Data Sheet

Cartridge Heaters

RS **stock numbers 731-209 to 731-344, 837-458 to 838-085 and 376-1584 to 376-2509**

Cartridge Heaters

This range of cartridge heaters has been designed to provide localised heat to a restricted work area requiring close thermal control. They are intended for installation within a heater block, thus enabling the indirect transfer of heat to the material in process. As the useful life of a cartridge heating element is determined by how quickly the heat generated in the resistance wire can be dissipated to the outside sheath, the construction of the low and moderate watt density elements utilises the conventional method of helical wire coils on a ceramic former. This ensures that even though the wire temperature is considerably higher than the sheath temperature, it is still well within the safe long life operating range of the unit. With the high watt density elements the heat is transferred to the sheath much more quickly. This is achieved by locating the element so that is is closer to the sheath and swaging the outside diameter of the heater, thereby compressing the magnesium oxide filler so that it becomes an improved conductor of heat while maintaining its dielectric properties. This improvement of the heat transfer rate therefore enables higher watt densities because the differential between the wire and sheath temperatures has been minimised.

WARNING: Althought the elements are insulated from the sheath by magnesium oxide powder, for reasons of safety the heater block and/or cartridge sheath **must** be bonded to earth.

Note: In order to obtain optimum performance of these products, it is advised that temperature sensing and control elements are included within the heating system.

Technical Specification

Supply voltage	120 or 230Vac (see catalogue)
Sheath material	Series 300 stainless steel
Sheath end cap	Ceramic
Element/Case insulation	Magnesium oxide powder
Connection lead length	12in
Connection lead insulation	
1/4in diameter	PFTE
3/8in = diameter	Fibreglass

Power calculation data

Basic heat formula

The following formula can be employed in determining the approximate power capacity required for different materials. Results should be confirmed by test.

Formula A: Power required for heat up =

$$\frac{\text{Weight of material (lb) x Specific heat x Temperature rise °F}}{\text{3.412 x Time (hours of fraction thereof)}}$$

Formula B: Power losses at operating temperature = Power loss/sq ft x Area in sq ft

See Power loss graphs, Figures 18-22

Formula C: Power for melting or vapourising =

$$\frac{\text{Weight of material (lb) x Heat of fusion of vapourisation (BTU/lb)}}{\text{3.412 x Heat up time (hours of fraction thereof)}}$$

Formula D: Power required to maintain heat (for insulated surface) =

$$\frac{\text{Coefficient of heat transfer (BTU/hour °F ft/inch) x Surface area (ft) x Temperature difference (°F)}}{\text{3.412 x Thickness of insulation (in)}}$$

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

Specific applications

For specific applications, substitute the basic heat formula (A, B, or C above) into the following:

To heat liquids

$$\text{Power for initial heat up} = (a) + \frac{(b)}{2}$$

Power for operating requirements = (a) for new material added + (b)

To ensure adequate capacity, add 20% to final power figures. This will compensate for added heat losses not readily computed.

To melt soft metals

$$\text{Power for initial heat-up} = \text{(a) to melting point} + \text{(c) to melt} + \text{(a) to heat above melting point} + \frac{(b)}{2}$$

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

To heat ovens

Power = (a) (for air) + (a) (all material introduced into oven) + (b). Add 25% to cover door heat losses.

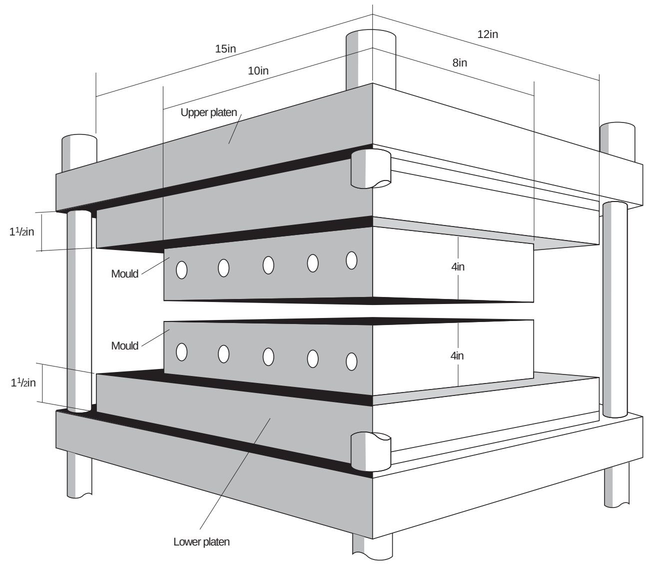
Forced air heating

$$\text{Power} = \frac{\text{CFM 3 temperature rise (°F)}}{3}$$

For explanation of basic heat formula, see example problem.

WARNING: This component part shall only be used where adequate electrical, thermal and mechanical barriers are provided to prevent access to hazardous parts without use of a tool.

Example problem Basic heating and heat loss



A steel mould is being used to form polyethylene parts. Each hour, 90 ounces of nylon is introduced to the mould. The mould itself measures 10in 3 8in 3 4in. The mould is attached between two stainless steel platens, each measuring 15in 3 12in 3 11⁄2in thick. The platens are insulated from the press mechanism with 1⁄2in thick insulation. Operating temperature of the mould is 400°F and is required to reach this temperature in 1 hour with an ambient temperature of 70°F.

1. From Table 1, specific heat of steel – .12/BTU/lb°F
2. From Table 1, specific heat of stainless steel – .12/BTU/lb°F
3. From Table 2, specific heat of polyethylene – .55/BTU/lb°F
4. From Figure 16, heat losses curves – A + B @ 400°F
5. From Table 1, converting cubic inches into pounds (density lb/cu in).

Formula A: Power required for heat up

To heat mould

(10in x 8in x 4in) = 320 cu in x 2 x .284 = 181.7 (lb) x .12 BTU/lb° F x (400-70) °F =
3.412 x 1
2,110 Watts

To heat platens

(15in x 12in x 11⁄2in) = 270 cu in x 2 x .286 = 154.5 (lb) x .12 BTU/lb°F x (400-70) °F =
3.412 x 1
1,800 Watts

To heat polyethylene

90 = 5.6 (lb) x .55 BTU/lb °F x (400-70) °F =
163.412 x 1
300 Watts

Compensation factor

20% (2.110 + 1,800 + 300) = 840 Watts

Formula B: Power losses at operating temperature (see graphs)

Heat loss from mould (vertical surfaces)

10in x 4in 3 4in + 8in x 4in x 4in = 2 sq ft x 350w/sq ft/hr =
144in
700 Watts

Heat loss from platen (vertical surfaces)

11⁄2in x 15in x 4in + 11⁄2in x 12in 3 4in = 1.1 sq ft x 350w/sq ft/hr =
144in
385 Watts

Heat loss from platen (horizontal surfaces, uninsulated)

15in x 12in x 2in – (10in x 8in x 2in) = 1.3 sq ft x 250w/sq ft/hr =
144in
350 Watts

Heat loss from platen (insulated surface)

15in x 12in x 2in = 2.5 sq ft x 100w/sq ft/hr =
144in
250 Watts

Compensation factor:

20% (700W + 385W + 350W + 250W) = 340 Watts

Total power losses at operating temperature = 2,025 Watts

Total power required for heat up = 5,050 Watts

Total power required = **7,075 Watts**

The number of holes in the mould would dictate the number of heaters required. Dividing the power by the number of heaters will equal the power rating of each heater.

System Control

The results 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 that area where a temperature change must be sensed with minimal **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 **Figure 1**.

Figure 1 **Poor liquid heating control**

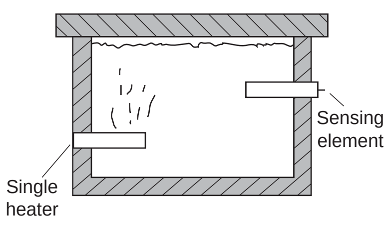


Figure 2: Applies to liquid and gas systems which require additional considerations. Because the heat demand is basically steady, the sensing element should normally be located close to and above the heat source to minimise system bandwidth. (Bandwidth is the total temperature variation above and below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

Figure 2 **Optimum liquid heating control**

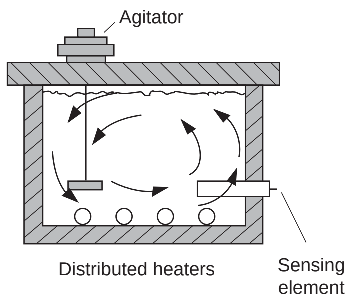
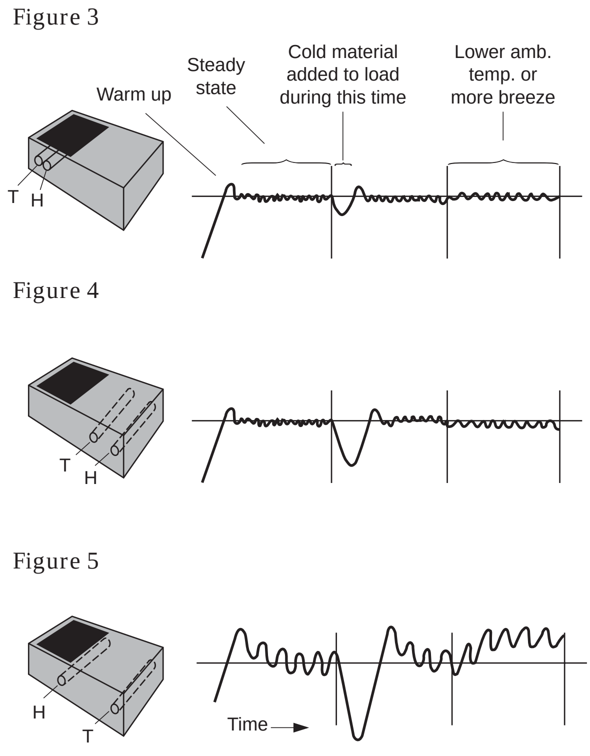


Figure 3: Close grouping of heater, sensing element and work. Where this layout is feasible, it gives excellent control under most conditions and is desirable when the thermal load changes frequently. The heat transfer paths from the work and heater to the thermostat are short, so that thermal lag is 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.

Figure 4: Thermostat between heater and load. This is a 'general purpose' arrangement for installations where the heat demand may 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.

Figure 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 one without excessive lag. This arrangement is presented primarily to emphasise that, unless you are careful in placing the element, the controller may find it impossible to maintain even fair control.

Temperature of the load



Electrical calculations

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 power with voltage change

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

E^2 = New voltage W^2 = New wattage

E^1 = Original heater voltage W^1 = Original wattage

Wiring diagram: Cartridge heaters

Figure 6 120V/240V single phase two or more heaters in parallel with thermostat rating adequate for line voltage and current

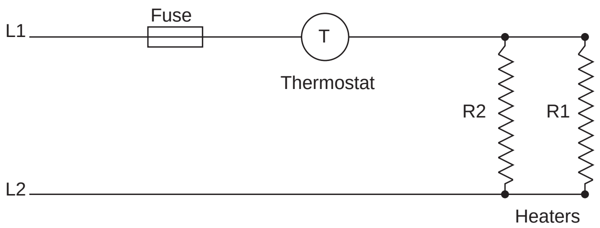


Figure 7 120V/240V three phase deltas (three phase star) with thermostat adequate for line voltage and current

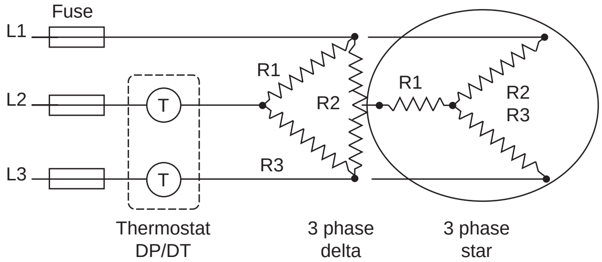


Figure 8 120V/240V single phase two or more heaters in series with thermostat rating adequate for line voltage and current

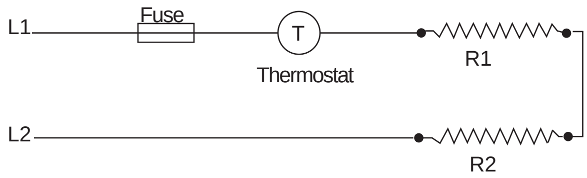


Figure 9 Two or more heaters wired in parallel with thermostat rating not adequate for line current (or voltage)

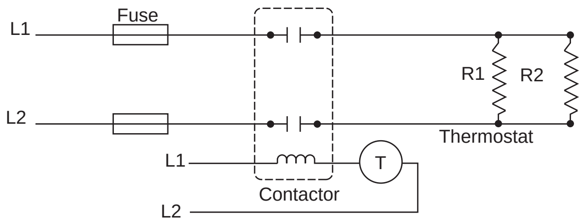


Figure 10 Two or more heaters wired in parallel in each leg of a three phase delta circuit. Thermostat rating not adequate for line current or voltage

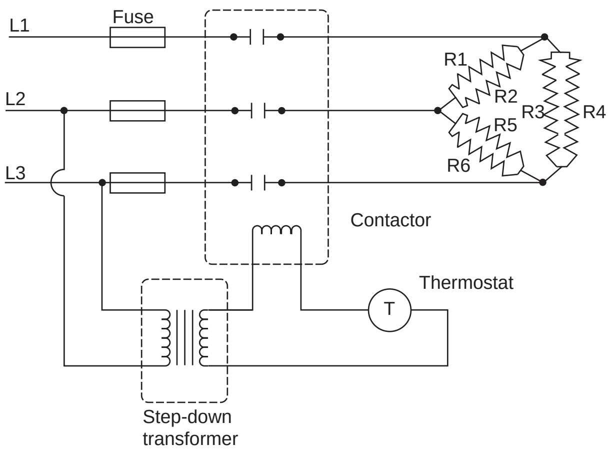


Figure 11 Single phase or three phase ac only with properly rated SCR power control with thermocouple input temperature controller

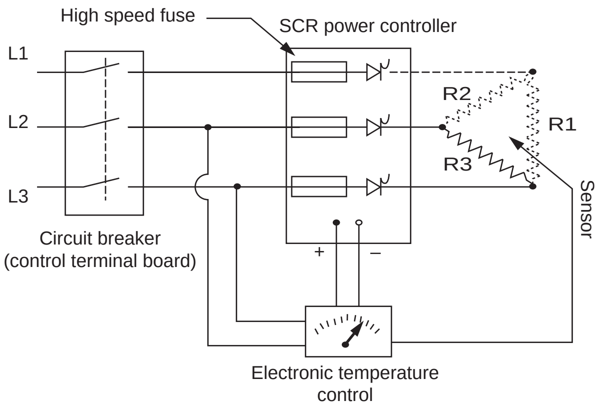


Figure 12 Special circuit for switching from parallel operation in a three phase delta circuit to a pair in series operation, with both contactors closed. Circuit operates at full power at element rated voltage.

With either #1 or #2 contactor open, circuit operates at $\frac{1}{4}$ power, with voltage across each element at $\frac{1}{2}$ rated voltage. Heater element power ratings must be equal to give balanced three phase current for both circuits

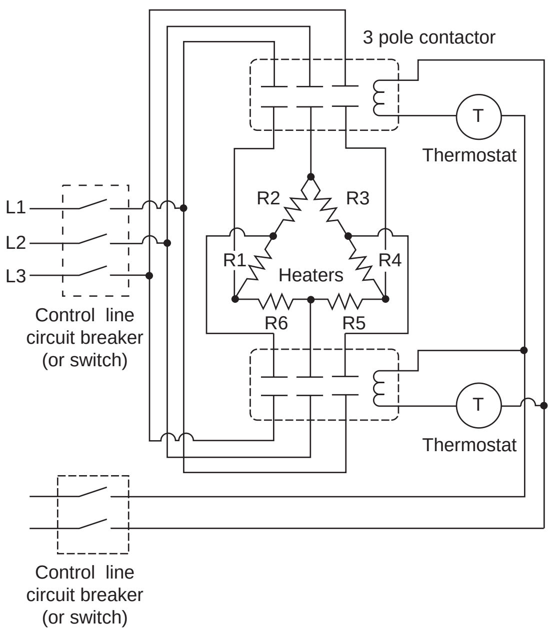
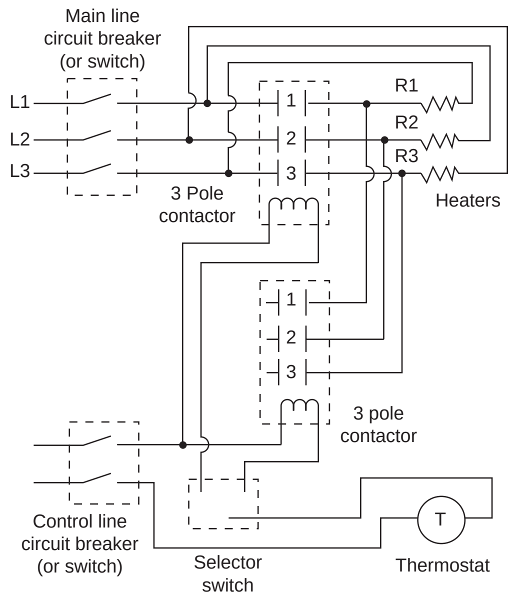
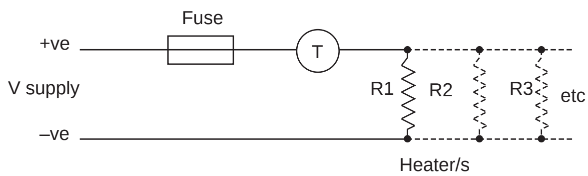


Figure 13 Circuit for switching from a three phase delta circuit for full power to a three phase star circuit at $\frac{1}{3}$ power



Heater mats

Figure 14 Standard circuit for heater mats. One (or more in parallel) corrected via suitable fuse and thermostat to 12 or 30Vdc as applicable.

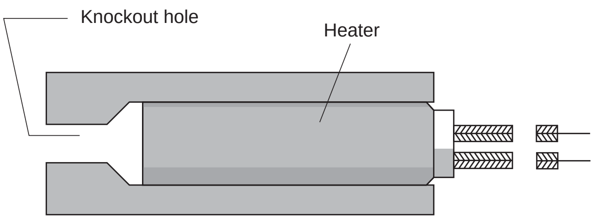


Installation

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.

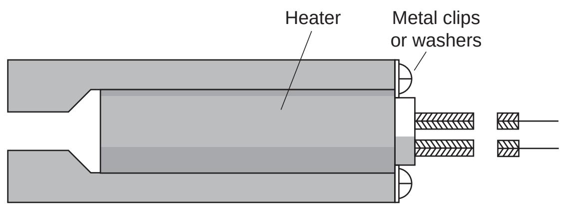
Cartridge units are made with special tubing which is a few thousandths undersize to ensure a free fit for easy installation. To install cartridge heaters, drill and ream holes to the proper length and the nominal diameter plus .001in maximum minus .000in of the cartridge heater (3⁄16in, 3⁄8in, 1⁄2in, 5⁄8in, etc). For example, a 1⁄2in cartridge heater actually measures .497in diameter. A hole should be drilled and reamed to 1⁄2in diameter +.001in – .000in to ensure proper fit. Always finish-ream drilled or cast holes to ensure a smooth, uniform metal to metal contact. A knockout hole (Figure 15) should be provided if possible to facilitate cartridge removal. The receptacle hole should be free from oil before cartridge heater installation to avoid contamination and short heater life.

Figure 15



If there is danger of a heater slipping from its hole, it should be held in place with metal clamps or washers (Figure 16).

Figure 16



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 (Figure 17) or protected with a lead clip.

Figure 17

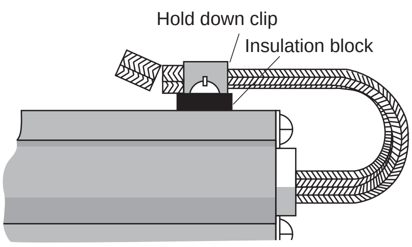


Table 1 **Properties of metals**

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)
Aluminium 2024-IT3	.100	.24	840	935	167
Aluminium 1100-00	.098	.24	1540	1190	169
Aluminium 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%NI 20%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±

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/in/°F)	Melting point (°F)
Asbestos	.070	.25±	5.2	–
Asphalt	.076	.40	5.3	–
Brickwork and 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±
Sulphur	.075	.175	1.9	246
PTFE	.078	.25	1.7	–
Vinyl	.046	.3 to .5	.8 to 2.0	–
Wood, Oak	.029	.57	1.1	–

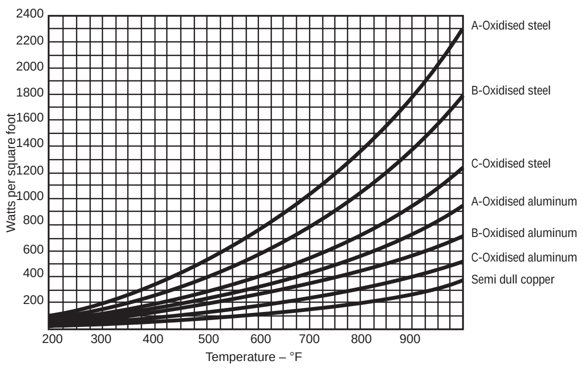
Table 3 **Properties of liquids**

Liquids	Density (at or near room temp.) (lb/cu ft)	Average specific heat (BTU/lb/°F)	Boiling point (°F)	Heat of vaporation (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 (1⁄3 dry glue, 2⁄3 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
Sulphur (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**

Gases	Density (at or near room temp. and atmospheric pressures) (lb/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 Vapour @ 212°F (steam)	.037	.482

Figure 18 **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.

Figure 19 **Losses from open hot water tanks**

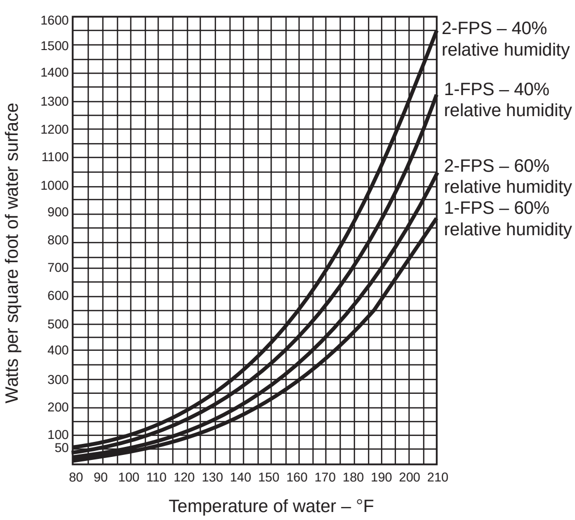


Figure 20 **Losses from molten metal surfaces**

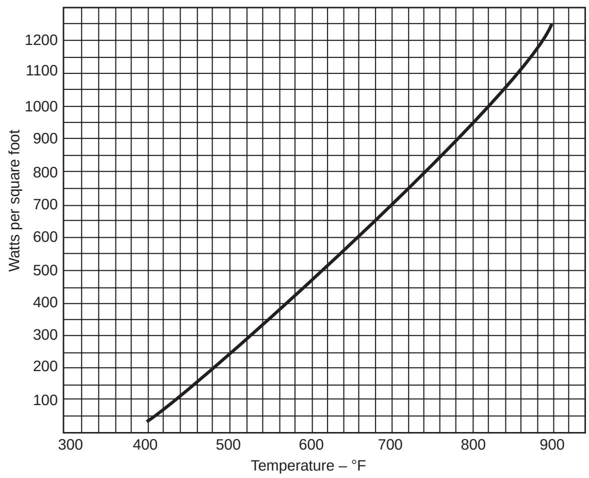


Figure 21 **Losses through insulated walls (ovens, pipes, etc.)**

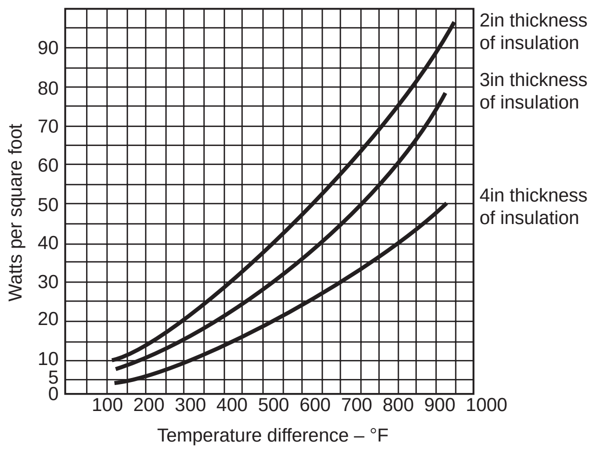
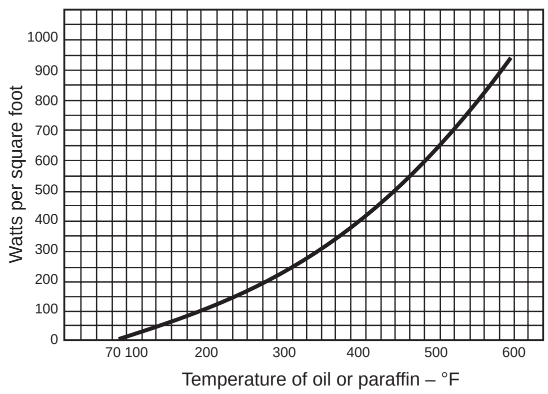


Figure 22 **Losses from surfaces of oil baths**



Conversion data – 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 conversion 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

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