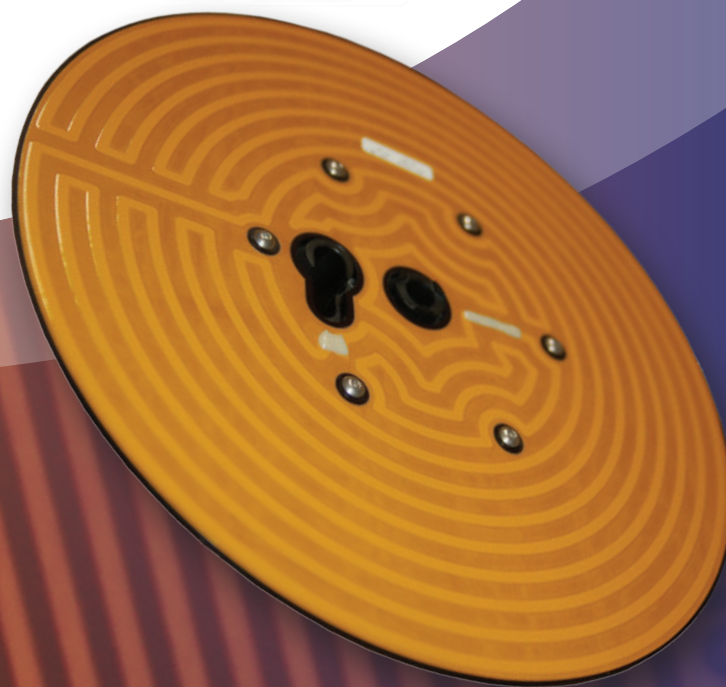




HEATER DESIGN MANUAL



**POLYIMIDE
SILICONE RUBBER ASSEMBLIES**

DOWNLOAD FROM OUR WEBSITE:

AllFlexInc.com

HEATER DESIGN MANUAL

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CORE VALUES

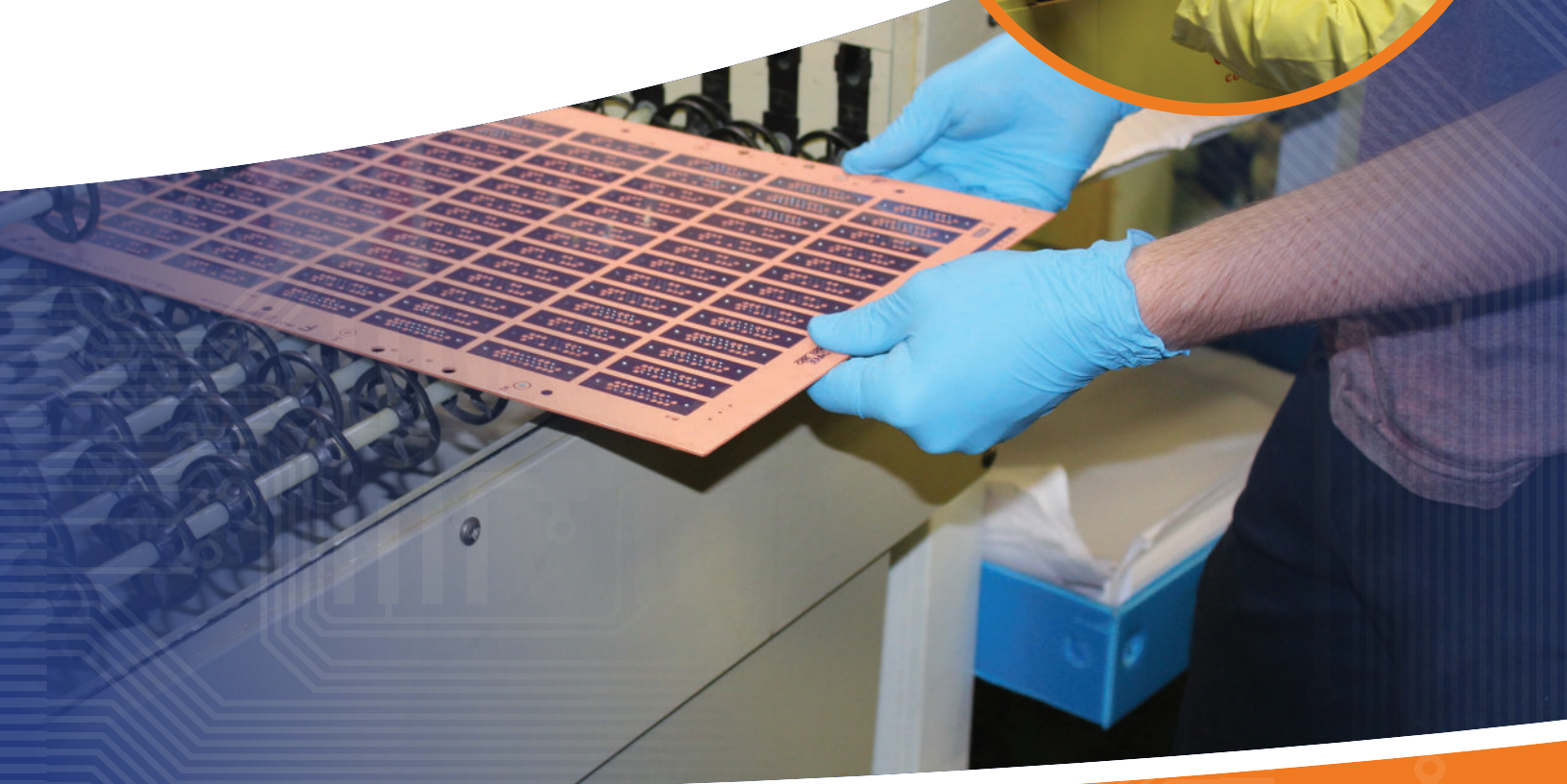
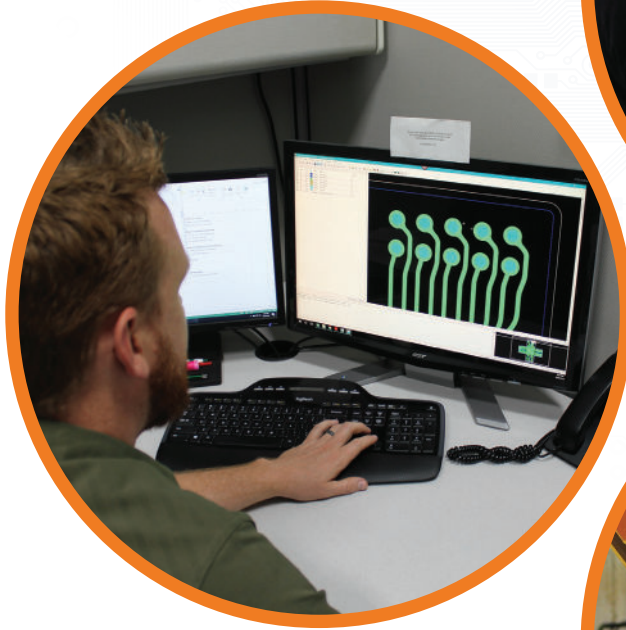
Customer Focused

We Find a Way

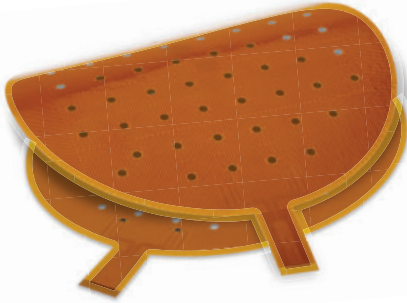
Be Entrepreneurial

People and Teamwork Matter

Rapid Response



ETCHED FOIL HEATING TECHNOLOGY: THE BASICS



RESISTIVE FOIL - NOT WIRE

Etched foil heaters are a product of Ohm's law, meaning that wattage (power emitted as heat) is created when voltage (volts), resistance (ohms), and current (amperes) are intermixed using an electrical conducting medium. When any of these three variables is altered, the resulting wattage is changed. The phenomenon is true with any type of conductive materials including wire, foil, polymers and resistive metals.

With etched foil heaters, the conductive medium is a resistive metal foil that is typically between 1 and 3 thousandths of an inch thick (also referred as 1 to 3 'mils' or .001 "/.003").

This foil is patterned in such a way that it provides a conductive path for the electricity to extend throughout the physical area of the heater. The general result is the power induced into the pattern is equally disbursed, therefore the thermal output is also uniformly disbursed. However, physical aspects of the heater and its mounting surface usually create non-uniform thermal results such as heat loss at edges, thermal variances near holes, or heat retention occurring from unique physical characters in the heat sink.

Another factor contributing to varying thermal results is if the foil pattern is not uniform, producing areas with gaps or areas where conductors are closer together, creating cooler or warmer areas. Yet etched foils are ideal for creating very uniform or customized thermal results because the conductor layout can be extremely precise in location, repeatability, and spacing.



THERMAL DISSIPATION

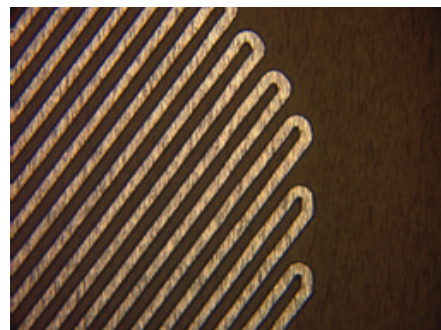
A favorable characteristic of flexible etched foil heaters is the materials that comprise the heater have excellent thermal conductive properties and are extremely thin (typically between .002" and .004" thick). This enables the heat generated from the embedded conductor to transfer away from the conductor quickly and into the mounting surface.



This feature becomes valuable in applications where quick/highly-responsive thermal adjustments are desired. This also enables polyimide-based heaters to deliver higher-than-expected wattages in a thin package. Even higher thermal output levels can be obtained if the heater is compressed between two heat sinks to extract the heat away from the foil quickly, preventing the high heat from weakening/degrading the bonding adhesive.

PRECISE PATTERNS

Etched foil heaters provide the opportunity for unlimited patterning of the thermal conductors, yet unlike wire-based flexible heaters, each heater produced in a production mode will be identical. The precision of the pattern can be ultra-fine (as evidenced by the image below of a .003" width/space layout) or the pattern can have varying space distances and/or varying conductor widths.



When coupled with the ability of the overall pattern to be variable as well, etched foil heaters can be 'tuned' in multiple ways to produce the desired thermal output. In addition, the heaters can have "two-in-one" heaters interwoven within one pattern. The precision of etched foil heaters also permits the modification of the layout to provide multiple zones, or to modify the heat production based upon the thermal losses in and around the heater.

GENERAL APPLICATION INFORMATION

BASIC UNDERSTANDING OF HEATERS

Flexible heaters are commonly specified by the wattage they deliver. However, customers are ultimately seeking to achieve a thermal result of their system. Therefore, it is important for users of flexible heaters to understand several key elements in order to define the wattage required:

- The minimum temperature value of the system before any heating is applied (minimum ambient temp).
- The desired maximum temperature of the system after heating is applied.
- The speed at which the temperature of the system needs to transition from the minimum ambient temperature to the desired maximum temperature (temperature rise slope).

WATTAGE VS. WATT DENSITY

Flexible heaters are defined by the wattage they deliver. It is common for the wattage to be noted in the specification or print of a heater. But users of heaters should understand that maintaining and controlling the thermal results are better managed using the unit of measure identified as watt density.

Watt density is the overall wattage of a heater divided by the area of the heater. For instance, a 100 watt heater that is 4"X 4" equates to a Watt Density of 6.2W/in². Utilizing watt density can be illustrated in this example. A designer may have two sizes of a product to which the heated surfaces on each of them are to be identical.

In order for the designer to specify the two heaters, he/she would utilize Watt Density to achieve identical results for both models.

THERMAL LIMITATIONS

Despite a common perception, thermal limits of etched foil heaters are not defined by a maximum watt density rating. Instead, the thermal limit is determined by the actual temperature the individual heater layers reach in the specific application.

Flexible heaters can deliver hundreds of watts per square inch, provided the heat generated is dissipated quickly away from the flexible heater. Quick dissipation of heat ensures the heater itself never exceeds the mechanical limits of holding itself together (delaminating). It is imperative the foil conductor is not powered so high or so quickly that the heat of the conductor cannot be dissipated away, causing a burn-out (open conductive path).

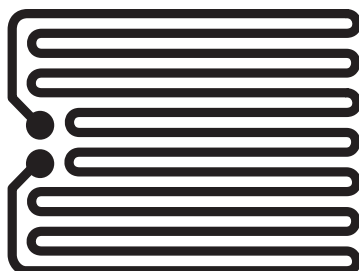
For example, the bonding agents of a silicone rubber heater will start to degrade at 230C. Yet a silicone rubber heater can be utilized to deliver 250C worth of temperature rise, provided the heater's starting temperature is -40C. Another example is a heater that is mechanically compressed between two heat sinks and must deliver unusually high wattage in order to raise the temperature of the heat sinks in a fast time frame. If the heater were to be suspended in air, the heaters would overheat. But since the heat is dissipated into the heat sinks, the layers of the heater itself don't reach the bonding limit or the conductor burn-out temperature.

DIFFERENT HEATER DESIGNS, SAME WATTAGE



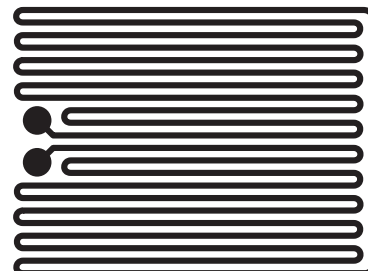
DESIGN #1:

15 watt / 5 volts / 1.67 ohms / 5 w/in² / 3 amps



DESIGN #2:

15 watt / 12 volts / 9.60 ohms / 5 w/in² / 12.5 amps



DESIGN #3:

15 watt / 18 volts / 21.6 ohms / 5 w/in² / .83 amps

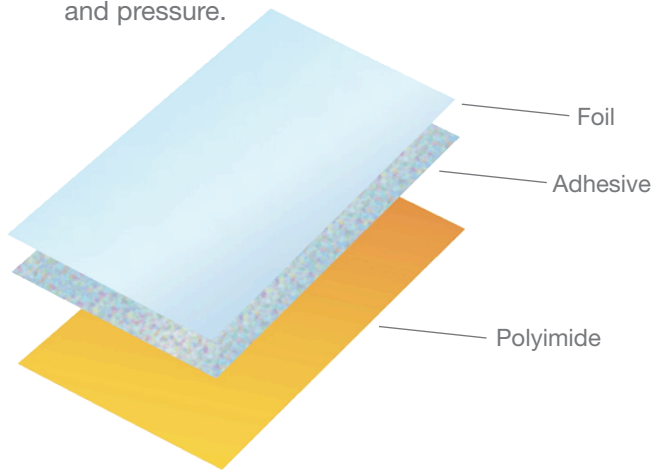
Producing a heater with a defined wattage can be accomplished in a variety of ways. The above images all represent a heater of the same wattage. Customers are to define the wattage of the heater, but All Flex will determine the foil type, foil thickness, and the conductive path design to produce the wattage. This enables All Flex to select the best combination for optimal cost, performance, and application criteria.

FABRICATING ETCHED FOIL HEATERS

All Flex produces its traditional etched-foil heaters utilizing fabrication sequences similar to those used in the printed circuit board industry as outlined below. This breadth of manufacturing technology enables All Flex to provide customization and added features from material alternatives to turnkey assemblies, including the mounting of flexible heaters, integrating flexible heaters and circuits, and attaching heat sinks. Our fabrication steps are streamlined for the fast turnaround requirements of our customers.

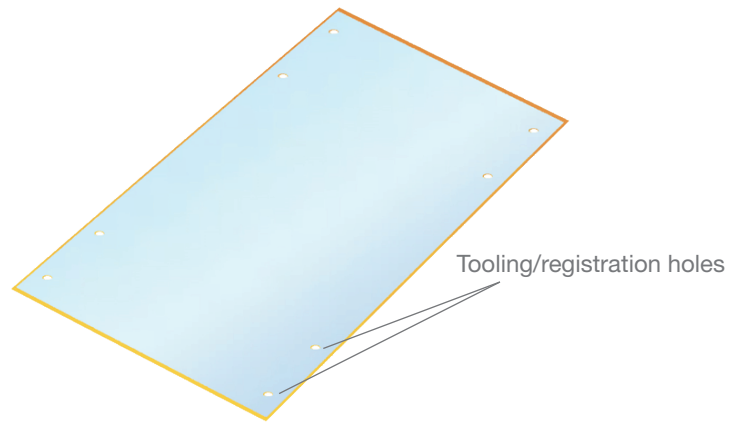
1 CREATING BASE LAMINATE

All Flex determines the resistive foil type and thickness and laminates it to the base dielectric film using a thermoset adhesive. The process is done under varied profiles of high temperature and pressure.



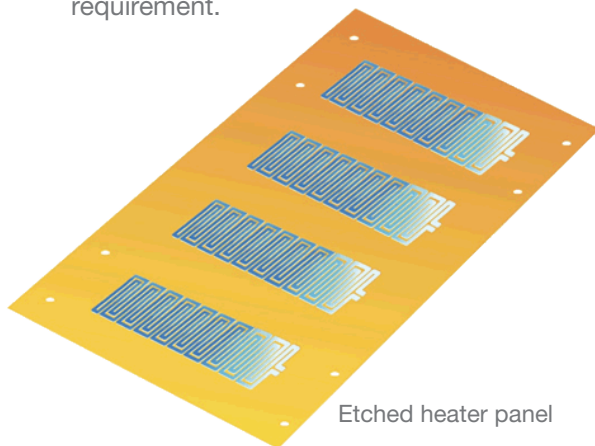
2 DRILLING OF TOOLING HOLES

In sheet form, the base laminate is drilled/routed to provide perimeter registration holes used for subsequent processing and fixturing. The holes may also be optically drilled or created using lasers.



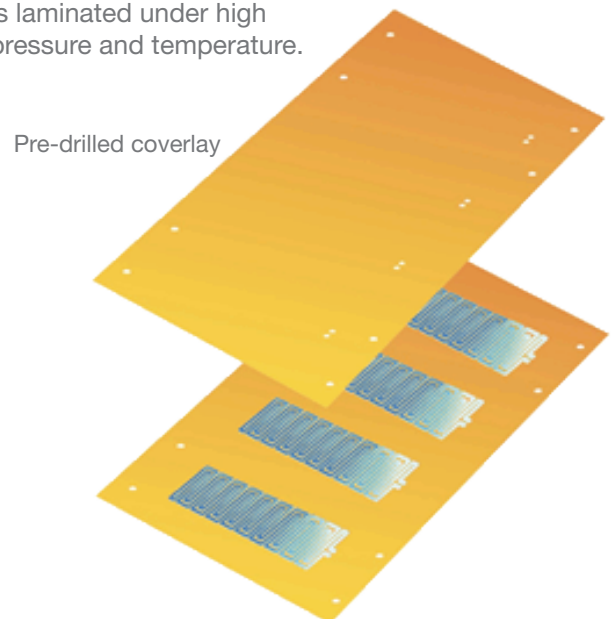
5 ETCHING

The panel is submerged in etchant chemistries that remove the “spacing” between the conductive pattern, leaving only the continuous heating element. A preliminary electrical test and/or automated optical inspection verifies resistance requirement.



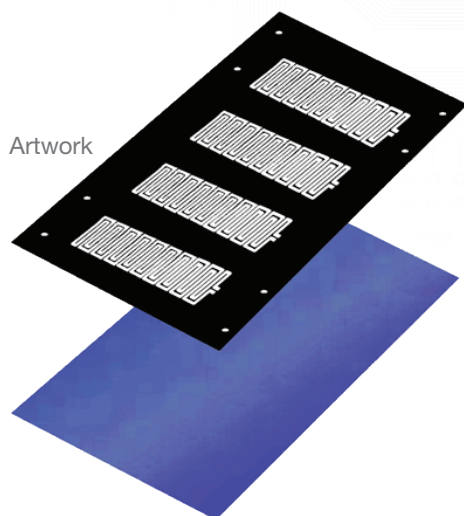
6 TOP DIELECTRIC LAMINATION

The etched panel is then encapsulated using a top dielectric/adhesive layer that has been pre-drilled with access holes aligned with positions of components and/or wire attachment locations. The dielectric layer is laminated under high pressure and temperature.



3 CREATING BASE LAMINATE

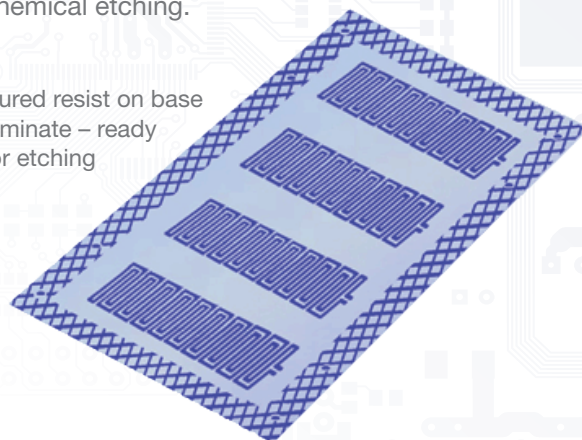
The pattern of the resistive foil is created by applying a photo-sensitive etch resist film onto the foil followed by exposing the film with an artwork or by utilizing a laser.



4 CURING OF ETCH RESIST

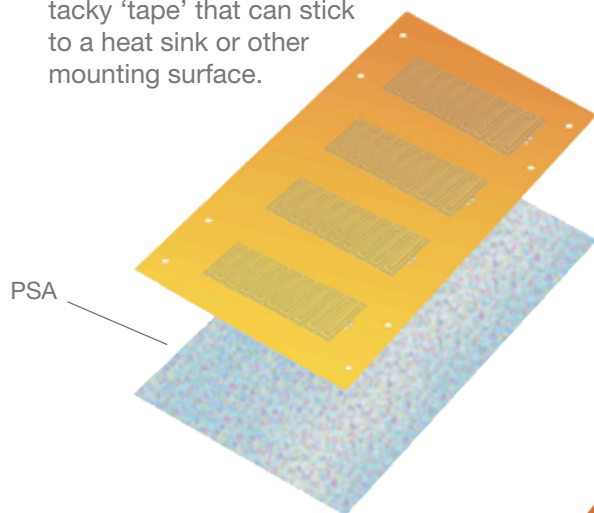
The photo-sensitive film is then cured to produce a hardened, chemically-resistive pattern that protects the conductors during chemical etching.

Cured resist on base laminate – ready for etching



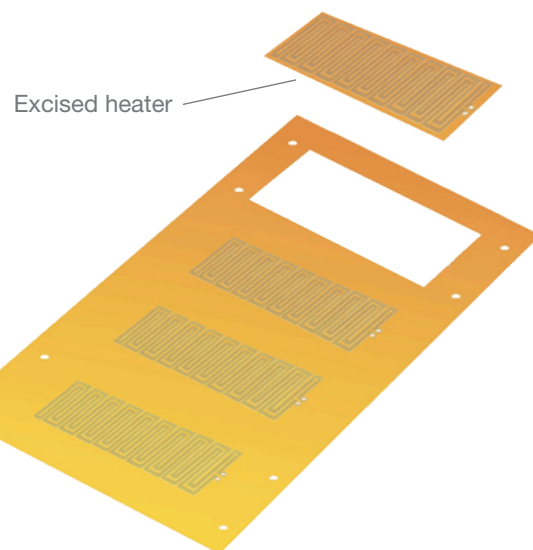
7 BACKSIDE ADHESIVE

Still in panel form, the adhesive used for mounting the finished heater is applied to the specified surface. This adhesive is commonly a pressure sensitive adhesive (PSA) or tacky 'tape' that can stick to a heat sink or other mounting surface.



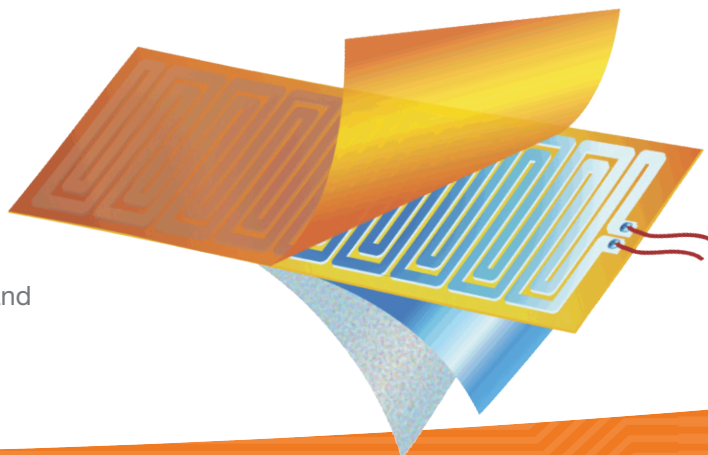
8 EXCISING OF INDIVIDUAL PARTS

Individual heaters are die cut or otherwise excised to remove them from the panel.



9 FINISHING COMPONENTS AND WIRE ATTACHMENT

Individual heaters are finished by adding wires, heat spreaders, populating components, testing, and completing any customer-specific requirements.



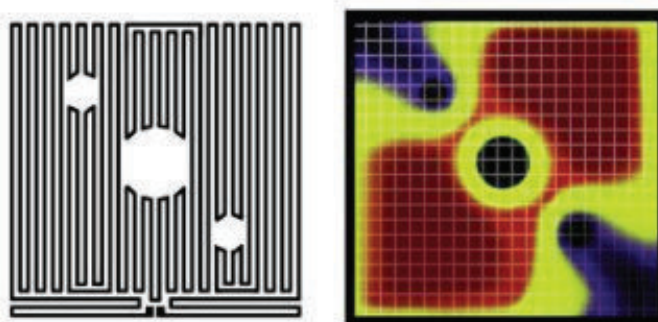
PROFILING AND THERMAL PATTERNING

OPTIMIZE THERMAL RESULTS

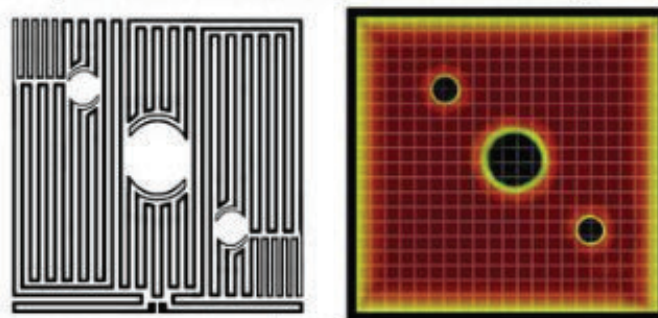
Etched foil heaters are ideally suited to provide differing thermal areas within one heater layout. Foil patterns can be adjusted to compensate for heat loss when the design requires uniform surface temperature throughout. Heat loss factors can include mass variance, airflow, attachment uniformity, and nearby heat-generating devices.

As shown in the upper images to the right, a heater with uniform patterning across the 4" square area has been mounted onto an 1/4" aluminum plate with three holes. The thermal results of the plate show significant thermal variation due to heat losses surrounding the holes.

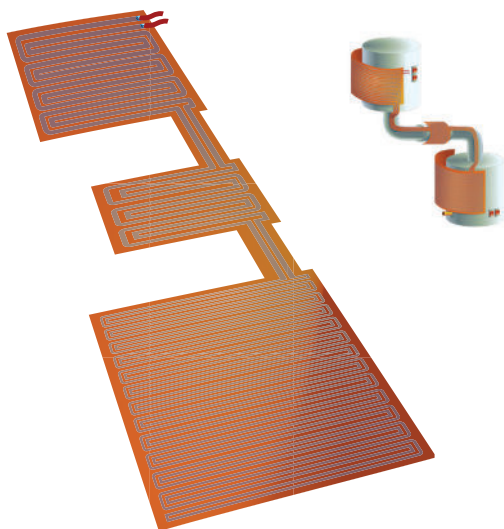
Alternately, All Flex utilized Finite Element Analysis (FEA) tools and expertise to optimize the thermal results in order to produce a uniform thermal pattern of the heat sink. The etched pattern of the heater was modified to increase thermal output in insulated areas surrounding the holes and the edges of the heater were also increased.



Thermal pattern using uniform element design (thermal pattern shown reflects final installation onto heat sink).



Thermal pattern using profiled element design resulting in even temperature distribution after heat sink installation.

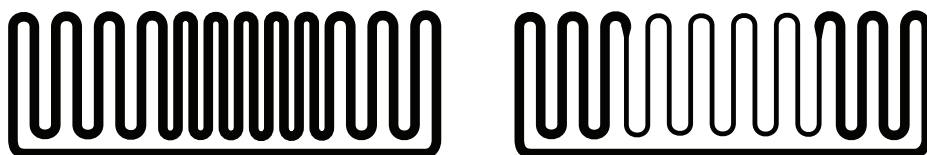


MULTI-ZONE HEATERS

Multi-zone heaters are another form of profiling, but instead of adjusting heat patterns to compensate for heat loss, specific areas are intentionally designed with different watt density levels.

- Used in applications where one physical heater is desired yet different heating levels are required in different areas.
- Can be designed to have one or multiple input power lines.
- Reduces assembly time by handling only one heater.

Variable heat zones within the body of a foil heater can be accomplished in several ways. In the examples below, increased thermal output in the center areas is shown: the left image shows conductors that are compressed together, while the right image shows a change of conductor width.



UNDERSTANDING YOUR OWN THERMAL APPLICATION

DETERMINING THE WATTAGE OF CUSTOM HEATERS

Defining the requirements of a flexible heater for an application falls into a gray area between mechanical/thermal engineering and electrical engineering. The engineer responsible for defining the thermal aspects of a system is not necessarily the same person managing electrical controls and how the system pulls power. Therefore, the decisions are usually made as a team.

The method to arrive at the wattage may involve experimenting and empirical analysis before an engineer can confidently specify the wattage of a custom-built heater.

#1 ESTIMATE THE POWER REQUIREMENT

An engineer may utilize the formula and data below to arrive at a preliminary wattage figure for an application. This basic technique does not take into account more advanced calculations involving heat loss variables and unusual factors. However this approach will enable an engineer to arrive at a general power requirement. In many applications, an engineer may then increase the calculated power level by an estimated percentage of 10-30% to anticipate other factors contributing to the power needs. This technique is often satisfactory, particularly when the estimated power calculation is followed-up with actual product tests.

$$\text{Power (watts)} = \frac{m C_p (T_f - T_i)}{t}$$

m = Mass of Object (g)
 C_p = Specific heat of material (J/g/°C)
 T_f = Maximum final temperature (°C)
 T_i = Maximum initial temperature (°C)
 t = Warm-up time (secs)

Data Chart

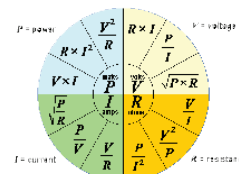
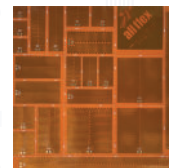
Material	Specific Heat (J/g/°C)
Air	1.005
Aluminum	.897
Brass	.375
Copper	.385
Glass (Pyrex)	.753
Phenolic Cast Resins	1.250 - 1.670
Polycarbonates	1.170 - 1.250
Natural Rubber	1.880
PTFE	1.172
PVC	.840 - 1.140
Steel	.490
Titanium	.523
Water (20°C)	4.182

Additional materials can be found at www.engineeringtoolbox.com.

#2 EXPERIMENTING AND OHM'S LAW

One simple and basic approach used to arrive at the wattage of a new heater is to follow these steps:

1. Determine the operating voltage you desire to use to drive the heater.
2. In a laboratory setting, create a test model that closely replicates the end system mechanical structure so test results can be expected to be repeated in the actual product.
3. Obtain a variable voltage supply with high current capability (10A) such as a Variac.
4. Obtain a heater sample sheet from All Flex that incorporates a variety of heater samples of different sizes and different resistances.
5. Select a heater that is approximately the size for the test model.
6. Measure the resistance of the selected heater.
7. Solder wires to the heater and attach it to the test model and to the Variac.
8. Slowly increase the voltage of the Variac and monitor the thermal performance of the test sample. Continue to experiment to determine the desired speed of the thermal rise and the resulting surface temperatures.
9. Once you have arrived at what appears to be a suitable thermal result, note the voltage of the Variac.
10. Using Ohm's law, calculate the wattage of the test.
11. Divide the wattage by the area of the heater to arrive at watt density.



At this point, specify the watt density for the custom heater to be ordered, noting the desired voltage for the design.

#3 KEY TOOL DURING DESIGN PROCESS

All Flex has developed an automated tool to assist engineers and designers at the early phases of design. Our Build-A-Heater online ordering tool enables engineers to select custom heaters and receive them in 1-2 weeks. The tool is available at www.allflexheaters.com.



All Flex also provides application engineering support during the design process. Engineers can contact All Flex to discuss particular applications and to obtain guidance.

PRODUCT TYPES

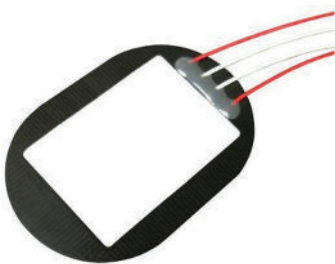
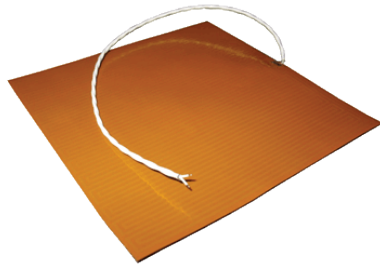
MATERIAL EXPERTISE

All Flex has extensive knowledge and experience in materials technology and in utilizing a wide range of material types to solve custom heater applications when needed. All Flex can accommodate any combination needed, including varying thicknesses, foil types, adhesive options, laminates, composites, and unusual combinations.

However, in general, All Flex etched foil heaters fall into three general categories.

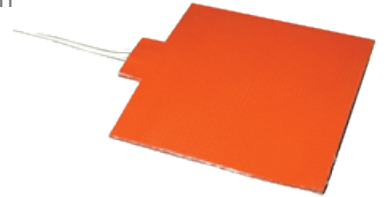
MATERIAL OPTION: POLYIMIDE - TRADITIONAL

Polyimide is the primary material type chosen when high thermal control is desired in the thinnest construction possible. The amber colored polyimide is often referred to as “Kapton,” a tradename of DuPont. Traditional polyimide heaters are constructed with two layers of polyimide film encapsulating the resistive foil layer which are bonded together using thermoset high performance adhesive (flame retardant (FR) grade and non-FR grade). The polyimide film is highly rugged and handles temperature exceeding 300C. Polyimide is excellent for low outgassing applications.



MATERIAL OPTION: SILICONE RUBBER

Silicone rubber (SR) is often utilized for general heater applications requiring its overall mechanical properties. Silicone rubber can be used for outdoor or wet environments and the overall thickness provides more mechanical protection from damage. All Flex silicone rubber heaters are fabricated using unusually thin reinforced silicone rubber so the overall thickness of the finished heater is approximately .020". Silicone rubber heaters can have a higher thermal rating at 232C.



However, SR heaters are less flexible, are not suited for component assembly, are much heavier, and have limits on bonding adhesives for peel and stick attachment.

As an option, All Flex will mount the heaters on heat sinks using a vulcanizing process where uncured silicone rubber is the bonding material.

Silicone rubber heaters are rugged solutions for industrial and general use applications. Avoid silicone rubber when outgassing requirements must be met.

MATERIAL OPTION: POLYIMIDE - HIGHTEMP™

All Flex has developed an all-polyimide heater construction for high temperature applications, maintaining its integrity to 300C. Utilizing advanced manufacturing processes, All Flex has eliminated the adhesive layer and its thermal limitation.

A High Temp heater is an excellent choice for applications where ambient temperatures are higher than normal and the heater is adding substantial heat into the system, resulting in the potential for the heater to reach 300C or higher. Another excellent application area is when the flexible heater is delivering extremely high wattage in a short time period resulting in the heater itself experiencing 300C even though the environment may not reach that level.



Data Chart

Characteristic	Typical Data Polyimide Traditional	Typical Data Silicone Rubber	Typical Data Polyimide HighTemp™
Size Range	< 1 / 2" sq to 16"x 6+ ft.	< 1 / 2" sq to 30"x 6+ ft.	< 1 / 2" sq to 16"x 6+ ft.
Temperature Range*	150-200C (300-390F)	Up to 235C (455F)	Up to 300C (572F)
Resistance Range	Up to 250 ohms per sq. in.	Up to 250 ohms per sq. in.	Up to 250 ohms per sq. in.
Metal Foil Thickness Range	.0005" - .0023"	.0005" - .0023"	.0005" - .0023"
Total Thickness Range	.0045" - .01 0"	.015" -.060"	.0035" - .01 0"
Insulation Resistance	4000-5000 V/mil	400-500 V/mil	5000-6000 V/mil
Example Power Densities	.1W/in 2 to 20W/in 2	.1W/in 2 to 50W/in 2	.1W/in 2 to 60W/in2
Resistance Tolerance	+/- 10%	+/- 10%	+/- 10%
Standard Top Dielectric Thickness	.001", .002", .003", .005"	.008", .015"	.001", .0015", .002", .003"
Leads (if required)	Length/AWG/Coating Options	Length/AWG/Coating Options	Length/AWG/Coating Options
Minimum Bend Radius**	.030"	.125"	.030"
General Chemical Resistivity	Better	Good	Best
Outgassing/ Aerospace	Good	Not Recommended	Good
Edge Insulation	.030"	.030"	.030"
Bond/Peel Strength (to fiat plate) using PSA***	101 oz/in	20 oz/in	101 oz/in

Note: These are standard parameters. Inquire for requirements beyond this range.

Note: Customer is responsible for ensuring an adequate bond of the heater to its mounting surface. Use proper surface preparation and pressure procedures to optimize thermal transfer.

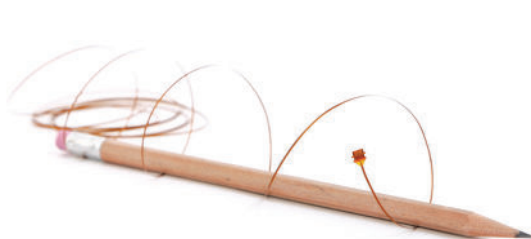
Note: For a small radius wrap, it is recommended that supplemental means be used to ensure the heater maintains a tight bond to its mounting surface. Polyimide tape (3M 5413 Amber) is one possible solution.

Note: HighTemp heater materials are UL rated to 94V-0 and 746F and meet IPC Specifications and RoHs.

* Continuous Operating Temperatures. Contact All Flex for short duration peaks. UL certification is not available above 105C.

** Application-specific and must be validated by customer.

*** Bond data per 3M specification and test protocol. Actual data will vary depending upon application.



MICRO

Polyimide-based flexible heaters with extremely fine conductor patterns fabricated in fractions of inches or unusually long lengths.



EXTENDED LENGTH / OVERSIZED MAXIFLEX

Polyimide and silicone rubber-based etched foil heaters in large-format sizes from 3 to 60+ feet in length.



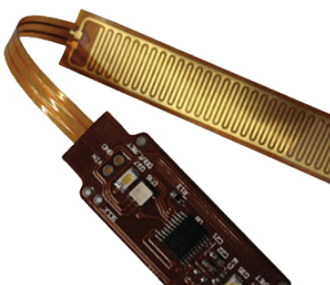
MULTI-ZONE

Heaters with different areas within the heater body that have different watt densities.



BI-FILAR

Heaters with dual independent patterns interwoven within one layer. This approach enables customers to have step-based heating controls.



COMBINATION

Heaters that have integrated control circuit boards built into one package. Combination heaters are commonly delivered with SMD components.



MULTIPLE PHASE

Silicone rubber or polyimide heaters that are run on one or three phase power.

DESIGN AND SPECIFY YOUR HEATER

1. DETERMINE YOUR HEATER REQUIREMENTS

Based upon experimentation or calculation, it is essential to determine the wattage or watt density of the heater that will deliver the desired thermal results. As stated earlier in this manual, understanding the thermal range, the rate of thermal rise, and the expected thermal loss variables are the primary factors in determining the overall wattage of the heater. Additional factors can also contribute when applications require more advanced or precise thermal results.

- After determining the wattage requirement, establish the voltage under which the system will operate under and ensure the power supply can deliver the required current (amperage) calculated using Ohm's law ($P / V = I$).
- The method of controlling the heater must be determined, and if required, identify the specific sensing devices that are to be mounted directly onto the heater.
- Identify the input wire details: Gauge size (by calculating the ampacity rating for the wire), insulation type (primarily for thermal properties), wire location on the heater, the side (front/back) and section of the heater the wires are attached to, the desired termination of the wires to the input power, and the length of the wires. Also determine if a potting/dielectric insulator is to be placed over the top of the wire attachment location.

- Determine how the heater will be mounted or attached and if mounting adhesive (commonly pressure sensitive adhesive - PSA) will need to be pre-mounted onto the heater. Also define which side(s) of the heater will require PSA. All Flex can also provide the mounting to heat sinks if desired. Silicone rubber heaters can be attached to heat sinks using PSA or it can be done at All Flex using vulcanized silicone rubber.

- Specify the size, shape and mechanical requirements of the heater. The typical tolerance on heater dimensions is $\pm .010"$. Tolerance of wire length is $\pm .25"$ and wire location is $\pm .15"$.

- Inspection of the heaters will be measured as the defined resistance with a tolerance of $\pm 10\%$.

2. SELECT PRODUCT TYPE

Determine the type of heater needed for your application (Traditional Polyimide, Silicone Rubber, High Temp) based upon the overall performance requirements, thermal needs, mechanical requirements, environmental specifications, etc.

3. WHAT TO SUPPLY

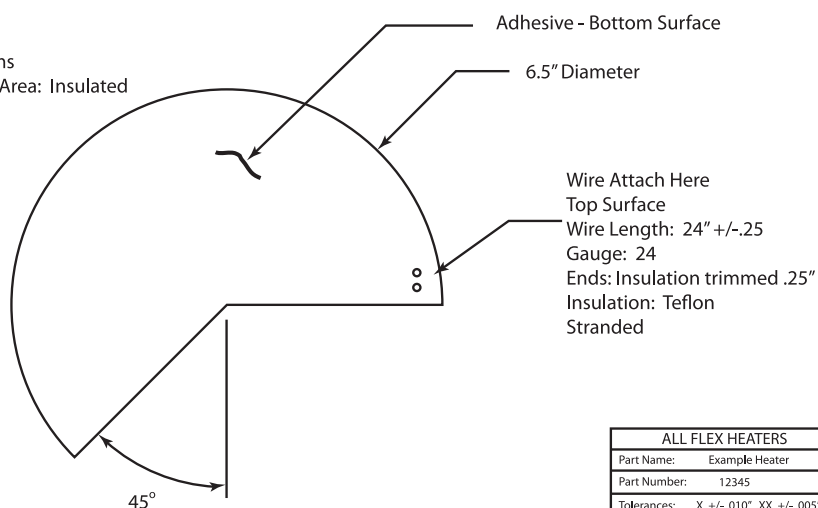
All Flex will need certain basic details in order to manufacture the heater. This information can be provided in a print, CAD file, or DXF file (preferred file format ODB ++). Or if the heater has a basic shape, the information can be supplied in text format.

PRINT EXAMPLE

The All Flex Build-A-Heater on line tool can also be utilized for fast/immediate pricing and order placement.

Notes:

Material: Silicone Rubber
Watts: 24
Voltage: 12
Resistance: 6 ohms
Wire Attachment Area: Insulated

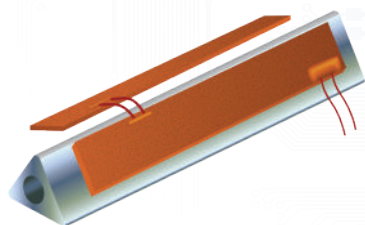


ALL FLEX HEATERS	
Part Name:	Example Heater
Part Number:	12345
Tolerances:	.X +/- .010" .XX +/- .005"
J Davis 04-22-17	Rev 01

SUPPLEMENTAL ITEMS

MOUNTING AN ETCHED FOIL HEATER

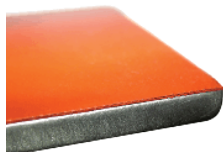
Foil heaters are flexible and can conform to curves, can bend around corners, and can attach to unusual contours. Heaters may be supplied with pressure sensitive adhesive (PSA) on one or more surfaces for this purpose.



For heaters that produce high thermal output, the potential exists that the heat does not extract from the heater into the attached heat sink if the attachment process is not done properly. Ensure there are no air bubbles trapped under the heater which will create an insulating gap, preventing thermal transfer and creating an isolated overheat spot and potential failure.



Silicone rubber heaters require silicone-based PSA's (compared to acrylic) and, as a result, have less strength in bonding to surfaces, particularly curved surfaces with a smaller radius. Therefore, an option to adhere the heater to its mounting surface is to vulcanize the heater to the heat sink. Vulcanizing requires pressure and temperature under an extended time period. All

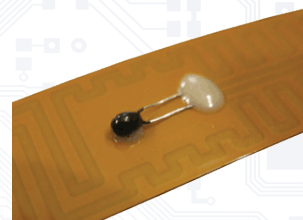


Flex offers this service but customers can also purchase uncured silicone rubber film or paste for this purpose.

Heaters can also be mounted using mechanical methods (bolts, clamps, etc.) without PSA or by compressing the heater between rigid surfaces.

CONTROLS AND SENSING DEVICES

Etched foil flexible heaters are commonly controlled using closed loop control schemes that sense the temperature and feed the data to a microprocessor to introduce fluctuation into the input power.



The controller may simply cease power to the heater when the temperature reaches its peak set point and reinstate power when the temperature reaches the low set point. However, controllers can also introduce modulation of the input power which enables the heater to ramp up and down at different rates as well as leveling power more efficiently. Some applications require more precise control of the heat while others are successful with 100% on/off power pulsation.

Sensors can be used and typically fall into five categories:

- Negative Temperature Coefficient NTC thermistors
- Positive Temperature Coefficient PTC thermistors
- Resistance Temperature Detectors (RTD)
- Thermocouples
- Semiconductor-based sensors

All Flex can integrate these sensors into flexible heaters if customers desire to take readings on the flexible heater surface. Often the sensing takes place elsewhere in the package or on the surface that is being heated.



Closed Loop Controller

Engineers will also introduce safety factors to protect from thermal, current, and voltage overload. A variety of options, such as thermal cut-off devices and thermal fuses, can be chosen for this purpose.

HEAT SPREADING OR DISSIPATION

In some applications, a layer of foil mounted onto one side of a flexible heater can provide needed thermal dissipation or to provide more stable thermal responsiveness. Foils are usually mounted with pressure sensitive adhesive. All Flex can also incorporate thermally-conductive adhesives to further enhance thermal transfer and responsiveness.



MARKING OPTIONS

All Flex can add markings and symbols onto flexible heaters in white permanent ink. We can add UL/CSA notations, part numbers logos, images and other notations that customers desire.



GENERAL TOPICS

FLEXIBLE HEATER RELIABILITY

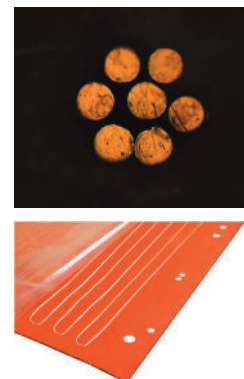
Etched foil heaters are highly reliable components to introduce warming and thermal management into a device or a piece of equipment. They are used in medical, military, industrial, automotive, consumer, instrumentation, and many other application areas. As with any electronic device, the product's reliability is dependent upon following established design rules and practices and in leveraging the experience of experts who deal with flexible heaters daily and have been exposed to wide varieties of applications. All Flex is dedicated to assisting designers and engineers in the application and technical use of flexible heaters as a commitment to having our products perform and last in the marketplace.

In general, four main factors have been shown to contribute to the reliability of flexible etched foil heaters and All Flex will assist customers in implementing good design practices to address these areas.

- Avoiding metallic fatigue in high thermal shock range exposures. This is particularly relevant when rapidly cycling from extremely cold to extremely hot temperatures for long durations. This can often be managed by introducing patterns in the design of the conductive element.
- Ensuring that the interconnections from the heater to other devices are reliable. Potential issues include poor wire attachment, inferior connection of wires, pinched wires, strained joints, faulty component attachment, and input power issues.
- Addressing the potential of thermal burn out. Typically caused by either thermal overage or amperage overload, the resistive foil fractures in isolated areas. Customers are encouraged to perform thorough testing and analysis on their overall thermal management system to identify application-specific performance requirements and to communicate this data to All Flex during the design phase.
- Neutralizing stress of the resistive foil due to repeated and active flexing of the heater in its application. Although the heaters can be flexed and handled, it is not a good practice to utilize flexible heaters in dynamic flex applications, particularly silicone rubber based heaters.

COMMON QUESTIONS AND ANSWERS

What is the difference between etched foil heaters and wire-wound heaters? The core difference is that the heating element itself is comprised of flat foil versus round wire (and usually a cluster of round wire) laid out across the heater body. Etched foil permits very precise and repeatable patterns for consistent results part-to-part.



I am experiencing colder areas around mounting holes and the edges of my aluminum plate. What can be done about this? Using our FEA modeling capabilities we can determine the thermal loss variances and implement adjustments in the heating element pattern to increase heat in selected areas so that the net result is even thermal distribution across the entire surface of your plate.

How hot can an etched foil heater get? Etched foil heaters can generate substantial temperature levels (>300C), yet the limitation is dependent on the ability of the surroundings to absorb the heat created so the bonding layers within the heater do not exceed their mechanical limit. A heater suspended in air will not maintain integrity as well as the same heater mounted to a heat sink which pulls the heat away from the heater.

How do I control the temperature? Etched foil heaters often utilize a closed loop control scheme to manage the temperatures of the system. The controller utilizes a sensing device that provides data representing temperature levels at a location within a package, and by setting the desired upper and lower temperature limits as well as the required rate of temperature rise, the controller will implement pulsating voltage or other limiting variables to raise and lower the resulting thermal output of the heater.

I'm unfamiliar with using a flexible heater and don't know the wattage or performance requirements. How can you help? Determining your wattage requirements can be done using empirical calculations from various sources available on the internet or in typewritten formats. However, accurately determining the wattage for your specific application is best accomplished with experimentation and prototype heaters. All Flex offers quick turn custom heaters, Build-A-Heater on-line heater ordering system, and a sheet of mixed heater sizes/ wattages for experimentation.

GLOSSARY OF TERMS

Build-A-Heater

All Flex's online automated ordering method to quickly specify and purchase custom heaters.

Closed Loop Controls

The generic term used to describe the common method of managing the performance of an etched foil heater. Closed loop control indicates that a sensing device coupled with digital control logic is actively identifying the temperature and is enacting the heater to change, resulting in altering heat rise/decline rates, on/off thresholds, and/or hold limits.

Combination Heaters

A heater that has both a printed circuit board (control logic) layout and a heating pattern in one single heater unit, reducing cost and improving assembly time in certain applications.

Conductor

The generic term for one individual line of the etched foil pattern.

Edge Insulation

The linear distance between the outermost conductor and the cut edge (cutline).

Etched Foil

Starting as a solid metal foil sheet typically between .0005" and .0020" thick, the heating element of an etched foil heater is patterned using a process utilizing UV or laser light exposure, followed by submersion in chemistries that etch away unwanted foil, resulting in a defined pattern.

Maxi-Flex®

All Flex's brand name for extended length and oversized heaters.

Mounting Adhesive

A tape mounted onto an etched foil heater for mounting the heater to a surface. Often the adhesive is a pressure sensitive adhesive (PSA) enabling the heater to be quickly stuck in-place. It is also common to have heaters mechanically held against the mating heat sink to ensure optimal thermal transfer, particularly in high temperature applications or when mounted onto curved surfaces.

Multi-Zone Heaters

Heaters that have two or more areas with differing watt densities within one overall physical heater. The multiple zones can be in segregated areas or interwoven.

Polyimide Heaters

A high performance, thin flexible plastic film with exceptional resistance to temperature extremes, chemical exposure, and dimensional variation while providing excellent electrical properties. Polyimide flexible etched foil heaters can be fabricated with thermosetting acrylic adhesives or adhesiveless bonding agents.

Profiled Heaters

A feature of etched foil heaters is that the pattern of the heating element can be altered and adjusted in order to provide varying thermal outputs in a given area. All Flex offers Finite Element Analysis evaluations to create the customized pattern that can take heat sink mass variances, heat loss factors, and other impact items into account in order to achieve the finished-state thermal pattern desired for the particular application.

PSA

Also known as Pressure Sensitive Adhesive, PSAs are the common 'sticky' adhesives that attach to the rear surface of the heater to enable it to be quickly attached to its mounting surface. Often an acrylic for polyimide heaters and a silicone-based adhesive for silicone rubber heaters.

Resistance

All heaters can be specified and measured as a resistance (Ohms) for ease of inspection and control, although heaters are ultimately defined by their wattage when voltage/current is applied.

Resistive Foil

The conductive metal foil used to create the heating element. Various foil options with differing resistances are used by All Flex to meet the wattage requirements and fabrication capabilities for each heater application.

Silicone Rubber Etched Foil Heaters

Typically re-enforced with fiber strands, silicone rubber heaters are fabricated using sheets of partially cured silicone rubber that are laminated under pressure and high temperatures to encase the heating element within. Although thicker than polyimide heaters, silicone rubber provides water resistance and increased mechanical protection in rugged environments.

Top Dielectric

The layer of insulation on the top side of the etched foil heater - usually on the side of the heater where the wires are attached. Also called "coverlay" or "coverfilm" for polyimide heaters.

Watt Density

The common unit of measure for heaters that enables universal design. Watt density is the overall wattage (power) of the heater divided by the area of the heater. Watt density is commonly measured in Watts/Square Inch, but the area unit of measure can be whatever the user specifies.

Wattage/Power

The unit of measurement for the overall heater performance, regardless of size or area of the heater itself.



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