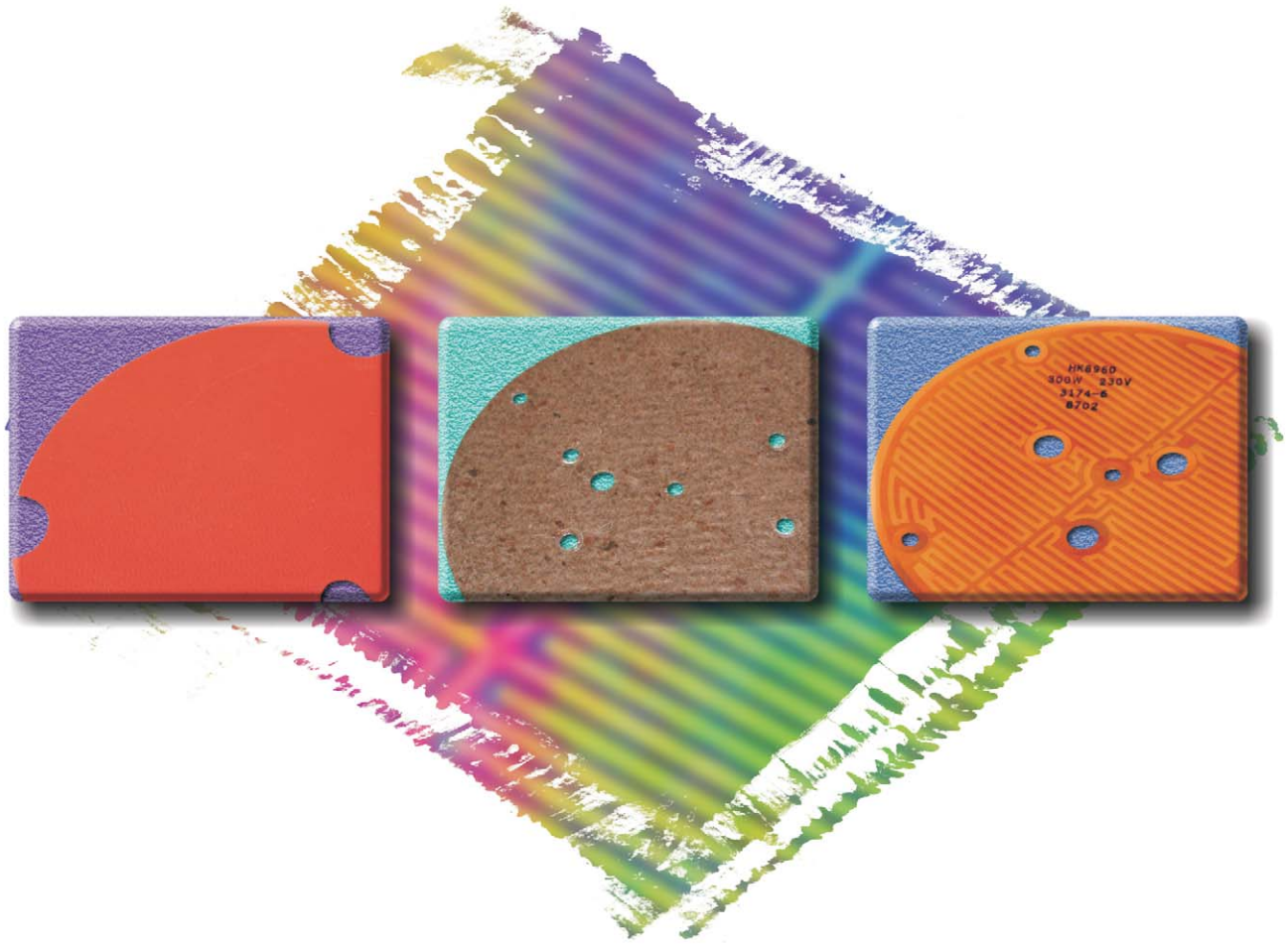
BULLETIN HS-202(B)

THERMOFOIL™ HEATERS



Kapton Heaters • Rubber Heaters • Mica Heaters • All-Polyimide Heaters
Thermal-Clear™ Heaters • Flexible, light weight, high watt density
Stock, standard and custom models • UL recognized
Temperature Controllers • Sensors • Accessories

MINCO

Minco Products, Inc.
7300 Commerce Lane • Minneapolis, MN 55432 U.S.A.
Tel: 1-763-571-3121 • Fax: 1-763-571-0927 • www.minco.com

Minco: The solution to heating problems

In 1959 Minco made flexible RTD temperature sensors for gyroscope navigation systems. The gyroscopes used a wire-wound heater to maintain a steady temperature, but the heaters would burn out when operated at full power.

Although Minco didn't build the heaters, our engineers identified the problem as poor heat transfer. The wire element covered only a small fraction of the surface so not enough power could be applied to keep the necessary temperature.

Minco etched heater patterns on a flexible substrate. With active heating element covering much more of the surface, it was possible to put more heat into the gyroscopes without burning out the elements.

These first Thermofoil™ heaters were the lightweight, efficient solution to a difficult problem. Thermofoil™ technology now solves problems in critical aerospace, medical and commercial products.

Minco continued to innovate. Examples are:

- First etched-foil heaters
- First integrated sensors in heaters
- First heaters on Kapton
- First profiled heaters for more uniform temperature
- First integral flex-circuits
- First foil heaters on mica
- First with CAD designed artworks and tooling
- First transparent wire heaters using NC winding

To date Minco has designed and built more than 15,000 models of heaters.

Minco facilities

Today Minco's heater production occupies three adjacent plants near Minneapolis, totaling 140,000 ft² (13,000 m²), with additional manufacturing in France.

Plant 1

Plant 2

Plant 3

The plants feature state-of-the-art equipment for heater design, etching, leadwire welding, and lamination. Assembly of layers takes place in a clean room to avoid entrapment of foreign material.

All chemical processing and waste-water treatment comply with strict Minnesota environmental laws. Minco has been recognized as a leader in recovering metal waste from etchant.

Quality assurance

Minco takes a multi-tiered approach to quality. A heater built for the Trident missile, for example, will have complete Class 1 documentation. A heater for a commercial application will require far less paperwork, but will still completely conform to its specifications. A dedicated, trained work force ensures full compliance.

Minco is ISO 9001: 2000 certified.

Engineered to work

Minco's engineering staff employs the latest tools to design the optimum heater for your application. They can select from the industry's broadest choice of materials to tailor the heater to the environmental conditions it will experience. CAD design is linked to production tooling to ensure repeatable fabrication.

A single source for thermal control

Thermal design is one of the most demanding disciplines within engineering. Minco makes it easier by furnishing all the components you need, from one manufacturer.

Minco is one of the nation's leading producers of temperature sensors. Because we construct our own sensors, start to finish, we can furnish sensors ideally suited for control of Thermofoil heaters. Flexible Thermal-Ribbon™ RTD's can be mounted alongside heaters or incorporated into them for accurate, responsive sensing. See page K-11 for a selection of popular sensors.

Minco also furnishes temperature controllers, from the unique sensorless Heaterstat™ to programmable microprocessor models with fuzzy logic. See section K for specific model information.

We'll help

Page L-4 lists additional publications that will assist in your design.

When you need personal consultation call Minco's expert sales engineers at 1-763-571-3121. Or contact your local field representative, who has received factory training in the design and application of Thermofoil heaters.

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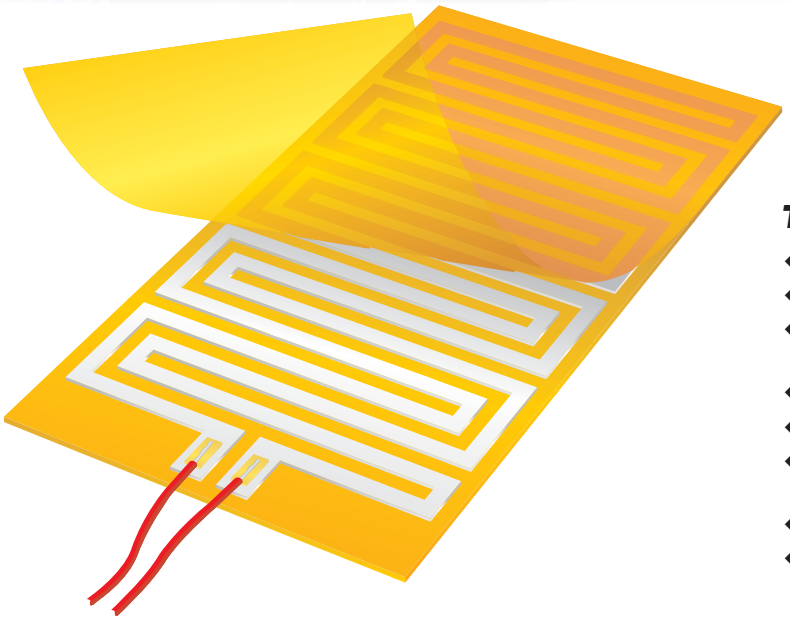
Thermofoil™ Solutions for Heating



Thermofoil™ etched foil heaters

- Foil element
- Uniform heat patterns
- Permits complex shapes and profiled heat patterns
- Thin, small bend radius
- Small sizes
- Many insulation options (Kapton™, silicone rubber, mica, polyester, PTFE)
- High watt density
- Welded leadwires

Thermofoil heaters are thin, flexible heating elements consisting of an etched foil resistive element laminated between layers of flexible insulation. Since their introduction by Minco over 25 years ago, Thermofoil heaters have demonstrated significant advantages over conventional electric heaters:

Precise heating

Thermofoil heaters put heat where you need it. You simply apply them to the surface of the part to be heated. Their thin profile gives close thermal coupling between the heater and heat sink. You can even specify profiled heat patterns higher watt densities in areas where heat loss is greater.

Faster warmup and longer life

The flat foil element of Thermofoil heaters transfers heat more efficiently, over a larger surface area, than round wire. Thermofoil heaters therefore develop less thermal gradient between the resistive element and heat sink. Heaters stay cooler. The result is higher allowable watt densities, faster warmup, and prolonged insulation life. Thermofoil heaters can safely run at wattages twice those of their wire-wound equivalents. Insulation life may be ten times greater. For high levels of reliable heat, the obvious choice is Thermofoil.

Space and weight savings

A Kapton heater typically weighs only 0.009 oz/in^2 (0.04 g/cm^2) and measures just 0.010" (0.25 mm) thick over the element. For applications with little room for a conventional heater — satellites and spacecraft, airplanes, portable instruments, high density electronic devices — Thermofoil heaters pack the heat in.

Custom tailored for better fit

Size and shape possibilities are limitless. Minco has built heaters as large as 18 feet long, and as small as 0.25" square. You can specify intricate geometries to follow the bumps and curves of your hardware. Computer aided design produces uniform or profiled heating elements to meet your precise needs.

Integral temperature sensors

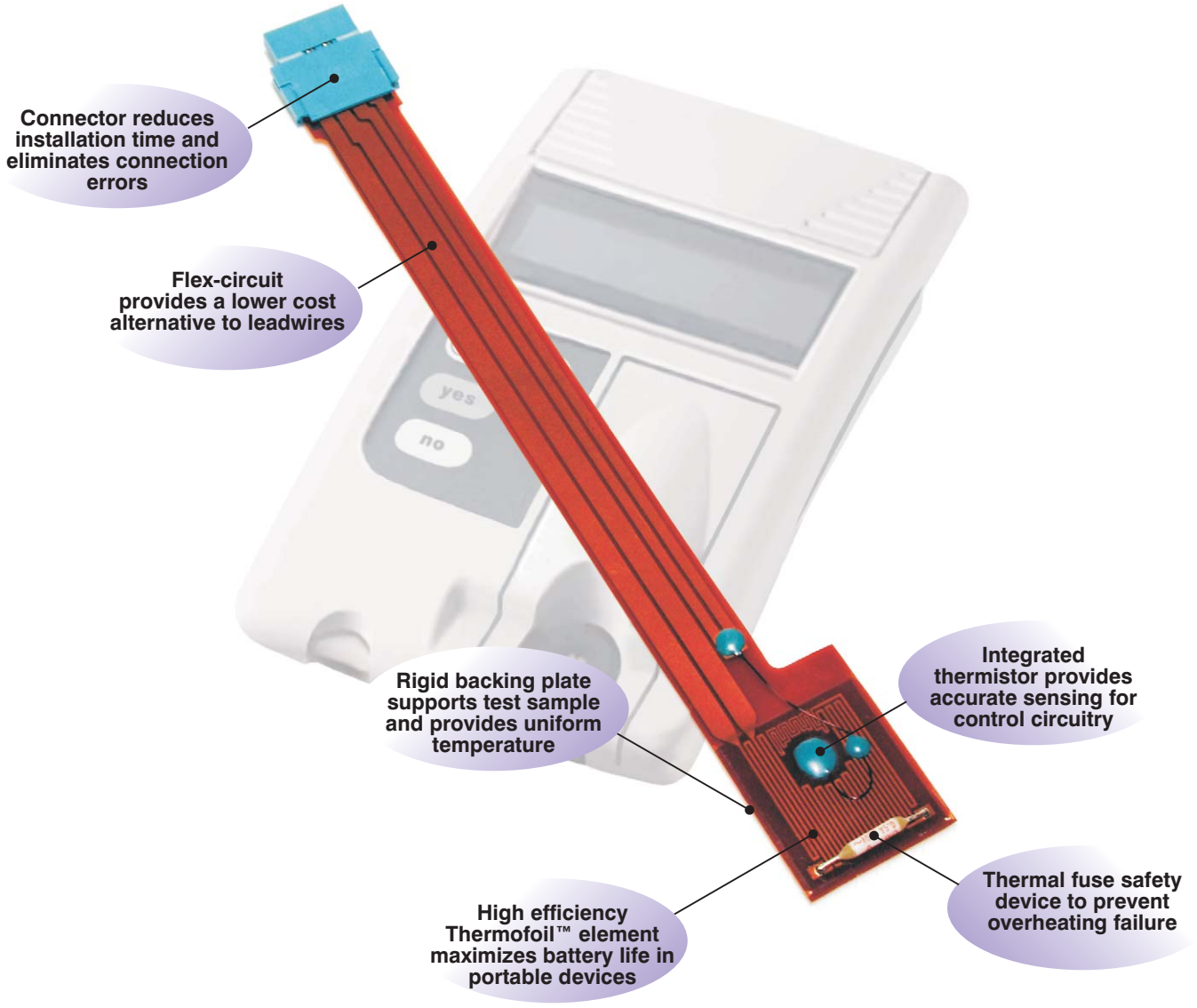
Minco is a leading manufacturer of temperature sensors and instruments. We can furnish heaters with integral resistance thermometers, thermocouples, thermistors, or thermostats. Minco controllers link sensors and heaters.

Heater subassemblies

As an added service, Minco can laminate, vulcanize, or clamp heaters to mating metal parts. Our specialized equipment guarantees tight bonds, high reliability, and superior performance. We mount the heater to your furnished parts, or fabricate heat sinks in our modern machine shop.

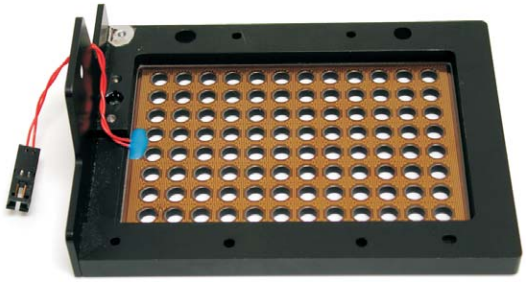
Thermofoil™ Solutions for Heating

When a leading manufacturer of medical diagnostic equipment needed a special heater design, they came to Minco . . .



. . . and working together, we created a solution that reduced cost, improved reliability, and helped launch a successful product.

DNA testing

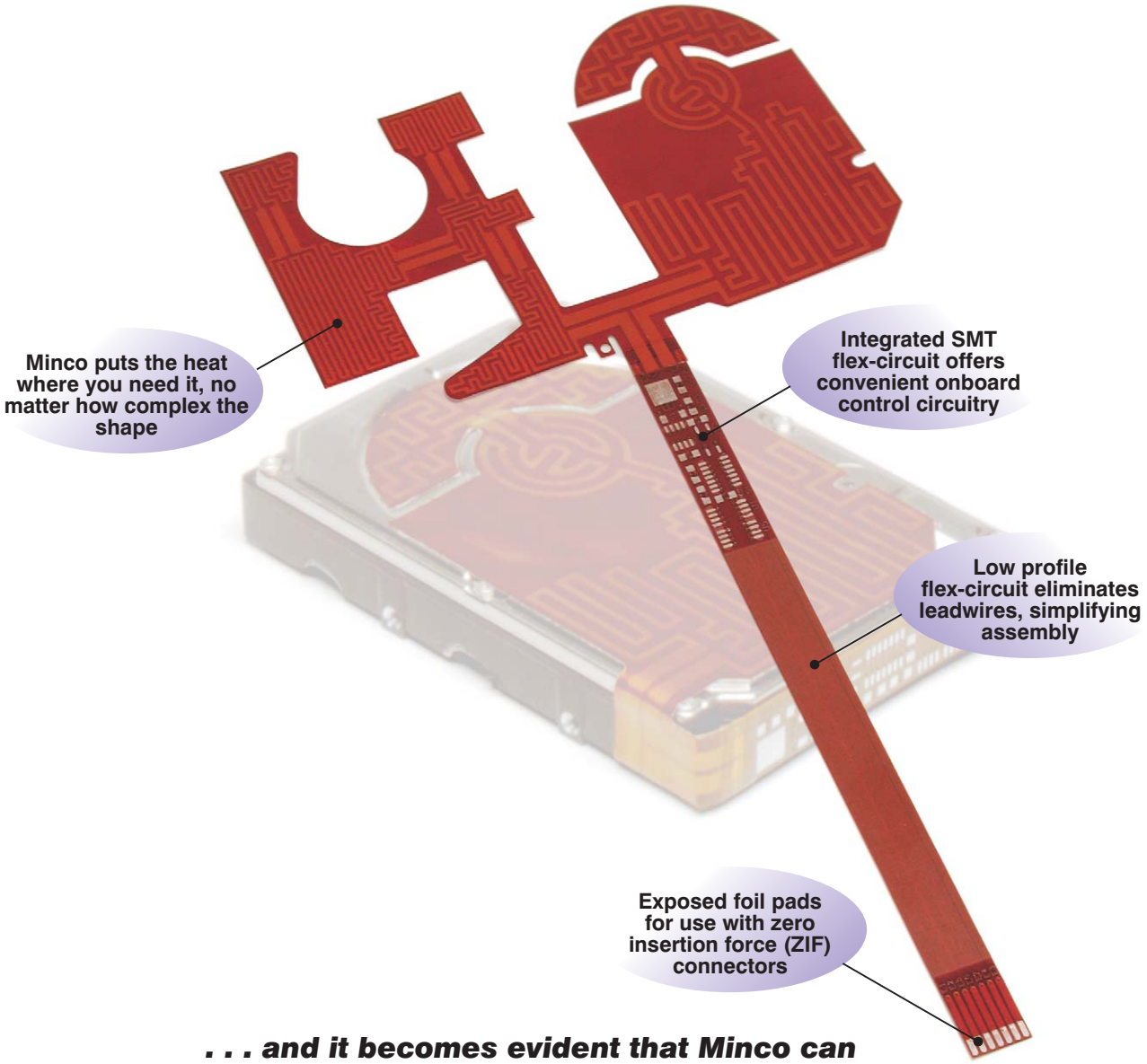


Respirator

Sample vial

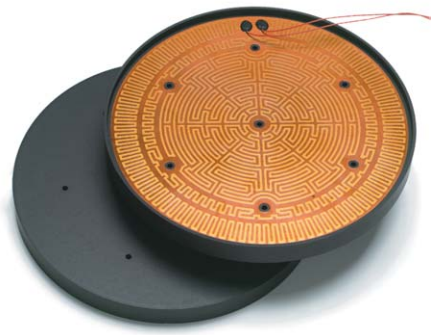
Thermofoil™ Solutions for Heating

With a 3-dimensional approach to heating design, the possibilities are endless. Add to that the ability to integrate temperature sensors, flexible circuits, and SMT control electronics . . .

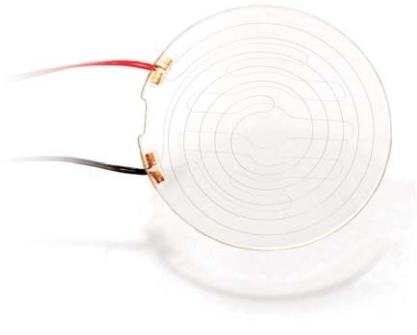


. . . and it becomes evident that Minco can provide a solution to nearly any heating problem.

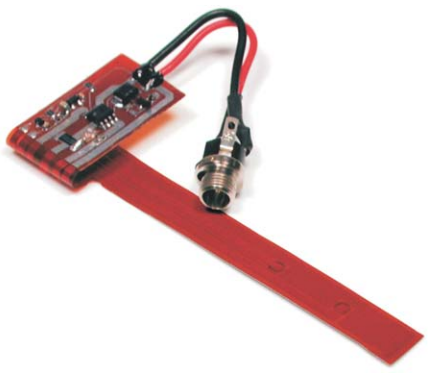
Heated chucks



Cockpit instrumentation

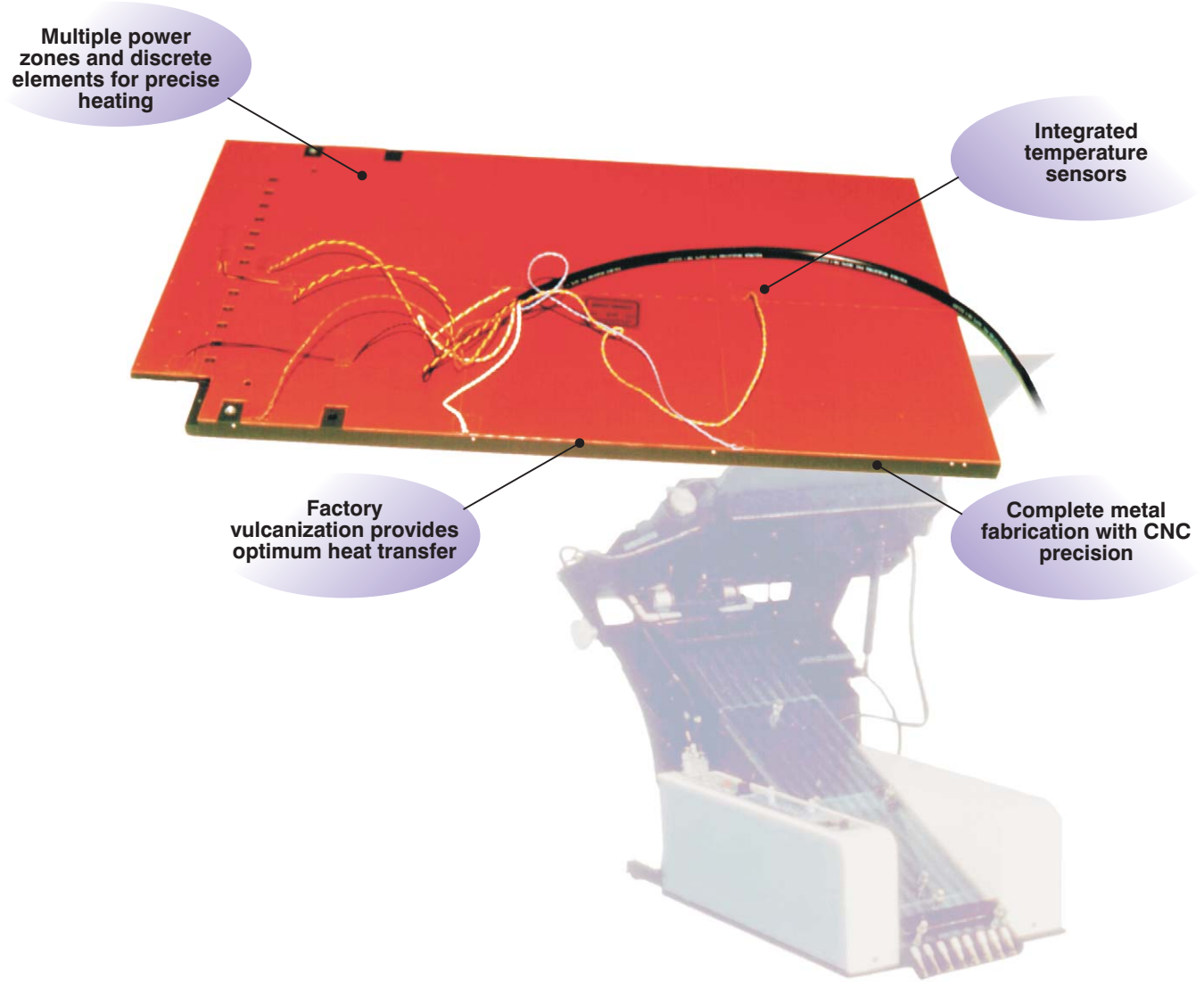


Industrial computing



Thermofoil™ Solutions for Heating

High volume testing machines for IC's require the best thermal performance with minimum down-time . . .

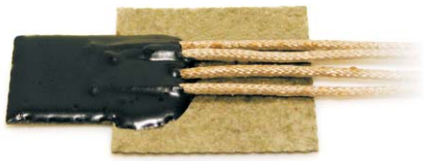


. . . Minco's complete assemblies include heating, sensing, protection and cables suitable for factory floor conditions.

Large motors

Food trays

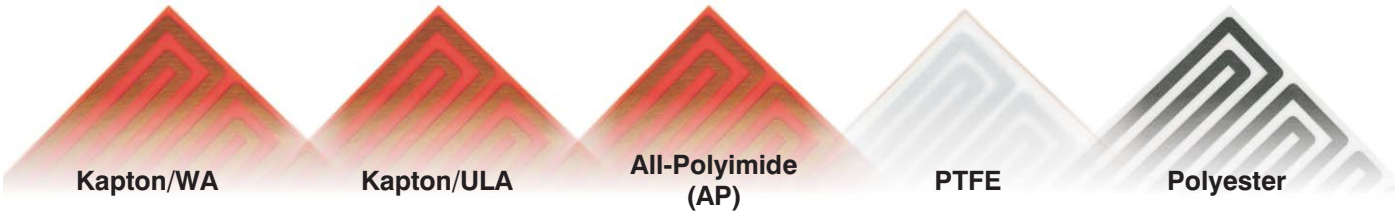
Chemical analyzers



Heater Insulations

Standard catalog insulations

Material	Temperature range	Max. size	Max. resistance density*	Comments
Kapton/FEP	-200 to 200°C -328 to 392°F	10" × 22" 250 mm × 560 mm	50-450 Ω/in² 8-70 Ω/cm²	See section B & D
Silicone rubber	-45 to 235°C -50 to 455°F	22" × 72" 560 mm × 1825 mm	200 Ω/in² 31 Ω/cm²	See section C & D (foil type) See section E (wire-wound type)
Mica	-150 to 600°C -238 to 1112°F	22" × 46" 560 mm × 1160 mm	11.5 Ω/in² 1.8 Ω/cm²	See section F
Optical grade polyester	-55 to 120°C -67 to 248°F	22" × 22" 560 mm × 560 mm	600-1200 Ω/in² 93-185 Ω/cm²	See section G



Alternative insulations (custom designs)

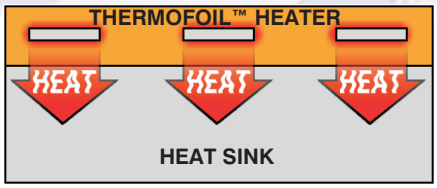
Material	Temperature range	Max. size	Max. resistance density*	Comments
Kapton/WA Polyimide film with acrylic adhesive	-200 to 150°C -328 to 302°F	22" × 72" 560 mm × 1825 mm	50-1500 Ω/in² 8-230 Ω/cm²	Similar to Kapton/FEP except lower cost, higher resistance densities, and lower temperature range. WA is preferred over FEP for most custom designs under 150°C.
Kapton/ULA Polyimide film with UL recognized acrylic adhesive	-200 to 150°C -328 to 302°F	22" × 72" 560 mm × 1825 mm	50-1500 Ω/in² 8-230 Ω/cm²	Similar to Kapton/WA except UL recognized (UL94V-0).
All-polyimide (AP) Polyimide film with polyimide adhesive	-200 to 260°C -328 to 500°F (to 300°C for short periods)	22" × 22" 560 mm × 560 mm	50-1500 Ω/in² 8-230 Ω/cm²	Higher temperatures and watt densities than standard Kapton construction at greater cost. Typical applications include semiconductor processing and laboratory equipment.
PTFE	-200 to 260°C -328 to 500°F	10" × 40" 254 mm × 1016 mm	50-450 Ω/in² 8-70 Ω/cm²	Fully sealed construction suitable for immersion in acids, bases, and other corrosive chemicals.
Polyester	-55 to 80°C -67 to 176°F	22" × 90" 560 mm × 2285 mm	50-300 Ω/in² 8-45 Ω/cm²	Low cost material for economic fabrication of large heaters.

* Resistance density varies with the size of the heater (higher density possible with smaller heaters).

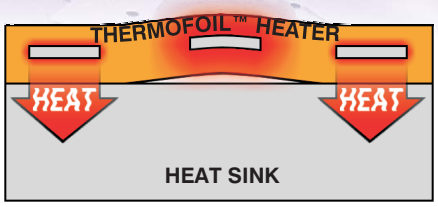
Heater Installation

Versatile Thermofoil™ heaters allow a variety of mounting methods.

Proper installation is crucial to heater performance. The heater must be in intimate contact with surface beneath, as any gaps can block heat and cause a hot spot.



Proper installation ensures good heat flow from the heater to the heat sink.



Voids or bubbles beneath the heater cause localized hot spots.

Pressure-sensitive adhesive (PSA) and #17 film

With factory-applied PSA, you simply remove the backing paper and press the heater in place.

#17 film for Kapton heaters requires high temperature and pressure to cure.

Description	Temperature rating	Comments	Installation instruction*
Acrylic PSA 0.002" (0.05 mm) acrylic film	See heater ordering information	♦ NASA approved for outgassing ♦ Flat surfaces only, unless aluminum backed	EI 138
#12 PSA 0.002" (0.05 mm) silicone film		♦ Flat or slightly curved surfaces	EI 266
#17 film 0.001" (0.03 mm) acrylic film (replaces #14 film)	-200 to 150°C -328 to 302°F	♦ NASA approved for outgassing ♦ Laminate at 160°C and 250 psi (17 bar)	EI 503

Epoxy and cement

Liquid adhesives require more care in application than PSA, but generally provide higher temperature/wattage performance.

Description	Temperature rating	Comments	Installation instruction*
#6 RTV cement Room temperature vulcanizing silicone for rubber heaters	-45 to 235°C -49 to 455°F	♦ Distance from center of heater to edge must be less than 5" (127 mm) ♦ 3 oz. tube covers 800-1300 in² (5000-8000 cm²)	EI 117
#15 epoxy 2-part epoxy for Kapton heaters	-70 to 115°C -94 to 239°F	♦ NASA approved for outgassing ♦ Bi-pack covers 150-300 in² (900-1800 cm²)	EI 507

Easy installation methods for cylindrical surfaces

Shrink bands are pre-stretched strips of film with adhesive coated ends. Wrap around the heater and heat to shrink. Stretch tape installs quickly with no heat required.

Description	Temperature rating	Comments	Installation instruction*
BM3 shrink band Polyester strip	-73 to 149°C -100 to 300°F	♦ To order, specify band width and cylinder diameter	EI 103
BK4 shrink band Kapton strip	-73 to 177°C -100 to 350°F		
#20 stretch tape Self-fusing silicone tape	-51 to 200°C -60 to 392°F	♦ Comes in 6 or 36 foot rolls, 1" wide. Figure 25% overlap when calculating length required.	EI 124

*Installation instructions and AA #22 available at www.minco.com/support

Clamping

Mechanical clamping is required for mica heaters and optional for Kapton (not recommended for rubber). Ask for Minco Installation instruction EI 347.

Factory vulcanization and lamination

See page J-4 for information on high-performance bonding of heaters to mating parts.

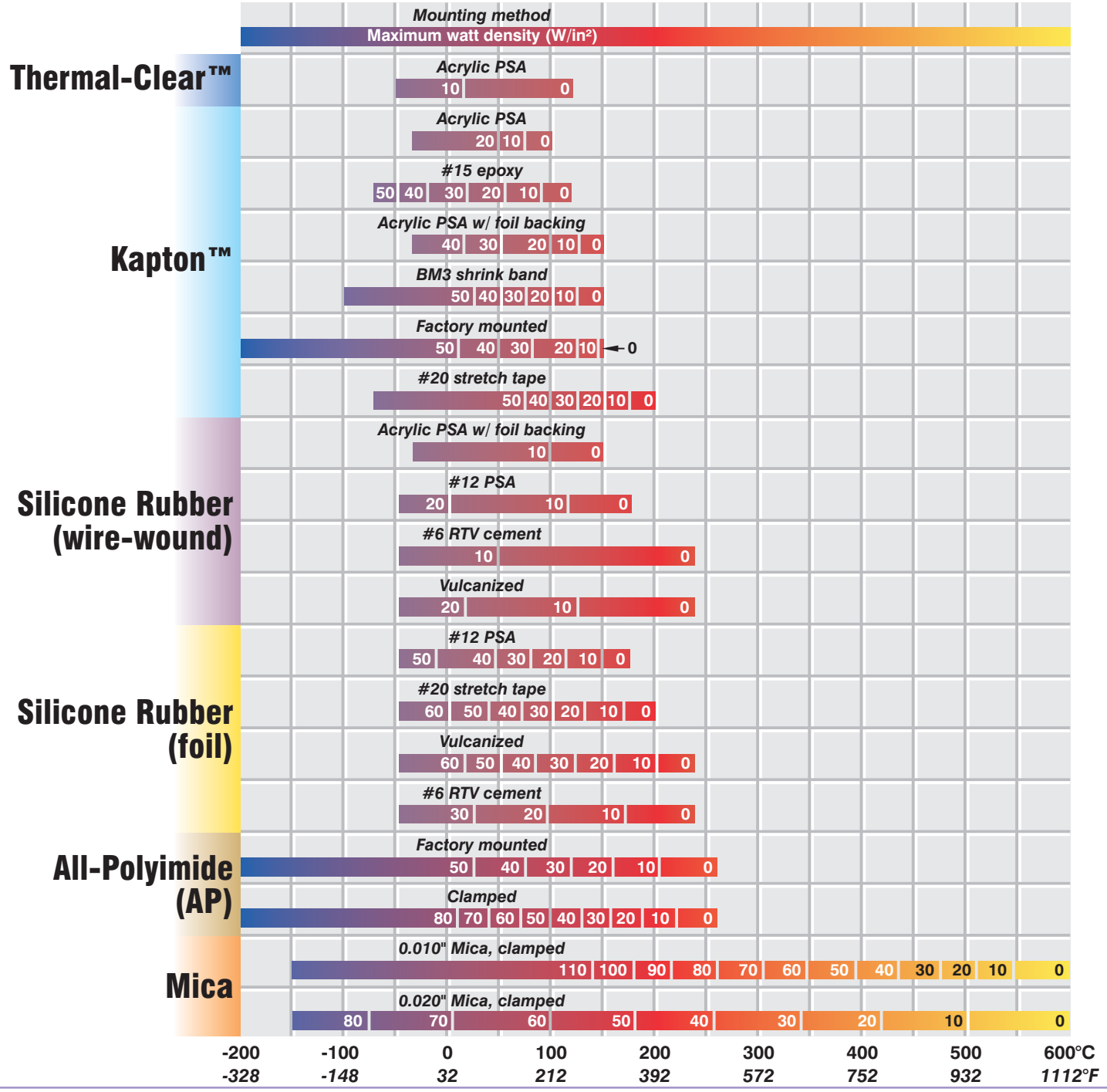
Maximum Watt Density

The power a heater can safely produce is limited by:

- The heater's insulation and internal adhesive
- The method used to install the heater
- The control temperature of the heat sink
- The area available for heating

Use the chart below to verify your selection of heater insulation and installation method with the required watt density:

1. Look up the effective area for the heater model in question. This is total heater area minus borders and lead attachment space (calculated by Minco).
2. Divide the power requirement in watts by this area to obtain watt density.
3. Draw a line from the heat sink temperature (at the bottom of the chart) to the colored bar labeled with the insulation and mounting method you have chosen.
4. The maximum watt density is indicated by the value printed in that segment of the colored bar. The individual sections of this catalog contain more detailed watt density charts.



Selecting a Catalog Heater

Calculating required wattage

The heater you select must produce enough power to (1) warm the heated object up to temperature in a specified time and (2) maintain that temperature.

The specific heat formula (page J-1) gives an estimate for warmup, assuming all heat enters the object and none is lost. Add at least 20% to account for unknown losses.

Heat loss factors include conduction, convection, and radiation. A more accurate wattage estimate will take these into account. For a general discussion of heat loss, request Minco Application Aid #21, "Estimating Power Requirements of Thermofoil Heaters." Also helpful is Thermal Calc, a free DOS program to assist with calculations (available at www.minco.com).

The best way to make a final determination of heat requirements is by experimentation. See page J-1 for tips, or request Application Aid #25, "Prototyping Techniques for Thermofoil™ Heaters."

Ohm's Law

A Thermofoil™ heater has a specific *resistance*. Its power output in watts depends on supply voltage ($W=E^2/R$).

R Ohms (Ω)			**P Watts (W)**			**I Amps (A)**			**E Volts (V)**		
$\frac{E}{I}$	$\frac{E^2}{P}$	$\frac{P}{I^2}$	EI	I^2R	$\frac{E^2}{R}$	$\sqrt{\frac{P}{R}}$	$\frac{P}{E}$	$\frac{E}{R}$	$\sqrt{PR}$	$\frac{P}{I}$	IR

Maximum wattage

The watt density tables on the following pages show the maximum allowable power for each heater type, expressed in watts per square inch of effective area. The rating depends on heater material, heat sink temperature, and the mounting method.

If wattage exceeds the maximum, the heater is in danger of burning up. Ways to obtain more power:

- Specify a larger size heater.
- Consider other heater materials, e.g. mica.
- Change the mounting method.
- Use proportional control to reduce power as the heat sink temperature rises. This requires a short controller cycle time and a fast responding sensor.
- Contact Minco for design assistance.

In addition to wattage, you should calculate the current (I) through the heater leadwires to keep it within the maximum rating for that AWG size.

Heater selection examples

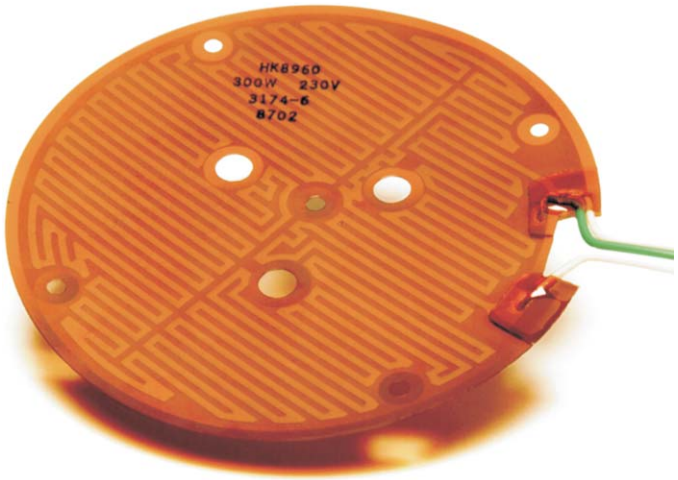
Desired temperature	60°C	100°C	100°C (same as left)	150°C
Power required	300 W at 115 V	500 W at 240 V		2500 W at 480 V
Heater size	3" × 6"	2" × 10"		9" diameter
Ideal resistance	$115^2/300 = 44.1\ \Omega$	$240^2/500 = 115\ \Omega$		$480^2/2500 = 92.2\ \Omega$
Mounting method	#3 shrink band	#6 RTV cement	Factory vulcanized	Clamped
Model chosen	HK5468 R46.1 L12 A	HR5430 R96.8 L12 A		HM6810 R83.4 L12 T2
Effective area	15.74 in²	18.20 in²		58.5 in²
Actual power	$115^2/46.1 = 287$ W	$240^2/96.8 = 595$ W		$480^2/83.4 = 2762$ W
Watt density	287/15.74 = 18 W/in²	595/18.20 = 33 W/in²		2762/58.5 = 47 W/in²
Max. watt density	36 W/in² at 60°C	19 W/in² at 100°C	36 W/in² at 100°C	54 W/in² at 150°C
Wattage OK?	Yes (18 < 36)	No! (33 > 19)	Yes (33 < 36)	Yes (47 < 54)
Leadwire current	115/46.1 = 2.5 A	240/96.8 = 2.5 A		480/83.4 = 5.8 A
Current OK?	Yes (2.5 < 7.5)	Yes (2.5 < 5.0)		Yes (5.8 < 11.0)

Kapton™ Heaters

200°C

Kapton is a thin, semitransparent material with excellent dielectric strength. Kapton heaters are ideal for applications with space and weight limitations, or where the heater will be exposed to vacuum, oil, or chemicals.

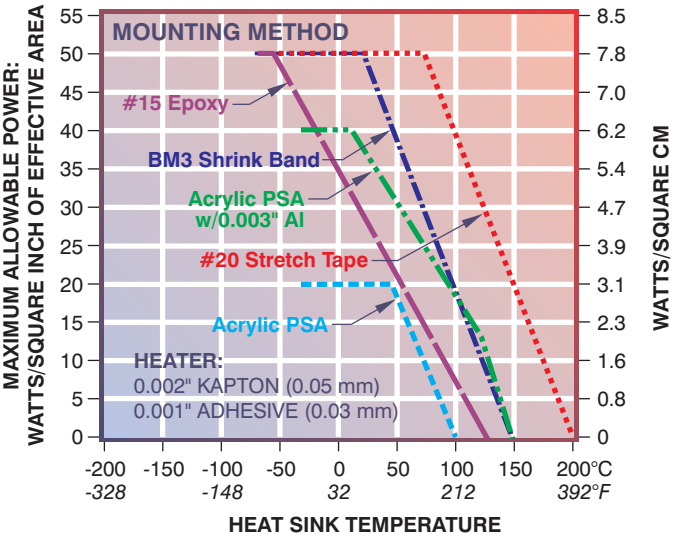
- FEP internal adhesive for use to 200°C
- UL component recognition available
- Suitable for vacuum environments (NASA-RP-1061)
- NASA approved materials for space applications (S-311-P-079)
- Resistant to most chemicals: acids, solvents, bases (except NaOH)
- Radiation resistant to 10^6 rads if built with polyimide-insulated leads (custom option)
- Can be made in very small sizes
- Fluid immersible models available (not standard)



Typical applications

- Medical diagnostic instruments: Heat sample trays, cuvettes, reagent bottles, etc.
- Warm satellite components
- Protect aircraft electronic and mechanical devices against cold at high altitudes
- Stabilize optoelectronic components
- Test or simulate integrated circuits
- Enable cold weather operation of outdoor electronics such as card readers or LCD's
- Maintain constant temperature in analytic test equipment

Maximum watt density, Kapton™ heaters



Example: At 50°C, the maximum power for a heater mounted with acrylic PSA is 18 W/in².

Specifications for catalog models

Temperature range: -200 to 200°C (-328 to 392°F). Upper limit with 0.003" (0.08 mm) foil backing is 150°C (302°F).

Material: Kapton/FEP, 0.002"/0.001" (0.05/0.03 mm).

Resistance tolerance: ±10% or ±0.5 Ω, whichever is greater.

Dielectric strength: 1000 VRMS.

Minimum bend radius: 0.030" (0.8 mm).

Leadwire: Red PTFE insulated, stranded.
Current capacity (based on 100°C max. ambient temp.):

AWG 30	AWG 26	AWG 24	AWG 20
3.0 A	5.0 A	7.5 A	13.5 A

Maximum heater thickness:

Over element	0.012" (0.3 mm)
Over leads	
AWG 30 (0.057 mm²)	0.050" (1.3 mm)
AWG 26 (0.141 mm²)	0.060" (1.5 mm)
AWG 24 (0.227 mm²)	0.065" (1.7 mm)
AWG 20 (0.563 mm²)	0.085" (2.2 mm)

Add 0.005" (0.1 mm) to above dimensions for foil backing.

Dimensional tolerance:

6" (150 mm) or less	±0.03" (±0.8 mm)
6.01 to 12" (150 to 300 mm)	±0.06" (±1.5 mm)
Over 12" (300 mm)	±0.12" (±3.0 mm)

Custom options

- Custom shapes and sizes to 10 × 22" (250 × 560 mm) with FEP adhesive; 12 × 72" (300 × 1830 mm) with WA/ULA
- Custom resistance to 450 Ω/in² (70 Ω/cm²)
- WA or ULA adhesive (see page A-8); preferred for custom designs below 150°C
- Available with surface mount sensors, connectors, even integral controllers
- TÜV or UL approval is optional
- Tighter resistance tolerance
- See section J for custom design assistance

*Kapton™ is the DuPont tradename for polyimide

Stock Kapton™ Heaters

These heaters are normally available from stock for immediate shipment. Voltage and wattage values are for reference only. Heaters may be operated at other voltages if they do not exceed the maximum allowable watt density ratings.

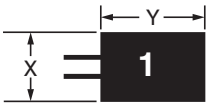
See section D for these and other models with additional ordering options:

- Greater selection of resistances
- Variable lead length
- More backing options
- UL recognition

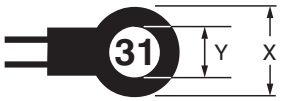
How to order stock heaters

HK5160R157L12	**Model number**
A	**Heater backing:** A = No adhesive -200 to 200°C B = Acrylic PSA -32 to 100°C
HK5160R157L12A ← Sample part number	

Type (configuration)



LEAD LENGTH:
12" (305 mm)

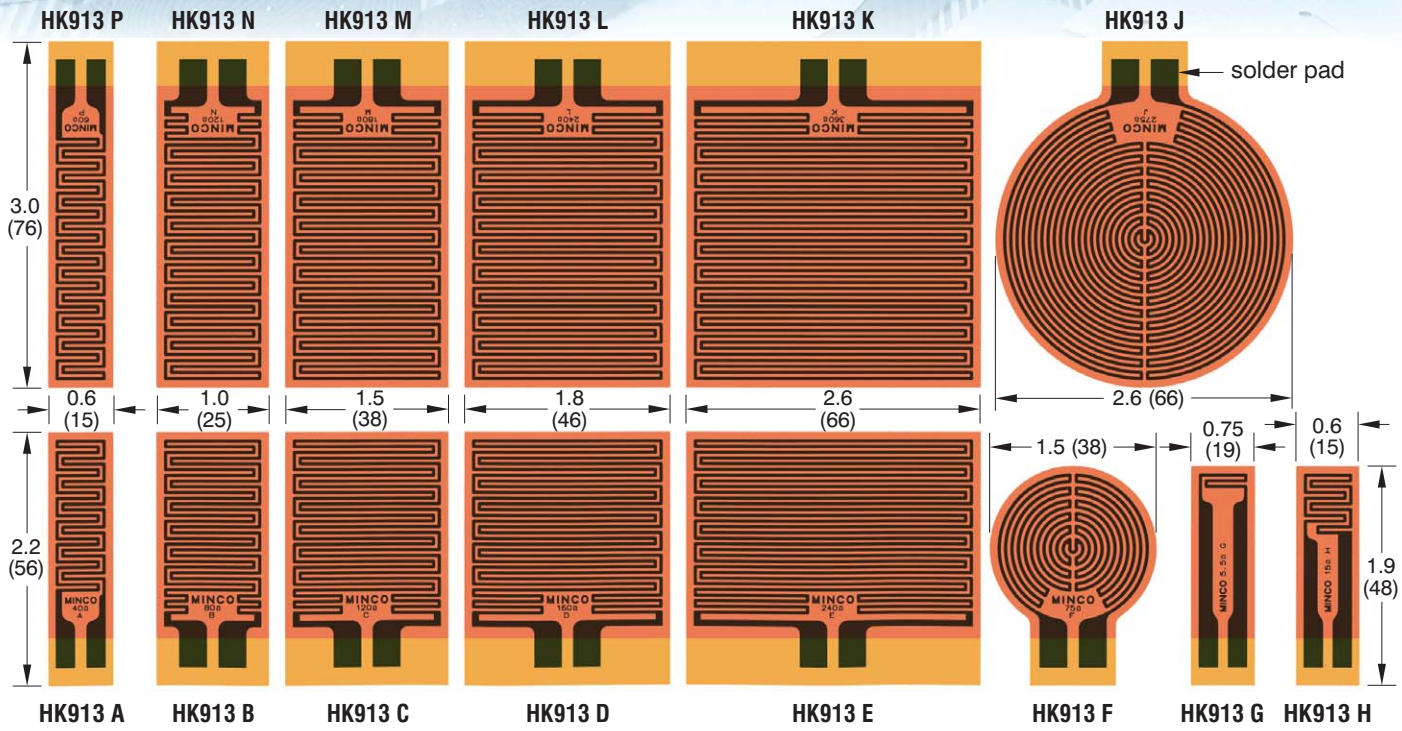


TAB DIMENSIONS:
AWG 30: 0.40" × 0.25" (10.2 × 6.4 mm)
AWG 24/26: 0.40" × 0.40" (10.2 × 10.2 mm)

Size (inches) X	Size (inches) Y	Size (mm) X	Size (mm) Y	Type	Resistance in ohms*	Typical power	Effective area (in²)	Lead AWG	Model number
0.50	2.00	12.7	50.8	1	157	5 W at 28 V	0.79	30	HK5160R157L12
0.50	4.00	12.7	101.6	1	78.4	10 W at 28 V	1.67	30	HK5161R78.4L12
0.50	6.00	12.7	152.4	1	52.3	15 W at 28 V	2.35	30	HK5162R52.3L12
1.00	1.00	25.4	25.4	1	157	5 W at 28 V	0.82	30	HK5163R157L12
1.00	2.00	25.4	50.8	1	78.4	10 W at 28 V	1.76	30	HK5164R78.4L12
1.00	3.00	25.4	76.2	1	52.3	15 W at 28 V	2.70	30	HK5165R52.3L12
1.00	5.00	25.4	127.0	1	529	25 W at 115 V	4.41	30	HK5166R529L12
1.00	10.00	25.4	254.0	1	264	50 W at 115 V	8.96	30	HK5167R264L12
1.00	15.00	25.4	381.0	1	176	75 W at 115 V	13.51	30	HK5168R176L12
2.00	2.00	50.8	50.8	1	661	20 W at 115 V	3.59	30	HK5169R661L12
2.00	3.00	50.8	76.2	1	441	30 W at 115 V	5.50	30	HK5170R441L12
2.00	4.00	50.8	101.6	1	331	40 W at 115 V	7.41	30	HK5171R331L12
2.00	6.00	50.8	152.4	1	220	60 W at 115 V	11.23	30	HK5172R220L12
2.00	12.00	50.8	304.8	1	110	120 W at 115 V	22.69	24	HK5173R110L12
3.00	3.00	76.2	76.2	1	294	45 W at 115 V	8.41	30	HK5174R294L12
3.00	5.00	76.2	127.0	1	176	75 W at 115 V	14.23	30	HK5175R176L12
3.00	10.00	76.2	254.0	1	88.2	150 W at 115 V	28.75	24	HK5176R88.2L12
3.00	15.00	76.2	381.0	1	58.8	225 W at 115 V	43.30	24	HK5177R58.8L12
4.00	4.00	101.6	101.6	1	165	80 W at 115 V	15.20	30	HK5178R165L12
4.00	8.00	101.6	203.2	1	82.7	160 W at 115 V	30.84	24	HK5179R82.7L12
4.00	12.00	101.6	304.8	1	55.1	240 W at 115 V	46.48	24	HK5180R55.1L12
5.00	5.00	127.0	127.0	1	106	125 W at 115 V	24.02	24	HK5181R106L12
5.00	10.00	127.0	254.0	1	52.9	250 W at 115 V	48.57	24	HK5182R52.9L12
5.00	15.00	127.0	381.0	1	35.3	375 W at 115 V	73.12	24	HK5183R35.3L12
10.00	10.00	254.0	254.0	1	26.4	500 W at 115 V	97.52	20	HK5184R26.4L12
10.00	15.00	254.0	381.0	1	17.6	750 W at 115 V	146.92	20	HK5185R17.6L12
0.50	0.09	12.7	2.4	31	25.0	1 W at 5 V	0.13	30	HK5186R25.0L12
1.00	0.09	25.4	2.4	31	157	5 W at 28 V	0.68	26	HK5187R157L12
3.00	0.12	76.2	3.1	31	378	35 W at 115 V	6.61	26	HK5188R378L12

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

HK913 Heater Kit



Dimensions in inches (mm)

The HK913 heater kit permits low-cost evaluation and prototyping of Thermofoil heaters. Available from stock, it contains 14 heating elements you can arrange in more than 1000 combinations. When ordering the complete kit, one sheet (6 × 12") of acrylic PSA is included for easy installation. Specify acrylic PSA for individual heaters, if desired.

Specifications

Temperature range: -200 to 200°C (-328 to 392°F), -32 to 100°C (-26 to 212°F) with acrylic PSA.
Material: Kapton/FEP, 0.002"/0.001" (0.05/0.03 mm).
Resistance tolerance: ±15%.
Minimum bend radius: 0.030" (0.8 mm).

How to order

HK913	**Model number**
E	**Individual element code from table (leave blank for entire kit)**
HK913E ← Sample part number	

Element code	Size (inches)	Size (mm)	Resistance in ohms	Effective area (in²)
A	0.6 × 2.2	15 × 56	40	0.58
B	1.0 × 2.2	25 × 56	80	1.20
C	1.5 × 2.2	38 × 56	120	1.86
D	1.8 × 2.2	46 × 56	160	2.45
E	2.6 × 2.2	66 × 56	240	3.67
F	1.5 Dia.	38 Dia.	75	1.03
G	0.75 × 1.9	19 × 48	5.5	0.04
H	0.6 × 1.9	15 × 48	15	0.21
J	2.6 Dia.	66 Dia.	275	4.49
K	2.6 × 3.0	66 × 76	360	5.59
L	1.8 × 3.0	46 × 76	240	3.75
M	1.5 × 3.0	38 × 76	180	2.87
N	1.0 × 3.0	25 × 76	120	1.87
P	0.6 × 3.0	15 × 76	60	0.94

Silicone Rubber Heaters (Foil) 235°C

See section E for wire-wound rubber heaters

Silicone rubber is a rugged, flexible elastomer material with excellent temperature properties. It is most suited to larger heaters and industrial applications.

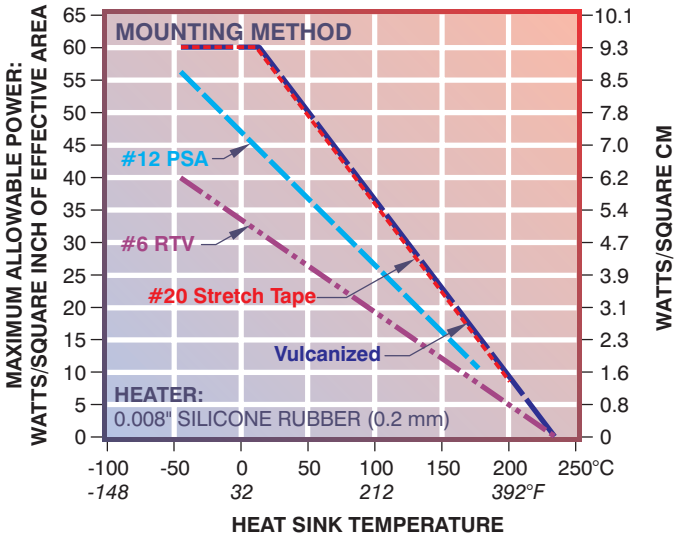
- High temperature capability to 235°C (455°F)
- UL component recognition available
- Can be factory vulcanized to metal parts without adhesive
- Resistant to many chemicals
- Not suitable for radiation, vacuum, or prolonged exposure to oil
- Most economical in large sizes

C

Typical applications

- Thermal developing in graphic imaging equipment
- Prevent condensation in motors or instrument cabinets
- Heat outdoor electronics
- Food service equipment
- Medical respirators
- Laminators
- Drums and other vessels
- Airplane engine heaters

Maximum watt density, rubber heaters



Example: At 100°C, the maximum power of a vulcanized heater is 36 W/in².

Specifications for catalog models

Temperature range: -45 to 235°C (-50 to 455°F).
With UL component recognition: -45 to 220°C (-50 to 428°F).
Material: Fiberglass reinforced silicone rubber, 0.008" (0.20 mm).
Resistance tolerance: ±10% or ±0.5 Ω, whichever is greater.
Dielectric strength: 1000 VRMS.
Minimum bend radius: 0.125" (3.2 mm).
Leadwire: Red PTFE insulated, stranded.
Current capacity (based on 100°C max. ambient temp.):

AWG 30	AWG 26	AWG 24	AWG 20
3.0 A	5.0 A	7.5 A	13.5 A

Maximum heater thickness:

	No adhesive (A):	#12 PSA (B):
Over element	0.020" (0.5 mm)	0.025" (0.6 mm)
Over leads		
AWG 30 (0.057 mm²)	0.070" (1.8 mm)	0.085" (2.2 mm)
AWG 26 (0.141 mm²)	0.080" (2.0 mm)	0.095" (2.4 mm)
AWG 24 (0.227 mm²)	0.090" (2.3 mm)	0.105" (2.7 mm)
AWG 20 (0.563 mm²)	0.120" (3.0 mm)	0.135" (3.4 mm)

Add 0.005" (0.1 mm) to above dimensions for foil backing.

Dimensional tolerance:

6" (150 mm) or less	±0.03" (±0.8 mm)
6.01 to 12": (150 to 300 mm)	±0.06" (±1.5 mm)
Over 12" (300 mm)	±0.12" (±3.0 mm)

Custom options

- Custom shapes and sizes to 22 × 72" (560 × 1830 mm)
- Custom resistance to 200 Ω/in² (30 Ω/cm²)
- Minco can factory vulcanize rubber heaters to metal shapes for best economy and performance
- Heaters can have integral snaps, straps, or Velcro® for removable installation
- Heaters can include thermostats, temperature sensors and cutouts, wiring harnesses, and connectors
- TÜV or UL approval is optional
- See section J for custom design assistance

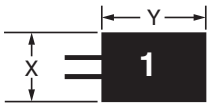
Stock Rubber Heaters (Foil)

These heaters are normally available from stock for immediate shipment. Voltage and wattage values are for reference only. Heaters may be operated at other voltages if they do not exceed the maximum allowable watt density.

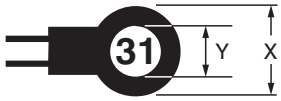
See section D for these and other models with additional ordering options:

- Greater selection of resistances
- Variable lead length
- More backing options
- UL recognition

Type (configuration)



LEAD LENGTH:
12" (305 mm)



TAB DIMENSIONS:
AWG 30: 0.40" × 0.25" (10.2 × 6.4 mm)
AWG 24/26: 0.40" × 0.40" (10.2 × 10.2 mm)

How to order stock heaters

HR5167R264L12	**Model number**
B	**Heater backing:** A = No adhesive -45 to 235°C B = #12 PSA -45 to 177°C
HR5167R264L12B ← Sample part number	

Size (inches) X	Y	Size (mm) X	Y	Type	Resistance in ohms*	Typical power	Effective area (in²)	Lead AWG	Model number
0.50	2.00	12.7	50.8	1	44.0	18 W at 28 V	0.79	30	HR5160R44.0L12
0.50	4.00	12.7	101.6	1	78.4	10 W at 28 V	1.67	30	HR5161R78.4L12
1.00	1.00	25.4	25.4	1	78.4	10 W at 28 V	0.82	30	HR5163R78.4L12
1.00	3.00	25.4	76.2	1	52.3	15 W at 28 V	2.70	30	HR5165R52.3L12
1.00	5.00	25.4	127.0	1	529	25 W at 115 V	4.41	30	HR5166R529L12
1.00	10.00	25.4	254.0	1	264	50 W at 115 V	8.96	30	HR5167R264L12
2.00	3.00	50.8	76.2	1	441	30 W at 115 V	5.50	30	HR5170R441L12
3.00	3.00	76.2	76.2	1	294	45 W at 115 V	8.41	30	HR5174R294L12
3.00	5.00	76.2	127.0	1	176	75 W at 115 V	14.23	30	HR5175R176L12
4.00	4.00	101.6	101.6	1	42.9	308 W at 115 V	15.20	30	HR5178R42.9L12
4.00	4.00	101.6	101.6	1	165	80 W at 115 V	15.20	30	HR5178R165L12
4.00	8.00	101.6	203.2	1	82.7	160 W at 115 V	30.84	24	HR5179R82.7L12
3.00	0.12	76.2	3.1	31	107	64 W at 115 V	6.61	26	HR5188R107L12

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

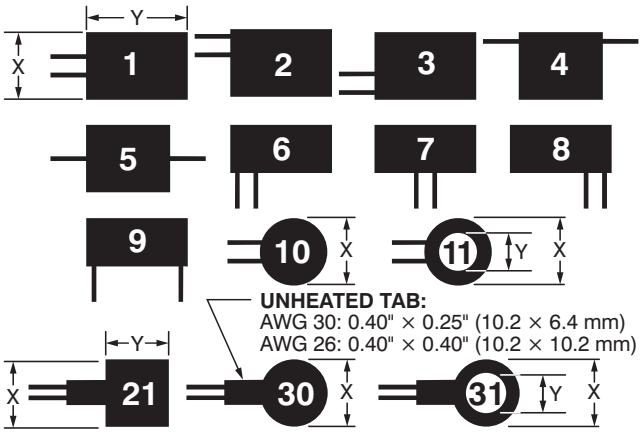
Standard Kapton & Rubber Heaters

In the following pages you'll find more than 400 standard foil heaters, suitable for prototype or production. Contact Minco for custom designs.

Each model is available with several resistance values. The wattage output at a particular resistance depends on voltage applied, per Ohm's law:

R Ohms (Ω)			P Watts (W)			I Amps (A)			E Volts (V)		
$\frac{E}{I}$	$\frac{E^2}{P}$	$\frac{P}{I^2}$	EI	I^2R	$\frac{E^2}{R}$	$\sqrt{\frac{P}{R}}$	$\frac{P}{E}$	$\frac{E}{R}$	$\sqrt{PR}$	$\frac{P}{I}$	IR

Type (configuration)



Types 21, 30, and 31 have lead connections on an external tab. The tab produces negligible heat and, in most cases, need not be adhered to the heat sink.

How to order standard heaters

Specifications on pages B-1 (Kapton) and C-1 (rubber).

HK	**Insulation:** HK = Kapton HR = Silicone rubber
5200	**Model number from tables on following pages**
R17.4	**Heater resistance in ohms**
L12	**Lead length in inches** 12" (305 mm) is standard Contact Minco for other lengths
A	**Heater backing option (see page A-9)**

	HK	HR
A = No adhesive	-200 to 200°C	-45 to 235°C
B = PSA backing	-32 to 100°C	-45 to 177°C
D = Foil backing	-200 to 150°C	-45 to 235°C
E = Foil/Acrylic PSA	-32 to 150°C	-32 to 150°C
F = Foil/#12 PSA	-73 to 150°C	-45 to 204°C

U	**U = Marked for UL component recognition:** Omit for no UL marking (lower cost) UL limits: 220°C for rubber heaters

HK5200R17.4L12AU ← Sample part number

Temperature sensitive elements

Heaterstats™ (page K-2) require temperature sensitive heating elements, such as those found in the "NiFe" and "Ni" columns. Their resistance increases with temperature. The resistances listed are measured at 0°C (32°F).

How to use the table of Standard Kapton & Silicone Rubber Heaters

Overall heater size in inches. Listed in ascending order, first by dimension X, then Y. Round heaters are last.

Heater type (lead exit configuration).

Element resistance options in ohms. Select resistance to produce desired wattage with available voltage (see Ohm's law)

Effective heating area. Use this value for calculating watt density.

Available heater insulation options for this model. K = Kapton R = rubber

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insulation	Model number
0.40	2.60	10.2	66.0	1	123	62.5	37.8	18.2				19.1	0.74	30	K	5215
0.41	4.80	10.4	121.9	6	100	50.1	30.2	14.5				15.5	1.40	26	K, R	5218
0.41	8.30	10.4	210.8		61.9				6.2	4.3		2.6	2.50	26	K, R	5219

Overall heater size in millimeters. Listed in ascending order, first by dimension X, then Y. Round heaters are last.

Temperature sensitive element resistance options (at 0°C) for use with Minco Heaterstat. Rubber (HR) models are not available with NiFe element.

Leadwire size. Maximum current capacities are listed on pages B-1 and C-1.

Base model number.

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →								Effective area (in²)	Lead AWG	Insulation	Model number
											NiFe	Ni				
0.25	0.25	6.4	6.4	21	10.0	5.3							0.04	30	K	5565
0.25	0.50	6.4	12.7	21	15.0	7.9	4.3						0.08	30	K	5566
0.25	0.75	6.4	19.1	21	20.0	10.5	5.7						0.13	30	K	5567
0.25	1.00	6.4	25.4	21	25.0	13.1	7.1				3.9		0.18	30	K	5568
0.25	1.25	6.4	31.8	21	30.0	15.8	8.5				4.7		0.23	30	K	5569
0.25	1.50	6.4	38.1	21	35.0	18.4	10.0	4.7			5.4		0.27	30	K	5570
0.25	1.75	6.4	44.5	21	40.0	21.0	11.4	5.3			6.2		0.32	30	K	5571
0.25	2.30	6.4	58.4	6	17.4	9.2	5.2						0.38	26	K, R	5200
0.25	6.82	6.4	173.2	9	100	46.7	28.2	13.6			15.5		1.22	26	K, R	5201
0.25	7.67	6.4	194.8	8	143	71.7	38.1	19.1			22.2		1.15	30	K, R	5202
0.25	10.40	6.4	264.2	5	160	80.1	48.4	23.3			24.8	5.7	1.55	26	K, R	5203
0.27	2.00	6.9	50.8	1	18.9	9.5	5.7						0.35	26	K, R	5204
0.27	5.50	6.9	139.7	8	153	76.5	40.7	20.4			23.7	5.5	0.87	30	K	5205
0.27	6.90	6.9	175.3	1	220	110	65.5	32.1			34.1	7.8	1.40	30	K	5206
0.30	1.50	7.6	38.1	1	42.1	20.7	12.5	6.1			6.5		0.30	30	K, R	5207
0.30	3.11	7.6	79.0	1	44.1	22.1	13.3	6.4			6.8		0.70	26	K, R	5208
0.30	3.11	7.6	79.0	1	31.7	15.8	9.6	4.6					0.72	26	K, R	5209
0.34	3.47	8.6	88.1	1	120	56.1	33.9	16.3			18.6		0.88	30	K	5210
0.36	7.95	9.1	201.9	8	225	113	68.3	32.8			34.9	8.0	1.97	26	K, R	5211
0.37	6.10	9.4	154.9	1	73.1	36.4	22.1	10.6			11.3		1.68	26	K, R	5212
0.37	20.20	9.4	513.1	1	130	65.0	39.3	18.9	12.9	9.1	20.2		5.54	26	R	5213
0.40	2.60	10.2	66.0	1	123	62.5	37.8	18.2			19.1		0.74	30	K, R	5215
0.41	4.80	10.4	121.9	6	100	50.1	30.2	14.5			15.5		1.40	26	K, R	5218
0.41	8.30	10.4	210.8	5	61.9	31.1	18.8	9.1	6.2	4.3	9.6		2.50	26	K, R	5219
0.41	9.00	10.4	228.6	5	199	99.7	60.3	29.1			30.8	7.0	2.77	26	K, R	5220
0.42	2.30	10.7	58.4	1	50.1	26.1	15.3	7.3			7.8		0.67	26	K, R	5222
0.42	4.90	10.7	124.5	1	198	100	60.2	28.9			30.7	7.0	1.55	26	K	5224
0.42	7.10	10.7	180.3	1	322	161	85.7	42.8			49.9	11.4	2.06	30	K, R	5225
0.42	14.40	10.7	365.8	1	709	354	189	94.3			110	25.2	4.17	30	K	5227
0.43	3.95	10.9	100.3	8	238	119	63.3	31.7			36.9	8.5	1.22	26	K	5228
0.43	5.50	10.9	139.7	1	131	65.8	35.0	17.5			20.3		1.70	30	K, R	5229
0.43	5.90	10.9	149.9	6	37.3	18.8	11.3	5.4	3.7		5.8		1.87	26	K, R	5230
0.44	3.00	11.2	76.2	6	27.8	13.6	8.2	3.9					1.03	26	K, R	5231
0.44	3.00	11.2	76.2	6	45.8	22.9	13.8	6.6			7.1		1.03	26	K, R	5232
0.44	3.00	11.2	76.2	6	77.7	38.8	23.5	11.3			12.0		1.03	26	K, R	5233
0.45	3.88	11.4	98.6	8	153	76.4	40.7	20.3			23.7	5.4	1.17	26	K	5234
0.45	3.88	11.4	98.6	1	102	51.1	30.9	14.8			15.8		1.16	26	K, R	5235
0.45	3.88	11.4	98.6	3	134	67.3	40.7	19.6			20.8		1.16	26	K	5236
0.45	3.88	11.4	98.6	8	102	51.2	27.2	13.6			15.8		1.17	30	K, R	5237
0.46	5.10	11.7	129.5	1	264	132	79.9	38.4			40.9	9.4	1.77	26	K	5238
0.48	4.50	12.2	114.3	8	47.1	23.6	14.3	6.8	4.7		7.3		1.60	26	K, R	5239
0.48	6.28	12.2	159.5	8	70.2	35.1	18.7	9.3	6.2	4.7	10.9		2.20	26	K, R	5240
0.49	4.80	12.4	121.9	8	170	85.1	51.5	24.7			26.4	6.0	1.60	26	K, R	5241
0.50	0.50	12.7	12.7	21	26.5	13.9	7.5				4.1		0.19	30	K	5572
0.50	0.75	12.7	19.1	21	30.0	15.7	8.5				4.7		0.30	30	K, R	5573
0.50	1.00	12.7	25.4	21	35.0	18.3	10.0	4.6			5.4		0.41	30	K, R	5574
0.50	1.25	12.7	31.8	21	40.0	20.9	11.4	5.3			6.2		0.52	30	K, R	5575
0.50	1.50	12.7	38.1	21	45.0	23.5	12.8	5.9	4.4		7.0		0.63	30	K, R	5576
0.50	1.75	12.7	44.5	21	50.0	26.1	14.2	6.6	4.9		7.8		0.74	30	K, R	5577

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insu-lation	Model number
0.50	2.00	12.7	50.8	1	157	78.4	44.0				24.3	5.6	0.79	30	K, R	5160
0.50	2.50	12.7	63.5	1	71.1	35.1	21.3	10.3			11.0		0.84	26	K, R	5242
0.50	3.00	12.7	76.2	1	124	65.0	35.3	16.4	12.3	9.3	19.2		1.09	26	K, R	5594
0.50	3.77	12.7	95.8	1	233	117	62.1	31.1			36.1	8.3	1.43	30	K	5243
0.50	3.77	12.7	95.8	1	163	81.5	43.4	21.7			25.3	5.8	1.36	30	K, R	5244
0.50	4.00	12.7	101.6	1	78.4	39.2	22.0				12.2		1.67	30	K, R	5161
0.50	4.00	12.7	101.6	1	43.9	22.1	13.3	6.4	4.4		6.8		1.63	30	K, R	5245
0.50	4.00	12.7	101.6	1	52.7	26.4	15.9	7.7	5.2	3.6	8.2		1.63	30	K, R	5246
0.50	5.00	12.7	127.0	5	36.7	18.3	11.1	5.3	3.6		5.7		1.63	26	K, R	5247
0.50	5.10	12.7	129.5	8	126	62.5	37.8	18.2			19.5		1.90	30	K, R	5248
0.50	6.00	12.7	152.4	1	52.3	26.1	14.6				8.1		2.35	30	K, R	5162
0.50	7.50	12.7	190.5	1	53.1	26.2	16.1	7.7	5.3	3.7	8.2		2.72	24	K, R	5249
0.50	12.87	12.7	326.9	6	230	115	69.5	33.5			35.7	8.1	4.80	26	K, R	5250
0.50	12.87	12.7	326.9	6	115	57.5	34.8	16.7	11.4	8.1	17.8		4.67	26	K, R	5251
0.50	12.87	12.7	326.9	6	77.1	38.5	23.3	11.2	7.7	5.4	12.0		4.67	26	K, R	5252
0.50	18.50	12.7	469.9	1	289	145	87.7	42.1	29.1	20.3	44.8	10.1	7.20	26	R	5253
0.52	8.20	13.2	208.3	8	224	112	59.6	28.8			34.7	7.9	3.46	26	K, R	5254
0.53	1.00	13.5	25.4	1	63.2	31.6	16.8	8.4			9.8		0.39	30	K	5255
0.53	1.20	13.5	30.5	1	59.6	29.8	15.9	7.9			9.2		0.39	30	K	5256
0.53	2.00	13.5	50.8	2	135	67.6	36.1	18.1			20.9		0.79	30	K	5257
0.53	4.60	13.5	116.8	3	166	83.3	50.4	24.2			25.7	5.9	1.76	24	K, R	5259
0.53	4.60	13.5	116.8	3	95.7	56.5	28.9	13.9			14.8		1.85	26	K, R	5260
0.54	2.00	13.7	50.8	1	135	67.5	40.8	19.6			20.9		0.75	30	K	5261
0.54	8.10	13.7	205.7	1	233	117	62.1	31.1			36.1	8.2	3.34	26	K, R	5262
0.55	1.20	14.0	30.5	1	24.9	12.9	7.8	3.7					0.35	26	K, R	5264
0.55	6.60	14.0	167.6	1	107	53.9	32.6	15.7	10.7	7.5	16.6		2.79	26	K, R	5267
0.55	15.00	14.0	381.0	1	217	108	65.8	31.7	21.7	15.2	33.6	7.6	6.38	24	K, R	5268
0.60	9.90	15.2	251.5	1	229	115	69.5	33.4	22.9	16.1	35.5	8.0	4.65	26	K, R	5270
0.60	10.65	15.2	270.5	6	360	180	95.9	47.9			55.8	12.7	4.84	30	K, R	5271
0.65	10.75	16.5	273.1	7	124	64.1	37.5	18.1	12.4	8.6	19.2		5.56	26	K, R	5273
0.75	0.75	19.1	19.1	21	35.0	18.3	9.9	4.6			5.4		0.48	30	K, R	5578
0.75	1.00	19.1	25.4	21	40.0	20.9	11.4	5.2			6.2		0.65	30	K, R	5579
0.75	1.25	19.1	31.8	21	45.0	23.4	12.8	5.9	4.4		7.0		0.82	30	K, R	5580
0.75	1.50	19.1	38.1	21	50.0	26.0	14.2	6.5	4.8		7.8		0.99	30	K, R	5581
0.75	1.75	19.1	44.5	21	55.0	28.6	15.6	7.2	5.3		8.5		1.17	30	K, R	5582
0.75	1.85	19.1	47.0	1	50.1	25.2	15.2	7.3	5.1	3.5	7.8		1.02	26	K, R	5274
0.75	2.00	19.1	50.8	21	124	64.9	35.3	16.4	12.2	9.2	19.2		1.34	26	K, R	5595
0.75	2.50	19.1	63.5	2	43.5	21.8	13.2	6.3	4.3		6.7		1.37	26	K, R	5275
0.75	3.00	19.1	76.2	1	144	71.7	43.6	21.1			22.3		1.72	26	K, R	5276
0.75	3.00	19.1	76.2	1	18.1	8.5	5.3						1.14	24	K, R	5277
0.75	3.25	19.1	82.6	6	160	80.1	48.5	23.3			24.8	5.6	1.95	26	K, R	5278
0.75	4.00	19.1	101.6	1	36.1	17.7	10.7	5.1	3.5		5.6		2.41	26	K, R	5279
0.75	4.00	19.1	101.6	1	24.5	11.1	6.9	3.3					1.69	24	K, R	5280
0.75	4.95	19.1	125.7	8	267	134	71.1	35.6			41.4	9.4	3.06	30	K	5281
0.75	5.00	19.1	127.0	1	30.6	14.1	8.7	4.2					2.24	24	K, R	5282
0.75	6.00	19.1	152.4	1	36.7	16.6	10.3	5.1			5.7		2.79	24	K, R	5283
0.75	7.00	19.1	177.8	1	38.8	19.4	12.1	5.5	4.1		6.0		3.34	24	K, R	5284
0.75	8.00	19.1	203.2	1	48.7	22.1	13.7	6.4	4.4	3.3	7.5		3.89	24	K, R	5285
0.75	9.00	19.1	228.6	1	54.7	25.1	15.6	7.1	5.1	3.6	8.5		4.44	24	K, R	5286

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

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Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insulation	Model number
0.75	10.00	19.1	254.0	1	60.8	27.7	17.2	7.7	5.5	4.1	9.4		4.99	24	K, R	5287
0.75	11.00	19.1	279.4	1	66.9	30.4	18.8	8.7	6.1	4.5	10.4		5.54	24	K, R	5288
0.75	11.00	19.1	279.4	1	200	100	60.5	29.1	19.9	13.9	31.0	7.0	6.32	24	K, R	5289
0.75	12.00	19.1	304.8	1	72.6	33.1	20.5	9.1	6.4	4.7	11.3		6.09	24	K, R	5290
0.78	2.76	19.8	70.1	6	83.7	41.9	22.3	11.1	7.4	5.6	13.0		1.79	30	K, R	5292
0.80	1.55	20.3	39.4	2	313	156	83.1	41.6			48.5	11.3	0.90	30	K	5294
0.80	1.55	20.3	39.4	2	105	52.5	27.9	14.0			16.3		0.94	30	K, R	5295
0.80	2.75	20.3	69.9	8	39.7	19.8	12.1	5.7	3.9		6.2		1.52	26	K, R	5296
0.80	6.00	20.3	152.4	8	123	61.8	37.4	17.9	12.3	8.6	19.1		4.23	26	K, R	5297
0.80	8.10	20.3	205.7	8	21.5	11.2	6.9						5.39	26	K, R	5298
0.80	11.50	20.3	292.1	8	166	83.2	50.3	24.2	16.5	11.6	25.7	5.8	7.52	24	K, R	5299
0.80	14.25	20.3	362.0	8	206	103	62.4	30.1	20.5	14.4	31.9	7.2	9.38	24	K, R	5300
0.81	4.81	20.6	122.2	2	64.7	32.9	19.6	9.4	6.4	4.5	10.0		3.33	26	K, R	5301
0.82	2.46	20.8	62.5	9	243	121	64.5	32.3			37.7	8.6	1.66	30	K, R	5302
0.85	1.00	21.6	25.4	6	70.2	35.1	20.6	9.9			10.9		0.60	30	K, R	5303
0.85	2.48	21.6	63.0	9	268	134	71.3	35.7			41.5	9.5	1.65	30	K	5304
0.85	4.90	21.6	124.5	3	207	104	55.1	27.5			32.1	7.3	3.60	26	K, R	5305
0.86	15.80	21.8	401.3	1	140	70.1	42.3	20.3	13.9	9.7	21.7		11.10	24	K, R	5306
0.87	8.65	22.1	219.7	8	561	281	149	74.7			87.0	19.8	6.39	26	K, R	5307
0.87	14.85	22.1	377.2	8	131	65.4	39.6	19.1	13.1	9.1	20.3		10.28	24	K, R	5308
0.88	5.35	22.4	135.9	8	62.6	31.3	18.9	9.1	6.2	4.4	9.7		3.85	26	K, R	5309
0.90	4.95	22.9	125.7	3	207	103	62.6	30.1			32.1	7.3	3.52	26	K, R	5310
0.94	3.90	23.9	99.1	9	119	59.6	31.8	15.9	10.6	7.9	18.4		2.94	30	K, R	5311
0.96	1.48	24.4	37.6	3	76.1	38.1	20.2	10.1			11.8		1.10	30	K, R	5312
0.97	1.21	24.6	30.7	3	84.3	42.2	22.4	11.2			13.1		0.90	30	K, R	5313
0.97	2.96	24.6	75.2	2	303	151	80.5	40.3			47.0	10.7	2.45	30	K, R	5314
0.98	1.48	24.9	37.6	6	80.1	39.7	24.1	11.6			12.4		1.13	26	K, R	5315
0.98	2.75	24.9	69.9	1	206	103	61.7	29.7			31.9	7.3	2.07	26	K, R	5316
1.00	1.00	25.4	25.4	1	157	78.4	44.0				24.3	5.6	0.82	30	K, R	5163
1.00	1.00	25.4	25.4	1	52.1	26.1	15.7	7.6			8.1		0.65	26	K, R	5318
1.00	1.00	25.4	25.4	21	70.0	36.6	19.9	9.2	6.8	5.2	10.9		0.88	30	K, R	5583
1.00	1.25	25.4	31.8	21	65.0	33.9	18.5	8.5	6.3	4.7	10.1		1.12	30	K, R	5584
1.00	1.50	25.4	38.1	21	75.0	39.1	21.3	9.8	7.3	5.4	11.6		1.35	30	K, R	5585
1.00	1.75	25.4	44.5	21	100	52.2	28.4	13.1	9.7	7.3	15.5		1.59	30	K, R	5586
1.00	2.00	25.4	50.8	1	78.4	39.2	22.0				12.2		1.76	30	K, R	5164
1.00	2.00	25.4	50.8	1	14.6	7.3	4.5						1.04	24	K, R	5319
1.00	2.30	25.4	58.4	3	220	110	58.4	29.2			34.1	7.8	1.82	30	K, R	5320
1.00	2.50	25.4	63.5	1	146	72.1	43.1	20.7			22.6	5.1	1.89	26	K, R	5321
1.00	2.50	25.4	63.5	1	107	53.3	32.3	15.5			16.6		1.89	26	K, R	5322
1.00	3.00	25.4	76.2	1	52.3	26.1	14.6				8.1		2.70	30	K, R	5165
1.00	3.00	25.4	76.2	1	23.9	10.7	6.6						1.84	24	K, R	5323
1.00	3.00	25.4	76.2	1	58.0	26.6	16.1	7.7	5.3	3.7	9.0		2.30	26	K, R	5324
1.00	3.00	25.4	76.2	1	36.4	17.9	10.8	5.2	3.6		5.6		2.30	26	K, R	5325
1.00	3.62	25.4	91.9	3	61.1	30.6	18.5	8.9	6.1	4.2	9.5		2.97	26	K, R	5326
1.00	3.72	25.4	94.5	3	445	223	118	59.2			69.0	15.8	3.15	30	K, R	5327
1.00	3.72	25.4	94.5	3	389	195	118	56.7			60.3	13.8	3.06	26	K, R	5328
1.00	3.82	25.4	97.0	2	160	80.1	48.5	23.3	15.9	11.2	24.8	5.6	3.29	26	K, R	5329
1.00	4.00	25.4	101.6	1	83.3	42.7	25.2	12.1	8.3	5.8	12.9		3.33	26	K, R	5330
1.00	4.00	25.4	101.6	1	30.8	13.9	8.6	4.2					2.64	24	K, R	5331

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insu-lation	Model number
1.00	4.75	25.4	120.7	6	302	151	91.6	44.1			46.8	10.6	4.29	24	K, R	5332
1.00	4.75	25.4	120.7	6	266	133	80.5	38.7			41.2	9.4	4.05	26	K, R	5333
1.00	5.00	25.4	127.0	1	529	264	148				82.0	18.7	4.41	30	K, R	5166
1.00	5.00	25.4	127.0	1	38.1	17.2	10.7	5.1			5.9		4.34	24	K, R	5334
1.00	6.00	25.4	152.4	1	45.3	20.8	12.9	5.8	4.1		7.0		4.24	24	K, R	5335
1.00	6.00	25.4	152.4	2	162	80.9	48.9	23.5	16.1	11.3	25.1	5.7	5.13	26	K, R	5336
1.00	7.00	25.4	177.8	1	52.1	24.1	14.9	6.8	4.7	3.5	8.1		5.04	24	K, R	5337
1.00	7.00	25.4	177.8	1	86.1	43.1	26.1	12.3	8.5	6.1	13.3		6.19	26	K, R	5338
1.00	7.05	25.4	179.1	1	111	55.7	33.7	16.2	11.1	7.7	17.2		6.12	26	K, R	5339
1.00	8.00	25.4	203.2	1	58.9	27.5	17.1	7.7	5.4	3.9	9.1		5.84	24	K, R	5340
1.00	9.00	25.4	228.6	1	66.1	30.4	18.8	8.7	5.9	4.4	10.2		6.64	24	K, R	5341
1.00	10.00	25.4	254.0	1	264	132	74.1				40.9	9.2	8.96	30	K, R	5167
1.00	10.00	25.4	254.0	1	73.4	34.1	21.1	9.4	6.6	4.9	11.4		7.44	24	K, R	5342
1.00	11.00	25.4	279.4	1	79.8	37.2	23.1	10.3	7.2	5.4	12.4		8.24	24	K, R	5343
1.00	12.00	25.4	304.8	1	86.5	40.3	24.9	11.1	7.7	5.8	13.4		9.04	24	K, R	5344
1.00	12.00	25.4	304.8	3	163	82.1	49.6	23.8	16.3	11.4	25.3	5.7	10.53	24	K, R	5345
1.00	12.00	25.4	304.8	1	1063	531	321	154			165	37.6	10.53	26	K, R	5346
1.00	12.10	25.4	307.3	1	155	76.6	46.3	22.3	15.2	10.6	24.0	5.4	10.62	26	K, R	5347
1.00	15.00	25.4	381.0	1	176	88.2	49.4				27.3	6.1	13.51	30	K, R	5168
1.00	19.00	25.4	482.6	1	121	60.8	36.8	17.7	12.1	8.5	18.8		13.88	24	R	5348
1.00	22.06	25.4	560.3	1	93.1	46.5	24.8	12.4	8.3	6.2	14.4		18.90	24	R	5349
1.02	10.00	25.9	254.0	5	946	473	252	126			147	33.5	8.60	24	K, R	5350
1.04	2.76	26.4	70.1	5	262	131	69.6	34.8			40.6	9.3	2.04	26	K, R	5351
1.04	4.35	26.4	110.5	1	87.6	43.8	23.3	11.7	7.8	5.8	13.6		4.06	26	K, R	5352
1.04	7.76	26.4	197.1	8	1321	660	352	176			205	47.1	6.80	30	K	5353
1.05	4.04	26.7	102.6	8	243	122	64.8	32.4			37.7	8.5	3.65	30	K, R	5354
1.05	4.65	26.7	118.1	8	152	74.1	44.4	21.3			23.6	5.3	4.05	26	K, R	5355
1.05	5.60	26.7	142.2	7	440	220	133	64.1			68.2	15.5	5.04	26	K, R	5356
1.05	9.70	26.7	246.4	1	276	138	73.4	36.7	24.5	18.3	42.8	9.6	8.80	24	K, R	5357
1.07	4.05	27.2	102.9	8	103	51.3	27.3	13.7	9.1	6.8	16.0		3.67	30	K, R	5358
1.10	4.00	27.9	101.6	1	600	300	181	87.3			93.0	21.3	3.75	30	K	5359
1.10	4.00	27.9	101.6	1	394	197	119	57.4			61.1	13.9	3.70	30	K, R	5360
1.10	18.50	27.9	469.9	3	350	175	106	50.1	34.8	24.3	54.3	12.2	17.64	24	R	5361
1.13	3.51	28.7	89.2	8	107	53.4	28.4	14.2	9.5	6.6	16.6		3.43	30	K, R	5362
1.17	1.91	29.7	48.5	2	125	62.5	37.8	18.2			19.4		1.79	26	K, R	5364
1.20	2.76	30.5	70.1	1	275	136	82.7	39.8			42.6	9.7	2.86	30	K, R	5366
1.20	3.40	30.5	86.4	7	92.0	45.7	26.6	13.3	9.1	6.4	14.3		3.41	26	K, R	5367
1.22	2.24	31.0	56.9	8	111	55.5	29.5	14.8	9.8	7.4	17.2		2.33	30	K, R	5368
1.23	2.48	31.2	63.0	2	101	50.8	27.1	13.5	9.4	6.7	15.7		2.60	30	K, R	5369
1.24	1.80	31.5	45.7	2	298	148	90.1	43.3			46.2	10.6	1.90	30	K	5370
1.25	1.25	31.8	31.8	21	100	52.2	28.4	13.1	9.7	7.3	15.5		1.42	30	K, R	5587
1.25	1.50	31.8	38.1	21	125	65.3	35.5	16.4	12.2	9.2	19.4		1.71	30	K, R	5588
1.25	1.75	31.8	44.5	21	150	78.4	42.6	19.7	14.6	11.0	23.3	5.3	2.01	30	K, R	5589
1.25	6.30	31.8	160.0	1	136	68.2	41.3	19.8	13.6	9.5	21.1		6.84	24	K, R	5371
1.25	8.80	31.8	223.5	1	51.9	25.9	15.7	7.5	5.1	3.6	8.0		9.86	24	K, R	5372
1.25	15.00	31.8	381.0	1	219	109	66.5	32.1	21.9	15.3	33.9	7.6	15.79	24	K, R	5373
1.35	5.60	34.3	142.2	3	876	438	265	127			136	31.1	6.57	30	K	5374
1.37	5.80	34.8	147.3	1	250	125	75.8	36.5	24.9	17.5	38.8	8.7	7.15	26	K, R	5375
1.38	2.75	35.1	69.9	2	305	152	92.1	44.2			47.3	10.8	3.21	26	K, R	5376

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

D

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insulation	Model number
1.40	2.34	35.6	59.4	1	197	98.7	52.5	26.3	17.5	13.1	30.5	6.9	2.90	30	K, R	5377
1.40	6.30	35.6	160.0	8	771	386	205	103			120	27.2	8.08	30	K, R	5378
1.45	2.40	36.8	61.0	8	106	53.4	32.3	15.5	10.6	7.4	16.4		2.90	26	K, R	5379
1.45	8.15	36.8	207.0	8	474	237	126	63.1	42.1	31.5	73.5	16.6	10.52	24	K, R	5380
1.48	10.10	37.6	256.5	1	126	62.9	33.5	16.7	11.2	8.4	19.5		13.40	24	K, R	5381
1.50	1.50	38.1	38.1	21	150	78.3	42.6	19.7	14.6	11.0	23.3	5.3	2.07	30	K, R	5590
1.50	1.75	38.1	44.5	21	175	91.4	49.7	23.0	17.1	12.9	27.1	6.2	2.43	30	K, R	5591
1.50	2.00	38.1	50.8	1	14.8	7.2	4.5						1.84	24	K, R	5382
1.50	3.00	38.1	76.2	1	21.8	10.7	6.6						3.14	24	K, R	5383
1.50	4.00	38.1	101.6	1	29.1	14.4	8.8	4.3					4.44	24	K, R	5384
1.50	4.10	38.1	104.1	2	103	51.7	27.5	13.7	9.2	6.9	16.0		4.00	30	K, R	5385
1.50	5.00	38.1	127.0	1	36.2	17.9	10.9	5.1	3.4		5.6		5.74	24	K, R	5386
1.50	6.00	38.1	152.4	1	43.3	21.7	13.2	6.2	4.2		6.7		7.04	24	K, R	5387
1.50	6.42	38.1	163.1	8	140	70.2	37.4	18.7			21.7		7.70	30	K, R	5388
1.50	6.42	38.1	163.1	8	1317	659	350	175			204	46.8	8.50	30	K, R	5389
1.50	7.00	38.1	177.8	1	50.1	25.1	15.2	7.2	4.7	3.5	7.8		8.34	24	K, R	5390
1.50	8.00	38.1	203.2	1	57.1	28.7	17.5	8.1	5.3	3.9	8.9		9.64	24	K, R	5391
1.50	8.05	38.1	204.5	2	304	152	92.1	44.3	30.3	21.2	47.1	10.6	10.80	26	K, R	5392
1.50	9.00	38.1	228.6	1	64.1	32.2	19.6	8.9	6.1	4.4	9.9		10.94	24	K, R	5393
1.50	10.00	38.1	254.0	1	71.4	35.7	21.8	10.1	6.7	4.9	11.1		12.24	24	K, R	5394
1.50	11.00	38.1	279.4	1	78.5	39.1	23.9	10.9	7.3	5.3	12.2		13.54	24	K, R	5395
1.50	11.00	38.1	279.4	1	391	180	118	57.1	38.9	27.3	60.6	13.6	14.77	24	K, R	5396
1.50	12.00	38.1	304.8	1	85.6	42.8	25.8	11.8	7.8	5.8	13.3		14.84	24	K, R	5397
1.53	3.05	38.9	77.5	8	176	88.4	53.4	25.7	17.6	12.3	27.3	6.2	3.89	26	K, R	5398
1.55	3.05	39.4	77.5	1	130	65.3	39.5	19.1	13.1	9.1	20.2		4.06	26	K, R	5399
1.61	2.15	40.9	54.6	1	205	102	54.5	27.3			31.8	7.2	3.00	30	K, R	5400
1.62	2.77	41.1	70.4	1	166	81.1	48.6	23.3	15.9	11.2	25.7	5.8	3.95	30	K, R	5401
1.65	3.00	41.9	76.2	2	128	64.1	38.8	18.3	12.8	8.9	19.8		4.50	30	K, R	5402
1.65	5.00	41.9	127.0	1	162	81.1	48.9	23.5	16.1	11.3	25.1	5.6	7.44	26	K, R	5403
1.70	5.10	43.2	129.5	1	580	290	154	77.2			89.9	20.4	7.77	24	K, R	5404
1.75	1.75	44.5	44.5	21	200	104	56.8	26.3	19.5	14.7	31.0	7.0	2.86	30	K, R	5592
1.75	2.73	44.5	69.3	2	159	79.5	48.1	23.1	15.8	11.1	24.6	5.6	3.77	26	K, R	5405
1.76	4.79	44.7	121.7	1	330	165	87.9	43.9	29.3	22.1	51.2	11.6	7.56	30	K, R	5406
1.78	4.30	45.2	109.2	1	737	369	196	98.1			114	26.1	6.66	30	K, R	5407
1.78	5.28	45.2	134.1	1	588	294	156	78.2			91.1	20.7	8.34	30	K, R	5408
1.80	1.80	45.7	45.7	3	251	126	66.8	33.4			38.9	8.9	2.70	30	K, R	5409
1.88	5.75	47.8	146.1	1	288	144	86.9	41.7	28.6	20.1	44.6	10.1	9.68	24	K, R	5410
1.90	3.16	48.3	80.3	6	236	118	62.8	31.4	20.9	15.7	36.6	8.3	5.48	26	K, R	5411
1.92	4.45	48.8	113.0	8	348	174	92.5	46.3	30.8	23.1	53.9	12.2	7.69	26	K, R	5412
1.94	5.29	49.3	134.4	6	508	254	135	67.6	45.1	31.6	78.7	17.8	9.38	30	K, R	5413
1.96	3.77	49.8	95.8	1	749	374	199	99.6			116	26.5	6.83	30	K, R	5414
1.97	2.16	50.0	54.9	3	112	56.3	34.1	16.4	11.2	7.8	17.4		3.79	26	K, R	5415
1.98	3.82	50.3	97.0	1	752	376	200	98.9			117	26.6	6.75	30	K, R	5416
2.00	2.00	50.8	50.8	1	661	331	185				102	23.6	3.59	30	K, R	5169
2.00	2.00	50.8	50.8	1	36.1	17.8	10.9	5.3			5.6		2.82	24	K, R	5417
2.00	2.60	50.8	66.0	7	344	172	104	51.8			53.3	12.1	4.75	26	K, R	5418
2.00	3.00	50.8	76.2	1	441	220	123				68.4	15.5	5.50	30	K, R	5170
2.00	3.00	50.8	76.2	1	53.3	25.9	15.9	7.5	5.4	3.6	8.3		4.62	24	K, R	5419
2.00	3.00	50.8	76.2	7	33.3	15.6	9.8	4.5			5.2		4.54	24	K, R	5463

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insulation	Model number
2.00	3.25	50.8	82.6	6	86.6	43.3	26.2	12.6	8.6	6.1	13.4		5.60	24	K, R	5420
2.00	3.25	50.8	82.6	6	75.6	37.8	22.8	10.9	7.5	5.3	11.7		5.50	26	K, R	5421
2.00	4.00	50.8	101.6	1	331	165	92.7				51.3	11.6	7.41	30	K, R	5171
2.00	4.00	50.8	101.6	1	70.1	34.6	21.2	10.4	6.9	4.8	10.9		6.73	24	K, R	5422
2.00	4.00	50.8	101.6	7	23.7	11.6	7.3						6.34	24	K, R	5487
2.00	5.00	50.8	127.0	1	88.1	43.2	26.2	13.1	8.6	5.9	13.7		8.22	24	K, R	5423
2.00	5.00	50.8	127.0	7	23.9	13.1	8.8	4.3					8.14	24	K, R	5506
2.00	6.00	50.8	152.4	1	220	110	61.6				34.1	7.7	11.23	30	K, R	5172
2.00	6.00	50.8	152.4	1	104	51.8	31.9	15.1	9.8	7.1	16.1		10.02	24	K, R	5424
2.00	6.05	50.8	153.7	1	99.7	49.9	30.2	14.5	9.9	6.9	15.5		11.00	24	K, R	5425
2.00	7.00	50.8	177.8	1	120	60.4	36.5	17.5	11.2	8.3	18.6		11.82	24	K, R	5426
2.00	8.00	50.8	203.2	1	137	68.9	41.9	20.1	12.9	9.4	21.2		13.62	24	K, R	5427
2.00	9.00	50.8	228.6	1	154	77.7	46.8	21.6	14.3	10.6	23.9	5.3	15.42	24	K, R	5428
2.00	10.00	50.8	254.0	1	171	85.8	52.1	23.8	16.1	11.6	26.5	5.9	17.22	24	K, R	5429
2.00	10.00	50.8	254.0	6	320	160	96.8	46.5	31.8	23.3	49.6	11.1	18.20	26	K, R	5430
2.00	11.00	50.8	279.4	1	188	94.1	57.1	26.4	17.7	13.1	29.1	6.5	19.02	24	K, R	5431
2.00	12.00	50.8	304.8	1	220	110	61.6	28.6			34.1	7.6	22.69	24	K, R	5173
2.00	12.00	50.8	304.8	1	206	102	61.9	28.5	18.8	14.1	31.9	7.2	20.82	24	K, R	5432
2.00	12.00	50.8	304.8	1	442	221	134	63.5	44.1	30.8	68.5	15.4	21.80	24	K, R	5433
2.05	2.70	52.1	68.6	8	725	362	219	97.3			112	25.7	5.19	30	K	5434
2.15	2.55	54.6	64.8	2	123	62.1	37.3	17.9	12.3	8.6	19.1		5.05	26	K, R	5435
2.17	3.80	55.1	96.5	1	681	340	181	90.6			106	24.0	7.20	30	K, R	5436
2.25	4.00	57.2	101.6	1	284	142	86.1	41.4	28.3	19.8	44.0	9.9	7.70	26	K, R	5437
2.25	4.50	57.2	114.3	6	140	70.3	42.5	20.4	14.1	9.8	21.7		8.82	24	K, R	5438
2.25	5.25	57.2	133.4	6	142	70.9	42.9	20.6	14.2	9.9	22.0		10.53	24	K, R	5439
2.25	5.25	57.2	133.4	6	160	80.1	48.6	23.4	15.9	11.2	24.8	5.6	10.40	24	K, R	5440
2.25	6.28	57.2	159.5	8	364	182	110	53.1	36.3	25.4	56.4	12.7	12.52	26	K, R	5441
2.30	9.07	58.4	230.4	6	1016	508	270	135	90.1	67.6	157	35.6	19.70	24	K, R	5443
2.35	4.10	59.7	104.1	7	168	84.1	50.9	24.4	16.7	11.7	26.0	5.9	8.58	24	K, R	5444
2.45	6.07	62.2	154.2	8	861	431	229	115			133	30.3	14.00	24	K, R	5445
2.50	3.00	63.5	76.2	1	421	210	127	61.2			65.3	14.8	6.40	26	K, R	5446
2.50	3.00	63.5	76.2	1	290	145	87.9	42.2	28.9	20.2	45.0	10.2	6.90	26	K, R	5447
2.50	4.00	63.5	101.6	1	576	288	174	83.8			89.3	20.2	8.90	30	K, R	5448
2.50	4.04	63.5	102.6	1	703	351	187	93.5			109	24.8	9.35	24	K, R	5449
2.50	5.00	63.5	127.0	1	231	115	69.9	33.6	22.9	16.1	35.8	8.0	11.30	26	K, R	5450
2.50	6.00	63.5	152.4	3	206	103	62.3	30.1	20.5	14.3	31.9	7.2	13.60	26	K, R	5451
2.50	8.00	63.5	203.2	1	315	157	95.3	45.8	31.3	21.9	48.8	11.0	18.70	26	K, R	5452
2.50	11.30	63.5	287.0	1	2341	1170	623	311			363	82.6	25.70	24	K, R	5453
2.50	11.42	63.5	290.1	1	2089	1045	556	278			324	73.6	26.40	24	K, R	5454
2.53	3.05	64.3	77.5	6	93.7	47.1	28.3	13.6	9.3	6.5	14.5		7.17	26	K, R	5455
2.55	3.05	64.8	77.5	8	165	82.9	50.1	24.1	16.4	11.5	25.6	5.8	7.00	30	K, R	5456
2.68	3.44	68.1	87.4	2	72.6	36.3	21.9	10.6	7.2	5.1	11.3		7.64	26	K, R	5457
2.75	12.00	69.9	304.8	1	243	121	73.6	35.4	24.2	16.9	37.7	8.4	30.90	24	K, R	5458
2.81	2.94	71.4	74.7	2	253	126	76.7	36.9	25.2	17.7	39.2	8.8	7.45	26	K, R	5459
2.87	16.41	72.9	416.8	6	1648	824	438	219	146	110	255	57.6	45.30	24	R	5460
2.92	6.82	74.2	173.2	3	713	357	190	94.8	63.2	47.4	111	24.9	18.50	24	K, R	5461
2.92	6.82	74.2	173.2	1	1566	784	474	228			243	55.2	18.50	26	K, R	5462
3.00	3.00	76.2	76.2	1	294	147	82.3				45.6	10.3	8.41	30	K, R	5174
3.00	3.00	76.2	76.2	1	46.5	23.3	14.6	6.4	4.9		7.2		7.34	24	K, R	5464

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

D

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insulation	Model number
3.00	3.10	76.2	78.7	1	44.4	22.2	13.4	6.5	4.4		6.9		7.98	24	K, R	5465
3.00	4.00	76.2	101.6	1	62.1	30.9	19.4	8.6	5.7	4.1	9.6		10.14	24	K, R	5466
3.00	4.00	76.2	101.6	7	35.1	17.1	10.8	4.6			5.4		10.14	24	K, R	5488
3.00	5.00	76.2	127.0	1	176	88.2	49.4				27.3	6.1	14.23	30	K, R	5175
3.00	5.00	76.2	127.0	1	77.7	38.7	24.2	10.3	7.1	5.1	12.0		12.94	24	K, R	5467
3.00	5.00	76.2	127.0	7	36.1	19.5	12.6	5.9	3.7		5.6		12.94	24	K, R	5507
3.00	6.00	76.2	152.4	1	93.8	46.1	29.1	12.9	8.6	6.1	14.5		15.74	24	K, R	5468
3.00	7.00	76.2	177.8	1	109	53.4	33.9	14.3	10.1	7.1	16.9		18.54	24	K, R	5469
3.00	8.00	76.2	203.2	1	125	60.9	38.8	16.1	11.4	8.1	19.4		21.34	24	K, R	5470
3.00	9.00	76.2	228.6	1	141	68.3	43.5	18.9	12.9	9.1	21.9		24.14	24	K, R	5471
3.00	9.00	76.2	228.6	1	407	203	123	59.2	40.5	28.3	63.1	14.2	25.50	26	K, R	5472
3.00	10.00	76.2	254.0	1		340	190	88.2	67.9	53.8	103	23.1	28.75	24	K, R	5176
3.00	10.00	76.2	254.0	1	156	75.8	48.3	20.3	14.9	10.2	24.2	5.4	26.94	24	K, R	5473
3.00	11.00	76.2	279.4	1	172	83.6	53.1	22.3	15.7	11.1	26.7	6.0	29.74	24	K, R	5474
3.00	12.00	76.2	304.8	1	188	91.1	57.7	23.9	16.7	12.1	29.1	6.5	32.54	24	K, R	5475
3.00	15.00	76.2	381.0	1		226	126	58.8	45.3	35.9	68.2	15.3	43.30	24	K, R	5177
3.03	3.03	77.0	77.0	3	1317	658	350	175			204	46.8	8.34	30	K	5476
3.10	4.10	78.7	104.1	1	306	153	92.7	43.8	18.1	12.7	47.4	10.7	11.40	26	K, R	5477
3.10	6.10	78.7	154.9	1	88.6	44.4	26.9	12.9	8.8	6.2	13.7		16.60	24	K, R	5478
3.10	7.10	78.7	180.3	3	104	52.3	31.6	15.2	10.4	7.3	16.1		19.80	24	K, R	5479
3.10	9.10	78.7	231.1	1	1500	750	454	218			233	52.7	25.60	26	K, R	5480
3.10	12.10	78.7	307.3	1	445	222	135	63.9	44.3	31.1	69.0	15.5	33.90	24	K, R	5481
3.25	3.25	82.6	82.6	7	172	86.1	52.1	25.1	17.1	12.1	26.7	6.0	9.80	26	K, R	5482
3.50	7.35	88.9	186.7	1	252	126	76.3	36.7	25.1	17.6	39.1	8.8	23.30	24	K, R	5483
3.63	16.27	92.2	413.3	1	795	398	212	106	70.5	52.9	123	27.7	56.00	24	R	5484
3.75	4.75	95.3	120.7	6	72.5	36.3	21.9	10.5	7.2	5.1	11.2		15.60	26	K, R	5485
3.80	8.60	96.5	218.4	1	243	121	73.6	35.4	24.2	16.9	37.7	8.4	29.80	24	K, R	5486
4.00	4.00	101.6	101.6	1	330	165	92.4	42.9			51.2	11.5	15.20	30	K, R	5178
4.00	4.00	101.6	101.6	1	46.5	23.3	14.3	6.1	4.9		7.2		13.94	24	K, R	5489
4.00	5.00	101.6	127.0	1	57.9	27.7	17.7	7.6	5.5	3.8	9.0		17.74	24	K, R	5490
4.00	5.00	101.6	127.0	7	48.5	25.9	16.8	7.3	5.1	3.5	7.5		17.74	24	K, R	5508
4.00	6.00	101.6	152.4	1	69.3	33.2	21.3	9.4	6.4	4.6	10.7		21.54	24	K, R	5491
4.00	7.00	101.6	177.8	1	80.7	38.6	24.7	10.9	7.2	5.3	12.5		25.34	24	K, R	5492
4.00	8.00	101.6	203.2	1		318	178	82.7	63.7	50.4	96.0	21.6	30.84	24	K, R	5179
4.00	8.00	101.6	203.2	1	92.3	43.9	28.3	12.3	8.4	6.1	14.3		29.14	24	K, R	5493
4.00	8.00	101.6	203.2	3	378	189	114	55.1	37.6	26.3	58.6	13.1	30.30	24	K, R	5494
4.00	9.00	101.6	228.6	1	103	49.5	31.7	13.4	9.3	6.8	16.0		32.94	24	K, R	5495
4.00	10.00	101.6	254.0	1	114	55.1	35.3	14.8	10.8	7.6	17.7		36.74	24	K, R	5496
4.00	11.00	101.6	279.4	1	126	60.6	38.8	16.2	11.7	8.3	19.5		40.54	24	K, R	5497
4.00	12.00	101.6	304.8	1		212	118	55.1	42.4	33.6	64.0	14.3	46.48	24	K, R	5180
4.00	12.00	101.6	304.8	1	137	66.1	42.1	17.6	12.2	9.1	21.2		44.34	24	K, R	5498
4.00	15.50	101.6	393.7	2	445	223	135	64.8	44.3	31.1	69.0	15.4	58.70	24	K, R	5499
4.00	16.80	101.6	426.7	6	720	360	218	105	71.6	50.1	112	25.0	63.00	24	R	5500
4.00	20.00	101.6	508.0	1	851	426	257	120	84.6	59.3	132	29.6	74.50	24	R	5501
4.05	8.05	102.9	204.5	1	617	312	186	89.9	61.4	43.1	95.6	21.5	30.40	26	K, R	5502
4.05	9.05	102.9	229.9	1	1400	700	420	210	139	97.1	217	49.0	34.10	26	K, R	5503
4.05	11.90	102.9	302.3	8	290	145	87.8	42.2	28.9	20.2	45.0	10.1	45.00	24	K, R	5504
4.50	19.40	114.3	492.8	1	30.1	15.1	9.1	4.3					81.30	24	R	5505
5.00	5.00	127.0	127.0	1		407	227	106	81.5	64.5	123	27.7	24.02	24	K, R	5181

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insu-lation	Model number
5.00	5.00	127.0	127.0	1	61.5	32.6	21.1	8.9	6.1	4.3	9.5		22.54	24	K, R	5509
5.00	6.00	127.0	152.4	1	72.4	38.8	24.9	10.6	7.3	5.1	11.2		27.34	24	K, R	5510
5.00	7.00	127.0	177.8	1	84.3	45.1	29.2	12.3	8.9	5.9	13.1		32.14	24	K, R	5511
5.00	8.00	127.0	203.2	1	96.2	51.4	32.9	14.1	9.7	6.8	14.9		36.94	24	K, R	5512
5.00	9.00	127.0	228.6	1	108	57.8	36.9	15.6	10.7	7.6	16.7		41.74	24	K, R	5513
5.00	10.00	127.0	254.0	1				85.7	66.1	52.9	105	23.5	48.57	24	K, R	5182
5.00	10.00	127.0	254.0	1	119	64.2	41.5	18.6	11.9	8.5	18.4		46.54	24	K, R	5514
5.00	11.00	127.0	279.4	1	131	70.5	44.9	19.2	12.8	9.4	20.3		51.34	24	K, R	5515
5.00	12.00	127.0	304.8	1	142	76.7	48.7	20.4	13.7	10.2	22.0		56.14	24	K, R	5516
5.00	12.10	127.0	307.3	1	377	190	114	54.8	37.5	26.3	58.4	13.1	56.40	24	K, R	5517
5.00	15.00	127.0	381.0	1				57.2	44.1	35.3	69.8	15.6	73.12	24	K, R	5183
5.00	15.97	127.0	405.6	8	271	136	72.2	36.1	24.1	18.1	42.0	9.4	76.00	24	K, R	5518
5.05	5.05	128.3	128.3	3	227	113	68.6	32.3	22.6	15.8	35.2	7.9	23.60	24	K, R	5519
5.05	5.05	128.3	128.3	3	262	131	79.4	38.2	26.1	18.3	40.6	9.1	23.60	24	K, R	5520
5.05	8.05	128.3	204.5	1	953	476	288	138	94.8	66.4	148	33.2	38.30	26	K, R	5521
5.05	10.10	128.3	256.5	1	660	330	205	98.2	65.7	46.1	102	23.0	48.00	26	K, R	5522
5.05	10.50	128.3	266.7	6	784	392	237	114	78.1	55.2	122	27.3	50.00	26	K, R	5523
5.10	12.10	129.5	307.3	1	523	261	158	76.2	52.1	36.4	81.1	18.2	58.00	26	K, R	5524
5.50	5.50	139.7	139.7	1	50.0	25.7	14.2	6.4	4.6	3.4	7.8		29.17	26	K, R	5596
5.50	7.00	139.7	177.8	1	384	192	116	55.8	38.1	26.7	59.5	13.3	35.80	24	K, R	5525
6.00	6.00	152.4	152.4	1	174	87.0	48.7	22.6	17.4	12.2	27.0	6.0	34.38	24	K, R	5560
6.06	8.06	153.9	204.7	6	362	182	109	52.6	36.1	25.2	56.1	12.6	45.70	24	K, R	5526
6.06	8.06	153.9	204.7	2	630	315	190	91.5	62.6	43.8	97.7	21.9	46.10	26	K, R	5527
6.90	9.00	175.3	228.6	2	88.1	44.1	26.1	12.8	8.8	6.2	13.7		58.30	24	K, R	5528
7.50	11.55	190.5	293.4	8	2890	1446	874	420			448	101	74.00	26	K, R	5529
7.90	18.30	200.7	464.8	8	241	120	73.1	35.1	24.1	16.8	37.4	8.3	140.00	24	R	5530
8.80	11.20	223.5	284.5	8	220	110	66.5	31.9	21.8	15.3	34.1	7.6	94.40	24	K, R	5531
9.00	12.00	228.6	304.8	3	545	273	165	79.3	54.2	38.1	84.5	18.9	103.00	24	K, R	5532
9.00	18.00	228.6	457.2	6	184	92.1	55.6	26.7	18.3	12.8	28.5	6.4	156.00	24	R	5533
10.00	10.00	254.0	254.0	1				42.8	33.1	26.4	52.2	11.7	97.52	20	K, R	5184
10.00	15.00	254.0	381.0	1				28.6	22.0	17.6	34.9	7.8	146.92	20	K, R	5185
10.00	18.00	254.0	457.2	1	161	80.4	48.6	23.4	16.1	11.2	25.0	5.6	173.00	24	R	5534
10.07	18.27	255.8	464.1	7	327	163	98.9	47.5	32.5	22.7	50.7	11.3	177.00	24	R	5535
10.70	11.00	271.8	279.4	6	807	403	244	117	80.3	56.1	125	28.0	114.00	24	K, R	5536
11.00	15.00	279.4	381.0	1	200	103	56.6	25.5	18.5	13.6	31.0	6.9	158.56	20	K, R	5600
0.50	0.09	12.7	2.4	31	25.0	12.8	7.1						0.13	30	K	5186
0.50		12.7		10	26.1	13.1	7.8	3.8					0.15	30	K	5537
0.75	0.12	19.1	3.1	31	39.2	20.6	11.2	5.2	3.9	3.0	6.1		0.35	26	K, R	5593
0.78		19.8		10	32.2	16.1	9.7	4.7					0.32	30	K, R	5538
0.78		19.8		10	70.1	35.2	21.1	10.2			10.9		0.32	30	K	5539
0.98	0.12	24.9	3.0	11	37.2	18.6	11.3	5.4			5.8		0.65	24	K, R	5540
1.00	0.09	25.4	2.4	31	157	80.5	44.4	19.9	14.4	10.5	24.3	5.6	0.68	26	K	5187
1.10	0.12	27.9	3.0	11	61.1	30.5	18.5	8.9			9.5		0.66	24	K, R	5541
1.18		30.0		30	288	144	80.6	37.4	28.8	20.2	44.6	10.4	0.90	30	K	5561
1.25	0.60	31.8	15.2	11	84.4	42.2	25.5	12.3			13.1		0.59	26	K, R	5542
1.32		33.5		10	38.0	19.0	10.6	4.9	3.8		5.9		1.19	30	K, R	5562
1.35	0.45	34.3	11.4	11	156	78.1	47.2	22.7			24.2	5.6	0.96	30	K	5543
1.50	0.12	38.1	3.1	31	75.0	39.0	21.3	9.8	7.2	5.4	11.6		1.60	26	K, R	5597
1.73		43.9		10	227	114	68.7	33.1			35.2	8.0	2.00	30	K, R	5544

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Rubber (HR) models not available with NiFe element

D

Kapton & Silicone Rubber Heaters

Size (in) X	Size (in) Y	Size (mm) X	Size (mm) Y	Type	Resistance options in ohms* R(0°C) [May be used with Heaterstat] →						NiFe	Ni	Effective area (in²)	Lead AWG	Insu-lation	Model number
1.75	0.12	44.5	3.0	11	61.1	30.5	18.5	8.9	6.1	4.2	9.5		2.19	24	K, R	5545
1.85	0.12	47.0	3.0	11	61.2	30.6	18.5	8.9	6.1	4.2	9.5		2.44	26	K, R	5546
1.90		48.3		10	156	78.4	47.4	22.8			24.2	5.5	2.48	24	K, R	5547
2.00	0.12	50.8	3.1	31	100	51.9	28.4	13.0	9.6	7.1	15.5		2.93	26	K, R	5598
2.13	1.12	54.1	28.4	11	180	90.1	54.6	26.3			27.9	6.3	2.16	26	K, R	5548
2.45		62.2		10	530	265	160	77.1			82.2	18.8	4.16	26	K, R	5549
2.85		72.4		10	200	100	56.0	26.0	20.0	14.0	31.0	7.0	5.98	30	K, R	5563
3.00	0.12	76.2	3.1	31	378	194	107	48.0	34.7	25.4	58.6	13.3	6.61	26	K, R	5188
3.40		86.4		10	198	99.0	55.4	25.7	19.8	13.9	30.7	6.9	8.34	24	K, R	5564
3.72	2.09	94.5	53.1	11	317	158	95.9	46.1	31.6	22.1	49.1	11.1	6.76	26	K, R	5550
4.30	3.42	109.2	86.9	11	405	206	125	60.1			62.8	14.3	3.91	26	K, R	5551
4.75	2.50	120.7	63.5	11	54.5	27.3	14.5	7.2	4.8	3.6	8.4		11.48	24	K, R	5552
6.00	0.12	152.4	3.1	11	150	77.4	42.5	19.2	14.0	10.3	23.3	5.2	27.02	26	K, R	5599
6.25	2.00	158.8	50.8	11	610	305	185	88.8	60.7	42.5	94.6	21.3	25.66	24	K, R	5553
6.75	4.75	171.5	120.7	11	251	125	76.1	36.6	25.1	17.5	38.9	8.7	15.79	26	K, R	5554
7.06		179.3		10	120	60.1	31.9	16.1	10.6	7.4	18.6		37.19	24	K, R	5555
8.25	4.32	209.6	109.7	11	670	335	202	97.4	67.1	47.4	104	23.3	36.13	24	K, R	5556
9.00	3.00	228.6	76.2	11	710	355	215	101	70.6	49.4	110	24.7	52.46	24	K, R	5557
9.60	0.90	243.8	22.9	11	72.7	36.3	21.9	10.6	7.2	5.1	11.3		67.65	24	K, R	5558
10.00	0.25	254.0	6.4	11	667	334	202	96.7	67.1	47.7	103	23.2	74.78	24	K, R	5559

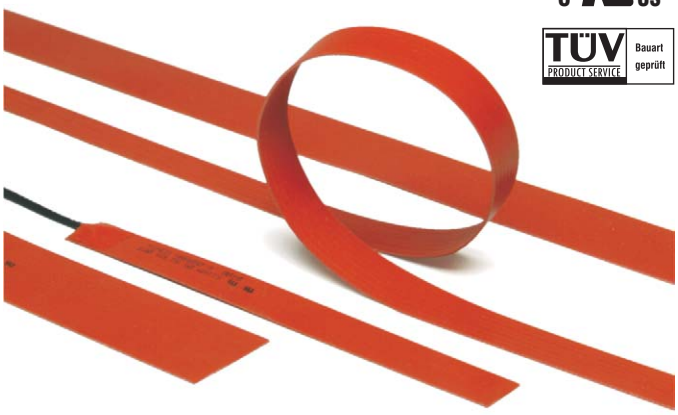
*Resistance tolerance is ±10% or ±0.5Ω, whichever is greater

Rubber (HR) models not available with NiFe element

Wire-Wound Rubber Heaters 220°C

These heaters have a wire element instead of foil. They are more economical in larger sizes, but are thicker and have reduced watt densities.

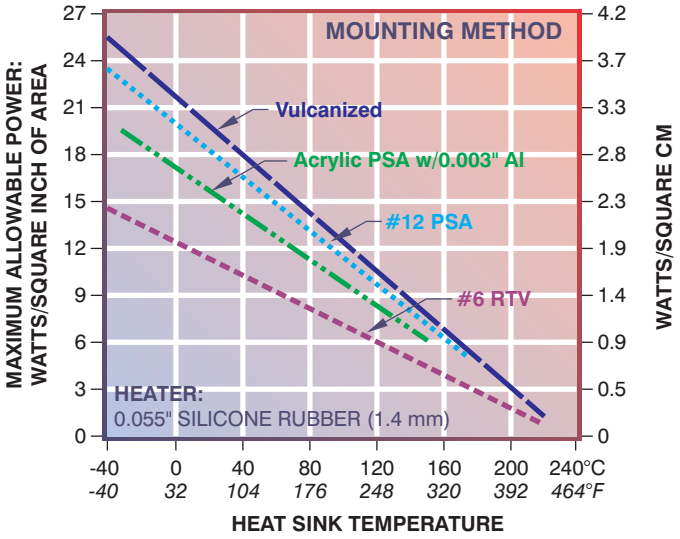
- Rugged
- Easy to install
- Uniform heating to 220°C (428°F)
- Lengths to 70" (1.8 m)
- Economical in large sizes
- Withstand repeated flexing
- Mount to flat or curved surfaces
- TÜV and UL component recognition marking are standard
- 2.5, 5, 10, 15 watts/in² at 120 or 240 VAC
- Lower leakage current due to capacitive coupling (may be important for large heaters used in medical applications)



Typical applications

- Prevent condensation in motors and generators
- Protect instrument cabinets from cold, humidity
- De-icing
- Heat valves and vessels to control fluid viscosity
- Heat industrial ovens and thermal processing equipment
- Heat platens
- Heat medical devices

Maximum watt density, rubber heaters



Example: At 100°C, the maximum power of a heater mounted with #6 RTV is 7 W/in².

Specifications for catalog models

Temperature range: -45 to 220°C (-50 to 428°F).
Thickness: 0.055" ±0.005" (1.4 ±0.13 mm). 0.250" (6.4 mm) maximum over leadwires.
Maximum voltage rating: 600 VAC (UL and TÜV recognition up to 250 VAC).
Leadwires: AWG 20 except where noted, PTFE insulated per UL 1199/CSA. Length on standard models is 12" (305 mm). Current capacity (based on 100°C max. ambient temp.):

AWG 20	AWG 18
13.5 A	16.0 A

Approvals: All wire-wound models comply with UL Standard 499 and Canadian Standard C22.2, No. 72-M1984 and European Standard EN60335 and may bear the corresponding recognition marks.
Wattage tolerance: ±5%.
Maximum size (custom): 12 × 70" (305 × 1780 mm).
Maximum resistance density (custom): 200 Ω/in² (31 Ω/cm²).

Custom options

- Custom shapes and sizes to 12 × 70" (300 × 1780 mm)
- Custom resistance to 200 Ω/in² (31 Ω/cm²)
- Integral thermostats
- See section J for custom design assistance

E

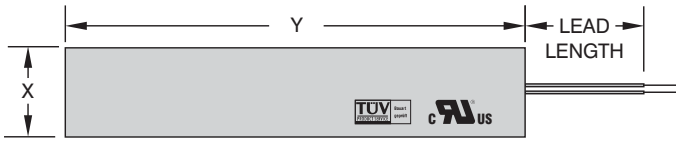
Stock Wire-Wound Rubber Heaters

Stock heaters

Normally available from stock for immediate shipment. Order by complete model number (e.g. HR6870A).

How to order stock models (below)

HR6850	**Model number**
A	**Heater backing** A = No backing
HR6850A ← Sample part number	



Watt density: 5 W/in² (0.8 W/cm²) at rated voltage.
Lead length: 24" (610 mm).

120 volt

Size (inches) X	Y	Size (mm) X	Y	Volts	Watts	Model number
1	6	25.4	152.4	120	30	HR6870A
1	10	25.4	254.0	120	50	HR6850A
1	12	25.4	304.8	120	60	HR6871A
1	20	25.4	508.0	120	100	HR6852A
1	24	25.4	609.6	120	120	HR6873A
1	30	25.4	762.0	120	150	HR6854A
1	40	25.4	1016.0	120	200	HR6856A
1	60	25.4	1524.0	120	300	HR6858A
2	10	50.8	254.0	120	100	HR6860A
2	20	50.8	508.0	120	200	HR6862A
2	24	50.8	609.6	120	240	HR6875A
2	30	50.8	762.0	120	300	HR6864A
2	40	50.8	1016.0	120	400	HR6866A
2	60	50.8	1524.0	120	600	HR6868A

240 volt

Size (inches) X	Y	Size (mm) X	Y	Volts	Watts	Model number
1	10	25.4	254.0	240	50	HR6851A
1	12	25.4	304.8	240	60	HR6872A
1	20	25.4	508.0	240	100	HR6853A
1	24	25.4	609.6	240	120	HR6874A
1	30	25.4	762.0	240	150	HR6855A
1	40	25.4	1016.0	240	200	HR6857A
1	60	25.4	1524.0	240	300	HR6859A
2	10	50.8	254.0	240	100	HR6861A
2	20	50.8	508.0	240	200	HR6863A
2	24	50.8	609.6	240	240	HR6876A
2	30	50.8	762.0	240	300	HR6865A
2	40	50.8	1016.0	240	400	HR6867A
2	60	50.8	1524.0	240	600	HR6869A

How to order standard models (next 2 pages)

HR6600	**Model number**	
R576	**Heater resistance in ohms**	
L12	**Lead length in inches** 12" (305 mm) is standard	
A	**Heater backing**	
	A = No backing	-45 to 220°C
	B = #12 PSA backing	-45 to 177°C
	D = Aluminum foil backing	-45 to 220°C
	E = Aluminum foil with Acrylic PSA	-32 to 150°C
	F = Aluminum foil with #12 PSA	-45 to 204°C
HR6600R576L12A ← Sample part number		

Standard Wire-Wound Rubber Heaters

Size (in)		Size (mm)		120 volt heaters								Model number
				2.5 W/in²		5 W/in²		10 W/in²		15 W/in²		
X	Y	X	Y	Watts	Resistance	Watts	Resistance	Watts	Resistance	Watts	Resistance	
1	5	25	127			25 W	576 Ω	50 W	288 Ω	75 W	192 Ω	HR6600
1	6	25	152			30 W	480 Ω	60 W	240 Ω	90 W	160 Ω	HR6693
1	10	25	254	25 W	576 Ω	50 W	288 Ω	100 W	144 Ω	150 W	96.0 Ω	HR6602
1	12	25	305	30 W	480 Ω	60 W	240 Ω	120 W	120 Ω	180 W	80.0 Ω	HR6694
1	15	25	381	38 W	384 Ω	75 W	192 Ω	150 W	96.0 Ω	225 W	64.0 Ω	HR6604
1	20	25	508	50 W	288 Ω	100 W	144 Ω	200 W	72.0 Ω	300 W	48.0 Ω	HR6606
1	24	25	610	60 W	240 Ω	120 W	120 Ω	240 W	60.0 Ω	360 W	40.0 Ω	HR6696
1	25	25	635	63 W	230 Ω	125 W	115 Ω	250 W	57.6 Ω	375 W	38.4 Ω	HR6608
1	30	25	762	75 W	192 Ω	150 W	96.0 Ω	300 W	48.0 Ω	450 W	32.0 Ω	HR6610
1	35	25	889	88 W	165 Ω	175 W	82.3 Ω	350 W	41.1 Ω	525 W	27.4 Ω	HR6612
1	40	25	1016	100 W	144 Ω	200 W	72.0 Ω	400 W	36.0 Ω	600 W	24.0 Ω	HR6614
1	60	25	1524	150 W	96.0 Ω	300 W	48.0 Ω	600 W	24.0 Ω	900 W	16.0 Ω	HR6616
1	70	25	1778	175 W	82.3 Ω	350 W	41.1 Ω	700 W	20.6 Ω			HR6618
2	5	51	127	25 W	576 Ω	50 W	288 Ω	100 W	144 Ω	150 W	96.0 Ω	HR6619
2	10	51	254	50 W	288 Ω	100 W	144 Ω	200 W	72.0 Ω	300 W	48.0 Ω	HR6621
2	15	51	381	75 W	192 Ω	150 W	96.0 Ω	300 W	48.0 Ω	450 W	32.0Ω	HR6623
2	20	51	508	100 W	144 Ω	200 W	72.0 Ω	400 W	36.0 Ω	600 W	24.0Ω	HR6625
2	24	51	610	120 W	120 Ω	240 W	60.0 Ω	480 W	30.0 Ω	720 W	20.0Ω	HR6698
2	25	51	635	125 W	115 Ω	250 W	57.6 Ω	500 W	28.8 Ω	750 W	19.2Ω	HR6627
2	30	51	762	150 W	96.0 Ω	300 W	48.0 Ω	600 W	24.0 Ω	900 W	16.0Ω	HR6629
2	35	51	889	175 W	82.3 Ω	350 W	41.1 Ω	700 W	20.6 Ω	1050 W	13.7Ω	HR6631
2	40	51	1016	200 W	72.0 Ω	400 W	36.0 Ω	800 W	18.0 Ω	1200 W	12.0Ω	HR6633
2	60	51	1524	300 W	48.0 Ω	600 W	24.0 Ω	1200 W	12.0 Ω			HR6635
2	70	51	1778	350 W	41.1 Ω	700 W	20.6 Ω	1400 W	10.3 Ω			HR6637
3	5	76	127	38 W	384 Ω	75 W	192 Ω	150 W	96.0 Ω	225 W	64.0 Ω	HR6638
3	10	76	254	75 W	192 Ω	150 W	96.0 Ω	300 W	48.0 Ω	450 W	32.0 Ω	HR6640
3	15	76	381	113 W	128 Ω	225 W	64.0 Ω	450 W	32.0 Ω	675 W	21.3 Ω	HR6642
3	20	76	508	150 W	96.0 Ω	300 W	48.0 Ω	600 W	24.0 Ω	900 W	16.0 Ω	HR6644
3	25	76	635	188 W	76.8 Ω	375 W	38.4 Ω	750 W	19.2 Ω	1125 W	12.8 Ω	HR6646
3	30	76	762	225 W	64.0 Ω	450 W	32.0 Ω	900 W	16.0 Ω	1350 W	10.7 Ω	HR6648
3	35	76	889	263 W	54.9 Ω	525 W	27.4 Ω	1050 W	13.7 Ω	1575 W	9.1 Ω	HR6650*
3	40	76	1016	300 W	48.0 Ω	600 W	24.0 Ω	1200 W	12.0 Ω			HR6652
3	60	76	1524	450 W	32.0 Ω	900 W	16.0 Ω					HR6654
3	70	76	1778	525 W	27.4 Ω	1050 W	13.7 Ω					HR6655
4	5	102	127	50 W	288 Ω	100 W	144 Ω	200 W	72.0 Ω	300 W	48.0 Ω	HR6656
4	10	102	254	100 W	144 Ω	200 W	72.0 Ω	400 W	36.0 Ω	600 W	24.0 Ω	HR6658
4	15	102	381	150 W	96.0 Ω	300 W	48.0 Ω	600 W	24.0 Ω	900 W	16.0 Ω	HR6660
4	20	102	508	200 W	72.0 Ω	400 W	36.0 Ω	800 W	18.0 Ω	1200 W	12.0 Ω	HR6662
4	25	102	635	250 W	57.6 Ω	500 W	28.8 Ω	1000 W	14.4 Ω	1500 W	9.6 Ω	HR6664*
4	30	102	762	300 W	48.0 Ω	600 W	24.0 Ω	1200 W	12.0 Ω			HR6666
4	35	102	889	350 W	41.1 Ω	700 W	20.6 Ω	1400 W	10.3 Ω			HR6668
4	40	102	1016	400 W	36.0 Ω	800 W	18.0 Ω	1600 W	9.0 Ω			HR6670*
4	60	102	1524	600 W	24.0 Ω	1200 W	12.0 Ω					HR6672
4	70	102	1778	700 W	20.6 Ω	1400 W	10.3 Ω					HR6673
5	5	127	127	63 W	230 Ω	125 W	115 Ω	250 W	57.6 Ω	375 W	38.4 Ω	HR6674
5	10	127	254	125 W	115 Ω	250 W	57.6 Ω	500 W	28.8 Ω	750 W	19.2 Ω	HR6676
5	15	127	381	188 W	76.8 Ω	375 W	38.4 Ω	750 W	19.2 Ω	1125 W	12.8 Ω	HR6678
5	20	127	508	250 W	57.6 Ω	500 W	28.8 Ω	1000 W	14.4 Ω	1500 W	9.6 Ω	HR6680*
5	25	127	635	313 W	46.1 Ω	625 W	23.0 Ω	1250 W	11.5 Ω			HR6682
5	30	127	762	375 W	38.4 Ω	750 W	19.2 Ω	1500 W	9.6 Ω			HR6684*
5	35	127	889	438 W	32.9 Ω	875 W	16.5 Ω					HR6686
5	40	127	1016	500 W	28.8 Ω	1000 W	14.4 Ω					HR6688
5	60	127	1524	750 W	19.2 Ω	1500 W	9.6 Ω					HR6690*
5	70	127	1778	875 W	16.5 Ω	1750 W	8.2 Ω					HR6691*

*AWG 18 leads (AWG 20 is standard)

E

Standard Wire-Wound Rubber Heaters

Size (in)		Size (mm)		240 volt heaters								Model number
				2.5 W/in²		5 W/in²		10 W/in²		15 W/in²		
X	Y	X	Y	Watts	Resistance	Watts	Resistance	Watts	Resistance	Watts	Resistance	
1	10	25	254			50 W	1152 Ω	100 W	576 Ω	150 W	384 Ω	HR6603
1	12	25	305			60 W	960 Ω	120 W	480 Ω	180 W	320 Ω	HR6695
1	15	25	381	38 W	1536 Ω	75 W	768 Ω	150 W	384 Ω	225 W	256 Ω	HR6605
1	20	25	508	50 W	1152 Ω	100 W	576 Ω	200 W	288 Ω	300 W	192 Ω	HR6607
1	24	25	610	60 W	960 Ω	120 W	480 Ω	240 W	240 Ω	360 W	160 Ω	HR6697
1	25	25	635	63 W	922 Ω	125 W	461 Ω	250 W	230 Ω	375 W	154 Ω	HR6609
1	30	25	762	75 W	768 Ω	150 W	384 Ω	300 W	192 Ω	450 W	128 Ω	HR6611
1	35	25	889	88 W	658 Ω	175 W	329 Ω	350 W	165 Ω	525 W	110 Ω	HR6613
1	40	25	1016	100 W	576 Ω	200 W	288 Ω	400 W	144 Ω	600 W	96.0 Ω	HR6615
1	60	25	1524	150 W	384 Ω	300 W	192 Ω	600 W	96.0 Ω	900 W	64.0 Ω	HR6617
2	5	51	127			50 W	1152 Ω	100 W	576 Ω	150 W	384 Ω	HR6620
2	10	51	254	50 W	1152 Ω	100 W	576 Ω	200 W	288 Ω	300 W	192 Ω	HR6622
2	15	51	381	75 W	768 Ω	150 W	384 Ω	300 W	192 Ω	450 W	128 Ω	HR6624
2	20	51	508	100 W	576 Ω	200 W	288 Ω	400 W	144 Ω	600 W	96.0 Ω	HR6626
2	24	51	610	120 W	480 Ω	240 W	240 Ω	480 W	120 Ω	720 W	80.0 Ω	HR6699
2	25	51	635	125 W	461 Ω	250 W	230 Ω	500 W	115 Ω	750 W	76.8 Ω	HR6628
2	30	51	762	150 W	384 Ω	300 W	192 Ω	600 W	96.0 Ω	900 W	64.0 Ω	HR6630
2	35	51	889	175 W	329 Ω	350 W	165 Ω	700 W	82.3 Ω	1050 W	54.9 Ω	HR6632
2	40	51	1016	200 W	288 Ω	400 W	144 Ω	800 W	72.0 Ω	1200 W	48.0 Ω	HR6634
2	60	51	1524	300 W	192 Ω	600 W	96.0 Ω	1200 W	48.0 Ω	1800 W	32.0 Ω	HR6636
3	5	76	127	38 W	1536 Ω	75 W	768 Ω	150 W	384 Ω	225 W	256 Ω	HR6639
3	10	76	254	75 W	768 Ω	150 W	384 Ω	300 W	192 Ω	450 W	128 Ω	HR6641
3	15	76	381	113 W	512 Ω	225 W	256 Ω	450 W	128 Ω	675 W	85.3 Ω	HR6643
3	20	76	508	150 W	384 Ω	300 W	192 Ω	600 W	96.0 Ω	900 W	64.0 Ω	HR6645
3	25	76	635	188 W	307 Ω	375 W	154 Ω	750 W	76.8 Ω	1125 W	51.2 Ω	HR6647
3	30	76	762	225 W	256 Ω	450 W	128 Ω	900 W	64.0 Ω	1350 W	42.7 Ω	HR6649
3	35	76	889	263 W	219 Ω	525 W	110 Ω	1050 W	54.9 Ω	1575 W	36.6 Ω	HR6651
3	40	76	1016	300 W	192 Ω	600 W	96.0 Ω	1200 W	48.0 Ω	1800 W	32.0 Ω	HR6653
4	5	102	127	50 W	1152 Ω	100 W	576 Ω	200 W	288 Ω	300 W	192 Ω	HR6657
4	10	102	254	100 W	576 Ω	200 W	288 Ω	400 W	144 Ω	600 W	96.0 Ω	HR6659
4	15	102	381	150 W	384 Ω	300 W	192 Ω	600 W	96.0 Ω	900 W	64.0 Ω	HR6661
4	20	102	508	200 W	288 Ω	400 W	144 Ω	800 W	72.0 Ω	1200 W	48.0 Ω	HR6663
4	25	102	635	250 W	230 Ω	500 W	115 Ω	1000 W	57.6 Ω	1500 W	38.4 Ω	HR6665
4	30	102	762	300 W	192 Ω	600 W	96.0 Ω	1200 W	48.0 Ω	1800 W	32.0 Ω	HR6667
4	35	102	889	350 W	165 Ω	700 W	82.3 Ω	1400 W	41.1 Ω	2100 W	27.4 Ω	HR6669
4	40	102	1016	400 W	144 Ω	800 W	72.0 Ω	1600 W	36.0 Ω	2400 W	24.0 Ω	HR6671
5	5	127	127	63 W	922 Ω	125 W	461 Ω	250 W	230 Ω	375 W	154 Ω	HR6675
5	10	127	254	125 W	461 Ω	250 W	230 Ω	500 W	115 Ω	750 W	76.8 Ω	HR6677
5	15	127	381	188 W	307 Ω	375 W	154 Ω	750 W	76.8 Ω	1125 W	51.2 Ω	HR6679
5	20	127	508	250 W	230 Ω	500 W	115 Ω	1000 W	57.6 Ω	1500 W	38.4 Ω	HR6681
5	25	127	635	313 W	184 Ω	625 W	92.2 Ω	1250 W	46.1 Ω	1875 W	30.7 Ω	HR6683
5	30	127	762	375 W	154 Ω	750 W	76.8 Ω	1500 W	38.4 Ω	2250 W	25.6 Ω	HR6685
5	35	127	889	438 W	132 Ω	875 W	65.8 Ω	1750 W	32.9 Ω	2625 W	21.9 Ω	HR6687
5	40	127	1016	500 W	115 Ω	1000 W	57.6 Ω	2000 W	28.8 Ω	3000 W	19.2 Ω	HR6689*

*AWG 18 leads (AWG 20 is standard)

Mica Heaters

600°C

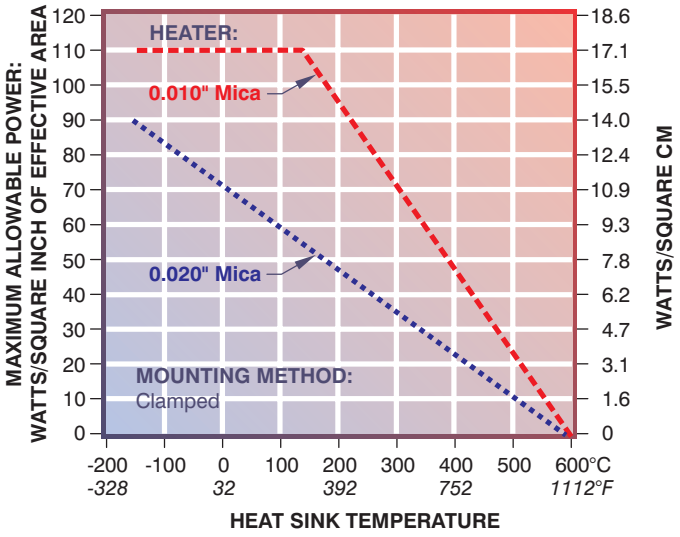
These heaters consist of an etched foil element sandwiched between layers of mica. An organic material binds the layers together and burns off during initial warmup. Installed by clamping to heat sinks, mica Thermofoil heaters provide the ultimate temperature and wattage capability for fast warmup.

- Extremely high temperature capability to 600°C (1112°F)
- Power rated to 110 watts per square inch — 50% higher than conventional mica strip heaters
- Can be factory formed to curves
- Clamp directly to heat sink for exceptional heat transfer
- Suitable for vacuum use after organic binder is burned off in initial power-up

Typical applications

- Semiconductor processing
- Packaging, strapping, and sealing equipment
- DNA analysis (mica heaters used for rapid temperature cycling)
- Food service appliances
- Plastics and rubber molding supplemental heat

Maximum watt density, mica heaters



Example: At 300°C, the maximum power of a 0.010" mica heater is 70 W/in².

Specifications for catalog models

Temperature range: -150 to 600°C (-238 to 1112°F). Lead tab area: 538°C (1000°F) max.

Material: 0.010" (0.25 mm) or 0.020" (0.51 mm) thick. 0.020" thickness recommended for operating voltage over 250 V.

Resistance tolerance: ±10% or ±0.5 Ω, whichever is greater.

Dielectric strength:
0.010" insulation: 1000 VRMS.
0.020" insulation: 2000 VRMS.

Mounting: Must be clamped to heat sink using bolt holes provided in heater and backing plate. See page F-3 for a detailed drawing of installation.

Burn-in: Organic binders will burn off, producing small amounts of smoke, when heaters are first powered. After this, layers can separate so heaters should not be reinstalled.

Leadwire: Mica/glass insulated, stranded nickel-clad copper, potted over termination with high temperature cement. Current capacity (based on 100°C max. ambient temp.):

AWG 22	AWG 20	AWG 18
8.0 A	9.0 A	11.0 A

Custom options

- Custom shapes and sizes to 22 × 22" (560 × 560 mm)
- Custom resistance to 11.5 Ω/in² (1.8 Ω/cm²)
- Factory forming
- Integral temperature sensors
- Clamped/encapsulated subassemblies
- See section J for custom design assistance

How to order heaters

HM6800	**Model number from table (following page)**
R4.5	**Heater resistance in ohms**
L12	**Lead length in inches** 12" is standard; contact Minco for other lengths
T1	**Insulation thickness:** T1 = 0.010" T2 = 0.020"
HM6800R4.5L12T1 ← Sample part number	

F

Standard Mica Heaters

These standard mica heaters are designed to fit a wide range of applications. You can clamp them to any flat surface either with a clamping mechanism outside the heater area or by using a backing plate and bolts through the pre-punched bolt holes. All heaters come with matching 0.125" (3 mm) thick ceramic paper for use as a resilient pad on the lead bulge side of the heater. Matching stainless steel backing plates and additional sheets of ceramic paper are also available.

Specification drawings, with heater dimensions and hole locations, are available at www.minco.com/support as Adobe PDF (Acrobat) files.

Size (inches) X	Y	Size (mm) X	Y	Resistance options in ohms*		Effective area (in²)	Lead AWG	Model number
1.00	4.00	25.4	101.6	11.0	21.2	2.5	22	HM6811
1.00	8.00	25.4	203.2	22.0	42.5	5.6	22	HM6812
1.00	10.00	25.4	254.0	29.0	56.0	7.1	22	HM6813
1.00	12.00	25.4	304.8	25.5	49.2	8.6	22	HM6814
1.50	3.00	38.1	76.2	4.5	8.7	3.2	22	HM6800
1.50	8.00	38.1	203.2	21.0	40.5	9.5	20	HM6801
1.50	12.00	38.1	304.8	13.7	26.4	14.7	18	HM6802
2.00	2.00	50.8	50.8	12.0	23.2	2.8	22	HM6815
2.00	4.00	50.8	101.6	26.0	50.2	5.9	18	HM6816
2.00	4.00	50.8	101.6	6.0	11.6	5.9	18	HM6817
2.00	6.00	50.8	152.4	21.9	42.3	9.2	20	HM6803
2.00	8.00	50.8	203.2	24.0	46.3	12.6	18	HM6818
2.00	10.00	50.8	254.0	20.0	38.6	15.9	18	HM6819
2.00	12.00	50.8	304.8	18.0	34.7	19.3	18	HM6820
3.00	3.00	76.2	76.2	31.0	59.8	6.5	20	HM6804
3.00	6.00	76.2	152.4	54.9	106.0	14.7	20	HM6805
3.00	12.00	76.2	304.8	18.0	34.7	30.7	18	HM6821
4.00	4.00	101.6	101.6	11.0	21.2	13.1	18	HM6822
4.00	4.00	101.6	101.6	55.0	106.2	13.1	18	HM6823
4.00	8.00	101.6	203.2	16.0	30.9	27.8	18	HM6824
4.00	12.00	101.6	304.8	16.0	30.9	42.2	18	HM6825
6.00	6.00	152.4	152.4	22.0	42.5	31.9	18	HM6826
6.00	9.00	152.4	228.6	15.0	29.0	48.7	18	HM6827
6.00	12.00	152.4	304.8	43.2	83.4	65.5	18	HM6806
8.00	8.00	203.2	203.2	22.0	42.5	58.3	18	HM6828
10.00	10.00	254.0	254.0	12.0	23.2	92.3	18	HM6829
Diameter (inches)		**Diameter (mm)**						
1.50		38.1		2.0	3.9	1.2	22	HM6807
2.00		50.8		9.5	18.3	2.2	22	HM6830
3.00		76.2		11.1	21.4	5.4	20	HM6808
4.00		101.6		40.0	77.2	10.0	18	HM6831
5.00		127.0		30.0	57.9	16.7	18	HM6832
6.00		152.4		32.7	63.1	24.7	18	HM6809
8.00		203.2		16.0	30.9	45.4	18	HM6833
9.00		228.6		43.2	83.4	58.5	18	HM6810
10.00		254.0		30.0	57.9	72.9	18	HM6834
10.00		254.0		11.5	22.2	72.9	18	HM6835
12.00		304.8		27.0	52.1	106.0	18	HM6836
12.00		304.8		11.5	22.2	106.0	18	HM6837

*Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

Mica Heater Accessories & Assemblies

Backing plates

Backing plates are 0.0625" (1.6 mm) thick stainless steel with pre-drilled holes matching the bolt pattern of the specified model. These backing plates do not have cut out areas for the lead bulge and may require modification, depending on the installation.

How to order backing plates

Order part number AC6800 for HM6800, etc.

Ceramic paper

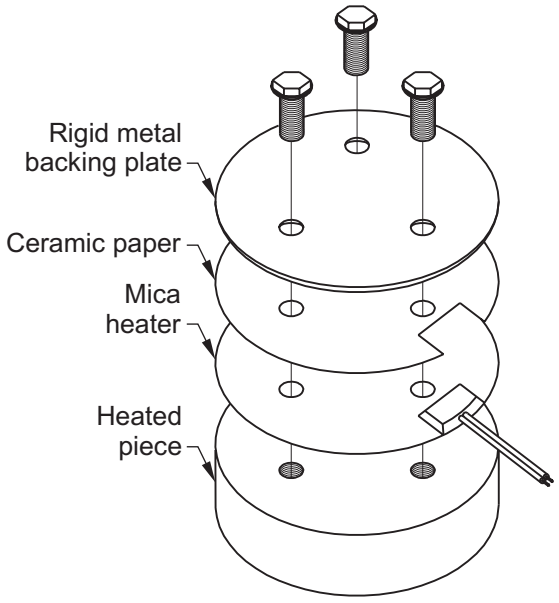
Each mica heater is supplied with two pre-trimmed sheets of 0.125" (3.2 mm) thick ceramic fabric paper for use as a resilient pad between the heater and backing plate. This paper does not have a cut out area for the lead bulge. If the backing plate being used does not have a cut out area for the leads attachment you must use two pieces of this paper and make this cut out in each. See page K-10 to order additional ceramic paper.

Mica sheets

Additional layers of 0.010" (0.25 mm) mica trimmed to the heater size are also available. Using an additional layer of mica will increase the dielectric strength, but it will also reduce the watt density limit by up to 50% across the temperature range. If used on the lead bulge side of the heater then the mica must be cut to allow for the ceramic and wires bulge on that side. See page K-10 to order mica sheets.

Installation instructions

Minco Engineering Instruction #347 describes mica heater installation in detail. Contact Minco for a copy or download the document at www.minco.com/support as an Adobe PDF (Acrobat) file.



Insulation	Maximum heater thickness			
	Over element	AWG #22	AWG #20	AWG #18
0.010" mica	0.030" (0.8 mm)	0.150" (3.8 mm)	0.200" (5.1 mm)	0.200" (5.1 mm)
0.020" mica	0.050" (1.3 mm)	0.170" (4.3 mm)	0.220" (5.6 mm)	0.220" (5.6 mm)

Factory formed heaters

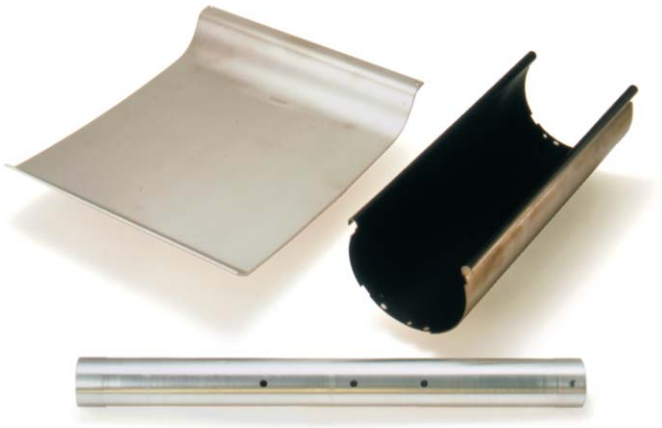
Mica insulated heaters are not flexible, but Minco can provide factory formed designs with simple curves. You can specify a custom model with a curve diameter as small as 1.0" (25 mm).

Heated rollers

Mica heaters installed inside tubes provide reliable, high wattage heating.

Heater assemblies

Minco can produce a complete heater assembly including metalwork for your custom OEM application. Our machine shop capabilities include milling, turning, welding, and forming aluminum, stainless steel or other metals. If you prefer, Minco can complete the subassembly with your supplied parts.



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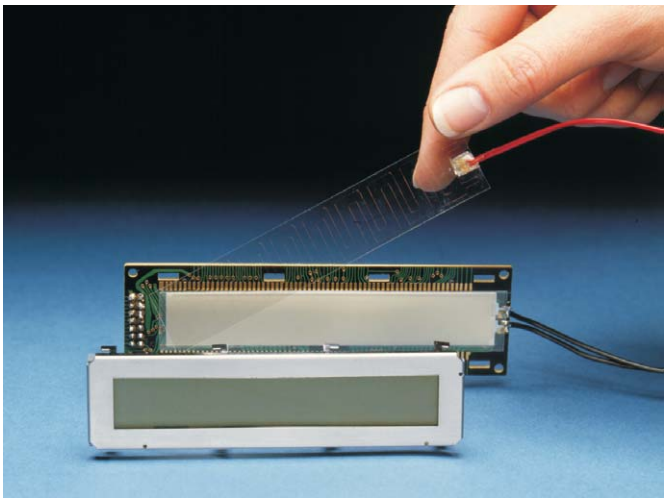
Thermal-Clear™ Transparent Heaters 120°C

Featuring a micro-thin wire heating element laid in a pattern between optical grade polyester sheets, Thermal-Clear heaters provide reliable heat without blocking light.

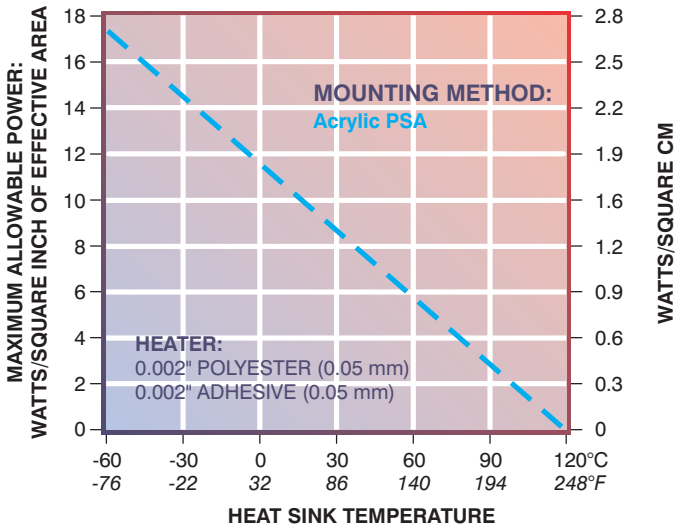
- Transmits over 80% of visible light
- For cold weather operation of LCD's and other applications
- Rugged, flexible construction
- Integral temperature sensors optional
- Rectangular, round, or irregular shapes
- Uniform or profiled heat patterns



Typical applications

- Cockpit displays
- Ruggedized computers
- Portable military radios
- Handheld terminals
- Outdoor card readers
- Portable and vehicular computers
- Camera enclosure deicing
- Defogging windows in environmental chambers
- Heating microscope stages

Maximum watt density, Thermal-Clear™ heaters



Specifications for catalog models

Temperature range: -55 to 120°C (-67 to 248°F).

Insulation: Optical grade polyester is standard. Glass and polycarbonate materials are available on custom models.

Transparency: 82% minimum light transmission over the visible spectrum.

Heating element: Resistive wire, diameter 0.0008" to 0.002" (0.02 to 0.05 mm).

Resistance tolerance: ±10% or ±0.5 Ω, whichever is greater.

Leadwires: PTFE insulated wire is standard. Lead connections are welded and anchored between heater layers for strength. Special terminations are available on custom models.

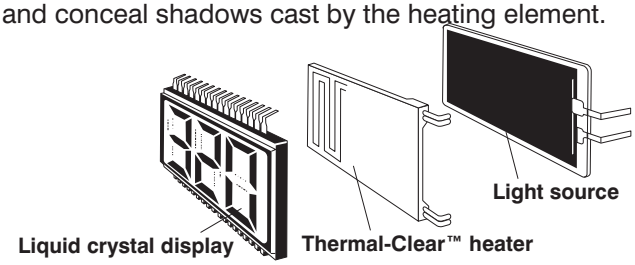
Custom options

- Integral RTD or thermistor sensors
- Flex-circuit terminations
- Rigid materials
- Custom shapes and sizes to 11" × 22"
- See section J for custom design assistance

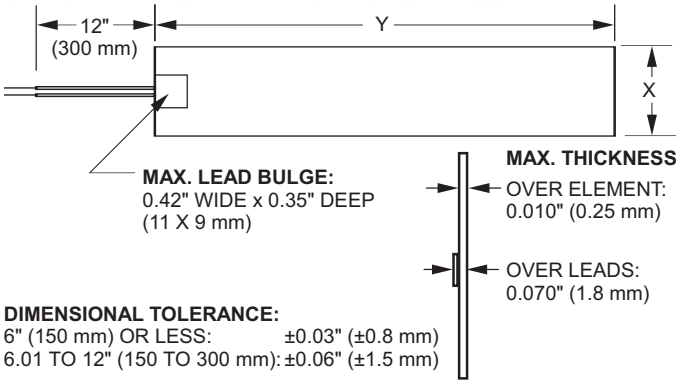
Thermal-Clear™ heaters and LCD's

Minco tests show that most dot matrix LCD's lose sharpness and response speed below 0°C. But you can achieve acceptable performance at much colder temperatures with a Thermal-Clear heater. One to two watts of heat per square inch will keep a typical LCD operating properly in ambients as low as -55°C.

Shown below is a typical installation on a backlit LCD. The heater is sandwiched between the backlight and the LCD. We recommend you also insert a light diffuser between the heater and LCD if there is no diffusion coating on the back of the LCD. Diffusion helps to soften and conceal shadows cast by the heating element.



Standard Thermal-Clear™ Heaters



DIMENSIONAL TOLERANCE:
6" (150 mm) OR LESS: ±0.03" (±0.8 mm)
6.01 TO 12" (150 TO 300 mm): ±0.06" (±1.5 mm)

How to order heaters

H6700	**Model number from table below**
R9.0	**Heater resistance in ohms**
L12	**Lead length in inches** 12" (305 mm) is standard
A	**Heater backing option (see page A-9)** A = No backing -55 to 120°C B = Acrylic PSA backing -55* to 120°C

HR6700R9.0L12A ← Sample part number

*Bonding strength deteriorates rapidly below -32°C. If the heater is not mechanically clamped, avoid excessive vibration and lead pull. Bonding strength recovers at temperatures above -32°C.

Size (inches) X	Y	Size (mm) X	Y	Resistance options (at 0°C) in ohms**					Effective area (in²)	Lead AWG	Model number
0.58	2.20	14.6	55.9	3.6	9.0	32.5	89.4		1.26	30	H6700
0.75	4.00	19.1	101.6	8.8	22.0	79.4	218		3.00	30	H6701
0.90	2.00	22.9	50.8	4.8	12.0	43.3	119		1.80	30	H6702
0.90	2.75	22.9	69.9	6.4	16.0	57.8	159		2.48	30	H6703
0.90	5.75	22.9	146.0	14.1	35.0	126	348		5.18	30	H6704
1.10	4.40	27.9	111.8	12.0	30.0	108	298		4.84	30	H6705
1.20	2.75	30.5	69.9	8.0	20.0	72.2	199		3.30	30	H6706
1.20	3.65	30.5	92.7	11.2	28.0	101	278		4.38	30	H6707
2.90	5.75	73.7	146.0	9.6	24.0	86.6	238		16.70	30	H6708
3.00	3.00	76.2	76.2	6.1	16.0	62.4	168		9.00	30	H6710
4.00	5.00	101.6	127.0	11.8	31.2	122	327		20.00	30	H6711
6.00	8.00	152.4	203.2	14.8	28.1	70.0	253	695	48.00	30	H6709
1.25 diameter		31.8 diameter			4.3	11.2	43.5	117	1.23	30	H6712
3.00 diameter		76.2 diameter			8.0	20.9	81.5	219	7.07	30	H6713
Element wire type and diameter:				Copper 0.0016" 0.04 mm	Copper 0.0016" 0.04 mm	Copper 0.001" 0.03 mm	Nickel 0.001" 0.03 mm	Nickel-iron 0.001" 0.03 mm			
Element TCR (Ω/Ω/°C):				0.00427	0.00427	0.00427	0.00672	0.00519			

**Resistance tolerance is ±10% or ±0.5 Ω, whichever is greater

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Heaterstat™ Sensorless Temperature Controller

Any Thermal-Clear heater will work with the CT198 Heaterstat™ Sensorless Temperature Controller, which directly regulates element temperature without requiring a separate sensor. See page K-3 for full specifications.

CT198-K4 Evaluation Kit

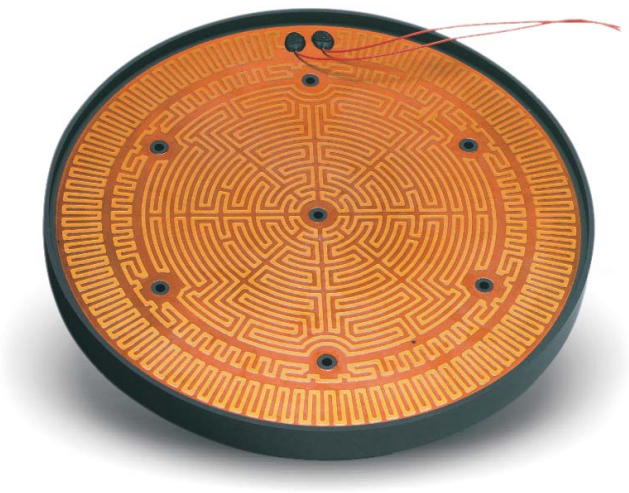
Contains H15227 Thermal-Clear heater and CT198-4 controller for easy prototyping.

Setpoint: Factory set at 50°C. Adjustable from -40 to 95°C.
Supply voltage: 4.75 to 10 VDC, 5 VDC nominal.
Heater power: 1.7 W at 50°C, assuming 5 VDC.
Heater Dimensions: 0.75" × 4" (19 × 102 mm).

All-Polyimide (AP) Heaters 260°C

AP heaters are a high performance alternative to Minco's standard Kapton heaters, allowing higher temperatures and watt densities. They must be factory mounted or clamped to heat sinks.

- Uniform heating to 260°C (500°F)
- Exceptional temperature uniformity when designed with a heat-profiled foil pattern
- Thin, flexible etched-foil construction
- Available in round, rectangular, and irregular shapes
- Can be factory bonded to mating parts with no clamping hardware!
- Power ratings to 80 watts per square inch
- Resistant to most chemicals
- Optional built-in temperature sensors
- Custom designs only



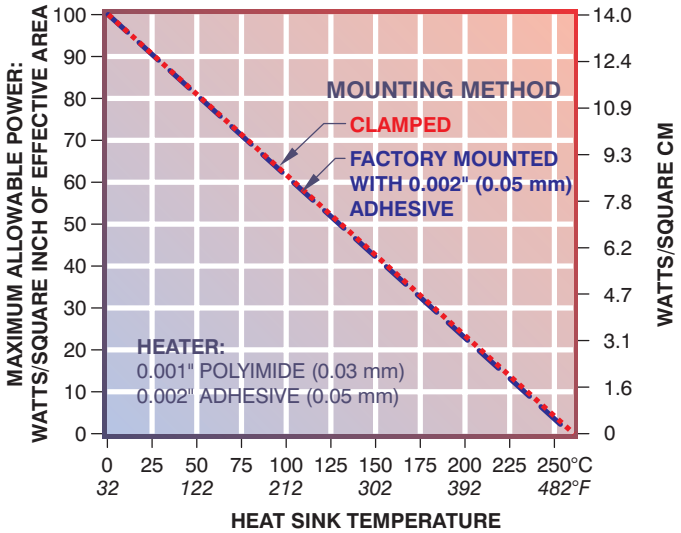
Typical applications

- Semiconductor wafer processing
- Satellites or other spacecraft
- Heating of electronic components
- Packaging, fusing, and splicing equipment

Specifications

Temperature range: -200 to 260°C (-328 to 500°F).
With UL component recognition: -200 to 240°C (-328 to 464°F).
Leadwires: Stranded, PTFE insulated, AWG 30 to AWG 20.
Heater thickness:
Over element: 0.012" (0.3 mm) max.
Over leadwire terminations: 0.150" (3.8 mm) ref.
Dielectric strength: 1000 VRMS at 60 Hz for 1 minute.
Insulation resistance: 1000 megohms min. at 500 VDC.
Outgassing: 0.36% total mass loss, 0.01% collected volatile condensable material, per NASA-JSFC.
Approvals: UL.
Maximum size: 24" × 42" (610 mm × 1067 mm).
Maximum resistance density: 1500 Ω/in².

Maximum watt density, AP heaters



Example: At 150°C, the maximum power of a factory-mounted AP heater is 22 W/in².

Standard Heater/Sensors 150°C

Integrated heater/sensors are the ideal solution for many temperature control problems. Combining an etched foil heating element with an accurate, stable RTD or thermistor sensor in a single package provides a reliable system with reduced parts count and simplified installation.

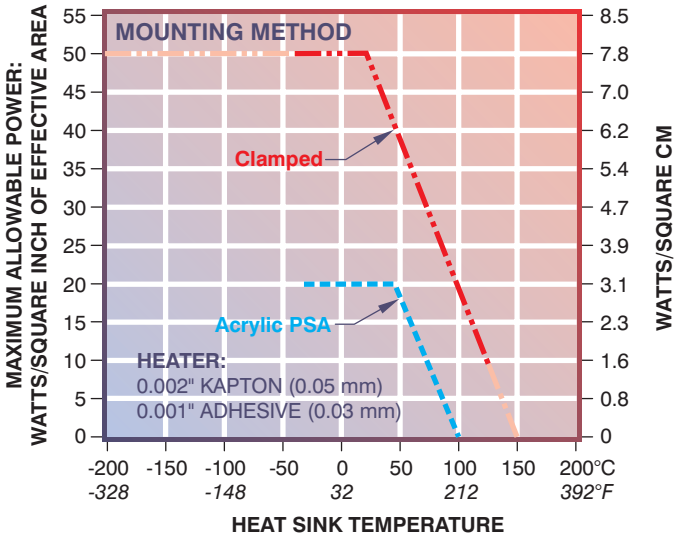
Minco standard heater/sensors have the sensor element located in a non-heating area to measure the heat sink temperature — not the heating element temperature. The result is a more accurate reading and better control. Precise location of the sensor ensures consistent readings every time.

These heaters are ideal for use with the CT325 Miniature DC Controller (page K-5).

Typical applications

- Medical diagnostic equipment
- Telecommunication equipment: DWDM, fiberoptic component enclosures
- Prototyping, experimentation and research

Maximum watt density, heater/sensors



Example: At 70°C, the maximum power of a heater/sensor mounted with acrylic PSA is 10 W/in².

Specifications

Temperature range: -40 to 125°C (-40 to 257°F).
"S0" option only: -200 to 150°C (-328 to 302°F).
"B" option only: -32 to 100°C (26 to 212°F).

Material: Kapton/acrylic, 0.002/0.001" (0.05/0.03 mm).

Resistance tolerance: ±10% or ±0.5 Ω, whichever is greater.

Sensor element: 100 Ω or 1000 Ω platinum RTD, R(100°C)/R(0°C)=1.385 per IEC 751, or 50k Ω NTC thermistor. Etched sensor leads add up to 0.4 Ω resistance to measured value.

Minimum bend radius:
0.030" (0.8 mm) except in sensor area 0.5" (12.7 mm).

Connection: Tinned solder pads. Four loose leadwires, AWG 26, PTFE insulated, 12" (305 mm) long, stripped and tinned, provided for optional attachment to solder pads (2 heater, 2 sensor).

Sensor time response: Less than 0.1 second in water at 3 ft/sec (sensor only); less than 0.5 second system time.

Sensor stability: Drift less than 0.1°C/year in normal use.

How to order

ASI5900	**Model number from table**
R71.4	**Heater resistance from table**
PD	**Sensor element** PD = Platinum 100 Ω ±0.12% at 0°C PF = Platinum 1000 Ω ±0.12% at 0°C TF = NTC Thermistor 50k Ω ±1% at 25°C S0 = No sensor element installed Note: Etched sensor leads add up to 0.4 Ω resistance to measured value.
A	**Backing options** A = No adhesive B = Pressure sensitive adhesive (PSA)
ASI5900R71.4PDA ← Sample part number	

Size (inches) X	Y	Size (mm) X	Y	Resistance in ohms ±10% or ±0.5 Ω, whichever is greater				Effective area (in²)	Model number
1.00	2.00	25.4	50.8	71.4	32.0	23.2	16.9	1.35	ASI5900
1.00	3.00	25.4	76.2	43.9	19.7	14.3	10.4	2.23	ASI5901
3.00	3.00	76.2	76.2	21.2	9.50	6.90	5.00	7.99	ASI5902
4.00	4.00	101.6	101.6	21.1	9.50	6.80	5.00	14.7	ASI5903
5.00	5.00	127.0	127.0	21.4	9.60	6.90	5.00	23.5	ASI5904
1.50 diameter		38.1 diameter		73.1	32.8	23.7	17.3	1.25	ASI5905
3.00 diameter		76.2 diameter		21.1	9.50	6.80	5.00	6.93	ASI5906

Designing with Thermofoil™ Heaters

Estimating power requirements

The total amount of power required for an application is the larger of two values:

1. Warmup power + Heat lost during warmup
2. Process heat + Heat lost in steady state

Warmup power: Watts required to bring an object to temperature in a given time. The basic formula is:

$$P(watts) = \frac{mC_p(T_f - T_i)}{t}$$

where:

m = Mass of object (g)
C_p = Specific heat of material (J/g/°C)
T_f = Final temperature of object (°C)
T_i = Initial temperature of object (°C)
t = Warmup time (seconds)

Material	Specific heat (J/g/°C)	Density (g/cm³)
Air	1.00	0.012
Aluminum	1.00	2.70
Copper	0.38	8.96
Glass	0.75	2.64
Oil (typical)	1.90	0.90
Plastic (typical)	1.25	Varies
Silicon	0.68	0.23
Solder	0.17	8.65
Steel	1.88	7.75
Water	4.19	1.00

For other materials see Application Aid #21.

To get:	Multiply:
J/g/°C	BTU/lb/°F × 4.19
g/cm³	lbs/ft³ × 0.016

Process heat: Heat required to process a material when the heater is performing useful work. The formula above also applies here, but must also include latent heat if material changes state (melts or evaporates).

Heat loss: All systems lose heat through convection (air or liquid movement), conduction through support structures, and thermal radiation.

Tools for analytical wattage estimation

Minco Application Aid #21 shows how to estimate these losses in the steady state, and provides a formula that includes loss factors in warmup calculations.

Thermal Calc program (DOS), free from Minco, assists with calculations. Contact Minco or visit www.minco.com.

Finite Element Analysis (FEA) creates a mathematical model of a thermal system. The calculations can include temperature gradients and conditions that other theoretical models are not capable of describing. However, FEA can be expensive and time consuming for complex systems.

Conducting experiments

Heat transfer theory is complex. It's usually best to prototype your system with actual heaters to observe behavior and fine-tune the design. Minco offers a variety of tools to help you:

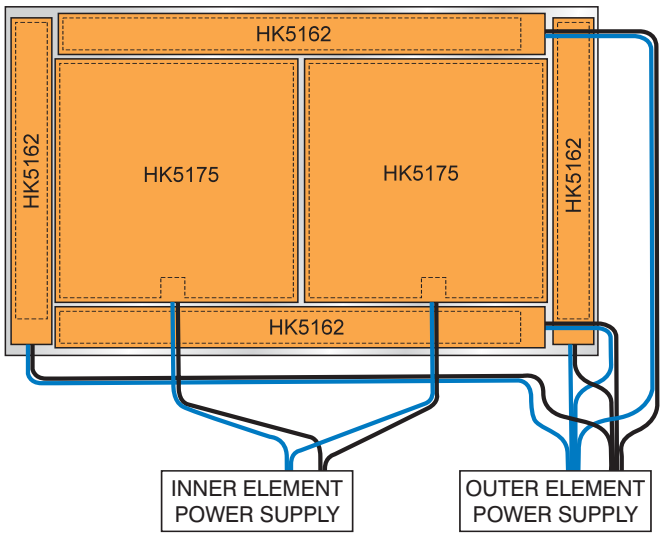
Catalog heaters: You usually can model a custom heater with one or more standard models from this catalog. Stock Kapton heaters (page B-2) are particularly useful. Any combination of models with the same nominal voltage (28 or 115), connected in *parallel*, will give the same watt output per square inch. Also note that HK913 heater kit models (page B-3) will give constant watt density when connected in *series*.

Variable power source: An AC power supply ("Variac"), power resistor, or rheostat lets you test different power levels (across the heater or zone by zone).

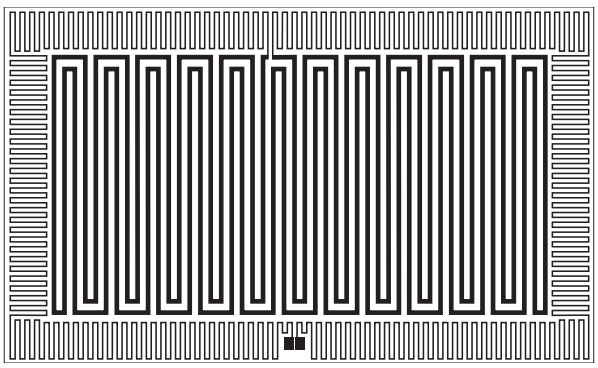
Temperature sensor(s): A small Thermal-Ribbon RTD such as model S17624 is easy to move and reapply to test temperature in various locations.

Indicator: Minco model TI142 handheld indicator provides good accuracy at low cost.

Controller: Models CT325, CT15, and CT16A cover the range from simple to sophisticated design for testing control schemes.



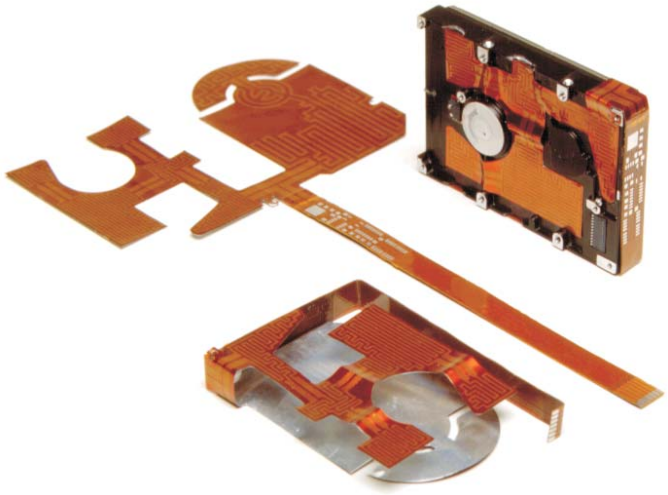
A mosaic of catalog heaters, with dual power supplies, helps to determine edge profiling for uniform temperature.



The resulting custom heater looks like this.

Custom Design Options

Thermofoil heaters give you design options other heater types can't match. Element patterns, outline shapes and heat profiles can be fine-tuned to create the exact thermal and physical component to fit your unique requirements.



Shaped to fit the application

Irregular outlines, holes, and cutouts are defined during initial setup.

Dual elements

Two individually powered heater elements let you:

- Use both elements during initial warmup, then shut one element off for better steady-state control.
- Design dual voltage heaters: Connect elements in parallel for 120 V, in series for 240 V.

Profiled and multi-zone heaters

A profiled element levels out temperature gradients by providing extra heat where losses occur, such as along edges or around mounting holes. In a typical case, profiling might reduce a ±25°C temperature variation across a surface to ±5°C or better. Once the best profile is determined for the application, Minco's photo-etching process ensures repeatability from heater to heater.

Methods to derive the profiling pattern include:

- Experimentation: Lay out a pattern with catalog heaters and vary the power levels until temperature reaches the desired uniformity. Or, Minco can provide a custom heater with separately powered zones for prototyping. Minco will then reproduce the successful profile with a single element.
- Finite Element Analysis (FEA): Although more expensive, FEA modeling of thermal systems can reduce the number of trials required to design a profiled heater. It may help to map the temperature resulting from uniform heat input (using a catalog heater), then work backward in FEA to derive the profiled pattern.

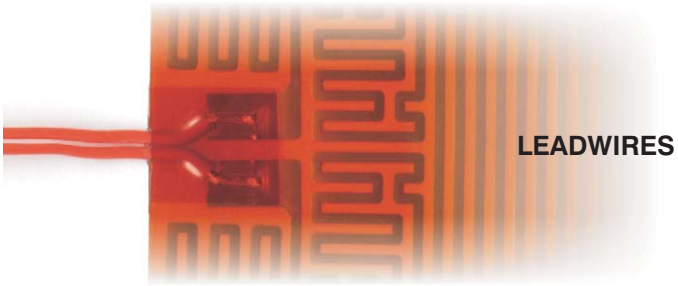
Tight uniformity goals may require more than one profiling iteration, and a given solution is optimized for only one setpoint temperature.

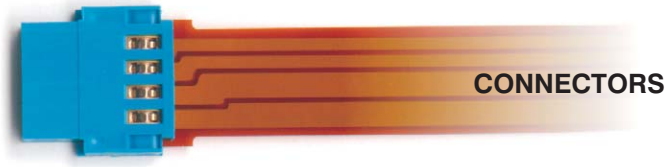
Other element options

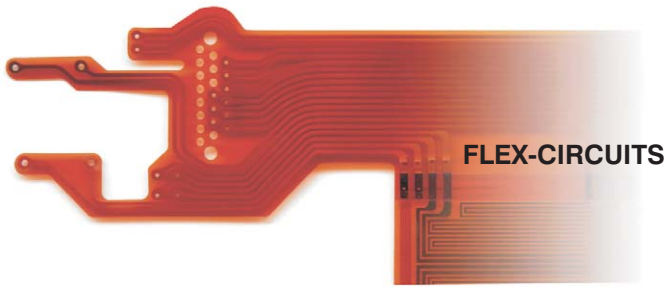
- Dual layer (higher resistance or inductance canceling)
- Non-magnetic materials

Electrical termination

Leadwires (standard)	Welded leadwires make a strong, reliable connection. Options include different colors, sizes, and insulating materials
Solder pads	Lowest cost, but limits foil/resistance options.
Connectors	Insulation displacement connectors crimped onto etched leads make an economical design. Other connector types are available.
Flex-circuits	Minco can supply flex-circuits integrally connected with heaters.







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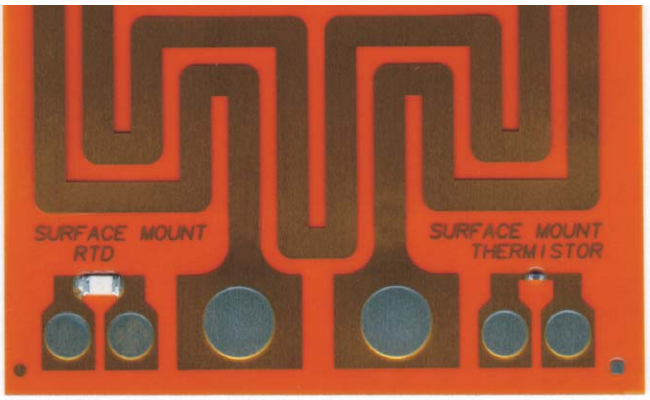
Custom Heater/Sensors

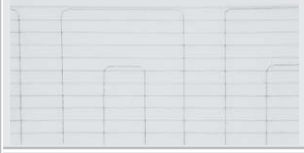
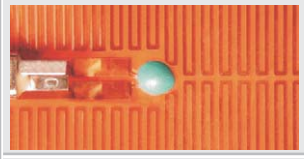
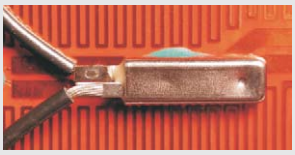
Integrating sensors into heaters simplifies your assembly operations while improving thermal response. The sensor sits in a window of the heating element. It reacts to temperature changes in the component beneath the heater, yet remains close to the heating element itself. This tight coupling of heater, sensor, and load can greatly improve control accuracy.

Sensors can be electrically connected via leadwires or flex-circuitry.

Most heater/sensors are custom designed. Minco recommends prototyping with standard heaters and Thermal-Ribbon™ sensors.



Types of sensors used in heater/sensors

	Description	Benefits	Options
	**Thin-film RTD's** Small ceramic elements laminated inside the heater or located on top	♦ Highly stable and accurate ♦ Standardized output ♦ Low cost ♦ Tight tolerance	♦ Platinum, 0.00385 TCR ♦ 100 to 10,000 Ω ♦ Wire leads or SMT ♦ 0.12% or 0.06% tolerance
	**Strip-wound RTD** Sensing wire wound around a flexible insulating strip and encapsulated inside heater	♦ Can average temperatures ♦ Any resistance possible	♦ Platinum, nickel, nickel-iron
	**Flat-wound RTD** Sensing wire laid in a predetermined pattern in a single plane	♦ Fast response (0.1 sec.) ♦ Average temp. over area	♦ Platinum, nickel, nickel-iron ♦ Uniform or profiled
	**Etched RTD** Heater and RTD etched from same temperature sensitive foil	♦ Lowest cost ♦ Fast response ♦ Loose tolerance	♦ Nickel or nickel-iron
	**Thermistor** Bare or coated bead embedded in heater or placed on top and covered with epoxy	♦ High sensitivity ♦ Low to moderate cost	♦ NTC or PTC ♦ Variety of resistances ♦ Bead or SMT
	**Thermocouple** Junction of dissimilar metals laminated inside heater	♦ Low cost ♦ Smallest sensor ♦ Wide temperature range	♦ Wire or foil ♦ E, J, K, or T standard
	**Thermostat** See page K-10 for standard thermostats	♦ No external controller ♦ Low system cost ♦ Slower response ♦ Looser control	♦ Snap action or creep action ♦ Specify setpoint ♦ Wired/mounted to heater

Heater Assemblies

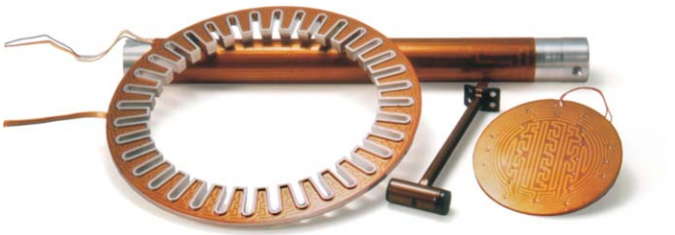
For best heater performance and reduced installed costs, consider Minco's capabilities in mounting heaters to make complete thermal subassemblies. You can furnish the heat sinks or we can fabricate them to your specifications. Either way, you get a guaranteed bond, superior reliability, and the benefits of Minco's experience with advanced adhesives and lamination equipment. In many cases we can affix the heater to the mating part in the same step used to bond its layers together. That saves money over a two-step process.

Vulcanized silicone rubber assemblies

Minco's proprietary vulcanization process uses no adhesive to bond heaters to mating parts. Eliminating the adhesive facilitates heat transfer, resulting in higher allowable watt densities and longer life.

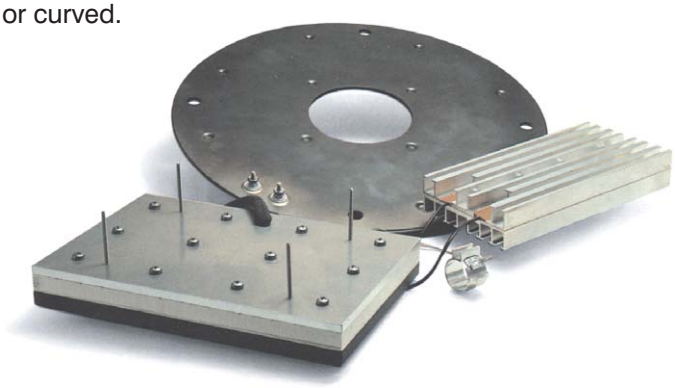
Laminated Kapton heaters

Kapton heaters can be mounted to flat or curved heat sinks using an acrylic adhesive and our specialized lamination equipment. The thin, uniform bond layer provides excellent heat transfer. Watt densities to 50 watts/in^2 are possible.



Clamped mica heaters

Mica heaters must be secured between rigid plates to prevent separation of layers. Minco can provide many styles of mica heater assemblies: bolted or welded, flat or curved.



Factory mounted All-Polyimide (AP) heaters

Factory bonded AP heaters eliminate clamping and provide optimum heat transfer to the heat sink. The excellent chemical resistance and low outgassing of AP heaters, together with Minco's precise machining capabilities, are the perfect solution for chuck heaters in semiconductor processing equipment.

Assembly options

- Minco-supplied heat sinks: Machined, formed, and extruded parts from Minco's advanced machine shop or qualified vendors
- Coatings: PTFE coating, anodizing, or plating with nickel, copper, or gold
- Temperature sensors: See page K-11 for more information
- Thermostats and thermal cutoffs for control or limit switching
- Wire harnesses, connectors, or flex-circuitry
- Electronic components

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Examples of Thermal Systems

Description	Heat a tank containing 2 kg of chemical solution from 20°C to 50°C in 10 minutes. The space available for mounting the heater is 4" × 5".	Heat moving film in a thermal processor. A sheet of polyester film weighing 5 g must be brought from 25°C to 90°C every 2 seconds. The heater will measure 2" × 12" and will be mounted on a metal platen.	An LCD heater must be capable of bringing the 6" × 8" display from -55°C to 0°C in 5 minutes and maintaining it there.
Wattage requirements	From Thermal Calc*, we need 450 watts minimum for warmup plus losses.	From Thermal Calc*, we need 275 watts minimum for warmup plus losses.	From Thermal Calc*, we need 50 watts for warmup and 20 watts for maintenance of temperature.
Electrical parameters	$R = E^2/W = 120^2/450 = 32\ \Omega$	$R = E^2/W = 120^2/275 = 52\ \Omega$	$R = E^2/W = 28^2/50 = 16\ \Omega$
Heater selection	Choosing Kapton for chemical resistance, the best choice is HK5490R27.7L12	Specifying silicone rubber for lower cost, the best choice is HR5433R44.1L12	From Minco's standard Thermal-Clear™ heaters we choose model H6709R14.8L12
Actual wattage	Wattage is $120^2/27.7 = 520$ W	Wattage is $120^2/44.1 = 327$ W	Wattage is $28^2/14.8 = 53$ W
Watt density	Watt density = W/effective area = $520/17.74\ in^2 = 29\ W/in^2$	Watt density = W/effective area = $327/21.80\ in^2 = 15\ W/in^2$	Watt density = W/effective area = $53/48\ in^2 = 1.1\ W/in^2$
Installation	From watt density charts we specify Acrylic PSA with aluminum backing (E option). This is rated to 31 W/in^2 at 50°C.	Any type of heater mounting will handle the watt density. We will factory vulcanize the heater for lowest installed cost.	We choose Acrylic PSA backing for convenience (B option). The watt density is well within the rated maximum.
Leadwire current	AWG 24 leadwire current rating is 7.5 A. Actual current is $I = 120/27.7 = 4.3$ A (OK).	AWG 24 leadwire current rating is 7.5 A. Actual current is $I = 120/44.1 = 2.7$ A (OK).	AWG 30 leadwire current rating is 3 A. Actual current is $I = 28/14.8 = 1.9$ A (OK).
Control	The CT16A controller with optional AC744 solid state relay will handle the current.	The customer integrates a custom controller into other electronic circuits.	A CT198-1005 Heaterstat™ will control the heater. Its setpoint will be adjustable from 6 to 62°C. We have chosen a model with a higher range in order to ensure that the LCD itself reaches 0°C: we know the setpoint will have to be higher because it controls the heater element which runs hotter than the surface beneath it.
Sensor	An S665 Thermal-Tab™ will be mounted to the side of the tank.	An S247 thin-film RTD will be potted into a hole in the platen. A thermostat with 100°C setpoint will provide overtemperature shutoff.	None: The heater acts as the sensor!
Custom options	An AP heater would provide a higher watt density for faster warmup (at higher cost). A rubber or mica heater would allow more watts for faster warmup, if acceptable in the application.	The sensor and thermostat could be integrated into the heater.	Placing the lead connections on an external tab would remove the lead bulge from the display area. Switching to a sensor and CT325 for control, instead of the Heaterstat, would allow higher wattage and finer control.

*Thermal Calc is a free DOS program, available at www.minco.com/support, to assist in estimating heater wattage requirements from known parameters.

Examples of Thermal Systems

Description	Warm a test instrument in an avionics system from as cold as -45°C to 70°C within two minutes with ±2°C accuracy. The instrument is a cylinder 1.25" (32 mm) diameter and 3.5" (89 mm) tall, providing a heating area of 3.9 × 3.5" (100 × 89 mm). The available voltage on the aircraft is 28 VDC.	Maintain 96 sample vials, each containing 10 ml of human blood, at 37°C. The vials are positioned in drilled blind holes in an aluminum block measuring 4.0" × 6.0" × 1.5" with a total mass of 500 g. The sample temperature must never exceed 40°C.	A 300 mm silicon wafer placed on a 325 mm diameter aluminum chuck must be heated from 40°C to 220°C during processing.
Wattage requirements	From Thermal Calc*, we need 60 watts warmup power and 25 watts maintenance power.	From Thermal Calc*, we need 60 watts for warmup and maintenance.	From Thermal Calc*, we need 800 watts to reach the required temperature within the time limit.
Electrical parameters	$R = E^2/W = 28^2/60 = 13.1\ \Omega$	$R = E^2/W = 24^2/60 = 9.6\ \Omega$	$R = E^2/W = 208^2/800 = 54.1\ \Omega$
Heater selection	Commercial and military avionics systems typically specify Kapton insulated heaters. Model HK5482R12.1L12A is selected.	Specifying Kapton because it is resistant to most chemicals and does not outgas, the best choice is HK5491R9.4L12B	The required temperature exceeds the limit for Kapton heaters, and the vacuum process does not allow silicone rubber. An All-Polyimide heater, factory mounted to the chuck, is required.
Actual wattage	Wattage is $28^2/12.1 = 65$ W	Wattage is $24^2/9.4 = 61$ W	Wattage is $208^2/54.1 = 800$ W
Watt density	Watt density = W/effective area = $65/9.8\ in^2 = 6.6\ W/in^2$	Watt density = W/effective area = $61/21.54\ in^2 = 2.8\ W/in^2$	Watt density = W/effective area = $800/109.9\ in^2 = 7.3\ W/in^2$
Installation	For this cylindrical shape heat sink, a BM 3 Shrink Band is selected.	Any type of heater mounting will handle the watt density. We recommend acrylic PSA for fast availability of prototypes.	Factory lamination of AP heaters provides optimum heat transfer and allows operating temperatures higher than other adhesives.
Leadwire current	AWG 26 current rating is 5.0 A. Actual current is I = 28/12.1 = 2.3 A (OK).	AWG 24 leadwire current rating is 7.5 A. Actual current is I = 24/9.4 = 2.6 A (OK).	AWG 20 leadwire current rating is 13.5 A. Actual current is I = 208/54.1 = 3.8 A (OK).
Control	The CT325 controller will be used to control the heater.	A custom control circuit integrated into the system electronics will control the heater. The controller is designed for a 1000 Ω platinum RTD element input.	All electrical and motion control of the wafer processing system is centrally controlled by a computer. Thermal control is integrated into the system.
Sensor	An S665 Thermal Tab provides easy installation in the prototype test system.	A 1000 Ω platinum RTD Thermal-Tab™ sensor is used. The customer tests the sensor in several positions around the aluminum block to determine the optimum location.	An S247 thin film RTD element with high-temperature extension leads will be cemented into a hole in the platen.
Custom options	Experiments confirm the power requirements, but also show that the sensor measures only one point rather than the average temperature of the cylinder. In the final custom design an integrated Thermal-Ribbon strip sensor wraps around the circumference of the cylinder to measure the average temperature.	Testing showed that edge losses required 20% higher watt density around the periphery of the heater to equalize temperature within the block. A custom design with profiled power output, integrated sensor, and 40°C thermal fuse provides a complete thermal system in one package.	The leads exit is located at the center of the heater to fit with the design requirements of the machine.

*Thermal Calc is a free DOS program, available at www.minco.com/support, to assist in estimating heater wattage requirements from known parameters.

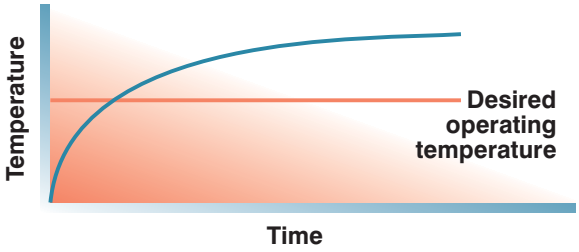
J

Temperature Controllers

Uncontrolled system

If powered without any regulation, a heater will rise in temperature until heat losses (increasing with temperature) equal heat input. This may be acceptable in rare situations, but normally is to be avoided because the equilibrium temperature is highly unpredictable.

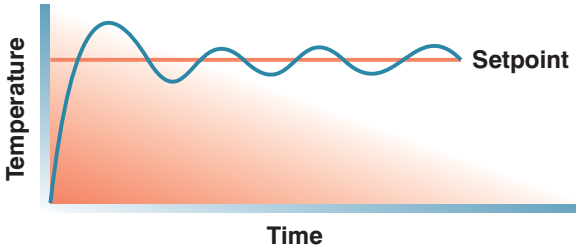
In most cases we want to control heater temperature. We can then ramp up to setpoint faster without fear of overshooting and burning out the heater.



On/off control

On/off is the most basic form of control: Full power on below setpoint, power off above setpoint. Electronic on/off controllers offer faster reaction time and tighter control than thermostats. All on/off controllers have a differential (hysteresis or deadband) between the on and off points to reduce rapid cycling and prolong switch life.

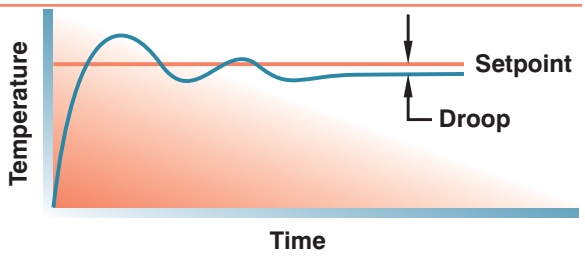
With on/off control, temperature never stabilizes but always oscillates around the setpoint.



Proportional control

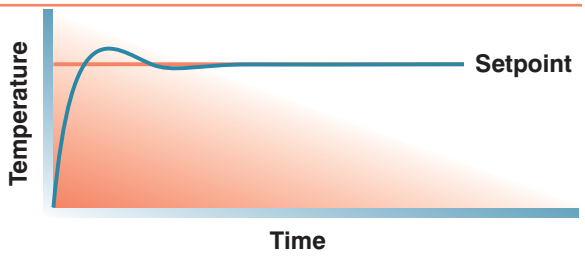
A proportional controller reduces power as the heater approaches setpoint. This reduces oscillation for steadier control. Note that most controllers are “time proportioning,” where they scale power by rapid on/off switching. Short cycle times usually require a solid state relay for power switching.

Simple proportional controllers can experience “droop” where the temperature settles at a point near the setpoint but not exactly on it.



PID controllers

Proportional/Integral/Derivative controllers solve the problem of droop and otherwise improve control accuracy through advanced digital algorithms. They have various tuning parameters for best control, but typically have some preset modes suitable for most situations.



Controller model	Control method	Supply power	Sensor input	Controlled output
CT198	On/off	4.75–60 VDC	None (uses high-TCR heater element as sensor)	Same as supply power
CT325	On/off	4.75–60 VDC	PD: 100 Ω platinum RTD PF: 1000 Ω platinum RTD TF: 50 kΩ thermistor	Same as supply power
CT15	PID, proportional, on/off (selectable)	100–240 VAC	PD: 100 Ω platinum RTD PF: 1000 Ω platinum RTD J, K, or T thermocouple	Internal SSR rated to 3.5 A at 250 VAC External SSR optional
CT16A	Fuzzy Logic, PID, proportional, on/off (selectable)	100–240 VAC (12–24 VDC optional)	PD: 100 Ω platinum RTD PF: 1000 Ω platinum RTD NB: 100 Ω nickel RTD Most thermocouple types	Internal SSR rated to 2.0 A at 240 VAC External SSR optional

Custom controllers

In high volume applications, a specially designed controller often gives the best performance and price. Controllers can be stand alone devices or embedded in other electronics.

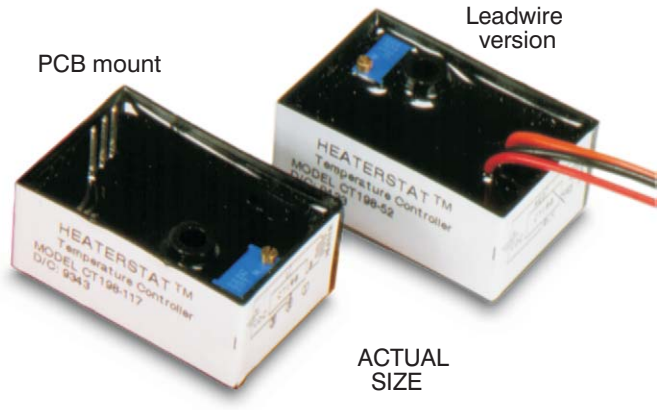
How Thermofoil heaters improve control accuracy

- Intimate thermal contact means less lag time.
- Profiling and multiple elements give more options for directing the heat where needed.
- Flexible Thermal-Ribbon™ sensors and combination heater/sensors ensure tight coupling between the heater, heated object, and control sensor.
- High watt density produces nimble response.

Heaterstat™ Sensorless DC Controller

- Uses heater as temperature sensor — no separate sensor or thermostat required
- Solid-state on/off control with adjustable setpoint
- Low power consumption — ideal for battery operated and vehicular devices
- Small PCB mount package
- Low cost
- For use with Minco Thermofoil™ and Thermal-Clear™ heaters

This unique DC controller does not require a separate sensor for temperature input. Instead, the Heaterstat takes temperature readings from its heater, a special model with a high temperature coefficient. You get accurate, efficient electronic control at prices comparable to thermostats.



Operation

The diagram below shows how the Heaterstat works. It periodically powers the heater just long enough to check resistance. If heater temperature is *above* setpoint (left side of graph), power shuts off within 0.010 seconds.

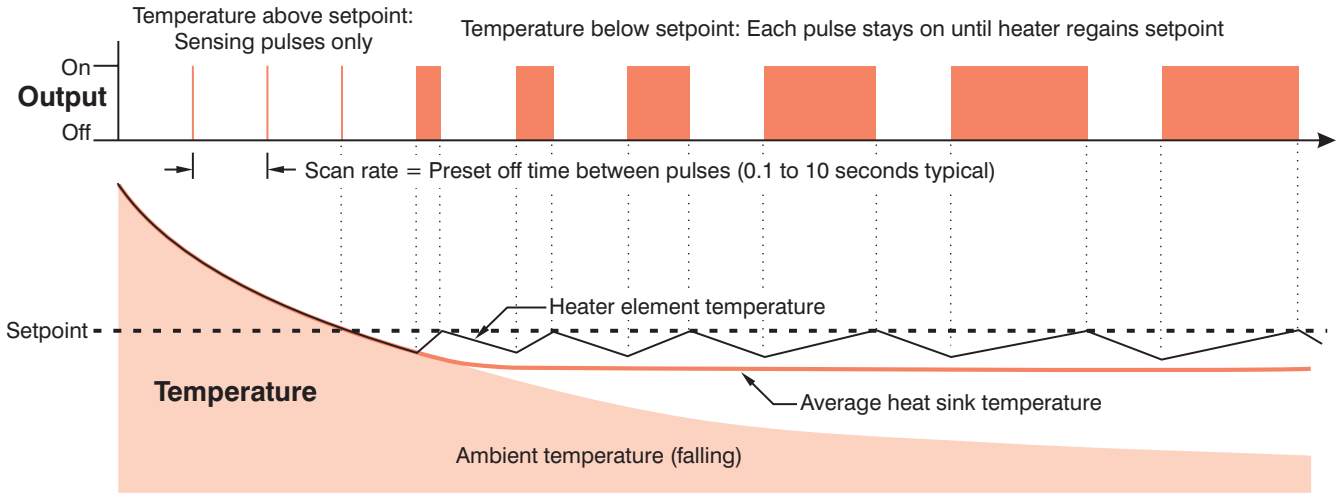
If heater temperature is *below* setpoint, the Heaterstat leaves power on and continually reads resistance until element temperature reaches setpoint. It then shuts off and waits until time for the next pulse.

Scan rate, the off-time between pulses, is factory set from 0.1 to 10 seconds (1 second is standard). Faster scans provide tighter control while slower scans conserve power during idle times (a 0.010 second pulse every 10 seconds takes only 0.1% of full-on power).

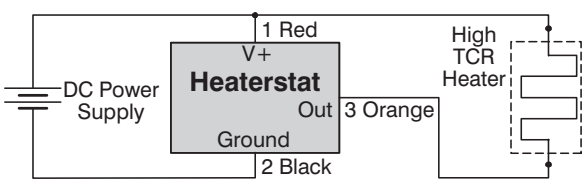
Applications

The Heaterstat's unique design makes it the ideal companion to Minco heaters for precise thermal control. Here are some ideas:

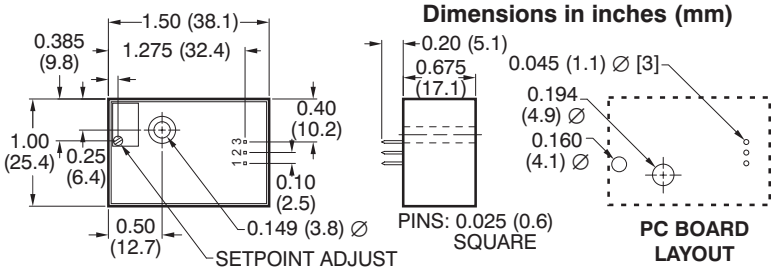
- Improve performance of LCD's or other electronics in cold storage areas.
- Replace bulky, slow-responding thermostats.
- Regulate temperature of miniature or low-mass heaters in situations where a temperature sensor is impractical or will impede response.
- Protect portable medical devices from effects of cold.
- Maintain temperature of critical circuit board components, such as crystals.
- Independently control individual sections of large area heaters, using one Heaterstat per zone.



Wiring



Dimensions in inches (mm)



K

Heaterstat™ Sensorless DC Controller

Specifications

Setpoint range: Nominal resistance ±20% min. Specify heater resistance to produce the necessary heat output in watts, given available voltage.

Connections: Three pins on 0.1" centers or AWG 22 wires.

Power supply voltage: 4.75 to 10 VDC or 7.5 to 60 VDC, depending on model. Ripple up to 10% has negligible effect; simple unregulated DC supplies are adequate for most applications.

Nominal heater current: 0.05 to 4 amps, depending on model. See ranges below. Higher current possible with special models.

Nominal heater current	Minimum current for proper sensing	Maximum current (1 minute)	Output ON resistance in series with heater (pin 3 to 2)	Minimum output OFF resistance
CT198				
0.05 to 0.2 A	0.012 A	0.5 A	2.3	50K
0.21 to 0.5	0.050	1.0	0.8	50K
0.51 to 1.5	0.125	2.0	0.5	50K
1.51 to 3.0	0.350	4.0	0.3	50K
CT248				
2.50 to 4.0	1.0	5.0	0.25	50K

Scan rate (temperature above setpoint): 1 second standard. 0.1 seconds to 10 seconds optional.

Scan pulse width: 10 milliseconds.

LED indicator: Indicates heater power on. Optional on leadwire versions.

Calibration accuracy: ±0.2% std*. Note that standard resistance tolerance on heaters is ±10%.

Hysteresis: 0.05%*.

Setpoint drift due to:
Self-heating: ±0.2%* (±0.4% for 1.5 to 4 A range).
Ambient temperature: ±0.02%/°C* (±0.06%/°C for 1.5 to 4 A range).
Supply voltage change: ±0.03%/volt*.

Supply voltage ripple effects: Negligible, assuming 50/60 Hz, 10% max. ripple.

Controller supply current:
Output ON: 3 mA max.
Output OFF: 2 mA max; 1 mA typical at 10 VDC.

Ambient temperature:
Operating: -40 to 70 C (-40 to 158 F).
Storage: -55 to 85 C (-67 to 185 F).

Relative humidity: 90% max.

Physical: Epoxy sealed for moisture resistance. Will withstand wave soldering and water/detergent wash; contact Minco before cleaning with other chemicals.

Weight: 1 ounce (25 g).

* To convert resistance deviations to temperature:

$$\Delta T = \%\,deviation\left(T + \frac{1}{TCR}\right)$$

Where:
TCR = Temperature coefficient of resistance (/ /°C)
T = Setpoint temperature (°C)
ΔT = Temperature deviation (°C)

For example, assume a Heaterstat setpoint of 50°C, and heater TCR of 0.00536 Ω/Ω/°C (nickel foil). Calibration accuracy is ±0.2% of nominal resistance, which translates to temperature as:

$$\Delta T = \pm 0.2\%\left(50°C + \frac{1}{0.00536}\right) = \pm 0.47°C$$

Mounting: Mounting hole for #6 screw through, or #8 thread forming screw.

Heater: Wire-wound or etched-foil heater with high temperature coefficient of resistance (TCR).

Heater element	TCR (Ω/Ω/°C)
Copper foil or wire (Cu)	0.00427
Nickel foil (Ni)	0.00536
Nickel wire (Ni)	0.00672
Nickel-iron foil or wire (NiFe)	0.00519

Design considerations

Minco will be pleased to provide assistance with any of the design steps below. Do not hesitate to call on us.

Heater: A heater intended for use with a Heaterstat must have a temperature-sensitive element. All Thermal-Clear heaters meet this requirement, as do foil heaters with resistances from the last two columns of the model table.

Installation: The Heaterstat is small enough to mount directly to printed circuit boards and will withstand both wave soldering and water wash. Secure it to the board through the mounting hole. If you intend to adjust the setpoint after installation you will need a hole in the board opposite the setpoint trimmer. The leadwire version does not require a circuit board.

System accuracy: The Heaterstat, by its design, controls the temperature of the heater instead of the heat sink. The heater's element always runs hotter than the surface to which it is mounted. For best accuracy under changing ambient conditions your design should attempt to either reduce this gradient or stabilize it to a predictable level. Some suggestions are:

- Use the proper amount of heat. Try to size the heater to run at least 50% of the time in normal operation and at no more than 5 watts per square inch.
- Maximize contact between the heater and heat sink.
- Stabilize the system. Maintain a fairly constant supply voltage and insulate the assembly from changes in ambient temperature.
- Specify standard 1-second scan rate or faster.
- Consider the CT325 miniature DC controller

Setpoint calibration: A Heaterstat is factory calibrated to the nominal resistance of the heater at the setpoint temperature. Standard heaters, however, have a resistance tolerance of ±10%, or >25°C. For best results we recommend you recalibrate your Heaterstat after installation. Simply adjust the setpoint until temperature settles at the desired value as verified by a digital thermometer such as the Minco TI142.

Where recalibration is impractical you can improve accuracy by ordering Heaterstats and heaters in matched sets. Minco can compensate for heater tolerance by calibrating the controller to the actual measured resistance of its mating heater rather than to the nominal resistance. The heater and controller will be marked with matching serial numbers. When ordering a Heaterstat for a matched set, specify model CT698 instead of CT198.

Heaterstat™ Sensorless DC Controller

Standard models

Specifications:
One second scan rate.
6" (150 mm) leadwires.
LED power indicator.
Calibration: Setpoint factory-calibrated to specified resistance.

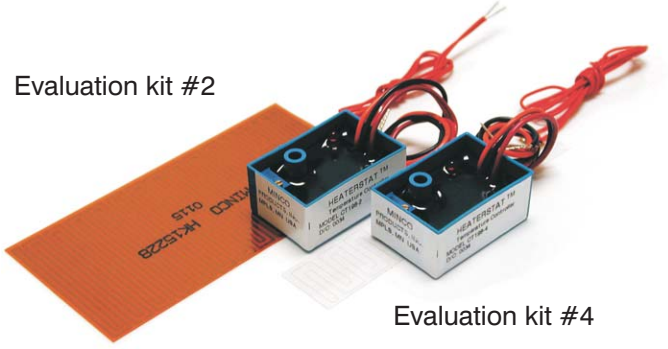
Model Number	Setpoint range (Ω)		Supply voltage (VDC)	
	Minimum	Maximum	Minimum	Maximum
CT198-1000	4.50	6.75	5	9.5
CT198-1001	5.63	8.44	8	16
CT198-1002	7.03	10.55	8	21
CT198-1003	8.79	13.18	8	26
CT198-1004	10.99	16.48	8	33
CT198-1005	13.73	20.60	8	41
CT198-1006	17.17	25.75	8	50
CT198-1007	21.46	32.19	8	50
CT198-1008	26.82	40.23	8	50
CT198-1009	33.53	50.29	8	50
CT198-1010	41.91	62.86	8	50
CT198-1011	52.39	78.58	8	50
CT198-1012	65.48	98.23	8	50
CT198-1013	81.85	122.78	8	50
CT198-1014	102.32	153.48	8	50
CT198-1015	127.90	191.85	8	50
CT198-1016	159.87	239.81	8	50
CT198-1017	199.84	299.76	8	50
CT198-1018	249.80	374.70	8	50
CT198-1019	312.25	468.38	8	50
CT198-1020	390.31	585.47	8	50
CT198-1021	487.89	731.84	9	50
CT198-1022	609.86	914.80	11	50

How to order standard models

CT198-1019	**Model number** CT198 = Heaterstat (nominal setpoint) CT698 = Heaterstat matched to heater
R	**Setpoint calibration code** R = Nominal heater resistance (CT198) T = Heaterstat/heater matched set (CT698)
365	**Initial calibration setpoint** Setpoint calibration code = R: Nominal heater resistance at set point temperature (in ohms).* Must be within allowable range for specified model. Setpoint calibration code = T: Temperature setpoint. Specify temperature and scale (°C or °F) Ex: 120F represents 120°F
L	**Leads** L = Leadwires (standard) P = Pins (LED not available)
1	**Scan rate** 0.1 to 10 seconds (1 second standard)
CT198-1019R365L1 ← Sample part number	

Evaluation kits

Test the concept and performance of Heaterstats before investing in a custom design. Each includes a controller and matching heater. You just supply electric power.



Evaluation kit #2

Evaluation kit #4

Evaluation kit #4

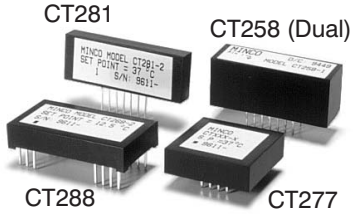
Contains H15227 Thermal-Clear transparent heater and CT198-4. Order CT198-K4.
Setpoint: Adjustable from -40 to 95°C.
Voltage: 4.75 to 10 VDC. 5 VDC nominal.
Watts: 1.7 W at 5 VDC and 50°C.
Heater dimensions: 0.75" × 4" (19 × 102 mm).
Scan rate: 10 seconds; LED indicator.

Evaluation kit #2

Contains HK15228 Kapton-insulated Thermofoil heater and CT198-2. Order CT198-K2.
Setpoint: Adjustable from 0 to 120°C.
Voltage: 7.5 to 38 VDC. 24 VDC nominal.
Watts: 40 W at 24 VDC and 80 C.
Heater dimensions: 2" × 4" (51 × 102 mm).
Scan rate: 1 second; LED indicator.

Miniature Heaterstat controllers

Minco can furnish SIP or DIP packages using remote digital setpoint adjustment.



* To determine heater resistance at temperature *T*:

$$R_T = \frac{R_{Ref} \times [(T \times TCR) + 1]}{(T_{Ref} \times TCR) + 1}$$

For example, model H6708R86.6 is 86.6 Ω (R_{Ref} = 86.6) at 0°C (T_{Ref} = 0) with a nickel wire element (TCR = 0.00672). At a control temperature of 60°C (T = 60), heater resistance (R_T) is:

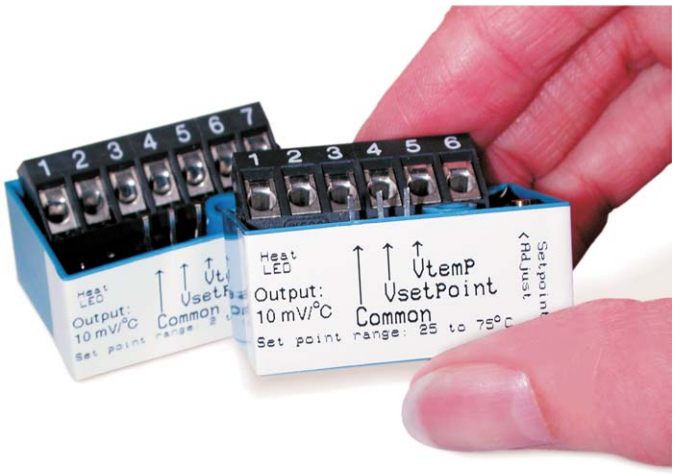
$$\frac{86.6 \times [(60 \times 0.00672) + 1]}{(0 \times 0.00672) + 1} = 122\,\Omega$$

The desired Heaterstat model with leadwires is:
CT198-1014R122L1
Resistance versus temperature tables are available at:
www.minco.com/sensorcalc

K

CT325 Miniature DC Controller

- Simple setup with voltage output pins for process and setpoint temperatures
- Tight control with ±0.5°C (1°F) deadband!
- Miniature package 1×1×1.5" (25×25×37 mm)
- Solid state on/off control with adjustable setpoint
- Uses standard 100 Ω or 1000 Ω platinum RTD or 50 kΩ thermistor sensor input
- Single DC power source provides power to the controller and heater up to 240 watts
- 3-wire RTD connection cancels lead resistance



The CT325 Miniature DC Temperature Controller is designed for use with Minco Thermofoil™ heaters and RTD or thermistor sensors. It offers inexpensive on/off temperature control of your process or equipment with accuracy many times better than bimetal thermostats.

Simply adjust the setpoint by connecting a standard voltmeter to the setpoint terminal and monitoring the 0.010 volt/°C output while adjusting the trim potentiometer. A second test point shows the actual temperature.

Operating from your 4.75 to 60 volt DC power supply, the controller can switch up to 4 amps power to the heater. A bright LED indicates when power is applied to the heater.

The entire unit is epoxy filled for moisture resistance, with a through-hole for a mounting bolt. A terminal block provides the power input, sensor input and heater output connections.

Specifications

Input: 100 Ω or 1000 Ω platinum RTD, 0.00385 Ω/Ω/°C, 2 or 3-leads, or 50 kΩ NTC thermistor, 2-lead.

Setpoint range:
2 to 100°C (36 to 212°F) for platinum RTD input.
2 to 200°C (36 to 392°F) for platinum RTD input.
25 to 75°C (77 to 167°F) for thermistor input.
Consult factory for other ranges.

Setpoint stability: 0.02% of span/°C.

Vtemp signal: 0.010 V/°C over specified range.

	Platinum RTD sensor		Thermistor sensor	
	2°C	0.02 V	25°C	0.25 V
	50°C	0.50 V	50°C	0.50 V
	100°C	1.00 V	75°C	0.75 V
	200°C	2.00 V		
Accuracy:	±1% of full scale		±2% of full scale	
Linearity:	0.1% of span		2% of span	

Deadband: 0.5°C.

Input power: 4.75 to 60 VDC.

Output: Open drain, 4 amps max. DC.

Leadwire compensation (3-wire RTD):
±0.06°C/Ω for 100 Ω or 1000 Ω platinum up to 25 Ω per leg.

Fault protection: Heater disabled on RTD short or thermistor open. No heater protection; external fuse recommended.

Operating ambient temperature range:
-40 to 70°C (-40 to 158°F).

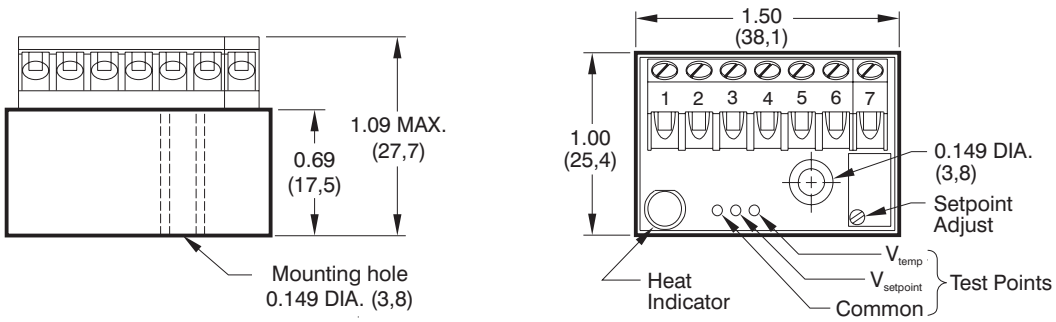
Relative humidity: 0 to 95% non-condensing.

Physical: Polycarbonate case, epoxy sealed. 1 oz. (28g).

Connections: Terminal block for wires AWG 22 to AWG 14.

Mounting: Mounting hole for #6 screw through or #8 thread forming screw.

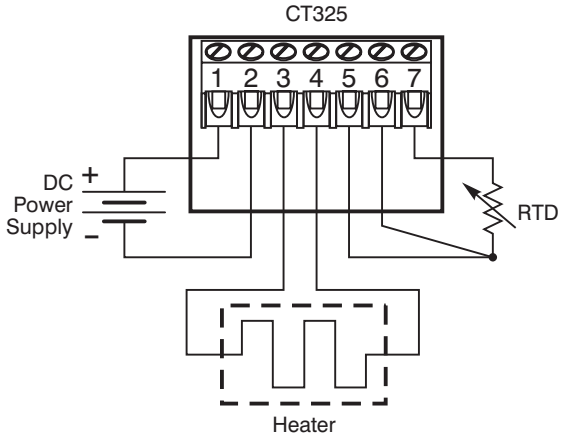
Dimensions

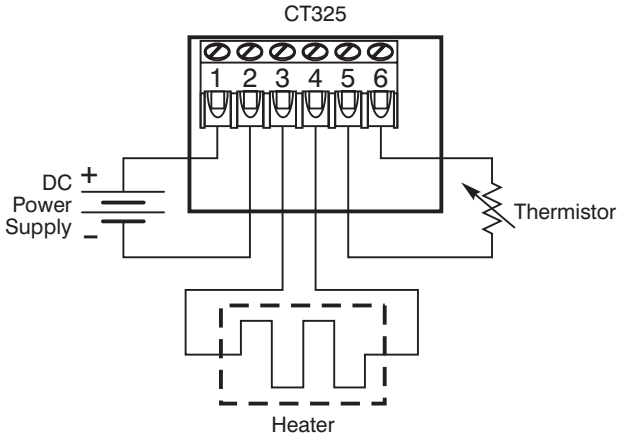


Dimensions are in inches (mm)

CT325 Miniature DC Controller

Wiring diagrams





How to order

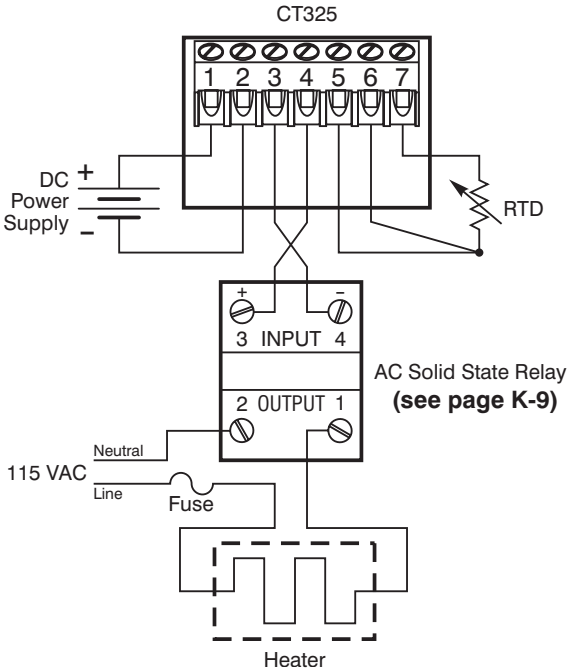
CT325	**Model number: CT325**
PD	**Sensor type:** PD = 100 Ω platinum RTD (2 to 100°C) PF = 1000 Ω platinum RTD (2 to 100°C) TF = 50 kΩ thermistor (25 to 75°C)
1	**Power supply:** 1 = 4.75 to 10 VDC 2 = 7.5 to 60 VDC
B	**Temperature range:** A = 25 to 75°C (TF sensor type only) B = 2 to 100°C (PD or PF sensor type only) C = 2 to 200°C (PD or PF sensor type only)
5	**Deadband:** 5 = 0.5°C
CT325PD1B5 ← Sample part number	

Custom design options

Minco can customize the design of the CT325 for special applications. Specific temperature ranges, other sensor options, and special packaging are possible for volume OEM applications. Proportional controllers are available in a slightly larger package.

AC powered heaters

The CT325 can provide the control signal to an external solid state relay (page K-9) to switch AC power. Use 15 VDC as the control voltage.



K

CT15 Temperature Controller

Advanced microprocessor control at an analog price. This single display controller can also serve as a simple indicator or indicating alarm.

User programmable functions (standard)

Control modes:

- PID: preset, programmable, Self-Tune
- On/off
- Manual (open loop)

Other features:

- Ramp to setpoint
- Anti-reset windup
- Digital sensor input correction
- Digital input filter adjustable for noisy or jittery processes
- 4 security levels
- Setpoint limits
- Non-volatile memory needs no battery backup
- Input fault timer

Factory options (specified in part number)

Alarms:

- Two independent setpoints: High, low, absolute, or deviation
- Single mechanical relay
- Manual or automatic reset, selectable inhibit

Control/monitor inputs:

RTD's are recommended for best accuracy.

- RTD: 100 Ω platinum, 2 or 3-wire, 0.00385 TCR (PD or PE)
- Thermocouple: J (factory default), K, T (selectable)

Control outputs:

- Solid state relay (SSR)
- Mechanical relay
- Switched voltage output to control external SSR

A solid state relay (SSR) is recommended for long life with proportional control. CT15 can be ordered with an internal SSR. For DC power or higher current ratings order external SSR's to be controlled by the switched voltage output of the controller (output option 2).

Specifications

Display: One 4 digit, 7 segment, 0.3" high red LED, °C or °F.

Control action: Selectable for Reverse (normally heating) or Direct (normally cooling).

Ramp: One ramp time adjustable from 0 to 100 hours.

Accuracy: ±0.25% of span, ±1° or 1 count.

Resolution: 1° or 0.1°, selectable.

Temperature stability: 100 ppm/°C typical, 200 ppm/°C max.

Isolation: Relay and SSR outputs are isolated. Current, voltage, and switched voltage outputs must not share common grounds with the input.

Supply voltage: 100 to 240 VAC nom., +10/-15%, 50 to 400 Hz, single phase; 132 to 240 VDC, nom., +10/-20%. 5 VA maximum.

Note: Do not confuse controller power with heater power. The controller does not pass power to the heater, but only acts as a switch. As an example, the controller could be operating on 115 VAC but controlling 12 VDC to the heater.

Temperature range:
Operating: -10 to 55°C (14 to 131°F).

Humidity range:
0 to 90% RH up to 40°C (104°F) non-condensing.
10 to 50% RH at 55°C (131°F) non-condensing.

Memory backup: Non-volatile memory (no batteries required).

Control output ratings:

- AC SSR: 3.5 A @ 250 VAC @ 25°C typical; derates to 1.25 A @ 55°C. Minimum 48 VAC and 100 mA minimum load required.
- Relay, Form A contact (SPST):
  3 A @ 250 VAC resistive.
  1.5 A @ 250 VAC inductive.
  Pilot duty: 250 VA, 2 A @ 125 VAC or 1 A @ 250 VAC.
- Switched voltage (non-isolated): 5 VDC @ 25 mA.

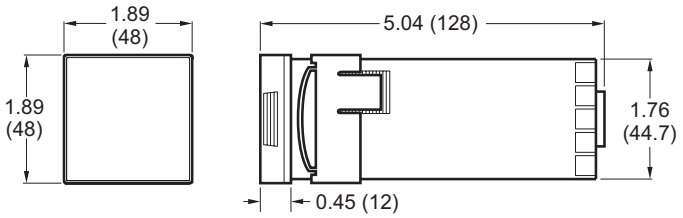
Alarm relay rating:
3 A @ 250 VAC resistive.
1.5 A @ 250 VAC inductive.
Pilot duty: 250 VA, 2 A @ 125 VAC or 1 A @ 250 VAC.

Weight: 227 g (8 oz.).

Agency approvals: UL & CSA.

Front panel rating: IP66; meets UL Type 4X.

Dimensions



PANEL CUTOUT: 1.775" × 1.775" (45 mm × 45 mm)
MAXIMUM PANEL THICKNESS: 0.25" (6.35 mm)
DIMENSIONS IN INCHES (mm)

How to order CT15

CT15	**Model number: CT15**
1	**Alarm relay:** 0 = No 1 = Yes
2	**Input:** 1 = J, K, or T thermocouple 2 = 100 Ω platinum RTD, type PD or PE
1	**Output:** 1 = Built-in AC SSR 2 = Switched voltage (5 VDC) for external SSR 3 = Built-in mechanical relay
CT15121 ← Sample part number	

See page K-9 for high power solid state relays (SSR) and other accessories.

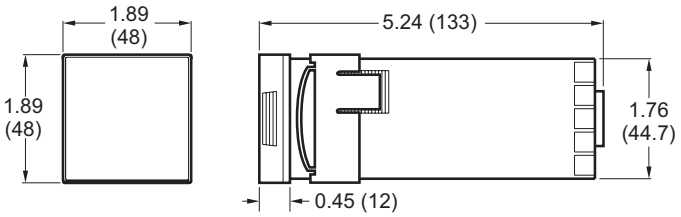
CT16A Temperature Controller

This economical controller packs sophisticated PID control into a compact 1/16 DIN enclosure. A wide range of control modes, sensor input types, and relay or SSR outputs give versatile control of Thermofoil™ heaters and lets you easily connect to other electronics.

Features

- Dual displays continuously show the set point and the actual temperature reading in resolutions of 1°, 0.1°, or engineering units
- Universal Input fits any measurement: Select from 10 thermocouple types, 4 RTD types, voltage, and current signals
- Isolated Outputs for safe, easy wiring
- Loop Break protection handles sensor or heater failure
- Peak / Valley records the maximum and minimum temperatures
- Front panel is waterproof and corrosion-resistant, making it ideal for sanitary applications. Illuminated keypad for easy operation
- Limit the temperatures which the operator can set via four password-protected Security Levels
- Controller can Self-Tune for best PID control
- Control modes: Self-Tune, pre-set or adjustable PID values, simple On/Off control, and open loop
- Fuzzy Logic provides better response time and reduces overshoot in processes with unpredictable inputs
- Alarms at one or two temperatures
- Alarm Relay option is programmable for high, low, absolute, or deviation, can be reset manually or automatically, and it controls a single electromechanical relay with voltage-free contacts
- Ramp & Soak option handles complex heating profiles of 16 segments with front-panel activation and a selectable time base (CT16A3)
- Auto / Manual option easily switches to manual control for set up or experiments (CT16A3)
- RS-232 or RS-485 Serial Communications access the temperature readings and all control parameters (optional)
- Retransmit either the sensed temperature or the set point as a voltage or current signal to a computer or recorder (optional)
- Vary the Set Point using a potentiometer, a voltage, or a current signal (optional)
- 4-Stage Set Point to quickly switch from one temperature to the next (optional)

Dimensions



PANEL CUTOUT: 1.775" × 1.775" (45 mm × 45 mm)
MAXIMUM PANEL THICKNESS: 0.25" (6.35 mm)
DIMENSIONS IN INCHES (mm)

Specifications

Selectable inputs:

- RTD: 2 or 3-wire, Minco types PD or PE (100 Ω IEC platinum), PA (100 Ω NIST platinum), PF (1000 Ω IEC platinum), or NA (120 Ω Nickel)
- Thermocouple: Type J (factory default), K, T, L, E, R, S, B, C, or N
- DC current: 0-20 mA or 4-20 mA (use with Temptran™ transmitters)
- DC voltage: 0-10 or 2-10 VDC, -10 to 10 mVDC, scalable

Input impedance:

- Voltage: 5000 Ω
- Thermocouple: 3 megohms minimum
- Current: 10 Ω
- RTD current: 200 μA

Sensor break or short protection: Selectable output: disabled, average output before fault, or preprogrammed output. Adjustable delay: 0.0 to 540.0 minutes.

Loop break protection: Error message is initiated and output is turned off in case of shorted sensor or open heater circuit. Break time adjustable from OFF to 9999 seconds.

Cycle rate: 1 to 80 seconds.

Setpoint range: Selectable from -212 to 2320°C (-350 to 4208°F), input dependent.

Displays: Two 4 digit, 7 segment 0.3" high LED's. Process Value red, Setpoint Value green. °C or °F.

Control action: Reverse (usually heating) or Direct (usually cooling), selectable.

Ramp/soak: (CT16A3 only) 16 separate ramp and soak times are adjustable in minutes or seconds from 0 to 9999. When the program has ended, you may choose to repeat, hold, revert to local setpoint, or turn the outputs off.

Accuracy: ±0.25% of span ±1 count.

Resolution: 1° or 0.1°, selectable.

Line voltage stability: ±0.05% over supply voltage range.

Temperature stability: 4 μV/°C (2.3 μV/°F) typical, 8 μV/°C (4.5 μV/°F) max. (100 ppm/°C typical, 200 ppm/°C max.).

Isolation:
Relay and SSR: 1500 VAC to all other inputs and outputs.
SP1 and SP2 current and voltage: 500 VAC to all other inputs and outputs, but not isolated from each other.
Process output (options 934, 936): 500 VAC to all other inputs and outputs.

Supply voltage: 100 to 240 VAC nom., +10/-15%, 50 to 400 Hz, single phase; 132 to 240 VDC, nom., +10/-20%. 5 VA maximum. 12 & 24 volt AC/DC optional.

Note: Do not confuse controller power with heater power. The controller does not supply power to the heater, but only acts as a switch. For example, the controller could be powered by 115 VAC, but controlling 12 VDC to the heater.

Operating temperature range: -10 to 55°C (14 to 131°F).

Memory backup: Non-volatile memory (no batteries required).

K

CT16A Temperature Controller

Control output ratings:

- AC SSR (SPST): 2.0 A combined outputs A & B @ 240 VAC @ 25°C (77°F); derates to 1.0 A @ 55°C (130°F). Minimum 48 VAC and 100 mA minimum load required. An SSR is recommended for longer life than a mechanical relay.
- Mechanical relay, SPST Form A (Normally Open) or Form B (Normally Closed):
  3 A resistive, 1.5 A inductive @ 240 VAC;
  pilot duty: 240 VA; 2 A @ 120 VAC or 1 A @ 240 VAC.
- Switched voltage (isolated): 15 VDC @ 20 mA.
- Proportional current (isolated): 0 to 20 mA, 600 max.
- DC SSR: 1.75 A @ 32 VDC max.
- Alarm relay, SPST Form A (Normally Open):
  3 A @ 240 VAC resistive; 1/10 HP @ 120 VAC.

Weight: 227 g (8 oz.).

Agency approvals: UL & CE.

Front panel rating: Type 4X (IP66).

Additional options for CT16A (board level)

924: Analog remote setpoint (0 to 10 VDC). Vary the setpoint using a voltage signal.

926: Analog remote setpoint (4 to 20 mADC). Vary the setpoint using a current signal.

928: Analog remote setpoint (0 to 10,000 ohms). Vary the setpoint using a potentiometer.

934: Analog retransmission of Process Variable or Set Variable, 4 to 20 mADC. For use as recorder, transmitter or computer A/D input. Linearized 4 to 20 mA DC signal follows the Process or Set variable. Scalable.

936: Analog retransmission of Process Variable or Set Variable, 0 to 10 VDC. Similar to option 934, but output signal is linearized 0 to 10 VDC.

948: 4-Stage setpoint. Four preset setpoints may be selected by external contacts. Each set point has its own set of PID values giving controller 4 distinct "recipes" for different process situations.

992: RS-485 Computer communication link. Allows remote computer to read and write all control parameters.

993: RS-232 Computer communication link. Allows remote computer to read and write all control parameters.

9502: 12 to 24 VDC / VAC power option. Controller is powered by low voltage instead of line voltage.

Note: Only option 9502 can be combined with another board level option.

How to order CT16A

CT16A	**Model number: CT16A**
2	**Feature set:** 2 = Standard 3 = Enhanced (ramp & soak, Auto/manual)
1	**Alarm relay:** 0 = No 1 = Yes
1	**Output A:** 1 = Built-in AC SSR 2 = Pulsed voltage (15 VDC) for external SSR 3 = Mechanical relay, SPST (normally open) 4 = Mechanical relay, SPST (normally closed) 5 = Current 8 = DC SSR
0	**Output B:** 0 = None 1 = Built-in AC SSR 2 = Pulsed voltage (15 VDC) for external SSR 3 = Mechanical relay, SPST (normally open) 4 = Mechanical relay, SPST (normally closed) 5 = Current 8 = DC SSR
-992	**Options (leave blank for none)**
CT16A2110-992 ← Sample part number	

Accessories

AC744: 1-10 A, 24 to 280 VAC SSR

AC745: 1-25 A, 24 to 280 VAC SSR

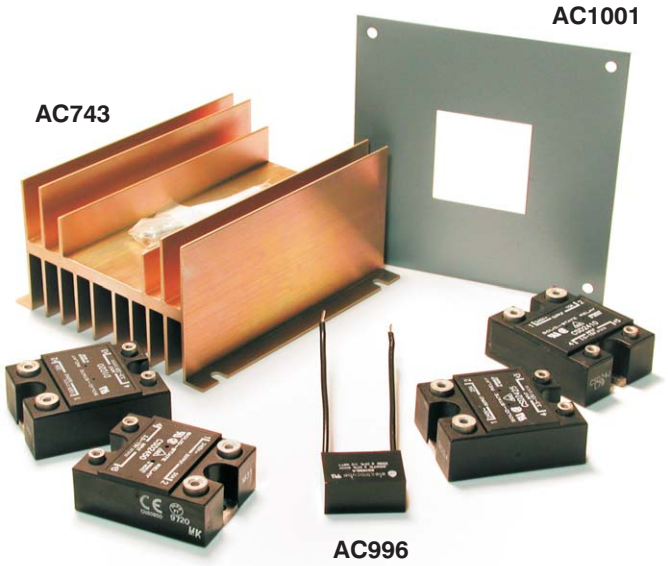
AC746: 1-50 A, 24 to 280 VAC SSR

AC1009: 1-20 A, 0 to 100 **VDC** SSR

AC743: SSR heat sink for high current or ambient temperature

AC996 R/C Snubber: Highly recommended to prolong relay contact life, if using the mechanical relay or SSR output to drive a relay or solenoid. Also, for the CT16A AC SSR output, make sure that the coil HOLDING current is greater than 100 mA and voltage is minimum 48 VDC.

AC1001: Steel 1/16 to 1/4 DIN adapter plate. 127 × 127 mm gray steel with 45 × 45 mm centered hole.

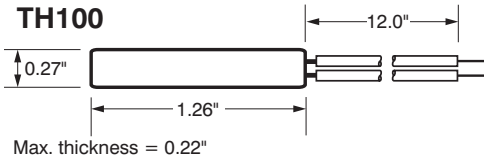


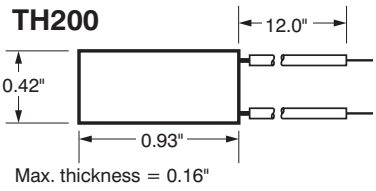
Accessories

Thermostats

Thermostats provide basic heater control at little cost. You can also use them as thermal cutoffs in conjunction with other control systems. All thermostats come with a 1.5" (38.1 mm) long, silicone rubber coated sleeve for electrical insulation (case is electrically live), and mounting adhesive.

These thermostats are ordered separately. For information on ordering heaters with factory installed thermostats contact Minco's Sales Department.





Specifications

Stock models:
TH100 creep action, 120 VAC maximum.
TH200 snap action, 240 VAC maximum.
Setpoint tolerance: ±5°C (±9°F).
Open/close differential: 5 to 10°C, typical.
Maximum current:
Model TH100: 6 amps at 120 VAC;
8 amps at 12 VDC;
4 amps at 24 VDC.
Model TH200: 4 amps at 240 VAC.
Life rating: 100,000 cycles.
Approvals: UL, CSA.

How to order

TH100	**Model number: TH100 (creep action)**
T40	**Setpoint options:** 5°C, 20°C, 40°C, 60°C, 80°C, 100°C, 150°C, 200°C
TH100T40 ← Sample part number	

TH200	**Model number: TH200 (snap action)**
T80	**Setpoint options:** 60°C, 80°C, 100°C, 150°C
TH200T80 ← Sample part number	

Pre-cut insulators

Trimmed to the same size as heaters, these pads provide thermal insulation to minimize heat loss. You can also place them between clamping plates and heaters for uniform pressure. Optional pressure sensitive adhesive (PSA) backing permits easy installation. It will not bond permanently and may be removed later without damaging the heater.

Material	Thickness	Temperature limit		R factor
		with PSA	no PSA	Uncompressed
Neoprene	0.125" (3.18 mm)	107°C	107°C	23.1 °C × m/W
Silicone rubber foam	0.125" (3.18 mm)	204°C	204°C	9.2 °C × m/W
Mica	0.010" (0.25 mm)	N/A	600°C	2.5 °C × m/W
Ceramic paper*	0.125" (3.18 mm)	N/A	600°C	11.5 °C × m/W

** Every mica heater comes with two sheets of ceramic paper free of charge. Order extra sheets here.*

How to order

IN	**IN = Insulating pad**
5334	**Matching heater model number**
N1	**Material:** N1 = Neoprene, R1 = Silicone rubber, M1 = Mica, C1 = Ceramic paper
B	**Pressure sensitive adhesive:** A = No PSA, B = With PSA backing (N/A with ceramic or mica)
IN5334N1B ← Sample part number	

You can estimate heat loss with the following formula:

$$\text{Heat loss}\,(W) = \frac{A\,(T_f - T_a)}{1000\,R\,L}$$

where:

W = Watts of heat lost through insulation
A = Heater area in square mm
T_f = Heat sink temperature in °C
T_a = Ambient temperature in °C
R = R factor in °C × m/W
L = Thickness of insulation in mm

K

Temperature Sensors

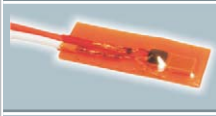
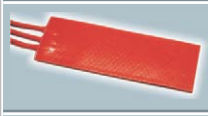
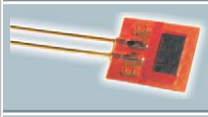
Minco is a leading manufacturer of temperature sensors. We currently stock more than 1,800 different models of sensor for immediate shipment. We also offer complete custom design capabilities. No one else can match our ability to tailor the sensor to your thermal system with the ideal combination of price, thermal responsiveness, stability, accuracy, and ease of installation.

Below is a selection of popular sensors for use with our heating elements and controllers. Request Bulletin TS-102 for Minco's full range of sensors and accessories, or visit www.minco.com/support for technical and application information.

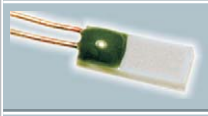
Note: Except where noted, all RTD's have 100±0.12% ohm platinum element, TCR = 0.00385 Ω/Ω/°C (Pt100 per IEC 751 Class B).

Thermal-Ribbon RTD's and thermocouples

Flexible Thermal-Ribbons mount easily to surfaces, alongside heaters or on top of them. All are available with self-stick adhesive.

	Model	Material	Dimensions	Temperature
	**S665PDY40A*** (100 Ω) **S665PFY40A*** (1000 Ω) **TS665TFY40A*** (50 kΩ at 25°C NTC thermistor)	Kapton substrate with elastomer cover, 2 or 3 PTFE leads	0.2" × 0.5" (5 × 12 mm) Lead length: 40" (1000 mm)	-50 to 155°C -58 to 311°F (except TS665 to 125°C/257°F)
	**S667PDY40A*** (100 Ω) **S667PFY40A*** (1000 Ω) (Available with 2 leads only) *Immersible*	Silicone rubber substrate with elastomer cover, 2 silicone rubber leads	0.2" × 0.6" (5 × 16 mm) Lead length: 40" (1000 mm)	-50 to 155°C -58 to 311°F
	**S17624PDYT40A*** (100 Ω) **S17624PFYT40A*** (1000 Ω) **S17624PSYT40A*** (10,000 Ω) *Wide temperature range*	Kapton substrate and cover, 2 or 3 PTFE leads	0.2" × 0.6" (5 × 15 mm) Lead length: 40" (1000 mm)	-50 to 200°C -58 to 392°F
	**S467PDY36A*** (100 Ω) **S468PFY36A*** (1000 Ω) *Flexible model designed for moist environments*	Silicone rubber body, 2 or 3 rubber leads	S467: 0.5" × 1.5" (13 × 38 mm) S468: 0.5" × 3.0" (13 × 76 mm) Lead length: 36" (900 mm)	-62 to 200°C -80 to 392°F
	**S651PDY24A*** (100 Ω) *Miniature spot sensor with wire-wound RTD element*	Kapton with foil backing 2 or 3 PTFE leads	0.30" × 0.30" (7.6 × 7.6 mm) Lead length: 24" (600 mm)	-200 to 200°C -328 to 392°F
	**TC40JT36A*** (Type J) **TC40KT36A*** (Type K) **TC40TT36A*** (Type T) *Patch-style thermocouple*	Kapton with PTFE leads	0.75" × 0.75" (19 × 19 mm) Lead length: 36" (900 mm)	-200 to 200°C -328 to 392°F

RTD probes and elements

	Model	Material	Dimensions	Temperature
	**S614PDY12T*** (100 Ω) **S614PFY12T*** (1000 Ω) *General purpose encased sensor*	Stainless steel, 2 or 3 PTFE leads	0.188" ∅ × 2" long 4.8 ∅ × 51 mm long Lead length: 12" (300 mm)	-269 to 260°C -452 to 500°F
	**S853PD120Y36*** (100 Ω) *Tip sensitive probe*	Stainless steel with copper alloy tip, 2 or 3 PTFE leads	0.250" ∅ × 12" long 6.4 ∅ × 305 mm long (other lengths available) Lead length: 36" (900 mm)	-50 to 260°C -58 to 500°F
	**S245PD12** (100±0.12 Ω) **S245PD06** (100±0.06 Ω) **S247PF12** (1000±0.12 Ω) **S247PF06** (1000±0.06 Ω)	Ceramic/glass body, silver leads	S245: 0.08" × 0.09" (2.0 × 2.3 mm) S247: 0.08" × 0.20" (2.0 × 5.0 mm) Lead length: 0.6" (15 mm)	-70 to 400°C -94 to 752°F
	**S270PD12** (100±0.12 Ω) **S270PD06** (100±0.06 Ω) *High temperature, high precision element*	Ceramic body, platinum leads	0.047" ∅ × 0.59" long (1.28 ∅ × 15 mm long) Lead length: 0.4" (10 mm)	-200 to 850°C -328 to 1562°F

*** Part number codes:** Change the "Y" to "Z" for 3-lead model. For Thermal-Ribbon models only, change the "A" to "B" for acrylic PSA backing.

Frequently Asked Questions

What is the correct voltage for this heater?

Catalog heaters are specified by resistance, not voltage. This lets you operate them at different power levels. In selecting a heater model you should consider the size, resistance, operating temperature, total wattage and watt density (watts/in² or watts/cm²) for your application. The watt density rather than the total wattage determines the maximum applied voltage. Maximum watt density depends on the insulation type, mounting method and operating temperature. Graphs of these limits are included in each product section of this bulletin.

Minco standard and stock wire-wound silicone rubber heaters are listed with a recommended voltage based on typical ambient conditions and operation.

It is often possible to exceed the listed limits. Contact Minco for more information if your application requires more power than the standard limits allow.

Can a Thermofoil heater be used suspended in air?

Because the mass of a Thermofoil heater is very small they are generally not suitable for heating in air. Thermofoil heaters operate best when mounted to an object that can be heated by conduction rather than convection or radiation.

What are the dimensions of the lead attachment area for standard heaters?

The size of the non-heated lead attachment area varies based on the leadwire size, insulation material, lead exit location and heater dimensions. For a Kapton insulated heater these range from 0.25 × 0.30" to 0.5 × 0.8" for sizes AWG 30 to AWG 20. Contact Minco for detail information on any specific model, or describe your space limitations when specifying a custom design. Leads can be attached to a non-heated tab outside the body of the heater.

What is the dielectric strength of each different insulation material?

Minco catalog heaters with Kapton, silicone rubber or mica insulation are tested to verify 1000 VAC minimum dielectric breakdown voltage. We can provide custom models with thicker insulation to increase the dielectric rating, but this will reduce the maximum power and temperature ratings for the heater.

Another consideration is the amount of dielectric leakage current at operating voltage. Because an etched element covers 50% or more of the heater surface area, it can act as a capacitor when AC power is applied. The result is a leakage due to the capacitive effect. This is not a failure of the insulation but it may exceed the very low limits required for some medical and other applications. Minco can use special design techniques to minimize this leakage if your application requires meeting tight limits.

What is the temperature coefficient of resistance (TCR) for Minco heater elements?

Standard etched element heaters (except resistance options listed under the “NiFe” and “Ni” columns) use very low TCR foil materials. These can be considered to have a flat resistance to temperature relation for most applications.

Etched element heaters under the “NiFe” and “Ni” columns use either Nickel (0.00536 Ω/Ω/°C) or Nickel-Iron (0.00519 Ω/Ω/°C) foil. Thermal-Clear heaters use copper wire (0.00427 Ω/Ω/°C), nickel wire (0.00536 Ω/Ω/°C), or nickel-iron wire (0.00519 Ω/Ω/°C). These higher TCR models are not self-limiting but can be used with Minco's Heaterstat controller where the heater element performs the sensor function.

See www.minco.com/sensorcalc to calculate resistance versus temperature for these heaters.

Can I immerse these heaters in water or other liquids?

Generally the answer is no. The materials used in Kapton insulated Thermofoil heaters are waterproof, but edges are not sufficiently sealed for immersion. Custom designs can include increased border areas and sealed leadwire connections that make these heaters immersible in water. Silicone rubber insulated heaters require RTV cement or similar materials along all exposed edges and leadwire attachment areas for immersion in water.

If your application requires contact with other liquids you should contact Minco with details and we can provide a solution.

Can I trim a Thermofoil heater to the size and shape I need?

No, Thermofoil heaters cannot be cut or trimmed. The element conductor covers the entire area to maximize the heat spreading effect of the etched foil design. Cutting into this would create an electrically open circuit and expose the electrically live element.

When would I specify aluminum foil backing for a heater?

Foil helps to spread heat between heater strands, improves adhesion of PSA, and makes Kapton less springy for better conformance to curves. It increases the temperature and watt density ratings of Kapton heaters with PSA. For silicone rubber heaters, foil with acrylic PSA is less expensive than #12 PSA applied directly to the rubber.

Glossary

Anti-reset windup: Turns off integral action outside the proportional band to prevent false accumulation of error during warmup.

AP (All-Polyimide): Heaters made with polyimide covers (sold by DuPont under the tradename Kapton™) and polyimide adhesive.

AWG (American Wire Gauge): An indicator of wire diameter. The larger the number, the smaller the diameter.

Conduction: The transfer of thermal energy between adjacent bodies (usually solids) or parts of the same body.

Convection: The transfer of thermal energy in fluids and gases by mixing warmer areas with cooler ones. Convection currents can form, due to differences in density. Generally, warmer fluids (or gases) are less dense and tend to rise.

Creep action: A switching method, often used in thermostats, in which a temperature-sensitive bi-metallic element causes slow make and break of electrical connections. In contrast to snap action, this method results in tighter temperature control, but greater electrical noise and usually shorter life.

Cycle time: The duration of an on/off cycle with time proportioning. With cycle time of 10 seconds, for example, 80% power would give 8 seconds on, 2 seconds off. General rule: Shorter times give better control and less oscillation, but require solid state relay.

Deadband: The temperature difference between full "on" (when temperature is falling), and full "off" (when temperature is rising), for an on/off controller. The deadband is intentionally designed to reduce oscillation.

Derivative: Adjustment to output based on the process's rate of change, usually to allow faster recovery from upsets. Also expressed as "rate." General rule: Increase derivative time if system frequently overshoots; decrease if system acts sluggish.

Dielectric strength: The maximum voltage (typically AC) that an insulation material can withstand before material breakdown occurs.

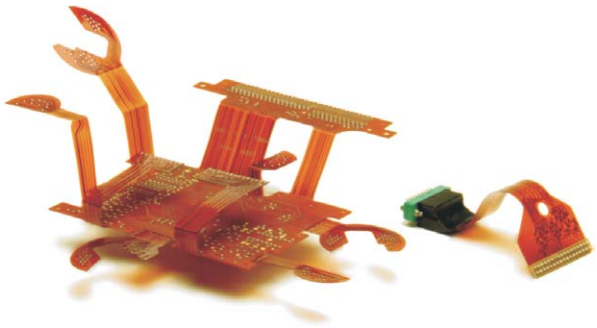
Droop: An error inherent in simple proportional control where the temperature reaches equilibrium at a point other than setpoint, but still within the proportional band.

Etched-foil: A method of producing pre-determined electrical paths, by chemically removing (etching) the areas which will not carry electric current. This process can be used to manufacture heaters, flex-circuits, and temperature sensors.

FEA (Finite Element Analysis): A numerical method used to predict the behavior of a heater/heat sink design. It is typically employed only if actual modeling is not practical.

FEP (Fluorinated Ethylene Propylene): A thermoplastic adhesive in the PTFE family of polymers.

Flex-circuit: A printed circuit made with flexible materials for compact electrical interconnects.



Fuzzy logic: A control scheme that operates in addition to PID and gives the controller more "common sense" for dealing with unpredictable systems. Not required for most heating situations.

Heat sink: The body to which a heater is affixed.

Heat transfer: The transfer of thermal energy between bodies of different temperature.

Heaterstat™: A Minco temperature controller that uses the heating element as a temperature feedback sensor.

Hysteresis: The temperature difference between full "on" (when temperature is falling), and full "off" (when temperature is rising), for an on/off controller.

Insulation resistance: The actual resistance of an electrically insulating material. Measuring devices typically use high DC voltage to perform the measurement.

Integral: A controller feature that continuously compensates for droop by integrating errors over time and adjusting the proportional band up and down. Also expressed as "reset" (integral time = 1/reset rate). General rule: Short integral times give faster correction, but too short causes oscillation.

ISO 9001: A quality management system that is accepted in over 90 countries around the world.

Laminate: To bond materials using heat and pressure.

Mica: A fairly brittle phyllosilicate mineral used to insulate heaters. It is used primarily for its high temperature and high watt density capabilities.

NASA (National Aeronautics and Space Administration): The U.S. agency for space exploration.

Ohm's law: $E = I \cdot R$. See page A-11.

On/off: A simple control scheme where output is on below the setpoint, off above, as with a thermostat.

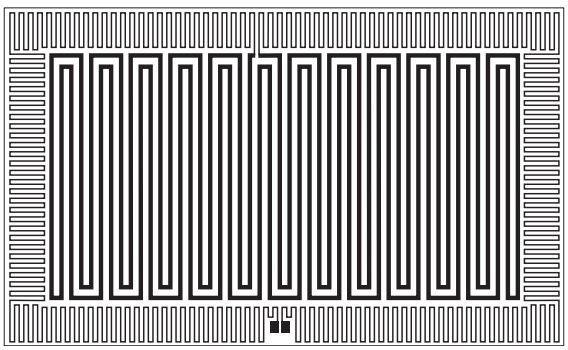
Outgassing: The expulsion of gases, especially in a vacuum or high temperature environment.

PID (Proportional, Integral, Derivative): A control algorithm incorporating proportional, integral, and derivative action.

Polyester: A synthetic polymer used to electrically insulate heaters, flex-circuits, and Thermal-Ribbons™. It is an economic alternative to polyimide, when high temperature and chemical resistance are not critical.

Polyimide (Kapton™): A flexible, amber-colored, translucent film to electrically insulate heaters, flex-circuits, and Thermal-Ribbons™. It is widely used for its temperature range and resistance to chemicals. DuPont's tradename for polyimide is Kapton™.

Profile: A method of providing uniform temperature, by varying watt density in a single heater to accommodate non-uniform heat loss from the heat sink.



Glossary

Proportional band: A region around the setpoint where the output is proportional to the process's distance from that setpoint. For example, 100% heater power during warmup is proportioned to 75%, then 50%, then 25% as temperature nears setpoint. General rule: Set just wide enough to prevent temperature from wandering outside band during normal operation.

Proportional control: A control method where the controller output is proportional to the temperature difference from setpoint.

PSA (Pressure-Sensitive Adhesive): An adhesive that does not require heat or extreme pressure to apply. Simply peel off the release liner, and firmly press into place.

PTFE (polytetrafluoroethylene): A flexible electrically insulating material known for its "non-stick" characteristic. It is often used for its excellent chemical resistance. DuPont's tradename for PTFE is Teflon™.

Radiation: The transfer of thermal energy through space (especially a vacuum) by electromagnetic waves.

Resistance density: Resistance per unit area. Usually listed as a maximum, it is dependant upon construction materials such as foil, adhesive, and insulation.

Resistance tolerance: The range of actual resistance from nominal (or target resistance), at a reference temperature (usually 0°C). Generally, wire elements have a tighter resistance tolerance than etched foil elements.

RS-485: A communication standard for interfacing computers to process instruments. Allows multiple instruments on a single twisted-pair cable. Convertible to RS-232 with proper adapter.

RTD (Resistance Temperature Detector): A sensor whose resistance changes with temperature. The most accurate of commonly used thermometer types.

Self-Tune: The ability of the CT15 or CT16A to set its own PID parameters to best match the process. Can be set either to learn once or to continuously observe and adjust.

SensorCalc: A web-based program that provides resistance versus temperature data for a variety of sensors and heaters.

Shrink band: Pre-stretched strips, that shrink when heat is applied, for mounting heaters or temperature sensors to cylinders.

Silicone rubber: A flexible, synthetic elastomer used to electrically insulate heaters and Thermal-Ribbons™.

SMT (Surface Mount Technology): A printed circuit wiring method that uses solder pads on the surface of the circuit to mount components, thereby eliminating through-holes.

Snap action: A switching method, often used in thermostats, in which a temperature-sensitive bi-metallic element causes fast make and break of electrical connections. In contrast to creep action, this method results in less electrical noise, but requires a significant differential between temperatures that open and close the connection, resulting in looser control.

Specific heat: The amount of heat per unit mass required to raise the temperature of a material 1°C.

SSR (Solid State Relay): A type of relay with no moving contacts to wear out, offering life many times that of mechanical relays. Best for time proportioning.

Stretch tape: An elastic, silicone rubber tape for mounting heaters or temperature sensors to cylinders.

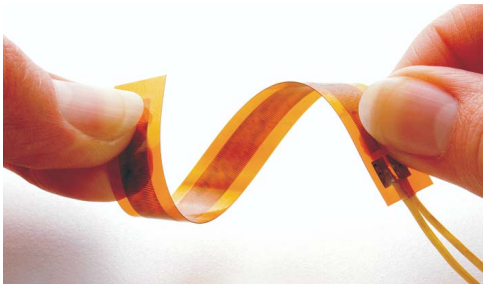
TCR (Temperature Coefficient of Resistance): The average resistance change per unit resistance between 0°C and 100°C. Sometimes it is simplified to the ratio of resistance at 100°C to the resistance at 0°C.

Thermal Calc: A DOS program to assist in calculating heater wattage requirements from known parameters. Thermal Calc is free from Minco on diskette, or downloadable from www.minco.com/support.

Thermal-Clear™: A heater made with transparent insulation and a fine wire element. Thermal-Clear heaters transmit over 80% of visible light.

Thermal conductivity: A measure of how fast heat travels through a material. Often referred to as the "k" value.

Thermal-Ribbon™: Minco's family of flexible temperature sensors, featuring a wide variety of resistance, TCR, and temperature ranges. Thermal-Ribbons can be integrated into a heater, or custom designed to virtually any shape.



Thermistor: A temperature sensor made from semiconductive material. Thermistors are highly sensitive (resistance changes dramatically with temperature), but non-linear and typically not very accurate.

Thermocouple: A temperature sensor made by joining two dissimilar metals at discrete points called junctions. Thermocouples produce a small voltage when there is a difference in temperature between junctions.

Thermofoil™: An innovative heating technology from Minco, which utilizes an etched foil process to create a flat, flexible heater for optimum heat transfer. Heaters can be designed in virtually any shape, and Minco can integrate temperature sensors, flex-circuits, and control electronics.

Thermostat: A temperature-sensitive switch used as an economical on/off controller, or for overtemperature protection. See "snap action" and "creep action."

Thin-film: An electrical component made by depositing a thin layer of metal on a substrate (usually ceramic). Thin film techniques can be used to make heaters or temperature sensors.

Time proportioning: Scaling of output by varying the ratio of on-time to off-time; i.e. 80% power = 80% full on, 20% off.

TÜV: A testing and certification organization, through which Minco has ISO 9001 accreditation, and other approvals.

UL (Underwriter's Laboratories): An independent product safety testing and certification organization, recognized mostly in the United States and Canada..

ULA: A thermosetting, acrylic adhesive that is UL recognized.

Vulcanize: A process, using heat and pressure, used to bond uncured rubber to rubber, metal, ceramic, glass, etc.

WA: A thermosetting acrylic adhesive.

Watt: The heat produced by one ampere of current through a resistive load of one ohm.

Watt density: The amount of power per unit area, often expressed as watts per square inch or watts per square centimeter.

Specifications

Astrium (consortium of British, French, German and Spanish manufacturers of aerospace and satellite equipment)

Specification MA1144 of the Space Components Procurement Agency and
Specification SHT-01-001

Minco has qualified and supplied hundreds of custom models of Thermofoil™ heaters for satellite applications with these partners for over 20 years.

CENELEC: European Committee for Electrotechnical Standardization

Specification EN50014: Electrical Apparatus for Potentially Explosive Atmospheres: General Requirements and Specification EC50019: Electrical Apparatus for Potentially Explosive Atmospheres: Increased Safety Apparatus

Minco has qualified specific models of Thermofoil™ heater assemblies used in potentially hazardous areas to these international requirements.

ISO 9001 certified compliant by TÜV Management Services

Minco's Quality Assurance system has been audited and certified compliant with this internationally recognized standard.

NASA: National Aeronautics and Space Administration of the United States

Specification S-311-P-079: Procurement Specification for Thermofoil™ Heaters

Minco has worked closely with NASA developing precise, reliable thermal components since the Mercury program in the 1960's. Hundreds of custom designed Thermofoil™ heaters have been built, tested and supplied for NASA projects. Minco is the only supplier of heating elements included in the NASA's QPL (Qualified Producer List).

Telcordia Technologies (Bellcore)

Specification GR-1221-CORE: General Reliability Assurance Requirements for Passive Optical Components

Kapton and rubber insulated Thermofoil™ heaters have been tested to these requirements of the telecommunications industry. Standard and custom designs, heater/sensors, and heater assemblies meet the requirements of this specification.

TÜV

Specification EN60335-1: Standards for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements

Thermofoil™ heaters, Kapton or silicone rubber insulated, standard or custom designs, may be marked as recognized components.

UL: Underwriters Laboratories

United States:
UL 499: Standard for Safety for Electric Heating Appliances

Canada:
Specification C22.2, 72-M1984

Standard and custom designed heaters with Kapton or silicone rubber insulation may be marked as recognized components. Specific models of mica insulated heater can also be approved.

For more information . . .

Application Aid #21, "Estimating Power Requirements of Thermofoil™ Heaters"
Procedure for calculating required wattage. 12 pages.

Application Aid #22, "Recommended Adhesives for Thermofoil™ Heater Installation"
Compares heater mounting methods. 4 pages.

Application Aid #25, "Prototyping Techniques for Thermofoil™ Heaters"
Methods and tools for thermal design. 4 pages.

Application Aid #29, "Designing Heated Chucks for Semiconductor Processing Equipment"
Discussion of design considerations for chucks used to process wafers. 4 pages.

Application Aid #30, "Comparison of Thin-film and Wire-element Heaters for Transparent Applications"
Benefits and drawbacks of thin-film and wire-element transparent heater construction. 4 pages.

Bulletin HR-1, "Electric Motor Anti-Condensation Heaters"
Wire-wound heaters for anticondensation. 2 pages.

Bulletin SEMI-1, "Minco Solutions for the Semiconductor Industry"
Products for the semiconductor industry. 4 pages.

Bulletin TF-8, "Chuck Heaters for Semiconductor Processing Equipment"
Discussion of materials and designs for heaters and chucks used in semiconductor processing equipment. 2 pages.

Index

Important note:
Minco reserves the right to change catalog heater specifications and designs without notice. For complete design control, contact Minco for a unique part number.

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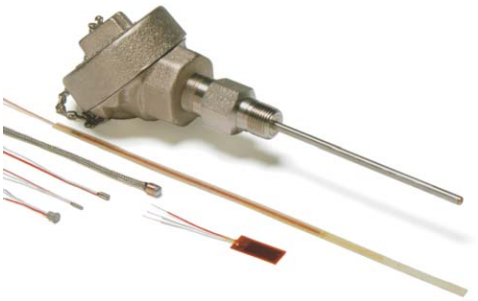
Other Minco products . . .

Temperature Sensors

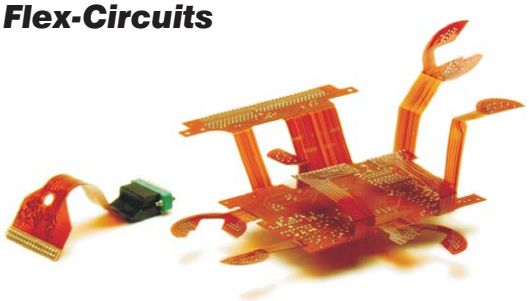


- Resistance Temperature Detectors (RTD's): Platinum, copper, nickel, and nickel-iron
- Thermocouples: E, J, K, and T
- Flexible Thermal-Ribbons™ for fast response surface sensing
- Tip-sensitive and high temperature probes, fittings, and accessories for process control and industry
- Temperature sensors for building automation (HVAC/R)
- Stator and miniature bearing detectors for overtemperature protection of rotating machinery
- Laboratory grade platinum probes and elements

Temperature Instruments

- PID and on/off temperature controllers
- Temptran™ 4-20 mA transmitters for building automation and process control
- Handheld and panel-mount temperature indicators
- Multichannel programmable temperature alarms

Flex-Circuits



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