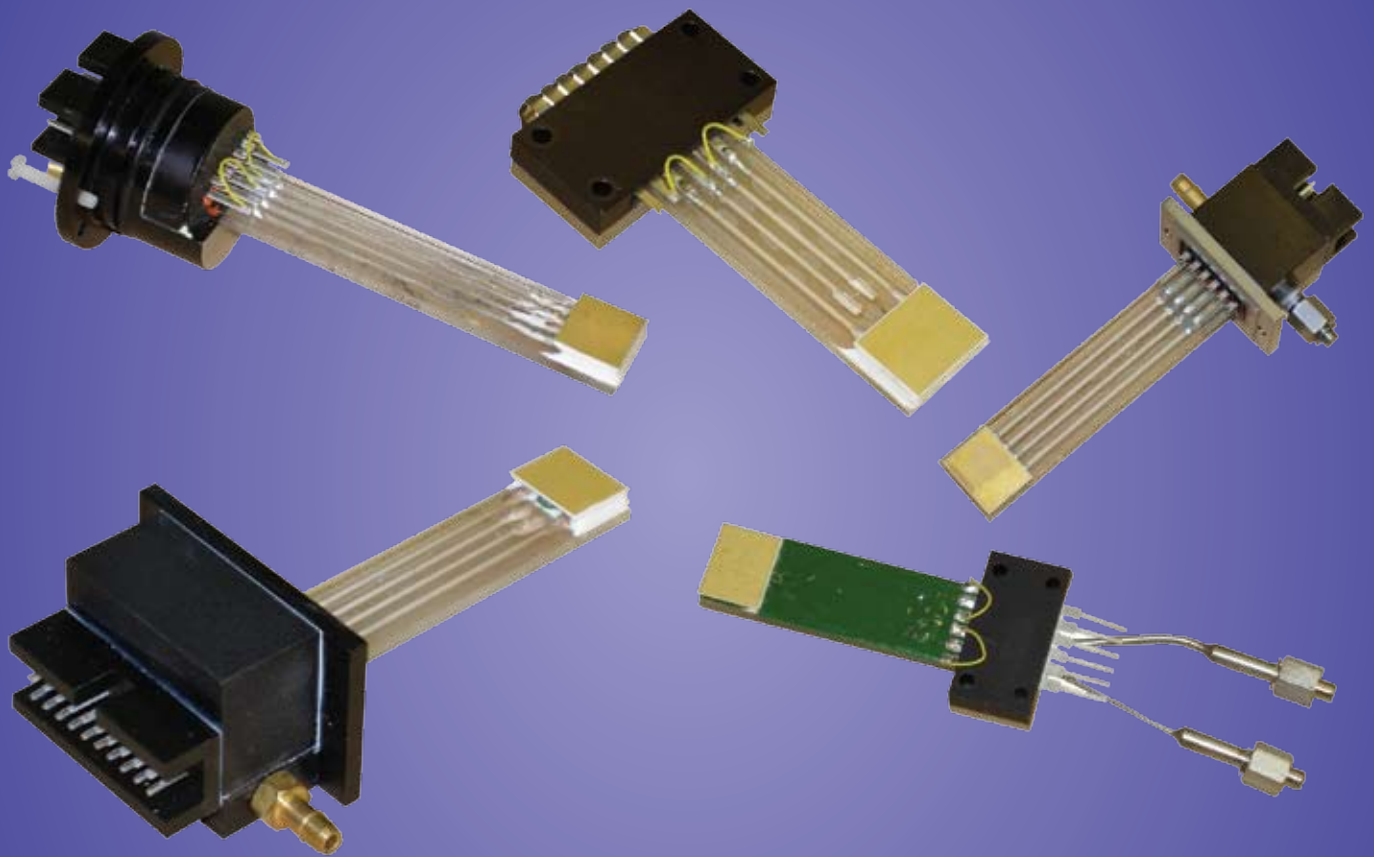


VARIABLE TEMPERATURE CONTROL WITH JOULE-THOMSON TEMPERATURE STAGES



*... the experts in variable temperature solid state
characterization!*

MMR

MMR Technologies, Inc

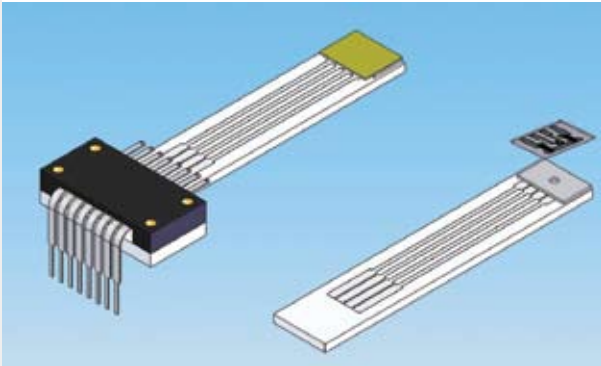
The Joule-Thomson Effect

When a non-ideal gas expands from a high pressure to a low pressure, there is a temperature change even though no other work is being done by the gas. This is the Joule-Thomson expansion of gas. The ratio of the temperature change to the pressure change is known as the Joule-Thomson Coefficient. When this ratio is positive, a drop in pressure results in a drop in temperature. At MMR Technologies, this principle; the expansion of compressed gas to atmospheric pressure generating liquid cryogen, is utilized in the microminiature refrigerator.

High pressure gas (blue arrow) enters the heat exchanger at approximately 1800 psig. The gas passes through capillary channels and undergoes two pressure drops (red circle and black circle) in short succession resulting in an overall temperature drop of 15 to 20 degrees. Roughly 80% of this precooled gas follows a second set of capillary channels out of the microminiature refrigerator, pre-cooling the new incoming gas. Repeated cycles of gas coming in, pre-cooling of the incoming gas by the outgoing, and the pressure drops results in liquefaction (blue circle) of the incoming gas when the thermal stage is under vacuum. The gas exits the thermal stage at less than 10 psig in pressure (red arrow).



Joule-Thomson Thermal Stages



Joule-Thomson Thermal Stages come in three basic temperature configurations: room temperature only, hot stages, or combination cold and hot stages designed for operation over extended temperature ranges. The basic construction of a thermal stage is the same, regardless of the temperature range or the specific instrument. The stage material is either a special laminated glass plate constructed with micro channels for cooling or it is a ceramic stage for room temperature or hot stage applications. One one end of the microminiature refrigerator, a connector is mounted which is unique to each specific instrument. The connector also contains electrical leads and gas connections necessary for the operation of the thermal stage. At the other end of the stage is a sample mounting pad. Heating is provided by a small resistive heater mounted beneath the stage. Leads from the

temperature sensors run from beneath the mounting pad to the connector.

Within the combination heating and cooling thermal stages, there are two types; thermal stages capable of temperatures down to 80K and thermal stages capable of temperatures down to 70K, which requires using nitrogen gas. The second type of thermal stage requires a vacuum assist at the refrigerator port to obtain temperatures below 80K.

A Typical Microminiature Thermal Stage System

A typical variable temperature Joule-Thomson thermal control system includes:

- ◆ High purity high-pressure gas (typically nitrogen or argon)
- ◆ A filter/dryer apparatus
- ◆ The thermal stage
- ◆ A temperature controller
- ◆ A vacuum chamber
- ◆ High pressure gas line tubing

Available Temperature Ranges on Thermal Stages

When a system is held under a vacuum pressure of at least 8 milliTorr, the following temperature ranges are available on the MMR Technologies' instruments:

- ◆ Room Temperature
- ◆ 70K to 580K*
- ◆ 80K to 580K
- ◆ 70K to 730K*
- ◆ 80K to 730K
- ◆ Room temperature to 730K

* Vacuum assist Joule-Thomson thermal stages require an auxiliary vacuum pump at the thermal stage gas exhaust. These thermal stages are not available on ultra high vacuum or scanning electron microscope systems.

When a thermal stage is used within an ambient pressure setup, with a well controlled atmosphere, as in atomic force microscopy, the following temperature ranges** are available using the appropriate thermal stage setup:

- ◆ -10 °C to 200 °C (using nitrogen gas) or -30 °C to 200 °C (using argon gas)
- ◆ -10 °C to 350 °C (using nitrogen gas) or -30 °C to 350 °C (using argon gas)
- ◆ Room temperature to 350 °C

** These are the maximum temperature ranges under ideal conditions like a glove box where there is no humidity and a dry, clean gas environment.



Specifications for Joule-Thomson Thermal Stages***

Operating Temperature Range:	Available between 70K and 730K
Minimum Temperature with no heat load:	80K with a nitrogen pressure of 1800 psi and 5 milliTorr vacuum 70K with vacuum assist at stage exhaust on "70K" thermal stages
Temperature Accuracy:	< 0.5K at 80K; +/- 0.5K between 80K and 400K; < 1.5K from 400K to 730K
Temperature Stability:	+/- 0.05K
Cooling Capacity:	250mW at 85K (nitrogen gas); 500mW at 95K (argon gas)
Maximum Cooling Rate:	No load cool down time from 300K to 80K in less than 20 minutes No load cool down time from 730K to 300K in less than 20 minutes
Maximum Heating Rate:	15 K/minute No load warm-up time from 80K to 300K is less than 5 minutes. No load warm-up time from 300K to 730K is less than 5 minutes.
Additional Power Supply Required:	Only on stages that go up to 730K
Temperature Sensor:	Platinum Resistance Thermometer
Sample Mounting Surface Size:	10 mm x 12 mm
Maximum Sample Weight Allowed:	No more than 5 grams
Sample Stage Material:	Aluminum Oxide
Thermal Stage Dimensions:	Approximately 35 mm x 100 mm (dependent on thermal stage model)
Weight of Thermal Stage:	Between 10 gram and 60 grams, depending on the model
Temperature Controller Requirements:	K-20 Programmable Temperature Controller
Filter/Dryer Requirements:	Either the standard filter dryer or the reversible filter dryer system
Gas Requirements:	99.998% Pre-Purified Nitrogen or Argon Gas of at least 1800 psi delivery pressure
Vacuum Requirements:	8 milliTorr or less within the vacuum chamber

*** The Joule-Thomson Thermal stages have similar specifications across all offered temperature ranges. Any differences are noted under the specification concerned. Thermal stage specifications may be changed at any time by the manufacturer. Please contact the manufacturer for the latest information and specifications.

Features and Benefits

Microminiature refrigerators or Joule-Thomson thermal stages provide many advantages in scientific applications:

- ◆ Fast cool-down and warm-up.
- ◆ Precise temperature control: +/- 0.1K
- ◆ Excellent temperature setability, stability, and reproducibility.
- ◆ Absence of mechanical, acoustic, or electrical noise.
- ◆ Small, compact size.
- ◆ Wide range of operation: 70K to 730K
- ◆ Non-magnetic electrical feedthroughs facilitate electrical connections directly to samples on the thermal stage.
- ◆ Low cost of operation: \$0.50/hour
- ◆ No liquid cryogenics to handle. All cryogenics are produced and consumed within the stage, making this safe and easy to use
- ◆ No maintenance required
- ◆ Very low power consumption - less than 12 watts on any stage.

Applications

MMR Technologies provides many different microminiature refrigerators or Joule-Thomson thermal stages for use in chemistry, physics, and materials science - as well as other special applications, including:

- ◆ Hall Effect Measurement Systems
- ◆ Seebeck Effect Measurement Systems
- ◆ Micro manipulation and Microprobe Systems
- ◆ Deep Level Transient Spectroscopy Studies
- ◆ Optical Microscopy
- ◆ Electron Microscopy
- ◆ Atomic Force Microscopy
- ◆ Optical Transmission Spectroscopy
- ◆ X-Ray Diffraction
- ◆ Raman and Fluorescence Studies
- ◆ Interface with customized vacuum and environmental control chambers

These systems are flexible, modular, and highly adaptable to fit into most applications, giving variable temperature control as a valuable addition to any experimental setup.

MMR Technologies, Inc.

1400 N. Shoreline Blvd, Suite A5
Mountain View, CA 94043

Phone: +1 (650) 962-9620

Fax: +1 (650) 962-9647

E-Mail: sales@mmr.com

Website: www.mmr.com