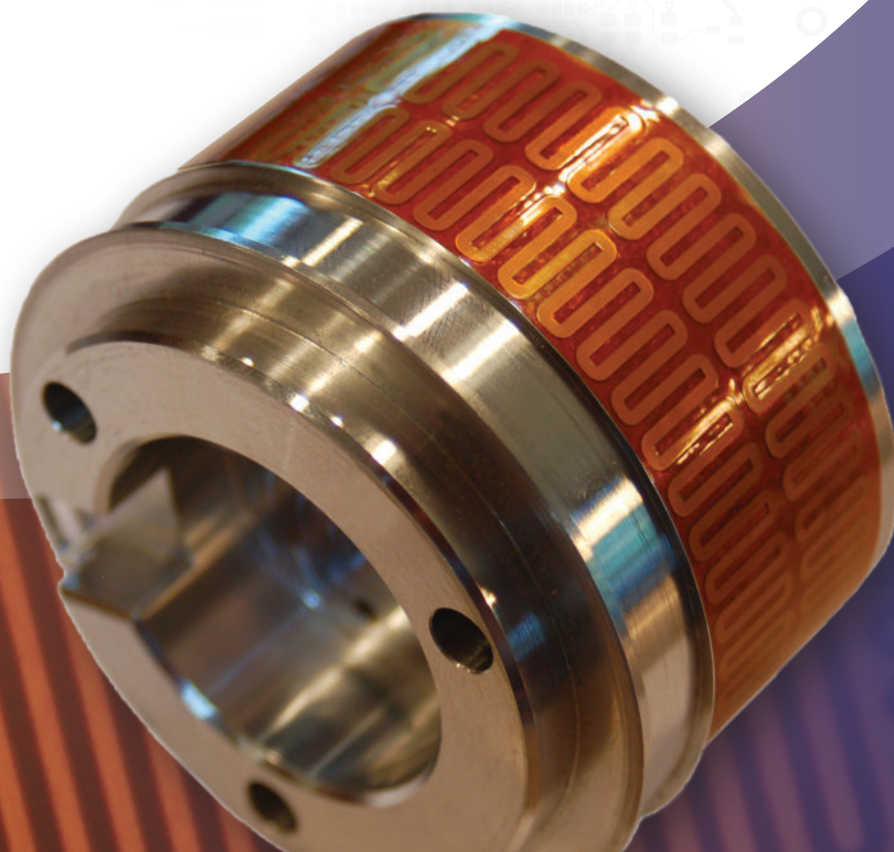
all flex
SOLUTIONS

HEATER DESIGN MANUAL



POLYIMIDE   SILICONE RUBBER   THERMAL SUB-SYSTEMS

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HEATER DESIGN MANUAL

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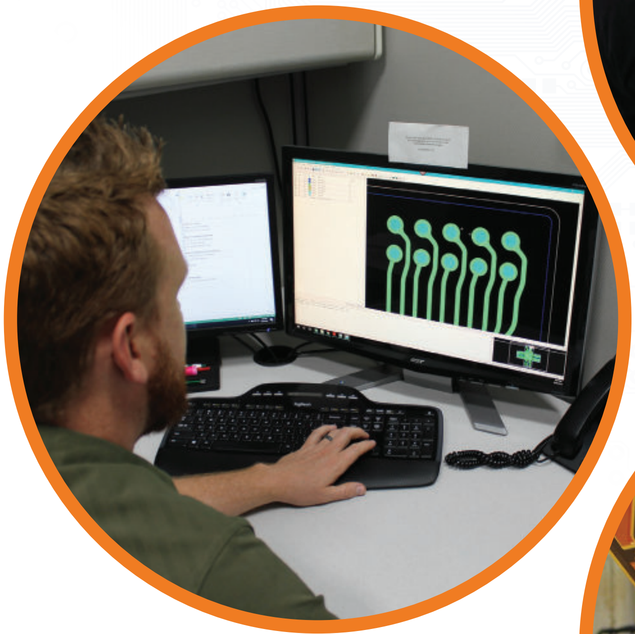
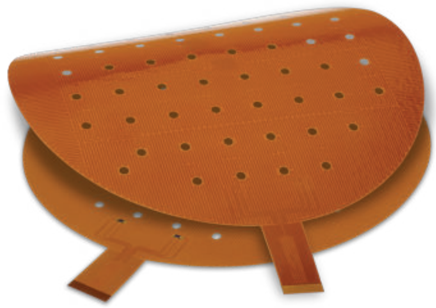
PRESERVE FREEDOM, SAVE LIVES AND CHANGE THE WORLD


MULTISTATION EVO 2S


ETCHED FOIL HEATING TECHNOLOGY: THE BASICS



HEATER - HEATER ELEMENT

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.

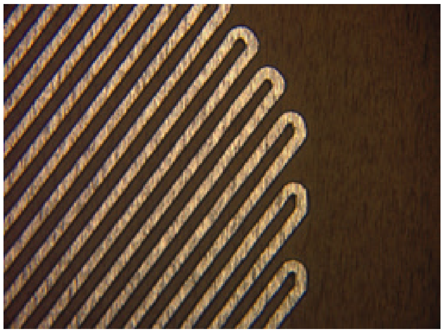
THERMAL EFFICIENCY

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

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.



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).

RELIABILITY FACTORS

Your thermal sub-system reliability is dependent on several key factors. Proper bonding without any air-pockets is the first ingredient to a reliable heater system, All Flex Solutions looks at the following during the design stage:

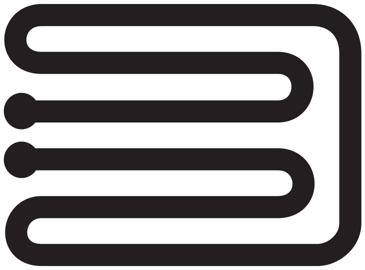
- Dissipation of energy
- Heater coverage
- Material Choice
- Thicknesses
- Temperatures.
- Method of attachment/bonding

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.

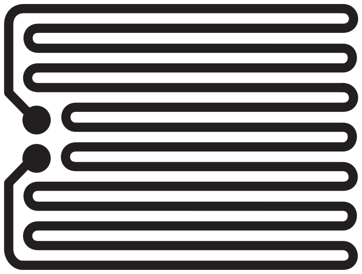
Flexible heaters can deliver hundreds of watts per square inch, provided the heat generated is dissipated quickly away from the flexible heater. Quick dissipation of heat ensures the heater itself never exceeds the mechanical limits of holding itself together (delaminating). It is imperative the foil 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.

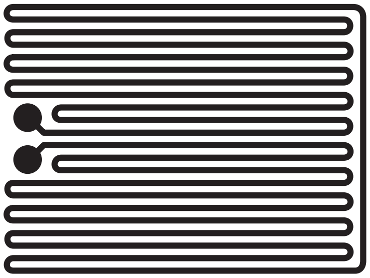
SAME WATTAGE – DIFFERENT VOLTAGES



DESIGN #1:
15 watt / 5 volts / 1.67 ohms / 5 w/in2 / 3 amps



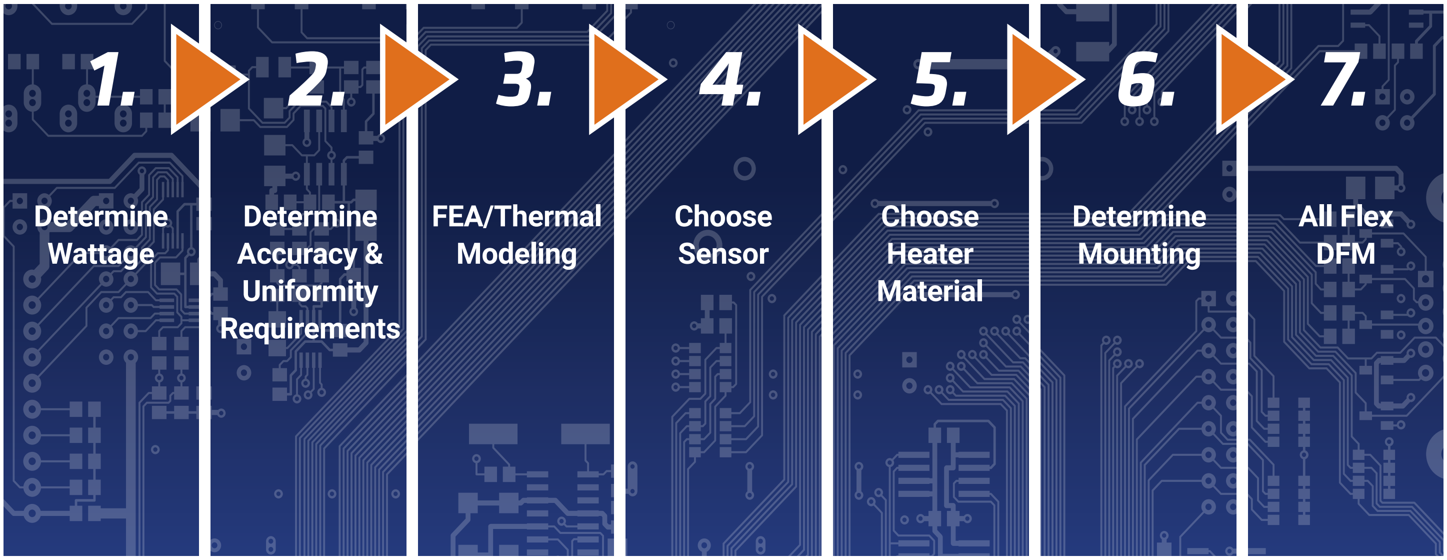
DESIGN #2:
15 watt / 12 volts / 9.60 ohms / 5 w/in2 / 12.5 amps



DESIGN #3:
15 watt / 120 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.

SENSOR GUIDE



SENSORS AND HEATER TYPE

Before selecting a temperature sensor, please check that the construction wil work with the type of heater you will be using. Not all constructions are suitable for SMD type components.

Heater Insulation Type	Thermistor SMD	RTD SMD	Thermistor with Pins	RTD with Pins
Polymide Heater	Yes	Yes	Yes	Yes
Silicone Rubber Heater	No	No	Yes	Yes

COMMERCIAL GRADE NTC THERMISTORS

Commercial Application Low Cost

NTC Thermistor							Interchangeability		
Type	**Mfg.**	**Base Resistance/ Curve**	**Mfg. Part Number**	**Drift**	**Temp Limit**	**Resistance Tolerance**	**0C**	**25C**	**100C**
0402 SMD	Vishay	47K @ 25C 4034 (B25/50)	NTCS0402E3473FXT	±3% after 10,000 hours at 150C	-55C to +150C	±1% of resistance @ 25C	±1.0C	±0.22C	±3.1C
0402 SMD	Vishay	10K @ 25C 3490 (B25/85)	NTC50402E3103FLT	±3% after 100 hours at 125C	-40C to +150C	±1% of resistance @ 25C	±1.0C	±0.26C	±3.6C
0805 SMD	Vishay	10K @ 25C 3940 (B25/85)	NTCS0805E3473FHT	±3% after 100 hours at 125C	-40C to +150C	±1% of resistance @ 25C	±1.0C	±0.26C	±3.6C
0201 SMD	Panasonic	10K @ 25C 3380K (B25/850)	ert-jzeg103fa	±3% after 100 hours at 125C	-40C to +150C	±1% of resistance @ 25C	±1.0C	±0.26C	±3.6C

HIGH ACCURACY NTC THERMISTORS

Medical / Scientific / Analytical High Accuracy, Low Drift

NTC Thermistor							Interchangeability		
Type	Mfg.	Base Resistance/ Curve	Mfg. Part Number	Drift	Temp Limit	Resistance Tolerance	0C	25C	100C
PC Pins	TE Connectivity	10K @ 25C 3976 (B25/50)	GA10K3A1AM	N/A	-40C to +125C	±0.05C between 32 and 44C	See to the left		
PC Pins	Littlefuse	10K @ 25C 3892 (B0/50)	PR103J2	±0.13C after 50K hours at 100C	-55C to +80C	±0.05C between 0 and 50C, ±1.13 @ 100C	±0.05C	±0.05C	NR
0805 SMD	Vishay	100K @ 25C 3590 (B25/85)	NTCS0805E3104SMT	±1.0C after 10K hours at any temp	-40C to +125C	±1% of resistance @ 25C	±0.8C	±0.25C	±1.6C

PLATINUM RTDs

RTD Meets IEC 751							Interchangeability		
Type	Mfg.	Base Resistance/ Curve	Mfg. Part Number	Drift	Temp Limit	Resistance Tolerance	0C	25C	100C
0805 SMD	Heraeus	100 ohms Platinum .00385 TCR	32207605 Est. Cost $2.00	±0.06% after 1,000 hours at 130C	-50C to +130C	±0.12C, Class B @ 0C	±0.3C	±0.4C	±0.8C
0805 SMD	Heraeus	100 ohms Platinum .00385 TCR	32208594 Est. Cost $2.00	±0.06% after 1,000 hours at 170C	-50C to +170C	±0.12C, Class B @ 0C	±0.3C	±0.4C	±0.8C
Pins	Heraeus	100 ohms Platinum .00385 TCR	32207702 Est. Cost $3.00	±0.04% after 1,000 hours at 300C	-50C to +300C	±0.06%, Class A @ 0C	±0.15C	±0.2C	±0.35C

Disclaimer: All information is believed to be accurate from the manufacturer.
Please consult the vendor directly before selecting for your application

	Kapton 105	Kapton 150	Kapton 200	Kapton 260	Rubber
Max Temp with	105C	150C	200C	260C	235C
Min. Thickness	.004”	.004”	.004”	.004”	.018”
Max Watt Density	30	30	50	100	60
Standrd Panel Size	16” x 22”	16” x 22”	16” x 22”	11” x 22”	22” x 34”
Maximize Size	22” x 120”	22” x 120”	22” x 22”	11” x 22”	22” x 120”
Meets NASA Outgassing	No	Yes	Yes	Yes	No
Minimum Standard Bend Radius	.030”	.030”	.030”	.030”	.125”
UL Flame Retrardant	Yes	No	No	Yes	Yes
SMT Component Compatible	Yes	Yes	Yes	Yes	No

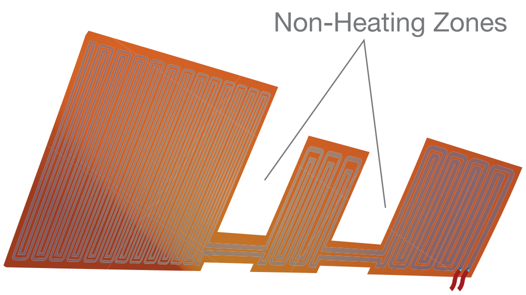
ACHIEVING THERMAL UNIFORMITY IN YOUR THERMAL SYSTEM

OPTIMIZE THERMAL RESULTS

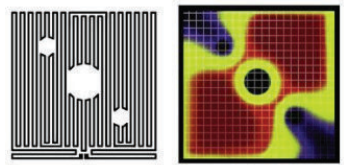
Etched foil heaters are ideally suited to provide differing thermal areas within one heater layout. Foil patterns can be adjusted to compensate for heat loss when the design requires uniform surface temperature throughout. Heat loss factors can include mass variance, airflow, attachment uniformity, and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

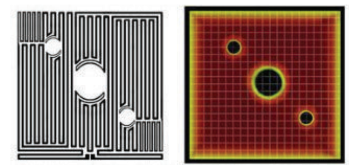
Alternately, All Flex utilized Finite Element Analysis (FEA) tools and expertise to optimize the thermal results in order to produce a uniform thermal pattern of the heat sink. The etched pattern of the heater was modified to increase thermal output in insulated areas surrounding the holes and the edges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



Two approaches, uniform power vs. uniform temporative profiles



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.
- Achieves thermal uniformity

THERMAL SIMULATION TO OPTIMIZE FLEXIBLE HEATER DESIGNS

Application: Using thermal simulations to reduce cost and design to production time.

Most often when designing heaters for new applications the designer knows the desired outputs and has created a 3D model of the application. What is usually unknown is the amount of heat and the optimal heat distribution to meet the desired outputs. Many times, customers will estimate the heat needed and attempt to design their application around an off-the-shelf stock heating option.

When customers are looking for this optimal solution All Flex is able to offer Finite Element Analysis (FEA) to complete a thermal analysis of the application. All Flex will take the model and vary the heating zones and wattage to achieve the desired heat distribution, temperature, and time to temperature. Utilizing this offering can often save money, time and provide you with the best possible solution.To the right are the steps taken when designing flexible heaters. You can see that using FEA greatly diminishes the amount of time necessary to complete a project, which in turn lowers costs and creates a more effiecient product.

Design Process Without Thermal Simulation

1. Establish Goals
2. Design
3. Wait for Parts
4. Test
5. Re-Design
6. Wait for Parts
7. Test

Design Process With Thermal Simulation

1. Establish Goals
2. FEA Thermal Analysis
3. Design
4. Wait for Parts
5. Test

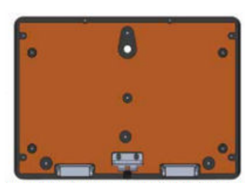


Figure 1: Model of flexible heater on customer supplied heat sink

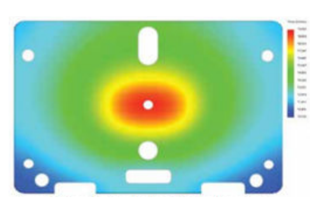


Figure 2: Example of application without uniform heating

Figure 3: Example of application with customized profiled heater

DETERMINING YOUR POWER REQUIREMENTS

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.

ESTIMATING POWER REQUIREMENTS

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 heating.

$$\text{Power (watts)} = \frac{mC_p\,(T_f - T_i)}{t}$$

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
Phoenolic 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.

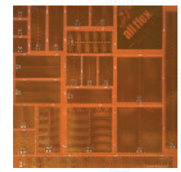
FEA / THERMAL MODELING

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.

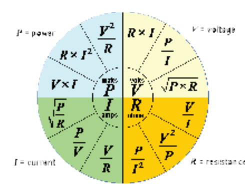
3. Obtain a variable voltage supply with high current capability (10A) such as a Variac.



4. 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.

5. Once you have arrived at what appears to be a suitable thermal result, note the voltage of the Variac.

6. Using Ohm's law, calculate the wattage of the test.



7. 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.

EXPERIMENTATION

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.

all flex Build-A-Heater
QUICK TURN CUSTOM HEATER SOLUTIONS

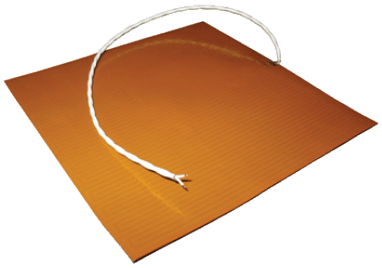
PRODUCT TYPES

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.

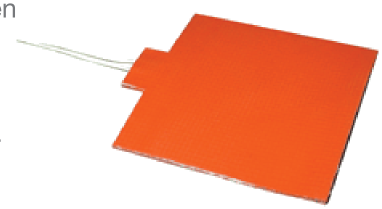
However, in general, All Flex flexible heaters fall into three general categories.

MATERIAL OPTION: POLYIMIDE - TRADITIONAL



Polyimide is the primary dielectric 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 element layer which are bonded together using thermoset adhesive. 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.

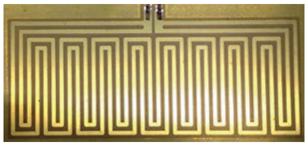
However, SR heaters are less flexible, are not suited for component assembly, are much heavier, and have limits on bonding adhesives for peel and stick attachment.

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. Do not use silicone rubber when outgassing requirements is a factor.

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.

TERMINATION OPTIONS

- Wires
- Surface Mount Connector
- ZIF Connector
- Through Hole Connector

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 limited to 105C.

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

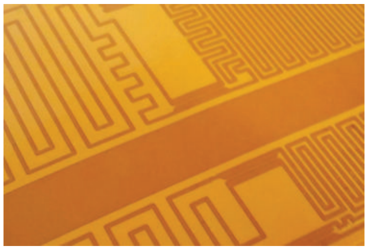
*** Bond data per 3M specification and test protocol. Actual data will vary depending upon application.

MICRO

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

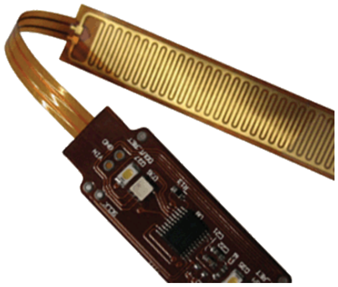
EXTENDED LENGTH / OVERSIZED MAXIFLEX

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



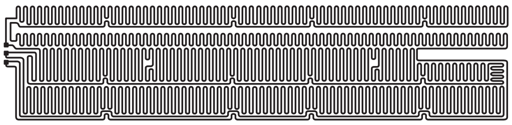
MULTI-ZONE

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



INTEGRATION

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 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 connection mwthod – wire, ZIF, SMT connector Gauge size (by calculating the ampacity rating for the wire), insulation type (primarily for thermal properties), wire location on the heater, the side (fronUback) 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. All Flex can laminate for improved performance and reliability.

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

• Inspection and/or test requirements.

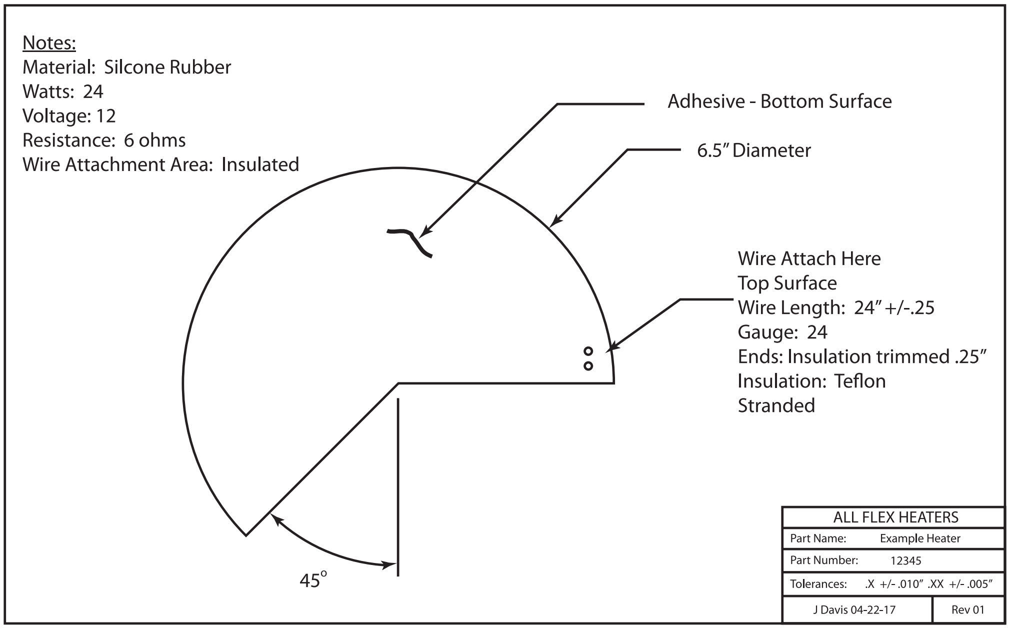
2. SELECT PRODUCT TYPE

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

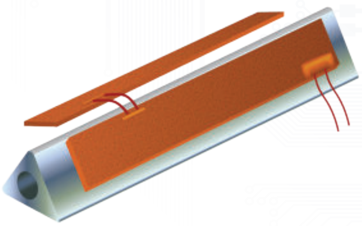
All Flex will need certain basic details in order to manufacture the heater. This information can be provided in a PDF print, CAD file, or DXF file.

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



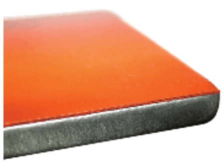
INTEGRATION

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.

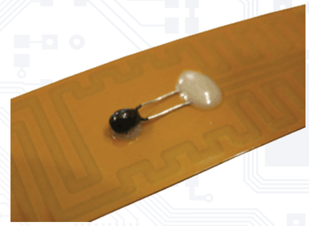
For heaters that produce high thermal output, the potential exists that the heat does not extract from the heater into the attached heat sink if the attachment process is not done properly. Ensure there are no air bubbles trapped under the heater which will create an insulating gap, preventing thermal 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 it 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 NT C thermistors
- Positive Temperature Coefficient PTC thermistors
- Resistance Temperature Detectors (RTD)
- Thermocouples
- Semiconductor-based sensors

Closed Loop Controller

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.

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.

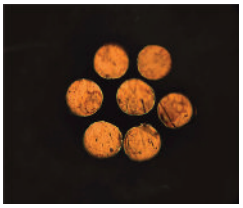
• Avoiding metallic fatigue in high thermal shock range exposures. This is particularly relevant when rapidly cycling from extremely cold to extremely hot temperatures for long durations. This can often be managed by introducing patterns in the design of the conductive element.

• 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.

all flex SOLUTIONS

Flex Circuit Center of Excellence
1705 Cannon Lane
Northfield, MN 55057

Rigid Flex Center of Excellence
1200 W 96th St
Bloomington, MN 55431

Flex Heater & Assembly Center of Excellence
9401 James Ave S Suite #120
Bloomington, MN 55431

(507) 663-7162
www.allflexinc.com

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