THERMOELECTRIC MODULES - DESIGN NOTES

Thermoelectric modules are compact and reliable solid state heat pumps which can be precisely controlled by varying the input power. Modules are produced in a wide range of sizes offering different combinations of both input currents and voltages so that a particular heat extraction requirement can be matched to various power inputs.

In order to select a thermoelectric module, the following system parameters must be known:

T_c Cold surface temperature
T_h Hot surface temperature
Q_c Amount of heat absorbed at the cold surface to maintain T_c

The working surface temperature of the hot side of the module (T_h) is determined by two major parameters:

1. The temperature of the ambient environment to which the heat is rejected.
2. The efficiency and mode of heat exchange between the hot side of the module and ambient e.g. water cooled, natural convection or forced air heat sinks.

To provide a practical example, the hot side temperature T_h may be 10°C to 15°C above ambient from a finned heat sink but may be only a few degrees above the temperature of the water passing through a water cooled heat sink.

The difference between T_h and T_c (ΔT) can thus be used in graphs to determine the heat pumped (Q_c) by a module at different working currents. It should be noted that the efficiency of the heat sink will determine the maximum current (I) that can be used. e.g. A module mounted on a water cooled heat sink will continue to increase in pumping up to its maximum stated current (I) whereas a similar module mounted on a natural convection finned sink might optimise at only 66% of its maximum current.

In estimating the total heat to be pumped by the module; radiation ,. conduction from leads and thermal shunts due to clamping are some of the factors that must be considered.

Heat rejected at the hot side (Q_h) will therefore be the total of these cold side loads plus the electrical power input to the module (V x I).

Coefficient of performance, (COP) = $\frac{Qc}{V \times I}$ in its maximum case means minimum input power and minimum heat to be rejected by the heat exchanger but would necessitate a larger module compliment.

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The DC input power used should be smooth (10-12% ripple) or the AC component will be a detrimental factor.

Degradation due to ripple is approximated to:

$$\frac{\Delta t}{\Delta t\ max} = \frac{1}{1+N^2}$$ where N is the percentage ripple.

Temperature control either in an on/off or proportional mode can be used to vary the DC input to the module.

Single stage thermoelectric devices are capable of producing temperature differentials of about 70ºC with no load (ΔT max). This can be extended by cascading or stacking one module on top of another usually in a power ratio of 3:1 or more. The design of such a composite device is very complex and requires specially modified modules for the bottom stage of a simple set up or a fully built up composite device with soldered interfaces.

Great care should always be taken to ensure that any side of the device does not exceed our stated maximum temperature (85ºC) or permanent damage may result. e.g. in water cooled systems a thermal cut off must be provided to protect against water failure. In cases where the current is reversed for heating or defrosting the same applies as the cold side assembly will usually be of a smaller thermal mass than the hot side heat sink and could therefore quickly overheat if there is no temperature limitation.

Thermo Electric Devices

Thermoelectric Cooling Modules

APPLICATION NOTES

Technical Data Sheet

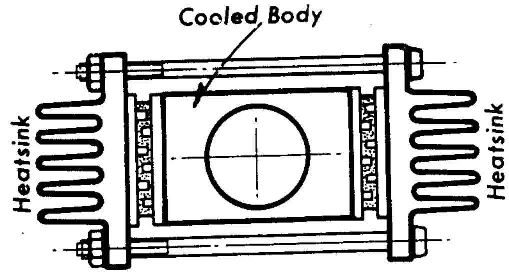
1. For clamped assemblies contact surfaces must be machined flat, preferably a lapped finish. Fixing screws should be of a low thermal conductivity e.g. thermal insulating washers under screw heads. Belleville washers or springs will prevent rigid clamping and screws should be tightened up in small increments to about 10lbs of torque per square inch of module area.

2. For tinned modules the heat transfer surfaces must be solderable and pre-tinned with indium/tin eutectic solder (MP 118°C). During soldering the temperature must be limited to an absolute maximum of 130 deg C. If more than one module is used in an assembly where hot sides are soldered, the cold faces should be faced to a common cold plate while the soldering operation is being carried out.

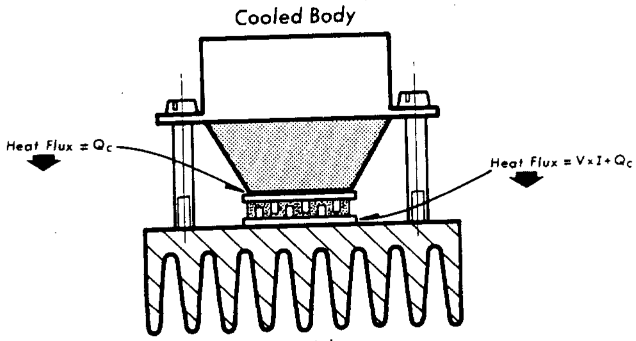
3. If two or more modules in a clamped assembly are used with common hardware they must be matched for thickness of at least 0.001 inches. If more than two are used it would be prudent to split either the hot or the cold side heat exchangers.

4. Lead wires are attached with bismuth/tin solder (MP 136°C) and should on no account be unsoldered or permanent damage will result.

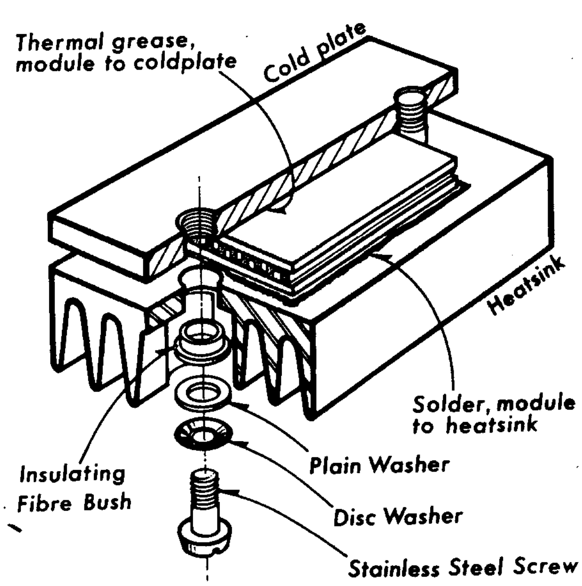
5. In any thermoelectric system, great attention should be paid to heat sink design and quality due to the relative high heat flux density at the hot side surface. e.g. . a CP1.4-127-045L module working at about half the maximum temperature difference and two thirds current would reject 100w approx. into the heat sink over an area of only 40mm x 40mm.



HOT side to HOT side clamping



Platforming on COLD side to increase the distance between hot and cold faces



Soldered, Greased, and Clamped Assembly

Thermo Electric Devices

Thermoelectric Cooling Modules

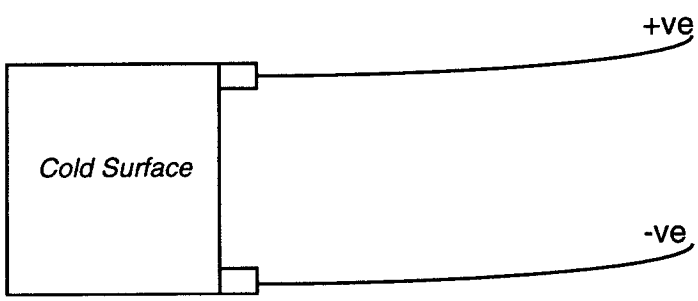
IDENTIFICATION OF HOT SIDE

Technical Data Sheet

The module leads are a thermal load on the device as heat is conducted along these in either direction. The leads are therefore connected to what is the hot side of the module when powered according to the colour coding on the leads.

If the current is reversed the module pumps heat in the opposite direction and the cold side becomes the side to which the leads are attached. It is therefore preferable to operate the module in cooling mode by passing the current in accordance with the lead colours.

Identification of the hot side on the larger modules is quite easy as the connection points are clearly visible. In order to establish the hot side on some of the smaller devices this can be achieved by following the instructions below.



Place the module on a flat surface with the leads positioned as opposite. The cold side is the uppermost surface.

RELIABILITY OF THERMOELECTRIC MODULES

Due to their solid state construction thermoelectric cooling modules are extremely reliable. Although reliability is somewhat application dependent, MTBF's calculated as a result of tests performed by various customers are of the order of 200,000 to 300,000 hours at room temperature. The very rare failures tend to be caused by high resistance or mechanical fracturing. Historical failure analysis has generally shown failures due to either:

1. Mechanical damage due to improper handling or assembly procedures.
2. Overheating due to poor hot side contact, heat sink failure or operation above limits.

As with other types of solder junctions, failures occur more often at elevated temperatures. Internal solders used are bismuth/tin (MP 136ºC).

Whereas TEC's can be used at temperatures in excess of the recommended 85ºC maximum; no guarantees as to their reliability or lifetime in any specific application can be given, as this is very much application dependent.

In order to maximise reliability the combination of correct handling, assembly techniques and low operating temperatures are desirable.

SHOCK AND VIBRATION

Thermoelectric modules used in military and aerospace applications have been successfully subjected to shock and vibration in aircraft, ship, ordinance and space systems.

While a thermoelectric device due to its complicated construction can easily be damaged by incorrect handling it is relatively robust when used in a clamped or soldered assembly. However, care should be taken in an environment of severe shock or vibration in the design of the hardware to ensure the correct compressive loading of the device.

Care should be taken in humid environments to ensure that moisture does not penetrate into the thermoelectric module area. A proper sealing method or dry atmosphere can eliminate these problems.

Based on overall field experience of our end users in systems, we can assume a conservative MTBF of 100,000 hours when operation and storage temperatures are limited to 80ºC.

Temperature cycling either by on/off or polarity reversal for cooling/heating modes has a negligible effect on inherent reliability .