Technical Information

Watt Density & Heater Selection - Guidelines

Understanding Watt Density

Watt density (W/in²) is the heat flux emanating from each square inch of the effective heating area (heated surface) of the element.

W/in² = Rated Watts ÷ Effective heating area

The effective heating area is the surface area per linear inch of the heater multiplied by the heated length. For strip heaters which are rectangular in shape, the surface area per linear inch is:

1-1/2" wide = 3.45 in² per linear inch
1" wide = 2.31 in² per inch.

The heated length (HL) of strip heaters is calculated as follows:

< 30-1/2" long	HL = Overall Length less 4"
≥ 30-1/2" long	HL = Overall Length less 5"

For tubular elements, watt density is determined by the following formulas.

Effective heating area = ϖ x Dia. x Heated Length

The surface area per linear inch of standard diameter tubular elements is shown below:

Size (Dia.)	In²/in.
0.246 inch (1/4)	0.77
0.315 inch (5/16)	0.99
0.375 inch (3/8)	1.18
0.430 inch (7/16)	1.35
0.475 inch	1.49
0.500 inch (1/2)	1.57

The following example illustrates the procedure for determining the watt density of a typical tubular heater.

Example — A 12 kW screw plug heater has three 0.475" diameter elements with a "B" dimension of 32 inches and a 2 inch cold end. The watt density is:

0.475 x ϖ x (32 in. - 2 in.) x 3 x 2 (Hairpin) = 268 in²

12,000 Watts ÷ 268 in² - 45 W/in²

For convenience in selecting equipment, all heaters in this catalog have the watt density specified for standard ratings.

Heater Selection Guidelines

Once the total heat energy requirements have been determined, the selection of the type of electric heater is based on three criteria.

- Maximum Sheath Temperature
- Sheath Material
- Recommended Maximum Watt Density

Maximum Sheath Temperature — The sheath temperature of an electric element should be limited to prevent damage to the heater and provide reasonable life. To a large extent, the maximum sheath temperature of the heating element is determined by the final operating temperature of the process. In direct immersion applications, the sheath temperature will approximate the temperature of the heated media. In clamp-on, air and gas heating applications, the operating sheath temperature can be estimated using factors derived from empirical charts and graphs.

Sheath Material — Element sheath material is selected based on the maximum allowable sheath temperature, the material being heated and corrosion resistance required. Depending on the sheath material and construction, metal sheathed electric resistance elements will operate satisfactorily at temperatures from less than -300°F (cryogenic) to approximately 1500°F. Copper sheath elements are commonly used for low temperature and direct immersion water heating. Steel is used for oil immersion and strip heater applications. Stainless steel and INCOLOY® are used for corrosive solutions, high-temperature gas or air heating and cartridge heaters. The table below lists the maximum recommended operating temperatures for common sheath materials (UL 1030):

Copper	350°F	Chrome Steel	1200°F
Iron	750°F	Stainless 300	1200°F
Steel	750°F	INCOLOY®	1600°F[1]
MONEL®	900°F	INCONEL®	1700°F[1]

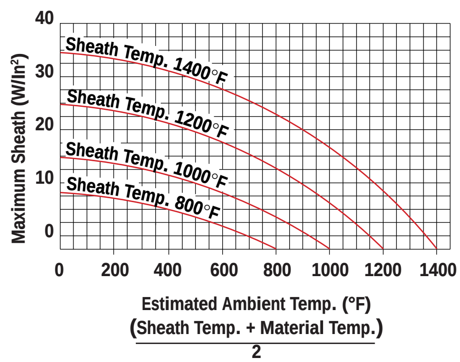
Maximum Recommended Watt Density — Some materials such as water, vegetable oils and salt baths can tolerate relatively high sheath watt densities. Other materials such as petroleum oils or sugar syrups require lower watt densities. These solutions have high viscosity and poor thermal conductivity. If the watt density is too high, the material will carbonize or overheat, resulting in damage to the heating equipment or material being heated. Other sections of this catalog provide guidelines and suggestions for sheath materials and recommended watt densities for many common heating problems.

Using the values determined in the selection criteria, choose the type of heater best suited to the application. For instance, water can be heated by direct immersion, circulation heaters or with tubular or strip heaters clamped to tank walls. The final choice of heater type will involve process considerations, appearance, available space both inside and outside, economy, maintenance, etc. The following pages cover the procedures for selecting heaters for clamp-on applications, liquid immersion heating, oil immersion heating, air or gas heating and cartridge or platen heating.

Clamp-On Heater Applications

The limiting factor in most clamp-on heater applications is the operating temperature of the heater sheath. Selecting heaters for clamp on applications requires an analysis of the maximum expected sheath temperature based on the estimated ambient temperature and the temperature of the material being heated. Graph G-175S provides a method of estimating the sheath temperature and allowable watt densities for tubular heaters for various ambient temperatures and wattage ratings.

Graph G-175S — Clamp-On Tubular Heaters



The example on the following page illustrates the procedure. 12 kW is required to heat material in a steel tank from 70°F to 800°F. Heat is to be supplied by tubular electric elements clamped to the side of the tank. Since the material is heated to 800°F, INCOLOY® sheath elements must be used.

Note 1 — For sheath temperatures above 1500°F, contact your Local Chromalox Sales office for application assistance.

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Allowable Watt Density & Heater Selection - Guidelines

Selecting Clamp-On Tubular Heaters (cont'd.)

From the chart, a maximum sheath temperature of 1200°F results in an average ambient temperature of (800°F + 1200°F) ÷ 2 = 1000°F. From the curves, the allowable watt density is 9.5 W/in^2. Based on size of container, 0.475 inch diameter TRI elements 28 in. long are selected.

The 0.475 TRI element has 1.49 in^2 per linear inch of sheath. The heated length is the overall sheath length less 6.5 inches. The allowable wattage rating on the element is (28 - 6.5) x 1.49 x 9.5 = 305 watts. The total number of elements required is 12,000W ÷ 305W = 39 elements. Order 39 elements similar to TRI-2845 except rated 305 watts. If the application requires the use of tubular elements whose overall length is not standard, each element rating would be determined as follows:

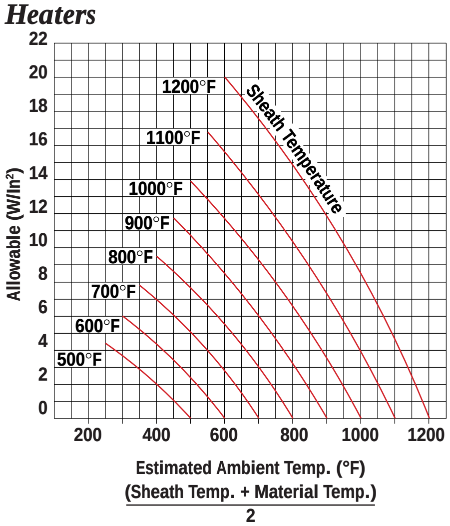
Heater Watts = (*A* - 2CE) (*Area* x 9.5W)

Where:
A = Sheath length, overall
CE = Cold pin length
Area = Effective heated area (in^2/in.)
9.5 = recommended W/in^2 from G-175S

Selecting Clamp-On Strips Heaters

Graph G-130S provides a method of estimating the maximum allowable watt density for strip heaters for clamp on applications based on sheath operating temperature and various ambients.

Graph G-130S — Clamp-On Strip Heaters



Using the previous 12 kW example, determine the number of strip heaters required. An 800°F material temperature requires chrome steel strip heaters. From Graph G-130S, a maximum sheath temperature of 1200°F results in an ambient temperature of 1000°F inside the space between the thermal insulation and the vessel, (800°F + 1200°F) ÷ 2 = 1000°F.

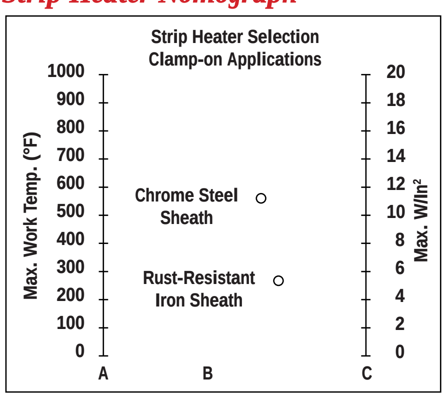
From the curve, the allowable watt density is 8 W/in^2. Based on the tank size, chrome steel sheathed strip heaters 24 inches long without mounting tabs were selected. To determine the number and wattage of strip heaters needed, use the formula: allowable watts per strip = (overall length minus 4" cold section) x 3.45 in^2 per lineal inch of sheath x 8 watts/in^2. Thus (25-1/2" - 4") x 3.45 x 8 = 593 (600) watts. The total number of strips required is 12,000W ÷ 600W = 20 strips. Order strips similar to OT-2507 in size but rated 600 watts. To avoid a special order, consider using 24 standard OT-2405, 500 watt strips. These heaters would have a watt density of:

500W ÷ ([23-3/4 - 4] x 3.45) = 7.35 W/in^2

If the application uses 3 phase power, the total element count should be a multiple of 3 to permit a balanced electrical load.

The nomograph below may also be used for heater selection in clamp-on strip heating applications.

Strip Heater Nomograph



To Use the Graph —

1. **Select** the maximum desired work temperature on A.
2. **Choose** either chrome steel or rust-resistant iron sheath (points B) on the basis of operating temperatures.
3. **Draw** a straight line through points A and B to C. C gives the maximum allowable watts per square inch.
4. **Select** desired length heater with equivalent or less watt density.

General Recommendations for Liquid Heating Applications

Chromalox standard immersion heater ratings match the suggested watt densities for general purpose immersion heating. Extended heater life will be obtained by using the lowest watt density practical for any given application.

Standard Ratings —

Water Heaters	45 - 75 W/in^2
Corrosive Solution Heaters	20 - 23 W/in^2
Oil Heaters (Light Wt.)	20 - 23 W/in^2
Oil Heaters (Medium Wt.)	15 W/in^2
Oil Heaters (Heavy Wt.)	6 - 10 W/in^2

Suggested Allowable Watt Densities for Liquids

Material	Max. Temp (°F)	Max. W/In^2
Acid solutions	180	40
Alkaline solutions (Oakite)	212	40
Asphalt, tar, and other heavy or highly viscous compounds	200 300 400 500	10 8 7 6
Bunker C fuel oil	160	10
Caustic soda 2% 10% 75%	210 210 180	45 25 15
Dowtherm® A	750	23
Dowtherm® A vaporizing	750	10
Dowtherm® J liquid	575	23
Electroplating tanks	180	40
Ethylene glycol	300	30
Freon	300	3
Fuel oil pre-heating	180	9
Gasoline, kerosene	300	20-23
Machine oil, SAE 30	250	18-20
Metal melting pot	500-900	20-27
Mineral oil	200 400	20-23 16
Molasses	100	4-5
Molten salt bath	800-950	25-30
Molten tin	600	20-23
Oil draw bath	400 600	20-23 16
Steel cast into aluminum	500-750	50
Steel cast into iron	750-1000	55
Heat transfer oils (Therminol®, Mobiltherm®, etc.)	500-650	23
Vapor degreasing solutions	275	20-23
Vegetable oil (fry kettle)	400	20-30
Water (process)	212	40-75
Water (washroom)	140	75-100

Note — The above watt densities are based on non-circulating liquids. The allowable watt density may be adjusted when heat transfer or flow rates are increased.