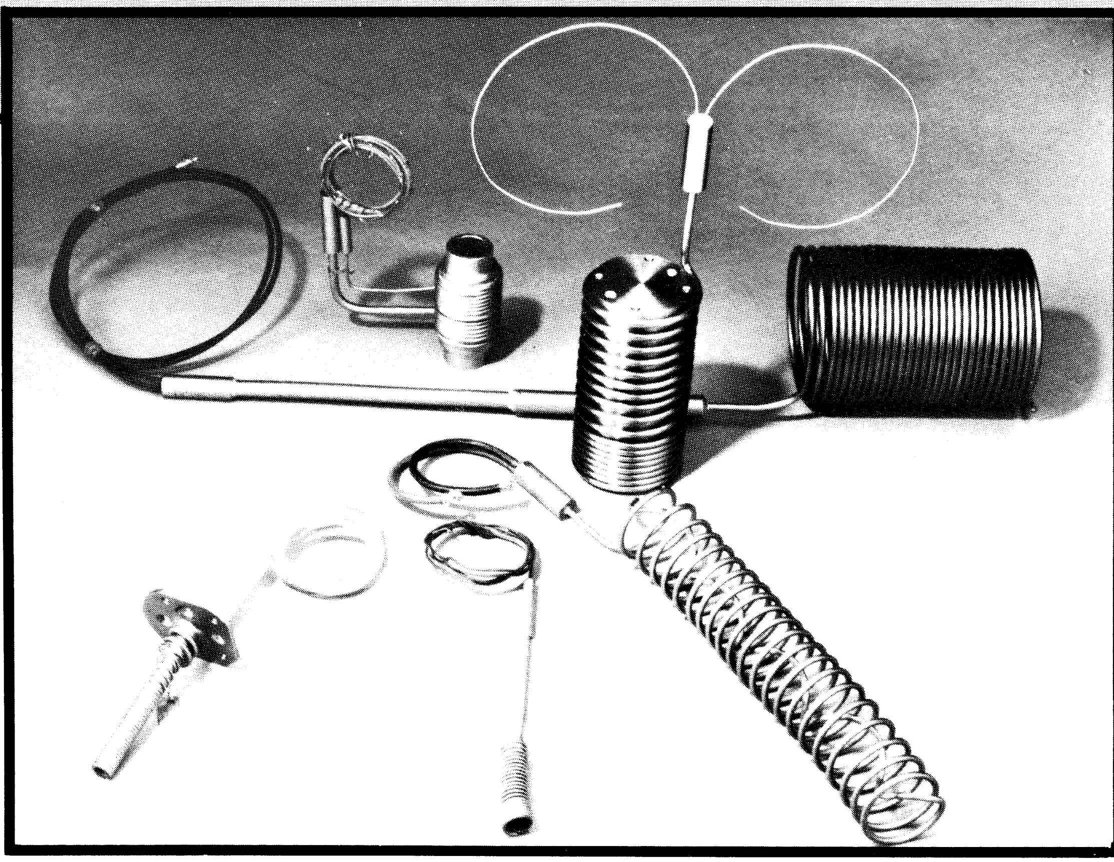
ENGINEERING DATA FILE 3

APPLICATION GUIDE

MINERAL INSULATED

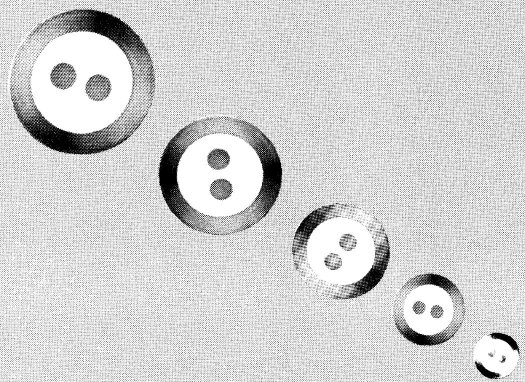
HEATERS

AerOrod®



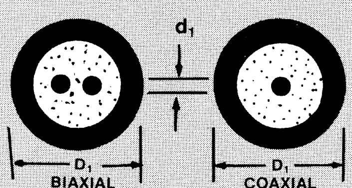
ARi Industries Inc

EDF 3
APRIL 1999



AerOrod® Heaters and Heater Cable are manufactured with highly compacted MgO insulation in a multiple reduction process that yields a uniform cross-section and minimum wire to sheath spacing for efficient heat transfer. This material can be easily formed, clamped or brazed in place to give maximum power levels in difficult situations.

Typical cross sections:



This application guide has been prepared to simplify the selection of heaters for most industrial applications. Materials data and selection curves are given to allow use of common sense and simple mathematics to solve otherwise exotic heat transfer problems.

EDF-3 Definitions

Aerobiax — Two wire M.I. heater cable

Aerocoax — Single concentric wire in M.I. cable

Area — For round sheath surface area or wire area in square inches. A=3.1415 DL $(\text{inch})^2$ with diameter and length in inches.

BTU (British Thermal Unit). Defined as the amount of heat (Q) needed to raise the temperature of 1 pound of pure water 1°F. 1 BTU=.2928 watt-hours. 1 BTU/MIN=17.57 watts=.252 Kg CAL/MIN.

Cold End BXX style heater. M.I. cable with an internal welded transition between 620 Ω/CMF inconel 600 heater wire and 60Ω CMF nickel wire used to thermally isolate heated section from temperature sensitive termination.

Convection Heat Loss
(Qc) (BTU/HR/FT^2), $Q_c = 0.296\,(T_s - T_a)^{1.25}\sqrt{\dfrac{V + 68.9}{68.9}}$

Where: T_s=Surface Temp in °F
T_a=Air Temp in °F
V=Wind velocity in ft/min (1 mph = 88 ft/min)

Density Weight of a unit volume of material, pounds per cubic foot.

Heat Tracing The addition of heat to process piping systems to compensate for heat losses or to maintain liquids above solidification or freezing temperatures. Additional heat obtained with steam, electrical heaters or direct skin effect electrical heating of metal piping.

Line Voltage 115 or 230 V, 60 Hz, single phase.

M.I. Mineral Insulation Usually refers to compacted magnesium oxide (MgO) powder used as internal insulation.

Ohms Law E(volts) = I (amps) X R(ohms)

O.D. Outer or external diameter of heater or thermocouple with circular cross-section

Power Electrical energy dissipation $P_{\text{watts}} = (E_{\text{volts}})\,(I_{\text{amps}}) = \dfrac{(E_{\text{volts}})^2}{(R_{\text{ohms}})} = (I_{\text{amps}})^2\,(R_{\text{ohms}})$

Note: Assumes power factor of 1.0 for a resistive load at 60 Hz.

Resistivity Resistance to current flow for a given material at a specified temperature. For wires it is expressed as ohms per circular mil foot 1 mil = 0.001″ (.010″ = 10 mils)

Sheath Continuous outer metal jacket of M.I. cable

Specific Heat Amount of thermal energy required to raise the temperature of one pound of a material by 1 °F as compared to water (specific heat of water = 1 BTU/pound/°F)

Temperature Coefficient of Resistivity Relationship of change in resistance or resistivity to temperature change. Expressed as ohms per ohm per °C or °F.

Termination An enlarged transition area for AeroRod® heaters between M.I. cable and flexible insulated lead wires. Termination is usually filled with epoxy or ceramic compound.

Thermal Conductivity Heat transfer value for a material within a specified temperature range. Expressed in BTU/hour, °F, Ft^2/Ft.

Watt Density Power dissipation per unit area. Expressed as watts per square inch of sheath surface area. (power density) related to surface temperature.

Index

Heater Power Determination:

The majority of heating situations require highest power during the warm-up period where a given mass must be brought from ambient to an elevated temperature within a given time. The total power required is influenced by the type and size of material involved. Time period, and the method of thermally coupling heater to heated surface. Determination of warm-up power requirements and the use a time proportioning controller will insure adequate initial power with maximum heater life under operating conditions. Warm-up power calculations include a 20% power addition to allow for heat losses in static systems.

This general rule may not be valid if flowing metals, liquids, or high velocity gases are involved. Calculation of operating power loss should be added for these situations to avoid the need for expensive booster heaters and unnecessarily complex control systems.

1. Determine weight of material to be heated and desired temperature rise. Obtain power requirement from Table 1. Multiply weight X specific power requirement X temp rise in °F to obtain power for a 60 minute heat up period.

   Approximate power required to heat materials from ambient to an elevated temperature within one hour heating period. The specific power values include a 20% factor for distributed heat losses.

   Formula: $\frac{\text{Weight (lbs.) X Specific Heat X Temp Rise (°F)}}{\text{3.412 (1 Watt = 3.412 BTU/HR)}}$ = Watts/Lb/°F (Specific power requirements for 1 hour heat up)

2. Determine operating heat losses from appropriate formula or curve from following pages.

Desired heater power level will then be the highest of these two.

Examples:

1. 10 lbs. of copper to be heated from 70°F to 350°F in one hour: 10 lbs. X .035 W/LB/°F X 280°F = 98 watts. To decrease heating period from 60 minutes to 5 minutes: $\frac{60}{5}$ X 98W = 1176 Watts
2. 5 lb. steel container with 8 lbs of water to be heated from 40°F to 200°F in 10 min.:

   Watts (Steel) = 5 lbs. X .042 W/LB/°F X 160°F = 33.6
   Watts (Water) = 8 lbs. X .352 W/LB/°F X 160°F = 450.6
   Total: 484.2 Watts

To decrease heating period from $\frac{60}{10}$ to 10 minutes: 60 X 484.2 Watts = 2905.2 Watts

Operating Heat Losses

1. Conduction losses to adjacent materials. Use Table 1 power requirements for the materials involved, assuming a temperature rise plus external surface losses as follows:
2. Surface losses, convection and radiation:

   A) Oil or paraffin
   Watts = $\frac{\text{1.5 (temperature in °F - 100}}{\text{Surface area in square feet}}$

   B) Molten Metals
   Watts = $\frac{\text{2.28 (temperature in °F - 380)}}{\text{surface area in square feet}}$

   C) Insulated walls (ovens, pipes, tanks, etc).
   Watts = $\frac{\text{0.2 (temperature difference in °F - 100)}}{\text{surface area in square feet}}$ (insulation thickness, inches

   D) Oxidized metal surfaces (see Figure 1)

   E) Open top water tanks (see Figure 2)

FIGURE 1
SURFACE HEAT LOSSES
From Oxidized Metals to 70°F Still Air, Watts/Ft.² vs °F

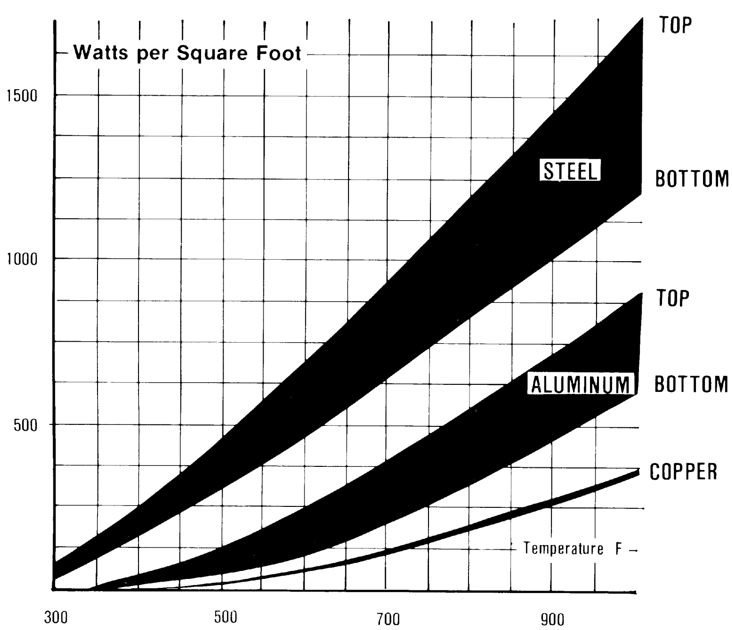


FIGURE 2
SURFACE HEAT LOSSES
From Water Tanks to 70°F Air, Watt Density vs Water Flow Rate and Air Humidity

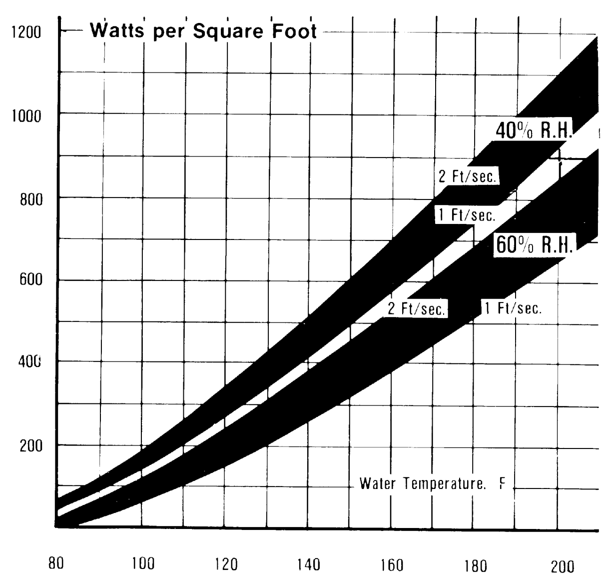


Table 1

	Material	Specific Power Requirement Watts/Lb/°F	Specific Heat BTU/Lb/°F	Density Lbs/Ft^3	Thermal Conductivity (K) BTU/Hr °F Ft^2/Ft	Maximum Power Density Watts/In^2
	Aluminum	0.082	.23	160	117	
	Antimony	.0176	.05	423	14	
S	Brass	.035	.10	525	130	
	Copper	.035	.10	550	224	
O	Epoxy	.156	.45	—	.80	
	Glass	.070	.20	165	.70	
L	Iron, Cast	.046	.13	450	28	
	Iron, Wrought	.042	.12	450	35	
I	Lead	.011	.03	710	20	
	Nickel	.039	.11	550	36	
D	Nylon	.176	.50	—	.15	
	Paper	.108	.45	58	.60	
S	Paraffin	.245	.70	—	56	
	Plastic, Ave	.13	.37	—	.15	
	Rubber	.14	.40	95	13	
	Silver	.021	.06	655	242	
	Stainless Steel	.042	.12	485	9	
	Steel	.042	.12	490	39	
	Teflon	.088	.25	—	.15	
	Tin	.021	.06	455	37	
	Zinc	.035	.10	455	65	
	Acetic Acid	.165	.47	66	—	40
L	Alcohol	.228	.65	55	.11	—
	Asphalt	.14	.40	65	—	10
I	Benzine	.165	.45	56	—	—
	Ether	.176	.50	46	—	—
Q	Freon	.084	.24	81	.05	3
	Gasoline	.176	.50	46	—	3
U	Glycerine	.204	.58	79	—	40
	Kerosene	.176	.50	51	.09	3
I	Lead	.014	.04	710	—	35
	Mercury	.011	.04	845	4.8	20
D	Oil, Hydraulic	.14	.40	58	—	20
	Petroleum	.178	.51	56	—	18
S	Tin	.021	.060	460	37	20
	Water	.352	1.0	62.4	.343	55
	Air	0.123	.35	.075	.025	
G	Ammonia	.183	.52	.05	—	
	Carbon Dioxide	.070	.20	.12	—	
A	Carbon Monoxide	.084	.24	.08	—	
	Chlorine	.046	.13	.20	—	
S	Helium	.44	1.25	.01	.08	
	Hydrogen	1.20	3.41	.005	.10	
E	Methane	.21	.60	.05	—	
	Nitrogen	.088	.25	.08	.014	
S	Oxygen	.072	.22	.09	.014	

Do not exceed recommended power density values when heating liquids unless local boiling or breakdown can be tolerated. Check Figure 3 to be sure.

FIGURE 3

AerOrod® Heater Surface Temperature vs Watt Density in 70° F Still Air

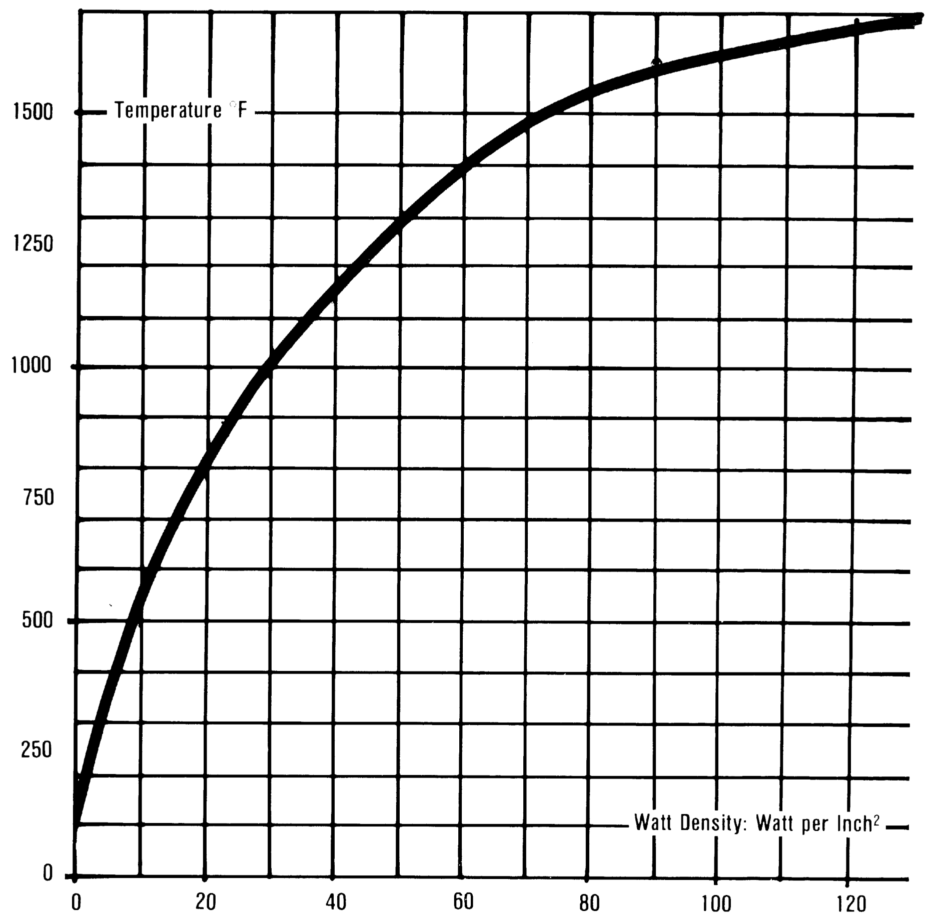
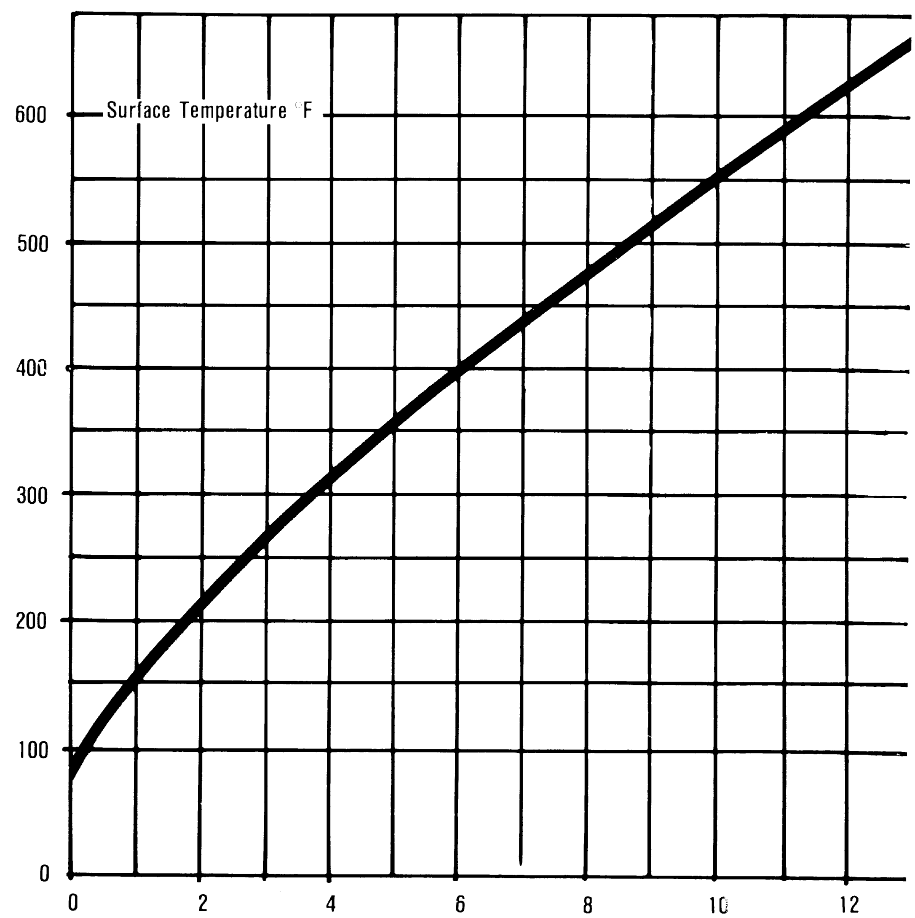


FIGURE 3A
EXPANDED FIG. 3 CURVE

From 70° F to 600° F
0 to 12 watts/in²



Heater Selection Methods

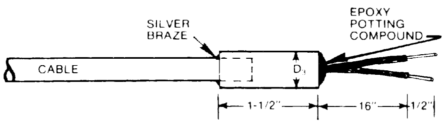
Given:	Selection Approach:
A. Surface Temperature Any Voltage	1. Obtain power density from Figure 3 or 3A in watts/in^2. 2. Select heater from Bulletin 5.2 options using power density column in Bulletin 5.2.
B. Power At 115V 50/60 Hz Line Voltage	1. Check Bulletin 5.2 for options using 115V column. 2. If Bulletin 5.2 stock heater cannot be used, determine heater length vs. heater O.D. from the following calculation: .040″ O.D. $\frac{5290}{\text{Power}}$ = length in inches .062″ O.D. $\frac{12245}{\text{Power}}$ = length in inches .093″ O.D. $\frac{26450}{\text{Power}}$ = length in inches .125″ O.D. $\frac{49532}{\text{Power}}$ = length in inches .188″ O.D. $\frac{113034}{\text{Power}}$ = length in inches .250″ O.D. $\frac{228017}{\text{Power}}$ = length in inches 3. Derive part number per Bulletin 5.2. 4. Determine total surface area from column 4 of table 2. Use this area to determine power density $\frac{\text{(Total Power)}}{\text{(Total Heated Area)}}$ = W/IN^2 and surface temperature from Figure 3 or 3A.
C. Heated Length At 115V 50/60 Hz	1. Check Bulletin 5.2 for length vs. heater sheath O.D. and power options. 2. If desired heated length is not listed in Bulletin 5.2, use the constant from Step B.2 above to obtain power vs. sheath O.D. options. $\frac{\text{Constant}}{\text{heated length}}$ = Power at 115V 3. Determine total surface area from column 4 of Table 2. Determine power density $\frac{\text{(Total Power)}}{\text{(Total Heated Area)}}$ and then surface temperature from Figure 3 or 3A.
D. Voltage and Power Voltage Other Than 115V	1. Determine Heater Resistance R(ohms) = $\frac{(\text{voltage})^2}{\text{Power}}$ 2. Determine heater length options using column 3, Table 2 resistance per inch. $\frac{\text{Heater Resistance}}{\text{ohms per inch}}$ = heater length in inches 3. Derive part number per Bulletin 5.2.
E. Power and Heated Length at a Voltage Other Than 115V	1. Determine total resistance for O.D. options from column 3 of Table 2 (heated length) X (ohms/inch) = heater resistance. 2. Determine voltage using power and resistance. Voltage = $\sqrt{(\text{power}) \times (\text{resistance})}$ 3. Determine heater area using column 4 from Table 2 (heated length) x (in^2/in) = area. 4. Determine power density $\frac{\text{total power}}{\text{total area}}$ = W/IN^2 power density 5. Determine heater surface temperature from Figure 3 or 3A.

Caution: Do not exceed the maximum applied voltage or current limits of Table 2 or watt density limitation on terminations per Table 5.

Table 2

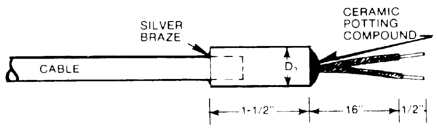
Heater Style	Sheath O.D. ±.005″	Ohms Per Inch Of Heated Length	Surface Area Per Inch of Heated Length $(in)^2$	Max Applied Voltage	Max Current (Amps)	Max Hi Pot Voltage (VAC) at 60 Hz
1	2	3	4	5	6	7
BXD-04 BXX-04	0045″	2.5	.141	120	2	250
BXD-05 BXX-06	0.063″	1.08	.196	120	4	350
BXD-09 BXX-09	0.093″	0.50	.292	230	7	500
BXD-13 BXX-13	0.125″	0.267	.393	240	9	750
BXB-19 BXD-19 BXX-19	0.188″	0.117	.591	350	17	1100
BXX-25	0.250″	0.058	.785	450	23	1500

TERMINATION DETAILS



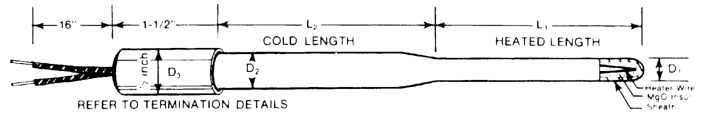
"K"-Termination:

1) Rated for continuous operation of 300°F (149°C)
2) D_3 = 1/4" for .040 to .188" cable diameter
   D_3 = 1/2" for .250 to .375" cable diameter
3) Standard lead wire length approximately 16"

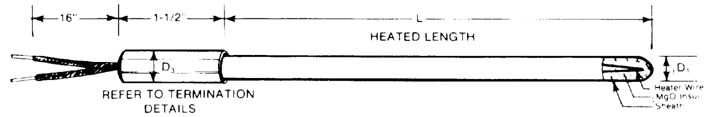


"T" Termination:

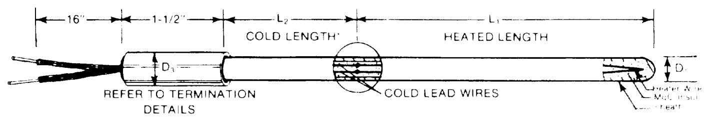
1) Rated for continuous operation of 800°F. (427°C.)
2) D_3 = 3/8" for .040 to .188" cable diameter
   D_3 = 1/2" for .250 to .375" cable diameter
3) Standard lead wire length approximately 16"



Style BXB



Style BXD

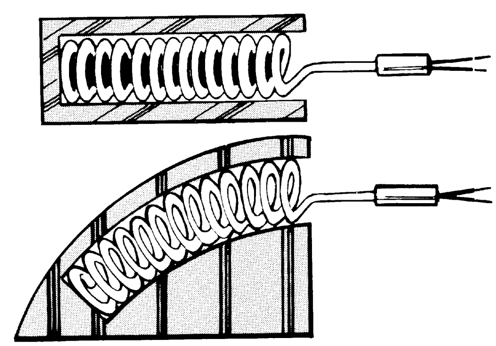


Style BXX

ARiCoil™ Cartridge Heater Design Procedure

ARiCoil™ Cartridge Heater

Straight AerOrod heaters formed into a coil form for insertion into tubes or blind holes. Can be used inside formed tubes or blind holes with drilling offset where traditional cartridge heaters cannot be used.



Required Data: 1) Power and applied voltage
2) Coil O.D. and coil length

Note: If power in watts is not known, refer to the heater selection methods. Power density (watts/in²) must be derived using effective surface area, if coiling pitch is equal to the sheath diameter up to twice sheath diameter.

$A = \pi$ (Coil I.D. + Coil O.D.) Coil Length

If preformed on an undersized mandrel, assume a total coil I.D. spring back equal to heater sheath diameter.
To determine power dissipation

$$\text{Power (watts)} = \frac{(\text{voltage})^2}{\text{total resistance}}$$

$$\text{Power at 115V} \quad P = \frac{13225}{\text{ohms}}$$

$$\text{Power at 230V*} \quad P = \frac{52900}{\text{ohms}}$$

*For 0.090" sheath diameter and larger heaters.

Table 4
Heater Coil Inner Diameter vs. Ohms Per Inch of Tightly Wound Heaters

Coil I.D.	Heater Sheath O.D. .040	.062	.090	.125	.188	.250
.180"	35.2Ω					
.188"	37.0Ω					
.250"	49.0Ω	13.5Ω				
.313"	61.2Ω	16.9Ω				
.375"	73.5Ω	20.3Ω	6.5Ω			
.437"	85.7Ω	23.6Ω	7.5Ω			
.500"	98.0Ω	27.0Ω	8.6Ω	3.3Ω		
.562"	110.2Ω	30.3Ω	9.6Ω	3.7Ω		
.625"	122.5Ω	33.8Ω	10.7Ω	4.1Ω		
.750"	147.2Ω	40.7Ω	13.0Ω	4.9Ω	1.4Ω	
.812"	159.2Ω	44.0Ω	14.0Ω	5.4Ω	1.5Ω	
.875"	171.7Ω	47.5Ω	15.1Ω	5.8Ω	1.6Ω	
1.000"	196.2Ω	54.0Ω	17.2Ω	6.6Ω	1.8Ω	0.72Ω

Coil I.D. is too small for heater sheath O.D. in this range.

Procedure

Given power in watts, voltage, coil dimensions

1. Determine total resistance in ohms $R = \frac{(\text{voltage})^2}{\text{power}}$
2. Refer to Table 4. Multiply coil length in inches by resistance per coil inch to obtain total resistance.
3. Compare resistances from steps 1 and 2 to obtain best match.

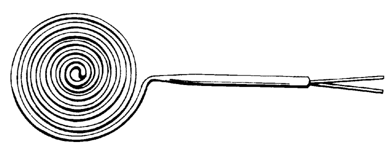
Note: Tightly wound coils can be opened up to a spacing of 3 times sheath diameter between turns.

Flat (archimedes) spiralled heaters

A flat pancake shaped coil is one of the most efficient methods of heating flat surfaces. Any of the AerOrod® heaters in the BXB, BXD, or BXX configurations can be used to form spiral heaters when the straight length is known. Considerations of applied voltage, power and power density (temperature) apply as derived in previous sections. For close wound (touching turns) spiral coils, the following table can be used if outer coil diameter is known and the innermost coil diameter is 4 times heater sheath O.D.

Straight heater length (in inches) = (constant) (coil diameter)^2

Sheath O.D.	Constant
.040"	19.63
.062"	12.66
.090"	8.72
.125"	6.28
.188"	4.18
.250"	3.14



For flat coils with a uniform space between turns, the center to center space between adjacent turns is defined as the pitch, used in the following formula

$$\text{Length (inches)} = \frac{.785\ (\text{coil diameter})^2}{\text{Pitch (in inches)}}$$

General Application of AerOrod® Heaters

The following section is specifically aligned towards the successful application of AerOrod® Heaters.

AerOrod® heaters consist of one or more resistance wires completely embedded in compacted magnesium oxide (MgO) and enclosed in a continuous Inconel 600 sheath. Material is tubular in nature with wire or wires straight and uniformly spaced within the sheath. Note: AerOrod® differs from electric stove type heating elements. Stove elements normally contain an internal helical coil of resistance wire. The use of the following approaches on heaters of the cartridge, blanket, or internal helix wire types are not recommended without a careful comparison of characteristics.

Maximum Temperatures:

Inconel 600 sheath: 2000°F
1500°F sulphurous
Magnesium Oxide: 3000°F
Heater Wires: 1800°F

Forming Limitations

Heater O.D. (Heated Section)	Minimum Bend Radius
.045	.09"
.062	.125"
.125	.250"
.250	.500"
.313	.625"

Note: Capacitance discharge welding to sheath is not recommended. Any breach in the sheath can cause a rapid drop in insulation resistance that will result in heater failure.

Brazing: Use minimum clearance between heater sheath and adjacent material. Restrain ends of heater.

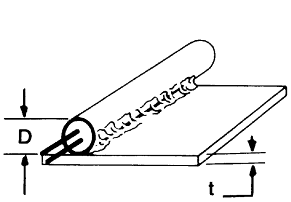
Torch Brazing:
For 1000°F max. service: Handy & Harmon Easy Flo. 1160°F melt.
For 1200°F max. service: Eutectic Eutecrod 1400 or Equal — 1425°F melt

TABLE 5
Watt Density Limitations on Terminations

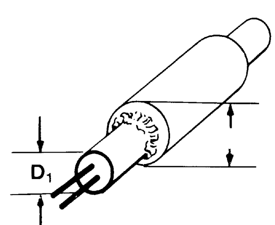
Heater Style	Term Type	Sheath Diameter in Inches .040	.062	.093	.125	.188	.250
BXD	K	30	25	20	15	10	10
	T	100	100	100	75	50	40
BXX	K	80	65	55	40	25	25
	T	150	150	150	140	100	100
BXB	K	150	130	110	80	50	40
	T	150	150	150	150	150	140

Welding:

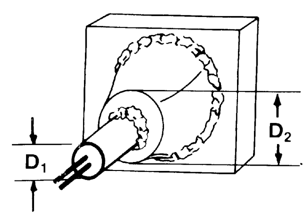
Sheath may be heliarc welded, if done carefully. Current limited DC systems and the following weld geometries are recommended.



$t \leq .15D$



$D_2 \leq 1.3D_1$



$D_2 \leq 1.3D_1$

Furnace Brazing:
1400-1800°F service, copper — 1982°F melt, Nicrobraz 50 — 1800°F flow

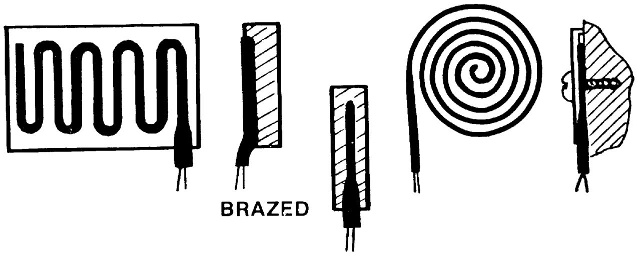
Note: Heater should be mechanically clamped or heliarc tack welded to brazing surface to avoid separation during a furnace brazing cycle.

Application of Heater

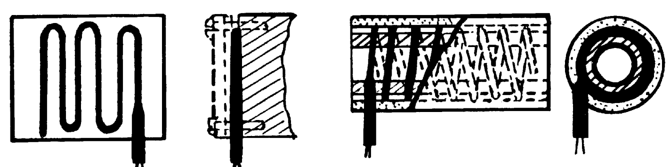
After the heater power level has been determined per the preceeding section, follow-up action is required to insure correct application. In general, insuring good thermal contact throughout the desired temperature range will yield both the highest efficiency and closest temperature control. Mechanical methods using a clamping force or straps will usually suffice for operating temperatures below 500° F or heater watt densities below 10 watts per square inch. Above either 10 watts/in. or 500° F surface oxidation on metals or heater sheath itself will add an insulating barrier. The lower thermal conductivity of such oxides will create an appreciable temperature drop between heater and heated surface, requiring additional power to maintain a given surface temperature and adding a controller setting error. In all cases, this temperature drop will shorten heater life and increase the deviation from set point. A 600° F ± 3° F system can be degraded to 600° F ±20° F by adding an oxide coating between heater and heated metal surface. The following recommendations are based on experience in applying AerOrod heaters to obtain maximum efficiency and life. (Maximum efficiency defined as the minimum power needed to attain and accurately hold a specified temperature)

Temperatures Below 500° F, Metal Surfaces:

1. Heater Built-In

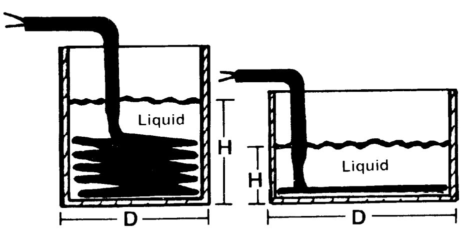


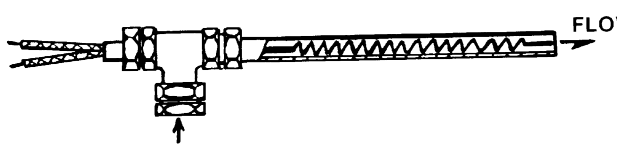
2. Replaceable Heater



Inner Sleeve		Outer Sleeve	
To Heat O.D.	To Heat I.D.	To Heat O.D.	To Heat I.D.
Ceramic Stainless Steel	Copper Aluminum Steel	Copper Aluminum Steel	Ceramic Stainless Steel

3. Heating Liquids

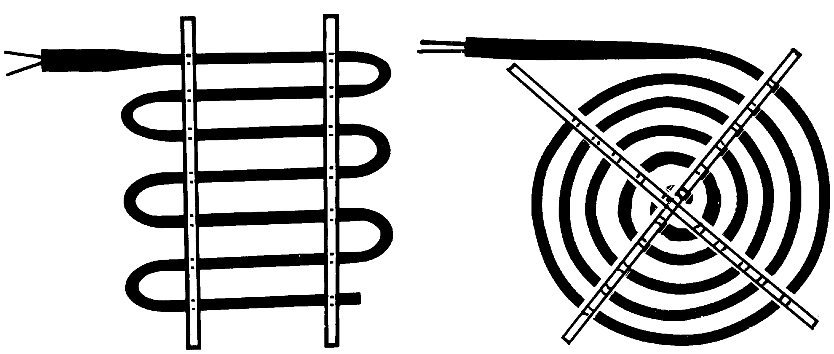




Flowing liquids or air

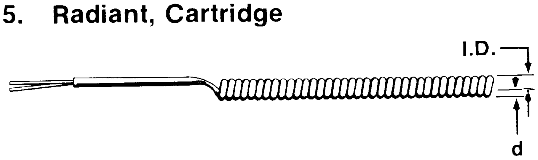
4. Radiant, 1000° F

Open grid pattern normally required. Form to fit desired heating pattern with a minimum of insulating or low conductivity supports to maintain shape. With AerOrod heaters, wire or strap of stainless steel may be used. Strap or wire thickness should be no more than 10% of heated section O.D.



Spacing Between Adjacent Coils should be Equal

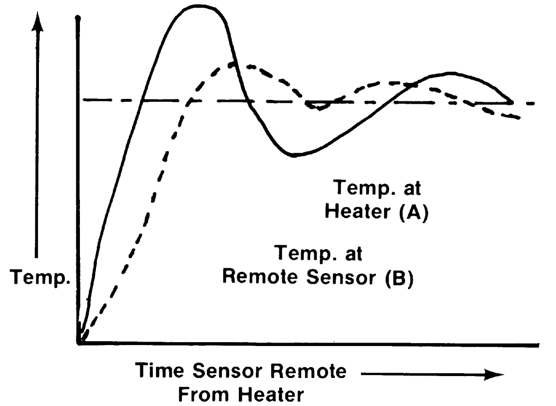
5. Radiant, Cartridge



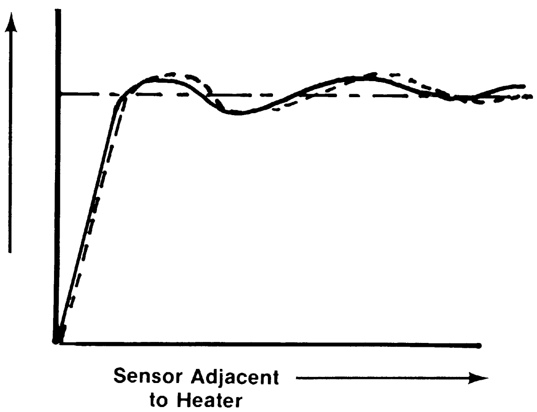
Heated Section

Close Wound, I.D. = 4d as a minimum

Temperature Sensors

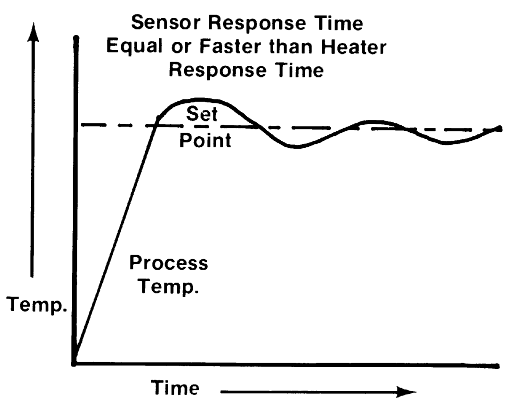


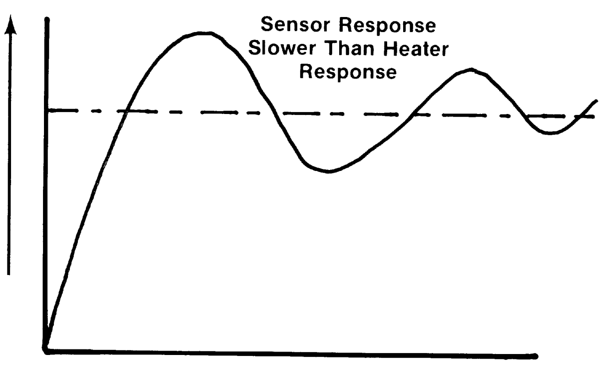
General: Both the location and mass of temperature sensors will affect control system performance. Best response to process changes is normally obtained by locating sensor adjacent to heat source. Location effects during process temperature change:



The mass or size of the sensor determines time response to process changes. If the sensor mass differs from the heater mass, the time response difference will cause excessive control system hunting, increasing temperature swings. It is possible to add anticipatory circuits to overcome this error, better to eliminate the need for compensation by selecting components that are compatible to each other and to the process.

Sensor Response

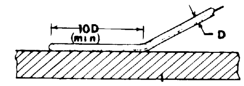




Heater-Sensor or Heater-Load mismatch and location problems may be overcome by adding system variables to the controller such as: variable proportional band, manual or automatic reset and rate. A more reliable and economical system can normally be obtained thru careful selection and matching of sensor and controller to the load. This approach will also result in the lowest possible power demand. Stan-Trol series 300 control system employs the unique approach of combining heater and sensor within one sheath, completely eliminating the possibility of sensor dislocation or time response mismatch.

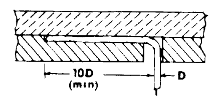
SENSOR ATTACHMENT & MOUNTING

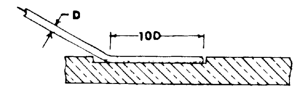
Temperature sensors must accurately generate a signal that is related to the media to be controlled. Therefore, immersion in gases and liquids or attachment to solids must result in minimum random errors caused by the method of installation. The following methods are recommended to decrease installation or application error that will cause control temperature errors or excessive temperature variations.



EXTERNAL

INTERNAL

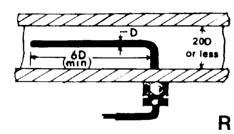




EXTERNAL — PREFERRED

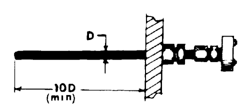
THERMOCOUPLE, METAL SHEATHED TYPE (M.I.)

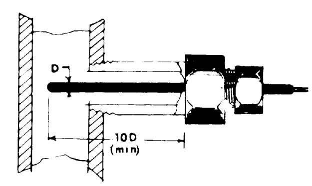
Thermocouples are always tip sensitive sensors, but can be affected by stem conduction. If insufficient sheath length is at process temperature.



RESTRICTED AREA

LARGE AREA





CONTROLLER SELECTION, MATCHED SYSTEMS

The following selection criteria is based on the philosophy of matching heater and sensor to the application, and matching a temperature controller to the selected heater and sensor. This approach will usually result in the most efficient system that will yield lowest cost as based on the initial purchase price and operating costs per hour.

A. TWO-WIRE CONTROLLERS.

Where sensor installation or long term sensor reliability are problem areas, the combined sensor/heater approach to temperature control is recommended. The model 300 controllers are unique in that the special heater is manufactured with a positive temperature coefficient wire to combine the functions of both heat source and resistance thermometer. When combined with the appropriate controller, the heater resistance is sensed by an input bridge circuit. Power demand then becomes a function of the difference in resistance between set point potentiometer and actual heater/sensor resistance. This approach yields a minimum component control systems that allows system accuracies to $\pm 1°F$ with fail-safe features. The positive temperature coefficient wire that is used will limit the power to approximately 50% of that at room temperature in the event that full power is applied continuously — acting as a power proportioning device to avoid the runaway that is possible with previous industrial heater systems. In addition, the heater/sensor employs an averaging effect as the entire heater is also an RTD. Therefore, the controlled temperature will represent the average temperature along the length of the heater/sensor — providing either a large volume temperature uniformity or shaped gradients as a function of the heater forming.

POWER LEVEL:	Determined from initial section of this guide.
INPUT VOLTAGE:	110 VAC line, limited to 1000 watts per circuit.
HEATER-SENSOR MATCHING:	Not required. Heater and sensor are the same unit.
HEATER-SENSOR APPLICATION:	"Prior art" control approaches requiring oversize heaters with large thermal masses added to the two-wire controller system will decrease system accuracy. Highest efficiency and accuracy can be obtained with minimum thermal mass between heater and process as the control system will automatically compensate for changes in heat demand. Minimum mass insures fastest heater sensing and response to such changes in demand.

TABLE 7
HEAT LOSSES OF GLASS FIBER (7 LB/CU FT) INSULATED PIPE IN WATTS/ LINEAR FOOT OF PIPE

PIPE SIZE SCHED 40	INSULATION THICKNESS, AVERAGE, INCH										
	1.0				2.0				3.0		
	TEMPERATURE DIFFERENCE, °F, ΔT										
	.50	150	250	350	50	150	250	350	250	400	500
1	2.3	7.2	12.6	18.4	1.6	5.3	9.1	13.2	7.6	12.8	16.6
2	3.5	10.7	18.7	27.4	2.3	7.3	12.6	18.3	10.3	17.4	22.6
4	5.5	17.1	30.3	44.2	3.6	11.3	19.6	28.6	15.2	25.7	33.2
6	7.4	23.7	42.0	61.7	4.8	15.1	26.2	38.0	20.0	33.9	43.8
8	9.5	30.1	52.6	77.2	5.8	18.6	32.3	46.9	23.7	40.1	51.7
10	11.6	36.1	63.4	93.3	6.9	21.9	37.8	55.1	28.6	48.1	62.3
12	13.6	42.0	74.2	109.1	8.0	25.3	43.8	63.5	32.5	55.3	71.4
14	15.2	48.4	85.0	124.4	9.1	28.6	49.5	72.4	36.3	61.6	79.6
18	19.1	61.1	106.8	156.8	11.3	35.6	62.1	90.5	45.0	76.0	98.6
20	20.9	67.4	117.7	173.0	12.4	39.2	68.1	99.1	49.1	83.2	107.7
24	25.3	80.6	140.1	205.7	14.6	46.2	80.4	117.4	57.8	97.9	126.5

TABLE 8
CORRECTION FACTOR (MULTIPLIER) FOR DIFFERENT INSULATION

INSULATION	TEMP. DIFF., °F			
	50	150	250	350
Glass Fibre 3 LB/CU FT	.95	.95	.96	.97
Calcium Silicate	1.24	1.21	1.20	1.19
Cellular Glass	1.50	1.50	1.50	1.50
85% Magnesium	1.60	1.55	1.50	1.40

TABLE 9
WIND CORRECTION FACTOR (MULTIPLIER) FOR OUTDOOR INSTALLATION

WIND SPEED MPH	CORRECTION
0 - 8	1.0
9 - 18	1.03
19 - 30	1.06
31 - 50	1.15

TABLE 10
RECOMMENDED HEATING CABLE LENGTH ALLOWANCE FOR VALVES

VALVE TYPE	NOMINAL VALVE SIZE																
	½"	¾"	1"	1½"	2"	2½"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"	30"
SCREWED OR WELDED	6"	9"	1'-0"	1'-6"	2'-0"	2'-6"	2'-6"	4'-0"	7'-0"	9'-6"	12'-6"	15'-0"	18'-0"	21'-6"	25'-6"	28'-6"	34'-0"	40'-0"
FLANGED	1'-0"	1'-6"	2'-0"	2'-6"	2'-6"	3'-0"	3'-6"	5'-0"	8'-0"	11'-0"	14'-0"	16'-6"	19'-6"	23'-0"	27'-0"	30'-0"	36'-0"	42'-0"
BUTTERFLY	0"	0"	1'-0"	1'-6"	2'-0"	2'-6"	2'-6"	3'-0"	3'-6"	4'-0"	4'-0"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"	10'-0"

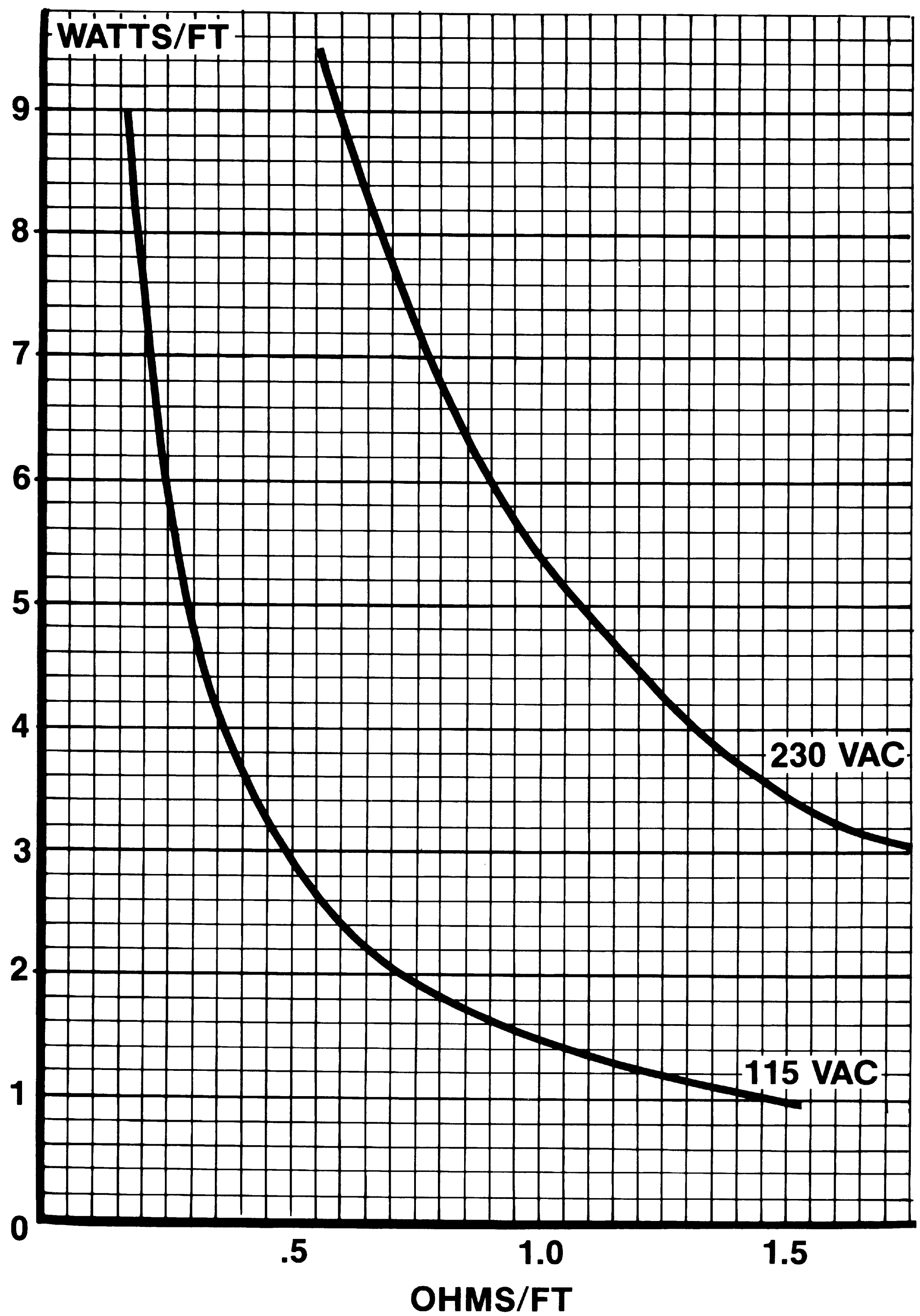
NOTES:
(1) Screwed, welded, and flanged valves include: wedge, plug, globe, diaphragm, gate, multiport, control, and gland.
(2) If multiple tracers are used, divide the length given in the chart by the number of tracers to find the allowance per tracer. Multiple passes may result in less heat applied at the valve. Consideration should be given to increasing the insulation thickness to compensate for this reduction.

HEATER CABLE SELECTION

Heater cables are listed by resistance (OHMS/FT). It is necessary to translate WATTS/FT into OHMS/FT to obtain the correct cable. The following graph can be used for 115 V or 230 V systems.

FIGURE 4

OVER
10 WATTS/FT
MULTIPLY
W/FT COLUMN
BY10, OR
OHMS/FT COLUMN
BY 0.1



UNDER
1 WATT/FT
MULTIPLY
W/FT COLUMN
BY 0.1, OR
OHMS/FT COLUMN
BY 10

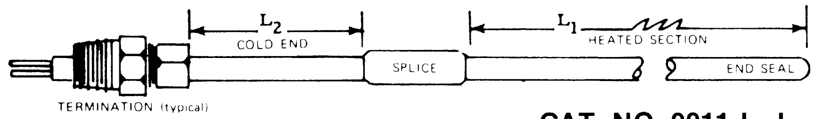
FOR VOLTAGES OTHER THAN 115 OR 230 VAC, USE THE FOLLOWING FORMULA

$$R = \frac{E^2}{(L)^2 P}$$

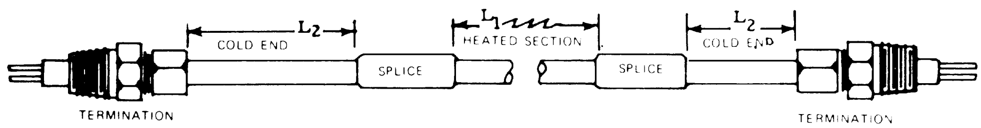
WHERE R IS IN OHMS/FT
L IS LENGTH IN FEET
P IS WATTS/FOOT

Refer to BULLETIN 5.3 for cable selection based on values of OHMS/FOOT and applied voltage.

TRACING HEATER ASSEMBLIES



CAT. NO. 9911-L_1-L_2



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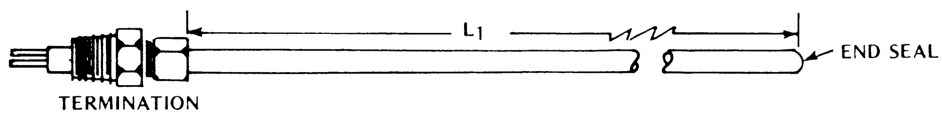

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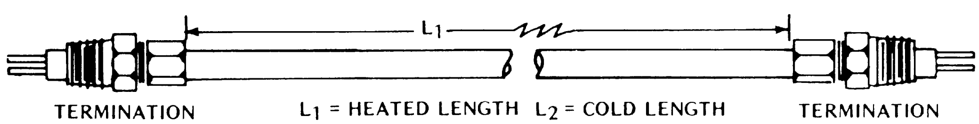
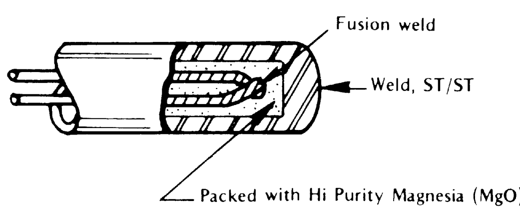


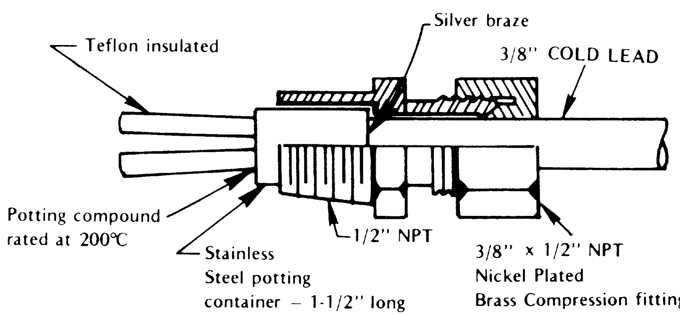
CAT. NO. 9913-L_1

END SEAL

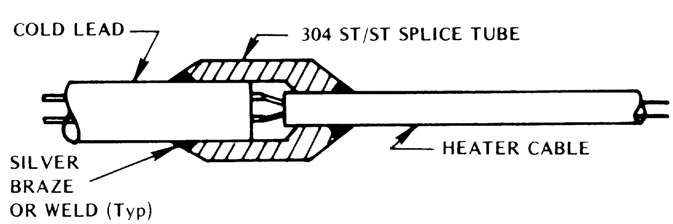


TERMINATION

12 inches of 12 ga Ni plated copper



SPLICE



Where small diameter instrumentation or analysis lines require tracing heaters, standard style BXD or BXX heaters from Bulletin 5.2 should be used.

ARi INDUSTRIES, INC. LINE OF FINE PRODUCTS

MINERAL INSULATED CABLE

- BASE METAL THERMOCOUPLE CABLE
- CONDUCTOR CABLE
- HEATER CABLE
- TRANSDUCER CABLE
- HIGH TEMPERATURE T/C CABLE
- HAZARDOUS AREA CABLE
- ION CHAMBER/FISSION COUNTER CABLE

ASSEMBLIES

- THERMOCOUPLES-BASE METAL
- THERMOCOUPLES-NOBLE METAL
- THERMOCOUPLES-REFRACTORY METAL
- THERMOCOUPLES-PAD TYPE
- THERMOCOUPLES-MULTIPOINT
- HEATERS-MINIATURE, FLEXIBLE
- PLATINUM RESISTANCE THERMOMETERS
- THERMOWELL SYSTEMS, THERMOCOUPLE, RTD
- NEUTRON DETECTORS

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