	64	3000	—	0.1001
Copper	8.89	1083	49.3	2300	1756	0.0928
Gold	19.3	1063	15.9	2600	446	0.0312
Iridium	22.42	2454 ± 3	26.1	4800	340	0.0323
Iron (99.97%)	7.87	1535	65	3200	1110	0.1075
Lead	11.342	327.4	6	1620	323	0.0297
Lithium	0.534	186	120.5	1200	—	0.96
Magnesium	1.74	651	70	1097	1300-1500	0.249
Manganese	7.2	1260	—	1900	1044	0.1211
Mercury	13.546	−38.87	2.776	356.9	71	0.0333
Molybdenum	10.2	2620	—	3700	176.8	0.0589
Nickel	8.85	1440	73	2900	1010	0.1032
Osmium	22.48	2700	—	5300	350	0.0311
Palladium	12.0	1553	35.93	2200	610	0.0538
Platinum	21.37	1773.5	26.9	4300	637	0.0319
Potassium	0.870	62.3	14.6	760	513	0.177
Rhodium	12.44	1966	—	>2500	620	0.058
Silver	10.5	960.5	25.9	1950	551.6	0.0557
Sodium	0.9712	97.5	27	880	1170	0.283
Steel	7.8	1398				0.12
Strontium	2.60	800	—	1150	1045	0.0735
Tantalum	16.6	2850	—	>4100	—	0.036
Tellurium	6.25	452	7.3	1390	159	0.0483
Thallium	11.95	303.5	—	1650	220	0.0326
Thorium	11.00	1845	—	>3000	—	0.0276
Tin	7.29 ±	231.89	14.4	2260	655	0.0548
Titanium	4.5	1800	—	>3000	1320	0.1125
Tungsten	19.0 ±	3382	—	5900	1183	0.032
Uranium	18.7	<1850	—	—	—	0.0280
Vanadium	5.6	1710	—	3000	—	0.1153
Zinc	7.14 ±	419.45	26.6	905 ± 2	426.8	0.0931
Zirconium	6.53	1900	—	>2900	—	0.066

*Sublimes

**To convert g-cal/g to Btu/lb multiply by 1.8.

††To convert g/cm³ to lb/ft³ multiply by 62.4

Non-metallic

Substance	Melt. pt.°F	Latent ht. fusion Btu/lb	Weight lb/ft³	Spec. ht. g-cal/g or Btu/lb
Asbestos	—	—	125	0.195
Asphalt	250	40	81	.40
Bakelite	—	—	—	.3-.4
Basalt	—	—	150	.20
Beeswax	144	75	60	—
Brickwork	—	—	144	.20
Carbon	—	—	140	.126
Graphite	—	—	—	.165
Diamond	—	—	—	.1044
Calcspar	—	—	—	.2005
Cellulose	—	—	—	.35
Chalk	—	—	120	.214
Clay	—	—	115	.22
Coal	—	—	90	.3
Coke	—	—	62	.265
Concrete	—	—	175	.156
Ebonite	—	—	—	.40
Glass	—	—	185	.1988
crown	—	—	—	.161
flint	—	—	200	.117
Granite	—	—	165	.192
Graphite	—	—	130	.20
Ice (−20°C)	—	—	—	.465
Ice (0°C)	—	—	—	.487
India rubber, Para				.481
Limestone	—	—	125	.22
Marble	—	—	165	.21
Mica	—	—	165	.10
Paper	—	—	58	.45
Plastics:				
ABS	—	52	62.2	.3-.4
Cellulosic	—	83	82.9	.3-.5
Epoxy		78	77.8	.25
Fluoroplastic	—	.133	133.1	.28
Nylon	—	69	69.1	.4
Phenolic	—	83	82.9	.3-.4
Polyethylene	—	57	57.0	.55
Polystyrene	—	64	63.9	.32
Vinyl		86	86.4	.2-.3
Porcelain	—	—	145	.26
Quartz	3150	—	138	.17
Rock salt	—	—	136	.188
Rubber	—	—	75	.48
Sand	—	—	90	.19
Selenium	—	—	301	.077
Silicon	—	—	151	.181
Sugar	320	320	105	.30
Sulfur, rhombic	—	—	125	.176
monoclinic	—	—	—	.181
Woods, general	—	—	—	.3-.7

PHYSICAL PROPERTIES OF GASES

Substance	Density (0°C) G/1	Density (0°C) lb/ft³	Melt pt. °C	Latent ht. fusion** g-cal/g	Boil pt. °C	Latent ht. vaporization g-cal/g**	Spec. ht.
Acetylene	1.173	0.07323	−81.3	—	−83.6	—	0.3832
Air	1.2929	.08071	—	—	—	51.0	0.2377
Ammonia	0.7710	.04813	−75	108.0	−33.5	327.1	0.5202
Argon	1.7837	.11135	−189.2	6.71	−185.7	37.7	0.1233
Arsine	3.48	.217	−113.5	—	−54.8	—	—
Butane-*iso*	2.637	.1669	−145.0	—	−10.2	87.4	—
Butane-*n*	2.519 (710 mm)	.1572 (710 mm)	−135.0	—	0.6	91.5	—
Carbon dioxide	1.9769	.12341	−57	45.3	−80 Subl.	137.9	0.2025
Carbon monoxide	1.2504	.07807	−207	8.00	−191.5	50.4	0.2425
*Carbon oxychloride (phosgene)	4.531	.283	−118	—	8.3	—	—
Carbon oxysulfide	2.72	.170	−138	—	−48	—	—
Chlorine	3.214	.2006	−101.6	23.0	−34.7	81	0.1125
Chlorine monoxide	3.89	.243	−20	—	3.8 (explodes)	—	—
Cyanogen	2.335	.146	−27.90	—	−21.17	—	0.4095
Ethane	1.3566	.08469	−172.0	—	−88.3	258.0	0.3861
Ethyl chloride	2.870	.1793	−138.7	—	12.2	92.5	0.2750
Ethylene	1.2604	.07868	−169.4	—	−103.8	—	0.399
Fluorine	1.696	.1059	−223	—	−187	40.5	0.182
Helium	0.1784	.01114	−272	—	−268.94	5.97	1.25
Hydrogen	0.08988	.005611	−259.14	14.0	−252.8	106.7	3.409
Hydrogen bromide	3.6445	.22752	−86.7	7.67	−68.7	48.7	0.082
Hydrogen chloride	1.6392	.10233	−111.3	13.4	−83.1 (755 mm)	105.9	0.194
Hydrogen fluoride	0.922	.0576	−92.3	—	−36.7 (755 mm)	—	0.343
Hydrogen iodide	5.789	.3614	−51.3	5.68	−35.7	33.92	0.06
Hydrogen selenide	3.670	.229	−64	—	−42	—	—
Hydrogen sulfide	1.539	.09608	−86	—	−62	131.9	0.2451
Hydrogen telluride	5.803	.363	−48	—	−1.8	—	—
Krypton	3.708	.2315	−169	—	−151.8	28	—
Methane	0.717	.0448	−182.5	14.53	−161.4	138	0.5929
Methyl chloride	2.3076	.14406	−103.6	—	−23.73	102.3	0.24
Methyl ether	2.1098	.13171	−138	—	−24.9	—	—
Methyl fluoride	1.5452	.09646	—	—	−78.0	—	—
Monomethylamine	1.396	.08715	−92.5	—	−6.8	—	—
Neon	0.9004	.05621	−248.67	2.84	−245.9	—	—
Nitric oxide	1.3402	.08367	−167	18.4	−153	—	0.232
Nitrogen	1.2506	.07807	−209.86	6.1	−195.8	47.8	0.2438
Nitrosyl chloride	2.992	.1868	−64.5	—	−5.5	—	—
Nitrous oxide	1.978	.1235	−102.4	—	−89.8	—	0.2126
Oxygen	1.42904	.089212	−218.4	3.33	−183.0	51	0.2175
Phosphine	1.529	.0955	−133.5	—	−87.4	—	—
Propane	2.020	.1261	−189.9	—	−44.5	—	—
Silicon tetrafluoride	4.68	.292	—	—	−68	—	—
Sulfur dioxide	2.9269	.18272	−76	—	−10	94.8	0.1544
Xenon	5.85	.365	−140	3.73	−109.1	24.4	—

*Phosgene
**To convert g-cal/g to Btu/lb. multiply by 1.8.

Cryogenic Properties of Gases

Properties	Gases He	Ne	A	Kr	Xe	H_2	CH_4	NH_3	N_2	O_2
Density, 32°F Atm. lb/ft³	.01114	.0562	.1113	.234	.368	.00561	.0448	.0481	.0781	.0892
Boiling pt. 1 Atm. °F	−452.0	−410.6	−302.4	−243.2	−162.6	−423.0	−258.7	−28.03	−320.4	−297.4
Melting pt. 1 Atm. °F	26 Atm −458.0	−415.7	−308.7	−250.8	−169.2	−434.6	−299.2	−107.9	−345.8	−361.1
Vapor dens. at B.P. lb/ft³	.999	.593	.368	.518	.606	.0830	.1124	.0556	.288	.296
Liquid dens. at B.P. lb/ft³	7.803	74.91	86.77	149.8	193.5	4.37	26.47	42.58	50.19	71.29
Vapor press. Solid at M.P. in mm. Hg.	<.02	323	516	549	612	54	70	45.2	96.4	2.0
Heat of Vapor at B.P. Btu/lb	<.03	37.4	70.0	46.4	41.4	194.4	248.4	588.6	85.7	91.6
Ht. of Fusion at M.P. Btu/lb	<1.8	7.2	12.1	7.0	5.9	25.2	26.1	151.2	11.0	5.9
CP. 50°F 1 Atm. Btu/lb/°F	−292°F 1.25	Ap. .25	.125	Ap. .06	Ap. .04	3.39	.528	.423	.248	.218
Cp/Cv. 59-68°F 1 Atm.	−292°F 1.65	1.64	1.67	1.68	1.66	1.41	1.31	1.31	1.40	1.40
Critical temp. °F	−450.2	−379.7	−188.5	−82.7	61.9	−399.8	−116.5	270.3	−232.8	−181.1
Critical pressure Atm.	2.26	26.8	48.0	54.2	58.2	12.8	45.8	111.5	33.5	50.1

PHYSICAL PROPERTIES OF LIQUIDS

Substance	†† Density g/cm³	Melt. pt °C	Latent ht. fusion** g-cal/g	Boil pt. (760 mm) °C	Latent ht. vaporization g-cal/g	Viscosity Poises†	Spec. ht.
Acetaldehyde (aldehyde)	0.806	−120.0	—	20.8	136.0	0.00231	—
Acetic acid	1.05	16.7	43.2	118.5	96.8	0.01222	0.522
Acetone	0.792	−94.6	19.6	56.1	124.5	0.0031	0.506
Allyl alcohol	0.847	−129.0	—	97.0	163.0	0.01363	0.665
Amyl alcohol	0.817	−78.5	—	137.9	120.2	—	—
Aniline	1.035	−6.24	20.95	183.9	110.0	0.04467	0.512
Benzene (benzol)	0.879	5.56	30.34	80.12	94.2	0.00654	0.340
Bromine	3.187	−7.2	16.2	58.8	48.8	0.01005	0.107
Butyl alcohol	0.810	−89.8	30.0	117.7	141.0	0.02948	0.687
Butyric acid	0.954	−5.55	30.10	163.5	114.0	0.01540	0.515
Carbolic acid (phenol)	1.07	41	29.03	182.2	—	0.1274	0.561
Carbon disulfide	1.293	−111.8	—	46.26	84.1	0.00376	0.240
Carbon tetrachloride	1.594	−22.8	41.57	76.75	46.4	0.00975	0.201
Castor oil	0.9603	—	—	—	—	9.86	0.434
Chloroform	1.489	−63.5	—	61.2	59.0	0.00571	0.226
Decane	0.747	−32.0	—	174.0	—	0.0077	0.500
Di-ethyl ether	0.714	−116.3	—	34.5	83.9	0.00245	0.529
Ether	0.503	—	—	35	—	—	0.503
Ethyl acetate	0.899	−83.6	—	77.1	—	0.0045	0.457
Ethyl alcohol	0.789	−114.6	24.89	78.32	204.3	0.012	0.548
Ethyl bromide	1.45	−119.0	—	38.4	59.9	0.00402	0.215
Ethyl chloride	0.918	−138.7	—	12.2	92.5	—	0.367
Ethyl iodide	1.944	−108.5	—	72.1	45.6	0.00592	0.161
Ethylene bromide	2.17	10.01	—	131.7	46.2	0.01721	0.173
Ethylene chloride	1.246	−35.3	—	83.7	77.33	0.00838	0.299
Formic acid	1.22	8.4	58.89	100.8	119.9	0.01784	0.525
Gasoline	0.66-0.69	—	—	70.0-90.0	—	—	0.5
Glycerin	1.261	18.1	47.5	290.0	—	8.30	0.576
Heptane	0.684	−90.7	—	98.4	76.3	0.00416	0.490
Hexane	0.660	−95.4	—	68.7	79.3	0.00326	0.600
Kerosene	0.78-0.82	—	—	—	—	—	0.5
Linseed oil	0.934	−20	—	287.0	—	0.331	—
Methyl acetate	0.927	−98.1	—	57.1	98.1	0.00388	0.468
Methyl alcohol	0.792	−97.8	22.0	64.7	262.8	0.00596	0.601
Methyl iodide	2.285	−64.0	—	42.3	45.9	0.00500	—
Naphthalene	1.152	80.2	35.6	218.0	75.5	0.040	0.396
Neatsfoot oil	0.913-0.917	—	—	—	—	—	—
Nitric acid (100%)	1.513	−47	9.53	86.0	114.9	—	—
Nitrobenzene	1.212	5.85	22.5	210.9	79.1	0.021	0.350
Nonane	0.718	−51.0	—	150.6	—	0.0062	0.503
Octane	0.707	−56.9	—	124.6	70.95	0.00542	0.578
Olive oil	0.918	20±	—	300±	—	0.840	0.471
Paraffin	0.71	—	—	400	—	—	0.71
Pentane	0.631	−129.9	—	36.0	—	0.0024	—
Petroleum	0.878	—	—	—	—	—	0.511
Propionic acid	0.99	−20.8	—	141.1	98.8	0.01102	0.560
Propyl alcohol	0.804	−127.0	—	97.5	164.4	0.02256	0.57
Rapeseed oil	0.913	−3.5	—	—	—	1.18	—
Soya bean oil	0.919	—	—	—	—	0.406	—
Sperm oil	0.88	—	—	—	—	0.420	—
Sulfur, melted	0.234	—	—	445	652	—	0.234
Sulfuric acid (100%)	1.831	10.49	24.03	330.0	122.08	0.50	0.344
Tallow	0.94	27-41	—	—	—	0.176	—
Toluene	0.882	−95.0	—	110.3	86.53	0.00590	0.440
Turpentine	0.873	−10	—	160.0	68.6	0.01487	0.411
Water	1.00	0	79.70	100.0	539.44	0.010050	1.0000
Xylene O	0.863	−27.1	—	142.0	82.9	0.00881	0.411

**To convert g/cm³ to Btu/b multiply by 1.8

†Dyne sec/cm²

††To convert g/cm³ to lb/ft³ multiply by 62.4

ENGINEERING DATA

DECIMAL AND MILLIMETER EQUIVALENTS

Fraction	Decimals	Millimeters
1/64	0.015625	0.397
1/32	.03125	0.794
3/64	.046875	1.191
1/16	.0625	1.588
5/64	.078125	1.984
3/32	.09375	2.2381
7/64	.109375	2.778
1/8	.1250	3.175
9/64	.140625	3.572
5/32	.15625	3.969
11/64	.171875	4.366
3/16	.1875	4.763
13/64	.203125	5.159
7/32	.21875	5.556
15/64	.234375	5.953
1/4	.2500	6.350
17/64	.265625	6.747
9/32	.28125	7.144
19/64	.296875	7.541
5/16	.3125	7.938
12/64	.328125	8.334
11/32	.34375	8.731
23/64	.359375	9.128
3/8	.3750	9.525
25/64	.390625	9.922
13/32	.40625	10.319
27/64	.421875	10.716
7/16	.4375	11.113
29/64	.453125	11.509
15/32	.46875	11.906
31/64	.484375	12.303
1/2	.5000	12.700
33/64	0.515625	13.097
17/32	.53125	13.494
35/64	.546875	13.891
9/16	.5625	14.288
37/64	.578125	14.684
19/32	.59375	15.081
39/64	.609375	15.478
5/8	.6250	15.875
41/64	.640625	16.272
21/32	.65625	16.669
43/64	.671875	17.066
11/16	.6875	17.463
45/64	.703125	17.859
23/32	.71875	18.256
47/64	.734375	18.653
3/4	.7500	19.050
49/64	.765625	19.447
25/32	.78125	19.844
51/64	.796875	20.241
13/16	.8125	20.638
53/64	.828125	21.034
27/32	.84375	21.431
55/64	.859375	21.828
7/8	.8750	22.225
57/64	.890625	22.622
29/32	.90625	23.019
59/64	.921875	23.416
15/16	.9375	23.813
61/64	.953125	24.209
31/32	.96875	24.606
63/64	.984375	25.003
1	1.000	25.400

1 mm = .03937″

.001″ = .0254 mm

MM	INCHES	MM	INCHES
.1	.0039	46	1.8110
.2	.0079	47	1.8504
.3	.0118	48	1.8898
.4	.0158	49	1.9291
.5	.0197	50	1.9685
.6	.0236	51	2.0079
.7	.0276	52	2.0472
.8	.0315	53	2.0866
.9	.0354	54	2.1260
1	.0394	55	2.1654
2	.0787	56	2.2047
3	.1181	57	2.2441
4	.1575	58	2.2835
5	.1969	59	2.3228
6	.2362	60	2.3622
7	.2756	61	2.4016
8	.3150	62	2.4409
9	.3543	63	2.4803
10	.3937	64	2.5197
11	.4331	65	2.5591
12	.4724	66	2.5984
13	.5118	67	2.6378
14	.5512	68	2.6772
15	.5906	69	2.7165
16	.6299	70	2.7559
17	.6693	71	2.7953
18	.7087	72	2.8346
19	.7480	73	2.8740
20	.7874	74	2.9134
21	.8266	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	3.9370

DELTA
MANUFACTURING
COMPANY INCORPORATED