

MICROTEMP® Thermal Fuses

Product Information and
Application Notes

G4



Upper Limit Temperature Protection

MICROTEMP®, the original thermal fuse from Therm-O-Disc, was developed in 1965 for jet fuel pumps and is now widely used in heating, appliances, and automotive applications. Therm-O-Disc offers the broadest combination of globally certified temperatures and electrical loads, as well as the broadest range of packages, mountings and design configurations on the market today.

MICROTEMP Features:

- Globally certified temperatures and electrical loads
- One-shot operation cuts off electrical power
- Current interruption capacity up to 25 amps @ 250VAC
- Low resistance
- Compact size
- RoHS compliant

Operating Principle

The active trigger mechanism of the thermal fuse is an exclusively formulated, electrically nonconductive pellet. Under normal operating temperatures, the solid pellet holds spring loaded contacts closed. When a predetermined temperature is reached, the pellet melts, allowing the compression spring to relax. The trip spring then slides the contact away from the lead and the circuit is opened.

After the thermal fuse opens a circuit, the fuse needs to be replaced. This replacement procedure must include correction of the fault condition before the product is operated again.

	G4	G5	Z6	G6	G7	G8	S9
Typical Resistive Rating at 250VAC	10A	20A	16A Higher Tm Than G6	16A More Temperature Ratings Than Z6	5A	25A	15A
Details found on page	3	5	7	See pages 14-15			

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NOTE: The terms *thermal fuse*, *thermal cutoff*, *thermal link*, and *TCO* are synonymous and may be used interchangeably throughout the catalog.

G4 MICROTEMP Thermal Fuses



G4 MICROTEMP - the Original Thermal Fuse

Providing reliable back-up protection for temperature controlling thermostats and other over-temperature conditions, the G4 series MICROTEMP thermal fuse is the industry standard for over-temperature protection. The G4 is rated for continuous operating currents up to 10 amps @ 250VAC.

Benefits

- The industry standard for over-temperature protection
- Available in a wide range of temperatures to offer design flexibility in your application
- Available in mounted and packaged designs

Features

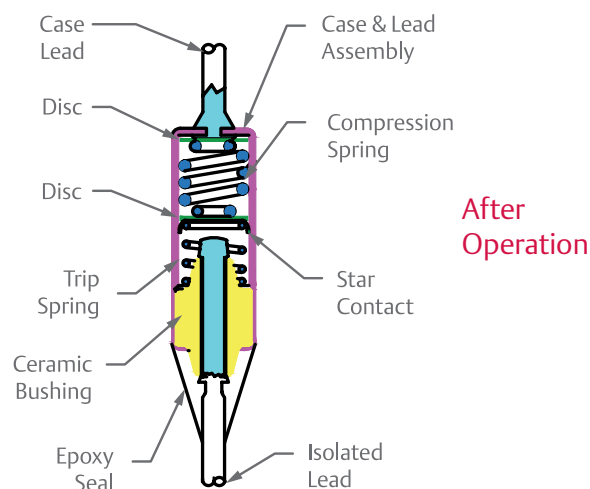
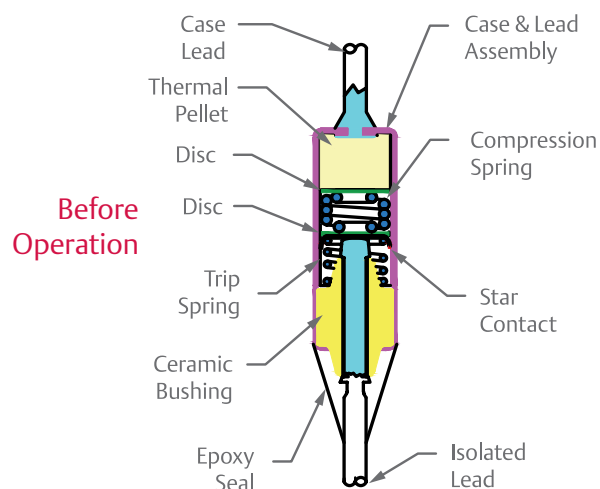
- One shot operation cuts off electrical power
- 10A/250VAC, 15A/120VAC, 5A/24VDC
- Low Resistance
- Compact size

Applications

- Portable Appliance
- Major Appliance
- HVAC
- Power Supplies
- Water Heater
- Other



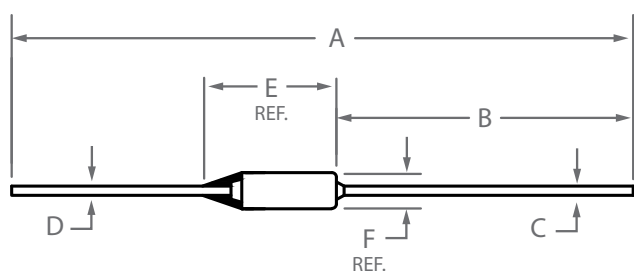
G4 MICROTEMP Product Information



Standard Dimensions

		Standard Leads
A	Overall Length $\pm .12"$ ($\pm 3.0\text{mm}$)*	2.51" (63.8mm)
B	Case Lead Length $\pm .06"$ ($\pm 1.5\text{mm}$)	1.38" (34.9mm)
C	Case Lead Diameter	0.040" (1.0mm)
	Case Lead Material	Tin Plated Copper
D	Isolated Lead Diameter	0.040" (1.0mm)
	Isolated Lead Material	Silver Plated Copper
E/F	Case Dimensions, Including Epoxy	.58" L x .158" D (14.7mm x 4.0mm)

* Overall length available up to 5.83" (148mm)



Electrical Ratings

Agency	Resistive	Inductive
UL/CSA	10A/250VAC 15A/120VAC 5A/24VDC	8A/250VAC 14A/120VAC
VDE	10A/250VAC	8A/250VAC
CCC	10A/250VAC	8A/250VAC
PSE JET	10A/250VAC	
Korea	10A/250VAC	

Operating Temperature Summary

Tf°C	Th°C	Tm°C
072	57	100
073	58	100
077	62	300
084	69	220
091	76	300
093	78	300
098	83	300
104	89	200
110	95	240
117	102	240
121	106	300
128	113	205
134	119	205
141	126	205
144	129	300
152	137	205
158	143	240
167	152	210
172	157	310
184	169	240
190	175	350
192	177	210
205	190	310
216	200	450
229	200	450
240	200	450
257	220	470

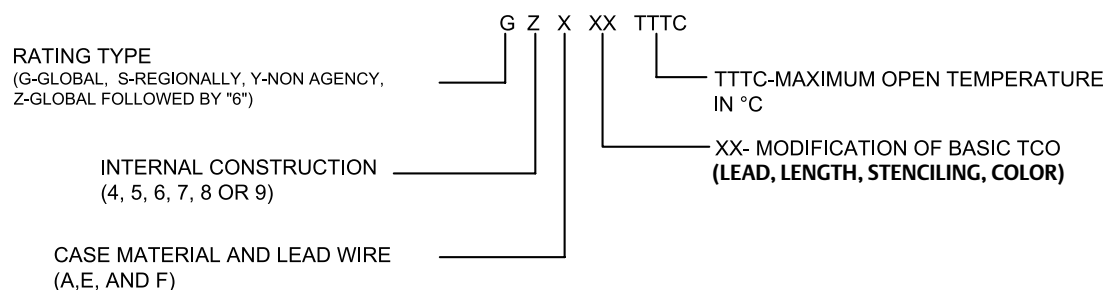
Tf = Functioning open temperature $+0/-5^{\circ}\text{C}$

Th = Maximum temperature of the thermal fuse, measured at the case end, at which the thermal fuse can be maintained for a period of at least 168 hours without opening

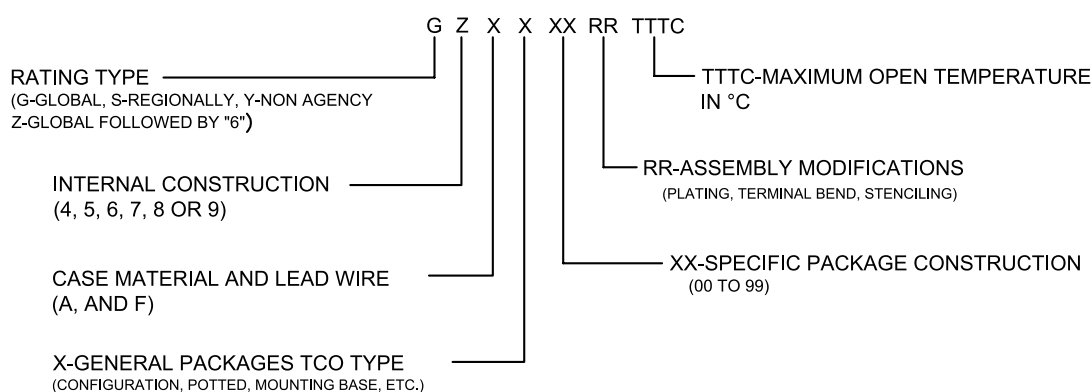
Tm = Maximum overshoot temperature. Temperature up to which the open thermal fuse will not change state

Product Nomenclature

MICROTEMP® THERMAL CUTOFF GLOBAL PRIMARY NUMBERING SYSTEM



MICROTEMP® THERMAL CUTOFF GLOBAL SECONDARY NUMBERING SYSTEM



As shown above, Therm-O-Disc MICROTEMP TCOs follow a consistent product nomenclature that identifies the basic product type, lead wire size, special features and packaging options. For example, a standard G4 series TCO calibrated to open at 192°C would have a part number G4A00192C.

MICROTEMP TCO Product Markings

XXXXXXXX	Special customer identification (when required, up to 9 characters)
MICROTEMP®	Registered trademark
PZZZZ	Manufacturing plant (P); date code
G Z X XX	Primary part number
GZXXXXRR	Secondary part number
T _F TTTC	Maximum open temperature °C
	Underwriters Labs logo

Temperature Ratings

MICROTEMP thermal fuses are available in a wide range of opening temperatures, providing designers a high degree of flexibility. The proper calibration will be affected by application variables such as I²R self heating of the thermal fuse, heat transfer through insulation and heat dissipation due to heat sinking and air flow. Thermocoupled thermal fuse samples, that match the physical and electrical characteristics of a functional thermal fuse, are available to help evaluate application specific variables.

Tf °C	G4A		G5A		G6A		G7F		G8A		Z6A	
	Th °C	Tm °C	Th °C	Tm °C	Th °C	Tm °C	Th °C	Tm °C	Th °C	Tm °C	Th °C	Tm °C
72	57	100	57	410	47	100	-	-	47	410	-	-
73	58	100	58	410	48	100	-	-	48	410	-	-
77	62	300	62	410	62	300	62	125	62	410	-	-
84	69	220	69	220	69	220	69	125	69	220	-	-
91	76	300	76	430	76	300	-	-	-	-	-	-
93	78	300	78	410	-	-	78	140	78	410	-	-
98	83	300	83	410	83	300	83	140	83	410	83	280
104	89	200	89	225	89	200	-	-	89	225	89	260
110	95	240	95	225	-	-	95	140	95	225	-	-
117	102	240	102	410	102	240	102	150	102	410	102	275
121	106	300	106	410	106	300	106	150	106	410	106	380
128	113	205	113	235	113	205	113	150	113	235	-	-
134	119	205	119	410	-	-	119	175	-	-	-	-
141	126	205	126	350	-	-	126	175	-	-	-	-
144	129	300	129	410	129	300	129	175	119	410	134	380
152	137	205	137	410	127	205	137	175	-	-	142	380
158	143	240	143	410	-	-	143	200	-	-	-	-
167	152	210	152	410	-	-	152	200	152	410	157	380
172	157	310	157	410	-	-	157	200	-	-	-	-
184	169	240	169	410	169	210	169	200	169	410	174	380
190	175	350	175	410	-	-	175	270	-	-	-	-
192	177	210	177	350	167	210	177	210	177	350	-	-
205	190	310	190	410	-	-	-	-	-	-	-	-
216	200	450	200	410	-	-	-	-	-	-	-	-
229	200	450	200	410	200	375	-	-	200	410	200	380
240	200	450	200	410	200	450	-	-	200	410	200	380
257	220	470	-	-	-	-	-	-	-	-	-	-

Tf = Functioning open temperature +0/-5°C

Th = Maximum temperature of the thermal fuse, measured at the case end, at which the thermal fuse can be maintained for a period of at least 168 hours without opening

Tm = Maximum overshoot temperature. Temperature up to which the open thermal fuse will not change state

NOTES:

- It is advised that TCOs are not exposed to continuous operating temperatures in excess of T_f -25°C
- Comparative tracking index (all primary TCOs): 250VAC
- G4, G5, G6, G7 and G8 series TCOs with Tf ≥ 175°C comply with UL conductive heat aging (CHAT) requirements.

Electrical Rating Summary

Electrical Current & Voltage Rating

Series	G4		G5	G6	Z6	G7		G8	S9
Agency	Resistive	Inductive	Resistive	Resistive	Resistive	Resistive	Inductive	Resistive	Resistive
UL/CSA	10A/250VAC 15A/120VAC 21A/240VAC ¹ 5A/24VDC	8A/250VAC 14A/120VAC	20A/250VAC 25A/120VAC 21A/240VAC 20A/277VAC	16A/250VAC	16A/250VAC	5A/250VAC 5A/24VDC	4.5A/120VAC ² 4.5A/250VAC ²	20A/277VAC 25A/250VAC	
VDE	10A/250VAC	8A/250VAC	20A/250VAC	16A/250VAC	16A/250VAC	5A/250VAC	4.5A/250VAC	25A/250VAC	
CCC	5A/24VDC 10A/250VAC	8A/250VAC	20A/250VAC	16A/250VAC	16A/250VAC	5A/24VDC 5A/250VAC	4.5A/250VAC	25A/250VAC	
PSE JET ³	10A/250VAC		15A/250VAC	15A/250VAC	16A/250VAC	5A/250VAC		25A/250VAC	15A/250VAC
Korea	10A/250VAC		16A/250VAC			5A/250VAC			

¹ For CSA only

² Except for 184C rating

³ MICROTEMP thermal fuse with primary part number GZX5XTTTC has PSE JET agency approval.

SJET	S4	S7	S9
125C	30A/16VDC		
152C		15A/16VDC	
172C	30A/16VDC		50A/16VDC
240C	30A/16VDC		50A/16VDC

Direct Current (DC) Applications

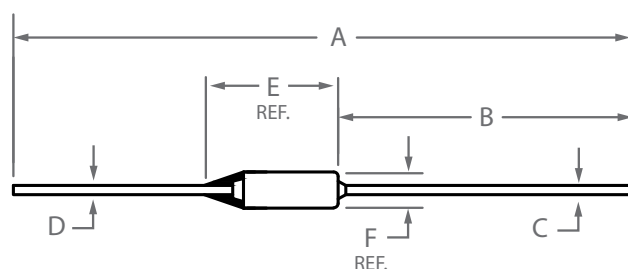
The G4, G7, S4, S7 and S9 series MICROTEMP thermal fuses have published electrical ratings for direct current (DC) applications. Current interruption capacity in DC circuits is highly application sensitive.

Therm-O-Disc recommends thorough testing of DC electrical applications.

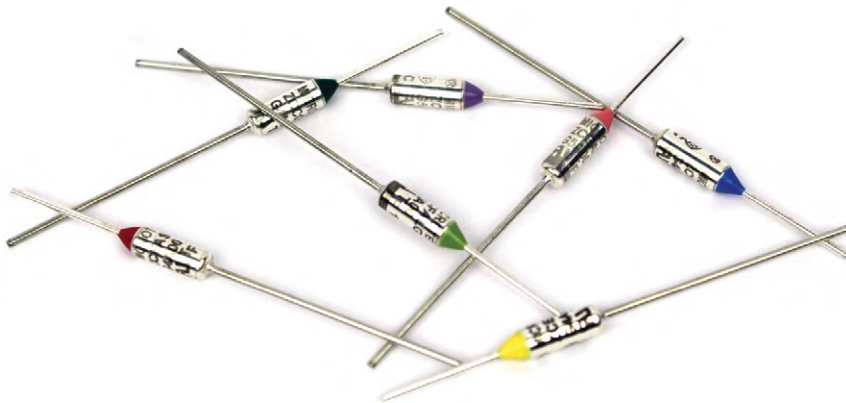
MICROTEMP TCO Standard Dimensions

		Dimensions - Inches (Millimeters)		G4, G5, G6, Z6, G8 Series	G7 Series	S9 Series
Standard Leads	A	Overall Length $\pm .12$ (± 3.0)		2.51 (63.8)*	N/A	2.51 (64.8)
	B	Case Lead Length $\pm .06$ (± 1.5)		1.38 (34.9)	N/A	1.38 (34.9)
Long Leads	A	Overall Length $\pm .12$ (± 3.0)		3.26 (82.9)	3.26 (82.9)	3.26 (82.9)
	B	Case Lead Length $\pm .06$ (± 1.5)		1.38 (34.9)	1.38 (34.9)	1.38 (34.9)
Lead Material & Diameter	C	Case Lead	Tin Plated Copper	0.040 (1.0)	0.023 (.57)	0.057 (1.4)
	D	Isolated Lead	Silver Plated Copper	0.040 (1.0)	0.023 (.57)	0.057 (1.4)
Case Dimensions	E	Case Length (Reference)		0.58 (14.7)	0.38 (9.6)	0.58 (14.7)
	F	Case Diameter (Reference)		0.158 (4.0)	0.118 (3.0)	0.158 (4.0)

*Overall length available up to 5.83" (148mm)



Application of Thermal Fuses



MICROTEMP® thermal cutoffs, available in a variety of standard and custom configurations, provide reliable one-shot, over-temperature protection in a wide range of applications. Performance can be affected by installation method and location of the thermal cutoff. Both application and installation is important in the overall performance of the product, and thorough testing is necessary for both AC and DC applications. The following guidelines will answer most questions concerning these two subjects.

General Considerations

Location

Sufficient time and effort must be used to determine the proper and most desirable location for a thermal fuse. The employment of infrared thermography, or a sufficient number of thermocouples to identify the highest temperature areas in the application during normal operation and fault conditions, should be considered. The location that provides the largest differential between these two conditions is generally most desirable.

Calibration Temperature

It is necessary to select a thermal fuse rating above the maximum temperature experienced by the thermal fuse during normal operation, including expected short-term temperature overshoots. The temperatures experienced by the thermal fuse during normal operation will determine the life expectancy of the thermal fuse. If the thermal fuse rating is too close to the temperature experienced during normal operation (including overshoot temperature after opening of a thermostat, etc.), the probability of a nuisance trip increases. Nuisance trips are caused by pellet shrinkage due to repeated operation at temperatures near but below calibration temperature, or excessive thermal gradients across the case of the TCO and its leads (see Thermal Gradients). The design engineer must make the decision between response and life of the TCO based on product requirements. It is important to remember that temperatures experienced in actual application will vary from unit to unit.

Thermal Gradients

Ideal thermal fuse placement subjects the entire thermal fuse case, leads, epoxy seal and internal components to a uniform temperature environment.

Care should be exercised in the placement of the thermal fuse to minimize thermal gradients across the thermal fuse body. In certain applications, the thermal fuse can be mounted in a position where heat is conducted to the body of the thermal fuse through one of the leads, resulting in thermal gradients across the thermal fuse. Over time, the thermal fuse life can be reduced by thermal gradients if the isolated (epoxy) lead is at a consistently lower temperature than the

case lead. Long term testing is recommended in determining whether these conditions exist in the application.

To minimize the effects of thermal gradients and the temperature increase of the TCO body from this heat flow, attach the isolated (epoxy) lead, rather than the case lead, to the heat source. Thermocoupled fuses can be supplied with the thermocouples on both ends to facilitate gradient evaluations.

Temperature Limits

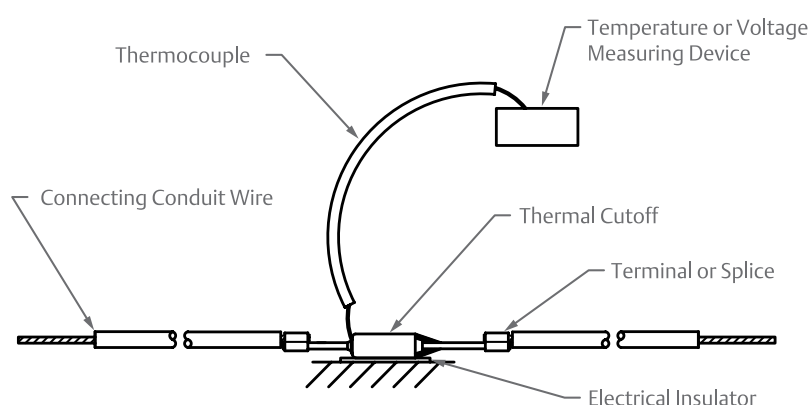
The temperatures experienced during normal operation, including expected temperature overshoots, will determine the life expectancy of the thermal fuse. Nuisance trips can result if the thermal fuse rating is too close to the temperatures experienced during normal operation. Thermal fuses of any temperature rating should not be subjected to continuous normal temperatures in excess of 200°C. Additionally, overshoot temperatures after the opening of the thermal fuse should be minimized to avoid possible dielectric breakdown and re-conduction of the thermal fuse.

Test Procedure

Application of Thermal Fuses

A thermal measurement procedure that utilizes a thermocoupled thermal fuse can assist in determining the appropriate calibration temperature and design location of MICROTEMP™ thermal fuses. The thermocoupled thermal fuse matches the electrical characteristics of the thermal fuse but does not have thermally responsive parts. The thermocoupled thermal fuse is supplied with a thermocouple attached to the case of the thermal fuse (see below). Thermocoupled thermal fuses can be supplied with Type J, Type T, or Type K thermocouples.

Install the thermocoupled thermal fuse in the electrical circuit that is to open in the event of a fault condition. Position it in the area that has been selected to be protected within the product based on prior determinations of the maximum permissible temperatures to be allowed. The thermocouple thermal fuse should be installed using the same mounting and electrical connection that will be used for functional thermal fuses in production. Connect the thermocouple leads to a digital temperature measuring device to record temperatures. The product to be protected can now be operated, and the normal operating temperature monitored. Note that the thermocouple thermal fuse is not a functional thermal fuse and therefore will not open the circuit in the test setup.



The figure above illustrates a typical installation of a thermocouple thermal fuse. Note that the body of the thermocouple thermal fuse is at the same potential as the connecting circuit; therefore, it must be electrically isolated from the surface against which the fuse is mounted. Also note that the thermocouple wire is at the same potential as the connecting circuit.

Installation, Processing and Handling of Thermal Fuses

CAUTION

To avoid a false reading of the unit under test, thermocouple wires must not make contact with each other except at the temperature sensing junction.

CAUTION

Ensure that the thermocouple wire insulation will provide isolation against short circuiting and shock hazards.

CAUTION

The terminal of the temperature measuring instrument, to which the thermocouple is attached, will be at the same potential as the connecting circuit wire. This instrument must be electrically isolated and considerable caution must be exercised in its use, since one of the thermocouple terminals is frequently grounded to the instrument chassis.

Before using measuring equipment powered directly from standard line voltages, check operation manuals. Be sure line voltages impressed on the thermocouple wires by the thermocoupled thermal fuse will not cause damage to the instrument.

Application testing is necessary to select a properly rated thermal fuse. Test factors include, but are not limited to, the heating effect of the current through the fuse, adjoining terminals and leads, heating or cooling effect of the terminals and external leads, rate of temperature rise, air flow, shock, vibration and other environmental and operating conditions unique to the application. The closer the actual operating and ambient conditions can be simulated during test, the more valid the test results will be.

The product and application being tested will determine the number of cycles that must be run to determine the maximum 'normal' operating temperature. 'Overshoot' temperatures should be included in the determination of the maximum 'normal' operating temperature. The overshoot temperature is often considerably higher than the temperature reached at the moment the thermal fuse opens. The conclusion of these tests will provide the maximum 'normal' operating temperature at the thermal fuse (at maximum anticipated voltage, ambient temperature, etc.). The overshoot temperature seen by the thermal fuse after the thermal fuse opens in the application must also be carefully examined and compared to overshoot temperature T_m .

Manufacturing tolerances and variations should be carefully considered, and a sufficient number of units evaluated, to provide statistical basis on which to determine the operating overshoot temperatures.

After obtaining the above information, test the product under fault conditions and monitor to determine that desired fault condition temperatures are not exceeded.

Where there are a variety of fault conditions, (eg, short-circuited thermostats and transform secondaries, locked motor rotors and solenoids, high ambient temperatures, restricted or blocked airflow, etc), consideration should be given to multiple fault conditions which could occur simultaneously during the lifetime of the product, and to faults which may cause localized overheating in areas away from the thermal fuse.

When the fault conditions have been set up, note the temperature of the thermocoupled fuses when the maximum desired temperature limit is reached. At this point the circuit is manually interrupted. This test should be run several times, in several different units. In some applications, it will not be possible to 'save' the tested item from damage, but only prevent the product from creating an external fire or electrical hazard. Damaged products should not be retest-

ed, since the results may not be the same as with undamaged units. The thermal fuse T_f selected should be equal to or less than the temperature recorded at the thermal fuse at the time the maximum desired temperature is reached.

⚠ CAUTION

Excessive overshoot temperature after the opening of the thermal fuse may cause dielectric breakdown of the thermal fuse and allow reconnection to occur. Functional thermal fuses should be tested to verify proper operation of the thermal fuses in the application (see MICROTEMP Thermal Fuse Operating Temperature Summary and Electrical Rating Summary on page 14).

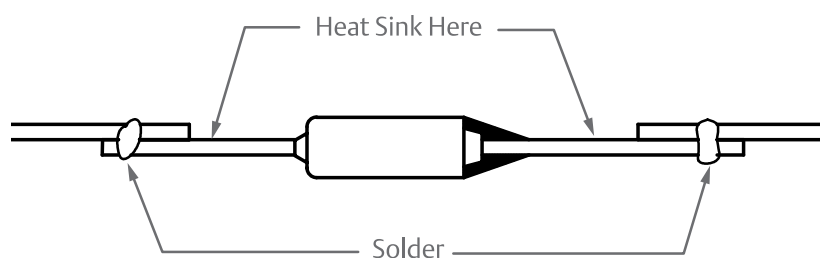


Substitute actual thermal fuses in a sufficient number of finished products and re-run the tests to obtain statistical verification of the results. For multiple thermal fuse applications, test functional thermal fuses under fault conditions so that the product overheats and each thermal fuse is independently called upon to interrupt the flow of current. Each thermal fuse should open the circuit independently of any other over-temperature limit controls, with product damage not exceeding an acceptable level. This test should be run using the maximum voltage and current the thermal fuse will be expected to interrupt and hold open.

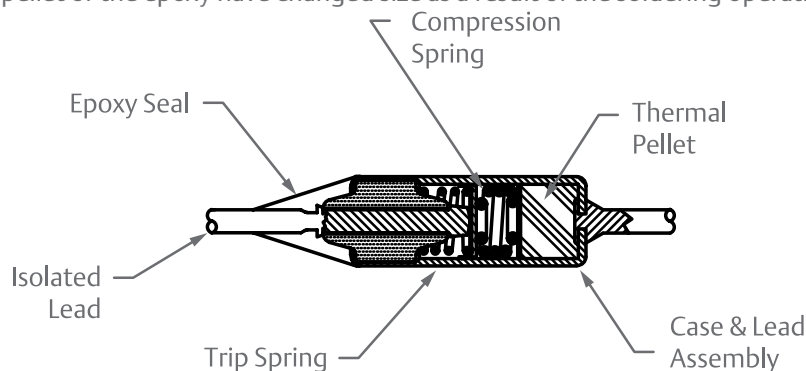
The performance of a MICROTEMP thermal cutoff can be affected by installation methods such as soldering, welding, splicing, lead bending, insulation, clamping and mounting. Certain precautions should be taken during installation to ensure that the MICROTEMP thermal cutoff is not damaged, which may cause it to not operate in its intended manner. Likewise, care should be taken during installation to ensure that the TCO in every unit experiences the expected temperature range environment previously determined during the calibration temperature selection. The following guidelines should be used to minimize undesirable conditions that can result from improper installation practices.

Soldering Leads

Thermal fuse leads should be heat-sinked during the soldering operation (see below). If excessive heat is conducted by the leads into the thermal fuse, it can shorten the life of the thermal fuse. In addition, excessive lead temperatures can damage the epoxy and possibly result in the thermal fuse failing to open. More heat-sinking is necessary for thermal fuses with lower T_f temperatures.

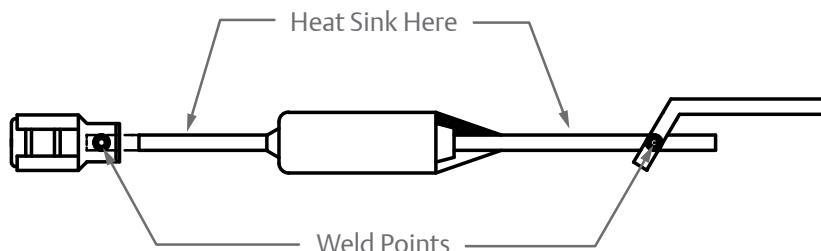


Test samples should be x-rayed before and after the soldering operation. The size of the pellet should be measured to verify that no shrinkage has occurred during the soldering operation. The epoxy seal should retain its size and shape and not discolor. If the pellet or the epoxy have changed size as a result of the soldering operation more heat sinking is required.



Welding Leads

The thermal fuse leads may also need to be heat sunk during a welding operation. The same precautions and tests described in the soldering section should be followed for welding leads.

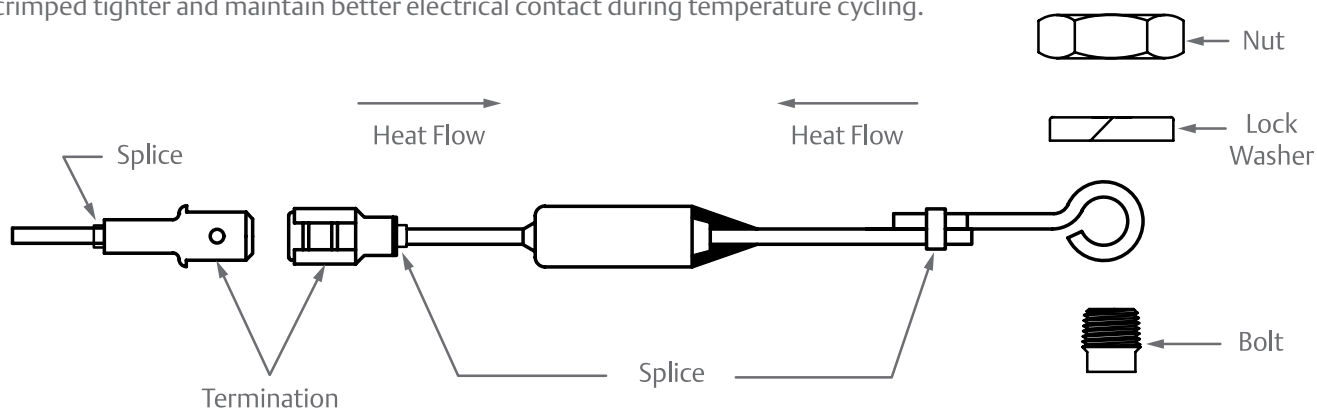


To avoid damaging or welding internal parts, care should be taken that none of the welding current is conducted through the thermal fuse. A welding current of hundreds of amperes can weld the internal parts together, resulting in the thermal fuse failing to open.

Thermal fuse leads must be supported during the weld operation to prevent damaging the thermal fuse epoxy seal.

Splices and Terminations

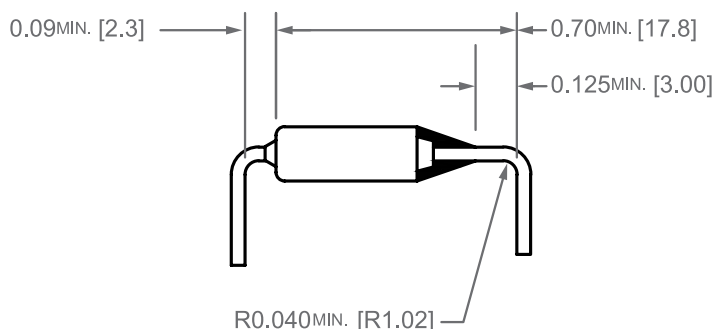
Insecure splices and terminations may produce high resistance junctions which can cause self-heating (I^2R) as power is dissipated across these junctions during product operation. Heat from these areas can flow down the thermal fuse leads and increase the temperature of the thermal fuse. Nuisance openings of the thermal fuse or degradation of the epoxy seal can occur as a result of the heat generated by high resistance junctions. The splice or termination junction may initially measure low resistance, but can change to a much higher resistance after several temperature cycles. It is generally better to splice thermal fuse leads to stranded lead wires rather than solid wires as the stranded wire may be crimped tighter and maintain better electrical contact during temperature cycling.



The temperature capabilities of the splice and/or termination should be considered. For example, solder back-up should be considered for splices of solid wires, and terminations in applications cycled at temperatures exceeding 150°C.

Bending Leads

When configuring leads, special care must be exercised in supporting the leads at each end near the body of the thermal fuse so that the case will not be distorted or the epoxy will not be cracked or broken. At least 0.125" (3mm) should be maintained between the epoxy seal and any lead bends.



CAUTION

The thermal fuse may fail to open the electrical circuit under certain conditions. Distortion of the case, breaking or cracking the seal, exposing the epoxy seal to cleaning solvents, compression of the leads and current surges that exceed the operating specifications of the thermal fuse may cause the thermal fuse not to open. In addition, pellet shrinkage due to thermal aging under some circumstances may also result in failure to open. Finally, a very low rate of temperature rise may produce conditions that may also result in failure to open. Care must be taken to avoid any mishandling or misapplication of the thermal fuse.

CAUTION

Although thermal fuses are highly reliable devices, a thermal fuse may fail to open for one or more of the reasons set forth above. These conditions must be taken into account by the product design engineer in determining the level of reliability needed for the application. If failure of the thermal fuse to open could result in personal injury or property damage, the product design engineer may want to consider using one or more redundant thermal fuses of different ratings to achieve the desired level of reliability. A number of consumer product design engineers have incorporated redundant thermal fuses of different ratings in their designs for this reason.

Samples and Quotations

Thermocoupled thermal fuse samples and thermal fuse samples are readily available for determining the correct response and desired performance in an application. Contact your nearest Therm-O-Disc sales office for more information.



Definition of Terms

Maximum Open Temperature or Rated Functioning Temperature (Tf or TF)

The maximum temperature at which the thermal fuse changes its state of conductivity to open circuit with detection current as the only load. The rated functioning temperature is measured during a temperature rise of approximately 0.5°C per minute.

Holding Temperature (Th or TH)

The maximum temperature of the thermal fuse, measured at the case end of the thermal fuse, at which the thermal fuse can be maintained for a period of 168 hours without opening. NOTE: It is advised that thermal fuses are not exposed to continuous operating temperatures in excess of Tf-25°C.

Maximum Overshoot Temperature or Maximum Temperature Limit (Tm or TM):

The maximum temperature at which the thermal fuse, having changed its state of conductivity, can be maintained at twice rated voltage for a specified period of time, during which its mechanical and electrical properties will not be impaired.

Rated Voltage

The maximum voltage that can be applied to the circuit in which the thermal fuse is used.

Rated Current

The maximum current that the thermal fuse is rated to interrupt at the rated voltage.

Thermal Fuse, Thermal Cutoff, Thermal Link, and TCO

All are synonymous and may be used interchangeably throughout the catalog.

Agency Recognition

MICROTEMP™ thermal fuses are recognized by the following major agencies



UL
Underwriters
Laboratories Inc.
(USA)



BEAB
British
Electrotechnical
Approvals Board



METI
Ministry of
Economy, Trade
and Industry of
Japan



CSA
Canadian
Standards
Association



China
Compulsory
Certificate
Certification



VDE
Verband
Deutscher
Elektrotechniker e.V.
(F. R. G.)

MICROTEMP™ thermal fuses are recognized by the major approval agencies throughout the world for AC circuit applications. These agency electrical ratings can be used as a guideline when evaluating specific thermal fuse applications. However, the electrical and thermal conditions to which the thermal fuse may be exposed in an application may differ significantly from agency test conditions. Accordingly, customers should not rely solely on agency ratings but rather must perform adequate testing on the particular application to confirm that the thermal fuse selected is appropriate for that application and will operate as intended.

Important Notice

Users must determine the suitability of the thermal fuse for their application, including the level of reliability required, and are solely responsible for the function of the end-use product.

These thermal fuses contain exposed electrical components and are not intended to withstand exposure to water or other environmental contaminants which can compromise insulating components. Such exposure may result in insulation breakdown and accompanying localized electrical heating.

A thermal fuse may remain permanently closed or open as a result of exposure to excessive mechanical, electrical, thermal or environmental conditions or at normal end-of-life. Failure to control the operation could result in personal injury or property damage. The user should incorporate supplemental system control features to achieve the desired level of reliability and safety. For example, backup temperature limiting devices have been incorporated in a number of applications for this reason.