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Wattage Calculation Formulas

Wattage Calculation Data

Basic Heating Formulas

The following formulae can be employed in determining wattage capacity required for different materials.

Formula A: Wattage required for heat-up = $\frac{\text{Weight of material (lbs) x Specific Heat x Temperature Rise °F}}{\text{3.412 x Time (Hours of fraction Thereof)}}$

For specific heat and weights of each material being heated, see tables 1, 2, and 3 on pages 145, 146, and 147

Formula B: Wattage losses at operating temperature = Wattage loss/sq. ft. x Area in sq. ft.
See curves on pages 150-151.

Formula C: Wattage for melting or vaporizing = $\frac{\text{Weight of material (lbs) x Heat of fusion or vaporization (BTU/lb)}}{\text{3.412 x Heat up time (Hours of fraction Thereof)}}$

When the specific heat of a material changes at some temperature during the heat-up, due to melting (fusion) or evaporation (vaporization), perform Formula A for heat absorbed from the initial temperature up to the temperature at the point of change, add Formula B, then repeat Formula A for heat absorbed from the point of change to the final operating temperature. See tables 1, 2, and 3 on pages 145-147, for heats of fusion and vaporization and temperatures at which these changes in state occur.

Specific Applications

For specific applications, substitute the Basic Heat Formulas (A, B, or C above) into the following:

To Heat Liquids
Wattage for initial heat-up = (a) + $\frac{(b)}{2}$

Wattage for operating requirements = (a) for new material added + (b)
To insure adequate capacity, add 20% to final wattage figures. This will compensate for added losses not readily computed.

To Melt Soft Metals
Wattage for initial heat-up = (a) to melting point + (c) to melt + (a) to heat above melting point + $\frac{(b)}{2}$

Wattage for operating requirements = [(a) to melting point + (c) to melt + (a) to heat above melting point] for added material + 11. To insure adequate capacity, add 20% to final wattage figures. This will compensate for added heat losses not really computed.

To Heat Ovens
Wattage = (a) (for air) + (a) (all material introduced into oven) + (b)
Add 25% to cover door heat losses

Forced Air Heating

Wattage = $\frac{\text{C.F.M. x temperature rise (°F)}}{3}$

For explanation of Basic Heat Formulas, see examples on pages 142-144.

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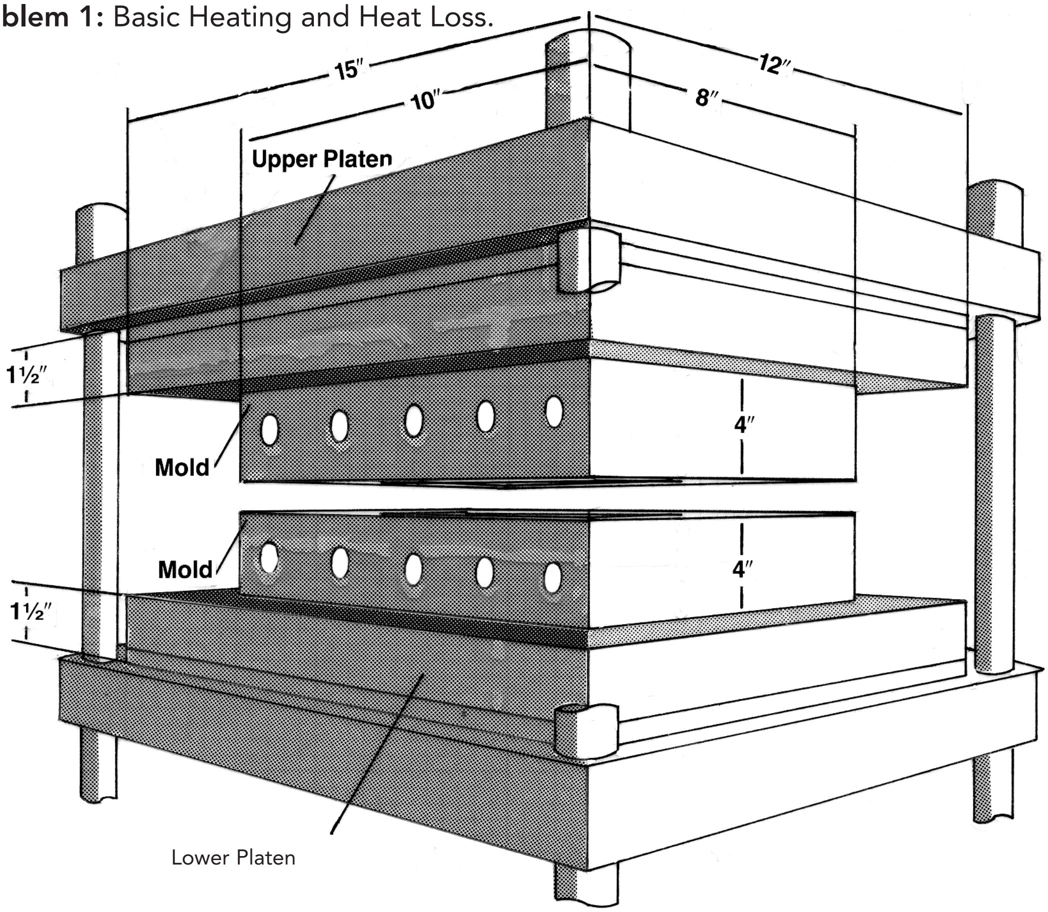
Wattage Calculation Formulas

Problem 1: Basic Heating and Heat Loss.



A steel mold is being used to form polyethelyne parts. Each hour, 90 ounces of nylon is introduced to the mold. The mold itself measures 10″ x 8″ x 4″. The mold is attached between two stainless steel platens, each measuring 15″ x 12″ 1½″ thick. The platens are insulated from the press mechanism with ½″ thick insulation. Operating temperature of the mold is 400˚F and is required to reach this temperature in 1 hour with an ambient temperature of 70˚F.

1) From Table 1, page 145: Specific heat of steel - .12/BTU/lb ˚F
2) From Table 1, page 145: Specific heat of stainless steel - .12/BTU/lb ˚F
3) From Table 2, page 146: Specific heat of polyethelyne - .55/BTU/lb ˚F
4) From Graph 1, page 150: Heat losses curves – A + B @ 400˚F
5) From Table 1, page 145: Converting cubic inches into pounds (density lb/cu. in.)

Formula A: Wattage required for heat-up

To heat mold $\frac{(10'' \times 8'' \times 4'') = 320 \text{ cu.in.} \times 2 \times .284 = 181.7 \text{ (lbs)} \times .12 \text{ BTU/lb °F} \times (400 - 70)\text{°F}}{3.412 \times 1} =$ 2,110 watts

To heat Platens $\frac{(15'' \times 12'' \times 1\tfrac{1}{2}'') = 270 \text{ cu.in.} \times 2 \times .286 = 154.5 \text{ (lbs)} \times .12 \text{ BTU/lb °F} \times (400-70)\text{ °F}}{3.412 \times 1} =$ 1,800 watts

To heat Polyethelyne $\frac{90}{16} = \frac{5.6 \text{ (lbs)} \times .55\text{BTU/lb °F} \times (400-70)\text{ °F}}{3.412 \times 1} =$ 300 watts

Compensation Factor 20% (2,110 + 1,800 + 300) = 840 watts

Total wattage required for Heat-up = 5,050 watts

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Formula B: Wattage losses at operating temperature (see graphs on pages 150 and 151).

Heat loss from mold (vertical surfaces)

$$\frac{10'' \times 4'' \times 4'' + 8'' \times 4'' \times 4''}{144''} = 2 \text{ sq. ft.} \times 350\text{w/sq.ft./hr.} = \quad 700 \text{ watts}$$

Heat loss from platen (vertical surfaces)

$$\frac{1\tfrac{1}{2}'' \times 15'' \times 4'' + 1\tfrac{1}{2}'' \times 12'' \times 4''}{144''} = 1.1 \text{ sq. ft.} \times 350\text{w/sq.ft./hr.} = \quad 385 \text{ watts}$$

Heat loss from platen (horizontal surfaces, uninsulated)

$$\frac{15'' \times 12'' \times 2'' - (10'' \times 8'' \times 2'')}{144''} = 1.3 \text{ sq. ft.} \times 250\text{w/sq.ft./hr.} = \quad 350 \text{ watts}$$

Heat loss from platen (insulated surface) 250 watts

$$\frac{15'' \times 12'' \times 2''}{144''} = 2.5 \text{ sq. ft.} \times 100\text{w/sq.ft./hr.} =$$

Compensation factor:	20% (700w + 385w + 350w + 250w) =	340 watts
	Total wattage losses at operating temperature =	2,025 watts
	Total wattage required for heat-up =	5,050 watts
	Total wattage required =	**7,075 watts**

The number of holes in the mold would dictate the number of heaters required. Divided the wattages by the number of heaters will equal the wattage rating of each heater.

Problem 2: Paraffin melting

An open top uninsulated steel tank: 18″ wide, 24″ long and 18″ deep weighs 140 pounds. This tank contains 168 pounds of paraffin which needs to be heated from 72˚F to 150˚F in 2 ½″ hours.

1.) From Table 1, page 145: Specific heat of steel - .12 BTU/lb-˚F
2.) From Table 2, page 146: Specific heat of solid paraffin - .70 BTU/lb-˚F
3.) From Table 2, page 146: Melting point of paraffin: -133˚F
4.) From Table 3, page 147: Heat of fusion of paraffin - 63 BTU/lb
5.) From Table 3, page 147: Specific heat of melted paraffin - .71 BTU/lb-˚F
6.) From Graph 5, page 151: Surface loss at 150˚F:70w/sq.ft./hr.
7.) From Graph 1, page 150: Surface loss at 150˚F:55w/sq.ft./hr.

Formula A: Wattage required for heat-up

To heat tank

$$\frac{140\text{lb} \times .12 \text{ BTU/lb-˚F} \times (150 - 72)}{3.412 \times 2.5} = \quad 155 \text{ watts}$$

To heat paraffin

$$\frac{168\text{lb} \times .70 \text{ BTU/lb-˚F} \times (133 - 72)\text{ ˚F}}{3.412 \times 2.5} = \quad 845 \text{ watts}$$

To heat melted paraffin (fusion occurs at melting point)

$$\frac{168\text{lb} \times .71 \text{ BTU/lb-˚F} \times (150 - 133)\text{ ˚F}}{3.412 \times 2.5} = \quad 240 \text{ watts}$$

Formula C: Wattage for melting or vaporizing
Heat of fusion to melt paraffin

$$\frac{168\text{lb} \times 63 \text{ BTU/lb}}{3.412 \times 2.5} = \quad 1{,}245 \text{ watts}$$

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Formula B: Wattage losses at operating temperature (see graphs on pages 150 and 151)

Average paraffin surface loss

3sq.ft. x 70w/hr. =	210 watts

Total losses

13.5sq.ft. x 55w/hr. =	740 watts

Compensation factor

20% (155 + 845 + 239 + 1,245 + 210 + 740) =	685 watts
Total wattage required =	**4,120 watts**

In addition to calculating the watts required for initial heat-up and heat losses, operating heat requirements must be calculated. Steel pins, each weighing .175 pounds, are to be placed in a 70 pound steel rack and dip-coated in the melted paraffin. 1,750 pins can be processed per hour with 25 pounds of paraffin.

Formula A: Wattage required for heat-up

To heat pins and rack

$$\frac{(1750 \times .175 + 70)\text{lbs/hr} \times .12\text{BTU/lb/}^\circ\text{F} \times (150 - 72)\,^\circ\text{F}}{3.412 \times 1 \text{ hour}} = \quad 1{,}030 \text{ watts}$$

To heat additional solid paraffin

$$\frac{25\text{lbs/hr} \times .70\text{BTU/lb}^\circ\text{F} \times (133 - 72)\,^\circ\text{F}}{3.412 \times 1 \text{ hour}} = \quad 310 \text{ watts}$$

To heat additional melted paraffin (fusion occurs at melting point)

$$\frac{25\text{lbs/hr} \times .71\text{BTU/lb}^\circ\text{F} \times (150\text{-}133)^\circ\text{F}}{3.412 \times 1 \text{ hour}} = \quad 90 \text{ watts}$$

Formula C: Wattage for melting or vaporizing
Heat of fusion, to melt additional paraffin

$$\frac{25\text{lbs/hr} \times 63\text{BTU/lb}}{3.412 \times 1 \text{ hour}} = \quad 460 \text{ watts}$$

Formula B: Wattage losses at operating temperature (see graphs on pages 150 and 151).
Paraffin surface loss

3sq.ft. x 70w/sq.ft./hr. =	210 watts

Tank surface loss

13.5sq.ft./ x 55w/sq.ft./hr =	740 watts

Compensation factor

20% (1,058 + 310 + 90 + 460 + 210 + 740) =	575 watts
Total wattage required =	**3,415 watts**

In the above calculations, the heat-up requirement is the greatest, therefore a heater with a wattage rating of 4,120 watts should be used in this application. The recommended watt density on the heater for this application is 16 watts per square inch (see page 148, table 1).

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Properties of Metals

Table 1: Properties of Metals

Material	Density (at or near room temp.) (lb/cu.in.)	Average Specific Heat (BTU/lb/˚F)	Thermal Conductivity (at or near room temp.) K(BTU/hr./sq.ft./˚F)	Melting Point (˚F)	Latent Heat of Fusion (BTU/lb)
Aluminum 2024-IT3	.100	.24	840	935	167
Aluminum 1100-00	.098	.24	1540	1190	169
Aluminum 30003	.099	.24	—	1190	167
Antimony	.245	.052	—	1166	25
Brass, Yellow	.306	.096	830	1710	—
Brass, Red	.316	.100	—	1877	—
Bronze	.318	.104	—	1832	75
Copper	.322	.095	2680	1981	91.1
Gold	.697	.030	—	1945	29
Incoloy 800	.290	.13	80	2475	—
Inconel 600	.304	.126	103	2500	—
Iron, Cast	.260	.12	346	2150	—
Iron, Wrought	.278	.12	—	2800	—
Lead, Solid	.410	.032	240	620	11.3
Lead, Liquid	.387	.037	108	—	—
Magnesium	.063	.27	1106	1202	160
Monel 400	.319	.11	151	2370	133
Monel 200	.321	.12	436	2615	133
Nickel 200	.321	.12	436	2615	133
Nickel Silver 18%80%NI20%CN	.314	.095	—	1931	—
Nichrome	.303	.11	—	2550	—
Platinum	.775	.032	—	3224	49
Silver	.379	.057	2900	1760	38
Solder 50%Pb 50%SN	.323	.051	310	361	17
Steel	.284	.122	460	2760	—
Stainless Steel 304	.286	.12	105	2550	—
Stainless Steel 316	.288	.118	108	2650	—
Stainless Steel 430	.275	.11	—	2650	—
Tin, Solid	.263	.065	455	450	26.1
Tin, Liquid	.253	.052	218	—	—
Titanium 99%	.164	.13	112	3035	—
Type Metal 85%Pb 15%Sb	.387	.040	—	500	14±

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Properties of Non-Metallic Solids

Table 2: Properties of Non-Metallic Solids

Material	Density (at or near room temp.) (lb/cu.in.)	Average Specific Heat (BTU/lb/˚F)	Thermal Conductivity (at or near room temp.) K(BTU/hr./sq.ft./˚F)	Melting Point (˚F)
Asbestos	.070	.25±	5.2	—
Asphalt	.076	.40	5.3	—
Brickwork & Masonry	.076	.22	3.7	—
Beeswax	.035	—	—	144
Carbon	.080	.28	165	6700
Cellulose Acetate	.047	.3 to .5	1.2 to 2.3	—
Butyrate	.043	.3 to .4	1.2 to 2.3	—
Delrin	.051	.35	1.6	—
Glass	.101	.161	7.5	—
Graphite	.075	.20	—	—
Lava, Grade A	.085	—	9±	2912
Mica	.102	.21	3.0	—
Magnesium, Compacted	.112	.209	20	—
Nylon	.040	.4	1.5	—
Paper	.034	.45	.62	—
Paraffin	.032	.70	1.6	133
Phenolic (general)	.046	.40	.6 to 1.2	—
Porcelain	.114	.26	—	3326
Polyethylene	.035	.55	2.3	—
Polystyrene	.038	.32	.7 to 1.0	—
Quartz	.080	.21	—	3150
Rubber	.044	.44	1.1	—
Rosin	.380	.5	—	—
Sugar	.073	.30	—	—
Steatite	.094	.20	17.5 to 23	2500±
Sulfur	.075	.175	1.9	246
Teflon	.078	.25	1.7	—
Vinyl	.046	.3 to .5	.8 to 2.0	—
Wood, Oak	.029	.57	1.1	—

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Properties of Liquids and Gases

Table 3: Properties of Liquids

Liquids	Density (at or near room temp.) (lb/cu.ft.)	Average Specific Heat (BTU/lb/°F)	Boiling Point (°F)	Heat of Vaperation (BTU/lb)
Acetic Acid 20%	64.1	.91	214 ±	810 ±
Alcohol (Ethyl)	49.6	.60	173	367
Benzene	56	.45	175	166
Brine (25% NaCL)	74	.81	221 ±	728 ±
Caustic Soda (18% NaOH)	74.9	.84	221 ±	795 ±
Dowtherm A	66.1	.44	496	42.2
Ether	46	.503	95	160
Ethylene Glycol	70.5	.602	387	—
Fish Oil	70.5	.602	387	—
Fuel Oil, Bunker C	61	.50	—	145-150
Freon 12	82.7@70psig	.23	-21.6	62
Gasoline	48.6	.675	158-194	137
Glue (⅓ dry glue, ⅔ water)	69	.895	—	—
Glycerine	79	.58	554	—
Kerosene	51.5	.47	—	108
Mercury	845	.0333	675	117
Milk	64.5	1(approx.)	—	—
Molasses	87.4	.6	—	—
NaK (78%K)	46.2	.21	1446	—
Nitric Acid 7%	64.7	.92	220 ±	918 ±
Oil, Cottonseed	60	.47	—	—
Oil, Machine	58	.40	—	—
Oil, Olive	58	.471	570 ±	—
Paraffin (melted)	47.1	.71	1400	63
Petroleum	56	.51	—	—
Potassium (K)	44.6	.18	—	—
Sodium (Na)	51.2	.3	1621	1810
Sulfur (melted)	—	.234	601	652
Thermonal FR-2	90.6	.3	648 ±	—
Turpentine	54.3	.41	318	123
Vegetable Oil	57.5	.43 ±	—	—
Water	62.3	1.0	212	970

Table 4: Properties of Gases

Gasses	Density (at or near room temp. and atmospheric pressures) (lbs/cu.ft.)	Specific Heat (BTU/LB/°F)
Air @ 80°F	.073	.240
Air @ 400°F	.046	.245
Ammonia	.044	.523
Acetylene	.073	.35
Argon	.102	.125
Carbon Dioxide	.113	.199
Carbon Monoxide	.072	.248
Chlorine	.184	.115
Hydrochloric Acid	.094	.194
Hydrogen	.0052	3.39
Methane	.041	.528
Nitrogen	.072	.248
Oxygen	.082	.218
Sulphur Dioxide	.172	.152
Water Vapor @ 212°F	.037	.482

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Suggested Watt Densities

The rates below are recommended watt densities for use with various materials. Safe values vary with operating temperature, flow velocity, and heat transfer rates. In general, the higher the material temperature, the lower the watt density should be, especially those materials which coke or carbonize, such as oils. Watt densities should be low if a material is being heated to a temperature near where the change of state to a vapor occurs (water to steam @212˚F.) since the vapor state has much poorer heat transfer capabilities.

Material being heated	Maximum Operating Temp. ˚F	Maximum Watts Per Sq. In.*
Acid Solutions:		
Acetic	212	40
Chromic (5%)	Boiling	40
Citric	Boiling	40
Ferric	Boiling	40
Chloride (40%)		
Hydrochloric	150	30
Nitric (50%)	Boiling	40
Sulphuric	Boiling	30
Alkai & selected oakite cleaning solution	212	40
Asphalt binder, tar, other viscous compounds	200	8
	300	7
	400	6
	500	5
Caustic Soda 2%	210	45
10%	210	25
75%	180	25
Coffee (direct immersion)	Boiling	90
Dowtherm A®		
Flowing at 1ft/sec or more	750	22
Non-flowing	750	10
Ethylene Glycol	300	30
± Fuel Oils		
Grades 1 & 2 (Distillate)	200	22
Grades 4 & 5 (Residual)	200	13
Grades 6 & Bunker C (Residual)	160	8
Gasoline, Kerosene	300	20
Glue (heat indirectly using water bath)	100	
Liquid ammonia plating baths	50	25
** Lubrication Oils		
SAE 10, @ 130˚F	250	22
SAE 20, @ 130˚F	250	22
SAE 30, @ 130˚F	250	22
SAE 40, @ 210˚F	250	13
SAE 50, @ 210˚F	250	13

**Some oils contain additives that will boil or carbonize at low watt densities. Where oils of this type are encountered a watt density test should be made to determine a satisfactory watt density.

Material being heated	Maximum Operating Temp. ˚F	Maximum Watts Per Sq. In.*
Metal melting pot	500 to 900	20-27
Mineral oil	200	20
	400	16
Molasses	100	2-3
Molten salt bath	800-950	40
Molten tin	600	20
Oil draw bath	600	20
	400	24
Paraffin or wax	150	16
Photographic solutions	150	70
Plating solutions:		
Cadmium plating		40
Chrome plating		40
Copper plating		40
Nickel plating		40
Tin plating		40
Zinc plating		40
Salt Bath	900	30
Sea Water	Boiling	90
Sodium cyanide	140	40
Steel tubing cast into aluminum	500 to 750	50
Steel tubing cast into iron	750 to 1000	55
Heat transfer oils	500	22
flowing at 1 ft/sec or more	600	22
	650	22
	750	15
Tricholretylene	150	20
Vapor degreasing solutions	275	20
Vegetable oil (fry kettle)	400	30
Water (process)	212	60
Water (washroom)	140	80-90

* Maximum watt densities are based on heated length, and may vary depending upon concentration of some solutions. Watt density should be kept as low as possible in corrosive applications since higher watt densities accelerate corrosive attack on element sheaths. Consult factory for limitations.

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Estimates of Wattage Required

Kilowatt Hours to Heat Steel

Lbs. of Steel	Temperature Rise F°						
	50°	100°	200°	300°	400°	500°	600°
	Kilowatts to heat in one hour						
25	.06	.12	.25	.37	.50	.65	.75
50	.12	.25	.50	.75	1.00	1.25	1.50
100	.25	.50	1.00	1.50	2.00	2.50	3.00
150	.37	.75	1.50	2.25	3.00	3.75	4.50
200	.50	1.00	2.00	3.00	4.00	5.00	6.00
250	.65	1.25	2.50	3.75	5.00	6.25	7.50
300	.75	1.50	3.00	4.50	6.00	7.50	9.00
400	1.00	2.00	4.00	6.00	8.00	10.00	12.00
500	1.25	2.50	5.00	7.50	10.00	12.50	15.00
600	1.50	3.00	6.00	9.00	12.00	15.00	18.00
700	1.75	3.50	7.00	10.50	14.00	17.50	21.00
800	2.00	4.00	8.00	12.00	16.00	20.00	24.00
900	2.25	4.50	9.00	13.50	18.00	22.50	27.00
1000	2.50	5.00	10.00	15.00	20.00	25.00	30.00

A 20% Safety Factor is included to compensate for high heat losses and/or low voltage.

Kilowatt Hours to Heat Water

Amount of Liquid		Temperature Rise F°						
Cubic Ft.	Gallons	20°	40°	60°	80°	100°	120°	140°
		Kilowatts to heat in one hour						
.66	5	0.3	0.5	0.8	1.1	1.3	1.6	1.9
1.3	10	0.5	1.1	1.6	2.1	2.7	3.2	3.7
2.0	13	0.8	1.6	2.4	3.2	4	4.8	5.6
2.7	20	1.1	2.2	3.2	4.3	5.3	6.4	7.5
3.3	25	1.3	2.7	4	5.3	6.7	8	9.3
4.0	30	1.6	3.2	4.8	6.4	8	9.6	12
5.3	40	2.1	4	6.4	8.5	11	13	15
6.7	50	2.7	5.4	8	10.7	13	16	19
8.0	60	3.3	6.4	9.6	12.8	16	19	22
9.4	70	3.7	7.5	11.2	15	19	22	26
10.7	80	4.3	8.5	13	17	21	26	30
12.0	90	5	10	14.5	19	24	29	34
13.4	100	5.5	11	16	21	27	32	37
16.7	125	7	13	20	27	33	40	47
20.0	150	8	16	24	32	40	48	56
23.4	175	9	18	28	37	47	56	65
26.7	200	11	21	32	43	53	64	75
33.7	250	13	27	40	53	67	80	93
40	300	16	32	47	64	80	96	112
53.4	400	21	43	64	85	107	128	149
66.8	500	27	53	80	107	133	160	187

Kilowatt Hours to Heat Oil

Amount of Oil		Temperature Rise F°					
Cubic Ft.	Gallons	50	100	200	300	400	500
.5	3.74	.3	.5	1	2	2	3
1	7.48	.5	1	2	3	4	6
2	14.96	1	1	2	4	6	11
3	22.25	2	3	6	9	12	16
4	29.9	2	4	8	12	16	22
5	37.4	3	4	9	15	20	25
10	74.8	5	9	18	29	40	52
15	112.5	7	14	28	44	60	77
20	149.6	9	18	37	58	80	102
25	187	11	22	46	72	100	127
30	222.5	13	27	56	86	120	151
35	252	16	31	65	100	139	176
40	299	18	36	74	115	158	201
45	336.5	20	40	84	129	178	226
50	374	22	45	93	144	197	252
55	412	25	49	102	158	217	276
60	449	27	54	112	172	236	302
65	486	29	58	121	186	255	326
70	524	32	62	130	200	275	350
75	562	34	67	140	215	294	375

Add 5% for uninsulated tanks.

A 20% Safety Factor is included to compensate for high heat losses and/or low voltage.

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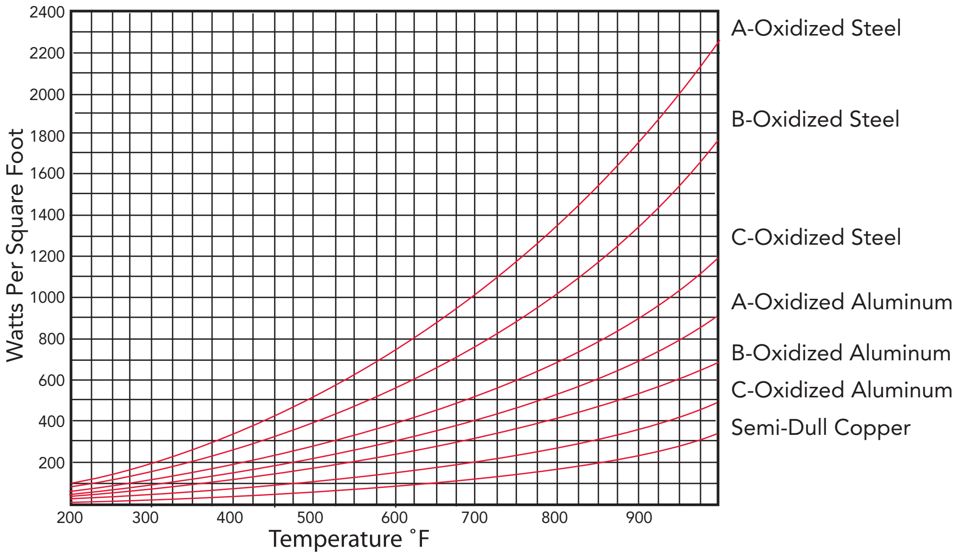
Guide for Heat Losses

Graph 1: Losses from Uninsulated Metal Surfaces.



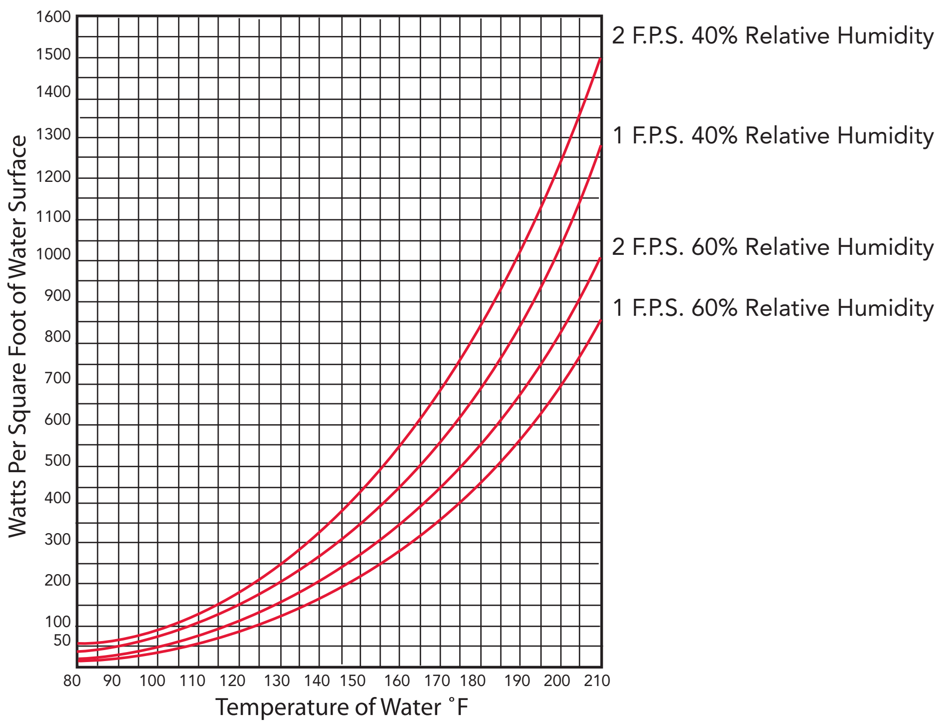
Curves "A" show heat losses from vertical surfaces of tanks, pipes, etc. and also top surface losses from a horizontal surface laid flat.

Curves "B" show average heat losses from top and bottom surfaces of a horizontal surface laid flat.

Curves "C" show heat losses from bottom surface of a horizontal surface laid flat.

All curves presuppose still air (approx. one foot per second) at 70˚F.

Graph 2: Losses from Open Hot Water Tanks



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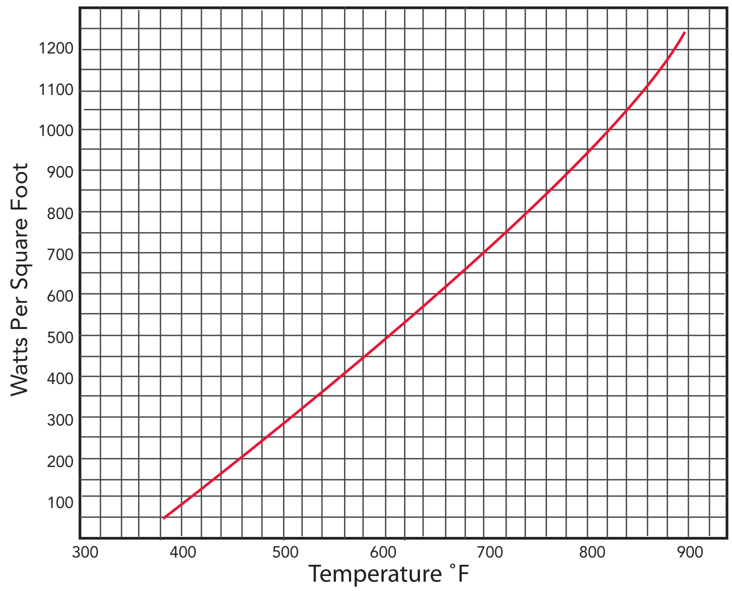
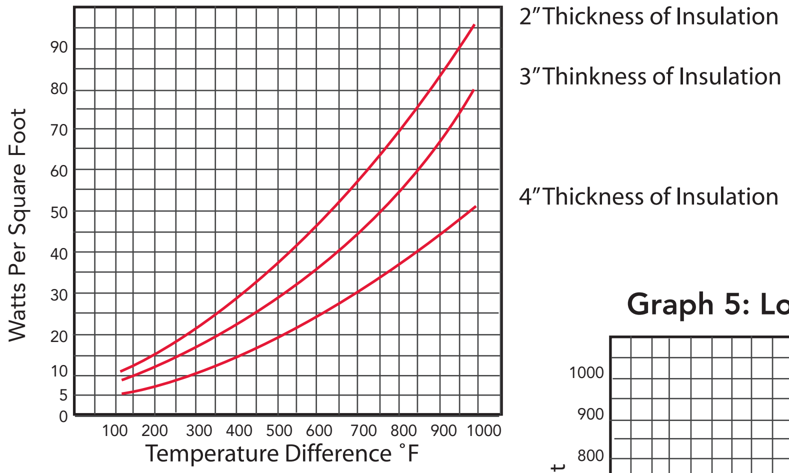
Guide for Heat Losses

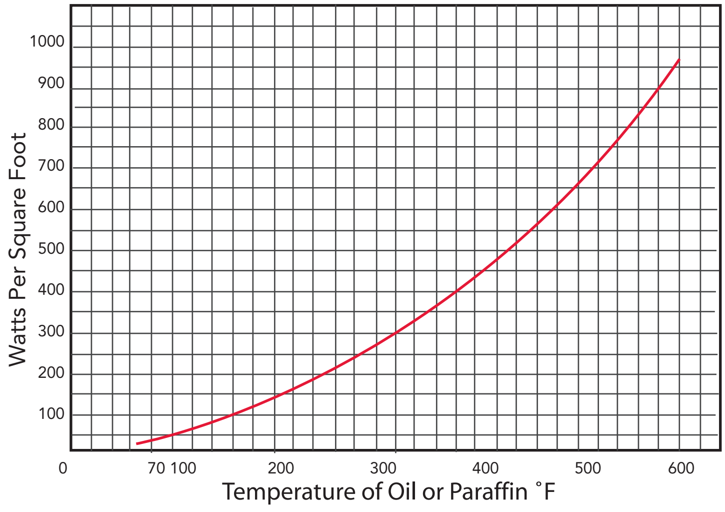
Graph 3: Losses from Molten Metal Surfaces.



Graph 4: Losses through Insulated Walls (ovens, pipes, etx.)



Graph 5: Losses from Surfaces of Oil Baths.



HOTWATT
HEATERS FOR EVERY APPLICATION

Technical

Suggested Sheath Materials

The following table of recommendations should only be used as a guide. The proper choice should be based upon your knowledge of the conditions which exist in each application.

Compound	Copper	Lead	Aluminum	Nickel	Iron and Steel	Cast Iron NI Resist	300 Series Stainless	Monel	Inconel Incoloy
Acetic Acid,									
Crude	2	x	2	2	x	3	2	2	3
Pure	2	2	1	2	—	x	—	1	3
Vapors	2	x	3	2	—	x	—	2	3
150 PSI; 400°F	2	x	3	2	—	—	—	2	3
Acetone	—	—	—	—	3	2	1	—	—
Alboloy Process	—	—	—	—	1	—	—	—	—
Aluminum Sulphate	2	1	3	3	x	3	2	2	—
Ammonia Gas									
Cold	3	1	1	—	1	1	1	1	—
Hot	x	x	—	—	3	3	3	3	—
Ammonia and Oil	—	—	—	—	1	—	—	—	—
Ammonium Chloride	x	1	x	2	3	1	2	2	—
Ammonium Hydroxide	x	1	2	—	1	1	1	3	1
Ammonium Nitrate	x	x	2	—	1	3	1	3	—
Ammonium Sulphate	2	1	—	—	1	1	1	1	—
Amyl Alcohol	1	—	—	—	—	—	—	1	—
Anhydrous Ammonia	x	—	—	—	1	—	—	—	—
Aniline, Aniline Oil	x	—	x	—	1	—	1	1	—
Aniline Dyes	—	—	—	—	—	—	1	1	—
Anodizing Solutions 10%	—	—	—	—	3	—	1	—	—
Chromic Acid 96°F	—	—	—	—	3	—	1	—	—
Sulphuric Acid 70°F	—	1	—	—	—	—	—	—	—
Sodium Hydroxide Alkaline	—	—	—	—	1	—	—	—	—
Nigrosine Black Dye	—	—	—	2	—	—	—	1	—
Nickel Acetate	—	3	—	2	—	—	—	1	—
Barium Hydroxide	x	x	x	1	—	—	1	—	—
Barium Sulphide	x	1	—	—	—	—	1	1	—
Bleaching Solution	—	—	—	2	—	—	—	1	—
1½lb. Oxalic Acid per Gallon of H_2O at 212°F	—	—	—	—	—	—	—	—	—
Bonderizing	—	—	—	—	3	2	1	—	—
Cadmium Plating	—	—	—	—	—	—	—	—	1
Carbolic Acid, Phenol	x	1	1	—	3	3	1	1	1
Carbon Dioxide									
Dry	1	1	1	—	1	1	1	1	1
Wet	2	x	2	—	2	3	1	1	1
Carbon Tetrachloride	3	2	3	—	3	3	3	1	1
Castor Oil	—	—	1	—	1	—	1	1	1
Chloroacetic Acid	x	x	x	2	x	—	x	—	—
Chlorine									
Dry	1	1	1	—	1	1	1	1	—
Wet	x	2	x	—	x	x	x	x	—
Chromic Acid	x	1	x	—	3	3	1	2	3
Chrome Plating	—	1	—	—	—	—	—	—	—
Citric Acid	1	1	1	—	x	3	1	1	1
Cobalt Acetate 130°F	—	—	—	—	—	—	—	1	1
Coconut Oil	—	—	—	1	—	—	—	2	—
Copper Chloride	3	1	x	—	2	—	x	2	—
Copper Cyanide	—	—	—	—	1	—	—	—	—
Copper Plating	—	—	—	—	1	—	—	—	—
Copper Sulphate	3	1	x	—	x	3	1	1	1
Creosote	1	—	1	—	1	1	1	1	—

Resistance Ratings: 1 = Good 2 = Fair 3 = Depends on Conditions x = Unsuitable

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Suggested Sheath Materials (con't)

Compound	Copper	Lead	Aluminum	Nickel	Iron and Steel	Cast Iron NI Resist	300 Series Stainless	Monel	Inconel Incoloy
Deoxidine	—	—	—	—	—	—	1	—	—
Deoxylyle	—	—	—	—	—	—	1	—	—
Dipenyl 300° - 350°F	—	—	—	—	1	—	—	—	—
Di Sodium Phosphate									
25% 180°F	—	—	—	—	1	—	—	—	—
Diversey No. 99	—	—	—	—	1	—	—	—	—
Downtherm	—	—	—	—	1	—	—	—	—
Ethers	1	1	1	—	1	—	—	1	1
Ethyl Chloride	1	—	—	1	1	—	1	1	—
Ethylene Gycol 300°F	—	—	—	—	—	—	1	1	—
Ferric Chloride	x	x	x	x	x	x	x	x	x
Ferric Sulphate	x	1	x	x	x	x	2-304	x	3
	—	—	—	—	—	—	1-316	—	—
Formaldehyde	2	x	2	—	2	2	1	1	1
Formic Acid	2	x	x	3	x	—	2	3	3
Freon	1	1	1	—	3	1	3	1	—
Fuel Oil	1	1	—	—	1	—	1	1	—
Fuel Oil, Acid	3	1	—	—	3	—	3	1	—
Gasoline, Sour	3	1	3	—	3	3	1	1	1
Gasoline, Refined	1	1	1	—	1	1	1	1	1
Glycerin, Glycerol	2	1	1	—	1	1	1	1	—
Holdens 310A Tempering Bath	—	—	—	1	—	—	—	—	—
Houghtons Mar Tempering Salt	—	—	—	3	3	—	—	—	—
Hydrochloric Acid									
< 150°F	x	2	x	3	x	x	x	3	—
> 150°F	x	x	x	3	x	—	x	3	—
Hydrofluoric Acid									
Cold < 65%	3	2	x	x	x	x	x	2	—
> 65%	2	3	x	—	2	—	x	1	—
Hot < 65%	x	x	x	x	x	—	x	3	—
> 65%	2	x	x	—	3	—	x	1	—
Hydrogen Peroxide	x	2	1	2	x	x	1	2	1
Irdite 1-part and 5-parts									
water 200°F	—	1	—	—	—	—	—	—	—
Isoproponel	2	—	—	—	3	—	—	1	—
Kerosene	1	1	—	—	1	—	1	1	1
Kolene	—	—	—	1	—	—	—	—	—
Lacquer solvents	3	—	1	—	3	1	1	1	—
Lard	—	—	—	—	2	—	—	—	—
Linseed oil	1	1	1	—	1	—	1	1	1
Magnesium chloride	2	x	x	2	2	2	2	2	—
Magnesium hydroxide	x	—	x	1	1	1	1	1	—
Magnesium sulphate	1	—	2	—	1	1	1	1	—
Mercuric chloride	x	—	x	x	3	3	x	x	x
Mercury	x	—	x	—	1	1	1	1	1
Methyl alcohol, methanol	1	1	1	—	1	—	1	1	—
Methyl chloride	1	1	—	1	1	—	—	1	—
Mineral oils	1	1	1	—	1	—	1	1	1
Naphthalene	—	—	—	—	1	—	—	—	—
Nickel chloride	x	—	x	—	—	—	2	3	—
Nickel plating, bright	—	1	—	—	—	—	—	—	—
Nickel plating, dull	—	1	—	—	—	—	—	—	—
Nickel sulphate	x	—	x	—	—	—	1	3	x
Nitric acid,									
Crude	x	x	3	x	x	—	3	x	x
Concentrated	x	x	1	x	x	—	2	x	x
Diluted	x	x	x	x	x	—	1	x	x

Resistance Ratings: 1 = Good 2 = Fair 3 = Depends on Conditions x = Unsuitable

Technical

Suggested Sheath Materials (con't)

Compound	Copper	Lead	Aluminum	Nickel	Iron and Steel	Cast Iron NI Resist	300 Series Stainless	Monel	Inconel Incoloy
Nitrbenzene	2	—	—	—	1	—	1	—	—
Oakite No. 20	—	—	—	—	1	—	—	—	—
Oakite No. 23	—	—	—	—	1	—	—	—	—
Oakite No. 24	—	—	—	—	1	—	—	—	—
Oakite No. 30	—	—	—	—	1	—	—	—	—
Oakite No. 32	—	—	—	—	—	—	—	—	—
Oakite No. 33	—	—	—	—	—	1-347	—	—	—
Oakite No. 36	—	—	—	—	—	—	—	—	—
Oakite No. 51	—	—	—	—	1	—	—	—	—
Oakite No. 90 @ 180˚F	—	—	—	—	1	—	—	—	—
Oleic acid	x	x	1	1	3	3	1	1	1
Oxalic acid	3	x	1	—	3	3	3	1	—
Paraffin	—	—	—	—	1	—	—	—	—
Parkerizing	—	—	—	—	3	2	1	—	—
Perchlorethylene	—	—	—	—	—	—	1	—	—
Permachlor	—	—	—	—	—	—	1	—	—
Petroleum oils, crude									
<500˚F	3	3	1	3	1	1	1	3	—
>500˚F	x	x	1	x	1	1	1	x	—
<1000˚F	x	x	x	x	x	—	3	x	—
	—	—	—	—	—	—	1-347	—	—
Phenol 85%, 120˚F	—	—	—	1	3	—	1	—	—
Phosphoric acid									
Crude	x	3	x	x	3	—	3	x	—
Pure <45%	2	1	3	3	x	—	1	2	—
>45% Cold	2	1	x	3	x	—	1	2	—
>45% Hot	3	x	x	—	x	—	x-304	3	—
	—	—	—	—	—	—	3-316	—	—
Photo fixing bath	—	—	—	—	—	—	1	3	—
Picric acid water solution	x	x	x	x	3	—	1	3	—
Potassium chloride	1	1	3	1	1	1	1	1	—
Potassium cyanide	x	x	x	—	1	—	1	1	—
Potassium dichromate 208˚F	—	—	—	—	—	—	1-347	—	—
Potassium hydroxide	x	x	x	1	3	1	2	1	—
Potassium sulphate	1	1	1	1	1	1	2	1	—
Prestone 350˚F	—	—	—	—	1	—	—	1	—
R5 Bright Dip for copper polish @ 180˚F	—	—	—	—	—	—	1-316	—	—
Soap solutions	3	1	—	—	1	1	1	1	—
Sodium carbonate <20%	—	—	—	—	1	—	—	—	—
Sodium chloride	2	1	x	1	1	1	2-304	1	1
	—	—	—	—	—	—	1-316	—	—
Sodium cyanide	x	x	x	—	1	3	1-316	2	—
Sodium hydroxide	x	2	x	1	1	1	2	1	1
Sodium hypochlorite	3	x	x	3	x	3	x	3	—
Sodium nitrate	2	1	1	1	1	1	2-304	1	1
	—	—	—	—	—	—	1-316	—	—
Sodium peroxide	—	—	1	1	3	1	1	1	—
Sodium silicate	3	x	x	1	1	1	1-316	1	—
Sodium sulphate	1	1	3	1	1	1	1	1	1
Sodium sulphide	x	1	x	2	1	1	1	2	1
Soybean oil	—	—	—	—	—	—	1	—	—
Steam									
<500˚F	1	3	1	1	1	—	1	1	1
500-1000˚F	3	x	3	3	3	—	1	3	1
>1000˚F	x	—	x	x	x	—	1	x	1
Stearic acid	3	1	3	1	3	3	1	1	1

Resistance Ratings: 1 = Good 2 = Fair 3 = Depends on Conditions x = Unsuitable

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Technical

Suggested Sheath Materials (con't)

Compound	Copper	Lead	Aluminum	Nickel	Iron and Steel	Cast Iron NI Resist	300 Series Stainless	Monel	Inconel Incoloy
Sulphur	x	—	1	x	1	3	2	x	1
Sulphuric acid<10%									
Cold	3	1	3	3	x	—	2	3	—
Hot	x	1	3	x	x	—	2-316	3	—
	—	—	—	—	—	—	x-304	—	—
10-75% Cold	x	1	3	3	x	—	x-304	3	—
	—	—	—	—	—	—	2-316	—	—
Hot	x	1	x	x	x	—	x	3	—
75-95% Cold	x	1	3	3	3	—	1	3	—
Hot	x	1	x	x	2	—	x	3	—
Fuming	x	1	3	x	3	2	3-304	x	—
	—	—	—	—	—	—	2-316	—	—
Sulphurous acid	3	1	3	x	1	—	3-316	x	—
	—	—	—	—	—	—	x-304	—	—
Tannic acid	1	x	x	1	—	—	2	1	—
Tar	—	—	1	—	1	—	1	—	1
Tartaric acid	—	1	1	3	—	—	3-304	3	—
	—	—	—	—	—	—	1-316	—	—
Tetrachlorethylene	—	—	—	—	1	—	—	—	—
Thermoil Granodine™	—	—	—	—	2	—	—	—	—
Therminol™									
Fr. 1-8-12W/Sq.In.640˚F	—	—	—	—	1	—	—	—	—
Tin plating	—	—	—	1	—	—	—	—	—
Toluene	—	1	1	—	1	—	1	1	—
Triad solvent	—	—	—	—	3	—	—	—	—
Trichloroethylene	3	2	3	—	3	3	3	1	—
Turco No. 2623	—	—	—	—	1	—	—	—	—
Turpentine	3	1	1	—	3	1	1	1	—
Urea ammonia liquor 48˚F	—	—	—	—	1	—	—	—	—
Vegetable oil	—	—	—	—	—	—	1	—	—
Vinegar	—	—	3	—	3	—	2-304	1	—
	—	—	—	—	—	—	1-316	—	—
Water, acid mine									
containing oxidizing salts	3	3	3	3	x	3	1	x	—
no oxidizing salts	—	—	1	—	3	1	x	1	—
Water, fresh	1	1	1	—	3	1	1	1	1
Distilled, Lab grade	x	x	1	1	x	x	1	3	1
Return condensate	1	1	1	—	1	1	1	1	1
Water, sea water	3	1	x	—	3	1	2	1	2
Whiskey and wines	1	—	—	—	x	3	2-304	1	1
	—	—	—	—	—	—	1-316	—	—
X-ray solution	—	—	—	—	—	—	1	—	—
Zinc chloride	x	1	x	—	3	3	x	1	—
Zinc plating	—	—	—	—	1	—	—	—	—
Zinc sulphate	x	—	3	—	3	1	1	1	1

Resistance Ratings: 1 = Good 2 = Fair 3 = Depends on Conditions x = Unsuitable

Because so many Factors are beyond our Power to control we cannot be responsible for any electric immersion heater failure that can be attributed to corrosion. This is in view of any warranties, written or verbal, relative to heater performance in a corrosive environment.

Technical

Thermal Systems

Thermal Systems

The result obtained with a precision temperature controller, as with any tool, depend upon how skillfully it is used. Close temperature control can be maintained only if the thermal system is properly designed so that it responds quickly and accurately to operating conditions.

Thermal systems have four elements, all of which contribute to systems control performance. They are: 1. WORK (or load) — the material or product which must be maintained at a controlled temperature; 2. HEAT SOURCE — the device which delivers the heat used by the system, such as gas, oil, or electric heaters; 3. HEAT TRANSFER MEDIUM — the material which transmits the heat from the heat source to the work; 4. CONTROLLER — the instrument which controls the heat flow on the basis of the difference between sensed temperature and controller's set point.

In addition, careful consideration must be given to the physical make-up of the system. The proper location of heat sensor and work-load, a good selection of the heat transfer medium, and use of reliable components are all essential to the development of a **good thermal system.**

Although in practice, thermal systems are not purely steady or variable, they usually are predominantly one or the other.

For basic system design, the following rule of thumb will be helpful: where the heat demand is relatively steady, the sensing element of the controller should be placed **close** to the **heat source**; where the demand is largely variable, it should be near the **work area.** A complicated system may require several different sensing element locations before a suitable one is found. One should always remember, however that the element should be closer to the area where a temperature change must be sensed with minimum **thermal lag.** (Thermal lag is the delay in heat transfer from place to place in the thermal system).

The effect of various sensing element locations on the control of predominantly static or dynamic systems is clearly illustrated in **Fig. 1.**

Fig 2 applies to liquid and gas systems which require additional considerations. Because the heat demand is basically steady, the sensing element should normally be located close to and above the heat source to minimize system **bandwidth.** (Bandwidth is the total temperature variation above and below the average operating temperature measured at some point in the system).

Fig. 1

Poor Liquid Heating Control

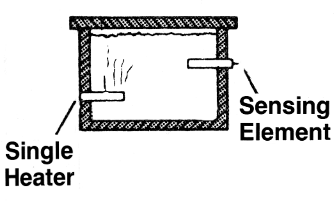


Fig. 2

Optimum Liquid Heating Control

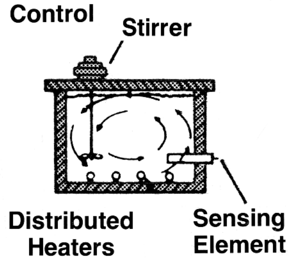
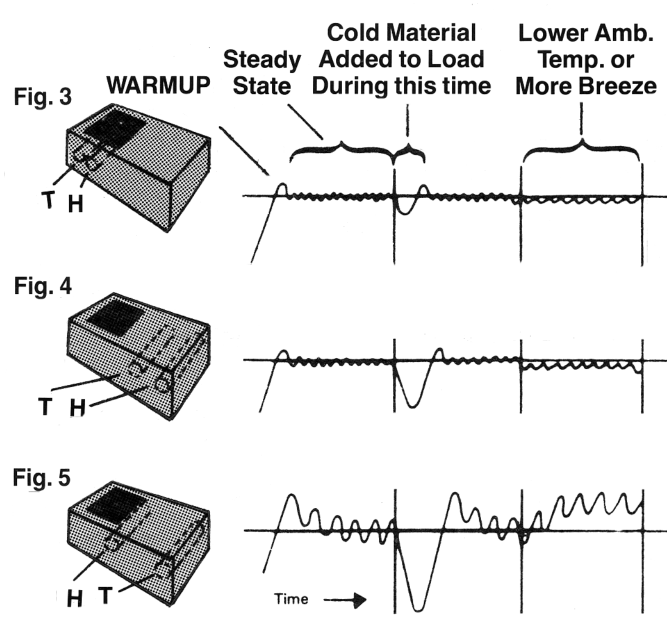


Fig. 3: Close grouping of heater, sensing element and work. Where this layout is feasible, it gives excellent control under most conditions and is desirable when the thermal load changes frequently. The heat transfer paths from he work and heater to the thermostat are short, so that thermal lag is slight. System inertia is low because of the small mass of heat transfer medium. Rapid cycling will hasten recovery of the system from thermal upsets.

Fig. 4: Thermostat between heater and load. This is a "general purpose" arrangement for installations where the heat demand my be alternately steady and variable. By being midway between them, the sensing element can respond to changes at the work and the heater without excessive lag in either instance.

Fig. 5: Heater at load, thermostat distant. This arrangement practically guarantees poor control. The sensing element is too far from either the heater or the load to respond to temperature changes from either one without excessive lag. The arrangement is presented primarily to emphasize that, unless you are careful in placing the element, the controller may find it impossible to maintain even fair control.

Temperature of the Load



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Technical

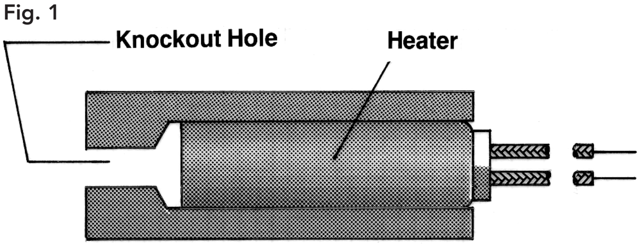
Installation

Cartridge/Superwatt Heater

The most important thing to remember about the installation of a cartridge heater is that the cartridge should be a close fit in the hole into which it is inserted. This results in fast heat transfer to the surrounding material and aids in keeping the element as cool as possible for long life.

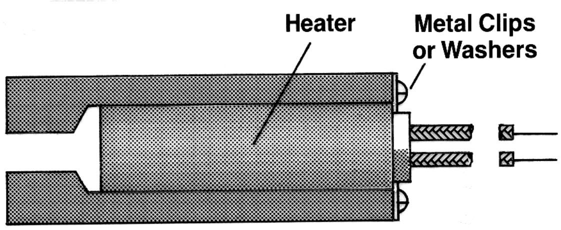
Cartridge units are made with special tubing which is a few thousandths undersize to insure a free fit for easy installation. To install cartridge heaters, drill and ream holes to proper length and the nominal diameter plus .001″ maximum minus .000″ of the cartridge heater (3/16″, 3/8″, 1/2″, 5/8″, etc.) For example, a 1/2″ cartridge heater actually measures .497″ diameter. A hole should be drilled and reamed to 1/2″ diameter + .001″ – .000″ to insure proper fit. Always finish-ream drilled or cast holes to insure smooth, uniform metal to metal contact. A knockout hole (Fig. 1) should be provided if possible to facilitate cartridge removal. The receptacle hole should be free from oil before cartridge installation to avoid contamination and shorter heater life.

Fig. 1



If there is danger of a heater slipping from its hole, it should be held in place with metal clips (Fig 2).

Fig. 2



Do not use set screws to hold cartridge heaters in place.

Lead wires, especially when the heater is used in a moving die or platen, should be supported (Fig. 3) or protected with a lead spring (Fig. 4) See SF5 on page 22.

Fig. 3

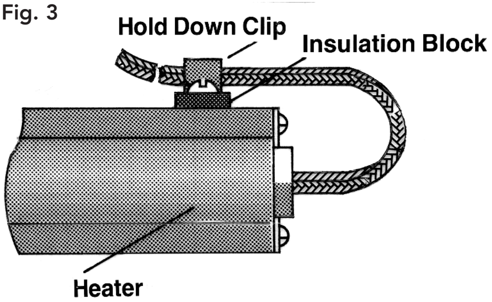
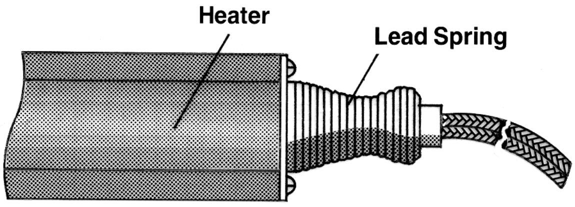
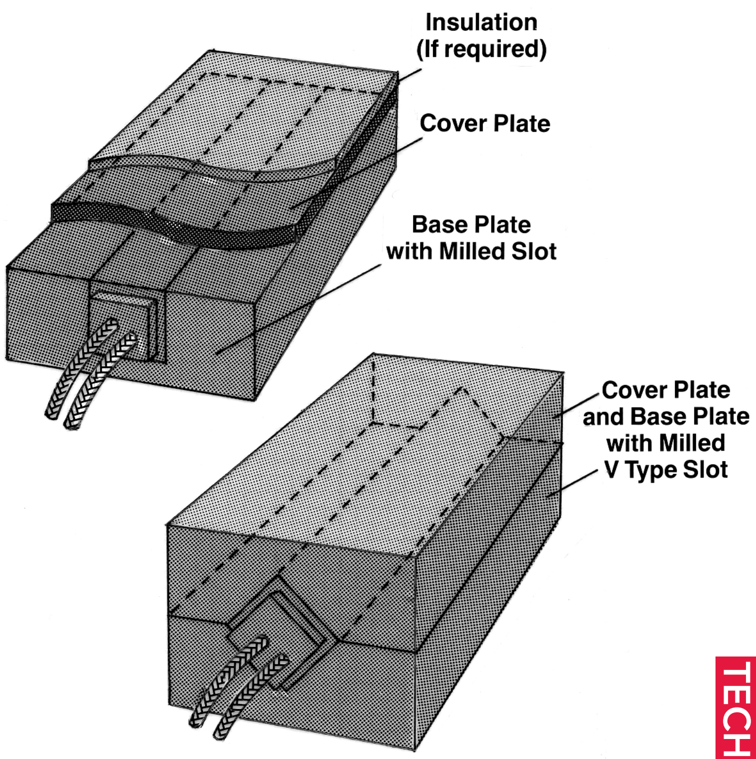


Fig. 4



On many applications plastic material, machine oil, and/or Moisture may be present. Cycling of a cartridge heater causes these materials to be absorbed. Heaters, therefore, should be carefully selected for these applications utilizing protective conduit for leads and if necessary, hermetic sealing for long heater life. Theses extras are available form the factory at a nominal additional charge (See pages 22-27).

Square/Rectangular Heaters



Technical

Installation

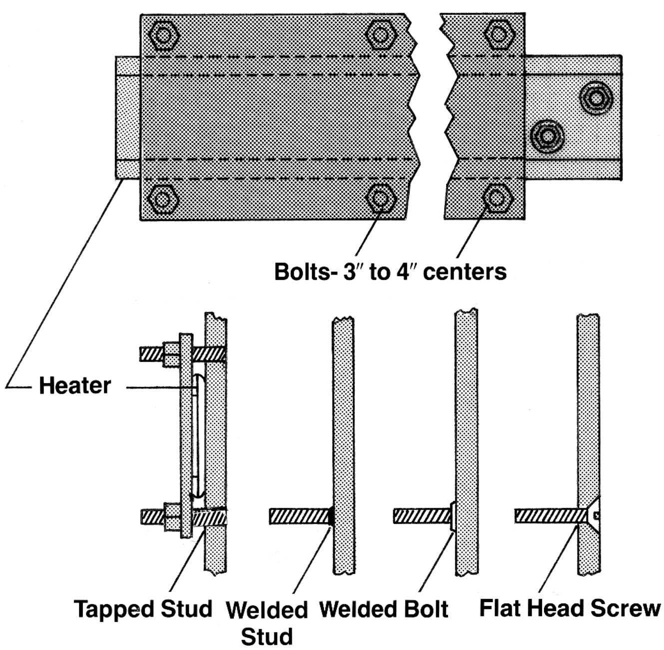
Strip Heaters

Strip heaters are designed for contact heating and therefore must be tightly clamped to the object to be heated to keep the heater from expanding away from the surface. Care should be taken to see that the heaters are placed squarely against the surface to be heated. Air gaps between the heater surface and the heater will result in poor heat transfer and shorter heater life.

Mounting

Strip Heaters should be firmly clamped with heavy metal strips. These should be arranged across the heater (or heaters) so that there will be bolts on each side of the heater. These bolts should be spaced approximately 3 to 4 inches apart (Fig 1). Use heaters with mounting holes only in air-heating applications, and only when necessary. The reason for this is that the heater heats up, it expands away from the surface to be heated causing air gaps and poor heat transfer.

Fig. 1



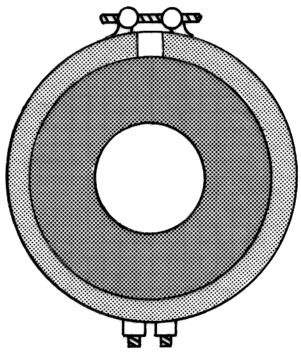
Using Mounting Holes

When strip heaters are fastened to the object to be heated utilizing mounting holes or used as an air heater, the screws that are used for mounting should be provided with lock washers and should not be drawn up tightly because the strip heater should be free to expand. Unit lengths beyond 24" may require special mounting to allow for expansion. Consult factory.

Band Heaters

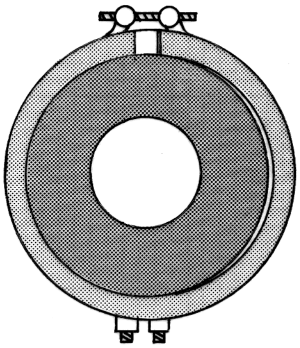
Band heaters should be clamped securely to the object to be heated. They should be mounted so that they are not tilted in assembly, but are placed squarely against the surface to be heated. Air gaps as a result of poor clamping, result in poor heat transfer, excessive heat loss, and short heater life. (Fig 2.)
Band heaters should be clamped securely and squarely to the surface to be heated, run at operating temperature and retightened to correct for the effects of expansion.

Fig. 1-Good



No Air Gap

Fig. 2-Poor



Air Gap

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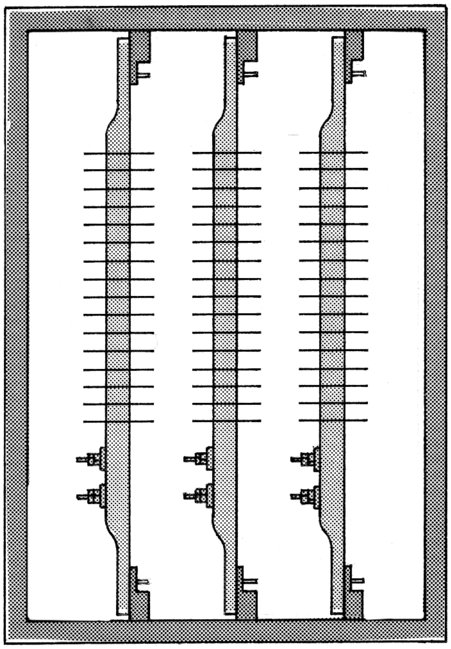
Installation

Installation in air Ducts: Finned strips and duct heater

1. Locate regulating thermostat on downstream side of heater near the top of the duct.

2. Mount heater with terminals at the duct bottom to prevent overheating.

3. As a safety feature in the event of abnormal temperatures or safety requirements, it is suggested to use a thermal cutout in conjunction with thermostatic control, or by itself when no thermostat is used.



Oven Heating (Stainless Steel Strip Heaters):

1. When mounting strip heaters in an oven, allow for expansion and contraction by loosely bolting one mounting tab and securing the other tab firmly.
2. Mount the strip with the terminals at the bottom or cooler part of the oven.
3. In a forced air system, the width of the strip should be parallel to the direction of the air flow.
4. Mount strips on edge in horizontal installation across the bottom and along the sides of the oven, allowing 3" minimum air space between the heaters and the bottom of the ovens wall to allow for proper circulation of heated air. For large ovens, allow greater clearance areas.
5. In horizontal mounting, install a protective screen or grill above the strips at the bottom of the oven.
6. Support strips on 36" centers to prevent sagging.

Technical

Ohms Law and Wiring Diagrams

Ohms Law

E = Volts, W = Watts, I = Amperes, R = Ohms

To Determine Watts (W):

$W = EI \quad W = I^2R \quad W = \frac{E^2}{R}$

To Determine Volts (E):

$E = \sqrt{WR} \quad E = \frac{W}{I} \quad E = IR$

To Determine Ohms (R):

$R = \frac{W}{I^2} \quad R = \frac{E^2}{W} \quad R = \frac{E}{I}$

To Determine Amperes (I):

$I = \frac{E}{R} \quad I = \frac{W}{E} \quad I = \sqrt{\frac{W}{R}}$

Variation of Wattage with Voltage Change

$$W^2 = W^1\left(\frac{E^2}{E^1}\right)^2$$

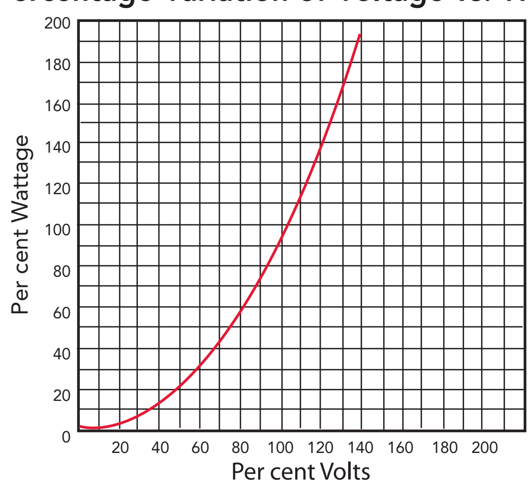
E^2 = New Voltage

E^1 = Original Heater Voltage

W^2 = New Wattage

W^1 = Original Wattage

Percentage Variation of Voltage vs. Wattage



Wiring Diagrams

Fig. 1: 120V or 240V single phase two or more heaters in parallel with thermostat rating adequate for line voltage and current

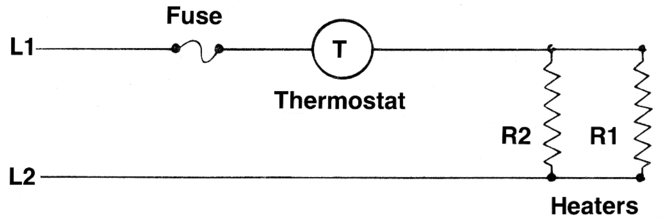


Fig. 2: 240V or 480V three phase deltas (three phase wye) with thermostat adequate for line voltage and current

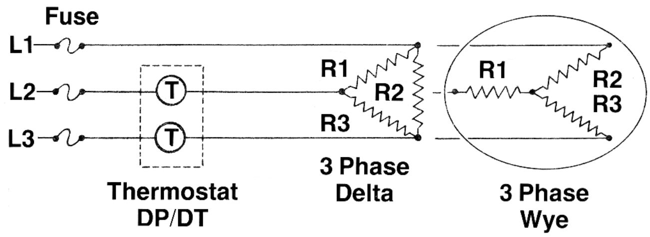


Fig. 3: 120V, 240V, 480V single phase two or more heaters in series with thermostat rating adequate for line voltage and current

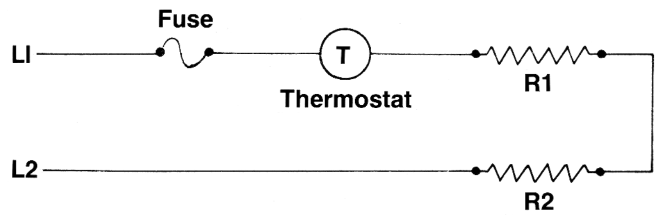
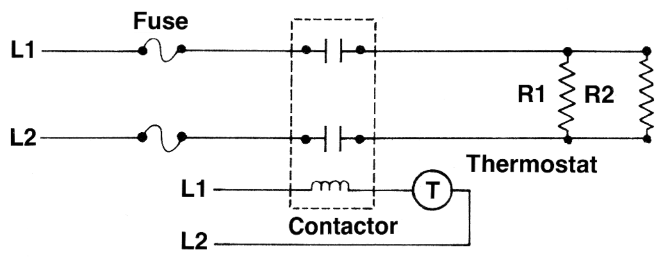


Fig. 4: Two or more heaters wired in parallel with thermostat not adequate for line current (or voltage)



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Technical

Wiring Diagrams (con't)

Wiring Diagrams

Fig. 5: Two or more heaters wired in parallel in each leg of a 3 phase delta circuit. Thermostat rating not adequate for line current or voltage.

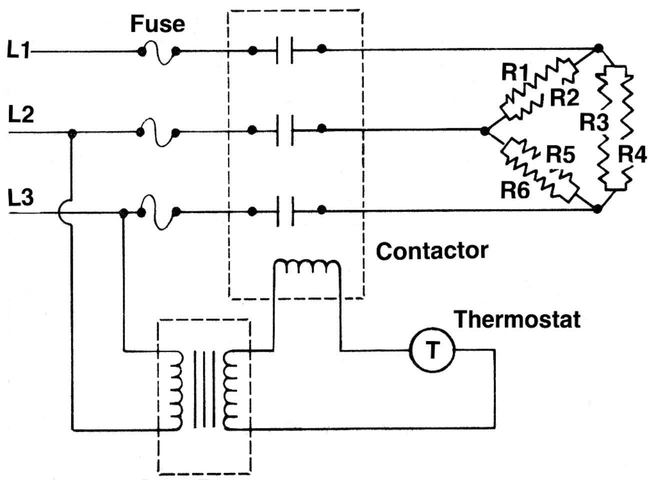


Fig. 6: Single phase or three phase AC only with properly rated SCR power control with thermocouple input temperature controller.

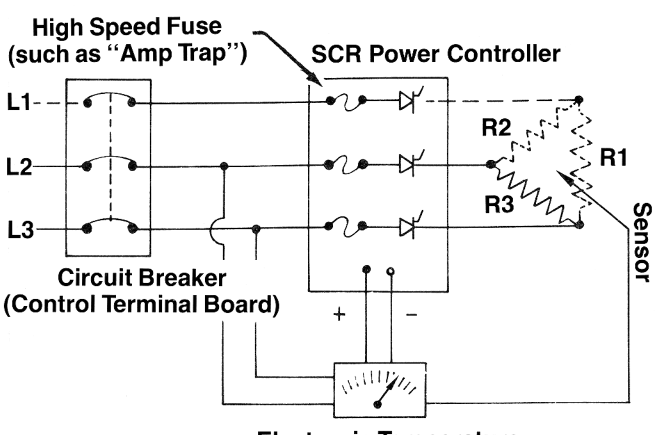


Fig. 7: Special circuit for switching from parallel operation in a 3 phase delta circuit to a pair in series operation, with both contractors closed. Circuit operates at full power at element rated voltage.

With either #1 or #2 contractor open, circuit operates at ¼ power, with voltage across each element at ½ rated voltage. Heater element wattages must be equal to give balanced 3 phase circuit for both circuits.

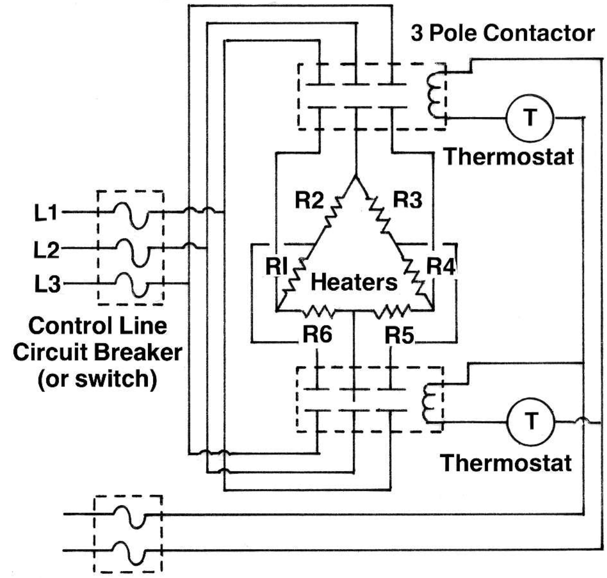
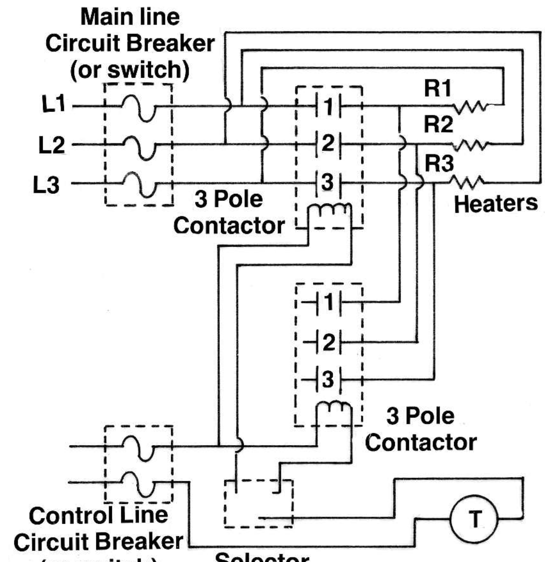


Fig. 8: Circuit for switching from a 3 phase delta circuit for full power to a 3 phase wye circuit at ⅓ power. Watt density of heaters is also dropped to ⅓ of original.



TECHNICAL

Technical

Mathematical Conversions

Inches to Millimeters

To convert to millimeters: Multiply Inches x 25.4

To convert to inches: Multiply millimeters x .03937

Inches			Inches			Inches			Inches		
Fraction	Decimals	Millimeters	Fraction	Decimals	Millimeters	Fraction	Decimals	Millimeters	Fraction	Decimals	Millimeters
	.00004	.001		.13780	3.5	19/32"	.59375	15.0812		1.57480	40
	.00039	.01	9/64"	.14063	3.5719		.600	15.24		1.65354	42
	.00079	.02		.150	3.810	39/64"	.60938	15.4781	1 3/4"	1.750	44.45
	.001	.025	5/32"	.15625	3.9688		.61024	15.5		1.77170	45
	.00118	.03		.15748	4	5/8"	.6250	15.875		1.88976	48
	.00157	.04	11/64"	.17188	4.3656		.62992	16		1.96850	50
	.00197	.05		.1750	4.445	41/64"	.64063	16.2719	2"	2.000	50.8
	.002	.051		.17717	4.5		.64961	16.5		2.04724	55
	.00236	.06	3/16"	.18750	4.7625		.650	16.51		2.16540	53
	.00276	.07		.19685	5	21/32"	.65625	16.6688		2.20472	56
	.003	.0762		.20	5.08		.66929	17	2 1/4"	2.250	57.15
	.00315	.08	13/64"	.20313	5.1594	43/64"	.67188	17.0656		2.36220	60
	.00354	.09		.21654	5.5	11/16"	.68750	17.4625	2 1/2"	2.500	63.5
	.00394	.1	7/32"	.21875	5.5562		.68898	17.5		2.51968	64
	.004	.1016		.2250	5.715		.700	17.78	2 3/4"	2.750	69.85
	.005	.1270	15/64"	.23438	5.9531	45/64"	.70313	17.8594		2.83464	72
	.006	.1524		.23622	6		.70866	18		2.95280	75
	.007	.1778	1/4"	.250	6.35	23/32"	.71875	18.2562	3"	3.000	76.2
	.00787	.2		.25591	6.5		.72835	18.5		3.14960	80
	.008	.2032	17/64"	.26563	6.7469	47/64"	.73438	18.6531	3 1/2"	3.500	88.9
	.009	.2286		.275	6.985		.74803	19		3.54330	90
	.00984	.25		.27559	7	3/4"	.750	19.050		3.9370	100
	.01	.254	9/32"	.28125	7.1438	49/64"	.76563	19.4469	4"	4.000	101.6
	.01181	.3		.29528	7.5		.76772	19.5		4.33070	110
1/64"	.01563	.3969	19/64"	.29688	7.5406	25/32"	.78125	19.8438	4 1/2"	4.500	114.3
	.01575	.4		.30	7.62		.78740	20		4.72440	120
	.01969	.5	5/16"	.3125	7.9375	51/64"	.79688	20.2406	5"	5.000	127
	.02	.508		.31496	8		.800	20.320		5.51180	140
	.02362	.6	21/64"	.32813	8.3344		.80709	20.5		5.90550	150
	.025	.635		.33465	8.5	13/16"	.81250	20.6375	6"	6.000	152.4
	.02756	.7	11/32"	.34375	8.7312		.82677	21		6.29920	160
	.0295	.75		.350	8.89	53/64"	.82813	21.0344		7.08660	180
	.03	.762		.35433	9	27/32"	.84375	21.4312		7.8740	200
1/32"	.03125	.7938	23/64"	.35938	9.1281		.84646	21.5	8"	8.000	203.2
	.0315	.8		.37402	9.5		.850	21.590		8.66140	220
	.03543	.9	3/8"	.375	9.526	55/64"	.85938	21.8281		9.44880	240
	.03937	1	25/64"	.39063	9.9219		.86614	22		9.84250	250
	.04	1.016		.39370	10	7/8"	.875	22.225	10"	10.000	254
3/64"	.04687	1.191		.400	10.16		.88583	22.5		10.23620	260
	.04724	1.2	13/32"	.40625	10.3188	57/64"	.89063	22.6219		11.02360	280
	.05	1.27		.41339	10.5		.900	22.860		11.8110	300
	.05512	1.4	27/64"	.42188	10.7156		.90551	23	12 (1 ft.)"	12.000	304.8
	.05906	1.5		.43307	11	29/32"	.90625	23.0188		12.59840	320
	.06	1.524	7/16"	.43750	11.1125	59/64"	.92188	23.4156		13.38580	340
1/16"	.06250	1.5875		.450	11.430		.92520	23.5		13.77950	350
	.06299	1.6		.45276	11.5	15/16"	.93750	23.8125		14.17320	360
	.06693	1.7	29/64"	.45313	11.5094		.94488	24		14.96090	380
	.07	1.778	15/32"	.46875	11.9062		.950	24.130		15.7480	400
	.07087	1.8		.47244	12	61/64"	.95313	24.2094	16"	16.000	406.4
	.075	1.905	31/64"	.48438	12.3031		.96457	24.5		17.71650	450
5/64"	.07813	1.9844		.49213	12.5	31/32"	.96875	24.6062		19.6850	500
	.07874	2	1/2"	.50	12.7		.98425	25	20"	20.000	508
	.08	2.032		.51181	13	63/64"	.98438	25.0031		23.6220	600
	.08661	2.2	33/64"	.51563	13.0969	1	1.00000	25.4	2 Feet	24.000	609.6
	.09	2.286	17/32"	.53125	13.4938		1.06229	27	3 Feet	36.000	914.4
	.09055	2.3		.53150	13.5		1.10240	28		39.370	1 Meter
3/32"	.09375	2.3812	35/64"	.54688	13.8906		1.18110	30	4 Feet	48.000	1,219.2
	.09843	2.5		.550	13.970	1 1/4"	1.250	31.75	5 Feet	60.000	1,524.0
	.1	2.54		.55118	14		1.29921	33	6 Feet	72.000	1,828.8
	.10236	2.6	9/16"	.56250	14.2875		1.3780	35		78.740	2 Meters
7/64"	.10937	2.7781		.57087	14.5		1.41732	36	8 Feet	96.000	2,438.4
	.11811	3	37/64"	.57813	14.6844	1 1/2"	1.500	38.1		118.110	3 Meters
1/8"	.1250	3.175		.59055	15		1.53543	39		196.850	5 Meters

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Technical

Mathematical Conversions

Circumferences and Areas of Circles.

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
1/64	0.0491	0.0002	2	6.2832	3.1416	5	15.7080	19.635
1/32	0.0982	0.0008	2 1/16	6.4795	3.3410	5 1/16	15.9043	20.129
1/16	0.1963	0.0031	2 1/8	6.6759	3.5466	5 1/8	16.1007	20.629
8/32	0.2945	0.0069	2 3/16	6.8722	3.7583	5 3/16	16.2970	21.135
1/8	0.3927	0.0123	2 1/4	7.0686	3.9761	5 1/4	16.4934	21.648
5/32	0.4909	0.0192	2 5/16	7.2649	4.2000	5 5/16	16.6987	22.166
3/16	0.5890	0.0276	2 3/8	7.4613	4.4301	5 3/8	16.8861	22.691
7/32	0.6872	0.0376	2 7/16	7.6576	4.6664	5 7/16	17.0824	23.221
1/4	0.7854	0.0491	2 1/2	7.8540	4.9087	5 1/2	17.2788	23.758
9/32	0.8836	0.0621	2 9/16	8.0503	5.1572	5 9/16	17.4751	24.301
5/16	0.9817	0.0767	2 5/8	8.2467	5.4119	5 5/8	17.6715	24.850
11/32	1.0799	0.0928	2 11/16	8.4430	5.6727	5 11/16	17.8678	25.406
3/8	1.1781	0.1104	2 3/4	8.6394	5.9396	5 3/4	18.0642	25.967
13/32	1.2763	0.1296	2 13/16	8.8357	6.2126	5 13/16	18.2605	26.535
7/16	1.3744	0.1503	2 7/8	9.0321	6.4918	5 7/8	18.4569	27.109
15/32	1.4726	0.1726	2 15/16	9.2284	6.7771	5 15/16	18.6532	27.688
1/2	1.5708	0.1963	3	9.4248	7.0686	6	18.8496	28.274
17/32	1.6690	0.2217	3 1/16	9.6211	7.3662	6 1/8	19.2423	29.465
9/16	1.7671	0.2485	3 1/8	9.8175	7.6699	6 1/4	19.6350	30.680
19/32	1.8653	0.2769	3 3/16	10.0138	7.9798	6 3/8	20.0277	31.919
5/8	1.9635	0.3068	3 1/4	10.2102	8.2958	6 1/2	20.4204	33.183
21/32	2.0617	0.3382	3 5/16	10.4065	8.6179	6 5/8	20.8131	34.472
11/16	2.1598	0.3712	3 3/8	10.6029	8.9462	6 3/4	21.2058	35.785
23/32	2.2580	0.4057	3 7/16	10.7992	9.2806	6 7/8	21.5984	37.122
3/4	2.3562	0.4418	3 1/2	10.9956	9.6211	7	21.9911	38.485
25/32	2.4544	0.4794	3 9/16	11.1919	9.9678	7 1/8	22.3838	39.871
13/16	2.5525	0.5185	3 5/8	11.3883	10.321	7 1/4	22.7765	41.282
27/32	2.6507	0.5591	3 11/16	11.5846	10.680	7 3/8	23.1692	42.718
7/8	2.7489	0.6013	3 3/4	11.7810	11.045	7 1/2	23.5619	44.179
29/32	2.8471	0.6450	3 13/16	11.9773	11.416	7 5/8	23.9546	45.664
15/16	2.9452	0.6903	3 7/8	12.1737	11.793	7 3/4	24.3473	47.173
31/32	3.0434	0.7371	3 15/16	12.3700	12.177	7 7/8	24.7400	48.707
1	3.1416	0.7854	4	12.5664	12.566	8	25.1327	50.265
1 1/16	3.3379	0.8866	4 1/16	12.7627	12.962	8 1/8	25.5254	51.849
1 1/8	3.5343	0.9940	4 1/8	12.9591	13.364	8 1/4	25.9181	53.456
1 3/16	3.7306	1.1075	4 3/16	13.1554	13.772	8 3/8	26.3108	55.088
1 1/4	3.9270	1.2272	4 1/4	13.3518	14.186	8 1/2	26.7035	56.745
1 5/16	4.1233	1.3530	4 5/16	13.5481	14.607	8 5/8	27.0962	58.426
1 3/8	4.3197	1.4849	4 3/8	13.7445	15.033	8 3/4	27.4889	60.132
1 7/16	4.5160	1.6230	4 7/16	13.9408	15.466	8 7/8	27.8816	61.862
1 1/2	4.7124	1.7671	4 1/2	14.1372	15.904	9	28.2743	63.617
1 9/16	4.9087	1.9175	4 9/16	14.3335	16.349	9 1/8	28.6670	65.397
1 5/8	5.1051	2.0739	4 5/8	14.5299	16.800	9 1/4	29.0597	67.201
1 11/16	5.3014	2.2365	4 11/16	14.7262	17.257	9 3/8	29.4524	69.029
1 3/4	5.4978	2.4053	4 3/4	14.9226	17.721	9 1/2	29.8451	70.882
1 13/16	5.6941	2.5802	4 13/16	15.1189	18.190	9 5/8	30.2378	72.760
1 7/8	5.8905	2.7612	4 7/8	15.3153	18.665	9 3/4	30.6305	74.662
1 15/16	6.0868	2.9483	4 15/16	15.5116	19.147	9 7/8	31.0232	76.589

Technical

Mathematical Conversions

Areas and Volume

Circles

To find circumference - Multiply the diameter by 3.1416; or, divide diameter by 0.3183.

To find diameter - Multiply the circumference by 0.3183; or, divide circumference by 3.1416.

To find radius - Multiply the circumference by 0.15915; or divide circumference by 6.28318; or, divide diameter by 2.

To find the side of a square to be inscribed in a circle - Multiply diameter by 0.7071; or, multiply the circumference by 0.2251; or, divide the circumference by 4.4428.

To find the side of a square to equal the area of a circle - Multiply the diameter by 0.8862; or, divide diameter by 1,1284; or, multiply the circumference by 0.2821; or, divide circumference by 3.545.

To find the area of a circle - Multiply the circumference by one-quarter of the diameter; or, multiply the square of the diameter by 0.7854; or, multiply the square of the circumference by 0.7958; or, multiply the square of one-half the diameter by 3.1416.

Doubling the diameter of a circle increases the area 4 times.

Squares

A side multiplied by 1.412 = the diameter of a circle which will circumscribe circle.

A side multiplied by 4.443 = the circumference of its circumscribing the given square.

A side multiplied by 1.1284 = the diameter of a circle equal in area to that given square.

A side multiplied by 3.545 = circumference of an equal circle.
To find diagonal of a square - multiply side by 1.4142.

Measurements From Other Geometrical Forms

To find the area of a ellipse - multiply the product of its axes by 0.7854; or, multiply the product of its semi-axes by 3.14159.

Contents of a cylinder = area of end X length

Contents of a wedge = area of triangular base X altitude.

Surface of a cylinder = length X circumference plus area of both ends.

Surface of a sphere = diameter squared X 3.1416; or. diameter X circumference.

Contents of a sphere = diameter cubed X 0.5236

Contents of a pyramid or cone, right or oblique, regular or irregular = area of base X one-third of the altitude.

Area of a triangle = base X one-half the altitude.

Area of parallelogram = base X altitude.

Area of a trapezoid = altitude X one-half the sum of parallel sides.

To find distance across the corners of hexagons - multiply the distance across the flats by 1.1547.

Conversion Factors

1 gal. water = 8.3 lb.
1 hp = 745.2 watts
1 BTU = .252 kg calories = 0.2930 watt hours
1 BTU per lb. = 1.8 cal per gram.
1 kw-hr = 3412 BTU per hour
1 kw-hr will evaporate 3.5 lb. of water 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 lites = .1337 cu.ft.
1 cu.ft. = 1728 cu.in = .03704 cu.yd. = 7.481 gal.

To find the equivalent, in terms of a unit in the customary system, of a given number of metric units, multiply or divide their number (as indicated) by the factor shown. Thus: 10 millimeters are equivalent to 10 x 0.03937 inches or to 10 ÷ 25.4 inches.)

Millimeters x .03937 = inches; or, ÷ 25.4 inches
Centimeters x .3937 = inches; or, ÷ 2.54 inches
Meters x 39.37 = inches
Meters x 3.28 = feet
Kilometers x 3280.8 = feet
Square meters x 10.764 = square feet
Cubic centimeters ÷ 16.387 = cubic inches
Cubic centimeters ÷ 3.70 = fluid drams (U.S.P.)
Cubic centimeters ÷ 29.57 = fluid ounces (U.S.P.)
Cubic centimeters x 3.531 x 10^{-5} = cubic feet
Cubic meters x 35.314 = cubic feet
Liters x 61.025 = cubic inches
Liters x 33.81 = fluid ounces (U.S.P.)
Liters x .2642 = gallons (231 cubic inches)
Liters÷ 3.785 = gallons (231 cubic inches)
Liters÷ 28.317 = cubic feet
Grams x 15.432 = grains
Grams (water) ÷ 29.57 = fluid ounces
Grams ÷ 28.35 = ounces avoirdupois
Grams per cubic centimeter ÷ 27.7 = lbs. per cubic inch
Kilograms x 2.2046 = pounds
Kilograms x 35.3 - ounces avoirdupois
Kilograms per square centimeter x 14.223 = pounds per square inch
Kilo per meter x .672 = pounds per foot
Kilo per cubic meter x .062 = pounds per foot
Kilowatts x 1.34 = h. p. (33,000 foot pounds per minute)
Watts÷ 746 = horse power
Centigrade x 1.8 + 32 = degrees fahrenheit

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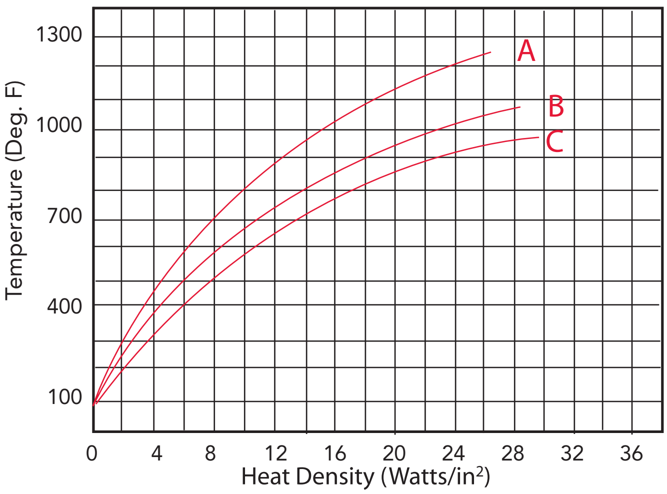
Technical

Temperature Conversions

Sheath Temperatures vs. Watt Density of Electric Heaters in Air



A: Sheath temperature of Cartridge, Superwatt, and Magnesium Oxide Stainless Steel Strip Heaters.
B: Sheath temperature of Mica Strip Band, and Rectangular Ceramic Heaters.
C: Sheath temperature of Round Ceramic Heaters.

High Temperature Judged by color

Degrees Centigrade	Degrees Fahrenheit	High Temperatures Judged by Color
400	752	Red heat visible in the dark
474	885	Red heat visible in the twilight
525	975	Red heat visible in the daylight
531	1077	Red heat visible in the sunlight
700	1292	Dark red
800	1472	Dull cherry red
900	1652	Cherry red
1000	1832	Bright cherry red
1100	2012	Orange-red
1200	2192	Orange-yellow
1300	2372	Yellow-white
1400	2552	White welding heat
1500	2732	Brilliant White
1600	2912	Dazzling white (bluish white)

Centigrade to Fahrenheit

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
-50°	-58°	75°	167°	200°	392°	325°	617°
-45°	-49°	80°	176°	205°	401°	330°	626°
-40°	-40°	85°	185°	210°	410°	335°	635°
-35°	-31°	90°	194°	215°	419°	340°	644°
-30°	-22°	95°	203°	220°	428°	345°	653°
-25°	-13°	100°	212°	225°	437°	350°	662°
-20°	-4°	105°	221°	230°	446°	355°	671°
-15°	-5°	110°	230°	235°	455°	360°	680°
-10°	14°	115°	239°	240°	464°	365°	689°
-5°	23°	120°	248°	245°	473°	370°	698°
0°	32°	125°	257°	250°	482°	375°	707°
5°	41°	130°	266°	255°	491°	380°	716°
10°	50°	135°	275°	260°	500°	385°	725°
15°	59°	140°	284°	265°	509°	390°	734°
20°	68°	145°	293°	270°	518°	395°	743°
25°	77°	150°	302°	275°	527°	400°	752°
30°	86°	155°	311°	280°	536°	405°	761°
35°	95°	160°	320°	285°	545°	410°	770°
40°	104°	165°	329°	290°	554°	415°	779°
45°	113°	170°	338°	295°	563°	420°	788°
50°	122°	175°	347°	300°	572°	425°	797°
55°	131°	180°	356°	305°	581°	430°	806°
60°	140°	185°	365°	310°	590°	435°	815°
65°	149°	190°	374°	315°	599°	440°	824°
70°	158°	195°	383°	320°	608°	445°	833°

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
450°	842°	575°	1067°	700°	1292°	825°	1517°
455°	851°	580°	1076°	705°	1301°	830°	1526°
460°	860°	585°	1085°	710°	1310°	835°	1535°
465°	869°	590°	1094°	715°	1319°	840°	1544°
470°	878°	595°	1103°	720°	1328°	845°	1553°
475°	887°	600°	1112°	725°	1337°	850°	1562°
480°	896°	605°	1121°	730°	1346°	855°	1571°
485°	905°	610°	1130°	735°	1355°	860°	1580°
490°	914°	615°	1139°	740°	1364°	865°	1589°
495°	923°	620°	1148°	745°	1373°	870°	1598°
500°	932°	625°	1157°	750°	1382°	875°	1607°
505°	941°	630°	1166°	755°	1391°	880°	1616°
510°	950°	635°	1175°	760°	1400°	885°	1625°
515°	959°	640°	1184°	765°	1409°	890°	1634°
520°	968°	645°	1193°	770°	1418°	895°	1643°
525°	977°	650°	1202°	775°	1427°	900°	1652°
530°	986°	655°	1211°	780°	1436°	905°	1661°
535°	995°	660°	1220°	785°	1445°	910°	1670°
540°	1004°	665°	1229°	790°	1454°	915°	1679°
545°	1013°	670°	1238°	795°	1463°	920°	1688°
550°	1022°	675°	1247°	800°	1472°	925°	1697°
555°	1031°	680°	1256°	805°	1481°	930°	1706°
560°	1040°	685°	1265°	810°	1490°	935°	1715°
565°	1049°	690°	1274°	815°	1499°	940°	1724°
570°	1058°	695°	1283°	820°	1508°	945°	1733°

Table of Values for Interpolation in Above Chart

1°C = 1.8°F	4°C = 7.2°F	7°C = 12.6°F
2°C = 3.6°F	5°C = 9.0°F	8°C = 14.4°F
3°C = 5.4°F	6°C = 10.8°F	9°C = 16.2°F
1°F = 0.55°C	4°F = 2.22°C	7°F = 3.88°C
2°F = 1.11°C	5°F = 2.77°C	8°F = 4.44°C
3°F = 1.66°C	6°F = 3.33°C	9°F = 5.00°C

HOTWATT
HEATERS FOR EVERY APPLICATION

Technical

Empirical Guideline for Cartridge Heater Life

1. Record block operating temperature 1.________________________
2. Determine heater density-watts/square inch__________________________
3. Determine heater fit in block_____________________
4. From Chart A determine the delta T (Temperature drop) across block hole. 4.________________________
5. From Chart B determine the heater internal delta T (Temperature drop) 5.________________________
6. Add steps 1, 4 and 5 to determine approximate heater internal wire temp.
7. Figure estimated heater life from internal wire temperature based on the following table:

Internal Wire temp.	Approximate Life
1200˚ F or less	years
1500˚F	2 years
1600˚F	1 year
1700˚F	3 months
1800˚F	20 days
1900˚F	Less than 100 hours

Chart "A"

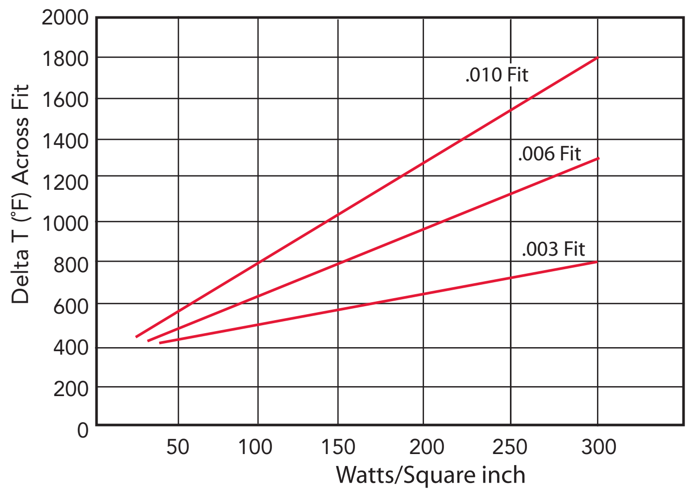
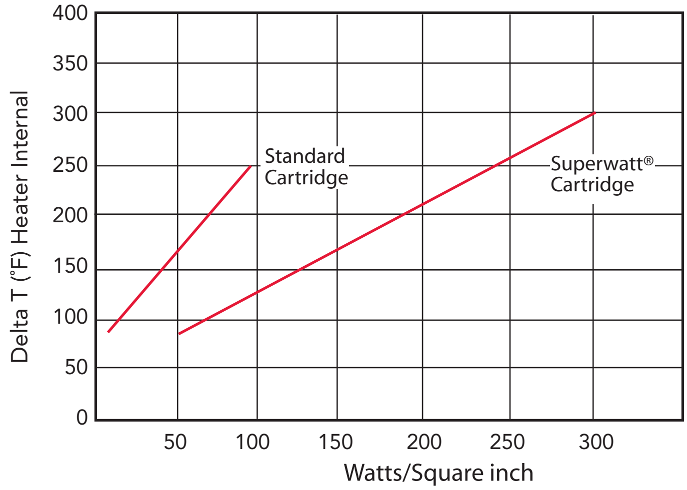


Chart "B"



TECHNICAL

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Technical

Wire, Cable and Current Capacities

Guide to High Temperature Wire and Cable

Common Wire and Cable Abbreviations

AWM – Appliance Wiring Material.

MGT – Stranded nickel conductor, mica, glass, and teflon - 450°C

MTW – Thermoplastic insulated machine tool wire.

SF – Silicone rubber insulated fixture wire, solid or 7/strand conductor, 200°C.

SFF – Same as SF, except flexible stranding 150°C.

SPT-1 – Thermoplastic 300volt two conductor light cord 300 volt.

-2 – Same only heavier construction

-3 – Same only still heavier construction (refrigerators/room air conditioners)

TBS – Switchboard wire, thermoplastic insulation, flameproof cotton braid, 600 Volt, 90°C.

TEW – CSA type appliance wire solid or stranded plastic insulated, 600 Volt, 150°C.

TF – Thermoplastic solid or 7/strand fixture wire 60°C.

TFF – Same as TF only flexible stranding 60°C

TGS – Solid or flexible copper, nickel-clad iron or copper, or nickel conductor. Teflon tape, silicone glass braid, 600 Volt, 250°C.

TGGT – Stranded nickel conductor, teflon, glass, teflon-250°C.

Approximate Current Carrying Capacities For Fiberglass Insulated Copper, Nickel Clad Copper, and Nickel (Grade D) Based on Ambient Temperature or 86°F.

Conductor Size (AWG)	Copper	Ni-Clad Copper	Nickel
24	7.5	5.3	3.1
22	10	7.0	4.1
20	13	9.1	5.4
18	17	11.9	7.1
16	22	15.4	9.2
14	30	21.0	12.5
12	40	28	16.8
10	50	35	21.0
8	65	45.5	27.0
6	85	59.5	36.0
4	115	80.5	48.0
3	131	91.7	55.0
2	147	103.0	62.0
1	172	120.4	72.0

Approximate Current Carrying Capacities of Copper Conductors in Amperes (not more than three conductors in cable)

Based on Ambient Temperature of 30°C

Size (AWG)	Rubber Type R Type RW type RU	Rubber Type RII	Thermoplastic Type I Type IW
14	15	15	15
12	20	20	20
10	30	30	30
8	40	45	40
6	55	65	55
4	70	85	70
3	80	100	80
2	95	115	95
1	110	130	110
0	125	150	125
00	145	175	145

Technical

Wire Gage Data

Wire Gauge Size Equivalents.

AWG or B & S	Diameter		Cross Section Area		
Number	Inches	MM	Square Inches	Square MM	Circular Mils
0000	.4600	11.68	.1662	107.2	211600.
000	.4096	10.40	.1318	85.03	167800.
00	.3648	9.266	.1045	67.43	133100.
0	.3249	8.252	.08289	53.48	105500.
1	.2893	7.348	.06573	42.41	83690.
2	.2576	6.543	.05123	33.63	66370.
3	.2294	5.827	.04134	26.27	52630.
4	.2043	5.189	.03278	21.15	41740.
5	.1819	4.620	.02600	16.77	33100.
6	.1620	4.115	.02062	13.30	26250.
7	.1443	3.665	.01635	10.55	20820.
8	.1285	3.264	.01297	8.366	16510.
9	.1144	2.906	.01028	6.634	13090.
10	.1019	2.588	.008156	5.261	10380.
11	.09074	2.305	.006467	4.172	8234.
12	.08081	2.053	.005129	3.309	6530.
13	.07196	1.828	.004067	2.624	5178.
14	.06408	1.628	.003225	2.081	4107.
15	.05707	1.450	.002558	1.650	3257.
16	.05082	1.291	.002028	1.309	2583.
17	.04526	1.150	.001609	1.038	2048.
18	.04030	1.024	.001276	.8231	1600.
19	.03589	.9116	.001012	.6527	1288.
20	.03196	.8118	.0008023	.5176	1022.
21	.02846	.7229	.0006363	.4105	810.1
22	.02535	.6439	.0005046	.3256	642.4
23	.02257	.5733	.0004001	.2582	509.5
24	.02010	.5105	.0003173	.2047	404.0
25	.01790	.4547	.0002517	.1624	320.4
26	.01584	.4049	.0001996	.1288	254.1
27	.01420	.3607	.0001583	.1021	201.5
28	.01264	.3211	.0001255	.08098	159.8
29	.01126	.2860	.00009954	.06422	126.7
30	.01003	.2548	.00007894	.05093	100.5
31	.008928	.2268	.00006260	.04039	79.7
32	.007950	.2019	.00004964	.03023	63.21
33	.007080	.1796	.00003944	.02545	50.22
34	.006305	.1601	.00003122	.02014	39.75
35	.005615	.1426	.00002476	.01597	31.52
36	.005000	.1270	.00001963	.01267	25.00
37	.004453	.1131	.00001557	.01005	19.83
38	.003965	.1007	.00001235	.00797	15.72
39	.003531	.0897	.00000979	.00632	12.47
40	.003145	.0799	.00000777	.00501	9.888
41	.002800	.0711	.00000616	.00397	7.842
42	.002494	.0633	.00000488	.00315	6.219
43	.002221	.0564	.00000387	.00250	4.932
44	.001978	.0502	.00000307	.00198	3.911
45	.001761	.0447	.00000244	.00157	3.102
46	.001568	.0398	.00000193	.00125	2.460
47	.001397	.0355	.00000153	.00099	1.951
48	.001244	.0316	.00000122	.00078	1.547
49	.001107	.0281	.00000096	.00062	1.227
50	.000986	.0251	.00000076	.00049	.973

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Technical

Pipe Sizes and Threads

Stainless Steel Pipe Sizes

Nominal Size (inches)	Outside Diameter (inches)	Schedule 5 Extra Light Weight			Schedule 10 Light Weight			Schedule 40 Standard Weight		
		Wall (inches)	I.D. (inches)	Wt./Ft. (lbs)	Wall (inches)	I.D. (inches)	Wt./Ft. (lbs)	Wall (inches)	I.D. (inches)	Wt./Ft. (lbs)
⅛″	0.405	–	–	–	.049	.307	.1863	.068	.269	.2447
¼″	0.540	–	–	–	.065	.410	.3297	.088	.364	.4248
⅜″	0.675	–	–	–	.065	.545	.4235	.091	.493	.5576
½″	0.840	.065	.710	.3580	.083	.674	.6710	.109	.622	.8510
¾″	1.050	.065	.920	.6838	.083	.884	.8572	.113	.824	1.131
1″	1.315	.065	1.185	.8678	.109	1.097	1.404	.133	1.049	1.679
1¼″	1.660	.065	1.530	1.107	.109	1.442	1.806	.140	1.380	2.273
1½″	1.900	.065	1.770	1.274	.109	1.682	2.085	.145	1.610	2.718
2″	2.375	.065	2.245	1.604	.109	2.157	2.638	.154	2.067	3.653
2½″	2.875	.083	2.709	2.475	.120	2.635	3.531	.203	2.469	5.793
3″	3.500	.083	3.334	3.029	.120	3.260	4.332	.216	3.068	7.576
3½″	4.000	.083	3.834	3.472	.120	3.760	4.973	.226	3.548	9.109
4″	4.500	.085	4.334	3.915	.120	4.260	5.613	.237	4.026	10.79
5″	5.568	.109	5.345	6.349	.134	5.295	7.770	.258	5.047	14.62
6″	6.625	.109	6.407	7.585	.134	6.357	9.289	.280	6.065	18.97

American Standard Taper Pipe Threads

Nominal Pipe Size	Outside Diameter or Pipe (Inches)	Threads per Inch	Pitch of Thread (Inches)	Pitch Diameter at Beginning of external Thread (Inches)	Handtight Engagement (Inches)	Effective Thread External (Inches)
1⁄16″	0.3125	27	0.03704	0.27118	0.160	0.2611
⅛″	0.405	27	0.03704	0.36351	0.1615	0.2639
¼″	0.540	18	0.05556	0.47789	0.2278	0.4018
⅜″	0.675	18	0.05556	0.61201	0.240	0.4078
½″	0.840	14	0.07143	0.75843	0.320	0.5337
¾″	1.050	14	0.07143	0.96768	0.339	0.5457
1″	1.315	11½	0.08696	1.21363	0.400	0.6828
1¼″	1.660	11½	0.08696	1.55713	0.420	0.7668
1½″	1.900	11½	0.08696	1.79609	0.420	0.7285
2″	2.375	11½	0.08696	2.26902	0.436	0.7565
2½″	2.875	8	0.12500	2.71953	0.682	1.1375

Technical

Resistance wire – Current vs. Temperature

Current Carrying Capacity of Straight Nickel Chromium Wire

Approximate amperes to heat straight, oxidized wire in quiet air to given temperature

Degrees F		400	600	800	1000	1200	1400
Degrees C		205	315	427	538	649	760
A.W.G or B. & S.	Inches Diameter	Amperes					
15	.057	7.2	10.0	12.8	16.1	20.0	24.5
16	.051	6.4	8.7	10.9	13.7	17.0	20.9
17	.045	5.5	7.5	9.5	11.7	14.5	17.6
18	.040	4.8	6.5	8.2	10.1	12.2	14.8
19	.036	4.3	5.8	7.2	8.7	10.6	12.7
20	.032	3.8	5.1	6.3	7.6	9.1	11.0
21	.0285	3.3	4.3	5.3	6.5	7.8	9.4
22	.0253	2.9	3.7	4.5	5.6	6.8	8.2
23	.0226	2.58	3.3	4.0	4.9	5.9	7.0
24	.0201	2.21	2.9	3.4	4.2	5.1	6.0
25	.0179	1.92	2.52	3.0	3.6	4.3	5.2
26	.0159	1.67	2.14	2.60	3.2	3.8	4.5
27	.0142	1.44	1.84	2.25	2.73	3.3	3.9
28	.0126	1.24	1.61	1.95	2.38	2.85	3.4
29	.0113	1.08	1.41	1.73	2.10	2.51	2.95
30	.0100	.92	1.19	1.47	1.78	2.14	2.52
31	.0089	.77	1.03	1.28	1.54	1.84	2.17
32	.0080	.68	.90	1.13	1.36	1.62	1.89
33	.0071	.59	.79	.97	1.17	1.40	1.62
34	.0063	.50	.68	.83	1.00	1.20	1.41
35	.0056	.43	.57	.72	.87	1.03	1.21
36	.0050	.38	.52	.63	.77	.89	1.04
37	.0045	.35	.46	.57	.68	.78	.90
38	.0040	.30	.41	.50	.59	.68	.78
39	.0035	.27	.36	.42	.49	.58	.66
40	.0031	.24	.31	.36	.43	.50	.57

Current Carrying Capacity of Ribbon Nickel Chromium Wire

At 1200° F approximate

	Width-Inches					
	1/64	1/32	1/16	3/32	1/8	3/16
Thickness Inches	Amps					
.0063	1.56	2.89	5.5	8.2	10.1	16.6
.0056	1.45	2.69	5.2	7.2	9.5	15.6
.0050	1.35	2.52	4.9	6.8	9.0	14.7
.0045	1.26	2.38	4.6	6.4	8.5	14.0
.0040	1.18	2.23	4.1	6.0	8.0	13.1
.0035	1.09	2.07	3.8	5.6	7.5	12.3
.0031	1.01	1.94	3.6	5.3	7.0	11.5
.0020	-	-	-	-	-	-
.0015	4	-	-	-	-	-

The current values in these are based on actual sheets of single strands of oxidized wire mounted in quiet air and operated at 1200°F. The tables are calculated for wire having a resistivity at 1200°F and a total surface watts-density of 28 watts per square inch.

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