User's Manual

7300 Series

VSM System

The 7300 Series includes:

Model 7304 VSM System with 4-inch Electromagnet
Model 7307 VSM System with 7-inch Electromagnet
Model 7312 VSM System with 12-inch Electromagnet

LakeShore®

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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 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 resulting from improper or inadequate maintenance, unauthorized modification or misuse, operation outside of the environmental specifications, or from buyer-supplied software interfacing. It does not apply to damage caused by accident, misuse, fire, flood or acts of God, or from failure to properly install, operate, or maintain the product in accordance with the printed instruction provided.

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.

FCC NOTICE

This equipment generates, uses, and can radiate radio-frequency energy and, if not installed and used in accordance with this manual, may cause interference to radio communications. As temporarily permitted by regulation, operation of this equipment in a residential area is likely to cause interference, in which case the user at his own facility will be required to take whatever measures that may be required to correct the interference.

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).

SOFTWARE LIMITATIONS

Lake Shore has worked to ensure that the 7300 Series VSM Software is as free of errors as possible, and that the results you obtain from the system are accurate and reliable. However, understand that with any computer software the possibility of software errors exists.

In any important research, as when using any laboratory equipment, results should be carefully examined and rechecked before final conclusions are drawn. Neither Lake Shore nor anyone else involved in the creation or production of this software can pay for loss of time, inconvenience, loss of use of the product, or property damage caused by this product or its failure to work, or any other incidental or consequential damages. Use of our product implies that you understand the Lake Shore license agreement and statement of limited warranty.

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Under the terms of this agreement you may use the VSM Software on any one computer. Archival floppy disks are permitted for the sole purpose of protecting the software from loss. Any unauthorized duplication or use of the VSM Software in whole or in part, in print, or in any other storage and retrieval system is forbidden.

TRADEMARK ACKNOWLEDGMENT

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this manual and Lake Shore was aware of a trademark claim, the designations have been printed in initial capital letters and the ™ or ® symbol used.

ASYST® is a trademark of MacMillian Software Co.

Duco® is a trademark of E.I. DuPont de Nemours

Hercules is a trademark of Hercules, Inc.

IDEAS® is a trademark of Unisys Corporation and is licensed for use with Lake Shore software drivers.

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Shockwatch® is a trademark of Media Recovery, Inc.

Swagelok® is a trademark of Swagelok Company

TACKIWAX® is a trademark of CSC Scientific Co., Inc.

Teflon® is a trademark of DuPont De Nemours

Tip-N-Tell is patented by ULine, Inc.

Vectra™ is a trademark of Hewlett-Packard

NICKEL SAMPLE

Serial Number: _____

This nickel sample was fabricated from 99.995% purity nickel. The moment was verified with two independent measurement techniques. Corrections for demagnetization effects were not made. The estimated accuracy of each determination is $\pm$2%. We recommend averaging the two measurements.

Method 1 involved a mass determination and the use of the magnetization values for nickel as stated in the ASTM Standard A 894-89. The density of nickel was taken as 8.908 gm/cm^3. The table below summarizes the magnetization values at 293 K:

Magnetic Field (kOe)	M_V ($\pm$2 emu/cm^3)	M_m ($\pm$0.2 emu/gm)
5	487	54.7
6	488	54.8
7	489	54.9
8	490	55.0
9	491	55.1
10	492	55.2

Method 2 was a direct experimental comparison with a NIST SRM 772 Nickel Sphere using a vibrating sample magnetometer.

Method 1

Mass: _____gm

Magnetic Moment: _____emu calculated at _____kOe

Method 2

Test Magnetic Field:_____kOe

Magnetic Moment: _____emu

Declaration of Conformity

$C\,E$

We,
Lake Shore Cryotronics, Inc.
575 McCorkle Blvd.
Westerville, OH 43082-8888 USA

hereby declare that the equipment specified conforms to the following Directives and Standards:

Application of Council directives:
73/23/EEC
89/336/EEC

Standard to which Conformity is declared:
EN55022
EN50082-1
EN61010-1

Type of Equipment:
Vibrating Sample Magnetometer (VSM)

Model Numbers:
7304, 7307, 7312
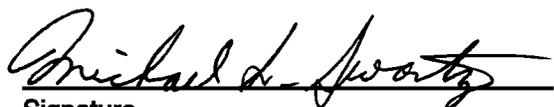
Signature
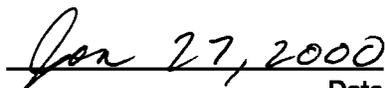
Date

Michael S. Swartz
Printed Name

Vice President of Research and Development
Position

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CHAPTER 1

INTRODUCTION

1.0   GENERAL

Lake Shore Cryotronics manufactures the 7300 Series Vibrating Sample Magnetometer (VSM) System to be one of the most versatile computer-controlled systems to characterize magnetic properties of matter. State of the art design augmented with a comprehensive applications software package allows greater adaptability to specific application requirements. The standard Model 7300 measures the magnetic moment of any magnetic material in any form from 5×10^{-6} emu to 1×10^{3} emu. Broad measurement capability, high sensitivity, fast measurement speed, and easy operation make the system equally attractive for either research and development or manufacturing.

1.1   SPECIFICATIONS

1.1.1   Measurements

The Model 7300 either directly measures the parameters below or derives them:

- Hysteresis Loops:
  - Saturation Magnetization (M_{SAT})
  - Retentivity or Remanent Magnetization (M_{REM})
  - Coercivity (Hc)
  - Slope at H_c, value of dM/dH, or Differential Susceptibility at H_c
  - Switching Field Distribution
  - Flatness
  - Squareness Ratio
  - Hysteresis Loss, Ws
- Minor Hysteresis Loops
- Initial Magnetization Curve
- IRM Remanence
- DLD Remanence
- Vector Measurements (m_x, m_y)
- Magnetization as a function of time
- Magnetization as a function of temperature for transition temperature and Curie point determinations (4.2 K to 1273 K with optional cryostat and/or oven)

1.1.2   Sample Materials

The Model 7300 measures the magnetic moment of any magnetic material in any form except gases. The only constraint is sample size; it must fit into the sample holder.

1.1.3   Requirements

The 7300 Series VSM System Software uses a Windows interface to control experiments. The VSM System Software includes a complete set of application and driver software for data acquisition. The hardware requirements for the VSM System are as follows.

- The VSM System requires an IBM-compatible PC and a Lake Shore VSM Controller connected via a National Instruments IEEE-488 Interface Card.
- Intel 300 MHz. (or better), 64 MB RAM, 2 MB VRAM (minimum), 17-inch (or larger) SVGA-compatible color monitor at 1024×768 High Color (16 bit), 200 MB free hard drive space.
- National Instruments PCI-GPIB for Windows NT. The driver can be downloaded by going to www.ni.com.

Requirements (Continued)

The additional software requirements for the VSM System are as follows.

- Microsoft Windows 2000 or Windows NT Version 4.
- Provided with VSM Software distribution:
  - 735 Momentmeter Software.
  - 450 Gaussmeter Software.
- Optional Lake Shore Software:
  - Lake Shore PDX driver for rotation.
  - Lake Shore driver for Models 330, 331, or 340 Temperature Controllers.

1.1.4 Standard 7300 Series VSM System

The standard 7300 Series VSM System includes the following components:

- Model 735 VSM Control Electronics.
- Either Model 730ESC Pick-Up Coils or Model 730EMSC Mini Pick-Up Coils.
- Magnet Power Supply (Model 662 for 4-inch electromagnets, Model 665 for 7-inch electromagnets, and Model 668 for 12-inch electromagnets).
- 4-, 7-, or 12-inch Electromagnet.
- VSM Drive Assembly and Mounting Structure.
- Model 450 Gaussmeter with ±30 kG Hall Probe.

1.1.6 VSM System Options (Refer to Chapter 6)

- The **Vector/Torque Magnetometer** option simultaneously measures either 2-axis or 3-axis magnetic moment vectors to investigate anisotropic and low dimensional magnetic materials.
- The **Auto-Rotation** option automatically rotates a sample over a full 720° with angular resolution of better than 1°. Use it with the Vector/Torque option to produce torque curves as a function of rotation angle.
- **High-temperature ovens** allow measurements from 25 °C to 1000 °C.
- **Low-temperature cryostats** allow measurements at cryogenic temperatures. Lake Shore offers four cryostats: Liquid Helium (4 K to 300 K), Liquid Nitrogen (77 K to 300 K), Liquid Helium/Nitrogen (6 K to 300 K), and the Closed Cycle Refrigerator which requires no liquid cryogens (15 K to 300 K).
- The **Model 340 Temperature Controller** couples with cryostats or ovens for industry-leading temperature control. It features two control loops and autotuning.
- The **Magnetoresistance (MR)** option features room-temperature and high-temperature versions that perform magnetoresistance measurements.
- The **Industrial (-IND)** option provides a single power source and emergency power off switch.

Table 1-1. General Electromagnet VSM Specifications

SPECIFICATION	MODEL 7304	MODEL 7307	MODEL 7312
Dynamic Range	5×10^{-6} emu to 10^3 emu.		
Noise	**730EMSC Detector Coils:** 5×10^{-6} emu @ 0.9-inch gap 50×10^{-6} emu @ 1.6-inch gap	**730EMSC Detector Coils:** 5×10^{-6} emu @ 2.0-inch gap with backplates 10×10^{-6} emu @ 2.0-inch gap without backplates **730EMSC Detector Coils:** 5×10^{-6} emu @ 1.0-inch gap	**730EMSC Detector Coils:** 5×10^{-6} emu @ 2.0-inch gap with backplates 10×10^{-6} emu @ 2.0-inch gap without backplates
Time Constants	0.1 second, 0.3 second, 1.0 second, 3.0 seconds, or 10.0 seconds		
Output Stability	Less than ±0.05% of full scale per day for fixed coil geometry at constant field and temperature		
Absolute Accuracy	Better than 2% of reading ±0.2% of full scale		
Reproducibility	Better than ±1%, or ±0.15% of full scale, whichever is greater		
Gaussmeter Ranges: Field Dynamic Range			
Field Noise	0.05 G for HST	0.05 G for HST	0.1 G for HST
Field Accuracy	1% or reading ±0.05% full scale		
Field Stability	±0.05% of full scale		
Maximum Field Strength	±14.5 kG @ 0.9-inch air gap	±10 kG @ 2.0-inch air gap and 6-inch pole face ±21 kG @ 0.9-inch air gap and 3-inch pole face	±20 kG @ 2.0-inch air gap and 6-inch pole face ±28.5 kG @ 0.9-inch air gap and 3-inch pole face (Co Tips)
Shipping Weight	3 crates: 352 kilograms (775 pounds)	4 crates: 1093 kilograms (2405 pounds)	5 crates: 3266 kilograms (7185 pounds)
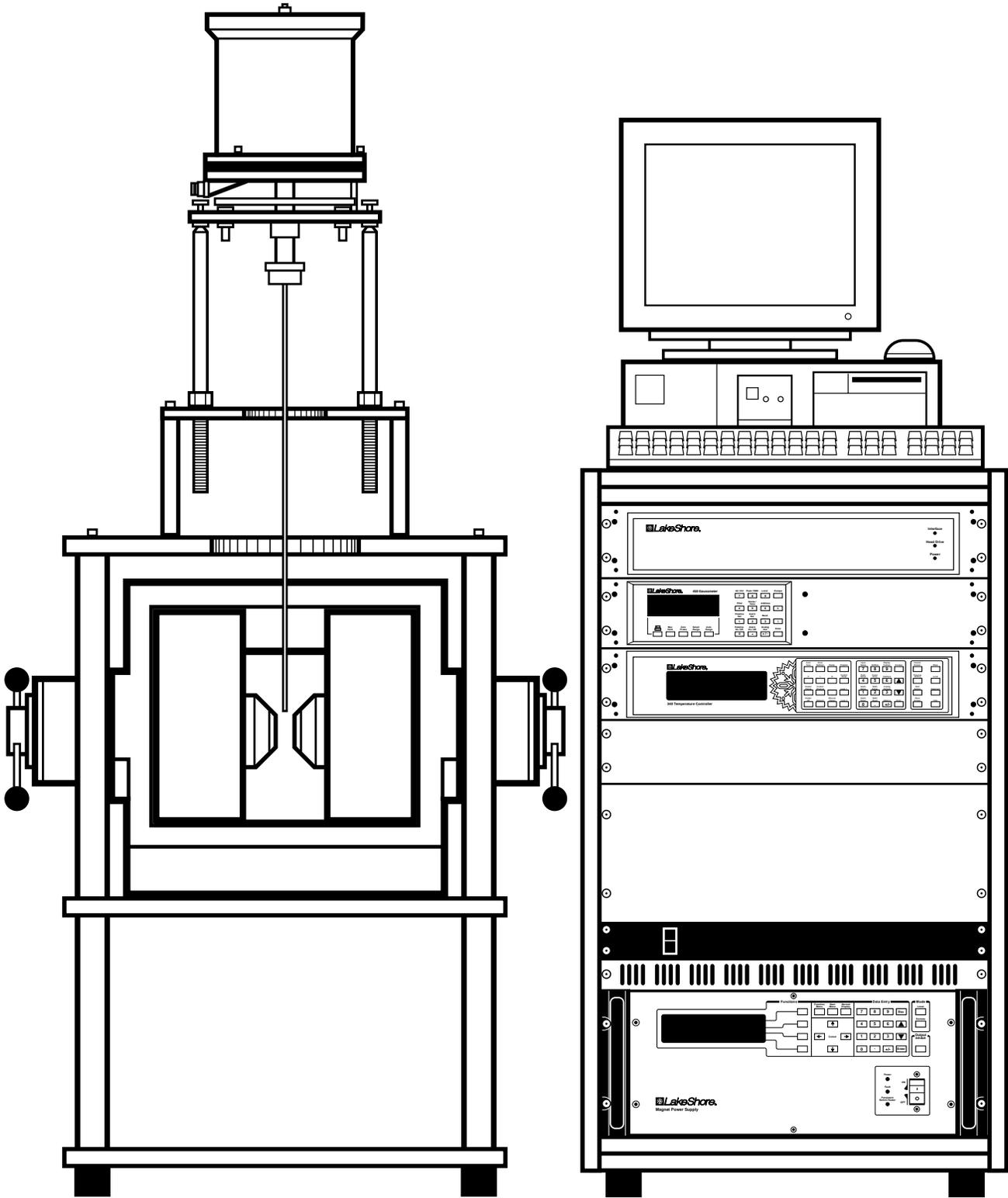
F-7300-1-1.eps

Figure 1-1. Typical Model 7304 4-Inch Electromagnet VSM System
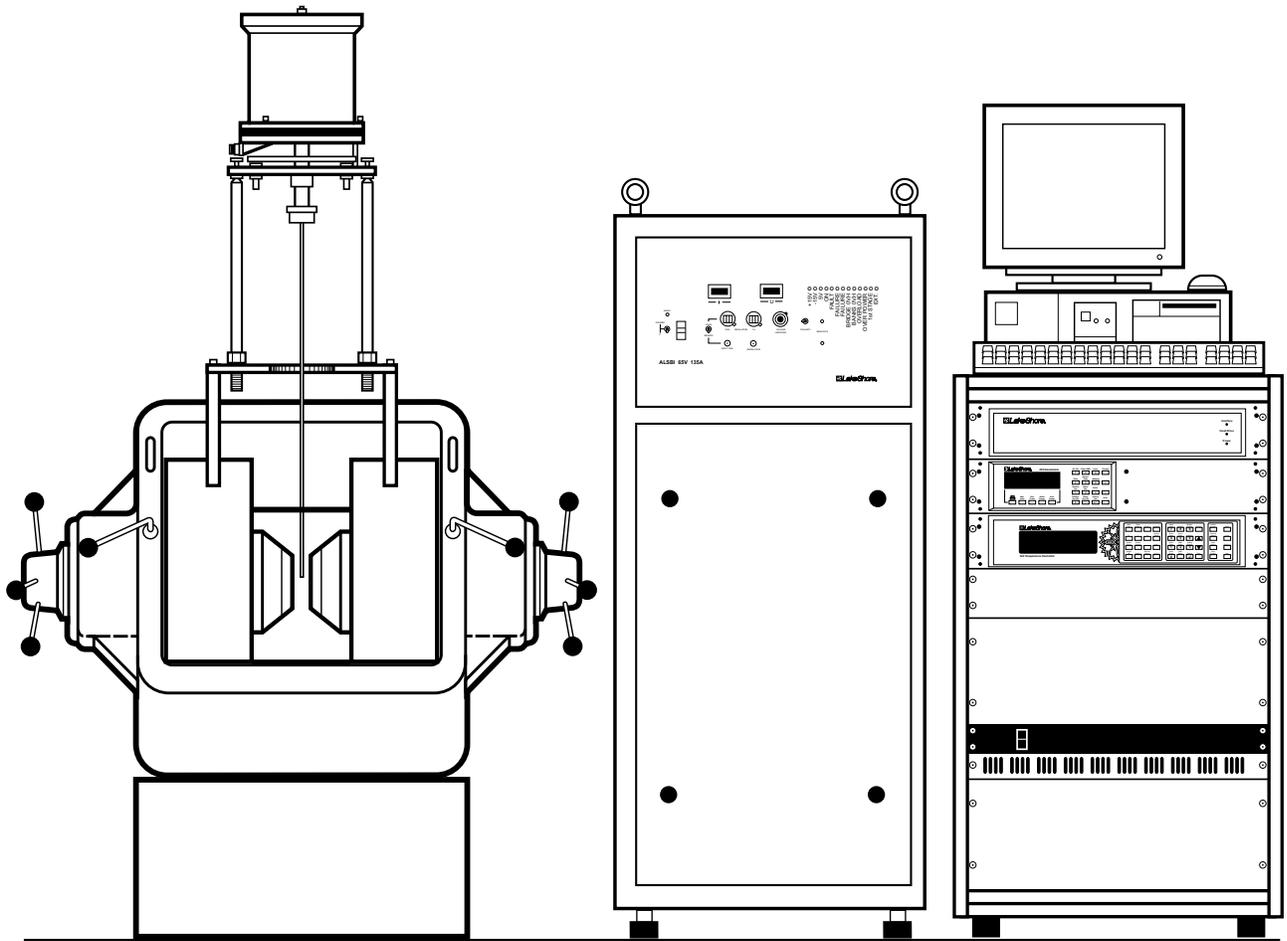
F-7300-1-2.eps

Figure 1-2. Typical Model 7307 7-Inch Electromagnet VSM System
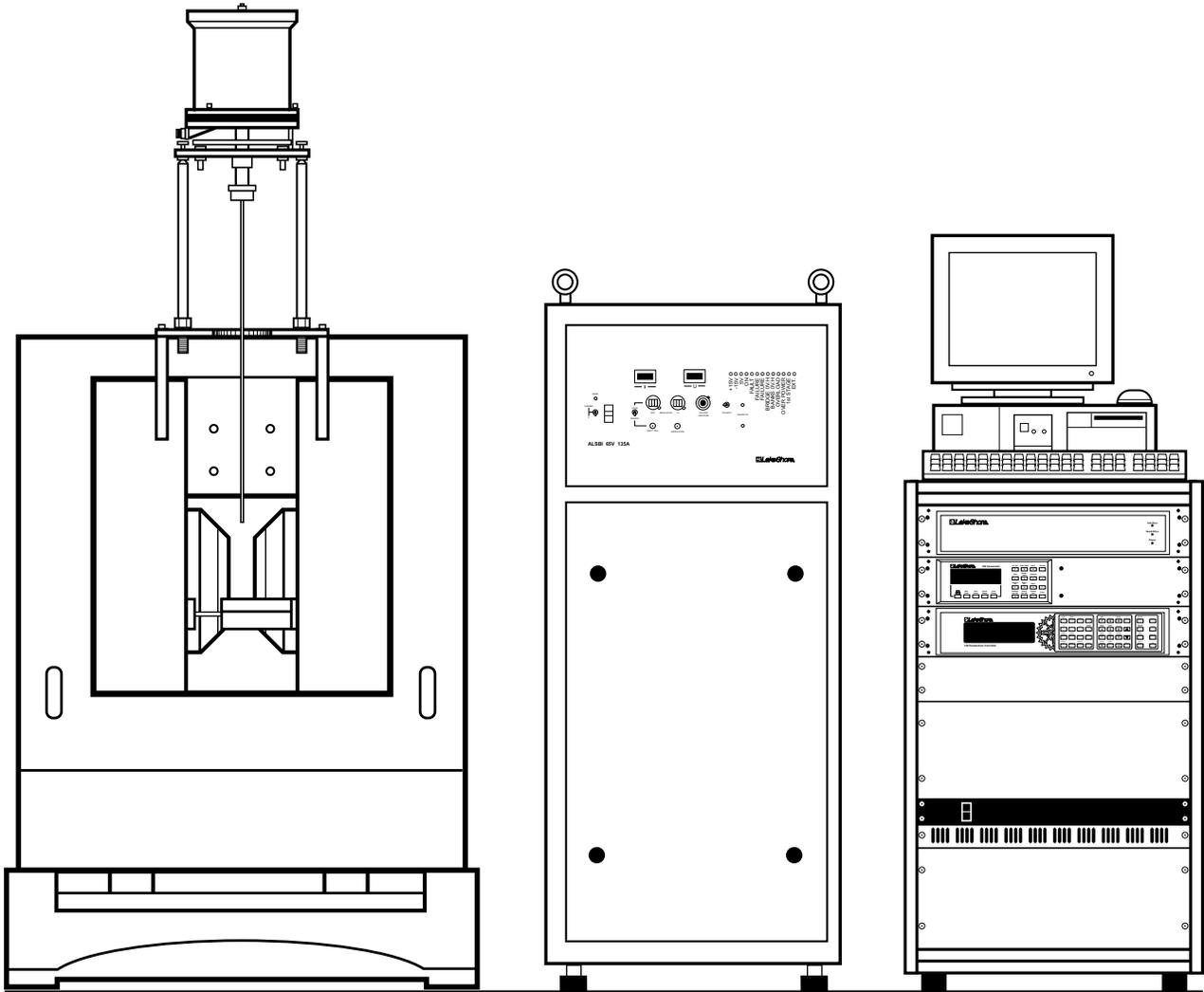
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Figure 1-3. Typical Model 7312 12-Inch Electromagnet VSM System

CHAPTER 2

PRE-INSTALLATION

2.0 GENERAL

The 7300 System was electrically and mechanically inspected and operationally tested prior to shipment. It should be free from mechanical damage and in perfect working order upon receipt. Study the 7300 User's Manual before attempting to run the system. Details for inspecting and unpacking your 7300 Series System are provided in Paragraph 2.1. Recommended site requirements are detailed in Paragraph 2.2. System power and ground requirements are provided in Paragraph 2.3. Environmental requirements are provided in Paragraph 2.4. Safety recommendations are detailed in Paragraph 2.5. Finally, line input assembly is described in Paragraph 2.6.

2.1 INSPECTING AND UNPACKING

Set pallets on level surface. Inspect shipping containers for external damage. Make all claims for damage (apparent or concealed) or partial loss of shipment in writing to Lake Shore within five (5) days from receipt of goods. If damage or loss is apparent, notify shipping agent immediately.

Carton Shockwatch® and Tip-n-Tell indicators aid in judging the condition of received goods (see Figure 2-1). A Shockwatch® sticker is also on the pallet under the units. Please accept shipment even if Shockwatch® is red. Note it on the bill of lading and inspect for damage immediately. Two Tip-n-Tell indicators are placed on the Instrument Console pallet. Blue beads above the line indicate the container was tipped or mishandled.
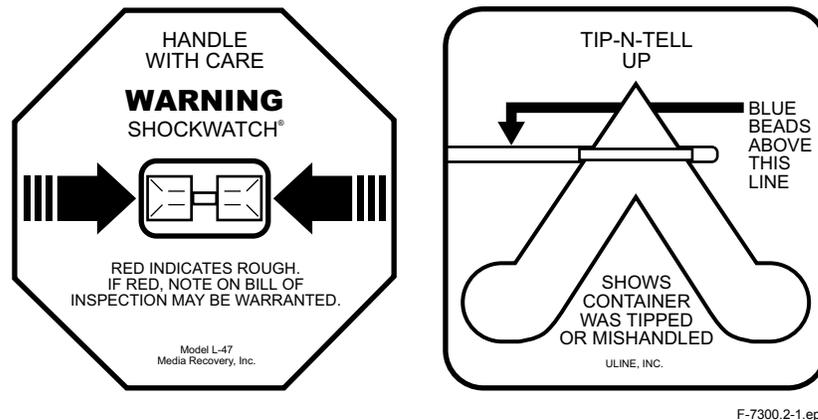
Figure 2-1. Shockwatch and Tip-n-Tell Indicators

Cut off strapping, lift off lid, and locate the packing list included with the system. Use it to check receipt of all components, cables, accessories, and manuals as the system is unpacked. Inspect for damage. Inventory all components supplied before discarding any shipping materials.

Remove the box from the top of the Instrument Console. Use four people to lift the Instrument Console from the pallet. Do not lift the console at the top: always lift from the bottom.

Note how the console was supported on the pallet for future reference. Foam blocks between the instruments support their weight during shipment; remove them, or simply leave them in place. To transport the unit, first insert the foam blocks.

The second pallet contains the electromagnet and stand. Verify receipt of all manuals. If any manuals are missing, contact Lake Shore immediately. **Be sure to fill out and send instrument warranty cards.**

INSPECTING AND UNPACKING (Continued)

If there is instrument freight damage, file claims promptly with the carrier and insurance company, and advise Lake Shore Cryotronics of such filings. Advise Lake Shore immediately of missing parts. Lake Shore cannot be responsible for any missing parts unless notified within 60 days of shipment. The standard Lake Shore Cryotronics, Inc. Warranty appears on the A Page (immediately behind the title page) of this manual.

2.2   SITE REQUIREMENTS

The Customer is responsible for site preparation. Plan the site before the 7300 System arrives. Research physical location, environment, power, ventilation, safety, and local building, electrical, and safety codes before system installation. See Figure 2-2 for physical dimensions of a suggested site. After initial screening, evaluate sites according to space, location, power, and structural integrity.

1. **Space**: Adequate for system installation, operation, potential expansion, service, and storage of supplies. Space and layout requirements depend on the system selected. The ceiling must be high enough to allow the sample rod assembly insertion and removal. Minimum clearance, measured from the center of the magnet pole pieces to the ceiling is 85 inches (215.9 cm); or 9 foot ceilings.

2. **Location**: Convenient for equipment and supply delivery, and handy to related work areas for efficient operation. Especially important is sufficient access for a lift to move and place an electromagnet. Place the magnet in an area free from major vibration from motors, pumps, forklifts, etc.; it may interfere with VSM System Operation. Place the magnet as far away as possible from equipment containing large AC magnetic fields, including the magnet power supply; they can induce signals large enough to overload the magnetometer input amplifiers. If necessary, shim the magnet to level it. Perform a complete check of the magnet and magnet power supply before proceeding with installation.

3. **Power**: Adequate for system requirements, potential expansion, and wiring for maximum efficiency and economy of operation. Refer to Paragraph 2.3.

4. **Structural Integrity**: Level floor strong enough to support anticipated loads and free from extraneous vibrations or magnetic fields. Vibrations transmitted to consoles may degrade system performance. For example, the 7-inch magnet weights 1500 pounds. The foot print is about 22 x 22 inches. In general, a ground floor is preferred over a higher floor. One also needs to have proper lifting equipment to move the heavy magnet to the final location.

5. **Cooling Water Requirement**: At 25 °C, the cooling water supply should have a capacity of 3 gallons per minute (11 liters per minute) for cooling the magnet and 2 gallons per minute (8 liters per minute) for the power supply at minimum of 50 psi (344 kPa) pressure. The magnet has one male and one female garden hose fittings and the power supply has ¼ NPT female fittings for both inlet and outlet.
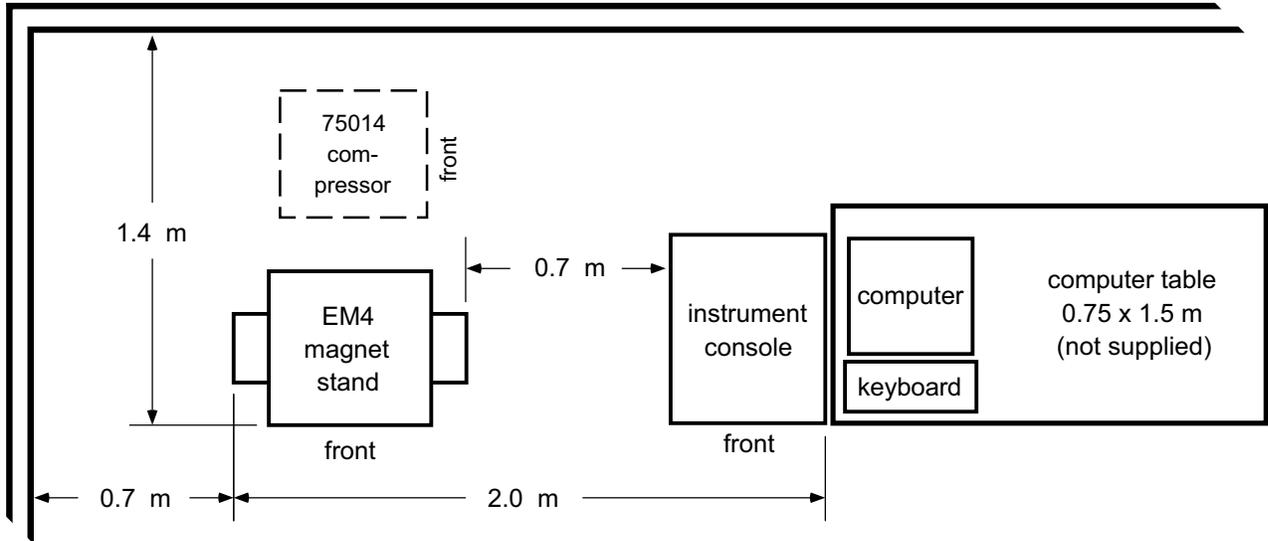
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Figure 2-2. Typical Model 7304 VSM System Floor Plan and Clearances
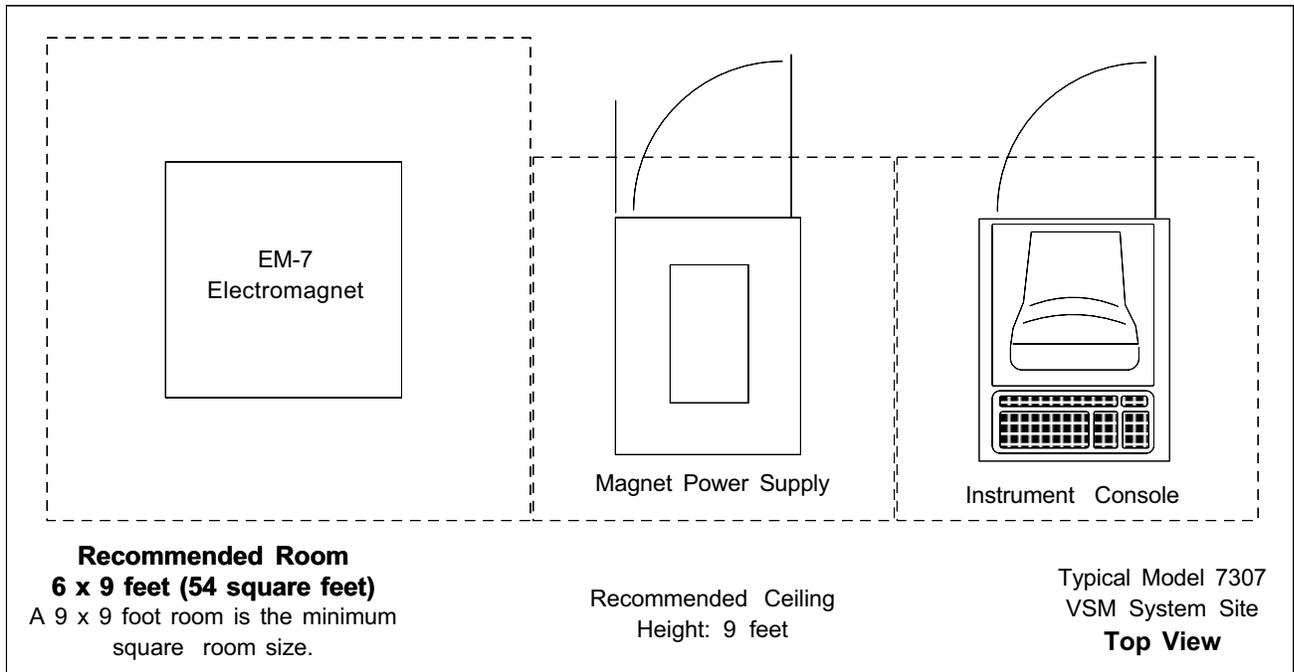
C-7300.2-3.eps

Figure 2-3. Typical Model 7307 VSM System Floor Plan and Clearances

2.3   SYSTEM POWER AND GROUND REQUIREMENTS

The AC power source for the Model 7300 System must be frequency and voltage regulated and isolated from sources that may generate Electromagnetic Interference (EMI). The equipment in the 7300 requires single-phase 3-wire AC power. Do not use two-wire (without ground) AC power. Ground Fault Interrupter (GFI) and Transient Surge Protection circuitry at the AC source are also strongly recommended.

Additional electrical requirements for Models that use the 665/668 Magnet Power Supply include 208 volt 3-phase power with safety ground. A 25 A (665) or 35 A (668) per phase disconnect box at the wall is required. You also need to provide a cable that goes from the disconnect to the circuit breaker terminal in the electrical box at back of the power supply. Lake Shore recommends #10 gauge four-conductor cables. Check with a electrician to ensure you conform to local electrical codes. You will also need 120 volt 25 ampere single-phase outlets for the instrument console and computer. For power supply running at 380 volt 3-phase, you will need 15 amperes per phase. You also need 230 volts 15 amperes for instrumentation.

In areas where AC voltage is variable, consider a constant voltage transformer. If power outages are a problem, consider an Uninterruptable Power Supply (UPS).

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

The factory presets Model 7300 electrical component power requirements for proper operation upon receipt. Set the input voltage for each instrument in the system on the rear panel. Before applying power to the main input power cable, verify input power settings for each instrument are correct for the power source voltage.

Ground instrument panels and cabinets. The safety ground provides a true ground path for electrical circuitry and, in the event of internal electrical faults such as shorts, carries the entire fault current to ground to protect users from electrical shock. The Power Strip in the Instrument Console has a three-conductor power input connector which grounds equipment in the Instrument Console when plugged into a 3-wire receptacle.

When the earth ground connection is likely impaired, render the Model 7300 inoperative and secure it against any unintended operation. The connection is likely impaired if the instrument:

1.   Shows visible damage.
2.   Fails to perform the intended measurement.
3.   Has been subjected to prolonged storage under unfavorable conditions.
4.   Has been subjected to severe transport stresses.

Do not use such apparatus until qualified service personnel verifies its safety.

Electromagnetic interference (EMI) is both a natural and man-made phenomena which, either directly or indirectly, may degrade electronic system performance. Natural EMI includes thunderstorms, solar disturbances, cosmic rays, etc. Man-made EMI includes fixed and mobile transmitters, high voltage power lines, power tools and appliances, florescent lights, and other equipment containing motors, heaters, etc. Protect the AC source from EMI. Consider transient surge protectors for lightning protection.

2.4   ENVIRONMENTAL REQUIREMENTS

To meet and maintain specifications, operate the system at an ambient temperature range of 18 to 28 °C (64.4 to 82.4 °F). Operate it within the range of 15 to 35 °C (59 to 95 °F) with less accuracy. The system is intended for laboratory use. Although no specific humidity or altitude specifications exist, relative humidity of 20% to 80% (no condensation) and altitudes from sea level to 2.4 km (8,000 feet) are generally acceptable.

Adequately ventilate the work area to prevent build up of potentially life-threatening concentrations of nitrogen gas (refer to Paragraph 2.1). Oxygen content monitor/alarms should be installed near the work site to warn against low oxygen levels if liquid cryogens are used. The air-conditioning system should filter dust and other particulates to reasonable levels. Consult an air-conditioning expert about special filtering if salt air, corrosive gases, or other air pollutants exist.

2.5   SAFETY

Train personnel in proper emergency measures such as electrical power shut off, fire department notification, fire extinguishing, and personnel and records evacuation. Here is a list of suggested personnel safety considerations:

- Ground Fault Interrupter (GFI) AC circuits.
- Cryogenic Safety Gloves, Apron, Goggles/Faceshield, and Apparel.
- Fire Extinguisher.
- Oxygen Concentration Monitor/Alarm.
- Magnetic Field Warning Signs.
- Fireproof Safe for Data, Original Software and Documentation Storage.
- Emergency Lighting.

Locate in the immediate vicinity fire extinguisher(s) that extinguish all three classes of fires: A, B, and C. Class A is ordinary combustibles like wood, paper, rubber, many plastics, and other common materials that burn easily. Class B is flammable liquids like gasoline, oil, and grease. Class C is energized electrical equipment including wiring fuse boxes, circuit breakers, machinery, and appliances. Do not use chemical extinguishers even though they are less expensive and cover all classes of fires. They may damage electronic equipment. Use a Carbon Dioxide or Halon fire extinguisher.

During the planning stage, consult local experts, building authorities, and insurance underwriters on locating and installing sprinkler heads, fire and smoke sensing devices, and other fire extinguishing equipment.

Locate an oxygen concentration monitor and alarm in the system work area near the system. Locate another in the dewar storage area. LHe and LN_2 can rapidly replace the breathing atmosphere in an enclosed area with no warning. Oxygen concentration monitor and alarms are the best way to reduce this potential hazard.

An electromagnet can generate large magnetic fields. Post signs at each entrance to the work area that state: "Warning: High Field Magnets – Fringe fields may be hazardous to pacemakers and other medical devices. Keep magnetic materials clear of area." Paint a yellow magnetic field warning line on the floor 1 meter (3 feet) from the sides of the electromagnets.

Locate a fireproof safe at or near the work site for temporary storage of data and copies of original system software and documentation. Store duplicate copies of vital data well away from the system area, also in a fireproof storage vault or safe.

Even where not required by code, install some type of automatic, battery-operated emergency lighting in case of power failure or fire.

2.5.1 Handling Liquid Helium and Liquid Nitrogen

Helium and Nitrogen are colorless, odorless, and tasteless gases. When properly cooled, the gases liquefy. Liquid helium (LHe) and liquid nitrogen (LN_2) may be used in conjunction with the Model 7300. Although not explosive, there are certain safety considerations in the handling of LHe and LN_2.

Operate all cryogenic containers (dewars) in accordance with manufacturer instructions. Safety instructions are normally posted on the side of each dewar. Keep cryogenic dewars in a well-ventilated place, protected from the weather, and away from heat sources. Figure 2-4 shows a typical cryogenic dewar.

Transfer LHe and LN_2 and operate storage dewar controls in accordance with manufacturer/supplier instructions. During transfer, follow all safety precautions written on the storage dewar and recommended by the manufacturer.

WARNING: **Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in an adequately ventilated area. DO NOT vent the container in confined spaces. DO NOT enter confined spaces where gas may be present unless area is well-ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.**
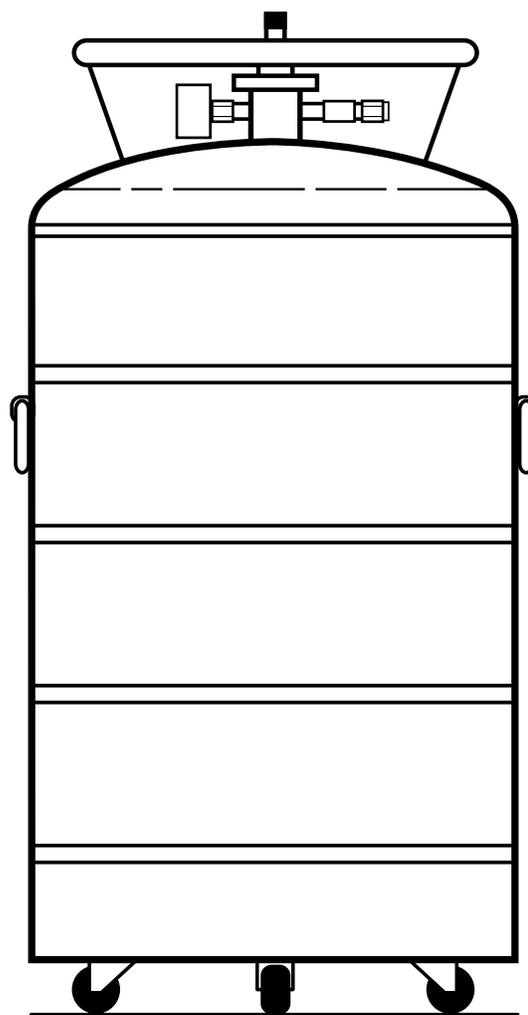
F-7300.2-4.eps

Figure 2-4. Cryogenic Storage Dewar

WARNING: **Liquid helium and liquid nitrogen can cause severe frostbite to exposed body parts. DO NOT touch frosted pipes or valves. For frostbite, consult a physician immediately. If a physician is unavailable, warm the affected parts with water that is near body temperature.**

Two essential safety aspects of handling LHe are adequate ventilation and eye and skin protection. Although helium and nitrogen gases are non-toxic, they are dangerous because they replace air in a normal breathing atmosphere. Liquid helium is an even greater threat because a small amount of liquid evaporates to create a large amount of gas. Store and operate cryogenic dewars in open, well-ventilated areas.

When transferring LHe and LN_2, protect eyes and skin from accidental contact with liquid or the cold gas issuing from it. Protect eyes with full face shield or chemical splash goggles; safety glasses (even with side shields) are inadequate. 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. Wear long sleeve shirts and cuffless trousers long enough to prevent liquid from entering shoes.

2.5.2 Recommended First Aid for LHe or LN2 Exposure

Post an appropriate Material Safety Data Sheet (MSDS) obtained from the manufacturer/distributor at every site that stores and uses LHe and LN$_2$. The MSDS specifies symptoms of overexposure and first aid.

If a person exhibits symptoms of asphyxia such as headache, drowsiness, dizziness, excitation, excessive salivation, vomiting, or unconsciousness, remove to fresh air. If breathing is difficult, give oxygen. If breathing stops, 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) by bathing it in warm water not exceeding 105 °F (40 °C). DO NOT rub the frozen part, either before or after rewarming. Protect the injured tissue from further damage and infection and call a physician immediately. Flush exposed eyes 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.

2.5.3 Electrostatic Discharge

Electrostatic Discharge (ESD) may damage electronic parts, assemblies, and equipment. ESD is 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 generates and retains static electricity. Simply walking across a carpet in low humidity may generate up to 35,000 volts of static electricity.

Current technology trends toward greater complexity, increased packaging density, and thinner dielectrics between active elements, which results in electronic devices with even more ESD sensitivity. Some electronic parts are more ESDS than others. ESD levels of only a few hundred volts may damage electronic components such as semiconductors, thick and thin film resistors, and piezoelectric crystals during testing, handling, repair, or assembly. Discharge voltages below 4000 volts cannot be seen, felt, or heard.

2.5.3.1 Identification of Electrostatic Discharge Sensitive Components

Below are various industry symbols used to label components as ESDS:

2.5.3.2 Handling Electrostatic Discharge Sensitive Components

Observe all precautions necessary to prevent damage to ESDS components before attempting installation. Bring the device and everything that contacts it to ground potential by providing a conductive surface and discharge paths. As a minimum, observe these precautions:

1. De-energize or disconnect all power and signal sources and loads used with unit.
2. Place unit on a grounded conductive work surface.
3. Ground technician through a conductive wrist strap (or other device) using 1 MΩ series resistor to protect operator.
4. Ground any tools, such as soldering equipment, that will contact unit. Contact with operator's hands provides a sufficient ground for tools that are otherwise electrically isolated.
5. Place ESDS devices and assemblies removed from a unit on a conductive work surface or in a conductive container. An operator inserting or removing a device or assembly from a container must maintain contact with a conductive portion of the container. Use only plastic bags approved for storage of ESD material.
6. Do not handle ESDS devices unnecessarily or remove from the packages until actually used or tested.

2.5.4   Instrument Safety

Observe these general safety precautions during all phases of instrument operation, service, and repair. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended instrument use. Lake Shore Cryotronics, Inc. assumes no liability for Customer failure to comply with these requirements.

Lake Shore instrumentation protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument. Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area.

• Temperature: 5 to 40 °C.

• Maximum relative humidity: 80% for temperature up to 31 °C decreasing linearly to 50% at 40 °C.

• Power supply voltage fluctuations not to exceed ±10% of the nominal voltage.

Ground Instruments
To minimize shock hazard, connect instrument chassis and cabinet to an electrical ground. Most Lake Shore instruments come with a three-conductor AC power cable. Plug the power cable into an approved 3-contact electrical outlet or use 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 instruments 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. Refer component replacement and internal adjustments to 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
Do not install substitute parts or perform any unauthorized modification to instruments. Return the instruments to an authorized Lake Shore Cryotronics, Inc. representative for service and repair to ensure that safety features are maintained.

2.5.5   Safety Symbols

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

2.6   LINE INPUT ASSEMBLY

On the rear of most Lake Shore instruments is the line input assembly (see Figure 2-5). It contains the line voltage selector, line fuse holder, and power cord connector. Verify appropriate line voltage setting and correct line fuse for all system instruments before initial power up (refer to Table 2-1). The factory configures line input if the final destination of the instruments is known when it ships. Verify this configuration; it is not unusual for instruments to change hands before reaching the user. All line voltages discussed are single phase.

Table 2-1. AC Line Input Definitions

Indicator	Line Voltage Range	Fuse (slow blow)
100	90-105 VAC	0.5 A
120	108-126 VAC	0.5 A
220	198-231 VAC	0.25 A
240	216-252 VAC	0.25 A

2.6.1   Line Voltage and Fuse Verification

To verify the proper line voltage selection look at the indicator in the window of the line input assembly. Table 2-1 lists the line voltage range for each indicator. If the range does not match your line voltage, change the line voltage selector (see Paragraph 2.6.2), and remove the fuse to verify its value (see Paragraph 2.6.3 for fuse replacement instructions). Use slow blow fuses of the value specified in Table 2-1. Fuse values are also printed on the instrument rear panel.

WARNING: To avoid potentially lethal shocks, turn off instruments and disconnect from AC power before performing these procedures. Only qualified personnel should perform these procedures.

CAUTION: For continued protection against fire hazard, replace only with the same fuse type and rating specified for the line voltage selected.

2.6.2   Line Voltage Selection

Below is the procedure to change the instrument line voltage selector. Verify the fuse value whenever line voltage is changed. See Figure 2.5.

1. Locate the line input assembly on the instrument rear panel.
2. Turn the line power switch OFF.
3. Remove the instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Slide out the removable plastic fuse holder from the drawer.
6. Rotate the fuse holder until the proper voltage indicator shows through the window.
7. Verify the proper fuse value.
8. Re-assemble the line input assembly in the reverse order.
9. Verify the voltage indicator in the window of the line input assembly.
10. Connect the instrument power cord.
11. Turn the line power switch ON.

2.6.3 Fuse Replacement

To replace a line fuse, use slow blow fuses with the value shown in Table 2-1. To change line input from the factory setting, use the appropriate fuse in the connector kit shipped with the instrument.
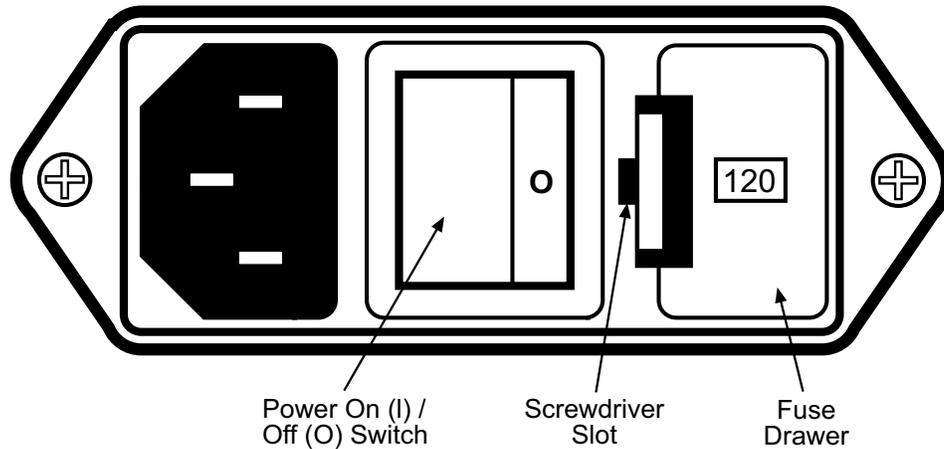
F-7300.2-5.eps

Figure 2-5. Line Input Assembly

1. Locate line input assembly on the instrument rear panel.
2. Turn the power switch OFF.
3. Remove the instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Remove fuse and replace it with appropriate slow blow fuse.
6. Re-assemble the line input assembly in reverse order.
7. Verify voltage indicator in line input assembly window.
8. Connect the instrument power cord.
9. Turn the power switch ON.

2.6.4 Power Cord

Lake Shore instrumentation includes a three-conductor power cord. Line voltage travels across the outer two conductors. The center conductor is a safety ground and connects to the instrument metal chassis when the power cord attaches to the power connector. For safety, plug the cord into an appropriate *grounded* receptacle.

2.6.5 Power Switch

The power switch turns instruments ON and OFF and is located in the line input assembly on the instrument rear. When **I** is raised on the switch, the instrument is ON; when **O** is raised, the instrument is OFF. A graphic above the switch illustrates the on and off positions. Do not remove instrument covers without first disconnecting the power cord, even if the instrument power switch is off.

CHAPTER 3

INSTALLATION

3.0   GENERAL

This chapter provides installation information for the 7300 Series VSM System. Details for mechanical assembly are provided in Paragraph 3.1. Computer connections are described in Paragraph 3.2. Console connections are described in Paragraph 3.3. Finally, electromagnet connections are described in Paragraph 3.4.

3.1   MECHANICAL ASSEMBLY

The following are the required tools:

*   Phillips Screwdriver.
*   Standard Screwdriver.
*   Level.
* $3/8$-inch Allen Wrench.
*   Open-End Wrench, $1^{1}/8$ inch.

NOTE: There are three U-Plate Mounting procedures, one for 4-inch magnets, 7-inch magnets, and 12-inch magnets. If you purchased a 7-inch or 12-inch magnet from Lake Shore, omit Step 1. For those magnet sizes, the factory drills and taps the mounting holes, and mounts the U-plate assembly for the customer.

3.1.1   U-Plate Assembly Mounting

3.1.1.1   4-Inch Electromagnet

1. The front edge of the U-plate contains the opening of the "U." See Figure 3-1. There are three holes along each side of the U-plate. Insert a $3/8$-16 x 1 inch socket head cap bolt with a $3/8$ inch flat washer through each U-plate hole and thread it into corresponding tapped hole of the saddle. Repeat for the other saddle. Tighten bolts

2. On the bottom edge of each saddle are three holes that correspond to holes on the top plate. Insert a $3/8$-16 x 1 inch socket head cap bolt with a $3/8$ inch flat washer through the bottom of each top plate hole and thread them into the corresponding tapped holes on the bottom edge of the saddles. Tighten the bolts.
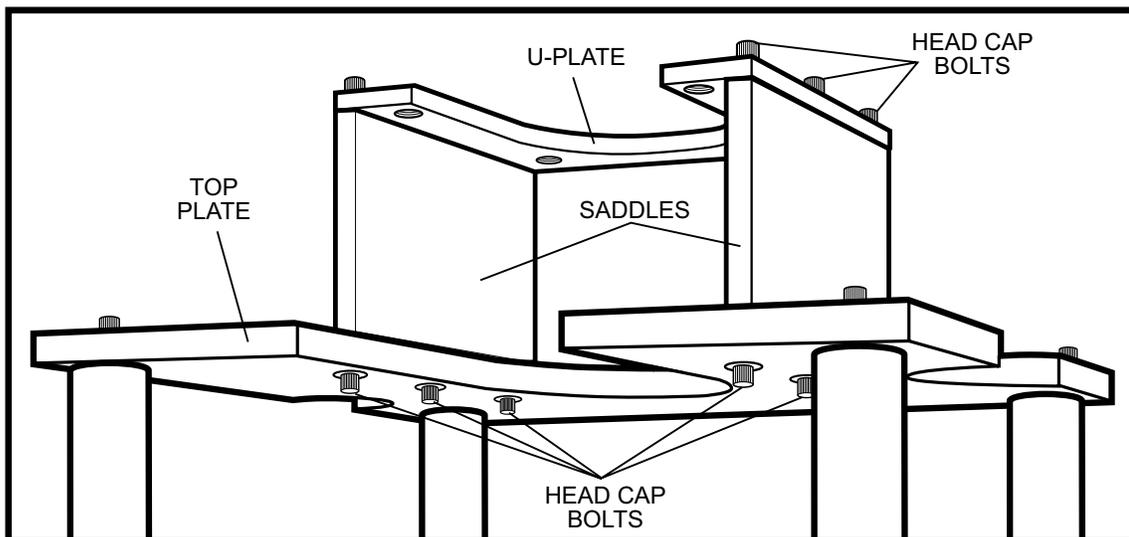
F-7300-3-1.eps

Figure 3-1. 4-inch Electromagnet U-Plate Assembly

3.1.1.2   7-Inch Electromagnet

1. The front edge of the U-plate contains the opening of the U. There are three holes along each side of the U-plate. Insert a $3/8$-16 x 1 inch socket head cap bolt with a $3/8$ inch flat washer through each hole on one side of the U-plate and thread it into the corresponding tapped hole of a saddle. Repeat for other saddle. Tighten bolts.

2. To attach bracket to saddles, insert a $3/8$-16 x 1 inch socket head cap bolt through each counter-bored bracket slot, and thread into corresponding holes on the angled side of the saddles.

3. Place assembly on magnet coils. Position it so space from edge of coil to outside of saddle is about the same on both sides.

4. Place a bubble level on the U-plate parallel to the straight sides of the U. If necessary, shim under the saddles to level the U-plate.
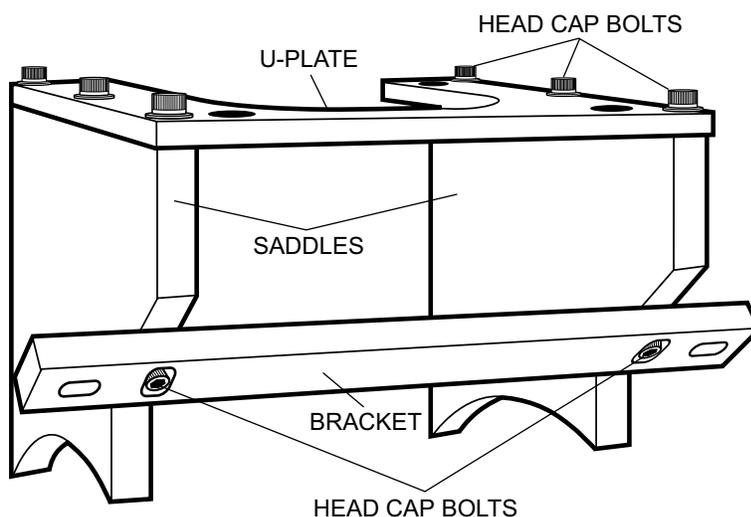
F-7300-3-2.eps

Figure 3-2. 7-inch Electromagnet U-Plate Assembly

3.1.1.3   12-Inch Electromagnet

1. The front edge of the U-plate is the edge containing the opening of the U. There are three holes along each side of the U-plate. Insert a $3/8$-16 x 1 inch socket head cap bolt with a $3/8$ inch flat washer through the hole nearest the front edge of the U-plate. Hand-thread it into the corresponding tapped hole of the saddle.

2. Align saddle edge with the U-plate edge. Verify the remaining U-plate holes align with the corresponding tapped holes in the saddle. Tighten the front bolt. Repeat for the second saddle.

3. Assemble the right-hand U-plate bracket (Figure 3-3) to U-plate by threading one $3/8$-16 x $1^1/2$ inch socket head cap bolt with a $3/8$ inch flat washer into each of the two rear U-plate holes. Push brackets forward (toward open end of "U") until the bolts reach the end of the slots. Thread bolts down until bracket just slides along slots. Repeat for left U-plate bracket.

4. Place assembly on the magnet coils. Position it so the space from the edge of the coil to the outside of the saddle is approximately the same on both sides.

5. Place a bubble level on the U-plate parallel to the straight sides of the "U." Slide saddles around the coil circumference until U-plate is level.

F-7300-3-3.eps
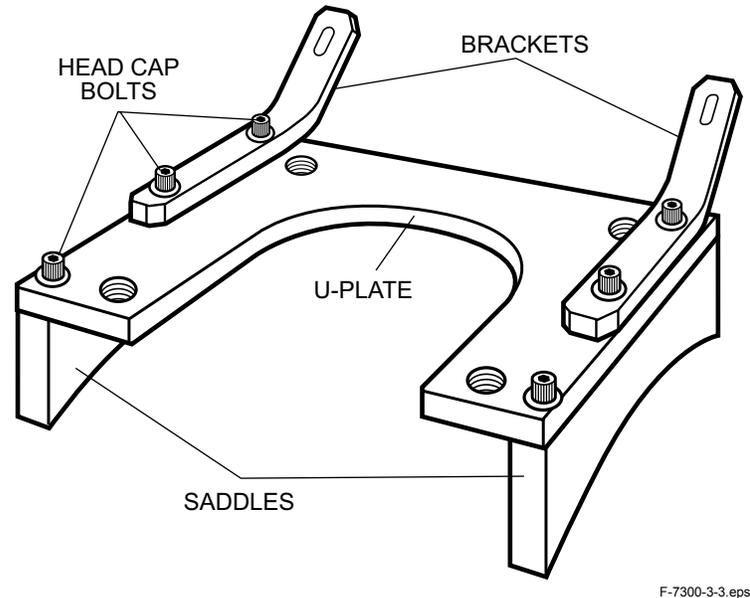
Figure 3-3. 12-inch Electromagnet U-Plate Assembly

3.1.2 Adjusting Rods

1. Install the 4 adjusting rods. Screw each rod down until its end is flush with bottom surface of U-plate.

2. Lock the adjusting rods in place temporarily by lightly tightening the $^3/_4$ -10 nuts.

3.1.3 Removing Packing Material and Mounting Magnetometer Drive

Inside the magnetometer drive, there are several pieces of protective material to remove before operation. The drive normally ships on a wood base.

1. Remove the three stainless steel rim screws (NOT the black anodized screws) and lift off the cover.

2. The mechanism under the cover is protected by a plastic bag, and sometimes, a piece of foam rubber outside the bag. Remove the foam rubber, if present, and the bag.

3. Remove the shock bumper which goes completely around the disk at the top of the assembly.

4. Remove the two rubber shock mounts at the top of the disk.

5. Before reinstalling cover, lightly grasp the copper weights to verify they have not worked loose in shipment. Do not use excessive torque. If they are loose (very unlikely), contact the factory.

6. Inspect wiring for breakage (also unlikely).

7. Replace the cover and rethread the rim screws.

8. Remove magnetometer assembly from the wooden block by removing the lag bolts in each corner.

9. Place magnetometer assembly on the adjusting rods, with the adjusting rod $^1/_4$ -20 threaded studs passing through the holes in the rubber shock mounts of the mounting plate. Secure it in place with the four $^1/_4$ -20 thumb nuts.

SHOCK MOUNTS

SHOCK
BUMPER

COPPER
WEIGHT

LAG
BOLT

LAG
BOLTS

WOOD
BASE
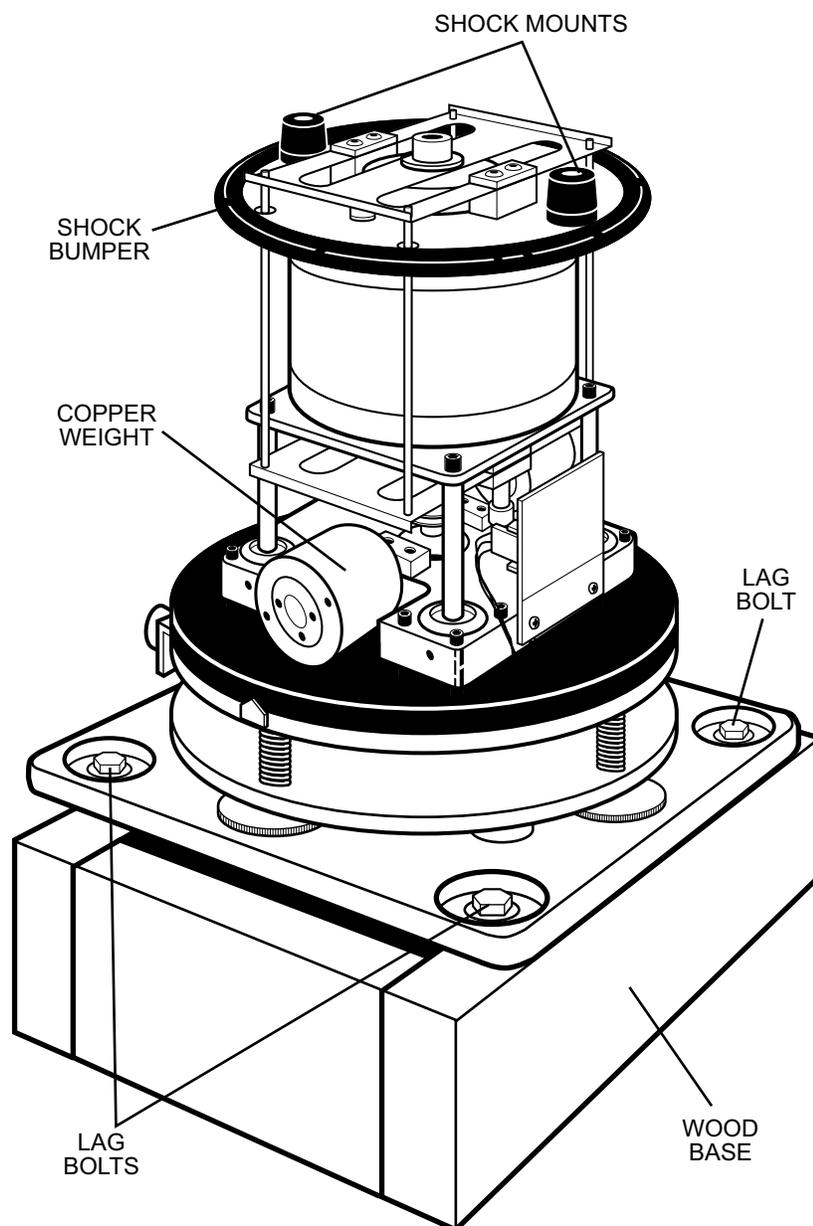
F-7300-3-4.eps

Figure 3-4. Drive With Cover Removed

3.1.4   Preliminary Position Adjustments

To independently adjust for coarse sample position along the X, Y, and Z direction, turn all four rods together. See Figure 3-5. For example, turn all four rods up or down by equal amounts to move along the Z axis, without movement along X and Y. Turn the two front rods up or down by equal amounts and the two back ones by the same amount in the opposite direction to move along the Y axis, without movement along the X or Z axis. For further information on the Vector Option, refer to Chapter 6.

Locate the X and Y sample position adjustments. These adjustments move the sample along the X and Y axes by tilting the magnetometer assembly. Their adjustment range is limited. When they are in the middle of their range, the magnetometer assembly bearing plate is parallel to the mounting plate. Set these adjustments to the middle of their range. Set the Z adjust to the middle of its range also.

The adjustments just described ensure that, when a sample is placed in the system, its position relative to the pickup coils will be nearly optimum, and well within range of the fine X, Y, and Z adjustments.

RIM
SCREWS

X
ADJUST

Y
ADJUST

THUMB
NUTS

Z
ADJUST

F-7300-3-5.eps
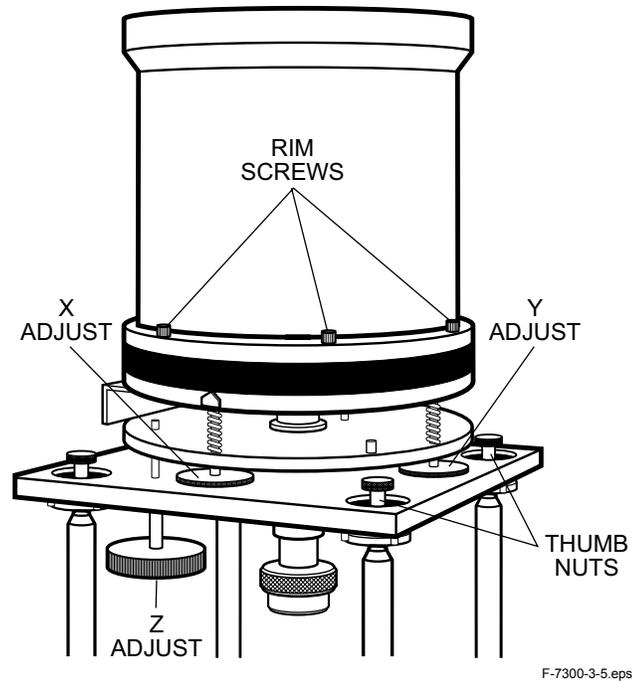
Figure 3-5. X-, Y-, and Z-Axis Adjustments

3.1.5   Mounting the Signal Pickup Coil Set

The coil type depends on magnet size. Magnets 7-inch and larger use either the 1- or 2-inch coil set (Paragraph 3.1.5.1 & and 3.1.5.2 respectively), while 4-inch magnets use only the 1-inch coil set.

3.1.5.1   Model ESC 2-Inch Coil Set and Hall Probe Holder Installation

There are two Lake Shore 2-inch Coil Sets. See Figure 3-6. The first is the standard coil set Model 730ESC described in this paragraph. The second is the Model 73032 Y Vector or Model 73033 Z Vector Coil Option (see Chapter 6). The 2-inch Coil Set installs on 7-inch or larger magnets. On variable gap magnets firmly lock the poles in position prior to coil set installation.

1.   Use 2 screws and spacers to attach the Hall Probe Holder to the right-hand coil. Position the holder so the Hall probe mounting hole mounts to the left of the coil.

NOTE: Two ¼ inch thick backing spacers mount behind the coil assemblies. These spacers increase coil set sensitivity and performance. If using the coils with the Model 73013 Cryostat or Model 73034 Oven, do not install the spacers. This leaves a gap large enough to accommodate the cryostat or oven.

2.   Pre-assemble coil set. Set top and bottom thumbscrews so coil set just fits between the magnet poles.

3.   Slide coil set between the coils. Turn top thumbscrew to place enough pressure on the coil to hold it against the poles.

4.   Use the mounting template to place the coils at the center of the poles. Exact horizontal or vertical alignment is not necessary. Calibration cancels any angular error.

5.   Tighten top and bottom thumbscrews.

6.   Remove template.

7.   Plug the 5-pin connector into the Signal Input Cable.

CAUTION: Exercise care when handling the Hall probe; its tip is very fragile. Stressing the Hall probe tip may alter its calibration. Any excess force can easily break the sensor. Broken sensors are irreparable.

Model ESC 2-Inch Coil Set and Hall Probe Holder Installation (Continued)

8. Carefully place the Hall probe into the holder. Turn Hall Probe thumbscrew to hold it in position. Always secure the Hall probe by the body; securing the tip can cause irreparable damage. To orient the probe for proper polarity, see Paragraph 3.2.5.3.

POSITIONING
TEMPLATE

TOP
THUMBSCREW

SPACER

INSERT
HALL PROBE
HERE

HALL PROBE
HOLDER

BOTTOM
THUMBSCREW

HALL PROBE
THUMBSCREW

X-COIL

F-7300-3-6.eps
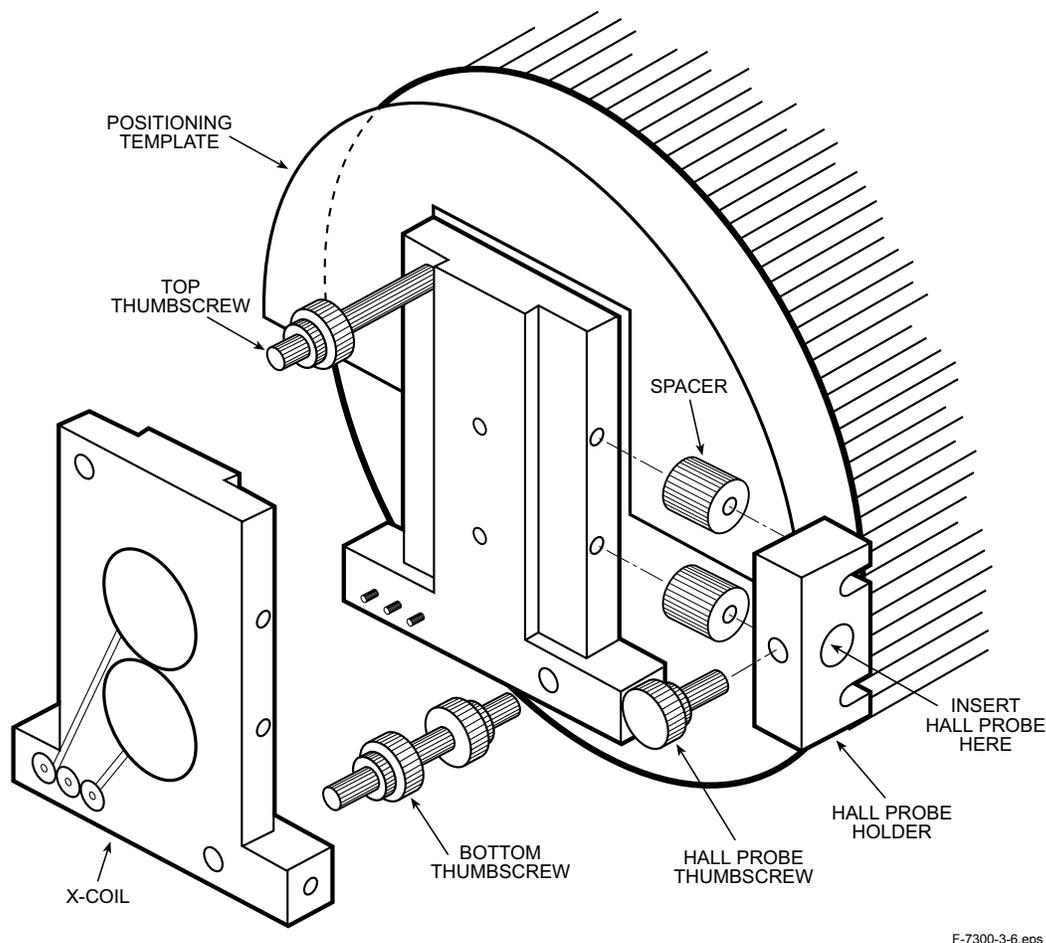
Figure 3-6. Model 730ESC 2-Inch Coil Installation

3.1.5.2   Lake Shore Model 730EMSC 1-Inch Coil Set

There are two Lake Shore 1-inch Coil Sets. The first is the standard coil set Model 730EMSC described in this paragraph. The second is the Model 73031XY Vector Coil Option (see Chapter 6). The 1-inch Coil installs on 4-inch magnets. See Figure 3-7.

1. Set the magnet pole gap to 0.9 inch for maximum field. Set the gap for 1.6 inches if using the Model 73034 High Temperature Oven. Before inserting coils, lock poles if using a variable gap magnet.
2. Pre-assemble coil set. Set top and bottom hex spacers so the coil set just fits between the magnet poles. There are two lengths of hex spacers: 0.9 and 1.6 inches. Use the proper hex spacer to provide the gap required for your application.
3. Slide coil set between the pole faces. Position the notch on the coils facing up. Position the wire connecting the two halves of the coil set towards the rear of the magnet.
4. Turn the top hex spacer to place enough pressure on the coil to hold it against the poles.
5. Center the coils in the poles. Exact horizontal or vertical alignment is not necessary. Calibration cancels any angular error.
6. Use a ¼-inch wrench to tighten the top and bottom threaded hex spacers.
7. Plug the 5-pin connector into the Signal Input Cable.
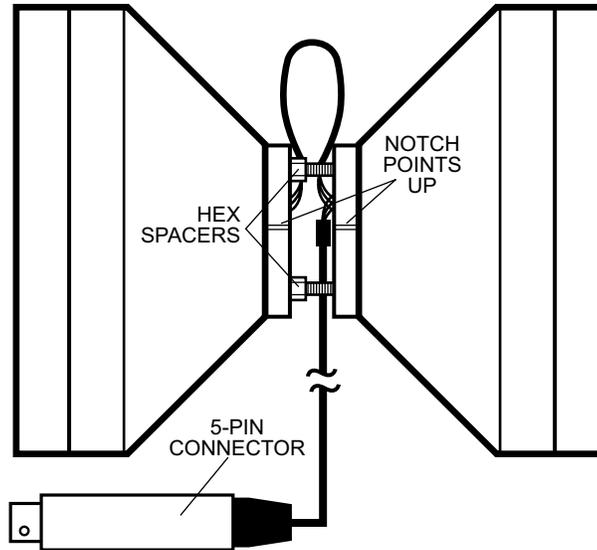
F-7300-3-7.eps

Figure 3-7. 1-Inch Coil Installation (Top View)

3.1.5.3   Hall Probe Holder Installation

1. Install Hall probe holder. Turn the 2 knurled end pieces to tighten against the coils. See Figure 3-8.

2. Tighten the front screw to lock the mounting block against the threaded rod. Do not over tighten.
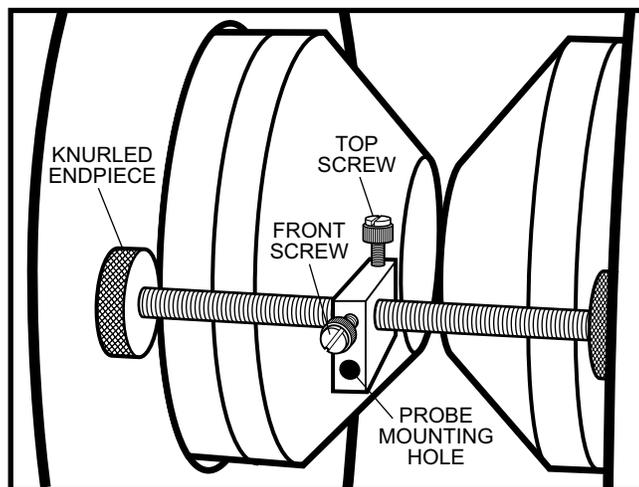
F-7300-3-8.eps

Figure 3-8. Hall Probe Holder Installation

CAUTION: Exercise care when handling the Hall probe; its tip is very fragile. Stressing the Hall probe tip may alter its calibration. Any excess force can easily break the sensor. Broken sensors are irreparable.

3. Carefully place the Hall probe into the holder. Turn top screw to hold it in position. Always secure Hall probe by the body; securing the tip can cause irreparable damage.

Hall Probe Holder Installation (Continued)

> **CAUTION: Hall probe orientation is critical to field control! If unsure of correct orientation, use the following procedure.**

1. With the magnet power supply OFF, place the Hall probe in the electromagnet noting the orientation of the Lake Shore Snowflake symbol.

2. Turn the power supply ON in MANUAL mode. Manually set a positive current of a few amps corresponding to approximately 500 Oe.

3. Read the front panel display of the Model 450 and ensure the field reading is positive. If the field reading is negative, reverse the orientation of the Hall probe.

4. When done, reduce current to zero and turn OFF power supply.

ITEM	QTY.	PART NO.	DESCRIPTION
1	1	652-162	Guide, Sample Rod, Upper
2	1	652-164	Rod, Extension
3	1	652-113A	Rod, Sample
4	1	652-163	Rod, Adapter
5	1	652-161	Guide Sample Rod, Lower
6	1	651-407	Sample Holder, Upper
7	1	651-406	Sample Holder, Bottom Cup
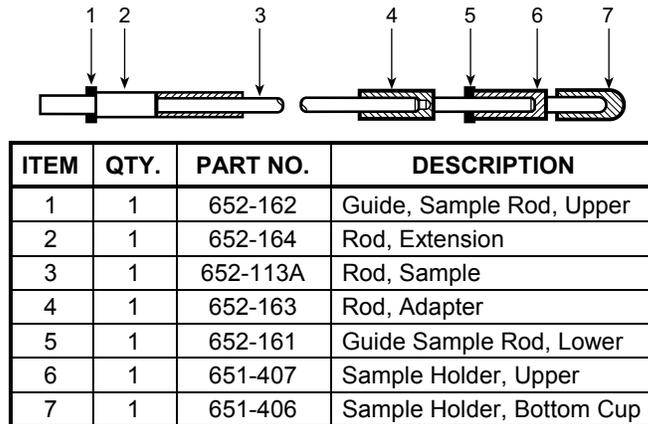
F-7300-3-9.eps

Figure 3-9. Standard Sample Holder Assembly

3.1.6 Mounting A Sample

1. Insert the nickel sample into the sample holder assembly. Thread the sample holder assembly into the bottom end of the sample rod assembly. Finger tighten. See Appendix B for details on sample holders included with the Model 7300.

NOTE: When assembling sample holder assembly parts to each other and to other system parts, do not use force when tightening threaded parts. It is a soft material, and the threads easily strip. Figure 3-9 details sample holder assembly parts.

2. Remove the cover plug. Pull it upward while gently twisting it. (See Figure 3-13).

NOTE: When replacing the cover plug, do not pinch the O-ring. Center it in the cover opening and apply gentle but firm downward pressure to the plug while slowly rotating it. To protect the O-ring and ease plug insertion and removal, lubricate the O-ring often. Do not put plug metal in contact with cover metal during plug insertion and removal; it may scratch the cover sealing surface and cause leakage at this seal.

3. Before inserting the sample rod assembly, examine the upper end with the captive knurled nut (see Figure 3-13). Note the two conical bushings with keyways cut in them. When the sample rod is in place in the mechanical assembly, the keyway in bushing #2 engages a key in the mounting. The keyway in bushing #1 enables it to pass by the key during insertion and removal.
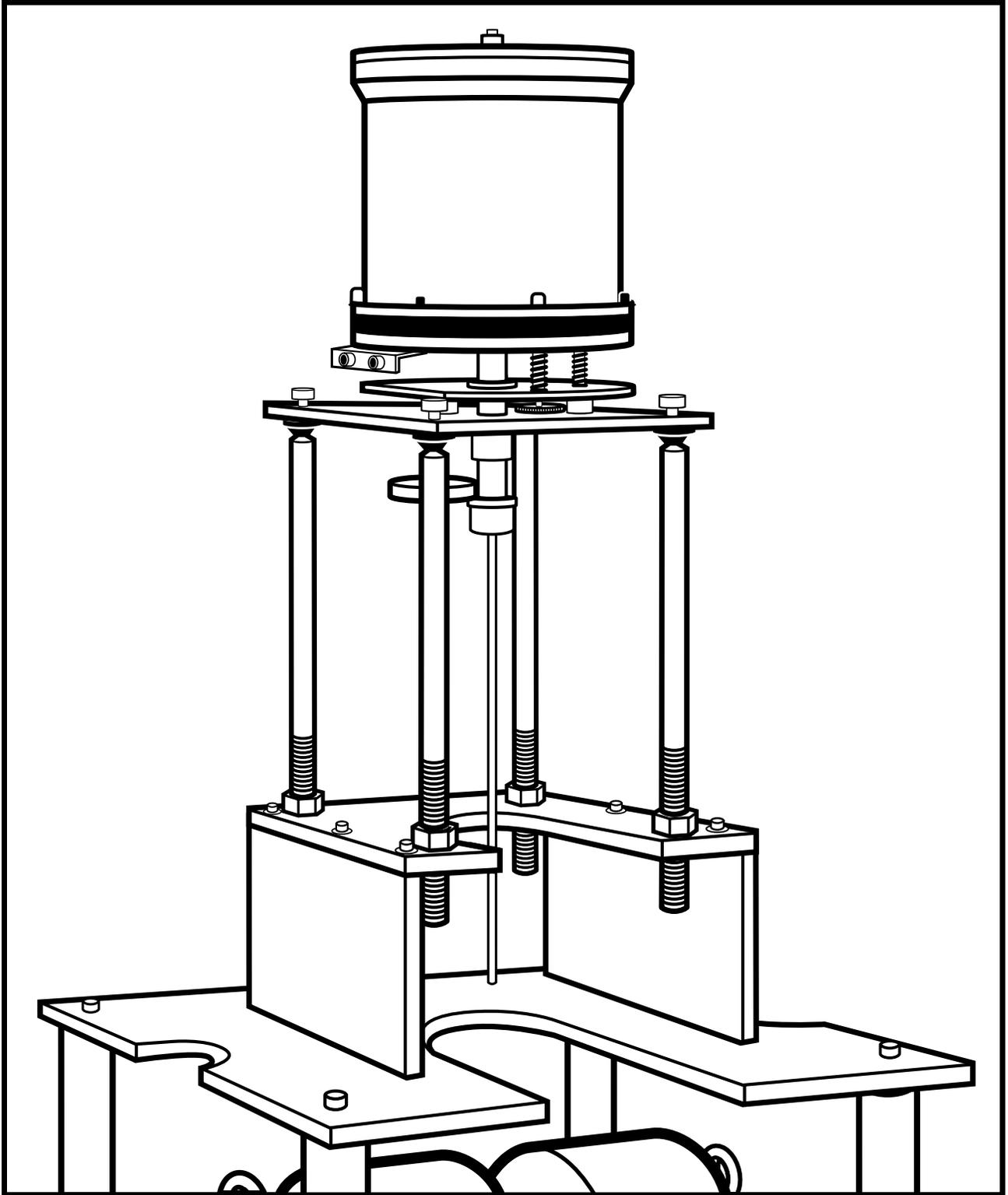
F-7300-3-10.eps

Figure 3-10. 4-Inch Electromagnet Drive Installation
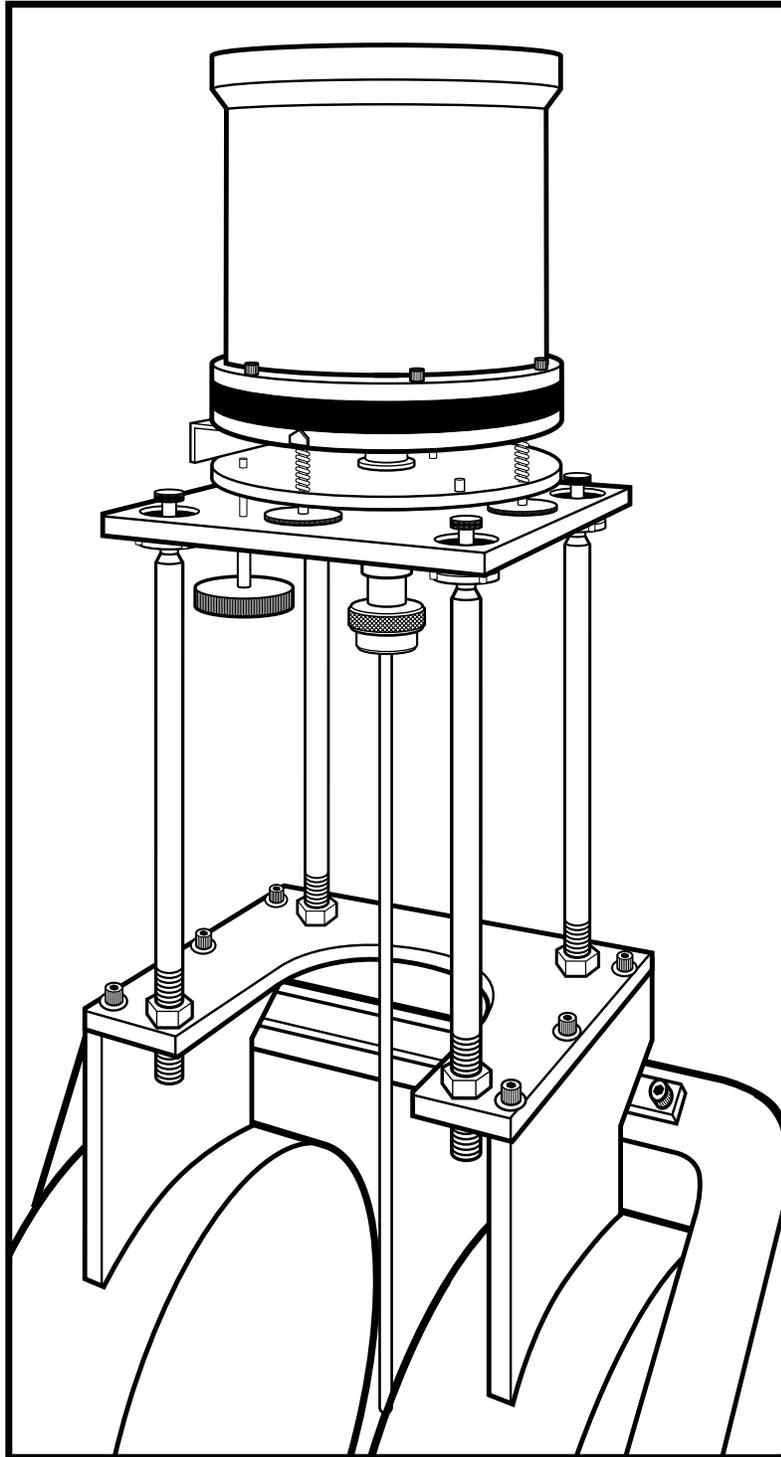
F-7300-3-11.eps

Figure 3-11. 7-Inch Electromagnet Drive Installation
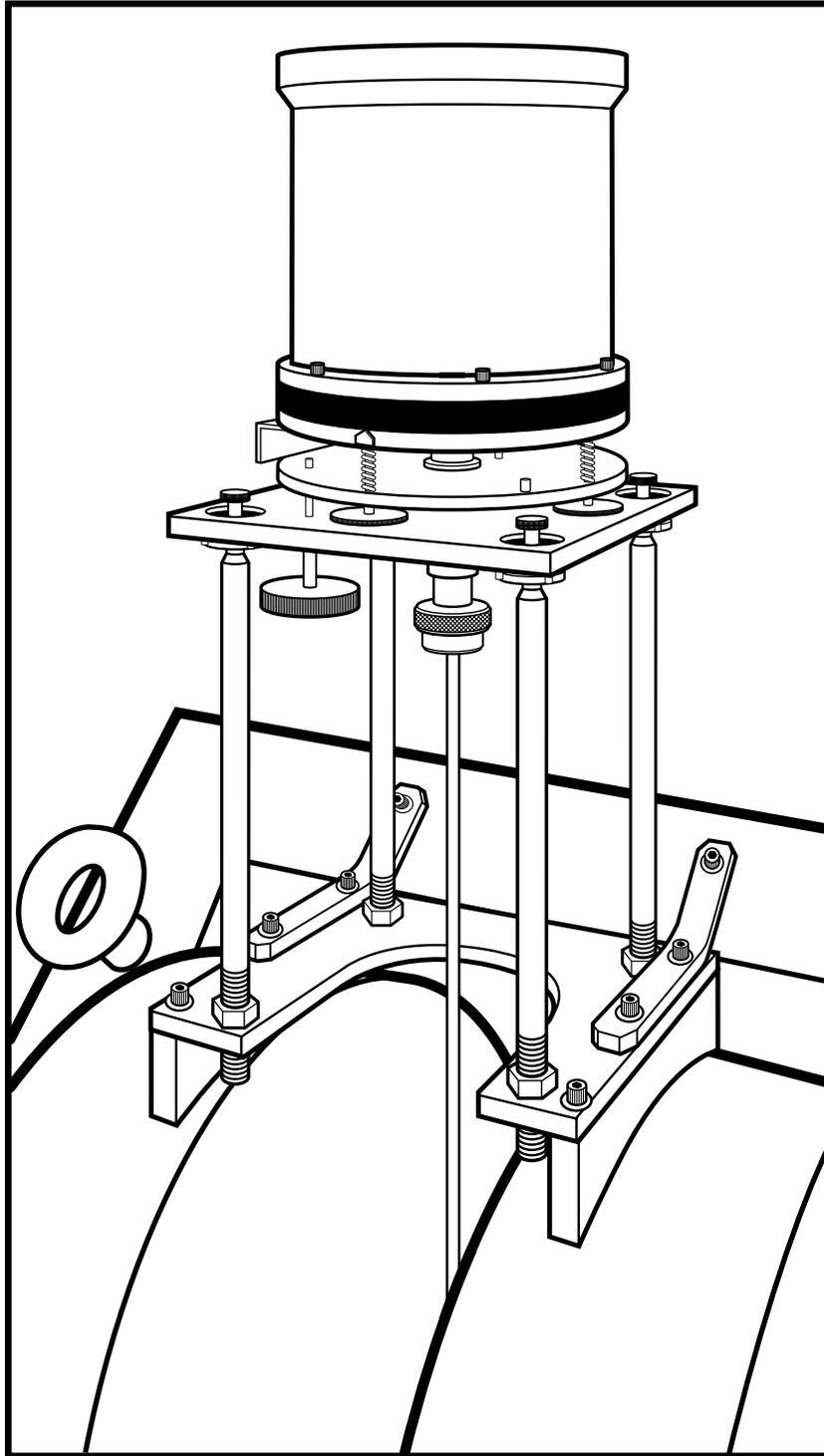
F-7300-3-12.eps

Figure 3-12. 12-Inch Electromagnet Drive Installation

Mounting A Sample (Continued)

4. Carefully guide the lower end of the sample rod into the hole through the inner mechanical assembly (visible through the hole in the top of the cover). Ease the sample rod down through the mechanical assembly until bushing #1 encounters the key. Slowly rotate the rod until the keyway aligns with the key, allowing the rod to move down. Lower the rod until the upper bushing #2 rests on the mounting. Engage the knurled nut by turning it clockwise and continue turning it until some resistance is felt. At this point, back off a half turn, and rotate the rod until the upper keyway aligns with the key, at which point it drops into place. Finger tighten the knurled nut as firmly as possible. Do not use pliers or any other tool to tighten the nut; it may damage the inner mechanical assembly.

5. Watch the end of the sample rod assembly as it approaches the pickup coils and guide it between the coils as it slides into place. When the assembly is in place, move its lower end by hand until it is centered laterally as well as fore and aft between the pickup coils. Observe the vertical position of a point on the sample holder about ¼ inch from its lower end relative to the windings of the pickup coils; this point should be centered vertically with respect to them. If it is not, move the magnetometer assembly vertically, by means of the adjusting rods, until it is. Do not disturb X and Y adjustments in the process.

6. Remove the sample rod assembly from the magnetometer. Turn the knurled nut counterclockwise until it clears its mating thread, then lift the sample rod assembly slowly upwards. After about 5 inches, bushing #1 hits the key. To free the assembly, rotate it slowly while maintaining a gentle upward force to align the key with the bushing keyway. Ease the assembly straight up until it clears the magnetometer assembly.

NOTE: Remove the sample rod assembly slowly. The bushings or the lower part of the assembly may catch on the internal structure. If this happens, relax the upward force and feel your way past the obstruction.
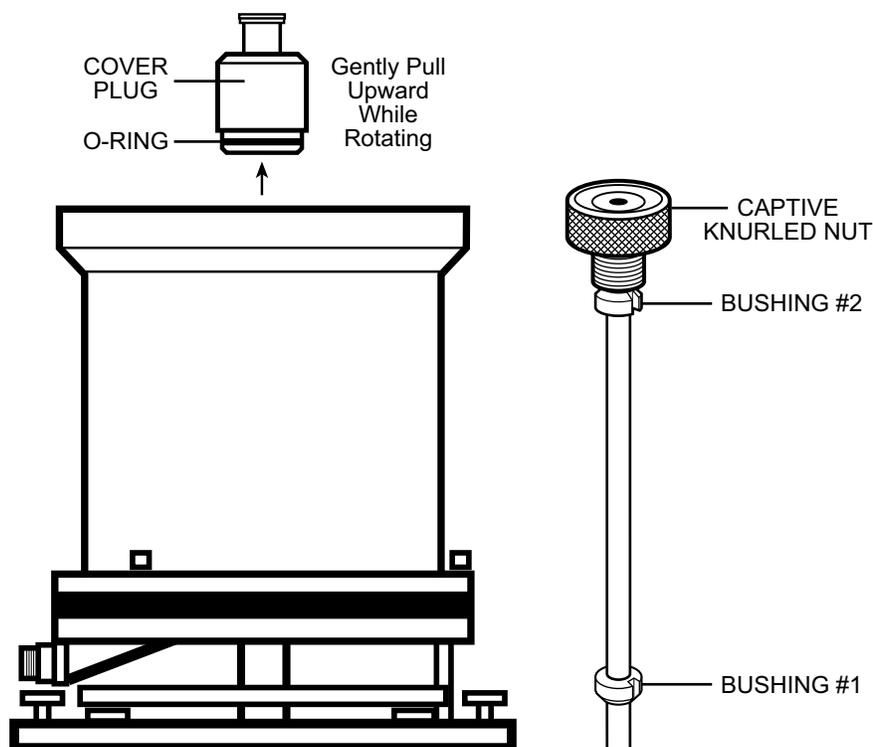
F-7300-3-13.eps

Figure 3-13. Cover Plug and Sample Rod Assembly

Mounting A Sample (Continued)

7. Replace the outer tubing assembly and check both its lateral and fore and aft centering with respect to the pickup coils. If necessary, correct the alignment by means of the X and Y adjustments. At this point it is useful to make a mark on the outer tubing assembly coinciding with the horizontal centerline of the pickup coil windings. If a line is scribed around the outer tubing assembly at this point, it may be used to make the vertical adjustments in future set-ups, making it possible to dispense with the procedure, described above, involving the sample rod assembly.

8. Tighten the four lock nuts and the four thumb nuts.

9. Mount the gaussmeter probe near the sample between the magnet pole pieces. Mount the flat side of the probe parallel with the pole faces and secure it as outlined in Paragraph 3.2.5.3.

NOTE: It is possible to install the probe so that its output polarity is reversed. See Paragraph 3.2.5.3 for a procedure to establish correct orientation.

3.1.6.1   Outer Tubing Assembly

The Outer Tubing Assembly is used in mechanically noisy environments to limit the influence of vibration on the VSM measurement. It restricts sample size to less than .28 inches ±0.0005 O.D.

1. The upper end of the outer tubing assembly has a large male thread which mates with the thread in the large knurled nut beneath the magnetometer assembly. Its upper end also has a projection with an O-ring, which seals against the inside surface of the tubing carrying the knurled nut when the assembly is in place. Never install outer tubing assembly without an O-ring; it may scratch the inside of the tubing and prevent a vacuum seal when the O-ring is in place. Always ease outer tubing assembly into place carefully to avoid damaging the O-ring. Lubricate the O-ring with a thin film of vacuum grease before installation.

2. Remove the shipping insert from the large knurled nut beneath the magnetometer assembly.

3. Thread the outer tubing assembly into the large knurled nut beneath the magnetometer head.

4. Slide the saddles laterally on the magnet coils until the lower end of the outer tubing assembly lies equidistant between the magnet pole faces.

5. Recheck the centering of the outer tubing assembly between the pole faces. Repeat adjustments until the outer tubing assembly is centered between the pole faces and the U-plate is level.
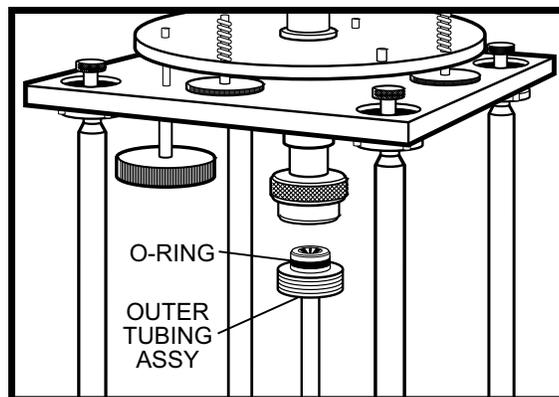
F-7300-3-14.eps

Figure 3-14. Outer Tubing Assembly

3.2   COMPUTER CONNECTIONS

The computer connects the same way regardless of system configuration.

1. Plug the mouse into the rear computer port with a mouse icon beneath it.

2. Plug the keyboard into the rear computer port with a keyboard icon beneath it.

COMPUTER CONNECTIONS **(Continued)**

3. Plug the Monitor into the rear computer port with a monitor icon beneath it.

4. Connect the IEEE-488 cable to the IEEE port on the back of the computer. Connect the other end to IEEE port of any other instrument connected in the system. Figure 3-15 shows the computer connected to the Model 735 IEEE port.

5. Plug the monitor power cord into the back of the monitor. Plug the other end into a power strip.

6. Plug the computer power cord into the back of the computer. Plug the other end into a power strip.
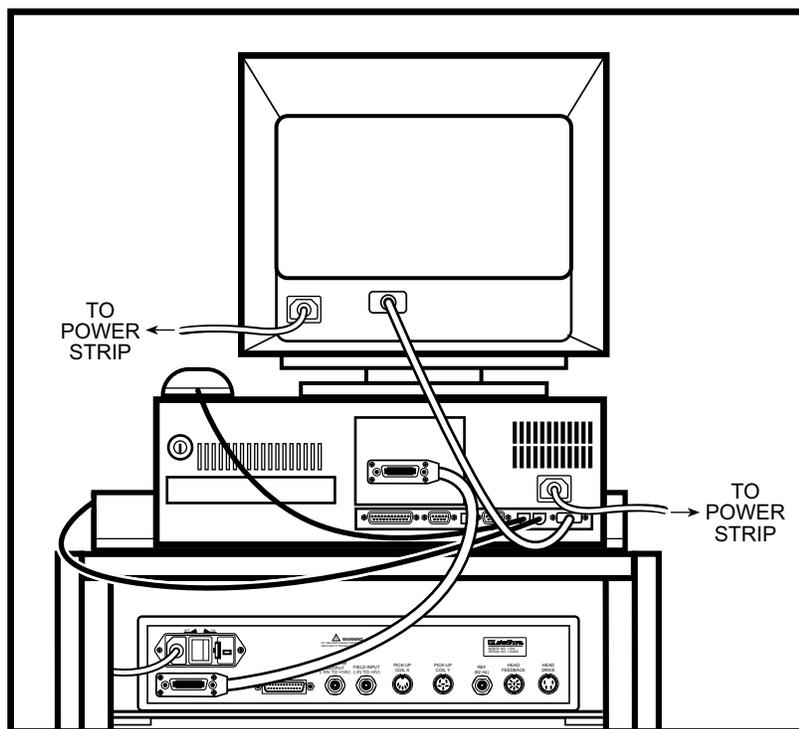
F-7300-3-15.eps

Figure 3-15. Computer Connections

3.3   CONSOLE CONNECTIONS

The factory may have already made some of the connections listed below.

1. Connect Model 735 BNC port labeled **Program Output** to Magnet Power Supply (MPS). For the Model 647 MPS, there is a BNC cable connected to rear panel connectors #15 and #11 respectively. For Models 665 and 668, connect to the BNC port labeled **Remote Reference**, see Figure 3-17.

2. Connect Model 735 IEEE-488 port to Model 450 IEEE-488 port with the IEEE-488 cable.

3. Connect the Model 735 BNC port labeled **Field Input** to the Model 450 BNC port labeled **Monitor** with 18-inch BNC cable.

4. Plug 5-pin X Coil Signal Input cable into Model 735 port labeled **Pick-Up Coil X**. If applicable, plug 6-pin Y Coil Signal Input cable into the port labeled **Pick-Up Coil Y**.

5. Plug 8-pin male connector end of the Head Feedback cable into Model 735 port labeled **Head Feedback**. Plug the other end (5-pin female) into the drive port, see Figure 3-18.

6. Plug 4-pin male connector end of the Head Drive cable into Model 735 port labeled **Head Drive**. Plug other end (3-pin female) into the drive port, see Figure 3-18.

7. Plug Hall Probe into the DB-15 port on the Model 450 rear labeled Probe Input. Carefully slide the probe into the Hall Probe Mount.

CAUTION: Hall probe orientation is critical to field control. See Paragraph 3.2.5.3.

F-7300-3-16.eps

Figure 3-16. Console Connections

Model 665 & 668 MPS Top Rear Panel

BNC Connector

Model 647 MPS Rear Panel

BNC Connector

F-7300-3-17.eps

Figure 3-17. Model 735/MPS Connection

F-7300-3-18.eps
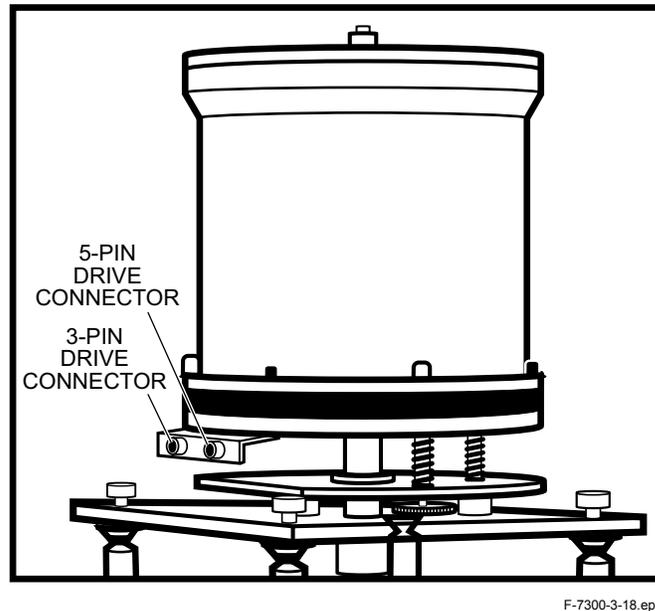
Figure 3-18. Model 735 Drive Connections

3.4   ELECTROMAGNET CONNECTIONS

The electromagnet connects to a water supply and a magnet power supply. Connections are the same for each size electromagnet. However, the magnets and their power supplies look different.

3.4.1   4-Inch Electromagnet Connections

1. Connect water supply to magnet inlet hose (Figure 3-19).
2. Connect flow switch to magnet outlet hose.
3. Connect water outlet to flow switch.
4. Connect Flow Switch wires to Model 647 Magnet Power Supply rear panel connectors #1 and #2. Red connects to #1 (+), Black connects to #2 (–).

NOTE: Power Supply will not function without a Flow Switch connected to it.

5. To the left of Power Supply connector #1 are two switches labeled **V** and **I**. Set the **V** switch to **INT**, and the **I** switch to **EXT**.
6. To the left of the V and I switches is a bank of DIP switches. Turn ON (up) switch #7 to cause a 3 sec. time delay before the MPS stops output upon recognizing no water flow through the magnet.
7. Connect power cables to Model 647 Magnet Power Supply power terminals. Red connects to Positive (+), Black connects to Negative (–).

NOTE: Figure 3-19 shows a Model CV or HV 4-inch electromagnet with power terminals wired in parallel. Model CS 4-inch electromagnet power terminals wire in serial.

8. Plug X Coil Set cable into Model 735 X Coil Signal Input Cable. If applicable, plug the Y Coil Set cable into the Model 735 Y Coil Signal Input Cable.
9. Plug the MPS power cord into the back of the unit. Plug the other end into an AC power outlet.

3.4.2   7-Inch and 12-Inch Electromagnet Connections

1. Connect water supply to upper magnet inlet hoses (Figures 3-20 and 3-21).
2. Connect water outlet to Flow Switch.
4. Plug Flow Switch into Model 665/668 Magnet Power Supply rear panel port labeled **Remote Control/Status**. The Power Supply will not function without a Flow Switch connected to it.
5. Connect power cables to Model 665/668 Magnet Power Supply power terminals. Red connects to Positive (+), Black connects to Negative (–).
6. Plug X Coil Set cable into Model 735 X Coil Signal Input Cable. If applicable, plug the Y Coil Set cable into the Model 735 Y Coil Signal Input Cable.
7. Plug the MPS power cord into the back of the unit. Plug the other end into an AC power outlet.
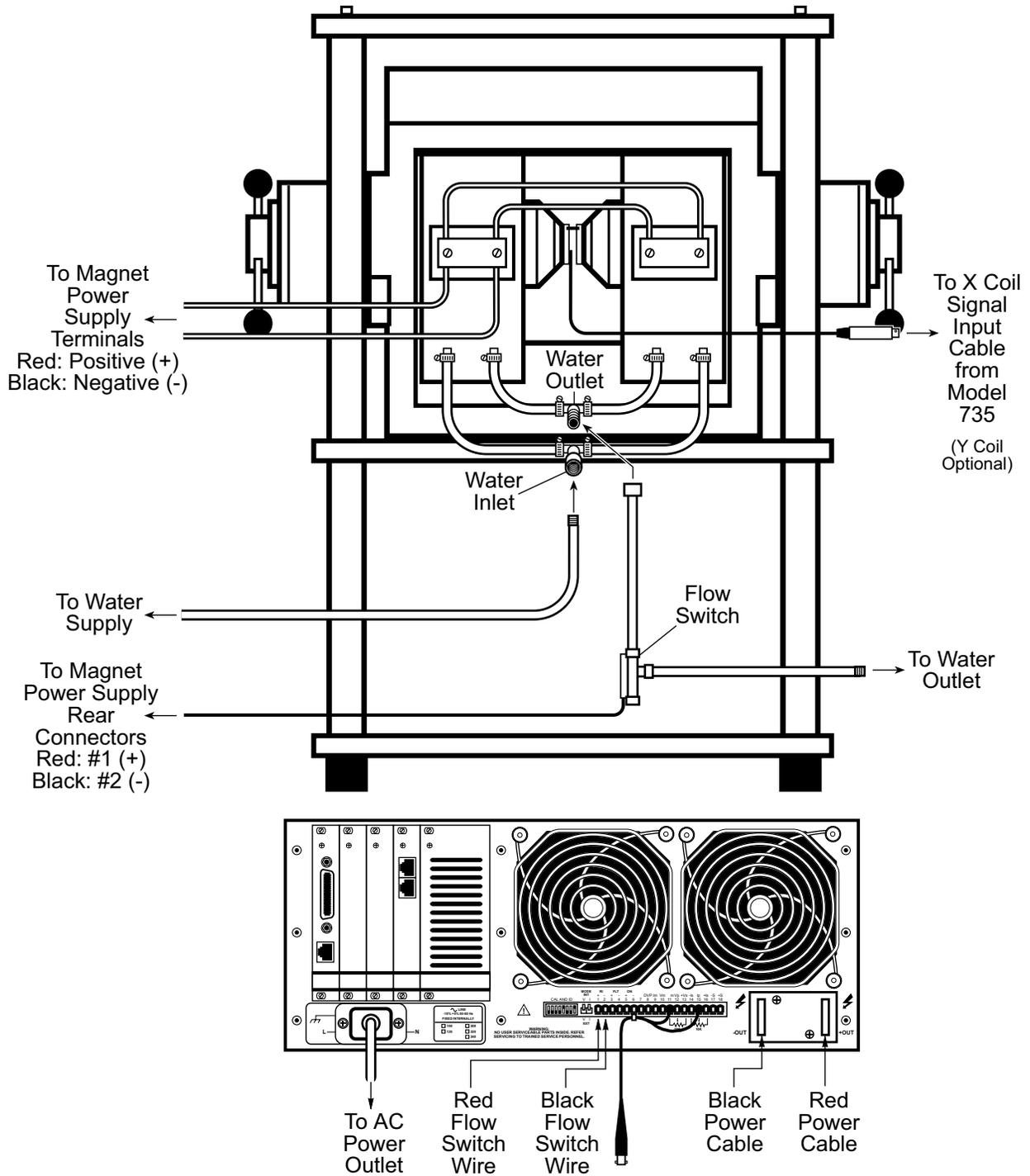
F-7300-3-19.eps

Figure 3-19. 4-Inch Electromagnet Connections

NOTE: Model CV or HV 4-inch electromagnet power terminals wire in parallel. Model CS 4-inch electromagnet power terminals wire in serial.
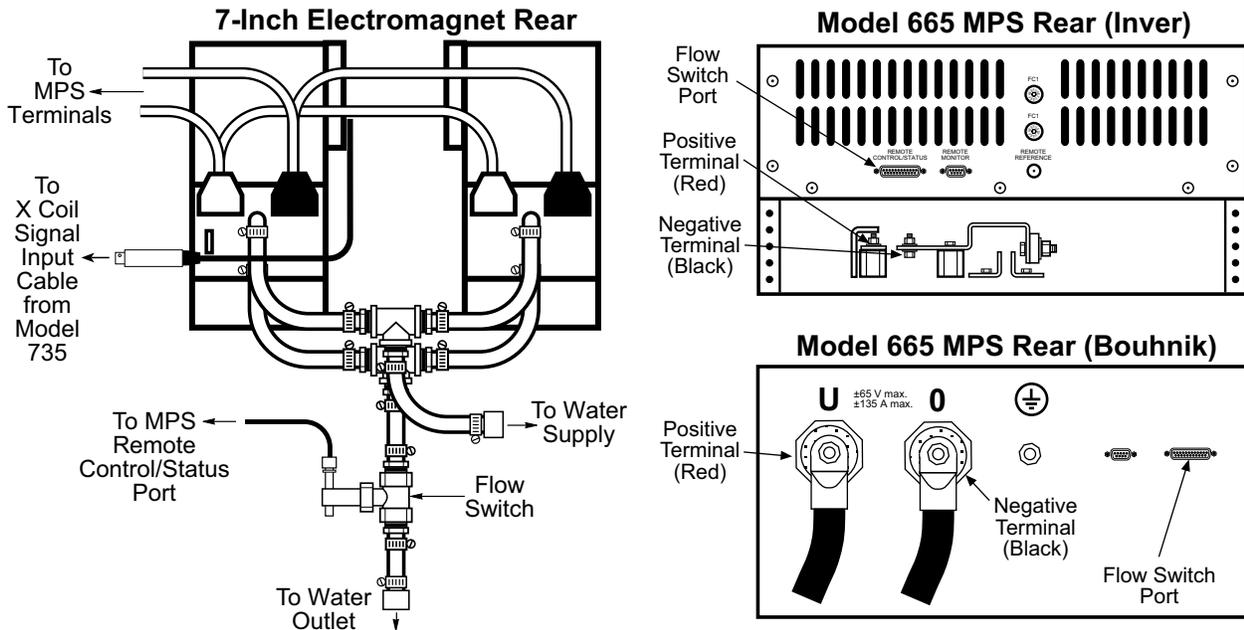
Figure 3-20. 7-Inch Electromagnet Connections
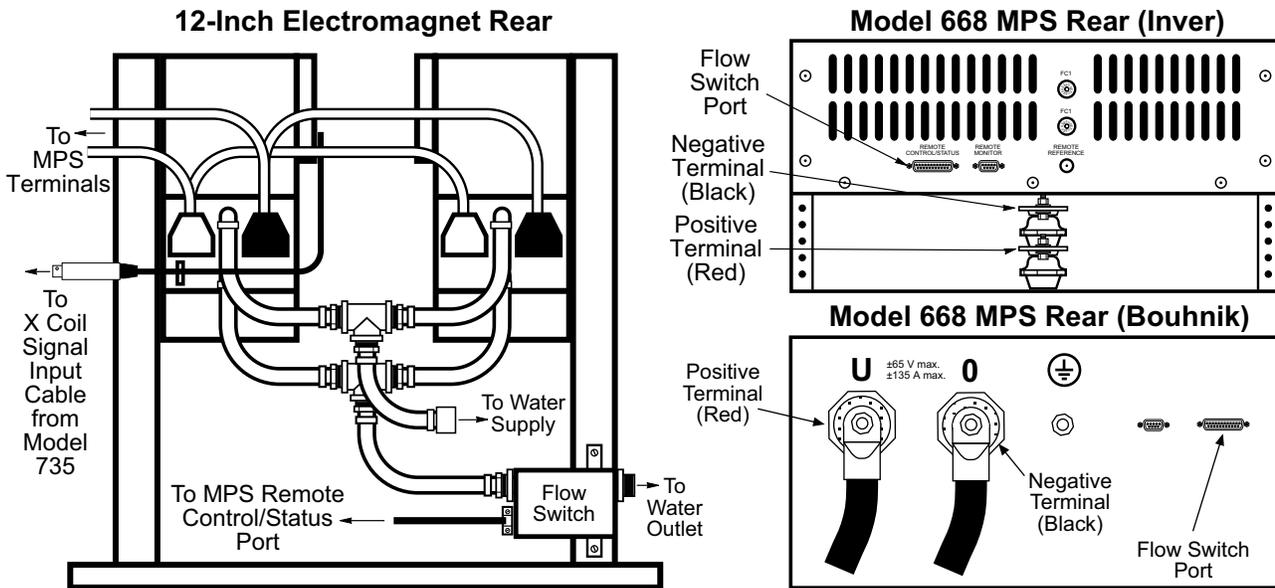
Figure 3-21. 12-Inch Electromagnet Connections

CHAPTER 4

CALIBRATION

4.0   GENERAL

This chapter provides calibration information for the 7300 Series VSM System. A description and theory are provided in Paragraph 4.1. Calibration is detailed in Paragraph 4.2. Finally, magnet and power supply selection are described in Paragraph 4.3.

4.1   DESCRIPTION AND THEORY

When a sample material is placed in a uniform magnetic field, a dipole moment proportional to the product of the sample susceptibility times the applied field is induced in the sample. A sample undergoing sinusoidal motion as well induces an electrical signal in suitably located stationary pick-up coils. This signal, which is at the vibration frequency, is proportional to the magnetic moment, vibration amplitude, and vibration frequency.

The material under study is contained in a sample holder, which is centered in the region between the pole pieces of a laboratory magnet (see Figure 2-1). A slender vertical sample rod connects the sample holder with a transducer assembly located above the magnet, which supports the transducer assembly with sturdy, adjustable support rods.

The transducer converts a sinusoidal AC drive signal, provided by a circuit located in the console, into a sinusoidal vertical vibration of the sample rod, and the sample is thus made to undergo a sinusoidal motion in a uniform magnetic field. Coils mounted on the pole pieces of the magnet pick up the signal resulting from the sample motion.

This AC signal at the vibration frequency is proportional to the magnitude of the moment induced in the sample. However, it is also proportional to the vibration amplitude and frequency. A servo system maintains constancy in the drive amplitude and frequency so that the output accurately tracks the moment level without degradation due to variations in the amplitude and frequency of vibration.

This technique depends on being able to use a vibrating capacitor located beneath the transducer to generate an AC control signal that varies solely with the vibration amplitude and frequency. The signal, which is at the vibration frequency, is fed back to the Oscillator where it is compared with the drive signal so as to maintain constant drive output. It is also phase adjusted and routed to the signal demodulator where it functions as the reference drive signal.

The signal from the sample is developed in the pickup coils, then buffered, amplified, and applied to the demodulator. There it is synchronously demodulated with respect to the reference signal derived from the moving capacitor assembly. The resulting DC output is an analog of the moment magnitude alone, uninfluenced by vibration amplitude changes and frequency drift.

4.2   CALIBRATION

The moment calibration of Vibrating Sample Magnetometers is traditionally performed with a nickel standard at an applied field above the saturation field of nickel, nominally 5000 Oe. Lake Shore supplies a nickel cylinder of 99.99% purity, an aspect ratio of nearly 1:1 and a mass of approximately 0.02 grams. These samples are etched and weighed prior to measuring their saturation magnetization. The saturation magnetization of the nickel samples are measured with a VSM calibrated with a NIST (NBS) nickel standard. Typical magnetization data is recorded between 5000 Oe and 10000 Oe.

Both Lake Shore VSMs, Model 7300 and Model 735 must pass a range linearity test; that is, both must meet the range to range and full range linearity specifications. Therefore, calibration on a single range ensures the overall calibration of the electronics.

CALIBRATION (Continued)

Lake Shore performs moment offset calibrations. Additional moment offset adjustments should not be required, but Lake Shore allows for software offset corrections to the moment readings.

The Model 735 operates with a Model 450 gaussmeter to accurately measure the applied magnetic field at the sample and to control the magnetic field. Lake Shore calibrates both the gain and the offset of the measurement\control loop to specification accuracy during final assembly and testing.

4.2.1 Moment Calibration for the Model 735

The Model 735 moment calibration is a software calibration. After positioning the nickel sample in a saturating field (H > 3500 Oe), the user initiates the software calibration procedure via the VSM software menu item. The VSM System Software Manual details how the software calibration functions and how to perform this procedure.

4.2.2 Moment Offset Calibration for the Model 735

Electronic and embedded software adjustments in the VSM controller eliminate 99.9% of the Model 735 moment offset calibrations. For the Model 735, Lake Shore moment offset adjustments are made on a per range basis resulting in a final offset typically less than 0.01% of the full scale of the range. Lake Shore included additional software adjustments for moment offset calibration; however, there is no significant advantage to this adjustment in a VSM system operating under normal conditions. The user initiates the software calibration procedure via the VSM software menu item. The VSM System Software Manual details how the software calibration functions and how to perform this procedure.

4.2.3 Gaussmeter Offset Calibration for the Model 735 and Model 450

The measurement\control loop of the applied magnetic field consists of integrating a Model 735 and a Model 450 along with the magnet power supply, magnet, and hall device as the field sensor (see Figure 4.1).

The measurement\control loop begins with the hall device converting magnetic flux into voltage, $V_{hall}(H_{applied})$. The Model 450 converts this voltage back to a field for display; however, the Lake Shore VSM does not use the field values displayed on the Model 450. The Model 450 rear panel has an analog output labeled Monitor Out (see the Model 450 hardware manual for details). The Monitor Out signal is proportional to the applied magnetic field and the **range** of the Model 450; this voltage can be represented by $V_{Monitor}(H_{applied}, Range_{450})$. Figure 4.2 shows the additional Model 450 electronics for this signal. The amplifier supplying the $V_{Monitor}(H_{applied}, Range_{450})$ typically has a gain (G) of 1 and offset of 0.

The Model 450 sends the field monitor voltage to the Model 735 which reads it and uses it to measure and control magnet power supply current. In addition to any offset in the amplifier, offsets may exist in the input amplifier of the Model 735 Field Input circuit, and from the usual sources between the two instruments, preventing 100% effective individual instrument calibration. The gain of these circuits can be measured accurately and the gain of each electronic component known and stored during calibration. Once the two electronic components are integrated, the offset of the overall circuit can be measured accurately.

The gain and offset of the circuit described above depends upon the Model 450 range. There are four ranges and an offset, gain pair measured and stored for each. These parameters are stored in the Model 450 gaussmeter EPROM, and read from the Model 450 EPROM each time the VSM software starts the IDEAS 450 software driver. The calibration parameters are sent to the Model 735 when the IDEAS 735 program starts. The current range of the Model 450 is also sent to the Model 735. This range synchronization is very important to maintain and the VSM, IDEAS 735 and IDEAS 450 software accomplishes most of the coordination. The user initiates Gaussmeter Offsets Calibration via the VSM software menu item. The details of how the software calibration functions and how to perform this procedure are in the VSM Software Manual.

The Monitor Output signal does not include the field compensation information for the hall device. This information is also read from the Model 450 Gaussmeter and used by the IDEAS 735 driver to correct the final reported field. See the 450 User's Manual for more details concerning field compensation.
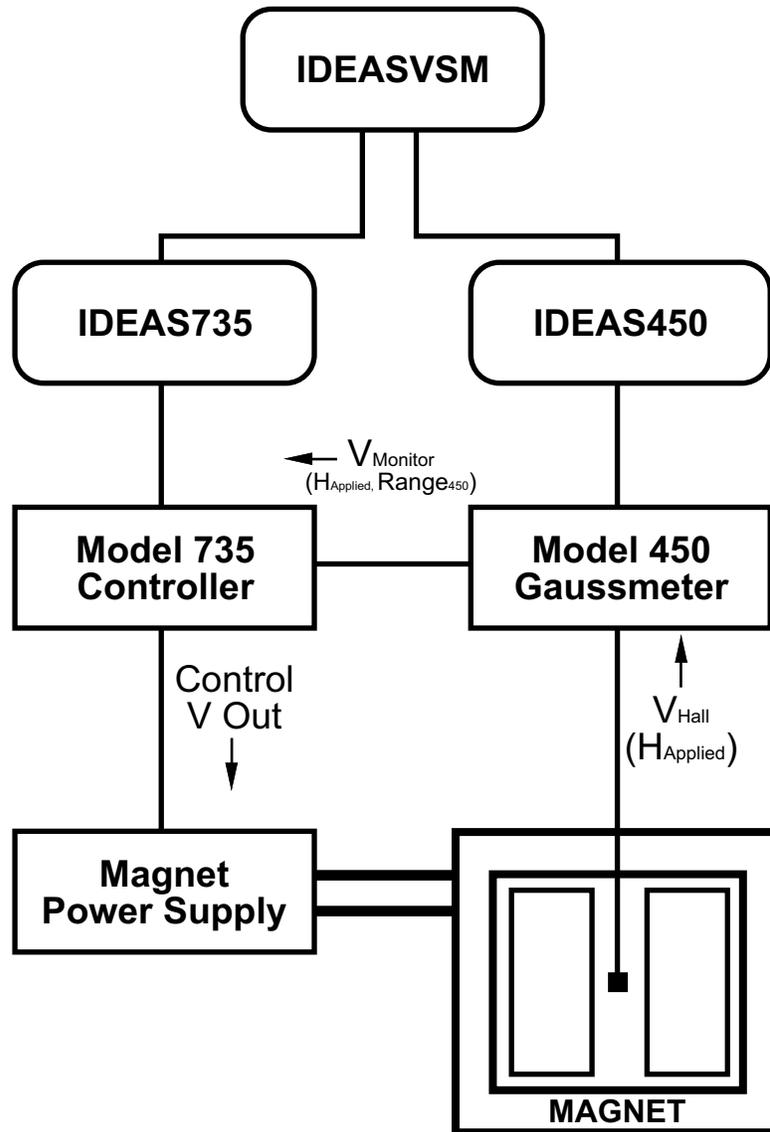
F-7300-4-1.eps

Figure 4-1. Block Diagram of VSM Field Measurement\Control Loop
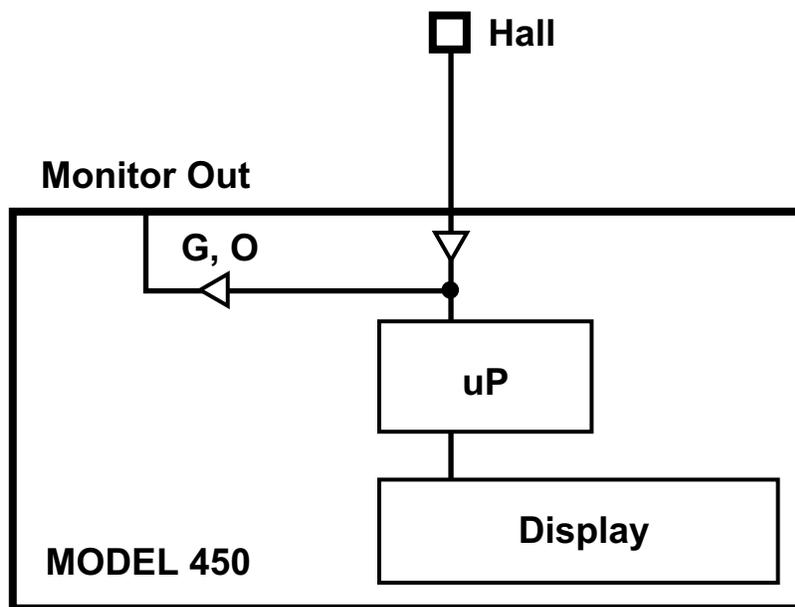
Figure 4-2. Model 450 Monitor Out Signal

4.3 MAGNET AND POWER SUPPLY SELECTION

Other than Manual, the Model 7300 VSM uses one of two modes to sweep the field:

Field Mode: This is the most accurate mode. The magnetic field strength is controlled by a feedback system consisting of the power supply, magnet, Model 450 gaussmeter, and Model 735 control unit.

NOTE: Use of only Lake Shore approved magnets and power supplies is **strongly** recommended in Field Mode. The control loop is not characterized for other magnets or power supplies. Other magnets or power supplies may set up a high-power system oscillation, damaging the magnet or other components.

Current Mode: In this mode, the feedback loop is not closed. The Model 735 controls power supply current output, and the gaussmeter simply monitors the applied field. As a result, the actual field strength may differ from the requested field. However, the actual field at which each reading occurs is still accurately known.

In Current Mode, it is possible to use other magnet/power supply combinations as long as they meet the following criteria:

1. The power supply must be designed to drive the magnet. Magnet resistance is critical. If unsure of this specification, measure it with an ohmmeter. When using an ohmmeter:

   a. Disconnect the magnet from the power supply.

   b. Make a four-wire resistance measurement; you may need to resolve the difference between $\frac{1}{2}$ Ω and $\frac{1}{4}$ Ω. Do not depend on a standard volt-ohm meter.

   NOTE: The resistance of a magnet equals the total resistance of both coils.

2. The power supply must be bipolar and have the capability of being remotely controlled by the Model 735. The Model 735 provides ±10 VDC as its analog control output signal.

3. The magnet must have a 2-inch (5 cm) air gap between the pole faces to accommodate pickup coils, sample rod, and either a high-temperature oven or cryostat. If only room-temperature measurements are to be performed, a 1½-inch (3.8-cm) air gap is acceptable.

Of course, the magnet must also accommodate the transducer (vibration head). In most cases, Lake Shore can provide the necessary hardware. When in doubt about mechanical compatibility, contact Lake Shore.

CHAPTER 5

REMOTE OPERATION

5.0   GENERAL

This chapter covers the VSM System Remote Operation. Communication with other Lake Shore instruments is covered in their respective User's Manuals. IEEE-488 Interface communication with the Model 735 is detailed in Paragraph 5.1. The command set is provided in Paragraph 5.2.

5.1   IEEE-488 INTERFACE

The IEEE-488 Interface is an instrumentation bus with hardware and programming standards that simplify instrument interfacing. The Model 735 IEEE-488 Interface complies with most of the IEEE-488.2-1987 standard and incorporates its functional, electrical, and mechanical specifications unless otherwise specified.

5.1.1   Interface Capabilities

- **SH1:** Source handshake capability
- **RL1:** Complete remote/local capability
- **DC1:** Full device clear capability
- **DT0:** No device trigger capability
- **C0:** No system controller capability
- **T5:** Basic TALKER, serial poll capability, talk only, unaddressed to talk if addressed to listen
- **L4:** Basic LISTENER, unaddressed to listen if addressed to talk
- **SR0:** Service request capability
- **AH1:** Acceptor handshake capability
- **PP0:** No parallel poll capability
- **E1:** Open collector electronics

5.1.2   Common Commands

Common Commands are addressed commands which create commonalty between instruments on the bus. All instruments that comply with the IEEE-488 1987 standard share these commands and their format. Common commands all begin with an asterisk. Common query commands end with a question mark (?). The only common command supported by the Model 735 is *IDN?.

5.1.3   Interface Settings

The IEEE-488 interface on the Model 735 is somewhat limited in flexibility because it is intended for use as part of a larger system. It is recommended to use the default interface settings below whenever possible.

Model 735 Default Interface Settings:

Address	9
Terminators	CrLf
EOI	On
Mode	Remote

To operate two Model 735's on the bus at one time, change the address of one with the ADDR command. Record the new address; the instrument will not respond at the default address after a change. The new address will be kept when instrument power is turned off. Local operation of the instrument is not possible so the mode is defined as remote.

5.1.4   Interface LED

There is and Interface LED on the Model 735 front panel. Its normal state is off, but it turns on momentarily each time an interface command is sent to the instrument. If the instrument performs a long task such as calibration, the LED remains on until the task is complete. The interface should not be used during this time except for the BUSY? Query that informs the user when the task is complete.

5.2 IEEE-488 COMMAND SUMMARY

There are several types of commands: Common in Paragraph 5.2.2, Interface in Paragraph 5.2.3, Reading Setup and Reading in Paragraph 5.2.4, Field Setting in Paragraph 5.2.5, Auxiliary in Paragraph 5.2.6, Miscellaneous in Paragraph 5.2.7, and Calibration in Paragraph 5.2.8.

5.2.1 Command List Structure

Command Name / Brief Description of Function

RANGE? — Manual Reading Query

Syntax of what user must input. → **Input:** `RANGE?`

Information returned in response to the query. → **Returned:** `0`, `1`, `2`, or `3`

Explanation and definition of returned data. → **Remarks:** Used to query the unit for manual range. Range is dependent on type of probe installed. There are four ranges possible for each probe, where 0 is the highest and 3 is the lowest range.

5.2.2   Common Commands

*IDN?   Identification query.
  Sent: ***IDN?**
  Returned: LSCI,MODEL 735,XXXXXX,MMDDYY[term]
  Remarks: Returns manufacturer, model number, six-digit instrument serial number, and firmware date.

5.2.3   Interface Commands

ADDR   Set instrument IEEE-488 address.
  Sent: **ADDR XX[term]**
  Returned: Nothing. Address return requires **ADDR?**.
  Remarks: Two ASCII digits (**XX**) set the IEEE-488 address between **01** and **31**. Default **09**.

ADDR?   Query instrument IEEE-488 address.
  Sent: **ADDR?[term]**
  Returned: XX[term]
  Remarks: Returns two ASCII digits (**XX**) of the IEEE-488 address between **01** and **31**. Default **09**.

END   Set instrument IEEE-488 EOI status.
  Sent: **END X[term]**
  Returned: Nothing. END return requires **END?**.
  Remarks: One ASCII digit (**X**) sets IEEE-488 EOI status: **0** = EOI enabled (EOI set with last data byte in transmission), **1** = EOI disabled (No EOI is set with last data byte in transmission). Default **0**.

END?   Query instrument IEEE-488 EOI setting.
  Sent: **END?[term]**
  Returned: X[term]
  Remarks: Returns one ASCII digit (**X**) indicating IEEE-488 EOI setting: **0** = EOI enabled (EOI set with last data byte in transmission), **1** = EOI disabled (No EOI is set with last data byte in transmission). Default **0**.

TERM   Set instrument IEEE-488 terminators.
  Sent: **TERM X[term]**
  Returned: Nothing. Terminator setting return requires **TERM?**.
  Remarks: One ASCII digit (**X**) sets instrument terminators: **0** = <CR> <LF>, **1** = <LF> <CR>, **2** = <LF>, and **3** = None. EOI must be set active with the END command. Default **0**.

TERM?   Query instrument IEEE-488 terminator setting.
  Sent: **TERM?[term]**
  Returned: X[term]
  Remarks: Returns one ASCII digit (**X**) IEEE-488 terminator setting: **0** = <CR> <LF>, **1** = <LF> <CR>, **2** = <LF>, and **3** = None. Default **0**.

5.2.4 Reading Setup and Reading Commands

ALLR?   Query all available reading data in the 100 point data buffer.

    Sent: **ALLR?[term]**

    Returned: NNN,XXXXXXXX,YYYYYYYY,FFFFFFFF,TTTTTTTT….[term].

    Remarks: **NNN** = three ASCII digits of an integer number of readings that follow. The X, Y and F fields are three eight-character ASCII representations of a binary floating point number: **X field** = voltage present at Channel X input, **Y field** = voltage present at Channel Y input, **F field** = voltage present at Field input. The T field is an eight digit decimal integer representing time in 10ms increments from initial instrument power up until the reading was taken.

                 All NNN readings are sent at the same time in order of oldest to newest. Data is taken and time stamped every period specified in the READP command from 100 ms to 1000mS. If NNN is 100, assume some readings were lost.

EMUR   Set range for either X or Y EMU input.

    Sent: **EMUR *X, YY*[term]**

    Returned: Nothing. Range setting return requires **EMUR?**.

    Remarks: One ASCII digit (**X**) sets desired channel: **0** = Channel X, **1** = Channel Y. Two ASCII digits, (**YY**) set the range from 00 to 3F hex (Default **00**):

00	= 2 V
01	= 200 mV
02	= 20 mV
03	= 2 mV
07	= 200 uV
0B	= 20 uV
1B	= 2 uV
2B	= 200 nV

EMUR?   Query range setting for either X or Y EMU input.

    Sent: **EMUR?*X*[term]**

    Returned: *YY*[term].

    Remarks: One ASCII digit (**X**) indicates desired channel: **0** = Channel X, **1** = Channel Y. Returns two ASCII digits (**YY**) indicating range from 00 to 3F hex (Default 00):

00	= 2 V
01	= 200 mV
02	= 20 mV
03	= 2 mV
07	= 200 uV
0B	= 20 uV
1B	= 2 uV
2B	= 200 nV

EMUTC   Set filter time constant for both X and Y EMU inputs.

    Sent: **EMUTC X[term]**

    Returned: Nothing. Time constant return requires **EMUTC?**.

    Remarks: One ASCII digit (**X**) sets filter time constant: **0** = 100 ms, **1** = 300 ms, **2** = 1 s, **3** = 3 s, **4** = 10 s. Default **0**.

EMUTC?   Query filter time constant setting for X and Y EMU inputs.

    Sent: **EMUTC?[term]**

    Returned: X[term].

    Remarks: Returns one ASCII digit (**X**) indicating filter time constant: **0** = 100 ms, **1** = 300 ms, **2** = 1 s, **3** = 3 s, **4** = 10 s. Default **0**. Default **0**.

HEAD   Set head drive on or off.

    Sent: **HEAD X[term]**
    Returned: Nothing. Head setting return requires **HEAD?**.
    Remarks: One ASCII digit (**X**) sets head drive on or off: **0** = OFF, **1** = ON. Default **0**.

HEAD?   Query head drive setting.

    Sent: **HEAD?[term]**
    Returned: X[term].
    Remarks: Returns one ASCII digit (**X**) indicating head drive status: **0** = OFF, **1** = ON. Default **0**.

NEWR?   Query the newest reading data in the 100 point data buffer.

    Sent: **NEWR?###[term]**
    Returned: NNN,XXXXXXXX,YYYYYYYY,FFFFFFFF,TTTTTTTT….[term].
    Remarks: **###** = number of data sets to be sent between 1 and 100. **NNN** = three ASCII digits of an integer number of readings that follow. The X, Y and F fields are three eight-character ASCII representations of a binary floating point number: **X field** = voltage present at Channel X input, **Y field** = voltage present at Channel Y input, **F field** = voltage present at Field input. The T field is an eight digit decimal integer representing time in 10 ms increments from initial instrument power up until the reading was taken.

              The newest ### readings are sent at the same time in order of oldest to newest. If fewer new readings are available, only valid readings are sent. All older readings are lost. Data is taken and time stamped every period specified in the READP command from 100 ms to 1000 mS.

OLDR?   Query the oldest reading data in the 100 point data buffer.

    Sent: **OLDR?###[term]**
    Returned: NNN,XXXXXXXX,YYYYYYYY,FFFFFFFF,TTTTTTTT….[term].
    Remarks: **###** = number of data sets to be sent between 1 and 100. **NNN** = three ASCII digits of an integer number of readings that follow. The X, Y and F fields are three eight-character ASCII representations of a binary floating point number: **X field** = voltage present at Channel X input, **Y field** = voltage present at Channel Y input, **F field** = voltage present at Field input. The T field is an eight digit decimal integer representing time in 10 ms increments from initial instrument power up until the reading was taken.

              The oldest ### readings are sent at the same time in order of oldest to newest. If fewer readings are available, only valid readings are sent. Newer readings are preserved for future retrieval. Data is taken and time stamped every period specified in the READP command from 100 ms to 1000 mS.

QUAD   Set channel Y quadrature on or off.

    Sent: **QUAD X[term]**
    Returned: Nothing. Return requires **QUAD?**.
    Remarks: One ASCII digit (**X**) sets channel Y quadrature on or off: **0** = OFF (Channel Y in phase with channel X), **1** = ON (Channel Y in quadrature with channel X). Default **0**.

QUAD?   Query channel Y quadrature setting.

    Sent: **QUAD?[term]**
    Returned: X[term].
    Remarks: Returns one ASCII digit (**X**) indicating channel Y quadrature: **0** = OFF (Channel Y in phase with channel X), **1** = ON (Channel Y in quadrature with channel X). Default **0**.

READ?
Query newest reading data.

Sent: **READ?[term]**
Returned: XXXXXXXX,YYYYYYYY,FFFFFFFF,TTTTTTTT[term].
Remarks: Returns three eight-character ASCII representations of a binary floating point number indicated by the X, Y and F fields: **X field** = voltage present at Channel X input, **Y field** = voltage present at Channel Y input, **F field** = voltage present at Field input. The T field is an eight digit decimal integer representing time in 10ms increments from initial instrument power up until the reading was taken. New data taken every 100mS.

READC
Clears data from the reading buffer.

Sent: **READC[term]**
Returned: Nothing.
Remarks: Data in the reading buffer is lost. Stores data taken after the READC command; return data using the **ALLR?** query.

READP
Set sample period for read buffer.

Sent: **READP XX[term]**
Returned: Nothing. READP setting return requires READP?.
Remarks: Two ASCII digits (**XX**) set sample period in .1 second increments. Setting range is **1** (0.1S) to **10** (1S). Default **1**.

READP?
Query read buffer sample period.

Sent: **READP?[term]**
Returned: X[term].
Remarks: Two ASCII digits (**XX**) indicate sample period in .1 second increments. Range is **1** (0.1S) to **10** (1S). Default **1**.

READS?
Query reading status for the X EMU, Y EMU, Field, and AUX inputs.

Sent: **READS?[term]**
Returned: XX[term].
Remarks: Two ASCII digits (**XX**) indicate overload on the input channels. Each digit represents a nibble (**0-F**) of an eight bit status byte. **0** = no error, **1** = error present. Bit weighting is as follows:

Bit	Weight	Use
0	01	EMUX A/D overload
1	02	EMUX PSDMON overload
2	04	EMUX PREMON overload
3	08	EMUY A/D overload
4	10	EMUY PSDMON overload
5	20	EMUY PREMON overload
6	40	Field A/D overload
7	80	Auxiliary A/D overload

Hex addition of the bit weights gives the complete status byte.

5.2.5 Field Setting Commands

CMODE	Set field setting mode.
Sent:	**CMODE X[term]**
Returned:	Nothing. Return requires **CMODE?**.
Remarks:	One ASCII digit (**X**) sets field setting mode: **0** = Manual setting mode (uses **COUT**), **1** = Current ramp mode (uses **RMPTO**, **RMPRT**), **2** = Field controlled ramp mode (uses **CONTO**, **CONRT**, **CONPI**, **CONLIM**). Default **0**.

CMODE?	Query field setting mode.
Sent:	**CMODE?[term]**
Returned:	X[term].
Remarks:	One ASCII digit (**X**) indicates field setting mode: **0** = Manual setting mode (uses **COUT**), **1** = Current ramp mode (uses **RMPTO**, **RMPRT**), **2** = Field controlled ramp mode (uses **CONTO**, **CONRT**, **CONPI**, **CONLIM**). Default **0**.

CONLIM	Set field output change limit for field controlled ramp.
Sent:	**CONLIM XXXXXXXX[term]**
Returned:	Nothing. Return requires **CONSCALE?**.
Remarks:	The X field is an eight ASCII character representation of a binary floating point number set in percent of full scale field output per minute. When **CMODE = 2**, the instrument will not change the field output faster than **CONLIM**. Default **00000000** (0 %/min).

CONLIM?	Query field output change limit for a field controlled ramp.
Sent:	**CONLIM?[term]**
Returned:	XXXXXXXX[term].
Remarks:	The X field is an eight ASCII character representation of a binary floating point number set in percent of full scale field output per minute. Default **00000000** (0 %/min).

CONPI	Set field controlled ramp P (proportional) and I (integral) parameters.
Sent:	**CONPI XXXXXXXX,YYYYYYYY[term]**
Returned:	Nothing. Return requires **CONPI?**.
Remarks:	The X field is an eight ASCII character representation of a binary floating point **P** (no units). The Y field is an eight ASCII character representation of a binary floating point **I** in seconds. When **CMODE = 2**, the instrument uses **the P** and **I** values in a PI control algorithm. Default **00000000,00000000** (0,0).

CONPI?	Query field controlled ramp P (proportional) and I (integral) parameters.
Sent:	**CONPI?[term]**
Returned:	XXXXXXXX,YYYYYYYY[term]
Remarks:	The X field is an eight ASCII character representation of a binary floating point **P** (no units). The Y field is an eight ASCII character representation of a binary floating point **I** in seconds. Default **00000000,00000000** (0,0).

CONRT	Set field controlled ramp rate.
Sent:	**CONRT XXXXXXXX[term]**
Returned:	Nothing. Return requires **CONRT?**.
Remarks:	The X field is an eight ASCII character representation of a binary floating point number set in field input volts per minute. When **CMODE = 2**, the instrument uses **CONRT** to approach the **CONTO** value. Default **00000000** (0 V/min).

CONRT?   Query the field controlled ramp rate.
  Sent: **CONRT?[term]**
  Returned: XXXXXXXX[term].
  Remarks: The X field is an eight ASCII character representation of a binary floating point number set in field input volts per minute. Default **00000000** (0 V/min).

CONSP?   Query current field controlled ramp setpoint.
  Sent: **CONSP?[term]**
  Returned: XXXXXXXX[term].
  Remarks: The X field is an eight ASCII character representation of the current field controlled ramp setpoint in volts per minute. Default **00000000** (0V).

CONST?   Query field controlled ramp status.
  Sent: **CONST?[term]**
  Returned: X[term].
  Remarks: One ASCII digit (**X**) indicates ramp status: **0** = no field controlled ramp active, **1** = Field controlled ramp active; **CONSP** approaching **CONTO**, **2** = **CONSP** reached **CONTO** and controlling to final value. Default **0**.

CONTO   Set ramp-to value for field controlled ramp of field output and initiate a ramp.
  Sent: **CONTO XXXXXXXX[term]**
  Returned: Nothing. Return requires **CONTO?**.
  Remarks: The X field is an eight ASCII character representation of a binary floating point number in voltage corresponding to the field input. Range and resolution are 5.00000 to +5.00000 V. Default **00000000** (0V).

  NOTE: CONTO initiates only if **CONRT** ≠ 0 and **CMODE** = 2.

CONTO?   Query ramp-to setting for field controlled ramp.
  Sent: **CONTO?[term]**
  Returned: XXXXXXXX[term].
  Remarks: The X field is an eight ASCII character representation of the control destination. Range and resolution are 5.00000 to +5.00000 V. Default **00000000** (0V).

  NOTE: CONTO? returns the ramp destination. Use **CONSP?** to obtain current field setpoint.

COUT   Manually set field output.
  Sent: **COUT XXXXXXXX[term]**
  Returned: Nothing. Return requires **COUT?**.
  Remarks: The X field is an eight character ASCII representation of a binary floating point number in percent of full scale field output. Use **COUT** when **CMODE** = 0. The range and resolution are -100.000 to +100.000%. Default **00000000** (0%).

  NOTE: COUT ends an active ramp and forces field output to the **COUT** setting value. **COUT?** is always active and will not stop a ramp.

COUT?   Query field output setting.
  Sent: **COUT?[term]**
  Returned: XXXXXXXX[term].
  Remarks: The X field is an eight character ASCII representation of a binary floating point number in percent of full scale field output. The range and resolution are -100.000 to +100.000%. Default **00000000** (0%).

  NOTE: COUT? always returns the field output even if **COUT** is not used to set it.

RAMP?   Query ramp status.

Sent: **RAMP?[term]**
Returned: X[term].
Remarks: One ASCII digit (**X**) indicates ramp status: **1** = ramp active, **0** = no ramp active. Use **RAMP?** when **CMODE** = **1**. Default **0**.

RMPRT   Set ramp rate in percent of full scale field output /min.

Sent: **RMPRT XXXXXXXX[term]**
Returned: Nothing. Return requires **RMPRT?**.
Remarks: The X field is an eight ASCII character representation of a binary floating point number in percent of full scale field output per minute. Range and resolution are 0.00 to +100.00%/min. Default **00000000** (0%/min). Use **RAMPRT** when **CMODE** = **1**.

NOTE: A ramp initiates only if a non-zero ramp rate is set.

RMPRT?   Query the ramp rate setting.

Sent: **RMPRT?[term]**
Returned: XXXXXXXX[term].
Remarks: The X field is an eight ASCII character representation of a binary floating point number in percent of full scale field output per minute. Range and resolution are 0.00 to +100.00%/min. Default **00000000** (0%/min).

RMPTO   Set ramp-to value for current ramp of field output and initiate a ramp.

Sent: **RMPTO XXXXXXXX[term]**
Returned: Nothing. Return requires **RMPTO?**.
Remarks: The X field is an eight ASCII character representation of a binary floating point number in percent of full scale field output. Range and resolution are -100.000 to +100.000%. Default **00000000** (0%). **RAMPTO** works for **CMODE** = **1** or **2**.

NOTE: A ramp initiates only if a non-zero ramp rate is set.

RMPTO?   Query ramp-to setting for current ramp.

Sent: **RMPTO?[term]**
Returned: XXXXXXXX[term].
Remarks: The X field is an eight ASCII character representation of a binary floating point number in percent of full scale field output. Range/resolution = -100.000 to +100.000%. Default **00000000** (0%).

NOTE: RMPTO? returns the ramp destination. Use **COUT?** to obtain current field output.

5.2.6   Auxiliary Commands

AUXAD?   Query one of seven auxiliary A/D readings.
Sent: **AUXAD?X[term]**
Returned: YYYYYYYY[term].
Remarks: One ASCII digit (**X**) indicates the A/D input from 1 to 7. The Y field is an eight ASCII character representation of a binary floating point number which is the voltage at the A/D input. Range: -5 V to +5 V. Resolution: 18 bits or greater.

NOTE: One A/D updates every 100 ms; 700 ms to update all seven.

AUXDA   Set output of auxiliary output D/A 1 or 2.
Sent: **AUXDA X, YYYYYYYY[term]**
Returned: Nothing. Output setting return requires **AUXDA?**.
Remarks: One ASCII digit (**X**) indicates output: **1** = Auxiliary output D/A 1, **2** = Auxiliary output D/A 2. The Y field is an eight ASCII character representation of a binary floating point number in percent of full scale for the output. Range/resolution = -100.00 to +100.00%. Default **00000000** (0%).

AUXDA?   Query output setting for auxiliary output D/A 1 or 2.
Sent: **AUXDA?X[term]**
Returned: YYYYYYYY[term].
Remarks: One ASCII digit (**X**) indicates output: **1** = Auxiliary output D/A 1, **2** = Auxiliary output D/A 2. The Y field is an eight ASCII character representation of the output setting. Range and resolution are -100.00 to +100.00%. Default **00000000** (0%).

AUXDI?   Query auxiliary digital input states.
Sent: **AUXDI?[term]**
Returned: XX[term].
Remarks: Two ASCII digits (**XX**) represent the digital inputs as a hex number from 00 to 1F. Each input is represented by an individual bit. **0** = logic low; **1** = logic high. Returns the hex sum of the bit weights. Bit weighting is as follows:

Bit	Weight	Use
0	01	Digital output 1
1	02	Digital output 2
2	04	Digital output 3
3	08	Digital output 4
4	10	Digital output 5

Hex addition of the bit weights gives all input states. Default **00**. **NOTE:** Digital outputs and inputs share pins on the auxiliary connector. To use a digital line as an input, set to output = 1.

AUXDO   Set all five auxiliary digital outputs.
Sent: **AUXDO XX[term]**
Returned: Nothing. Output return requires **AUXDO?**.
Remarks: Two ASCII digits (**XX**) represent the five digital outputs. Each output is represented by an individual bit. **0** = logic low; **1** = logic high. The hex sum of the bit weights create a setting value from 00 to 1F hex. Bit weighting is as follows:

Bit	Weight	Use
0	01	Digital output 1
1	02	Digital output 2
2	04	Digital output 3
3	08	Digital output 4
4	10	Digital output 5

Hex addition of the bit weights gives all input states. Default **00**. **NOTE:** Digital outputs and inputs share pins on the auxiliary connector. To use a digital line as an input, set to output = 1.

AUXDO?   Query auxiliary digital output setting.

Sent: **AUXDO?[term]**

Returned: XX[term].

Remarks: Two ASCII digits (**XX**) represent the five digital outputs. Each output is represented by an individual bit. **0** = logic low; **1** = logic high. The hex sum of the bit weights create a setting value from 00 to 1F hex. Bit weighting is as follows:

Bit	Weight	Use
0	01	Digital output 1
1	02	Digital output 2
2	04	Digital output 3
3	08	Digital output 4
4	10	Digital output 5

Hex addition of the bit weights gives all output states. Default **00**.

RELAY   Set state of one of four auxiliary relays.

Sent: **RELAY X, Y[term]**

Returned: Nothing. Relay state return requires **RELAY?**.

Remarks: One ASCII digit (**X**) indicates desired relay: **1** = Auxiliary Relay 1, **2** = Auxiliary Relay 2, **3** = Auxiliary Relay 3, **4** = Auxiliary Relay 4.
One ASCII digit (**Y**) is the relay state: **0** = Normal, **1** = Active. Default **0**.

RELAY?   Query the state setting of an auxiliary relay.

Sent: **RELAY?X[term]**

Returned: Y[term].

Remarks: One ASCII digit (**X**) indicates desired relay: **1** = Auxiliary relay 1, **2** = Auxiliary relay 2, **3** = Auxiliary relay 3, **4** = Auxiliary relay 4. Returns one ASCII digit (**Y**) which is the relay state: **0** = Normal, **1** = Active. Default **0**.

5.2.7   Miscellaneous Commands

BEEP Sets main board beeper on or off.
  Sent: **BEEP X[term]**
  Returned: Nothing. Beeper setting return requires **BEEP?**.
  Remarks: One ASCII digit (**X**) specifies beeper setting: **0** = OFF, **1** = ON. Default **0**.

BEEP? Query beeper setting.
  Sent: **BEEP?[term]**
  Returned: X[term].
  Remarks: One ASCII digit (**X**) indicates beeper setting: **0** = OFF, **1** = ON. Default **0**.

IDSW? Query the four ID switches on the instrument main board.
  Sent: **IDSW?[term]**
  Returned: X[term].
  Remarks: Returns one ASCII digit (**X**) which represents the switch states as a hex number from 0 to 1F. An individual bit represents each of the four switches. **0** = closed; **1** = open. Returns the hex sum of the bit weights. Bit weighting is as follows:

Bit	Weight	Use
0	01	Switch 1
1	02	Switch 2
2	04	Switch 3
3	08	Switch 4 **NOTE:** Hex addition of bit weights gives all switch states.

POKE Sets the value of any location in EEPROM memory.
  Sent: **POKE XXX,YY[term]**
  Returned: Nothing. Return requires **POKE?**.
  Remarks: Three ASCII digits (**XXX**) represent the decimal memory address from 0 to 511.
  Two ASCII digits (**YY**) represent the 8 bit data byte in hex. No default.

POKE? Query the value in any location in EEPROM memory.
  Sent: **POKE?XXX[term]**
  Returned: YY[term].
  Remarks: Three ASCII digits (**XXX**) represent the decimal memory address from 0 to 511. Returns two ASCII digits (**YY**) which represent the 8 bit data byte in hex. No default.

PON? Query instrument power on status.
  Sent: **PON?[term]**
  Returned: X[term].
  Remarks: One ASCII digit (**X**) represents the instrument power on status: **1** = instrument powered off then on again since last **PON?** query; **0** = instrument not powered off since last **PON?** query.

XMEM Sets the value of any location in external memory.
  Sent: **XMEM XXXX,YY[term]**
  Returned: Nothing. Return requires **XMEM?**.
  Remarks: Four ASCII digits (**XXXX**) represent the 16 bit hex memory address. Two ASCII digits (**YY**) represent the 8 bit data byte in hex. No default.

XMEM? Query the value in any location in external memory.
  Sent: **XMEM?XXXX[term]**
  Returned: YY[term].
  Remarks: Four ASCII digits (**XXXX**) represent the 16 bit hex memory address. Returns two ASCII digits (**YY**) which represent the 8 bit data byte in hex. No default.

5.2.8   Calibration Commands (NOTE: CALSAVE must be sent to save calibrations)

ADFILT   Sets filter pole of A/D converters.
Sent: **ADFILT XXX[term]**
Returned: Nothing. Return requires **ADFILT?**.
Remarks: Three ASCII digits (**XXX**) indicate the hex value of the A/D pole setting. The pole is computed in decimal as f pole = 10MHz/(512*setting). The converter sample rate is 1/f pole. Convert the pole setting to hex before sending. Default **188** (50Hz).

ADFILT?   Queries filter pole setting of A/D converters.
Sent: **ADFILT?[term]**
Returned: XXX[term].
Remarks: Returns three ASCII digits (**XXX**) which indicate the hex value of the A/D pole setting. Default **188** (50Hz).

APCAL   Initiates instrument auto phase calibration.
Sent: **APCAL [term]**
Returned: Nothing. Return requires **PCAL?**.
Remarks: A large in-phase signal should reside in the instrument EMUX input before sending this command. It takes at least 10 seconds to complete, and **BUSY?** = 1 during the task. Send **CALSAVE** to permanently store the calibration.

BUSY?   Informs user when a long calibration is complete.
Sent: **BUSY?[term]**
Returned: X[term]
Remarks: Returns one ASCII digit (**X**). If **X** = **1**, the instrument is calibrating. If **X** = **0** the instrument is performing normal operation.

CALCLEAR   Clears instrument calibration memory.
Sent: **CALCLEAR [term]**
Returned: Nothing.
Remarks: The instrument writes default calibration data to EEPROM where it is read on power up. All software calibrations are lost including serial number. It takes at least two seconds to complete, and **BUSY?** = 1 during the task.

CALSAVE   Saves a calibration.
Sent: **CALSAVE [term]**
Returned: Nothing.
Remarks: The instrument writes calibration data to EEPROM where it is read on power up. A software calibration done without **CALSAVE** is lost when the instrument is turned off. It takes at least two seconds to complete, and **BUSY?** = 1 during the task.

PCAL   Sets instrument phase calibration.
Sent: **PCAL XXXX[term]**
Returned: Nothing. Return requires **PCAL?**.
Remarks: Four ASCII digits of serial number specify phase calibration. Default **0000**.

PCAL?   Instrument phase calibration setting query.
Sent: **PCAL?[term]**
Returned: XXXX[term].
Remarks: Returns four ASCII digits which indicate phase calibration setting. Default **0000**.

SNUM   Sets instrument serial number.
  Sent: **SNUM XXXXXX[term]**
  Returned: Nothing. Setting return requires **SNUM?**.
  Remarks: Six ASCII digits specifies serial number. Default ######.

SNUM?   Query instrument serial number.
  Sent: **SNUM?[term]**
  Returned: XXXXXX[term].
  Remarks: Returns six ASCII digits which indicate instrument serial number. Default ######.

ZCAL   Auto zero calibrates both X and Y inputs on all ranges.
  Sent: **ZCAL X [term]**
  Returned: Nothing.
  Remarks: One digit (**X**) indicates the channel: **0** = X, **1** = Y. The instrument should have no signal into the EMUX or EMUY input before sending this command. It takes at least ten seconds to complete, and **BUSY?** = 1 during the task. Send **CALSAVE** to permanently store the calibration.

CHAPTER 6

OPTIONS

6.0 GENERAL

This chapter provides details on the 7300 Series VSM System options. The Vector Option is described in Paragraph 6.1, Rotation Option in Paragraph 6.2, High Temperature Oven in Paragraph 6.3, Closed-Cycle Refrigerator Option in Paragraph 6.4, Cryostat Option in Paragraph 6.5, Magnetoresistance (MR) Option in Paragraph 6.6, and the Industrial (-IND) Model Option in Paragraph 6.7.

6.1 VECTOR OPTION

In reference to the Vector Option pick-up coil set, the x-axis measures the magnetic moment parallel to the applied magnet field and the y-axis measures the magnetic moment perpendicular to the applied magnet field. The 735 VSM Controller can obtain both x- and y-axis magnetic moment measurements simultaneously.

6.1.1 Installation

To install the vector coil set, loosen the front and back screws holding the x-axis and y-axis coils together, (see Figure 6-1). Remove the Hall probe mounting bracket. Adjust the top and bottom brass thumb screws to allow the x-axis coil plates to be pushed in as far as possible. Fit the coil set into the magnet gap between the pole faces and secure it in place by adjusting the top and bottom brass thumb screws to force the x-axis coil plates against the pole face. Carefully tighten the front and back screws holding the x-axis and y-axis coils together. Place the Hall probe mounting bracket onto the coil set and place the Hall probe in to the indexed stop. Tighten the front right Hall probe mounting bracket screws. To adjust Hall Probe orientation, see Paragraph 3.2.5.3.

6.1.2 Maintenance

When handling the vector coil set, take care not to break any wires. The pick-up coil wires are encased within the coil form, but damage may occur if the unit is dropped or exposed to moisture or large electrical currents. When separating the x-axis coils from the y-axis coils take care not to strain any of the cables or their pin connectors. In addition, when adjusting the coil set, do NOT disassemble the coil protection mount; loosen only the x-axis and y-axis coil plate holding screws.

6.1.3 Calibration

Y-axis coils calibration uses X-axis coils calibration as a reference. Calibrate Y-axis coils with a permanent magnet at an applied field of zero gauss. First, measure the magnetic moment of a permanent magnet with the X-axis coils. Rotate the permanent magnet 90° to produce a positive moment in the Y-axis coils (see Figure 6-2). Adjust the Y-axis coil moment reading to equal the X-axis coil moment reading.

NOTE: The magnetization axis of the permanent magnet rotates **–90°** according to the rotation index on the VSM drive head. Proper calibration requires the sample saddled after rotation. For the Y-axis coils, the minimum and maximum emu outputs required to saddle the sample interchange. The X-direction saddle is now a maximum emu output and the Y-direction saddle is a minimum emu output.

After obtaining the new saddle point, allow the software to measure the Y-axis emu value and determine a calibration constant. This calibration constant is stored until a new calibration is performed.

1. Brass Thumb Screw.
2a. Right X-Axis Coil Plate.
2b. Left X-Axis Coil Plate.
3a. Front Y-Axis Coil Plate.
3b. Rear Y-Axis Coil Plate.
4. Hall Probe Mounting Bracket.
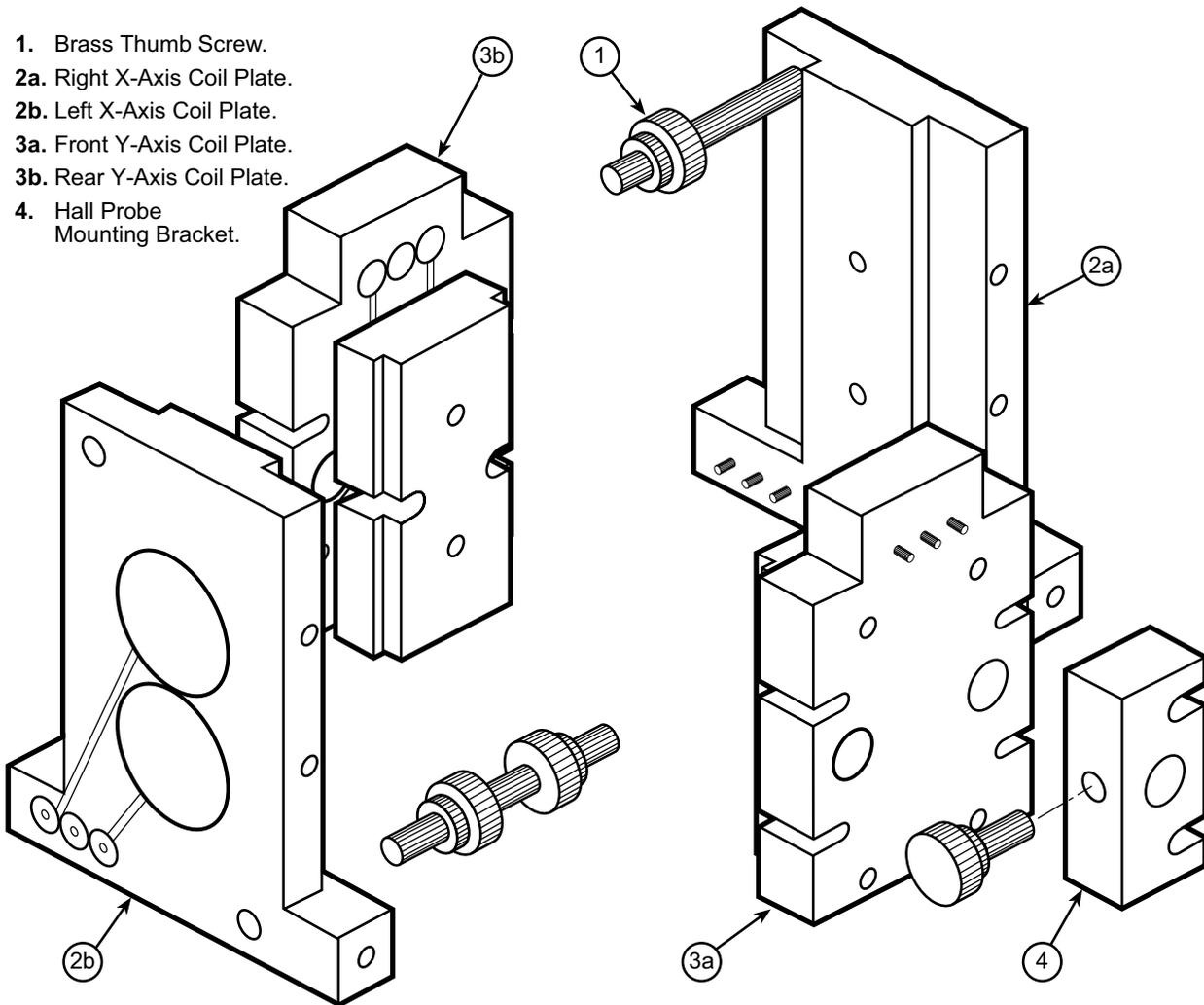
F-7300-6-1.eps

Figure 6-1. Vector Option Exploded View

6.2 ROTATION OPTION

The Rotation Option varies sample orientation relative to the direction of applied magnetic field. The angle of rotation is within a single plane defined by the direction of applied magnetic field, called the x-axis, and perpendicular to the direction of vibration, called the z-axis (see Figure 6-2). A stepping motor on the VSM drive head controls the motion. Two limit switches determine HOME and END positions of rotation. All stepping motor controller communication is through the RS-232 serial interface to the PC.

Find further information about the stepping motor, its drive, and the interface software in the VSM Software User's Manual.
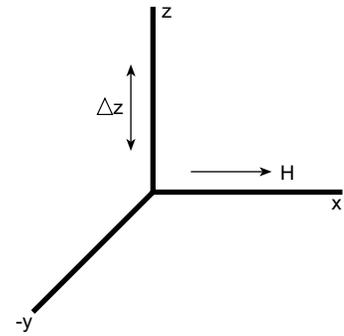
**Figure 6-2.
VSM Reference Frame**

6.2.1 Installation

1. Remove mechanical drive from its box and set it on the bench with its electrical connectors to your left.

    CAUTION: **The gear that runs around the bottom of the VSM head has a small 1/16 inch diameter pin protruding from the bottom of it. This pin signals the limit switch that it has reached its limit of travel. Handle the VSM head carefully to avoid damaging this pin.**

2. If the large gear is not already installed on the mechanical drive cover, remove the cover and replace the decorative black ring with the gear. Position the gear so its mounting holes line up with the holes in the cover and the pin faces away from the cover. The gear should fit tight against the cover. Draw the gear onto the cover with the long mounting screws. After the gear seats, replace the mounting screws with the proper cap screws. Thread the screws gradually and evenly. Re-install the cover. The pin should be on the right side with the drive positioned at zero degrees.

3. Install the limit switch bracket to the right side of the cover base with two #4-40 screws. Install the switches on top of the bracket with the cable exiting at the bottom.

    NOTE: After tightening the set screw, use a gear puller to remove the gear from the shaft.

4. Install the stepper motor bracket to the mechanical drive leveling plate with the two hex bolts. Visually line up the two gears. Adjust the gear on the motor shaft so the teeth are at the same level as the larger gear. Tighten the set screws at the gear. Use a gear puller to remove the gear from the shaft.

5. Install the timing belt over the pulleys. Rotate the cover 90 degrees to seat the belt in the gear teeth. Move motor bracket outward with one hand while tightening mounting screws. Use hand force only.

6. Install metal belt cover.

7. Connect DB-25 Adapter and 5-Pin Motor Connector to the Stepper Motor Controller. Connect the RJ-45 connector from the Limit Switch to the RJ-45 plug on the DB25 Adapter. Connect the RJ-11 connector on the RS-232 Cable into the RJ-11 plug on the DB-25 Adapter.

8. Connect the RJ-11 connector on the other end of the RS-232 cable to the DB-9 Adapter. Plug the DB-9 Adapter into COM1 of your PC.

9. Verify all 8 DIP switches on the Stepper Motor Controller are OFF.

10. Plug in the power cord. Note that the unit does not have an On/Off Switch.

If the Rotation Option shipped with the VSM System, the correct software is already installed in the computer and automatically detects the presence of the stepping motor drive when the program starts.

If the Rotation Option shipped after receipt of the VSM System, install the proper PC operation software before using the option. Follow the instructions included with the software to install the program.
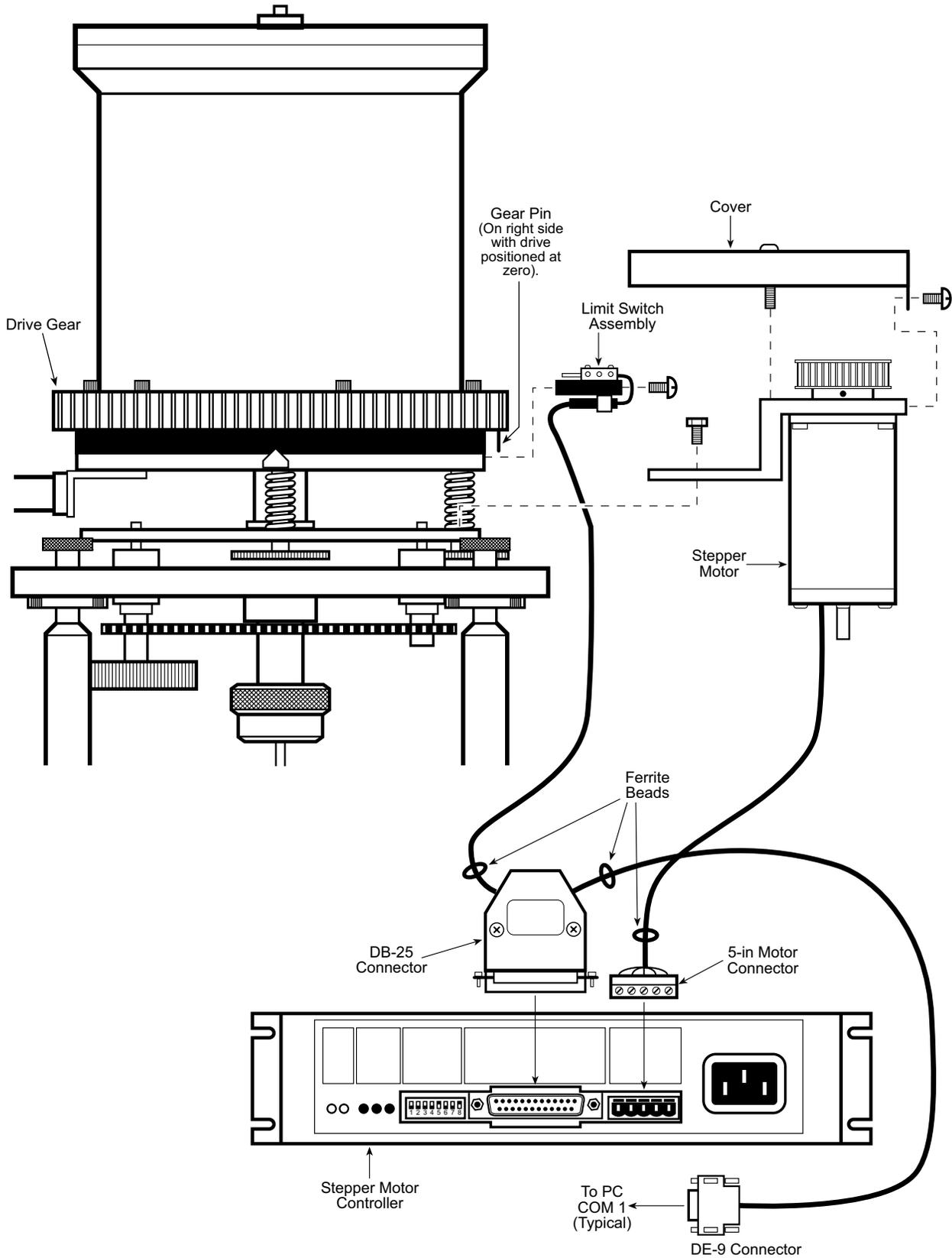
Figure 6-3. Rotation Option Installation

6.2.2 Software Guide

Periodically calibrate the rotation option to ensure an accurate degree/steps constant. Install the Nickel sample prior to calibration. To initiate calibration, select **Rotation** under the **Calibration** menu.

To set an angle for a field or temperature sweep, use the **Static Control** menu under the **Magnetometer Operations** menu.

To perform a magnetization versus angle experiment at a fixed field and temperature, use the **Angle** menu under the **Define Experiment** menu to setup the data points.

6.2.3 Wiring Information

DB-25 to RJ-11 and RJ-45 Adapter

Function	DB-25	RJ-11	RJ-45
Tx	14	5 (Black)	
Rx	15	2 (Yellow)	
Ground	7	3 (Green) & 4 (Red)	3 (Yellow)
CW Limit	3	—	2 (Brown)
CCW Limit	4	—	5 (Red)

Motor Connection to PDX Drive

Function	5-Pin Connector	Motor Cable
A+	Top 1	Red and Blue
A–	2	Black and Yellow
Ground	3	Shield
B+	4	Green and Orange
B–	5	White and Brown

RJ-45 Cable for Limit Switch

Function	DB25	Switch, Left	Switch, Right
Common	3 (Black)	Common	Common
CW Limit	2 (Orange)	NC	—
CCW Limit	5 (Green)	—	NC

6.3 MODEL 73034 HIGH TEMPERATURE OVEN OPTION

The Model 73034 allows the Model 7300 to investigate magnetic properties of materials at high temperatures.

This convenient, high-efficiency accessory made of non-magnetic materials consists of an electrically heated outer tube assembly with efficient vacuum and reflective thermal insulation. The sample-zone temperature range extends to 1000 °C and it requires only 61 watts to maintain this temperature. Even at the highest operating temperature, outer case temperature is nominally only 200 °C at the hottest spot. The inner sample-zone chamber is lined with stainless steel for easy cleaning. The sample holder consists of a quartz tube extension attached to a boron-nitride sample cup. The Model 73034 comes with a 90-day warranty.

To install the Model 73034 in an existing Model 7300 magnetometer, remove the standard outer-tubing assembly and replace it with the Model 73034. The 1/8 inch thick shim plates between the pick-up coil assembly and the magnet pole face must be removed to accommodate the 3/4 inch thickness of the outer tubing assembly. Installation is even easier with a Model 7300 fitted with a Model 73013 Cryostat because cryostat installation requires shim plate removal. The user must supply a mechanical vacuum pump, capable of maintaining inlet pressures down to one micron.

To exclude atmospheric oxygen which may react with the sample, either evacuate the sample zone or fill it with an inert gas. Magnetically observe oxidation/reduction reactions by back-filling with appropriate gas mixtures. A chromel-alumel thermocouple facilitates temperature measurement and control. Add the Model 73034 to a Model 7300 with a Model 73013 Cryostat for magnetic investigations over a temperature range from near absolute zero to 1000 °C. Use the Model 73034 in systems that do not include a 7300 as well; just satisfy Model 73034 current and vacuum requirements and monitor temperature.

The Model 73034 is perfect for measuring Curie temperatures of materials up to 1000 °C. The inherent sensitivity of the 7300 Magnetometer determines Curie temperature at relatively low field intensities. The steeper change in magnetic moment significantly increases accuracy.

6.3.1 Specifications

FUNCTION: Extends Model 7300 VSM temperature range. Obtains controlled sample-zone temperatures to 1000 °C.

INSTALLATION: Replaces standard outer tubing assembly. No Model 7300 modification necessary.

HEATER: Integral 20Ω (±20%) heater coil.

POWER REQUIREMENTS: 0 to 2.0 A (max) of well-filtered DC. Sustain maximum rated temperature with nominal 61 watts. Never exceed 80 watts maximum power. In systems with a Model 7300, the 7300 supplies power if equipped with Temperature Controller board. Also, the user may supply power with his own external supply.

TEMPERATURE MEASUREMENT AND CONTROL: Internal chromel-alumel thermocouple senses heater temperature. Thermocouple output cables to 7300 for convenient automatic temperature monitoring. Without a 7300, monitor the thermocouple output with potentiometer pyrometer to track temperature.

SAMPLE ENVIRONMENT: Evacuate the sample zone or fill it with gas appropriate to the experiment.

Heater and Thermocouple Connecter
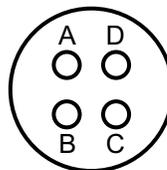
A: + Power Supply, DC

B: - Power Supply, DC

C: Positive, Type K Thermocouple Lead (Chromel, Yellow)

D: Negative, Type K Thermocouple Lead (Alumel, Red)

Pumping Tubulation
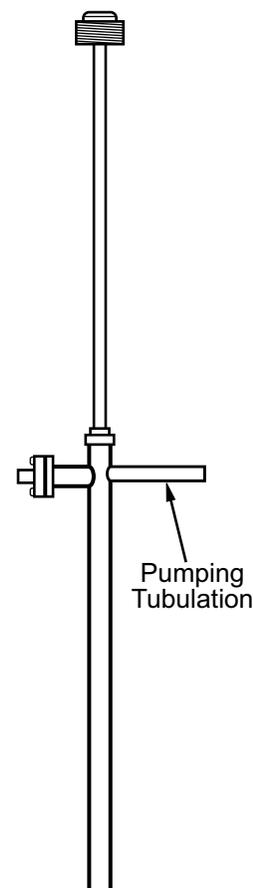
Figure 6-4. Model 73034

HEATING RATE: Maximum heating rate of at least 80 °C/minute at maximum input power of 80 watts. Figure 6-5 shows a typical heating/cooling cycle at 25 °C ambient and a 50 μ vacuum. Heats to 1000 °C in about 15 minutes, cools in about three hours. See Cooling Rate below for faster cool-down.

COOLING RATE: With vacuum of 50 microns or better, cooling time constant is nominally 1000 seconds. MAINTAIN VACUUM WHILE COOLING. For faster cool-down, valve off pump and allow pressure to rise to 500 microns, BUT NO HIGHER. Do not allow pressure to rise above this level until temperature drops below 200 °C, at which point the annulus may be opened to the atmosphere.

SAMPLE ZONE DIMENSIONS: Inside diameter = 9/32 inch; Outside diameter = ¾ inch (at signal coils).

VACUUM CONNECTION: 3/8 inch O.D. tube to attach flexible hose to vacuum pump.

HEATER/THERMOCOUPLE CONNECTOR: Hermetically sealed electrical receptacle. Matching plug furnished with unit.

SAMPLE ROD EXTENSION: Special inner-rod subassembly attaches to standard 7300 drive rod by threaded fitting. Subassembly consists of fused quartz extension with high-purity boron-nitride guides and sample holder.

Figure 6-5. Heating and Cooling Curves

ADDITIONAL EQUIPMENT NEEDED:

1. Mechanical pump capable of a blanked-off pressure of one micron or lower.

2. Model 73034/25 Vacuum pump Back-Streaming Line Filter. Filters out 0.1 micron particles to keep vacuum pump oil from entering the Model 73034. Vacuum pump oil in the Model 73034, severely shortens heater life.

6.3.2 Operation Overview

Model 73034 operation is straightforward. It replaces the standard 7300 outer tubing assembly. The Model 73034 Power/Sensor cable interconnects the Model 73034 and the 7300. One end of this cable has a single connector, the other has two. The single connector connects to the Model 73034 Heater/Thermocouple connector. One of the other connectors connects to the HEATER POWER connector on the 7300 console rear. The remaining one connects to the THERMOCOUPLE CONTROL connector. The special high-temperature sample-rod parts replace the corresponding standard sample-rod parts. (There is no need to cool the oven to change the sample.) After establishing the required vacuum, Begin operation at elevated temperatures.

Always exercise caution to ensure proper operation and avoid damage to the Model 73034 or sample-rod components. Some suggestions:

1. Always use a Backstreaming Filter capable of removing 0.1 micron particles in the vacuum line. Failure to use a filter may allow vacuum pump oil to reach the heater, and severely reduce its life.

2. Never try to achieve temperatures higher than 1000 °C. Higher temperatures may severely shorten the Model 73034 life.

3. Always maintain vacuum with temperatures above 200 °C. While operating, maintain a pressure of not over 50 microns. Pressure may rise to 500 microns, BUT NO HIGHER, during cool down. DO NOT open annulus to the atmosphere at temperatures above 200 °C. Exceeding these limits damages the Model 73034.

4. Handle the special boron-nitride high-temperature sample-rod components with care; they are fragile.
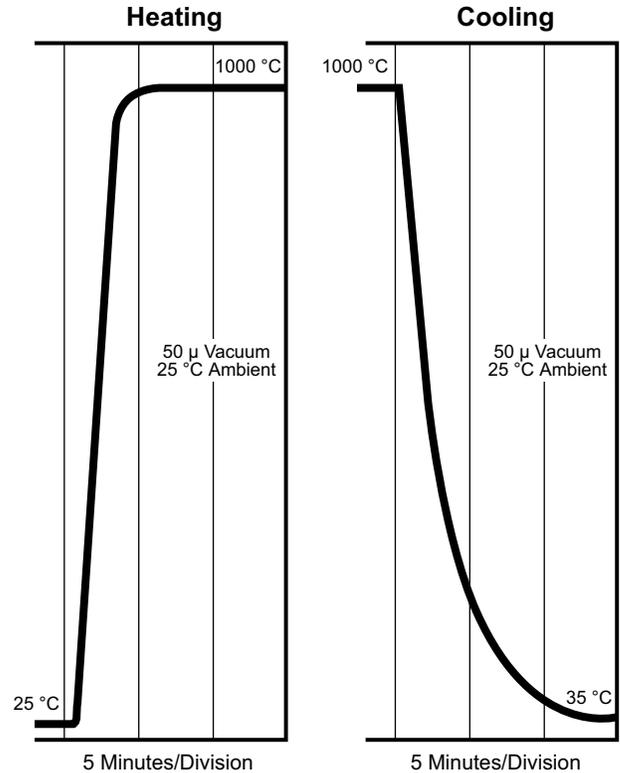
6.3.3   Installation

1. Adjust spacing between the signal pick-up coils to one inch to permit the lateral motion required to achieve a proper saddle point (this term is explained in the 7300 manual). If spacing is not one inch, remove the shims or adjust the magnet pole pieces as needed.

2. Remove the Model 7300 Outer Tube Assembly (Model 73013 Dewar, where appropriate) by unscrewing the large knurled nut at the bottom of the Driver Head.

3. Install the Model 73034 in place of the outer tube assembly and tighten the knurled nut.

4. Attach a good mechanical pump to the Model 73034 tubulation (see Figure 6-4). Use rubber or Tygon vacuum hose and spiral it loosely around the upper part of the unit. Anchor the hose to the magnet frame to prevent pump vibration from reaching the oven. Connect a thermocouple-type or Pirani vacuum gauge between the tubulation and the pump to monitor the vacuum insulation annulus pressure. Connect a backstreaming filter in the line to prevent vacuum oil from reaching the heater element; it is essential.

5. **The following step does not apply if using a Model 7300 with the Model 73034, because the thermocouple cables directly to the 7300:**

    If **not** using a Model 7300 with the Model 73034, connect a **potentiometer-type** pyrometer to the thermocouple leads. Other type pyrometers may indicate lower than actual temperatures causing possible damage to the Model 73034. Customer must supply Type K thermocouple wires. An ice-bath reference junction may be used. For X-Y plots of moment versus temperature, connect the output emf to one channel of a high input-impedance X-Y recorder.

6. Pump on the vacuum annulus to a pressure of not over 50 microns. Maintain this vacuum during heating and measurement periods. Although vacuum must be maintained during cool down, pressure may rise moderately (up to 500 microns) to achieve a more rapid cool down.

7. **The following step does not apply if using a Model 7300 with the Model 73034, because the 7300 provides power to the Model 73034:**

    If **not** using a Model 7300 with the Model 73034, connect a source of adjustable direct current to the heater pins of the Model 73034 connector (see Figure 6-4). A standard laboratory supply capable of supplying zero-to-forty volts DC at 2.0 A suffices. Input to the heater element must not exceed 80 watts. Higher power may damage the Model 73034. Such damage is not covered by the Warranty.

8. Attach quartz and boron-nitride extension rod to the magnetometer Inner Tubing Assembly. Then attach the boron nitride sample cup, using a boron nitride centering washer at the lower end. See Figure 6-6.

CAUTION: Boron-nitride elements are fragile. Exercise extreme caution during assembly, insertion, and removal. Boron nitride was chosen for these parts because of its resistance to high temperature, its chemical inertness, and its relatively non-magnetic nature. Although other materials may be used, appropriate care must be exercised in their selection.

9. Bearing in mind the preceding caution, insert the Inner Tubing Assembly into the Model 73034 and take the measurement in the usual manner.

10. Because the sample zone is in common connection with the driver head assembly, users may evacuate it or fill it with an appropriate gas. Helium gas is good; it is inert and has high thermal conductivity for good thermal contact between the sample and the heated wall surrounding it. Use oxidizing or reducing atmospheres to observe changes in moment as a function of sample oxidation or reduction. However, since the atmosphere in the Model 7300 Mechanical Head Assembly is the same as the oven atmosphere, avoid corrosive atmospheres.

Item	Part No.	Description
1	652-212	Rod, Extension
2	652-196	Guide, Sample Rod
3	652-200	Rod, Sample
4	652-199	Rod, Adapter
5	652-198	Holder, Sample Disposable
6	652-197	Holder, Sample

10.75 inches
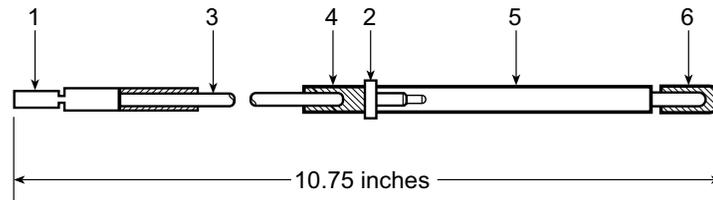
NOTE: Join Items 1 & 4 to item 3 with Sauereisen Ceramic Cement Type 1.

F-7300-6-6.eps

Figure 6-6. Model 73034 Sample Holder Assembly

6.3.4 Heater Temperature vs. Sample Zone Temperature

It is important to distinguish between heater temperature and sample zone temperature. The supplied internal thermocouple monitors the heater temperature. Changes in sample zone temperature always lag changes in heater temperature. This may be important in some experiments. Figure 6-7 shows a plot of sample zone temperature versus heater temperature for an instrumented Model 73034 with a thermocouple installed inside the sample holder. The measurements were made while rapidly sweeping the temperature from 30 °C to 750 °C in about eight minutes. Temperature differences between the heater and the sample zone as large as 150 °C occurred. Smaller temperature differences occur with a slower sweep. To ensure good results, sweep the temperature slowly.
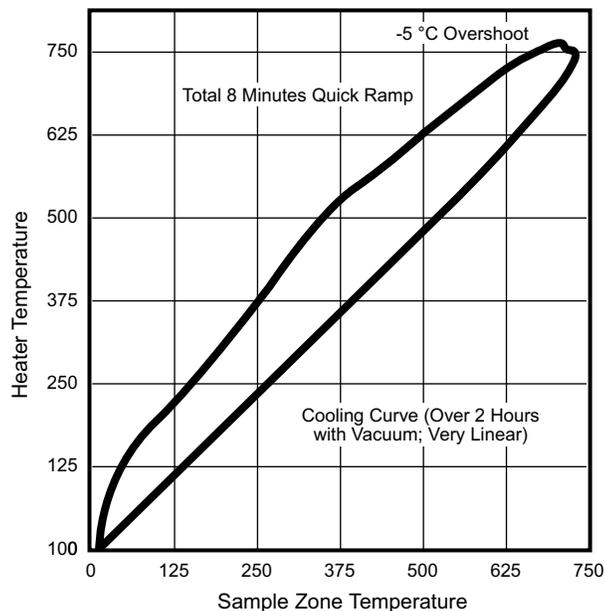
F-7300-6-7.eps

Figure 6-7. Sample Zone Temperature Versus Heater Temperature

6.3.5   Curie Temperature Measurements

Temperature sweep rates also influence Curie temperature measurements. Temperature that increases too rapidly may yield invalid results. Figure 6-8A shows results of a half-hour EMU vs. TEMPERATURE measurement of a Nickel sample. Note how the rapid temperature sweep causes the curve to flatten and drop almost vertically starting at about 400 °C. This is not a valid measurement. Figure 6-8B shows much better results by repeating the same measurement with a two-hour temperature sweep. To ensure good results, sweep the temperature slowly.

A: HALF-HOUR SWEEP   **B: TWO-HOUR SWEEP**
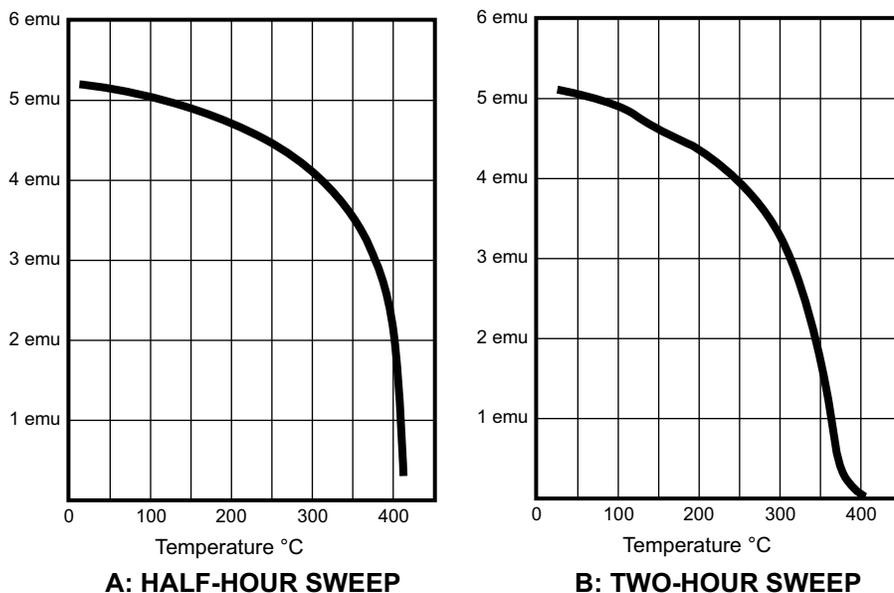
F-7300-6-8.eps

**Figure 6-8. Demagnetization of Nickel as a Function of Temperature
at Two Temperature Sweep Speeds**

6.3.6   Storage

Store the Model 73034 in any position. Stopper the vacuum tubulation to minimize moisture absorption by the ceramic heater insulation which causes outgassing on subsequent heating.

6.3.7   Sample Holder Cleaning

To ensure measurement accuracy, keep sample-holder parts free of contamination. High temperatures produced by the Model 73034 tend to compound contamination. Fortunately, boron-nitride is a relatively inert material. Use a strong cleaning solution without fear of damage to sample holder parts. In most instances, a solution of 50% concentrated hydrochloric acid and 50% concentrated nitric acid suffices.

6.4 CLOSED CYCLE REFRIGERATOR OPTION

6.4.1 Installation

To install the Refrigerator Option, remove the VSM drive head and pick-up coils from the magnet. Referencing the Janis Research, Inc. CCS-750 Closed Cycle Refrigerator Manual, Page 1, mount the refrigerator to the magnet stand using four M10 bolts supplied with the unit. Shim the refrigerator to a level position using the brass shim stock supplied with the unit. Attach all control cables and pressure lines to the refrigerator. See the CTI-Cryogenics Model 22C/350C Cryodyne Refrigerator Manual for a detailed discussion covering installation and operation.

To install the VSM vector coil set, carefully remove the right x-axis plate, but do not separate the coil plates more than one or two inches. Slip the coil set around the refrigerator and replace the right x-axis plate in its original position. If the right x-axis plate does not fit together flush, adjust the coil separation with the brass thumb screws to ensure a flush fit. Put the coil set in between the magnet poles and spread the coils to fit flush against the magnet pole faces using the brass thumb screws.

Re-install the VSM drive head. Verify good alignment between the drive head and refrigerator. Tighten o-ring clamp at the drive head/refrigerator coupling.

6.4.2 Vacuum and Helium Gas Plumbing

See the Janis Research, Inc. CCS-750 manual for detailed vacuum requirements. The refrigerator requires no helium gas for operation if it is at room temperature and the compressor is off. The refrigerator requires helium gas for operation if it is cold and/or the compressor is on.

Attach helium gas supply, 98% pure or better, to the valve at the top of the refrigerator. A supplied latex tube with a 0.5 psi pop-off valve attaches to the VSM drive head exhaust port. Verify all o-ring seals seat properly. **NOTE:** Regularly maintain all o-rings. Flush the sample space with helium gas before turning on the compressor. To maintain a positive gas pressure during operation, adjust the helium gas cylinder regulator to a level just low enough not to open the 0.5 psi pop-off on the VSM drive head; check for positive pressure on the refrigerator pressure gauge.

After attaching the refrigerator to the VSM drive head, follow standard procedure to change samples. **Exception:** To change samples while the refrigerator is cold, a flow of helium gas is required to eliminate cryopumping of atmospheric gases and moisture.

6.4.3 Model 340 Temperature Controller

See the VSM Software Manual for details on VSM temperature control operations. Typical parameters to set for a temperature sweep are: starting and stopping temperatures, number of points in the sweep, Gain (P), Reset (I), and Rate (D). Over a long temperature span, e.g., 15 K to 300 K, optimal PID settings vary with temperature, and normally, users either sacrifice optimum temperature control or operate each temperature sweep over a small temperature span. However, the Model 340 Temperature Controller software operates in a pre-programmed mode called ZONE mode, which provides an enhanced turn-key VSM.

To place the Model 340 in ZONE mode, press the front panel **Autotune** button. The front panel display reads "zone" when the instrument is in ZONE mode. If it is not in ZONE mode, hold **Autotune** while pressing the up/down arrow key to toggle the Model 340 into ZONE mode.

The Model 340 supplied with the VSM is programmed with a look-up table containing PID and heater range settings for ten temperature range "zones." Lake Shore experimentally determines PID and heater range settings for the Janis CCS-750; Table 6-1 lists these PID values.

The Model 340 in ZONE mode can perform a temperature sweep over the entire temperature range (15 K to 300 K) in a single temperature span using optimum preset PID and heater ranges at each temperature.

Model 340 Temperature Controller (Continued)

**Table 6-1. Experimentally Determined
PID and Heater Range Settings for UHK-VSM**

ZONE Number	Temperature Zone	P (Gain)	I (Reset)	D (Rate)	Heater Range
1	15	2	50	0	high
2	20	2	50	0	high
3	30	2	50	0	high
4	50	5	50	0	high
5	75	10	80	0	high
6	100	10	160	0	high
7	125	10	200	0	high
8	150	50	250	0	high
9	200	50	250	0	high
10	300	50	250	0	high

The Model 340 defaults to these values upon power up. However, users may temporarily overwrite any PID or heater range setting. First, place the instrument within the required temperature zone by entering a setpoint within that temperature zone. For example, enter a setpoint of 270 K to place the Model 340 in temperature zone10. Next, enter a new PI or D value. Make these temporary changes from either the Model 340 front panel or the VSM software. The Model 340 maintains the new PI or D setting for this zone until it exits this particular zone; then it uses default parameters for all the zones.

To permanently change any zone default value, access the Model 340 via an IEEE-488.2 editor. The National Instruments IEEE-488.2 card supplied with the computer includes an editor with a file name IBIC.EXE. See the National Instruments Software Reference Manual, Chapter 6. Enter new default zone parameters one zone at a time with the procedure below.

From the DOS prompt, start-up the IBIC program. Once the IBIC software initializes, type the following command at the prompt: **ibfind dev12**. If no error messages appear, the computer is interactively communicating with the Model 340.

The commands to read parameters for a single zone are: **ibwrt "zone?x"<return>** and **ibrd 100<return>**, where **x** is the zone number 1-10. The returned data string format is: **zone temperature,heater range,P,I,D**.

For example, the data string returned from the command **ibwrt "zone?6"**; **ibrd 100**, is **100,3,10,160,0** according to the above default table. Note that heater ranges are indexed 0-3 for OFF, LOW, MED, HIGH.

To change default values for any zone, use the command **ibwrt "zone temperature,heater range,P,I,D"**.

For example, to change the gain from 10 to 70 for temperature set points between 200 K and 300 K, type the following command: **ibwrt "300,3,70,250,0"**.

To verify the change, use the "zone?10" command discussed above. It is *not* recommended to change any zone parameters until the user clearly understands refrigerator thermodynamics.

The Model 340 Temperature Controller only reads and displays in Kelvin temperature scale with this software installed.

6.5   MODEL 73013 CRYOSTAT OPTION

6.5.1   Equipment Needed for Model 73013 Cryostat Installation

1. A mechanical vacuum pump with pressure capability below 10^{-2} Torr and pumping speed of at least 30 liters per minute or, for temperatures below the lambda point of helium, a pumping speed of 150 liters per minute or better.

2. A Pirani or thermocouple vacuum gauge capable of measuring pressures from 1 – 500 or 1000 microns (10^{-3} –1 Torr).

3. A gas cylinder and regulator capable of delivering clean, dry, helium gas at controlled low pressure. Gauges should be capable of measuring delivery pressures of 10-to-25 centimeters of mercury above atmospheric pressure (2 – 5 psi).

4. A liquid helium storage vessel. The transfer line furnished with the Model 73013 Cryostat is well suited for 25 liter storage vessels, and readily adaptable to other capacity storage vessels. Cryogenic fluid suppliers often furnish these storage vessels on a rental basis.

5. Temperature readout instrumentation suitable for use with copper vs. constantan thermocouples. A cold junction at 0 °C 77.19 K (liquid nitrogen) is suggested.

6. A variable power supply for the heater capable of 0 – 10 volts at up to 0.5 amps of well-filtered direct current. The Lake Shore Model DRC-91CA Temperature Controller performs this function.

7. Miscellaneous vacuum hose, rubber stoppers, and hose for helium gas. These are usually on hand in any established laboratory.

6.6   MAGNETORESISTANCE (MR) OPTION

This section details the Magnetoresistance (MR) System option. Information on the High Temperature MR Option includes fixture and instrumentation installation in Paragraph 6.6.1, manifold pressure/vacuum box in Paragraph 6.6.2, Model 340 Temperature Controller initial setup in Paragraph 6.6.3,startup and system operation in Paragraph 6.6.4, and room temperature MR Option in Paragraph 6.6.5. A theory of operation and software operation for both MR versions is provided in Paragraphs 6.6.6 and 6.6.7.

CAUTION: Always raise the probe head when removing the sample. Remember to wait until the sample cools enough to be handled.

6.6.1   MR Fixture and Instrumentation Installation

The instrumentation needed to operate the MR unit should be installed into the instrument rack and that all the connections are made according to Figure 9.

1. Ensure that the magnet pole faces are 2.4 inches (6.1 cm) apart and that the air gap between the pole faces is evenly centered between the magnet.

2. Carefully place the MR unit between the pole faces so that the sample tray is facing the front. Secure the MR unit to the frame using the fastening bolts and channel nuts. The MR unit should be centered evenly between the pole pieces. The VSM Sense Coils, if installed, must not touch the MR Unit. There must be a small air gap between the MR Unit and the sensing coils.

3. Connect the 10-pin connector coming from the instrumentation to the sample tray connection.

4. Connect the 4-pin connector coming from the instrumentation to the connector on the MR unit.

5. Ensure that the cabling to the power supply is hooked up correctly.

6.6.2   Manifold Pressure/Vacuum Box

1. The Gas/Air/Vacuum Manifold should be attached to a convenient location on the frame that surrounds the magnet. Attach the tubing connections to the manifold as shown in Figure 11.

2. Connect the air pressure/vacuum/gas hoses to the proper connections on the MR unit. Please refer to Figure 12 for the specific locations of these connectors on the MR unit.

NOTE: Maximum pressure for the gas and compressed air supplies should not exceed 50 psi.

3. The gas supply should be that of an inert gas such as argon.

WARNING: Do not use any volatile gas supplies. The use of any volatile gases, such as hydrogen or oxygen, could result in an explosion.

4. The **VAC/GAS Switch** controls if vacuum will be pulled on the sample chamber or if the gas will be allowed to flow into the chamber.

5. The **CHAMBER FILL VALVE Switch** controls whether or not the chamber is open or closed to either the vacuum or gas.

REGULATING SAMPLE CHAMBER PRESSURE

6. Use the regulator valve to adjust the amount of gas flowing into the MR unit's chamber. The regulator valve has a locking mechanism. To adjust the regulator, pull the handle out. To lock the regulator, push the handle in.

7. Ensure that the sample tray is closed and the thumbscrews have been tightened when doing this, so that the back pressure can be taken into account.

8. Push the **VAC/GAS Switch** to the gas position.

9. Push the **CHAMBER FILL VALVE Switch** to the open position.

Manifold Pressure/Vacuum Box (Continued)

10. Use the regulator on the manifold to adjust the gas pressure to be within 1–3 psi, as read on the meter on the manifold box. Excess pressure will cause the pop-off valve on the MR unit to vent.

PURGING THE SAMPLE CHAMBER

11. In order to not cause a build-up of oxidation on the copper heater block, the MR unit will need to be purged of ambient atmosphere and filled with a inert gas such as argon. This is only necessary for temperatures above 100°C.

12. Evacuate the sample chamber by placing the **VAC/GAS Switch** to the VAC position.

13. Push the **CHAMBER FILL VALVE Switch** to the open position.

14. After about a minute the chamber should be fairly well evacuated.

15. Purge the MR unit with an inert gas by moving the **VAC/GAS Switch** to the GAS position. When the chamber has filled with the inert gas, evacuate it again. Do this several times to ensure that no ambient atmosphere is left inside the unit.

6.6.3   Lake Shore Model 340 Temperature Controller Initial Set-Up

1. The Model 340 Temperature Controller must be set up in order to ensure good temperature control and stability.

2. The user should review the manual that came with the Model 340 Temperature Controller.

3. The zones on the Model 340 Temperature Controller need to be setup to accommodate the MR unit. Below are the suggested values that should be used.

Zone Settings				
Top °C (K)	P	I	D	Heater Range
50 (323)	20	10	0	4
100 (373)	20	10	0	4
150 (423)	50	15	0	4
400 (463)	10	15	50	5

6.6.4   Startup and System Operation

1. Start the computer. When Windows has finished loading, start the MR software. Refer to the MR software section for proper usage. **THE MR PROGRAM MUST BE RUNNING BEFORE THE POWER SUPPLY IS TURNED ON.** This ensures that the power supply does not receive any false control signals, thus spiking the power supply.

2. Turn on the magnet power supply by placing the Mains switch to Standby. Push the green button to operate. The power supply should now be operational.

LOADING THE SAMPLE TRAY

3. The sample should now be loaded into the sample tray.

4. Switch the probe head to the "up" position by using the **4-PT PROBE Switch** on the manifold box.

5. Open the sample tray by loosening the thumb screws that are located above and below the sample tray.

6. Slide the sample tray to the open position.

7. Place the sample in the middle of the tray.

8. Carefully slide the sample tray back into position. Tighten the thumb screws.

9. Lower the probe head by placing the **4-PT PROBE Switch** on the manifold box to the down position.

Startup and System Operation (Continued)

10. With the head in the down position, optimum probe placement is now needed.

11. With the MR software running, press the **RESISTANCE MEASUREMENT** button on the screen. Enter the values that will be used to test your sample. For more information on using the Resistance Measurement feature, please see the software section.

12. Press the **MEASURE RESISTANCE** Button. The display will show the resistance measurement of the sample. It is updated at twice a second.

13. Using the 4-point adjustment micrometer, and while watching the resistance display, raise (turn knob counter-clockwise) or lower (turn knob clockwise) until 4-point probe just touches the sample.

14. Lower the head further by turning the micrometer knob two full rotations clockwise. The probe head should now be in optimum contact with the sample.

15. If samples of the same thickness are to be tested, this process does not need to be repeated. It only needs to be repeated with samples of differing thickness.

16. Purge the sample chamber as described in Paragraph 6.7.2 Step 11.

17. The sample is now ready to be tested. Follow the steps in the software operation manual for setting up and running experiments.

18. When removing the sample, **always remember to raise the probe head.** If the probe head is not raised when the sample is removed, damage to the probe head and sample could take place. Also, remember to wait until the temperature cools enough for the sample to be handled.

CAUTION: Always raise the probe head when removing the sample. Remember to wait until the sample cools enough to be handled.

19. Repeat the above steps when testing a new sample

WIRE/CABLE	DESCRIPTION
A,B,C	Voltage/Current Source Cable From Switching Unit (See Figure 6-9 For Proper Installation)
D	Trigger Link Cable
E	9-Pin Connector With Pins 8 And 9 Shorted
F	4-Pin Connector Cable To MR Unit
G,N	12-Inch Coax Cable
H	IEEE-488 Interface Cable
J	Coax Cable To Banana Plug Connector
K	10-Pin Connector To MR Unit
L	Twinax Cable To Power Supply
M	Coax Cable To VSM Model 735 Control Unit – Program Output (–10 V To +10 V)
P	Coax Cable To VSM Model 735 Control Unit – Field Input (–3 V To +3 V)
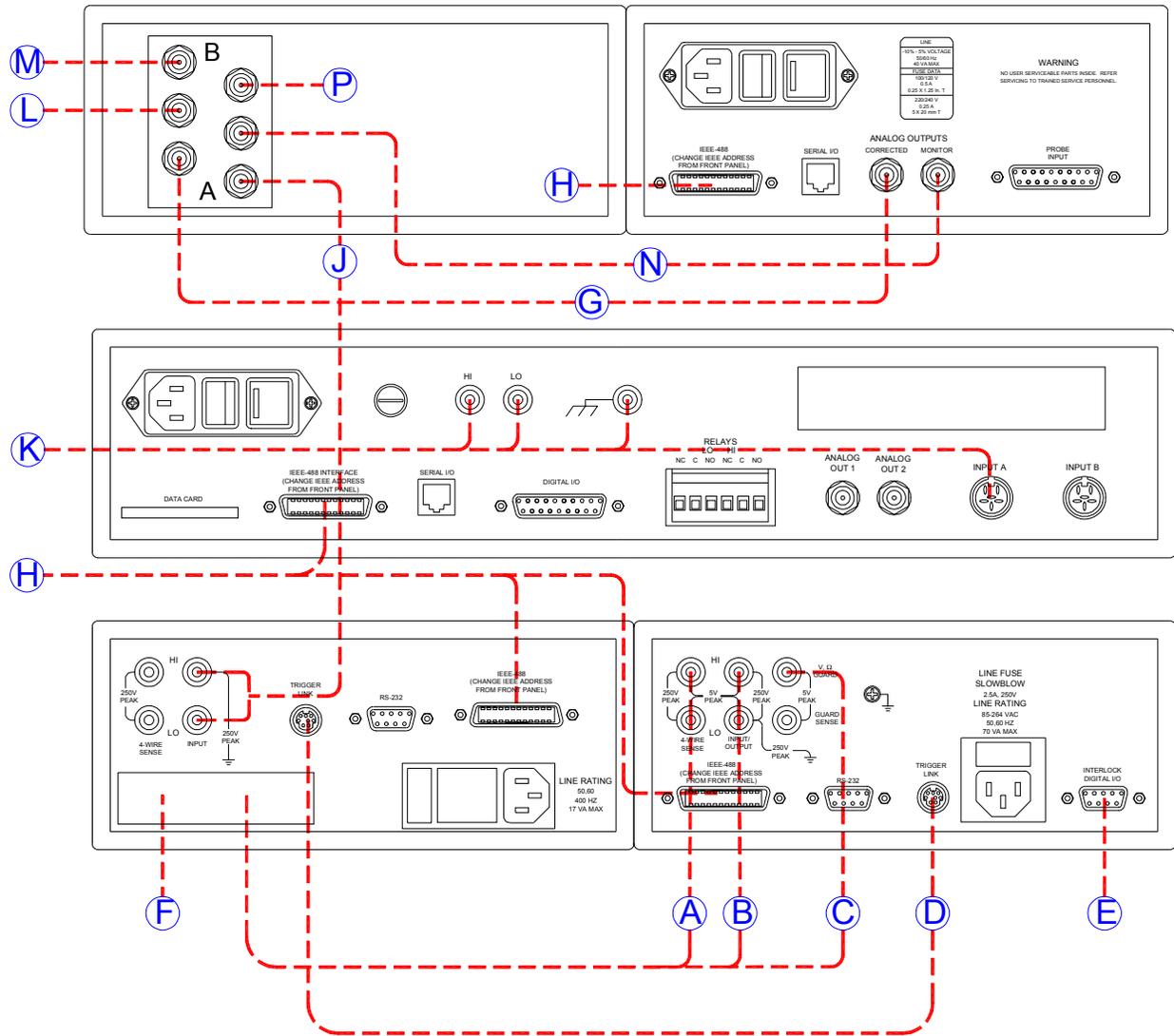
Figure 6-9. MR Option Wiring Diagram
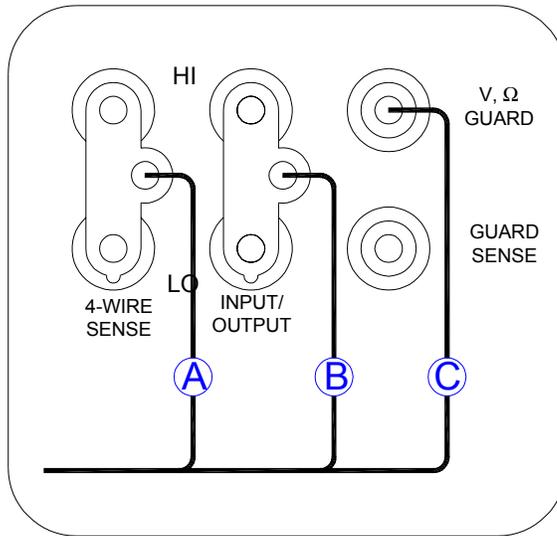
Figure 6-10. Voltage/Current Source Lead Hookup
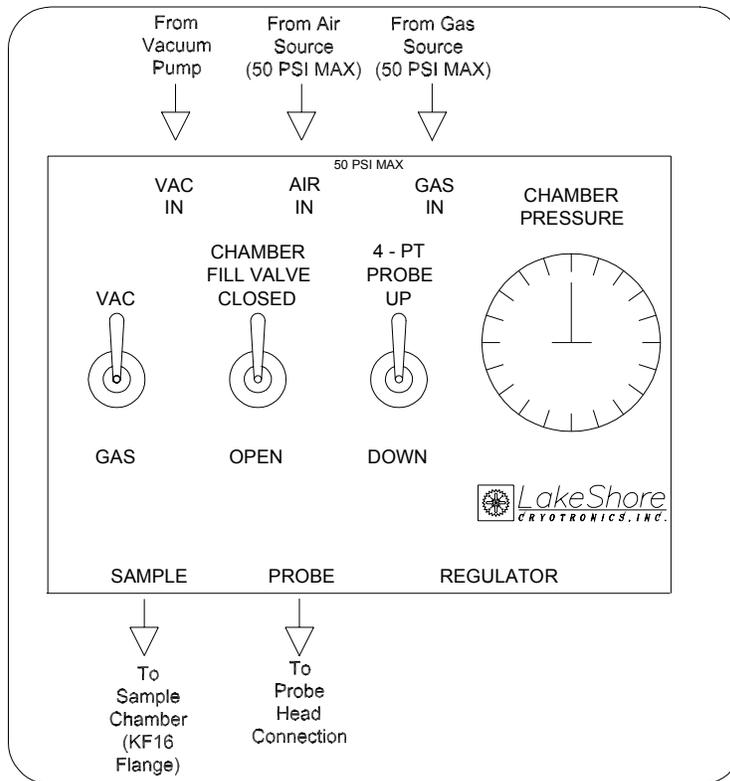
Figure 6-11. Manifold Pressure/Vacuum Box

Air Pressure For
Probe Head

KF16 Flange For
Vacuum/Gas
Connection

Rear

Sample Tray

Upper
Thumb-
screws

10-Pin Connector
For Heaters and
Temperature
Sensors

Lower
Thumb-
screws

4-Pin Connector For
4-Point Probe
Measurements

3-4 PSI Pop-Off Valve

Front
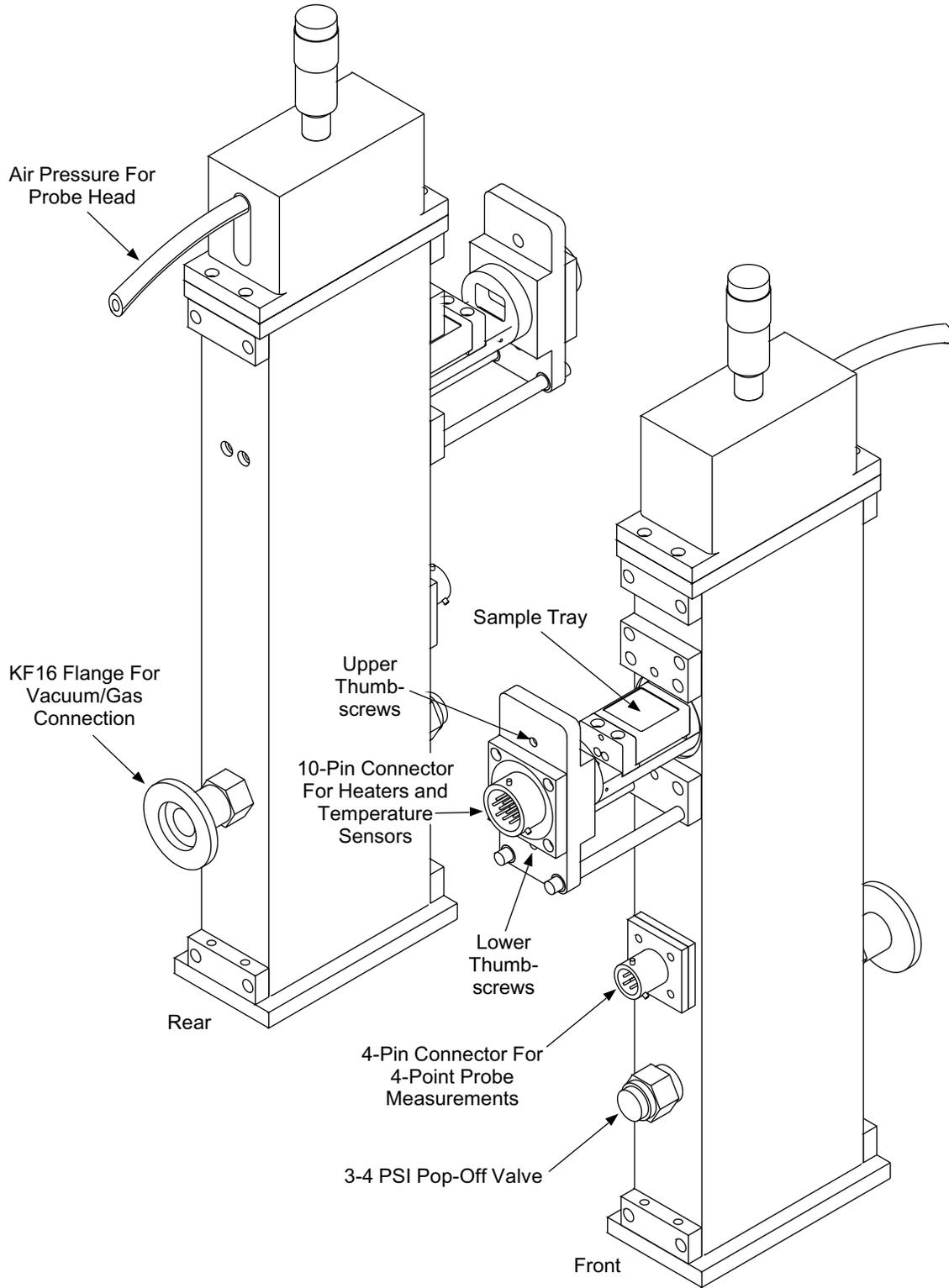
C-7300-6-18.eps

Figure 6-12. High-Temperature MR Unit Assembly

6.6.5 Room Temperature MR Unit

Operation of the Room Temperature MR System is very similar to the High Temperature Magnetoresistance System. The same software, instrumentation, and cabling is utilized. The difference lies in the simplified fixture mounted into the magnet gap for holding the sample. See Figure 6-13 for an illustration of the Room-Temperature MR Fixture.

6.6.5.1 Installation

The electromagnet gap should be set to a nominal 2-inch air gap. Mount the room temperature fixture to the option supporting bracket below the magnet gap. Use the fastening bolts and channel nuts provided. Be sure to center the fixture between the poles and between the VSM sensing coils if present. The hinge on the fixture cover should be oriented towards the front of the magnet.

The instrumentation should be connected as described for the high temperature MR system. Note that the Model 340 Temperature Controller is not needed, so connections or cables to that instrument will not be utilized. The 4 pin connector cable (refer to cable F) connects to the room temperature fixture. This cable contains the 2 current and 2 voltage leads required for making the resistance measurement. The mating connector for this cable is not seen in the view shown for the room temperature fixture but is found on the rear of the fixture when properly mounted in the magnet.

6.6.5.2 Operation

The room temperature MR fixture may be rotated in and out of the magnet gap. Pull the locking plunger out to rotate the fixture forward. There are mating holes for the locking plunger to lock the fixture in either the forward position or in the magnet gap. Rotating the fixture out of the gap not only facilitates sample loading, but also permits a VSM measurement to be done without having to remove the fixture from the supporting bracket below the magnet gap.

Load a sample by raising the hinged cover, placing the sample on the sample mounting plate, and then re-closing the cover. The 4-point spring contacts are mounted on the underside of the cover and will contact the sample when the cover is closed.

Follow the directions in the MR software manual for setting up and running experiments.

6.6.5.3 Maintenance

The 4-point probes are spring loaded assemblies. Each probe is a self contained spring loaded pogo pin that is held in place by a socket. The pins are replaceable. Contact the factory for the appropriate part if replacement is necessary (Mfg P/N 653-227).

COVER, 4-PT. PROBE

SAMPLE MOUNTING PLATE

4 PIN CONNECTOR
FOR 4-PT. PROBE

BOTTOM MOUNTING
PLATE

LOCKING
PLUNGER

TO FRONT OF MAGNET
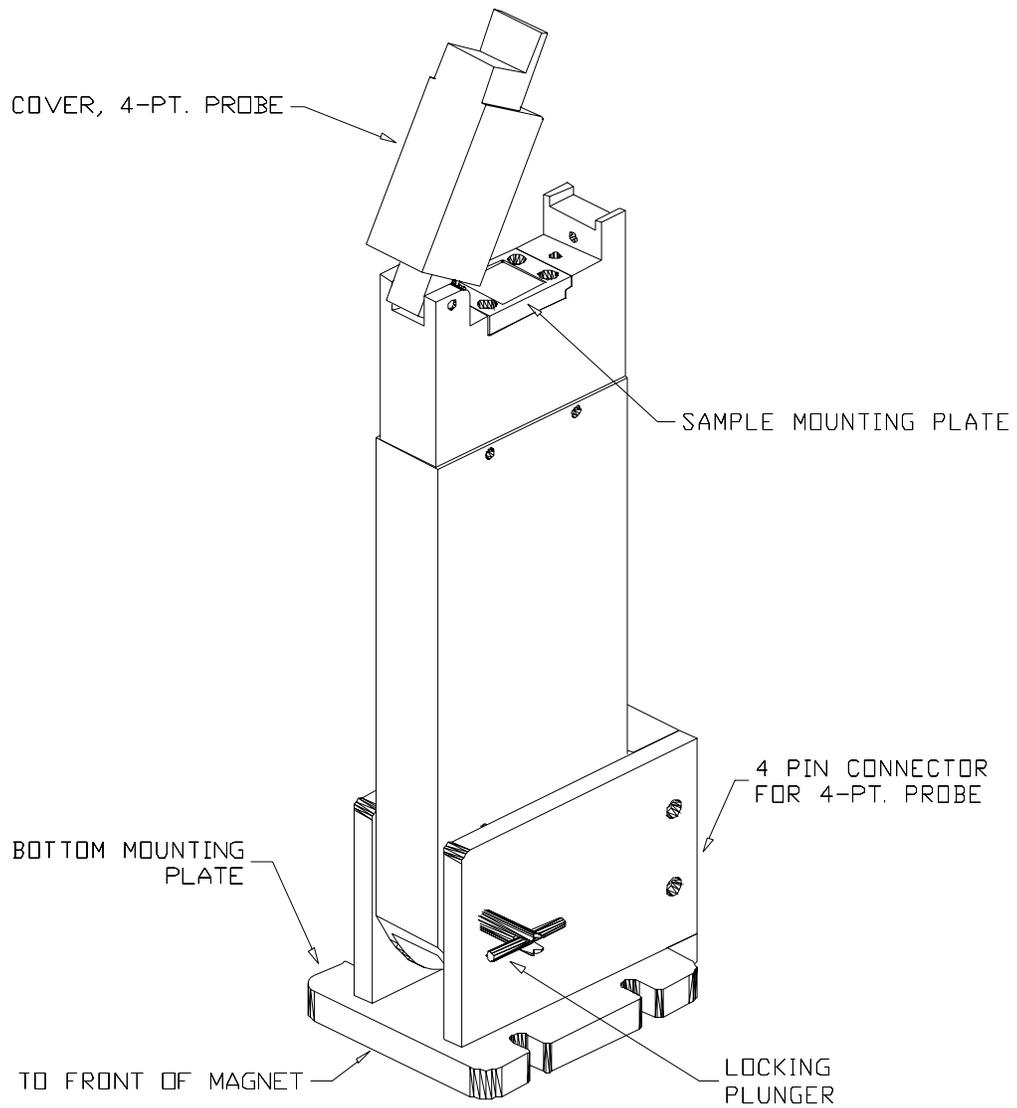
Figure 6-13. Room-Temperature MR Unit Assembly

6.6.6   Theory Of Operation

A magnetoresistance (MR) experiment consists of a field sweep with a sample under a level of current excitation. A profile may consists of MR experiments as well as time or temperature ramp functions spaced between these field sweeping MR experiments.

The sourcemeter provides the source of DC current excitation to the sample. The current excitation is through the outermost pins contacting the sample. The inner pins contacting the sample are used to read the voltage in a four wire type of measurement. The sourcemeter then calculates the resistance.

Actual resistance data is collected by executing two parallel processes. The data is gathered automatically by the multimeter and sourcemeter once given the command from the high level software on the computer. The field is swept by the corrected analog output line from the gaussmeter under software control on the computer. The software actively controls the sweeping of the field. But the data collection process is started by a command from the high level software and runs autonomously until instrument buffers are filled and read by the computer.

The multimeter and sourcemeter are connected via a trigger cable. The multimeter is used to provide a time-based trigger to itself and to the sourcemeter. As the multimeter is storing uncalibrated field readings at regular clock intervals, the sourcemeter is storing resistance readings based on the same trigger signal. By this method, the field and resistance data are stored synchronously. Data is stored every 20 milliseconds. The buffers on both instruments are used to store 1000 samples of data. Therefore the buffers are filled after 20 seconds of operation. Two sets of data are collected during a measurement. The first set of data of 1000 samples is stored when the field is swept from the positive maximum field to the negative maximum field. The instrument buffers are emptied at this time to the computer. Then a second set of data of 1000 samples is collected as the field is swept from the negative maximum field to the positive maximum field. So 2000 field readings and resistances are collected on each complete field swept resistance measurement. This number of data points is constant for all measurements. Measurements with smaller field excursions will have a denser number of data points. It doesn't matter what the field excursion is, a half scan between maximum and minimum field always takes 20 seconds. The entire data collection portion of a measurement takes 40 seconds. But additional time is incurred in the measurement in several other places. The proportional, integral field controller must ramp the field initially to the maximum positive field. After the first scan of data, the field controller operates again briefly to accurately settle on the negative maximum field. Finally at the end of the measurement, the field is ramped back to zero before the measurement is completed. The total measurement time will include all these factors.

The field information is obtained from the gaussmeter. The software uses the gaussmeter for several functions. First, some field readings are done over the IEEE-488 serial bus. This is done typically when a measurement is not in progress and the software is sitting statically. In this state, there is a measure of field control exerted to try to keep the field in the gap as close to zero as possible. The field control that exists going to the initial maximum field and returning to zero field also reads the field directly over the serial bus.

When actual resistance data is being collected during a field sweep, the analog monitor output from the gaussmeter that reflects the magnetic field provides input to the multimeter. The multimeter has a storage buffer that stores 1000 field readings during the first half of the sweep and stores another 1000 readings during the second half of the sweep.

The field readings that are stored in the multimeter from the monitor analog line from the gaussmeter are uncalibrated. The software uses information from the "mr_450_probe_data.txt" file to post process these readings after collection and retrieval from the multimeter to generate correct field values. This file is created when the system hardware is assembled and installed initially.

The gaussmeter is also used to control the magnet power supply directly. The corrected analog output from the gaussmeter is programmed by the software as a control voltage going to the analog control input on the magnet power supply. The magnet power supply is not controlled via the IEEE-488 serial bus but only by an analog control line. The update rate coming from the gaussmeter to the power supply is around 16 – 17 times per second.

Theory Of Operation (Continued)

The measurement data is stored in a simple text file. The text file consists of general header information followed by user selected parameter information. Following the parameter information is the raw data. This consists of all 2000 data points and includes the field and resistance data. The raw data is comma delimited and suitable for use in other software packages for further analysis.

The resistance graph displayed on the main form can be customized by opposite clicking or double-clicking the mouse on it and choosing various features.

Ramping to temperatures before and after resistance measurement scans can be done using the ramping features in profiles. In order to ramp to temperatures, a temperature controller must be present in the system and the relevant zone information programmed into the instrument through the front panel. The file "temperature controller ramp rates.txt" that resides in the same directory as the application must also be set up with the correct zones, ramp rates, settle thresholds, and settle times.
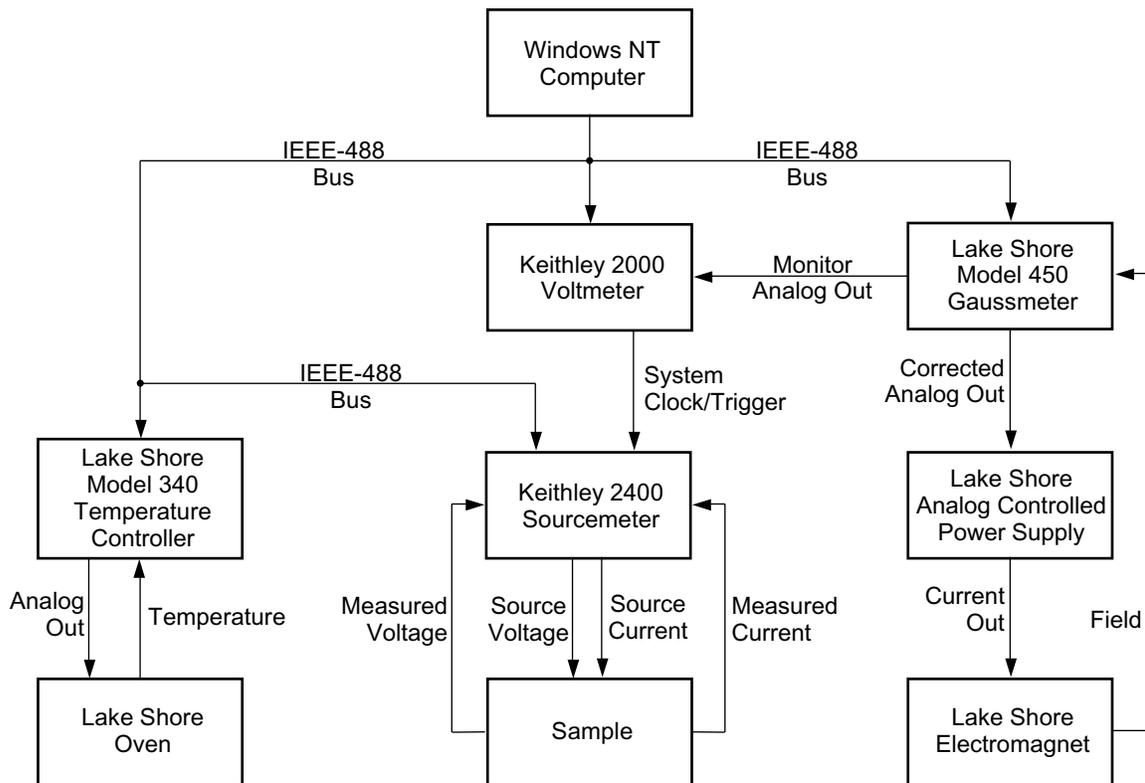
C-7300-6-20.eps

Figure 6-14. MR System Option Block Diagram

6.6.7　Software Operation

The software operation is detailed as follows: main screen in Paragraph 6.6.7.1, contact formation setup window in Paragraph 6.6.7.2, measure resistance setup window in Paragraph 6.6.7.3, measurement setup window in Paragraph 6.6.7.4, parameter extraction selection window in Paragraph 6.6.7.5, make calibration file in Paragraph 6.6.7.6, and file export window in Paragraph 6.6.7.7.

6.6.7.1　Main Screen

Press the Form Contacts button to run a sample contact formation algorithm. Initially, a setup screen will be displayed allowing the user to input parameters that control the algorithm. This button cannot be pressed when a experiment or profile is being executed.

Press the Measure Resistance button to get the resistance of the sample. Initially, a setup screen will be displayed allowing the user to input parameters that control the measurement. This button cannot be pressed when a experiment or profile is being executed.

Press the Start button to start the execution of an experiment or profile.

Press the Stop button to stop the execution of an experiment or profile.

Press the New Experiment button (or select from menu) to define a new experiment.

Press the New Profile button (or select from menu) to define a new profile.

The resulting data and/or graphic display may be printed or exported by selecting any of the following menu items, or by opposite clicking or double-clicking the mouse on the graph and choosing the export option.

File/Print Data Menu

This selection prints the parameter data for the experiment. This information is obtained from the output text file for the experiment. The raw data that is present in this file is not printed with this command.

File/Print Plot Menu

This selection prints the graph as it is displayed on the screen. Changes may be made to the graph by double-clicking or opposite clicking the mouse on it and making desired selections before printing.

File/Print Both Menu

This selection simply combines the previous two selections and prints the data and graph on separate pages.

6.6.7.2   Contact Formation Setup Window
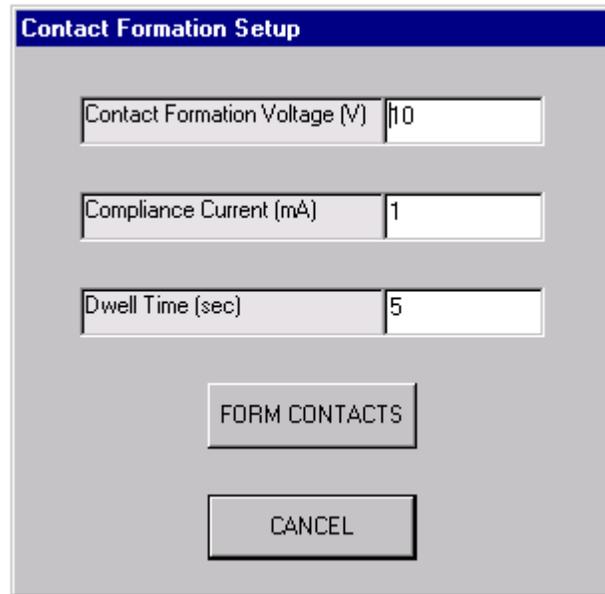
```
┌─────────────────────────────────────────────┐
│ Contact Formation Setup                      │
├─────────────────────────────────────────────┤
│                                              │
│   ┌──────────────────────────┐ ┌──────────┐  │
│   │ Contact Formation Voltage (V) │ │ 10       │  │
│   └──────────────────────────┘ └──────────┘  │
│                                              │
│   ┌──────────────────────────┐ ┌──────────┐  │
│   │ Compliance Current (mA)  │ │ 1        │  │
│   └──────────────────────────┘ └──────────┘  │
│                                              │
│   ┌──────────────────────────┐ ┌──────────┐  │
│   │ Dwell Time (sec)         │ │ 5        │  │
│   └──────────────────────────┘ └──────────┘  │
│                                              │
│              ┌────────────────────┐          │
│              │   FORM CONTACTS    │          │
│              └────────────────────┘          │
│                                              │
│              ┌────────────────────┐          │
│              │      CANCEL        │          │
│              └────────────────────┘          │
│                                              │
└─────────────────────────────────────────────┘
```

Contact Formation Voltage

This is the DC voltage in "volts" that the sourcemeter will output to the sample. The actual voltage that the sample will see depends on the lead resistance as well. The sourcemeter is capable of an output of 200 volts. Refer to the sourcemeter manual for further details.

Compliance Current

This is the DC compliance current setting in "milliamps" on the sourcemeter. The current setting may range up to 1000 milliamps. Refer to the sourcemeter manual for further details.

Dwell Time

This is the excitation dwell time in "seconds." The sourcemeter will turn on the output for this period of time and then turn the output off. The switching card in the multimeter is used to switch the excitation voltage to the second set of contacts and repeat the process. Therefore, there are two cycles involved in the contact formation process. During each cycle, the sourcemeter output will be turned on for the dwell time.

Form Contacts Button

Pressing this button will cause the contact formation algorithm to run. The setup screen will disappear and a status line indicating that contact formation is taking place will be displayed. The general idea is that contact formation will occur with the set voltage and presumed "high" resistance and then as contacts are formed, resistance will lower and current compliance will take effect so that excessive current does not go through the sample. The nominal time for the procedure to complete is two times the dwell time. Press the cancel button on the setup screen to stop the procedure from continuing. If current compliance does occur, a message box will be displayed on each cycle after it occurs.

6.6.7.3 Measure Resistance Setup Window
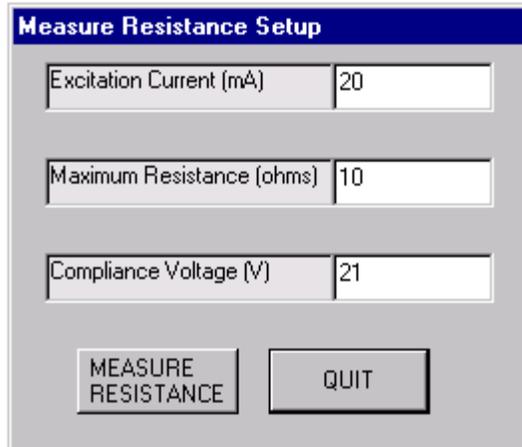
Excitation Current

This is the DC current in "milliamps" that the sourcemeter will output to the sample. The actual setting may range up to 1000 milliamps. Refer to the sourcemeter manual for further details.

Maximum Resistance

This is the expected maximum resistance of the sample. The allows the range on the sourcemeter to be set for maximum resistance accuracy. Refer to the sourcemeter manual for further details.

Compliance Voltage

This is the DC compliance voltage setting in "volts" on the sourcemeter. The voltage setting may range up to 200 volts. Refer to the sourcemeter manual for further details.

Measure Resistance Button

Pressing this button will turn on the excitation current from the sourcemeter and pop up a window with the current resistance displayed.

Quit Button

Pressing this button closes the measure resistance setup window and returns to the main program window.

Resistance Window
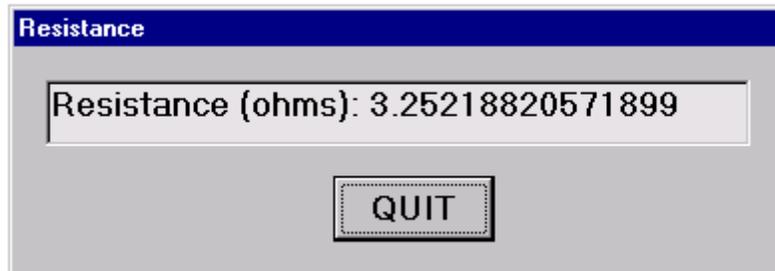
This window displays the current resistance and updates the resistance twice a second. If the sourcemeter is in voltage compliance, a compliance message will be displayed instead of the resistance.

Quit Button

Pressing this button will turn off the excitation current and close the resistance window. The software will return to the measure resistance setup window where further iterations with different setup parameters may be done.

6.6.7.4 Measurement Setup Window

Measurement Setup

Maximum Field (gauss)	1000
Proportional (gain) Control	0.0001
Integral (reset) Control	0.00005
Time Interval Control (seconds)	1
Excitation Current (mA)	20
Maximum Resistance (ohms)	10
Compliance Voltage (V)	21

CANCEL CHANGES   EXIT   PARAMETER SETUP

Maximum Field

The maximum field is the positive field the system will ramp to initially. During this ramping, the field is under a classical proportional, integral controller. Once the maximum field is reached, a different field control algorithm is utilized to ramp the field swiftly to the negative maximum field. The field is swept quickly back to the positive maximum field again before returning to zero field once again under the classical proportional, integral controller.

Proportional (gain) Control

The number entered here is used to control the field when ramping to maximum field and back to zero field at the end of a measurement.

Integral (reset) Control

The number entered here is used to control the field when ramping to maximum field and back to zero field at the end of a measurement.

Time Interval Control

The number entered here is used to control the field when ramping to maximum field and back to zero field at the end of a measurement. This is the time interval at which the controller calculates an error value and makes a corresponding adjustment to the power supply to control the field. A minimum value of 0.1 seconds has been used successfully for quick response with good results

Excitation Current

This value is the current in milliamps that will be set on the sourcemeter and enabled to excite the sample. The sourcemeter is capable of outputting 1000 milliamps. See the sourcemeter manual for further details.

Maximum Resistance

This is the expected maximum resistance of the sample. The allows the range on the sourcemeter to be set for maximum resistance accuracy. Refer to the sourcemeter manual for further details.

Measurement Setup Window (Continued)

Compliance Voltage

This is the DC compliance voltage setting in "volts" on the sourcemeter. The voltage setting may range up to 200 volts. Refer to the sourcemeter manual for further details.

Parameter Setup Button

Pressing this button will display the parameter extraction setup screen for this experiment.

6.6.7.5 Parameter Extraction Selection Window

Minimum field value for calculation window (gauss):	-900

The selected extracted parameters are calculated between the minimum field setup value and the maximum field setup value. It is possible at the end of the two individual field sweeps that make a measurement that the exact maximum field endpoint will not be reached (especially for low field excursions). If the raw data collected does not extend to the setup limits, parameters will not be calculated. Therefore, the magnitude of this value should be set slightly less than the magnitude of the maximum field setup for the field sweep excursion.

Maximum field value for calculation window (gauss):	900

The selected extracted parameters are calculated between the minimum field setup value and the maximum field setup value. It is possible at the end of the two individual field sweeps that make a measurement that the exact maximum field endpoint will not be reached (especially for low field excursions). If the raw data collected does not extend to the setup limits, parameters will not be calculated. Therefore, the magnitude of this value should be set slightly less than the magnitude of the maximum field setup for the field sweep excursion.

☑ DeltaR/R maximum

This parameter is calculated for data between the setup field limits. It is calculated as follows: ((maximum resistance) – (minimum resistance)) * 100 / (minimum resistance).

The resistance values are the values obtained from the raw data. No interpolation is done between raw data points.

☑ R at initial zero field

This parameter is obtained at the beginning of a measurement before sweeping the field to the maximum value. A resistance reading is done at the beginning of a measurement. Then the field is swept to the maximum value. When the system is not running a measurement or profile, field control is being exerted to keep the field as close to zero as possible. So the actual field when the resistance is measured may fluctuate from zero depending on the state of the field control at that time.

☑ R at first field = 0 crossing

This parameter is derived from the first set of data points when the field sweeps from the positive maximum field to the negative maximum field. It is the resistance value when the field crosses the value of zero. The resistance value is derived from the discrete raw data by using interpolation techniques.

☑ R, DeltaR, and DeltaR/R at maximum field value

These parameters are calculated at the maximum field for calculation limit. The resistance is the average of the two resistances for the two data curves at the maximum setup field. Each resistance is interpolated from the raw data and then averaged together to get the final resistance. The delta resistance is calculated as follows: (averaged resistance) - (minimum resistance of the entire data set). The final parameter is calculated as follows: (delta resistance) * 100 / (minimum resistance of the entire data set).

Parameter Extraction Selection Window (Continued)

☑ R, DeltaR, and DeltaR/R at minimum field value

These parameters are calculated at the minimum field for calculation limit. The resistance is the average of the two resistances for the two data curves at the minimum setup field. Each resistance is interpolated from the raw data and then averaged together to get the final resistance. The delta resistance is calculated as follows: (averaged resistance) - (minimum resistance of the entire data set). The final parameter is calculated as follows: (delta resistance) * 100 / (minimum resistance of the entire data set).

☑ Hex1, interlayer coupling field and Hc1, free layer coercivity

Hex1, the interlayer coupling field, is the center of the free layer. Hc1, the free layer coercivity, is the half width of the free layer. First, the halfway resistance level is calculated as follows: (maximum resistance + minimum resistance) / 2. Then the data curves are searched for resistance crossings at this level. There must be only two crossings for these parameters to be calculated. Interpolation is used to get the exact two field points corresponding to the halfway resistance crossings. Hex1 is calculated as follows: absolute value of (field point one + field point two) / 2. Hc1 is calculated as follows: absolute value of (field point one - field point two) / 2.

☑ Hex2, exchanged pinning field and Hc2, pinned layer coercivity

Hex2, the exchanged pinning field, is the center of the pinned layer. Hc2, the pinned layer coercivity, is the half width of the pinned layer. First, the halfway resistance level is calculated as follows: (maximum resistance + minimum resistance) / 2. Then the data curves are searched for resistance crossings at this level. There must be greater than two crossings for these parameters to be calculated. The smallest field value at a halfway resistance crossing is used for one point and the next field value at a halfway resistance crossing as the curve progresses is used for the second field value. Interpolation is used to determine these values more accurately. Hex2 is calculated as follows: absolute value of (field point one + field point two) /2 . Hc2 is calculated as follows: absolute value of (field point one - field point two) / 2.

☑ Hsw2, pinned layer switching field

This parameter is calculated using the four user entered fitting fields. The fields are applicable to the first data curve that is collected that goes from the positive maximum field to the negative maximum field. The fields are sorted in descending order. A linear fit is done using the data between the first two field points.

Then a linear fit is done using the data between the second two field points. The intersection of these two lines yields Hsw2.

Hsw2 fitting fields (gauss):	-100	-200
	-400	-500

These fields are used in the calculation of Hsw2. The fields need to be different but the order is not important. The software will sort them when calculating Hsw2.

☑ R near field = 0 on positive to negative field sweep

This selection yields several parameters derived from the positive maximum field to the negative maximum field data (first set of curve data). Data is analyzed between the user entered +/– field window around zero field. The maximum resistance and minimum resistance within the field window are obtained. A delta resistance is calculated as follows: maximum resistance – minimum resistance. Finally a delta resistance divided by minimum resistance is calculated as follows: delta resistance * 100 / minimum resistance.

Parameter Extraction Selection Window (Continued)
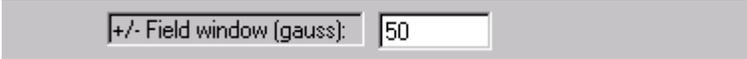
+/- Field window (gauss):   50

This parameter is used for R near field = 0 on positive to negative field sweep. This is the data analysis window around zero field.

☑ R near field = 0 on negative to positive field sweep

This selection yields several parameters derived from the negative maximum field to the positive maximum field data (second set of curve data). Data is analyzed between the user entered +/– field window around zero field. The maximum resistance and minimum resistance within the field window are obtained. A delta resistance is calculated as follows: maximum resistance – minimum resistance. Finally a delta resistance divided by minimum resistance is calculated as follows: delta resistance * 100 / minimum resistance.
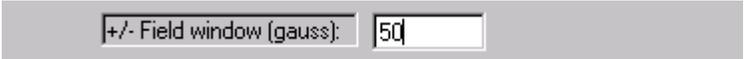
+/- Field window (gauss):   50

This parameter is used for R near field = 0 on negative to positive field sweep. This is the data analysis window around zero field.

6.6.7.6   Make Calibration File

When the hardware for the magnetoresistance (MR) system is installed, a calibration file must be created that is dependent on the gaussmeter and gaussmeter probe assembly. This text file resides in the same directory as the MR application. The name of this file is "mr_450_probe_data.txt." In this file is unique information related to the gaussmeter probe and the gaussmeter itself. This file is created by the user when the hardware in the system is assembled. After system assembly and installation, there should be no need to recreate this file. If this file is missing, error messages will appear at different states in the software reporting this fact and measurements cannot be done.

To create the Calibration file, choose this menu selection and follow the instructions as they appear. The first message states: "Place Hall probe into zero gauss chamber." Physically remove the gaussmeter probe from the magnet and inserting it into the zero gauss chamber. Press OK, then wait while the instruments perform the calibration. A status line will provide an indication of percentage of task completion. Once the calibration is complete, the message "Place Hall probe back into position in electromagnet" will appear. The whole process only takes a couple of minutes to complete.

6.6.7.7 File Export Window

This selection displays an option screen for selecting various export options for the data or graph. The option screen can also be displayed by opposite clicking or double-clicking the mouse on the graph and choosing the export option.
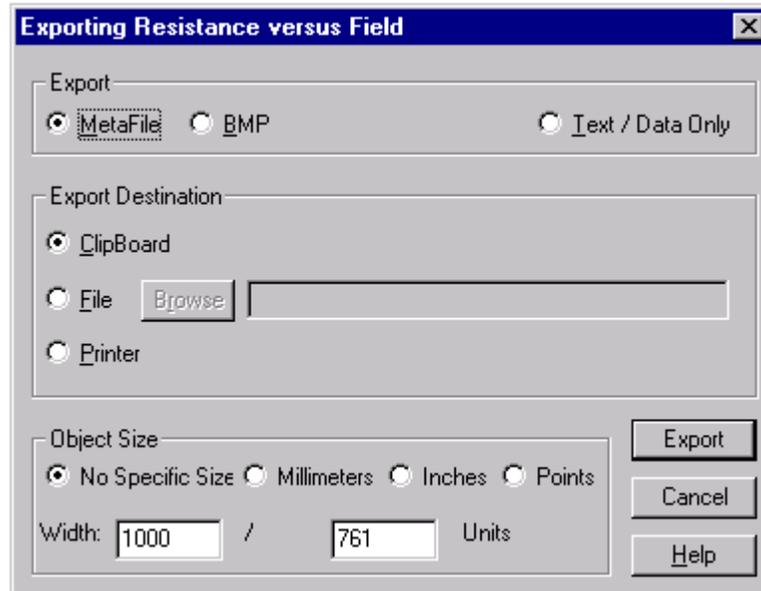
Export

There are three choices of Export format: Metafile, BMP, and Text/Data Only. Metafile will produce a graphic file with a .WMF file extension. BMP will produce a graphic file with a .BMP file extension. Text/Data Only will produce a text only file with a .TXT file extension.

Export Destination

There are three choices for Export Destination: Clipboard, File, or Printer. Clipboard will export the file, in the format selected above, to the computer clipboard. This allows the file to be "pasted" into another application. If you select File, you must first select the file name, and then the file will be exported according to the file type selected above. Finally, selecting Printer will send the file directly to whatever is currently selected as your default printer.

Object Size

There are four choices for Object Size: No Specific Size, Millimeters, Inches, or Points. Selection of Millimeters, Inches, or Points will force the graphic output to the size specified by the Width and Units entries.

6.7   INDUSTRIAL MODEL (-IND) OPTION

When requested by the customer, the Industrial Option (-IND) is incorporated. This option has two major features: a single-input power source and an emergency power off switch. This allows the user to provide a single power junction box on the wall to power all measurement equipment. To provide additional personnel safety, the following components are installed:

•   Three-phase power distribution box.

•   Instrument console rear door power interlock switch (shuts power off to equipment when door opens).

•   Remote Power On/Off switch and Emergency Power Off button.

•   Magnet power supply remote output On indication lamp.

•   Flexible conduit for power input leads to the Magnet Power Supply.

•   To prevent accidental exposure to potentially harmful electric terminals, covers are placed on all electrical terminals with voltage above 30 V.

The single power cable from the power distribution box mounted in the instrument console needs to be connected to the appropriate power source (provided by the customer). All equipment including the free-standing magnet power supply are powered through this power distribution box. In addition, a remote power On/Off panel with the Emergency Power Off (EPO) button and a power interlock switch on the instrument rear door are also provided.

During normal operation, in order to power up the equipment, the remote ON switch must be in the ON position, the EPO in the OFF position, and the rear console door closed. In addition, to provide power to the magnet, the ON switch must be energized at the magnet power supply. Power to the equipment will be disrupted if the EPO button is activated or the instrument console rear door is opened.

NOTE: Component locations shown above are typical. Actual installations may vary.
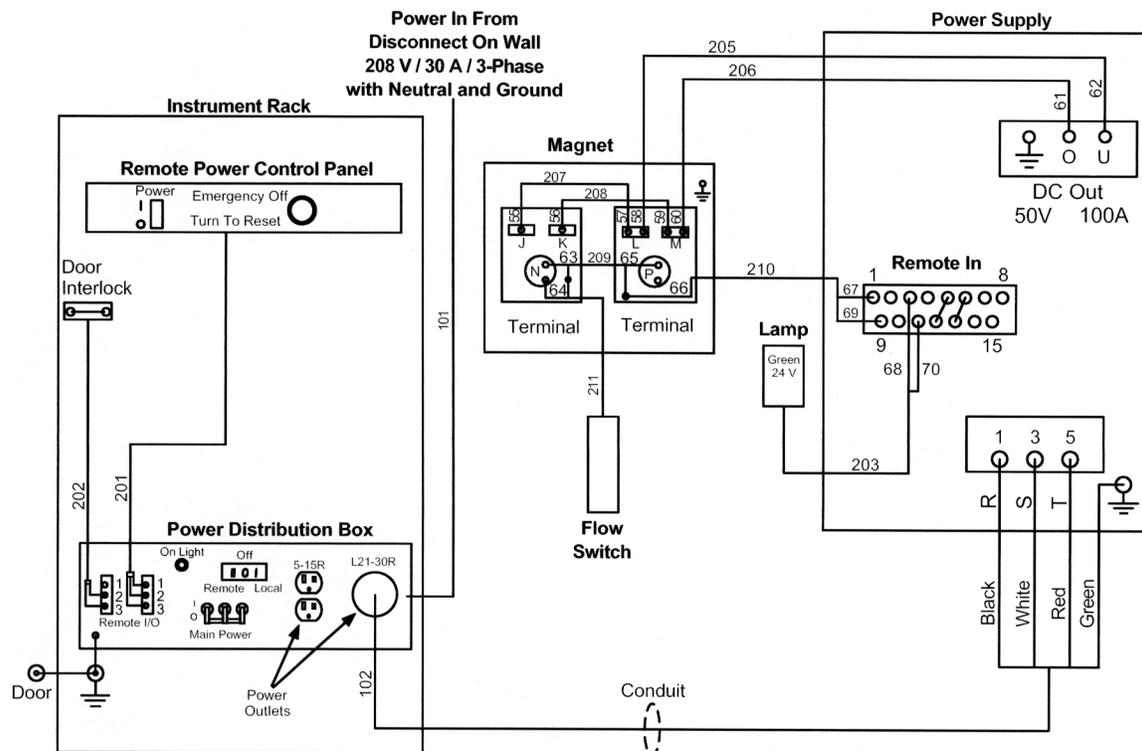
C-7300-6-21.bmp

Figure 6-15. Industrial Option Wiring Diagram

APPENDIX A

GLOSSARY OF TERMINOLOGY

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.

actuator arm. Pivot arm with coil assembly on one end and read/write heads on the other end.

algorithm. A set of well-defined rules for the solution of a problem in a finite number of steps.[1]

American Standard Code for Information Exchange (ASCII). A standard code used in data transmission, in which 128 numerals, letters, symbols, and special control codes are represented by a 7-bit binary number as follows:

b4 b3 b2 b1	Row	0	1	2	3	4	5	6	7
0 0 0 0	0	NUL	DLE	SP	0	`	P	@	p
0 0 0 1	1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	2	STX	DC2	"	2	B	R	b	r
0 0 1 1	3	ETX	DC3	#	3	C	S	c	s
0 1 0 0	4	EOT	DC4	$	4	D	T	d	t
0 1 0 1	5	ENG	NAK	%	5	E	U	e	u
0 1 1 0	6	ACK	SYN	&	6	F	V	f	v
0 1 1 1	7	BEL	ETB	'	7	G	W	g	w
1 0 0 0	8	BS	CAN	(	8	H	X	h	x
1 0 0 1	9	HT	EM	)	9	I	Y	i	y
1 0 1 0	10	LF	SS	*	:	J	Z	j	z
1 0 1 1	11	VT	ESC	+	;	K	[	k	{
1 1 0 0	12	FF	FS	,	<	L	~	l	―
1 1 0 1	13	CR	GS	—	=	M	]	m	}
1 1 1 0	14	SO	RS	.	>	N	^	n	|
1 1 1 1	15	SI	US	/	?	O	_	o	DEL

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

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 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 with 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]

+ Anode ▶|— Cathode −

area. A measure of the size of a two-dimensional surface, or of a region on such a surface.[1]

area·turns. A coil parameter produced by the multiplication of a magnet's area and number of turns. Gives an indication of the sensitivity of a coil.

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

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]

bipolar magnet. A permanent magnet that has been magnetized in two different field directions, with one side being designated north and the other south.

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

CalCurve™ Service. The service of storing a mathematical representation of a calibration curve on an EEEPROM or installed in a Lake Shore instrument. Previously called 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]

$$+ \quad \text{Anode} \quad \blacktriangleright\!\!|\!\!- \quad \text{Cathode} \quad -$$

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.

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

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.

compliance voltage. *See* current source.

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.

demagnetization. when a sample is exposed to an applied field (H_a), poles are induced on the surface of the sample. Some of the returned flux from these poles is inside of the sample. This returned flux tends to decrease the net magnetic field strength internal to the sample yielding a true internal field (H_{int}) given by: $H_{int} = H_a - DM$, where M is the volume magnetization and D is the demagnetization factor. D is dependent on the sample geometry and orientation with respect to the field.

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

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 absolute temperature (in Kelvin) must be used in these expressions.

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]

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.

electron. An elementary particle containing the smallest negative electric charge. *Note:* The mass of the electron is approximately equal to 1/1837 of the mass of the hydrogen atom.[2]

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]

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.

flux (ϕ). The electric or magnetic lines of force in a region.[1]

flux density (B). Any vector field whose flux is a significant physical quantity; examples are magnetic flux density, electric displacement, and gravitational field.[1]

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 = 1 Mx/cm^2 = $line/cm^2$. 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.

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 $10/4\pi$ 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	A	Iota	ι	I	Rho	ρ	P
Beta	β	B	Kappa	κ	K	Sigma	σ	Σ
Gamma	γ	Γ	Lambda	λ	Λ	Tau	τ	T
Delta	δ	Δ	Mu	μ	M	Upsilon	υ	Y
Epsilon	ε	E	Nu	ν	N	Phi	ϕ	Φ
Zeta	ζ	Z	Xi	ξ	Ξ	Chi	χ	X
Eta	η	H	Omicron	o	O	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 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), American physicist.

Hall mobility. The quantity μH in the relation $\mu H = R\sigma$, where R = Hall coefficient and σ = conductivity.[2]

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.

Helmholtz coils. A pair of flat, circular coils having equal numbers of turns and equal diameters, arranged with a common axis, and connected in series; used to obtain a magnetic field more nearly uniform than that of a single coil.[1]

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

hole. A mobile vacancy in the electronic valence structure of a semiconductor that acts like a positive electron charge with a positive mass.[2]

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.

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.

integrator. A circuit or network whose output waveform is the time integral of its input waveform.[1]

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).

$$B_i = B - \mu_O H \quad (SI) \qquad\qquad B_i = B - H \quad (cgs)$$

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

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.

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 of flux. An imaginary line in a magnetic field of force whose tangent at any point gives the direction of the field at that point; the lines are spaced so that the number through a unit area perpendicular to the field represents the intensity of the field. Also know as a Maxwell in the cgs system of units.

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

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.

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 scalar potential. The work which must be done against a magnetic field to bring a magnetic pole of unit strength from a reference point (usually at infinity) to the point in question. Also know as magnetic potential.[1]

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.

magnetostatic. Pertaining to magnetic properties that do not depend upon the motion of magnetic fields.[1]

material safety data sheet (MSDS). OSHA Form 20 contains descriptive information on hazardous chemicals under the OSHA 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.

Maxwell (Mx). A cgs electromagnetic unit of magnetic flux, equal to the magnetic flux which produces an electromotive force of 1 abvolt in a circuit of one turn link the flux, as the flux is reduced to zero in 1 second at a uniform rate.[1]

neutral zone. The area of transition located between areas of a permanent magnet which have been magnetized in opposite directions.

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).

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

National Institute of Standards and Technology (NIST). Government agency located in Gaithersburg, Maryland and Boulder, Colorado, that defines measurement standards in the United States. *See* Standards Laboratories for an international listing.

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

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 the temperature in kelvin and R is the resistance in ohms.

oersted (Oe). The cgs unit for the magnetic field strength (H). 1 oersted = $10\frac{3}{4}\pi$ ampere/meter $\approx$ 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 ith fit coefficient and x_i is some function of the dependent variable.

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.

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 the physical display of an instrument. 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.

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]

scalar. A quantity which has magnitude only and no direction, in contrast to a vector.[1]

semiconducting material. A conducting medium in which the conduction is by electrons, and holes, and whose temperature coefficient of resistivity is negative over some temperature range below the melting point.[2]

semiconductor. An electronic conductor, with resistivity in the range between metals and insulators, in which the electric charge carrier concentration increases with increasing temperature over some temperature range. Note: Certain semiconductors possess two types of carriers, namely, negative electrons and positive holes.[2]

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]

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

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

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:

	kelvin	Celsius	Fahrenheit
Boiling point of water	373.15 K	100 °C	212 °F
Triple point of water	273.16 K		
Freezing point of water	273.15 K	0 °C	32 °F
Absolute zero	0 K	−273.15 °C	−459.67 °F
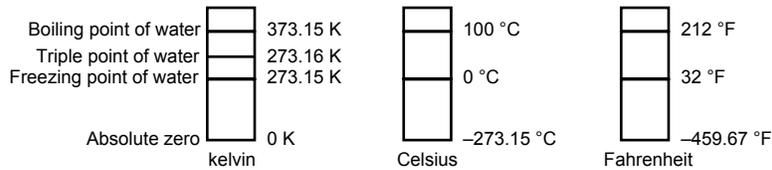
To convert kelvin to Celsius, subtract 273.15.
To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or: °F = (1.8 × °C) + 32.
To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or: °C = (°F − 32)/1.8.

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]

tolerance. The range between allowable maximum and minimum values.

torque. For a single force, the cross product of a vector from some reference point to the point of application of the force with the force itself. Also known as moment of force and rotation moment.[1]

torque constant (K_t). The ratio of the torque delivered by a motor to the current supplied to it. K_t = N·m/A.

turns (N). One complete loop of wire.

Underwriters Laboratories (UL). An independent laboratory that establishes standards for commercial and industrial products.

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

vector. A quantity that has both magnitude and direction, and whose components transform from one coordinate system to another in the same manner as the components of a displacement. Also known as a polar vector.[1]

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]

weber (Wb). The unit of magnetic flux in the mks system, equal to the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.[1]

References:

1   Sybil P. Parker, Editor. *Dictionary of Scientific and Technical Terms: Fifth Edition*. New York: McGraw Hill, 1994 (IBSN 0-07-113584-7)

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

REFERENCE INFORMATION

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$^{3\text{h}}$	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$^{2\text{i}}$
(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$^{-\frac{1}{2}}$ ·g$^{\frac{1}{2}}$·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 uder SI, even thoug 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, $\mu 0ce2/2h$	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 ($T_0 = 273.15$K, $p_0 = 1$ 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.