User's Manual

MTD Series

Modular Test Dewar Cryotest System

The MTD Series Consists Of:

MTD-140 – Single-position, pour-fill dewar system

MTD-144 – Four-position, LCC pour-fill dewar system

MTD-150B – Single-position, continuous-flow cryostat system

MTD-154 – Four-position, continuous-flow cryostat

MTD-158 – Eight-position, continuous-flow cryostat

MTD-260B – Single-position, closed-cycle refrigerator

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Revision 1.1 P/N 119-693 **14 November 2001**

LIMITED WARRANTY

Lake Shore Cryotronics, Inc. (henceforth Lake Shore), the manufacturer, warrants this product to be free from defects in material and workmanship for a period of twelve (12) months from the date of shipment. During the warranty period, under authorized return of instruments or component parts to Lake Shore freight prepaid, the company will repair, or at its option replace, any part found to be defective in material or workmanship, without charge to the Owner for parts, service labor or associated customary shipping cost. Replacement or repaired parts will be warranted for only the unexpired portion of the original warranty.

All products are thoroughly tested and calibrated to published specifications prior to shipment. Calibration Certifications are offered for six month periods only. Where such documentation must be updated, a re-certification service is offered by Lake Shore at a reasonable cost.

LIMITATION OF WARRANTY

This warranty is limited to Lake Shore products purchased and installed in the United States, or Internationally through our approved distribution agents. This same protection will extend to any subsequent owner during the warranty period. It does not apply to damage caused by accident, misuse, fire, flood, or acts of God, from failure to properly install, operate, or maintain the product in accordance with the printed instructions provided. This warranty does not apply to defects resulting from improper or inadequate maintenance, unauthorized modification or misuse, operation outside of the environmental specifications for any product or part or buyer-supplied software interfacing.

This warranty is in lieu of any other warranties, expressed or implied, including merchantability or fitness for a particular purpose, which are expressly excluded. The owner agrees that Lake Shore's liability with respect to this product shall be set forth in this warranty, and incidental or consequential damages are expressly excluded.

CERTIFICATION

Lake Shore certifies that this product has been inspected and tested in accordance with its published specifications and that this product met its published specifications at the time of shipment. The accuracy and calibration of this product at the time of shipment are traceable to the United States National Institute of Standards and Technology (NIST); formerly known as the National Bureau of Standards (NBS).

TRADEMARK ACKNOWLEDGMENT

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CHAPTER 1

INTRODUCTION

1.0 GENERAL

This chapter provides an introduction to the Modular Test Dewar (MTD) Cryotest System. The MTD System was designed and manufactured in the United States of America by Lake Shore Cryotronics, Inc. The MTD Series consists primarily of the Model MTD-150, a Single-Position Continuous Flow Cryostat System. Other configurations can be made from the basic MTD-150 unit. By design, the MTD Cryotest System is versatile and easily configured per individual Customer requirement. Some of the other optional accessories that can be incorporated include multiple positions, single- and dual-focal plane arrays, a pour-fill dewar, internal radiation sources, various fanout and personality boards, breakout modules and boxes, etc. Details on options and accessories are provided in Chapter 6.

Since it is not practical to cover all the possible configurations, this MTD Cryotest System Manual will cover the Model MTD-150 in detail. If required, additional details specific to a Customer configuration will be included in the Appendices.

The MTD Cryotest System uses the Lake Shore Series DT-470 Silicon Diode Temperature Sensor. Interchangeable, repeatable, accurate, wide range customized for cryogenics. Sensor installation is covered in detail in the Lake Shore Product Catalog, Application Notes, and Technical Data (as listed on the next page under List of Associated Lake Shore Publications).

User information is presented in the following chapters. Chapter 1 provides an introduction to the entire system. Also included in Chapter 1 is a list of Model MTD-150 Specifications. Connection pin definitions are also provided in Chapter 1. Chapter 2 provides unpacking, inspection, and return information. Chapter 3 is used for system installation. System operation is described in Chapter 4. Troubleshooting is provided in Chapter 5. Finally, Options and accessories are covered in Chapter 6.

Several appendices have been included to enhance the usability of the manual. Appendix A is a glossary of terminology. Appendix B is a list of units for magnetic properties. Temperature Scales are discussed in Appendix C. A table of elements is provided in Appendix D. Handling of liquid helium and liquid nitrogen is discussed in Appendix E. The optional pour-fill dewar is detailed in Appendix F. Filter wheel assemblies for testing of infrared focal plane arrays are detailed in Appendix G. Finally, the Model MTD-260 with closed-cycle refrigerator is described in Appendix H.

1.1 MTD CRYOTEST SYSTEM GENERAL DESCRIPTION

The Model MTD-150 is a flexible tool which provides high signal quality and optical performance, precise temperature control, rapid test cycling, and an expandable design. The MTD-150 accommodates virtually all present and future requirements for developmental and production testing of infrared focal plane arrays and integrated circuits. The unique design of the MTD optimizes test integrity by greatly minimizing the potential for vacuum leaks and signal interference while, at the same time, providing users with fast, easy access to a test chamber capable of supporting essentially any kind of device package. System features include the following:

- A versatile, modular, and easy access test chamber
- Superior electrical characteristics
- High signal quality
- Fast Device Under Test (DUT) turnaround due to rapid temperature cycling capability
- Interchangeable fanout boards
- Precise monitoring and control over a wide temperature range
- High optical performance

Table 1-1. Model MTD-150 Cryotest System Specifications

Temperature Range:
Less than 4 kelvin to 400 kelvin with liquid helium (LHe), or from 77 kelvin to 400 kelvin with liquid nitrogen (LN_2).

Temperature Control Stability:
Dependent upon temperature controller selected. Typical control stability ±0.01 K or better.

Cooling Capacity:
4 watts at 5 K and with 6 liters/hour cryogen flow; 330 mW at 5 K with 0.5 liter/hr flow.

Vacuum:
Before cooldown, the chamber should be pumped down to at least 10 – 20 microns.
Leak rate: 10^{-8} cc/sec (standard gaseous helium).

Cryogen Consumption:
(Typical) 4 – 5 liters of LHe required for cool down; 0.25 liter/hr to maintain steady state operation at 5 K, with LHe throttled back and without use of heater control. With cooled filter wheel assembly: 1 liter/hr LHe at 5 K; 0.5 liter/hr at 10 K; 0.25 liter/hr at 77 K.

Cooldown Time:
(Typical, with LHe supply pressure at 8 psig.) The DUT cooling stage reaches 5 K in ≈50 minutes; the radiation shield is cooled to LN_2 temperature in 65 minutes and reaches 20 K in ≈80 minutes.

Warmup Time:
Approximately 20 minutes from test temperature to 300 K with the Model 1015 Warm-Up Power Supply.

Optical performance:
Wide range of configurations available, from less than F/1 to greater than F/8. An accommodation for the installation of a 5.1 cm (2-inch) diameter window with a 3.8 cm (1.5-inch) diameter clear aperture is provided in the chamber end closure. The minimum focal plane distance to the outside of the window is 3.8 cm (1.5 inches). This optional window is mounted in a down-looking orientation. Optional filter and aperture wheel assemblies, which can be cooled to below 8 K, accommodate 2.54 cm (1-inch) diameter filters that can vary from 1 mm to 3.2 mm in thickness. Typically, less than 5% non-uniformity (illumination) is achieved.

Signal quality and performance:
Coaxial signal lines (100 standard—up to 256 can be accommodated) are 50 Ω impedance with 15 – 20 picofarads of input capacitance. Suitable for bandwidths to 100 MHz. Typically, systems exhibit bandwidths of 20 MHz due to parasitic losses in leadless chip carriers, focal plane arrays and sockets. With a signal generator operating at 1 MHz, cross-talk is 1.0% or less on unterminated adjacent leads, and 0.1% when the adjacent lead is terminated. Signal line shields are electrically connected at cold plate terminals. Shield Dewar equivalent input noise is approximately 8×10^{-15} amp/√Hz.

Feedthrus:
Four, high-density, 50-pin, 50 Ω impedance feedthrus located on the base plate of the vacuum chamber. A single 19-pin instrumentation feedthru is also provided.

System orientation:
May be installed to operate in any orientation.

Mechanical Components:
Hard-anodized (black), machined aluminum vacuum chamber with integrated handle/ring stand assembly. Chamber end closure mated to main vacuum shroud body by means of captive o-ring seal and spring-loaded, quick-release clamps. Incorporates cold stage radiation shield. Includes MTD-100 high efficiency continuous flow cryostat with exhaust gas heater and bayonet receptacle.

NOTE: Device test set assembly kit hardware (Model 1520K) is ordered separately. This kit, configured to initial DUT test requirements, consists of fanout boards with the required chip carrier socket, chip carrier clamp assembly and cold finger pedestal. Refer to Chapter 6 for list of options and accessories.

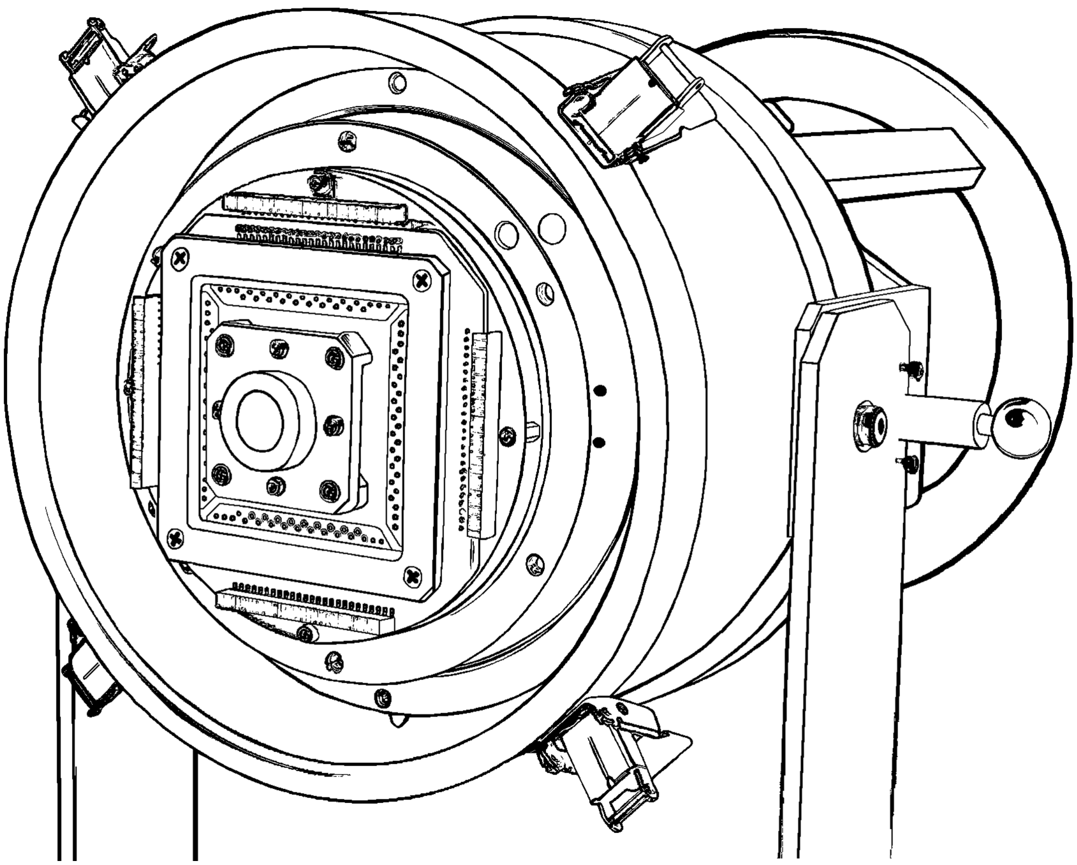
Table 1-1. Model MTD-150 Cryotest System Specifications (Continued)

Temperature Measurement and Control:
DT-470-CU-12A silicon diode temperature sensors and 25 Ω heaters mounted on the first and second stage heat exchangers.

NOTE: Recommend use with the optional vacuum-insulated, LHe transfer line, Model 1205, or LN_2 transfer line, Model 1210.

System Dimensions (Typical):
10 inches (25.4 cm) in diameter by 18 inches (45.7 cm) long

Net Weight (Typical):
29 pounds (13.2 kilograms)



P-MTD-1-01.bmp

Figure 1-1. Model MTD-150B with Vacuum Shroud and Radiation Shield Removed

1.1.1 MTD CRYOTEST SYSTEM APPLICATION

The modular design of the MTD reduces the time required for reconfiguration, device setup and cycle testing. The MTD test chamber serves as a base unit that interfaces with a variety of compatible sample test fixtures to provide qualified structure and performance analysis of electro-optic (infra-red) detector arrays, detector readout chips, Complementary Metal Oxide Semiconductor (CMOS) devices, digital integrated circuits, and other devices.

Reconfiguring from one test setup to another is accomplished by simply interchanging device package hardware and fanout board assemblies. Test Dual In-line Package (DIP) components then Leadless Chip Carrier (LCC) components quickly and easily—without soldering.

1.1.2 EASY ACCESS TO DEVICE TEST AREA

The chamber end closure is mated to the main vacuum shroud body by means of a captive o-ring seal and spring-loaded, quick-release clamps. Only captive screws are used to secure the cold stage radiation shield beneath the end closure. Removal of this shield exposes the device test area. Regardless of the test configuration, access is quick and simple.

1.1.3 INTERCHANGEABLE FANOUT BOARDS ACCOMMODATE VIRTUALLY ANY DEVICE PACKAGE

Fanout boards can be easily and quickly interchanged in the device test area. These boards are available in three basic configurations. The boards can be designed to accept specific device packages and their individual contact arrangement; personality fanout boards are configured to enable the user to reroute contact connections of a device package under prototype test conditions; or they can be configured as general purpose boards to adapt custom-made devices or complete modules.

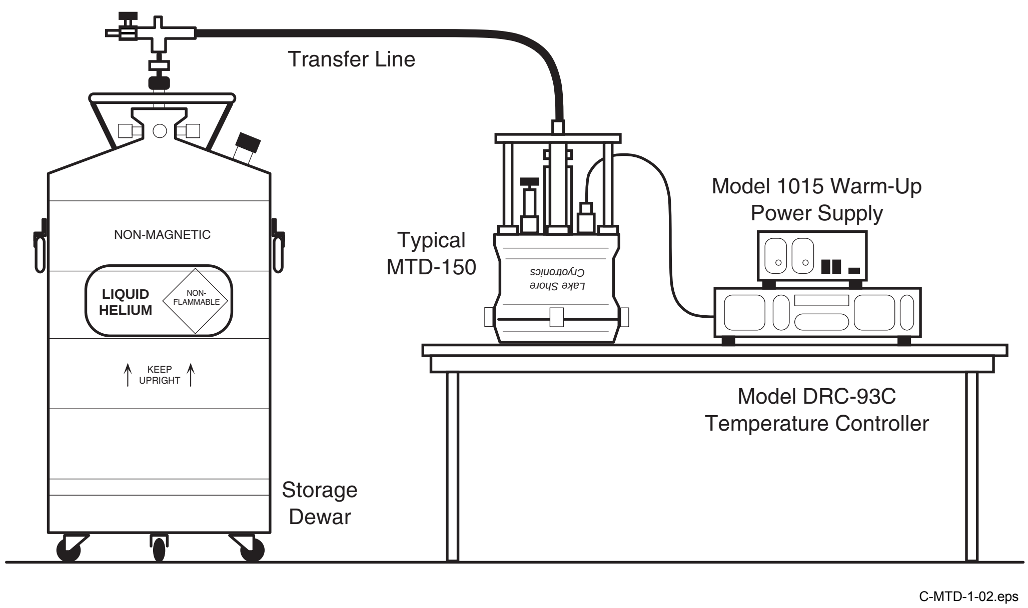
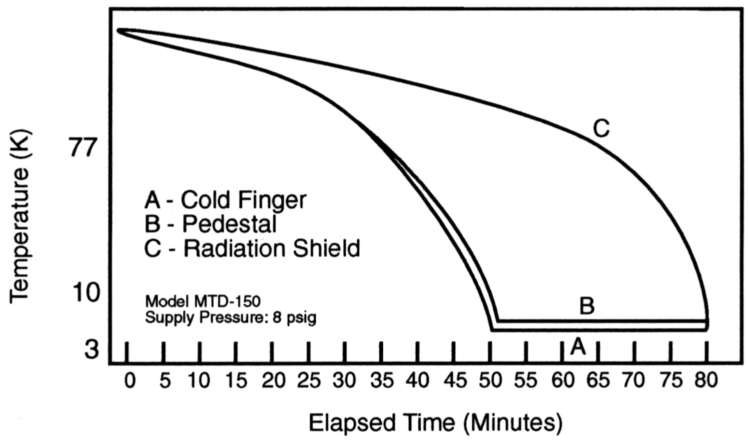


Figure 1-2. Typical MTD-150 Cryotest System

1.1.4 RAPID TEMPERATURE CYCLING CAPABILITY

Rapid temperature cycling between ambient and test temperatures assures a higher device throughput. A two-stage, continuous-flow cryostat utilizes two high-efficiency heat exchangers to provide rapid cooling of the sample mounting structure, radiation shield, and heat sinks. The cryostat can be operated with either liquid helium (LHe) or liquid nitrogen (LN_2).



Temp_Chart.bmp

1.1.5 SUPERIOR VACUUM CHARACTERISTICS

The MTD design minimizes problems such as vacuum leaks and signal interference that can distort test data. Instead of penetrating the test chamber with individual feedthrus, each a potential source for a vacuum leak, all MTD signal lines (100 standard) terminate into four, high density, 25-line feedthru connectors on the base plate of the chamber housing. By reducing the number of discrete penetrations into the vacuum chamber from 100 to 4, the integrity of the test environment is enhanced.

1.1.6 HIGH SIGNAL QUALITY

The MTD system utilizes high quality components and materials throughout, including coaxial signal cable to minimize the potential for crosstalk interference, or other signal problems. Coaxial signal lines leading to the DUT are all 50 Ω impedance with 15-20 picofarads input capacitance per lead. At 1 MHz, crosstalk is measured to be 0.1% when the adjacent lead is terminated. Variations in system design can accommodate as many as 256 signal lines.

1.1.7 1520K DEVICE TEST ASSEMBLY KIT

A typical kit includes a fanout board (shown with 24-pin DIP package) configured with a specific chip carrier socket, chip carrier clamp assembly and cold finger pedestal—against which the clamp assembly positions the chip carrier. Limiting apertures or 2.54 cm (1-inch) diameter filters can be accommodated in the clamp assembly.

1.1.8 SUPERIOR OPTICAL PERFORMANCE

The MTD system produces low background radiation; the black-anodized surface minimizes reflections. Cooled filter and aperture wheel assemblies are available.

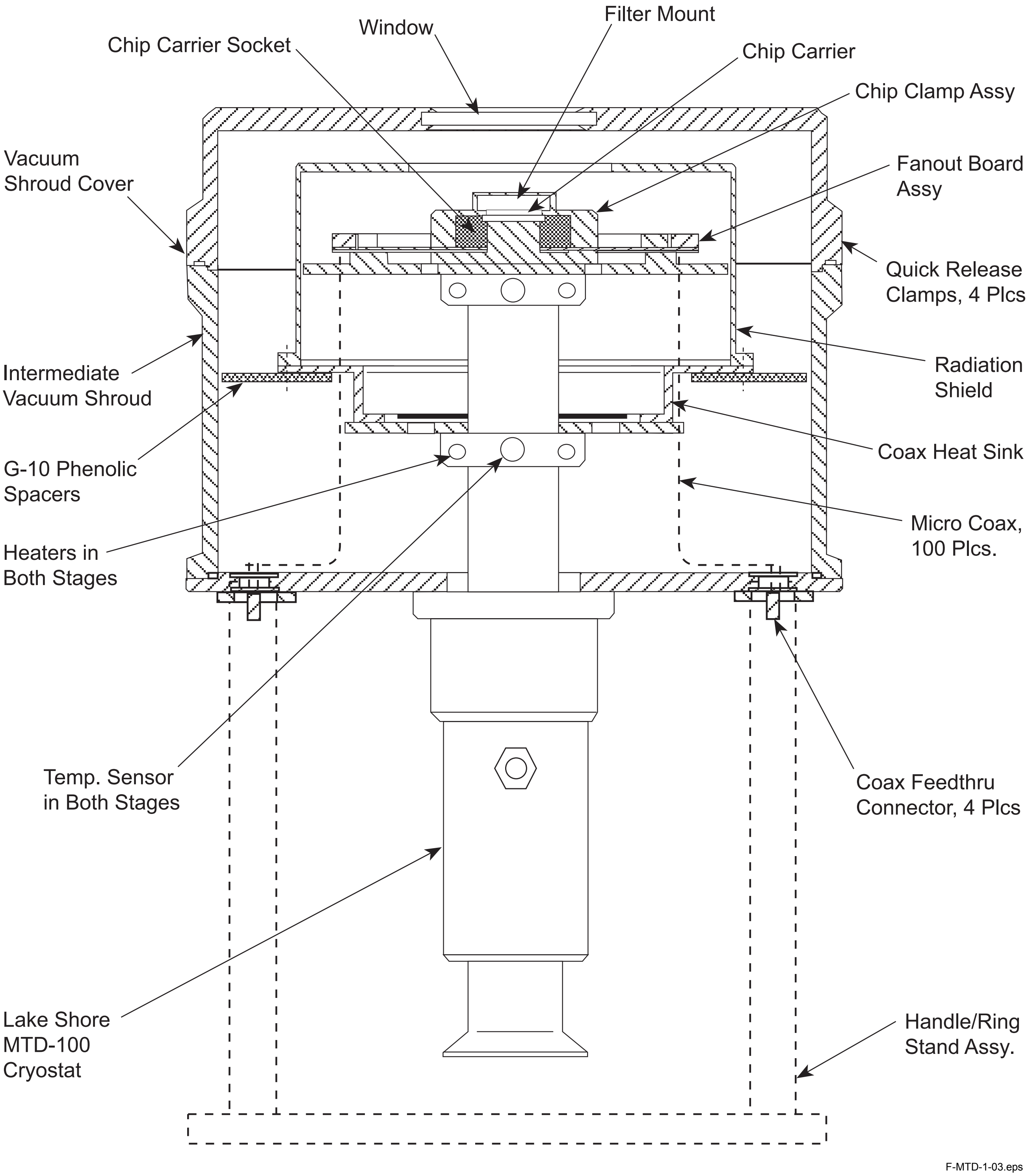


Figure 1-3. Typical Model MTD-150 Cutaway

1.1.9 PRECISE MONITORING AND CONTROL OF TEMPERATURE OVER A WIDE RANGE

Select from Lake Shore's full line of temperature controllers and sensors to complete system operational requirements. Shown is the Model 330 temperature controller, which offers Autotuning of Proportional, Integral, and Derivative (PID) parameters, front panel programming. The temperature sensor is a Lake Shore DT-470 series silicon diode which produces an accurate and repeatable measurement from 1.4 K to 475 K.

1.2 HARDWARE DESCRIPTIONS AND FUNCTIONS

The following are definitions of the primary components of a typical MTD Cryotest System. The list is presented in alphabetical order.

BAYONET COUPLING: Ladish® flange used to securely connect transfer line to MTD-150 cryostat.

CHIP CARRIER CLAMP ASSEMBLY: Secures the chip carrier in the device socket and against the cold pedestal. It may also be used to hold the fixed aperture disks and optical filters. It is spring loaded to ensure good thermal contact between the ceramic substrates on the device package and the cold pedestal. All interior optical surfaces are vapor-blasted and black-anodized to minimize optical reflections.

COLD PEDESTAL: Mounted to the center of the cold plate. Makes direct thermal contact to the DUT. Indium foil or Apiezon® "N" grease is used between the cold pedestal and the ceramic substrates on the DUT to assure good thermal contact.

COLD PLATE: Mounted to the second stage heat exchanger, it provides a cooled mounting surface for the interface board, cold pedestal, fanout board and chip carrier clamp assembly through the cold pedestal.

CRYOSTAT (MTD-100): Continuous flow two-stage cryostat which operates with either LHe or LN_2 in any attitude and incorporates a female bayonet type coupling which mates to the transfer line male bayonet coupling. Consists of two main sections; cold finger (inside vacuum chamber) and main body (outside of vacuum chamber). See Figure 1-4.

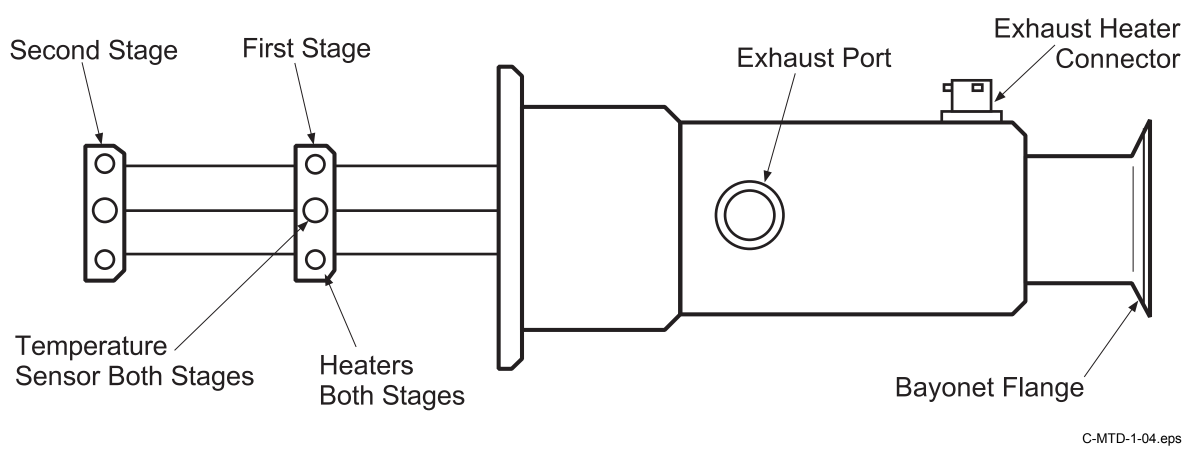
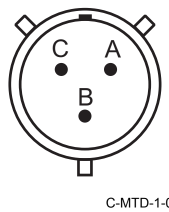


Figure 1-4. Typical MTD-100 Cryostat Profile

EXHAUST GAS HEATER: The exhaust gas heater warms the exhaust gas to room temperature before exiting the cryostat. This minimizes frosting on the MTD-100 Cryostat and prevents premature hardening of the o-rings. A flow control valve may be connected to the exhaust port to apply back pressure to the gas flow, enhancing the efficiency of cryogen consumption. A power cable is provided with the MTD System. See Figure 1-5 for cryostat connector pin definitions. The AC power cable is defined in Figure 5-1.



PIN NO.	DESCRIPTION
A	Heater AC
B	Heater AC
C	Case Ground

Figure 1-5. 3-Pin Exhaust Gas Heater Connector

FANOUT BOARD: The square Fanout board is used with MTD-150B. (The round Fanout boards used in older MTD-150s are not interchangeable with the MTD-150B.) The Fanout Board has 50 Ω impedance signal lines which interface the DUT socket to the microcoax lines through the spring loaded contacts on the interface board. Held in place by a fanout board retaining ring. Each fanout board requires a specific test set assembly kit. Several models of fanout boards and commonly used chip carrier sockets are available. A typical fanout board wiring is shown in Figure 1-6. The top view of a typical square fanout board is shown in Figure 1-7. Refer to Chapter 6 – Options and Accessories for details on available fanout boards.

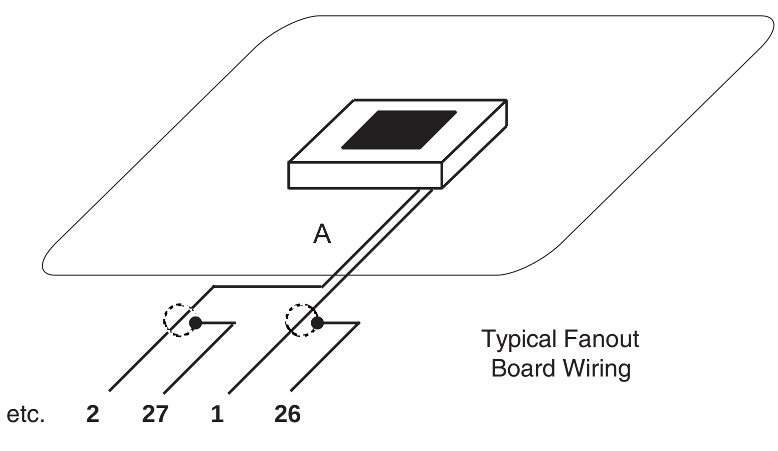


Figure 1-6. Typical Fanout Board Wiring

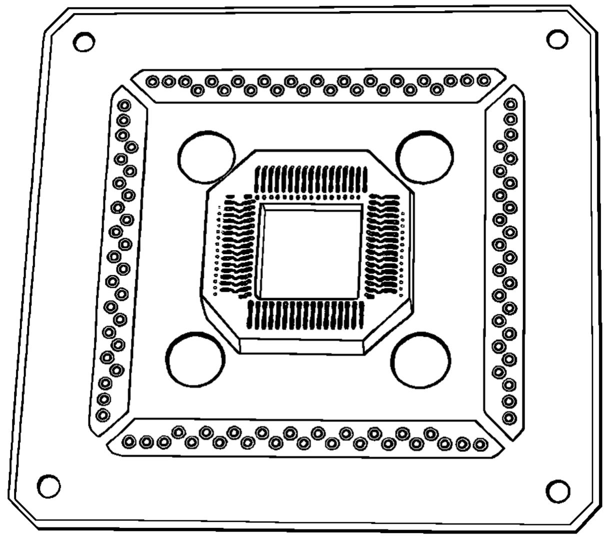


Figure 1-7. Typical Square Fanout Board (Top View)

FIRST STAGE HEAT EXCHANGER: Located on the cryostat cold finger. This stage provides cooling to the radiation shield and signal lead heat sinks. A DT-470 series silicon diode temperature sensor and 2 cartridge heaters are mounted to this stage for temperature monitoring, temperature control and rapid warm-up.

FLOW VALVE: Controls flow of cryogen through the transfer line.

INSTRUMENTATION FEEDTHRU CONNECTOR: The 19-pin Instrumentation Feedthru Connector is located on the underside of the dewar. Temperature control and measurement electrical connections are made through the O-ring sealed electrical feedthru. Only 8 of the 19 pins are used in a standard Model MTD-150 Installation. This allows for future installation of additional instrumentation leads. See Figure 1-8 for connector definition.

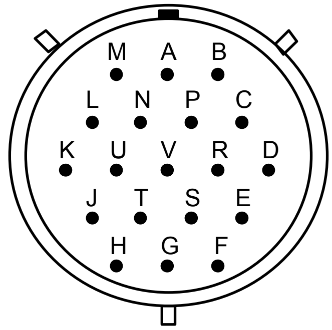
INTERFACE BOARD: Provides electrical interface between signal lines and fanout board. Contains spring loaded, gold plated beryllium copper fingers which contact the 50 Ω stripline transmission lines on the fanout board.

MAIN CHAMBER: Main section of vacuum chamber, mounted to vacuum chamber base plate. May be removed for access to system wiring and mechanical components.

MICROCOAX CABLING SIGNAL LINES: 100 semi-rigid stainless steel microcoax cables which interconnect the interface board and the four 25-line feedthru connectors. The 100 cables are thermally sunk with epoxy to the radiation shield base plate to reduce heat conduction along the lines to the cold plate. The maximum current on any one signal line is 100 mA. If additional current is required, use copper leads and the spare pins on the Instrumentation Feedthru Connector.

RADIATION SHIELD: Gold plated radiation shield which controls the radiation environment around the DUT. When removed, provides access to the test set assembly.

SECOND STAGE HEAT EXCHANGER: Located on the cold finger end. Contains a DT-470 series silicon diode temperature sensor and 2 cartridge heaters. Provides cooling and temperature control for the DUT and accessories (e.g., filter wheels) attached to the cold plate.



PIN NO.	DESCRIPTION
* A	2nd Stage Sensor; –Current, –Voltage
B	Not Used
* C	1st Stage Sensor; –Current, –Voltage
D	Not Used
E	Not Used
* F	1st Stage Heater
* G	1st Stage Heater
* H	2nd Stage Heater
* J	2nd Stage Heater
K	Filter Wheel Temperature Sensor; +Current, +Voltage
L	DUT Temperature Sensor; +Current, +Voltage
* M	2nd Stage Sensor; +Current, +Voltage
N	DUT Temperature Sensor; –Current, –Voltage
* P	1st Stage Sensor; +Current, +Voltage
R	Not Used
S	Not Used
T	Not Used
U	Filter Wheel Temperature Sensor; –Current, –Voltage
V	Not Used

* Standard Pins

Figure 1-8. 19-Pin Instrumentation Feedthru Connector

SIGNAL FEEDTHRU CONNECTOR: Four 50-pin connectors that pass through the 100 connections from the fanout board. The connectors are labeled A, B, C, and D. The default setup for a Model MTD-150 is the outer row of 25 pins being the signal line and the inner row is the shield for that corresponding line. All shields are grounded at the ground plane board with a jumper. The Customer can isolate the shield from ground by removing the jumper. See Figure 1-9 for external definition of signal feedthru connector.

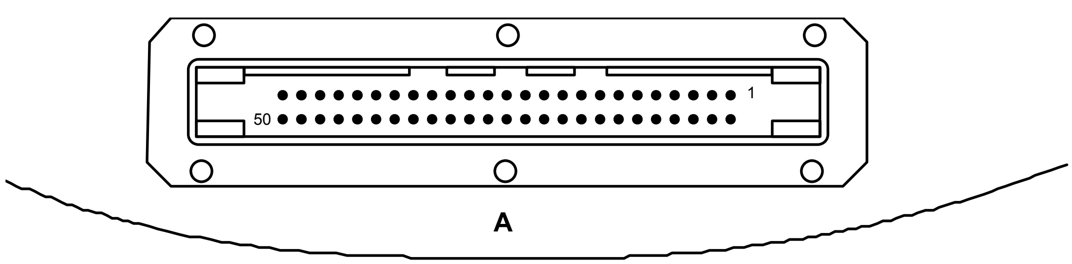


Figure 1-9. 50-Pin Signal Feedthru Connector

TEST SET ASSEMBLY: Consists of the cold pedestal, fanout board, and chip carrier clamp assembly.

TRANSFER LINE: The optional Model 1205 transfer line is a conventional, flexible, vacuum-insulated line consisting of a long rigid withdrawal tube which can be inserted into a LHe storage vessel or modified LN_2 container. The withdrawal tube contains a filter to prevent foreign matter from plugging the small diameter inner tube. A LN_2 transfer line is available. Refer to Chapter 6 – Options and Accessories for additional details.

VACUUM CHAMBER BASE PLATE: All electrical feedthrus and mechanical linkages pass through the base plate which is located on the bottom of the vacuum chamber. The four 25-line feedthru connectors and provisions for installation of the optional filter wheel assembly drive shafts are also found here.

VACUUM CHAMBER END CLOSURE: When removed, allows access to testing area. Held in place by four pull-down clamps. Also, embedded in chamber end closure is an o-ring. It assures a vacuum tight fit between the main chamber and chamber end closure. A two inch window is present in order to illuminate the DUT during testing.

VACUUM CHAMBER: Black anodized machined aluminum cylinder which encloses the cryostat cold finger. Consists of main chamber, chamber end closure and vacuum chamber base plate.

VACUUM PORT AND VACUUM PUMPOUT VALVE: Located on the underside of the dewar, the vacuum port and pumpout valve is used to connect a vacuum pump in order to evacuate/isolate the vacuum chamber space. It also serves as a pressure relief in case of vacuum chamber overpressure. Operation of the valve is shown in Figure 1-10. To operate, the handle pushed up to the seat and rotated clockwise (3 to 4 revolutions) to thread into the valve seat. Pull out the handle to open (vent) the vacuum space and push in to close.

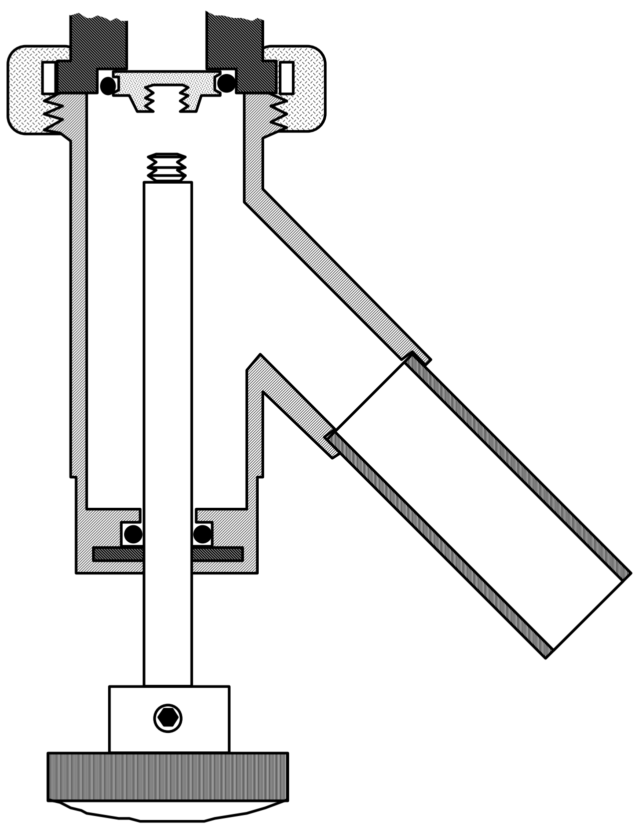


Figure 1-10. Vacuum Valve Cutaway

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CHAPTER 2

PRE-INSTALLATION

2.0 GENERAL

This chapter discusses inspection, unpacking, and reshipment aspects of the MTD Cryotest System. Inspection and unpacking are detailed in Paragraph 2.1, repackaging for shipment in Paragraph 2.2, general installation precautions in Paragraph 2.3, electrostatic discharge in Paragraph 2.4, safety summary in Paragraph 2.5, and safety symbols in Paragraph 2.6. Refer to Appendix E for safety instructions for handling liquid helium and nitrogen.

2.1 INSPECTION AND UNPACKING

Inspect shipping containers for external damage. All claims for damage (apparent or concealed) or partial loss of shipment must be made in writing to Lake Shore within five (5) days from receipt of goods. If damage or loss is apparent, please notify the shipping agent immediately.

Open the shipping containers. A packing list is included with the system to simplify checking that all components, cables, accessories, and manuals were received. Please use the packing list and the spaces provided to check off each item as the system is unpacked. Inspect for damage. Be sure to inventory all components supplied before discarding any shipping materials. If there is damage to the instrument in transit, be sure to file proper claims promptly with the carrier and insurance company. Please advise Lake Shore Cryotronics of such filings. In case of parts or accessory shortages, advise Lake Shore immediately. Lake Shore cannot be responsible for any missing parts unless notified within 60 days of shipment. The standard Lake Shore Cryotronics Warranty is included on the A Page (immediately behind the title page) of this manual.

2.2 REPACKAGING FOR SHIPMENT

If it is necessary to return any part of the MTD Series for repair or replacement a Return Goods Authorization (RGA) number must be obtained from a factory representative before returning the instrument to our service department.

When returning an instrument for service, the following information must be provided before Lake Shore can attempt any repair.

1. Instrument model and serial number
2. User's name, company, address, and phone number
3. Malfunction symptoms
4. Description of system
5. Returned Goods Authorization (RGA) number

If possible, the original packing material should be retained for reshipment. If not available, consult Lake Shore for shipping and packing instructions.

2.3 GENERAL INSTALLATION PRECAUTIONS

The following are general safety precautions that are not related to any specific procedure and therefore do not appear elsewhere in this publication. These are recommended precautions that personnel should understand and apply during the installation phase.

Keep away from live circuits. Installation personnel shall observe all safety regulations at all times. Turn off system power before making or breaking electrical connections. Regard any exposed connector, terminal board, or circuit board as a possible shock hazard. Components that retain a charge shall be discharged only when such grounding does not result in equipment damage. If a test connection to energized equipment is required, make the test equipment ground connection before probing the voltage or signal to be tested.

General Installation Precautions (Continued)

Do not install or service equipment alone. Personnel shall not under any circumstances reach into or enter any enclosure for the purpose of servicing or adjusting the equipment without immediate presence or assistance of another person capable of rendering aid.

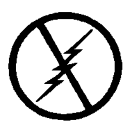
2.4 ELECTROSTATIC DISCHARGE

Damage can occur to electronic parts, assemblies, and equipment from electrostatic discharge (ESD). ESD is defined as a transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. The low-energy source that most commonly destroys Electrostatic discharge Sensitive (ESDS) devices is the human body, which in conjunction with nonconductive garments and floor coverings generates and retains static electricity. Simply walking across a carpet in low humidity can generate up to 35,000 volts of static electricity.

The current trends in technology are toward greater complexity, increasing packaging density, and hence thinner dielectrics between active elements, resulting in electronic devices becoming even more sensitive to ESD. Various electronic parts are more ESDS than others. These can be damaged by ESD levels commonly generated by personnel testing, handling, repairing, and assembling electronic components without their being aware that a discharge of static electricity has even occurred. Many ESDS electronic devises such as semiconductors, thick and thin film resistors, chips and hybrid devises, and piezoelectric crystals can be damaged or destroyed by ESD levels of a few hundred volts, which is far below the 4000 volt human threshold of awareness. Discharges below this level cannot be seen, felt, or heard.

2.4.1 Identification of Electrostatic Discharge Sensitive Components

A number of symbols are used in the industry to label components as ESDS. These symbols, along with the circular ESD symbol used throughout this manual, are shown as follows:

2.4.2 Handling of Electrostatic Discharge Sensitive Components

Precautions necessary to ensure prevention of damage to ESDS components should be observed before attempting installation. This means that the device and everything that contacts it must be brought to ground potential by providing a conductive surface and discharge paths. As a minimum, the following precautions must be observed:

1. De-energize or disconnect all power and signal sources and loads used with the unit.
2. Place the unit on a grounded conductive work surface.
3. The technician should be grounded through a conductive wrist strap (or other device) using a 1 MΩ series resistor.
4. Ground any tools, such as soldering equipment, that will contact the unit. Contact with the operator's hands provides a sufficient ground for tools that are otherwise electrically isolated.
5. When ESDS devices and assemblies are not in the unit, they should be on the conductive work surface or in conductive containers. When a device or assembly is inserted in or removed from a container, the operator should maintain contact with the conductive portion of the container. Do not use plastic bags unless they have been impregnated with a conductive material.
6. Do not handle ESDS devices unnecessarily or remove them from their packages until actually used or tested.

2.5 SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Lake Shore Cryotronics, Inc. assumes no liability for the customer's failure to comply with these requirements.

Ground The Instrument

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

Do Not Operate In An Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

Keep Away From Live Circuits

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Substitute Parts Or Modify Instrument

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an authorized Lake Shore Cryotronics, Inc. representative for service and repair to ensure that safety features are maintained.

Dangerous Procedure Warnings

A WARNING heading precedes potentially dangerous procedures throughout this manual. Instructions in the warnings *must* be followed.

2.6 SAFETY SYMBOLS

- Direct current (power line).
- Alternating current (power line).
- Alternating or direct current (power line).
- 3∼ Three-phase alternating current (power line).
- Earth (ground) terminal.
- Protective conductor terminal.
- Frame or chassis terminal.
- On (supply).
- Off (supply).
- Equipment protected throughout by double insulation or reinforced insulation (equivalent to Class II of IEC 536 - see Annex H).
- Caution: High voltages; danger of electric shock. Background color: Yellow; Symbol and outline: Black.
- Caution or Warning - See instrument documentation. Background color: Yellow; Symbol and outline: Black.
- Fuse.

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CHAPTER 3

INSTALLATION

3.0 GENERAL

This chapter provides instructions and equipment required to install the MTD Cyrotest System. Environmental requirements are detailed in Paragraph 3.1, system power and ground requirements in Paragraph 3.2, physical support requirements in Paragraph 3.3, liquid cryogen requirements in Paragraph 3.4, storage dewar pressurizing in Paragraph 3.5, hookup of the exhaust gas heater in Paragraph 3.6, instrument hookup in Paragraph 3.7, inserting a Device Under Test (DUT) in Paragraph 3.9, changing the fanout board in Paragraph 3.10, and changing the test set assembly in Paragraph 3.11. After following installation procedures, proceed to Chapter 4 – Operation.

3.1 ENVIRONMENTAL REQUIREMENTS

To meet and maintain the specifications in Table 1-1, the electronic equipment associated with the MTD System must be operated at an ambient temperature range of 18 – 28 °C (64.4 – 82.4 °F). The equipment may be operated within the range of 15 – 35 °C (59 – 95 °F) with less accuracy. The system is intended for laboratory use: no specific humidity or altitude specifications have been determined. However, relative humidity of 20 – 80% (no condensation) and altitudes from sea level to 2.4 kilometers (8,000 feet) are generally acceptable.

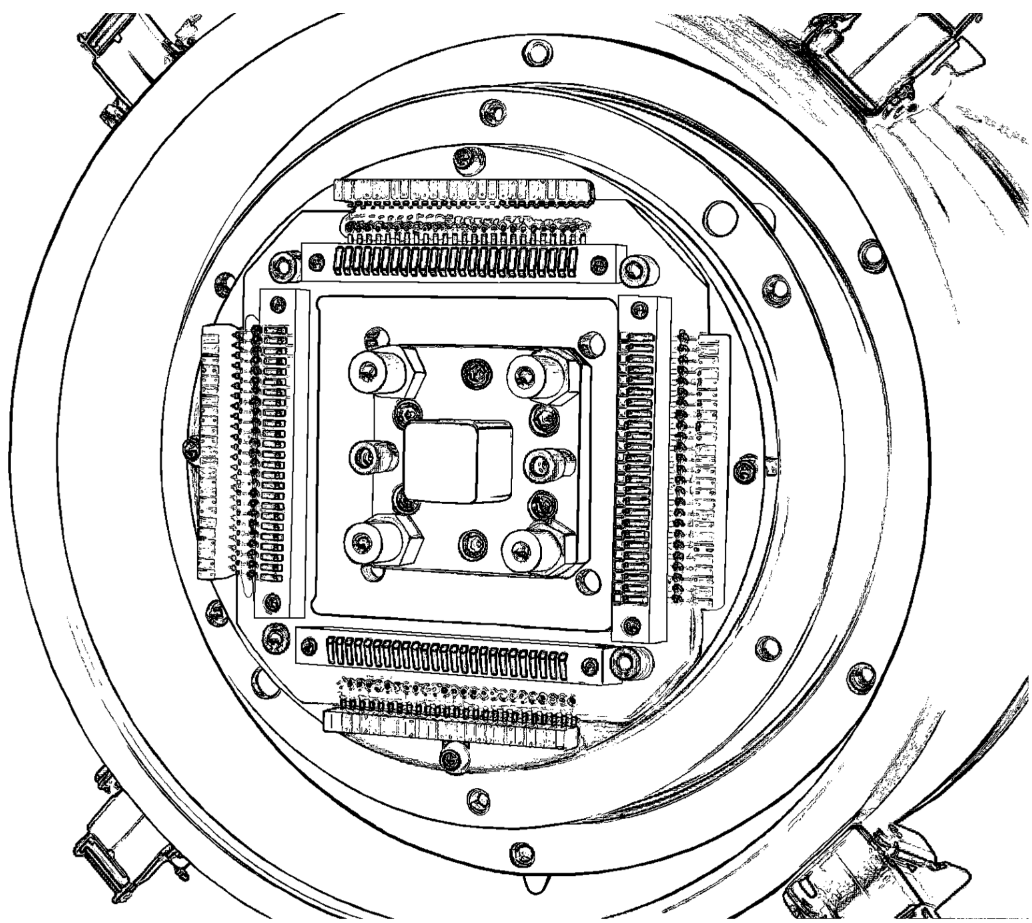

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Figure 3-1. Typical MTD Internal View with Fanout Board Removed

Environmental Requirements (Continued)

It is imperative that adequate ventilation of work area be provided. This will prevent build up of potentially life-threatening concentrations of helium and nitrogen gas. Refer to Appendix E for further information. Oxygen content monitor/alarms should be installed near the work site to warn against low oxygen levels. The air-conditioning system should provide filtering to reduce dust and other particulate matter to a reasonable level. If salt air, corrosive gases, or other air pollutants are present, special filtering arrangements may be required and an air-conditioning expert should be consulted.

3.2 SYSTEM POWER AND GROUND REQUIREMENTS

The AC power source for components associated with the MTD System must be frequency and voltage regulated and isolated from sources that may generate Electromagnetic Interference (EMI). The MTD exhaust gas heater is designed for single-phase 3-wire alternating current (AC) power. Two-wire (without ground) AC power must not be used. Ground Fault Interrupter (GFI) and Transient Surge Protection circuitry at the AC source is also strongly recommended.

In areas where the AC voltage is variable, the Customer should consider the use of a constant voltage transformer. If power outages are a problem, an Uninterruptable Power Supply (UPS) should also be considered.

CAUTION: Do not attempt to apply electrical power to the MTD System until all instruments have been checked for proper input power settings and fuse or circuit breaker ratings.

To protect operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends, and the National Electrical Safety Code requires, instrument panels and cabinets be grounded. The safety ground has two functions: (1) to provide a true ground path for electrical circuitry, and (2) in the event of internal electrical faults, such as shorts, to carry the entire fault current to ground, thus protecting operating personnel from hazardous shock. This instrument is equipped with a detachable three-prong power cable which powers the exhaust gas heater that, when plugged into a 3-wire receptacle, grounds equipment in the Instrument Console.

EMI is an electromagnetic phenomena which, either directly or indirectly, can contribute to a degradation in performance of an electronic system. EMI can be both natural and man-made. Natural sources of EMI include thunderstorms, solar disturbances, cosmic rays, etc. Man-made sources of EMI include fixed and mobile transmitters, high voltage power lines, power tools and appliances, florescent lights, and other equipment containing motors, heaters, etc. Ensure that the AC source is well protected from these types of EMI. Transient surge protectors should be considered for lightning protection.

3.3 PHYSICAL SUPPORT REQUIREMENTS

It is important to stabilize the MTD to prevent the system from tipping over or falling. The preferred method is the use of the optional Model 1705 Horizontal Cradle Mount Assembly. An alternative method is to clamp the MTD Handle/Ring Stand Assembly to a table surface.

NOTE: If the MTD System is rotated more than 90° off the vertical position (e.g., with the handle/ring stand down), the liquid helium flow rate will have to be increased.

3.4 LIQUID CRYOGEN

The Model MTD-150 Cryostat can be operated with either liquid helium or liquid nitrogen. This manual assumes operation with liquid helium. The operating procedure for liquid nitrogen is essentially identical except for control valve settings. The MTD-150 system is designed to avoid problems associated with the high latent heat of liquid nitrogen when operating in a variable temperature mode (77 – 400 K).

3.5 STORAGE DEWAR PRESSURIZING

A cylinder of welding grade helium gas is suitable to pressurize the storage dewar whether it is filled with liquid helium or liquid nitrogen. A pressure regulator and gauge with a range of 0 – 10 psig is recommended. A vapor port on the storage dewar neck allows for the pressurization connection. Storage dewars not equipped with a pressurization provision can use an adapter tube and pressure hat.

Storage Dewar Pressuring (Continued)

The transfer line withdrawal tube should be sealed at the storage dewar neck to allow pressure build up. The standard seal is a ½-inch compression fitting. Consult instructions supplied with the storage dewar for proper pressurizing procedure.

3.6 EXHAUST GAS HEATER

A three prong detachable power cord configured for the Customer's power requirements (110 or 220 VAC) is included. The exhaust gas heater should only be plugged in after the system has been pumped out.

CAUTION: The MTD-150 system should always be operated with the exhaust gas heater on when cryogens are used.

3.7 INSTRUMENTATION HOOKUP INSTRUCTIONS

A number of different Lake Shore instruments can be used with the MTD System. Hooking up the Model 1015 Warm-Up Power Supply to the MTD System is shown in Figure 3-2. The Model 330 Autotuning Temperature Controller is shown in Figure 3-3. Finally, the Models DRC-91CA or DRC-93CA Temperature Controller is shown in Figure 3-4. The Model 8271-21M Cable Assembly used with the Model 1015, DRC-91CA, and DRC-93CA is detailed in Figure 5-1. The Model 8271-30M Cable Assembly used with the Model 330 is detailed in Figure 5-2.

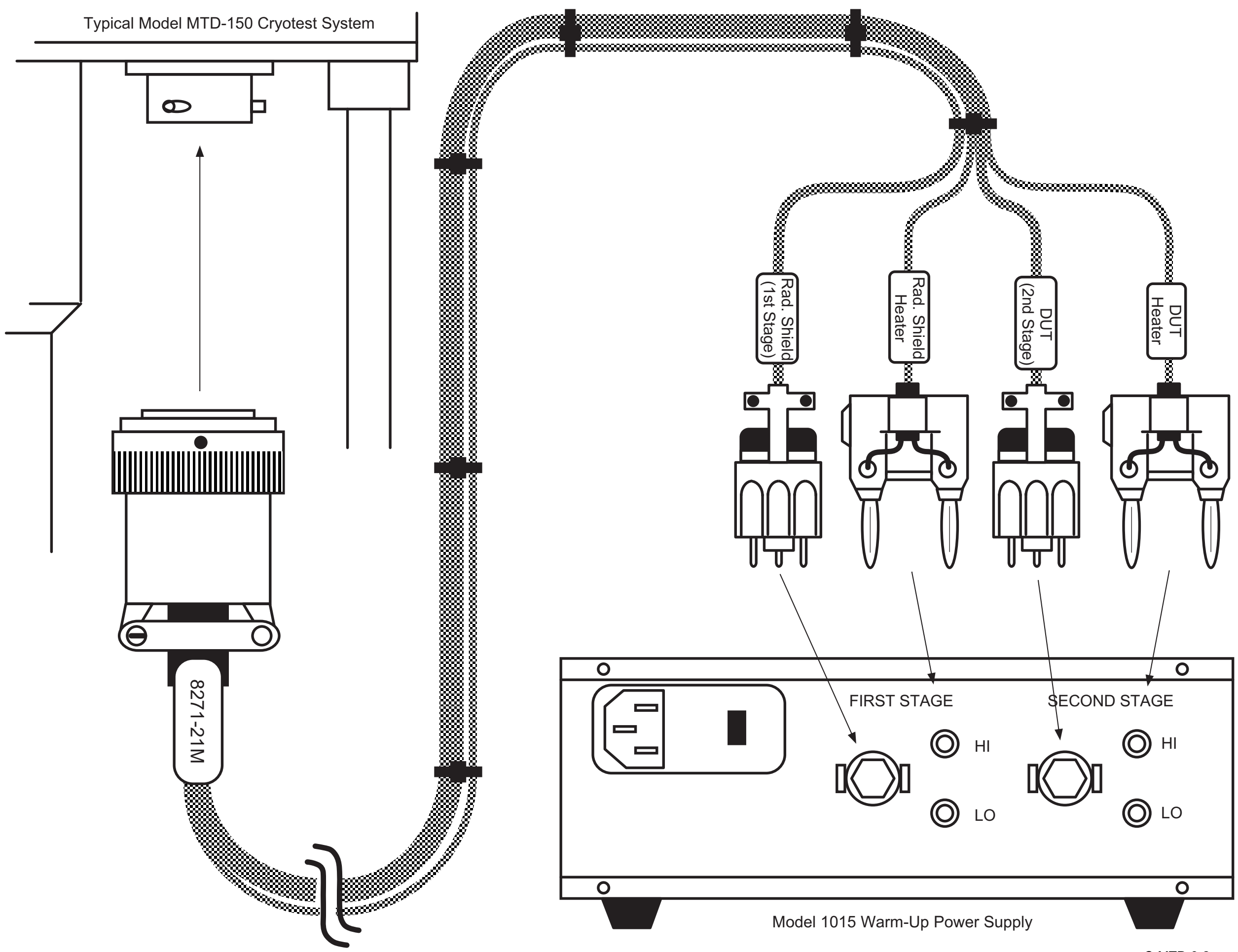

Figure 3-2. MTD System Hookup to the Model 1015 Warm-Up Power Supply

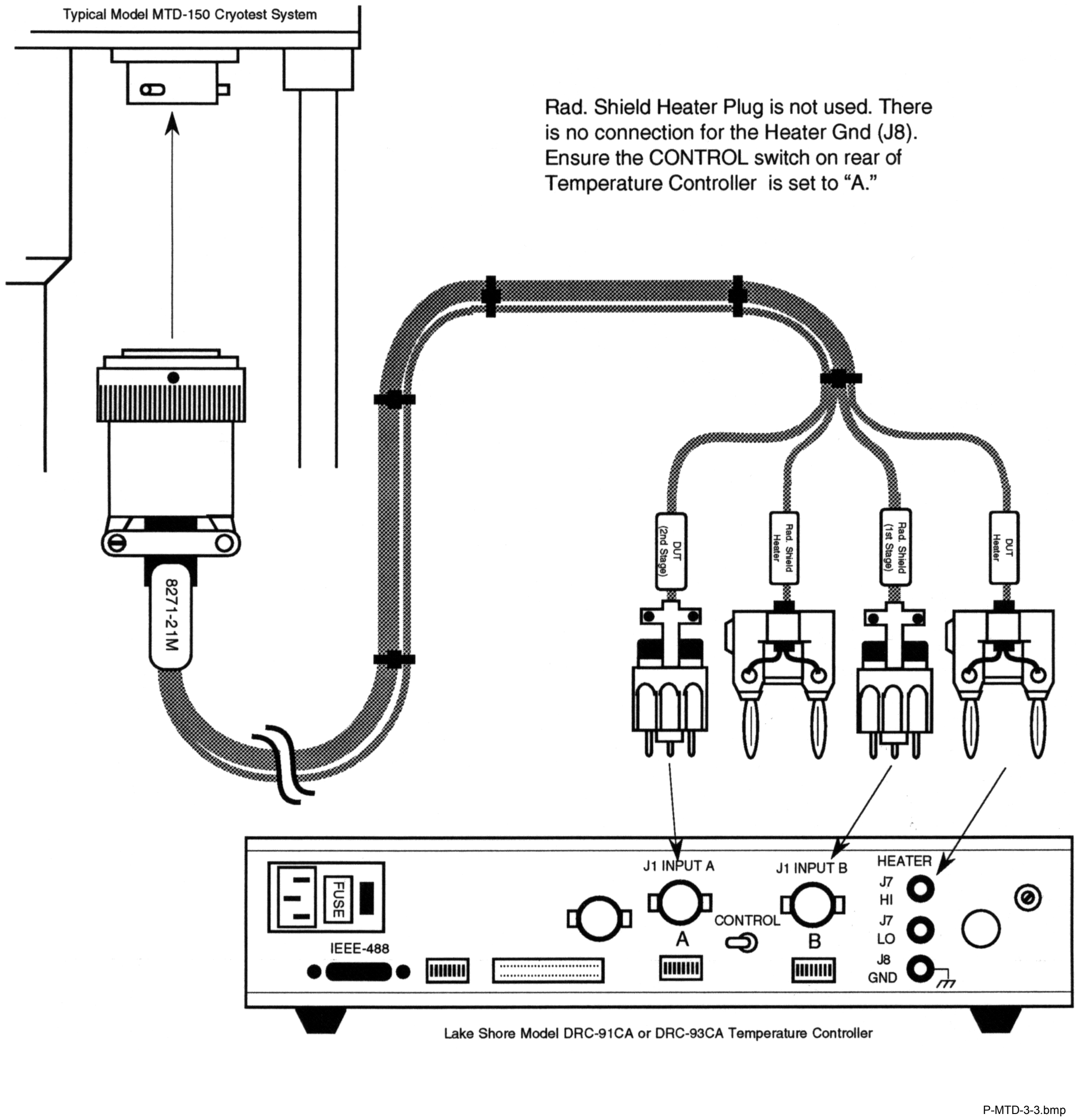

Figure 3-3. MTD System Hookup to the Model DRC-91CA or DRC-93CA Temperature Controller

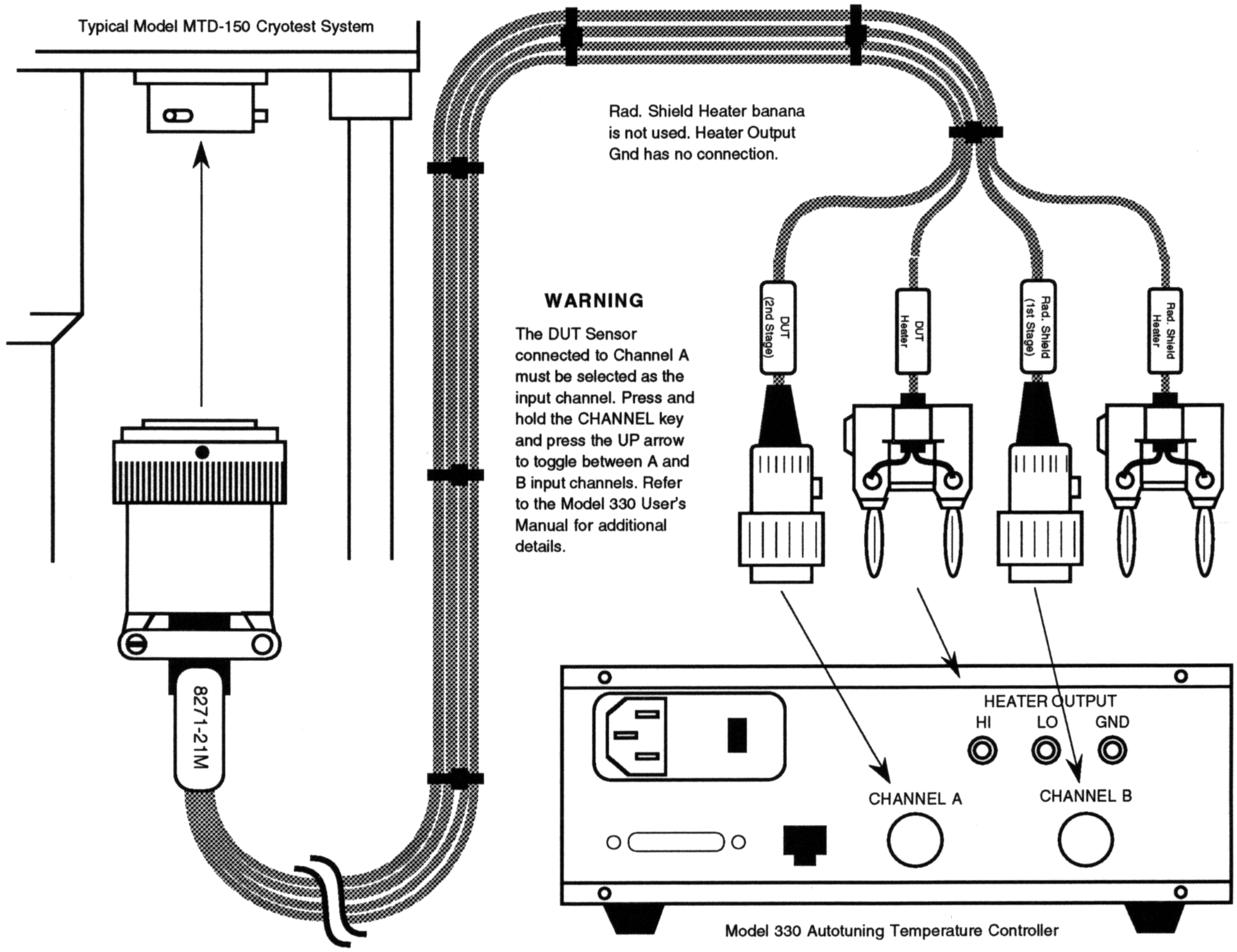

Figure 3-4. MTD System Hookup to the Model 330 Temperature Controller

3.8 MISCELLANEOUS PRECAUTIONS

The following are miscellaneous precautions associated with MTD System operation.

- When necessary, the transfer line should be evacuated with a nitrogen-trapped diffusive-type vacuum system.
- The transfer line should not be bent to less than a 12-inch (30 cm) radius.
- Heater power should not exceed 80 watts (first or second stage on cryostat).
- The DUT mount or any part of the MTD-150 should never be heated above 100 °C.
- Do not "break" vacuum in the chamber while the first or second stage is cold.
- Do not "break" transfer line vacuum with helium gas.
- Avoid contact with cold gas when depressurizing the storage dewar.
- Periodically, the o-ring seals that are routinely accessed and their mating surfaces on the MTD-150 should be cleaned with a paper wipe and re-greased with Apiezon® "N" grease.

3.9 INSERTING A DEVICE UNDER TEST (DUT)

The MTD-150 System should be stabilized at room temperature and the transfer line removed.

1. Open the vacuum pumpout valve on cryostat to vent system.
2. Release the 4 pull-down clamps and remove the vacuum chamber end closure.

NOTE: Place vacuum chamber end closure so that the o-ring is face up to prevent damage.

3. Remove radiation shield by unscrewing the six captive socket head screws.
4. If cooled filter wheel assemblies are installed, remove each by loosening the drive shaft collett lock hex nut and unscrewing the 3 captive screws holding the module to the filter wheel mounting bracket. Refer to Paragraph 4.3 – Filter Wheel Assemblies.
5. Remove the chip carrier clamp assembly held in place by 4 captive socket head screws.
6. Place the DUT in the device socket on the fanout board and ensure that its contacts line up with the socket contacts.
7. Carefully place the chip carrier clamp assembly over the DUT and check that it compresses the DUT into the socket without binding.
8. Replace the chip carrier clamp assembly mounting screws in a 1–2–3–4 sequence to ensure uniform clamping pressure.

CAUTION: Do not over tighten mounting screws or completely tighten one at a time. Tighten each screw one-half turn, continuously repeating the 1–3–2–4 sequence until all four screws are snug.

9. Replace the cooled filter wheel assemblies, if used, and tighten the 3 captive screws and the drive shaft collett lock hex nut. Ensure that the filters/apertures are properly aligned.
10. Replace the radiation shield.
11. Clamp down the vacuum chamber end closure.

3.10 CHANGING THE FANOUT BOARD

If it is necessary to change the fanout board, the steps below should be followed:

NOTE: The MTD-150 System should be stabilized at room temperature and the transfer line removed.

1. Perform Steps 1 thru 5 from Paragraph 3.9 – Inserting A DUT.
2. Remove the fanout board retaining ring held in place by 4 phillips flat head screws.
3. The fanout board may now be removed. Care should be exercised to protect the spring finger contacts exposed by removal of the fanout board.

NOTE: Some test set assemblies (such as the Model 1520-24D, 24-pin DIP with Zero Insertion Force socket) have additional mounting screws that hold the cold pedestal adapter piece in the center of the device socket. These screws must also be removed.

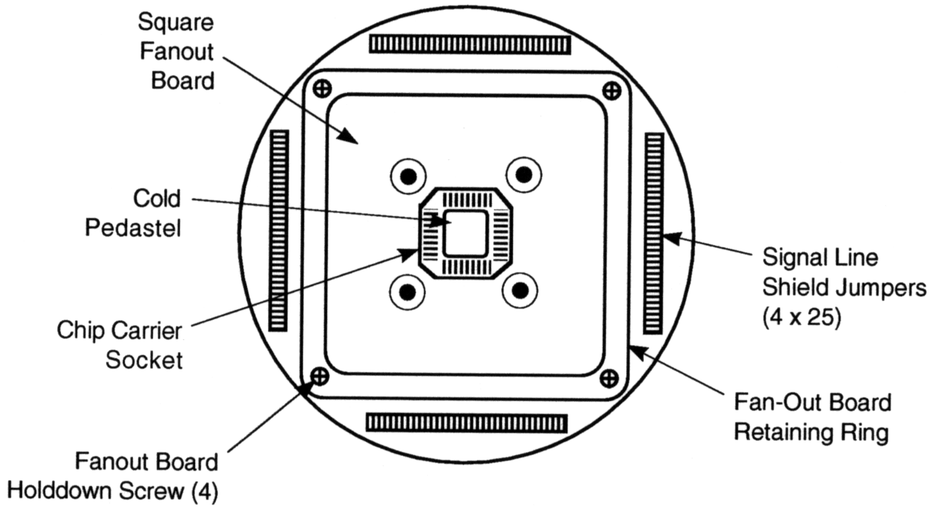

Figure 3-5. Retaining Ring and Fanout Board

4. Install the fanout board so that the cold pedestal protrudes through the device socket.

CAUTION: The cold pedestal and fanout board should not bind. Do not try to force the socket over the cold pedestal.

5. Replace the fanout board retaining ring with the 4 flat head screws.
6. Place the DUT in the device socket on the fanout board and ensure that its contacts line up with the socket contacts.
7. Carefully place the chip carrier clamp assembly over the DUT and check that it compresses the DUT into the socket without binding.
8. Replace the chip carrier clamp assembly mounting screws in a 1–2–3–4 sequence to ensure uniform clamping pressure.

CAUTION: Do not over tighten mounting screws or completely tighten one at a time. Tighten each screw ½ turn, continuously repeating the 1–3–2–4 sequence until all four screws are snug.

9. Replace the cooled filter wheel assemblies, if used, and tighten the 3 captive screws and the drive shaft collett lock hex nut. Ensure that the filters/apertures are properly aligned.
10. Replace the radiation shield.
11. Clamp down the vacuum chamber end closure.

3.11 HOW TO CHANGE THE TEST SET ASSEMBLY

This procedure is necessary when switching a Dual In-Line Package (DIP), Leadless Chip Carrier (LCC), or other device that require a different fanout board and socket.

NOTE: The MTD-150 System should be stabilized at room temperature and the transfer line removed.

1. Follow Steps 1 thru 3 in Paragraph 3.10 – Changing the Fanout Board.
2. Remove the 4 gold plated posts which hold the cold pedestal in place.

CAUTION: Handle posts with care. They are made of gold plated aluminum and threads can be easily damaged.

3. The cold pedestal may now be removed.

NOTE: It may be necessary to gently pry the cold pedestal base from the cold plate as the indium foil at the thermal interface tends to stick to the mated surfaces.

4. Clean the cold plate surface where the cold pedestal will contact the cold plate with rubbing alcohol and a paper wipe. Make sure that the cold pedestal base plate is also clean.
5. Cut pieces of 0.07 – 0.127 mm (0.003 – 0.005 inch) thick indium foil to the shape of the cold pedestal base plate.
6. Fasten the cold pedestal to the cold plate (with the indium foil placed carefully between the surfaces) using the 4 gold plated posts supplied with the test set assembly kit. Also, be sure to use the Belleville spring washers.

CAUTION: Do not over tighten the posts and remember to handle with care.

7. Install the fanout board so that the cold pedestal protrudes through the device socket.

CAUTION: The cold pedestal and fanout board should not bind. Do not try to force the socket over the cold pedestal.

8. Replace the fanout board retaining ring with the 4 phillips flathead screws.
9. Place the DUT in the device socket on the fanout board and ensure that its contacts line up with the socket contacts.
10. Carefully place the chip carrier clamp assembly over the DUT and check that it compresses the DUT into the socket without binding.
11. Replace the chip carrier clamp assembly mounting screws in a 1–2–3–4 sequence to ensure uniform clamping pressure.

CAUTION: Do not over tighten mounting screws or completely tighten one at a time. Tighten each screw one-half turn, continuously repeating the 1–2–3–4 sequence until all four screws are snug.

12. Replace the cooled filter wheel assemblies, if used, and tighten the 3 captive screws and the drive shaft collett lock hex nut. Ensure that the filters/apertures are properly aligned.
13. Replace the radiation shield.
14. Clamp down the vacuum chamber end closure.

CHAPTER 4

OPERATION

4.0 GENERAL

This chapter describes the operation and shutdown of the MTD Cryotest System. Be sure to read the entire manual before continuing. Also ensure that all instruments are working correctly prior to operating the system. MTD System Operation is provided in Paragraph 4.1. MTD System Shutdown is provided in Paragraph 4.2.

4.1 MTD SYSTEM OPERATION

The follow is a typical procedure for operation of the MTD Cryotest System. See the typical operational setup in Figure 4-1.

1. To evacuate vacuum chamber, attach suitable nitrogen-trapped vacuum pumping system capable of <20 millitorr to vacuum port. Turn on vacuum pump.

2. Fully open vacuum pumpout valve mounted on cryostat. In a clean system, 20 millitorr should be reached in 20–30 minutes.

CAUTION: Do not pump on the MTD System when cold or contamination from the pumping system may be "cryopumped" onto cold surfaces. Also, do not vent and back fill system with gas during warm-up. The Model 1015 Warm-up Power Supply should be used for rapid return to room temperature.

3. Fully close valve pumpout valve and disconnect vacuum line.

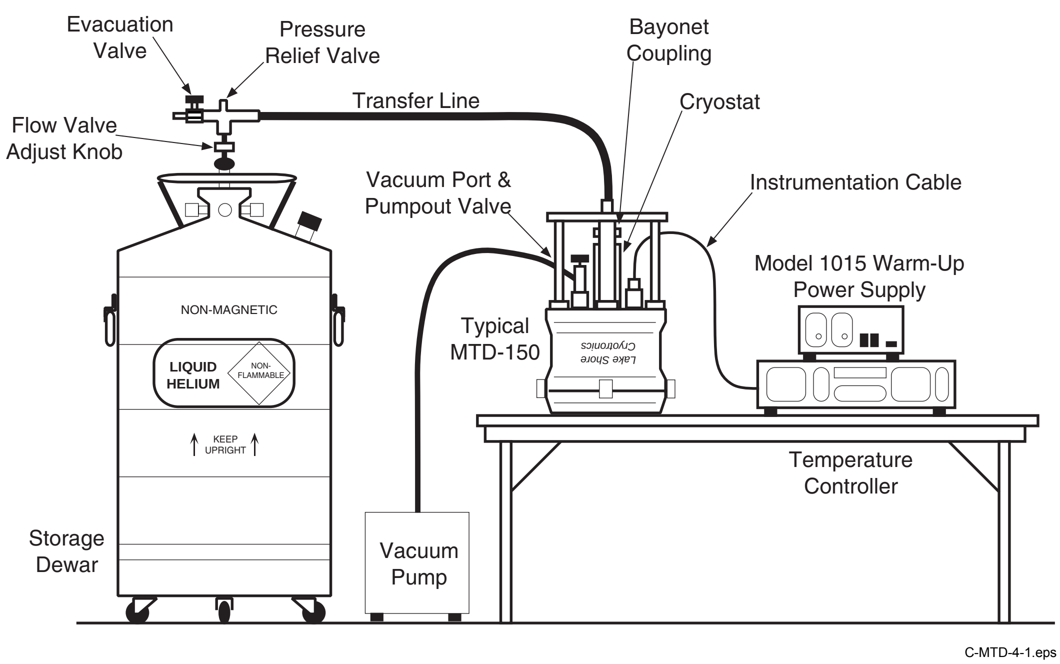

Figure 4-1. Typical MTD Cryotest System Operational Setup

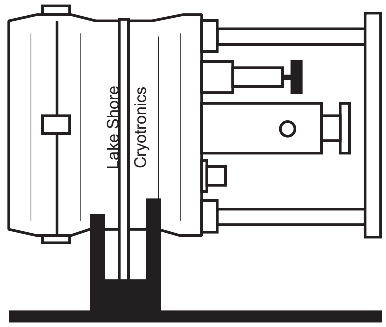

Figure 4-2. Typical MTD with Model 1705 Horizontal Mount Cradle Assembly

CAUTION: It is important to stabilize the MTD to prevent the system from tipping over or falling. The preferred method is the use of the optional Model 1705 Horizontal Cradle Mount Assembly. An alternative method would be to clamp the MTD Handle/Ring Stand Assembly to the table surface.

4. Run heated gas thru the transfer line to ensure that no moisture has accumulated in the line.

NOTE: The fuller the transfer dewar, the more an external source of gaseous helium is needed. Less than full dewars often have a sufficient internal gas pressure to force the liquid cryogen through the transfer line.

5. Open the transfer line valve 1 to 2 turns. Slowly insert the appropriate end of the transfer line into the transfer dewar (until a slight gas pressure can be heard on the other end).

6. Seal storage dewar to allow pressure buildup. Actual seal depends on storage dewar used. Standard seal is a ½-inch compression fitting which provides a gas seal and supports the withdrawal tube.

7. Attach helium gas pressurizing hose to proper pressurizing provision on storage dewar. (If using a pressure hat, this would be 3/8 O.D. tube soldered or welded to hat.) The procedure to hook up an external gas source to the transfer dewar is as follows:

   a. Check both Gaseous Helium and Transfer Dewar pressure gages to ensure they read zero. If not, record the reading.

   b. Connect the proper sized adapter to the transfer dewar vent line.

   c. Turn on the gaseous Helium source valve.

   d. Set the pressure to ≈1 psi. (Use the reading taken in step a to determine 1 psi if the gage was not on zero.)

   e. Open vent valve on transfer dewar.

   f. Usually one turn on the transfer line valve is sufficient.

8. When cold gas begins escaping from transfer line bayonet fitting, remove clamp from the bottom of the MTD cryostat, remove the metal cover, and insert the transfer line into the MTD cryostat bayonet receptacle. Secure with bayonet clamp.

NOTE: Ensure rubber bayonet seal is installed before securing the bayonet clamp.

NOTE: If more than 5 minutes elapses without feeling any cold gas, there may be an ice plug in the line. Depressurize the storage dewar and pull the withdrawal tube out of the storage dewar, warm the transfer line with a heatgun, and purge the line with dry helium gas. (Refer to Chapter 5 – Troubleshooting if attempting a warm-start cool down and there appears to be no gas flow.)

9. Locate 3-pin connector at base of MTD cryostat. Attach the exhaust gas heater cable (provided). Plug the other end of the cryostat heater to an AC power source after the MTD begins to cool. Normally, if cooling at a good rate, you will see a slight white vapor coming from the MTD vent. A sure sign of too rapid cooling is seeing liquid cryogen spitting from the MTD vent.

10. Connect provided Model 8271-XXM Instrumentation Cable to 19-pin instrumentation feedthrough connector located on cryostat.

11. Connect other end of Instrumentation Cable to Temperature Controller. Refer to Figure 3-3 for hookup to Model DRC-91CA or DRC-93CA or Figure 3-4 for hookup to Model 330 Autotuning Temperature Controller.

CAUTION: Check to ensure that the proper sensor is connected to the control input channel on the temperature controller and the correct heater plug is connected to the controller output. Improper connections could cause damage due to applying heater power to one stage while sensing temperature on the other stage.

NOTE: Consult appropriate Temperature Controller User's Manual for controller operation.

12. Wait for the MTD System to cool down to desired temperature. Once temperature is reached, throttle back flow of cryogen. (One-half turn open is sufficient in most cases.)

13. Adjust setpoint on Temperature Controller to desired value. Temperature Controller will apply current to heater of second stage to maintain temperature at setpoint. Consult Application Note *Fundamentals For Usage of Cryogenic Temperature Controllers* normally included in Temperature Controller User's Manual for setting proportional, integral and derivative (PID) constants.

14. To connect Customer instrumentation, connect appropriate cables to four 50-pin feedthrough connectors on vacuum chamber base plate. Connectors are labeled A, B, C, and D. A typical 50-pin connector is illustrated in Figure 4-3. MTD is now ready to perform tests.

NOTE: Although the instrumentation connectors have 50 pins, there are only 25 signal lines per connector. Twenty-five signal lines times four connectors equals the one hundred connections on a typical fanout board. When viewing the instrumentation connector as shown in Figure 4-3, the default setup for a standard MTD-150 assigns the outer row of 25 pins for signals from the DUT. The inner row of 25 pins has connections for the shield. The shield pin corresponds to the signal pin directly adjacent to it.

NOTE: Other wiring configurations are possible per Customer Order. Consult the factory with questions concerning alternative wiring configurations.

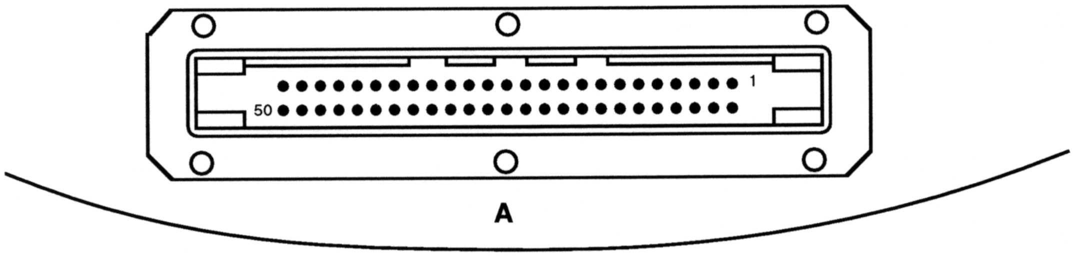

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Figure 4-3. Typical 50-Pin Connector

4.2 MTD SYSTEM SHUTDOWN

At the completion of the test, the following steps will ensure proper shutdown of the system and avoid contamination of the DUT by water vapor or other contaminants.

1. Shut off flow of cryogen by closing transfer line flow valve.

CAUTION: Do not over-tighten the flow valve. Over-tightening may damage the valve seat.

2. Disconnect transfer line from MTD cryostat bayonet receptacle. Remove transfer line.

3. Immediately cap MTD bayonet receptacle with the blank flange. Ensure rubber seal is used between flange surfaces.

4. Slowly depressurize storage dewar before removing withdrawal tube.

NOTE: Follow proper helium handling procedures. Refer to Appendix E – Handling of Liquid Helium and Nitrogen for further information.

5. Slowly remove withdrawal tube from storage dewar allowing it to warm so that o-ring seal does not freeze.

6. Wipe all moisture from transfer line withdrawal tube and bayonet coupling.

NOTE: In order to prevent condensation of moisture, do not open the MTD System until all internal parts are at room temperature. Because the MTD is designed to be thermally efficient, this will take several hours without assistance.

NOTE: Do not vent and back-fill system with gas for a rapid warm-up.

NOTE: The MTD may be warmed to room temperature more rapidly by setting the temperature controller to 295 – 305 Kelvin. This warms the second stage only. Therefore, additional warming time is necessary once the second stage has warmed to ensure that the radiation shield is also warmed.

NOTE: The Optional Model 1015 Warm-Up Power Supply may be used to rapidly warm the system. This unit contains two power supplies and sensor monitor circuits. Both the first and second stages can be warmed quickly and automatically. Power to the first and second stage heaters is automatically shut off when room temperature is achieved. Typical warm up time using the Model 1015 is 30 minutes at full power. Refer to Chapter 6 – Options and Accessories.

CHAPTER 5

TROUBLESHOOTING

5.0 GENERAL

This chapter covers possible difficulties that may occur. Please read the entire chapter before attempting to troubleshoot the MTD Cryotest System.

5.1 NO CRYOGEN FLOW AND NO COOLING

During a warm start cool down, latent heat must be removed from the transfer line. Therefore, the flow rate may be low during this "flat" period and difficult to observe. Allow sufficient time (5 minutes) to make sure that there is no flow before following the procedure below. If there is no cryogen flow and no cooling there may be frozen air or moisture inside the system.

1. Depressurize the storage dewar.
2. Remove the transfer line withdrawal tube from the storage dewar and allow the tube to warm.
3. Attach a helium gas line to the transfer line and purge the transfer line with helium gas for 3–5 minutes.
4. Close the transfer line flow valve using (full counter-clockwise rotation when looking down at the knob).
5. Remove helium gas line from the transfer line.

5.2 CRYOGEN FLOW BUT NO COOLING

If sufficient time has passed to have completed the normal "flat" period and there is cryogen flow but no cooling, check the vacuum integrity of the transfer line. It may be necessary to re-evacuate the transfer line. If the transfer line vacuum is "good," check the vacuum in the MTD-150 vacuum chamber. The vacuum chamber should not feel cold.

5.3 WATER CONDENSES ON OUTER SURFACE OF VACUUM CHAMBER

If the vacuum chamber "sweats," check the vacuum integrity of the chamber.

5.4 INSTABILITY IN MAINTAINING SELECTED TEMPERATURE

If an automatic temperature controller is being used, check that the gain setting is not too high. Make sure there are no electric shorts to the sensors and heaters.

5.5 UNABLE TO REACH COLD TERMINAL TEMPERATURE

This may be caused by any of the following:

- Experimental heat load too high.
- Improper anchoring of instrumentation and DUT lines or poor wiring practices.
- "Soft" vacuum in the vacuum chamber or transfer line.
- Thermal short between DUT and radiation shield or radiation shield and vacuum chamber.
- Poor interfacing between DUT and mount and/or between temperature sensor and cold finger.
- Insufficient cryogen flow rate.

5.6 NO RESPONSE TO CONTROL HEATER

First, make sure the problem is not in the cables to the 19-pin instrumentation feedthrough located on the cryostat main body or in the power supply or controller. Then, check the heater lines with an ohm meter. If approximately 25 ohms are not measured, visually observe the wiring for a solution to the problem; otherwise, the heater will need replacement. Consult the factory for instructions.

5.7 TRANSFER LINES

Lake Shore's transfer lines are shipped with the vacuum jacket evacuated. This is a result of the final testing at the factory, and ensures a clean vacuum space. As a precaution against deterioration of the vacuum which arises sometimes during transit or a prolonged storage periods, the vacuum jacket should be re-evacuated prior to use. This is best done with a good pumping station (e.g., a cold-trapped rotary/diffusion pumping station) capable of an ultimate pressure of approximately 10^{-5} Torr. After evacuation, the evacuation valve should be firmly closed, but care should be exercised to avoid damaging the valve seat by over tightening.

When evacuation is initiated, ensure pressure on the pump side of the evacuation valve is lower than the vacuum space pressure. This is done to avoid drawing oil vapor from the pump into the vacuum space. Thus, one should not pump the vacuum jacket while liquid helium is passing through the inner line, since the liquid helium could cryopump to a lower pressure than the pumping station in use.

The withdrawal tube of the transfer line has a built-in activated charcoal getter to help maintain excellent vacuum when inserted in cryogen. It is important to maintain this space under vacuum at all times and never allow helium gas or moist air into this space. In the event moisture or helium does accidentally enter the space, a pumping station should be attached to the space for several days in order to bring the pressure down to an acceptable level.

On completion of an experiment, the needle valve at the bottom of the transfer line withdrawal tube should be closed, and a one way (or pressure relief) valve should be placed at the vacuum port on the MTD. This prevents any cryogen from reaching the DUT mount and allows any cryogen remaining in the inner line to vent safely outside the cryostat while stopping any air or moisture from entering the inner line region. The storage dewar should then be de-pressurized, and the withdrawal tube removed in order to reduce the heat input into the liquid inside the dewar.

5.7.1 TRANSFER LINE GENERAL PRECAUTIONS

It is important to maintain a vacuum in the transfer line at all times, and re-evacuate it whenever it feels colder than normal during transfer. Evacuation should be done while the inner line is at room temperature. Helium gas and moist air should never be allowed into the vacuum jacket.

- Do not bend the transfer line to a radius of less than 12 inches (30 cm).
- Do not over tighten the needle (flow control) valve at the bottom of the withdrawal tube.
- It is preferable to have an anti-oscillation device on your helium storage dewar, and keep the end of the withdrawal about one centimeter above the bottom of the storage dewar.

5.8 CABLE ASSEMBLIES

Details of the MTD Cable assemblies are provided in Figures 5-1 through 5-3. The Exhaust Gas Heater Cable Assembly is defined in Figure 5-1. The P/N 8271-21M Cable Assembly in Figure 5-2 is used to connect a MTD with either the Lake Shore Model 1015 Warm-Up Power Supply, DRC-91CA, or DRC-93CA Temperature Controllers. The P/N 8271-30M Cable Assembly in Figure 5-3 is used to connect a MTD with the Lake Shore Model 330 Autotuning Temperature Controller.

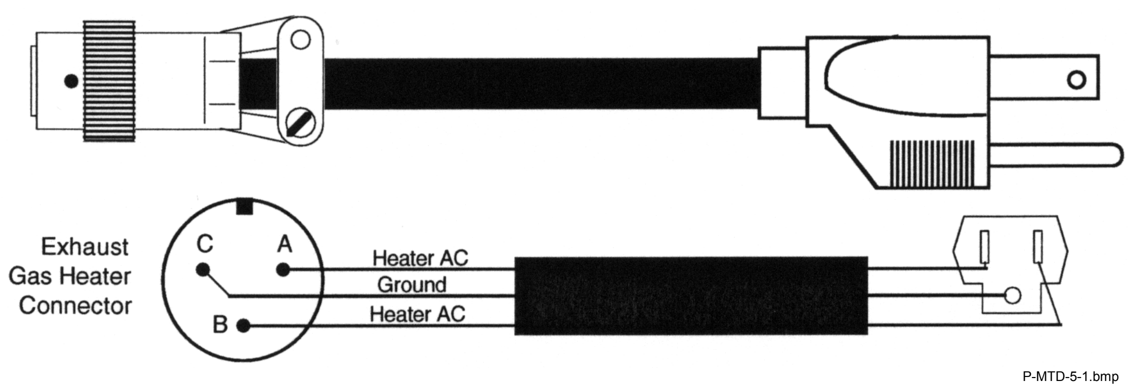


Figure 5-1. Definition of Exhaust Gas Heater Cable Assembly

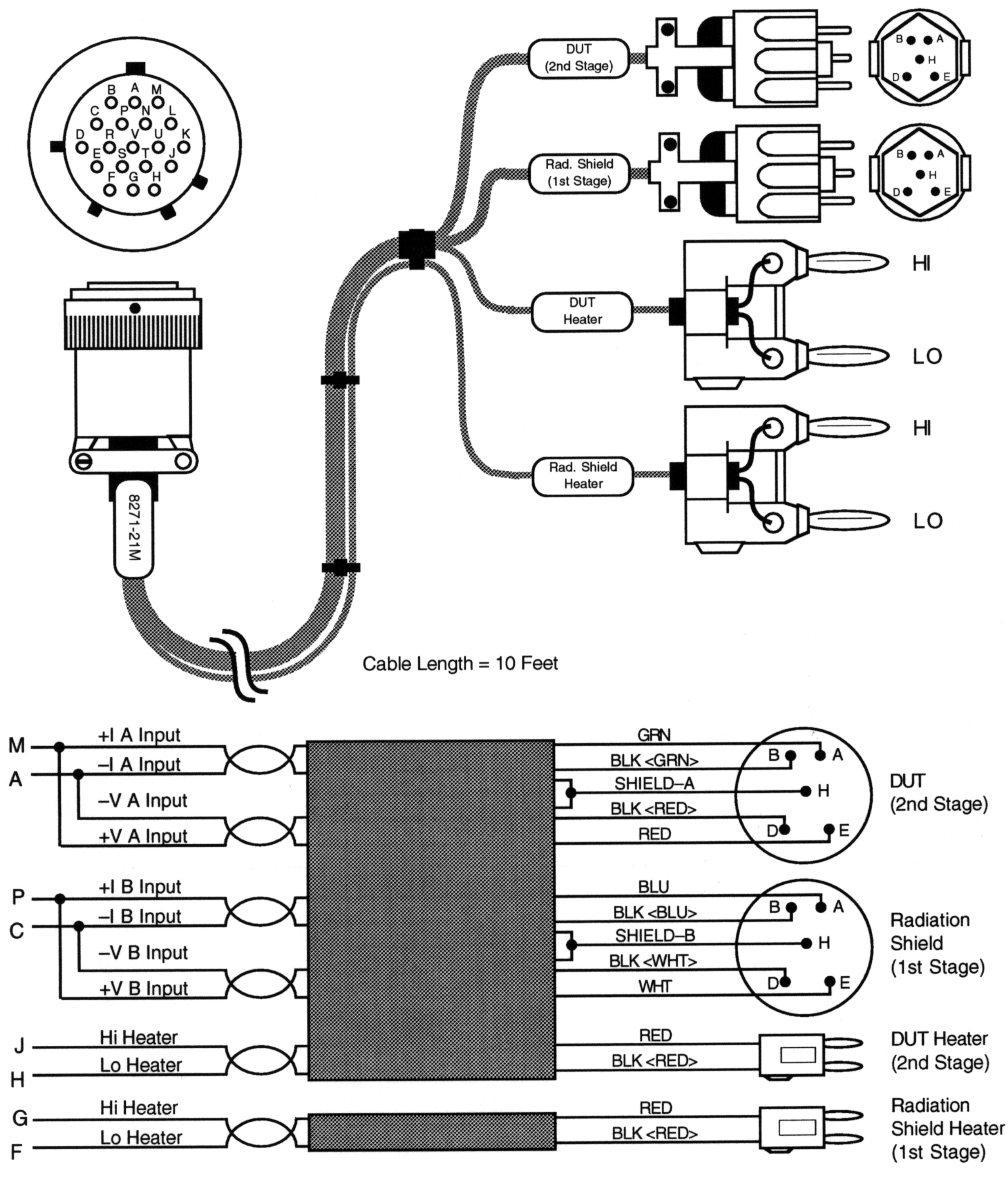


Figure 5-2. Definition of Model 8271-21M Cable Assembly

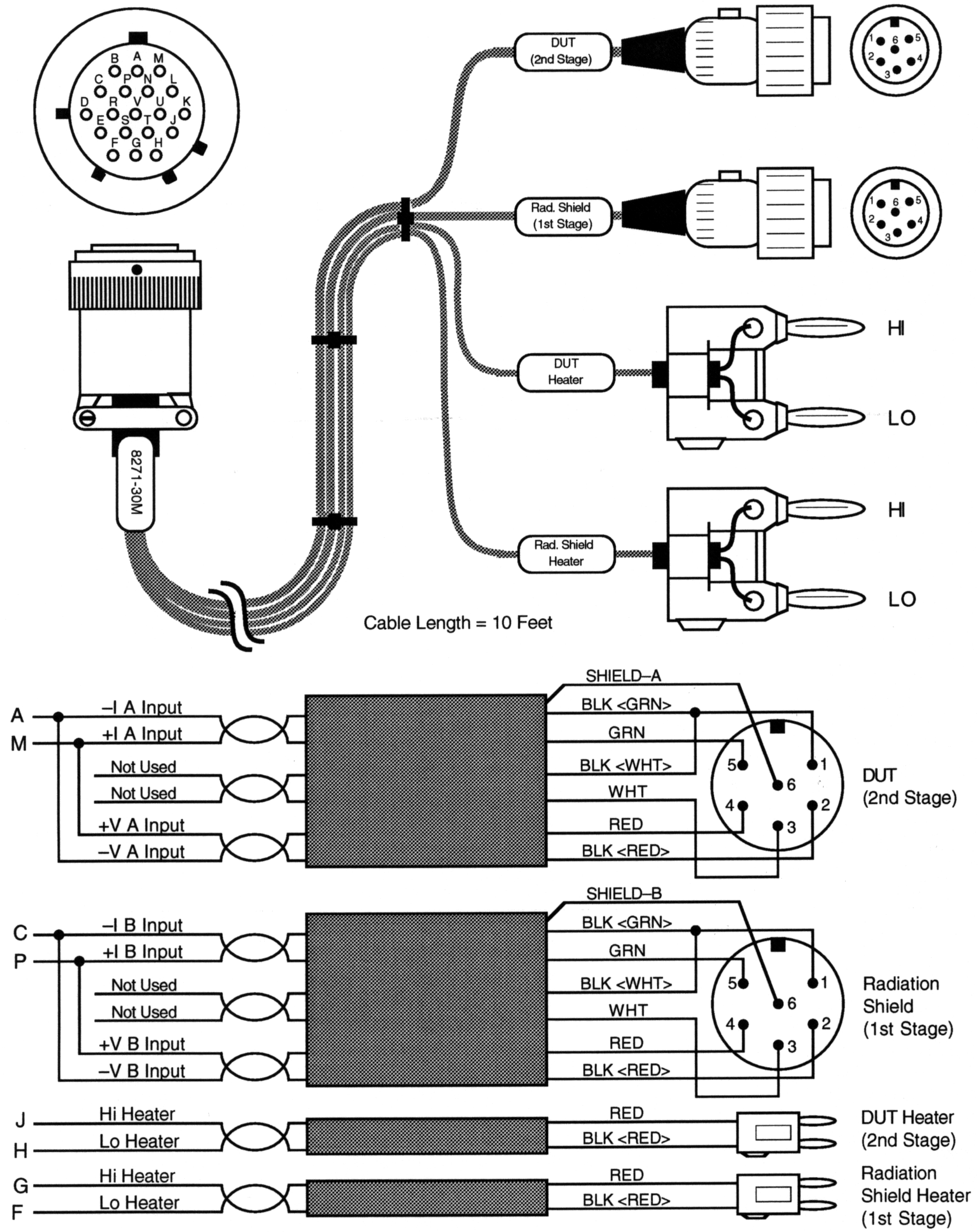


Figure 5-3. Definition of Model 8271-30M Cable Assembly

CHAPTER 6
OPTIONS AND ACCESSORIES

6.0 GENERAL

This chapter provides lists of MTD Cryotest System options and accessories. Options are detailed in Paragraph 6.1. Accessories are detailed in Paragraph 6.2. Finally, a list of associated Lake Shore Publications is provided in Paragraph 6.3.

6.1 MTD CRYOTEST SYSTEM OPTIONS

A list of major MTD Cryotest System Model numbers is provided below. The MTD Cryotest System can be tailored to fit many custom applications. Therefore, there are many possible MTD configurations. Please consult the factory for assistance in designing a new MTD for your application. Further information on the Model 140 and 144 Pour-Fill Dewar is provided in Appendix F. A typical filter wheel assembly is described in Appendix G.

MODEL	DESCRIPTION OF SYSTEM OPTIONS
MTD-140	Single-Position, Pour-Fill Dewar System.
MTD-144	Four-Position, LCC Pour-Fill Dewar System.
MTD-150	Original Single-Position, Continuous-Flow Cryostat System, with round fanout board.
MTD-150B	New Single-Position, Continuous-Flow Cryostat System, with revised cold finger and square fanout board (S/N 10182B and after).
MTD-154	Four-Position, Continuous-Flow Cryostat.
MTD-158	Eight-Position, Continuous-Flow Cryostat.

6.2 ACCESSORIES

Accessories are devices that perform a secondary duty as an aid or refinement to the primary unit. A list of accessories available for the MTD System is as follows. A cross reference of accessory to MTD System Model Number is provided in Table 6-1.

MODEL	DESCRIPTION OF ACCESSORY
330-11	**Model 330 Autotuning Temperature Controller**. The Lake Shore Model 330 digital control unit provides precise temperature measurement and stable temperature control for the test device(s) over the full useful temperature range of the MTD Systems. The Model 330 features both AutoTuning and manual PID temperature controlling modes, SoftCal™, dual sensor inputs, RS-232C, and IEEE-488 Computer Interfaces. The Model 330-11 is recommended for use with MTD Models 150, 154, and 158. Please consult the Lake Shore Product Catalog for configuration, options, and accessory details.
330-11-W50	**Model 330 Autotuning Temperature Controller with 50W Heater Output**. Same as the Model 330-11 but with 50 watt heater output. The Model 330-11-W50 is recommended for use with the MTD Models 140 and 144. Please consult the Lake Shore Product Catalog for configuration, options, and accessory details.
1015	**Warm-Up Power Supply**. The Model 1015 provides up to 80 watts of heater power on each of two channels to warm up both the first (cold finger) and second (radiation shield) stages of the MTD System to room temperature for rapid sample turnaround. Independent temperature control loops are provided for each channel so that each stage may be monitored and shut down automatically when it reaches room temperature. Two different power supply levels are available to each channel, supplying a low range of 25 watts or a high range of 80 watts into a 25 Ω load. The Model 1015 is recommended for use with Models MTD-150, -154, and -158. Please consult the Lake Shore Product Catalog for configuration, option, and accessory details.

ACCESSORIES (CONTINUED)

MODEL	DESCRIPTION OF ACCESSORY
1025	**Breakout Box with 100 BNC Connectors**. Often there is a need to perform simple electrical tests on individual elements of the DUT that are not as accessible in automated testing due to the random nature of the test requirements. Breakout boxes provide the means to accomplish this. Breakout boxes are comprised of a set of floating BNC connectors, one for each signal line. Coaxial ribbon cable is used to connect these signal line to the four 25-line feedthrus on the vacuum chamber base plate. The BNC connectors are arranged in four quadrants, each corresponding to the contacts on one side of the device package. The box makes provision for a schematic representation of the device package to simplify cross-matching of connector locations. Dimensions for the Model 1025 are 12 inches long by 12 inches wide by 4 inches high.
1026	**Breakout Box with 100 Triax Connectors**. Same as Model 1025 but with Triax connectors.
1035	**Breakout Module with 25 BNC Connectors**. Breakout modules are similar in function to the 1025/1026 Breakout Boxes except that they attach directly to the MTD System and contain only 25 coax BNC connectors; which correspond to one side (or quadrant) of the device package. The 1035 mounts directly to the multiple line feedthrus on the base plate of the vacuum chamber. This configuration eliminates the need for an interconnecting cable, reducing potential noise pickup and parasitic capacitance. These modules can also house a variety of electronics, buffer amplifiers, transimpedance amplifiers, and drive electronics.
1036	**Breakout Module with 25 Triax Connectors**. Same as Model 1035 but with Triax connectors.
1045	**Breakout Module with BNC Connectors**. Same as Model 1035 but with 17 floating BNC connectors and the appropriate multi-pin mating connector for use with the Model MTD-158.
1046	**Breakout Module with Triaxial Connectors**. Same as Model 1045 but with 17 floating triaxial connectors and the appropriate multi-pin mating connector for use with the Model MTD-158.
1205	**Liquid Helium/Liquid Nitrogen Transfer Line**. This conventional, flexible vacuum-insulated line consists of a long, rigid withdrawal tube that can be inserted into a liquid helium storage vessel or modified liquid nitrogen container. It can also be used to operate the MTD System in a continuous flow mode. The withdrawal tube contains a filter to prevent foreign matter from plugging the small diameter inner tube, and an integral valve assembly for control of the cryogen flow rate. The other end of the transfer line is terminated in a bayonet fitting which is easily mated to the MTD-100 liquid transfer cooling unit. The transfer line vacuum space is fitted with a vacuum pumpout valve and safety pressure relief valve.
1210	**Liquid Nitrogen Transfer Line**. Flexible vacuum-insulated line for transferring LN_2 from a pressurized storage dewar to an MTD System. It can also be used to operate the MTD System in a continuous flow mode. Consists of a 1 meter (3 foot) long withdrawal tube that can be inserted into a modified liquid nitrogen container. The withdrawal tube incorporates filter to prevent foreign matter from plugging the small diameter inner tube and an insulated valve assembly for control of cryogen flow. The other end of the transfer line is terminated in a bayonet fitting which is easily mated to the MTD-100 liquid transfer cooling unit.
1215	**Liquid Nitrogen Precooling Transfer Line**. Flexible stainless steel transfer line used to quickly and economically precool an MTD System to ≈80 K with LN_2 before cooling the system to 5 K with more costly LHe.

ACCESSORIES (CONTINUED)

MODEL	DESCRIPTION OF ACCESSORY
1220-50	**Liquid Nitrogen 50 Liter Storage Dewar**. The Storage Dewar is a rugged 50-liter self-pressurized dewar configured to be compatible with the Model 1210 and 1215 Transfer Lines. The top of the dewar is equipped with a port which will accommodate the transfer line 0.5 inch rigid withdrawal tube to permit siphonal withdrawal of the LN_2 (the same withdrawal process which is commonly used with laboratory LHe storage dewars). Permanent vacuum insulation and mulitlayer reflective shielding with getter materials ensure normal LN_2 evaporation losses of <1.5 liters per day. The polished stainless steel dewar is supplied with a ½-inch fill and withdrawal valve, a 3/8-inch vent valve, and a liquid level gauge. It is mounted on casters for easy mobility. Liquid Capacity: 50 Liters Loss Rate: 1.5 liters per day, maximum Operating Pressure: 10 psi, maximum Pressure Gauge: 0 – 30 psig Weight: Empty: 100 pounds Full: 180 pounds Shipping: 150 pounds Outside Diameter: 18 inches Overall Height: 42 inches Connections: Fill and Withdrawal: ½ inch male flare Vent: 3/8 inch male NPT Transfer Line Port: 0.5 inch I.D.
1305	**Cooled Filter/Aperture Wheel Assembly – Manual**. When it is necessary to illuminate the DUT through a series of filters, those filters should be as close in temperature to the DUT. The MTD system solves this problem. Fully enclosed filter wheel assemblies may be fitted inside an extended height (length) vacuum shroud end closure and radiation shield over the sample test area. The wheel features eight 25.4 mm (1 inch) diameter filter mounts positioned to be rotated directly into the optical axis of the system. The filter wheel is coupled to a drive shaft assembly which protrudes through the base plate. There it terminates in a high resolution drive mechanism coupled to a 3-digit position indicator that precisely aligns each filter with the optical axis. For finer control of light entering the test chamber, a second filter wheel assembly may be mounted in the standard MTD System. It is independently rotated by its own drive assembly. Will accommodate 25.4 mm (1 inch) diameter filters, 1–2 mm thick, in standard configuration. Adapters for 12.7 mm (0.5 inch) diameter filters are available. Compatible with MTD-140 and 150. ***Filter wheel assemblies are factory installed and must be specified at time of initial order.***
1306	**Cooled Filter/Aperture Wheel Assembly – Manual**. Recommended for device testing at low background levels out to 30 microns. The wheel module is enclosed on all sides and a low temperature/low radiation background enclosure surrounds the assembly. Compatible with MTD-140 and 150. ***Filter wheel assemblies are factory installed and must be specified at time of initial order.***
1307	**Cooled Filter/Aperture Wheel Assembly – Manual**. Compatible with MTD-144 and 154. ***Filter wheel assemblies are factory installed and must be specified at time of initial order.***
1308	**Cooled Filter/Aperture Wheel Assembly – Manual**. Compatible with MTD-158. ***Filter wheel assemblies are factory installed and must be specified at time of initial order.***
1310	**Dual Cooled Filter/Aperture Wheel Assembly – Manual**. Includes a second eight-position filter wheel assembly installed above the first wheel. Compatible with MTD-140 and 150. ***Filter wheel assemblies are factory installed and must be specified at time of initial order.***
1401	**Motorized Driver and Controller Assembly**. Motorized driver and controller assemblies are used with the Cooled Filter/Aperture Wheel Assemblies whenever fully automated, computer controlled device testing is required. Operation is manual using the front panel or remotely via the standard RS-232C Serial Computer Interface. Compatible with MTD-140, 144, 150, and 154. ***Motorized assemblies are factory installed and must be specified at time of initial order.***

ACCESSORIES (CONTINUED)

MODEL	DESCRIPTION OF ACCESSORY
1402	**Dual Motorized Driver and Controller Assembly**. Motorized driver and controller assemblies are used with the Cooled Filter/Aperture Wheel Assemblies whenever fully automated, computer controlled device testing is required. They can also be used for lifting and rotating the test device carousel in the MTD-158 Carousel System. Operation is manual using the front panel or remotely via the standard RS-232C Serial Computer Interface. Compatible with MTD-140 and 150. ***Motorized assemblies are factory installed and must be specified at time of initial order***.
1403	**Triple Motorized Driver and Controller Assembly**. Motorized driver and controller assemblies are used with the Cooled Filter/Aperture Wheel Assemblies whenever fully automated, computer controlled device testing is required. They can also be used for lifting and rotating the test device carousel in the MTD-158 Carousel System. Operation is manual using the front panel or remotely via the standard RS-232C Serial Computer Interface. Compatible with MTD-158. ***Motorized assemblies are factory installed and must be specified at time of initial order***.
1520	**Fanout Boards**. A fanout board is a printed circuit board which is used to interconnect the Device Under Test (DUT) to the coax signal lines (via the interface board) in the MTD System. The socket for a particular device package is mounted on the fanout board and the socket contacts are soldered to the board traces. The fanout board 50 Ω stripline transmission traces are gold plated to enhance the electrical connections and to inhibit corrosion. The Model 1520 Series fanout boards/DIP fanout boards may be configured with any commonly used chip carrier sockets. Will accommodate zero insertion force, DIP (to 64-pin capacity) devices, or 68-, 84-, or 100-pin LCCs. Custom package configurations are also available. Consult Lake Shore for further information. 1520-68 – For 68-pin LCC devices 1520-84 – For 84-pin LCC Devices 1520-xxD– For DIP devices ("xx" up to 64 pin maximum) 1520-40Z – For 40-pin Zero Insertion Force (ZIF) devices
1520K	**Device Test Set Assembly Kit**. This kit includes a fanout board/DIP fanout board with any commonly used chip carrier sockets, chip carrier clamp assembly, and cold finger pedestal—all gold plated. The clamp assembly positions the chip carrier against the cold pedestal and holds the fixed aperture disks and optical filters. A 1-inch (2.54 cm) diameter aperture disks with one or two cold filters is inserted in the optical path and held in place by a screw-on cap with a 0.8 inch (2.93 cm) aperture. All interior optical surfaces are vapor-blasted and black-anodized to minimize optical reflections. The test set assembly kit is ordered separately from the basic MTD system mainframe. Each test set is configured to accommodate the standard or modified fanout board/chip carrier socket arrangement you require. One test set is required per MTD mainframe. Consult Lake Shore for further information. 1520K-68 – Kit for 68-pin LCC devices 1520K-84 – Kit for 84-pin LCC Devices 1520K-xxD– Kit for DIP devices ("xx" up to 64 pin maximum) 1520K-40Z – Kit for 40-pin Zero Insertion Force (ZIF) devices
1521	**Personality Fanout Boards**. Model 1521 Series personality boards have their circuit traces interrupted and terminated in bifurcated pins, offering a means to reroute contact connections. Available in 68-, 84-, and 100-pin configurations. Consult Lake Shore for further information. 1521-68 – Kit for 68-pin LCC devices 1521-84 – Kit for 84-pin LCC Devices 1521-xxD– Kit for DIP devices ("xx" up to 64 pin maximum) 1521-40Z – Kit for 40-pin Zero Insertion Force (ZIF) devices

ACCESSORIES (CONTINUED)

MODEL	DESCRIPTION OF ACCESSORY
1521K	**Device Test Set Assembly Kit**. The Model 1521K Series of test set assembly kits are complete device kits incorporating the Model 1521 personality-style fanout boards with specific device socket, a clamp assembly, and the appropriate cold finger pedestal—all gold plated. The clamp assembly positions the chip carrier against the cold pedestal and holds the fixed aperture disks and optical filters. A 1-inch (2.54 cm) diameter aperture disks with one or two cold filters is inserted in the optical path and held in place by a screw-on cap with a 0.8 inch (2.93 cm) aperture. All interior optical surfaces are vapor-blasted and black-anodized to minimize optical reflections. The test set assembly kit is ordered separately from the basic MTD system mainframe. Each test set is configured to accommodate the standard or modified fanout board/chip carrier socket arrangement you require. One test set is required per MTD mainframe. Consult Lake Shore for further information. 1521K-68 – Kit for 68-pin LCC devices 1521K-84 – Kit for 84-pin LCC Devices 1521K-xxD– Kit for DIP devices ("xx" up to 64 pin maximum) 1521K-40Z – Kit for 40-pin Zero Insertion Force (ZIF) devices
1521CC-100	**Chip Carrier/Personality Fanout Board**. The Model 1521CC-100 is a personality-style fanout board with a built-in chip carrier. The 100-pin fanout board incorporates a 1 inch square chip well with an Invar mounting base in the center of the board to accommodate DUT chips. The 1521CC board has 100 wire bond pads for connections to the DUT chip. A G-10 fiberglass ring is installed over the wire bond pad traces for protection. The 1521CC-100 board can be used with an MTD-140 or -150 System. The mounting hardware from a 1521CCK-100 test set assembly kit is required. Typically, the user bonds or laminates the DUT chip to the 1521CC-100 Invar mounting base and wire bonds the chip lead connections to the contact pads on the board. Using the solderable through-plated holes, the user then wires (breadboard style) the bond pad traces to the signal line traces on the board to complete the electrical connection to the coaxial signal line of the MTD System.
1521CCK-100	**Chip Carrier/Personality Fanout Board Kit**. The Model 1521CCK-100 includes one 1521CC-100 chip carrier/personality fanout board and all hardware necessary to properly install the board in an MTD-140 or -150 System and to clamp the DUT chip to the cold plate. The complete kit includes the chip carrier fanout board, board mounting hardware, a clamp assembly for the DUT chip, and a cold finger pedestal for the Invar mounting base of the board. All of the clamp assembly interior optical surfaces are bead-blasted and black anodized to minimize optical reflections. **NOTE**: The device clamp housing can be custom configured to accommodate special filters or apertures. The custom clamp housing would position the filter/aperture directly above the test device.
1522	**General Purpose Fanout Board**. The Model 1522 is a versatile tool which gives the user of an MTD-140 or -150 System the flexibility to configure their system to test custom devices or complete modules. The Model 1522 is an annular board with 100 signal traces terminated into bifurcated pins around the 7.6 cm (3 inch) diameter center hole. The 1522 fanout board is installed in the MTD System by mounting it directly on the interface board fingers and clamping it into place with the fanout board retaining ring. The bifurcated pins are now connected to the 100 signal lines. Using Customer-supplied installation hardware, (device mounting hardware, device clamping hardware, cold pedestal) the device/module to be tested is mounted directly on the cold plate or on a cold pedestal. The test device/module leads are then wired to the 1522 bifurcated pins for connection to the coax signal lines.

ACCESSORIES (CONTINUED)

<table>
<tr><th>MODEL</th><th>DESCRIPTION OF ACCESSORY</th></tr>
<tr><td>1522-Matrix</td><td> General Purpose Fanout Board – Special Version . A special version of the 1522 General Purpose Fanout Board with a center pin grid matrix. The 1522-Matrix is a very versatile tool which the Customer can use to configure an MTD-140 or -150 System to bread-board test any custom device or module. There is a 24 x 24 pin grid matrix in the center of the board in place of the standard Model 1522 center hole. The 576 holes in the pin grid matrix are 0.04 inch diameter and are through-plated. The 100 signal lead traces are terminated with bifurcated pins around the periphery. The 1522-Matrix board is installed by mounting it directly on the interface board fingers and clamping it in place with the fanout board retaining ring. When installed in the MTD System, the bifurcated pins are connected to the 100 coaxial signal lines. Installation: The Customer configures or modifies the board to accommodate the requirements of the custom device to be tested. The Customer supplies the cold pedestal to provide the thermal interface between the test device and the cold plate of the MTD system and provides the clamp assembly to hold the custom test device against the cold pedestal. In a typical installation, the MTD System user makes a cold pedestal and a clamp assembly appropriately sized for the device to be tested, and cuts a hole in the fanout board grid matrix to fit this cold pedestal. The socket/carrier for the custom device, if applicable, is mounted on the board over the cold pedestal hole. The remainder of the pin grid matrix is used to bread-board the DUT connections to the signal line bifurcated pins on the periphery of the card. </td></tr>
<tr><td>1550</td><td>DT-470 Sensor and Chip Heater Pre-Mounted in a Customer-Supplied Leadless Chip Carrier (LCC) Mounting Base. This is a service provided by Lake Shore for Customers who want one of their own LCC mounting bases configured with a temperature sensor and heater. This accessory normally uses a Lake Shore Model DT-470-SD-12A silicon diode cryogenic temperature sensor. Please contact Lake Shore for further information on this service.</td></tr>
<tr><td>1620</td><td> Four 25-Lead Ribbon Cables. A set of four 25-lead ribbon coax cables terminated in Insulation Displacement Contact (IDC) style 50 pin (0.1 x 0.1 inch spacing) female socket headers on both ends. Length is 1 meter (3 feet). The female socket headers are compatible with the male sockets in the 1025 Breakout Box and the 25-line/50-pin vacuum feedthrough connectors on all models of the MTD System. Compatible with the Model 1025 Breakout Box and 25 line/50 pin vacuum feedthrough connectors on most MTD Systems. Specifications are listed below. Electrical Specifications:
Impedance: 50 ±3 Ohms
Capacitance: 31 pF/ft (304.8) nom.
Crosstalk Constant* (Adjacent Pair):
Far End 2%, Near End 4%
Crosstalk Constant* (All Other Lines):
Far End 0%, Near End 0%
Propagation Display: <1.6 ns/ft. (304.8)
Risetime Degredation (20-80%):
<400 ps/10 ft (305 m)
Attenuation (at 100 MHz):
<14 dB/100 ft (30.48 m) * Terminated Cable Assembly
Dimensions are in inches with metric equivalents in parenthesis Mechanical Specifications:
Center Conductor: 28 AWG
(0.08-0.09 mm^2) Cu
Insulation Coating: Alkyd Enamel
Dielectric: Polyproplylene
Dielectric Constant: 2.3 nom.
Diameter: 0.041 (1.04) nom.
Shield: Al Mylar Foil 0.00135
(0.03429) thick
Drain Conductor: 28 or 30 AWG
(0.09-0.05) mm^2 Tin Plated Cu
Jacket: PVC (Fr)
Color per EAI STD RS-359: Black
Centerline Spacing: 0.100 (2.54) If you wish to buy Socket Strips and solder your own cables, mating socket connectors can be ordered from Samtec, P.O. Box 1147, New Albany, IN 47151-1147, 812-944-6733. Different styles are available. For 50 pins, we suggest the Hi-Temp 0.025-inch square Socket Strips P/N SSW-125-04-G-D, and for 34 pins P/N SSW-117-04-G-D. </td></tr>
<tr><td>1630</td><td>Socket/BNC Cable Assembly. The 1630 provides the MTD user with the capability of making convenient BNC connections to the individual signal lines in an MTD System. The 1630 consists of 3 feet of coaxial ribbon cabling with connectors on each end. On one end is a 50-pin female socket header which mates with the 25-line/50-pin vacuum feedthrus for the signal lines on all MTD Systems. The other end of the cable has 25 individual female BNCs attached to the 25 coax lines of the ribbon cable. The center pin is the conductor and case is the shield. Length is 1 meter (3 feet). Electrical and mechanical specifications are as listed for the Model 1620.</td></tr>
</table>

ACCESSORIES (CONTINUED)

MODEL	DESCRIPTION OF ACCESSORY
1705	**Horizontal Cradle Mount Assembly**. The heavy duty, horizontal cradle mount assembly securely clamps the MTD unit in a horizontal, side-looking position. Construction is 12.7 cm (0.5 inch) aluminum plate with black-anodized finish. Compatible with all MTD Models; standard with the Model MTD-158.
1710	**Gimbal Base Assembly**. Pivots an MTD system on the gimbal's horizontal support axis for placement in a down-looking, up-looking, or horizontal orientation. Construction is 12.7 cm (0.5 inch) aluminum plate with black-anodized finish. Compatible with Models MTD-140 and MTD-150 (10-inch diameter dewars).
1711	**Gimbal Base Assembly**. Same as the Model 1710 but compatible with Models MTD-144, -154, and -158 (12-inch diameter dewars).
1810	**Blackbody Source/Chopper Wheel Assembly**. The 1810 is a blackbody source and chopper wheel assembly. It is available for installation on all MTD Systems. Arrangement and dimensions may vary according to individual customer requirements.
8271-21M	**MTD Instrumentation Cable Assembly**. This cable assembly is used to interconnect any MTD System with a Lake Shore Model DRC-82C, -91C, -91CA, -93, or -93CA Temperature Controller. The cable consists of laboratory-quality, twisted, shielded cable and is 2.74 meters (10 feet) in length.
8271-30M	**MTD Instrumentation Cable Assembly**. This cable assembly is used to interconnect any MTD System with a Lake Shore Model 320 or 330 AutoTuning Temperature Controller. The cable consists of laboratory-quality, twisted, shielded cable and is 2.74 meters (10 feet) in length.
9001-00X	**Lake Shore Cryogenic Wire**. Lake Shore sell the following types of cryogenic wire: DT = Duo-Twist™, MN = Single Strand, MW = Manganin, NC = Nichrome Heater, ND = Heavy Duty, QL = Quad-Lead™, and QT = Quad-Twist™. Please refer to the Lake Shore Catalog for wire details.
9004-020	**Apiezon® "N" Grease, 25 gram Tube**. General purpose grease well-suited for cryogenic use because of its low viscosity. It is often used as a means of thermally anchoring cryogenic sensors as well as lubricating joints and o-rings. Contains high molecular weight polymeric hydrocarbon additive which give it a tenacious, rubbery consistency allowing the grease to form a cushion between mating surfaces.
9005-014	**19-Pin Vacuum Feedthrough Connector Without Flange**. See Figure 6-1.
9005-015	**Mating Connector for 9005-014 and 9005-016 19-Pin Vacuum Feedthrough Connectors**. Hardware for attaching connector to a Customer-supplied cable is included. See Figure 6-3.
9005-016	**19-Pin Vacuum Feedthrough Connector With Flange**. See Figure 6-2.
9005-017	**Mating Adapter for Mounting P/N 9005-016**. Used for mounting a P/N 9005-016 in 3/8 inch (0.53-mm) NPT Male Thread. See Figure 6-4.
9007-002	**Indium Foil (5 Pieces)**. Indium is a semi-precious non-ferrous metal, softer than lead, and extremely malleable and ductile. It stays soft and workable down to cryogenic temperatures. May be used as a sealing gasket for covers, flanges, and windows in cryogenic applications.
DRC-91CA	**Model DRC-91CA Temperature Controller**. The Lake Shore Model DRC-91CA is a temperature controller mainframe featuring analog controls. Please consult the Lake Shore Product Catalog for configuration, option, and accessory details.
DRC-93CA	**Model DRC-93CA Temperature Controller**. The Lake Shore Model DRC-93CA is a temperature controller mainframe featuring digital controls. Please consult the Lake Shore Product Catalog for configuration, option, and accessory details.

Table 6-1. MTD Accessory to Model Number Cross Reference

Accessory	MTD-140	MTD-144	MTD-150	MTD-154	MTD-158
330-11 AutoTuning Temperature Controller			X	X	X
330-11-W50 AutoTuning Temperature Controller	X	X			
1015 Warm-Up Power Supply			X	X	X
1025 Breakout Box with 100 BNCs	X	X	X	X	
1026 Breakout Box with 100 Triaxial Connectors	X	X	X	X	
1035 Breakout Module with 25 BNCs	X	X	X	X	
1036 Breakout Module with 25 Triaxial Connectors	X	X	X	X	
1045 Breakout Module with 17 BNCs					X
1046 Breakout Module with 17 Triaxial Connectors					X
1205 LHe & LN_2 Transfer Line	X	X	X	X	X
1210 LN_2 Transfer Line	X	X			
1215 LN_2 Precooling Transfer Line			X	X	X
1220-50 LN_2 50 Liter Storage Dewar	X	X	X	X	X
1305 Cooled Filter/Aperture Assembly	X		X		
1306 Cooled Filter/Aperture Assembly	X		X		
1307 Cooled Filter/Aperture Assembly		X		X	
1308 Cooled Filter/Aperture Assembly					X
1310 Cooled Filter/Aperture Assembly	X		X		
1401 Motorized Driver & Controller Assembly	X	X	X	X	
1402 Dual Motorized Driver & Controller Assembly	X		X		X
1403 Triple Motorized Driver & Controller Assembly					X
1520 Series Fanout Boards	X		X		
1520K Series Fanout Board Test Set Assembly	X		X		
1521 Series Fanout Board	X		X		
1521K Series Fanout Board Test Set Assembly	X		X		
1522 General Purpose Fanout Board	X		X		
1522-Matrix Fanout Board	X		X		
1550 Installation of Lake Shore DT-470 Sensor	X	X	X	X	X
1620 Coax Cable	X	X	X	X	
1630 Socket/BNC Ribbon Coax Cable Assembly	X	X	X	X	
1705 Cradle Base Assembly	X	X	X	X	Std.
1710 Gimbal Base Assembly	X		X		
1711 Gimbal Base Assembly		X		X	X
1810 Blackbody Source/Chopper Wheel Assembly	X	X	X	X	X
8271-21M Instrumentation Cable Assembly	X	X	X	X	X
8271-30M Instrumentation Cable Assembly	X	X	X	X	X
9005-014 19-Pin Feedthru Connector w/o Flange					
9005-015 Mating Connector for 9005-014 & -016					
9005-016 19-Pin Feedthru Connector w/Flange					
9005-017 Mating Adapter for Mounting 9005-016					
DRC-91CA AutoTuning Temperature Controller					
DRC-93CA AutoTuning Temperature Controller					

6.3 LIST OF ASSOCIATED LAKE SHORE PUBLICATIONS

A list of Lake Shore Technical Publications, Application Notes, and literature that may be associated with the MTD Series are listed as follows:

NUMBER	TITLE
MAN-1015	Model 1015 Warm-Up Power Supply User's Manual.
MAN-330	Model 330 Autotuning Temperature Controller User's Manual.
MAN-91C	Model DRC-91CA Temperature Controller User's Manual.
MAN-93C	Model DRC-93CA Temperature Controller User's Manual.
—	Application Note – DT-470 Series Temperature Sensors Installation and Operation
—	Application Note – Fundamentals For Usage of Cryogenic Temperature Controllers
—	Article Reprint – Performance Characteristics of Silicon Diode Cryogenic Temperature Sensors, by Dodrill, Krause, Swinehart, and Wang
—	Lake Shore Measurement and Control Technologies Product Catalog
—	Technical Data – DT-470 Series Temperature Sensors Interchangeability
—	Technical Data – Standard Curve #10

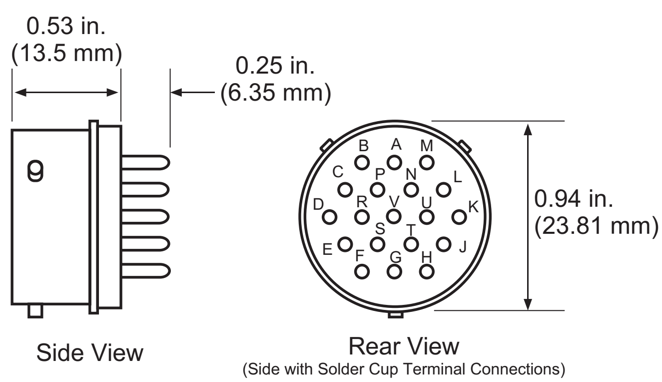


Figure 6-1. 19-Pin Vacuum Feedthrough Without Flange (P/N 9005-014)

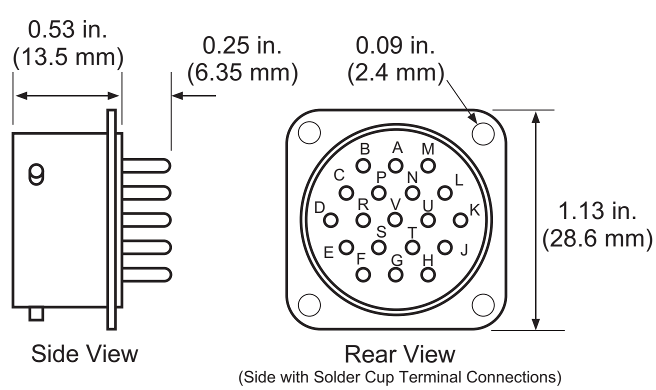


Figure 6-2. 19-Pin Vacuum Feedthrough With Flange (P/N 9005-016)

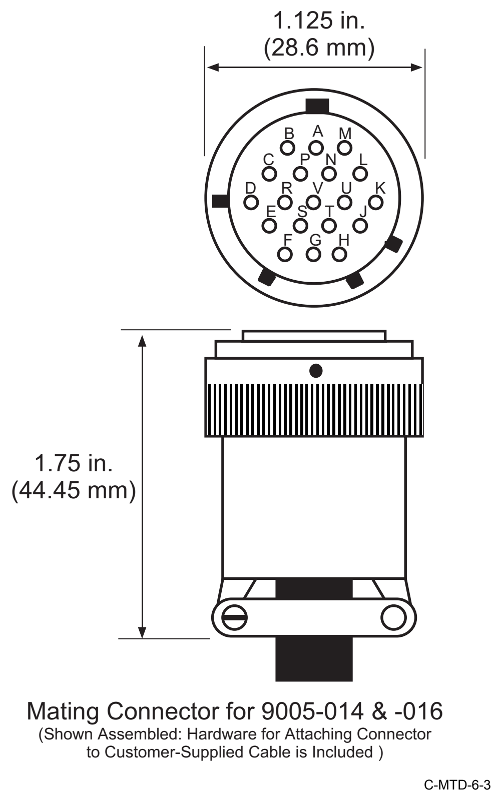


Figure 6-3. Mating Connector (P/N 9005-015)

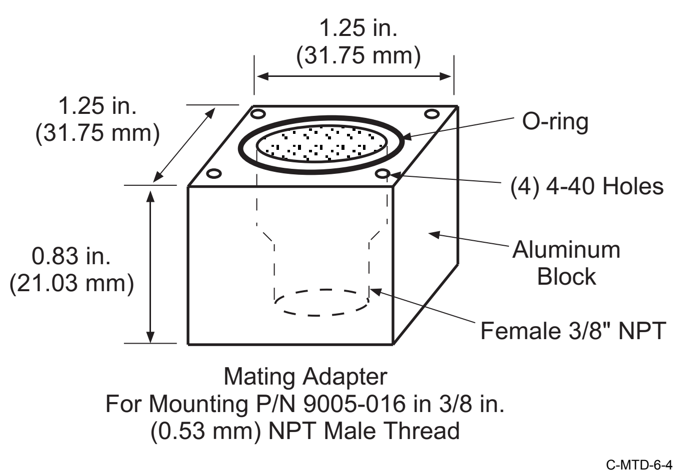


Figure 6-4. Mating Adapter (P/N 9005-017)

APPENDIX A

GLOSSARY OF TERMINOLOGY

absolute zero. The temperature of –273.15 °C, or –459.67 °F, or 0 K, thought to be the temperature at which molecular motion vanishes and a body would have no heat energy.[1]

accuracy. The degree of correctness with which a measured value agrees with the true value.[2]

electronic accuracy. The accuracy of an instrument independent of the sensor.

sensor accuracy. The accuracy of a temperature sensor and its associated calibration or its ability to match a standard curve.

Alumel™. An aluminum-nickel alloy which comprises the negative lead of a Type K thermocouple.

American Wire Gage (AWG). Wiring sizes are defined as diameters in inches and millimeters as follows:

AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm
1	0.2893	7.348	11	0.0907	2.304	21	0.0285	0.7230	31	0.0089	0.2268
2	0.2576	6.544	12	0.0808	2.053	22	0.0253	0.6438	32	0.0080	0.2019
3	0.2294	5.827	13	0.0720	1.829	23	0.0226	0.5733	33	0.00708	0.178
4	0.2043	5.189	14	0.0641	1.628	24	0.0207	0.5106	34	0.00630	0.152
5	0.1819	4.621	15	0.0571	1.450	25	0.0179	0.4547	35	0.00561	0.138
6	0.1620	4.115	16	0.0508	1.291	26	0.0159	0.4049	36	0.00500	0.127
7	0.1443	3.665	17	0.0453	1.150	27	0.0142	0.3606	37	0.00445	0.1131
8	0.1285	3.264	18	0.0403	1.024	28	0.0126	0.3211	38	0.00397	0.1007
9	0.1144	2.906	19	0.0359	0.9116	29	0.0113	0.2859	39	0.00353	0.08969
10	0.1019	2.588	20	0.0338	0.8118	30	0.0100	0.2546	40	0.00314	0.07987

ambient temperature. The temperature of the surrounding medium, such as gas or liquid, which comes into contact with the apparatus.[1]

ampere. The constant current that, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one meter apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.[2] This is one of the base units of the SI.

ampere-turn. A MKS unit of magnetomotive force equal to the magnetomotive force around a path linking one turn of a conducting loop carrying a current of one ampere; or 1.26 gilberts.

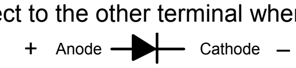
ampere/meter (A/m). The SI unit for magnetic field strength (H). 1 ampere/meter = $4\pi/1000$ oersted ≈ 0.01257 oersted.

analog controller. A feedback control system where there is an unbroken path of analog processing between the feedback device (sensor) and control actuator (heater).

analog data. Data represented in a continuous form, as contrasted with digital data having discrete values.[1]

analog output. A voltage output from an instrument that is proportional to its input. From an instrument such as a digital voltmeter, the output voltage is generated by a digital-to-analog converter so it will have a discrete number of voltage levels.

anode. The terminal that is positive with respect to the other terminal when the diode is biased in the forward direction.[2]



asphyxiant gas. A gas which has little or no positive toxic effect but which can bring about unconsciousness and death by displacing air and thus depriving an organism of oxygen.

autotuning. In Lake Shore Temperature Controllers, the Autotuning algorithm automatically determines the proper settings for Gain (Proportional), Reset (Integral), and Rate (Derivative) by observing the time response of the system upon changes in setpoint.

B. Symbol for magnetic flux density. *See* Magnetic Flux Density.

bar. Unit of pressure equal to 10^5 pascal, or 0.98697 standard atmosphere.

baud. A unit of signaling speed equal to the number of discrete conditions or signal events per second, or the reciprocal of the time of the shortest signal element in a character.[2]

bel (B). A dimensionless unit expressing the ration of two powers or intensities, or the ratio of a power to a reference power, such that the number of bels is the common logarithm of this ratio.[1]

bifilar windings. A winding consisting of two insulated wires, side by side, with currents traveling through them in opposite directions.[1]

bit. A contraction of the term "binary digit"; a unit of information represented by either a zero or a one.[2]

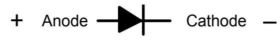
BNC. Bayonet Nut Connector.

boiling point. The temperature at which a substance in the liquid phase transforms to the gaseous phase; commonly refers to the boiling point at sea level and standard atmospheric pressure.

CalCurve Service. The service of storing a mathematical representation of a calibration curve on an EEPROM or installed in a Lake Shore instrument. Previously called a Precision Option.

calibration. To determine, by measurement or comparison with a standard, the correct (accurate) value of each scale reading on a meter or other device, or the correct value for each setting of a control knob.[1]

cathode. The terminal from which forward current flows to the external circuit.[2]



Carbon-Glass™. A temperature sensing material fabricated from a carbon-impregnated glass matrix used to make the Lake Shore CGR family of sensors.

Caution. An operation or maintenance procedure, practice, condition, statement, etc., which, if not strictly observed, could result in damage or destruction of equipment, or loss of effectiveness.

Celsius (°C) Scale. A temperature scale that registers the freezing point of water as 0 °C and the boiling point as 100 °C under normal atmospheric pressure. Celsius degrees are purely derived units, calculated from the Kelvin Thermodynamic Scale. Formerly known as "centigrade." *See* Temperature for conversions.

Cernox™. A Lake Shore resistance temperature detector based on a ceramic-oxy-nitride resistance material.

CGR. Carbon Glass Resistor.

cgs system of units. A system in which the basic units are the centimeter, gram, and second.[2]

Chromel™. A chromium-nickel alloy which comprises the positive lead of Type E and K thermocouples.

coercive force (coercive field). The magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero.

coercivity. generally used to designate the magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero from saturation. The coercivity would be the upper limit to the coercive force.

cold finger. A cryogenically cooled component incorporated into the dewar of an infrared detector assembly in order to maintain the sensing elements at the proper temperature (77 K or colder).

compliance voltage. *See* current source.

Constantan. A copper-nickel alloy which comprises the negative lead of Type E, J, and T thermocouples.

cryogen. *See* cryogenic fluid.[1]

cryogenic. Refers to the field of low temperatures, usually –130 °F or below, as defined by 173.300(f) of Title 49 of the Code of Federal Regulations.

cryogenic fluid. A liquid that boils at temperatures of less than about 110 K at atmospheric pressure, such as hydrogen, helium, nitrogen, oxygen, air, or methane. Also known as cryogen.[1]

cryostat. An apparatus used to provide low-temperature environments in which operations may be carried out under controlled conditions.[1]

Curie temperature (Tc). Temperature at which a magnetized sample is completely demagnetized due to thermal agitation. Named for Pierre Curie (1859-1906), a French chemist.

current source. A type of power supply that supplies a constant current through a variable load resistance by automatically varying its compliance voltage. A single specification given as "compliance voltage" means the output current is within specification when the compliance voltage is between zero and the specified voltage.

curve. A set of data that defines the temperature response of a temperature sensor. It is used to convert the sensor's signal to temperature.

Curve 10. The voltage versus temperature characteristic followed by all DT-400 Series Silicon Diode Temperature Sensors.

decibels (dB). A unit for describing the ratio of two powers or intensities, or the ratio of a power to a reference power; equal to one-tenth bel; if P_1 and P_2 are two amounts of power, the first is said to be *n* decibels greater, where $n = 10 \log_{10}(P_1/P_2)$.[1]

degree. An incremental value in the temperature scale, i.e., there are 100 degrees between the ice point and the boiling point of water in the Celsius scale and 180 degrees between the same two points in the Fahrenheit scale.

deviation. The difference between the actual value of a controlled variable and the desired value corresponding to the setpoint.[1]

Dewar. A vacuum-insulated bottle used to contain cryogenic fluid.

differential permeability. The slope of a B versus H curve: $\mu_d = dB/dH$.

differential susceptibility. The slope of a M versus H curve: $\chi_d = dM/dH$.

digital controller. A feedback control system where the feedback device (sensor) and control actuator (heater) are joined by a digital processor. In Lake Shore controllers the heater output is maintained as a variable DC current source.

digital data. Pertaining to data in the form of digits or interval quantities. Contrast with analog data.[2]

dimensionless sensitivity. Sensitivity of a physical quantity to a stimulus, expressed in dimensionless terms. The dimensionless temperature sensitivity of a resistance temperature sensor is expressed as $S_d = (T/R)(dR/dT)$ which is also equal to the slope of R versus T on a log-log plot, that is $S_d = d \ln R / d \ln T$. Note that the absolute temperature (in kelvin) must be used in these expressions.

DIN. Deutsches Institut fur Normung.

drift, instrument. An undesired but relatively slow change in output over a period of time, with a fixed reference input. *Note:* Drift is usually expressed in percent of the maximum rated value of the variable being measured.[2]

DUT. Device Under Test.

electromagnet. A device in which a magnetic field is generated as the result of electrical current passing through a helical conducting coil. It can be configured as an iron-free solenoid in which the field is produced along the axis of the coil, or an iron-cored structure in which the field is produced in an air gap between pole faces. The coil can be water cooled copper or aluminum, or superconductive.

electrostatic discharge (ESD). A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

error. Any discrepancy between a computed, observed, or measured quantity and the true, specified, or theoretically correct value or condition.[2]

excitation. Either an AC or DC input to a sensor used to produce an output signal. Common excitations include: constant current, constant voltage, or constant power.

Fahrenheit (°F) Scale. A temperature scale that registers the freezing point of water as 32 °F and the boiling point as 212 °F under normal atmospheric pressure. *See* Temperature for conversions.

fanout board. A fanout board is a printed circuit board which is used to interconnect the Device-Under-Test (DUT) to the coax signal lines (via the interface board) in the MTD System. The socket for a particular device package is mounted on the fanout board and the contacts of the socket are soldered to the board traces. The 50 Ω stripline transmission traces on the fanout board are gold plated to enhance the electrical connections and to inhibit corrosion.

feedthru. Provides leak-proof (hermetic) access from one volume to another without breaking the integrity of either space. In Lake Shore equipment, a feedthough is used to provide wiring from the room temperature environment to the cryogenic environment inside a dewar.

four-lead. measurement technique where one pair of excitation leads and an independent pair of measurement leads are used to measure a sensor. This method reduces the effect of lead resistance on the measurement.

FPA. Focal Plane Array.

GaAlAs. Gallium-aluminum-arsenide semiconducting material used to make the special Lake Shore TG family of diode temperature sensors.

gamma. A cgs unit of low-level flux density, where 100,000 gamma equals one oersted, or 1 gamma equals 10^{-5} oersted.

gauss (G). The cgs unit for magnetic flux density (B). 1 gauss = 10^{-4} tesla. Named for Karl Fredrich Gauss (1777 – 1855) a German mathematician, astronomer, and physicist.

gaussian system (units). A system in which centimeter-gram-second units are used for electric and magnetic qualities.

general purpose interface bus (GPIB). Another term for the IEEE-488 bus.

germanium (Ge). A common temperature sensing material fabricated from doped germanium to make the Lake Shore GR family of resistance temperature sensor elements.

gilbert (Gb). A cgs electromagnetic unit of the magnetomotive force required to produce one maxwell of magnetic flux in a magnetic circuit of unit reluctance. One gilbert is equal to 10/4π ampere-turn. Named for William Gilbert (1540 – 1603), an English physicist; hypothesized that the earth is a magnet.

gilbert per centimeter. Practical cgs unit of magnet intensity. Gilberts per cm are the same as oersteds.

Greek alphabet. The Greek alphabet is defined as follows:

Alpha	α	Α	Iota	ι	Ι	Rho	ρ	Ρ
Beta	β	Β	Kappa	κ	Κ	Sigma	σ	Σ
Gamma	γ	Γ	Lambda	λ	Λ	Tau	τ	Τ
Delta	δ	Δ	Mu	μ	Μ	Upsilon	υ	Υ
Epsilon	ε	Ε	Nu	ν	Ν	Phi	φ	Φ
Zeta	ζ	Ζ	Xi	ξ	Ξ	Chi	χ	Χ
Eta	η	Η	Omicron	ο	Ο	Psi	ψ	Ψ
Theta	θ	Θ	Pi	π	Π	Omega	ω	Ω

ground. A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of relatively large extent that serves in place of the earth. *Note:* It is used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground current to and from the earth (or of the conducting body).[2]

H. Symbol for magnetic field strength. *See* Magnetic Field Strength.

Hall effect. The generation of an electric potential perpendicular to both an electric current flowing along a thin conducting material and an external magnetic field applied at right angles to the current. Named for Edwin H. Hall (1855 – 1938), an American physicist.

hazard communication standard (HCS). The OSHA standard cited in 29 CFR 1910.1200 requiring communication of risks from hazardous substances to workers in regulated facilities.

hertz (Hz). A unit of frequency equal to one cycle per second.

hysteresis. The dependence of the state of a system on its previous history, generally in the form of a lagging of a physical effect behind its cause.[1] Also *see* magnetic hysteresis.

I.D. Inner diameter.

IEC. International Electrotechnical Commission.

IEEE. Institute of Electrical and Electronics Engineers.

IEEE-488. An instrumentation bus with hardware and programming standards designed to simplify instrument interfacing. The addressable, parallel bus specification is defined by the IEEE.

initial permeability. The permeability determined at H = 0 and B = 0.

initial susceptibility. The susceptibility determined at H = 0 and M = 0.

infrared (IR). For practical purposes any radiant energy within the wavelength range 770 to 10^6 nanometers is considered infrared energy.[2] The full range is usually divided into three sub-ranges: near IR, far IR, and sub-millimeter.

input card. Electronics on a printed circuit board (card) that plug into an instrument main frame. Used by configurable instruments to allow for different sensor types or interface options.

interchangeability. Ability to exchange one sensor or device with another of the same type without a significant change in output or response.

international system of units (SI). A universal coherent system of units in which the following seven units are considered basic: meter, kilogram, second, ampere, kelvin, mole, and candela. The International System of Units, or Système International d'Unités (SI), was promulgated in 1960 by the Eleventh General Conference on Weights and Measures. For definition, spelling, and protocols, *see* Reference 3 for a short, convenient guide.

interpolation table. A table listing the output and sensitivity of a sensor at regular or defined points which may be different from the points at which calibration data was taken.

intrinsic coercivity. The magnetic field strength (H) required to reduce the magnetization (M) or intrinsic induction in a magnetic material to zero.

intrinsic induction. The contribution of the magnetic material (B_i) to the total magnetic induction (B).

$B_i = B - \mu_0 H$ (SI) $B_i = B - H$ (cgs)

IPTS-68. International Practical Temperature Scale of 1968. Also abbreviated as T_{68}.

isolated (neutral system). A system that has no intentional connection to ground except through indicating, measuring, or protective devices of very-high impedance.[2]

ITS-90. International Temperature Scale of 1990. Also abbreviated as T_{90}. This scale was designed to bring into as close a coincidence with thermodynamic temperatures as the best estimates in 1989 allowed.

Kelvin (K). The unit of temperature on the Kelvin Scale. It is one of the base units of SI. The word "degree" and its symbol (°) are omitted from this unit. *See* Temperature Scale for conversions.

Kelvin Scale. The Kelvin Thermodynamic Temperature Scale is the basis for all international scales, including the ITS-90. It is fixed at two points: the absolute zero of temperature (0 K), and the triple point of water (273.16 K), the equilibrium temperature that pure water reaches in the presence of ice and its own vapor.

LCC. Leadless Chip Carrier.

line regulation. The maximum steady-state amount that the output voltage or current will change as the result of a specified change in input line voltage (usually for a step change between 105 – 125 or 210 – 250 volts, unless otherwise specified).

line voltage. The RMS voltage of the primary power source to an instrument.

liquid helium (LHe). Used for low temperature and superconductivity research: minimum purity 99.998%. Boiling point at 1 atm = 4.2 K. Latent heat of vaporization = 2.6 kilojoules per liter. Liquid density = 0.125 kilograms per liter.

EPA Hazard Categories: Immediate (Acute) Health and Sudden Release of Pressure Hazards
DOT Name: Helium, Refrigerated Liquid
DOT Label: Nonflammable Gas
DOT Class: Nonflammable Gas
DOT ID No: UN 1963

liquid nitrogen (LN_2). Also used for low temperature and superconductivity research and for its refrigeration properties such as in freezing tissue cultures: minimum purity 99.998%, O_2 8 ppm max. Boiling point at 1 atm = 77.4 K. Latent heat of vaporization = 160 kilojoules per liter. Liquid density = 0.81 kilograms per liter.

EPA Hazard Categories: Immediate (Acute) Health and Sudden Release of Pressure Hazards
DOT Name: Nitrogen, Refrigerated Liquid
DOT Label: Nonflammable Gas
DOT Class: Nonflammable Gas
DOT ID No: UN 1977

load regulation. A steady-state decrease of the value of the specified variable resulting from a specified increase in load, generally from no-load to full-load unless otherwise specified.

LSCI. Lake Shore Cryotronics, Inc.

M. Symbol for magnetization. *See* magnetization.

magnetic air gap. The air space, or non-magnetic portion, of a magnetic circuit.

magnetic field strength (H). The magnetizing force generated by currents and magnetic poles. For most applications, the magnetic field strength can be thought of as the applied field generated, for example, by a superconducting magnet. The magnetic field strength is not a property of materials. Measure in SI units of A/m or cgs units of oersted.

magnetic flux density (B). Also referred to as magnetic induction. This is the net magnetic response of a medium to an applied field, H. The relationship is given by the following equation: $B = \mu_o (H + M)$ for SI, and $B = H + 4\pi M$ for cgs, where H = magnetic field strength, M = magnetization, and μ_O = permeability of free space = $4\pi \times 10^{-7}$ H/m.

magnetic hysteresis. The property of a magnetic material where the magnetic induction (B) for a given magnetic field strength (H) depends upon the past history of the samples magnetization.

magnetic induction (B). *See* magnetic flux density.

magnetic moment (m). This is the fundamental magnetic property measured with dc magnetic measurements systems such as a vibrating sample magnetometer, extraction magnetometer, SQUID magnetometer, etc. The exact technical definition relates to the torque exerted on a magnetized sample when placed in a magnetic field. Note that the moment is a total attribute of a sample and alone does not necessarily supply sufficient information in understanding material properties. A small highly magnetic sample can have exactly the same moment as a larger weakly magnetic sample (*see* Magnetization). Measured in SI units as $A \cdot m^2$ and in cgs units as emu. 1 emu = 10^{-3} $A \cdot m^2$.

magnetic units. Units used in measuring magnetic quantities. Includes ampere-turn, gauss, gilbert, line of force, maxwell, oersted, and unit magnetic pole.

magnetization (M). This is a material specific property defined as the magnetic moment (m) per unit volume (V). M = m/V. Measured in SI units as A/m and in cgs units as emu/cm^3. 1 emu/cm^3 = 10^3 A/m. Since the mass of a sample is generally much easier to determine than the volume, magnetization is often alternately expressed as a mass magnetization defined as the moment per unit mass.

mains. *See* line voltage.

material safety data sheet (MSDS). OSHA Form 20 contains descriptive information on hazardous chemicals under OSHA's Hazard Communication Standard (HCS). These data sheets also provide precautionary information on the safe handling of the gas as well as emergency and first aid procedures.

microcontroller. A microcomputer, microprocessor, or other equipment used for precise process control in data handling, communication, and manufacturing.[1]

MKSA System of Units. A system in which the basic units are the meter, kilogram, and second, and the ampere is a derived unit defined by assigning the magnitude $4\pi \times 10^{-7}$ to the rationalized magnetic constant (sometimes called the permeability of space).

MTD. Modular Test Dewar.

NBS. National Bureau of Standards. Now referred to as NIST.

NbTi. Niobium-titanium. A superconductive alloy with a transition temperature typically near 9 K in zero magnetic field.

negative temperature coefficient (NTC). Refers to the sign of the temperature sensitivity. For example, the resistance of a NTC sensor decreases with increasing temperature.

National Institute of Standards and Technology (NIST). Government agency located in Gaithersburg, Maryland and Boulder, Colorado, that defines measurement standards in the United States.

noise (electrical). Unwanted electrical signals that produce undesirable effects in circuits of control systems in which they occur.[2]

normalized sensitivity. For resistors, signal sensitivity (dR/dT) is geometry dependent; i.e., dR/dT scales directly with R; consequently, very often this sensitivity is normalized by dividing by the measured resistance to give a sensitivity, s_T, in percent change per kelvin. s_T = (100/R) (dR/dT) %K, where T is temperature in kelvin and R is resistance in ohms.

normally closed (N.C.). A term used for switches and relay contacts. Provides a closed circuit when actuator is in the free (unenergized) position.

normally open (N.O.). A term used for switches and relay contacts. Provides an open circuit when actuator is in the free (unenergized) position.

Note. An operation or maintenance procedure, practice, condition, statement, etc., which is essential to emphasize. Multiple warnings, cautions, or notes will be prefaced with bullets.

O.D. Outer diameter.

oersted (Oe). The cgs unit for the magnetic field strength (H). 1 oersted = 10¾π ampere/meter ≈ 79.58 ampere/meter.

ohm (Ω). The SI unit of resistance (and of impedance). The ohm is the resistance of a conductor such that a constant current of one ampere in it produces a voltage of one volt between its ends.[2]

pascal (Pa). The SI unit of pressure equal to 1 N/m^2. Equal to 1.45×10^{-4} psi, 1.0197×10^{-5} kg_f/cm^2, 7.5×10^{-3} torr, 4.191×10^{-3} inches of water, or 1×10^{-5} bar.

permeability. Material parameter which is the ratio of the magnetic induction (B) to the magnetic field strength (H): μ = B/H. Also *see* Initial Permeability and Differential Permeability.

platinum (Pt). A common temperature sensing material fabricated from pure platinum to make the Lake Shore PT family of resistance temperature sensor elements.

polynomial fit. A mathematical equation used to fit calibration data. Polynomials are constructed of finite sums of terms of the form $a_i x_i$, where a_i is the i^{th} fit coefficient and x_i is some function of the dependent variable.

pop-off. Another term for relief valve.

positive temperature coefficient (PTC). Refers to the sign of the temperature sensitivity. For example, the resistance of a PTC sensor increases with increasing temperature.

pounds per square inch (psi). A unit of pressure. 1 psi = 6.89473 kPa. Variations include psi absolute (psia) measured relative to vacuum (zero pressure) where one atmosphere pressure equals 14.696 psia and psi gauge (psig) where gauge measured relative to atmospheric or some other reference pressure.

ppm. Parts per million, e.g., 4×10^{-6} is four parts per million.

precision. Careful measurement under controlled conditions which can be repeated with similar results. *See* repeatability. Also means that small differences can be detected and measured with confidence. *See* resolution.

prefixes. SI prefixes used throughout this manual are as follows:

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

probe. A long, thin body containing a sensing element which can be inserted into a system in order to make measurements. Typically, the measurement is localized to the region near the tip of the probe.

proportional, integral, derivative (PID). A control function where output is related to the error signal in three ways. Proportional (gain) acts on the instantaneous error as a multiplier. Integral (reset) acts on the area of error with respect to time and can eliminate control offset or droop. Derivative (rate) acts on the rate of change in error to dampen the system, reducing overshoot.

quench. A condition where the superconducting magnet goes "normal," i.e., becomes non-superconductive. When this happens, the magnet becomes resistive, heat is generated, liquid Helium is boiled off, and the Magnet Power Supply will shut down due to the sudden increase in current demand.

rack mount. An instrument is rack mountable when it has permanent or detachable brackets that will allow it to be securely mounted in a 19-inch instrument rack. A full rack instrument requires the entire width of the rack. Two half rack instruments will fit horizontally in a rack width.

relief valve. A type of pressure relief device which is designed to relieve excessive pressure, and to reclose and reseal to prevent further flow of gas from the cylinder after reseating pressure has been achieved.

remanence. The remaining magnetic induction in a magnetic material when the material is first saturated and then the applied field is reduced to zero. The remanence would be the upper limit to values for the remanent induction. Note that no strict convention exists for the use of remanent induction and remanence and in some contexts the two terms may be used interchangeably.

remanent induction. The remaining magnetic induction in a magnetic material after an applied field is reduced to zero. Also *see* remanence.

repeatability. The closeness of agreement among repeated measurements of the same variable under the same conditions.[2]

resistance temperature detector (RTD). Resistive sensors whose electrical resistance is a known function of the temperature, made of, e.g., carbon-glass, germanium, platinum, or rhodium-iron.

resolution. The degree to which nearly equal values of a quantity can be discriminated.[2]

display resolution. The resolution of an instrument's physical display. This is not always the same as the measurement resolution of the instrument. Decimal display resolution specified as "*n* digits" has 10^n possible display values. A resolution of *n* and one-half digits has 2×10^n possible values.

measurement resolution. The ability of an instrument to resolve a measured quantity. For digital instrumentation this is often defined by the analog to digital converter being used. A n-bit converter can resolve one part in 2^n. The smallest signal change that can be measured is the full scale input divided by 2^n for any given range. Resolution should not be confused with accuracy.

RhFe. Rhodium-iron. Rhodium alloyed with less than one atomic percent iron is used to make the Lake Shore RF family of sensors. Rhodium-iron is a spin fluctuation alloy which has a significant temperature coefficient of resistance below 20 K where most metals rapidly lose sensitivity.

RJ-11. A modular connector with 6 conductors commonly used with telephones.

Roman numerals. Letters employed in the ancient Roman system of numeration as follows:

I	1	VI	6	L	50
II	2	VII	7	C	100
III	3	VIII	8	D	500
IV	4	IX	9	M	1000
V	5	X	10		

root mean square (RMS). The square root of the time average of the square of a quantity; for a periodic quantity the average is taken over one complete cycle. Also known as effective value.[1]

room temperature compensation. Thermocouples are a differential measurement device. Their signal represents the difference in temperature between their ends. An ice bath is often used to reference the measurement end to 0 °C so most curves are normalized to that temperature. Room temperature compensation replaces an ice bath by monitoring the temperature of the thermocouple's terminals and normalizing the reading mathematically.

RS-232C. Bi-directional computer serial interface standard defined by the Electronic Industries Association (EIA). The interface is single-ended and non-addressable.

Seebeck effect. The development of a voltage due to differences in temperature between two junctions of dissimilar metals in the same circuit.[1]

self-heating. Heating of a device due to dissipation of power resulting from the excitation applied to the device. The output signal from a sensor increases with excitation level, but so does the self-heating and the associated temperature measurement error.

sensitivity. The ratio of the response or change induced in the output to a stimulus or change in the input. Temperature sensitivity of a resistance temperature detector is expressed as $S = dR/dT$.

setpoint. The value selected to be maintained by an automatic controller.[1]

serial interface. A computer interface where information is transferred one bit at a time rather than one byte (character) at a time as in a parallel interface. RS-232C is the most common serial interface.

SI. Système International d'Unités. *See* International System of Units.

silicon diode. Temperature sensor based on the forward voltage drop at constant current through a pn semiconductor junction formed in crystalline silicon.

SoftCal™. In Lake Shore instruments, SoftCal™ is used to improve the accuracy of a DT-400 Series Silicon Temperature Diode Sensor. This reduces the error between the sensor and the Standard Curve 10 used by the instrument to convert input voltage from the diode to a corresponding temperature.

stability. The ability of an instrument or sensor to maintain a constant output given a constant input.

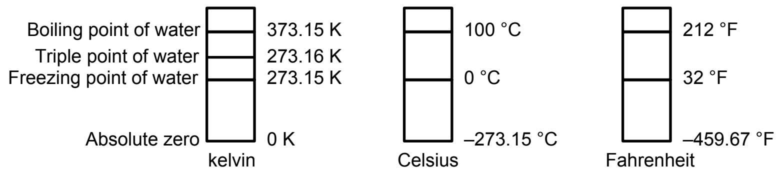
strain relief. A predetermined amount of slack to relieve tension in component or lead wires. Also called stress relief.

superconducting magnet. An electromagnet whose coils are made of a type II superconductor with a high transition temperature and extremely high critical field, such as niobium-tin, Nb_3Sn; it is capable of generating magnetic fields of 100,000 oersteds and more with no steady power dissipation.[1] *See* electromagnet.

susceptance. In electrical terms, susceptance is defined as the reciprocal of reactance and the imaginary part of the complex representation of admittance: [suscept(ibility) + (conduct)ance].

susceptibility (χ). Parameter giving an indication of the response of a material to an applied magnetic field. The susceptibility is the ratio of the magnetization (M) to the applied field (H). χ = M/H. In both SI units and cgs units the volume susceptibility is a dimensionless parameter. Multiply the cgs susceptibility by 4π to yield the SI susceptibility. *See* also Initial Susceptibility and Differential Susceptibility. As in the case of magnetization, the susceptibility is often seen expressed as a mass susceptibility or a molar susceptibility depending upon how M is expressed.

temperature scales. *See* Kelvin Scale, Celsius Scale, and ITS-90. Proper metric usage requires that only kelvin and degrees Celsius be used. However, since degrees Fahrenheit is in such common use, all three scales are delineated as follows:



To convert kelvin to Celsius, subtract 273.15.

To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or: °F = (1.8 x °C) + 32.

To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or: °C = (°F. 32)/ 1.8.

temperature coefficient, measurement. The measurement accuracy of an instrument is affected by changes in ambient temperature. The error is specified as an amount of change (usually in percent) for every one degree change in ambient temperature.

tesla (T). The SI unit for magnetic flux density (B). 1 tesla = 10^4 gauss

thermal emf. An electromotive force arising from a difference in temperature at two points along a circuit, as in the Seebeck effect.[1]

thermocouple. A pair of dissimilar conductors so joined at two points that an electromotive force is developed by the thermoelectric effects when the junctions are at different temperatures.[2]

thixotropy. Property of certain gels which liquefy when subjected to vibratory forces, such as ultrasonic waves or even simple shaking, and then solidify again when left standing.[1]

tolerance. The range between allowable maximum and minimum values.

torr. Unit of pressure. 1 torr ≈ 1 mm of mercury. 1 atmosphere = 760 torr.

two-lead. Measurement technique where one pair of leads is used for both excitation and measurement of a sensor. This method will not reduce the effect of lead resistance on the measurement.

unit magnetic pole. A pole with a strength such that when it is placed 1 cm away from a like pole, the force between the two is 1 dyne.

volt (V). The difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.[2]

volt-ampere (VA). The SI unit of apparent power. The volt-ampere is the apparent power at the points of entry of a single-phase, two-wire system when the product of the RMS value in amperes of the current by the RMS value in volts of the voltage is equal to one.[2]

watt (W). The SI unit of power. The watt is the power required to do work at the rate of 1 joule per second.[2]

Warning. An operation or maintenance procedure, practice, condition, statement, etc., which, if not strictly observed, could result in injury, death, or long-term health hazards to personnel.

References:

1 Sybil P. Parker, Editor. *Dictionary of Scientific and Technical Terms: Third Edition*. New York: McGraw Hill, 1969 (IBSN 0-395-20360-0)

2 Christopher J. Booth, Editor. *The New IEEE Standard Dictionary of Electrical and Electronic Terms: IEEE Std 100-1992, Fifth Edition.* New York: Institute of Electrical and Electronics Engineers, 1993 (IBSN 1-55937-240-0). Definitions printed with permission of the IEEE.

3 Nelson, Robert A. *Guide For Metric Practice,* Page BG7 - 8, Physics Today, Eleventh Annual Buyer's Guide, August 1994 (ISSN 0031-9228 coden PHTOAD)

APPENDIX B

UNITS FOR MAGNETIC PROPERTIES

Table B-1. Conversion from CGS to SI Units

Quantity	Symbol	Gaussian & CGS emu[a]	Conversion Factor, C[b]	SI & Rationalized mks[c]
Magnetic flux density, Magnetic induction	B	gauss (G)[d]	10^{-4}	tesla (T), Wb/m^2
Magnetic Flux	ϕ	maxwell (Mx), G·cm^2	10-8	weber (Wb), volt second (V·s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization[g]	M	emu/cm^3[h]	10^3	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2[i]
(Mass) magnetization	σ, M	emu/g	1 $4\pi \times 10^{-7}$	A·m^2/kg Wb·m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	A·m^2, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	Wb·m[i]
(Volume) susceptibility	χ, κ	dimensionless emu/cm^3	- $(4\pi)^2 \times 10^{-7}$	Henry per meter (H/m), Wb/(A·m)
(Mass) susceptibility	χ_ρ, κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$ $(4\pi)2 \times 10^{-10}$	m^3/kg H·m^2/kg
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$ $(4\pi)^2 \times 10^{-13}$	m^3/mol H·m^2/mol
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A·m)
Relative permeability[j]	μ_r	not defined	-	dimensionless
(Volume) energy density, energy product[k]	W	erg/cm^3	10^{-1}	J/m^3
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

NOTES:

a. Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.

b. Multiply a number in Gaussian units by C to convert it to SI (e.g. 1 G x 10^{-4}T/G = 10^{-4}T).

c. SI (Système International d'Unités) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where to $\mu_0 = 4\pi \times 10^{-7}$H/m. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.

d. 1 gauss = 10^5 gamma (γ).

e. Both oersted and gauss are expressed as $cm^{-½} \cdot g^{½} \cdot s^{-1}$ in terms of base units.

f. A/m was often expressed as "ampere-turn per meter" when used for magnetic field strength.

g. Magnetic moment per unit volume.

h. The designation "emu" is not a unit.

i. Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.

j. $\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ.

k. $B \cdot H$ and $\mu_0 M \cdot H$ have SI units J/m^3, $M \cdot H$ and $B \cdot H/4\pi$ have Gaussian units erg/cm^3.

R.B. Goldfarb and F.R. Fickett, U.S. Department of Commerce, National Bureau of Standards, Bolder, Colorado 80303, March 1985, NBS Special Publication 696. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table B-2. Recommended SI Values for Physical Constants

Quantity	Symbol	Value (SI units)
Permeability of Vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Speed of Light in Vacuum	c	2.9979×10^{8} m s^{-1}
Permitivity of Vacuum	$\varepsilon_0 = (\mu_0 c^2)^{-1}$	8.8542×10^{-12} F m^{-1}
Fine Structure Constant, µ0ce2/2h	α α^{-1}	0.0073 137.0360
Elementary Charge	e	1.6022×10^{-19} C
Plank's Constant	h $h = h/2\pi$	6.6262×10^{-34} J Hz^{-1} 1.0546×10^{-34} J s
Avogadro's Constant	N_A	6.0220×10^{23} mol^{-1}
Atomic Mass Unit	$lu = (10^{-3}$ kg mol^{-1}/N_A	1.6605×10^{-27} kg
Electron Rest Mass	m_e	0.9109×10^{-30} kg 5.4858×10^{-4} u
Proton Rest Mass	m_p	1.6726×10^{-27} kg 1.0073 u
Neutron Rest Mass	m_n	1.6749×10^{-27} kg 1.0087 u
Magnetic Flux Quantum	$\phi = h/2e$ h/e	2.0679×10^{-15} Wb 4.1357×10^{-15} J Hz^{-1} C^{-1}
Josephson Frequency-Voltage Ratio	2e/h	483.5939 THz V^{-1}
Quantum of Circulation	$h/2m_e$ h/m_e	3.6369×10^{-4} J Hz^{-1} kg^{-1} 7.2739×10^{-4} J Hz^{-1} C^{-1}
Rydberg Constant	R_∞	1.0974×10^{7} m-1
Proton Moment in Nuclear Magnetons	μ_p/μ_N	2.7928
Bohr Magneton	$\mu_B = eh/2m_e$	9.2741×10^{-24} J T^{-1}
Proton Gyromagnetic Ratio	γ_p	2.6752×10^{8} s^{-1} T^{-1}
Diamagnetic Shielding Factor, Spherical H_2O Sample	$1 + \sigma(H_2O)$	1.0000
Molar Mass Constant	R	8.3144 J mol^{-1} K^{-1}
Molar Volume, Ideal Gas (T_0 = 273.15K, p_0 = 1 atm)	$V_m = RT_0/p_0$	0,0224 m^3 mol^{-1}
Boltzman Constant	$k = R/N_A$	1.3807×10^{-23} J K^{-1}
Stefan-Boltzman Constant	$\sigma = (\pi^2/60)\ k^4/h^3\ c^2$	5.6703×10^{-8} W m^{-2} K^{-4}
First Radiation Constant	$c_1 = 2\pi hc^2$	3.7418×10^{-16} W m^{-2}
Second Radiation Constant	$c_2 = hc/k$	0.0144 mK
Gravitation Constant	G	6.6720×10^{-11} N m^2 kg^{-2}

Data (abbreviated to 4 decimal places) from CODATA Bulletin No. 11, ICSU CODATA Central Office, 19 Westendstrasse, 6 Frankfurt/Main, Germany. Copies of this bulletin are available from this office.

APPENDIX C

TEMPERATURE SCALES

C1.0 DEFINITION

Temperature is a fundamental unit of measurement which describes the kinetic and potential energies of the atoms and molecules of bodies. When the energies and velocities of the molecules in a body are increased, the temperature is increased whether the body is a solid, liquid, or gas. Thermometers are used to measure temperature. The temperature scale is based on the temperature at which ice, liquid water, and water vapor are all in equilibrium. This temperature is called the triple point of water and is assigned the value 0 °C, 32 °F, and 273.15 K. These three temperature scales are defined as follows:

Celsius. Abbreviation: °C. A temperature scale that registers the freezing point of water as 0 °C and the boiling point as 100 °C under normal atmospheric pressure. Formerly known as "Centigrade." Originally devised by Anders Celsius (1701–1744), a Swedish astronomer.

Fahrenheit. Abbreviation: °F. A temperature scale that registers the freezing point of water as 32 °F and the boiling point as 212 °F under normal atmospheric pressure. Originally devised by Gabriel Fahrenheit (1686–1736), a German physicist residing in Holland; developed use of mercury in thermometry.

Kelvin. Abbreviation: K. An absolute scale of temperature, the zero point of which is approximately –273.15°C. Scale units are equal in magnitude to Celsius degrees. Originally devised by Lord Kelvin, William Thompson, (1824–1907), a British physicist, mathematician, and inventor.

C2.0 COMPARISON

The three temperature scales are graphically compared in Figure C-1.

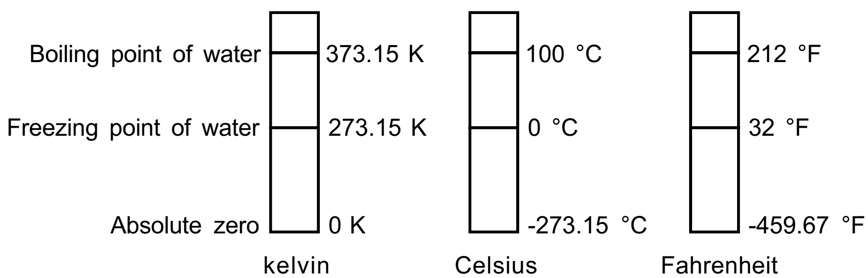


Figure C-1. Temperature Scale Comparison

C3.0 CONVERSIONS

To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or:

°C = °F – 32 ÷ 1.8

To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or:

°F = (1.8 x °C) + 32

To convert Fahrenheit to kelvin, first convert °F to °C, then add 273.

To convert Celsius to kelvin, add 273.

Table C-1. Temperature Conversion Table

°F	°C	K	°F	°C	K	°F	°C	K
-459.67	-273.15	0	-292	-180	93.15	-129.67	-89.82	183.33
-454	-270	3.15	-290	-178.89	94.26	-120	-84.44	188.71
-450	-267.78	5.37	-289.67	-178.71	94.44	-119.67	-84.26	188.89
-449.67	-267.59	5.56	-280	-173.33	99.82	-117.67	-83.15	190
-441.67	-263.15	10	-279.67	-173.15	100	-112	-80	193.15
-440	-262.22	10.93	-274	-170	103.15	-110	-78.89	194.26
-439.67	-262.04	11.11	-270	-167.78	105.57	-109.67	-78.71	194.44
-436	-260	13.15	-269.67	-167.59	105.56	-100	-73.33	199.82
-430	-256.67	16.48	-261.67	-163.15	110	-99.67	-73.15	200
-429.67	-256.48	16.67	-260	-162.22	110.93	-94	-70	203.15
-423.67	-253.15	20	-259.67	-162.04	111.11	-90	-67.78	205.37
-420	-251.11	22.04	-256	-160	113.15	-89.67	-67.59	205.56
-419.67	-250.93	22.22	-250	-156.67	116.48	-81.67	-63.15	210
-418.00	-250	23.15	-249.67	-156.48	116.67	-80	-62.22	210.93
-410	-245.56	27.59	-243.67	-153.15	120	-79.67	-62.04	211.11
-409.67	-245.37	27.78	-240	-151.11	122.04	-76	-60	213.15
-405.67	-243.15	30	-239.67	-150.93	122.22	-70	-56.67	216.48
-400	-240	33.15	-238	-150	123.15	-69.67	-56.48	216.67
-399.67	-239.82	33.33	-230	-145.56	127.59	-63.67	-53.15	220
-390	-234.44	38.71	-229.67	-145.37	127.78	-60	-51.11	222.04
-389.67	-234.26	38.89	-225.67	-143.15	130	-59.67	-50.93	222.22
-387.67	-233.15	40	-220	-140	133.15	-58	-50	223.15
-382	-230	43.15	-219.67	-139.82	133.33	-50	-45.56	227.59
-380	-228.89	44.26	-210	-134.44	138.71	-49.67	-45.37	227.78
-379.67	-228.71	44.44	-209.67	-134.26	138.89	-45.67	-43.15	230
-370	-223.33	49.82	-207.67	-133.15	140	-40	-40	233.15
369.67	-223.15	50	-202	-130	143.15	-39.67	-39.82	233.33
-364	-220	53.15	-200	-128.89	144.26	-30	-34.44	238.71
-360	-217.78	55.37	-199.67	-128.71	144.44	-29.67	-34.26	238.89
-359.67	-217.59	55.56	-190	-123.33	149.82	-27.67	-33.15	240
-351.67	-213.15	60	189.67	-123.15	150	-22	-30	243.15
-350	-212.22	60.93	-184	-120	153.15	-20	-28.89	244.26
-349.67	-212.04	61.11	-180	-117.78	155.37	-19.67	-28.71	244.44
-346	-210	63.15	-179.67	-117.59	155.56	-10	-23.33	249.82
-340	-206.67	66.48	-171.67	-113.15	160	-9.67	-23.15	250
-339.67	-206.48	66.67	-170	-112.22	160.93	-4	-20	253.15
-333.67	-203.15	70	-169.67	-112.04	161.11	0	-17.78	255.37
-330	-201.11	72.04	-166	-110	163.15	+0.33	-17.59	255.56
-329.67	-200.93	72.22	-160	-106.67	166.48	8.33	-13.15	260
-328	-200	73.15	-159.67	-106.48	166.67	10	-12.22	260.93
-320	-195.56	77.59	-153.67	103.15	170	10.33	-12.04	261.11
-319.67	-195.37	77.78	-150	-101.11	172.04	14	-10	263.15
-315.67	-193.15	80	-149.67	-100.93	172.22	20	-6.67	266.48
-310	-190	83.15	-148	-100	173.15	20.33	-6.48	266.67
-309.67	-189.82	83.33	-140	-95.96	177.59	26.33	-3.15	270
-300	-184.44	88.71	-139.67	-95.37	177.78	30	-1.11	272.04
-299.67	-184.26	88.89	-135.67	-93.15	180	30.33	-0.93	272.22
-297.67	-183.15	90	-130	-90	183.15	32	0	273.15

APPENDIX D

TABLE OF ELEMENTS

Element	Symbol	Atomic Number[1]	Atomic Weight	Element	Symbol	Atomic Number[1]	Atomic Weight
Actinium	Ac	89	227.0278	Mercury	Hg	80	200.59
Aluminum	Al	13	26.98154	Molybdenum	Mo	42	95.94
Americium	Am	95	(243)	Neodymium	Nd	60	144.24
Antimony	Sb	51	121.75	Neon	Ne	10	20.179
Argon	Ar	18	39.948	Neptunium	Np	93	237.0482
Arsenic	As	33	74.9216	Nickel	Ni	28	58.69
Astatine	At	85	(210)	Niobium	Nb	41	92.9064
Barium	Ba	56	137.33	Nitrogen	N	7	14.0067
Berkelium	Bk	97	(247)	Nobelium	No	102	(259)
Beryllium	Be	4	9.01218	Osmium	Os	76	190.2
Bismuth	Bi	83	208.9804	Oxygen	O	8	15.9994
Boron	B	5	10.81	Palladium	Pd	46	106.42
Bromine	Br	35	79.904	Phosphorus	P	15	30.97376
Cadmium	Cd	48	112.41	Platinum	Pt	78	195.08
Cesium	Cs	55	132.9054	Plutonium	Pu	94	(244)
Calcium	Ca	20	40.08	Polonium	Po	84	(209)
Californium	Cf	98	(251)	Potassium	K	19	39.0983
Carbon	C	6	12.011	Praseodymium	Pr	59	140.9077
Cerium	Ce	58	140.12	Promethium	Pm	61	(145)
Chlorine	Cl	17	35.453	Protactinium	Pa	91	231.0359
Chromium	Cr	24	51.996	Radium	Ra	88	226.0254
Cobalt	Co	27	58.9332	Radon	Rn	86	(222)
Copper	Cu	29	63.546	Rhenium	Re	75	186.207
Curium	Cm	96	(247)	Rhodium	Rh	45	102.9055
Dysprosium	Dy	66	162.50	Rubidium	Rb	37	85.4678
Einsteinium	Es	99	(252)	Ruthenium	Ru	44	101.07
Erbium	Er	68	167.26	Samarium	Sm	62	150.36
Europium	Eu	63	151.96	Scandium	Sc	21	44.9559
Fermium	Fm	100	(257)	Selenium	Se	34	78.96
Fluorine	F	9	18.998403	Silicon	Si	14	28.0855
Francium	Fr	87	(223)	Silver	Ag	47	107.8682
Gadolinium	Gd	64	157.25	Sodium	Na	11	22.98977
Gallium	Ga	31	69.72	Strontium	Sr	38	87.62
Germanium	Ge	32	72.59	Sulfur	S	16	32.06
Gold	Au	79	196.9665	Tantalum	Ta	73	180.9479
Hafnium	Hf	72	178.49	Technetium	Tc	43	(98)
Helium	He	2	4.00260	Tellurium	Te	52	127.60
Holmium	Ho	67	164.9304	Terbium	Tb	65	158.9254
Hydrogen	H	1	1.00794	Thallium	Tl	81	204.383
Indium	In	49	114.82	Thorium	Th	90	232.0381
Iodine	I	53	126.9045	Thulium	Tm	69	168.9342
Iridium	Ir	77	192.22	Tin	Sn	50	118.69
Iron	Fe	26	55.847	Titanium	Ti	22	47.88
Krypton	Kr	36	83.80	Tungsten	W	74	183.85
Lanthanum	La	57	138.9055	Uranium	U	92	238.0289
Lawrencium	Lr	103	(260)	Vanadium	V	23	50.9415
Lead	Pb	82	207.2	Xenon	Xe	54	131.29
Lithium	Li	3	6.941	Ytterbium	Yb	70	173.04
Lutetium	Lu	71	174.967	Yttrium	Y	39	88.9059
Magnesium	Mg	12	24.305	Zinc	Zn	30	65.38
Manganese	Mn	25	54.9380	Zirconium	Zr	40	91.22
Medelevium	Md	101	(258)				

1 The atomic weight of many elements are not invariant but depend on the origin and treatment of the material. The values of atomic weight given here apply to elements as they exist naturally on Earth and to certain artificial elements. Values in parentheses are used for radioactive elements whose atomic weights cannot be quoted precisely without knowledge of the origin of the elements. The value given is the atomic mass number of the isotope of that element of longest known half-life.

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APPENDIX E

HANDLING OF LIQUID HELIUM AND NITROGEN

E1.0 GENERAL

Liquid Helium (LHe) and liquid nitrogen (LN_2) are used in the operation of the MTD Series System. Although not explosive, there are a number of safety considerations to keep in mind in the handling of LHe and LN_2.

E2.0 PROPERTIES

LHe and LN_2 are colorless, odorless, and tasteless gases. Gaseous nitrogen makes up about 78 percent of the Earth's atmosphere, while helium comprises only about 5 ppm (Reference 1). Most helium is recovered from natural gas deposits. Once collected and isolated, the gases will liquefy when properly cooled. A quick comparison between LHe and LN_2 is provided in Table E-1.

Table E-1. Comparison of Liquid Helium to Liquid Nitrogen

PROPERTY	LIQUID HELIUM	LIQUID NITROGEN
Boiling Point @1 atm, in °K	4.2	77
Thermal Conductivity (Gas), w/cm–°K	0.083	0.013
Latent Heat of Vaporization, Btu/liter	2.4	152
Liquid Density, pounds/liter	0.275	0.78

E3.0 HANDLING CRYOGENIC STORAGE DEWARS

Cryogenic containers (dewars) must be operated in accordance with the manufacturer's instructions. Safety instructions will also be posted on the side of each dewar. Cryogenic dewars must be kept in a well-ventilated place where they are protected from the weather and away from any sources of heat. A typical cryogenic dewar is shown in Figure E-1.

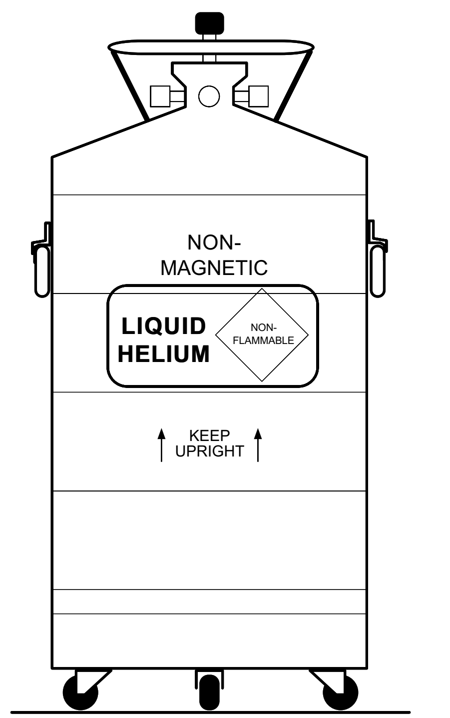


Figure E-1. Typical Cryogenic Storage Dewar

E4.0 LIQUID HELIUM AND NITROGEN SAFETY PRECAUTIONS

Transferring LHe and LN_2 and operation of the storage dewar controls should be in accordance with the manufacturer/supplier's instructions. During this transfer, it is important that all safety precautions written on the storage dewar and recommended by the manufacturer be followed.

WARNING: Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.

WARNING: Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

The two most important safety aspects to consider when handling LHe and LN_2 are adequate ventilation and eye and skin protection. Although helium and nitrogen gases are non-toxic, they are dangerous in that they replace the air in a normal breathing atmosphere. Liquid products are of an even greater threat since a small amount of liquid evaporates to create a large amount of gas. Therefore, it is imperative that cryogenic dewars be stored and the MTD System be operated in open and well ventilated areas.

Persons transferring LHe and LN_2 should make every effort to protect eyes and skin from accidental contact with liquid or the cold gas issuing from it. Protect your eyes with full face shield or chemical splash goggles. Safety glasses (even with side shields) are not adequate. Always wear special cryogenic gloves (Tempshield Cryo-Gloves® or equivalent) when handling anything that is, or may have been, in contact with the liquid or cold gas, or with cold pipes or equipment. Long sleeve shirts and cuffless trousers that are of sufficient length to prevent liquid from entering the shoes are recommended.

E5.0 RECOMMENDED FIRST AID

Every site that stores and uses LHe and LN_2 should have an appropriate Material Safety Data Sheet (MSDS) present. The MSDS may be obtained from the manufacturer/distributor. The MSDS will specify the symptoms of overexposure and the first aid to be used. A typical summary of these instructions is provided as follows.

If symptoms of asphyxia such as headache, drowsiness, dizziness, excitation, excess salivation, vomiting, or unconsciousness are observed, remove the victim to fresh air. If breathing is difficult, give oxygen. If breathing has stopped, give artificial respiration. Call a physician immediately.

If exposure to cryogenic liquids or cold gases occurs, restore tissue to normal body temperature (98.6°F) as rapidly as possible, then protect the injured tissue from further damage and infection. Call a physician immediately. Rapid warming of the affected parts is best achieved by bathing it in warm water. The water temperature should not exceed 105 °F (40 °C), and under no circumstances should the frozen part be rubbed, either before or after rewarming. If the eyes are involved, flush them thoroughly with warm water for at least 15 minutes. In case of massive exposure, remove clothing while showering with warm water. The patient should not drink alcohol or smoke. Keep warm and rest. Call a physician immediately.

References:

1. Linde Union Carbide Document No. L-3499H, Dated December 1988, Safety Precautions for Oxygen, Nitrogen, Argon, Helium, Carbon Dioxide, Hydrogen, and Fuel Gases

APPENDIX F

POUR-FILL DEWAR

F1.0 GENERAL

This appendix will provide general information on the optional pour-fill dewar for the MTD Cryotest System.

F2.0 DESCRIPTION

The operation of the pour-fill dewar is similar to the operation of the standard MTD-150. Internal differences are illustrated in Figure F-1. The main chapters of this manual should be read before using-the pour-fill system. The following differences should be noted between the systems.

1. The pour-fill dewar is primarily designed to operate at Liquid Nitrogen (LN_2) temperature.

2. The pour-fill dewar can be operated either horizontally or with the fill port up (looking down). If operating in a horizontal position, ensure the fill port is above the vacuum pump out valve.

3. No special helium transfer line is required. However, to ensure efficient cooling during liquid nitrogen transfer, make sure the opening of the transfer line reaches the bottom of the reservoir. If a funnel is used for pouring the cryogen, a length of tubing long enough to reach the bottom of the reservoir should be added to the opening of the funnel.

NOTE: Do not let liquid cryogen cool down the base plate or vacuum leaks may develop.

NOTE: To ensure safety to users and the system, fasten the test dewar to some kind of fixture before transferring cryogen.

4. No exhaust gas heater is used.

5. Liquid nitrogen hold time is approximately 8 hours when the system is stood upright (with the fill port up) or 6 hours if it is in the horizontal orientation.

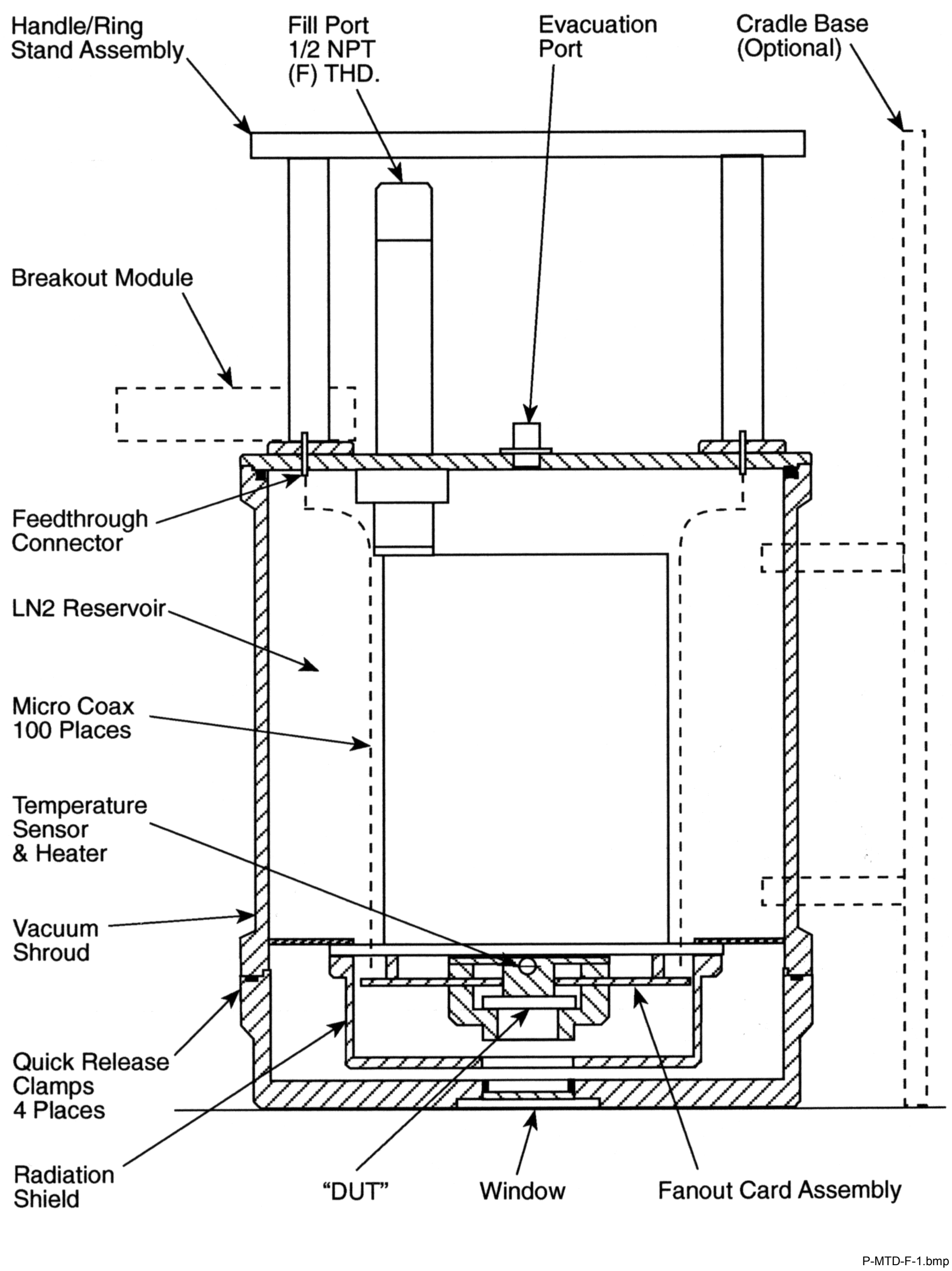


Figure F-1. Typical MTD Pour-Fill Dewar

APPENDIX G

FILTER WHEEL ASSEMBLIES

G1.0 GENERAL

This appendix will describe typical operation of the optional filter wheel assembly used with the MTD Cryotest System.

G2.0 DESCRIPTION

Filter wheel assemblies allow optical testing of infrared focal plane arrays with multiple filters. The filter wheel is coupled via a drive shaft assembly which protrudes through the vacuum chamber base plate. There it connects to a multiple-turn drive mechanism with a digital position indicator. A three-digit readout allows for precise alignment of each filter with the optical axis. Up to two filter wheels may be factory installed at time of initial order. Each accommodates eight 1-inch filters.

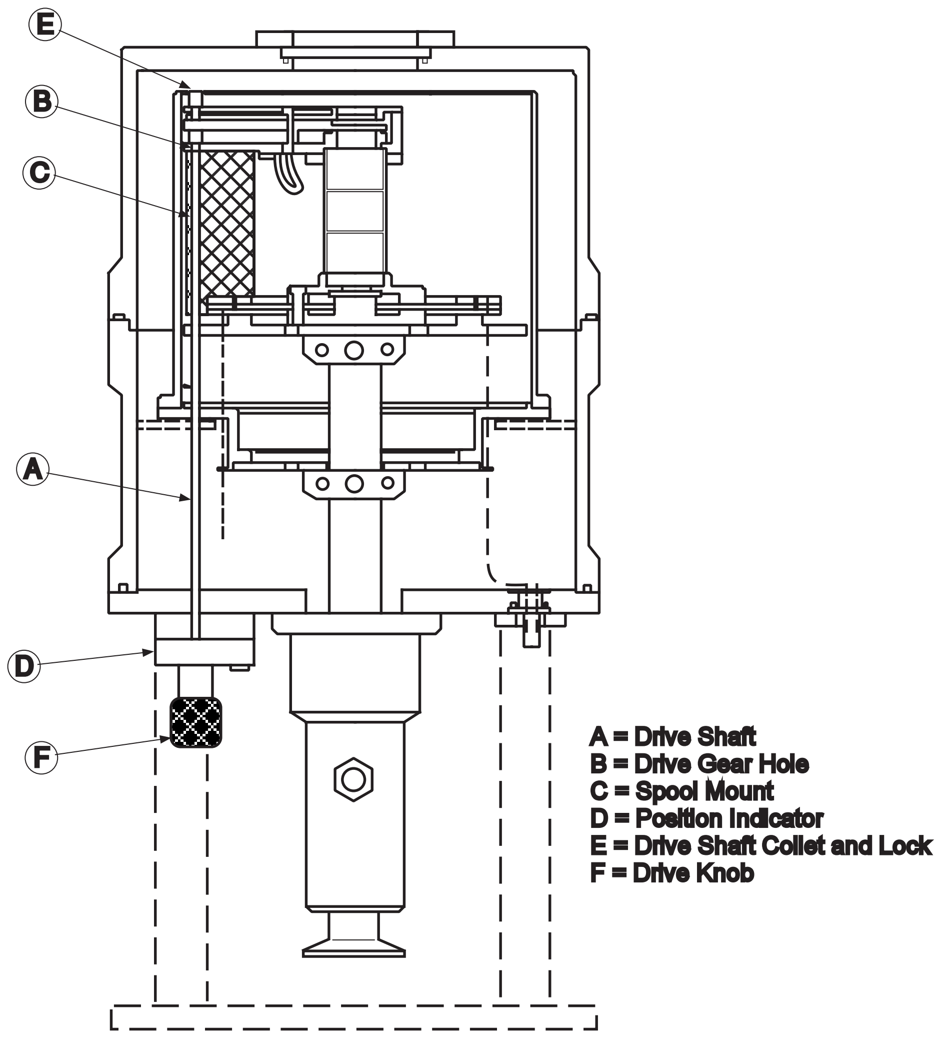


Figure G-1. Typical MTD with Optional Filter Wheel Assembly

G3.0 ASSEMBLY INSTALLATION

The MTD-150 System should be stabilized at room temperature and the transfer line removed. The system should be stood upright on its ring stand.

1. Open the vacuum pumpout valve to vent system.
2. Release the 4 pull-down clamps and remove the vacuum chamber end closure.

NOTE: Place vacuum chamber end closure so that the o-ring is face up to prevent damage.

3. Remove radiation shield by unscrewing the six captive socket head screws.
4. Align the drive shaft with the drive gear through opening and lower the module onto the spool mount.
5. Tighten the three captive socket head screws.

CAUTION: Do not grease the drive mechanism or the moveable module components.

NOTE: Be sure to use a light film of Apiezon "N" grease at the interface.

6. Align the module wheel position number one with the indicator reading 1.00 located on the vacuum chamber base plate.
7. Torque down the drive shaft collett lock by placing an open end wrench on the base and then tightening the hex nut.

NOTE: Do not rotate the drive gear when fastening the nut.

8. Check the operation of the module be rotating the drive knob located on the position indicator. Rotate the mechanism from position one to position two and so forth. It should rotate freely with minimal torque required.

NOTE: The module wheel has an over travel stop and can not be rotated a full 360°.

G4.0 ASSEMBLY REMOVAL

The following procedure is for filter wheel assembly removal.

1. To remove the module, loosen the hex nut on the drive shaft collett lock.
2. Loosen the three captive socket head screws.
3. Lift the module off of the spool mount.

NOTE: The same procedure is used to remove a second filter wheel assembly, if installed.

4. Replace the radiation shield.
5. Clamp down the vacuum chamber end closure.

G5.0 FILTER AND APERTURE INSTALLATION AND REMOVAL

The MTD-150 System should be stabilized at room temperature and the transfer line removed. The system should be stood upright on its ring stand.

1. Perform steps 1-3 from Paragraph G3.0 – Assembly Installation.
2. Remove the module cover plate by removing the six flat head screws.
3. Remove the wheel cover by removing the twelve flat head screws.
4. Place a ring of indium foil into the bottom of each recess.
5. Place the filters or apertures into the recesses.
6. Place the black aluminum washers provided into each recess.
7. Place the wavy spring washers provided into each recess.
8. Replace the wheel cover and screw down flat with the twelve flat head screws.
9. Replace the module cover plate and screw down tight with the six flat head screws.

CAUTION: It is very important that the moving parts are not contaminated. To prevent freeze-up problems, clean the wheel surfaces with alcohol and blow dry before final assembly.

NOTE: Take care that the spring loaded seals do not fall out during the assembly procedure.

10. Replace the radiation shield.
11. Clamp down the vacuum chamber end closure.

APPENDIX H

Model MTD-260B Cryotest Workstation

H1.0 GENERAL

This appendix provides information on the Model MTD-260B Closed-Cycle 20 K Cryotest Workstation with a closed-cycle refrigerator. The Model MTD-260B is used for testing focal plane arrays and integrated circuits from <20 K to 350 K without the use of cryogens. The user area is identical to the Model MTD-150B described in the main portion of this manual.

H2.0 DESCRIPTION

The MTD-260B is a user-configurable, single-test-position, closed-cycle Modular Test Dewar (MTD) system for testing infrared focal plane arrays or integrated circuits at temperatures from <20 K to 350 K. The installation of a Test Set Assembly Kit completes the workstation setup configuration. The user can quickly reconfigure the system for testing devices with different style packages by simply interchanging device Test Set Assembly Kits. The standard system configuration includes an optical window port over the interior device test location.

Eight- or sixteen-position filter/aperture wheels and calibrated blackbody/chopper assemblies can be added to enhance the optical test capability of the system. The MTD-260B features a closed-cycle, helium refrigeration system for cryogenic cooling. The cryotest dewar mainframe can be operated in any orientation.

The following are typical features of the Model MTD-260B Cryotest Workstation:

- Modular design accommodates virtually any device package.
- Fast sample turnaround time.
- High signal quality.
- Superior optical performance
- Precise monitoring and control of temperature.
- Superior vacuum characteristics.
- Utilizes proven refrigerator design. The need for cryogens is completely eliminated.
- The refrigerator can be operated intermittently or continuously for 10,000 hours without maintenance.
- Higher device test throughput with shortened warm-up and cool-down cycles.

The MTD-260B System utilizes most of the options and accessories available for the Lake Shore Model MTD-150 continuous flow cryotest system. Please refer to Chapter 6 of this manual.

Please refer to the separate manufacturer's manual for information on operation of the closed cycle refrigerator.

H3.0 SPECIFICTIONS

The following are specifications for the Model MTD-260B Cryotest Workstation:

- Lateral displacement when the refrigerator is operating is <0.001 inch with 2 millisecond pulse width. The expander piston frequency is 2.78 Hertz.
- The cooling capacity is as follows:

  At 10 K, the cooling capacity is ≈1.5 watts

  At 15 K, the cooling capacity is ≈5.2 watts

  At 20 K, the cooling capacity is ≈7.8 watts

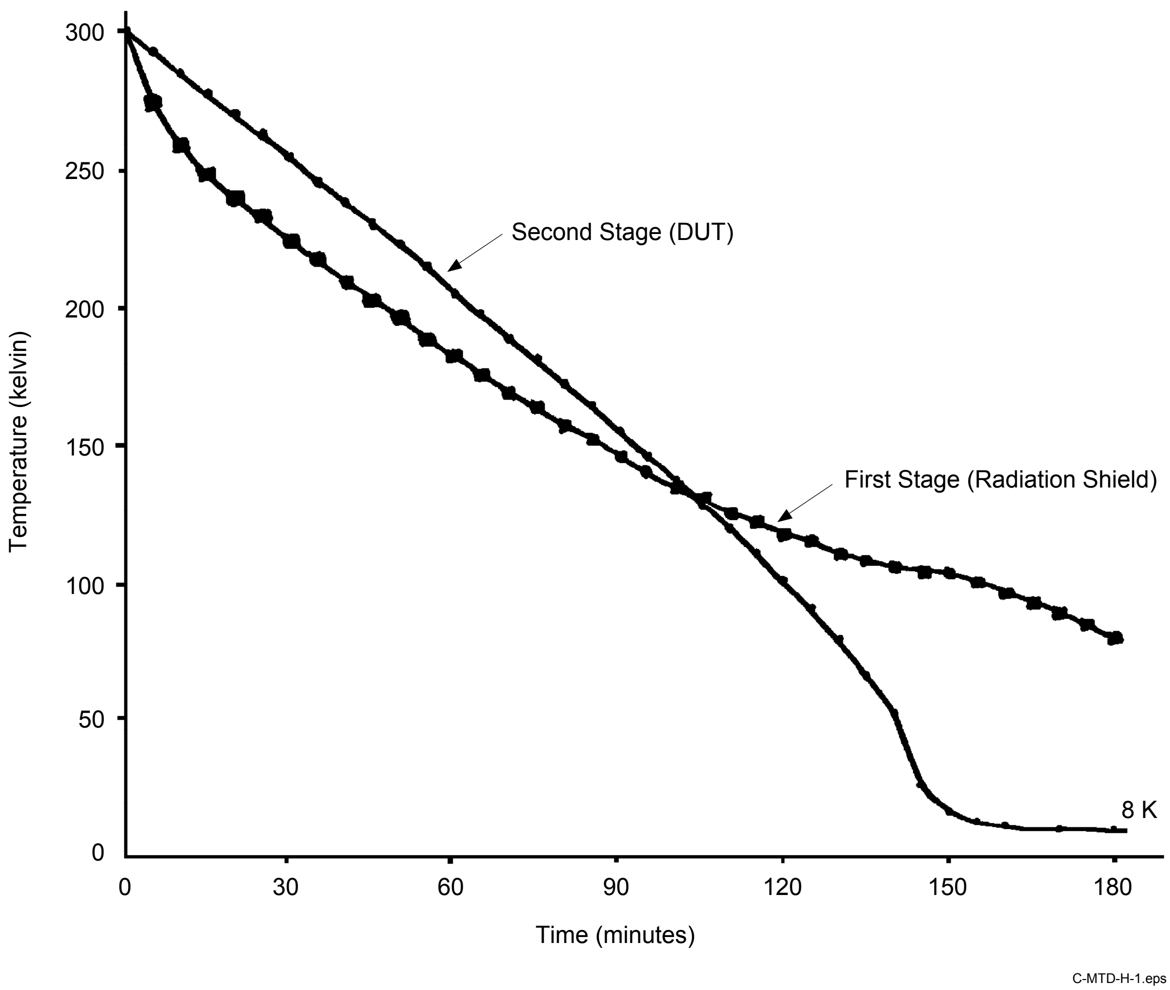
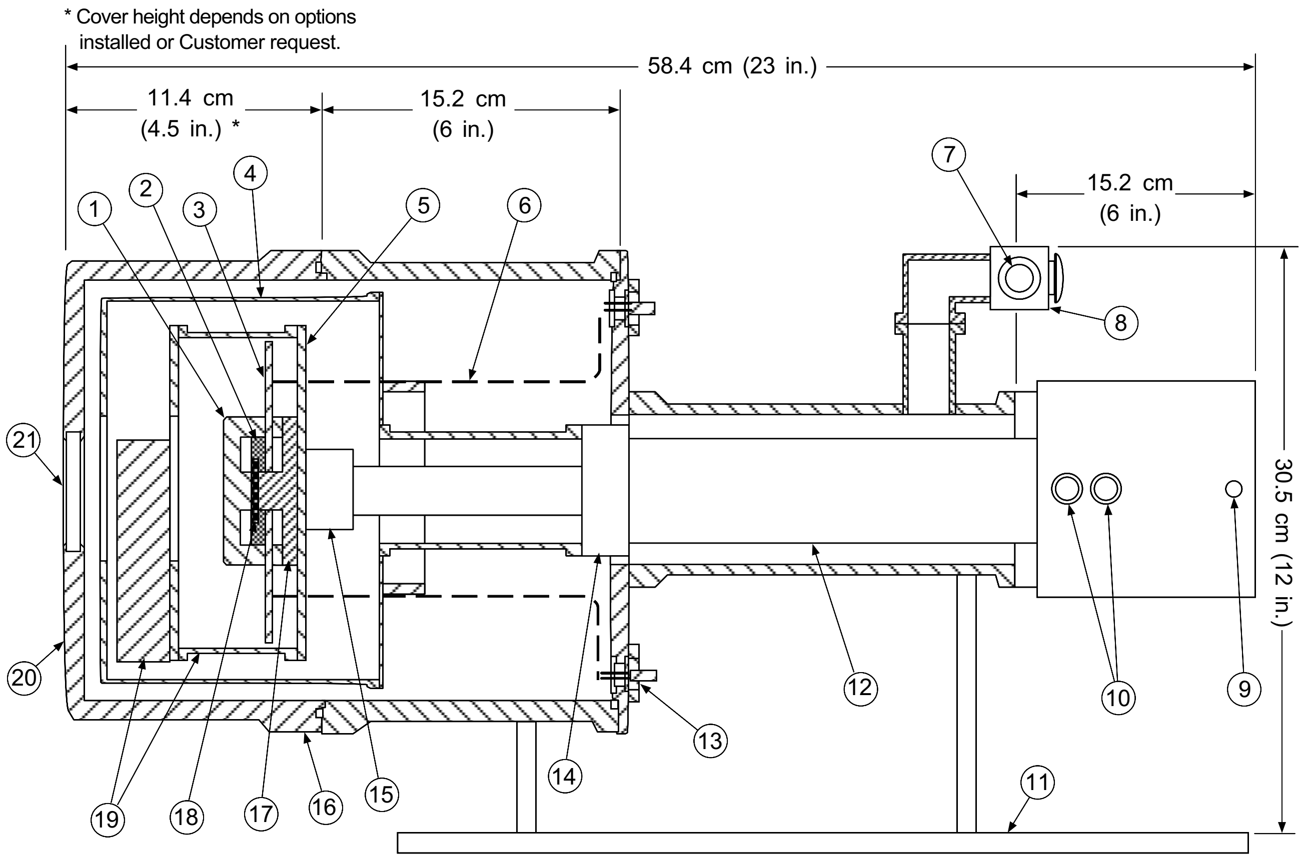


Figure H-1. Typical Model MTD-260B Cool Down Rate (with 68-pin Test Set Installed)



1. DUT Clamp Assembly
2. DUT Socket
3. Fanout Board
4. Radiation Shield
5. Cold Plate
6. Micro-Coaxial Cable (100 places)
7. Pump-Out Port, NW-25
8. Vacuum Valve
9. Refrigerator Motor Electrical Connection
10. Refrigerator Gas Line Connector (2 places)
11. Cradle Base
12. Refrigerator Expander
13. Signal Feedthru Connector (4 places)
14. First Stage Heater and Temperature Sensor
15. Second Stage Heater and Temperature Sensor
16. Quick Release Clamp (4 places)
17. Pedestal
18. Device Under Test (DUT)
19. Filter/Aperature Wheel Assembly (Optional)
20. Vacuum Chamber Cover
21. Window Port

C-MTD-H-2.eps

Figure H-2. Typical Model MTD-260B Cutaway Diagram

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APPENDIX I

MOTOR DRIVE CONTROLLER

I1.0 GENERAL

This appendix provides information on the Motor Drive Controller. The controller is described in Paragraph I2.0. Operation is described in Paragraph I3.0. Finally, serial interface operating instructions are provided in Paragraph I4.0.

I2.0 DESCRIPTION

The motor drive can control up to four independent stepping motors: the filter wheel, aperture wheel, carousel wheel, and cold stage. The controller is configured to operate specific features depending on the MTD model and options you purchased. You may not have all the functions available to you.

Before you plug the power cord to the power source, make sure all the other cables are connected and the input power is set to the correct voltage. Rotate the voltage select wheel in the fuse housing to change the voltage setting if necessary. Plug the power cord into the power receptacle.

Before operating the controller, open the cover of the MTD and make sure no packing material is left in the vacuum space of the dewar. Follow the instructions in Paragraph I3.0 in local mode operate the Motor Drive Controller to cycle through all the eight positions without installing any sample and filter.

CAUTION: Do not remove the wheels or drive gears. The assembly has been calibrated with the Motor Drive controller.

I3.0 OPERATION

Filter Wheel. When the instrument is powered up, it will not remember the wheel location from the last power down. Displace will indicate a letter "U." Push the local button (LOC). Push the filter button (FLTR) and enter button (ENT) to select function. For select position, push a number button (1 thru 8) and the enter button (ENT). The motor will rotate the filter wheel to the selected position. After the motor rotation, the display should read 11, 22, up to 88 depending on your selection. The filter position reading is the first digit and the selected location is the second digit. They should be the same. The controller reads the motor shaft position to determine the filter wheel location.

Aperture Wheel. Follow the same steps as detailed above except set function to aperture by pushing the APER and ENT keys before selecting the position.

Carousel and Cold Stage. The carousel and cold stage must work together if the motorized option is purchased. This option can be installed on an MTD-158 or MTD-268.

CAUTION: The stage must be separated from the carousel before operating the carousel motor. The stage must be engaged before making any sample measurements.

Push stage up button (SEP) followed by the enter (ENT) button. The SEP light will light up to indicate the separation of the stage from the carousel. Push the carousel function and enter buttons to select carousel motor functions. Input position you want the carousel to go to same as it is done in operating the Filter Wheel above. Engage the stage by pushing the ENG button and the enter (ENT) buttons.

I3.1 FILTER REMOVAL

In normal operations, the filter wheel assembly should not be removed from the drive shaft. To change or install filters, remove the cover plate of the assembly. If you need to remove the assembly, use the Controller to move the wheel to position 1 and follow the instructions in Appendix G.

CAUTION: Do not operate the motor when the wheels are dismounted from the drive shaft. The wheel must be indexed properly with respect to the drive shaft for the unit to operate properly.

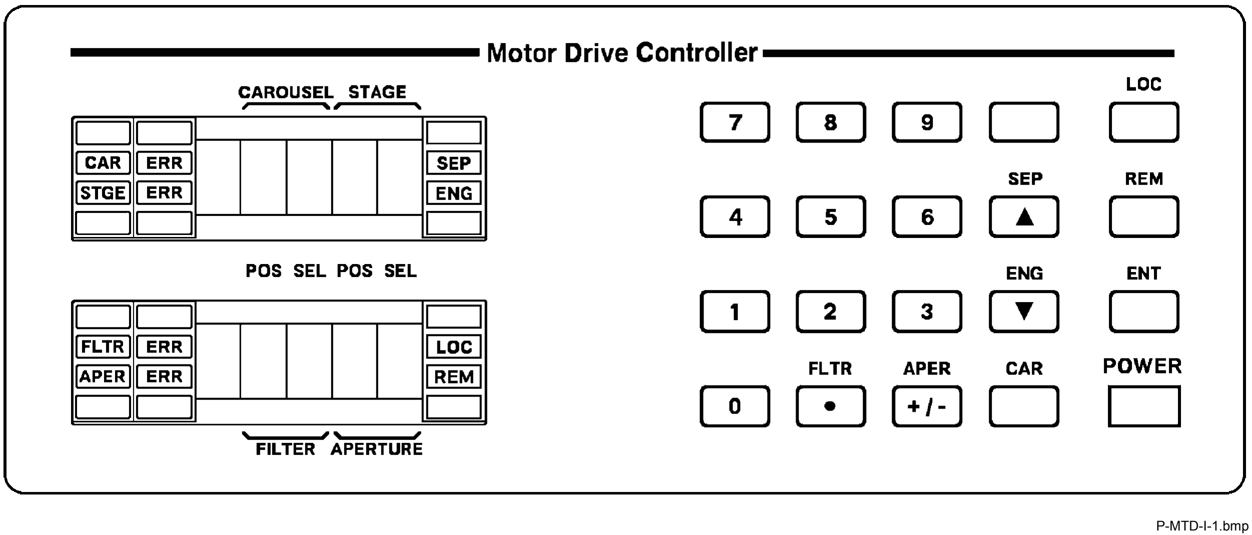

Figure I-1. Motor Drive Controller Front Panel

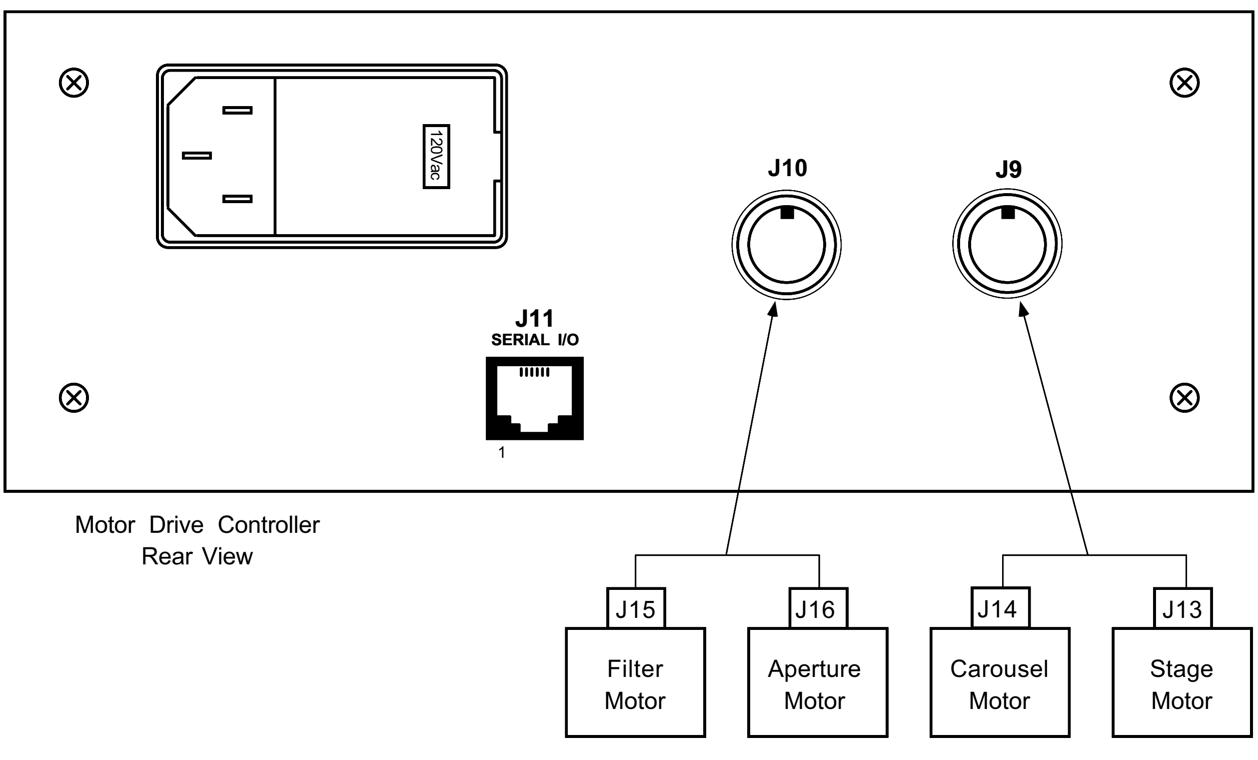

Figure I-2. Motor Drive Controller Rear Panel

I4.0 SERIAL INTERFACE OPERATING INSTRUCTIONS

The following are operating instructions used with the Motorized Drives Included With Carousel or Filter Wheel Assemblies. The motor control unit has a built-in RS-232 Serial Interface. Connection is made through a 9-pin D-connector mounted on the back panel of the controller. Data is transmitted from the controller on Pin 3 and received on Pin 2. Pin 7 provides a common ground return. The data format used is 8 data bits, 1 start bit, and 1 stop bit.

The following commands are used to control the unit through the serial interface. Every command must be followed by a line feed (LF) and carriage return (CR).

To Separate the Stage Drive (J13):

Send ASCII D, ASCII S, ASCII LF, and an ASCII CR.

DS (LF) (CR)

To Engage the Stage Drive (J13):

DE (LF) (CR)

To Move the Carousel to a Desired Position: (Positions are 1 thru 8) (J14)

C1 (LF) (CR)	This moves the carousel to position 1
C2 (LF) (CR)	This moves the carousel to position 2
C3 (LF) (CR)	This moves the carousel to position 3
C4 (LF) (CR)	This moves the carousel to position 4
C5 (LF) (CR)	This moves the carousel to position 5
C6 (LF) (CR)	This moves the carousel to position 6
C7 (LF) (CR)	This moves the carousel to position 7
C8 (LF) (CR)	This moves the carousel to position 8

To Move the Filter Wheel to a Desired Position: (Positions are 1 thru 8) (J15)

F1 (LF) (CR)	This moves the filter wheel to position 1
F2 (LF) (CR)	This moves the filter wheel to position 2
F3 (LF) (CR)	This moves the filter wheel to position 3
F4 (LF) (CR)	This moves the filter wheel to position 4
F5 (LF) (CR)	This moves the filter wheel to position 5
F6 (LF) (CR)	This moves the filter wheel to position 6
F7 (LF) (CR)	This moves the filter wheel to position 7
F8 (LF) (CR)	This moves the filter wheel to position 8

To Move the Aperture Wheel to a Desired Position: (Positions are 1 thru 8) (J16)

A1 (LF) (CR)	This moves the aperture wheel to position 1
A2 (LF) (CR)	This moves the aperture wheel to position 2
A3 (LF) (CR)	This moves the aperture wheel to position 3
A4 (LF) (CR)	This moves the aperture wheel to position 4
A5 (LF) (CR)	This moves the aperture wheel to position 5
A6 (LF) (CR)	This moves the aperture wheel to position 6
A7 (LF) (CR)	This moves the aperture wheel to position 7
A8 (LF) (CR)	This moves the aperture wheel to position 8

It is important to remember that each command (one at a time) be followed by a line feed and carriage return. The controller will respond to each command with one of four answers.

OK	Command was successful
EO	Requested command not an option (for units without all motor options)
E?	Did not understand the request (unknown error)
ES	Drive not separated error (if requesting to position the carousel while the drive is still engaged)

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APPENDIX J

STANDARD CURVE 10

Standard Curve 10: Measurement Current = 10 µA ±0.05%

T (K)	Voltage	dV/dT (mV/K)	T (K)	Voltage	dV/dT (mV/K)	T (K)	Voltage	dV/dT (mV/K)
1.40	1.69812	–13.1	16.0	1.28527	–18.6	95.0	0.98564	–2.02
1.60	1.69521	–15.9	16.5	1.27607	–18.2	100.0	0.97550	–2.04
1.80	1.69177	–18.4	17.0	1.26702	–18.0	110.0	0.95487	–2.08
2.00	1.68786	–20.7	17.5	1.25810	–17.7	120.0	0.93383	–2.12
2.20	1.68352	–22.7	18.0	1.24928	–17.6	130.0	0.91243	–2.16
2.40	1.67880	–24.4	18.5	1.24053	–17.4	140.0	0.89072	–2.19
2.60	1.67376	–25.9	19.0	1.23184	–17.4	150.0	0.86873	–2.21
2.80	1.66845	–27.1	19.5	1.22314	–17.4	160.0	0.84650	–2.24
3.00	1.66292	–28.1	20.0	1.21440	–17.6	170.0	0.82404	–2.26
3.20	1.65721	–29.0	21.0	1.19645	–18.5	180.0	0.80138	–2.28
3.40	1.65134	–29.8	22.0	1.17705	–20.6	190.0	0.77855	–2.29
3.60	1.64529	–30.7	23.0	1.15558	–21.7	200.0	0.75554	–2.31
3.80	1.63905	–31.6	24.0	1.13598	–15.9	210.0	0.73238	–2.32
4.00	1.63263	–32.7	25.0	1.12463	–7.72	220.0	0.70908	–2.34
4.20	1.62602	–33.6	26.0	1.11896	–4.34	230.0	0.68564	–2.35
4.40	1.61920	–34.6	27.0	1.11517	–3.34	240.0	0.66208	–2.36
4.60	1.61220	–35.4	28.0	1.11212	–2.82	250.0	0.63841	–2.37
4.80	1.60506	–36.0	29.0	1.10945	–2.53	260.0	0.61465	–2.38
5.00	1.59782	–36.5	30.0	1.10702	–2.34	270.0	0.59080	–2.39
5.50	1.57928	–37.6	32.0	1.10263	–2.08	280.0	0.56690	–2.39
6.00	1.56027	–38.4	34.0	1.09864	–1.92	290.0	0.54294	–2.40
6.50	1.54097	–38.7	36.0	1.09490	–1.83	300.0	0.51892	–2.40
7.00	1.52166	–38.4	38.0	1.09131	–1.77	310.0	0.49484	–2.41
7.50	1.50272	–37.3	40.0	1.08781	–1.74	320.0	0.47069	–2.42
8.00	1.48443	–35.8	42.0	1.08436	–1.72	330.0	0.44647	–2.42
8.50	1.46700	–34.0	44.0	1.08093	–1.72	340.0	0.42221	–2.43
9.00	1.45048	–32.1	46.0	1.07748	–1.73	350.0	0.39783	–2.44
9.50	1.43488	–30.3	48.0	1.07402	–1.74	360.0	0.37337	–2.45
10.0	1.42013	–28.7	50.0	1.07053	–1.75	370.0	0.34881	–2.46
10.5	1.40615	–27.2	52.0	1.06700	–1.77	380.0	0.32416	–2.47
11.0	1.39287	–25.9	54.0	1.06346	–1.78	390.0	0.29941	–2.48
11.5	1.38021	–24.8	56.0	1.05988	–1.79	400.0	0.27456	–2.49
12.0	1.36809	–23.7	58.0	1.05629	–1.80	410.0	0.24963	–2.50
12.5	1.35647	–22.8	60.0	1.05267	–1.81	420.0	0.22463	–2.50
13.0	1.34530	–21.9	65.0	1.04353	–1.84	430.0	0.19961	–2.50
13.5	1.33453	–21.2	70.0	1.03425	–1.87	440.0	0.17464	–2.49
14.0	1.32412	–20.5	75.0	1.02482	–1.91	450.0	0.14985	–2.46
14.5	1.31403	–19.9	80.0	1.01525	–1.93	460.0	0.12547	–2.41
15.0	1.30422	–19.4	85.0	1.00552	–1.96	470.0	0.10191	–2.30
15.5	1.29464	–18.9	90.0	0.99565	–1.99	475.0	0.09062	–2.22

Lighter numbers indicate truncated portion of Standard Curve 10 corresponding to the reduced temperature range of DT-471 diode sensors. The 1.4 – 325 K portion of Curve 10 is applicable to the DT-450 miniature silicon diode sensor.

POLYNOMIAL REPRESENTATION

Curve 10 can be expressed by a polynomial equation based on the Chebychev polynomials. Four separate ranges are required to accurately describe the curve. Table 1 lists the parameters for these ranges. The polynomials represent Curve 10 on the preceding page with RMS deviations of 10 mK. The Chebychev equation is:

$$T(x) = \sum_{i=0}^{n} a_i t_i(x) \tag{1}$$

where T(x) = temperature in kelvin, $t_i(x)$ = a Chebychev polynomial, and a_i = the Chebychev coefficient. The parameter x is a normalized variable given by:

$$x = \frac{(V - VL) - (VU - V)}{(VU - VL)} \tag{2}$$

where V = voltage and VL and VU = lower and upper limit of the voltage over the fit range. The Chebychev polynomials can be generated from the recursion relation:

$$t_{i+1}(x) = 2x t_i(x) - t_{i-1}(x)$$
$$t_0(x) = 1, t_1(x) = x \tag{3}$$

Alternately, these polynomials are given by:

$$t_i(x) = \cos\left[i \times \arccos(x)\right] \tag{4}$$

The use of Chebychev polynomials is no more complicated than the use of the regular power series and they offer significant advantages in the actual fitting process. The first step is to transform the measured voltage into the normalized variable using Equation 2. Equation 1 is then used in combination with equations 3 and 4 to calculate the temperature. Programs 1 and 2 provide sample BASIC subroutines which will take the voltage and return the temperature T calculated from Chebychev fits. The subroutines assume the values VL and VU have been input along with the degree of the fit. The Chebychev coefficients are also assumed to be in any array A(0), A(1),..., A(i_{degree}).

An interesting property of the Chebychev fits is evident in the form of the Chebychev polynomial given in Equation 4. No term in Equation 1 will be greater than the absolute value of the coefficient. This property makes it easy to determine the contribution of each term to the temperature calculation and where to truncate the series if full accuracy is not required.

```
FUNCTION Chebychev (Z as double)as double
REM Evaluation of Chebychev series
   X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
   Tc(0)=1
   Tc(1)=X
   T=A(0)+A(1)*X
   FOR I=2 to Ubound(A())
      Tc(I)=2*X*Tc(I-1)-Tc(I-2)
      T=T+A(I)*Tc(I)
   NEXT I
   Chebychev=T
END FUNCTION
```

Program 1. BASIC subroutine for evaluating the temperature *T* from the Chebychev series using Equations (1) and (3). An array T_c (i_{degree}) should be dimensioned. See text for details.

```
FUNCTION Chebychev (Z as double)as double
REM Evaluation of Chebychev series
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    T=0
    FOR I=0 to Ubound(A())
        T=T+A(I)*COS(I*ARCCOS(X))
    NEXT I
    Chebychev=T
END FUNCTION
```

NOTE: $\arccos(X) = \frac{\pi}{2} - \arctan\left[\frac{X}{\sqrt{1-X^2}}\right]$

Program 2. BASIC subroutine for evaluating the temperature *T* from the Chebychev series using Equations (1) and (4). Double precision calculations are recommended.

Table 1. Chebychev Fit Coefficients

2.0 K to 12.0 K		12.0 K to 24.5 K		24.5 K to 100.0 K		100 K to 475 K	
VL =	1.32412	VL =	1.11732	VL =	0.923142	VL =	0.079767
VU =	1.69812	VU =	1.42013	VU =	1.13935	VU =	0.999614
A(0) =	7.556358	A(0) =	17.304227	A(0) =	71.818025	A(0) =	287.756797
A(1) =	–5.917261	A(1) =	–7.894688	A(1) =	–53.799888	A(1) =	–194.144823
A(2) =	0.237238	A(2) =	0.453442	A(2) =	1.669931	A(2) =	–3.837903
A(3) =	–0.334636	A(3) =	0.002243	A(3) =	2.314228	A(3) =	–1.318325
A(4) =	–0.058642	A(4) =	0.158036	A(4) =	1.566635	A(4) =	–0.109120
A(5) =	–0.019929	A(5) =	–0.193093	A(5) =	0.723026	A(5) =	–0.393265
A(6) =	–0.020715	A(6) =	0.155717	A(6) =	–0.149503	A(6) =	0.146911
A(7) =	–0.014814	A(7) =	–0.085185	A(7) =	0.046876	A(7) =	–0.111192
A(8) =	–0.008789	A(8) =	0.078550	A(8) =	–0.388555	A(8) =	0.028877
A(9) =	–0.008554	A(9) =	–0.018312	A(9) =	0.056889	A(9) =	–0.029286
		A(10) =	0.039255	A(10) =	0.116823	A(10) =	0.015619
				A(11) =	0.058580		