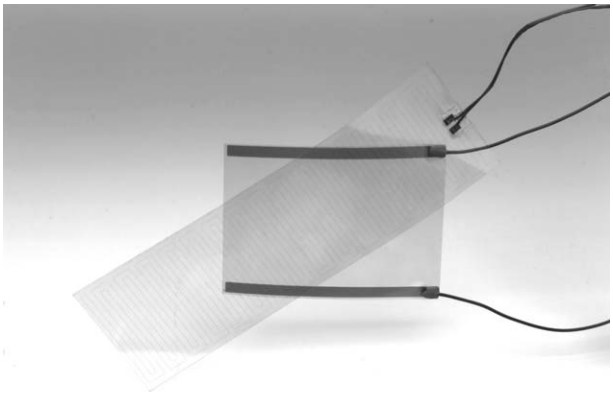
Comparison of Thin-film and Wire-element Heaters for Transparent Applications



Warming a glass plate, test chamber window or LCD display creates difficult design problems. Flexible heaters with silicone rubber or Kapton insulation block light, making viewing through the material impossible. Heating only around the edges with a larger cartridge style heater or opaque flat heater may not provide enough heat to warm the entire surface, or may lead to temperature gradients that can fracture glass. The solution is a clear heating element that can provide heat to the entire surface.

Two types of clear heaters are commonly used. The first is constructed with a very thin coating of Indium Tin Oxide (ITO) metal film deposited on a polyester sheet. This film is generally transparent to visible light, with an electrical resistance that provides heat when powered.

The second type of heater is constructed with a small diameter resistive wire, typically about 25μ (0.001 inch) diameter, laid in a pattern between two sheets of polyester. The Minco trade name for this construction is the Thermal-Clear™ heater.

Each of these types has different features, advantages, and limitations. This Application Aid discusses the differences and considerations when selecting a clear heating element.

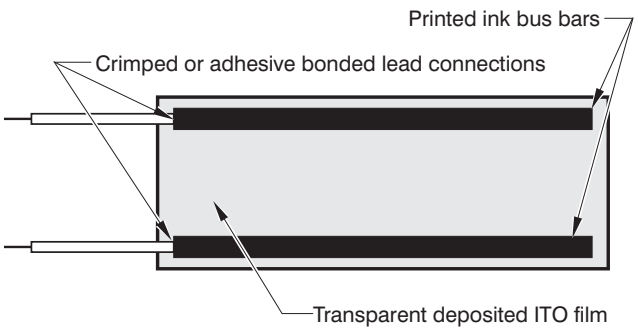
Why heat an LCD display?

The response speed of an LCD display decreases as the temperature drops. Many manufacturers rate their LCD displays to 0°C (32°F) minimum operating temperature. Below the rated temperature the display may react only very slowly, or it may show meaningless characters.

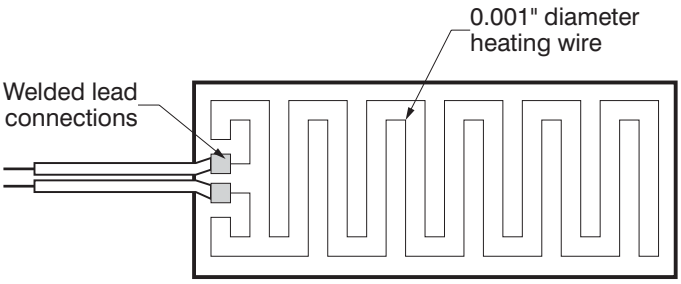
LCD displays in instruments and machinery may be exposed to extreme temperatures. Test and maintenance devices are often used outdoors in frigid winter temperatures. Dataloggers or bar code scanners may be used in industrial freezers. These situations require a fast acting display while operating at temperatures to -40°C or colder.

The solution to keeping the devices working in cold temperatures is to heat the display. Wire or etched element heaters with opaque insulation can be bonded to the LCD, but if the display has electroluminescent, LED or fluorescent backlighting the heater must allow light transmission.

Thin-film ITO heater

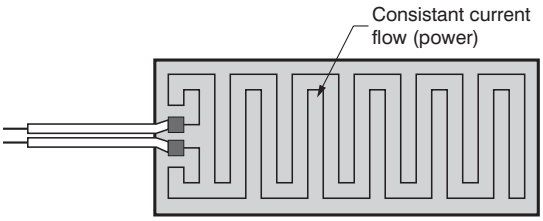


Minco Thermal-Clear heater



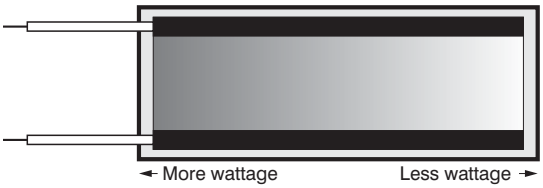
Watt density

Wire-wound Thermal-Clear heaters deliver uniform watt density (heat flux) across the entire heater area.



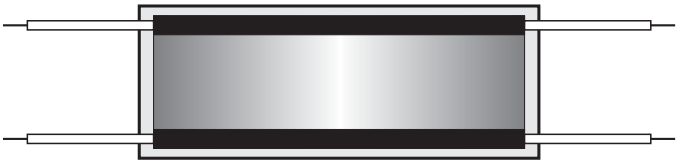
Since electrical current travels the path of least resistance, the watt density in ITO heaters decreases with distance from power connection points. This is due to the voltage drop along the length of the bus bars.

The heating profile is shown below with darker shading representing higher watt density:



This effect can be minimized by reducing the resistance in the bus bars. One method is widening the bus bars. However, this increases the non-heated zones of the heater and reduces viewing area.

A second method is to attach leadwires on both ends of the bus bars to effectively cut the resistance in half:



Resistance tolerances

Thermal-Clear heater resistance tolerances start at ±10% standard and can be built down to ±2%.

ITO heaters have resistance tolerances of ±20-25% and cannot be tightened. The tolerance depends on the uniformity of the extremely thin ITO coating. Even the smallest variation in thickness will have a substantial effect on resistance. Most ITO vendors specify ±20% due to this variability. Resistance shifts can also occur during manufacturing, so the final product must have an even wider tolerance. If the device is battery powered, +25% resistance may not provide enough heat and –25% will reduce battery life.

Resistance repeatability/stability

Repeatability tells how steady the resistance readings are at the same temperature. Stability is the absence of long term shift.

Some ITO heater users have seen a resistance shift over time and even from cycle-to-cycle. Resistance instability can result in erratic heating and power draw.

The repeatability/stability of a wire-wound Thermal-Clear heater is similar to wire-wound resistance thermometers. Ordinary industrial models will drift less than 0.1% per year in normal use.

Electrical connections

A Thermal-Clear heater has all electrical connections welded together to ensure reliable connections.

ITO heater bus bars are made of a very thin screen printed layer of conductive ink. Terminations to pins or hook-up wires are done by mechanically crimping the materials together or bonding the terminal to the conductive ink.

Conductive elements

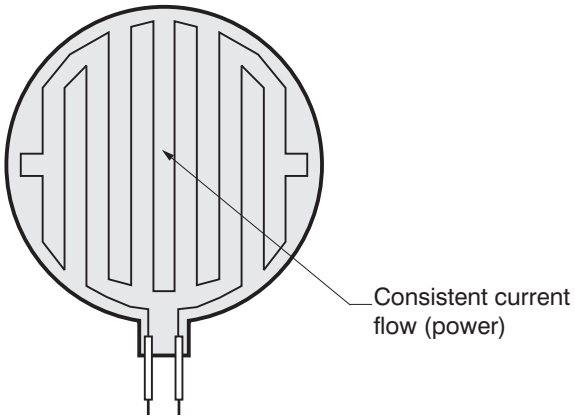
A Thermal-Clear heater consists of fine wire elements. To achieve the required design resistance density, different wire sizes, materials and spacing can be used. Since such a small percentage of the overall heater area is covered by the fine wire, the effect on light transmission is minimal.

An ITO heater consists of a very thin layer of ITO. To get lower resistances, a thicker layer of ITO is needed. This can lower the light transmission to less than 75%. ITO heaters with very high resistance are the clearest. Many transparent heater applications are battery operated and require a very low resistance heating area, resulting in lower light transmission.

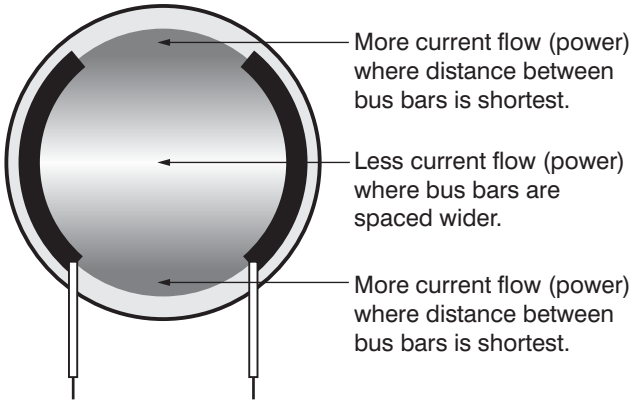
Because the ITO layer is so thin (1000 Å typical), the slightest scratch can cause a small fracture. Even a light sweep of a static brush to clean the surface of dust can fracture the coating. Electrical current crowds around the edges of any fracture in the ITO coating resulting in a hot spot. Once inititated, this hot spot will propagate across the heater until the electrical circuit becomes open.

Heater shape

A Thermal-Clear heater can be designed to any shape with uniform watt density.

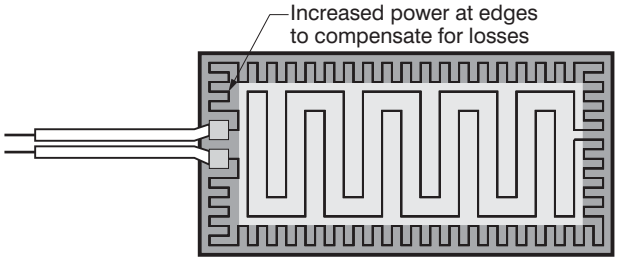


Watt density in an ITO heater becomes much less uniform with non-retangular heaters or non-parallel bus bars. Changing distance between bus bars will change the wattage profile. Again, the figure below shows higher wattage as darker shading.



Varying power density

A unique option with Thermal Clear heaters is the ability to design the heater for extra power precisely where it is needed. For example, an LCD often loses more heat around the edges where the mounting bracket acts like a heat sink. By varying the distance within the wire pattern it is possible to put just enough extra heat on the edges to compensate. This is often referred to as "profiling" the watt density. The result is optimum temperature across the entire surface, without adding excess heat.

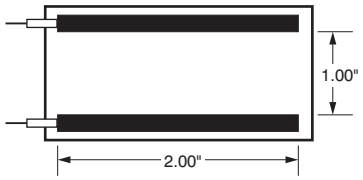


Resistance

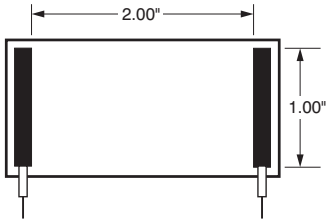
Thermal-Clear heaters can be designed to any resistance by adjusting element wire material and/or the diameter of the element wire.

ITO heater resistance is based on the base resistance of the coating and shape (not size) of the heater.

$$Resistance = \frac{(distance\ between\ bus\ bars) \times (resistivity)}{(length\ of\ bus\ bars)}$$

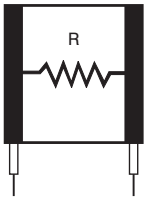


$$Resistance = \frac{(1\ in.) \times (60\ \Omega)}{(2\ in.)} = 30\ \Omega$$

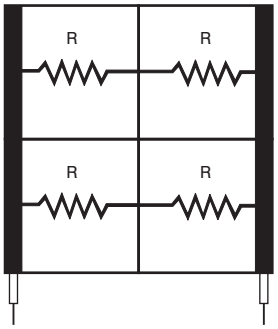


$$Resistance = \frac{(2\ in.) \times (60\ \Omega)}{(1\ in.)} = 120\ \Omega$$

For instance, assume you have an ITO coating with a resistivity of 60 Ω/square. A 1" X 1" heater would have 60 Ω. And a 2" X 2" heater would have 60 Ω. Consider each 1" square as a resistor of resistance=R and use Kirchhoff's Current Law for series/parallel resistance circuits:



$$Resistance = R$$



$$\frac{1}{Resistance} = \frac{1}{R+R} + \frac{1}{R+R} = \frac{2}{2R} = \frac{1}{R}$$

$$Resistance = R$$

Comparison of Minco's wire-wound Thermal-Clear™ heater to typical ITO heaters

Characteristic	Minco Thermal-Clear heaters	ITO film heaters
Light transmission	Excellent (>82% of visible light).	Good (up to 75% of visible light, less for very low resistance films).
Transparent area	Light transmission edge to edge. Leadwire attachment can be on external tab outside of viewing area.	Bus bars intrude on viewing area. Locating power connections on external tabs increases power loss in bus bar areas.
Light obstruction	The small diameter heating wire may create visible shadows on the display.	Entire visible area is consistent clarity – no shadows or disruptions of light.
Resistance tolerance	±10% standard, to ±2% at higher cost.	±20 to 25%.
Resistance range	Any value to 3000 Ω / in² (lower limit may depend on wire used).	Usually 2 to 4 options available within 5 to 100 Ω/square range.
Outline shape	Any two-dimensional shape possible.	Rectangle only to ensure most consistent watt density.
Power uniformity	Output power proportional to resistance density across the heater.	Wattage decreases with distance from power connection points due to bus bar resistance.
Power profiling to compensate for edge losses	Controlled and repeatable power density profiling available within any heater shape.	No power profiling.
Maximum power density	Up to 10 watts/in² for fast warm-up; typical applications require 1 watt/in² to maintain temperature.	Can be damaged at greater than 2-3 watts/in².
Maximum temperature rating	Up to 120°C.	Up to 100°C.
Leadwire connections	Welded connections with strain relief for maximum strength.	Mechanically crimped or epoxy bonded wires.
Integrated sensor options	Point sensor or flat, averaging RTD sensors available.	Point sensor only.
Control options	Use a sensor with electronic control or Minco's Heaterstat™ sensorless controller. Heaterstat can be match calibrated with a specific heater for optimum control.	Use sensor with electronic control.

Thermal-Clear transparent heaters

Minco has standard models of Thermal-Clear heaters in stock for immediate delivery. For your special requirements our experienced Sales and Engineering groups can design a custom model to precisely fit your design.

We can incorporate design options such as flex leads to connect the heater to your electronics, integrated RTD or thermistor temperature sensors, and unique size or shape requirements.

Request bulletin HS-2 for complete information on standard and custom design Thermal-Clear heaters.

Heaterstat™ sensorless temperature controller

The CT198 Heaterstat works with any Thermal-Clear heater and gives you precise control of heater temperature while conserving power. It can regulate up to 3 A at 7.5 to 60 VDC. The CT198 is ideal for battery powered or vehicular applications where space, weight, and energy are at a premium. Pins for circuit-board mount are optional.

The Heaterstat needs no temperature sensor. It reads temperature directly from the Thermal-Clear heater's element. At regular intervals the CT198 pulses power to the heater to take a reading, and switches full-on only if the temperature has fallen below setpoint. It then stays on until heater temperature regains setpoint.

Request Bulletin CT198 for complete data.

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