USER'S MANUAL

7000 SERIES

AC SUSCEPTOMETERS

Model 7120 AC Susceptometer System
Model 7120A AC Susceptometer System
Model 7121 AC Susceptometer System
Model 7125 AC Susceptometer System
Model 7129 AC Susceptometer System
Model 7130 AC Susceptometer System

AC SUSCEPTOMETER/DC MAGNETOMETERS

Model 7221 AC Susceptometer/DC Magnetometer System
Model 7225 AC Susceptometer/DC Magnetometer System
Model 7229 AC Susceptometer/DC Magnetometer System

The 7000 Series Software May Include:
ACS7000 AC Susceptometer Software
DCM7000 DC Magnetometer Software
ACM7000 AC Moment Software
RES7000 AC/DC Resistance Software

Applicable U.S. Patents:
5,506,500
5,311,125
5,280,240
5,283,524

LakeShore.

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Manual No. MAN-7000-A5 **29 April 1996**

Subject	Paragraph, Figure (F), Table (T) Number

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V

W - X - Y - Z

LIMITED WARRANTY

Lake Shore Cryotronics, Inc. (henceforth Lake Shore), the manufacturer, warrants this product for a period of twelve (12) months (six months for sensors) 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.

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

THIS WARRANTY IS IN LIEU OF ANY OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, WHICH ARE EXPRESSLY EXCLUDED. THE OWNER AGREES THAT LAKE SHORE'S LIABILITY WITH RESPECT TO THIS PRODUCT SHALL BE SET FORTH IN THIS WARRANTY, AND INCIDENTAL OR CONSEQUENTIAL DAMAGES ARE EXPRESSLY EXCLUDED.

SOFTWARE LIMITATIONS

Lake Shore has worked to ensure that the 7000 Series 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.

SOFTWARE LICENSE AGREEMENT

This software is protected by United States copyright law and international treaty provisions. Lake Shore provides this software package and grants you (the user of the software) a non-exclusive and non-transferable right to use this software. Unless as provided in this Agreement, any attempt to sublicense, lease, rent, assign, or transfer this license or this software is void. To maintain software warranty, the source code must not be modified. Any changes made to the ACS source code are at the user's risk. Lake Shore will assume no responsibility for damage or errors incurred as result of any changes made to the source code.

Under the terms of this agreement you may use the ACS7000, DCM7000, ACM7000, and RES7000 Software solely on the computer system provided with the 7000 Series System. The software should already be loaded on the computer hard drive. Archival floppy disks are provided for the sole purpose of protecting the software from loss. Any unauthorized duplication or use of the Lake Shore 7000 Series System Software in whole or in part, in print, or in any other storage and retrieval system is forbidden.

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).

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 recertification service is offered by Lake Shore at a reasonable cost.

PATENTS

The AC/DC measurement method employed by the Lake Shore 7000 Series is protected by U.S. Patents 5,506,500, "Magnetic Property Characterization System Employing A Single Sensing Coil Arrangement To Measure Both AC Susceptibility and DC Magnetization," and 5,311,125, "Magnetic Property Characterization System Employing A Single Sensing Coil Arrangement to Measure AC Susceptibility and DC Moment of a Sample." In addition, Lake Shore has an exclusive license agreement for use the following patents: U.S. Patent 5,280,240, "Methodology Using Odd Harmonics Components of an Induced Magnetic Field for Analyzing Superconducting Magnetic Materials and their Properties," and U.S. Patent 5,283,524, "AC Magnetic Susceptometer with Odd Harmonic Measurement for Analyzing Superconductive Magnetic Materials," A.A. Shaulov, R.N. Bhargava, D.R. Dorman, assignees to U.S. Philips Corporation.

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.

Cryo-Gloves® is a trademark of Tempshield
MS-DOS© is a trademark of Microsoft Corporation
NI-488.2™ is a trademark of National Instruments
PolyFlo™ is a trademark of Imperial Eastman
Shockwatch® is a trademark of Media Recovery, Inc.
SigmaPlot™ is a trademark of Jandel Scientific
Swagelok® is a trademark of Swagelok Company
Teflon® is a trademark of DuPont De Nemours
Tip-N-Tell is patented by ULine, Inc.
Vectra™ is a trademark of Hewlett-Packard

Subject	Paragraph, Figure (F), Table (T) Number

T

7000 SERIES SYSTEM CONFIGURATION

Sales Order Number: ______________________________

System Serial Number: ______________________________

Shipping Date: ______________________________

Power Settings:

Instrument Console: ______________________________

Pump Box: ______________________________

Magnet Power Supply: ______________________________

Level Monitor: ______________________________

This is a list of all the major systems and options you have ordered. Please read all the related chapters in this manual before attempting to install and operate the equipment.

________ **Model 7120** or **7120A** AC Susceptometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7121** AC Susceptometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7125** AC Susceptometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7129** AC Susceptometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7130** AC Susceptometer System

________ **Model 7221** AC Susceptometer/Magnetometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7225** AC Susceptometer/Magnetometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

________ **Model 7229** AC Susceptometer/Magnetometer System with the following options:
- ❒ 30 Liter Dewar, or ❒ 60 Liter Dewar
- ❒ Model 700TLF Helium Transfer Line

All Models
- ❒ Model 700ACM AC Moment Measurement Option
- ❒ Model 700HM Harmonic Measurement Option
- ❒ Model 700LT Low Temperature Cryostat Option
- ❒ Model 700RES AC/DC Resistance Measurement Option
- ❒ Jandel Scientific SigmaPlot™ Option

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TABLE OF CONTENTS

ALPHABETICAL INDEX

The following is an alphabetical index of the headings and major topics contained in the Lake Shore 7000 Series System User's Manual. An alphabetical index is different than a page number index: the reader is referred directly to a paragraph, figure, or table number. A paragraph number reference is simply a number in the point system (1.1.1). Figure and table numbers are prefaced with an F or T respectively. Information in the Appendices is prefaced with the Appendix Letter (A-1.0). A figure or table reference in an appendix is delineated by a slash (/), e.g., T/A-1. Major topic headings are shown in all capitals with subordinate headings indented and in alphabetical order.

LIST OF ILLUSTRATIONS

ACSCU IEEE Commands (Continued)

MSTAT?

Motor Status Query.

Input: `MSTAT?`

Returned: `0`, `1`, `2`, or `3`

Remarks: Returns the status of the last motion of the stepper motor. The value returned will be 1 digit. A "0" returned means the motion is still in progress, a "1" returned means the motion is complete, a "2" returned means the motor is at the upper limit and a "3" returned means the motor is at the lower limit.

Example: If the motion is still in progress, MSTAT?[term] would return 0[term].

RATE

Stepper Motor Step Rate Command.

Input: `RATEXXX`

Returned: Nothing

Remarks: Command to set the stepper motor step rate. Fill in the step rate constant with a value from 1 to 255. The actual step rate will be constant *50 µs per step.

Example: RATE010[term] would move the stepper motor shaft at a rate of 500 µs per step.

RATE?

Motor Step Rate Constant Query.

Input: `RATE?`

Returned: `XXX`

Remarks: Returns the current motor step rate constant. The value returned will be 3 digits. Leading zeroes will be returned for step rate constants less than 100.

Example: If the current step rate constant is 20, RATE?[term] will return 020[term].

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

ACSCU IEEE Commands (Continued)

HARM

Set Harmonic Reference Command.

Input: `HARM XX`

Returned: Nothing

Remarks: Sets the harmonic reference. Fill in the harmonic parameter with a value from 1 through 10. The 1st, 2nd, and 3rd harmonics are available for all frequencies. The 4th through the 10th harmonics are available for selected frequencies. See the harmonic table below.

HARMONICS	FREQUENCIES
1, 2, 3	All frequencies.
4 to 10	f = 1, 2, 3, 4, 5,6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 24, 25, 28, 30, 32, 35, 36, 40, 45, 48, 50, 56, 60, 64, 70, 72, 75, 80, 90, 100, 120, 125, 140, 150, 160, 175, 180, 200, 225, 240, 250, 280, 300, 320, 350, 360, 375, 400, 450, 500, 600, 625, 700, 750, 800, 875, 900, 1000, 1200, 1250, 1400, 1500, 1600, 1750, 1800, 2000, 2250, 2500, 3000, 3500, 4000, 4500, 5000, 6000, 7000, 8000, 9000, 9530

Example: HARM05[term] would select the fifth harmonic reference.

ISTAT?

Current Status Query.

Input: `ISTAT?`

Returned: `0`, `1`, or `2`

Remarks: One digit is returned; where 0 = current off, 1 = current on and in compliance, or 2 = current on and out of compliance. The "2" condition will also light the red LED on the Model 140 front panel.

MOVE

Move Stepper Motor Shaft Command.

Input: `MOVE±XXXXX`

Returned: Nothing

Remarks: Command to move the stepper motor shaft. Choose + for up motion or – for down motion. Fill in the # of steps parameter with a value from 1 through 65000.

Example: MOVE+1000[term] would move the stepper motor shaft up 1000 steps.

MOVE?

Stepper Motor Shaft Query.

Input: `MOVE?`

Returned: `±XXXXX`

Remarks: Returns the last motion up or down and the number of steps. The value returned will be 6 digits. The first digit will be a + for up motion or a - for down motion. The next five digits will be the number of steps. Leading zeroes will be present if the number of steps is less than 10000.

Example: If the last motion were 400 steps up, MOVE?[term] would return +00400[term].

FOREWORD

PURPOSE AND SCOPE

This manual contains user instructions for the 7000 Series AC Susceptometer and AC Susceptometer/ Magnetometer System. The system was designed, assembled, and portions manufactured in the United States of America by Lake Shore Cryotronics, Inc. The material in this manual is subject to change without notice.

We welcome your comments concerning this manual. Although every effort has been made to keep it free of errors, some may occur. When reporting a specific problem, please describe it briefly and include the manual part number, the paragraph/figure/table number, and the page number. Send your comments to Lake Shore Cryotronics, Inc. Attn: Technical Publications, 64 East Walnut Street, Westerville, Ohio 43081.

HARDWARE COVERED

AC Susceptometer Systems are available in the following configurations:

Model 7120 Complete AC Susceptometer System including a 30 or 60 liter helium dewar.

Model 7120A AC Susceptometer System featuring a 30 or 60 liter helium dewar but does not include a computer or vacuum pumping system.

Model 7121 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 1 Tesla Magnet.

Model 7125 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 5 Tesla Magnet.

Model 7129 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 9 Tesla Magnet.

Model 7130 Complete AC Susceptometer System which replaces the dewar with a Closed Cycle Refrigerator.

AC Susceptometer/DC Magnetometer Systems are available in the following configurations:

Model 7221 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 1 Tesla Magnet.

Model 7225 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 5 Tesla Magnet.

Model 7229 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 9 Tesla Magnet.

SOFTWARE COVERED

The 7000 Series AC Susceptometer/Magnetometer System has three software packages available depending on the model and options ordered:

ACS7000 Lake Shore ACS7000 Software is standard for all systems.

DCM7000 The Lake Shore DCM7000 Software is standard for all AC Susceptometer/DC Magnetometer Systems.

ACM7000 The optional Lake Shore ACM7000 Software is provided when the Model 700ACM AC Moment Option is included.

RES7000 The optional Lake Shore RES7000 Software is provided when the Model 700RES Resistance Option is included.

Model 700HM The Model 700HM Harmonics option is also available for all models. If included, the software becomes parts of the ACS7000 Software package.

Model 700PLOT SigmaPlot™, by Jandel Scientific, is also available as an option for all models.

ACSCU IEEE Commands (Continued)

DCI

Set DC Current Command.

Input: `DCI±XXX.XXXXXX`

Returned: Nothing

Remarks: Fill in the polarity of current (+ or –) and the current parameter with a value from 0 through 500.000000. The units are milliamperes. The decimal point is free floating.

Example: DCI+23.05[term] will set the DC current to +23.05 mA.

DCI?

DC Current Query.

Input: `DCI?`

Returned: `±XXX.XXXXXX`

Remarks: Returns DC current setting. The value returned will be a + or - followed by 10 digits with a decimal point between the 4th and 5th digits. Multiple leading and trailing zeroes are possible.

Example: If the present DC current is +23.05 mA then DCI?[term] will return +0023.050000[term].

FREQ

Set AC Current Source Frequency Command.

Input: `FREQ XXXXX`

Returned: Nothing

Remarks: Fill in the frequency parameter with a value from 1 through 10000. The units are Hz (Hertz). The available frequencies are: 1 to 1000 Hz in 1 Hz increments, and 1100 to 10000 Hz in 100 Hz increments.

Example: FREQ5200[term] would select a frequency of 5200 Hz.

FREQ?

AC Current Source Frequency Query.

Input: `FREQ?`

Returned: `XXXXX`

Remarks: The value returned will be 5 digits. Leading zeroes will be returned for frequencies less than 10000 Hz.

Example: If the frequency is 500 Hz , FREQ[term] returns 00500[term].

HARM?

Harmonic Reference Query.

Input: `HARM?`

Returned: `XX`

Remarks: Returns the current harmonic reference setting in the form of a two digit number 01 through 10.

Example: If the currently selected harmonic is the 5th then HARM?[term] would return 05[term].

A definition of system software is provided in Chapter 1 of this manual. ACS7000 Software operation is covered in Chapter 5. DCM7000 Software operation is covered in Chapter 6. The optional ACM7000 AC Moment Software operation is described in Chapter 7. The optional RES7000 AC/DC Resistance Software operation is described in Chapter 8. The optional Harmonics Software is described in Chapter 9. The optional SigmaPlot™ Software is described in the Jandel Software User's Manual.

HOW TO USE THIS MANUAL

User information is presented in the following chapters. Chapter 1 provides an introduction to the entire system. Chapter 2 is used for system installation. Detailed Hardware descriptions are provided in Chapter 3. System operation procedures and operational considerations are provided in Chapter 4. ACS7000 and DCM7000 Software are described in Chapters 5 and 6 respectively. The optional ACM7000 and RES7000 Software operation is described in Chapters 7 and 8 respectively. Options, accessories, and cables are covered in Chapter 9. Finally, system level troubleshooting is provided in Chapter 10.

The manual also includes an extensive Table of Contents and Alphabetical Index. The Table of Contents at the front of the manual lists all paragraph headings and their associated page number. Also included is a complete List of Illustrations and Tables. At the rear of the manual is the Alphabetical Index. An alphabetical index is different than a page number index: the reader is referred directly to a paragraph, figure, or table number. Individual components and topics of interest have been arranged alphabetically and are referenced to paragraph, figure, or table numbers as appropriate. A paragraph number reference is simply a number in the point system (1.1.1). Figure and table numbers are prefaced with an F or T respectively. Information in the Appendices is prefaced with the Appendix Letter (A-1.0). A figure or table reference in an appendix is delineated by a slash (/), e.g., T/A-1. Major topic headings are shown in all capitals with subordinate headings indented and in alphabetical order.

EFFECTIVITY CODING

As detailed in Hardware Covered, there are seven different configurations that comprise the 7000 Series. Effectivity coding is the only means to positively identify which version is being documented. Effectivity coding is used to identify which model is being covered in order to alleviate confusion and/or potential errors. If there is no mention of effectivity coding, then the information is common to all models of the unit.

The following are examples of effectivity coding. If a heading that reads "Description of 7000 Series," the information is good for all models. If a heading reads "Computer Description (Except Model 7120A)", the information is good for all models of the 7000 Series except the Model 7120A. If a heading reads "Description of 1 Telsa Magnet (Model 7221 Only)," the information is only good for the designated model.

LIST OF ASSOCIATED LAKE SHORE PUBLICATIONS

A list of Lake Shore Cryotronics, Inc. Technical Publications associated with the 7000 Series AC Susceptometer/Magnetometer System are provided as follows:

NUMBER	***TITLE***
MAN-91	Model DRC-91CA Temperature Controller User's Manual.
MAN-241	Model 241 Liquid Helium Level Monitor User's Manual.
MAN-623	Model 622/623 Superconducting Magnet Power Supply User's Manual (with Model 610 Addendum)

APPENDIX G

ACS CONTROL UNIT IEEE-488 COMMANDS

G1.0 GENERAL

The Lake Shore Model 140 ACS Control Unit (ACSCU) responds to IEEE-488 commands. Under normal circumstances, the ACSCU will be under control of the 7000 Series System Software. However, the following is provided for circumstances when knowledge of the specific IEEE-488 commands is required.

---

*IDN?

Identification Query.

Input: `*IDN?`

Returned: Manufacturer,model number,00000,software date

Remarks: Identifies the instrument manufacturer, model number, five zeros, and the software date.

Example: LSCI,MODEL 140,00000,110292[term]

ACI

Set AC Current Magnitude Command.

Input: `ACIXXX.XXXXXX`

Returned: Nothing

Remarks: Sets the AC current magnitude. Fill in the current parameter with a value from 0 through 250.000000. The units are milliamperes. The decimal point is free floating.

Example: ACI23.05[term] will set the AC current to 23.05 mA.

ACI?

AC Current Query.

Input: `ACI?`

Returned: `XXX.XXXXXX`

Remarks: Returns AC current setting. The value returned will be 10 digits with a decimal point between the 4th and 5th digits. Multiple leading and trailing zeroes are possible. The units are milliamperes.

Example: If the present AC current is 23.05 mA then ACI?[term] will return 0023.050000[term].

DATE?

Software Date Query.

Input: `DATE?`

Returned: `MMDDYY`

Remarks: Six digits are returned in the format MMDDYY, where MM = month, DD = day, and YY = year.

Example: 110292[term] equals November 2, 1992.

LIST OF REFERENCE DOCUMENTATION

The following is a list of sub-vendor technical manuals, specifications, and other documents. Lake Shore Cryotronics, Inc. is not responsible for errors, omissions, or updates to reference documentation. Actual documentation received is determined by the configuration of the ACS Model purchased.

NUMBER	***TITLE***
062199	ALCATEL-CIT Type 5011 Molecular Drag Pump Instruction Manual.
182-901-01	Keithley Instruments, Model 182 Sensitive Digital Voltmeter Instruction Manual.
219567-A-MNL-C	EG&G Princeton Applied Research, Model 5209 Lock-In Amplifier Instruction Manual and Quick Reference Manual.
320282-01	National Instruments, NI-488.2™ Software Reference Manual for MS-DOS.
320320-01	National Instruments, Getting Started with your GPIB-PCII/IIA and the NI-488.2™ MS-DOS Handler.
5960-6803	Hewlett Packard, HP D1194A Super VGA Display & HP D1195A Ergonomic Super VGA Display Installation Guide.
C331-05-885	Edwards High Vacuum International, SP Speedivalves Instructions.
D2675-990021	Hewlett Packard, Setting Up Your HP Vectra 486N PC.
PA-350	Keithley Instruments, Model 182-LS Addendum.
—	ALCATEL-CIT Type 2002 BB Mechanical Vacuum Pump Instruction Manual.
—	American Magnetics, Inc., Helium Vapor Cooled Current Leads Installation, Operation, and Maintenance Instructions.
—	Comptech Inc., Series 200 Thermocouple Gauge Control.
—	Jandel Scientific, SigmaPlot™ Scientific Graphic Software User's Manual for IBM® PC and Compatible Version 4.0.
—	Janis Research Company, Inc., Series RD and VRD Research Dewars Operating Instructions.

ABBREVIATIONS AND ACRONYMS

Abbreviations and acronyms used in this manual are defined as follows. Also refer to the Glossary of Terminology in Appendix A, Units for Magnetic Properties in Appendix B, Temperature Scales in Appendix C, and Table of Elements in Appendix D.

A	Amperes
AC	Alternating Current
ACS	AC Susceptometer
ANSI	American National Standards Institute
BNC	Bayonet Nut Connector
C	Celsius (was Centigrade)
cgs	centimeter, gram, second
CMOS	Complementary Metal Oxide Semiconductor
DAC	Digital to Analog Converter
DC	Direct Current
DIN	Deutsche Industrial Norms
DVM	Digital Volt Meter
EPROM	Erasable Programmable Read-Only Memory
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ESDS	Electrostatic Discharge Sensitive
F	Fahrenheit
GFI	Ground Fault Interrupter
GPIB	General Purpose Interface Bus (IEEE-488 Bus)
Hz	Hertz
I.D.	Inner Diameter
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
I/O	Input/Output
K	Kelvin
LHe	Liquid Helium
LN_2	Liquid Nitrogen
LSCI	Lake Shore Cryotronics, Inc.
MPS	Magnet Power Supply
MSDS	Material Safety Data Sheet
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturer's Association
NIST	National Institute of Standards and Technology
NPT	National Pipe Thread
O.D.	Outer Diameter
PCB	Printed Circuit Board
PID	Proportional, Integral, and Derivative
PLC	Power Line Cycles
psi	Pounds per Square Inch
RAM	Random Access Memory
RGA	Return Good Authorization
RMS	Root Mean Square
ROM	Read Only Memory
RTD	Resistance Temperature Detector
SHD	Superinsulated Helium Dewar
SI	Système International d'Unités; or International System of Units
TC	Thermocouple
UL	Underwriters Laboratories
VDC	Volts Direct Current

Table F-3. EG&G Model 5209 Lock-In Amplifier IEEE-488 Device Characteristics

```
LOCK-IN Configuration:
Primary GPIB Address ..........  22
Secondary GPIB Address ........  NONE
Timeout setting ...............  10sec
Serial Poll Timeout ...........  1sec

Terminate Read on EOS .........  Yes
Set EOI with EOS on Writes ....  Yes
Type of compare on EOS ........  7-Bit
EOS byte ......................  0Ah
Send EOI at end of Write ......  Yes

Enable Repeat Addressing ......  Yes
```

Table F-4. Lake Shore Model 140 ACS Control Unit IEEE-488 Device Characteristics

```
ACSCU Configuration:
Primary GPIB Address ..........  24
Secondary GPIB Address ........  NONE
Timeout setting ...............  10sec
Serial Poll Timeout ...........  1sec

Terminate Read on EOS .........  Yes
Set EOI with EOS on Writes ....  Yes
Type of compare on EOS ........  7-Bit
EOS byte ......................  0Ah
Send EOI at end of Write ......  Yes

Enable Repeat Addressing ......  Yes
```

Table F-5. Keithley Model 182LS Sensitive DVM IEEE-488 Device Characteristics

```
K182DVM Configuration:
Primary GPIB Address ..........  7
Secondary GPIB Address ........  NONE
Timeout setting ...............  10sec
Serial Poll Timeout ...........  1sec

Terminate Read on EOS .........  Yes
Set EOI with EOS on Writes ....  Yes
Type of compare on EOS ........  7-Bit
EOS byte ......................  0Ah
Send EOI at end of Write ......  Yes

Enable Repeat Addressing ......  Yes
```

GENERAL INSTALLATION PRECAUTIONS

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

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

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

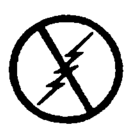
ELECTROSTATIC DISCHARGE

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

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

Identification of Electrostatic Discharge Sensitive Components

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

F4.0 SUMMARY OF IEEE-488 INTERFACE CHARACTERISTICS

IEEE-488 bus characteristics for each device in Tables F-1 through F-5 were derived from the National Instruments GPIB-PC Software Configuration Utility, file GPIB.COM, as follows.

Table F-1. National Instruments GPIB Board Characteristics

```
GPIB0 Configuration:
Primary GPIB Address .......... 0
Secondary GPIB Address ........ NONE
Timeout setting ............... 10sec

Terminate Read on EOS ......... Yes
Set EOI with EOS on Writes .... Yes
Type of compare on EOS ........ 7-Bit
EOS byte ...................... 0Ah
Send EOI at end of Write ...... Yes

System Controller ............. Yes
Assert REN when SC ............ Yes
Enable Auto Serial Polling .... No
Enable CIC Protocol ........... No
Bus Timing .................... 500nsec
Parallel Poll Duration ........ Default

Use this GPIB board ........... Yes
Board Type .................... PCII
Base I/O Address .............. 2B8h
```

Table F-2. Lake Shore Model DRC-91CA Temperature Controller IEEE-488 Device Characteristics

```
91C Configuration:
Primary GPIB Address .......... 23
Secondary GPIB Address ........ NONE
Timeout setting ............... 10sec
Serial Poll Timeout ........... 1sec

Terminate Read on EOS ......... Yes
Set EOI with EOS on Writes .... Yes
Type of compare on EOS ........ 7-Bit
EOS byte ...................... 0Ah
Send EOI at end of Write ...... Yes

Enable Repeat Addressing ...... Yes
```

Handling of Electrostatic Discharge Sensitive Components

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

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

SAFETY SUMMARY

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

Ground The Instrument

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

Do Not Operate In An Explosive Atmosphere

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

Keep Away From Live Circuits

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

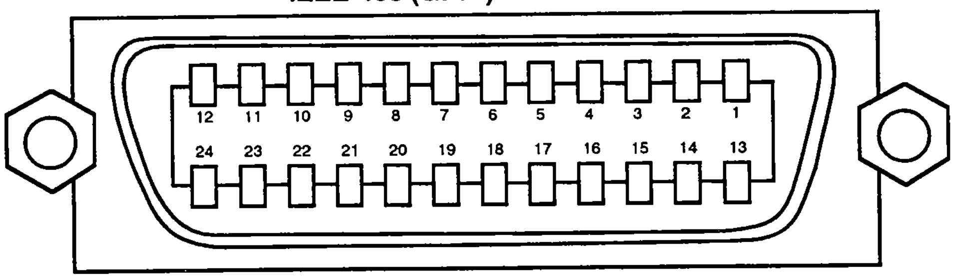
Do Not Substitute Parts Or Modify Instrument

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

F3.0 IEEE-488 INTERFACE CONNECTOR

The IEEE-488 Interface Connector used with the 7000 Series System is as specified in the IEEE-488-1978 standard. The cable has 24 conductors with an outer shield. The connectors at each end are 24-way Amphenol 57 Series (or equivalent) with piggyback receptacles to allow daisy-chaining. The connectors are secured in the receptacles by locking screws. The total length of cable allowed in a system is 2 meters for each device on the bus, or 20 meters maximum. A system may be composed of up to 15 devices. Figure F-1 provides a definition of the standard IEEE-488 Interface Connector.

IEEE-488 (GPIB) INTERFACE



C-450-U-F-1

PIN	SYMBOL	DESCRIPTION
1	DIO1	Data Input/Output Line 1
2	DIO2	Data Input/Output Line 2
3	DIO3	Data Input/Output Line 3
4	DIO4	Data Input/Output Line 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable Shield
13	DIO5	Data Input/Output Line 5
14	DIO6	Data Input/Output Line 6
15	DIO7	Data Input/Output Line 7
16	DIO8	Data Input/Output Line 8
17	REN	Remote Enable
18	GND 6	Ground Wire – Twisted pair with DAV
19	GND 7	Ground Wire – Twisted pair with NRFD
20	GND 8	Ground Wire – Twisted pair with NDAC
21	GND 9	Ground Wire – Twisted pair with IFC
22	GND 10	Ground Wire – Twisted pair with SRQ
23	GND11	Ground Wire – Twisted pair with ATN
24	GND	Logic Ground

Figure F-1. IEEE-488 Interface Connector Definition

SAFETY SYMBOLS

Product will be marked with this symbol in order to protect against damage to the instrument.

Indicates dangerous voltage (terminals fed by voltage exceeding 1000 volts must be so marked).

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of a fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating equipment.

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).

Direct current (power line).

Alternating or direct current (power line).

USE OF WARNINGS, CAUTIONS, AND NOTES

The following definitions apply to warnings, cautions, and notes found throughout this manual. Warnings, cautions, and notes will always precede the step to which they pertain.

WARNING

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

CAUTION

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

NOTE

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

HANDLING LIQUID HELIUM AND NITROGEN

Liquid helium (LHe) and liquid nitrogen (LN_2) are potential asphyxiants and may cause severe frostbite. Please observe all proper safety precautions to ensure proper handling of LHe and LN_2. Consult your local LHe and LN_2 dealer for detailed handling instructions. Refer to Appendix E for general handling instructions.

WARNING

- Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.
- Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

APPENDIX F

IEEE-488 INTERFACE CONFIGURATION

F1.0 GENERAL

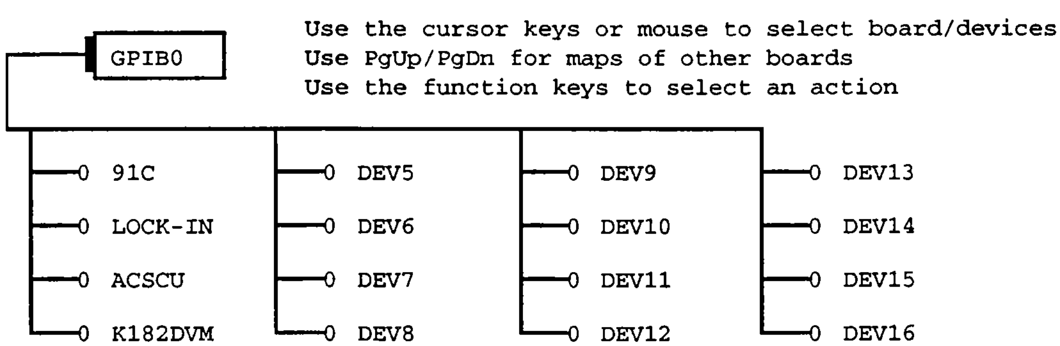
The instruments in the ACS System communicate via the IEEE-488 bus; also known as the General Purpose Interface Bus (GPIB). In all models of the ACS, the HP Computer, Lake Shore Models 140 Control Unit and DRC-91CA Temperature Controller, and EG&G Model 5209 Lock-In Amplifier communicate via the IEEE-488 bus. In Models 7221 and 7225 only, the Keithley Model 182LS Sensitive DVM also communicates on the IEEE-488 bus. A fully configured AC and DC system will be described in the following paragraphs. If you do not have the DC option, i.e., no Keithley Model 182LS, please ignore information pertaining to the DVM. In systems purchased from Lake Shore, the National Instruments GPIB Board, mounted in slot 3 of the computer, is the bus controller.

F2.0 IEEE-488 INTERFACE BOARD CONFIGURATION

If the ACS System is purchased without a computer or IEEE-488 interface, the user is responsible for proper configuration of the National Instruments GPIB-PC Interface Card. The 7000 Series Software has been written specifically for the National Instruments Card, but the software should be operational on any 80286-based personal computer running MS-DOS Version 3.3. The exact setup of the IEEE-488 interface will depend on the computer, extra option cards, and any other peripherals which may be attached to the computer. The only display options supported are VGA and EGA.

Use the following procedure to configure the National Instruments GPIB-PC Interface Card.

1. Turn off and disconnect power from computer and monitor.
2. Remove computer cover. Use a flat screwdriver and remove the three screws located at back of computer. Slide cover forward and lift up on back. It is not necessary to remove cover completely.
3. Set IRQ (interrupt line) jumper on National Instruments IEEE Card to IRQ3.
4. Install interface card in computer.
5. Replace computer cover and replace three cover screws.
6. Connect power turn on computer and monitor.
7. Setup GPIB card using IBCONF.EXE program. Refer to data in Paragraph F4.0 as appropriate.
8. Setup GPIB Device Map as follows:



Changes made in the IEEE-488 configuration and in the CONFIG.SYS file do not become active until the system is rebooted (power off or Ctrl–Alt–Delete).

CHAPTER 1
INTRODUCTION

1.0 GENERAL

This chapter contains the physical principles behind the operation of the Lake Shore 7000 Series AC Susceptometer and AC Susceptometer/DC Magnetometer Systems. The mathematical details incorporated into both the data acquisition program and the data analysis program are given.

Paragraph 1.1 provides a general description of the 7000 Series System. Paragraph 1.2 provides a description of Models 7120, 7120A, 7121, 7125, and 7129. Paragraph 1.3 provides a description of the Model 7130. Paragraph 1.4 provides a description of the Models 7221, 7225, and 7229. Paragraph 1.5 provides a general overview of the ACS7000 and DCM7000 data acquisition/control and analysis software designed by Lake Shore. General system principles of operation are provided in Paragraph 1.6. Demagnetization factors and sample movement are discussed in Paragraphs 1.7 and 1.8 respectively. The calibration coefficient is discussed in Paragraph 1.9. Real and imaginary components of complex susceptibility are provided in Paragraph 1.10. Mass susceptibility is discussed in Paragraph 1.11. Finally, information on DC magnetic moment measurements (for Models 7221, 7225, and 7229 only) is provided in Paragraph 1.12.

1.1 7000 SERIES SYSTEM GENERAL DESCRIPTION

The 7000 Series AC Susceptometer and AC Susceptometer/DC Magnetometer Systems were designed and assembled in the United States of America by Lake Shore Cryotronics, Inc. The entire system is generally referred to as an ACS or ACS System. The configuration of the system depends on the model, as detailed below.

AC Susceptometer Systems are available in the following configurations:

Model 7120 Complete AC Susceptometer System including a 30 or 60 liter helium dewar. Refer to Paragraph 1.2.1.

Model 7120A AC Susceptometer System featuring a 30 or 60 liter helium dewar but does not include a computer, monitor, or vacuum pumping system. Refer to Paragraph 1.2.1.

Model 7121 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 1 Tesla Magnet. Refer to Paragraph 1.2.2.

Model 7125 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 5 Tesla Magnet. Refer to Paragraph 1.2.2.

Model 7129 Complete AC Susceptometer System including a 30 or 60 liter helium dewar and a 9 Tesla Magnet. Refer to Paragraph 1.2.2.

Model 7130 Complete AC Susceptometer System which replaces the dewar with a Closed Cycle Refrigerator. Refer to Paragraph 1.3.

AC Susceptometer/DC Magnetometer Systems are available in the following configurations:

Model 7221 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 1 Tesla Magnet. Refer to Paragraph 1.4.

Model 7225 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 5 Tesla Magnet. Refer to Paragraph 1.4.

Model 7229 Complete AC Susceptometer/DC Magnetometer System including a 30 or 60 liter helium dewar and a 9 Tesla Magnet. Refer to Paragraph 1.4.

E4.0 LIQUID HELIUM AND NITROGEN SAFETY PRECAUTIONS

A LHe transferring procedure is provided in Chapter 6 of this manual. Transferring LN_2 is handled in a similar manner. In all cases, operation of the storage dewar controls should be in accordance with the manufacturer/supplier's instructions. During this transfer, it is important that all safety precautions written on the storage dewar and recommended by the manufacturer be followed.

WARNING

- Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.
- Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

The two most important safety aspects to consider when handling LHe and LN_2 are adequate ventilation and eye and skin protection. Although helium and nitrogen gases are non-toxic, they are dangerous in that they replace the air in a normal breathing atmosphere. Liquid products are of an even greater threat since a small amount of liquid evaporates to create a large amount of gas. Therefore, it is imperative that cryogenic dewars be stored and the 7000 Series System be operated in open and well ventilated areas.

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

E5.0 RECOMMENDED FIRST AID

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

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

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

References:

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

Lake Shore Software for various system configurations is available as follows:

ACS7000	Lake Shore ACS7000 Software is standard for all systems. Refer to Chapter 5.
DCM7000	The Lake Shore DCM7000 Software is standard for all AC Susceptometer/DC Magnetometer Systems. Refer to Chapter 6.
ACM7000	The optional Lake Shore ACM7000 Software is provided when the **Model 700ACM** AC Moment Option is included. Refer to Chapter 7.
RES7000	The optional Lake Shore RES7000 Software is provided when the **Model 700RES** Resistance Option is included. Refer to Chapter 8.
Model 700HM	The Model 700HM Harmonics option is also available for all models. If included, the software becomes parts of the ACS7000 Software package. Refer to Paragraph 9.6.
Model 700PLOT	SigmaPlot™, by Jandel Scientific, is also available as an option for all models as a separate unloaded software package.

Lake Shore Hardware Options for various system configurations are available as follows. A complete list of options, accessories, and cables is provided in Chapter 9.

Model 700HL	The Model 700HL option consists of a Lake Shore Model 241 LHe Level Indicator, Level Probe, and Cable. The Model 700HL is standard on all ACS Systems except the Model 7130.
Model 700LT	The Model 700LT Low Temperature Cryostat is for collecting data below 4.2 K.
Model 700RP	The Model 700RP Resistance Sample Probe Assembly is an extra probe for use with any 7000 Series System equipped with the Model 700RES Resistance Option.
Model 700SP	The Model 700SP Sample Probe Assembly is an extra probe for use with any 7000 Series System.
Model 700TLF	The Model 700TLF Flexible Helium Transfer Line is optional for all systems except Model 7130.

1.2 MODELS 7120, 7120A, 7121, 7125, AND 7129 DESCRIPTION

The Models 7120, 7120A, 7121, 7125, and 7129 AC Susceptometers are built into dual consoles; referred to as the Instrument and Dewar Consoles. All models are available with either 30 or 60 liter superinsulated helium dewars. The 7120A is a complete system without computer, monitor, or vacuum pumping system. The Models 7121, 7125, and 7129 also feature a 1, 5, or 9 tesla magnet, respectively. The systems come complete with cryogenic and electronic instrumentation, and data acquisition and control software, thus simplifying the accurate measurement of AC susceptibility. Physical, environmental, and performance characteristics are detailed in Table 1-1. Instrument and Dewar Console dimensions are provided in Figures 1-1 and 1-2. Close up views of the front and back of the Dewar Console are provided in Figures 1-3 and 1-4 respectively.

1.2.1 Model 7120 and 7120A AC Susceptometer Features

The Model 7120 and 7120A AC Susceptometers feature separate Instrument and Dewar Consoles. Both systems include a 30 or 60 liter superinsulated helium dewar, and measure both real (χ') and imaginary (χ'') components of susceptibility as a function of temperature, amplitude and frequency of AC field. As with all the Series 7000 Susceptometers, a small DC bias field from 0.1 A/m (.00125 Oe) to 1600 A/m (20 Oe) can be applied with the primary coil in both models.

The Model 7120A is identical to the 7120 except for the absence of a computer, monitor, and vacuum pumping system. The following is a list of Model 7120 and 7120A features:

- 30 or 60 liter superinsulated helium dewar.
- Cryostat probe insert assembly.
- Sample positioning assembly featuring DC stepping motor control.
- Sample probe assembly with sample holder (disposable Delrin container); accommodates up to 3.6 mm (diameter) x13 mm (long) samples in powder, bulk or thin film form, including single crystals.

APPENDIX E

HANDLING OF LIQUID HELIUM AND NITROGEN

E1.0 GENERAL

Liquid Helium (LHe) and liquid nitrogen (LN_2) are used in the operation of the 7000 Series System. Although not explosive, the following are safety considerations in the handling of LHe and LN_2.

E2.0 PROPERTIES

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

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

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

E3.0 HANDLING CRYOGENIC STORAGE DEWARS

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

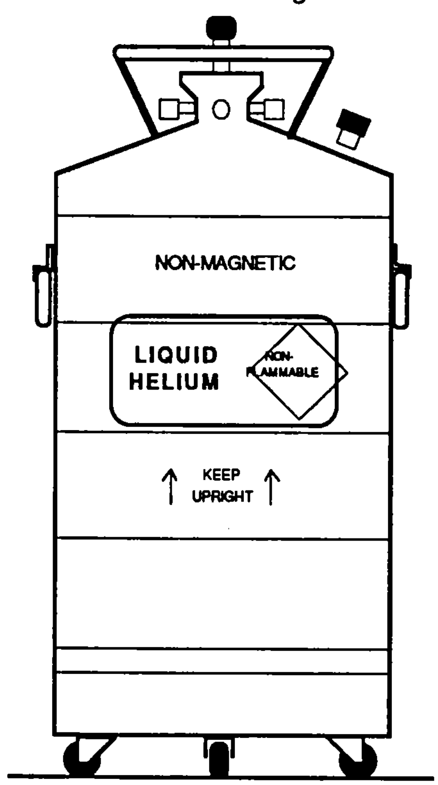


Figure E-1. Typical Cryogenic Storage Dewar

- Lake Shore ACS Control Unit with built-in AC/DC current source.
- Lake Shore Model DRC-91CA Temperature Controller with dual diode inputs.
- Lake Shore ACS7000 AC Susceptibility control software.
- Lake Shore Model 241 Liquid Helium Level Monitor.
- EG&G Model 5209 Lock-In Amplifier/Phase-Sensitive Detector.

Model 7120 Only Features:

- Hewlett-Packard Vectra™ series computer with National Instruments IEEE-488 interface.
- Vacuum pumping system with molecular drag pump.

Model 7120A Requires The Following Customer-Supplied Items:

- Customer-owned vacuum pump. A pumping port is supplied in the right side of the console towards the back for customer-supplied pump. The port is terminated with a KF-16 flange and will be nominally 6 inches (15 cm) from the top. The user supplied pump should be capable of 10^{-6} torr. If an oil diffusion pump is used, the pump should have a liquid nitrogen cold trap to prevent oil contamination from getting into the system. System includes vacuum gauges.
- Customer-owned PC-compatible computer with minimum 640 Kilobyte (KB) memory. VGA-compatible color monitor, and hard disk drive with minimum of 20 Megabyte (MB).
- Customer-owned National Instruments GPIB-PCII IEEE-488 interface card with software revision C5.3 or later.

1.2.2 Model 7121, 7125, and 7129 AC Susceptometer Features

The Model 7121 7125, and 7129 AC Susceptometers are dual console systems featuring separate Instrument and Dewar Consoles. All systems are available with either the 30 or 60 liter helium dewar, and measure both real (χ') and imaginary (χ'') components of susceptibility as a function of temperature, amplitude and frequency of AC field.

As with all the Series 7000 Susceptometers, a small DC bias field from 0.1 A/m (.00125 Oe) to 1600 A/m (20 Oe) can be applied with the primary coil in all models. The Model 7121, 7125, and 7129, however, are configured with a 1, 5, or 9 tesla superconducting magnet for AC susceptibility measurements with DC bias fields ranging from ±1, ±5, or ±9 tesla, respectively. The following is a list of Model 7121, 7125, and 7129 features:

- 30 or 60 liter superinsulated helium dewar.
- Cryostat probe insert assembly.
- Sample positioning assembly featuring DC stepping motor control.
- Sample probe assembly with sample holder (disposable Delrin container); accommodates up to 3.6 mm (diameter) x13 mm (long) samples in powder, bulk or thin film form, including single crystals.
- Vacuum pumping system with molecular drag pump.
- Lake Shore ACS Control Unit with built-in AC/DC current source.
- Lake Shore Model DRC-91CA Temperature Controller with dual diode inputs.
- EG&G Model 5209 Lock-In Amplifier/Phase-Sensitive Detector.
- Hewlett-Packard Vectra™ series computer with National Instruments IEEE-488 interface.
- Lake Shore ACS7000 AC Susceptibility control software.
- 1, 5, or 9 tesla Superconducting Magnet.
- Lake Shore Model 610 Superconducting Magnet Power Supply.
- Lake Shore Model 241 Liquid Helium Level Monitor.

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Table 1-1. Model 7120, 7121, 7125, and 7129 Specifications

Temperature:	
Range:	<4.2 K to 325 K
Accuracy:	±0.2 K or ±0.5% of T, whichever is greater (At 0-field)
Stability:	±0.1 K
Uniformity:	±(0.1 K +0.5% of T)
AC/DC Magnetic Field (Primary Coil):	
Range:	4-digit selectable from 0.1 A m^{-1} (0.00125 Oe) to 1600 A m^{-1} (20 Oe) RMS, both AC and DC
Accuracy:	±1.0%
Uniformity:	±0.3% inside secondary coils
Stability:	to within ±0.05%
Frequency:	1 Hz to 1 kHz, 1 Hz steps and 1 kHz to 10 kHz, 10 Hz steps
System Accuracy:	Calibration constants (both AC & DC) are accurate within ±1.0 %
AC Susceptibility Sensitivity:	To 2 x 10^{-8} emu in terms of equivalent magnetic moment
DC Moment Sensitivity:	5 x 10^{-5} emu
1 Tesla Superconducting Magnet Specifications (Model 7121):	
Field Range:	±10,000 gauss, (±1 tesla)
Uniformity:	Better than ±0.1% over 6 cm span
Resolution:	<0.1 gauss, –10,000 to +10,000 gauss
Accuracy:	±1.0%, –10,000 to +10,000 gauss
Stability:	± 0.5 gauss (±10, 000 gauss)
Remnant Field:	1.5 gauss (<0.1 gauss after demagnetization cycle)
5 Tesla Superconducting Magnet Specifications (Model 7125):	
Field Range:	±50,000 gauss, (±5 tesla)
Uniformity:	Better than ±0.1% over 6 cm span
Resolution:	<1.0 gauss, –50,000 to +50,000 gauss
Accuracy:	±1.0%, –50,000 to +50,000 gauss
Stability:	±5 gauss (±50, 000 gauss)
Remnant Field:	15 gauss (<0.5 gauss after demagnetization cycle
9 Tesla Superconducting Magnet Specifications (Model 7129):	
Field Range:	±90,000 gauss, (±9 tesla)
Uniformity:	Better than ±0.1% over 6 cm span (–9 to +9 tesla)
Resolution:	<2.0 Oe (–9 to +9 tesla)
Accuracy:	±1.0% of setting
Stability:	±10 Oe (–9 to +9 tesla)
Remnant Field:	30 gauss (<15 gauss after demagnetization cycle
Dewar Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 64.5 inches (163.8 cm). Allow 4 feet clearance above unit for sample loading.
Instrument Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 56.375 inches (143.2 cm). *Allow 3 ft separation between consoles.*
Weight:	**7120** = 159 kgs / 350 pounds **7121** = 177 kgs / 390 pounds **7221** = 182 kgs / 400 pounds
Power Consumption:	120/220 VAC, 50/60 Hz, 10/5 Amps
Recommended Circuit:	120 VAC – 15 Amp; 220 VAC – 10 Amps
Auxiliary Equipment Required:	He gas source, 0–1 psig (99.5 % pure), cryogens & transfer accessories
Helium Capacity:	30 or 60 liters
Static Boil-Off:	0.2 liters/hour (Model 7120 – nominal boil-off), 0.45 liters/hour with vapor cooled leads (Models 7121, 7125, & 7229 – nominal boil-off)

With system pre-cooled to liquid nitrogen temperature, the 30 liter dewar will require 45 liters of helium for initial transfer, while the 60 liter dewar will require 75 liters of helium for initial transfer.

Specifications are subject to change without notice.

APPENDIX D
TABLE OF ELEMENTS

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

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

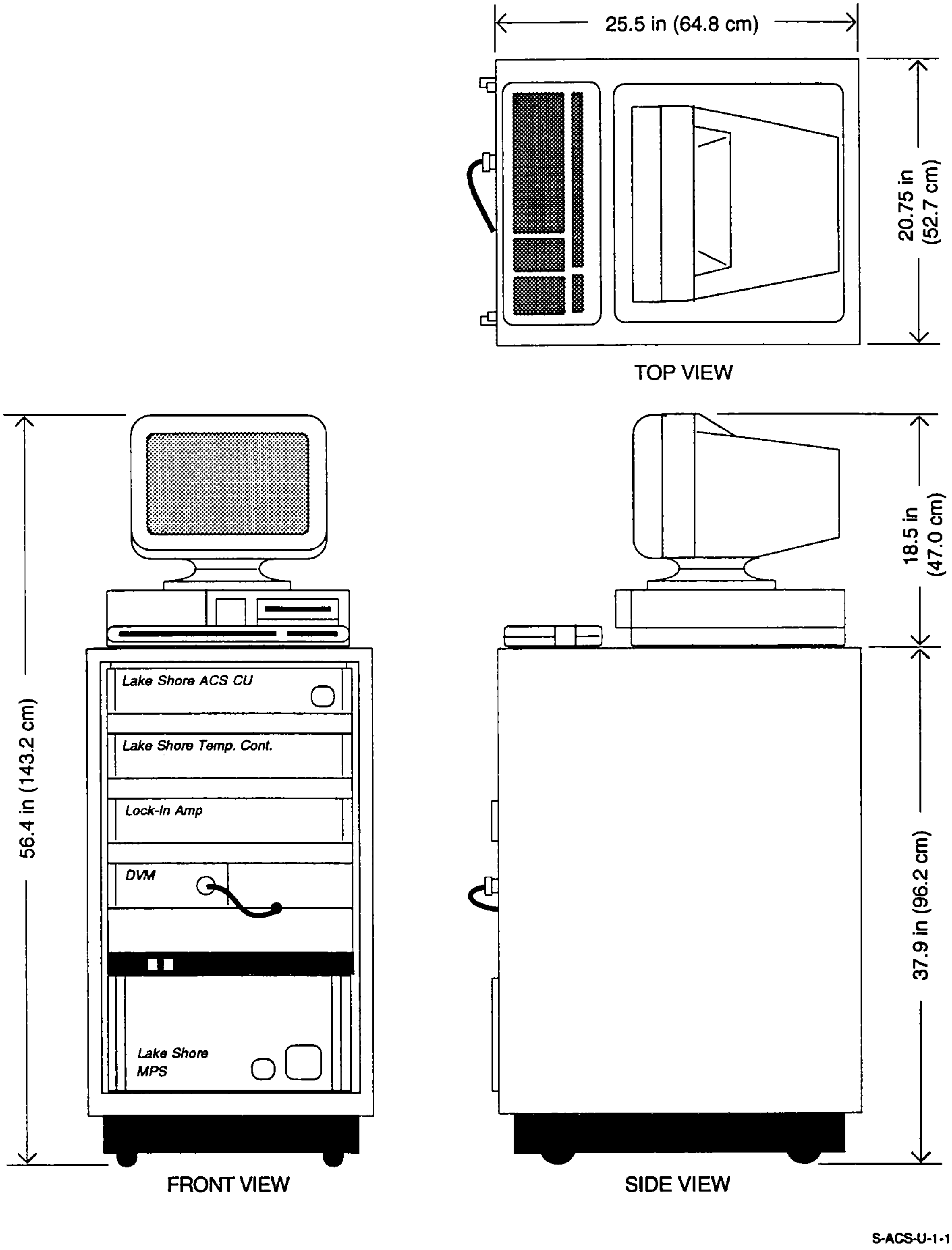

Figure 1-1. Typical 7000 Series Instrument Console Physical Dimensions

Table C-1. Temperature Conversion Table

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

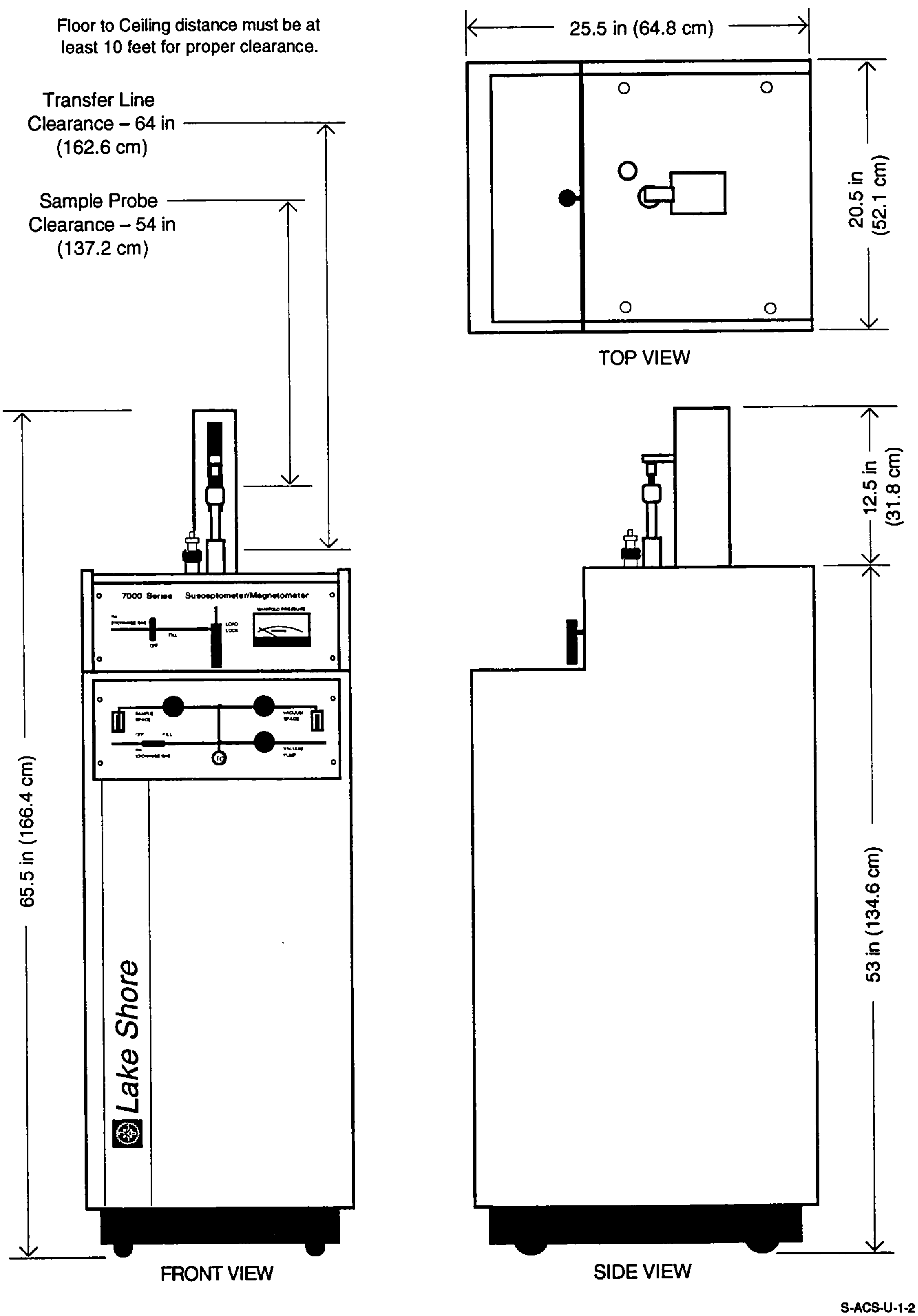

Figure 1-2. Typical 7000 Series Dewar Console Physical Dimensions

APPENDIX C
TEMPERATURE SCALES

C1.0 DEFINITION

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

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

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

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

C2.0 COMPARISON

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

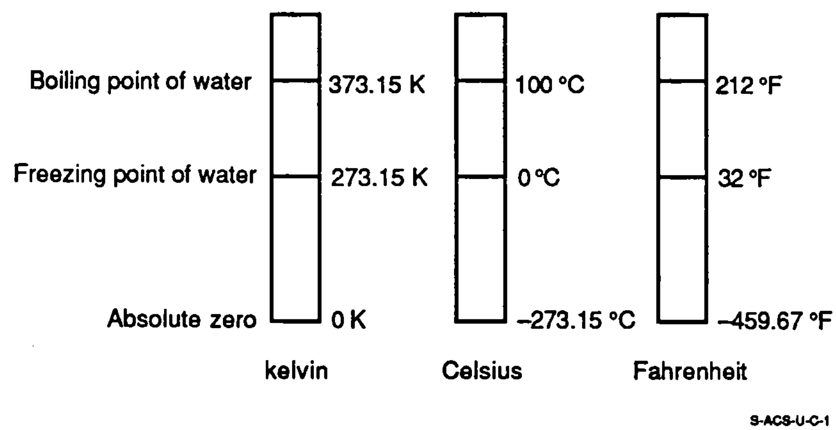

Figure C-1. Temperature Scale Comparison

C3.0 CONVERSION

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

°C = °F- 32 / 1.8.

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

°F = (1.8 °C) + 32.

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

To convert Celsius to kelvin, add 273.

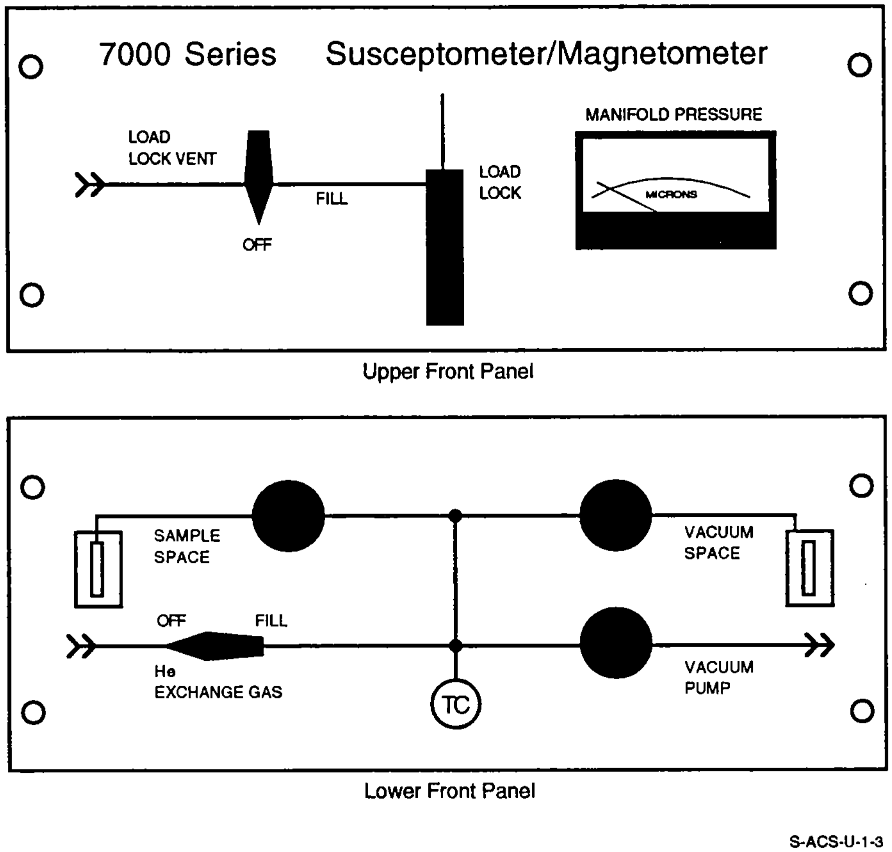

Figure 1-3. Typical Dewar Console Upper and Lower Front Panels

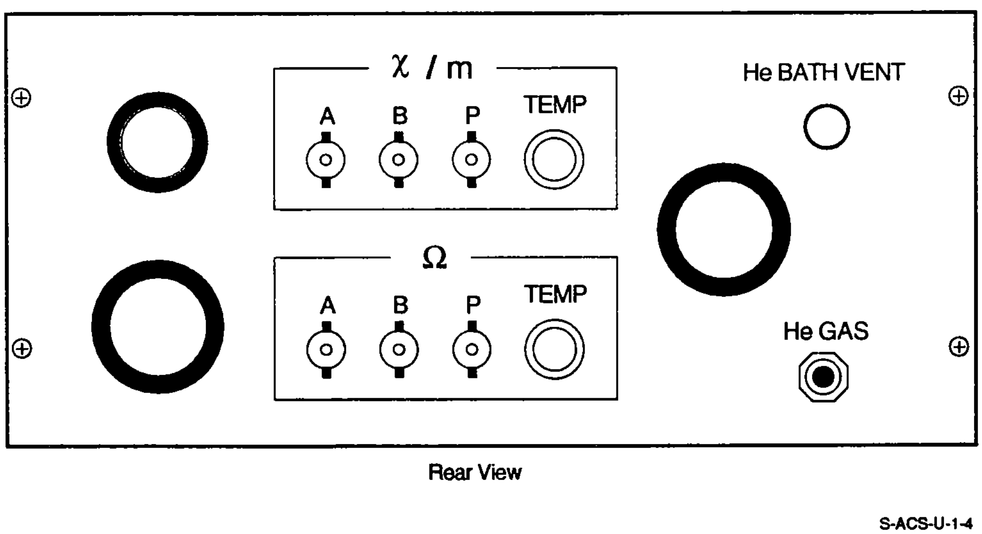

Figure 1-4. Typical Dewar Console Rear Panel

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1.3 MODEL 7130 DESCRIPTION

The Models 7130 AC Susceptometer is built into our standard dual console enclosures. This model provides an absolute measurement of both the real (χ') and imaginary (χ'') components of magnetic susceptibility as a function of temperature, amplitude and frequency of an applied AC field. The system is a cost-effective solution for the material research community. They are complete with cryogenic and electronic instrumentation, and data acquisition and control software, thus simplifying the accurate measurement of AC susceptibility. Physical, environmental, and performance characteristics are detailed in Table 1-2. Enclosure dimensions are provided in Figures 1-1 and 1-2.

1.3.1 Model 7130 (With Closed Cycle Refrigerator) Features:

The Model 7130 is configured with a closed cycle refrigerator system and is ideal for laboratories where liquid helium is either not available or not cost effective. The system is virtually identical to the Model 7110 but requires no liquid cryogen for operation below room temperature. The system measures both real (χ') and imaginary (χ'') components of susceptibility as a function of temperature, amplitude and frequency of AC field. The temperature range of use is <15K to 325K. As with all the Series 7000 Susceptometers, a small DC bias field from 0.1 A/m (.00125 Oe) to 1600 A/m (20 Oe) can be applied with the primary coil. The features of the Model 7130 are the same as Model 7120 except with a CTI Closed Cycle Refrigerator.

Table 1-2. Model 7130 Specifications

Temperature:	
Range:	15 K to 325 K
Accuracy:	±0.2 K or ±0.5% of T, whichever is greater
Stability:	±0.1 K
Uniformity:	±(0.1 K +0.5% of T)
AC/DC Magnetic Field (Primary Coil):	
Range:	4-digit selectable from 0.1 A m^{-1} (0.00125 Oe) to 1600 A m^{-1} (20 Oe) RMS, both AC and DC
Accuracy:	±1.0%
Uniformity:	±0.3% inside secondary coils
Stability:	to within ±0.05%
Frequency:	1 Hz to 1 kHz, 1 Hz steps and 1 kHz to 10 kHz, 10 Hz steps
System Accuracy:	The calibration constant supplied with the system is accurate to within ±1.0%.
AC Sensitivity:	To 2 x 10^{-8} emu in terms of equivalent magnetic moment.
Dewar Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 69 inches (175.2 cm). Allow 4 feet clearance above unit for sample loading.
Instrument Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 56.375 inches (143.2 cm). Allow 3 ft separation between consoles.
Gross Weight:	182 kgs/400 pounds
Power Consumption:	120/220 VAC, 50/60 Hz, 10/5 Amps
Recommended Circuit:	120 VAC – 15 Amp; 220 VAC – 10 Amps
Compressor Power:	198/250 VAC, 60 Hz or 180/220 VAC, 50 Hz. at 9 A (1.8 kW). A 25 A Circuit is recommended.
Compressor Cooling:	Cooling water at 70 °F, 0.5 gpm, 3.5 psid between inlet and outlet.
Auxiliary Equipment Required:	Helium gas source, 0 to 1 psig (99.5 % pure). Cooling water is required for compressor and unit on Model 7130.

Specifications are subject to change without notice.

APPENDIX B

UNITS FOR MAGNETIC PROPERTIES

Quantity	Symbol	Gaussian & cgs emu[a]	Conversion Factor, C[b]	SI & rationalized mks[c]
Magnetic flux density, magnetic induction	B	gauss (G)[d]	10^{-4}	tesla (T), Wb/m^2
Magnetic flux	Φ	maxwell (Mx), G•cm^2	10^{-8}	weber (Wb), volt second (V•s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization[g]	M	emu/cm^3[h]	10^3	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2[i]
(Mass) magnetization	σ, M	emu/g	1	A•m^2/kg
			$4\pi \times 10^{-7}$	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	4π	dimensionless
			$(4\pi)^2 \times 10^{-7}$	henry per meter (H/m), Wb/(A•m)
(Mass) susceptibility	χ_ρ, κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$	m^3/kg
			$(4\pi)^2 \times 10^{-10}$	H•m^2/kg
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$	m^3/mol
			$(4\pi)^2 \times 10^{-13}$	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 $\mu_0 = 4\pi \times 10^{-7}$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$^{-1/2}$•g$^{1/2}$•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 under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.
j. $\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ.
k. B • H and μ_0M • H have SI units J/m^3; M • H and B • H/4π have Gaussian units erg/cm^3.

1.4 MODEL 7221, 7225, AND 7229 DESCRIPTION

The Model 7221, 7225, and 7229 AC Susceptometer/DC Magnetometer is the most versatile magnetic measurement system available. The Models 7221, 7225, and 7229 have the capability to perform both AC and DC magnetization measurements in a single instrument. Since the two sensing coils and movement assembly are identical in both the AC and DC measurement, except for some minor cable switching, the system can switch from one measurement mode to the other without major hardware reconfiguration. There is no exchanging of cryogenic probes, sample probes, or coil assemblies. The test sample need not even be removed from the system.

The Models 7221, 7225, and 7229 measure both real (χ') and imaginary (χ'') components of susceptibility as a function of temperature, amplitude and frequency of AC field, with or without DC bias fields of ±1, ±5, or ±9 tesla, respectively. In addition, the system measures magnetic moment as a function of temperature, and applied DC fields of ±1, ±5, or ±9 tesla, including hysteresis loops. The Model 7221, 7225, and 7229 features the Lake Shore Model 610 Superconducting Magnet Power Supply (MPS) featuring true four-quadrant operation with smooth, continuous transitions through zero. The MPS permits fast, continuous ramping of the DC magnetic field.

Both AC and DC measurements are fully calibrated. Absolute accuracies of a few percent are typical, and accuracies of ±1 % can be achieved. Both measurements are performed automatically through data acquisition and control software packages that enable the researcher to adjust variables in temperature, frequency, amplitude of AC and DC field, in virtually any combination, for the measurement of AC susceptibility or DC moment. Model 7221, 7225, and 7229 features include:

- 30 or 60 liter superinsulated helium dewar.
- 1, 5, or 9 tesla superconducting magnet.
- Cryostat probe insert assembly.
- Sample positioning assembly featuring DC stepping motor control.
- Sample probe assembly with sample holder (disposable Delrin container); accommodates up to 3.6 mm (diameter) x13 mm (long) samples in powder, bulk or thin film form, including single crystals
- Vacuum pumping system with molecular drag pump.
- Lake Shore ACS Control Unit with built-in AC/DC current source.
- Lake Shore Model DRC-91CA Temperature Controller with dual diode inputs.
- Lake Shore Model 610 Superconducting Magnet Power Supply.
- Lake Shore Model 241 Liquid Helium Level Monitor.
- EG&G Model 5209 Lock-In Amplifier/Phase-Sensitive Detector.
- Keithley Model LS-182 Sensitive Digital Voltmeter (DVM).
- Hewlett-Packard Vectra™ series computer with National Instruments IEEE-488 interface.
- ACS7000 AC Susceptibility and DCM7000 DC Magnetization control software.

Physical, environmental, and performance characteristics are detailed in Table 1-3. The Instrument Console is shown in Figure 1-1. The Dewar Console is shown in Figure 1-2. The upper and lower front panels on the front of the dewar are shown in Figure 1-3. The dewar rear panel is shown in Figure 1-4.

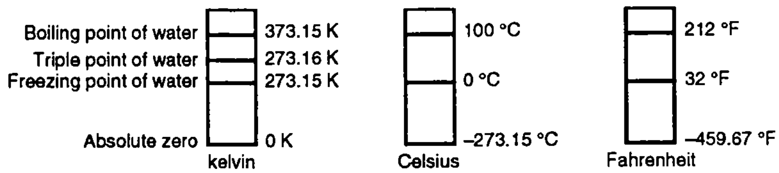
strain relief. A predetermined amount of slack to relieve tension in component or lead wires. Also called stress relief.

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

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

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

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



To convert kelvin to Celsius, subtract 273.15.
To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or: °F = (1.8 x °C) + 32.
To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or: °C = (°F. 32)/ 1.8.

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

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

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

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

tolerance. The range between allowable maximum and minimum values.

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

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

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 it is placed 1 cm away from a like pole, the force between the two is 1 dyne.

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

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

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

References:

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

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

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

Table 1-3. Model 7221, 7225, and 7229 Specifications

Temperature:	
Range:	<4.2K to 325K (Operation below 4.2 K requires auxiliary vacuum pump)
Accuracy:	±0.2 K or ±0.5% of T, whichever is greater (At 0-field)
Stability:	±0.1 K
Uniformity:	±0.1 K +0.5% of T (Measured from center to center of 2 secondary coils)
AC/DC Magnetic Field (Primary Coil):	
Range:	4-digit selectable from 0.1 A m^{-1} (0.00125 Oe) to 1600 A m^{-1} (20 Oe) RMS, both AC and DC
Accuracy:	±1.0%
Uniformity:	±0.3% inside secondary coils
Stability:	To within ±0.05%
Frequency:	1 Hz to 1 kHz, 1 Hz steps, 1 kHz to 10 kHz, 10 Hz steps
System Accuracy:	Calibration constants (both AC & DC) are accurate within ±1.0 %
AC Susceptibility Sensitivity:	To 2 x 10^{-8} emu in terms of equivalent magnetic moment
DC Moment Sensitivity:	9 x 10^{-5} emu
1 Tesla Superconducting Magnet Specifications (Model 7221):	
Field Range:	±10,000 gauss, (±1 tesla)
Uniformity:	Better than ±0.1% over 6 cm span
Resolution:	<0.1 gauss, –10,000 to +10,000 gauss
Accuracy:	±1.0%, –10,000 to +10,000 gauss
Stability:	± 0.5 gauss (±10, 000 gauss)
Remnant Field:	1.5 gauss (<0.1 gauss after demagnetization cycle)
5 Tesla Superconducting Magnet Specifications (Model 7225):	
Field Range:	±50,000 gauss, (±5 tesla)
Uniformity:	Better than ±0.1% over 6 cm span
Resolution:	<1.0 gauss, –50,000 to +50,000 gauss
Accuracy:	±1.0%, –50,000 to +50,000 gauss
Stability:	±5 gauss (±50, 000 gauss)
Remnant Field:	15 gauss (<0.5 gauss after demagnetization cycle
9 Tesla Superconducting Magnet Specifications (Model 7229):	
Field Range:	±90,000 gauss, (±9 tesla)
Uniformity:	Better than ±0.1% over 6 cm span (–9 to +9 tesla)
Resolution:	<2.0 Oe (–9 to +9 tesla)
Accuracy:	±1.0% of setting
Stability:	±10 Oe (–9 to +9 tesla)
Remnant Field:	30 gauss (<15 gauss after demagnetization cycle
Dewar Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 69 inches (175.2 cm). Allow 4 feet clearance above unit for sample loading.
Instrument Console Dimensions:	20.75 inches (52.7 cm) x 25.5 inches (64.8 cm) x 56.375 inches (143.2 cm). *Allow 3 ft separation between consoles.*
Weight:	**7221** = 159 kgs / 350 pounds **7225** = 177 kgs / 390 pounds **7229** = 182 kgs / 400 pounds
Power Consumption:	120/220 VAC, 50/60 Hz, 10/5 Amps
Recommended Circuit:	120 VAC – 15 Amp; 220 VAC – 10 Amps
Auxiliary Equipment Required:	He gas source, 0-1 psig (99.5 % pure, cryogens & transfer accessories
Helium Capacity:	30 or 60 liters
Static Boil-Off:	0.2 liters/hour (Model 7120 – nominal boil-off), 0.45 liters/hour with vapor cooled leads (Models 7121, 7125, & 7229 – nominal boil-off)

With system pre-cooled to liquid nitrogen temperature, the 30 liter dewar will require 45 liters of helium for initial transfer, while the 60 liter dewar will require 75 liters of helium for initial transfer.

Specifications are subject to change without notice.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

standards laboratories. The following are some of the standards laboratories from around the world:

Australia	National Measurement Laboratory (NML)
Canada	National Research Council of Canada (NRC)
China	National Institute of Metrology (NIM)
France	Institut National de Metrologie (INM)
Germany	Physikalich-Technische Bundesanstalt (PTB)
Italy	Instituto di Metrologia "G. Colonetti" (IMGC)
Japan	National Research Laboratory of Metrology (NRLM)
Russia	Institute of Metrology (VNIIM)
United Kingdom	National Physical Laboratory (NPL)
United States	National Institute of Standards and Technology (NIST)

1.5 DATA ACQUISITION/CONTROL AND ANALYSIS SOFTWARE

The 7000 Series Susceptometer/Magnetometer systems feature data acquisition/control software which controls all system functions automatically for unattended operation. The software features an easy-to-use menu driven format and real-time color graphic feedback of processed susceptibility or moment data in tabular or graphical format. The software is quickly and easily tailored to address specific research requirements. In addition, a post processing program permits analyzing previously recorded data and also features tabular and graphical display formats. The software programs allow for setup of the following options:

- Ability to input information pertinent to the sample (e.g. volume, mass, and molar).
- Output of SI or CGS units.
- Input of demagnetization factor.
- Calibration constant alteration.
- Capability of subtracting contributions arising from the sample rod and container.
- Manual mode for keyboard control of instrument operating parameters.
- Customized field and temperature profiling.
- Phase measurement and adjustment.
- The optional SigmaPlot™ analysis package to reprocess raw data and to store data in an ASCII file for data manipulation, reduction, and for generation of publication-quality plots.

1.5.1 ACS7000 AC Susceptibility Software

In the AC susceptibility mode, data can be recorded at a single AC field/frequency, or under an array display format where data is recorded at multiple field/frequency combinations input by the user, with or without an applied DC field. The software's flexibility derives from four basic sample measurement schemes:

1. Dual Phase ($\chi' + \chi''$)/Sample Movement (for the most precise and comprehensive data collection), where data is recorded in dual phase in both the top and bottom coil positions. The output voltage is read sequentially in the bottom and top coils.
2. Dual Phase ($\chi' + \chi''$)/No Sample Movement (for more rapid data collection), where data is recorded in dual phase. The sample remains fixed in either the top or bottom coil.
3. Single Phase (χ' only)/Sample Movement, where data is logged at one fixed phase setting. The output voltage is read sequentially in the bottom and top coils.
4. Single Phase (χ' only)/No Sample Movement (for survey measurements - usually in sweep or drift mode), where data is logged at one fixed phase setting. The sample remains fixed in either the top or bottom coil.

Further details on the ACS7000 software are provided in Chapter 5 of this manual.

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

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

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.

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

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

O.D. Outer diameter.

oersted (Oe). The cgs unit for the magnetic field strength (H). 1 oersted = $10^3/4\pi$ ampere/meter ≈ 79.58 ampere/meter.

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

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

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

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

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

pop-off. Another term for relief valve.

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

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

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

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

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

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

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

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

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

1.5.1.1 Temperature Control

There are three temperature control modes available:

1. Fixed point mode – This mode is used for the acquisition of data at stable temperatures. The user inputs discrete temperature points or increments (minimum 0.1 K increments) over a specified temperature range. During data acquisition, the temperature is automatically adjusted to, and controlled at a setpoint. Once stability criteria are satisfied, the susceptibility data is automatically recorded. The temperature is then adjusted to the next setpoint and the process repeats itself.
2. Sweep mode – For acquiring data quickly, the user defines lower and upper temperature limits and a sweep rate from 0.1 to 3 K/minute. Up to three ranges may be selected per operating sequence. During data acquisition, the temperature is automatically ramped at the defined sweep rate, and data is recorded either at user-defined intervals or continuously.
3. Drift mode – In this mode there is no active temperature control. Data is recorded at user-defined time intervals. This mode of operation is useful for recording data during cooldown or as a function of time.

1.5.1.2 AC Field/Frequency control

With the variable field/frequency capabilities of the Series 7000, data can be recorded at one field and frequency, or under an array display format where data is recorded at multiple field/frequencies selected by the user. This can be done with or without an applied DC field. Measurement sequences in the AC susceptibility software provide the user freedom to record data with or without automated sample movement, and in single or dual phase (for imaginary component determinations) schemes.

1.5.2 DCM7000 DC Moment Software

The DCM7000 software permits the measurement of magnetic moment as a function of temperature, applied DC field, and time for magnetization relaxation studies.

The DC moment measurement is defined as the process which outputs a single moment measurement. The default measurement sequence consists of a single scan (i.e. the sample is moved from the bottom coil to the top coil and then back to the bottom coil). The measurement sequence can consist of up to 10 single scans. The actual output is the average of the scans. This mode of operation is useful for measuring samples with low level signals or when extra precision is required. Further details on the DCM7000 software are provided in Chapter 6 of this manual.

1.5.2.1 Temperature Control

The specification of the desired temperature data points are operationally and functionally identical to the three modes in the ACS7000 software (fixed point, sweep and drift).

1.5.2.2 DC Field Control

Data can be recorded at stable discrete fields input by the user. The software includes a demagnetization cycle designed to minimize remnant fields. There are provisions in the software for generating a DC field table for which data will be recorded at each point. The system steps through each value in the table and records moment data at each point.

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

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

LCC. Leadless Chip Carrier.

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

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

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

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

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

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

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

LSCI. Lake Shore Cryotronics, Inc.

M. Symbol for magnetization. *See* magnetization.

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

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

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

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

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

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

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

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

mains. *See* line voltage.

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

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

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

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

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

1.6 7000 SERIES PRINCIPLES OF OPERATION

AC susceptometers have been used quite extensively in the study of the magnetic properties of materials, primarily due to their relative simplicity. The principle of operation involves subjecting the sample material to a small alternating magnetic field. The flux variation due to the sample is picked up by a sensing coil surrounding the sample and the resulting voltage induced in the coil is detected. This voltage is directly proportional to the magnetic susceptibility of the sample.

Figures 1-5 through 1-7 show schematically how the principles of AC susceptometry are incorporated into the 7000 Series. The alternating magnetic field is generated by a solenoid (P) which serves as the primary in a transformer circuit. The solenoid is driven with an AC current source with variable amplitude and frequency. A DC field may also be applied by supplying a DC current to the primary coil. Two identical sensing coils (S_1 and S_2) are positioned symmetrically inside of the primary coil and serve as the secondary coils in the measuring circuit. Figure 1-8 shows a cross-sectional view of the coil assembly. The two sensing coils are connected in opposition in order to cancel the voltages induced by the AC field itself or voltages induced by unwanted external sources. Assuming perfectly wound sensing coils and perfect symmetry, no voltage will be detected by the lock-in amplifier when the coil assembly is empty.

When a sample is now placed within one of the sensing coils, the voltage balance is disturbed. The measured voltage will be proportional to the susceptibility of the sample but will also be dependent on a number of other experimental parameters as given by the following relationship:

$$v = (1/\alpha)\, VfH\chi \qquad (1.1)$$

where v = measured RMS voltage
α = calibration coefficient
V = sample volume
f = frequency of AC field
H = RMS magnetic field
χ = volume susceptibility of sample

The calibration coefficient is dependent on the sample and coil geometry and will be discussed in further detail in the following sections. The magnetic field H as selected in the 7000 Series software is the RMS field at the center of the sensing coils and is determined from the physical parameters of the solenoid P and the operating current.

The relationship given in Equation 1.1 between the output voltage and the measurement parameters is extremely important in guiding the proper experimental set-up of the AC susceptometer. For example, if the output voltage for a given sample is too low to measure adequately, an increase in either the frequency or the field amplitude may increase the output voltage to an acceptable level. Another option in this situation would be to increase the sample volume, i.e., sample size.

Rearranging Equation 1.1 gives the relationship used in determining the sample susceptibility, χ, from the experimental parameters.

$$\chi = \alpha v/(VfH) \qquad (1.2)$$

Note that the absolute accuracy of the susceptibility depends on the accuracy with which each of the five parameters in Equation 1.2 can be determined.

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

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

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

gilbert (Gb). A cgs electromagnetic unit of the magnetomotive force required to produce one maxwell of magnetic flux in a magnetic circuit of unit reluctance. One gilbert is equal to $10/4\pi$ 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	ο	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 relatively large extent that serves in place of the earth. *Note:* It is used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground current to and from the earth (or of the conducting body).[2]

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

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

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

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

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

I.D. Inner diameter.

IEC. International Electrotechnical Commission.

IEEE. Institute of Electrical and Electronics Engineers.

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

Initial permeability. The permeability determined at $H = 0$ and $B = 0$.

Initial susceptibility. The susceptibility determined at $H = 0$ and $M = 0$.

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

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

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

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

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

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

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

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

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

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

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

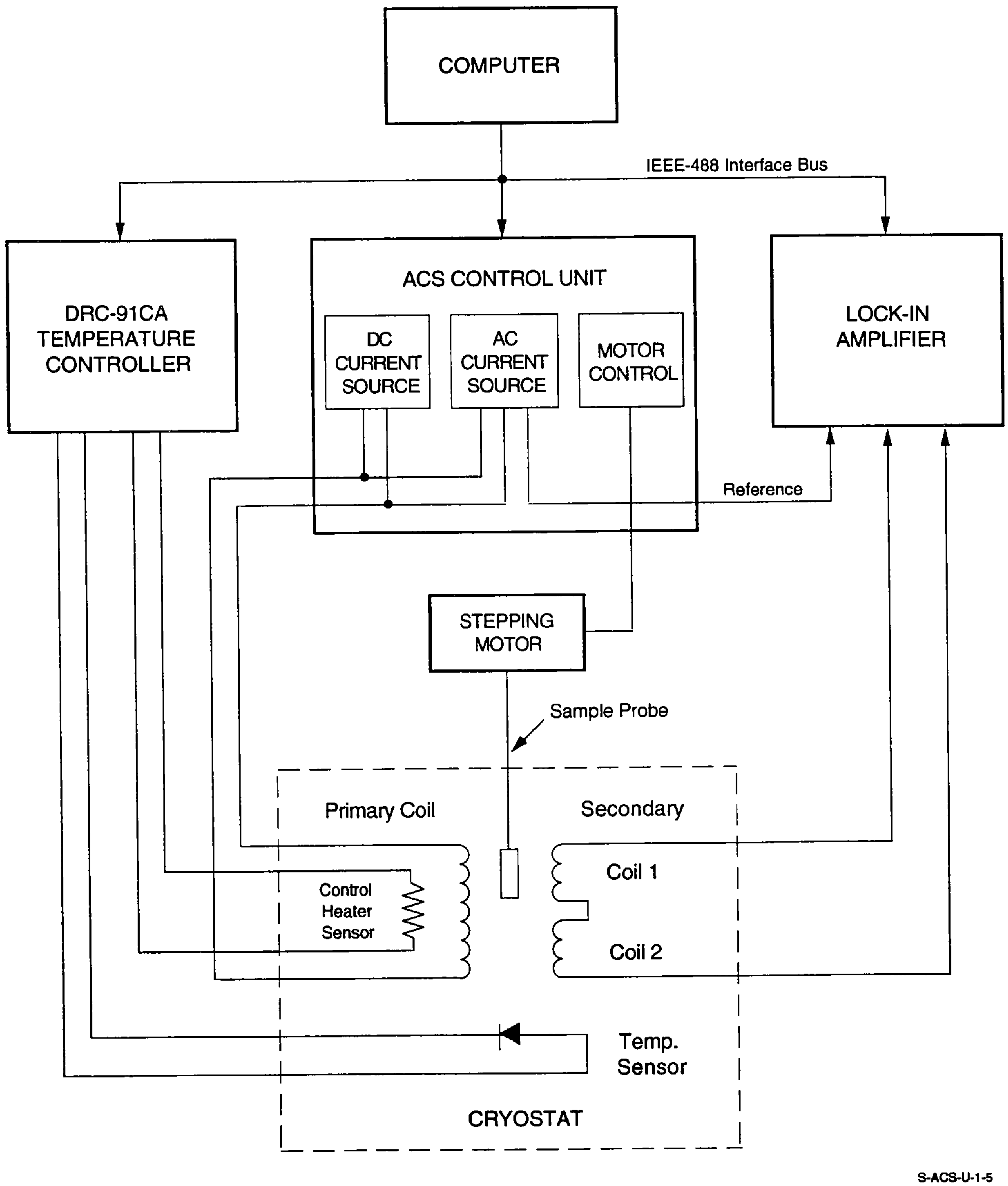


Figure 1-5. Model 7120, 7120A, and 7130 AC Susceptometer Block Diagram

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

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

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]

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

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

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

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

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

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

DIN. Deutsches Institut fur Normung.

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

dynamic data exchange (DDE). A method of interprocess communication which passes data between processes and synchronized events. DDE uses shared memory to exchange data between applications and a protocol to synchronize the passing of data.

dynamic link library (DLL). A module that contains code, data, and Windows resources that multiple Windows programs can access.

DUT. Device Under Test.

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

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

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

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

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

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

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

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

FPA. Focal Plane Array.

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

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

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

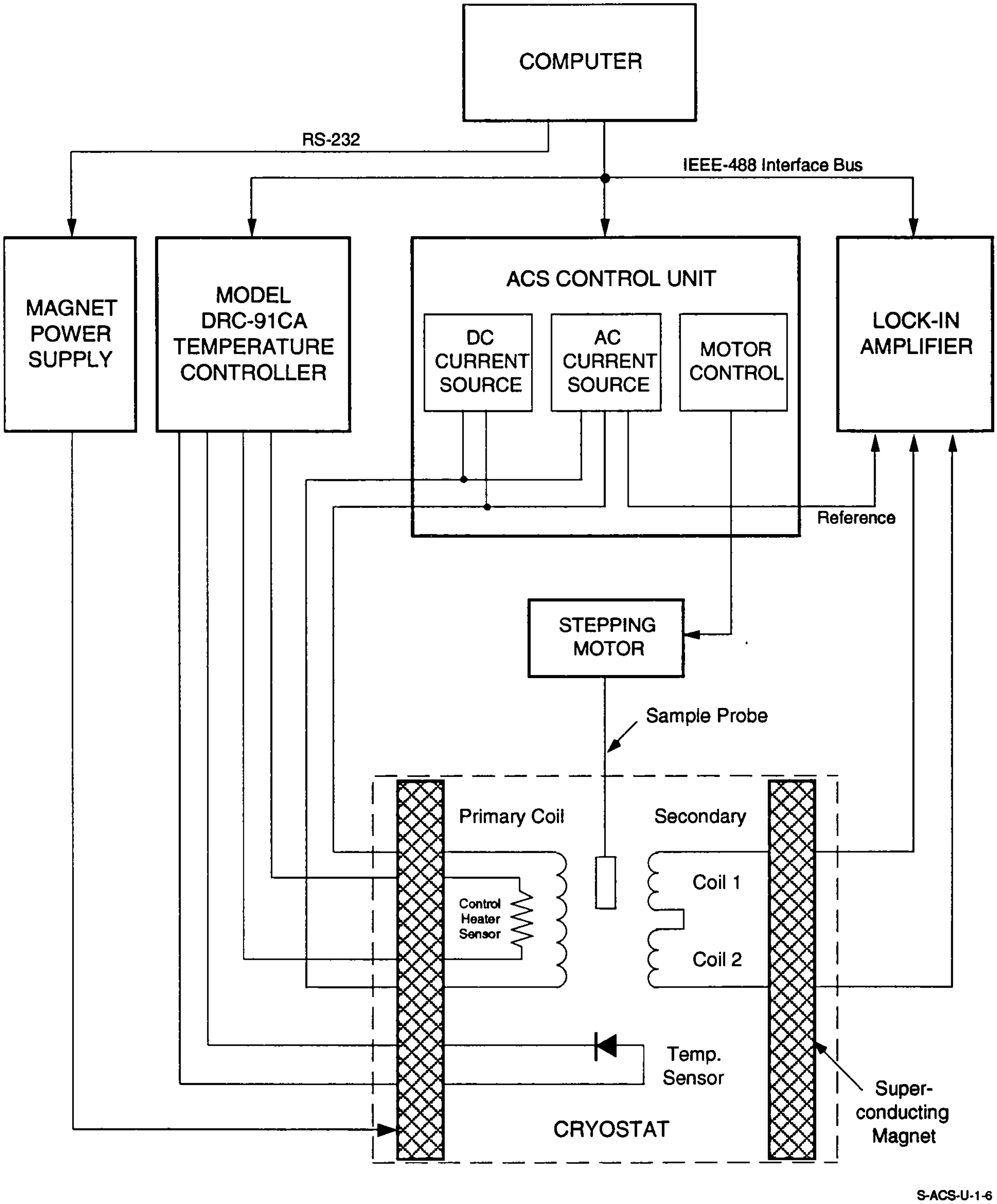


Figure 1-6. Model 7121, 7125, and 7129 AC Susceptometer Block Diagram

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

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

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

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

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

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

binary coded decimal (BCD). A coding system in which each decimal digit from 0 to 9 is represented by four binary digits as follows:

Decimal Digit	Binary Code	Decimal Digit	Binary Code
0	0000	5	0101
1	0001	6	0110
2	0010	7	0111
3	0011	8	1000
4	0100	9	1001

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

BNC. Bayonet Nut Connector.

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

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

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

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

+ Anode —▶|— Cathode –

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

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

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

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.

cryogen. *See* cryogenic fluid.[1]

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

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

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

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

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

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

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

DCM. Direct Current Magnetometer.

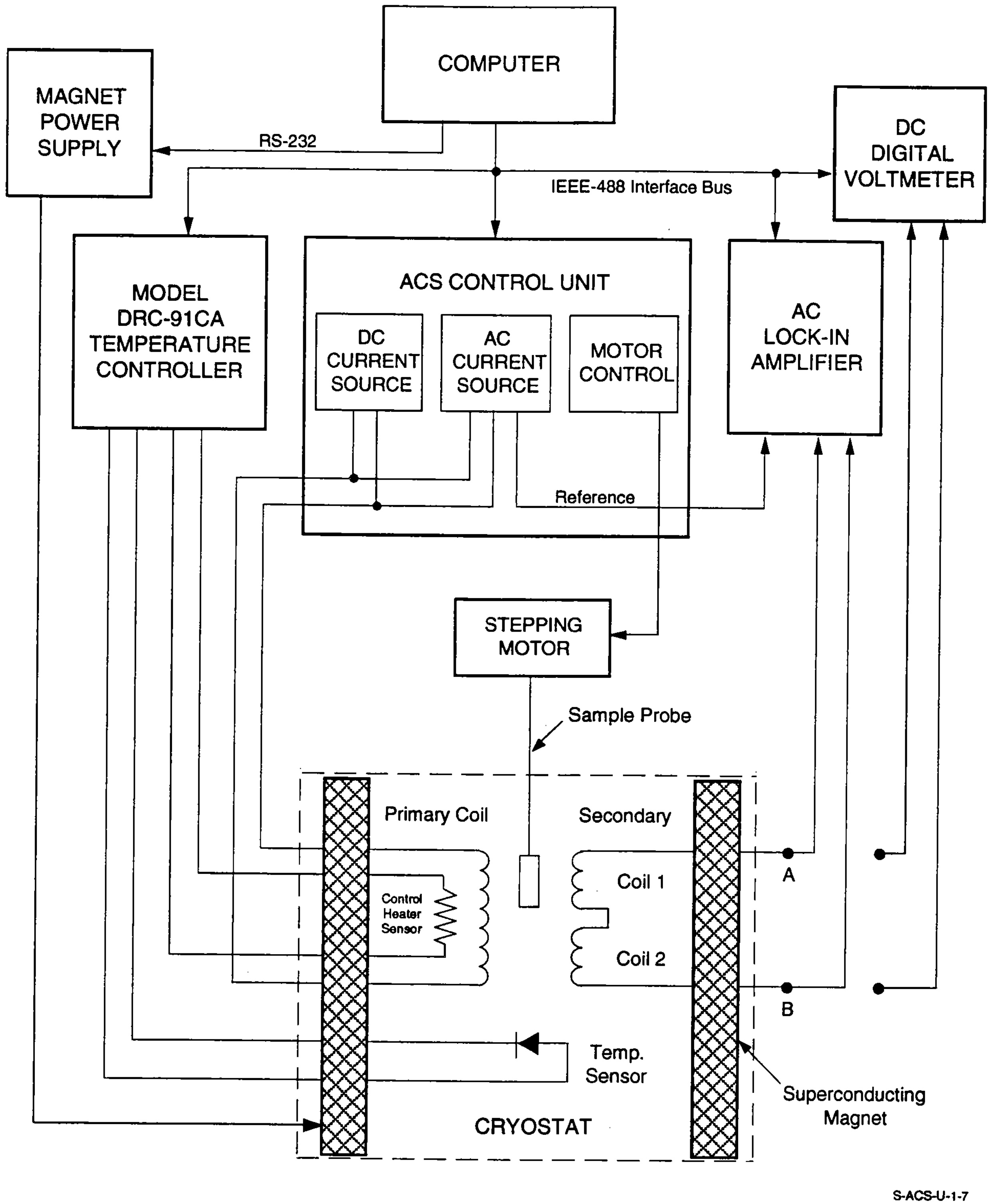


Figure 1-7. Model 7221, 7225, and 7229 AC Susceptometer/DC Magnetometer Block Diagram

APPENDIX A

GLOSSARY OF TERMINOLOGY

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

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

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

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

ACS. Alternating Current Susceptometer.

American Standard Code for Information Exchange (ACSII). 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:

Bits b7 b6 b5 →					000	001	010	011	100	101	110	111
b4	b3	b2	b1	Row \ Col	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

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

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

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

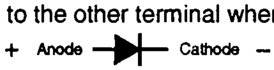
ampere/meter (A/m). The SI unit for the magnetic field strength (H). 1 ampere/meter = $4\pi/1000$ oersted ≈0.01257 oersted.

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

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

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

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



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

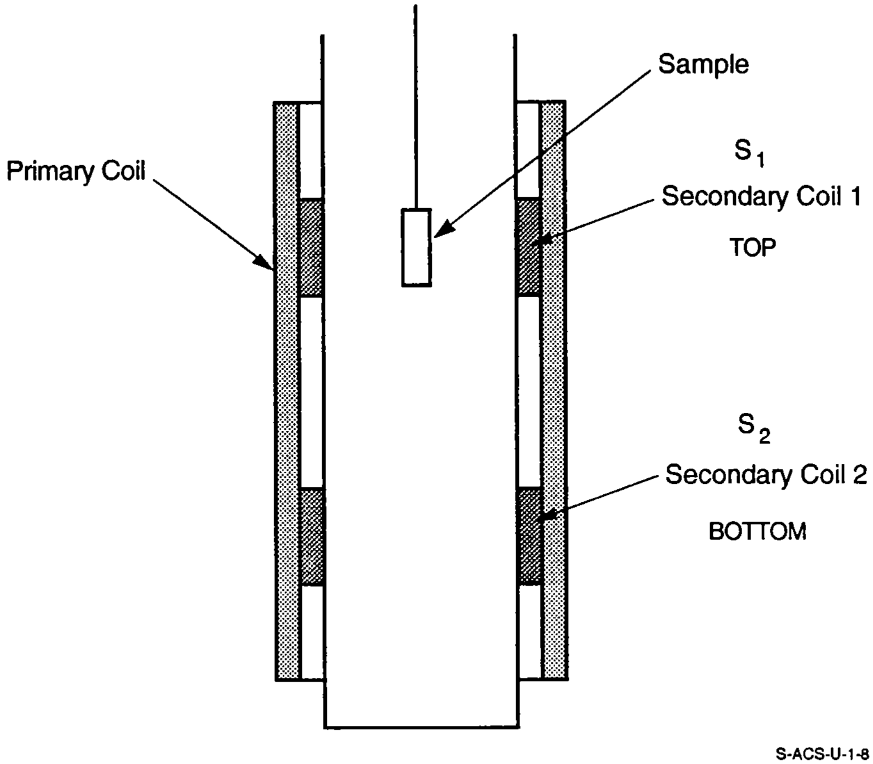


Figure 1-8. Cross-sectional View of Primary and Secondary Coils

1.7 DEMAGNETIZATION FACTOR

For precision measurements or when the susceptibility is large, the measured susceptibility in (1.2) must be corrected for demagnetization effects in order to obtain the actual material susceptibility. This effect is a geometric one and accounts for the fact that the internal field in the sample may differ from the applied field. The true internal susceptibility is given by the following relationship:

$$\chi_{int} = \chi/(1-D\chi) \quad (1.3)$$

where D is the demagnetization factor and χ is the measured susceptibility from Equation 1.2.

Table 1-4 lists the demagnetization factor for some common geometrical configurations. (Reference 6 gives a detailed analysis for demagnetization factors in cylinders.) Since the correction in Equation 1.3 depends on the magnitude of the susceptibility, the demagnetization correction can not be properly made when the susceptibility is expressed in "arbitrary units."

Table 1-4. Demagnetizing factors

Specimen Shape	D (SI)
Sphere	1/3
Long Needle, H perpendicular	1/2
Long Needle, H parallel	0
Thin Film, H perpendicular	1
Thin Film, H parallel	0

10.11.3 Removing Instruments

Instructions for removing instruments are as follows:

1. Contact factory before doing this.
2. If it is necessary to remove any of instruments for repair/service, turn instruments off and disconnect power to unit.
3. Unplug electrical connections from rear of instrument.
4. Remove screws holding instrument to rack/console and lift instrument out.

10.12 SAMPLE LOAD SEAL

Periodically clean and apply a light coat of vacuum grease to the O-ring. This will aid in maintaining a vacuum tight seal between the sample load seal and sample probe seal assembly.

10.13 SAMPLE PROBE FREEZE-UP

If the sample probe freezes in the sample space due to accidental contamination entering the vacuum space, do not apply excessive force in attempting to remove the sample probe. This may permanently damage the system. The following procedure should be used:

1. Open Sample Space valve and Vacuum Space valve so that both spaces are being pumped on simultaneously with vacuum pump.
2. Using Auto_T adjust feature discussed in Chapter 5, warm system to 300 K.
3. Remove probe as discussed in Paragraph 4.8 for all models except 7225 or Paragraph 4.9 for Model 7225 only.
4. Remove water vapor from diaphragm pump per procedure provided in Paragraph 10.11.3.

10.14 REPLACING TEFLON® SEALS IN THE SAMPLE SEAL ASSEMBLY

The two Teflon® seals in the sample seal assembly will require periodic replacement. The following procedure should be used:

1. Remove nut from top of sample probe. Slide seal assembly off sample probe.
2. Use a snap ring pliers to remove internal retaining rings at both ends of seal assembly. Washers behind ring should drop out. Clean these parts and save re re-assembly.
3. From opposite end of opening use wood end of a cotton swab to push old Teflon® seals out of assembly. (You may also use a metal tweezers to pull seals out.) Clean internal part of seal housing with cotton swab and alcohol. Blow dry. Examine old seals. metal spring should not protrude out.
4. For ease of installation, apply a very small (pin head) amount of vacuum grease to outer diameter of new Teflon® seals. Wipe off with finger. Only a very thin layer is required. Fit Teflon® seals to seal housing ends with spring facing outward. Reinstall flat washers. Push seals into seats with even force with flat end of pen or similar tool. You can feel a snap action when seal has correctly seated itself. Do not use too much force. Repeat steps 3 and 4 if seals do not go in easily.
5. Check position of washers and reinstall retaining rings.
6. Clean sample probe with towel and alcohol. Slide seal assembly over probe.

CAUTION

Other than the small amount of vacuum grease used to install the Teflon seals, do not apply any other greases or lubricants to the probe or seal.

1.8 SAMPLE MOVEMENT

The electronic sensitivity of the measurement system exceeds the physical capability of manufacturing two identical secondaries. As a result, a slight offset voltage is read on the lock-in even when no sample is present. The ability to move the sample precisely between the two secondaries and make two position measurements provides compensation for the offset voltage. Note that the offset voltage will vary with temperature, frequency and magnetic field amplitude.

To illustrate how this compensation is accomplished, assume that a constant offset voltage of v_o is present with the sample induced voltage v. Note that the offset voltage can include any system dependent offsets and is not strictly limited to just the imbalance between the secondary coils. In S_1, the lock-in amplifier will give the following indication:

$$v_1 = v + v_o$$

When the sample is moved to S_2, the sample dependent voltage read on the lock-in amplifier changes sign since S_1 and S_2 are connected in opposition. The offset voltage, however, remains constant and is unaffected by the sample movement. Therefore, the following voltage will be indicated on the lock-in amplifier when the sample is in S_2:

$$v_2 = -v + v_o$$

The true sample induced voltage can now be determined from the measurements v_1 and v_2:

$$v = (v_1 - v_2)/2 \qquad (1.4)$$

In the 7000 Series, Equation 1.4 is defined with v_1 being the voltage measured in the top coil and v_2 the voltage measured in the bottom coil.

In many circumstances, the presence of an offset voltage will be unimportant and data acquisition time can be saved by measuring the sample in only one position. Some instances where sample movement may be unnecessary are when transition temperatures are being studied or when the sample signal is large compared to any offset voltage present.

Equation 1.4 establishes a sign convention which must be maintained throughout the data analysis in order to process the data correctly and determine the proper sign for the susceptibility. For single position measurements, the voltage v in Equation 1.2 is either v_1 for top coil measurements or $-v_2$ for bottom coil measurements.

1.9 CALIBRATION COEFFICIENT

Calibration of the 7000 Series refers to determining the numerical value of the calibration coefficient, α. When α is known, absolute values of the susceptibility can be obtained from Equation 1-5 and the experimental parameters.

The use of standard materials in the calibration of magnetic measurement systems has long been accepted and utilized. In many circumstances, this is the only method to achieve a reliable system calibration. However, the design of the 7000 Series allows the calibration to be determined without the use of standard materials. The calibration can be determined directly from physical geometry of the susceptometer coils. The calibration coefficient supplied with the 7000 Series is a calculated coefficient which assumes a magnetic dipole and which fully takes into account interactions with both sensing coils.

1.9.1 Calibration Through Calculation

The calibration coefficient relates the magnetic flux coupling between the sample and the sensing coil, so the exact value of α will be dependent on the sample size and geometry. In principle, the value of α can be calculated from the sample geometry and the sensing coil specifications. These calculations assume that the experimental system has been designed to avoid extraneous effects on the measurement, such as the generation of eddy currents in surrounding conductive materials.

10.11.1 Disassembly Of Cryostat Insert

If it is necessary to remove the ACS probe assembly/cryostat insert for repair/service purposes or if something is dropped and needs to be removed from the sample space, use the following:

1. Contact factory before proceeding.
2. Make sure unit is warmed up to room temperature.
3. Remove sample probe.
4. Turn off instruments and power switch.
5. Disconnect power to console.
6. Let air into system by opening all valves at front and closing them after system is completely vented.
7. Open door at rear of Dewar Console.
8. Remove knurl nuts and hold down clamp, if applicable, at top of cryostat above console top.
9. Remove two screws holding movement drive to console top and cable to instrument Model 140.
10. Lift movement drive out of console top and lay it aside.
11. Replace three knurl nuts to cryostat.
12. Disconnect BNC and 10-pin connector cables from feed-throughs on cryostat.
13. Disconnect two thermocouple gauge cables at gauge tubes.
14. Disconnect two bellows connecting cryostat to pumping lines at cryostat.
15. Loosen screws on each of valve shaft couplings.
16. Disconnect extension shafts and knobs from valve shafts of cryostat by pulling forward.
17. Loosen Swagelok™ nuts at back of helium exchange gas valves. It takes about 1/2 turn. Make sure two wrenches are used when turning nuts.
18. Disconnect Swagelok™ nuts at sample and vacuum space valve bodies. Make sure two wrenches are used when turning nuts.
19. Lift 1/4 inch copper tubing and nut off fittings and rotate away from cryostat.
20. Remove #8 cap screws which hold down cryostat flange to dewar.
21. Grasp LHe fill tubes and lift cryostat out of dewar. It is necessary to rotate cryostat 90° while lifting, in order to clear console top.
22. Cover dewar so that nothing falls into it.

CAUTION

Always store the cryostat in an upright position.

23. If something has dropped into sample space, turn cryostat upside down and allow it to fall out (load lock valve must be open). Support vacuum can when doing this to minimize stress on weld joints.

10.11.2 Cryostat Insert Replacement

Instructions for replacing the cryostat are as follows:

1. To replace cryostat insert, repeat Steps 1-21 in Paragraph 10.12.1 in reverse order.
2. Once cryostat insert is replaced, system should be leak checked. This can be accomplished either with a leak detector or by performing tests outlined in Paragraph 10.6.

The easiest situation to deal with is a sample which can be approximated by a magnetic dipole. This would occur with a uniformly magnetized spherical sample or a sample which is small with respect to the sensing coil. The resulting expression (in cgs) for the calibration coefficient is quite simple (Reference 1, 2, 3):

$$\alpha = (10^8 / 8\pi^2 NL) [L^2 + d^2]^{1/2} \qquad (1.5)$$

where N = number of turns per centimeter on the sensing coil
L = length of the sensing coil in centimeters
d = diameter of the sensing coil in centimeters

In order to convert the calibration coefficient into SI, divide α (cgs) by 1000. The question which must be addressed is the validity of this approximation and over what range in sample sizes it can be used.

Extending the calculation of the calibration coefficient to large samples with different geometries greatly increases the complexity of the mathematics. Expressions and techniques for cylindrical samples have been published (Reference 2, 4). The most general is the technique of Goldfarb and Minervini where the cylindrical sample is modeled by an equivalent solenoid. The mutual inductance is calculated (using numerical techniques) between two coaxial solenoids; i.e., the sample "solenoid" and the sensing coil. The calibration coefficient is then determined from the mutual inductance and the sample size. This technique is valid for uniformly, axially magnetized cylinders as in the cases of samples with small susceptibility (non-ferromagnets), or samples which are relatively long with respect to their diameter.

Assuming a typical 7000 Series coil geometry, inductance calculations were carried out for samples with diameters ranging from 0.1 to 0.6 cm and with lengths up to 1.5 cm. In the limit of small samples, the inductance value for the calibration coefficient agrees with the calculated values from Equation 1.5 within 0.1%. Samples of the same length, but different diameters, yield values for the calibration coefficient which agree to within ±0.5%. This indicates that for most applications α can be treated as independent of sample diameter. However, there is a dependence in the calibration coefficient on the sample length as shown in Figure 1-9. In Figure 1-9, the ratio of the inductance calculated value for α to the magnetic dipole value (Equation 1-5) is plotted as a function of the sample length. The variations with diameter are too small to clearly show in the scale of Figure 1-9, so only a mean behavior is plotted.

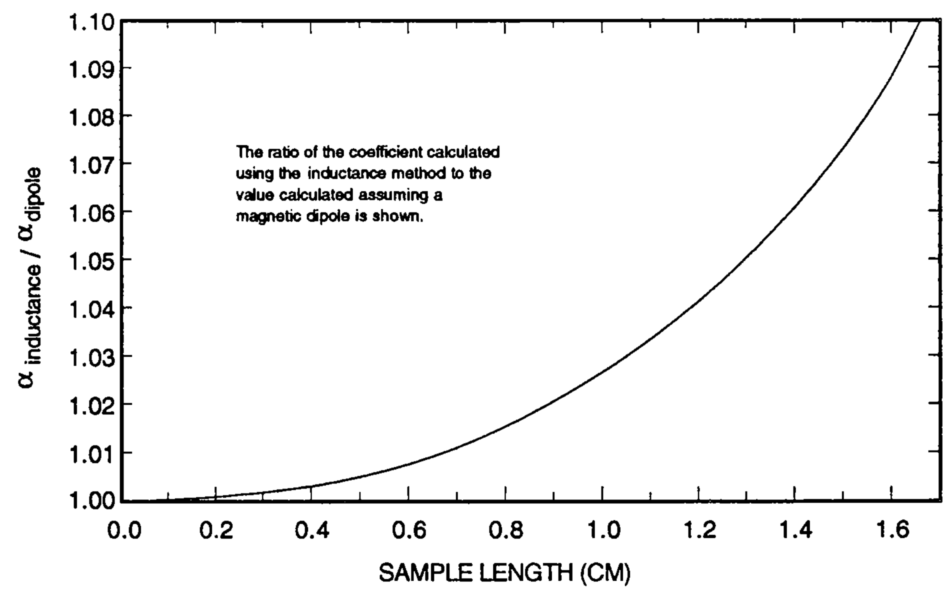


Figure 1-9. Variation Of Calibration Coefficient With Sample Length

7. To verify temperature sensor mounted on resistance probe is functioning properly, use a multimeter in a diode measurement mode. (If one is not available, proceed to Paragraphs 8.3 and 8.4.)
8. Place positive test lead on pin A and negative test lead on first pin B and then pin C. In both cases voltage measured should be approximately 0.6 volts. (This is voltage measured at room temperature. At 77 K measured voltage will be approximately 1 volt and at 4.2 K it will be approximately 1.6–1.7 volts.)
9. With negative test lead on pin J, zero volts (a short) should be indicated.

10.10.4 Liquid Helium Level Indicator (Optional)

If the liquid helium level indicator is not functioning properly, check the following:

1. Verify unit is plugged in and turned on.
2. Verify cable is connected to both 5-pin connector on cryostat and instrument.
3. Disconnect 5-pin cable connector. With an ohmmeter check level sensor using following cable/pin definition:

REAR OF LEVEL METER		PROBE 5-PIN CONNECTOR
Red	(I+)	A
Black	(I-)	B
Blue	(V+)	E
Yellow	(V-)	D

4. Place one test lead on pin A and with other check across pins B and D. Measured resistance should be approximately 100 Ω. (Resistances are room temperature values.)
5. Place other test lead on pin E. Measured resistance should be on order of a few ohms. If OK and there still seems to be a problem, consult level indicator manual.

10.10.5 Cables

Instructions for checking cables are follows:

1. If there appears to be a problem with an instrument, but a specific problem can not be isolated, cables should be checked.
2. Refer to Paragraph 10.4 - Thermometry Check for test procedure and wiring definition of cable that connects DRC-91CA to cryostat feed-through. (Refer to Paragraph 10.10 - Option: Resistance Probe and Cables for cable definitions for resistance cabling and liquid level indicator cabling respectively).
3. 4 BNC cables should be checked for continuity and shorts.
4. Power and IEEE cables should be visually inspected to ensure they are securely fastened.

10.11 DISASSEMBLY AND RETURN OF HARDWARE

This paragraph contains information and instructions pertaining to the removal of the cryostat insert and instrumentation and instructions for returning goods to the factory for repair or service. If the 7000 Series System or any component of the system appears to be operating incorrectly, contact Lake Shore Cryotronics (614-891-2243; 8 A.M. – 5 P.M. EST) or a factory representative for a Returned Goods Authorization (RGA) number. Attach a tag with the following information when returning:

- RGA number
- System/instrument model and serial number
- User's name, company, address and phone number
- Malfunction symptoms

Before removing and returning any instrument or the cryostat insert, contact the factory for proper shipping and packing instructions.

These results indicate that even for a large sample which fits in the sample cup supplied with the 7000 Series (maximum length = 1.3 cm., diameter = 0.36 cm), the magnetic dipole approximation used in determining α should be valid to within 5%. If closer estimates for α are desired for large samples, Figure 1-9 can be used to estimate the factor by which the dipole value has to be increased.

Verification of the calculated coefficients have been done using a number of different standard materials (MnF_2, Ni, superconductors). In all instances the values have agreed to within the experimental uncertainties of a few percent. This is consistent with the findings of other researchers (Reference 2, 4). The use of a calculated value for α can yield results as accurate as a value obtained from a standard material.

Equation 1.5 assumes the sample is only interacting with the sensing coil within which it is centered. This is a good approximation in the 7000 Series, as the effect of the second sensing coil is only 0.5%. A modified form of Equation 1.5 is used to account for the second coil in determining α. Note also that the results presented here are valid only for the geometry of the sensing coils in the 7000 Series.

1.9.2 Calibration Through Standard Materials

Standard materials with a known susceptibility and volume can be used to experimentally determine the calibration coefficient. Equation 1.2 is simply solved for α using the experimental parameters measured with the standard. Note the accuracy of α will be no better than the accuracy with which the susceptibility and the volume of the standard is known. Also, if demagnetization corrections must be made, any uncertainties in the demagnetization factor will be reflected in α.

Unfortunately, the selection of a suitable standard is not necessarily straight-forward and there is no overall consensus in the scientific literature as to what to use. Many laboratories have their own "favorite" material which is used to verify and test system performance. Paramagnetic salts which obey Curie's Law are often used to test the temperature dependence of a magnetic system, although they may not be the best choice to serve as absolute standards. The temperature dependence of the susceptibility of chromium potassium alum is used as a quality control check with the 7000 Series.

Susceptibility standards accurate to ±0.5% are available from the National Institute of Standards and Technology (NIST)—formerly the National Bureau of Standards (NBS)—through their Office of Standard Reference Materials in Gaithersburg, MD. The manganese fluoride standard (SRM 766) is preferred for use in the 7000 Series and is routinely used in quality control testing by Lake Shore.

Other options are discussed in Reference 4, including the use of soft ferromagnets with infinite internal susceptibility and superconducting samples with perfect diamagnetism. In these cases, corrections for the demagnetization factor must be taken into consideration. For example, consider a superconducting sphere which will have a demagnetization factor (SI) of 1/3 and an internal susceptibility (χ_{int}) of −1 for perfect diamagnetism. From Equation 1.3, the measured susceptibility will be −3/2 and this should be the value for χ used in Equation 1.2 in solving for the calibration constant.

The resulting calibration using a standard material is strictly valid only for samples which are identical in size and shape to the standard. The results in Figure 1-9 give an indication as to what variation to expect in α if the sample size varies from that of the standard.

10.10.1 Power

Power checks are as follows:

1. If there is no power to instruments, check that they are plugged in.
2. Ensure fuse(s) have not blown. There is a breaker in the power strip located in Instrument Console.

10.10.2 ACS Software

ACS Software checks are as follows:

1. If ACS or ACSDATA program will not run, verify ACS.DAT file resides in same directory as ACS and ACSDATA programs. It must be in order for programs to run.
2. If in INITIALIZING INSTRUMENTS mode of ACS program, computer prompts user with statement:

   "[*Instrument*] not responding to commands, check instrument and press ESC to continue."

   Check instrument and press ESC. If instrument still does not respond to commands then refer to appropriate segment in Paragraph 10.3 - Instruments Check.
3. If during operation of ACS program user is prompted with statement:

   "Warning: Temperature Sensor and Control Sensor Disagree, Press ESC to Continue."

   Press ESC. If prompted again, refer to thermometry segment in Paragraph 10.4 and DRC-91CA Temperature Controller segment in Paragraph 10.3.

WARNING

Do not continue running the ACS program if the thermometer does not function properly. The system may overheat and cause irreversible damage. Play it safe and turn the DRC-91CA Heater OFF.

4. If unable to load a data file into ACSDATA program, verify that ACS.DAT resides on same directory as ACSDATA.EXE and [data file].CFG resides on same directory as [data file].DAT file.
5. If ACSDATA program appears to produce erroneous susceptibility data, verify data parameters were input correctly (e.g., sample volume, cgs or SI units, phase, demagnetization factor ,and mass or volume susceptibility).

10.10.3 Resistance Probe (Optional)

If the optional resistance operation is not performing correctly then check the following:

1. Verify 10-pin cable connector extending out of rear of Dewar Console is plugged into probe.
2. Check 2 BNC cables labeled A and B are plugged into rear of Lock-in Amplifier.
3. Check BNC cable labeled P is plugged into rear of Model 140.
4. Check 5-pin connector labeled B is plugged into B input of DRC-91CA.
5. Verify resistance sample card is securely plugged into socket and element is electrically attached.
6. Remove 10-pin cable connector from socket on probe. Resistance probe pin definitions are as follows:

LEAD IDENTIFICATION			10-PIN CONNECTOR IDENTIFICATION
Sensor:	V+		A
	V–		B
	I–		C
	I+		J
Sample:	V+	(2)	H
	V–	(4)	D
	I–	(3)	F
	I+	(1)	K

1.10 COMPLEX SUSCEPTIBILITY: REAL AND IMAGINARY COMPONENTS

One of the most useful features of the AC Susceptometer is that both the real or in phase component χ' and the imaginary or out of phase component χ'' of the susceptibility can be measured. The proper separation of the two components requires an understanding of how phasing is handled in a lock-in amplifier and how to make the appropriate adjustment for the sample being studied. The control software supplied with the 7000 Series is designed to make this separation with minimal effort.

As shown in Figures 1-5 through 1-7, the lock-in detector requires a reference signal which is at the same frequency and in phase with the current from the AC current source. The reference signal serves two purposes. First, it "tunes" the lock-in amplifier to the frequency of the reference signal, and secondly, the lock-in amplifier provides an output (E_{out}) which is sensitive to the phase difference (Φ) between the input signal (E_{in}) and the reference signal:

$$E_{out} = E_{in} \cos \Phi$$

The measurement as shown in Figures 1-5 through 1-7 will have two contributions to the phase angle Φ. One contribution arises from the circuit itself which, in the case of ideal inductors, would introduce a 90° phase shift in the circuit of Figures 1-5 through 1-7. In reality the circuit phase shift will deviate a few degrees from the ideal case and will have a slight frequency dependence. The second contribution to the phase shift will arise from the signal due to the sample.

Information concerning the phase angle Φ can be obtained through the phase adjust feature on the lock-in. The phase adjustment introduces a phase shift (Θ) in the reference channel of the lock-in so the output signal is modified:

$$E_{out} = E_{in} \cos (\Phi - \Theta) \qquad (1.6)$$

The value of Θ is read directly from the lock-in and is completely variable from –180° to +180°.

"Phasing" a lock-in amplifier refers to the process of setting the phase shift Θ equal to Φ. When the lock-in amplifier is phased the output signal is a maximum. An equal negative output should then be detected at Θ + 180° and a 0 output at either Θ + 90° or Θ + 270°. The obvious method for phasing the lock-in is simply to adjust the phase on the lock-in until a maximum signal is observed; i.e., $\Theta = \Phi$. In practice, however, this is not the most sensitive way to phase the lock-in amplifier. The lock-in amplifier is most accurately phased by adjusting the phase for a zero output and then shifting the phase setting by 90°.

In order to separate the real and imaginary components of the susceptibility, the phase angle Θ must be determined. The proper separation of χ' and χ'' requires that the phasing be performed with either a test sample with a known $\chi'' = 0$ or under measurement conditions where $\chi'' = 0$ for the sample under study. Once this phase is determined, the lock-in amplifier signal measured at Θ will be proportional to χ' and the signal measured at Θ + 90° will be proportional to χ''. The specific method used in phasing the system will depend on the materials under study and the manner in which the 7000 Series is used.

The phase setting should be fairly consistent from run to run for a given set of measurement parameters. However, variations can occur with time and use of the susceptometer, and since the phasing process can be quickly done, the recommended procedure would be to check the phase each time data are recorded where the phase information is critical. As will be discussed below, phasing is not required for many situations.

The obvious approach to determining χ' and χ'' would be to measure the lock-in voltage using a dual phase measurement where the data is logged at the phase angle settings of Θ and Θ + 90°. However, in this measurement technique, data files will be accumulated containing data that were logged with different lock-in settings for each sample and frequency. As a result, this technique is not the most convenient way to handle the data acquisition and can actually limit the flexibility in the data analysis.

NOTE

If the control sensor significantly lags the control setpoint and the heater power is in excess of 90%, abort the system warm up and allow the system to reach room temperature without any active control. Pump on the sample and vacuum spaces continuously during this process. If the sample space can not be evacuated, close the sample space valve and pump only on the vacuum space. There is a safety check valve integrated into the cryostat in case of pressure build-up.

3. Once system is at room temperature, open sample space valve.
4. Allow sample space to be fully evacuated. This will take several hours. Sample space should be pumped until entire system maintains room temperature without any active temperature control.
5. If upon re-cooling system same problem occurs again, consult factory.

10.9 SAMPLE MOVEMENT CHECK

If the motion control does not respond to movement commands then check the following.

1. Verify instrument Model 140 is plugged in and turned on. Verify IEEE address is set to 24.
2. Ensure sample probe is not frozen in sample space and that it freely moves through sample probe seal.
3. Visually check movement shaft to see that it is centered and not bent.
4. Ensure 8-pin DIN connector is plugged into 8-pin socket on rear of instrument.
5. Check motor winding and 8-pin cable for continuity.

PIN	COLOR	DC RESISTANCE
1 and 6	yellow and black	≈8.5 Ω
3 and 7	orange and yellow	≈8.5 Ω
8 and 1	red and yellow	≈4.3 Ω
8 and 6	red and black	≈4.3 Ω
8 and 7	red and orange	≈4.3 Ω
8 and 3	red and brown	≈4.3 Ω
2 and 4	white and blue	open at intermediate limit <1 Ω at bottom limit
2 and 5	white and green	open at intermediate limit <1 Ω at bottom limit

PIN	CABLE COLOR	MOTOR/SWITCH LEAD COLOR	DEFINITION
1	yellow	yellow	coil 1
2	white (2)	white (2)	common-limit switches
3	brown	brown	coil 4
4	blue	blue	bottom limit
5	green	green	top limit
6	black	black	coil 2
7	orange	orange	coil 3
8	red	red	common-coils

6. If above appear to be satisfactory and problem persists, consult factory.

10.10 MISCELLANEOUS CHECKS

Miscellaneous checks consist of the following: power checks in Paragraph 10.10.1, ACS Software checks in Paragraph 10.10.2, optional resistance probe checks in Paragraph 10.10.3, optional liquid helium level indicator in Paragraph 10.10.4, and cables in Paragraph 10.10.5.

In order to maintain consistency in the data acquisition and to guarantee that no information is lost for future analysis, all dual phase data are measured with the lock-in amplifier phase set to 0° and 90°. The phase angle Θ is then used in the data analysis to convert the measured voltages to the equivalent in phase and out of phase voltage signal:

$$V' = v_0 \cos\Theta + v_{90} \sin\Theta$$

$$V'' = v_{90} \cos\Theta - v_0 \sin\Theta \qquad (1.7)$$

where v_0 = lock-in voltage at 0°
v_{90} = lock-in voltage at 90°
V' = in phase voltage reading for sample = voltage at phase angle Θ
V'' = out of phase voltage reading for sample = voltage at phase angle Θ + 90°.

Note that v_0 and v_{90} are determined following the conventions in Paragraph 1.7 for voltages recorded with or without sample movement. Each phase is treated independently in Equation 1.4.

The voltage V' is then used in Equation 1.2 to determine the measured susceptibility, χ'. The imaginary component of the measured susceptibility is determined from the following relationship:

$$\chi'' = -\alpha V''/(VfH)$$

This is the same as Equation 1.2 except for the negative sign. The sign difference arises from the phasing conventions used in the 7000 Series.

Uncertainties in the determination of the phase angle may produce non-physical results for χ'' such as $\chi'' < 0$. In these situations, the data analysis allows adjusting the phase angle slightly in Equation 1.7 to eliminate these ambiguities.

Since the susceptibility is complex, Equation 1.3 must be modified in order to correctly separate the real and imaginary components of the internal susceptibility. The real and imaginary internal susceptibilities are interdependent on both the real and imaginary measured susceptibilities:

$$\chi'_{int} = \frac{\chi'(1-D\chi') - D\chi''^2}{(1-D\chi')^2 + D^2\chi''^2} \qquad \chi''_{int} = \frac{\chi''}{(1-D\chi')^2 + D^2\chi''^2} \qquad (1.8)$$

Note that for χ'' = 0, Equation 1.8 reduces to Equation 1.3 (Reference 4).

In many circumstances the samples being studied will not have an imaginary component or the magnitude of the susceptibility alone gives sufficient information. In these situations dual phase data acquisition is a convenient way to record data and not have to worry about any phasing of the system or worry about phase variations with frequency if multiple frequency measurements are being made. The voltage used to calculate the susceptibility from Equation 1.2 is simply the square root of the sum of the squares of the 0° and 90° reading:

$$v = [(v_0)^2 + (v_{90})^2]^{1/2} \qquad (1.9)$$

For samples with χ'' = 0, this technique gives the identical result to phasing the system and measuring the data with the phase angle set to Θ.

Single phase data acquisition is useful if rapid data acquisition is desired such as in temperature sweeping. Single phase acquisition requires that the system is phased properly and that the lock-in amplifier phase angle is set and fixed at Θ during the data acquisition. In this mode of operation, some information may be lost since the out of phase signal is not monitored or recorded.

Caution must be emphasized in working with the phase settings on the lock-in amplifier as the initial set-up can be somewhat arbitrary. What is important is consistency in the manner that the phase is dealt with and consistency with the way the 7000 Series has been set-up. Improper phase adjustments most often will result in sign errors in the susceptibility values.

10.7.6 Rapid Boil Off

Rapid boil off of liquid helium may be due to an insufficient amount of liquid nitrogen in the outer nitrogen dewar or a "soft" dewar. If the dewar is soft (i.e., has lost its vacuum) it will be very cold to the touch and in worse case water will condense over the outside surface.

1. Warm system to room temperature
2. Pump out the dewar vacuum space through the valve located on dewar.

CAUTION

This should only be done when there is no liquid nitrogen in the outer nitrogen dewar. This may also be caused by too much exchange gas in the vacuum space. To avert this, it is recommended the vacuum space be continuously pumped on.

10.7.7 Liquid Nitrogen Leak At Fill Port

If liquid nitrogen is observed leaking at the fill port, check the following:

1. If liquid nitrogen leaks out of fill port located on top left hand side of table top during filling, ensure that hose connection is tight.
2. If cracks appear in table top near liquid nitrogen fill port, there may be a leak. Tighten hose connection.

10.7.8 Excessive Frost

If there is excessive frost on the upper portion of the cryostat insert after a liquid helium transfer, then either too much liquid helium was transferred or the transfer was performed too fast.

10.7.9 Cracking Or Popping Noises

Occasional cracking or popping noises when filling the outer nitrogen dewar with liquid nitrogen is normal and not cause for alarm.

10.7.10 Warming Too Fast

If during a run the system is warming faster than the setpoint and is unable to control, there is probably insufficient cooling power (i.e., insufficient liquid helium) to maintain a given temperature setpoint. A few liters are normally required.

10.8 SAMPLE SPACE CHECK

This paragraph contains information and instructions for removing the sample probe if it has become stuck in the sample space due to freezing gasses. It also outlines the procedure for unblocking an obstructed sample space. (If something was dropped into the sample space, refer to Paragraph 10.12.)

CAUTION

- If the load lock valve is accidentally opened to the atmosphere when cold it is possible that liquid nitrogen or ice will form in the sample space, hence freezing the probe in the space. If the sample probe is stuck or cannot be fully inserted into the sample space, there is probably solid nitrogen or ice in the sample space.
- Do not force the sample probe or try to free it.

1. To free sample probe use AUTO T ADJUST routine in MANUAL MODE of ACS software to warm system to 300 K while pumping on sample and vacuum spaces.
2. During this process, if sample space can not be evacuated, close sample space valve and pump only on vacuum space.

1.11 MASS SUSCEPTIBILITY

The mass susceptibility is related to the volume susceptibility through the following relationship:

$$\chi_m = \chi/d \quad (1.10)$$

where d is the mass density. This is a straightforward conversion if the density is known. However, the most easily determined quantity experimentally is the mass and accurate values of the density are often unavailable. This difficulty can be overcome by substituting Equation 1.2 into Equation 1.10.

$$\chi_m = \alpha v/(dVfH) = \alpha v/(mfH) \quad (1.11)$$

where m is the mass. The mass susceptibility can be determined in the 7000 Series with no knowledge of the density by simply replacing the volume with the mass. This approach is valid only if the demagnetization factor is zero. If the demagnetization is not zero a value for the density is required.

1.12 DC MAGNETIC MOMENT MEASUREMENTS (MODELS 7221, 7225, AND 7229 ONLY)

With the inclusion of a 1, 5, or 9 Tesla magnet, the Models 7221, 7225, and 7229 (respectively) are capable of DC Magnetic Measurements. The following paragraphs provide an introduction to these magnetic measurements. Paragraph 1.12.1 provides principles of operation. Demagnetization is discussed in Paragraph 1.12.2. Finally, the Calibration Coefficient is discussed in Paragraph 1.12.3.

1.12.1 DC Magnetic Measurement Principles

The measurement of the magnetic moment is performed by using what has traditionally been called an extraction technique. This terminology is used generally to describe any method which relies on detecting a flux change as the sample is removed (extracted) from a sensing coil. The change in flux is then related directly to the moment of the sample.

The configuration of the basic 7000 Series AC Susceptometer can be readily adapted to perform such an extraction measurement. The AC current source is disabled and the Lock-In Amplifier is replaced with a high-speed integrating digital voltmeter (DVM); as shown in Figure 1-7. The stepping motor is then used to move the sample between the centers of the two secondary coils. Since the DVM can operate on a much faster time scale than the sample movement, the output voltage can be recorded and the signal characterized as shown in Figure 1-10. The integral of the voltage over time can then be determined and directly related to the moment of the sample:

$$m = k\, I_v \quad (1.12)$$

where m = magnetic moment
k = DC moment calibration coefficient
I_v = $\int v\, dt$ = voltage integral over time

As currently implemented in the 7000 Series, the DVM has been modified to integrate over a 2 second period and display directly:

$$V = \frac{1}{2}\int_0^2 v(t)dt$$

The most consistent results are obtained by defining the measurements as a complete movement cycle; i.e., moving the sample from coil 1 to coil 2 and then back to coil 1 again. This defines a single "scan." Multiple scans can be performed and averaged to yield measurements with greater precision.

In order to eliminate errors due to thermal electromotive forces (EMFs) or other zero offsets, the voltage is actually monitored a short period of time both before the sample movement starts and after the movement stops. Since there should be no voltage output when the sample is at rest, these readings define the baseline voltage which serves as the reference for the voltages measured during sample movement.

The above measurement gives the value for the moment of the sample . If the mass or volume of the sample is known, the mass magnetization or the volume magnetization can be determined by dividing the moment by the appropriate quantity.

10.7 CRYOGENICS CHECKS

The various cryogenic checks are as follows.

10.7.1 Unable To Condense Liquid Helium Into Dewar

If unable to condense liquid helium into the dewar, perform the following:

1. Verify there is liquid in storage dewar.
2. Verify there is sufficient pressure in to storage dewar to force liquid over to 7000 Series dewar.
3. Check fittings on storage dewar are tight around transfer line.
4. If there is any liquid or solid nitrogen in dewar, it must be removed before liquid helium can be transferred.

10.7.2 Able To Condense But Unable To Transfer A Full Load (≈18 Inches)

If able to condense the liquid helium but unable to transfer a full load (≈18 Inches), verify there is sufficient pressure into the storage dewar to force the liquid over to the Model 7000 dewar, the transfer line is inserted far enough into the storage dewar, and there still is liquid in the storage dewar.

10.7.3 Able To Condense And Transfer Full Load But Indicated Temperature Is <4.2 K

If able to condense and transfer a full load of liquid helium but temperature indicated by DRC-91CA or ACS Software is less than 4.2 K, perform the following:

1. Verify there is approximately 500-1000 microns of helium exchange gas in sample space (only needed if sample probe is in place) and approximately a few hundred microns of helium exchange gas is in vacuum space. This exchange gas should be added to spaces before commencing a liquid helium transfer when system is at approximately 100 K. As temperature is lowered, exchange gas pressure (indicated by gauges) will decrease somewhat as gas condenses on cold surfaces (and also because of $pV=nRT$).
2. Check DRC-91CA is not attempting to control at a temperature higher than 4.2 K.

10.7.4 System Cooling Too Slowly

If the system seems to be cooling too slowly, check the following:

1. Verify there is approximately 500-1000 microns of helium exchange gas in sample space (if sample probe is inserted) and a few hundred microns of exchange gas in vacuum space. This gas should be added to spaces when system is at approximately 100 K before helium transfer is commenced.

NOTE

The exchange gas enhances thermal contact between the sample space and the liquid helium bath. It is only necessary to put a few hundred microns of exchange gas into the vacuum space at 100 K. Greater pressures will not serve to further enhance thermal contact and will significantly increase the time required to evacuate the space.

10.7.5 Difficult To Maintain Or Control Temperature At Or Near 4.2 K

If it is difficult to maintain or control the temperature at or near 4.2 K, check the following:

1. A few hundred microns of helium exchange gas must be maintained in vacuum space.
2. This gas should be evacuated before warming to higher temperatures.
3. If, in process of warming, sample thermometer and control sensor indicate a significantly lower temperature than control setpoint or if DRC-91CA seems to be operating at an abnormally high power output, there is probably too much exchange gas in vacuum space. If this is case, use **AUTO T ADJUST** routine in **MANUAL MODE** of ACS software to warm system up to 10 K while pumping continuously on vacuum space.
4. Allow space to be pumped on for 5-10 minutes and then use ACS software to reset setpoint to 0 K. System will relax back to 4-5 K at which point run can be re-initiated.

1.12.2 Demagnetization

As in the AC susceptibility measurement, demagnetization effects can have a significant impact on the data. Although the moment itself is not modified by the demagnetization factor as in the case of χ_{int} and χ_{ext}, the actual magnetizing field experienced by the sample (H_{int}) will be different from the applied field (H_a):

$$H_{int} = H_a - DM$$

where M is the sample magnetization and D is the demagnetization factor. These effects must be kept in mind when the magnitude of the magnetizing field is critical.

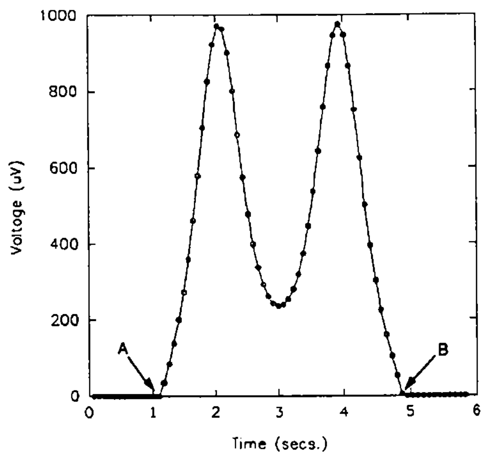


Figure 1-10. Typical Signal Detected During Sample Movement.

1.12.3 Calibration Coefficient

The DC moment calibration coefficient (k) is closely related to the AC susceptibility calibration coefficient (α). This is expected since each coefficient relates the flux coupled between a magnetized sample and a sensing coil. The numerical relationship between the two is given by the following equation which is valid for both SI and cgs units:

$$k = \pi\,\alpha$$

As in the case of the AC susceptibility, the value of k which is supplied with the system is a calculated value assuming a magnetic dipole which interacts with both secondary coils.

The previous discussion concerning the determination of α can be carried over directly to k with very little modification. Figure 1-10 can also be used for making corrections to k for large sample geometries.

The use of the calculated k probably will yield better results than can be achieved through most standard samples. If a standard sample is desired for the DC moment, the best recommendation is the standard nickel sphere, SRM 772, available from NIST through their Office of Standard Reference Materials in Gaithersburg, MD.

References:

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4. Close load lock valve.
5. Open rear door of Dewar Console.
6. Turn pump on and allow several minutes for vacuum lines to be evacuated and molecular drag pump to come up to speed.
7. After a few minutes, check to see green Light Emitting Diode (LED) on pump box is on.
8. If yellow or red LEDs are lit, consult factory.
9. If green LED is on, open sample space valve and allow sample space above load lock to be evacuated. (This should take a few minutes.)
10. If sample space thermocouple gauge indicates space is evacuated, check status of LEDs again. If yellow or red LEDs are lit, consult factory.
11. If green LED is on, open load lock valve and allow entire sample space to be pumped for a few minutes.
12. Once thermocouple gauge indicates a vacuum, check LED status again. Consult factory if yellow or red LEDs are lit.
13. If green LED is on, close sample space valve and open vacuum space valve.
14. Allow vacuum space to evacuate. (This should take a few minutes.)
15. Check LED status once again after vacuum space gauge indicates a vacuum. If yellow or red LEDs are lit, consult factory.
16. If green LED is on, pumping system is operating properly and system has no gross leaks.
17. As a final check, open both sample and vacuum space valves and allow entire system to evacuate (15 to 20 minutes should suffice).
18. Close both valves while monitoring thermocouple gauges. Pressure in both spaces will probably increase to a few hundred microns and then stabilize. A leak may be present if pressure continues to increase unabated.
19. Leak check system if a leak detector is available. Consult factory for details before performing test.

The increase in pressure observed when closing the sample or vacuum space valves or when the system is warmed may be due to one or more of the following:

Outgassing
Vacuum Space: Some of the construction materials used include epoxies, composites, and adhesives. At low temperatures, outgassing of these materials is minimized. However, as the temperature increases, adsorbed gasses are released and outgassing may become significant. Continuous pumping of the vacuum space during operation is recommended.

Insufficient Pumpout of Sample Space or Virtual Leak
Depending on the sample configuration (e.g., powder, bulk, etc.) and because of the large surface area to volume ratio and small narrow sample space, pumpout of the space is relatively slow and outgassing may be significant. If the sample space was not initially pumped out sufficiently, residual gas can make it appear as if there were a leak in the sample space. Pump out the sample space for a longer period of time if this is suspected.

Sample Movement
As the sample probe is moved into and out of the sample space, gas is "wiped" into the system. Refer to Paragraph 4.10.

The Ideal Gas Law
The Ideal Gas Law ($pV=nRT$) applies, so as the temperature is increased, the pressure of the gas increases. These pressure increases are normal and not cause for alarm unless the spaces can not be evacuated.

CHAPTER 2
HARDWARE INSTALLATION

2.0 GENERAL

This chapter contains information and instructions pertaining to 7000 Series System hardware installation. Included are inspection and unpacking guidelines in Paragraph 2.1. Site requirements are described in Paragraph 2.2. Installation procedures are provided in Paragraph 2.3. Post-installation procedures are provided in Paragraph 2.4. System shutdown and repackaging for storage or shipment procedures are provided in Paragraph 2.5. Instructions for returning equipment to Lake Shore are provided in Paragraph 2.6. Finally, instructions for completing the Hazardous Declaration Form are provided in Paragraph 2.7.

2.1 INSPECTION AND UNPACKING

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

To aid in judging the condition of received goods, Shockwatch® and Tip-n-Tell indicators are placed on the external cartons. See Figure 2-1. A Shockwatch sticker is also on the pallet under the units. Please accept shipment even if Shockwatch is red. Make note on the bill of lading and inspect for damage immediately. To cover tipping in four directions, two Tip-n-Tell indicators are placed on the pallet containing the Instrument and Dewar Consoles. If the blue beads are above the line, it shows the container was tipped or mishandled.

Cut off the strapping and lift off the lid. Locate the packing list included with the system. The packing list is included to simplify checking that all components, cables, accessories, and manuals were received. Please use the packing list and the spaces provided to check off each item as the system is unpacked. Inspect for damage. Be sure to inventory all components supplied before discarding any shipping materials.

Remove the packing material. Locate and remove the sample probe and optional transfer line stored on top between the two consoles. Remove the screws and wood supports around the box. Remove the box as a whole from the top. Some time it may help to have a second person pushing the consoles inward during removal of the box. Remove the plastic ties and wrap around the consoles. Ensure the shock indicator on the pallet is not activated.

Remove the box from the top of the Instrument Console. It contains documents, hardware kit, sample movement motor assembly, Model 241 Level Monitor, and the external mechanical pump. Lift the Dewar and Instrument Consoles from the pallet. Four people should be used to lift an Instrument Console containing a Magnet Power Supply (MPS). Do not lift the console at the top: always lift from the bottom.

Make note of the way the consoles were supported on the pallet for future reference. Foam blocks have been placed between the instruments to support their weight during shipment. The blocks may be removed or simply left in place. If the unit is ever transported, the foam blocks should be inserted.

For all ACS Systems other than the Model 7120A, a second pallet must be unpacked that contains the computer and monitor. Make sure all the manuals were received. If any manuals are missing, contact Lake Shore immediately. **Be sure to fill out and send instrument warranty cards.**

If there is damage to any instruments in transit, be sure to file proper claims promptly with the carrier and insurance company. Please advise Lake Shore Cryotronics of such filings. In case of parts shortages, advise Lake Shore immediately. Lake Shore cannot be responsible for any missing parts unless notified within 60 days of shipment. The standard Lake Shore Cryotronics, Inc. Warranty is detailed on the A Page (immediately behind the title page) of this manual.

3. Unplug two 5-pin connectors labeled A and B from rear of DRC-91CA. Pin assignments are as follows:

5-PIN CONNECTOR	SIGNAL
A	(I+)
B	(I–)
D	(V+)
E	(V–)
H	Not Used

4. Using a multimeter with a diode measurement mode (if not available, proceed to step 5), place the positive test lead on pin A and the negative test lead on first pin B and then pin D. In both cases a voltage of approximately 0.6 volts* should be measured. Place the negative test lead on pin E. A zero voltage reading (a short) should be observed. Perform this test with both sensors. If they appear to be functioning properly, see Paragraph 10.3 - DRC-91CA Check. If not, go to step 5. Also check for isolation to system ground.

   * This is the nominal voltage read at room temperature. At 77 K, the voltage will be approximately 1 volt and at 4.2 K it will be approximately 1.6–1.7 volts.

5. To perform a check on the cable, disconnect the two 5-pin connectors and the banana plug from the rear of the DRC-91CA and disconnect the 10-pin cable connector from the cryostat insert.
6. Pull the cable out of the unit and check it for continuity/short with an ohmmeter. Wiring definitions are as follows:

TERMINATION		10-PIN CONNECTOR IDENTIFICATION
Banana Plug		D, E
5-Pin, Input B:	E	A
	D	B
	A	J
	B	C
5-Pin, Input A:	E	H
	D	G
	A	K
	B	F

7. If cable appears to be functioning properly, see Paragraph 10.3.2 - DRC-91CA Check.

10.5 THERMOCOUPLE GAUGES CHECK

The thermocouple gauge check is as follows:

1. Turn power off to instruments and disconnect power to unit.
2. Open rear door of Dewar Console.
3. Disconnect two thermocouple gauge cables at gauge tubes.
4. Using an ohmmeter, hold one test lead on pin 1 and with other test lead check across pins 3, 5, and 7. In each case, measured resistance should be approximately 10-15 Ω.
5. Consult factory if an open circuit is indicated.

10.6 VACUUM PUMP CHECKS

The system should be warm (at room temperature) before starting this test.

1. Remove sample probe.
2. Place sample seal plug in sample load seal and tighten sample load seal.
3. Close vacuum and sample space valves. Make sure helium exchange gas valves are tightly closed.

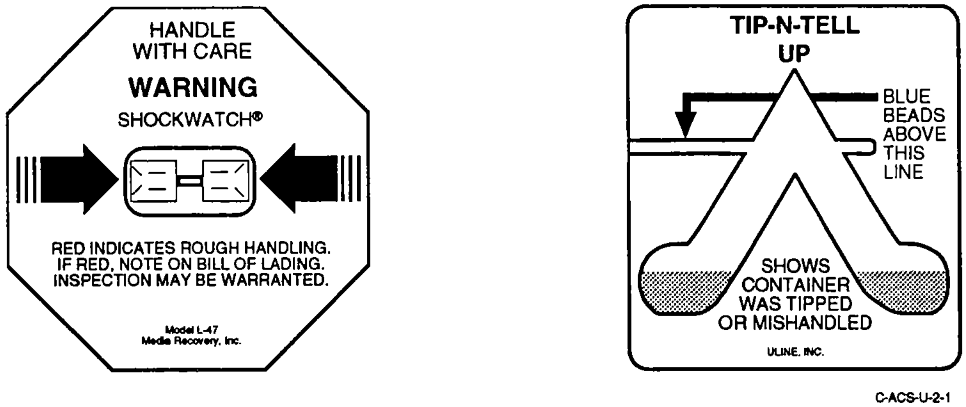


Figure 2-1. Shockwatch and Tip-n-Tell Indicators

2.2 SITE REQUIREMENTS

The Customer is responsible for site preparation and system installation. Site planning should be done before the 7000 Series System arrives. There are several requirements to consider, including physical location, environment, cryogenic storage and access, power, ventilation, and safety. Local building, electrical, and safety codes should also be researched before system installation. Physical dimensions of a suggested 7000 Series site are provided in Figure 2-2.

Proposed sites that survive preliminary screening should be evaluated according to the following criteria: space, location, power, and structural integrity.

1. Space. Whether there is adequate space for system installation, operation, potential expansion, service, and storage of supplies. Depending on the system selected, space and layout requirements will differ.
2. Location. Whether the location is convenient for delivery of equipment and supplies, and handy to related work areas for efficient operation. Especially important is sufficient access for the large liquid helium (LHe) and liquid nitrogen (LN_2) dewars.
3. Power. Whether the available power is adequate for system requirements and potential expansion, and whether the site can be wired for maximum efficiency and economy of operation.
4. Structural Integrity. Whether the floor loading of the proposed area is or can be made strong enough to withstand anticipated loads. Floors must be level and free from extraneous vibrations or magnetic fields. Vibrations transmitted to the consoles may degrade system measurement performance.

After the proper site is selected, the additional requirements outlined in the following paragraphs must be considered. This includes system power and ground requirements in Paragraph 2.2.1. Environmental requirements in Paragraph 2.2.2. Cryogenic Liquid and gas supply requirements in Paragraph 2.2.3. Finally, a summary of safety requirements in Paragraph 2.2.4.

2.2.1 System Power And Ground Requirements

The AC power source for the 7000 Series System must be frequency and voltage regulated and isolated from sources that may generate Electromagnetic Interference (EMI). The equipment in the 7000 Series is designed for single-phase 3-wire alternating current (AC) power. Two-wire (without ground) AC power must not be used. Ground Fault Interrupter (GFI) and Transient Surge Protection circuitry at the AC source are also strongly recommended.

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

CAUTION

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

10.3.3 Lake Shore Model 140 ACS Control Unit Check

The following procedure checks proper operation of the Lake Shore Model 140 ACS Control Unit.

1. Perform system checks outlined in Paragraph 10.1. If results observed indicate problems with Model 140, check following before contacting factory.
2. Ensure instrument is plugged in and turned on.
3. Check fuse if there is no power to instrument.
4. Ensure that electrical connections to rear of instrument are secure.
5. Open rear doors from Dewar and Instrument Consoles.
6. Check dip switch settings on rear of instrument. Make sure IEEE address is set to 24.
7. Unplug BNC cable labeled P from cryostat feed-through.
8. Place a nominal 10 kΩ resistor (A resistor box or discrete component will suffice) between center conductor of P and P shield.
9. Using ACS Software, set AC field to 1 A/m and frequency to 100 Hz.
10. Using multimeter with an AC voltage measurement mode, measure AC voltage drop across resistor. A voltage drop of ≈1 volt should be measured.
11. Replace 10 kΩ resistor with a 1 kΩ resistor and adjust field to 10 A/m. A voltage drop of ≈1 volt should be measured.
12. Repeat process again. This time use a 100 Ω resistor and set field to 100 A/m. A voltage drop of ≈1 volt should be measured.
13. Repeat process again. This time use a 10 Ω resistor and increase field to 1000 A/m. Voltage drop should be ≈1 volt.
14. If this test yields correct results, Model 140 AC output current is correct. Plug BNC cable back into jack labeled P on cryostat insert and perform general system check outlined in Paragraph 10.1 again. Consult factory if problem persists.

10.3.4 HP VECTRA™ Computer Check

Consult the Hewlett-Packard (HP) Vectra™ Computer Instruction Manual if problems arise with the computer hardware. If there are problems with the ACS7000 Software, see Paragraph 10.10.2.

10.4 HEATER AND THERMOMETRY CHECK

Heater and thermometry checks consist of a heater check in Paragraph 10.4.1 and a thermometry check in Paragraph 10.4.2.

10.4.1 Heater Check

The heater check is performed as follows:

1. Turn power off to instruments and disconnect power to unit.
2. Open rear door of Instrument Console.
3. Unplug banana plugs from rear of DRC-91CA.
4. Check resistance of heater using an ohmmeter. It should be approximately 25 Ω. (This is resistance measured at room temperature. Resistance will decrease with decreasing temperature.) Also check for isolation to system ground.
5. If heater appears to be operating correctly, proceed to Paragraph 10.4.2 – Thermometry Check.

10.4.2 Thermometry Check

If the sample thermometer and control sensor do not agree or if there is an error display on the DRC-91CA Temperature Controller, perform the following;

1. Turn power off to instruments and disconnect power to unit.
2. Open rear door to Instrument Console.

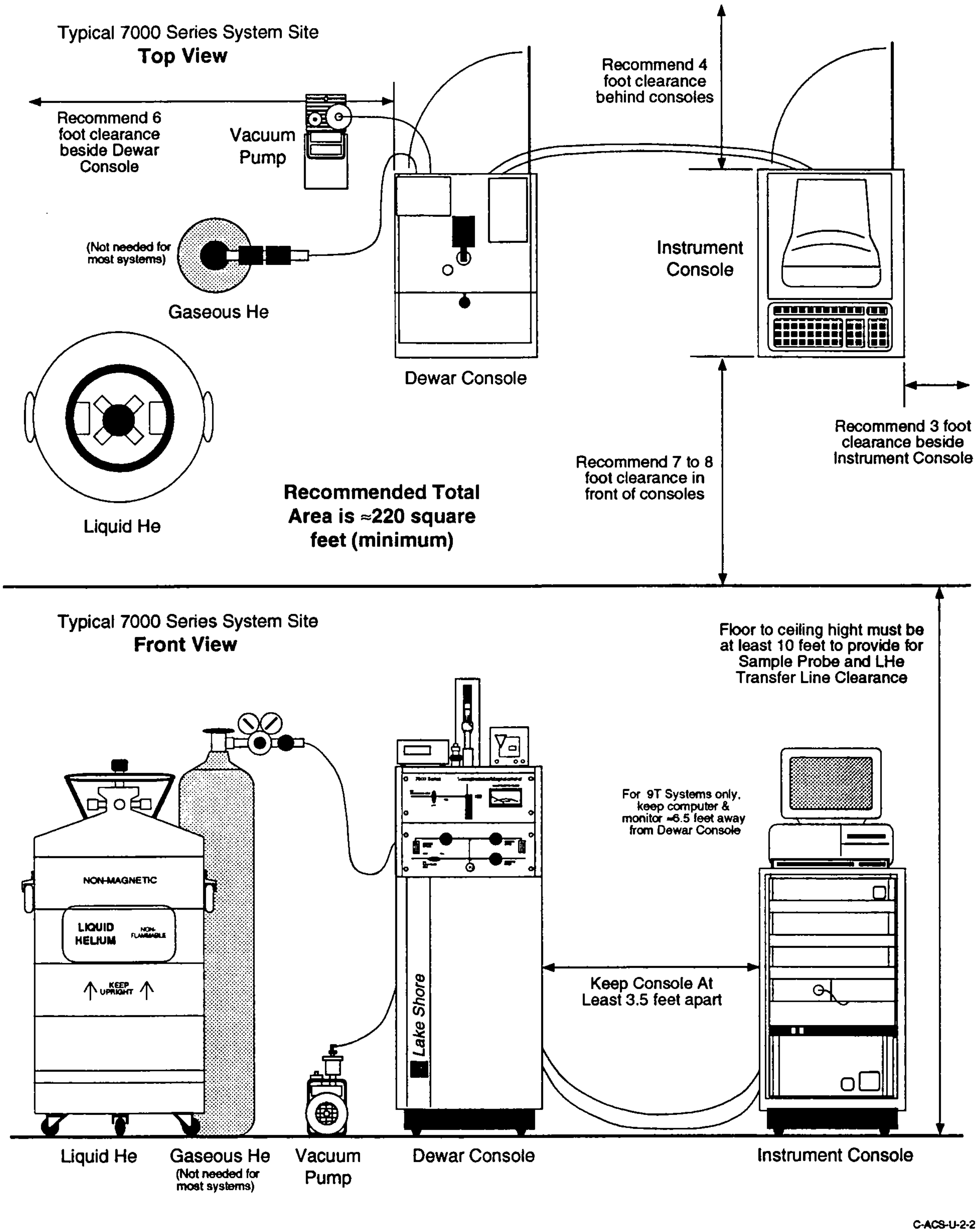


Figure 2-2. Typical 7000 Series System Site Dimensions

6. Hold one test lead on center conductor of A and with other test lead check following:

TEST POINT	MEASURED RESISTANCE
A Shield	180Ω*
B Center	180Ω
B Shield	180Ω
Cryostat (system ground)	(>20 MΩ) open

* Nominal resistance measured at room temperature. Measured resistance will decrease with decreasing temperature.

NOTE

These resistance values are only nominal. If the measured resistances are significantly different than the above values, disconnect the three BNC cables from the cryostat and check them with and ohmmeter for continuity and shorts. If these are satisfactory, contact the factory.

10.3 INSTRUMENTATION CHECK

Instrumentation check consists of the following: Lock-in Amplifier Check in Paragraph 10.3.1, Lake Shore Model DRC-91CA Temperature Controller Check in Paragraph 10.3.2, Lake Shore Model 140 ACS Control Unit Check in Paragraph 10.3.3, and the HP Vectra™ Computer Check in Paragraph 10.3.4.

10.3.1 Lock-in Amplifier Check

The following procedure is checks proper operation of the EG&G Model 5209 Lock-In Amplifier.

1. Perform system checks outlined in Paragraph 10.1. If results observed indicate problems with lock-in, check following before consulting EG&G Model 5209 Lock-In Amplifier Instruction Manual.
2. Verify lock-in is plugged in and turned on.
3. Check fuse if there is no power to instrument.
4. Ensure that electrical connections to rear of instrument are secure.
5. Verify hardware switches on front panel of lock-in are set to [A-B] and Ground on.
6. Make sure IEEE address is set to 22. This is done by putting lock-in into LOCAL mode and then selecting CONFIG and GPIB on front panel. IEEE address will be displayed on far right LCD. If it is not set to 22, use front panel up/down (↑↓) keys to properly set it. ACS program will have to be restarted.
7. Perform initial check outlined in lock-in manual.
8. If lock-in is still not functioning properly, consult lock-in manual or contact Lake Shore.

10.3.2 Lake Shore Model DRC-91CA Temperature Controller Check

If the system will not warm up or if there is zero power output when the control setpoint is above system temperature Make sure the tests to verify the heater and temperature sensors are operating correctly have been performed (Paragraph 10.4). Then proceed with the following steps:

1. Ensure instrument is plugged in and turned on.
2. Check fuse if there is no power to instrument.
3. Open rear door of Instrument Console.
4. Check dip switch setting on rear of instrument. Make sure instrument IEEE address is set to 23.
5. Ensure that dip switch settings 6, 7 and 8 on sensor ID [A] and 6 and 7 on sensor ID [B] are closed.
6. Verify input cards in instrument are working properly if only one of sensors is reading correctly. To do this, interchange 5-pin connectors labeled A and B on rear panel of DRC-91CA (i.e., plug connector B into input A and connector A into input B). If sensor which was reading incorrectly is now reading correctly and vise versa, input card in instrument has failed and must be replaced.
7. Consult factory.

The power requirements for the electrical components of the 7000 Series System are preset at the factory for proper operation at the shipping destination. The input voltage for each instrument in the system is individually set on the rear panel. Before applying power to the main input power cable, check each instrument to ensure that input power settings are correct for the power source voltage. The procedure to check component power settings and fuse/circuit breaker ratings is provided in Paragraph 2.3.11.

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

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

2.2.2 Environmental Requirements

To meet and maintain the specifications in Table 1-1, the 7000 Series System must be operated at an ambient temperature range of 18 to 28 °C (64.4 to 82.4 °F). The system may be operated within the range of 15 to 35 °C (59 to 95 °F) with less accuracy. The system is intended for laboratory use: no specific humidity or altitude specifications have been determined. However, relative humidity of 20 to 80 percent (no condensation) and altitudes from sea level to 2.4 km (8,000 feet) are generally acceptable.

It is imperative that adequate ventilation of work area be provided. This will prevent build up of potentially life-threatening concentrations of helium and nitrogen gas. Refer to Paragraph 2.2.4 and Appendix E for further information. Oxygen content monitor/alarms should be installed near the work site to warn against low oxygen levels. The air-conditioning system should provide filtering to reduce dust and other particulate matter to a reasonable level. If salt air, corrosive gases, or other air pollutants are present, special filtering arrangements may be required and an air-conditioning expert should be consulted.

2.2.3 Cryogenic Gas Supply Requirements

Helium exchange gas is used by most models of the 7000 Series to provide efficient initial cooling of the cryostat and efficient heat exchange between the sample and the cryostat. If required, an external supply of gas is readily available from local suppliers. Purity of the gas is not critical and commercial grade (99. 5% pure) may be used. The supply pressure to the Dewar Console He Gas inlet should be between 0 to 1 psig.

NOTE

During normal operation with LHe, the ACS System does not require external helium exchange gas. However, external gaseous helium is still required for cryogen transfer, dewar purging, and if any cryogen other than LHe is used in the dewar.

10.1.2 System Check 2

The following is system check number 2 for systems not running at room temperature.

1. Perform Steps 1 through 6 listed in Paragraph 10.1.1.
2. Position sample in bottom secondary coil (manually or with the auto-positioning routine.)
3. Using ACS software, set frequency to 10 Hz and the field to 8 A/m.
4. Log data in MANUAL MODE of ACS software using a two position, single phase at 90° measurement sequence. Average voltage at 90° will be displayed on monitor.

	Frequency (Hz)		
H (A/m)	10	100	1000
8			
80			
800			

5. Insert appropriate voltage values and write results down in the table shown above.
6. When stepping through table of allowed frequencies, verify lock-in frequency display (middle LCD) reads correctly. Output voltage should vary proportional to frequency and field values.

NOTE

Since the voltage output is directly proportional to the product of the field strength and frequency, the values should scale accordingly. For example, the measured value at 8 A/m and 100 Hz should be approximately equal to the measured value at 80 A/m and 10 Hz, and these should be approximately 10 times the voltage measured at 8 A/m and 10 Hz. If the recorded values along a row or column seem incorrect, this could indicate problems with the following;

a. Coils (refer to Paragraph 10.2)
b. Lock-in Amplifier (refer to Paragraph 10.3.1)
c. Model 140 ACS Control Unit (refer to Paragraph 10.3.3)
d. Cables between Model 140 and coils (refer to Paragraph 10.10.5)

10.2 COIL CHECK

The coil check is performed as follows:

1. Turn power off to instruments and disconnect power to unit.
2. Open rear door on Dewar Console.
3. Unplug two bayonet nut connector (BNC) cables labeled A and B at rear of lock-in.
4. Remove BNC cable labeled P from rear of Model 140 ACS Control Unit.
5. Using an ohmmeter, hold one test lead on center conductor of P and with other test lead check following:

TEST POINT	MEASURED RESISTANCE
P Shield	15Ω
A Center	(>20 MΩ) open
A Shield	open
B Center	open
B Shield	open
Cryostat (system ground)	open

2.2.4 Safety Requirements Summary

There are several safety requirements to consider in the planning and installation of the 7000 Series System. Although the individual safety requirements are mentioned in other paragraphs, this paragraph provides a summary of safety requirements. The safety precautions herein are recommended, not because the installation is inherently dangerous, but because there is no substitute for advance planning for personnel safety.

Personnel should be trained in such emergency measures as the proper method of shutting off electrical power, notifying the fire department clearly and promptly, handling fire extinguishing in the correct manner, and evacuating personnel and records. A summary of suggested personnel safety considerations are as follows:

- Ground Fault Interrupter (GFI) AC Circuits (Paragraph 2.2.1).
- Cryogenic Safety Gloves, Apron, Goggles/Faceshield, and Apparel (Appendix E).
- Fire Extinguisher.
- Oxygen Concentration Monitor/Alarm.
- Magnetic Field Warning Signs.
- Fireproof Safe for Data, Original Software and Documentation Storage.
- Emergency Lighting.

The two essential safety aspects to consider when handling LHe and LN_2 are adequate ventilation and eye and skin protection. Although helium and nitrogen gases are non-toxic, they are dangerous since they replace the air in a normal breathing atmosphere. Liquid products are of a greater threat since a small amount of liquid evaporates to create a large amount of gas. Therefore, it is imperative that cryogenic dewars be stored and the 7000 Series System be operated in open and well ventilated areas.

WARNING

- Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.
- Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

Persons transferring LHe and LN_2 should make every effort to protect eyes and skin from accidental contact with liquid or the cold gas issuing from it. Protect your eyes with a 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 might have been, in contact with the liquid or cold gas, or with cold pipes or equipment. Long sleeve shirts and cuffless trousers of sufficient length to prevent liquid from entering the shoes are recommended.

A fire extinguisher(s) should be located in the immediate vicinity. The type of extinguisher(s) selected must cover all three classes of fires: A, B, and C. Class A is ordinary combustibles; materials like wood, paper, rubber, many plastics, and other common materials that burn easily. Class B is flammable liquids; substances like gasoline, oil, and grease. Class C is for energized electrical equipment including wiring fuse boxes, circuit breakers, machinery, and appliances. Dry chemical extinguishers are the type commonly found since they are less expensive and cover all classes of fires. However, dry chemical may damage electronic equipment. Therefore, a Carbon Dioxide or Halon fire extinguisher is strongly recommended. Because properly locating and installing sprinkler heads, fire and smoke sensing devices, and other fire extinguishing equipment requires specialized experience and expertise, local experts should be consulted during the planning stage, and the recommendations of insurance underwriters and local building authorities should be sought and followed as closely as possible.

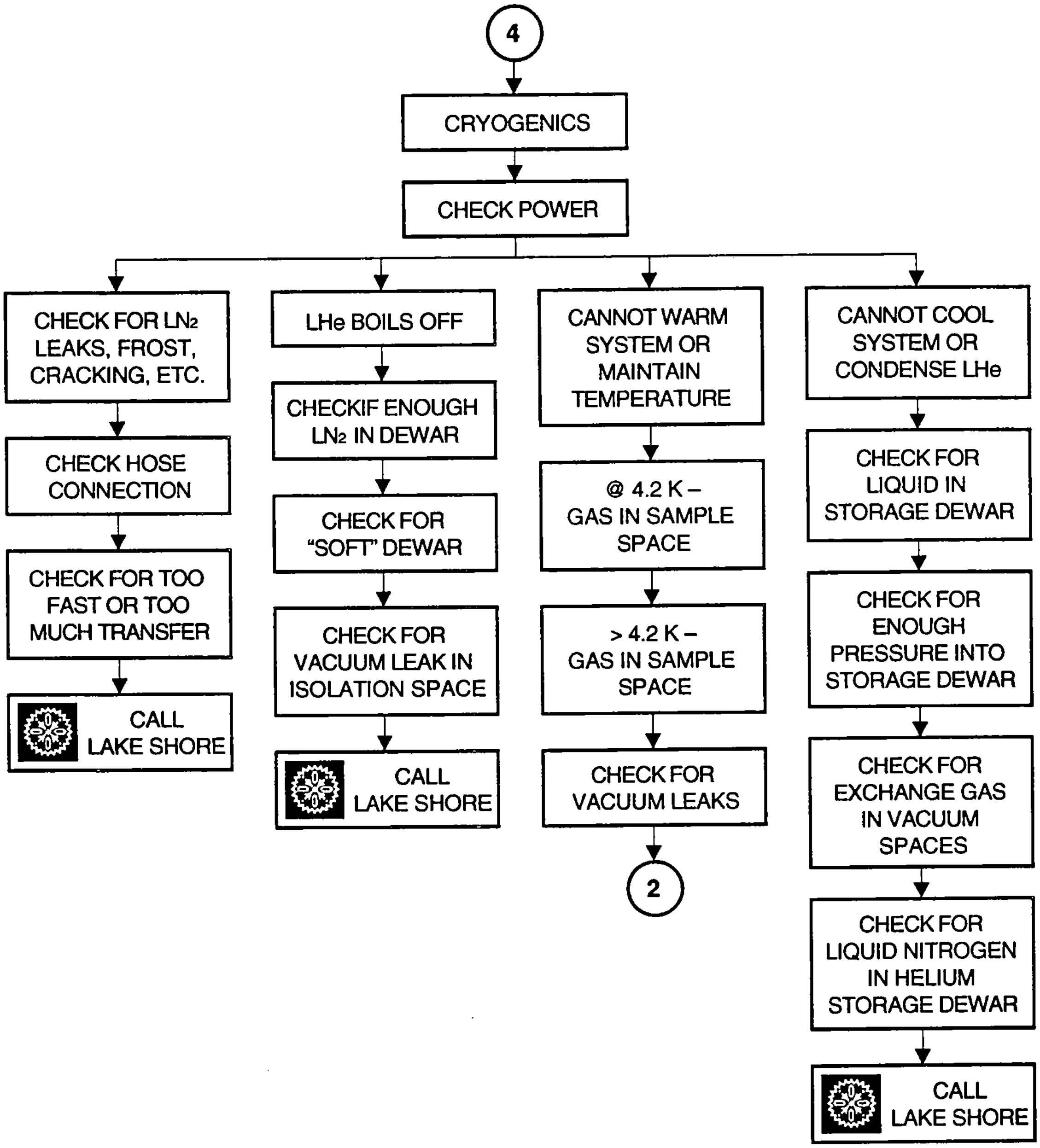


Figure 10-1. ACS System Troubleshooting Flowchart (Sheet 4 of 4)

Safety Requirements Summary (Continued)

An oxygen concentration monitor and alarm should be located in the system work area near the Dewar Console. Another monitor and alarm should be located in the dewar storage area. As has been stated before, 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.

Models 7121, 7125, 7129, 7221, 7225, and 7229 have a superconducting magnet that can generate a large magnetic field outside the console. Signs should be posted at each entrance to the work area that states: "Warning: High Field Magnets – Fringe fields may be hazardous to pacemakers and other medical devices. Keep magnetic materials clear of area." A yellow magnetic field warning line may also be painted on the floor 3 feet from the sides of the Dewar Console.

A fireproof safe should be located at or near the work site for temporary storage of data and for keeping copies of the original system software and documentation. Adequate duplicate copies of vital data should be stored well away from the system area, also in a fireproof storage vault or safe. Data and records are an important and vital resource that deserve protection similar to that accorded to the system itself.

Even where not required by code, some type of emergency lighting should be installed to provide emergency lighting in case of power failure or fire. This battery-operated lighting system should come on automatically when the normal lighting system fails.

2.3 SYSTEM INSTALLATION

After unpacking the system and verifying receipt of the items listed on the packing list, you may proceed to system installation. Remove the Instrument and Dewar Consoles from the pallet. The consoles are on casters and can be moved easily on flat surfaces. Carefully move the consoles to the installation site. As shown in Figure 2-2, position the Dewar Console to the left of the instrument Console. Perform the instructions in the following paragraphs in the order presented to assemble the system. Remove the equipment from the remaining pallet for installation as required.

System Installation is provided in the following paragraphs:

2.3.1 Movement Motor Assembly Installation

The movement motor assembly is packaged separate from the Dewar Console. The movement motor assembly must be mounted on the top surface of the Dewar Console. Use six 1/4 x 20 screws and washers to attach the top to the console. See Figure 2-3. Route cable to the rear of the console, through the lower-left cutout, through the Instrument Console cutout, and plug into Motor Control on rear of Model 140 ACS Control Unit.

Verify that when the movement is locked into position, the finger which extends out from the movement unit aligns with the sample load seal located directly below. This has been adjusted at the factory and should be in good alignment. If not, notify the factory immediately.

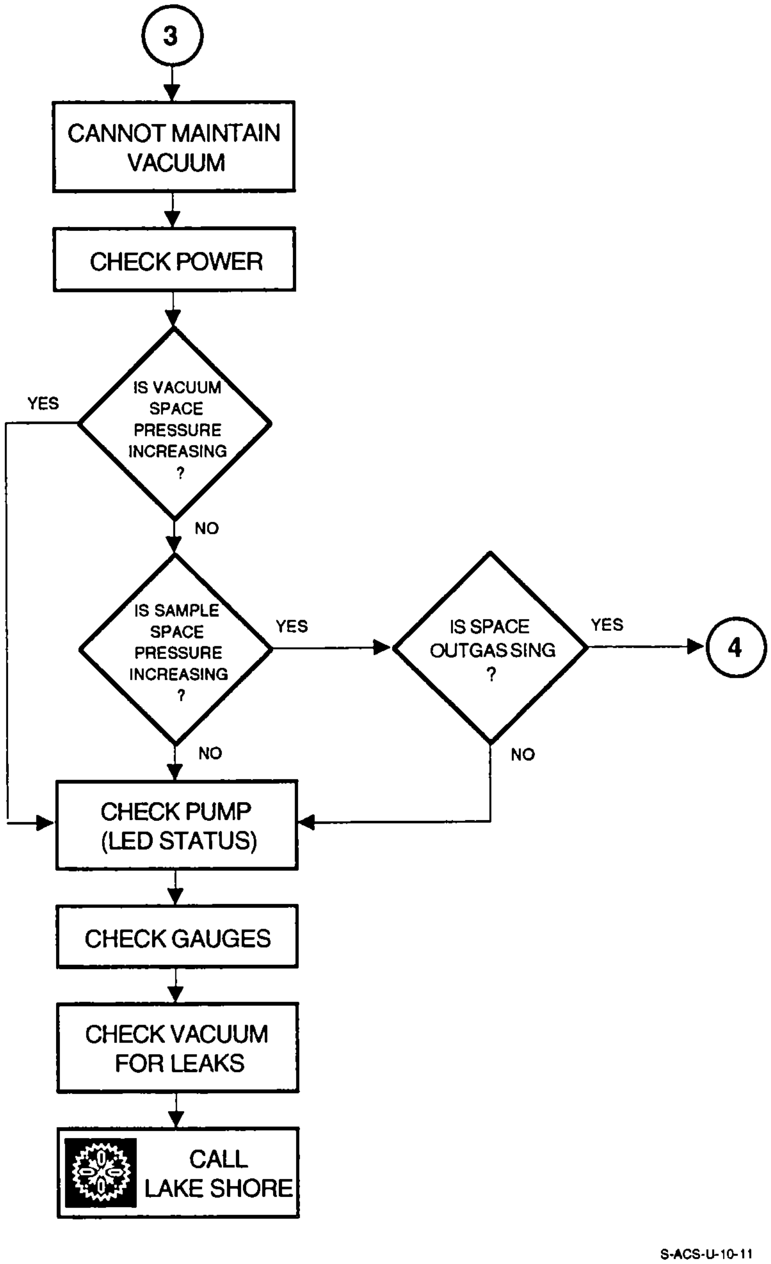


Figure 10-1. ACS System Troubleshooting Flowchart (Sheet 3 of 4)

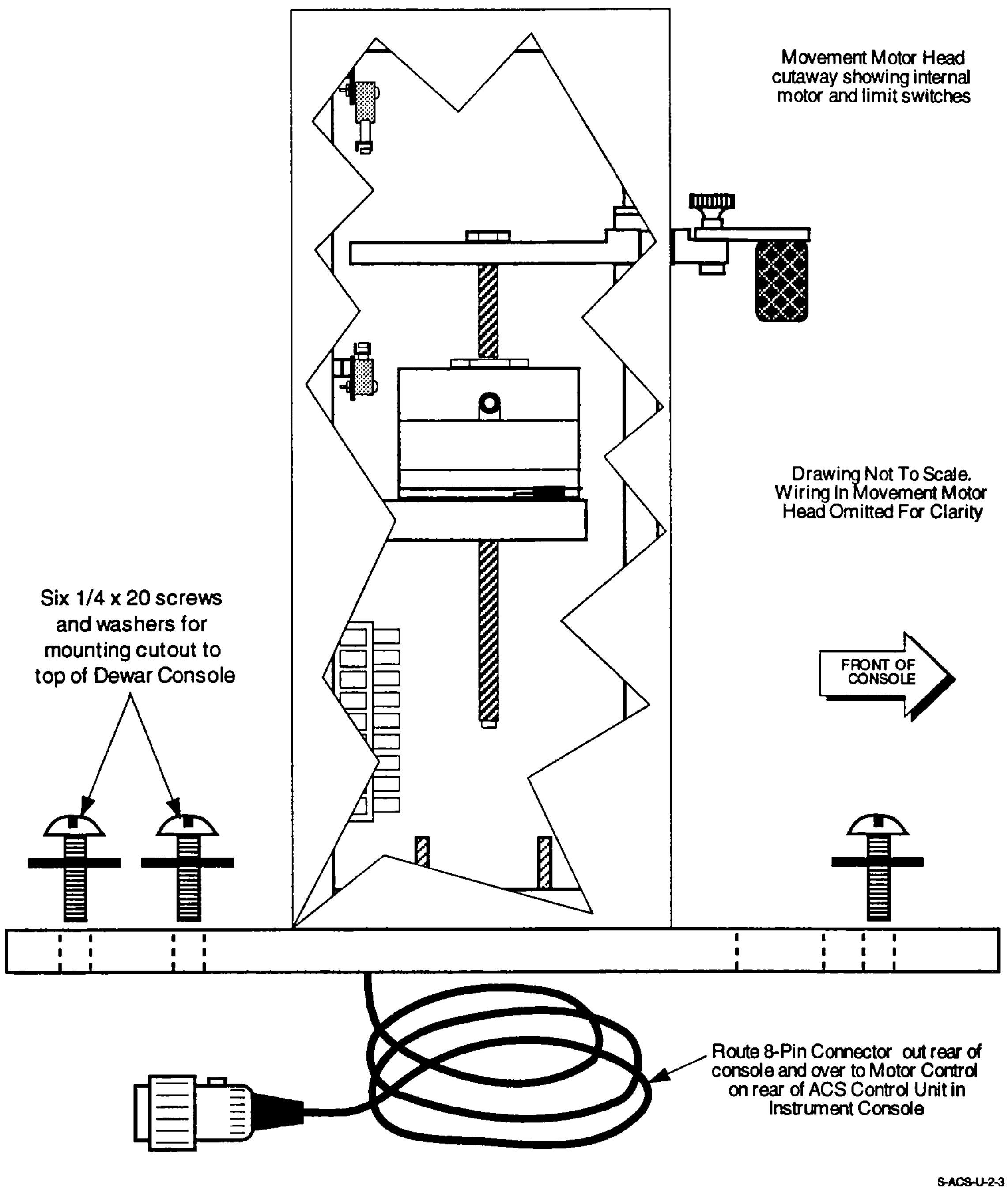


Figure 2-3. Movement Motor Assembly

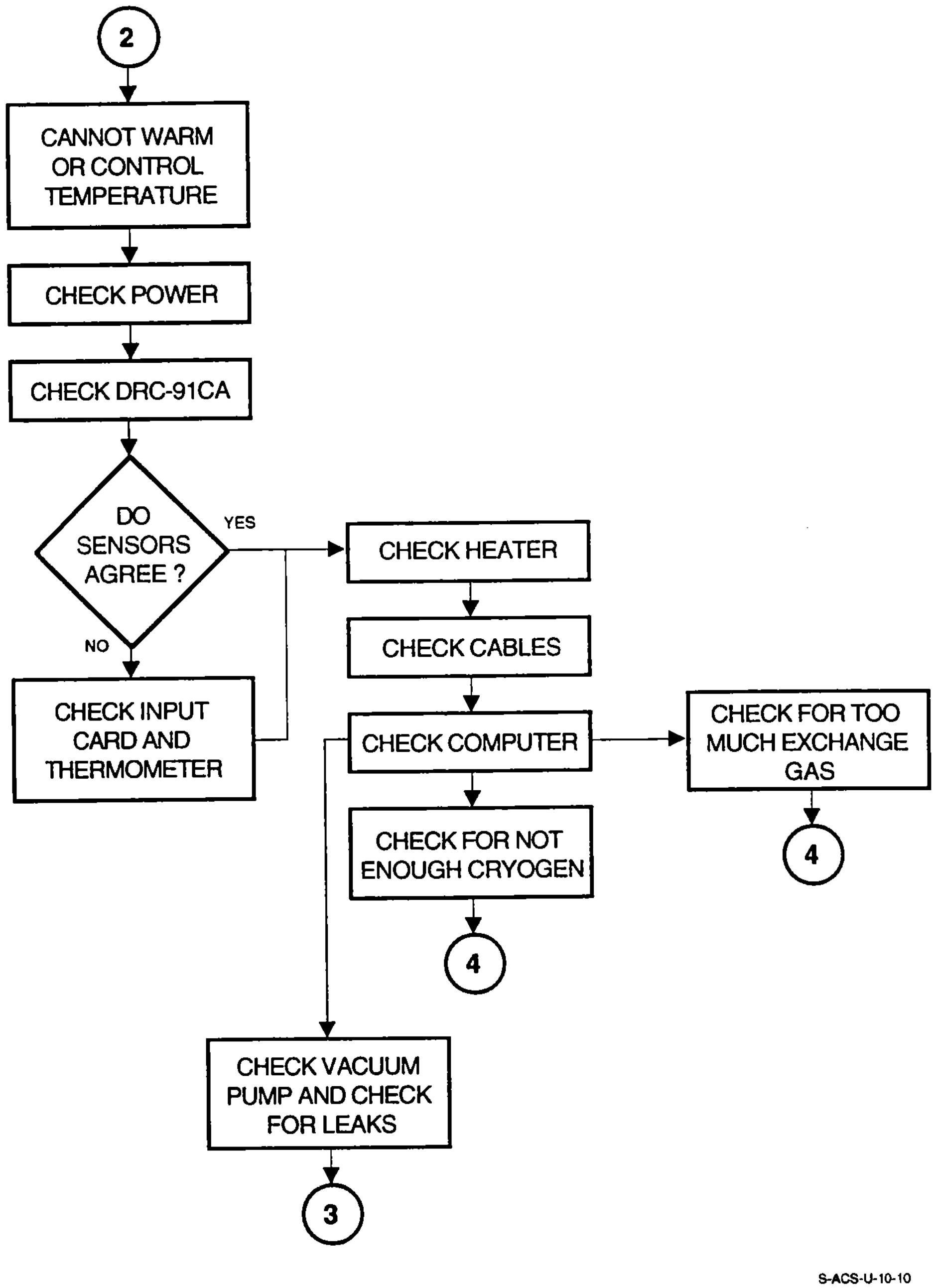


Figure 10-1. ACS System Troubleshooting Flowchart (Sheet 2 of 4)

2.3.2 Helium Bath Vent Valve Installation

The Helium Bath Vent Valve and Relief Valve can be found in a clear plastic container located in the miscellaneous parts box (that contained the Movement Motor Assembly). The valve assembly must be installed in He Bath Vent port on the rear of the Dewar Console before filling and operating the dewar.

1. Locate the He Bath Vent port on rear of Dewar Console and remove plastic cover from port.
2. Place at least one wrap of Teflon® tape around valve threads.
3. Install valve into He Bath Vent port. Orient as shown in Figure 2-4.

Before transferring LHe or any maintenance on the dewar, pressure in the dewar must be relieved by opening the He Bath Vent Valve.

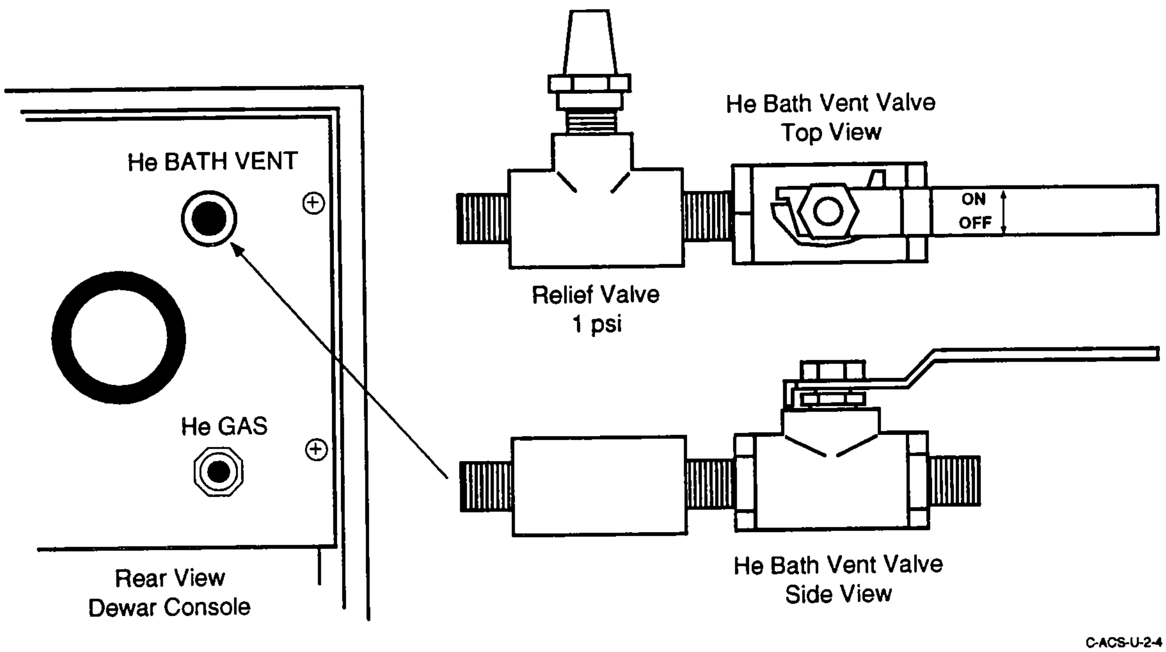


Figure 2-4. He Bath Vent Valve Installation

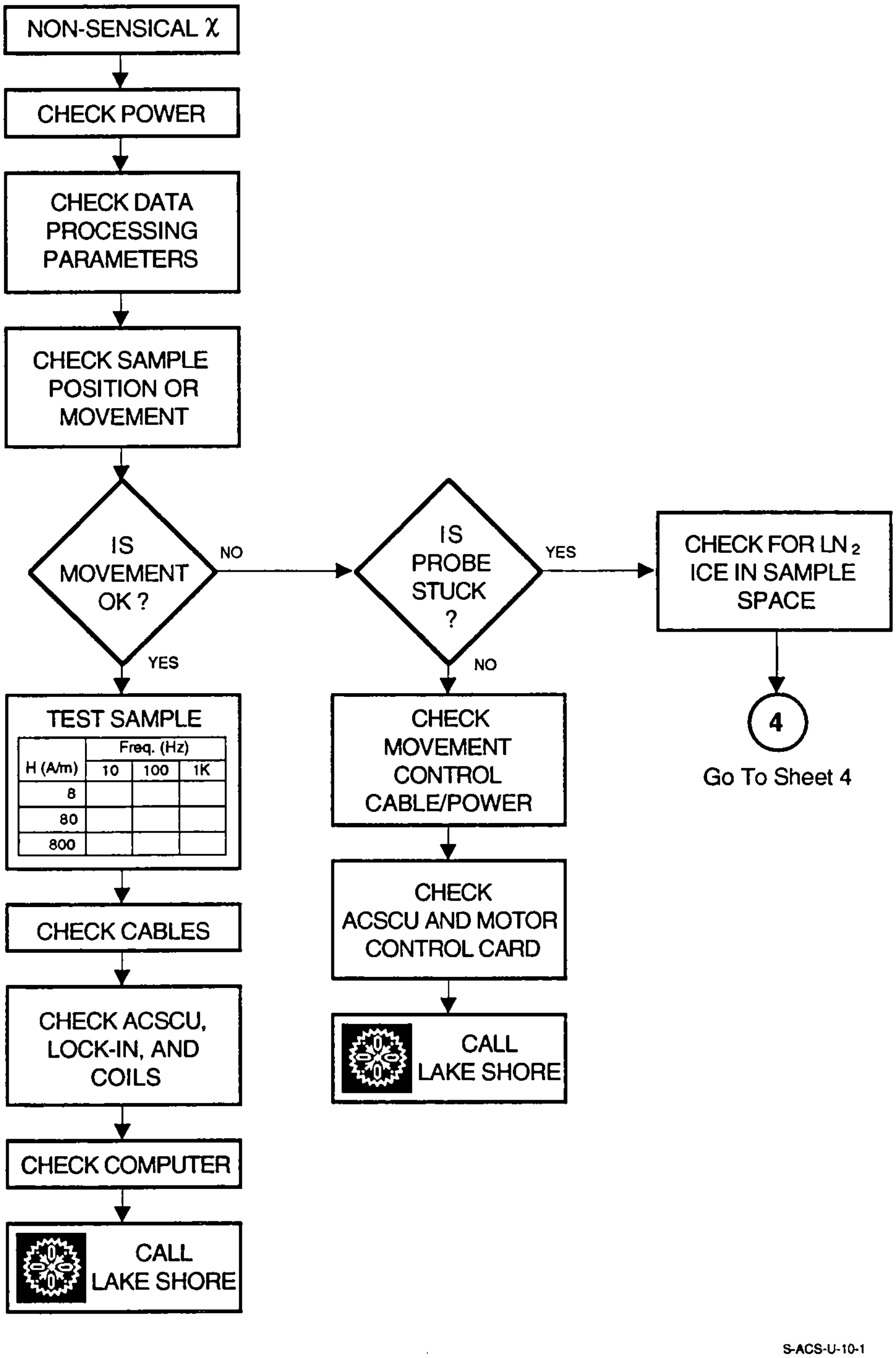


Figure 10-1. ACS System Troubleshooting Flowchart (Sheet 1 of 4)

2.3.3 Vacuum Pumping System Installation

The vacuum pumping system consists of the Alcatel Model 2002 Mechanical Pump that sits outside the Dewar Console and the Alcatel Model 5011 Molecular Drag Pump that is already mounting inside the Dewar Console. To prepare the Model 2002 Mechanical Pump for use, follow the instructions in Paragraph 2.3.3.1. To connect the external electronic control unit to the Model 5011 Drag Pump, follow the instructions in Paragraph 2.3.3.2.

2.3.3.1 Alcatel Model 2002 Mechanical Pump Installation

Place the Alcatel-CIT Model 2002 Oil-Sealed Mechanical Pump to the left of the Dewar Console. The Mechanical Pump should contain the following items.

Model 2002BB Alcatel-CIT Mechanical Pump with pump oil
Power Transformer (supplied only when requested operating power is not compatible with rotary pump power requirements)
Oil Mist Eliminator
Assimilation Trap with replacement copper filter
KF-16 Screen Filter and O-ring
KF-16 / Elbow Hose Attachment
Vacuum Hose
KF-16 Centering Ring and O-ring
KF-16 Clamps (2)
Hose Clamps (2)

1. Verify the pump power requirements and the line voltage available. If they are not compatible, do not attempt to operate the pump. If a power transformer has been supplied, follow the instructions enclosed with the transformer for making the appropriate power connection.
2. Follow the instructions with the Alcatel Model 2002 BB pump for filling with oil and for installing the oil mist eliminator on the pump exhaust.
3. The assimilation trap comes pre-filled with a copper element. Verify there are no loose copper filaments or fragments. Use the KF-16 Screen Filter and Clamp to attach the assimilation trap to the inlet of the rotary pump.
4. Use the KF-16 Centering Ring and Clamp to attach the KF-16 / Elbow Hose Attachment to the assimilation trap.
5. Set the pump on the floor in a convenient location next to the cryogenic console.
6. Using vacuum grease, lightly grease the nipple attachments. This should include the nipple on the exhaust of the molecular drag pump mounted inside the Dewar Console.
7. Connect the exhaust of the molecular drag pump to the rotary pump assembly using the ⅜ inch I.D. vacuum line provided and tighten the hose connections with the hose clamps.
8. The pump should now be ready to plug in and turn on.

CAUTION

Always turn on the Mechanical Pump *before* starting the molecular drag pump.

NOTE

- Replace the element in the assimilation trap every six months. This will eliminate the potential for oil backstreaming into the system.
- The mechanical pump and its vacuum hose should not touch the sides of the console. Vibrations induced by the pump may interfere with system performance.

Table 10-1. 7000 Series System Symptoms (Continued)

SYMPTOM/PROBLEM	PROBABLE CAUSE	REFER TO PARAGRAPH	NO.
No sample movement	Motor control Model 140 Sample probe stuck No power to instrumentation Cables	Sample Movement Check Model 140 Check Sample Space Check Power Cables	10.9 10.3 10.8 10.10 10.10
Dewar/cryostat insert frosty cracks in table top	"Soft" dewar, too much/too fast LHe transfer	Cryogenics Check	10.7
Sample probe stuck	Obstruction in sample space	Sample Space Check	10.8
Liquid nitrogen leaks	Loose connections	Cryogenics Check	10.7
Liquid helium boils off too rapidly	"Soft" dewar or not enough LN_2	Cryogenics Check	10.7
Programs will not load/run or cannot access data files	Computer/software No power to instrumentation Instrumentation IEEE address	ACS Software Power Lock-In Check DRC-91CA Check Model 140 Check	10.10 10.10 10.3 10.3 10.3
Liquid helium level indicator not working	No liquid Indicator malfunction	Cryogenics Check Liquid Helium Level Indicator	10.7 10.10
OPTION: Resistivity not working (erroneous readings)	Resistance probe card not plugged in Model 140 Lock-In Computer Probe/cable not plugged in No power to instrumentation Cables	Option: Resistance Probe Model 140 Check Lock-In Check HP Vectra™ Computer Check Resistance Probe Power Cables	10.10 10.3 10.3 10.3 10.10 10.10 10.10

10.1 GENERAL SYSTEM CHECK

If erroneous readings have been encountered, the following tests will verify the 7000 Series System is operating properly.

NOTE

The system should be at room temperature. If it is not, then either use the AUTO T ADJUST routine in the MANUAL MODE of the ACS software to adjust the temperature to 300 K or proceed to Paragraph 10.1.2.

10.1.1 System Check 1

The following is system check number 1 for systems running at room temperature.

1. Check data processing or acquisition parameters. If parameters were incorrect, try again with proper parameters.
2. Check power to instruments. Reset breaker on power strip if necessary.
3. Verify sample is positioned properly and sample movement is functional. If sample is not positioned properly, reposition sample and try again. If movement is not working, see Paragraph 10.9.
4. Remove sample and insert test sample supplied into sample space.
5. Attach motor control unit.
6. Using ACS software, set frequency to 100 Hz and field to 80 A/m.
7. Turn sample movement on and specify single phase data acquisition at 90°.
8. Position sample in bottom secondary coil. (This can be done manually or with auto-positioning routine.)
9. Use TAKE DATA routine in MANUAL MODE to log a single data point.
10. Compare reading to reading supplied by Lake Shore on test sample report. If two agree to within ±3%, system is functioning properly. If not, verify correct measurement parameters were input in step 6 and sample is positioned properly.
11. If there are still problems, proceed to System Check 2.

2.3.3.2 Alcatel Model CFV100 Drag Pump Electronic Control Unit Installation

The Alcatel Model CFV100 Frequency Converter serves as the Electronic Control Unit for the Alcatel Model 5011 Molecular Drag Pump. Place the control unit on the top of the Dewar Console to the left of the Movement Motor Assembly (when viewing from the rear). See Figure 2-5. Use the two existing phillips head screws to connect the 10-pin connector to J2 on the rear of the control unit. Route the cable through the right hole in the rear of the dewar console, then connect the other end of the cable to the Drag Pump.

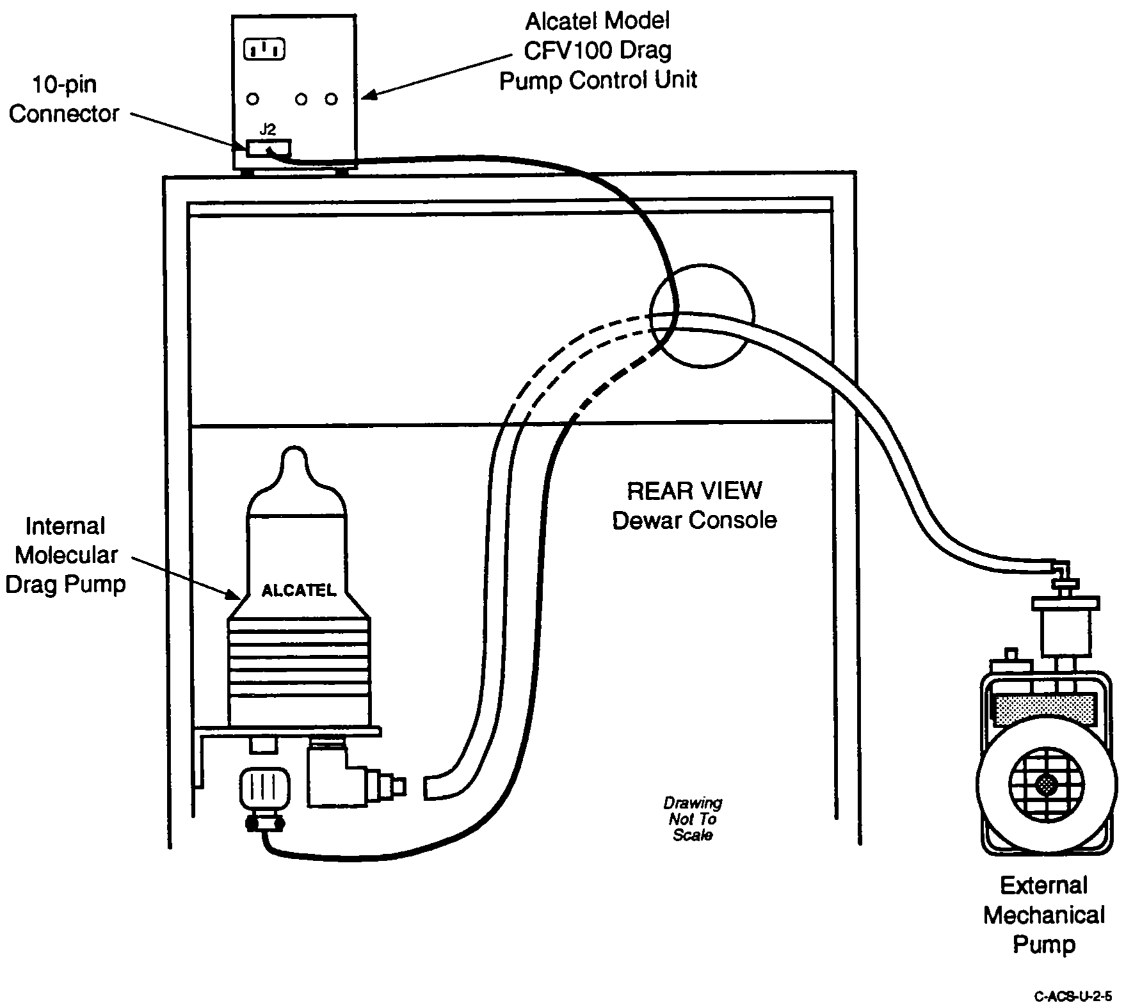


Figure 2-5. Vacuum Pumping System Installation

CHAPTER 10
SYSTEM SERVICE

10.0 GENERAL

This service chapter for the Lake Shore 7000 Series AC Susceptometer/DC Magnetometer is designed to help the user isolate and correct common problems encountered in the field. Most difficulties experienced are usually easily corrected and do not require consulting the factory. Table 10-1 provides a list of possible symptoms, probable cause, and reference to a paragraph for further troubleshooting. Figure 10-1 provides a troubleshooting flowchart to further aid in system troubleshooting. Individual component Instruction Manuals should be read before attempting to operate and troubleshoot the system.

Table 10-1. 7000 Series System Symptoms

SYMPTOM/PROBLEM	PROBABLE CAUSE	REFER TO PARAGRAPH	NO.
Instrument or system not working	No power to instrument	Power	10.10
Nonsensical χ	Data processing	System Checks	10.1
		ACS Software	10.10
	Lock-in	Lock-In Check	10.3
	Sample not positioned correctly	System Checks	10.1
	Coils	System Checks	10.1
		Coil Check	10.2
	Model 140 ACS Control Unit	Model 140 Check	10.3
	Computer	HP Vectra™ Computer Check	10.2
		ACS Software	10.10
	Cables	Cables	10.10
Unable to maintain vacuum	Vacuum/gauges	Thermocouple Gauges Check	10.5
	Outgassing	Vacuum Pump/System Check	10.6
	Vacuum pump/leaks	Vacuum Pump/System Check	10.6
	No power to instrument or pump	Vacuum Pump/System Check	10.6
Pressure increase in sample space	Outgassing	Vacuum Pump/System Check	10.6
	Vacuum/gauges	Thermocouple Gauges Check	10.5
	Vacuum pump/leaks	Vacuum Pump/System Check	10.6
	LN_2 or ice in sample space	Sample Space Check	10.8
Unable to cool system or condense liquid helium during LHe transfer	Insufficient exchange gas, LHe, or pressure. LN_2 in dewar	Cryogenics Check	10.7
System will not warm	No power to instrumentation	Power	10.10
	Thermometry	Thermometry Check	10.4
	DRC-91CA	DRC-91CA Check	10.3
	No heater output	Heater Check	10.4
	Cables	Cables	10.10
	Too much exchange gas	Cryogenics Check	10.7
	LN_2 or ice in sample space	Sample Space Check	10.8
	Vacuum pump/leaks	Vacuum Gauges Check	10.5
		Vacuum Pump/System Check	10.6
Temperature and control sensors do not agree	DRC-91CA	DRC-91CA Check	10.3
	Thermometry	Thermometry Check	10.4
	Cables	Cables	10.10
	Computer	HP Vectra™ Computer Check	10.3
		ACS Software	10.10
Unable to maintain temperature	Not enough/too much cooling power	Cryogenics Check	10.7
	Heater	Heater Check	10.4
	DRC-91CA	DRC-91CA Check	10.3
	Thermometry	Thermometry Check	10.4
	No power to instrumentation	Power	10.10
	Cables	Cables	10.10

2.3.4 Cryostat Installation (Model 7229 Only)

The cryostat shipping box should be opened by removing the one side panel labeled for removal and carefully removing all packing material. Inspect the cryostat for any hidden damage.

The cryostat should always be supported in a vertical position and can be carried by the upper flange or by the two tubes labeled "Lift Cryostat Here." Use the shipping container for storing the cryostat until ready for installation.

Identify the bag of parts attached to the top of the cryostat labeled "Cryostat Assembly Parts." This should contain the following items:

Item Description	Quantity
#8-32 x 3/4 inch hex head bolts for cryostat/dewar attachment	8
1/2 inch nut with lock washer for load lock valve handle	1 set
KF-16 O-ring assembly	2
KF-16 clamp	2
1/4 inch Swagelock Nuts (spare)	2
1/4 inch Swagelock Back Ferrules (spare)	2
1/4 inch Swagelock Front Ferrules (spare)	2
5 inch length of 1/4 inch copper tubing (spare)	1

Also locate the hex head and open end wrench sets supplied with the system. Other required items include a screwdriver and an adjustable wrench.

The installation of the cryostat into the dewar console is described in the following steps. Be careful not to drop anything into the open neck of the dewar and two people should be available for step 7. Completely read the installation procedure before starting.

1. Remove the Load Lock Handle from its secured position by cutting the nylon tie inside the dewar console.
2. Completely remove the aluminum L supporting bracket on the inside front of the console. This bracket passes over the top front of the 5 inch dewar opening. Remove the bolts where it attaches to the left and right sides of the console and also where it is fastened to the top of the dewar.
3. On the inside of the console, locate the insulated 3/8 inch copper helium bath vent line and be sure it is rotated clear of the dewar opening. Note this line connects to the helium bath vent valve on the back panel of the console.
4. Insert the cryostat into the dewar. Make sure the O-ring on the top of the dewar is clean and in position. Be sure the valve stem on the load lock valve faces forward and lift the cryostat only by the lines so labeled. Two people should be available for this step; one for lifting the cryostat and a second to help guide it into the dewar.
5. Align the holes in the top flange of the cryostat with the threaded mating holes in the dewar. Bolt the cryostat to the top of the dewar using the hex head bolts provided. Do not place a bolt in the front hole at this time.
6. Place the aluminum L supporting bracket back into its original position and loosely reattach the bracket to the left and right sides of the dewar console. The L bracket should be passing over the top of the cryostat flange and over the front bolt hole left open in the previous step. Bolt the L bracket / cryostat / dewar together using the last of the 8-32 bolts.

9.7.5 SOFTWARE ADDITIONS

These additions are specific to the low temperature option and cover both the ACS7000 and DCM7000 software packages.

Append Path: Collection | Experimental | Log

Used instead of **Begin** to log data and append the data to a file already containing previously recorded data. Only single valued measurements as a function of one parameter, such as susceptibililty $\chi(T)$ or moment m(T), can be appended and appended data must be of the same experimental configuration as the data already existing in the file. For example, do no mix single and dual phase susceptibility measurements. Complex experimental conditions involving such things as arrays or hysteresis loops can not be appended.

Note that **Begin** overwrites the existing file in contrast to **Append** which adds to the existing file. **Append** can only be used to append to files created during one session in operating the software. Once the software program is exited, any ability to append to existing files is lost.

Append Path: Collection | Auto

Used instead of **Begin** to start automatic data acquisition and append the data to a file containing data previously recorded using **Log**. Only single valued measurements as a function of one parameter, such as susceptibililty $\chi(T)$ or moment m(T), can be appended and appended data must be of the same experimental configuration as the data already existing in the file. For example, do no mix single and dual phase susceptibility measurements. Complex experimental conditions involving such things as arrays or hysteresis loops can not be appended.

Note that **Begin** overwrites the existing file in contrast to **Append** which adds to the existing file. **Append** can only be used to append to files created during one session in operating the software. Once the software program is exited, any ability to append to existing files is lost.

Suspend Path: Collection | Auto

Used to momentary pause or stop the system during automatic data acquisition. In order to avoid effecting the data, the best point to suspend is during the temperature wait period as the system is waiting for temperature stabilization. During a suspended operation, pressing the H-key will toggle the heater output of the temperature controller on and off. Pressing any other key will resume operation.

Toggle-Pot-Status Path: Collection | Auto

Prompts for input on whether or not the helium pot is being used. This selection is required for proper selection of the temperature controller proportional/integral/derivative (PID) parameters used in automatic data acquisition. The default status assumes the helium pot is not in use. This option needs to be accessed only if the helium pot is going to be used with the temperature controller.

Cryostat Installation – Model 7229 Only (Continued)

7. Make sure the load lock valve is in the open position; the valve stem should be positioned vertically.
8. Mount the movement assembly on top of the dewar console and insert the sample rod into position. Check for approximate alignment between the sample rod and where it attaches to the movement assembly.

NOTE

Foam shims may have been factory installed between the sides of the dewar and the inside left and right walls of the console to maintain alignment during shipping and installation of the cryostat. If a large misalignment is noted, adjust these shims until an approximate alignment is reached. Detailed alignment can be done after this installation is complete by loosening (loosen only but do not remove) the bolts on the underside of the movement platform and adjusting the movement for alignment. The top of the sample probe should be in line with the treaded attachment in the movement finger. The bolts are then retightened when the proper positioning is achieved.

9. Remove the sample probe and movement assembly.
10. Tighten the aluminum L bracket in place.
11. Remove any foam shims along the side of the dewar.
12. Mount the front panel using the four wood screws which were removed earlier.
13. Attach the load lock valve handle to the load lock valve using the lock washer and nut from the Cryostat Assembly Parts bag and the 1/2 inch wrench. The handle and the open part of the c shaped coupling on the handle stem should be pointing left when the load lock valve is in a closed position and should be pointing down when the valve is in an open position.
14. Attach the load lock vent valve to the front panel using a 3/4 inch wrench and the nut removed previously. Also, replace the handle on this valve.
15. Locate the internal/external valve on top of the cryostat and note the 1/4 inch copper tubing line with Swagelock compression fittings which lines up with the valve. Connect this line to the valve using a 9/16 inch wrench. Be sure to use a second back-up wrench on the mating part during this process to prevent any torque or rotation from being transmitted to the valve assembly.
16. Rotate the helium bath vent line (the insulated 3/8 inch copper line) into position and attach the Swagelock compression fitting to the top of the cryostat. Use an 11/16 inch wrench to tighten both ends of this line. Be sure to use a second back-up wrench on the mating part to prevent any torque or rotation from being transmitted to other fittings or joints.
17. Connect the two bellows vacuum lines to the cryostat using the KF-16 O-ring assemblies and clamps which are provided. The O-ring s may be lightly greased with vacuum grease. The clamps should be only hand tightened.
18. Locate the two ten pin connector cables on the inside of the dewar console that are labeled with orange and yellow marking tape. Connect these two cables to the similarly coded connector on the cryostat.
19. Connect the magnet power supply output leads to the vapor-cooled leads on the cryostat. Match the red and black color coding on the leads.
20. Replace the gray panel insert.

The installation of the cryostat is now complete and system installation can be continued.

9.7.4.1 Preparation

The controller should be set to control on the B sensor. This is done by switching the toggle on the back of the controller to the B position.

Follow the steps above for filling the pot with liquid helium. Slowly open the vacuum regulator valve until it is wide open and let the system cool to its lowest temperature.

9.7.4.2 Data Acquisition

Set up an experimental run over the temperature range from the lowest temperature to the highest temperature desired. The data can be logged using the AUTO option which will automatically control the temperature with the temperature controller. Before starting the data acquisition select the TOGGLE-POT-STATUS option under AUTO and respond to the prompt with a Y (yes). This tells the system that the helium pot is being used. Start the run by pressing BEGIN.

At approximately 2.2 K the run should be paused by pressing SUSPEND. Turn the heater off through the software by pressing the H key. When the software is in suspend mode, the H key functions as a toggle to turn the heater power on and off. With the heater off, the temperature of the system will immediately start decreasing back to 1.5 K.

The needle valve should now be slowly opened approximately 1 turn. The pot is now operating in a continuous flow mode. In this mode of operation, the lowest obtainable temperature is around 2.1 K, so the system temperature should increase and stabilize around this value. Adjust the position of the needle valve as necessary to maintain this temperature.

Turn the heater back on using the H key and resume the data acquisition by pressing any other key on the keyboard. The software should prompt as to the status of the helium pot and respond with a Y (yes) to indicate the pot is still in use. Let the run continue until 5 K and again SUSPEND the data acquisition. If a transition or other interesting phenomenon is occurring around 5 K, changing modes of operation at this point may not be desirable. In these situations, allowing data acquisition to continue to slightly higher temperatures before suspending operation is acceptable.

NOTE

If temperatures below approximately 2.1 K are not required, the helium pot does not have to be filled with liquid helium before cooling below 4.2 K. Instead of filling the pot, simply pump wide open on the empty pot (vacuum regulator valve completely open) and open the needle valve approximately 1 turn. In this continuous flow mode, the system should cool to around 2.1 K. Close or open the needle valve to maximize cooling efficiency as needed.

9.7.4.3 Transition To T > 5 K

At this point, the pot is most likely empty and operating in a continuous flow mode. Turn the heater off through the software by pressing the H key. Set the controller back to controlling on the A sensor and then turn the heater back on. Allow the system to stabilize for about 5 minutes. Note the temperature of the sample may decrease during this time period.

Close the needle valve and allow the pot to pump out completely as indicated by the thermocouple gauge. Close the helium pot valve. The vacuum regulator valve may now be closed and the vacuum pump turned off.

Note that if the helium pot does not pump out within a few minutes, there may still be liquid remaining in the pot. The liquid may be removed by either of the methods outlined in the preceding section.

After the pot is empty and temperature control has been established, data acquisition can be resumed by pressing any other key (besides H) on the keyboard. Respond to the prompt on the status of the helium pot with a N (no).

2.3.5 Keithley Model 182-LS Sensitive DVM Installation

The Keithley Model 182-LS Sensitive Digital Voltmeter (DVM) is shipped already installed in the Instrument Console. The input cable connector requires connection to the front panel. The other end of the cable is routed out the rear of the Instrument Console and plugged into the χ/m A and B BNC connections during DC measurements. See Figure 2-6. (The A and B cables are disconnected during ac measurements.) Open the rear of the Instrument Console and look at the rear of the Keithley DVM. Verify the IEEE-488 and power cables have been connected. The DVM IEEE address has been set to 7 at the factory. Refer to Appendix F for further IEEE-488 interface information.

NOTE

The Keithley Model 182-LS Sensitive DVM installed in the 7000 Series System is a special modification. Some of the standard Model 182 features have been eliminated or modified to produce the Model 182-LS. Use as a stand-alone instrument is not recommended. The Keithley Model 182-LS Addendum (PA-350) details the differences between the 182 and 182-LS. Erroneous measurements may result if used improperly.

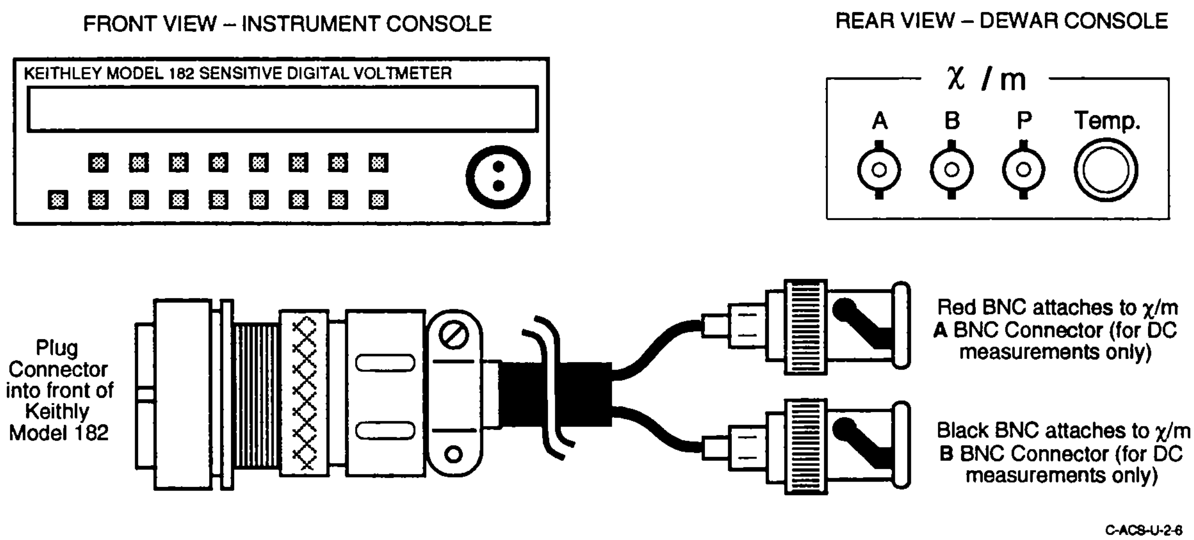


Figure 2-6. Typical Keithley DVM Cable Installation

9.7.3.4 DATA ACQUISITION

After the temperature has stabilized, the computer can be triggered to log a data point. Use the LOG option if a single point or a measurement as a function of field (such as a hysteresis loop) is desired. If a temperature dependent experiment is being performed (such as m(T) or χ(T)) where multiple temperatures are desired, record data using the APPEND option found in the LOG submenu. This will write all data to a single file for later processing. Note the APPEND option is designed to be used for appending single value measurements such as m(T) and χ(T) and should not be used under array conditions or for hysteresis loops and other m(H) profiles.

Once the data has been recorded, the vacuum regulator valve can be adjusted for the next data point.

9.7.3.5 EMPTYING THE POT

On completion of the data acquisition, the pot should be emptied of liquid helium by boiling off any remaining liquid in the pot. There are two ways for doing this. The first is a relatively slow, but controlled process, where the temperature of the sample will not go over 4.2 K. The second method is a quick emptying of the pot using the temperature controller to boil off the helium. However, the temperature of the system and sample may increase to 8 K or more during the emptying process.

The first step in either method should be to open the regulator valve wide open.

For the slow, controlled boil off method, close the vacuum pump valve and add several shots of helium exchange gas into the outer vacuum space. Let the system sit until the helium pot goes empty. The emptying of the pot is indicated when the temperature of the system warms to 4.2 K and the pressure in the helium pot as read with the thermocouple gauge starts to drop and indicates the pot is being evacuated. This process can take up to an hour depending upon how much liquid helium remains in the pot after the low temperature data acquisition is completed.

In order to quickly boil off the helium, set the setpoint of the temperature controller to approximately 8 K, the gain to 50, and the heater power to the –1 range. This can be easily done using the options under TEMP_CTR. Now wait until the helium pot empties which is indicated by the heater output power dropping and the system temperature warming. Also the pressure in the helium pot as read with the thermocouple gauge will drop rapidly to indicate the pot is being evacuated. This process should nominally take 10 minutes. When the pot is empty, a shot of exchange gas can be added to the outer vacuum space if necessary to cool back to 4.2 K.

9.7.3.6 CONTINUATION ABOVE 4.2 K

Close the helium pot valve, the regulator valve, and the bypass valve. The helium pot vacuum pump may be turned off. Start pumping out any exchange gas in the outer vacuum space by opening the vacuum pump valve and the outer vacuum space valve.

Proceed with data acquisition above 4.2 K as described in the main manual. If a variable temperature run is being performed to record m(T) or χ(T), use the APPEND option in the AUTO submenu. This option will append new data to a preexisting file recorded with the APPEND option in the LOG submenu. Note the APPEND option cannot be used with arrays or hysteresis loops.

9.7.4 HELIUM POT OPERATION – TEMPERATURE CONTROLLER

The following describes a procedure for taking data as the sample is warmed from the lowest temperature to 4.2 K using the temperature controller. The temperature controller requires significantly different control parameters depending upon whether or not the helium pot is being used. In order to maintain maximum flexibility in the way data is recorded, the software has been set up for the user to input the state of the helium pot as opposed to forcing an algorithm to be used. The state of the pot is selected using the TOGGLE-POT-STATUS option in the AUTO submenu and the temperature controller parameters are then automatically set. Note when this option is called in the following procedure. The default condition for the system is that the helium pot is not in use.

2.3.6 EG&G Model 5209 Lock-In Amplifier Installation

All cable connections to the Lock-In Amplifier have already been made at the factory. Like the other instruments in the system, the Lock-In Amplifier is controlled by the computer via the IEEE-488 Interface. The Lock-In Amplifier IEEE address has been set to 22 at the factory. Refer to Appendix F for further IEEE-488 interface information.

Unlike the other instruments, however, there are five pushbutton switches on the front panel that are not under computer control and require specific settings before proper system operation can begin. At the far left side of the Lock-In front panel, under the SENSITIVITY heading, ensure the five pushbutton switches are in the following positions: V A = out, V A-B = in, I 10^6 V/A = out, I 10^8 V/A = out, and FLOAT/GROUND = in.

The Lock-In Amplifier has three BNC cables connected to the rear. The A- and B-input are connected to the A and B terminal on the χ/m rear panel of the Dewar Console when performing ac measurements. (The A and B cables are disconnected when performing dc moment measurements.) REF AC IN on the Lock-In is connected to REFERENCE on the ACS Control Unit. Note the A and B inputs on the front of the Lock-In are not usable.

2.3.7 HP VECTRA™ Computer Installation

Unpack the HP Vectra™ Computer, monitor, and keyboard. The computer may be placed on top of the Instrument Console. However, the monitor should be placed on a desk (not provided) to the right of the Instrument Console. This is the advisable position for the monitor in systems with a superconducting magnet, since the magnetic field may interfere with the operation of the monitor. Although the HP Computer instruction manuals are included with the system documentation, please *do not use them to setup the computer.* The IEEE-488 (GPIB) Board has been installed, the hard disk initialized, and operating software has already been installed at the factory.

NOTE

Upon receipt of a new system, do not reconfigure the computer hard drive. All necessary software for operating the system have been installed and tested at the factory.

Using Figure 2-7 as a guide, make the following connections:

① HP Monitor Power Cable. Feed the Monitor Power Cable through the panel cutout behind the Instrument Console and plug into AC power strip.

② HP Computer Power Cable. Feed the Computer Power Cable through the panel cutout behind the Instrument Console and plug into AC power strip.

③ HP Keyboard Cable. On the rear of the HP Computer, plug cable into connector above keyboard icon.

④ MPS RS-232C Cable. Installation of this cable is covered in Paragraph 2.3.8.

⑤ IEEE-488 (GPIB) Cable. One end of the IEEE-488 cable is already attached to the Model 140 ACS Control Unit. Locate the other end of this cable and pull it through the panel cutout. Attach the IEEE-488 Cable to the connector located in Slot 2 of the HP Computer.

⑥ HP Monitor Video Graphics Adapter Cable. On the rear of the HP Computer, plug cable into connector above monitor icon. Refer to the HP Manual for additional information.

9.7.3 HELIUM POT OPERATION – VACUUM REGULATOR VALVE

This section describes the standard method for using a helium pot to achieve temperatures below 4.2 K. Data is acquired as the sample is cooled.

9.7.3.1 Preparation

The helium level should be at least 50% (30 cm).

For best performance and hold times, the outer vacuum space should be pumped out of any helium exchange gas for at least 30 to 60 minutes at a temperature greater than 15 K. To pump on this space open both the vacuum space and vacuum pump valves on the front panel. If the system software is running, the temperature controller can be set to control at 15 K by using the AUTO_T option in the TEMP_CTR submenu to set the system to 15 K after the transfer is complete.

After the pumping period, cooling to 4.2 K can be accomplished by turning off the heater output (use the options in the TEMP_CTR submenu if the software is running) and opening the needle valve three or four turns to admit helium into the pot. The needle valve is opened by turning the needle valve extension handle counter-clockwise. Allow the molecular drag pump to pump continuously on the outer vacuum space.

The sample space should be operated with approximately 2000 microns of exchange gas. This is more than what is required for operation above 4.2 K, but the higher exchange gas pressure aids in stabilizing the sample temperature if sample movement is being used.

Verify heater output of the temperature controller is turned off.

9.7.3.2 POT FILLING

The vacuum regulator valve should be closed and the vacuum pump turned on. Open the bypass valve and let the vacuum lines evacuate.

Close the bypass valve and open the helium pot pumping valve.

If the needle valve is already open from the preparation pump-out step above, allow the system to cool to 4.2 K. Otherwise, open the needle valve now by rotating the needle valve extension handle counter-clockwise three or four turns. Wait one or two minutes.

In order to verify there is helium in the pot and make sure the pot is filling properly, open the bypass valve slightly until the vacuum pump "gurgles." Note that the temperature decreases below 4.2 K and then close the valve. Wait one or two minutes and repeat this step.

Wait a few more minutes or until the sample temperature recovers to 4.1 K to 4.2 K. The pot should now be filled with liquid helium.

Close the needle valve.

9.7.3.3 CONTROLLING TEMPERATURE

Slowly open the vacuum regulator valve while watching the temperature displayed on the temperature controller. As the valve is opened the pressure in the pot will be reduced and the system should start cooling. When the desired temperature is reached, stop opening the valve and allow the temperature to stabilize. Proceed with data acquisition at this temperature.

Note that the vacuum regulator valve is generally used to take data on cooling and care should be exercised to avoid any significant under cooling of the desired setpoint. Closing the regulator valve will stop pumping on the pot and eventually the temperature will warm and come under control. However, the thermal response times of the system will make data acquisition on warming a very slow process.

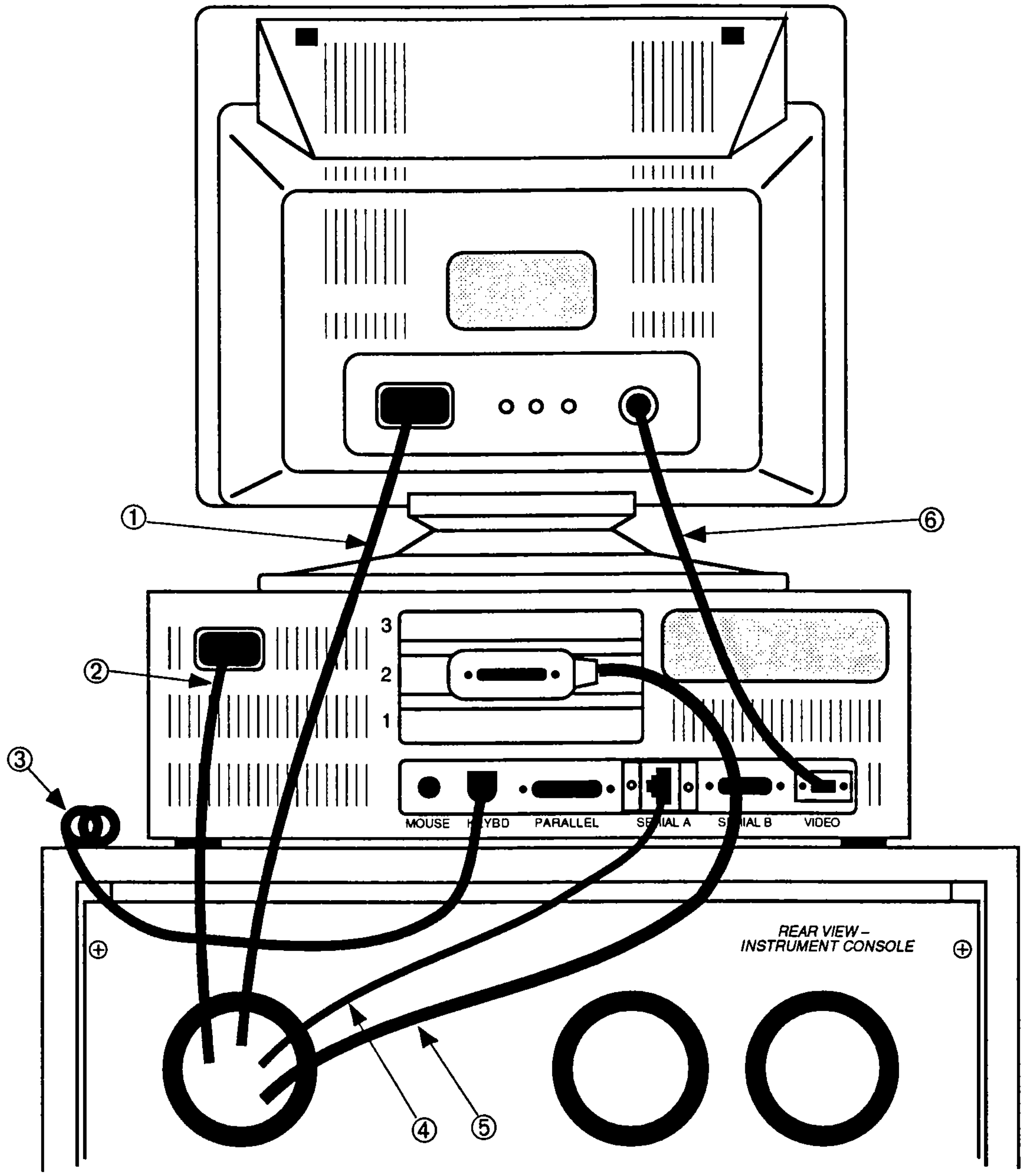


Figure 2-7. Typical Computer Cable Installation

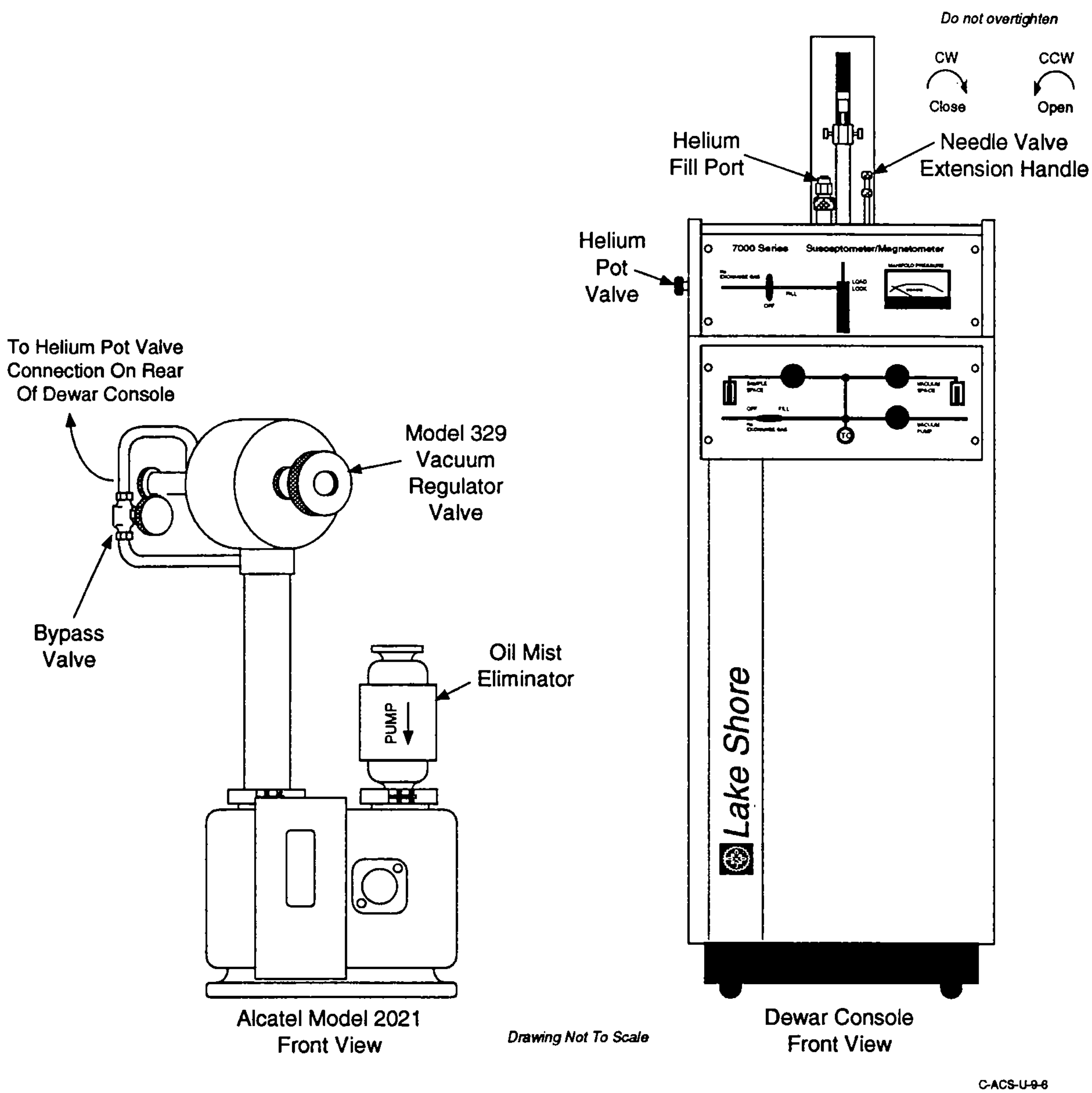


Figure 9-6. Low Temperature Dewar Console and Pumping Configuration

2.3.8 Lake Shore Model 610 Magnet Power Supply Installation

For Models 7121, 7125, 7129, 7221, 7225, and 7229, the magnet, magnet leads, and helium level indicator have been installed in the Dewar at the factory. The Model 610 Magnet Power Supply (MPS) Mainframe is installed in the bottom of the Instrument Console. Refer to the steps below and see Figure 2-8 for MPS installation procedures.

WARNING

When the superconducting magnet is in operation, all personnel should avoid contact with the MPS power cable and the two current carrying cables running to the vapor cooled leads.

CAUTION

The computer monitor should be placed on a work surface at least 5 – 6 feet away from the magnet in the Dewar Console. The monitor's CRT display becomes distorted when high fields are on and may be permanently damaged with prolonged exposure.

NOTE

Twisting the MPS Cables while routing will help to reduce electrical noise in the system.

1. One end of MPS cables has been attached to magnet leads. Route other end of cables through left slot at bottom of Dewar Console. Use provided bolts and nuts to attach red lead to +OUT and black lead to –OUT on the rear of MPS.
2. Plug supplied RS-232 serial port cable into "telephone jack" at the rear of the RS-232 Adapter in SERIAL A on rear of computer. Route cable through Instrument Console rear panel cutout. Connect other end of cable to either "telephone jack" behind the Model 610 MPS.
3. Plug MPS power cable into an outlet capable of a minimum 1 kVA.

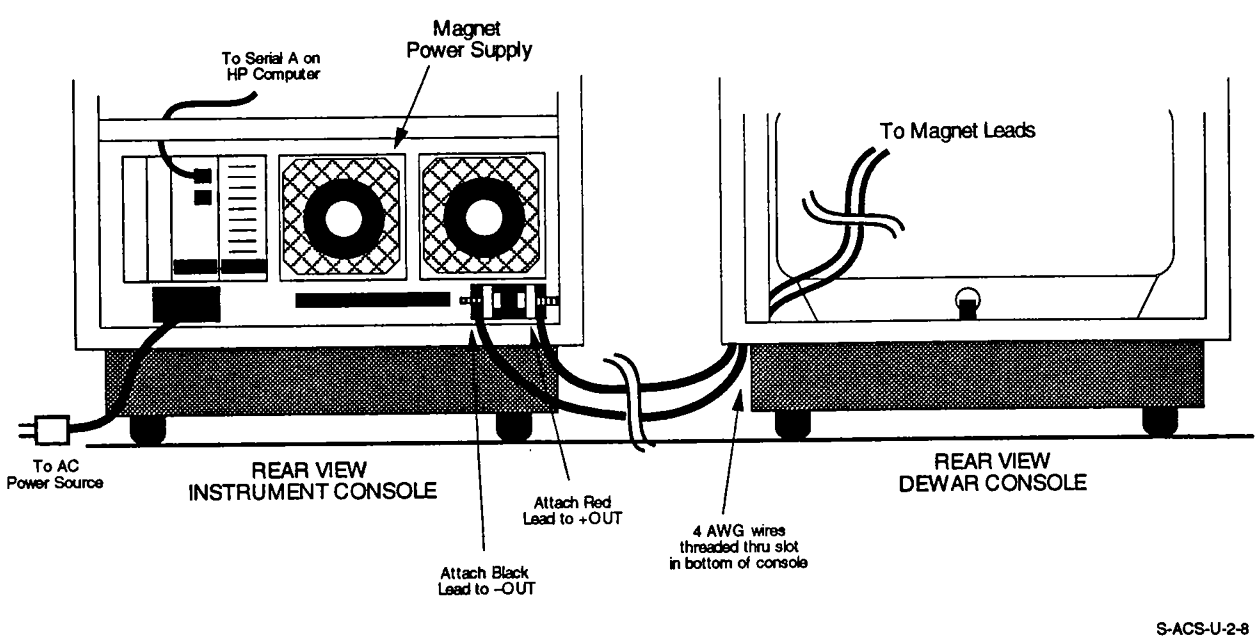


Figure 2-8. Magnet Power Supply Cable Installation

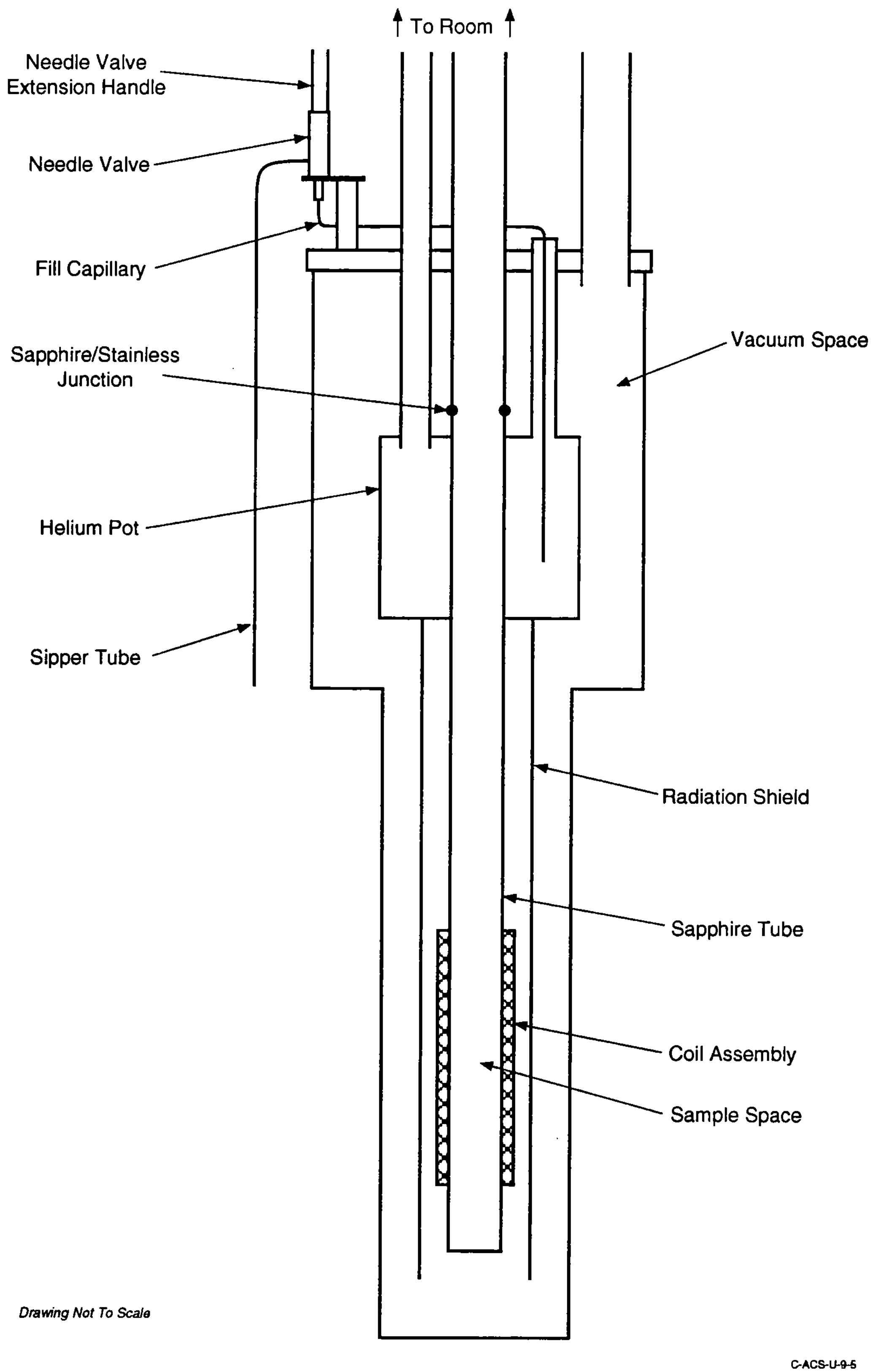


Figure 9-5. Lower Section of Low Temperature Cryostat

2.3.9 Lake Shore Model 241 Liquid Helium Level Monitor Installation

Install LHe Level Monitor on top of the Dewar Console to the left of the Movement Motor Assembly (when viewing from the front), or any other flat surface within cable reach of the console. A cable is provided to connect the indicator with the level probe in the dewar. The end that connects to the monitor has a single 9-pin connector. The other end of the cable has a 10-pin circular connector that attaches to the helium level probe connector mounted on the cryostat (on top of the dewar). See Figure 2-9.

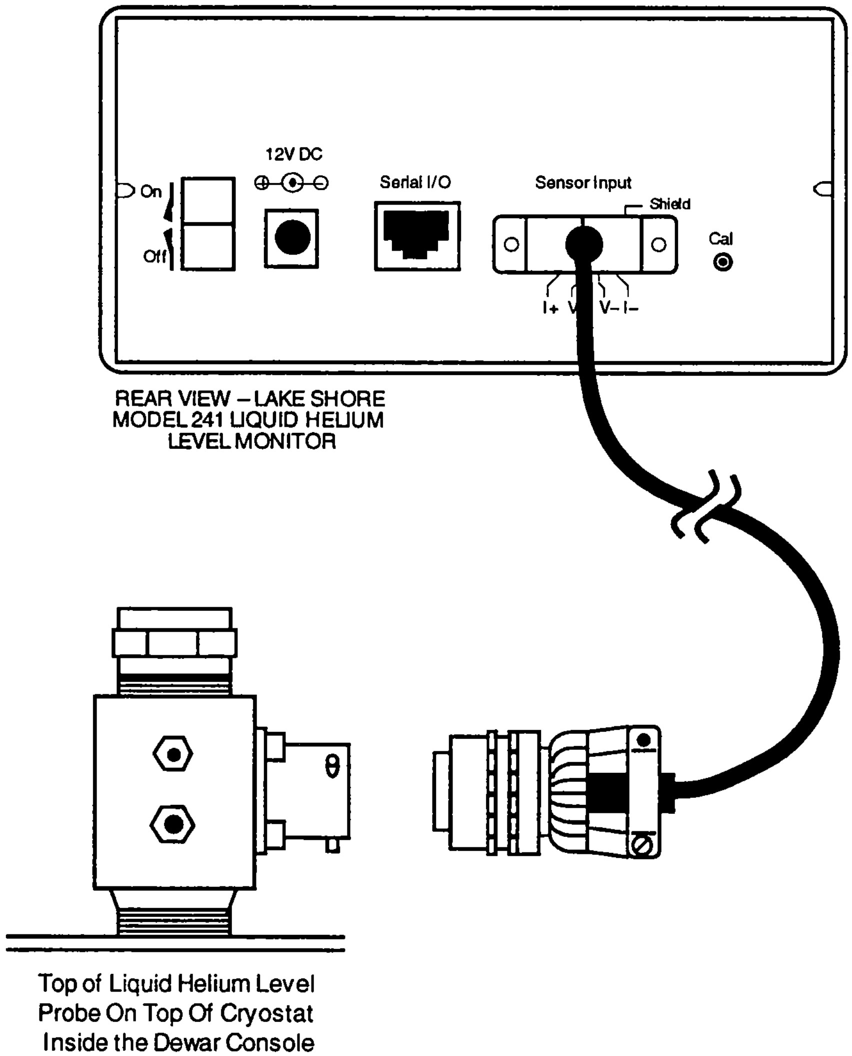


Figure 2-9. Lake Shore Model 241 LHe Level Monitor Cable Installation

9.7 MODEL 700LT LOW TEMPERATURE CRYOSTAT OPTION

The Model 700LT Low Temperature Cryostat provides the capability for expanding the temperature range of the Series 7000 systems to below 1.5 K through the use of a small helium pot located within the outer vacuum space and thermally coupled to the sample space. In the normal mode of operation, the pot is filled with liquid helium from the main helium bath by opening a needle valve and then cooled below 4.2 K by pumping with an auxiliary vacuum pump. Temperature control is performed by controlling the vapor pressure over the liquid in the pot using a Lake Shore Model 329 Vacuum Regulator Valve. In this data acquisition scheme, data is recorded as the sample is cooled from 4.2 K to the lowest temperature. Alternate control schemes permit data acquisition to be carried out as the sample is warmed from the low temperature up to 4.2 K using the temperature controller supplied with the Series 7000. Figures 9-5 and 9-6 illustrate the cryostat and console with all major components identified.

9.7.1 INSTALLATION

The only special installation required is assembly of the auxiliary vacuum pump and associated vacuum lines and regulator valve. The vacuum pump is an Alcatel Model 2021 two-stage rotary pump with oil-mist eliminator. This should be assembled and oil added to the rotary pump per instructions supplied with the Alcatel pump.

The regulator valve and vacuum lines are designed to attach directly to the inlet of the Alcatel pump. Refer to Figure 9-2. Connect the flexible vacuum line between the regulator valve and the helium pot pumping valve on the console using the KF-25 flanges which are provided.

9.7.2 INITIAL HELIUM TRANSFER

Before transferring liquid helium into the dewar, the helium pot should be evacuated. Close the needle valve by rotating the needle valve extension handle on the top of the dewar console clockwise.

CAUTION

Use extreme care in closing the needle valve and do not over tighten. Placing too much torque on the valve can cause permanent damage to the valve seat. Tighten only enough to seal the valve. Monitoring the pressure in the helium pot with the thermocouple gauge gives a good indication of when the valve is sealed.

Turn on the vacuum pump and open the helium pot pumping valve. The Model 329 Vacuum Regulator Valve should be closed. Open the small bypass valve located next to the regulator valve and let the helium pot pump out. Close the helium pot pumping valve.

Start the helium transfer as described in the Series 7000 manual. After approximately 30 minutes, the helium pot lines should be thoroughly purged with helium gas. This is done by drawing helium gas from the dewar through the needle valve. First, open the helium pot pumping valve and then open the needle valve approximately one turn. Note the pressure increase as indicated by the pot thermocouple gauge and listen for the sound of the vacuum pump as it draws helium gas through the pot lines. Close the needle valve and then close the helium pot pumping valve. This will leave the helium pot under vacuum.

Finish the helium transfer. If temperatures below 4.2 K are not required, the vacuum pump may be turned off and data acquisition can proceed as if no pot were present.

2.3.10 Signal Cable Installation

Many of the signal carrying cables have been installed at the factory. The remaining signal cables to be hooked up are summarized in Table 2-1 and shown in Figures 2-10 and 2-11. (Connections already made at the factory are not listed.) Power cables are handled separately in Paragraph 2.3.12. All connections should be double-checked to verify that nothing came loose in shipping. A complete list of IEEE-488 instrument addresses is provided in Appendix F.

Cable 8 in Table 2-1 is of special importance. The cable has two connections at the Dewar Console end and three connections at the Instrument Console end. Inside the Dewar Console, the 10-pin connector to the probe wiring bulkhead feedthough should already be connected. The other connection at the Dewar Console is to the χ/m TEMP connector on the rear panel. In the instrument Console, the cable splits into three connectors. The first cable, labeled AAAAA, must be connected to the rear panel of the DRC-91CA Temperature Controller at the 5-pin receptacle labeled J1 – INPUT A (Control Sensor, Curve 7). The second cable, labeled BBBBB, must be connected to the 5-pin receptacle labeled J2 – INPUT B (Sample Sensor, Curve 6). The third cable has banana connections that are connected to the HEATER outputs: J7 – HI, J8 – LO, and J8 – GND. The CONTROL toggle switch on the back of the DRC-91CA must be set to A and the IEEE address to 23. Refer to the Lake Shore DRC-91CA User's Manual for further details.

The Model 140 ACS Control Unit should have four cables attached. One BNC cable is the reference connection to the Lock-In detector. The second BNC connects Current Out from the control unit to the P terminal on the cryostat. The dual banana 5 volt output serves as the power supply for the thermocouple gauges (do not reverse the leads). The ACS Control Unit IEEE address has been set to 24 at the factory. Refer to Appendix F for further IEEE-488 interface information.

See Figure 2-12 (foldout at the end of this chapter) for a typical 7000 Series color-coded cable wiring diagram. A copy of this diagram is normally included inside the rear door of the Instrument Console.

Table 2-1. Signal Cable Installation List

#	CABLE NAME	LENGTH	FROM	TO
1	Control Unit to Drag Pump	8 feet	Control Unit 10-pin Connector	Alcatel Drag Pump Connector
2	Movement Motor	9 feet	Movement Motor Assembly	Model 140 MOTOR CONTROL
3	HP Monitor to Computer	3 feet	Rear of HP Monitor	HP Computer Connector with Monitor Icon
4	HP Keyboard to Computer	4 feet	Rear of HP Keyboard	HP Computer Connector with Keyboard Icon
5	HP Computer to Model 140 IEEE-488	4 feet	HP Computer Slot 3	Model 140 IEEE-488
6	Primary Coil P, Secondary Coil A, and Secondary Coil B	6 feet	Model 140 CURRENT OUT (white), EG&G Lock-In Amplifier INPUT A (Red) BNC, & INPUT B (Black) BNC	Dewar Console Rear Panel, χ/m P (White) BNC, χ/m A (Red) BNC, and χ/m B (Black) BNC
7	DRC-91CA Temperature Sensor, Probe Heater, and Vacuum Meter Power	8 feet	DRC-91CA J1 INPUT A, J2 INPUT B, J6 HI (+), and J7 LO (–); Vacuum Gage In Dewar Console	Dewar Console, 10-Pin Connector on Probe Wiring Bulkhead Feedthru; Model 140 METER SUPPLY, Hi and Lo
8	LHe Meter	8.5 feet	LHe Probe Connector in Dewar Console	Model 241 Level Monitor
9	HP Computer to MPS Communications	8 feet	HP Computer Slot 5	MPS Phone Jack
10	Keithley DVM Input	10 feet	Keithley Model 182-LS Front Panel Connector	Dewar Console Rear Panel, χ/m A and B BNCs

Table 9-1. Table of Available Harmonics

HARMONICS	FREQUENCIES
1, 2, 3	All frequencies.
4 to 10	f = 1, 2, 3, 4, 5,6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 24, 25, 28, 30, 32, 35, 36, 40, 45, 48, 50, 56, 60, 64, 70, 72, 75, 80, 90, 100, 120, 125, 140, 150, 160, 175, 180, 200, 225, 240, 250, 280, 300, 320, 350, 360, 375, 400, 450, 500, 600, 625, 700, 750, 800, 875, 900, 1000, 1200, 1250, 1400, 1500, 1600, 1750, 1800, 2000, 2250, 2500, 3000, 3500, 4000, 4500, 5000, 6000, 7000, 8000, 9000, 9530

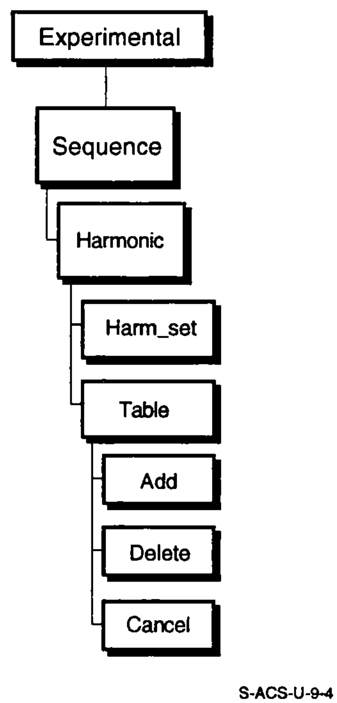


Figure 9-4. Harmonic Command Flowchart

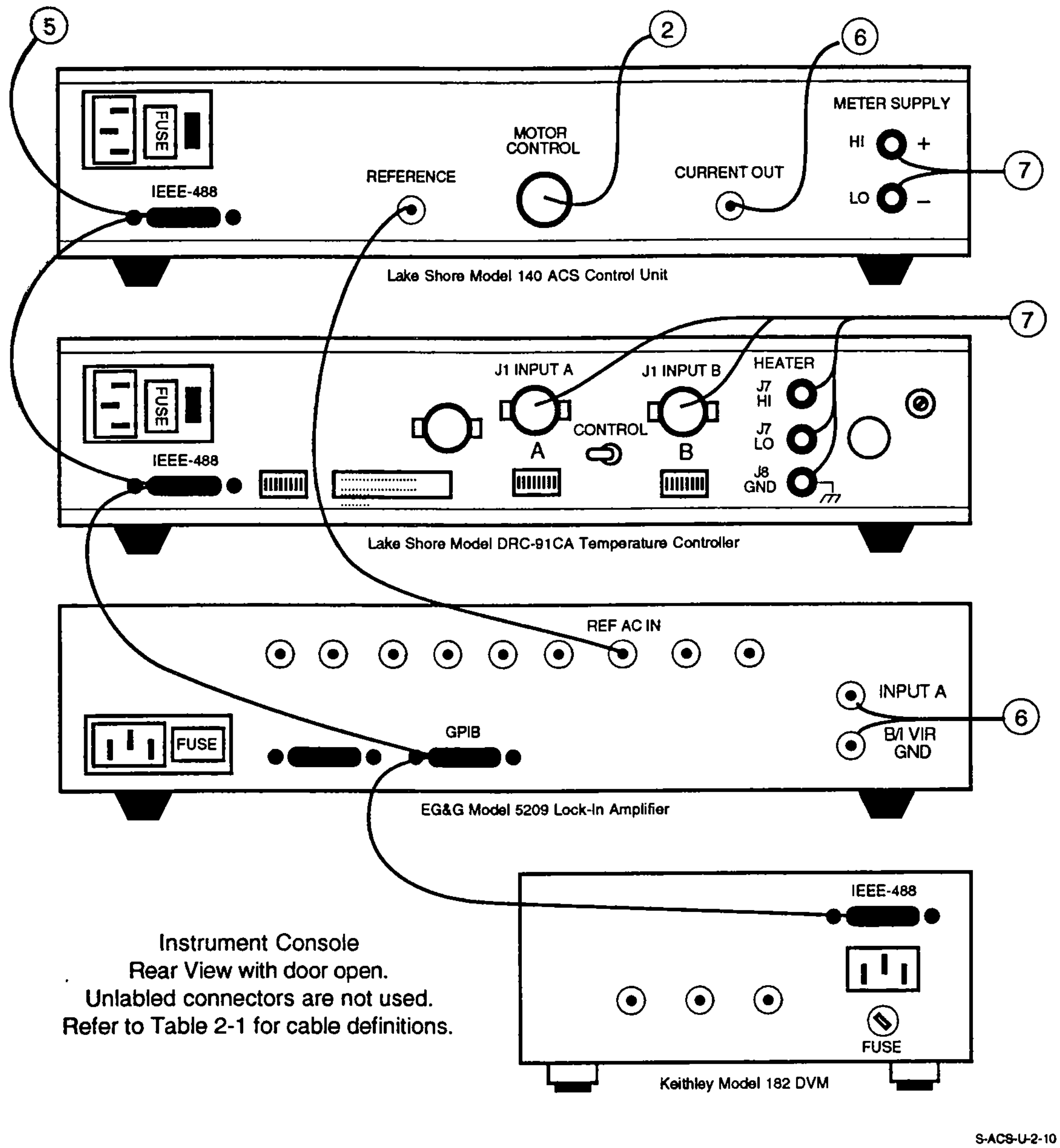


Figure 2-10. Instrument Console Cable Installation

The phase separation requires that the relative phase between all signals and the phase shifts introduced by the electronics are consistent and repeatable. This is difficult to guarantee and uncertainties can be large. However, for most applications the interest is in only the presence of a harmonic or the relative magnitude of the harmonic. This greatly simplifies the data acquisition.

9.6.2 RECOMMENDED MEASUREMENT PROCEDURE

Set the desired operating frequency and AC field amplitude. Specify the desired harmonic using the Harm_set option or if more than one harmonic is desired use the Table option. Specify dual phase data acquisition with sample movement. Set the temperature and field parameters as in normal operation and record data.

When processing the data, specify Single Phase to output the magnitude of the harmonic susceptibility:

$$|\chi_n| = \frac{\alpha}{nVH_{ac}f}\left[v_n'^2 + v_n''^2\right]^{1/2}$$

Note that Parm_select must be used to sort data when logging data at multiple harmonics, DC fields, and temperatures.

9.6.3 SOFTWARE COMMAND DEFINITIONS

The following are definitions of software commands added by the harmonics option.

Harm_set: Harmonic sub-menu of Sequence Menu.

A prompt will appear asking which harmonic (1 through 10) is to be measured and the harmonic selected will be indicated on the display in the Measurement Sequence box. All 10 harmonics are not available for every frequency. Table 9-1 indicates the available choices. An error message will be displayed on the screen if an improper selection is made.

Table: Harmonic sub-menu of Sequence Menu.

This results in three available options: Add, Delete, and Cancel. By using the Add or Delete selection, a table of harmonic values (1 through 10) can be set up for use during automatic data acquisition. Measurements will be recorded for each harmonic specified in the table. If the harmonic selection is not consistent with Table 9-1, an error message will be displayed. Cancel will erase any harmonic table which has been set up.

NOTE

When a harmonic table has been set up, an array of multiple fields/frequencies will not be allowed. Only a single field and single frequency is permitted with a harmonic table.

After specifying a harmonic, either with Harm_set or Table, any subsequent change in the frequency may result in a frequency/harmonic combination not permitted in Table 9-1. When changing frequencies using the frequency window in the Frequency selection, an inconsistent frequency selection is indicated by a *red* highlight (cursor) as the cursor is moved through the available frequencies. Do not set the system to one of these frequencies without going back and altering the harmonic selection.

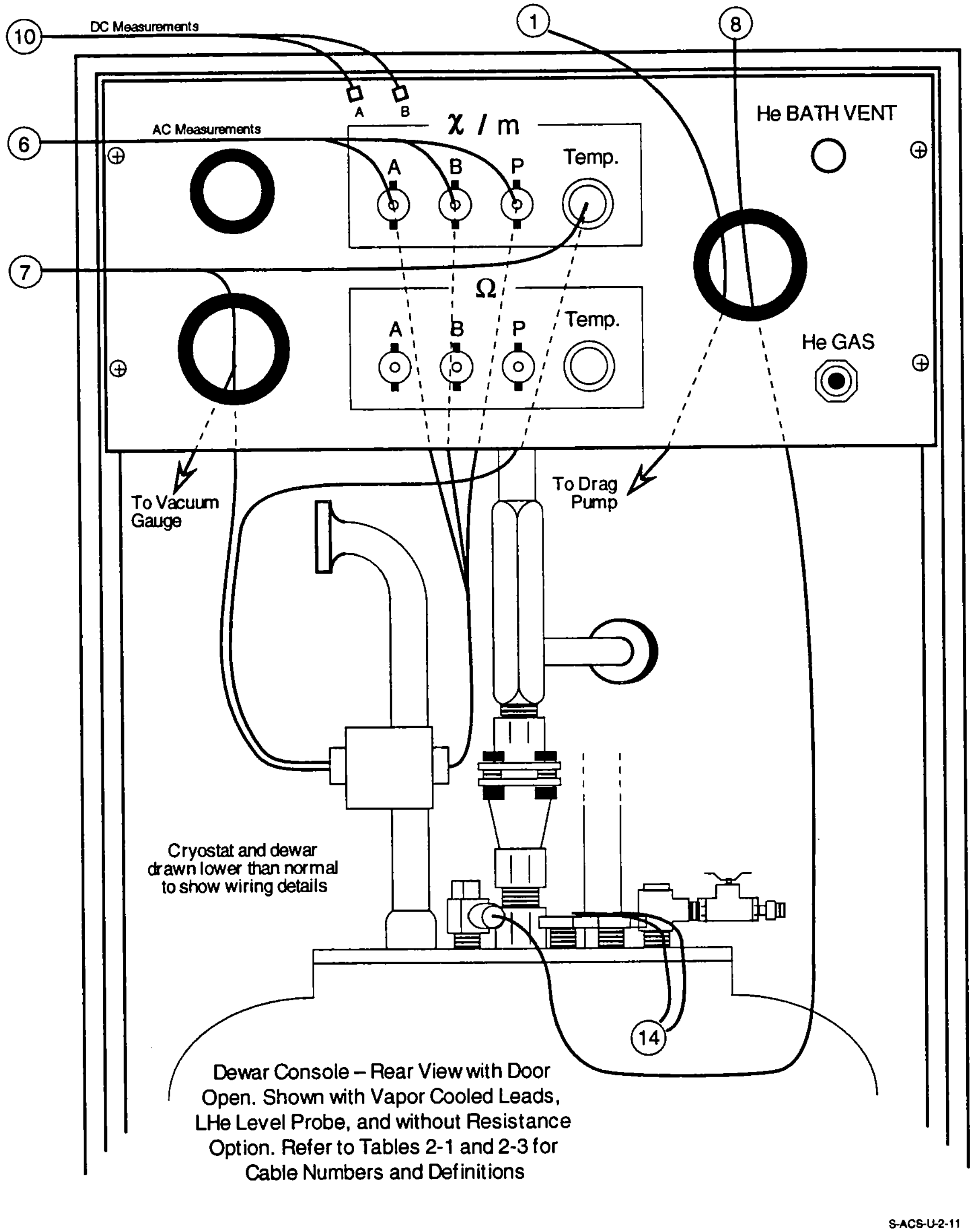


Figure 2-11. Dewar Console Cable Installation

9.6 MODEL 700HM HARMONICS MEASUREMENT OPTION

The Model 700HM Harmonics Measurement Option permits the measurement of the harmonic susceptibilities. When installed in the Series 7000, the only item visibly different for the user is the addition of a Harmonic menu item appearing under the Sequence menu in the ACS program. The operation of the core ACS program remains unchanged. The definitions of the new options available are given in the following paragraphs.

9.6.1 PRINCIPLES OF OPERATION

The response of a sample when exposed to an external AC field

$$H(t) = H_{ac} \sin(\omega t)$$

may not necessarily be a pure sine response. Depending upon the magnetic behavior of the material, the time response of the magnetization resulting from $H(t)$ should be generalized to the following expansion: [1]

$$M(t) = H_{ac} \sum_{n=1}^{\infty} \left[\chi_n' \sin(n\omega t) - \chi_n'' \cos(n\omega t) \right]$$

This equation defines what is referred to as the harmonic susceptibilities and, for n=1, the definition is consistent with what is generally thought of as the real and imaginary components of susceptibility as discussed in Chapter 1.

In a measurement scheme such as employed in the 7000 Series, the parameter actually measured is the voltage output from a sensing coil surrounding the sample. This voltage also will not be a simple sine response but will be proportional to the rate of change of the magnetization:

$$v(t) = \sum_{n=1}^{\infty} \left[v_n' \cos(n\omega t) + v_n'' \sin(n\omega t) \right]$$

$$\propto \frac{dM(t)}{dt} = \frac{1}{V} \frac{dm(t)}{dt}$$

$$= H_{ac} n\omega \sum_{n=1}^{\infty} \left[\chi_n' \cos(n\omega t) + \chi_n'' \sin(n\omega t) \right]$$

Equating terms and comparing with Equations 1.1 and 1.2 yield the following results for the harmonic susceptibilities:

$$\chi_n' = \frac{\alpha v_n'}{nVH_{ac}f} \qquad \chi_n'' = \frac{\alpha v_n''}{nVH_{ac}f}$$

The measurement of the voltage harmonics, v_n' and v_n'', involves driving the primary coil at the fundamental frequency f while the reference input to the Lock-In Amplifier is at a frequency nf. The Lock-In Amplifier is also set to a band-pass filter mode of operation.

If the system is completely phased, a separation of real and imaginary harmonic susceptibilities can be made. The process requires a linear, no loss sample and phasing must be done for all harmonics of interest. If the *nth* harmonic of a frequency f is required, the system should first be phased with an output and reference both set at frequency nf; i.e., specify the operating frequency to be nf and specify the first harmonic. This will yield a system phase angle Θ_n. Now set the operating frequency to f and specify the nth harmonic. Record data and analyze the data using the phase angle Θ_n.

References:

1. T. Ishida and R. B. Goldfarb, Phys Rev B 41, 8937 (1990)

2.3.11 Verify Power Settings And Fuse Ratings

Verify instrument power settings and fuse/circuit breaker ratings as appropriate per Table 2-2.

Table 2-2. Fuse and Circuit Breaker List

UNIT	90 – 125 VAC	210 – 250 VAC
Lake Shore Model 140 ACS Control Unit	2.0 A Slow Blow	1.0 A Slow Blow
Lake Shore Model DRC-91CA Temperature Controller	2.0 A Slow Blow	1.0 A Slow Blow
EG&G Model 5209 Lock-In Amplifier	1.0 A Slow Blow	0.5 A Slow Blow
Keithley Model 182-LS Sensitive Digital Voltmeter	3/8 A Slow Blow	3/16 A Slow Blow
Instrument Console Power Strip	15 A Circuit Breaker	15 A Circuit Breaker
Lake Shore Model 610 Magnet Power Supply	20 A Circuit Breaker	20 A Circuit Breaker
Alcatel CFV100 Control Unit Rear Panel Power Fuse	1.0 A	0.5 A
Alcatel CFV100 Control Unit PCB Power Fuse	1.0 A	0.5 A
Lake Shore Model 241 Liquid Helium Level Monitor	1.0 A	1.0 A
Hewlett Packard Super VGA Color Monitor	Internally Protected	Internally Protected
Hewlett Packard Vectra™ PC	Automatic Power and Frequency Switching – Internally Protected	

2.3.12 Power Cable Installation

Install power cables shown in Table 2-3. The remaining power connections have been made at the factory. Do not connect power cables until all signal cables are connected and AC Fuse and Circuit breakers have been verified. To avoid confusion, the power cables are identified with a number sequence that continues from the signal cable numbers detailed in Table 2-1.

WARNING

When the superconducting magnet is in operation, all personnel should avoid contact with the MPS power cable and the two current carrying cables running to the magnet leads.

CAUTION

Power cable should be disconnected from AC power before any service is to be performed inside either the Instrument or Dewar Consoles.

Table 2-3. Power Cable Installation List

#	CABLE NAME	LENGTH	FROM	TO
11	External Mechanical Pump Power	8 ft.	External Mechanical Pump	AC Source
12	HP Computer Power	6 ft.	HP Computer	Instrument Console Power Strip
13	HP Monitor Power	6 ft.	HP Monitor	Instrument Console Power Strip
14	MPS to Magnet Leads	8 ft.	Model 610 MPS, red lead to +OUT and black lead to –OUT	Magnet Leads
15	MPS Power	8 ft.	Model 610 MPS	AC Source
16	LHe Indicator Power	6 ft.	Model 241 LHe Level Monitor	AC Source
17	Power Strip Power	12 ft.	Instrument Console Power Strip	AC Source

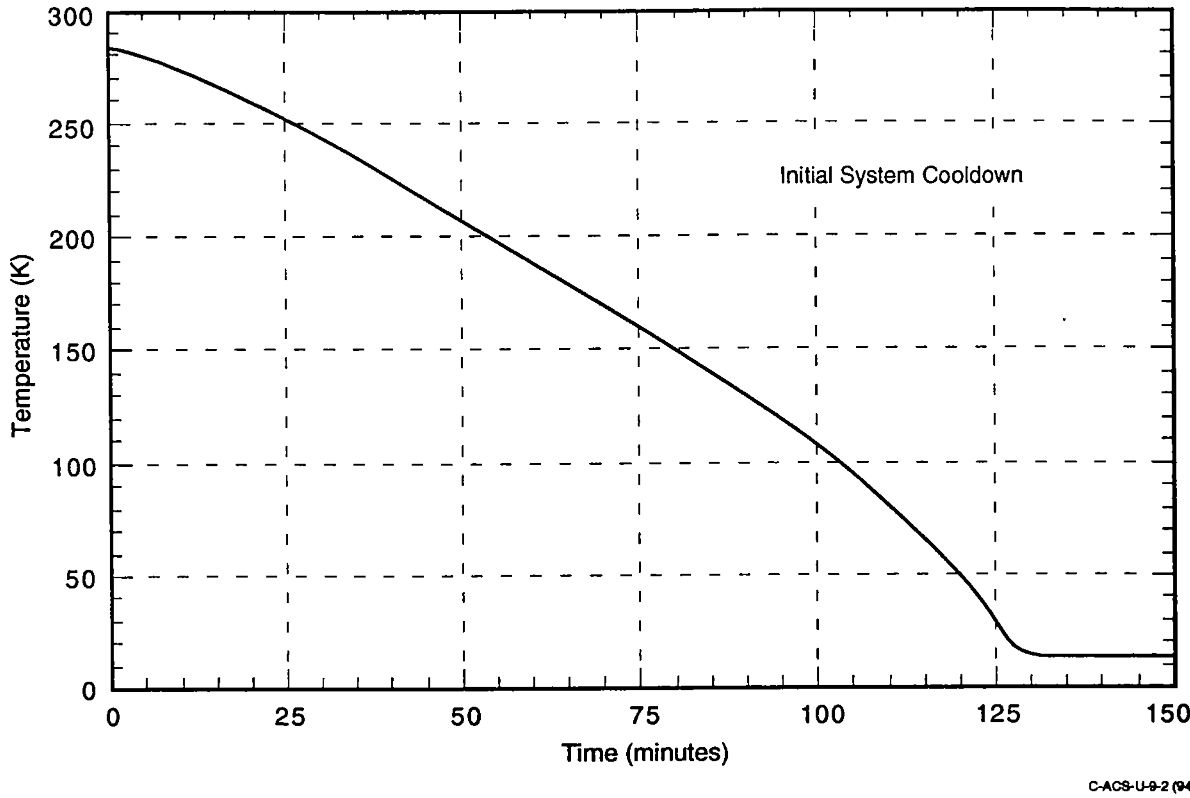


Figure 9-2. Typical Cooling Rate With Closed Cycle Refrigerator Completely At Room Temperature

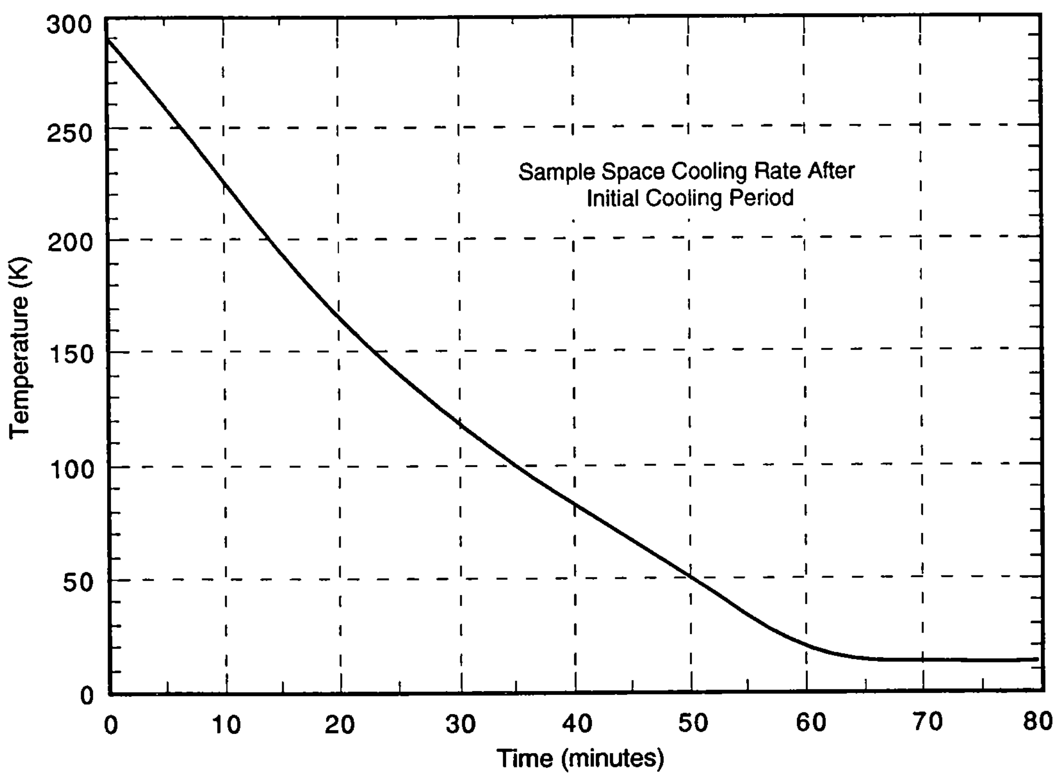


Figure 9-3. Typical Sample Space Cooling Rate After Refrigerator Is Cold

2.4 POST-INSTALLATION INSTRUCTIONS

The 7000 Series 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. To confirm this, the instrument should be visually inspected for damage and tested electrically to detect any concealed damage upon receipt. The complete 7000 Series User's Manual should be studied before attempting to run the ACS System. Running the AC/DC Demo Software is also recommended.

Once the system has been set-up and the manual read, a functional test should be performed using a test sample which has a large signal output. The large signal makes it easy to verify that the system is operating as expected and as outlined in the later chapters of this manual. A small piece of ferromagnetic steel should provide a sufficient signal for the functional test. Load the test sample into a sample cup and insert into the system. Then following the operation instructions in Chapter 4.

2.5 SYSTEM SHUTDOWN AND REPACKAGING FOR STORAGE OR SHIPMENT

The following procedure provides general guidelines for system shutdown for storage or reshipment. If the intent of the repackaging is to return something to Lake Shore, please refer to Paragraph 2.6 for details on obtaining a Return Goods Authorization (RGA) Number.

1. Warm up system to room temperature. Turn off power to pump and all instruments. Unplug power cords to pump, instrument rack, and power supply at source.
2. Remove or disconnect the following:
   a. IEEE-488, RS-232, and power cables to computer and monitor. Gather inside Instrument Console.
   b. Instrument cable at back of DRC-91CA Temperature Controller (A, B, and heater). Movement and vacuum gauge supply cables at back of Model 140 ACS Control Unit. Temperature connector (8-pin) at Dewar Console back panel.
   c. Detector cables (A, B, and P) at Dewar Console back panel. Level probe cable at level meter.
   d. Remove sample probe and seal sample space with plug.
   e. Replace movement motor assembly with insert plate. The movement cable will stay with assembly as it is being removed from Dewar Console. Plug all openings at top of cryostat.
   f. Pumping line at exhaust of molecular drag pump. Disconnect plastic tubing from external mechanical pump. Use a piece of foam to protect pins. Plug all openings after disconnect.
   g. Magnet current output cables from power supply.
3. Disconnect input cable to voltmeter and tie to rack mount handle.
4. Gather magnet current cables on side of Dewar rack. All other cables inside their respective consoles.
5. Box up computer and monitor and pack on a small pallet. Movement assembly, level meter, magnet power supply cable, external mechanical pump, and other hardware are packed into another box (20 x 20 x 15 inches).
6. Lift and place Dewar Console to left and Instrument Console to right on a second larger pallet. They should be separated by 2 inches of packing material. Each console is supported by dense foam at four corners. Additional foam is used in front of Instrument Console for weight of MPS. The sample probe, transfer line, and MPS cables are stored between consoles and packing material. Ensure all cables are tied and instruments in rack are supported. Put packing box for hardware on top of Instrument Console.
7. Wrap plastic sheets around consoles to protect and keep them together. Pack cardboard sides outside consoles and re-install lid. Packing box should rest on pallet and fit tight against consoles.
8. Strap whole box to pallet. Screw wood stops against box to pallet.
9. Label both pallets for storage or shipment.

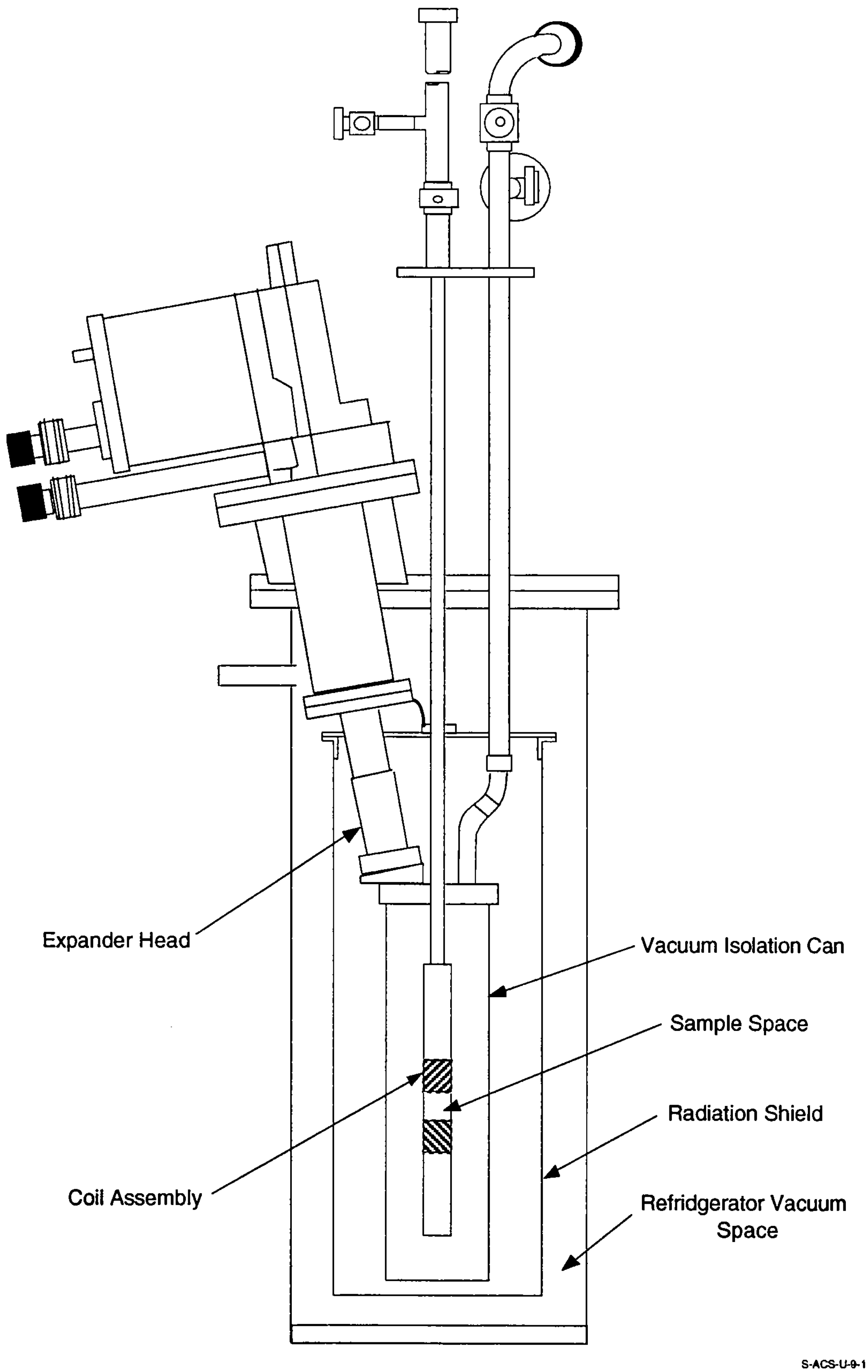
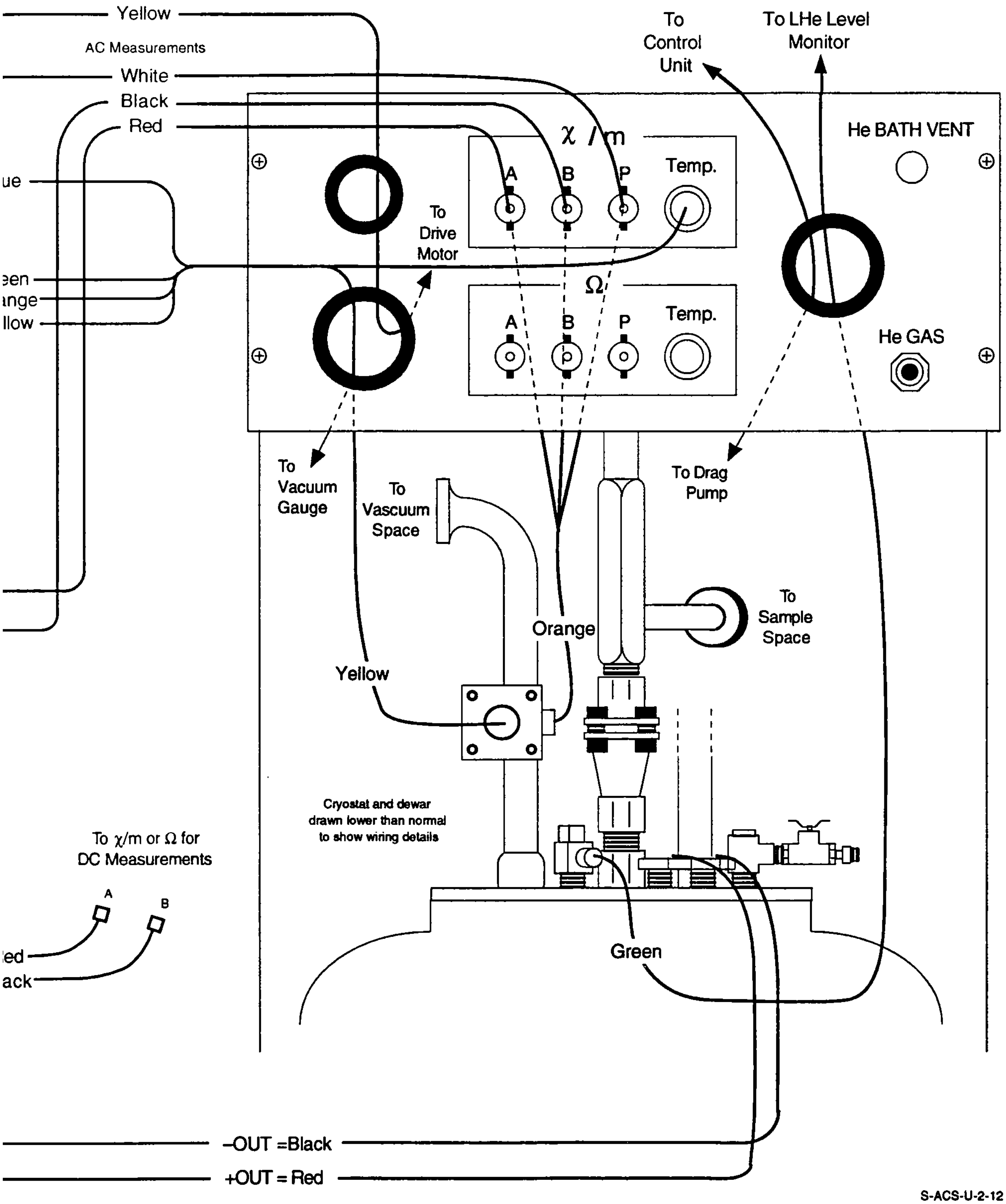


Figure 9-1. Cross Section of Model 7130 Closed Cycle Refrigerator Cryostat



Note: Color Codes Located At Cable Ends

Figure 2-12. Typical 7000 Series Cable Wiring Diagram

9.5.3 INITIAL SYSTEM COOL DOWN FROM ROOM TEMPERATURE

Verify the refrigerator has been connected properly and the refrigerator space has been thoroughly evacuated.

A vacuum should now be pumped on both the sample space and the vacuum isolation space at room temperature. Plug the sample load seal and open the sample space valve and the load lock valve. Open the vacuum space valve and turn on the vacuum pump. After several minutes, the thermocouple gauges should start indicating a vacuum. Allow the system to pump out thoroughly and then close all valves. About 30 minutes of pumping should be sufficient.

Using the helium exchange gas valve, add ≈500 to 1000 microns of helium exchange gas to both the sample space and the vacuum isolation space. Turn on the closed cycle refrigerator. About 2 to 3 hours will be required for the system to cool to below 15 K. A typical cooling rate is shown in Figure 9-2. If desired, a sample may be loaded during the cooling process. Proceed with susceptibility measurements as outlined in Chapters 3 through 6.

9.5.4 SAMPLE SPACE COOLING

After the initial cooling, subsequent sample cooling rates will be faster since the vacuum isolation can is maintained cold through its contact with the cold finger of the closed cycle refrigerator. In order to cool the sample space after completion of a data acquisition, simply close the vacuum isolation valve and add several hundred microns of helium exchange gas to the vacuum isolation space. Typical cooling rates to the base temperature are shown in Figure 9-3 for the sample space starting at 300 K.

Note that during normal data acquisition, the vacuum isolation space is pumped on continuously with the vacuum pump and the sample space contains 500 to 1000 microns of helium exchange gas. Refer to the main manual for details.

9.5.5 TROUBLESHOOTING: SAMPLE PROBE FREEZE-UP

If the sample probe freezes in the sample space due to accidental contamination entering the vacuum space, do not apply excessive force in attempting to remove the sample probe. This may permanently damage the system. The following procedure should be used:

1. Open the sample space valve and the vacuum space valve so that both spaces are being pumped on simultaneously with the vacuum pump.
2. Turn the closed cycle refrigerator off.
3. Using the Auto T adjust feature discussed in Chapter 4 – ACS7000 Software Operation. Warm the system to 300 K.
4. Allow the system to fully warm to room temperature.
5. Remove the sample probe as discussed in Paragraph 4.8.

9.5 MODEL 7130 SYSTEM CLOSED CYCLE REFRIGERATOR OPTION

Operation of the Model 7130 with the Closed Cycle Refrigerator option is virtually identical to operating with the system as supplied with the standard liquid helium/nitrogen dewar. The only difference lies in the means in which the system is cooled.

The main structural difference between the two systems is in the manner in which the vacuum isolation can is cooled. In the standard system, the vacuum isolation can is in direct contact with the liquid cryogen. With the refrigerator option, the dewar body is replaced by a large vacuum container enclosing what will be referred to as the refrigerator vacuum space (see Figure 9-1). The Expander Head is mounted on the top of this space with the cold stages extending into the interior. The vacuum isolation can is also suspended inside and is in permanent contact with the cold stage of the closed cycle refrigerator. The isolation can is then maintained at the same temperature as the second stage of the refrigerator.

The closed cycle refrigerator cryostat consists of three separate vacuum spaces:

1. The sample space where the sample probe and sample is inserted into the coil assembly.
2. The vacuum can isolation space which serves to thermally isolate the sample and coil assembly from the isolation can.
3. The refrigerator vacuum space which serves to thermally isolate the cold head and vacuum isolation can from room temperature.

9.5.1 REFRIGERATOR INSTALLATION

The compressor (refrigerator) can be operated at different voltages and frequencies. Refer to the CTI Refrigerator Manual for instructions before performing this operation. To ensure proper operation, read and follow all appropriate manuals before attempting installation.

The refrigerator expander and cryostat assembly are already mounted on the inside of the console. The gas lines and electrical cable connecting the compressor and refrigerator expander must be installed. This installation will require removing the rear panel and passing the lines through the access hole in the panel before re-assembly. Cooling water must be supplied for the compressor unit. Consult the refrigerator manuals for details.

9.5.2 INITIAL PUMP-OUT

The refrigerator vacuum space must be thoroughly evacuated at room temperature before attempting to cool down the system. The space is pumped through the pump-out valve located inside the rear of the Dewar Console.

CAUTION

The refrigerator vacuum space should never be pumped when the refrigerator is cold.

The refrigerator space was evacuated prior to shipment and a vacuum should still be indicated on the mechanical gauge located near the pump-out valve. In order to pump on the refrigerator space, close the vacuum space valve and the sample space valve located on the front of the console. Turn on the vacuum pump and allow a few minutes for the molecular drag pump to reach speed. Open the pump-out valve. The refrigerator space is now being pumped on by the molecular drag pump. Allow the system to pump for 4 to 6 hours and then close the pump-out valve. The system should now be ready to cool down.

A periodic pumping of the refrigerator space is recommended to maintain good vacuum integrity. This should be done on a monthly basis or as needed if any deterioration in the lowest achievable temperature is observed.

The refrigerator may be operated continuously. Frequent cycling of the refrigerator may increase the frequency with which the refrigerator vacuum space must be pumped.

CHAPTER 3
HARDWARE DESCRIPTION

3.0 GENERAL

This chapter includes a detailed description of the 7000 Series Susceptometer/Magnetometer hardware. Chapter 4 contains system operating instructions that supplement the information provided in the individual vendor manuals. Both Chapters 3 and 4 should be read in their entirety before attempting to operate the unit.

Details on the cryostat are provided in Paragraph 3.1. The Sample Probe assembly is described in Paragraph 3.2. The vacuum pumping system is described in Paragraph 3.3. Paragraph 3.4 provides information on the Model 7225 vacuum/exchange gas system. Paragraph 3.5 contains information on the Model 700SHD Superinsulated Helium Dewar. (The Closed Cycle Refrigerator in the Model 7130 is described in Chapter 9.) Finally, information on superconducting magnets is provided in Paragraph 3.6.

3.1 CRYOSTAT

The cryostat is shown in Figure 3-1. The cryostat is inserted in the 5-inch I.D. opening at the top of the dewar and is designed to be operated with a liquid cryogen surrounding the vacuum isolation can. The cryostat consists of two separate vacuum spaces. The sample space is accessed through the sample load seal and evacuated through the Sample Space valve and the Load Lock valve. The lower end of this space is fabricated from a sapphire tube with the necessary coil windings, heaters, and sensors attached to the outside of the tube. The vacuum isolation can surrounds the lower part of the sample space and provides the necessary thermal isolation when the system is in operation. This space is evacuated through the Vacuum Space valve. The vacuum isolation can is sealed to its supporting flange with an indium seal. Note that the sample space is not thermally isolated outside of the vacuum space can. This design allows the sample to be precooled before entering the temperature controlled space inside the vacuum can by slowly inserting the sample probe.

When the cryostat is installed in the Dewar Console, the only parts which are visible and accessible are the helium fill port(s) and sample load seal which extends from the top of the system, and the valve handles which extend in the front of the console. The helium fill port is normally sealed with a pop-off during normal operation. The pop-off should always be in place to prevent condensation of air in the dewar space when the dewar is cold.

3.2 SAMPLE PROBE ASSEMBLY

The sample probe assembly used in all models is shown in Figure 3-2. The main part of the sample probe is a long polished stainless steel tube. On the tube is the sample probe seal which is movable along the polished stainless tube. The seal contains spring loaded Teflon® seals which are designed to operate "dry." Do not apply any grease to the seal or rod. Always wipe the sample probe clean before attempting to move the probe seal along the rod or damage to the sample probe assembly may result. No more than 10 pounds of force should be required to move the probe seal along the rod.

CAUTION

Handle the sample probe with care in order to avoid scratching or marring the surface of the stainless steel tube. Do not remove the sample probe seal from the sample probe during normal use.

At the top of the probe is a threaded region with a cylindrical thumb nut that is used in attaching the probe to the motor drive unit for sample movement. The lower end of the probe consists of a nylon rod and a sample holder bushing. A loading/unloading mark is etched in the stainless steel rod slightly above where the nylon rod and the stainless steel tubing join. This mark should be visible above the sample probe seal whenever the sample is loaded into or unloaded from the cryostat. The mark informs the operator that the load lock valve can be closed without damaging the sample probe.

9.2 ACCESSORIES

A list of accessories available for the 7000 Series System are as follows:

MODEL NUMBER	DESCRIPTION OF ACCESSORY
700SP	Susceptibility Sample Probe Assembly
700RP	Resistance Sample Probe Assembly
700SC,xx	Standard Sample Cups, where xx defines quantity
700RSH	Resistance Sample Holder

A list of accessories available for the Lake Shore Model DRC-91CA Temperature Controller are as follows:

MODEL NUMBER	DESCRIPTION OF ACCESSORY
HTR-50	50 Ω Cartridge Heater, 50 W, 1/4 inch diameter x 1 inch long
HTR-25	25 Ω Cartridge Heater, 25 W, 3/8 inch diameter x 1 inch long
RM-3F	Rack Ears for DRC-91CA case
RM-3F-H	Rack Ears with handles for DRC-91CA case

9.3 CABLES

A list of cables available for the Lake Shore Model DRC-91CA Temperature Controller is as follows:

CABLE NUMBER	DESCRIPTION OF CABLE
8271-21 Sensor/Heater Cable	10 feet (3 meters) long
8271-22 Sensor/Heater Output Cable	10 feet (3 meters) long
8072 IEEE-488 Interconnect Cable	3.3 feet (1 meter) long

9.4 SPECIAL EQUIPMENT

A list of special equipment available for the Lake Shore Model DRC-91CA Temperature Controller is as follows:

MODEL NUMBER	DESCRIPTION OF SPECIAL EQUIPMENT
None	Calibration and Service PCB Assembly

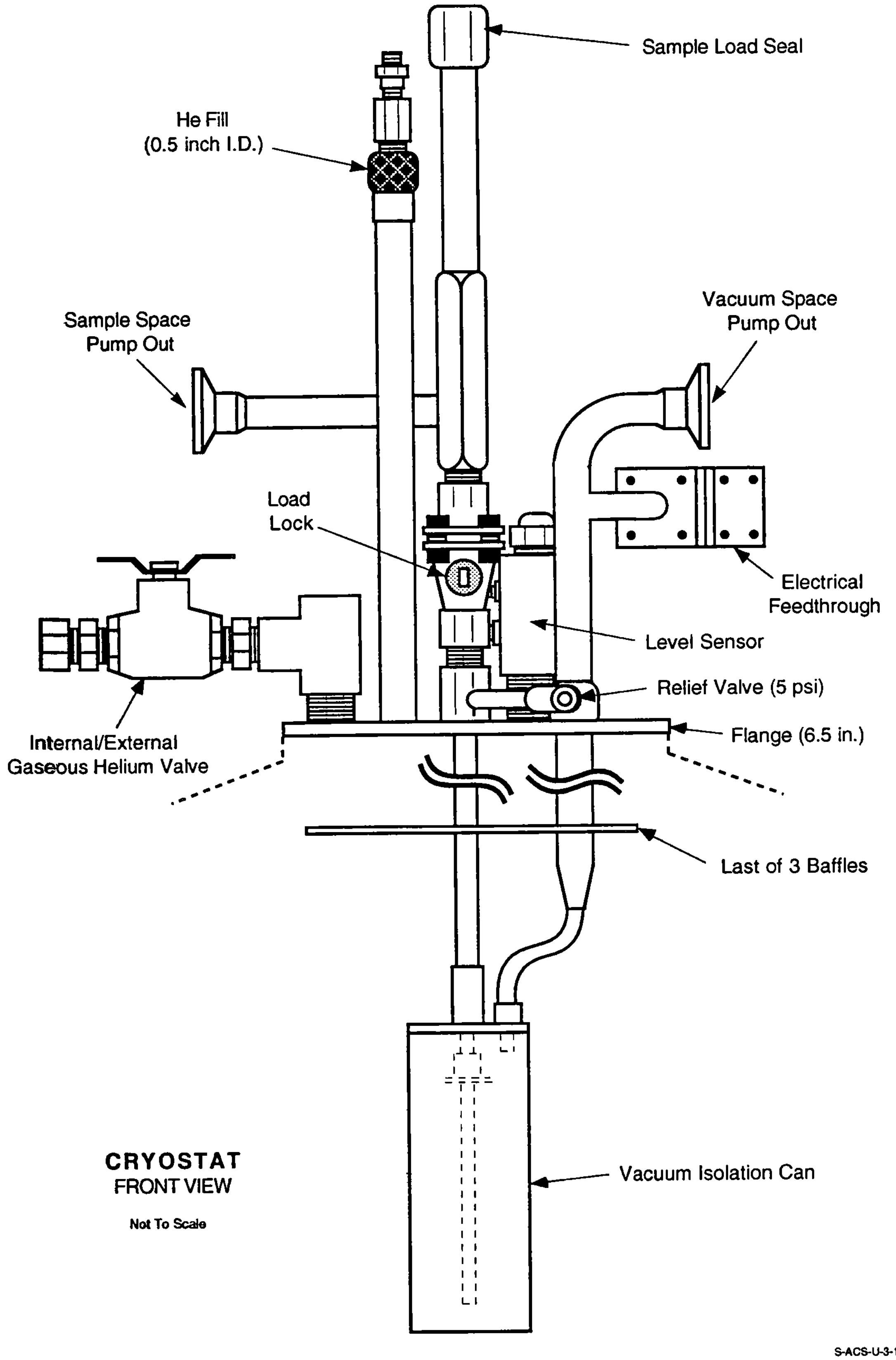


Figure 3-1. Cryostat Assembly

CHAPTER 9
OPTIONS, ACCESSORIES, AND CABLES

9.0 GENERAL

This chapter provides lists of options, accessories, cables, and special equipment available for the 7000 Series System. For convenience, options and accessories for individual Lake Shore models are also included in this chapter.

9.1 OPTIONS

A list of optional equipment available for the 7000 Series System is as follows:

MODEL NUMBER	DESCRIPTION OF OPTION
700ACM	AC Moment Measurement Option (Refer to Chapter 7)
700HL	Liquid Helium Level Indicator (Standard equipment on magnet systems)
700HM	Harmonics Measurement Option (Refer to Paragraph 9.6)
700LT	Low Temperature Cryostat Option (Refer to Paragraph 9.7)
700RES	AC/DC Resistance Measurement Option (Refer to Chapter 8)
700TLF	Flexible Liquid Helium Transfer Line

A list of options available for the Lake Shore Model DRC-91CA Temperature Controller are as follows:

MODEL NUMBER	DESCRIPTION OF OPTION
8001 Precision Option	Custom programming of specific Sensor calibrations curve(s) at factory. Provides highest degree of temperature readout accuracy
8223 RS-232C Interface	Provides remote operation of the same parameters as the IEEE-488
8225 Analog Output	Provides analog output proportional to Kelvin temperature of display sensor (10 mV/K) at <10 Ω output resistance
8229 Scanner Input Option	Adds four additional channels to the "A" input. Scans up to six sensors with programmable dwell times
W50	50 Watt (1.0 A, 50V) output for 50 Ω heater
W60	60 Watt (1.5 A, 40V) output for 25 Ω heater

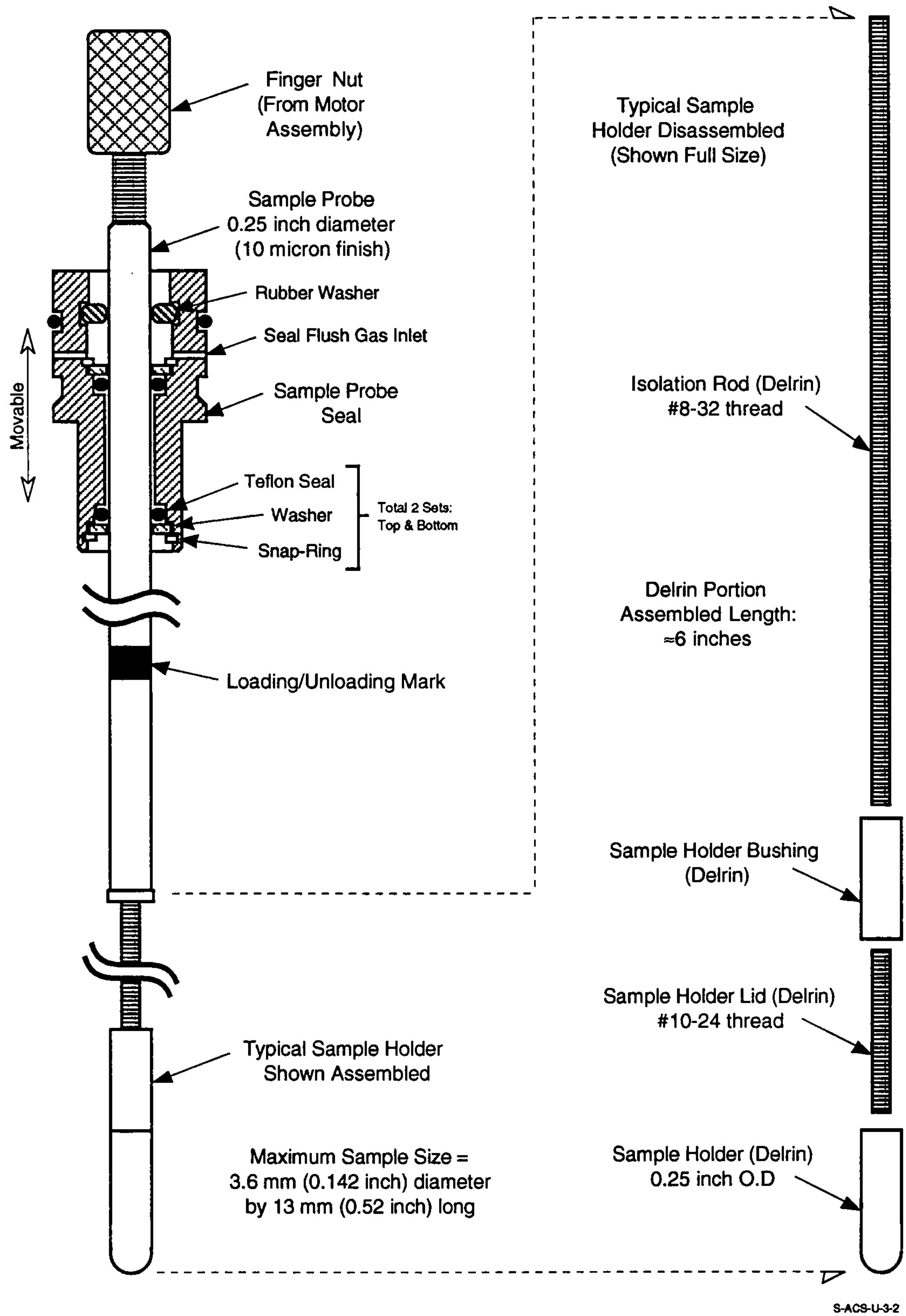


Figure 3-2. Sample Probe – Cutaway View

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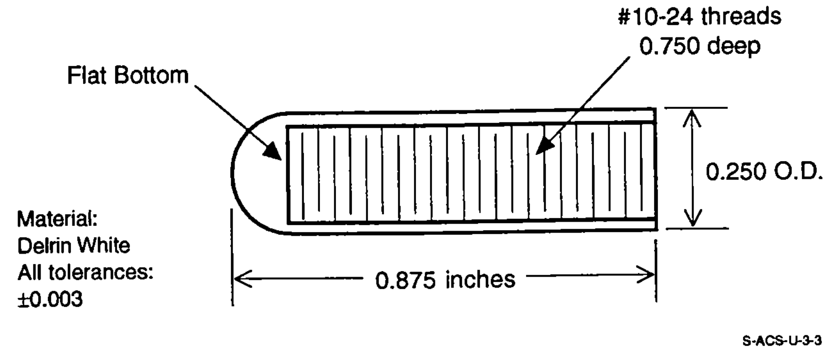

Figure 3-3. Model 700SC Sample Cup – Cutaway View

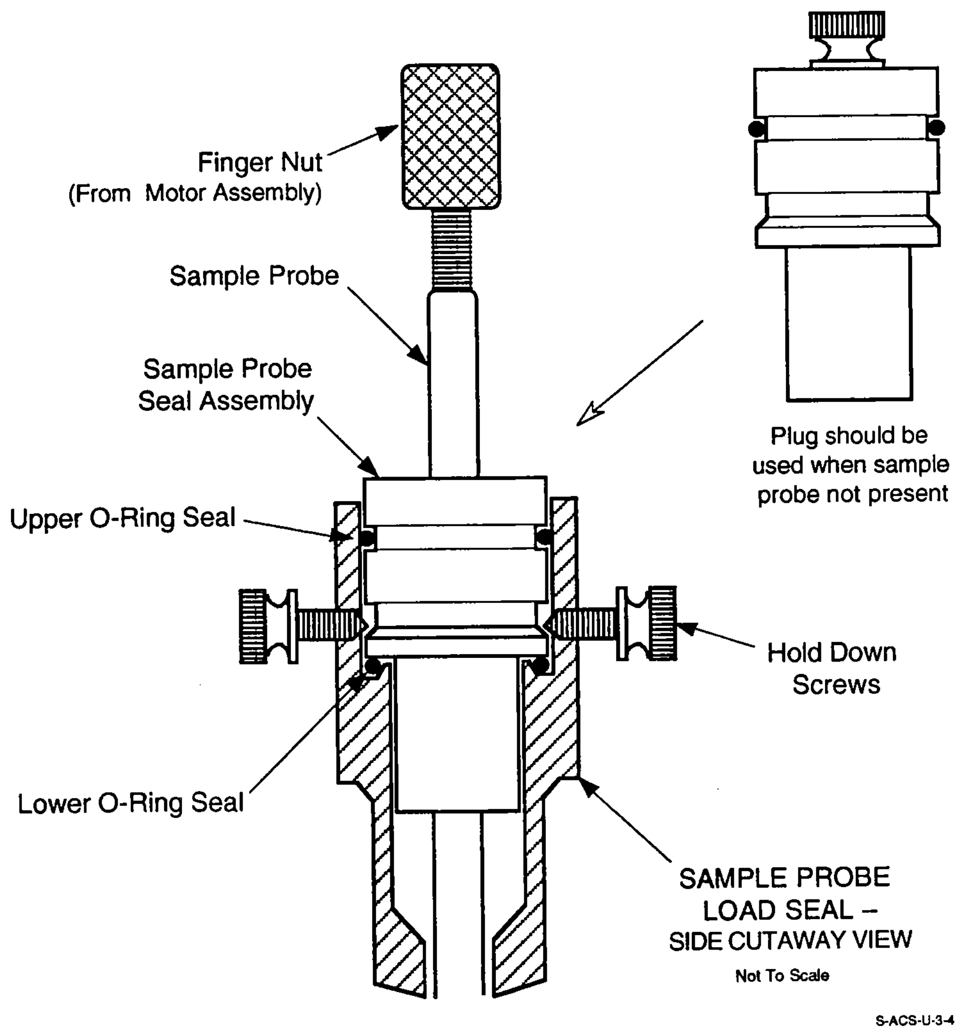

Figure 3-4. Sample Probe Load Seal – Cutaway View

Tuning:
Path: Collection / Lock-In / Tuning

This allows you to specify what parameter is displayed on the tuning display of the lock-in amplifier. When selected, the following sub-menu will be displayed.

Phase: When selected, the display indicates the phase shift introduced either by the software or the user.

Osc_freq: When selected, the display will indicate the set oscillator frequency.

Level: When selected, the display will indicate the amplitude of the oscillator frequency.

Filter_freq: When selected, the display will indicate the frequency to which the input filter (Band_pass, Low_pass, or Notch) is tuned.

Ref_freq: When selected, the display will indicate the reference frequency.

The default display condition is Ref_freq.

Up:
Path: Collection / Lock-In / Constant / Up

Increases Lock-In Amplifier time constant setting one unit.

Units:
Path: Units

This setting will cause all numerical values to be displayed in either SI or cgs units.

View:
Path: Analysis / View

This enables you to specify how processed data is viewed on the screen. When selected, the following sub-menu will be displayed.

Tabular: This is an on/off toggle. When on, the processed data will be displayed on the screen. You can scroll through the data using the Home/End keys or the PgUp/PgDn keys. Esc to exit.

Graphical: This is an on/off toggle. When on, the processed data will be displayed on the screen. Scaling is fully automated. Press Esc to exit.

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through the available options in your data set. When done, a window will display the selections which have been made. Esc to exit.

Zero_Offset:
Path: Collection / Experimental / H_field / Zero_Offset

This feature is used to adjust the current output of the MPS to account for zero drifts in the power supply output due to fluctuations in the operating environment (e.g., room temperature variations). The magnitude of these zero drifts are $<\pm 1$ gauss and utilization of this feature reduces this to the tenth gauss level. The "zeroing" is accomplished automatically upon selection.

When using this feature, the output current (at zero current) is read (i.e., I_0) and the current is then set to $-I_0$. In addition, any field that is then set using MPS_field is corrected by this I_0. This feature is particularly useful for operation at low DC fields and also to obtain the best accuracy in the resultant DC field.

Figure 3-3 shows an interior view of the Model 700SC sample cup. Figure 3-4 shows the sample probe seal installed in the sample load seal. An O-ring located on the bottom of the load seal makes a vacuum tight seal between the two assemblies. An additional O-ring is located at the top of the sample probe seal. In operation, a small flow of He gas feeds through the seal/probe region to eliminate any air leakage into the sample space. The gas input is permanently attached to the load seal and exits around the probe above the probe seal assembly. The thumb screws serve a dual purpose when tightened. They are designed to pull the probe seal downward to compress the O-ring on the bottom of the load seal and they also hold the seal snugly in place to prevent any relative movement between the seal during sample movement.

3.3 VACUUM PUMPING SYSTEM

The valve panel on the front of the Dewar Console shows a schematic representation of the various pumping lines. Valving is provided for pumping and isolating both the sample space and the vacuum isolation space. In addition, helium exchange gas can be added independently to each space to aid in thermal contact, warming, cooling, etc. One thermocouple gauge monitors the pressure of the vacuum manifold. Dewar console front and rear panel layouts are shown in Figures 3-5 and 3-6. The vacuum plumbing layout is shown in Figure 3-7.

3.3.1 Dual Vacuum Pumps

The vacuum pumping system consists of a molecular drag pump and mechanical pump combination. An external Alcatel Model 2002 Mechanical Vacuum Pump is provided with the 7000 Series System. This pump is located in close promiximity to the Dewar Console. The mechanical pump is external to the Dewar Console to reduce vibration. The second vacuum pump is the Alcatel Model 5011 Molecular Drag Pump mounted inside the Dewar Console. This combination is designed to provide the high vacuum required for thermal isolation in cryogenic systems, yet it is capable of handling the bursts of pressure which occur when pumping out exchange gas or the load lock.

The Drag Pump is controlled by the Alcatel Model CFV100 Frequency Converter Control Unit. This control unit sits on top of the Dewar Console. Details of the front panel of the control unit are provided in Figure 3-8.

At room temperature, the pumping system will require about three minutes to evacuate the cryostat and lines from atmospheric pressure. The pumping system is not designed for a continuous high volume throughput of gas or for long-term operation at elevated pressures. The pumps will not function properly if there are vacuum leaks, partially open valves, or pumping on any condensed gases.

The following are some vacuum pumping system general guidelines:

- Always turn on the mechanical pump before turning on the molecular drag pump.
- Never pump for extended periods with the mechanical pump alone. Always operate with the molecular drag pump running.
- Replace the element in the assimilation trap every 6 months. This will eliminate potential of oil backstreaming into the system.
- In case of power failure, immediately close all valves. Although the mechanical pump is equipped with an anti-suckback valve, caution is warranted.

3.3.2 Vacuum Gauge Description

The ACS System has one thermocouple gauge located on the front of the Dewar Console. The gauge monitors the vacuum in the manifold. A manual from Comptech Inc. on the Series 200 Thermocouple Gauge is included with the system documentation. Power for the gauge is provided by a cable that connects to the METER SUPPLY Hi and Lo outputs at the rear of the Model 140 Control Unit in the Instrument Console.

Tabular: Path: Analysis / View / Tabular

Path: Collection / Auto / Real-time / Tabular

Path: Collection / Experimental / Log / Tabular

The purpose of Tabular is the same in all sub-menus. When selected, the processed data will be displayed on the screen in tabular mode according to the defined measurement sequence and the selection made in Parm_select, if applicable.

Temp_Ctlr: Path: Collection / Temp_Ctlr

This routine enables you to set, change or modify a number of parameters on the DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

Setpoint: For manual selection of control setpoint on temperature controller.

Heater_Range: For selection of heater range on temperature controller.

Gain: For selection of gain setting on temperature controller.

Derivative: For selection of derivative (rate) setting on temperature controller.

Integral: For selection of integral (reset) setting on temperature controller.

Auto_T: Used to enter the desired setpoint from 4.2 to 325.0 K. System will automatically warm or cool to this setpoint (at a rate of 3 K per minute) and then maintain this temperature.

These commands are described alphabetically within this section. Esc to exit.

Temp_Spec: Path: Collection / Experimental / Temp_Spec

This routine enables you to define the temperature specifications used during automatic data acquisition. When selected, the following sub-menu will be displayed.

List: For selection of individual temperature points used in automated data acquisition.

Incremental: This is for selection of temperatures, entered incrementally, to be used in automated data acquisition.

Edit: Allows the user to delete temperatures from list defined by Enter List or Incremental and also for changing sweep rates or temperature spacings in sweep mode.

Cancel: Used to cancel a previously entered temperature specification.

Setpt_Adjust: Used to fine tune the setpoint when exact setpoint values are required.

These commands are described alphabetically within this section. Esc to exit.

Time_dwell: Path: Collection / Experimental / H_field / Field_Settle / Time_dwell

Used to input a field stabilization time period, in addition to the default time periods contained in the software. When selected, you will be prompted for an input (in seconds). Type in a value and press Enter. Whenever a field change occurs during data acquisition, the system will remain idle for the default wait period plus the Time Dwell. This will allow extra time for field stabilization prior to recording data. The default value of Time Dwell is 0 seconds.

Track: Path: Collection / Lock-In / Mode / Track

Selection of this sets the tuning filter mode of the Lock-in Amplifier to Track.

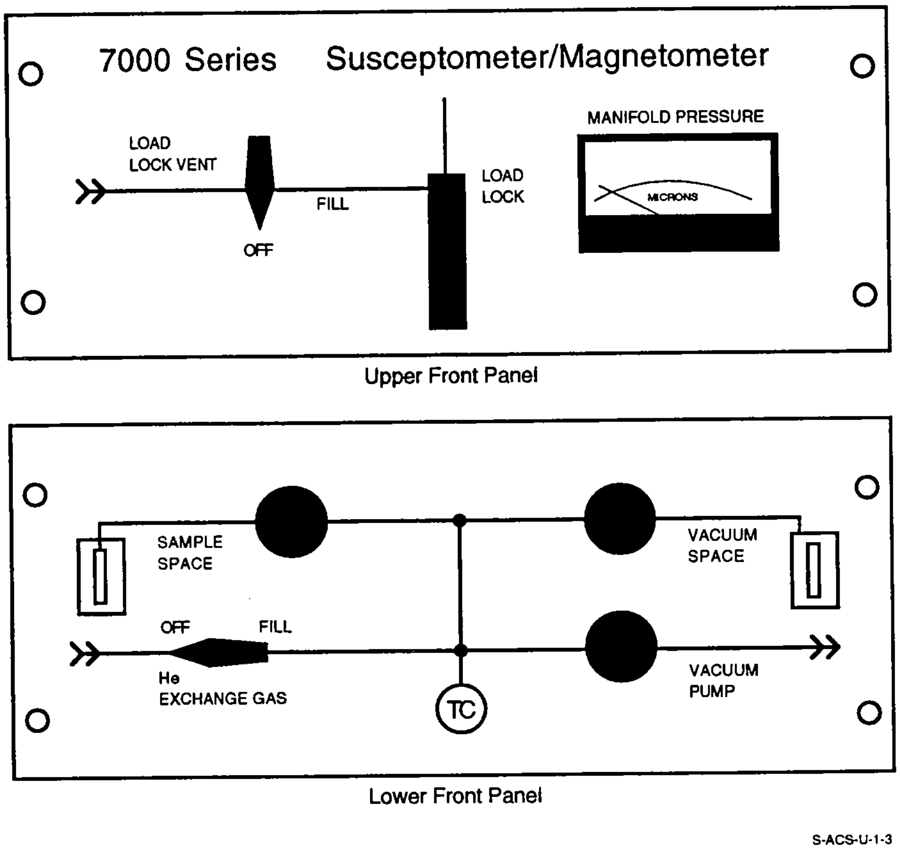

Figure 3-5. Dewar Console Upper and Lower Front Panel Controls

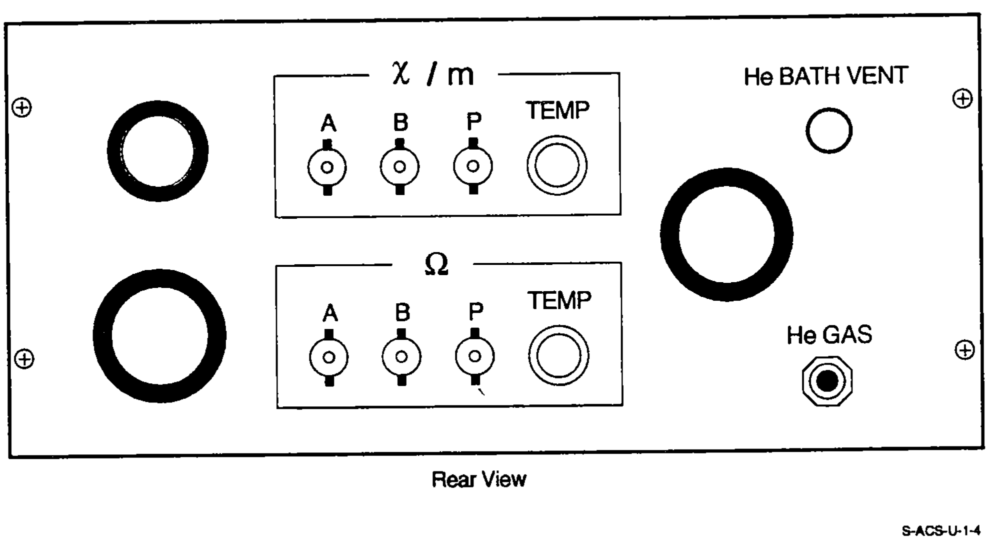

Figure 3-6. Dewar Console Rear Panel Controls

Setpt_Adjust (Continued)

This option compensates for the fact that the system contains two temperature sensors. The sample temperature sensor is positioned to optimize both the temperature control and minimize the time required for temperature stabilization. When temperatures are input from the keyboard, these values are control temperature values. The actual sample temperature will vary from the control value depending upon temperature range and system status. The Setpt_Adjust option has a feedback control routine to modify the controller setpoint to bring the sample temperature closer to the input value.

Signal:

Path: Collection / Lock-In / Display / Signal

When selected, the Lock-In Amplifier output LCD indicates the signal amplitude in voltage. This is the default setting.

Slow:

Path: Collection / Keithley_DVM / Slow

Set digital filter to slow. Esc to exit.

STAB:

Path: Collection / Lock-In / Reserve / STAB

Selection of this gives the Lock-In Amplifier a FLAT mode dynamic reserve of 20 dB.

Sweep:

Path: Collection / Experimental / Temp_Spec / Sweep

This routines allows you to set the temperature sweep parameters that are to be used during an automated data acquisition sequence. When selected, you will be prompted for a lower temperature, a higher temperature, and a temperature sweep rate (0.1 to 3 K/min) (e.g., 10 to 100 K @ 1 K/min). The following information will be displayed on the screen in a window.

Range Number	Low Temp(K)	High Temp(K)	Rate (K/min.)	Spacing (K)	Minimum Spacing	Number of Data Points

One of the parameters displayed will be temperature spacing. This is the approximate default spacing according to the defined measurement sequence (i.e. minimum spacing). The cursor will be on the sweep rate entry. If you desire to change the sweep rate, Simply press Enter and input a new value. If you desire to change the temperature spacing, move the cursor to that value and press Enter and then input a new value (with the condition that the new value be greater than or equal to the default value).

The software provides for up to three different sweep ranges. If you desire only one sweep range, press Esc to exit. If you desire a second sweep range (& third), press Enter. Now you will be prompted for an ending temperature for the second sweep range (the starting temperature of the second sweep range is the ending temperature of the first, & so on), and a sweep rate. The new information will be added to the window, and changes to the rate and spacing can be made as outlined above. To input a third range, press Enter and continue as outlined above. Press Esc at any time to exit.

T_change:

Path: Collection / Experimental / H_field / Profile / T_change

This routine is used to select a field that will be set at the completion of a measurement profile, before the temperature setpoint is changed or adjusted. When selected, you will be prompted for a value. Input a value, and press Enter. The default value for this is 0-field.

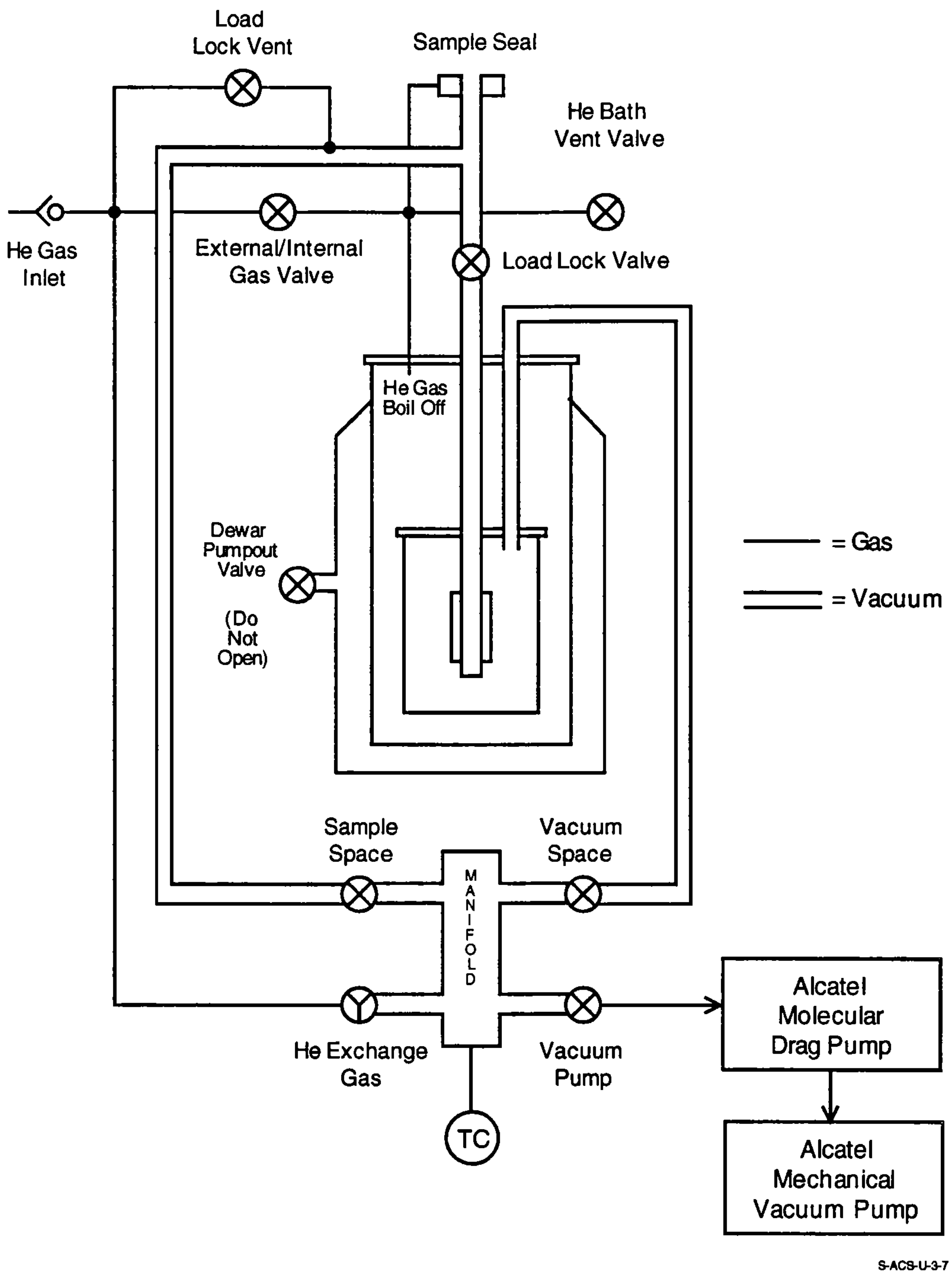

Figure 3-7. Vacuum System Block Diagram

Ref_freq: Path: Collection / Lock-In / Tuning / Ref_freq

When selected, the Lock-In Amplifier LCD display will indicate the reference frequency.

RES: Path: Collection / Lock-In / Reserve / RES

Selection of this gives a FLAT mode dynamic reserve of 60 dB.

Reserve: Path: Collection / Lock-In / Reserve

This is used to set the Dynamic Reserve of the Lock-in Amplifier. When selected the following sub-menu will appear.

STAB: High Stability – gives a FLAT mode dynamic reserve of 20 dB.

NORM: Normal – gives a FLAT mode dynamic reserve of 40 dB.

RES: High Reserve – gives a FLAT mode dynamic reserve of 60 dB.

The default setting is STAB. During automatic data acquisition, this setting is adjusted automatically if the need arises.

Reset: Path: Collection / Experimental / Current / Reset

Reset current control to Constant Current. Esc to exit.

Save: Path: Edit / Save

This enables you to save any changes that were made in Constants, MPS_rates, or Phase/Frequency to the RES.DAT file. When selected, you will be prompted with "Are you sure? Yes/No." If Yes is selected, the new information will be written to RES.DAT. If No is selected, the new information will not be written to RES.DAT.

Setpoint: Path: Collection / Temp_Ctlr / Setpoint

This routine enables you to adjust or change the temperature setpoint of the DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

1_+10: Increments the temperature setpoint +10 K from its current value.
2_–10: Decrements the temperature setpoint –10 K from its current value.
3_+1: Increments the temperature setpoint +1 K from its current value.
4_–1: Decrements the temperature setpoint –1 K from its current value.
5_+.1: Increments the temperature setpoint +0.1 K from its current value.
6_–.1: Decrements the temperature setpoint –0.1 K from its current value.
Enter_Setpoint: Sets the setpoint at a user defined value. When selected, you will be prompted for an input. Input a setpoint (selectable to within 0.1 K) and press Enter.

Setpt_Adjust: Temp Spec sub-menu of Experimental Menu.

This is an on/off toggle for use with fixed point temperature data acquisition. When this option is active, the system temperature control routines are modified such as to make the actual sample temperature closer to the setpoint values input by the user. Activating this option will increase the data acquisition time by approximately a factor of 1.5 to 2.

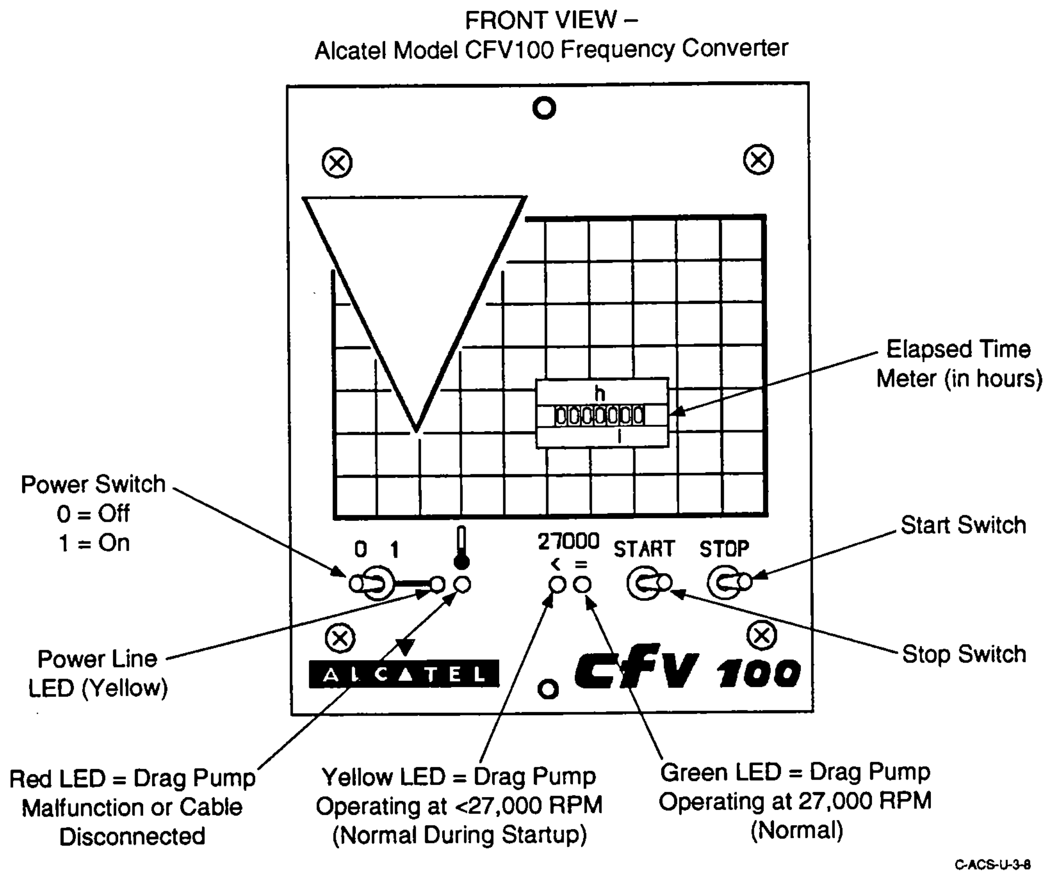

Figure 3-8. Drag Pump Control Unit Front Panel Controls

3.4 VACUUM/EXCHANGE GAS SYSTEM

The ACS System vacuum manifold system is described in Paragraph 3.4.1. The internal/external gas source requirements are discussed in Paragraph 3.4.2.

3.4.1 Vacuum Manifold System

As shown in Figure 3-7, the ACS System uses a central manifold through which the vacuum pumping and exchange gas is coupled into the various system spaces. Note, for example, when vacuum pumping on a particular space, two valves must be opened. First, the vacuum pump valve should be opened so the vacuum pump is pumping on the manifold. Once the manifold is pumped out as indicated by the thermocouple (TC) gauge labeled Manifold Pressure, the valve to the desired space may then be opened. Always be sure to first evacuate the manifold region with the vacuum pump before opening any other valve to avoid possible contamination from entering the system.

The He Exchange Gas valve is not a direct connection between the helium gas line and the manifold, but rather a three way valve connecting a small dead volume. When the valve is in the Off position, the dead volume is connected to the gas line. When in the Fill position, the dead volume is connected to the manifold. This setup permits adding small controlled amounts of helium exchange gas into the manifold region and subsequently into the vacuum isolation space or the sample space. Repeated rotations of the valve between the Off and Fill positions permits adding more or less gas as required.

Profile:

Path: Collection / Experimental / H_field / Profile

This routine enables you to define a field profile (e.g., for recording data as a function of field) at which data will be recorded during automated data acquisition. When selected, the following sub-menus will be displayed.

Discrete: Build/define a table of discrete field values.

Incremental: Build/define a table of discrete field values by selecting a low and high field, and then a field increment.

T_change: Enter a field which will be set after the completion of a field profile sequence, before the temperature is changed.

Edit: Edit a defined field profile. When selected, the window containing the field set-up will be displayed and field entries can be deleted, added, or changed.

Maintain: Define a field that will be set at the completion of an automated data acquisition run.

Cancel: Cancels a previously defined field profile.

Range:

Path: Collection / Keithley_DVM / Range

Used to select voltmeter range. When selected, a table of available voltage ranges will be displayed. Move the highlight to the desired range and press Enter. Esc to exit.

Ratio:

Path: Collection / Lock-In / Display / Ratio

When selected, the output LCD indicates the ratio of the Lock-in Amplifier output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Real-time:

Path: Collection / Auto / Real-time

This feature will display, either graphically or tabularly, the processed magnetization data vs. temperature on the screen in real-time (i.e., as the data is being recorded). When selected, the following sub-menu will be displayed.

Tabular: This is an on/off toggle. When on, the processed data will be displayed on the screen. You can scroll through the data using the Home/End keys or the PgUp/PgDn keys. Esc to exit.

Graphical: This is an on/off toggle. When on, the processed data will be displayed on the screen. Press Esc to exit. Also, you cannot "View" raw data.

Parm_select: When selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish and press Enter. Parm_select will guide you through the available options in your data set. When done, a window will display the selections which have been made. Esc to exit.

Recall:

Path: Collection / Recall

Permits loading of a previously generated configuration file. This is useful when samples are often run using the same experimental conditions or parameters. When selected, you will be prompted for a file name (no extension). After typing a file name, press Enter. Changes to the experimental configuration can then be made through the software if required.

The Load Lock Vent valve is a direct connection between the gas lines and the load lock. This is used for venting the load lock and bringing it to atmospheric pressure for inserting or removing the sample probe.

CAUTION

When the system is cold, close the load lock valve before venting.

3.4.2 Internal/External Gas Source

Helium exchange gas is required to operate the system as described in Figure 3-7. Either an external source is to be supplied (Paragraph 2.2.3) or the system can be set up to use the internal boil-off from the helium dewar as the gas source.

The use of the internal source of gas simply requires opening the Internal Gas valve located inside the Dewar Console. The He Gas port on the rear panel of the Dewar Console is then not used. Note the He Gas port consists of a built-in check valve which is automatically opened when the matching male connector is plugged into it. When the Internal Gas valve is open for internal operation, the male mating connector must *not* be plugged into the He Gas port. The system is shipped configured for internal operation.

If an external source of gas is to be used, the Internal Gas valve should be closed and the gas source connected to the He Gas port at the rear of the Dewar Console. The male connector should be used with the source.

3.5 MODEL 700SHD SUPERINSULATED HELIUM DEWAR

A 30 or 60 liter Superinsulated Helium Dewar is standard equipment on all except the Model 7130. (The Closed Cycle Refrigerator in the Model 7130 is described in Chapter 9.) Dewar specifications are listed in Tables 1-1 and 1-3. Safety issues are discussed in Paragraph 3.5.1. The magnet leads are discussed in Paragraph 3.5.2. Finally, service and maintenance considerations are presented in Paragraph 3.5.3.

3.5.1 Safety

Cryogenic containers (dewars) must be operated in accordance with manufacturer's instructions. Safety instructions are also posted on the side of each dewar. Consult your local supplier for information specific to the cryogens and dewars which they supply. Be sure the operation of the storage dewar is completely understood before proceeding. Refer to Appendix E for further information.

WARNING

- Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.
- Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

CAUTION

The superinsulated dewars are evacuated and tested at the factory. No vacuum pumpout of the dewar is required. Consult with Lake Shore before opening the Dewar Pumpout Valve.

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

Percent: Path: Collection / Lock-In / Display / Percent

When selected, the output LCD indicates lock-in output in % of full scale for all sensitivities.

Phase: Path: Collection / Lock-In / Tuning / Phase

When selected, the Lock-In Amplifier LCD display indicates the reference phase shift introduced either by the software or the user.

Phase: Path: Collection / Experimental / Phase

When this Phase is accessed, the following sub-menu will be displayed.

Auto: This will automatically set the phase for a particular sample under study. When selected, measurements at 0 and 90 degrees will be performed and the following computation performed.

$$\theta = tan^{-1} (v_{90} / v_{0})$$

The phase of the lock-in will then be set to this value.

1_+90: Will rotate the phase by +90°.
2_-90: Will rotate the phase by –90°.
3_+10: Will rotate the phase by +10°.
4_-10: Will rotate the phase by –10°.
5_+1: Will rotate the phase by +1°.
6_-1: Will rotate the phase by –1°.
7_+0.1: Will rotate the phase by +0.1°.
8_-0.1: Will rotate the phase by –0.1°.
Set: Allows you to enter the phase. Upon selecting, you will be prompted for an input. Input the value and press Enter.

Phases/Frequencies: Path: Edit / Phases/Frequencies

When selected, a table containing 32 frequencies with their associated phase angles appears in a window. The frequencies listed in this table are the default frequencies which will appear in the selection window used during experimental operation (Refer to the Frequency command.) As supplied, the system is configured with 32 preset frequencies which may be changed to meet required needs. Frequencies can be selected from 1 to 1000 Hz in 1 Hz steps and 1000 to 10,000 Hz in 10 Hz steps. Press Esc to exit.

Printer: Path: Analysis / Output / Printer

This is an on/off toggle for specifying that processed data be printed to a hard copy device.

3.5.2 Service And Maintenance

The term "service", as it is commonly used, is not applicable to the dewar. There are no parts to wear out. If due care is exercised, no difficulties should arise which would require replacement parts.

During normal operation, if the dewar is cold to the touch or moisture condenses on the outside surface, it may be necessary to evacuate the dewar vacuum space. The dewar pump out valve is located in the back of the dewar and half way down. Open the rear door of the Dewar Console, disconnect the vacuum line connected to the vacuum isolation space, and connect the line to the dewar pump put. Turn on the vacuum pump and then open the dewar valve. Allow one-half hour for pumping.

CAUTION

- The superinsulated dewars are evacuated and tested at the factory. No vacuum pumpout of the dewar is required. Consult with Lake Shore before opening the Dewar Pumpout Valve.
- The dewar should never be pumped when it is cold or contaminants may be cryopumped into the dewar from the attached vacuum pump. *The system must be completely at room temperature.*

When completed, re-connect the vacuum line to the vacuum isolation space. If you experience any trouble with your dewar, advise the factory and give a description of the difficulties.

3.6 SUPERCONDUCTING MAGNETS

A Superconducting Magnet is standard equipment on the Model 7121, 7125, 7129 AC Susceptometer, and 7221, 7225, and 7229 AC Susceptometer/DC Magnetometer Systems. Specifications for the 1, 5, and 9 Tesla Superconducting Magnets are provided in Tables 1-1 and 1-3. Operation of the ACS System with the magnet installed is virtually identical to operating without the magnet. The only significant difference (in terms of operation) is in controlling the Magnet Power Supply (MPS) through the software described in Chapters 5 thru 8. A Model 610 MPS is included with the Model 7121, 7125, 7129, 7221, 7225, and 7229 Systems.

NOTE

An error may be detected by the ACS7000 program if the MPS is turned on and the magnet is not superconducting. If this occurs, simply turn the MPS off and continue with the program. The program will indicate that the MPS is inoperative, but will permit access to all other features of the system. The program should be exited and restarted once the magnet is superconducting and the MPS has been turned on.

3.6.1 Safety

The Magnet Power Supply is a high current power supply. Great care must be exercised when operating the system. Exposed current leads, connecting the power supply to the superconducting magnet, should be avoided. The apparatus should be properly labeled with warning signs, labels, etc.

CAUTION

- Never attempt to connect or disconnect the high current leads from the magnet leads or the magnet power supply unless the magnet power supply is turned off and unplugged.
- When the magnet is energized, keep all magnetic materials (credit cards, nuts, bolts, etc.) at least 3 feet away from Dewar Console. Do not open or access the Dewar Console when magnet is energized.

All personnel must be aware of the magnetic field levels around the Dewar Console. Nominal radial field distributions for the 1 T, 5 T, and 9T magnets are provided in Figures 3-9, 3-10, and 3-11 respectively. Nominal vertical field distributions for all three magnets are provided in Figure 3-12.

Overshoot_Ctrl: Field_Settle sub-menu of H Field sub-menu of Experimental Menu.

This is an on/off toggle which can be used to activate a special MPS/field control routine used to minimize any field overshoot which may occur on changing fields. The feature functions by pre-settling the field at a value slightly different than the targeted value. After pre-settling, the final field value is set. Activating this feature will add approximately 45 seconds to the time required for field stabilization.

Changing the rates specified for field ramping using the MPS_rates option will also increase or decrease the amount of overshoot depending upon whether the rates are increase or decreased, respectively.

Output: Path: Analysis / Output

This routine allows you to specify that the processed data be either written to a file (ASCII file format) or dumped to a hard copy device. When selected, the following sub-menu is displayed. What is written to a file or hardcopy depends on selection made in Parm_select, if applicable.

Printer: On/off toggle to specify that the data be printed to a hard copy device.

File: When selected, you will be prompted for a file name (no extension). After typing the file name, press Enter.

The fields are separated or delimited by a single white space.

Override: Path: Collection / Auto / Override

During fixed temperature point data acquisition, override will bypass certain Wait periods built into the software. Specifically, once a certain setpoint is reached, a Wait period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the Wait is dependent on the particular temperature range. Upon completion of the Wait, a Drift Check is initiated where the temperature drift per minute is monitored. Once this Drift/Min. is below 0.1 K per minute, the data acquisition/measurement sequence will begin. Selecting Override once will override the designated Wait period and initiate the Drift Check. Selecting Override again will override this as well and data will be recorded immediately.

While the temperature is being adjusted from one setpoint to another, Override can be selected to record data at some intermediate temperature. When Override is selected, the temperature ramping will cease and the above mentioned Wait period will be initiated.

Parm_select: Path: Analysis / Parm_select

Path: Analysis / View / Parm_select
Path: Collection / Auto / Real-Time / Parm_select
Path: Collection / Experimental / Log / Parm_select

Depending upon the experimental set-up, a single acquisition run can yield a complex matrix of resistance data recorded at different AC or DC currents, DC magnetic fields, and temperatures. The processed data is organized for output and is used in both real time feedback operation and in analysis.

When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through the available options in your data set. When done, a window will display the selections which have been made. Press Esc to acknowledge.

3.6.2 Cryogenics

The magnet is wound with NbTi superconducting wire. Therefore, the solenoid must be maintained at a temperature less than 9.2 K in order to operate. Refer to Paragraph 3.4.5 for instructions regarding helium filling of the superinsulated helium dewar. Minimum safe LHe levels are specified in Table 3-1.

Table 3-1. Magnet Operation and Minimum Safe Liquid Helium Level

Model	Magnet	Minimum Required Liquid Helium Level	Maximum Operating Field
7121, 7221	1 T	10 cm	1 T (10 kG)
7125, 7225	5 T	15 cm	5 T (50 kG)
7129, 7229	9 T	25 cm	9 T (90 kG)
	9 T	15 cm	5 T (50 kG)

3.6.3 MPS Ramp Rates

Ramp rates for the MPS have been established in the operating software. The default settings are specified in Table 3-2 and should *not be changed*.

Table 3-2. MPS Ramp Rates

Magnet	Ramp Rate	Magnet Current
1 Tesla	2.0 Ampere/second	I < 50
5 Tesla	0.40 Ampere/second	I < 25
	0.25 Ampere/second	25 < I < 35
	0.15 Ampere/second	35 < I < 44
	0.10 Ampere/second	44 < I < 50
9 Tesla	0.030 Ampere/second	I < 20
	0.025 Ampere/second	I < 45

3.6.4 Quench Protection (Magnet Normal)

The current output of the MPS will be set to zero by the control software if the superconducting magnet were to "quench" (i.e., to go normal, because of insufficient helium). The software monitors the compliance voltage of the power supply. If the compliance voltage is detected, a zero amps command code is sent to the supply and a message indicating that a "Magnet Fault" has been detected is displayed on the screen. If the MPS output current changes rapidly (indicative of a magnet quench), and the magnitude of the current exceeds the output current step limit of the MPS, the output settings will automatically be reset to 0 A and 1 V. If a data acquisition run were in process, the data file will be closed and the run terminated. This error message will also be displayed if the magnet is normal and a field is set using the **MPS_field** option.

MPS_rates: Path: Edit / MPS_rates

Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Name: Path: Collection / Experimental

This allows you to specify a data file to which the data logged will be written. When selected, you will be prompted for a file name with no extensions. After typing a file name, press Enter. If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG. If the file name selected already exists, you will be prompted for a new file name. If a new file name is not specified, the new data will overwrite the data currently contained in the file.

Noise: Path: Collection / Lock-In / Display / Noise

When selected, the output LCD indicates the rectified output noise in percent of full scale.

NORM: Path: Collection / Lock-In / Reserve / NORM

Selection of this gives a FLAT mode dynamic reserve of 40 dB.

Notch: Path: Collection / Lock-In / Filter / Notch

This provides a stop band with very deep attenuation at f_0 (the reference frequency).

Off: Path: Collection / Keithley_DVM / Off

This selection turns the Keithley DVM digital filter off (the default filter setting). Esc to exit.

OFF: Path: Collection / Temp_Ctlr / Heater Range / OFF

Selection will turn the heater power off.

Offset: Path: Collection / Lock-In / Display / Offset

When selected, the output LCD on the Lock-in Amplifier indicates the offset value in effect.

Osc_freq: Path: Collection / Lock-In / Tuning / Osc_freq

When selected, the display will indicate the set the Lock-In Amplifier oscillator frequency.

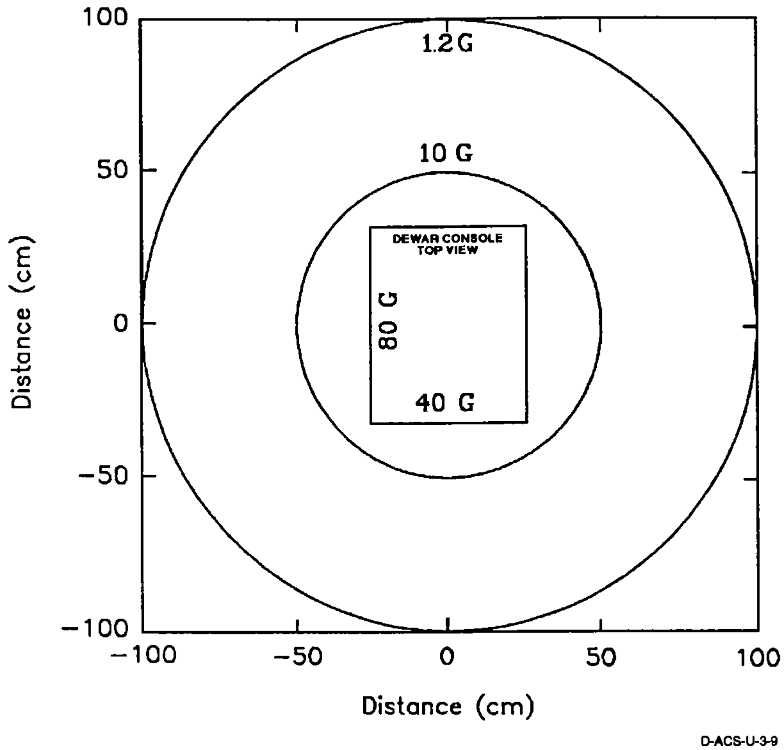

Figure 3-9. 1 Tesla Magnet Nominal Radial Field Distribution

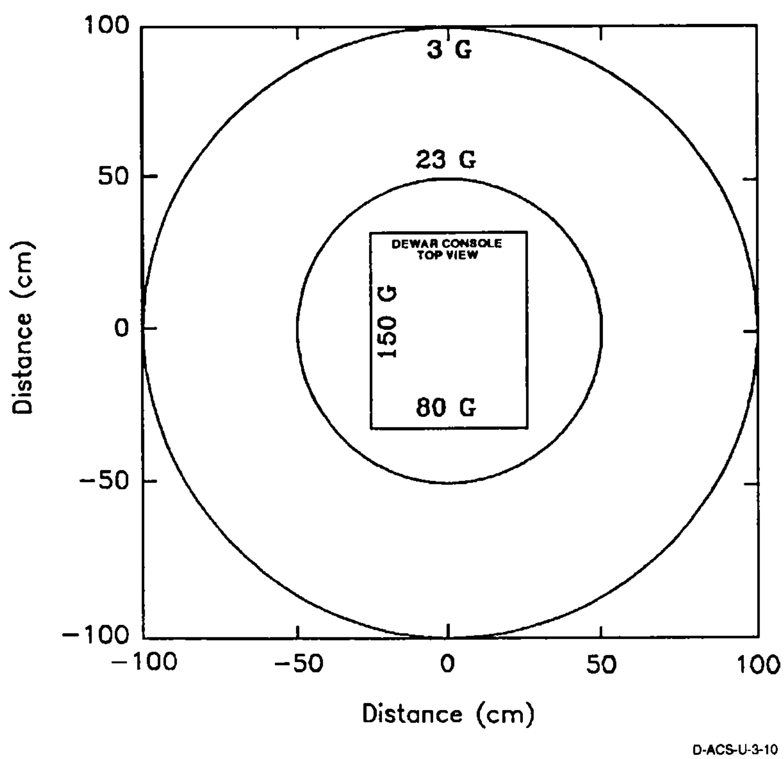

Figure 3-10. 5 Tesla Magnet Nominal Radial Field Distribution

Log_ratio: Path: Collection / Lock-In / Display / Log_ratio

When selected, the output LCD indicates the logarithm of the output described in Ratio.

Low-pass: Path: Collection / Lock-In / Filter / Low-pass

The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on Low-pass.

Maintain: Path: Collection / Experimental / H_field / Profile / Maintain

This is an on/off toggle that will leave the DC field set to whatever value it was set to at the termination of data acquisition. Esc to exit.

Manual: Path: Collection / Lock-In / Mode / Manual

Selection of this sets the tuning filter mode of the Lock-in Amplifier to Manual.

MAX: Path: Collection / Temp_Ctlr / Heater_Range / MAX

Selection will set the heater range to maximum power.

Medium: Path: Collection / Keithley_DVM / Medium

Set digital filter to medium. Esc to exit.

Mode: Path: Collection / Experimental / Mode

Change operating mode. When selected, the following sub-menu will be displayed.

AC_Resistance: Select AC Resistance mode. Esc to exit.

DC_Resistance: Select DC Resistance mode. Esc to exit.

Mode: Path: Collection / Lock-In / Mode

Selects either of two filter frequency tuning modes: Track or Manual. This is an on/off toggle. The default setting is Manual. In this case, the filter tunes to the reference channel operating frequency. If Manual is selected, the frequency is tuned to the frequency set by the PARAMETER keys on the front panel of the lock-in amplifier.

MPS_field: Path: Collection, Experimental / H_field / MPS_field

This sets the DC magnetic field of the 1 or 5 tesla magnet. When selected, you will be prompted to input a field value in kA/m. (Typical units for the 1 tesla magnet are 0 to 800,000 Am^{-1} in SI units or 0 to 10,000 Oe in cgs units.) After entering a value, press return. The MPS current will then be automatically adjusted to and stabilized at the selected field.

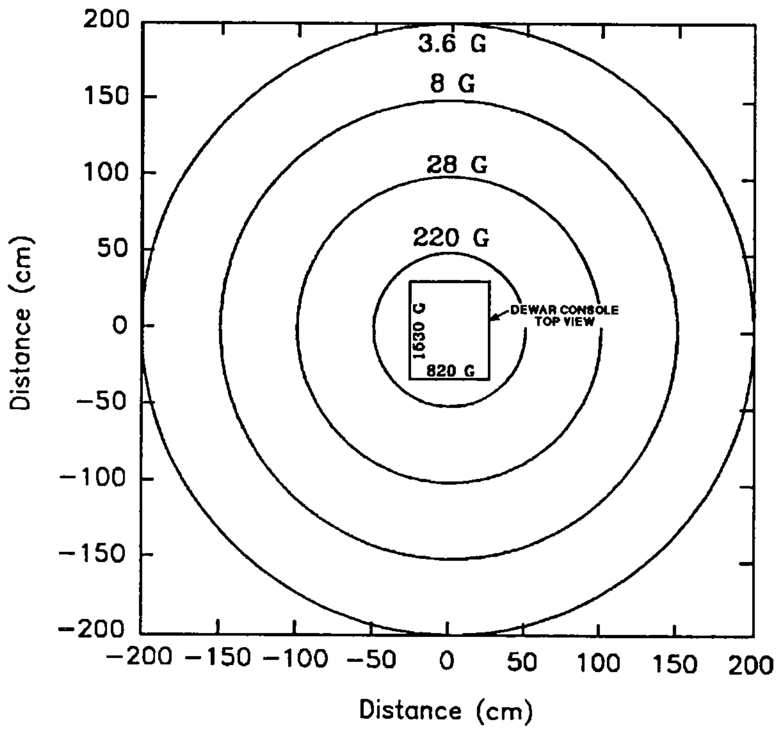

Figure 3-11. 9 Tesla Magnet Nominal Radial Field Distribution

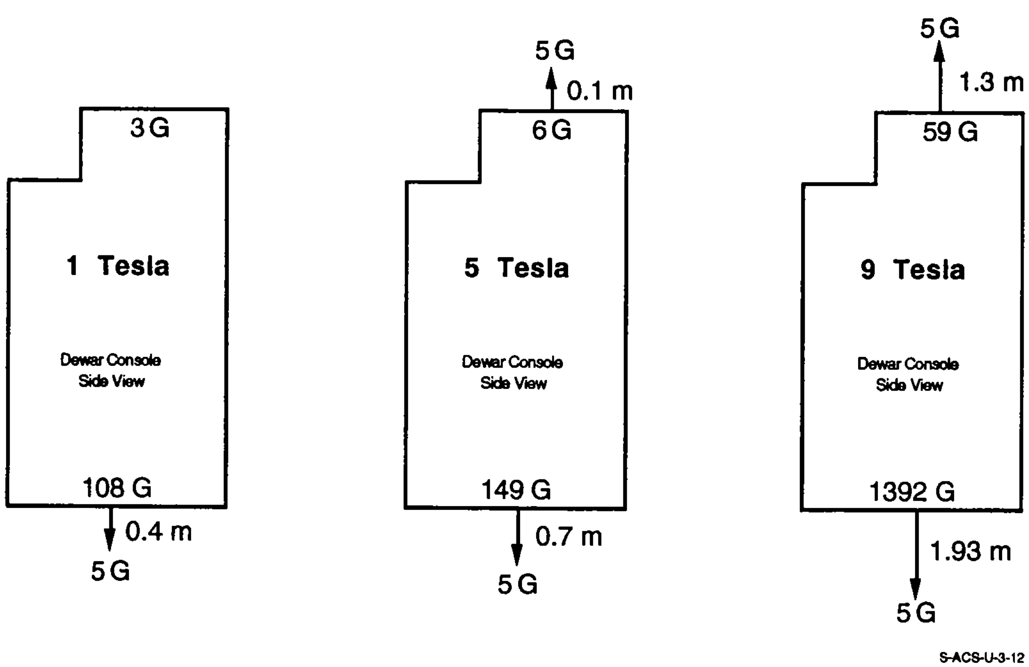

Figure 3-12. Nominal Vertical Field Distributions

Lock-In: Path: Collection / Lock-In

This enables you to change/modify certain parameters/features of the lock-in amplifier. When selected, the following sub-menu will be displayed.

Mode For selection of Track or Manual filter frequency Lock-in Amplifier tuning modes.

Filter Permits access to the Flat, Notch, Low-pass, and Band-pass menu selection. Allows selection of the signal channel filter on the lock-in amplifier.

Tuning Permits access to the Phase, Osc_freq, Level, Filter_freq, and Ref_freq menu selections. Used to select the display parameter on the tuning LCD of the lock-in amplifier.

Constant Permits access to the Up and Down menu selections. Used for adjustment of the time constant setting on the lock-in amplifier.

Display Permits access to the Percent, Signal, Offset, Noise, ration, and Log_ratio menu selections. Used for selection of the display parameter on the output LCD of the lock-in amplifier.

Reserve Permits access to the STAB, NORM, and RES menu selections. Used for adjustment of the dynamic reserve setting of the lock-in amplifier.

These commands are described alphabetically within this section. Esc to exit.

Log:

Path: Collection / Experimental / Log

Selection of this will record a single measurement sequence as defined and also, if specified, will execute an incremental current array or field profile. These measurements are done at the current temperature. When automatic temperature control and variable temperatures are required as specified in the Temp_spec option, the Auto menu should be used. Data can be stored to a file. If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG.

Begin: This initiates the data acquisition process, and will display the results as they are recorded in the lower left-hand feedback block. Esc to exit.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. Scaling is performed automatically. Esc to exit.

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through the available options in your data set. When done, a window will display the selections which have been made. Esc to exit.

Cancel: Terminate the data acquisition.

This data can be written to a field specified using Name. If no field name is specified it will be written to TEMPFILE.DAT and TEMPFILE.CFG. To abort the Log sequence, select Cancel.

CAUTION

If Log is used successively, and no file specification is made, the contents of TEMPFILE.DAT will be overwritten.

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Incremental: Path: Collection / Experimental / Temp_Spec / Incremental

Defines discrete temperature points for fixed point data acquisition by entering the points incrementally. You will be prompted first for a low temperature value, then a high, and finally an increment, e.g., 10 to 100 K in 5 K increments. The table of selected values will be displayed on the screen as a window. To input another range, press Enter. Esc to exit.

NOTE

List and Incremental can be used together to build a table of discrete temperature points for fixed point data acquisition.

Integration_time: Path: Collection / Keithley_DVM / Integration_time

Toggle integration time – 1 PLC/100 ms. Esc to exit.

Integral: Path: Collection / Temp_Ctlr / Integral

Allows you to change the Reset setting of the DRC-91CA Temperature Controller. When accessed, you will be prompted for an input (0–99). After typing a value, press Enter. The default value is 0 and during automated data acquisition the reset will be set/reset to 0.

Keithley_DVM: Path: Collection / Keithley_DVM

Manual adjustment of Keithley DVM. When selected, the following sub-menu will be displayed.

Autorange:	Autorange toggle – on/off. Esc to exit.
Range:	Select voltmeter range. Esc to exit.
Integration_time:	Toggle integration time – 1 PLC/100 ms. Esc to exit.
Off:	Turn digital filter off. Esc to exit.
Fast:	Set digital filter to fast. Esc to exit.
Medium:	Set digital filter to medium. Esc to exit.
Slow:	Set digital filter to slow. Esc to exit.

Level:

Path: Collection / Lock-In / Tuning / Level

When selected, the display will indicate the amplitude of the oscillator frequency.

List:

Path: Collection / Experimental / Temp_Spec / List

This command enters temperatures individually in order to build a list of temperatures at which data will be recorded during automated data acquisition. You will be prompted for a temperature input. Input a value between 0.1 and 325.0 K and press Enter. A window will be displayed on the screen with this single temperature value. Continue to input as many temperatures as desired (pressing Enter after each entry). Each additional entry will be added to the window. Regardless of the entry order, values are automatically arranged in ascending order. Esc when completed to exit.

NOTE

Enter List and Incremental can be used together to build a table of discrete temperature points for fixed point data acquisition.

CHAPTER 4
SYSTEM OPERATION

4.0 GENERAL

Where Chapter 3 provided a description of system hardware, Chapter 4 will provide procedures to accomplish the various tasks associated with ACS System operation. Vacuum pump startup procedure is provided in Paragraph 4.1. Initial pump out is provided in Paragraph 4.2. Cryogenic safety considerations are provided in Paragraph 4.3. Warm and cold helium filling procedures are provided in Paragraph 4.4. Sample mounting is discussed in Paragraph 4.5. Sample probe loading and unloading procedures are provided in Paragraph 4.6. Sample and vacuum isolation space operating parameters are discussed in Paragraph 4.7. Helpful hints and tips in conducting AC Susceptometer measurements is provided in Paragraph 4.8. Finally, Helpful hints and tips in conducting DC moment measurements is provided in Paragraph 4.9.

4.1 VACUUM PUMP STARTUP PROCEDURE

In order for the check valve in the vacuum line to operate and open properly, the vacuum pump requires a small throughput of gas when starting from a power-off condition. This throughput can be guaranteed at start-up by venting the vacuum pump lines each time the system is to be powered down. The following procedure is recommended:

1. Close Vacuum Space valve.
2. Remove sample probe as discussed in Paragraph 4.6 with one modification: before closing Load Lock valve, open Sample Space and Vacuum Pump valve to pump out any residual exchange gas contained in sample space. Then close Sample Space and Load Lock valves. Vent load lock and remove sample probe. Leave sample load seal open.
3. Turn off vacuum pumps. Allow molecular drag pump to wind down for several minutes.
4. Open Sample Space valve. Vacuum lines are now vented to atmosphere.
5. Close sample load seal with plug which is provided.

This procedure leaves a vacuum in both the sample and vacuum spaces but vents the vacuum lines and load lock to atmosphere. The vacuum pumping system should be ready to turn on the next time the system is to be used.

4.2 INITIAL PUMP OUT

Before transferring liquid helium, the system must be completely evacuated at room temperature. To accomplish the initial pump out, use the following procedure.

1. All valves should be closed or in off position and solid plug should be placed in sample probe load seal as shown in Figure 4-1.
2. Turn on vacuum pump.
3. Open vacuum pump valve to start pumping on manifold volume.
4. Open Vacuum Space valve to start pumping on manifold vacuum isolation space.
5. Open Sample Space valve to start pumping on load lock and then open Load Lock valve to start pumping on sample space.
6. Rotate He Exchange Gas valve to fill position.
7. Pump for about 15 minutes. Pressure on Manifold Pressure gauge should drop to near zero.

H_Settle: H Field sub-menu of Experimental Menu.

This routine provides for two options to fine tune the settling of the magnetic field set in the superconducting magnet.

Overshoot_Ctrl: An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.

Time_Dwell: Permits specifying extra time for the field to settle after each field change.

These commands are described alphabetically within this section.

Heater_Range: Path: Collection / Temp_Ctlr / Heater_Range

This allows you to set or change the heater range setting on the DRC-91CA Temperature Controller. When selected, the following sub-menu is displayed.

MAX: Selection will set the heater range to maximum power.
1_ -1: Selection will set the heater range to –1.
2_ -2: Selection will set the heater range to –2.
3_ -3: Selection will set the heater range to –3.
OFF: Selection will turn the power off.

The heater range is automatically set when in automatic data acquisition mode.

Incremental: Path: Collection / Experimental / Current / Incremental

This is used to define a list of discrete currents (either AC or DC depending on the selection made in Mode) at which data will be recorded. When selected, you will be prompted for first a low, then high current, and finally an increment. All entries are in milliamperes. Esc to exit.

Incremental: Path: Collection / Experimental / H_field / Incremental

Permits definition of discrete field points for fixed field data acquisition by entering them incrementally. When selected, you will be prompted for a first field value, then a second range value, and finally an increment value. The table of selected values will be displayed on the screen as a window. To input another range, press Enter. To exit, press Esc.

NOTE

Discrete and Incremental can be used together to build a table of discrete field points for fixed field point acquisition.

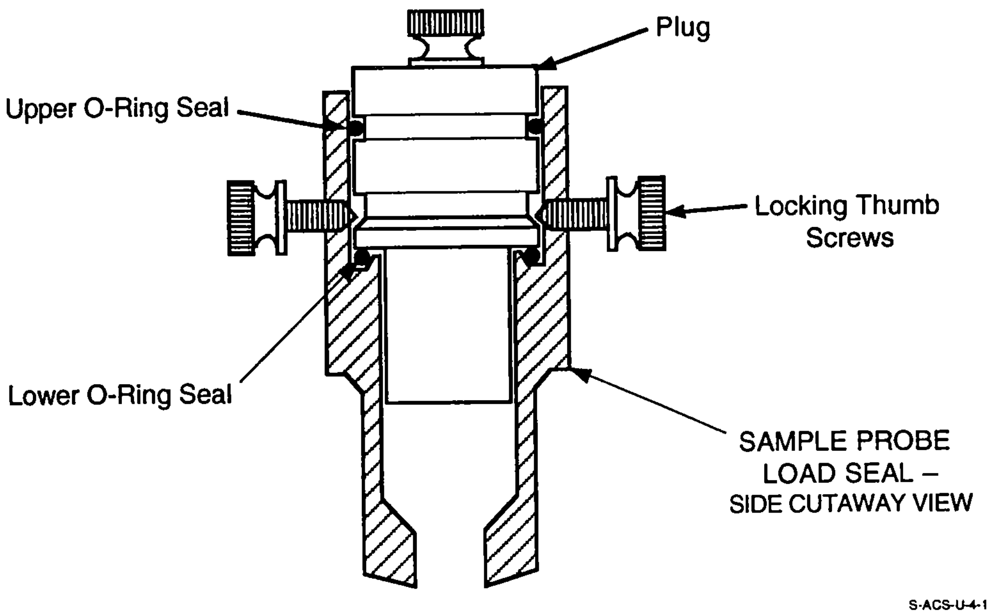

Figure 4-1. Load Seal With Plug Installed – Cutaway

4.3 CRYOGENIC SAFETY

Cryogenic containers (dewars) must be operated in accordance with manufacturer's instructions. Safety instructions are also posted on the side of each dewar. Consult your local supplier for information specific to the cryogens and dewars which they supply. Be sure the operation of the storage dewar is completely understood before proceeding. Refer to Appendix E for further information.

WARNING

- Liquid helium and liquid nitrogen are potential asphyxiants and can cause rapid suffocation without warning. Store and use in area with adequate ventilation. DO NOT vent container in confined spaces. DO NOT enter confined spaces where gas may be present unless area has been well ventilated. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical help.
- Liquid helium and liquid nitrogen can cause severe frostbite to the eyes or skin. DO NOT touch frosted pipes or valves. In case of frostbite, consult a physician at once. If a physician is not readily available, warm the affected areas with water that is near body temperature.

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

4.4 HELIUM FILLING

The economical transfer of liquid helium is particularly dependent upon techniques used. The transfer operation should be initiated slowly since the helium section of the dewar must be cooled to 4.2 K before any liquid will collect. Too rapid a transfer will result in excessive "blow-off" or waste of liquid. It should be remembered that liquid helium has the smallest latent heat of vaporization of the cryogenic liquids. For this reason, the cold vapor should be used to accomplish the necessary further cooling rather than by just vaporizing liquid. The following checklist should be observed to ensure an efficient transfer.

Three filling procedures are provided to cover the three filling scenarios. Warm transfer using the internal He gas source is detailed in Paragraph 4.4.1. Warm transfer using an external He gas source is detailed in Paragraph 4.4.2. Cold transfer is detailed in Paragraph 4.4.3.

Gain:

Path: Collection / Temp_Ctlr / Gain

Used to change the gain setting of the DRC-91CA Temperature Controller. When selected, you will be prompted for an input (0–99). After typing a value, press Enter. The default value is 99 and during automated data acquisition the gain will be set/reset to this value.

Graphical:

Path: Analysis / View / Graphical

This is an on/off toggle. When selected, the processed data chosen using File in analysis will be graphically displayed on the screen according to the selection made using Parm_select. All scaling is handled automatically. Depending on the experimental conditions that were used during automated data acquisition and the selection made in Parm_select, the graphical display will show: Resistance vs. Temperature, Current vs. Voltage, or Resistance vs. Field.

Graphical:

Path: Collection / Auto / Real-Time / Graphical

This is an on/off toggle. When selected, the (processed) data will be graphically displayed on the screen according to the selection made in Parm_select. All scaling is handled automatically. Depending on the experimental conditions used during data acquisition, and the selection made in Parm_select, the graphical display will show: Resistance vs. Temperature, Current vs. Voltage, or Resistance vs. Field. Esc to exit.

Graphical:

Path: Collection / Experimental / Log / Graphical

This is an on/off toggle. When selected, the (processed) data will be graphically displayed on the screen according to the defined measurement sequence and profile. All scaling is handled automatically. Possibilities include: Resistance vs. Field or Current vs. Voltage.

H_field:

Path: Collection / Experimental / H_field

This is used to set the amplitude of the DC magnetic field. When selected, the following sub-menu will be displayed.

MPS_field: Used to change the operating MPS magnetic field.

Profile: Used to set the field profile.

Demag_sample: Used to eliminate any remnant fields which may reside in the system after the application of a high DC magnetic field.

Zero_offset: Used to change the MPS field to 0 and recalculate the zero offset.

Time_dwell: Used to set the dwell time for field changes.

H_Settle: Provides for two options to fine tune settling of magnetic field.

- **Overshoot_Ctrl:** An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.
- **Time_Dwell:** Enables input of an additional wait period for field stabilization.

These commands are described alphabetically within this section. Esc to exit.

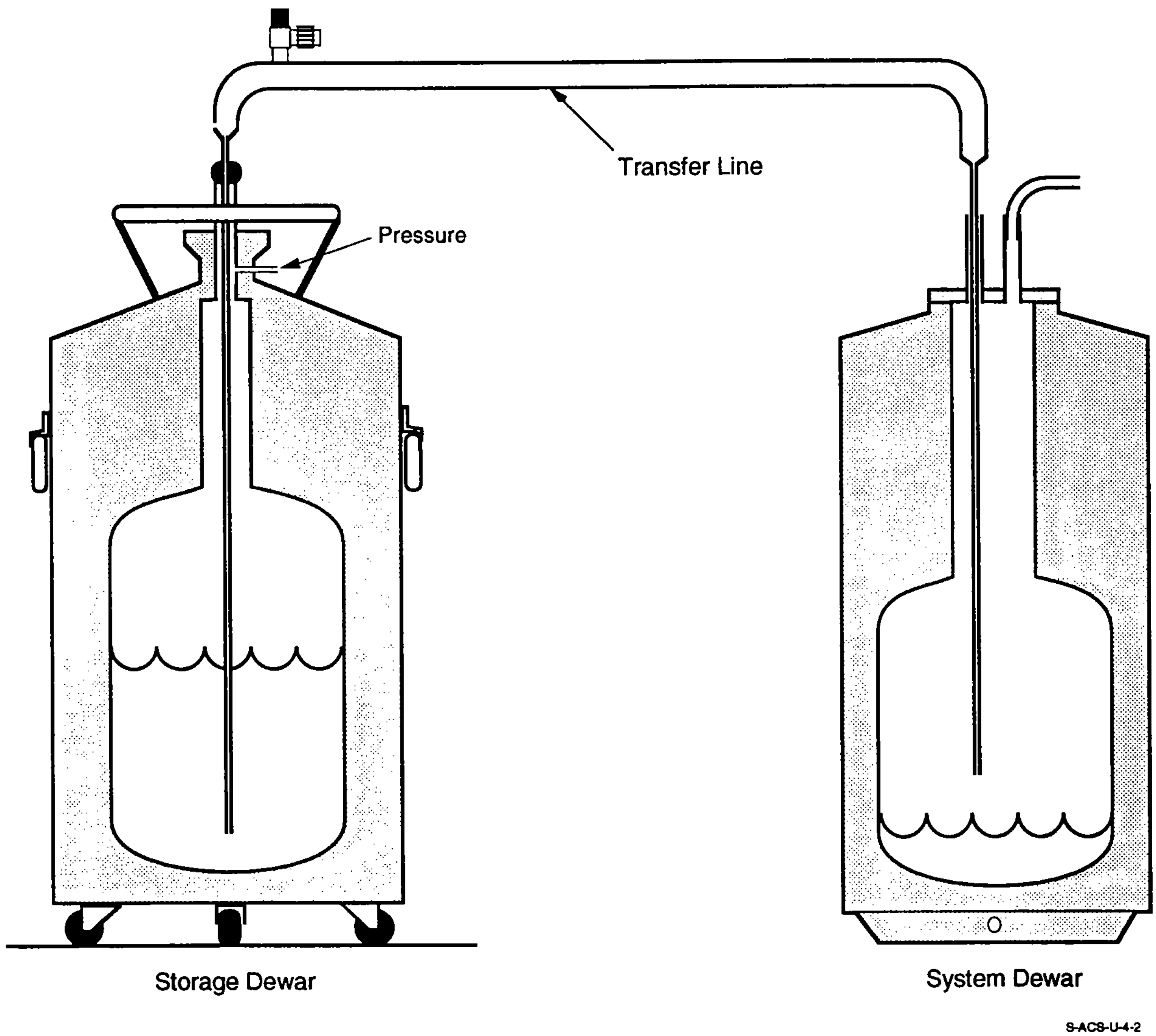

Figure 4-2. Typical Liquid Helium Filling

4.4.1 Warm Transfer – Using Internal Helium Gas Source

If the system is at room temperature or has *no* liquid helium in the dewar and internal gas has been selected, the following checklist should be observed to perform a warm transfer. This procedure assumes the valve status according to completion of the initial pump-out procedure detailed in Paragraph 4.2. Please read all the steps before performing the procedure.

1. Turn the He Bath Vent valve, located on the rear panel of the dewar console, to the On position. This releases any helium pressure in the dewar and serves as the helium vent during transfer.

2. Insert one end of transfer line into liquid helium storage dewar. See Figure 4-2. The transfer line must be long enough to reach dewar bottom and should be positioned with end of transfer line slightly above dewar bottom.

CAUTION

To prevent a rapid build up of pressure, open the He Bath Vent valve at the rear of the Dewar Console and insert the transfer line slowly into the dewar. Venting excessive gas is usually necessary during the initial insertion of the transfer line.

Filter:

Path: Collection / Lock-In / Filter

This enables you to set the signal channel filters on the lock-in amplifier. When accessed the following sub-menu will be displayed.

Flat: No filtering occurs with this selection.

Notch: This provides a stop band with very deep attenuation at f_0 (the reference frequency).

Low-pass: The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on Low-pass.

Band-pass: The band-pass filter attenuates above and below f_0 but with less harmonic rejection than would be provided by Low-pass.

Filter_freq:

Path: Collection / Lock-In / Tuning / Filter_freq

Will display the frequency to which the input filter is tuned. Filter options include Band-pass, Low-pass, or Notch.

Fixed_Range:

Path: Collection / Experimental / Current / Fixed_Range

This defines the voltage range to be used in constant voltage mode. When selected, a window will either show the Lock-in voltage ranges (if AC mode were selected in Mode), or the Keithley voltage ranges (if DC were selected in Mode). Move the highlight to the desired voltage range and press Enter. Esc to exit.

Flat:

Path: Collection / Lock-In / Filter / Flat

This enables you to set the signal channel filters to Flat on the lock-in amplifier. No filtering occurs with this selection.

Frequency:

Path: Collection / Experimental / Frequency

This allows the selection of the frequency for the applied AC field. A window appears containing the 32 frequency entries which are the default values specified in RES.DAT. (Refer to the Edit and Phases/Frequencies commands.) To select or change a frequency, move the cursor to that frequency and press Esc. Note that the actual frequency is changed in real-time as the cursor moves through the values in the window.

A red highlight indicates the selected frequency is not compatible with the ac field amplitude and that frequency will not be set. Allowed frequency/field combinations are as follows:

$f < 10$ kHz for $H < 110$ A/m
$f < 2500$ Hz for $H < 1110$ A/m
$f < 1000$ Hz for $H < 2000$ A/m

The field limits are nominal and will vary slightly from system to system.

Frequencies not explicitly contained in the window can be manually selected by pressing Enter. A prompt will appear to input the desired frequency and this value will be displayed at the bottom of the frequency window. The allowed frequencies are integral values from 1 to 1000 Hz and 1000 Hz to 10,000 Hz in 10 Hz steps.

3. Insert other end of transfer line into the fill port on top of dewar console. Transfer line should extend to within a few inches (cm) of dewar bottom. Total length is 54 inches (137 cm).
4. Transfer slowly. Often simply sealing/closing storage dewar and allowing transfer to proceed under ambient pressure is sufficient for initial phase.
5. After the transfer has been started, allow ≈15 minutes for the dewar to be totally flushed with helium gas.
6. Close the Load Lock valve.
7. Close the Vacuum Space valve.
8. Momentarily turn the Load Lock Vent valve to Fill and then immediately return to the Off position. This action opens the gas lines to the vacuum pump, purges the lines of any air contamination, and draws helium gas into the lines from the dewar. An increase in pressure should be noted on the Manifold Pressure thermocouple gauge and a change in sound of the vacuum pump should be detected as it pumps the high gas throughput.
9. Allow the system to pump for a few minutes and then open the Load Lock valve and the Vacuum Space valve.
10. Rotate the He Exchange Gas valve to the Off position. This automatically charges a fixed volume used for adding exchange gas to the sample space and vacuum isolation space.
11. Close the Vacuum Pump valve.
12. Rotate the He Exchange Gas valve to the Fill position to admit helium gas into the sample space and vacuum space. The valve may be rotated back and forth several times to admit more or less gas. Several hundred microns is sufficient as indicated on the Manifold Pressure gauge. Leave the valve in the off position.
13. Close the Load Lock valve and the Sample Space valve.
14. The Manifold Pressure gauge is now reading the exchange gas pressure in only the vacuum isolation space.
15. About 2 to 3 hours should be allowed to bring temperature of system from room temperature to under 40 K. (Allow 4 to 6 hours for 9 Tesla systems.) Since the Model 241 Level Monitor uses a superconductive probe, level readings will not begin until temperature in the dewar is <10 K. When system is nearing 4.2 K (or as needed), apply pressure to storage dewar to force liquid helium over. Typically 1 to 5 psi (7 to 35 kPa) pressure is required to transfer helium. Monitor helium level indicator and fill to desired level. The standard helium capacity is about 60 liters at a depth of 24 inches (61 cm). Another 15 to 30 minutes will be required for this stage.

NOTE

The specifics of helium transfer are dependent on the combined properties of the storage dewar, transfer line, and receiving dewar. Each user will have to determine the optimum transfer characteristics for their type of storage dewar and transfer line as they relate to the 7000 Series System.

16. In an efficient transfer, a 30 liter dewar will require ≈45 liters of LHe, while the 60 liter dewar will require ≈75 liters of LHe for initial filling.

NOTE

The helium level monitor supplied with the Model 60 liter dewar is calibrated for a 61 cm (24 inch) probe. Refer to the Model 241 Liquid Helium Level Monitor User's Manual for further information.

17. Remove both ends of transfer tube. Gloves should be worn when performing this operation.

CAUTION

After a lengthy transfer, ice build-up may prevent removal of the deflection tube or immediate replacement of the fill plug. A gentle hot air gun can be used to warm the fill opening and melt the ice. Do *not* over-heat.

18. Firmly fix pop-off in fill port and close He Bath Vent valve on rear of dewar console. This ensures proper gas flow through vapor-cooled leads and prevents air condensation inside helium dewar.

Edit:

Path: Collection / Experimental / H_field / Profile / Edit

This allows you to edit the field profile specification which was defined using either Discrete or Incremental. When Edit is selected, the window of discrete field points will be displayed. Field values can be deleted by moving the cursor to that value and pressing Del. If you wish to enter fields, position the highlight and press INS. You will now be prompted for an input. Esc to exit. Esc to exit.

End:

Path: Collection / Auto / End

This is the only way to terminate an experimental run at any point prior to its completion as defined. When selected, you will be prompted with Yes/No. If Yes is selected, the file will be closed and the run aborted. If No is selected, the run will continue as defined.

Enter_Setpoint:

Path: Collection / Temp_Ctlr / Setpoint / Enter_Setpoint

Sets the temperature setpoint on the DRC-91CA Temperature Controller to a user defined value. When selected, you will be prompted for an input. After typing a value, press Enter.

Experimental:

Path: Collection / Experimental

Is used to define the experimental parameters or conditions that are used for an automated data acquisition process. When accessed, the following sub-menu will be displayed:

Frequency: Allows you to set the frequency of oscillation of the AC current.

H Field: This allows you to set the amplitude of the applied DC field. MPS menu items will only appear if the Model 610/612 is included with the system.

Mode: Used to change operating mode between AC resistance and DC resistance.

Temp Spec: This is used to define the temperature specifications that are used in automated data acquisition.

Name: This is for entering a file name to which the data will be written.

Current: Used to change the control current.

Log: This will log one measurement as currently defined.

Phase: Used in setting or changing the phase angle from default settings.

These commands are described alphabetically within this section. Esc to exit.

Fast:

Path: Collection / Keithley_DVM / Fast

Set digital filter to fast. Esc to exit.

File:

Path: Analysis / File

In the Analysis Menu, File is used to load a data file for data processing. When accessed, file names with drive or sub-directory information can be entered and the file will be appropriately accessed. There is no need to specify extensions. If Enter is pressed, the data files contained in the working directory will be displayed in a window. To load a particular file, move the cursor to that file and press Enter. If "a:" is specified, the floppy disk contained in the A drive will be accessed.

In the Output sub-menu, File is used to specify a file to which processed data will be written. When accessed, you will be prompted for a file name. There is no need to specify extensions. Type a file name and press Enter.

4.4.2 Warm Transfer – Using External Helium Gas Source

If the system is at room temperature or has *no* liquid helium in the dewar and external gas has been selected, the following checklist should be observed to perform a warm transfer. This procedure assumes the valve status according to completion of the initial pump-out procedure detailed in Paragraph 4.2. Please read all the steps before performing the procedure.

1. Turn the He Bath Vent valve, located on the rear of the dewar console, to the On position. This releases any helium pressure in the dewar and serves as the helium vent during transfer.
2. Insert one end of transfer line into liquid helium storage dewar. See Figure 4-2. The transfer line must be long enough to reach dewar bottom and should be positioned with end of transfer line slightly above dewar bottom.

CAUTION

To prevent a rapid build up of pressure, always insert the transfer line slowly into the dewar. Venting excessive gas may be necessary during the initial insertion of the transfer line.

3. Insert other end of transfer line into the fill port on top of dewar console. Transfer line should extend to within a few inches (cm) of dewar bottom. Total length is 54 inches (137 cm).
4. Transfer slowly. Often simply sealing/closing storage dewar and allowing transfer to proceed under ambient pressure is sufficient for initial phase.
5. Rotate the He Exchange Gas valve to the Fill position to admit helium gas into the sample space and vacuum space. The valve may be rotated back and forth several times to admit more or less gas. Several hundred microns is sufficient as indicated on the Manifold Pressure gauge. Leave the valve in the off position.
6. Close the Load Lock valve and the Sample Space valve.
7. The Manifold Pressure gauge is now reading the exchange gas pressure in only the vacuum isolation space.
8. About 2 to 3 hours should be allowed to bring temperature of system from room temperature to under 40 K. (Allow 4 to 6 hours for 9 Tesla systems.) Since the Model 241 Level Monitor uses a superconductive probe, level readings will not begin until temperature in the dewar is <10 K. When system is nearing 4.2 K (or as needed), apply pressure to storage dewar to force liquid helium over. Typically 1 to 5 psi (7 to 35 kPa) pressure is required to transfer helium. Monitor helium level indicator and fill to desired level. The standard helium capacity is about 60 liters at a depth of 24 inches (61 cm). Another 15 to 30 minutes will be required for this stage.

NOTE

The specifics of helium transfer are dependent on the combined properties of the storage dewar, transfer line, and receiving dewar. Each user will have to determine the optimum transfer characteristics for their type of storage dewar and transfer line as they relate to the 7000 Series System.

9. In an efficient transfer, a 30 liter dewar will require ≈45 liters of LHe, while the 60 liter dewar will require ≈75 liters of LHe for initial filling.

NOTE

The helium level monitor supplied with the Model 60 liter dewar is calibrated for a 61 cm (24 inch) probe. Refer to the Model 241 Liquid Helium Level Monitor User's Manual for further information.

10. Remove both ends of transfer tube. Gloves should be worn when performing this operation.

CAUTION

After a lengthy transfer, ice build-up may prevent removal of the deflection tube or immediate replacement of the fill plug. A gentle hot air gun can be used to warm the fill opening and melt the ice. Do *not* over-heat.

Edit (Continued)

Phases/frequencies: When selected, a table containing 32 default frequencies with their associated phase angles (θ) appears in a window. The frequencies may be changed to meet user requirements. Frequencies can be selected from 1 to 1000 Hz. in 1 Hz. steps and 1000 to 10,000 Hz. in 10 Hz. steps.

The phase angle associated with each frequency is used during data acquisition and analysis, so proper specification of the phase angle is required. The phase angle from the phase/frequency table is then used to process the data to yield the correct resistance. In order to change a particular phase or frequency, move the cursor to that entry and press Enter. A new value can then be input. Esc to exit.

MPS_rates: Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Save: This will save any changes made in either Constants, MPS_rates, or Phases/Frequencies to the RES.DAT file. When selected, you will be prompted with "Are you sure?" Yes saves the new information to the RES.DAT file and No does not write the new values to the RES.DAT file.

Edit:

Path: Collection / Experimental / Current / Edit

This allows you to edit the incremental (AC or DC) currents which were input using Incremental. When Edit is selected, the window of discrete current values will be displayed. Current values can be deleted by moving the cursor to that value and pressing Del. If you wish to change a current value, move the highlight to that value and press Enter. You will now be prompted for an input in milliamperes. If you wish to add a value to the list, position the highlight and press Ins. At the prompt, enter a value. Esc to exit.

Edit:

Path: Collection / Experimental / Temp_Spec / Edit

This allows you to edit the temperature specification that was defined using either List, Incremental, or Sweep in the Temp Spec sub-menu. If List or Incremental were used to define the temperature specification, then when Edit is selected the window of discrete temperature points will be displayed. Temperatures can be deleted by moving the cursor to a particular temperature and pressing the Del key.

If the temperature specification is a sweep, when Edit is selected, the sweep window will be displayed. Edit allows you to change sweep rates or nominal temperature spacing. Move the cursor to the rate or spacing you wish to change and press Enter. You can now enter a new value. Esc to exit.

11. Firmly fix pop-off in fill port and close He Bath Vent valve on rear of dewar console. This ensures proper gas flow through vapor-cooled leads and prevents air condensation inside helium dewar. Close all valves.

4.4.3 Cold Transfer

If external helium gas supply is used or the internal helium has been selected and the system already contains liquid helium, the following checklist should be observed to perform a cold transfer. The procedure assumes the valve status according to completion of the initial pump-out procedure detailed in Paragraph 4.2. Please read all the steps before performing the procedure.

1. Rotate the He Exchange Gas valve to the Off position. This automatically charges a fixed volume used for adding exchange gas to the sample space and vacuum isolation space.
2. Close the vacuum pump valve.
3. Rotate the He Exchange Gas valve to the Fill position to admit helium gas into the sample space and vacuum space. The valve may be rotated back and forth several times to admit more or less gas. Several hundred microns as indicated on the Manifold Pressure gauge is sufficient. Leave the valve in the off position.
4. Close the Load Lock valve and the Sample Space valve.
5. The Manifold Pressure thermocouple gage is now reading the exchange gas pressure in only the vacuum isolation space.
6. Turn the He Bath Vent valve, located on the rear of the dewar console, to the On position. This releases any helium pressure in the dewar and serves as the helium vent during transfer.
7. Remove pop-off valve from fill port on top of Dewar Console.
8. Insert one end of transfer line into liquid helium storage dewar. See Figure 4-2. Transfer line must be long enough to reach bottom of dewar and should be positioned with end of transfer line slightly above dewar bottom.
9. Apply pressure (if required) to storage dewar while watching exposed end of transfer line. When a sputtering sound is heard and a vapor cloud (jet) forms at end of transfer line, insert transfer line into system dewar. The length of transfer line must be long enough to reach "belly" of dewar (30 inches; 76 cm) but should not extend below helium level already present in system.

NOTE

When inserting the transfer line into the system dewar, there will be extra gas released due to boil-off caused by the warm transfer line entering the dewar and boiling-off the liquid already present.

10. Transfer and fill dewar to desired level by pressurizing storage dewar. A "cold transfer" should only take 15 to 30 minutes to fill dewar. Since the Model 241 Level Monitor uses a superconductive probe, level readings will be interrupted if the temperature in the dewar is >10 K.

NOTE

The helium level monitor supplied with the Model 60 liter dewar is calibrated for a 61 cm (24 inch) probe. Refer to the Model 241 Liquid Helium Level Monitor User's Manual for further information.

11. Remove both ends of transfer tube. Gloves should be worn when performing this operation.

CAUTION

After a lengthy transfer, ice build-up may prevent removal of the deflection tube or immediate replacement of the fill and vent plugs. A gentle hot air gun can be used to warm the fill and vent openings and melt the ice. Do *not* over-heat.

12. Firmly fix plug in fill port and close He Bath Vent valve on rear of dewar console. This ensures proper gas flow through vapor-cooled leads and prevents air condensation inside helium dewar. Close all valves.

Discrete: Path: Collection / Experimental / H_field / Profile / Discrete

This routine enables you to enter DC field values individually in order to build your own list of DC fields at which data will be recorded during automated data acquisition.

When selected, you will be prompted for a field input (kAmp/m if SI, kOe if cgs). Input a value and press Enter. A window will be displayed on the screen with this single field value. Continue to enter as many fields as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which fields are entered is the order in which the fields will be set, and data recorded, during data acquisition. Esc when completed to exit.

NOTE

Discrete and Incremental can be used together to build a table of discrete field points for fixed point data acquisition.

Display: Path: Collection / Lock-In / Display

Allows you to set the function that is displayed on the output LCD of the lock-in amplifier. When accessed, the following sub-menu is displayed.

Percent: When selected, output LCD indicates lock-in output in % of full scale for all sensitivities.

Signal: When selected, output LCD indicates the signal amplitude in voltage. This is the default setting.

Offset: When selected, output LCD indicates the offset value in effect.

Noise: When selected, output LCD indicates the rectified output noise in percent of full scale.

Ratio: When selected, output LCD indicates the ratio of the Lock-in amplifier output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Log Ratio: When selected, output LCD indicates the log of the output described in Ratio.

Signal is the default setting. Regardless of what is chosen in Display when automatic data acquisition (i.e., Auto) is selected, the output LCD will indicate (or be changed to) Signal.

DOS: Path: DOS

Enables you to exit to the Disk Operating System (DOS). When selected, you will be prompted with the sub-menu "No/Yes." Selecting No leaves you in the Main Menu and selecting Yes exits to DOS.

Down: Path: Collection / Lock-In / Constant / Down

Decreases lock-in amplifier time constant setting by one unit.

Edit: Path: Edit

This feature allows you to change/modify system constants/default values contained in RES.DAT. When selected, the following sub-menu is accessed.

Constants: When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will now be prompted for an input. After typing a value, press Enter. The system constants contained in the window are:

Maximum MPS current = XX amperes
MPS field-to-current conversion constant = XXXXX

4.5 SAMPLE MOUNTING

A sample is easily attached to the sample probe. Place the sample inside the sample holder and screw on a sample lid, leaving ≈1/4 inch extending above the sample holder. Sample lids can be trimmed to accommodate different sized samples. Screw the exposed threaded part of the lid into the sample holder bushing. The sample holder should be gently tightened against the sample holder bushing.

4.6 SAMPLE PROBE LOADING AND UNLOADING

As with any cryogenic system, contamination or condensation from air must be avoided. In order to avoid this contamination and move a sample into and out of a temperature controlled region, a load lock arrangement is used. With all valves either closed or in the off position, the following procedure should be used in loading a sample.

1. Clean sample probe of any dust or dirt which may have accumulated on its surface.
2. Move the sample probe seal towards the bottom of the sample probe so the dark loading/unloading mark is visible above the seal.
3. Remove sample seal plug and insert sample probe seal completely into the sample load seal and finger tighten thumb screws. See Figure 4-3.
4. Open the Vacuum Pump valve and then the Sample Space valve. Allow sufficient time for the load lock to evacuate as indicated by the Manifold Pressure thermocouple gauge. Five to ten minutes is generally sufficient.
5. Close the Vacuum Pump valve and open the Load Lock valve.
6. Note the pressure as indicated by the Manifold Pressure thermocouple gauge. Approximately 500 to 1000 microns of helium exchange gas is required for proper operation. There may be enough residual exchange gas in the sample space below the Load Lock valve from previous operation so that nothing needs to be done. If there is not enough gas, add helium exchange gas by momentarily turning the He Exchange Gas valve to Fill. Rotate the valve back to the Off position. Note that this valve admits a fixed amount of gas each time it is turned to the Fill position. If desired, exchange gas can be removed by opening the Vacuum Pump valve.
7. Close Sample Space valve.
8. Slowly push the sample probe downward, allowing the probe to cool before reaching the vacuum isolation can. Several minutes should be allowed for lowering the sample. If the sample is lowered too fast, the temperature as read on the DRC-91CA Temperature Controller will indicate warming as the sample enters the coil assembly and more LHe will be boiled off.
9. Lower sample until the top of sample probe is just below the threads on the Movement extension. See Figure 4-4.
10. Rotate finger nut clockwise until top portion of sample probe threads are exposed. Swing movement extension out until threads are in alignment with the sample rod. Move the sample rod until the threaded portion meets threads on movement extension.
11. Rotate clamping lever clockwise to lock the movement extension into place.
12. Once the threads are aligned, rotate the finger nut counter-clockwise until tightened on the movement extension. (Some rotation of the sample probe many be needed to align the threads.)

Constants: Path: Edit / Constants

This is used to adjust/modify system constants. When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will then be prompted for an input. After typing a value, press Enter again. Esc to exit. The system constants that are displayed and can be modified are:

Maximum MPS current = XX amperes
MPS field-to-current conversion constant = XXXXX

Constant_Current: Path: Collection / Experimental / Current / Constant_Current

This defines the constant excitation current (either AC or DC, depending on the selection made in Mode) to be used during data acquisition. When selected, you will be prompted to input a current in milliamperes. Esc to exit.

Current: Path: Collection / Experimental / Current

Change current control. When selected, the following sub-menu will be displayed.

Constant_Current:	Select current value to be held constant. Esc to exit.
Fixed_Range:	Constant voltage simulation. Esc to exit.
Incremental:	Set up table of current values. Esc to exit.
Edit:	Edit table of current values. Esc to exit.
Reset:	Reset current control. Esc to exit.

DC_Resistance: Path: Collection / Experimental / Mode / DC_Resistance

Selects the DC Resistance mode.

Demag_sample: Path: Collection / Experimental / H_field / Demag_sample

This function is used to demagnetize the system and eliminate any remnant fields which may be present. After the application of a DC field, remnant fields may reside in the system and Demag_sample will reduce this to effectively zero, leaving only the earth's ambient field. When selected, the cycle is performed automatically. The routine steps through a cycle in which the field direction is alternately changed and the field amplitude is decreased with each change. The entire cycle takes approximately five minutes to complete.

NOTE

Whenever operation of the system with the magnet is completed, or prior to using the system, Demag_sample should be used to eliminate any stray fields that may be present.

Derivative: Path: Collection / Temp_Ctlr / Derivative

This allows you to set the Rate value on the DRC-91CA Temperature Controller. When selected, you will be prompted for an input (0–9.9). After typing a value, press Enter. The default setting for this parameter is 0. During automated data acquisition, this parameter will be set to 0.

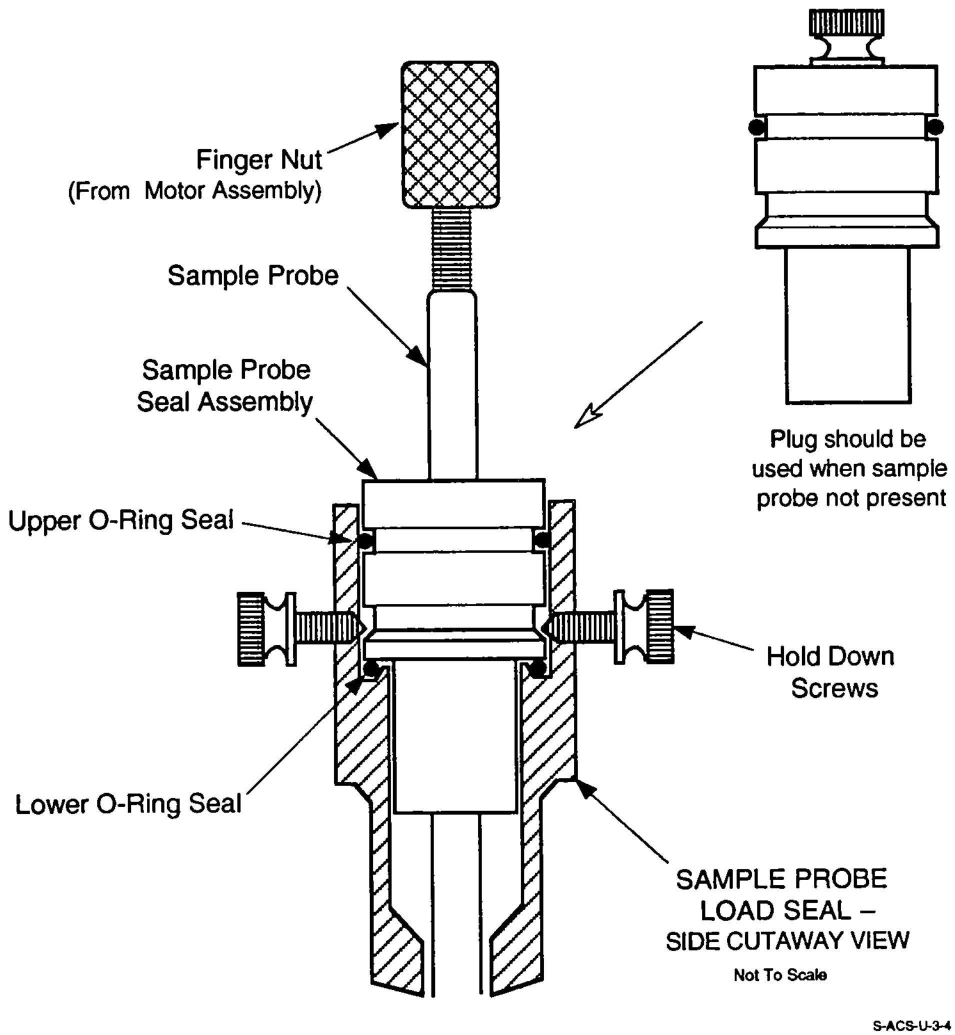

Figure 4-3. Sample Probe Load Seal – Cutaway

In unloading the sample, the following procedure should be followed:

1. Detach the sample probe from the movement control. This is the reverse procedure used to make the connection.
2. Slowly pull the probe upwards. As the sample probe is withdrawn, cold sections of the tube will have a tendency to freeze the seals in the sample probe seal. If a tightness or stiffness is felt when withdrawing the probe, simply pause a minute or so to allow the probe to warm before continuing the withdrawal. Stop withdrawing the probe when the loading/unloading mark just appears above the sample probe seal. Several minutes will be required for this entire process.

CAUTION

Never force the sample rod through a frozen seal as damage to the Teflon® seals may result.

Begin:
Path: Collection / Experimental / Log / Begin

Initiates data acquisition process and will display the results as they are recorded in the lower left-hand feedback block. Esc to exit.

Cancel:
Path: Analysis / Cancel

Used to cancel the currently specified hard copy device or file.

Cancel:
Path: Collection / Experimental / H_field / Profile / Cancel

Selection of this will cancel a previously defined field profile.

Cancel:
Path: Collection / Experimental / Log / Cancel

Selection of this will terminate the Log sequence.

Cancel:
Path: Collection / Experimental / Temp_Spec / Cancel

Used to cancel temperature points/control and start over.

Collection:
Path: Collection

Collection is used to define the experimental parameters that are to be used when logging data for a particular sample or experiment. When selected, the following sub-menu will be presented.

Experimental: Selection of this brings up the experimental set-up menu where experimental parameters are defined for automated data acquisition.

Auto: Provides access to subsequent Begin, End, Override, and Real-time commands.

Temp Ctlr: This allows software interaction with the DRC-91CA Temperature Controller.

Lock-In: This allows software interaction with the lock-in amplifier.

Keithley_DVM: This allows software interaction with the Keithley DVM.

Recall: Allows input of a previously generated configuration file or experimental set-up.

These commands are described alphabetically within this section. Esc to exit.

Constant:
Path: Collection / Lock-In / Constant

The changing of the time constant setting of the lock-in amplifier is performed here. When selected, the following menu is accessed.

Up: Increases time constant setting one unit.

Down: Decreases time constant setting one unit.

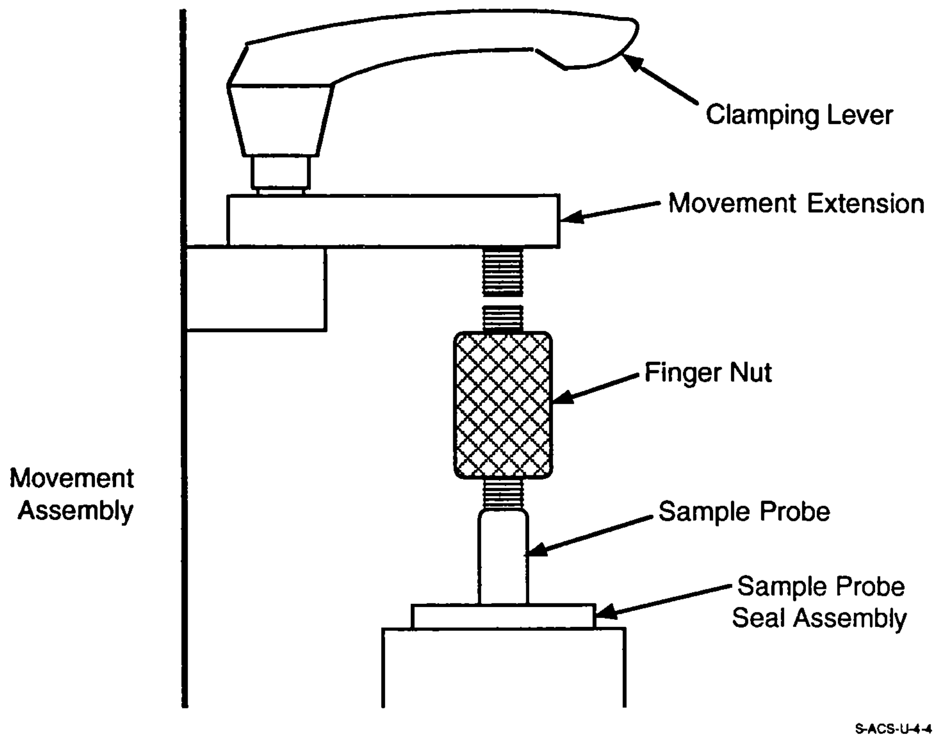

Figure 4-4. Sample Rod Connection

3. Close the Load Lock valve. If the Sample Space valve is open, close this valve also.

CAUTION

Do not close the Load Lock valve unless the loading/unloading mark is visible above the sample probe seal. Damage to the sample probe and load lock may result.

4. Fill the load lock space with helium gas at atmospheric pressure by turning the Load Lock Vent valve to Fill. Close the valve and allow a few minutes for the sample to warm completely to room temperature.
5. Loosen the holding screws and remove the sample probe and probe seal as one unit.
6. Insert the plug into the load seal to prevent any contamination from entering the system.

4.7 OPERATING PARAMETERS

Sample space and vacuum isolation space operating parameters consists of the following paragraphs. Sample space information is contained in Paragraph 4.7.1. Details on the vacuum isolation space are contained in Paragraph 4.7.2.

4.7.1 Sample Space

The sample space is designed to run with ≈500 to 1000 microns of helium exchange gas present. This assures thermal contact between the sample, temperature sensors, and control heaters. The precise amount of gas is not very critical, but it is critical that exchange gas be present during operation.

During operation with sample movement, slight amounts of contamination may be wiped into the sample space through the sample seal due to absorbed gases on the stainless steel shaft of the sample probe. When stationary, the sample seal should be vacuum tight as tested with a helium leak detector. Although no problem or loss of accuracy should be observed with this trace contamination, periodically pumping out the sample space when the system is above 100 K is recommended when the system is to be maintained cold for extended periods of time.

Auto: (continued)

Real-time: Selection of this activates real-time feedback of processed resistance data. When selected, the following sub-menu is accessed.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. Scaling is performed automatically. Esc to exit.

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through the available options in your data set. When done, a window will display the selections which have been made. Esc to exit.

Auto:

Path: Collection / Experimental / Phase / Auto

This will automatically measure the phase of a particular sample. When selected, the signal due to the sample will be measured at both 0 and 90 degrees. The phase will then be calculated using the following equation:

$$\theta = tan^{-1} (v_{90} / v_0)$$

The phase of the lock-in will then be set to this value of θ.

Autorange:

Path: Collection / Keithley_DVM / Autorange

This selection will toggle the Keithley DVM Autorange feature on or off. Esc to exit.

Auto_T:

Path: Collection / Temp_Ctlr / Auto_T

Will automatically warm the system up to a user input temperature at a rate of 3 K per minute When selected, you will be prompted for a setpoint. After typing a setpoint and pressing Enter, the control sensor will be read and the setpoint will be set equal to the control sensor temperature reading and the control setpoint will start to increase at a rate of 3 K per minute

Once the setpoint is reached, the temperature will continue to be controlled at that temperature. Pressing the Esc key will cause ramping to cease. The temperature will be controlled at the setpoint determined when the Esc key was pressed.

Band-pass:

Path: Collection / Lock-In / Filter / Band-pass

This is an on/off toggle for the Band-pass filter option of the lock-in amplifier.

Begin:

Path: Analysis / Begin

When selected, processed data will be printed to a hard copy device or a designated file in an ASCII file format.

Begin:

Path: Collection / Auto / Begin

Used to start up the auto-collection process.

4.7.2 Vacuum Isolation Space

During any automatic operation or under any temperature control with the DRC-91CA, the vacuum isolation space should be pumped continuously with the vacuum pump. This requires that the Vacuum Space and Vacuum Pump valves must also be open. Always open the Vacuum Pump valve to fully evacuate the manifold lines as indicated on the Manifold Pressure thermocouple gauge before opening the Vacuum Space valve.

When changing samples and pumping out the load lock, be sure that the Vacuum Space valve is closed to avoid any contamination or backstreaming into the vacuum isolation can. When the new sample is in position and the Sample Space valve is closed, the Vacuum Space valve should be opened again.

In some instances operating with exchange gas in the isolation space can be useful. If samples are being measured only at liquid helium temperature or liquid nitrogen temperature (when liquid nitrogen is being used), maintaining several hundred microns of exchange gas in the vacuum isolation space thermally anchors the coil and sample to the surrounding bath temperature.

Another instance when exchange gas is useful is when rapid thermal cycling is being done. For instance, suppose the system is operating with liquid nitrogen and the temperature range of interest is 80 to 150 K. When the first run is complete to 150 K, exchange gas should be added to the isolation can so the system cools rapidly back to 80 K. While the system is cooling, another sample can be loaded and the system set up to begin another run.

CAUTION

- When the system is rapidly cooled using exchange gas, moderate pressure may build up inside the dewar. This is particularly the case when liquid helium is being used. The excess gas will be heard to vent through the pop-off which is normal.
- When using exchange gas in the vacuum isolation space for cooling or maintaining the temperature at the bath temperature, no more than 500 to 1000 microns should be added. Greater pressures will not significantly increase the thermal contact, but may significantly increase the pump out time required when vacuum is desired in the vacuum space.
- When warming the system using the DRC-91CA, the control should be through automatic data acquisition or the auto T adjust feature in the ACS Software package. System problems may develop if lengthy heating on maximum power at 100% output is utilized.

4.8 AC SUSCEPTOMETER MEASUREMENTS

The 7000 Series AC Susceptometer System allows a wide combination of data acquisition and processing options which may seem confusing for the person being introduced to AC susceptometry for the first time. This paragraph will elaborate on some of the choices available in ACS operation and offer suggestions when to use the various options. A background and definition of AC susceptometry is provided in Paragraph 4.8.1. Frequency and field selection is discussed in Paragraph 4.8.2. Information on single- versus two-position measurements is provided in Paragraph 4.8.3. Addenda corrections are discussed in Paragraph 4.8.4. Information on fixed point versus temperature sweep, dual phase versus single phase, and phase adjustments is provided in Paragraphs 4.8.5 through 4.8.7 respectively. Noise rejection through frequency selection is discussed in Paragraph 4.8.8. Autorange ON/OFF operation of the phase sensitive detector is discussed in Paragraph 4.8.9. Finally, Paragraph 4.8.10 provides information on high frequency operation above 2000 Hz.

8.6.3 Command Breakdown And Functional Description

The following is a complete list of RES7000 Software Commands presented in alphabetical order. The menu path to find each command is defined for each command listed. The pathway begins with one of the five menu selections presented when the program starts: Analysis, Collection, Edit, Units, and DOS. To access the commands, you may either type the highlighted letter, or use the right/left arrow keys and press enter.

AC_Resistance: Path: Collection / Experimental / Mode / AC_Resistance

Selects the AC Resistance mode.

Analysis: Path: Analysis

This is the data processing program for processing data contained in data files defined in the Experimental sub-menu of the Collection menu. When selected, the following sub-menu will be displayed.

Begin: Selection of this will either print the processed data to a hard copy device or write the contents to an ASCII file as specified by selecting Output.

Cancel: This will abort or cancel selection of Begin.

File: Used to input a file name containing data to be processed.

View: Provides selection of method of display of processed data on screen: Tabular, Graphical, or Parm_select.

Output: Is for specifying that the processed data be printed to a specified hard copy device or written to an ASCII file. Note that the Begin option must be used to execute the selection.

Parm_select Select analysis display parameters.

The function of each of these subroutines will be described in more detail in subsequent paragraphs. Esc to return to the Main Menu.

Auto: Path: Collection / Auto

Starts automatic data acquisition. When selected, the following sub-menu is accessed.

Begin: Begins automatic data acquisition process.

End: When selected, you will be prompted with; "Are you sure? Y/N?" If "Y" is selected the automatic data acquisition process will be terminated. Data recorded up to that point will be saved if a file has been specified. To continue with data acquisition, select "N."

Override: During fixed temperature points data acquisition mode, selection of this key will over-ride certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent on the particular temperature range. Upon completion of the WAIT, a DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once this DRIFT/MIN is below 0.1 K per minute the data acquisition/ measurement sequence will automatically begin. Selecting Override once will override the designated WAIT period and initiate the DRIFT CHECK. Selecting Override again will override this as well and data will be recorded immediately.

4.8.1 Background And Definition

The critical parameter in setting up the system for data acquisition is the voltage read on the lock-in detector. The voltage will consist of three separate contributions:

1. v = voltage due to the sample. The lowest detectable sample signal is on the order of a few tenths of a microvolt while larger samples with high susceptibilities may have output voltages of 1 mV or more. If the signal is less than a few microvolts, the sample will probably have to be positioned using the procedure outlined for low level signals.
2. v_0 = coil offset voltage. This voltage will range from less than 1 microvolt at low fields and frequencies to several hundred microvolts at the highest fields and frequencies. This voltage is totally independent of the sample probe/position and may vary slightly from cool down to cool down. v_0 will vary with temperature. Refer to Paragraph 1.8 and the Coil Test Report.
3. v_a = voltage due to the empty sample holder and support rod. Typically this is less than 1 microvolt at 500 Hz and 80 A/m.

If no compensation procedures are used to account for v_0 or v_a, the added uncertainty in the susceptibility measurement will be significant when v_0 and v_a are comparable in magnitude to v itself. The percentage additional uncertainty will be given by

$$100\,(v_0 + v_a)/v$$

When setting the system up for data acquisition, the questions to consider are the magnitudes of the voltage signals and the desired accuracy of the susceptibility.

4.8.2 Frequency/Field Selection

One primary function of the variable field and frequency is to adjust the sample signal v so it can easily be measured. Note that both v_0 and v_a are also field and frequency dependent. Simply increasing the field and frequency may not increase the measurement accuracy or resolution if, in order to read the signal, the lock-in must read on a less sensitive scale.

For example, consider an extreme situation where v = 1 μV and v_0 = 10 μV. The lock-in will read on the 10 μV scale; yielding a resolution of 0.01 μV or 1% of the sample signal. On increasing the frequency (or field) by a factor of 10, v will increase to 10 μV and let us assume v_0 also increases by a factor of 10 to 100 μV. The lock-in will now read on the 100 μV scale, yielding a resolution of 0.1 μV. This still represents 1% of the sample signal, so there has been no net gain in measurement resolution by increasing the signal level.

The variable frequency/field also permits examining the effects these parameters have on the material being studied. This should always be considered to assure the proper interpretation of the data. For example, with conductors, the generation of eddy currents, which are frequency dependent, in the sample could significantly alter the susceptibility measurement.

4.8.3 Single- Versus Two-Position Measurements

As discussed in Paragraph 1.8, using the option for two position measurements (sample movement) will totally eliminate the measurement uncertainty due to v_0. For any measurement where the highest accuracy is desired, the two position option should be used. The other instance when it is mandatory is for any sample with a low output signal, i.e., when $v \le v_0$. If v_0 is not properly compensated for, details in the variation of χ with temperature may be distorted due to variations in v_0 with temperature.

However, if v_0 is small with respect to the signal voltage v or the additional uncertainty in the susceptibility measurement is acceptable, single position measurements are most useful and can save considerable time. Single position measurements are most often used in conjunction with the sweep mode of operation to obtain a quick profile of $\chi(T)$ or to identify a transition temperature.

Collection (continued)

Lock-in (continued)

Tuning	Tuning display function (Ref phase, Osc Freq, Osc Lvl, Filter Freq, Ref Freq)
Phase	Display reference phase.
Osc_freq	Display oscillator frequency.
Level	Display oscillator level.
Filter_freq	Display filter frequency.
Ref_freq	Display reference frequency.
Constant	Time constant movement – up/down.
Up	Move time constant up.
Down	Move time constant down.
Display	Output display options.
Percent signal	Display % full scale.
Signal	Display signal.
Offset	Display offset value.
Noise	Display noise value.
Ratio	Display voltage ratio.
Log Ratio	Display voltage as logarithmic ratio.
Reserve	Dynamic reserve (HI STAB, NORM HI RES)
STAB	HI STAB
NORM	Normal
RES	HI RES

Keithley_DVM

Manual adjustment of Keithley DVM.

Autorange	Autorange toggle – on/off.
Range	Select voltmeter range.
Integration_time	Toggle integration time – 1 PLC/100 ms.
Off	Turn digital filter off.
Fast	Set digital filter to fast.
Medium	Set digital filter to medium.
Slow	Set digital filter to slow.

Recall

Load previously defined experimental configuration.

Edit

Modify system defaults (from RES.DAT).

Constants	Change system constants.
Phases/Freq's	Change system phases (THETA) and frequencies.
MPS_rates	Change MPS ramp rates.
Save	Save changes to RES.DAT.

Recall

Load previously defined experimental configuration.

Units

Select units, cgs or SI, for display purposes.

DOS

Exit to DOS.

4.8.4 Addenda Correction (AC Susceptibility Measurements)

To use the addenda correction option, a data run must be performed with the sample rod and empty container. The position of the sample rod will have to be determined using the procedure described for low level signal samples (Paragraph 5.2.4.1). The data must be recorded using the fixed point, two position, and dual phase options (Paragraph 5.2.6). When you run a background test, you should ideally use the same sample cup as you will be using for the actual measurement.

The primary function of the addenda correction is to correct for the voltage v_a. Since v_a is quite low, most samples will have $v >> v_a$ and the correction is not needed. For the highest accuracy and for samples with low output signals, the addenda correction should be used.

The secondary function of the addenda correction is as a first order correction for v_o when single position measurements are made. The potential error associated with v_o is generally much greater than the error associated with v_a. The addenda correction will not compensate for any run to run variations which occur in v_o. The addenda correction can reduce the percentage error associated with the offset voltage ($100^* v_o/v$) by approximately a factor of 5 to 10.

Note that v_a is dependent only upon the physical nature of the sample rod and should not vary with time unless something is added or subtracted from the sample holder. If the addenda correction is used only to correct for v_a, the addenda data needs to be recorded only once for a given sample holder. On the other hand, the offset voltage is dependent on the coil assembly and may vary with thermal cycling as the coils expand and contract and possibly shift slightly. If the addenda correction is used to correct for v_o, the addenda data should be re-run and updated periodically to account for possible shifts and variations in the offset voltage.

4.8.5 Fixed Point Versus Temperature Sweep

To achieve the best temperature accuracy (refer to specifications) and to guarantee that data is logged under isothermal conditions, fixed point data acquisition should be used.

Faster data acquisition and rapid sample screening can be accomplished using the temperature sweep option. There will be a reduction in the temperature accuracy since in a sweep mode the system is in a dynamic situation. The added uncertainty cannot be exactly specified as it will be a function of the sweep rate and a function of the particular sample. For example, the additional temperature errors due to a 3 K/min sweep are estimated to fall in the range from 0.5 K to as high as 2 K. This is based on observing the transition temperatures of high temperature superconductors. Slower sweep rates will have correspondingly better accuracy specifications.

4.8.6 Dual Phase Versus Single Phase

Single phase data acquisition is used when only one component of the susceptibility is of interest. Generally, this will be the real component. Dual phase data acquisition should be used for two situations:

1. Both the real and imaginary component of the susceptibility are desired.
2. The real part of the susceptibility is desired, $\chi' >> \chi''$, and the data is processed to give the magnitude of the susceptibility. This will give a result for χ' which requires no phase determination, but is equivalent to phasing the system and logging data single phase with the system set to that phase. This set-up is useful for high accuracy measurements of samples with no imaginary component to the susceptibility.

Collection (continued)

Experimental (continued)

Phase	Measure and set phase for current sample.
Auto	Measures phase angle for current sample.
1	Adjust phase by +90°.
2	Adjust phase by –90°.
3	Adjust phase by +10°.
4	Adjust phase by –10°.
5	Adjust phase by +1°.
6	Adjust phase by –1°.
7	Adjust phase by +0.1°.
8	Adjust phase by –0.1°.
Set	Input phase angle.

Auto

Proceed with automatic data acquisition.

Begin	Start up auto-collection process.
End	Terminate an in-process auto-collection.
Override	Override temperature settlement wait period.
Real-time	Real-time feedback mode – Tabular/Graphical.
Tabular	Display real-time tabular auto-collection feedback.
Graphical	Display real-time graphical auto-collection feedback.
Parm_select	Select auto-collect feedback display parameters.

Temp-Ctlr

Manual adjustment of temperature controller.

Setpoint	Manually adjust temperature.
1	Adjust setpoint up +10 K.
2	Adjust setpoint down –10 K.
3	Adjust setpoint up +1 K.
4	Adjust setpoint down –1 K.
5	Adjust setpoint up +0.1 K.
6	Adjust setpoint down –0.1 K.
Enter_Setpoint	Enter setpoint value.
Heater_Range	Enter heater range.
MAX	Adjust heater range to MAX.
1	Adjust heater range to –1.
2	Adjust heater range to –2.
3	Adjust heater range to –3.
Off	Adjust heater range to OFF.
Gain	Enter DRC-91CA gain value.
Derivative	Enter DRC-91CA derivative (rate) value.
Integral	Enter DRC-91CA integral (reset) value.
Auto_T	Enter desired setpoint (0.1 to 325.0).

Lock-in

Manual adjustment of lock-in amplifier.

Mode	Select filter mode – Track/Manual.
Track	Tuning filter mode – Track.
Manual	Tuning filter mode – Manual.
Filter	Select filter function (Flat, Notch, Low-pass, Band-pass).
Flat	Use flat filter.
Notch	Use notch filter.
Low-pass	Use low-pass filter.
Band-pass	Use band-pass filter.

4.8.7 Phase Adjustments

For most applications where only the real component of the susceptibility is of interest, simply using phase angles of 90° in ACS should provide satisfactory results and the problem of "phasing" the system can be ignored. This can greatly simplify the system operation. If single phase data acquisition is used with a 90° phase setting, a nominal 1% in the susceptibility accuracy is sacrificed.

The proper phase determination must be made whenever the imaginary component is desired. Also, in single phase operation, the proper phase setting should be determined and the system set at that phase to achieve the full system capability and eliminate the extra uncertainty associated with a 90° phase setting. Refer to Paragraph 1.10 for further details.

4.8.8 Noise Rejection Through Frequency Selection

Depending on the operating environment and powerline frequency, certain frequency selections may be inherently noisier than others. Before beginning data acquisition, the voltage signal should be observed to verify that the signal is acceptable. If the signal appears unstable, simply going up or down one step in frequency often eliminates the noise.

As a rule, the powerline frequency and higher multiples of the powerline frequency should be avoided as an operating frequency.

4.8.9 Phase Sensitive Detector: Autorange On/Off

The default setup of ACS contains an autoranging feature for the phase sensitive detector. This guarantees that each voltage reading is made on the sensitivity scale which maximizes the resolution of the voltage and automatically compensates for any variation with temperature. Generally, this feature should not be disabled and should prove satisfactory for most applications.

However, there are two circumstances where turning off the autorange feature may be beneficial. The first is to speed up the data acquisition process. Due to the way in which a phase sensitive detector responds, the ranging process itself is relatively slow. The increase in data acquisition rate is particularly evident in a single phase sweep mode of data acquisition.

The second situation where the autorange feature should be turned off is when the system is really being pushed to the sensitivity limit. Disabling the autoranging guarantees that all voltage measurements are made on the same sensitivity range. This avoids discontinuities inherent in most instrumentation when making measurements on different sensitivity ranges.

Operation with the autorange feature off discussed in Paragraph 5.2.1 should be reviewed before attempting this mode of operation. Specifically, the maximum signal level should be known before attempting data acquisition and the sensitivity range should be set to accommodate this maximum signal. Details in the susceptibility versus temperature characteristics may be lost if the measurement signal changes much over the temperature range of interest.

4.8.10 High Frequency Operation Above 2000 Hz.

When performing ac measurements above 2000 Hz., additional phase uncertainties will arise due to increasing effects of inter-coil capacitances and also the decreasing input impedance of the Lock-in Amplifier. The phase errors show up as an amplitude dependence in the phase angle. These effects are minimal in the measurement of the real component of the susceptibility, but can be significant (equivalent to several degrees of phase error at 10 kHz.) when measuring the imaginary components. When attempting to separate real and imaginary components at these higher frequencies, the amplitude related phase errors can be minimized by phasing the system at lock-in signals of approximately the same size as the sample being measured.

8.6.2 Menu Breakdown and Functional Description

The following is a text-based representation of the RES7000 software configuration.

- **Analysis** — Processing of previously stored data files.
  - **Begin** — Begin analysis program.
  - **Cancel** — Cancel the in-process analysis.
  - **File** — Input data file for processing.
  - **View** — View processed input data on screen.
    - **Tabular** — Display processed data in tabular mode.
    - **Graphical** — Display processed data in graphical mode.
    - **Parm_select** — Select analysis display parameters.
  - **Output** — Select output of data: printer or file.
    - **Printer** — Analysis output to go to printer.
    - **File** — Analysis output to go to file (input file name).
  - **Parm_select** — Select analysis display parameters.
- **Collection** — Experimental data acquisition and measurement.
  - **Experimental** — Set experimental parameters/manual testing.
    - **Frequency** — Change operating frequency.
    - **H_field** — Change operating DC magnetic field (MPS).
      - **MPS_field** — Change operating MPS magnetic field.
      - **Profile** — Set field profile.
      - **Demag_sample** — Demagnetization cycle.
      - **Zero_offset** — Change MPS field to 0 and recalculate zero offset.
      - **H_Settle** — Provides options for controlling settling of the magnetic field.
        - **Overshoot_Ctrl** — On/off toggle for minimization of field overshoots.
        - **Time_dwell** — Select time (in addition to default time settings) for field stabilization.
    - **Mode** — Change operating mode – AC/DC.
      - **AC_Resistance** — Select AC resistance mode.
      - **DC_Resistance** — Select DC resistance mode.
    - **Temp_Spec** — Define temperature data points and control.
      - **List** — Enter individual temperature points.
      - **Incremental** — Enter incremental temperature table.
      - **Sweep** — Enter temperature sweep range(s)/rate(s).
      - **Drift** — Adjust time interval between measurement sequences.
      - **Edit** — Delete temperatures from list or edit ranges.
      - **Cancel** — Cancel temperature points/control and start over.
      - **Setpt_Adjust** — Fine tune of setpoint on/off.
    - **Name** — Input file name for data storage.
    - **Current** — Change current control.
      - **Constant_Current** — Select current value to be held constant.
      - **Fixed_Range** — Constant voltage simulation.
      - **Incremental** — Set up table of current values.
      - **Edit** — Edit table of current values.
      - **Reset** — Reset current control.
    - **Log** — Log one measurement as currently defined.
      - **Begin** — Begin logging data manually.
      - **Tabular** — Display real-time manual tabular feedback.
      - **Graphical** — Display real-time manual graphical feedback.
      - **Parm_select** — Select manual logging display parameters.
      - **Cancel** — Cancel manual logging.

4.9 DC MAGNETIC FIELD/SUPERCONDUCTING MAGNET

The 7000 Series DC Magnetometer System allows a wide combination of data acquisition and processing options which may seem confusing for the person being introduced to DC magnetic measurements for the first time. This paragraph will elaborate on some of the choices available in DCM operation and offer suggestions when to use the various options. DC magnetic field and superconductor magnet measurements are discussed in the following paragraphs. Inductive coupling is discussed in Paragraph 4.9.1. Information on performing low DC field measurements is provided in Paragraph 4.9.2. Finally, DC moment measurements is discussed in Paragraph 4.9.3.

4.9.1 Inductive Coupling

Since the primary coil and the superconducting magnet are inductively coupled, AC currents will be induced in the superconducting magnet when AC susceptibility measurements are being performed. These induced currents depend upon the mutual inductance between the primary and the superconducting coil and on the impedance of the superconducting magnet/power supply circuit. In the 7000 Series System, these effects are both field and frequency independent and are such that the net AC field seen by the sample is reduced by ≈1% for the 1 Tesla Magnet, ≈3% for the 5 Tesla Magnet, and 1% for the 9 Telsa Magnet, from the set field in the primary. This reduction can be eliminated if the superconducting magnet is not being used. Simply turn off the power supply and disconnect one current lead to the magnet. This leaves the magnet open circuited and prohibits any induced currents in the magnet circuit. This is the preferred mode of operation if pure AC measurements will be performed with no DC bias field and the frequency is less than 1000 Hz.

For frequencies greater than 1000 Hz., the Magnet Power Supply (MPS) should remain connected to the magnet, or, equivalently, the magnet leads should be shorted together. The MPS may be turned off when not in use. This effective ac short across the magnet eliminates LC resonances which may occur at higher frequencies due to the inductance (both mutual and self) and inter-winding capacitances.

4.9.2 Low DC Field Measurements

For applied DC fields limited to less than 10 oersted, the **Small_field** option should be used. This option sets a DC field using the primary coil and ACS Control Unit rather than the superconducting magnet. Setting the field in this manner will provide greater resolution and accuracy than could be achieved with the magnet power supply. In this mode of operation, the superconducting magnet can also be left open to avoid any inductive coupling. For higher fields, the superconducting magnet must be utilized.

To more accurately set a low field in the superconducting magnet, the **Zero_offset** command should be used. This feature adjusts the current output from the magnet power supply to account for any instrument zero drifts which may occur due to fluctuations in the operating environment.

Once a superconducting magnet has been energized, trapped flux within the magnet can generate a non-zero field even when the current has been reduced to zero. This remanant field, typically on the order of several oersted, can create a problem if subsequent zero field or low level field measurements are attempted. Through use of the **Demag_sample** command in the software, the remnant field can be eliminated. This option should routinely be selected before any low-level measurements are performed.

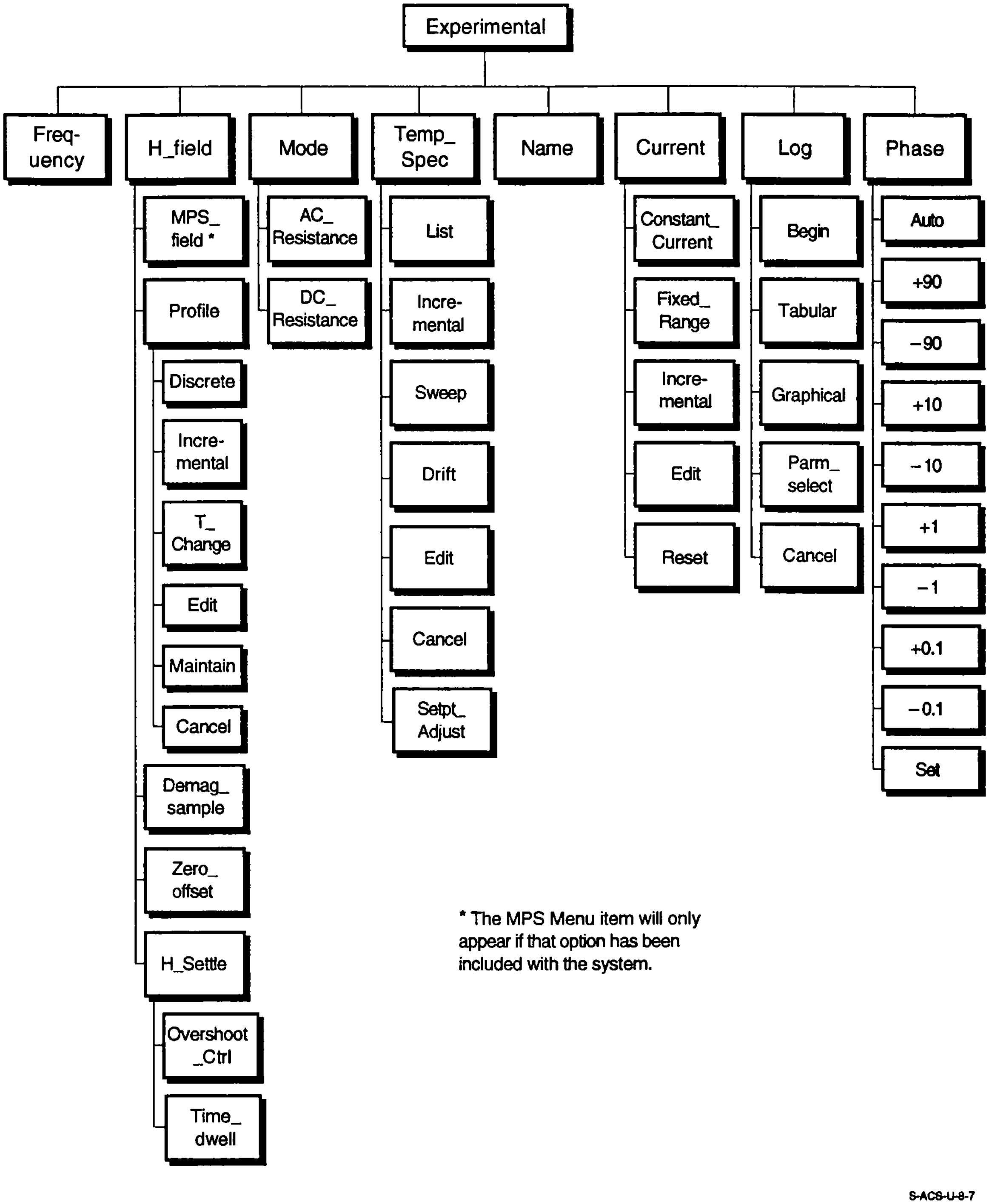

Figure 8-7. Experimental Menu Block Diagram

4.9.3 DC Moment Measurements

The sensitivity/noise level of the DC moment measurement is determined by the sum of two contributions: digital voltmeter noise and the overall experimental parameters. An understanding of the relationship between these three items is essential in obtaining the maximum in system performance. Voltmeter sensitivity and noise are discussed in Paragraph 4.9.3.1. Experimental parameters are discussed in Paragraph 4.9.3.2.

4.9.3.1 Voltmeter Sensitivity And Noise

The digital voltmeter (DVM) integrates the voltage signal during the sample extraction and displays,

$$v = \frac{1}{2}\int_0^2 v(t)dt$$

As configured for the moment measurement, voltage resolutions to 1 nV are obtained with standard deviations of ≈25 nV at low fields. In terms of moment sensitivity and noise, this translates into a standard deviation of 1.3×10^{-7} Am^2 (1.3×10^{-4} emu) for single scan measurements.

The base performance can be improved using multiple scans and averaging. Assuming a normal distribution of readings, the uncertainty in the mean of n scans should improve the moment measurement by the square root of n. For example, performing 10 scans will reduce the uncertainty to $\approx 4 \times 10^{-8}$ Am^2 (4×10^{-5} emu). Although results in the low 10^{-8} Am^2 (10^{-5} emu) range are achievable, averaging over more than 10 scans will probably not be expedient. Note the capability for automatically recording and averaging over multiple scans is built into the software.

4.9.3.2 Experimental Parameters

There are several experimental parameters which can affect the measurement. The most obvious parameter is the magnetic field and whether a temperature sweep is being done. For fixed fields, an increase in the noise level may be observed at the highest field settings. In the situation of sweeps, the sweep rate will have a dramatic effect on the quality of the data since the moment itself is dynamically changing and additional errors arise due to extraneous voltages generated by the dynamics. Secondary effects are related to the sample itself; physical size, magnitude of moment, and susceptibility.

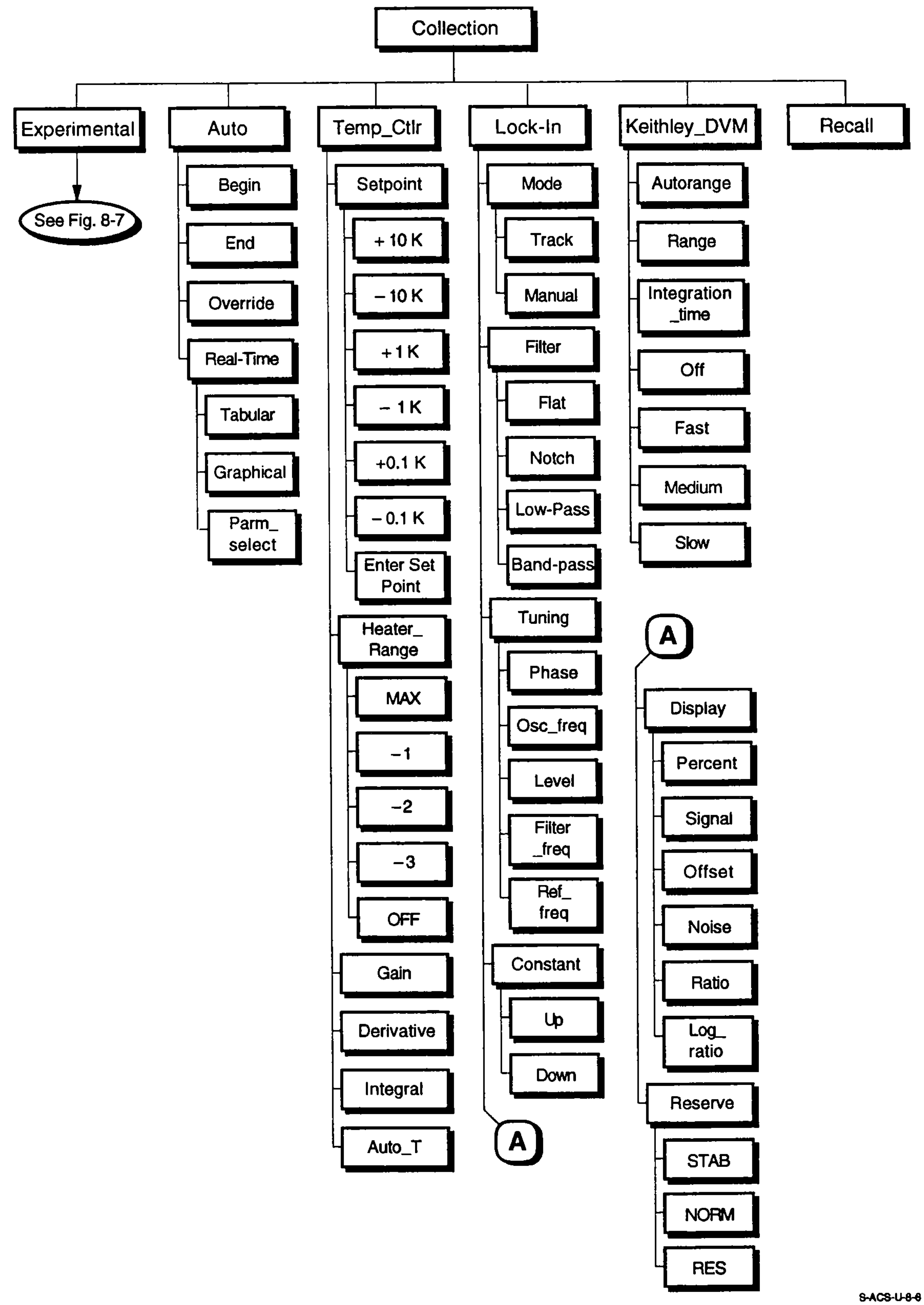

Figure 8-6. Collection Menu Block Diagram

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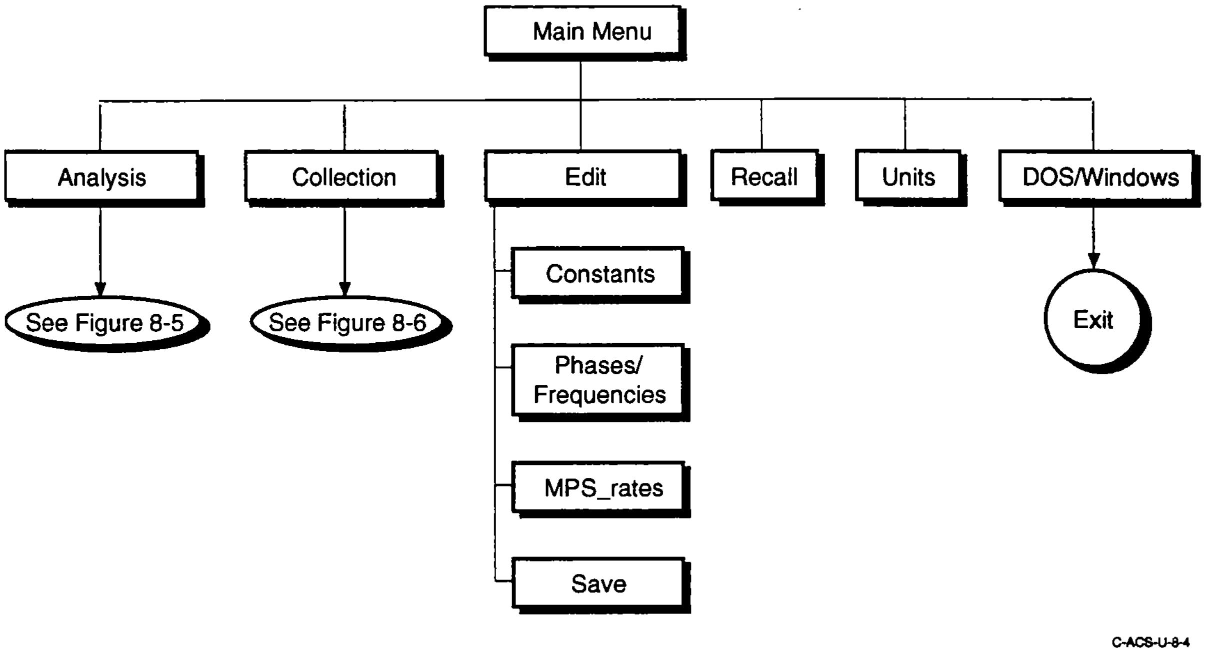


Figure 8-4. Main Menu Block Diagram

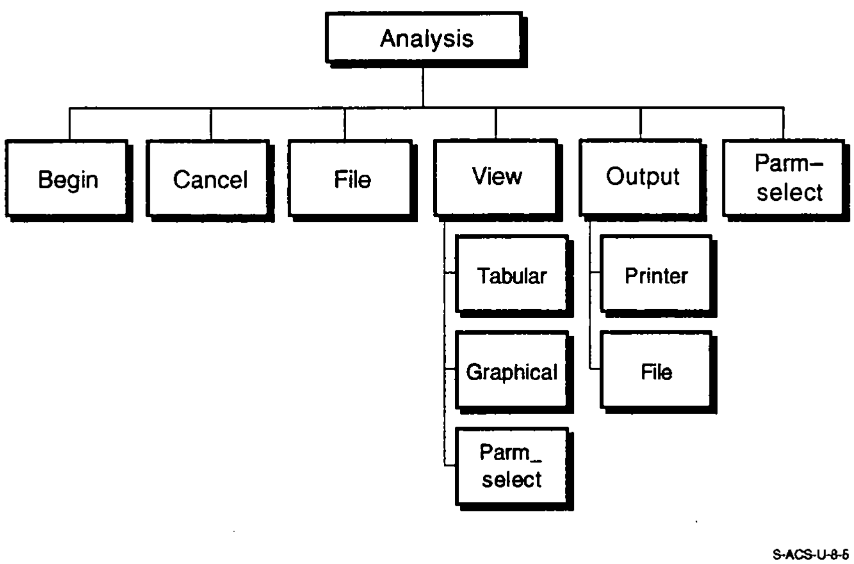


Figure 8-5. Analysis Menu Block Diagram

CHAPTER 5

ACS7000 SOFTWARE OPERATION

5.0 GENERAL

This chapter provides ACS7000 Software operation. The chapter consists of the following. Basic Information is provided in Paragraph 5.1. Principles of Operation are presented in Paragraph 5.2. Finally, starting the ACS Program is detailed in Paragraph 5.3.

5.1 BASIC INFORMATION

This paragraph provides basic information needed to properly run the ACS7000 Software Package. First is software installation data in Paragraph 5.1.1. Second is information on the ACS.DAT file in Paragraph 5.1.2. Finally, .DAT and .CFG file conventions are discussed in Paragraph 5.1.3.

5.1.1 Software Installation

NOTE

It is not necessary to run LSINSTAL on systems shipped with a computer, since the computer is per-configured at Lake Shore with all files installed in the proper hard disk directories. LSINSTAL is provided on the backup floppy disk in case of hard disk failure or accidental erasure of crucial files.

Each of Lake Shore's programs is installed in a separate directory on the hard disk of the computer to aid in data file management. ACS7000 is in the ACS directory, DCM7000 is in the DCM directory, ACM7000 is in the ACM directory, and RES7000 is in the RES directory. (Refer to Chapter 6 for further details on DCM7000 software, Chapter 7 for further details on ACM7000 software, and Chapter 8 for RES7000 software.) The program LSINSTAL.EXE provided with each system will create these directories if they do not already exist and copy all the required files from the floppy disk to the proper directories on the hard disk. LSINSTAL may be run from the floppy disk provided in either the A: or the B: drive.

LSINSTAL checks the files AUTOEXEC.BAT and CONFIG.SYS on the default (hard) drive. If they exist, they are checked for compatibility with Lake Shore's software and modified if necessary. (The existing AUTOEXEC.BAT and CONFIG.SYS files are first renamed AUTOEXEC.OLD and CONFIG.OLD.) If they do not exist, these files are copied from the floppy disk.

Batch command files are provided (ACS.BAT, DCM, BAT, and RES.BAT) for running Lake Shore software from the root directory. A pre-configured GPIB.COM file (the National Instruments GPIB driver file) is copied to the root directory.

Since DOSSHELL is no longer included, the ACS7000 software must be run from DOS. At the C prompt, type "cd acs." Once the prompt displays the appropriate directory, type "ACS7000." To return to the main C prompt, type "cd\."

Printouts from the ACS7000 program should be compatible with most popular printers. User changes to the source code will require Microsoft BASIC Version 7.1 or higher. Any changes made to the ACS7000 source code are at the user's risk. Lake Shore will assume no responsibility for damage or errors incurred as result of any changes made to the source code.

8.5 Connector Definitions

Table 8-1 gives the pin definitions for the 10-pin connector on the top of the AC/DC Resistance Sample Probe. Table 8-2 gives the interconnections in the AC/DC Resistance Cable.

Table 8-1. AC/DC Resistance Probe Pin Definition

Lead Identification		Pin Connector Identification
Sensor:	V+	A
	V–	B
	I–	C
	I+	J
Sample:	V+	H
	V–	D
	I–	F
	I+	K

Table 8-2. AC/DC Resistance Cable Definition

AC 10 PIN	A BNC	B BNC	P BNC	SENSOR 8 PIN
A				E
B				D
C				B
J				A
D		C		
E		S		
F			S	
K			C	
G	S			
H	C			

For the BNC connectors, S denotes the shield and C denotes the center conductor.

8.6 RES7000 Program Description

RES7000 is the data acquisition and analysis software which automatically controls all system functions for the AC/DC Resistance Option. The software is structured in the same menu driven, easy to use format as the ACS7000 and DCM7000 software. The software features real-time feedback in either tabular or graphical format, and an analysis package for post-processing of previously recorded data.

Since DOSSHELL is no longer included, the RES7000 software must be run from DOS. At the C prompt, type "cd res." Once the prompt displays the appropriate directory, type "RES7000." To return to the main C prompt, type "cd\." To enter the collection mode, the instruments must be turned on first. The analysis mode can be run with the instruments off.

CAUTION

If for any reason an instrument has to be turned off after the program has initialized the instruments, it will be necessary to restart the RES7000 program.

8.6.1 Menu Breakdown and Option Description

The following information consists of three major portions:

- A flowchart of menu and sub-menu selections.
- A menu and sub-menu breakdown including a brief functional description of each option.
- An alphabetical listing of each of the menu and sub-menu options. Each entry describes in detail where that option is found and how it is used.

5.1.2 ACS.DAT File

In order to run ACS, the file ACS.DAT must reside on the same directory. ACS.DAT contains configuration information specific to each 7000 Series AC Susceptometer/Magnetometer. The contents of the ACS.DAT file consists of the following 34 lines. In normal usage, all necessary changes to this file can be made from within the ACS7000 program using the Edit command.

Line 1 : Seven entries separated by a comma:

1. "A6" (with quotation marks).
2. Superconducting Magnet Calibration Constant: ratio of the H field (A/m) to the current (A). Set to –1 if no magnet is installed.
3. Primary Coil Calibration Constant: ratio of the H field (A/m) to the current (A).
4. AC Susceptibility Calibration Coefficient.
5. Magnet Power Supply (MPS) Compliance Voltage. Normally set to 5.
6. Maximum allowed output current (A) for MPS. Normally set to 48 for 1 tesla magnet and 75 for 5 tesla magnet.
7. System serial number in quotation marks.

Lines 2 thru 33: These entries make up the 32 default frequencies and phases for the system operation. The values have been qualified at Lake Shore and used in the Quality Control (QC) testing of the system. The phase angle for each of the 32 frequencies has been determined using a no-loss sample ($\chi'' = 0$). These phases should be periodically checked to verify consistency. There are two entries per line separated by a comma. Each line consists of he following:

1. Frequency – an integer value consistent with system operating limits.
2. Corresponding Phase Angle – to the nearest tenth degree.

CAUTION

Any change in the frequency from the default values should also include a determination of the proper phase angle to be used with that specific frequency.

Line 34: These entries specify how the superconducting magnet is to be ramped in current. Four ranges are specified and for each range the ramp rate (A/sec) and upper current limit (A) are required. There are eight entries separated by a comma.

1. Ramp rate for Range 1.
2. Upper current limit for Range 1.
3. Ramp rate for Range 2.
4. Upper current limit for Range 2.
5. Ramp rate for Range 3.
6. Upper current limit for Range 3.
7. Ramp rate for Range 4.
8. Upper current limit for Range 4.

5.1.3 File Conventions

During data acquisition, two files will be created and stored to the ACS directory. These files will have the same name but will have different extensions, .DAT and .CFG. The first contains the actual measurement data, while the second contains information concerning the experimental setup. Both files are required for the data analysis routines.

8.4 Resistance Measurements

The resistance measurements require that the cabling attached to the rear of the Dewar Console be modified as shown in Figure 8-3. During susceptibility measurements, the four connections at the rear of the Dewar Console are made to the A, B, P, and Temp connectors labeled χ/m. To perform resistance measurements, these four connectors should be moved down and reattached to the corresponding connections labeled ohm (Ω).

The AC/DC Resistance Cable can now be connected. This cable connects the resistance sample probe with the Ω connections, which in turn are connected back to the Instrument Console. Feed the end of the AC/DC Resistance Cable through the upper circular cutout on left-hand side of the Dewar Console. Connections for A, B, P, and Temp should be made to the corresponding connection on the inside of the panel.

The front panel of the Lock-in Amplifier should have the voltage selection set for reading A-B as is used for susceptibility measurements. The default value for the phase setting is 0 degrees and for most applications this should not be varied. Data is logged and recorded using the RES7000 Software described in Paragraph 8.6.

When making resistance measurements, it is important to remember that the ACS Control Unit has a compliance voltage of 5 VDC. If the combination of sample resistance and current requires a voltage higher than 5 VDC, a message will appear on the screen. The user will then have the opportunity to continue logging data or stop the experiment. Example compliance situations would be 100 Ω sample at 0.05 A = 5 V, 10 Ω at 0.5 A = 5 V, etc.

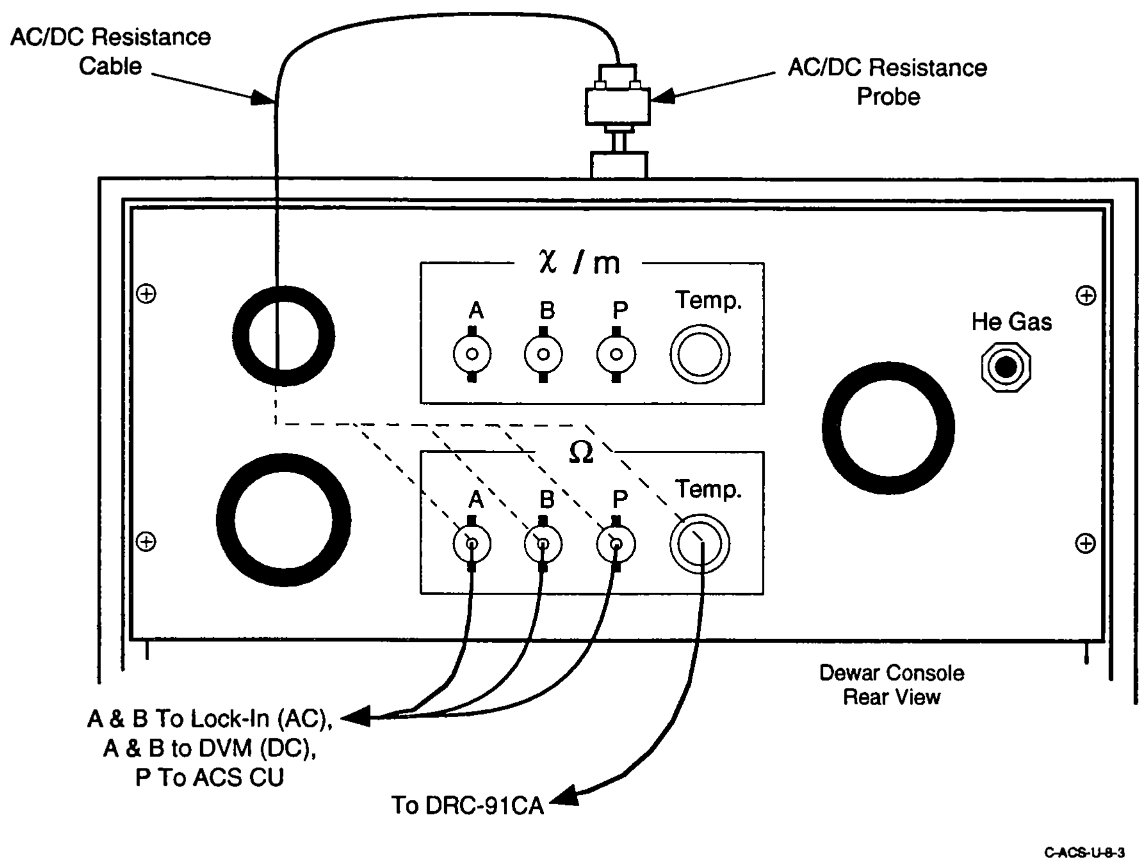


Figure 8-3. Dewar Console Resistance Connections

5.2 PRINCIPLES OF OPERATION

The ACS7000 Software Package is designed to control the 7000 Series instrumentation (DRC-91CA Temperature Controller, ACS Control Unit, 610/612 Magnet Power Supply, and Lock-In Amplifier) in both manual and automatic modes of operation. Instrument functions are accessible through the keyboard. In addition, ACS logs and records the voltage/temperature measurements during automatic data acquisition.

5.2.1 Autorange: Lock-in Amplifier

During automatic operation, ACS has a built in autoranging routine for the Lock-in Amplifier which automatically adjusts the sensitivity range. This autorange feature refers to specific control software contained in ACS and does not refer to any autorange feature which may be present in the Lock-in Amplifier itself.

The response of a Lock-in Amplifier to a signal is not immediate and depends considerably on the time constant setting, noise environment, operation frequency, and also on whether or not an overload condition has been encountered. A properly designed autoranging feature must take into account these conditions in order to guarantee that the signal is measured on the proper sensitivity range and also that the instrument has properly stabilized. As a result, the measurement process may appear somewhat slow but this is necessary for proper performance.

Whenever a reading of the Lock-in Amplifier is to be recorded, ACS automatically goes through the following autoranging routine:

1. Five second settling period to allow for initial stabilization of any signal or parameter change.
2. Ten time constant settling period for final signal stabilization.
3. The Lock-in Amplifier is read and checked for overload status and proper sensitivity range. If everything is acceptable, step 4 is executed. If not, appropriate changes are made in the Lock-in Amplifier parameters. This may involve either sensitivity range changes or changes in the dynamic reserve (depending upon the overload status). Control then passes back to step 1.
4. Read and record the voltage reading.
5. Exit autorange.

ACS has a default time constant of 1 second for the Lock-in Amplifier. This means that the Lock-in Amplifier can not be expected to respond any faster than 15 seconds to a change in setting or signal. When changing the time constant setting to longer time periods, keep in mind step 2 above and the effect it may have on the total data acquisition time.

NOTE

ACS automatically remembers the range setting for the last measurement made for each phase in each coil position. Therefore, lengthy searches for the proper sensitivity range are avoided, except possibly for the very first reading. The above discussion is a somewhat simplified discussion of the autorange feature and the exact details are more complicated but not presented here.

By default, the autoranging routine is active. However, the autorange feature may be turned off using ACS (see Sequence Sub-menu of Experimental Menu). When the autorange feature is off, the sensitivity range of the Lock-in Amplifier will remain fixed at whatever range is set when automatic data acquisition is started. A 6 time constant settling period is allowed whenever a measurement is to be made with the Lock-in Amplifier.

When the autorange is off, the sensitivity setting of the Lock-in Amplifier should be such that no overload conditions are encountered during data acquisition. If the Lock-in Amplifier does go into an overload, there is no guarantee that 6 time constants is a sufficient time to allow for signal stabilization. This will require some prior knowledge of the susceptibility behavior of the material being measured and will limit the measurement flexibility of the 7000 Series ACS. However, operating with the autorange off may be desirable for certain circumstances.

The probe should be adjusted so the upper mark is just visible above the sample seal assembly. Positioning is not as critical as in the case of making susceptibility measurements. As with the susceptibility measurements, the resistance sample probe is designed to operate with 500 to 1000 microns of helium exchange gas present in the sample vacuum space.

8.2.2 Sample Card

The sample card is used to mount the resistance sample. See Figure 8-2. The sample card is nominally 0.2 inch wide x 1.1 inch long with a four pin plug located at one end. The top surface of the card has four soldering pads for connecting leads to the sample. The area between the bonding pads, ≈0.2 inch x 0.5 inch, is the region where the sample is to be mounted. When looking at the top surface of the sample card with the four pin plug at the top, the soldering pads on the left edge (labeled 1 and 3) are the current connections and those on the right edge (labeled 2 and 4) are the voltage connections.

The following procedure is recommended for mounting a sample to the sample card:

1. Attach four leads to the sample. The exact method used to contact the sample will vary widely depending on what is being investigated. Possibilities include spot welding, silver filled epoxy, or soldering. The best technique to be used must ultimately be determined by the user.
2. Position the sample on the sample card between the four soldering pads. Even though the leads to the sample may fully support the sample, tying the sample in place using fine nylon thread (dental floss) is recommended in most cases.
3. Solder the current and voltage leads to the four terminal pads on the sample card.
4. Turn the sample card on edge, insert the card into the cut out slot on the lower end of the sample probe, and plug the card into the mating socket on the sample probe. The terminal pads 2 and 4 (voltage connections) should be down when inserting the card into the sample probe socket.
5. Check to make sure that the sample and connecting leads do not protrude outside of the stainless tube. Also check to make sure the leads are not touching or shorting to the probe.

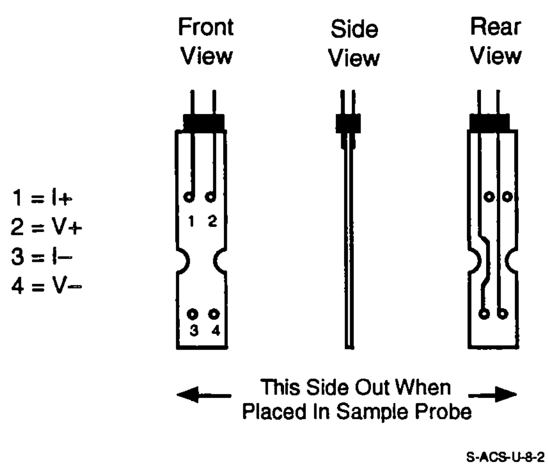


Figure 8-2. Typical Resistance Sample Card

8.3 Constant Voltage or Constant Current

The selection between constant voltage operation and constant current operation depends on the sample characteristics. If the sample resistance varies orders of magnitude with temperature, a constant voltage operation should be used to maintain measurement resolution and avoid possible compliance limit problems as the temperature is varied. For samples which may have current dependent effects (for example, self-heating due to high contact resistance, superconductors, etc.) then constant current operation may be required. In situations such as superconductors, where V=0 below the transition temperature, constant voltage operation can not be maintained.

When doing an auto run only, the system sets the lock-in amplifier to default values for dynamic reserve and sensitivity. When beginning a new run, the system retakes the first data point to ensure the data is valid with the new values for dynamic reserve and sensitivity.

5.2.2 AC Susceptibility Measurement Sequences

There are four basic susceptibility measurement sequences which are allowed in ACS. These are listed below with an approximate time required to complete each measurement sequence when the autorange routine is active. Note the time given assumes a 1 second time constant for the Lock-in Amplifier and only one loop through the autoranging routine. This is a good approximation for samples where the susceptibility is not varying dramatically and hence, may require numerous autoranging steps.

1. Dual Phase/Sample Movement: Data is logged at the Lock-in Amplifier phase settings of 0° and 90° and the output voltage is read with the sample in first the bottom coil and then the top coil. Approximately 80 seconds are required to complete this measurement sequence (60 seconds if no DC field exists).
2. Dual Phase/No Sample Movement: Data is logged at the Lock-in Amplifier phase settings of 0° and 90°. The sample remains in a fixed position in either the top or bottom coil. Approximately 30 seconds are required to complete this measurement sequence.
3. Single Phase/Sample Movement: Data is logged at one fixed phase setting on the Lock-in Amplifier. The output voltage is read with the sample first in the bottom coil and then the top coil. Approximately 50 seconds are required to complete this measurement sequence (40 seconds if no DC field exists).
4. Single Phase/No Sample Movement: Data is logged at one fixed phase setting on the Lock-in Amplifier. The sample remains in a fixed position in either the top or bottom coil. Approximately 15 seconds are required to complete this measurement sequence.

In addition, multiple frequencies/fields (e.g., Array) may be specified and data will then be logged at each frequency/field combination during the run. Note that this can significantly increase the time for a run to be completed. In general, the minimum time (t) in seconds required to complete a sequence can be expressed as follows:

$$t = [6T_C + A\,(5 + 4T_C)]\,(P)\,(M) + 4[m-1] + 20[m-1]\,D$$

where T_C = time constant setting of Lock-in Amplifier
A = 1 for autorange on 0 for autorange off
P = 2 for dual phase acquisition
1 for single phase acquisition
M = 2 for sample movement on
1 for sample movement off
D = 1 DC field exists
0 no DC field

If multiple fields or frequencies are specified, the time derived from the equation above must be increased accordingly. The time required to complete a measurement sequence can be reduced considerably by turning off the autoranging feature. However, note the limitations discussed above in operating with the autorange feature disabled.

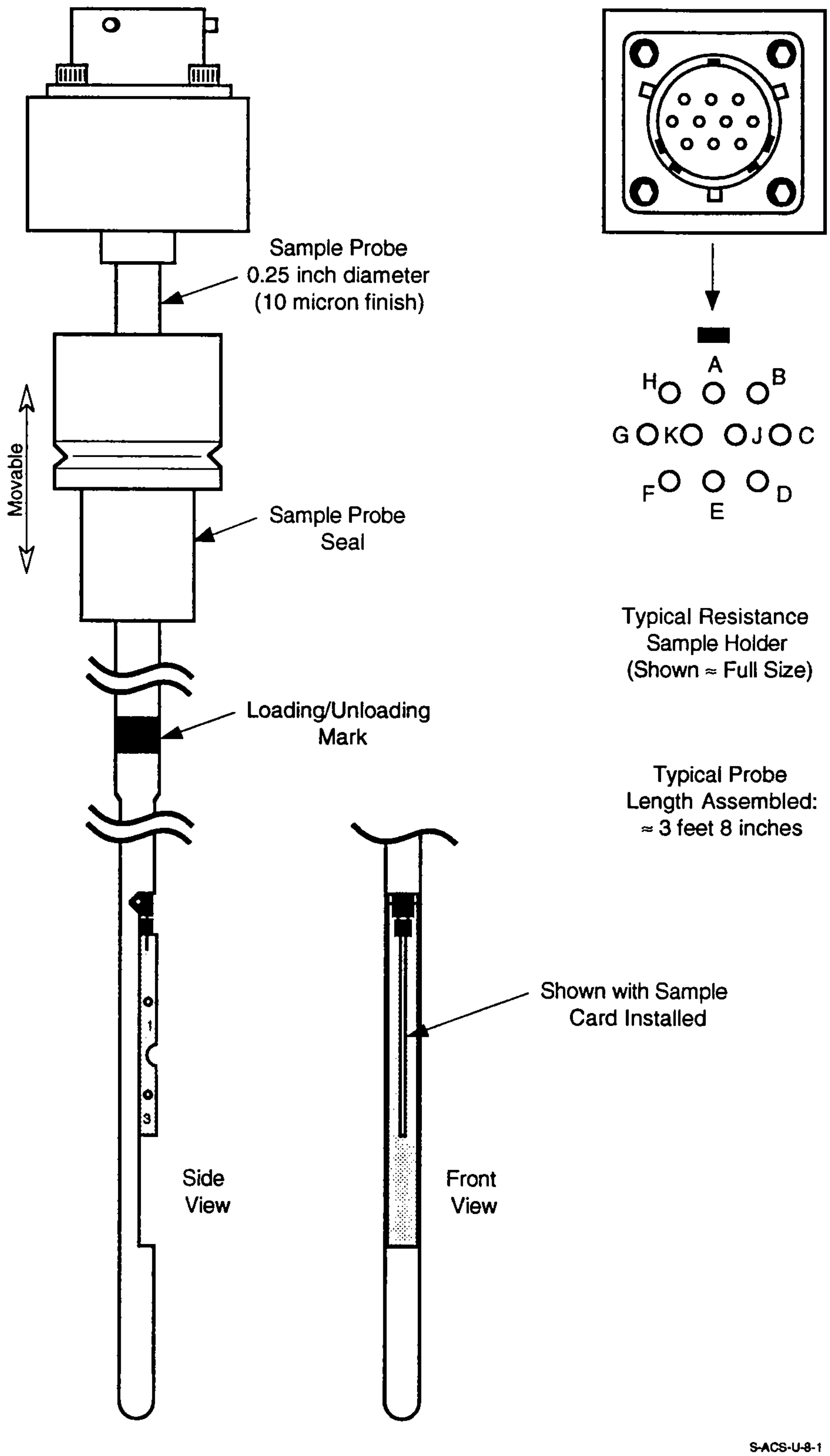


Figure 8-1. Typical Resistance Sample Probe – Exploded View

5.2.3 Temperature Control

Temperature control and the specification of the desired temperature data points are accessed through ACS. There are three ways in which the control can be maintained:

1. Fixed Point: With fixed point acquisition, individual temperature data points are entered either incrementally or one at a time. The susceptometer automatically stabilizes and controls at each temperature point before logging any susceptibility data using the specified measurement sequence. The temperature control proceeds as follows:

   a. Warm at approximately 3 K per minute to desired temperature.

   b. Depending on temperature, a wait period ranging from 2 to 7 minutes (or as specified in Wait_times) is commenced to allow sample temperature to initially stabilize. The temperature drift of system in terms of K per minute is monitored.

   c. After wait period, continue to monitor temperature stability until it decreases below 0.1 K per minute. (The 0.1 K per minute is adjustable in Wait_times.)

   d. When temperature drift is less than 0.1 K per minute, data is logged according to measurement sequence defined.

   e. After data acquisition is complete, proceed to next temperature data point according to step **a** above.

2. Temperature Sweep: The temperature is ramped up continuously at a user input rate from 0.1 to 3 K per minute. The sweep rate is nominal and some deviation should be expected during actual operation. The temperature sweep is suspended momentarily if the susceptibility is varying rapidly and the autorange routine is changing sensitivity ranges. This will allow the signal to settle on one range of the Lock-in Amplifier and avoids the problems which may be created if the autoranging routine is "chasing" a rapidly changing signal.

   If only one sweep rate is desired over the full temperature range, then only one sweep range needs to be specified. If different sweep rates are desired over different temperature ranges, up to three different temperature sweeps can be specified. For each range, the lower and upper temperature limit and the desired sweep rate in K per minute are input. The upper limit of the first range is assumed to be the lower limit of the second range and so on.

   To aid in setting up the experiment, the program displays the estimated number of data points which will be recorded for each range and the nominal temperature spacing between the data points. A minimum allowed temperature spacing between data points is also indicated. The minimum spacing is based on the defined measurement sequence and the specified sweep rate. Data can not be logged any faster than the measurement sequence. The program default is that data is logged continuously, i.e., a new measurement sequence is started immediately upon completion of the old sequence. The program allows modifying the number of data points by either altering the sweep rate or increasing the temperature spacing between data points. An increase in the temperature spacing simply adds a wait period between measurement sequences.

   Note that the number of data points and their spacing depends on the specified measurement sequence. If the measurement sequence is redefined after specifying the sweep parameters, the number of data points and their spacing will change. A good rule is to always set the sweep after specifying the measurement sequence. Some care must be exercised in setting up a sweep experiment to avoid accumulating an unwieldy number of data points. The feedback which is provided in ACS should serve as a good guide to the outcome of the experiment.

   In sweep mode, the temperature accuracy specification may degrade since, in any sweep situation, thermal stability and uniformity is not present. The magnitude of the error will depend on the sweep rate and the thermal properties of the sample being measured.

   Data acquisition using multiple fields and frequencies are not allowed in sweep mode.

3. Drift: No active temperature control is maintained. Data is simply logged continuously at the time interval input from the keyboard until the cancel key is pressed. Caution must be exercised to avoid accumulating an unwieldy number of data points.

Sample Card – The sample card is used to mount the resistance sample. The sample card is nominally 0.2 inch wide x 1.1 inch long with a four pin plug located at one end. The top surface of the card has four soldering pads for connecting leads to the sample. Details on the sample card are provided in Paragraph 8.2.2 and Figure 8-2.

AC/DC Resistance Cable – For AC/DC measurements, this cable connects the sample probe to the DRC-91CA Temperature Controller (B input, curve 8) for the temperature measurement and connects the sample probe to either the Lock-in detector or the Keithley Model 182LS Voltmeter for the voltage measurement and ACS Control Unit for the AC/DC current excitation. The AC/DC Resistance output is defined as voltage divided by current (V/I). Details on the cable assembly are provided in Paragraph 8.5.

RES7000 Software – The control software used to automatically log data for the resistance measurement is called RES7000. Many of the features are similar to the ACS7000 AC Susceptibility Software. Details on the RES7000 Software are provided in Paragraph 8.6.

8.1 Specifications

AC/DC Resistance Option specifications are as follows:

Resistance Probe: Configured for four-lead measurements.

AC Resistance Current:
Range: 10 μA to 250 mA, 5 Volt Compliance
Frequency: 1 Hz to 1 kHz, 1 Hz selectability,
1 kHz to 10 kHz, 10 Hz selectability
Resolution: Better then 0.1% of setting

AC Resistance Accuracy: 3%

DC Resistance Current:
Range: ±0.1 μA to ±500 mA, 5 Volt Compliance
Resolution: Better then 0.1% of setting

DC Resistance Accuracy: 1%

Temperature:
Range: <4.2 K to 325 K
Accuracy: ±0.2 K or ±0.5% of T, whichever is greater.
Stability: ±0.1 K

Software: Includes data acquisition, control, and analysis routines for automated measurement of AC or DC resistance. Also features real-time feedback in graphical or tabular formats.

8.2 Hardware Description and Operation

The overall operation of the system hardware is identical to what is outlined in Chapter 3 of this manual. Familiarity with 7000 Series System Susceptometer/Magnetometer operation is assumed.

8.2.1 Sample Probe Assembly

Operation of the resistance sample probe is very similar to the susceptometer sample probe. Both probes consist of a long polished stainless steel tube with a movable sample probe seal to allow inserting the sample into the temperature controlled region of the cryostat. See Figure 8-1. Although the procedure used to insert and remove the resistance sample probe is identical to the susceptometer probe, there are several important differences.

Electrical connections to the sample and probe temperature sensor are made through the electrical connection on top of the probe. The probe is not attached to the sample movement assembly. The lower end of the probe has a cut out slot and socket for mounting the sample card (Figure 8-2).

In addition to the loading and unloading mark near the lower end of the sample probe, there is a similar mark near the upper end of the probe. This upper mark is to be used to position the sample in the temperature controlled region of the cryostat during data acquisition.

5.2.4 Sample Positioning

Once the sample is loaded and attached to the motor control the sample must be properly positioned or centered in one of the secondary coils. This is a simple matter of moving the sample up and down and finding the location where the Lock-in Amplifier gives a peak (either maximum or minimum) signal output. The software provides for course and fine motor movement and then triggering the computer as to whether the sample was positioned in the top or bottom coil. The exact position of the sample probe will vary slightly depending on the sample size. The following procedure is recommended for positioning the sample:

1. Set Lock-in Amplifier phase to 90 degrees. Recall from Chapter 1 that in-phase component of signal is approximately at phase setting of 90 degrees on Lock-in Amplifier. With this setting, a sample with a positive susceptibility will have a positive signal in top secondary coil and a negative signal in bottom secondary.
2. Move sample probe to highest position. Stops are automatically built in to avoid moving sample probe too high or too low.
3. Using course down adjustment, lower sample probe one step at a time and monitor Lock-in Amplifier voltage. As sample goes through top coil, a peak in signal should be detected. Continue to move sample downward. When sample is between two coils a zero output should be detected, and then when sample moves into bottom coil a peak in signal should occur of opposite sign as that in top coil (any deviation from equal magnitudes is a result of offset voltage). Adjustments in field amplitude or frequency may be necessary so that signal level is large enough to be detected.
4. Move sample back to either top or bottom coil and using fine adjustment, position sample so a peak in signal is detected.
5. Select appropriate software option as to whether sample was positioned in top or bottom coil.

Samples with a large signal output as compared with the zero offset are very straightforward to adjust and in most instances peak positive and peak negative signals are encountered in the top or bottom coil. However, some care must be exercised when the sample signal approaches the offset voltage of the coil assembly. Recall the discussion leading to Equation 1.4. If the offset voltage is 5 µV and the sample signal is 2 µV, the Lock-in Amplifier reads 7 µV in the top coil and 3 µV in the bottom coil. Although positioning the sample still involves looking for the maximum or minimum in voltage, both are positive in this circumstance.

5.2.4.1 Samples With Very Low Signals

Some samples require special attention to ensure that usable signals are produced. Samples with extremely low signal levels (<1 µV) are sometimes difficult to position by observing the output voltage on the Lock-in Amplifier. The following procedure is recommended for positioning these samples.

1. Position sample probe in bottom coil using a small sample which has a large output signal. At Lake Shore we use a 1/16 inch diameter steel ball bearing.
2. Using an indelible marker, make a reference mark on top of sample rod to locate position of rod. A convenient point to mark and use for alignment is top surface of sample probe seal assembly. Be sure that sample probe seal assembly is seated in its proper position in cryostat load seal.
3. Determine nominal length of sample to be measured and load sample into susceptometer.
4. Move sample rod to location determined in step 1 above.
5. Move sample rod down a distance equal to one-half length of sample. Note:

   coarse steps = 0.254 cm = 0.1 inch
   fine steps = 0.0254 cm = 0.01 inch
6. Sample should now be centered in bottom coil and experimental run can be initiated.

CHAPTER 8
RES7000 SOFTWARE OPERATION

8.0 GENERAL

The RES7000 AC/DC Resistance Measuring Option (Model 700RES) adds to the capability of the 7000 Series Susceptometer/ Magnetometer system enabling determinations of AC and/or DC resistance versus temperature, and applied DC field. The resistivity probe is configured for four lead sample measurements and is inserted into the same temperature controlled space as the susceptibility sample probe. The current source in the ACS Control Unit is used to excite the sample. The system phase-sensitive detector is used for the AC voltage measurements, and a modified Keithley digital voltmeter capable of nanovolt resolution is used for the DC measurement. The current source has a user selectable AC current range from 10 microamps to 250 milliamps, at frequencies ranging from 1 Hz to 10 kHz (1 Hz selectability below 1 kHz, 10 Hz selectability above). The DC current range extends from 0.1 μAmps to 500 mAmps.

If this option is used with the models with a magnet, AC or DC resistance can be measured as a function of applied magnetic field (±1 tesla for the Models 7121 and 7221, ±5 tesla for the Model 7225, and ±9 tesla for the Model 7229), enabling magneto-resistance studies.

As in the 7000 Series Susceptometer/Magnetometer Systems, data acquisition and control software automatically records AC or DC resistance data and controls all system functions. Features of the Model 700RES Option include the following:

Temperature Control – The 700RES option is supplied with data acquisition and analysis software. The software is structured in the same menu driven, easy to use format as the ACS7000 and DCM7000 software, and utilizes the same temperature control routines. Therefore, resistance measurements can be made at stable, discrete temperatures input by the user, or while the temperature is automatically ramped from one value to another, for more rapid characterization. For accurate temperature determinations, a calibrated diode thermometer in included in the resistance probe located immediately next to the sample being measured.

AC Resistance: Variable Amplitude and Frequency The amplitude and frequency of the AC excitation current can be varied, and provision is made in the control software for recording data using multiple currents.

DC Resistance: Variable Amplitude and Current Reversal – The amplitude of the DC excitation current can be varied, and current reversal is automatically performed for each measurement point so that thermal EMFs generated in the connecting leads are negated.

Current/Voltage Characteristics: Transport J_C – AC or DC Current/Voltage curves (i.e., IV-curves) can be automatically recorded as a function of temperature, or magnetic field (Models 7121, 7221, 7225, and 7229) using discrete temperature points, or field points. This feature is ideally suited for the study of high T_c superconductors. For example, as the current is increased, a finite voltage drop across the sample would indicate that the sample's critical current density has been exceeded.

Four accessories are supplied with this option: (1) Resistance Sample Probe, (2) Sample Card, (3) AC/DC Resistance Cable, and (4) RES7000 Software.

Resistance Sample Probe – A resistance sample probe is supplied for use in the AC/DC Resistance measurement. The sample probe has a moveable seal and is loaded into the 7000 Series similar to the susceptibility sample probe. The probe is designed to allow for mounting one resistivity sample and making a four lead measurement on that sample. The temperature is monitored with a calibrated silicon diode temperature sensor mounted next to the sample. Electrical connections are made to both the sample and temperature sensor through a connector at the top of the probe. Details on the sample probe are provided in Paragraph 8.2.1 and Figure 8-1.

5.2.4.2 Auto-Positioning Of Samples

A feature for automatically positioning the sample in the bottom coil is available in the position option discussed below. The positioning is done by first moving the sample to the lowest position and then incrementing the sample upward through the bottom coil while monitoring the Lock-in Amplifier voltage. After passing through the bottom coil, the recorded measurements are used to automatically locate the sample in the bottom coil.

The auto-positioning only works reliably for samples which have relatively large output levels that give a definite peak voltage. If the peak voltage is <3 µV or less than 10% of the Lock-in Amplifier sensitivity range, a warning message is displayed to indicate either manual positioning or use of the procedure discussed for low level signals in Paragraph 5.2.4.1 is required.

An operator familiar with the 7000 Series can probably position a sample faster manually than using the auto-positioning function.

5.2.5 Adjustable Parameters

Instrument parameters are adjustable from the keyboard during manual operation with ACS. During automatic operation, the temperature control has no user adjustable parameters. However, there is flexibility allowed in changing the Lock-in Amplifier parameters from the default values in which ACS initializes the instruments. The major parameter of interest is probably the time constant which is set to the default value of 1 second. To change a parameter from the default value, simply change the parameter through the software menu and proceed with the automatic data acquisition. The only Lock-in Amplifier parameters which the software modifies during data acquisition are the following: sensitivity setting, phase angle, and dynamic reserve.

5.2.6 Addenda Data

The addenda is used to describe the empty sample holder, support rod, and anything else which may generate a background signal during a susceptibility measurement. The capability for subtracting this background signal from the data recorded with a sample present is built into the software package.

The addenda data should be recorded using fixed-point dual-phase data acquisition with sample movement. Twenty to thirty data points recorded from 4.2 to 300 K with spacing ranging from 1 K at the lower end to 25 K spacing at the higher temperatures should be sufficient data for the addenda. A special option in the data analysis program processes the addenda data and stores the temperature/voltage data to a file for later use. The actual voltage stored is a reduced voltage, v/fH. Note that there will be a reduced voltage corresponding to both 0° and 90° for both the bottom and top coil positions.

When the addenda file is recalled for use with a data file, the addenda voltages are subtracted from the measured sample voltages using the following steps:

1. Check temperature T at which sample data was recorded.
2. Use temperature/voltage data in addenda file to determine addenda voltage at temperature T. A simple linear interpolation is performed with data in addenda file.
3. Scale up addenda voltage according measurement frequency and field used in measuring sample.
4. Subtract addenda voltage from actual sample voltage data. The subtraction is done for each component of voltage measured at 0° or 90° and top and bottom coil position. If single phase data acquisition is performed at a phase angle , appropriate addenda voltage component at an angle is subtracted.
5. Proceed with calculation of susceptibility as outlined above.

The primary value of the addenda is to correct for contributions arising from the empty sample holder and support rod. In most circumstances the signal from the sample holder and support rod will be small (generally <1 µV at 80 A/m, 500 Hz) with respect to the sample signal and any addenda correction may be ignored.

View:

Analysis Menu.

This enables you to specify what processed data is viewed on the screen. When selected, the following sub-menu will be displayed.

Tabular: This is an on/off toggle. When on, the processed data will be displayed on the screen in the following format.

Moment:	m vs H
Volume Magnetism:	m(v) vs H
Mass Magnetism:	m(m) vs H

You can scroll through the data using the Home/End keys or the PgUp/PgDn keys. ESC to exit.

Graphical: This is an on/off toggle. When on, the processed data will be displayed on the screen in the following format.

Moment:	m vs H
Volume Magnetism:	m(v) vs H
Mass Magnetism:	m(m) vs H

Scaling is fully automated. Press ESC to exit. Also, you cannot "View" raw data.

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through all available options in your data set. When done, a window will display the selections which have been made. ESC to exit. Also, you cannot "View" raw data.

Vol:

Sample sub-menu of Analysis Menu and Sample sub-menu of Collection Menu

Selection of this specifies that volume magnetization is to be computed. When selected, you will be prompted for a sample volume. Input a value and press Enter.

Zero_Offset:

MPS sub-menu of H Field sub-menu of Experimental Menu

This feature is used to adjust the current output of the MPS to account for zero drifts in the power supply output due to fluctuations in the operating environment (e.g., room temperature variations). The magnitude of these zero drifts are <±1 gauss and utilization of this feature reduces this to the tenth gauss level. The "zeroing" is accomplished automatically upon selection.

When using this feature, the output current (at zero current) is read (i.e., I_0) and the current is then set to $-I_0$. In addition, any field that is then set using **MPS_field** is corrected by this I_0. This feature is particularly useful for operation at low DC fields and also to obtain the best accuracy in the resultant DC field.

In a strict sense, subtracting the addenda from the sample data should not only compensate for the empty sample holder and support rod, but also for any "fixed" zero offset which the sample movement is also designed to eliminate (refer to Paragraph 1.7). In this situation, the need for sample movement would be unnecessary. In practice, however, the sample movement will produce a more accurate result. The addenda file will not compensate for any short or long term zero offset drifts in the system, but assumes everything is constant from one run to the next. Sample movement offers a point by point correction and requires stability only over the time period required to make a single measurement. For this reason, when the addenda correction is applied for no sample movement, the correction should be only viewed as a first order type correction for zero offsets. In addition, the zero offset may have a slight frequency dependence and not scale precisely with changes in frequency.

Note that in most instances the zero offset voltage, v_o, is greater than the signal from the empty sample holder. This emphasizes the importance of sample movement if low level precision measurements are required.

The addenda data may also be recorded and processed using applied DC fields and the field profile option. The addenda correction then involves a two dimensional interpolation in both H_{dc} and T. When setting up to record the initial addenda data, the specified range for H_{dc} should be large enough to span the field range over which the sample will be measured.

When the Series 7000 System is equipped with a superconducting magnet, the data used to create an addenda file must be recorded at multiple DC fields (≥2) and multiple temperatures (≥2). The range of the fields and temperatures should be slightly greater than the range of interest.

If the 7000 Series System has no superconducting magnet, the addenda file is created with data logged only at one field; i.e., $H_{dc} = 0$. Multiple temperatures (≥2) must be used.

5.2.7 Field Control

Field control and the specification of the desired field points at which data will be recorded is also accessed through ACS. There are several field control options available through the software.

A. Constant Field: The field can be set and maintained at a single value throughout data acquisition. The field will be turned off at the completion of an automated data acquisition run (e.g., as a function of temperature), or can be changed or turned off by the operator.

B. Field Profiles: Field profiles require fixed point temperature control and cannot be performed in temperature sweep or drift modes of operation.

   1. Field Table: There are provisions in the software for generating a DC field table for which data will be recorded at each point. The individual field points can be entered incrementally or one at a time. The susceptometer/magnetometer automatically steps through each value in the table in order of entry, verifies that it is set to the correct value, and records AC susceptibility data at each point. The field control process proceeds as follows:

      a. The output current of the MPS is automatically ramped to a user defined value, $I_{set} = H_{set}/\beta_2$ where H_{set} is the field selected by the user, and β_2 is the field to current conversion factor for the superconducting magnet.

      b. The current output of the MPS is continually monitored. Once the current is within ±0.1 amps of I_{set}, a 5 second wait is initiated.

      c. At the completion of this 5 second wait period, an additional user defined WAIT is initiated to allow the field to stabilize and reach equilibrium. This WAIT is set in the ACS software (refer to Time_dwell). For most applications, the default values in the software are sufficient for field stabilization. For applications requiring the maximum field stability, the WAIT should be set to ≥30 seconds.

      d. The AC susceptibility measurement is then performed according to the defined measurement sequence.

      e. After data acquisition is complete, proceed to the next field value in the table according to step **a.** above.

Top:

Position sub-menu of Collection Menu.

This is a top coil toggle which allows you to specify that the sample is positioned in the top secondary coil.

Tuning:

Lock-In sub-menu of Collection Menu.

This allows you to specify what parameter is displayed on the tuning display of the lock-in amplifier. When selected, the following sub-menu will be displayed.

Phase: When selected, the display indicates the phase shift introduced either by the software or the user.

Osc Freq: When selected, the display will indicate the set oscillator frequency.

Level: When selected, the display will indicate the amplitude of the oscillator frequency.

Filter Freq: When selected, the display will indicate the frequency to which the input filter (BAND PASS, LOW PASS, or NOTCH) is tuned.

Ref Freq: When selected, the display will indicate the reference frequency.

The default display condition is **Ref Freq.**

Up:

Constants sub-menu of Lock-In sub-menu of Collection Menu

Increases time constant setting one unit.

1 Up Coarse:

Position sub-menu of Collection Menu.

Selection of this will move the sample up 0.1 inch (0.254 cm) from its current position.

1 Up Fine:

Position sub-menu of Collection Menu.

Selection of this will move the sample up 0.01 inch (0.0254 cm) from its current position.

Units:

Main Menu.

This is simply a SI/cgs units toggle.

5.2.8 Data Processing ACS

ACS processes the voltage/temperature data which are recorded and outputs the susceptibility results. Figure 5-1 demonstrates how the measured data flows through ACS and relates back to the discussion in Chapter 1.

The output can be either the volume, mass, molar, arbitrary units, or raw. The volume susceptibility requires the volume of the sample to be input. The mass susceptibility allows for two conditions as discussed in Paragraph 1.11. If the demagnetization factor is zero, only the mass of the sample is required for determining the mass or molar susceptibility. However, if a non-zero demagnetization factor is used, both the mass of the sample and the density must be input.

The method for processing the temperature measurements needs some clarification. During data acquisition, the temperature is read in conjunction with each Lock-in Amplifier reading. For example, in dual phase data acquisition with sample movement, four temperatures are recorded since the Lock-in Amplifier is read four times in a measurement sequence. Similarly, for a single phase, no sample movement measurement, the Lock-in Amplifier is only read once so only one temperature measurement is recorded. Each measurement sequence discussed in Paragraph 5.2.2 defines one data point. The temperature for that data point is determined by the average of the temperature readings.

5.2.9 Using Parm_select

The latest version of the ACS7000 software allows the user to enter any equation they wish in order to process the data taken in collection. The equations entered affect the Tabular, Graphical, and Analysis output. In each case where Parm_select appears as a menu item, the information below applies (i.e., under Log, View, Realtime_data, etc., there are no distinctions between each instance of Parm_select.)

Upon choosing Parm_select, the following sub-menu items will appear: X-Axis_equation, Y-Axis_equation, Susceptibility_display, and Data_output, as described in the following paragraphs.

5.2.9.1 X-Axis_equation and Y-Axis_equation Commands

When entering an equation, the following variables must be used in order to correctly process the equation. Parm_select will flash the error message "Unknown Variable" if it encounters a variable it cannot identify. Parm_select is not case-sensitive.

F	Frequency
H	DC Field
HAC	AC Field
N	Harmonic
T	Temperature
TI	Time
χ	Susceptibility

Parm_select also accepts constants, both numerical and in exponential form. Upon entering an equation, Parm_select checks to see if more than one variable has been entered, e.g., T*F. In this case, Parm_select forces the user to decide which variable to "fix." For the example T*F, the user must decide whether to plot all temperatures or all frequencies; both cannot be plotted. Upon choosing the varying parameter, say T, then the table of frequencies will appear and the user will be forced to select which frequency to "fix" F at.

Upon entering an equation, the system will ask the user to "fix" any of the remaining variables if necessary. For example, if the user enters "T" as the equation, and arrays of frequencies and fields exist, a window will appear forcing the user to select at which field and frequency to view all temperatures. Note that upon choosing χ as the equation, no windows will appear because none are necessary. χ is the fixed result of a particular combination of the other parameters (T, F, HAC, etc.)

Signal: Display sub-menu of Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates the signal amplitude in voltage. This is the default setting.

Stab: Reserve sub-menu of Lock-In sub-menu of Collection Menu

Selection of this gives a FLAT mode dynamic reserve of 20 dB.

Magnetization: Sample sub-menu of Analysis Menu and Sample sub-menu of Collection Menu

Allows you to select volume or mass magnetization.

Tabular: View sub-menu of Analysis Menu and Real Time sub-menu of Auto sub-menu of Collection Menu.

The purpose of **Tabular** is the same in both sub-menus. When selected, the processed data will be displayed on the screen in tabular mode according to the defined measurement sequence and the selection made either in Field/Frequency or Parm_select, if applicable.

Temp Ctlr: Collection Menu.

This routine enables you to set, change or modify a number of parameters on the DRC-91CA temperature controller. When selected, the following sub-menu will be displayed.

SetPoint: For selection of control setpoint on temperature controller.

Heater Range: For selection of heater range on temperature controller.

Gain: For selection of gain setting on temperature controller.

Derivative: For selection of rate setting on temperature controller.

Integral: For selection of reset setting on temperature controller.

Auto T: For selection of setpoint that system will then be automatically warmed to at a rate of 3 K per minute and subsequently controlled at.

A more detailed description of each of these functions can be found in preceding or subsequent paragraphs of this manual.

Temp Spec: Experimental Menu.

This routine enables you to define the temperature specification used during automatic data acquisition. When selected, the following sub-menu will be displayed.

List: For selection of individual temperature points used in automated data acquisition.

Incremental: This is for selection of temperatures, entered incrementally, to be used in automated data acquisition.

Edit: Allows the user to delete temperatures from list defined by **Enter List** or **Incremental** and also for changing sweep rates or temperature spacings in sweep mode.

Cancel: Used to cancel a previously entered temperature specification.

A more detailed description of each of these functions is described in previous or subsequent paragraphs of this manual.

5.2.9.2 Susceptibility_display Command

Depending on the equations entered, and if the data is collected in DUAL phase, it may be necessary, when viewing the data Graphically, to see each curve separately. This is because automatic scaling could make the "dominant" curve visible while rendering the features of the second curve indistinguishable. Therefore, Susceptibility_display allows the user to display single and dual phases together or separately, or if desired, the magnitude of the two curves. This feature is useful when viewing an equation such as "T vs. $1/\chi$."

Susceptibility_display also affects Analysis_output and Tabular_output. If data is recorded in Dual Phase and χ' is selected, the double prime phase (χ'') will have a heading but will be blank.

5.2.9.3 Data_output Command

Depending on the available options as dictated by the sample parameters, this option allows the user to choose the type of output they desire: Volume χ, Mass χ, Molar χ, Volume Magnetization, Mass Magnetization, Molar Magnetization, or raw data (in Analysis mode only). In the ACS system, Arbitrary units assigns a default volume of 0.1 cm^3 and calculates Volume χ based on that number.

5.2.10 Miscellaneous Program Information

The ACS7000 program may be paused by pressing **Ctrl - P**. A message will be displayed on the screen stating the program is paused. Press the **Esc** key to resume normal operation.

Screen dumps to a printer or plotter may be done while in Analysis Mode only. The applicable printer driver must be loaded before running the ACS7000 program. More information on available printer drivers may be found by typing **Help Graphics** at the DOS prompt. Once the correct driver has been identified, type **Graphics X** where X is the name of the appropriate printer driver. Then, while running the ACS7000 program in Analysis mode, press **Shift - Print Screen** to send a screen dump to the printer.

For extra insurance during taking data, a **.tmp** file is created by the program. The file name of the .tmp file will be the same as the experiment file name. If power should fail during a data run, the .tmp file will be available to retrieve data. If the data run is successfully completed, the .tmp file will be automatically deleted.

5.3 THE ACS7000 PROGRAM

To start the program, simply type and enter ACS after the prompt C:\>. To enter the collection mode, the instruments must be turned on first. The analysis mode can be run with the instruments off.

CAUTION

If for any reason an instrument has to be turned off after the program has initialized the instruments, it will be necessary to restart the program ACS.

5.3.1 Menu Breakdown And Option Description

The following information consists of three major portions:

- A flowchart of menu and sub-menu selections.
- A menu and sub-menu breakdown including a brief functional description of each option.
- An alphabetical listing of each of the menu and sub-menu options. Each entry describes in detail where that option is found and how it is used.

Sequence (Continued)

Autorange On/Off: This is an on/off toggle for specifying whether or not autoranging is performed on the lock-in amplifier during data acquisition. The default condition is **On**. If the autorange is disabled, data will be recorded on the same range of the lock-in amplifier (namely the range that it is set prior to logging data).

Cycle_Select: Toggle between Full-Cycle (360°) or Half-Cycle (180°). If Half-Cycle, then the data for the other half is not taken but calculated.

Set:

Phase sub-menu of Edit sub-menu of Main Menu

Selection of this allows you to enter the phase. Upon selecting, you will be prompted for an input. Input the value and press Enter.

Setpt_Adjust: Temp Spec sub-menu of Experimental Menu.

This is an on/off toggle for use with fixed point temperature data acquisition. When this option is active, the system temperature control routines are modified such as to make the actual sample temperature closer to the setpoint values input by the user. Activating this option will increase the data acquisition time by approximately a factor of 1.5 to 2.

This option compensates for the fact that the system contains two temperature sensors. The sample temperature sensor is positioned to optimize both the temperature control and minimize the time required for temperature stabilization. When temperatures are input from the keyboard, these values are control temperature values. The actual sample temperature will vary from the control value depending upon temperature range and system status. The Setpt_Adjust option has a feedback control routine to modify the controller setpoint to bring the sample temperature closer to the input value.

Set Point: Temp Ctlr sub-menu of Collection Menu.

This routine enables you to adjust or change the temperature setpoint of the DRC-91CA temperature controller. When selected, the following sub-menu will be displayed.

1 +10: Increments the temperature setpoint +10 K from its current value.

2 -10: Decrements the temperature setpoint –10 K from its current value.

3 +1: Increments the temperature setpoint +1 K from its current value.

4 -1: Decrements the temperature setpoint –1 K from its current value.

5 +0.1: Increments the temperature setpoint +0.1 K from its current value.

6 -0.1: Decrements the temperature setpoint –0.1 K from its current value.

Enter Setpoint: Sets setpoint at a user defined value. When selected, you will be prompted for an input. Input a setpoint (selectable to within 0.1 K) and press Enter.

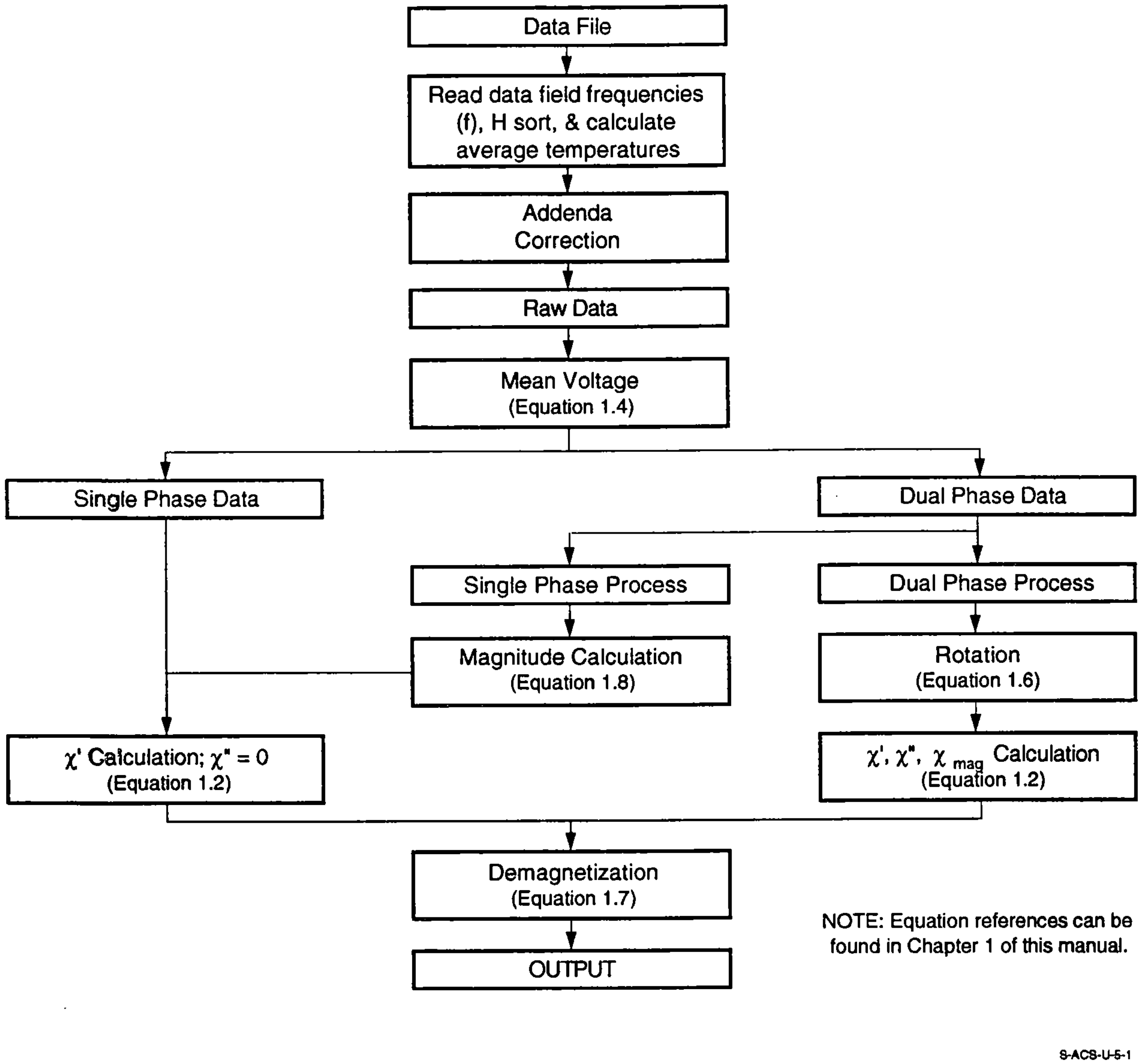


Figure 5-1. Data Processing Program Data Flow

Sample (Continued)

Calibration Coefficient: Enables you to change the system calibration coefficient. When selected, you will be prompted for an input. After typing a value, press Enter.

Label: Allows you to enter a sample label that will be printed on the hard copy print-out of the processed data when the **Print** option is selected. When selected, you will be prompted for an input. After typing a label, press Enter.

Sample: Collection Menu

This enables you to input sample parameters that are used in the computation of magnetization from the raw data. When selected, the following sub-menu will be displayed.

Magnetization: When selected, the following sub-menu is displayed.

Vol: This specifies that volume magnetization is to be computed. When selected, you will be prompted for the sample volume. After typing a value, press Enter.

Mass: This specifies that mass magnetization is to be computed. When selected, you will be prompted for the sample mass. After typing a value, press Enter. If **Mass Magnetization** had been previously accessed to specify a non-zero D, then you will also be prompted for a sample density.

Demagnetization: This enables you to input a sample demagnetization factor. When selected, you will be prompted for an input. After typing a value, press Enter. If mass magnetization has been specified, you will also be prompted for a sample density.

Calibration Coefficient: This enables you to change the system calibration coefficient. When selected, you will be prompted for an input. After typing a value, press Enter.

Addenda: This enables you to input an addenda file to be used in processing the data in real time. When selected, you will be prompted for an addenda file name (no extension). After typing a valid file name, press Enter.

Save: Edit sub-menu of Main Menu.

This enables you to save any changes that were made in **Constants**, **MPS_rates**, or **Phase/ Frequency** to the ACS.DAT file. When selected, you will be prompted with "**Are you sure?" Yes No.**" If **Yes** is selected, the new information will be written to ACS.DAT. If **No** is selected, the new information will not be written to ACS.DAT.

Select: Addenda sub-menu of Analysis Menu.

This selects the Addenda file to be used in processing the data in **Analysis**. When selected, you will be prompted for an Addenda file name (no extension). After typing a valid file name, press Enter.

Sequence: Experimental Menu.

Used to define the measurement sequence that is used when logging data. When selected, the following sub-menu will be displayed.

Phase Increment: Select $\Delta\theta$ for traversing the Hysteresis Loop.

Movement On/Off: This is an on/off toggle for specifying whether or not sample movement is used during a data logging sequence.

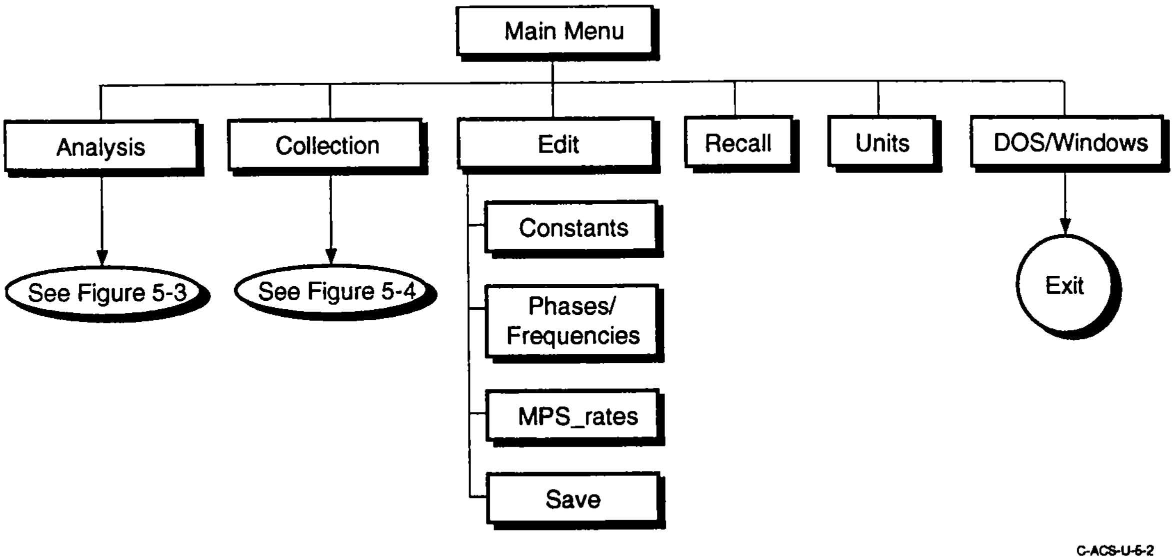


Figure 5-2. Main Menu Block Diagram

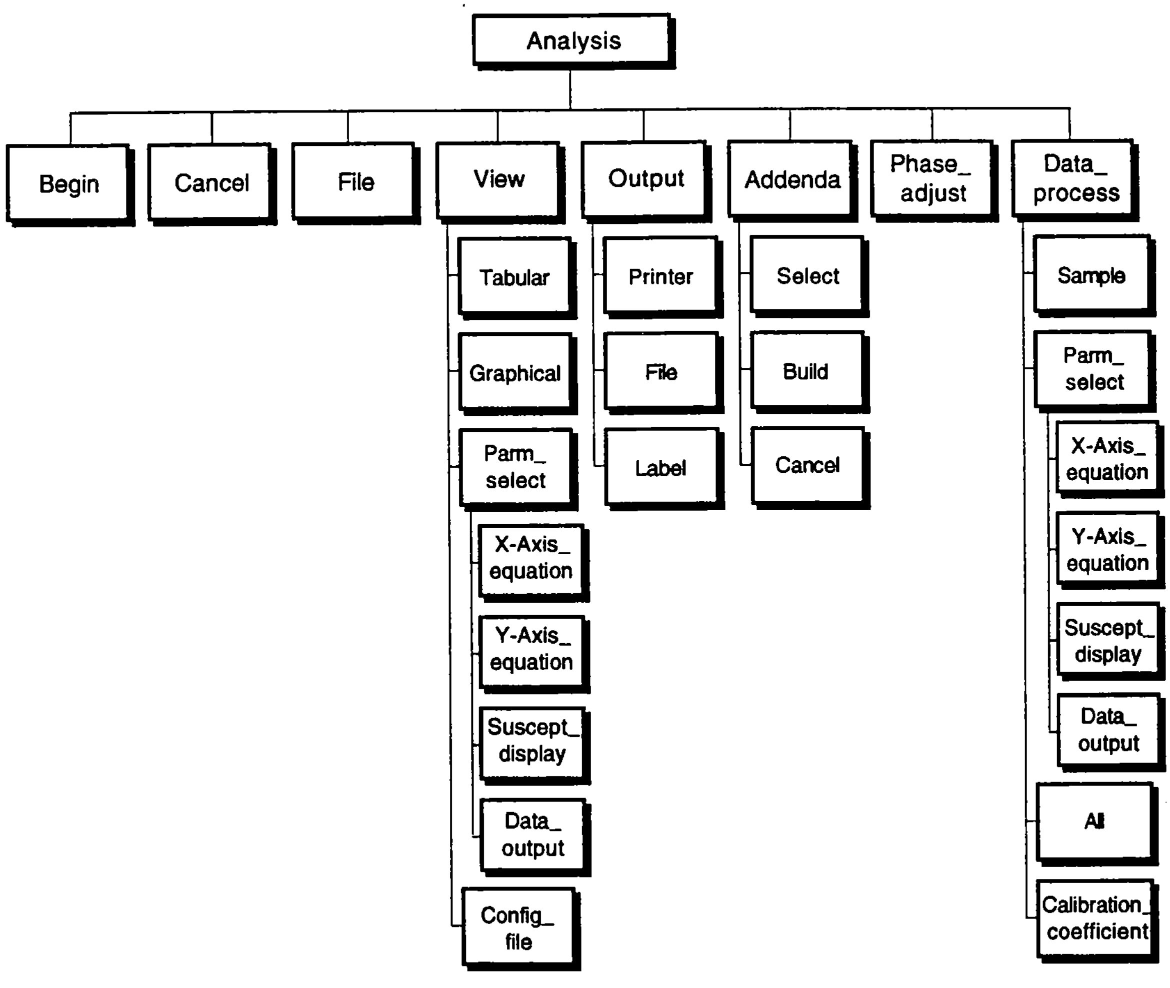


Figure 5-3. Analysis Menu Block Diagram

Real-Time (Continued)

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through all available options in your data set. When done, a window will display the selections which have been made. ESC to exit. Also, you cannot "View" raw data.

Recall: Collection Menu.

This routine enables you to load a previously generated configuration file. This is useful when samples are often run using the same experimental conditions or parameters. When selected, you will be prompted for a file name (no extension). After typing a file name, press Enter. Changes to the experimental configuration can then be made through the software if required.

Ref Freq: Tuning sub-menu of Lock-In sub-menu of Collection Menu

When selected, the Lock-In Amplifier LCD display will indicate the reference frequency.

Res: Reserve sub-menu of Lock-In sub-menu of Collection Menu

Selection of this gives a FLAT mode dynamic reserve of 60 dB.

Reserve: Lock-In sub-menu of Collection Menu.

This is used to set the Dynamic Reserve of the lock-in amplifier. When selected the following sub-menu will appear.

Stab: Selection of this gives a FLAT mode dynamic reserve of 20 dB.

Norm: Selection of this gives a FLAT mode dynamic reserve of 40 dB.

Res: Selection of this gives a FLAT mode dynamic reserve of 60 dB.

The default setting is STAB. During automatic data acquisition, this setting is adjusted automatically if the need arises.

Sample: Analysis Menu.

This enables you to input sample parameters that enter into the calculations of magnetization from raw data. When selected, the following sub-menu is displayed.

Magnetization: Allows you to select volume or mass magnetization.

Vol: Selection of this specifies that volume magnetization is to be computed. When selected, you will be prompted for a sample volume. Input a value and press Enter.

Mass: Selection of this specifies that mass magnetization is to be computed. When selected, you will be prompted for a sample mass. After typing a value press Enter. If **Demagnetization** had been previously accessed to specify a non-zero D, then you will also be prompted for a sample density.

Demagnetization: This enables you to input a sample demagnetization factor. When selected, you will be prompted for an input. After typing a value, press Enter. If mass magnetization has been specified, you will also be prompted for a sample density.

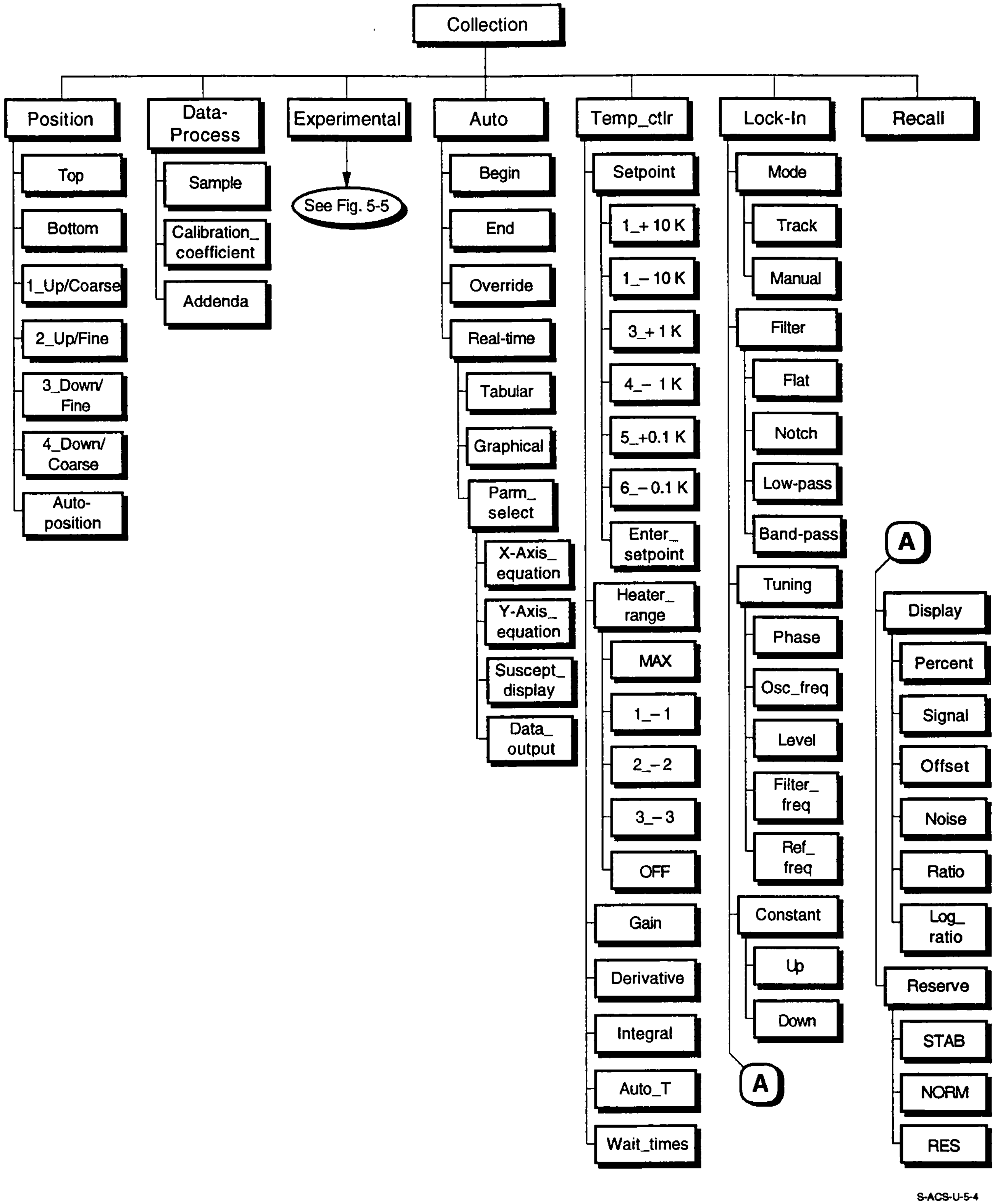


Figure 5-4. Collection Menu Block Diagram

Position: Collection Menu.

This routine is used to position the sample in one of the two secondary coils. When accessed, the following sub-menu is displayed.

Top: This toggle specifies the sample is positioned in the top secondary coil.

Bottom: This toggle specifies the sample is positioned in the bottom secondary coil.

1 Up Coarse: The sample will move up 0.1 inch (0.254 cm) from its current position.

2 Up Fine: The sample will move up 0.01 inch (0.0254 cm) from its current position.

3 Down Fine: The sample will move down 0.01 inch (0.0254 cm) from its current position.

4 Down Coarse: The sample will move down 0.1 inch (0.254 cm) from its current position.

Auto Position: Automatically centers the sample in the bottom secondary coil. When selected, the sample will be automatically moved to the bottom limit switch and then incrementally moved up at 0.1 inch increments, the lock-in voltage will be read each time. Once a peak (in absolute value) in the voltage is measured, the sample will continue to move up 3 additional steps. This operation is performed so that a curve can be fit to the voltage vs. position data and a maximum determined. This maximum in voltage vs. position defines the center of the bottom secondary coil and the sample will be automatically moved to that position and the sample position status will indicate "Bottom Coil."

NOTE

There are safeguards built into the software that are designed to keep the sample from being positioned improperly. There will be instances where the voltage induced by the sample is so small that a maximum cannot be readily determined. In this case, you will be prompted with the statement "**Center position cannot be found.**" It may be necessary to find the center position using an alternate technique. Refer to Paragraph 4.2.4 for sample positioning techniques.

Printer: Output sub-menu of the Analysis Menu.

This is simply an on/off toggle for specifying that processed data be printed to a hard copy device.

Ratio: Display sub-menu of Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates the ratio of the lock-in's output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Real-Time: Auto sub-menu of Collection Menu.

This feature will display, either graphically or tabularly, the processed magnetization data vs. temperature on the screen in real-time (i.e., as the data is being recorded). When selected, the following sub-menu will be displayed.

Tabular: This is an on/off toggle. When on, the processed data will be displayed on the screen in the following format: Moment: m vs H, Volume Magnetism: m(v) vs H, or Mass Magnetism: m(m) vs H. You can scroll through the data using the Home/End keys or the PgUp/PgDn keys. ESC to exit.

Graphical: This is an on/off toggle. When on, the processed data will be displayed on the screen in the following format: Moment: m vs H, Volume Magnetism: m(v) vs H, or Mass Magnetism: m(m) vs H. Scaling is fully automated. Press ESC to exit. Also, you cannot "View" raw data.

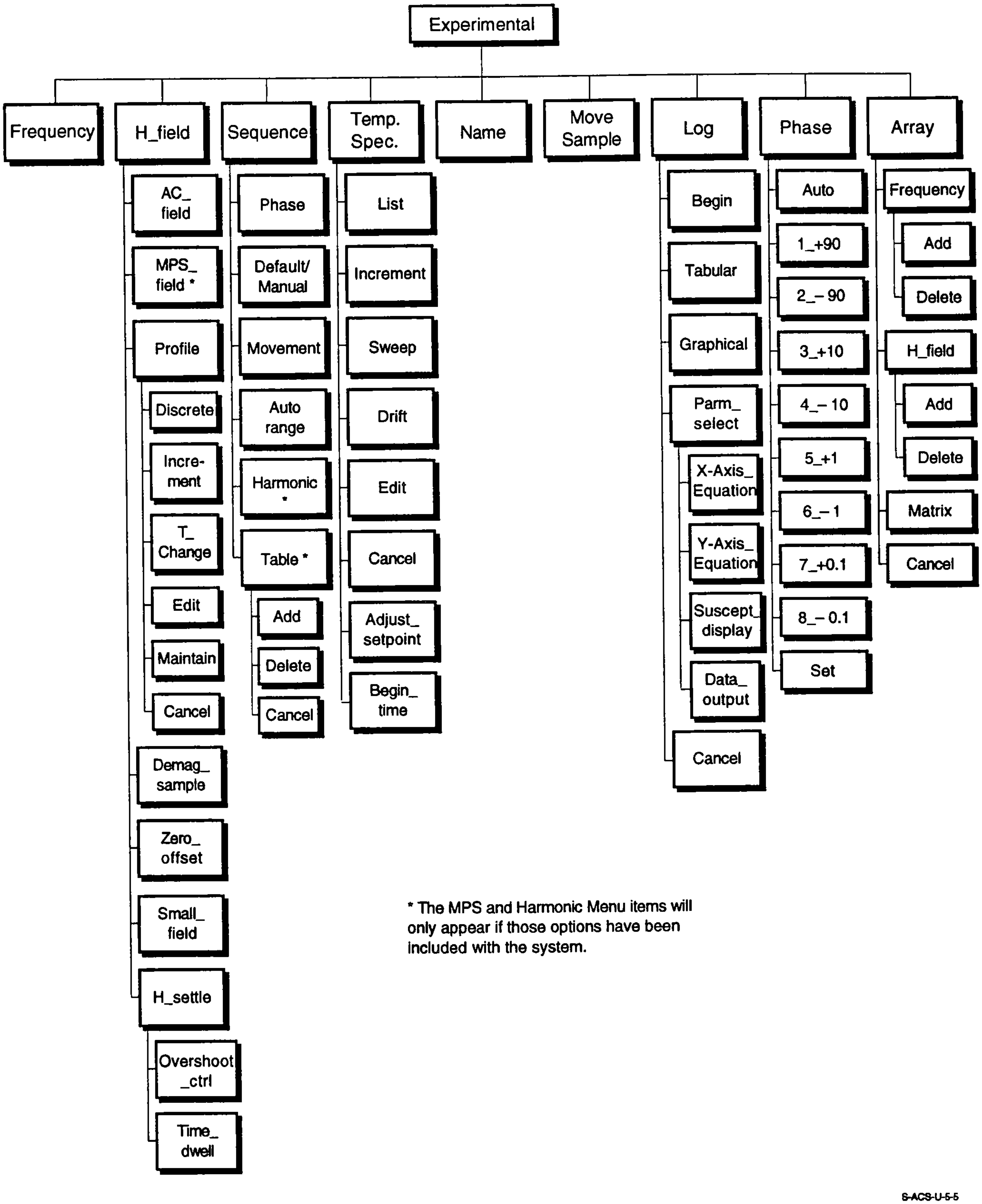


Figure 5-5. Experimental Menu Block Diagram

Phase: Experimental sub-menu of Main Menu

When this **Phase** is accessed, the following sub-menu will be displayed.

Auto: This will automatically set the phase for a particular sample under study. When selected, measurements at 0 and 90 degrees in both the top and bottom coil will be performed and the following computation performed.

$$\theta = 90 - \{\tan^{-1}[(v_0^{top} - v_0^{bot})/(v_{90}^{top} - v_{90}^{bot})]\}$$

Where:

v_0^{top} = voltage at 0° in top coil.
v_{90}^{top} = voltage at 90° in top coil.
v_0^{bot} = voltage at 0° in bottom coil.
v_{90}^{bot} = voltage at 90° in bottom coil.

The phase of the lock-in will then be set to this value of .

1 +90: Will rotate the phase by +90°.
2 -90: Will rotate the phase by –90°.
3 +10: Will rotate the phase by +10°.
4 -10: Will rotate the phase by –10°.
5 +1: Will rotate the phase by +1°.
6 -1: Will rotate the phase by –1°.
7 +0.1: Will rotate the phase by +0.1°.
8 -0.1: Will rotate the phase by –0.1°.
Set: Allows you to enter the phase. Upon selecting, you will be prompted for an input. Input the value and press Enter.

Phase Adjust: Analysis Menu.

This enables you to input phase values to see the effect of phase changes on the processed magnetization values. When selected, you will be prompted for an entry. After typing a value, press Enter.

Phases/Frequencies: Edit sub-menu of Main Menu.

When selected, a table containing 32 frequencies with their associated phase angles appears in a window. The frequencies listed in this table are the default frequencies which will appear in the selection window used during experimental operation (Refer to the **Frequency** command.) As supplied, the system is configured with 32 preset frequencies which may be changed to meet required needs. Frequencies can be selected from 1 to 1000 Hz in 1 Hz steps and 1000 to 10,000 Hz in 10 Hz steps.

The phase angle associated with each frequency is used during data acquisition and analysis, so proper specification of the phase angle is required. The phase angle from the phase/frequency table is then used to process the data to yield the correct moment.

In order to change a particular phase or frequency, move the cursor to that entry and press Enter. A new value can then be input. Press ESC to exit.

5.3.2 MENU BREAKDOWN AND FUNCTIONAL DESCRIPTION

The following is a text-based representation of the information presented in the menu block diagrams.

Analysis	Display the analysis menu.
Begin	Processed data sent to printer or file depending on options selected in Data_process.
Cancel	Cancel data-processing if in progress.
File	Input data-file for processing.
View	Display processed data on screen.
Tabular	Displays processed data on screen according to the Data_output selected.
Graphical	Displays processed data graphically on screen according to the Data_output selected.
Parm_select	Selects X, Y equations & susceptibility type for displaying data & processing.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Susceptibility_display	Choose display option (χ' and χ'', χ', χ'', or χ_{mag}).
Data_output	Select type of susceptibility (mass, volume, molar, etc.)
Configuration_file	View the contents of the configuration file (filename.CFG).
Output	Select output device: printer or file.
Printer	Outputs data to a printer.
File	Outputs data to an ASCII file.
Label	Input sample label to be outputted.
Addenda	Select/create addenda file.
Select	Selects previously created addenda file.
Build	Creates addenda file to be built from data file.
Cancel	Cancels previously selected addenda file (if any).
Phase_adjust	Modify/adjust phase.
Data_process	Define parameters affecting data processing.
Sample	Input sample specifications.
Parm_select	Selects X, Y equations & susceptibility type for displaying data & processing.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Susceptibility_display	Choose display option (χ' and χ'', χ', χ'', or χ_{mag}).
Data_output	Select type of susceptibility (mass, volume, molar, etc.)
All	Processes data for an appropriate array defined by the equations under Parm_select.
Calibration_coefficient	Modify calibration coefficient.

Collection	Display the collection menu.
Position	Position sample in secondary coil.
Top	Specify top coil position.
Bottom	Specify bottom coil position.
1_Up/Coarse	Moves sample up 0.1 inch (0.254 cm).
2_Up/Fine	Moves sample up 0.001 inch (0.0254 cm).
3_Down/Fine	Moves sample down 0.001 inch (0.0254 cm).
4_Down/Coarse	Moves sample down 0.1 inch (0.254 cm).
Autoposition	Automatically centers sample in bottom secondary coil.

Override: Auto sub-menu of Collection Menu

During fixed temperature points data acquisition mode, selection of this key will override certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent on the particular temperature range. Upon completion of the WAIT, a DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once this DRIFT/MIN is below 0.1 K per minute, the data acquisition/measurement sequence will automatically begin. Selecting **Override** once will override the designated WAIT period and initiate the DRIFT CHECK. Selecting **Override** again will override this as well and data will be recorded immediately.

While the temperature is being adjusted from one setpoint to another, **Override** can be selected to record data at some intermediate temperature. When **Override** is selected, the temperature ramping will cease and the above mentioned WAIT period will be initiated.

Parm_select: View sub-menu of Analysis Menu, Auto sub-menu of Collection, and Log sub-menu of Experimental

Depending upon the experimental set-up, a single acquisition run can yield a matrix of moment data recorded at different AC fields and temperatures. The processed data is organized for output and is used in both real time feedback operation and in analysis.

When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through all available options in your data set. When done, a window will display the selections which have been made. Press ESC to acknowledge.

Percent: Display sub-menu of Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates lock-in output in % of full scale for all sensitivities.

Phase: Tuning sub-menu of Lock-In sub-menu of Collection Menu

When selected, the Lock-In Amplifier LCD display indicates the phase shift introduced either by the software or the user.

Collection (continued)

Data_process	Define parameters affecting data processing.
Sample	Input sample specifications.
Calibration_coefficient	Modify calibration coefficient.
Addenda	Enter addenda file name to be used in processing data.
Experimental	Set all experimental parameters.
Frequency	Select frequency of AC field.
H_field	Select amplitude of AC field, DC field and DC field of MPS.
MPS_field	Set the DC magnetic field of the superconducting magnet.
Profile	Define field profile/control.
Discrete	Enter individual field values.
Increment	Enter first/last field values and an increment.
T_change	Select field to be set after the field profile is completed.
Edit	Change existing profile (if present).
Maintain	On/off toggle to leave field on after the completion of automatic data acquisition.
Cancel	Cancel existing setup.
Demag_sample	Selection performs demagnetization cycle for elimination of remnant fields.
Zero_offset	Selection compensates for any MPS zero-drifts.
Small_field	Allows setting small fields with the primary coil/140 current source.
H_settle	Provides options for controlling settling of the magnetic field.
Overshoot_ctrl	On/off toggle for minimization of field overshoots.
Time_dwell	Select time (in addition to default time settings) for field stabilization.
Sequence	Define measurement sequence.
Phase	Select single/dual phase.
Default/Manual	Select system phase or user defined phase.
Movement	Sample movement on/off.
Autorange	Enable/disable lock-in auto-range.
Harmonic	Define Harmonic (1 thru 10) to be measured.
Table	Either Add, Delete, or Cancel from table of Harmonic values.
Temp_spec	Define temperature setup.
List	Enter individual points.
Increment	Enter first/last temperature and increment.
Sweep	Enter low/high temperature and sweep rate (3 ranges max).
Drift	No temperature control, select time between measurements.
Edit	Change existing set-up (if present).
Cancel	Cancel existing set-up (including Begin_time if specified).
Adjust_setpoint	Toggle fine-tuning of setpoint on/off.
Begin_time	Enter time (in minutes) to wait before initiating auto-collection.
Name	Enter file name for data storage.
Move_sample	Move sample from one coil position to the other.

Name:
Experimental Menu.

This allows you to specify a data file to which the data logged will be written. When selected, you will be prompted for a file name with no extensions. After typing a file name, press Enter. If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG. If the file name selected already exists, you will be prompted for a new file name. If a new file name is not specified, the new data will overwrite the data currently contained in the file.

Noise:
Display sub-menu of Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates the rectified output noise in percent of full scale.

Norm:
Reserve sub-menu of Lock-In sub-menu of Collection Menu

Selection of this gives a FLAT mode dynamic reserve of 40 dB.

Notch:
Filter sub-menu of Lock-In sub-menu of Collection Menu

This provides a stop band with very deep attenuation at f_0 (the reference frequency).

OFF:
Heater Range sub-menu of Temp Ctlr sub-menu of Collection Menu

Selection will turn the power off.

Offset:
Display sub-menu of Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates the offset value in effect.

Osc Freq:
Tuning sub-menu of Lock-In sub-menu of Collection Menu

When selected, the display will indicate the set oscillator frequency.

Output:
Analysis Menu.

This routine allows you to specify that the processed data be either written to a file (ASCII file format) or dumped to a hard copy device. When selected, the following sub-menu is displayed. What is actually written to a file or hardcopy depends on selection made in Parm_select, if applicable.

Printer: On/off toggle to specify that the data be printed to a hard copy device. The format consists of seven columns as follows:

T	H_{ac}	f	H_{dc}	m	H	Moment
T	H_{ac}	f	H_{dc}	m(v)	H	Volume Magnetism
T	H_{ac}	f	H_{dc}	m(m)	H	Mass Magnetism
T	H_{ac}	f	H_{dc}	Vb	Vt	Raw Data

File: When selected, you will be prompted for a file name (no extension). After typing the file name, press Enter. The file format consists of seven columns as follows:

T	H_{ac}	f	H_{dc}	m	H	Moment
T	H_{ac}	f	H_{dc}	m(v)	H	Volume Magnetism
T	H_{ac}	f	H_{dc}	m(m)	H	Mass Magnetism
T	H_{ac}	f	H_{dc}	Vb	Vt	Raw Data

The fields are separated or delimited by a single white space.

Collection (continued)

Experimental (continued)

Log	Log data points according to the defined measurement sequence except for those defined in Temp_spec.
Begin	Begin logging data.
Tabular	Display real-time data in tabular mode.
Graphical	Display real-time data in graphical mode.
Parm_select	Selects X,Y equations & susceptibility type for displaying data & processing.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Susceptibility_display	Choose display option (χ' and χ'', χ', χ'', or χ_{mag}).
Data_output	Select type of susceptibility (mass, volume, molar, etc.)
Cancel	Cancel logging of data (if in progress).
Phase	Adjust phase.
Auto	Automatically measures phase for particular sample.
1_+90	Change by +90°.
2_–90	Change by –90°.
3_+10	Change by +10°.
4_–10	Change by –10°.
5_+1	Change by +1°.
6_–1	Change by –1°.
7_+0.1	Change by +0.1°.
8_–0.1	Change by –0.1°.
Set	Input phase.
Array	Define field and frequency arrays.
Frequency	Add/delete frequencies.
H_field	Add/delete AC fields.
Matrix	Add/delete field/frequency combinations.
Cancel	Cancel arrays.

Auto

Auto	Begin automatic data acquisition (with Temp_spec).
Begin	Begin data acquisition.
End	Ends data acquisition (if in progress).
Override	Over-rides Begin_time, wait period, or drift-per-minute criteria.
Real-time	Selects real-time feedback.
Tabular	Displays real-time feedback in tabular form.
Graphical	Displays real-time feedback in graphical form.
Parm_select	Selects X,Y equations & susceptibility type for displaying data & processing.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Susceptibility_display	Choose display option (χ' and χ'', χ', χ'', or χ_{mag}).
Data_output	Select type of susceptibility (mass, volume, molar, etc.)

Temp_ctlr

Temp_ctlr	Adjust temperature control parameters.
Setpoint	Enter temperature setpoint.
1_+10	Increment by +10 K.
2_–10	Decrement by –10 K.
3_+1	Increment by +1 K.
4_–1	Decrement by –1 K.
5_+0.1	Increment by +0.1 K.
6_–0.1	Decrement by –0.1 K.
Enter_setpoint	Input setpoint.
Heater_range	Select heater power range
MAX	Sets to maximum.
1_–1	Sets to first range.
2_–2	Sets to second range.
3_–3	Sets to third range.
OFF	Turns off heater range.

LP:

Filter sub-menu of Lock-In sub-menu of Collection Menu

The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on LP.

Mass:

Sample sub-menu of Analysis Menu and Sample sub-menu of Collection Menu

Specifies that mass magnetism is to be computed. When selected, you will be prompted for a sample mass. After typing a value press Enter. If **Demagnetization** had been previously accessed to specify a non-zero D, then you will also be prompted for a sample density.

MAX:

Heater Range sub-menu of Temp Ctlr sub-menu of Collection Menu

Selection will set the heater range to maximum power.

Mode:

Lock-In sub-menu of Collection Menu.

Selects either of two filter frequency tuning modes, **Track** or **Manual**. This is an on/off toggle. The default setting is **Manual**. In this case, the filter tunes to the reference channel operating frequency. If **Manual** is selected, the frequency is tuned to the frequency set by the PARAMETER keys on the front panel of the lock-in amplifier.

Movement:

Sequence sub-menu of Experimental Menu.

This is an on/off toggle to set sample movement conditions for a measurement sequence. When on, the sample will be automatically moved from the bottom secondary coil to the top secondary coil and back during the logging of a data point. When movement is off, the sample will remain in the bottom coil.

Move Sample:

Experimental Menu.

Selection of this simply moves the sample from one secondary coil to the other. The sample must be first positioned in one of the secondary coils before this function can be utilized.

MPS_Field:

MPS sub-menu of H_Field sub-menu of Experimental Menu

This sets the DC magnetic field of the 1 or 5 tesla magnet. When selected, you will be prompted to input a field value (0 to 800,000 Am^{-1} in SI units or 0 to 10,000 Oe in cgs units for the 1 tesla magnet). After entering a value, press return. The MPS current will then be automatically adjusted to and stabilized at the selected field.

MPS_rates:

Edit sub-menu of Main menu.

Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Collection (continued)

Experimental (continued)

Gain Input gain setting.
Derivative Input derivative/rate.
Integral Input integral/reset.
Auto_T Input setpoint. Temperature will automatically be adjusted to that setpoint (unlike Enter_setpoint).
Wait_times Adjust the wait period in seconds for each temperature range as well as the drift criteria for those ranges.

Lock-In

Set or adjust lock-in control parameters.

Mode Track/Manual toggle.
Filter Select filter options:
- **Flat**
- **Notch**
- **Low-pass**
- **Band-pass**

Tuning Select tuning display option:
- **Phase**
- **Osc_freq**
- **Level**
- **Filter_freq**
- **Ref_freq**

Constant Select time constant:
- **Up**
- **Down**

Display Select display mode:
- **Percent**
- **Signal**
- **Offset**
- **Noise**
- **Ratio**
- **Log_ratio**

Reserve Select dynamic reserve:
- **STAB** High stability
- **NORM** Normal
- **RES** Reserve

Recall

Recall a previously defined experimental configuration.

Edit

Adjust/edit coil parameters and phases contained in ACS.DAT.

Constants

Modify coil parameters contained in ACS.DAT.

Phases/Frequencies

Modify system phases and frequencies contained in ACS.DAT.

MPS_rates

Current ramping rates used in charging the superconducting magnet contained in ACS.DAT.

Save

Save any changes to ACS.DAT.

Units

Toggle between Système International d'Unités (SI) or centimeter–gram–second (cgs).

DOS/Windows

Exit to DOS or Windows.

Lock-In: Collection Menu.

This enables you to change/modify certain parameters/features of the lock-in amplifier. When selected, the following sub-menu will be displayed.

Mode	For selection of filter frequency tuning modes of the lock-in amplifier.
Filter	Allows selection of the signal channel filter on the lock-in amplifier.
Tuning	Used to select the display parameter on the tuning LCD of the lock-in amplifier.
Constant	For adjustment of the time constant setting on the lock-in amplifier.
Display	For selection of the display parameter on the output LCD of the lock-in amplifier.
Reserve	Allows adjustment of the dynamic reserve setting of the lock-in amplifier.

Each of these are described in preceding or subsequent pages of this manual.

Log: Experimental Menu.

Selection of this will record a single measurement sequence as defined and also, if specified, will execute an array or field profile. These measurements are done at the current temperature. When automatic temperature control and variable temperatures are required as specified in the Temp_spec option, the Auto menu should be used. Data can be stored to a file. If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG.

Begin:	This actually initiates the data acquisition process, and will display the results as they are recorded in the lower left-hand feedback block. ESC to exit.
Tabular:	When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. Moment: m vs. H, volume magnetism: m(v) vs. H, mass magnetism: m(m) vs. H. ESC to exit.
Graphical:	When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. Moment: m vs. H, volume magnetism: m(v) vs. H, mass magnetism: m(m) vs. H. Scaling is performed automatically. ESC to exit.
Parm_select:	When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through all available options in your data set. When done, a window will display the selections which have been made. ESC to exit.
Cancel:	Terminate the data acquisition.

This data can be written to a field specified using **Name**. If no field name is specified it will be written to TEMPFILE.DAT and TEMPFILE.CFG. To abort the **Log** sequence, select **Cancel**.

CAUTION

If Log is used successively, and no file specification is made, the contents of TEMPFILE.DAT will be overwritten.

Log Ratio: Display sub-menu or Lock-In sub-menu of Collection Menu

When selected, the output LCD indicates the log of the output described in **Ratio**.

5.3.3 COMMAND BREAKDOWN AND FUNCTIONAL DESCRIPTION

The following is a complete list of ACS7000 Software Commands presented in alphabetical order.

AC_field: Path: Collection / Experimental / H_field / AC_field

This sets the amplitude (RMS) of the AC field. When selected, the user will be prompted for an input (3-digit selectable, 0.1 to 2000 A/m). After typing a value, press Enter. Esc to exit.

Addenda: Path: Analysis / Addenda

The following sub-menu is accessed.

Select: Prompts for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by File in the Analysis menu.

Build: An Addenda file with the extension .add will be created from whatever file has been specified. An addenda file can be created only from data logged in fixed point mode, dual phase, with sample movement.

Cancel: Cancels a previously selected addenda file.

Addenda: Path: Collection / Data_process / Addenda

When selected, the user will be prompted for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by Name in the Experimental Menu.

Adjust_setpoint: Path: Collection / Experimental / Temp_spec / Adjust_setpoint

This is an on/off toggle for use with fixed point temperature data acquisition. When this option is active, the system temperature control routines are modified such as to make the actual sample temperature closer to the setpoint values input by the user. Activating this option will increase the data acquisition time by approximately a factor of 1.5 to 2.

This option compensates for the fact that the system contains two temperature sensors. The sample temperature sensor is positioned to optimize both the temperature control and minimize the time required for temperature stabilization. When temperatures are input from the keyboard, these values are control temperature values. The actual sample temperature will vary from the control value depending upon temperature range and system status. The Adjust_setpt option has a feedback control routine to modify the controller setpoint to bring the sample temperature closer to the input value.

All: Path: Analysis / Data_process / All

This option permits processing all data recorded using multiple fields, frequencies, or temperatures set up in arrays. When a file output has been specified, the processed data will be stored in files of the same name but with different extensions: filename.001, filename.002, filename.003, etc. If X has n entries, and if Y has m entries, there would be n*m files created. The extension incrementing scheme starts at the lowest element in the X column, steps through the elements of the Y row, and then proceeds to the next element in the X column, until all data is processed. This process is illustrated below. When output from only one set of array elements is desired, they should be selected through the X-Axis_equation and Y-Axis_equation options. Depending on the variable parameter chosen via X-Axis_equation and Y-Axis_equation, a different array processing scheme will be activated:

Variable Parameter	X Column	Y Row
T, H, N, TI	Frequency	AC Field
HAC	Frequency	Temperature
F	AC Field	Temperature

X (column) / Y (row)

.001	.004	.007	.010	.013
.002	.005	.008	.011	.014
.003	.006	.009	.012	.015

File extension numbering scheme for a set-up of 3 fields and 5 frequencies

Incremental: Temp Spec sub-menu of Experimental Menu.

This allows you to define discrete temperature points for fixed point data acquisition by entering them incrementally. When selected, you will be prompted for first a low temperature value, then a high, and finally an increment (e.g., 10 to 100 K in 5 K increments). The table of selected values will be displayed on the screen as a window. To input another range, press Enter. To exit, press ESC.

NOTE

Enter List and **Incremental** can be used together to build a table of discrete temperature points for fixed point data acquisition.

Integral: Temp Ctlr sub-menu of Collection Menu.

Allows you to change the Reset setting of the DRC-91CA temperature controller. When accessed, you will be prompted for an input (0–99). After typing a value, press Enter. The default value is 0 and during automated data acquisition the reset will be set/reset to 0.

Label: Sample sub-menu in Analysis Menu.

Allows you to input a label which will be printed at the head of a hard copy of your processed data.

Level: Tuning sub-menu of Lock-In sub-menu of Collection Menu

When selected, the display will indicate the amplitude of the oscillator frequency.

List: Temp Spec sub-menu of Experimental Menu.

This routine enables you to enter temperatures individually in order to build your own list of temperatures at which data will be recorded during automated data acquisition.

When selected, you will be prompted for a temperature input. Input a value and press Enter. A window will be displayed on the screen with this single temperature value. Continue to input as many temperatures as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which temperatures are entered is not important. They will be automatically ranked in ascending order upon entry. ESC when completed to exit.

NOTE

Enter List and **Incremental** can be used together to build a table of discrete temperature points for fixed point data acquisition.

Analysis: Main Menu.

This is the data processing program for processing data contained in files collected from the defined experiment in the Collection menu. When selected, the following sub-menu will be displayed.

Begin: Selection of this will either print the processed data to a hard copy device or write the contents to an ASCII file as specified by selecting Output.

Cancel: This will abort or cancel selection of Begin.

File: Used to input a file name containing data to be processed.

View: This is a toggle for displaying processed data on the screen.

Output: Specifies processed data be printed to a hard copy device or written to an ASCII file. Note that Begin must be used to execute the selection.

Addenda: This allows the user to create or select an addenda file to be used when processing data.

Phase_adjust: Allows the user to change or modify default phase angles that are used in processing raw voltage values.

Data_process: This allows the user to specify how the data is to be processed. Sample parameters, computations of χ, etc.

ESC to return to the Main Menu.

Array:

Path: Collection / Experimental / Array

Selection of Array enables the user to enter multiple fields and frequencies at which data will be recorded under Log or Automatic operation. The following sub-menu is accessed.

Frequency: The following sub-menu is accessed.

- **Add:** When selected, the window of allowed frequencies is displayed and the frequencies that data are to be recorded at are selected by moving the cursor to the particular frequency(s) of interest and pressing Enter. Esc to exit.
- **Delete:** When selected, the window of selected frequencies is displayed and the frequencies are deleted by moving the cursor to the particular frequency(s) of interest and pressing Enter. Esc to exit.

H_field: The following sub-menu is accessed.

- **Add:** When selected, the user are prompted for data input (3-digit selectable, 0.1 to 2000 A/m). Each field value input is entered into the field array by pressing Enter. As entries are added to the array, the field values selected will be displayed in a window. Esc to exit.
- **Delete:** When selected the window of selected field values is displayed. To delete a particular field entry, move the cursor to that entry and press Enter. Esc to exit.

Matrix: When selected, a field/freq. matrix is displayed. X's mark the field/frequencies which will be used. Individual field/freq. combinations can be deleted or subsequently added to the table by moving the cursor to that element and pressing Enter. Esc to exit.

Cancel: When selected the user are prompted with "Are the user sure? Y/N." If "Y" is selected the arrays are canceled. Select "N" to exit.

Graphical: Real-Time sub-menu of Auto sub-menu of Collection Menu.

This is an on/off toggle. When selected, the processed data will be displayed graphically on the screen. Scaling is handled automatically. Exactly what is displayed will depend on the selection mode in Parm_select, if applicable. ESC to exit.

Graphical: View sub-menu of Analysis Menu

This is an on/off toggle. When selected, the processed data chosen using **File** in analysis will be displayed graphically on the screen. Exactly what is displayed will depend on the selection mode in Parm_select, if applicable. ESC to exit.

H Field: Experimental Menu.

This is used to set the amplitude of both the AC and DC magnetic fields. When selected, the following sub-menu will be displayed.

AC: When selected, you will be prompted to input the amplitude of the AC field.

MPS_field: This is used for setting a single, fixed DC magnetic field of the superconducting magnet.

Demag_sample: Used to eliminate any remnant fields which may reside in the system after the application of a high DC magnetic field.

Zero_offset: Used to more accurately "zero" the zero current setting of the magnet power supply.

H Field: Array sub-menu of Experimental Menu.

This is used to set the AC fields that are used when logging data with multiple field or frequency conditions. When selected, the sub-menu "**Add Delete**" is displayed. If **Add** is selected, you are prompted for data input. Input each field value desired and press Enter after each entry. The fields selected will be displayed in a window. ESC to exit. If **Delete** is selected, the window of selected values will be displayed. To delete a particular entry, move the cursor to that value and press Enter. ESC to exit.

Heater Range: Temp Ctlr sub-menu of Collection Menu.

This allows you to set or change the heater range setting on the DRC-91CA temperature controller. When selected, the following sub-menu is displayed.

MAX: Selection will set the heater range to maximum power.
1_ -1: Selection will set the heater range to –1.
2_ -2: Selection will set the heater range to –2.
3_ -3: Selection will set the heater range to –3.
OFF: Selection will turn the power off.

The heater range is automatically set when in automatic data acquisition mode.

Auto:

Path: Collection / Auto

Starts automatic data acquisition. When selected, the following sub-menu is accessed.

Begin: Begins automatic data acquisition process.

End: When selected, the user will be prompted with; "Are the user sure? Y/N?" If "Y" is selected, the automatic data acquisition process will be terminated. Data recorded up to that point will be saved if a file has been specified. To continue with data acquisition, select "N."

Override: This selection will override certain waits built into the software as well as the wait defined by Begin_time. Specifically, once a certain setpoint is reached, a wait period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the wait is dependent on the temperature range and the values defined under Wait_times. Upon completion of a wait, a drift check is initiated where the temperature drift per minute is automatically monitored. Once this drift/min is below 0.1 K/min (or that specified by the user under Wait_times) the data acquisition measurement sequence will begin. Pressing Override after the initial wait will override the drift check procedure.

Real-time: Selection of this activates real-time feedback of data. When selected, the following sub-menu is accessed.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

Dual Phase:

X-Axis Eq. v' (μV) v'' (μV) Y-Axis' Y-Axis"

or

X-Axis Eq. v' (μV) v'' (μV) Y-Axis magnitude

Single Phase:

X-Axis Eq. v(phase) (μV) Y-Axis Eq.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence and the option chosen for Susceptibility_display. If no display parameters are selected, the program will use the following defaults: if data is logged in single phase, χ' (vertical axis) vs. T (K) (horizontal axis) will be plotted; if data is logged in dual phase, both χ' and χ'' vs. T(K) will be displayed. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a complex matrix of susceptibility data recorded at different fields, frequencies, and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T:	Temperature	N:	Harmonic	TI:	Time
HAC:	AC field	F:	Frequency		
H:	DC field	χ:	Susceptibility		

Refer to Paragraph 5.2.9.1 for further information. Esc to exit.

Filter:

Lock-In sub-menu of Collection Menu.

This enables you to set the signal channel filters on the lock-in amplifier. When accessed the following sub-menu will be displayed.

Flat: No filtering occurs with this selection.

Notch: This provides a stop band with very deep attenuation at f_0 (the reference frequency).

LP: The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on LP.

BP: The band-pass filter attenuates above and below f_0 but with less harmonic rejection than would be provided by LP.

Flat:

Filter sub-menu of Lock-In sub-menu of Collection Menu

No filtering occurs with this selection.

Frequency: Experimental Menu.

This allows the selection of the frequency for the applied AC field. A window appears containing the 32 frequency entries which are the default values specified in ACS.DAT. (Refer to the Edit and Phases/Frequencies commands.) To select or change a frequency, simply move the cursor to that frequency and press ESC. Note that the actual frequency is changed in real-time as the cursor moves through the values in the window.

A red highlight indicates the selected frequency is not compatible with the ac field amplitude and that frequency will not be set. Allowed frequency/field combinations are as follows:

$f < 10$ kHz for $H < 110$ A/m
$f < 2500$ Hz for $H < 1110$ A/m
$f < 1000$ Hz for $H < 2000$ A/m

The field limits are nominal and will vary slightly from system to system.

Frequencies not explicitly contained in the window can be manually selected by pressing Enter. A prompt will appear to input the desired frequency and this value will be displayed at the bottom of the frequency window. The allowed frequencies are integral values from 1 to 1000 Hz and 1000 Hz to 10,000 Hz in 10 Hz steps.

NOTE

If proper phase separation is required, always select an operating frequency from the frequency window; i.e., select the frequency by using the cursor key. This automatically accesses the phase angle built into the ACS.DAT file. *Do not use manual entry.* Frequencies entered manually assume a default phase angle of 90 degrees. If proper phase separation is required, the phase must be determined experimentally for the frequency selected.

Gain:

Temp Ctlr sub-menu of Collection Menu.

Allows you to change the gain setting of the DRC-91CA temperature controller. When selected, you will be prompted for an input (0–99). After typing a value, press Enter. The default value is 99 and during automated data acquisition the gain will be set/reset to this value.

Auto:

Path: Collection / Experimental / Phase / Auto

This will automatically measure the phase of a particular sample. When selected, the signal due to the sample will be measured in both the top and bottom coil positions at both 0 and 90 degrees. The phase will then be calculated using the following equation:

$$\theta = 90 - \{\tan^{-1} [(v_0^{top} - v_0^{bot})/(v_{90}^{top} - v_{90}^{bot})]\} \text{ (degrees)}$$

where: v_0^{top} = voltage measured at 0° in the top coil.
v_{90}^{top} = voltage measured at 90° in the top coil.
v_0^{bot} = voltage measured at 0° in the bottom coil.
v_{90}^{bot} = voltage measured at 90° in the bottom coil.

The phase of the Lock-in Amplifier will then be set to this value of θ.

CAUTION

The auto-phase routine automatically phases to the sample signal. For samples with negative susceptibilities (e.g., superconductors), this phase angle will be 180° out of phase with what the system expects. In this situation, use the auto-phase option to do the phasing but then shift the phase 180° by pressing the "1" key twice in the Phase routine.

Autoposition:

Path: Collection / Position / Autoposition

This automatically centers a sample in the bottom secondary coil. When selected, the sample will be moved to the bottom limit switch and then incrementally moved up at 0.1 inch increments (the Lock-in Amplifier voltage being read each time). Once a peak (in absolute value) in the voltage is measured, the sample will continue to move up 3 additional steps. This operation is performed so that a curve can be fit to the voltage vs. position data and a maximum determined. This maximum in voltage vs. position defines the center of the bottom secondary coil and the sample will be automatically moved to that position and the sample position status will indicate "Bottom Coil."

There are safeguards built into the software that are designed to keep the sample from being improperly positioned. There will be instances where the voltage induced by the sample is so small that a maximum cannot be readily determined. In this case, the user will be prompted with the statement;

"Failed to find bottom coil position (2). Please find manually."

In this case, it may be necessary to find the center position using an alternate technique. Refer to Paragraph 5.2.4 for a sample positioning techniques.

Autorange:

Path: Collection / Experimental / Sequence / Autorange

This allows the autorange feature of the Lock-in Amplifier, which is controlled by the software, to be disabled. It is an on/off toggle. Refer to Paragraph 5.2.1 for a description of when and why the user might want this feature disabled. Esc to exit.

Auto_T:

Path: Collection / Temp_ctlr / Auto_T

Will automatically warm the system up to a user input temperature at a rate of 3 K per minute When selected, the user will be prompted for a setpoint. After typing a setpoint and pressing Enter, the control sensor will be read and the setpoint will be set equal to the control sensor temperature reading and the control setpoint will start to increase at a rate of 3 K per minute

Once the setpoint is reached, the temperature will continue to be controlled at that temperature. Pressing the ESC key will cause ramping to cease. The temperature will be controlled at the setpoint determined when the ESC key was pressed.

Experimental: Collection Menu.

This routine is used to set-up or define the experimental parameters or conditions that are used for an automated data acquisition process. When accessed, the following sub-menu will be displayed:

Frequency: Allows you to set the frequency of oscillation of the AC field.

H Field: This allows you to set the amplitude of the AC or DC field. MPS menu items will only appear if the Model 610/612 is included with the system.

Sequence: Used to define the measurement sequence that is used when data is recorded.

Temp Spec: This is used to define the temperature specifications that are used in automated data acquisition.

Name: This is for entering a file name to which the data will be written.

Move Sample: Acts as a toggle for moving the sample from the center of one secondary coil to the other.

Log: This will log a single data point as defined in **Sequence**.

Phase: Used in setting or changing the phase angle from default settings.

Array: This is for defining multiple fields.

The function of each of these sub-menus is described in more detail in previous or subsequent paragraphs of this manual.

File: Analysis Menu and Output sub-menu of Analysis Menu.

In the Analysis Menu, **File** is used to load a data file for data processing. When accessed, file names with drive or sub-directory information can be entered and the file will be appropriately accessed. There is no need to specify extensions. If Enter is pressed, the data files contained in the working directory will be displayed in a window. To load a particular file, move the cursor to that file and press Enter. If "a:" is specified, the floppy disk contained in the A drive will be accessed.

In the Output sub-menu, **File** is used to specify a file to which processed data will be written. When accessed, you will be prompted for a file name. There is no need to specify extensions. Type a file name and press Enter.

Filter Freq: Tuning sub-menu of Lock-In sub-menu of Collection Menu

When selected, the display will indicate the frequency to which the input filter is tuned. Filter options include Band Pass (BP), Low Pass (LP), or Notch.

Begin:

Paths: Analysis / Begin, Collection / Auto / Begin, and Collection / Experimental / Log / Begin

When selected, processed data will be printed to a hard copy device or a designated file in an ASCII file format.

Begin is also contained in the Auto sub-menu of the Collection menu and Log sub-menu of Experimental. When this Begin is selected automatic data acquisition is initiated. See Auto.

Begin_time:

Path: Collection / Experimental / Temp_spec / Begin_time

Enter a time in minutes as to when the Auto Collection process should actually start after the Begin key is pressed. Entering zero will reset this value.

Bottom:

Path: Collection / Position / Bottom

This is a toggle for specifying that the sample is positioned in the bottom secondary coil.

Band-pass:

Path: Collection / Lock-In / Filter / Band-pass

This selects the band-pass filter option of the Lock-in Amplifier. It is an on/off toggle. For harmonic susceptibilities (i.e., n>1), Band-pass is the default setting.

Build:

Path: Analysis / Addenda / Build

An addenda file will be created with the extension .add from whatever file has been specified. The addenda file can only be created from data logged in fixed temperature points mode, with dual phase and sample movement.

Calibration_coefficient

Paths: Analysis / Data_process / Cal_coeff. and Collection / Data_process / Cal_coeff.

This command will enable the user to make adjustments to the system calibration constant. The calibration normally will remain constant as supplied by the factory. Slight modifications may be required when the user performs his own independent calibration of the system. (Refer to the Lake Shore Application Note "Susceptibility Calibration.")

When selected, the user will be prompted for an input. After typing a value, press Enter.

Cancel:

This command is included 2 times under Analysis and 5 times under Collection

This command has various functions depending on where it is located in the menu hierarchy. In general, when cancel is selected, data processing (if in progress) will be canceled.

When **Cancel** in Analysis / Addenda is selected, a previously selected addenda file will be canceled.

When **Cancel** in Collection / Experimental / Temp_spec is selected, a previously entered temperature specification will be canceled.

When **Cancel** in Collection / Experimental / Array is selected, a previously entered array will be canceled.

Edit (Continued)

Phase/Freq: When selected, a table containing 32 frequencies with their associated phase angles appears in a window. The frequencies listed in this table are the default frequencies which will appear in the selection window used during experimental operation (Refer to the **Frequency** command). As supplied, the system is configured with 32 preset frequencies which may be changed to meet required needs. Frequencies can be selected from 1 to 1000 Hz. in 1 Hz. steps and 1000 to 10,000 Hz. in 10 Hz. steps.

The phase angle associated with each frequency is used during data acquisition and analysis, so proper specification of the phase angle is required. The phase angle from the phase/frequency table is then used to process the data to yield the correct moment. In order to change a particular phase or frequency, move the cursor to that entry and press Enter. A new value can then be input. ESC to exit.

MPS_rates: Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Save: This will save any changes made in either **Constants, MPS_rates**, or **Phases/Frequencies** to the ACS.DAT file. When selected, you will be prompted with **"Are you sure?" Yes** saves the new information to the ACS.DAT file and **No** does not write the new values to the ACS.DAT file.

Edit:

Temp Spec sub-menu of Collection Menu.

This allows you to edit the temperature specification that was defined by using either **Enter List**, or **Incremental**. If **Enter List** or **Incremental** were used to define the temperature specification, then when **Edit** is selected the window of discrete temperature points will be displayed. Temperatures can be deleted by moving the cursor to a particular temperature and pressing Enter.

End:

Auto sub-menu of Collection Menu.

This is the only way to terminate an experimental run at any point prior to its completion as defined. When selected, you will be prompted with **"Yes No."** If **Yes** is selected, the file will be closed and the run aborted. If **No** is selected, the run will continue as defined.

Enter Setpoint:

Set Point sub-menu of Temp Ctlr sub-menu of Collection Menu.

This routine sets the temperature setpoint on the DRC-91CA temperature controller to a user defined value. When selected, you will be prompted for an input. After typing a value, press Enter.

Collection: Main Menu

Collection is used to define the experimental parameters that are to be used when logging data for a particular sample or experiment. When selected, the following sub-menu will be presented.

Position: Position the sample in one of the secondary coils.

Data_process: Input sample parameters that are to be used in the computation of χ from raw data for the real-time feedback feature.

Experimental: Initiates a submenu where experimental parameters are defined for automatic data acquisition.

Auto: Initiates a submenu for automatic collection.

Temp_ctlr: Allows interaction with the DRC-91CA Temperature Controller thru software.

Lock-In: Allows interaction with the Lock-in Amplifier through software.

Recall: Permits input of a previously generated configuration file. If Enter is pressed by itself, a list of .CFG files will be displayed allowing the user to choose which one to recall.

Press Esc to return to the Main Menu.

Configuration_file: Path: Analysis / View / Configuration_file

When selected, a window will be displayed containing all the relevant information in the .CFG file. This window allows the user to see the experimental setup without having to jump around to the other menu items. Esc to exit.

Constant: Path: Collection / Lock-In / Constant

The changing of the time constant setting of the Lock-in Amplifier is performed here. When selected, the following menu is accessed.

Up: Increases time constant setting one unit.

Down: Decreases time constant setting one unit.

Constants: Path: Edit / Constants

This is used to adjust/modify system constants. When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will then be prompted for an input. After typing a value, press Enter again. Esc to exit. The system constants that are displayed and can be modified are:

Field-to-Current Conversion
Calibration Coefficient
MPS field-to-current conversion factor
Maximum allowed current through magnet

NOTE

Calibration coefficient is the only system constant which may require adjustment.

Data_output: This command is included in 4 locations

The command is located in three different locations: Analysis / View / Parm_select, Analysis / View / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. Selecting this command will produce a window in which the user chooses the desired susceptibility output (either volume, mass, molar, arbitrary units, or raw data). Raw data can only be displayed under Analysis.

Display: Lock-In sub-menu of Collection Menu.

Allows you to set the function that is displayed on the output LCD of the lock-in amplifier. When accessed, the following sub-menu is displayed.

Percent: When selected, the output LCD indicates lock-in output in % of full scale for all sensitivities.

Signal: When selected, the output LCD indicates the signal amplitude in voltage. This is the default setting.

Offset: When selected, the output LCD indicates the offset value in effect.

Noise: When selected, the output LCD indicates the rectified output noise in percent of full scale.

Ratio: When selected, the output LCD indicates the ratio of the lock-in's output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Log Ratio: When selected, the output LCD indicates log of the output described in **Ratio.**

Signal is the default setting. Regardless of what is chosen in **Display** when automatic data acquisition (i.e., **Auto**) is selected, the output LCD will indicate (or be changed to) **Signal.**

DOS: Main Menu.

Enables you to exit to the Disk Operating System (DOS). When selected, you will be prompted with the sub-menu "**No Yes.**" Selecting **No** leaves you in the Main Menu and selecting **Yes** exits to DOS.

Down: Constants sub-menu of Lock-In sub-menu of Collection Menu

Decreases time constant setting one unit.

4 Down Coarse: Position sub-menu of Collection Menu.

When selected, the sample will be moved down 0.1 inch (0.254 cm) from its current position.

3 Down Fine: Position sub-menu of Collection Menu.

When selected, the sample will be moved down 0.01 inch (0.0254 cm) from its current position.

Edit: Main Menu

This feature allows you to change/modify system constants/default values contained in ACS.DAT. When selected, the following sub-menu is accessed.

Constants: When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will now be prompted for an input. After typing a value, press Enter. The system constants contained in the window are:

Field-to-Current Conversion
Calibration Coefficient
MPS Field-to-Current Conversion Factor
Maximum allowed current through the superconducting magnet

The calibration coefficient is the only constant that may need to be changed. (Refer to **Calibration Coefficient** command.)

Data_process: Path: Analysis / Data_process

When selected, the following sub-menu will be presented.

Sample: Toggles a window in which the user can enter the sample specs (mass, density, etc.).

Parm_select: Selects the X, Y equations and data output option for processing data.

All: Toggles the processing of arrays on/off.

Calibration_coefficient: Enter a new value for the calibration coefficient.

Press Esc to exit.

Data_process: Path: Collection / Data_process

When selected, the following sub-menu will be presented.

Sample: Toggles a window in which the user can enter the sample specs (mass, density, etc.).

Calibration_coefficient: Enter a new value for the calibration coefficient.

Addenda: Select an addenda file to be used when processing data during collection.

Press Esc to exit.

Default/Manual: Path: Collection / Experimental / Sequence / Default/Manual

This allows the user to set your own phase value for logging data in single phase. Default is the default setting/condition specified in ACS.DAT. In this case, when logging data in single phase, the phase is set to the value defined in the table for the particular frequency which data is being recorded. When Default/Manual is selected, Manual is toggled on. In this case, when logging data in single phase, the phase is left at whatever value it was set to (i.e., the value displayed on the screen) prior to logging data.

If data is logged in dual phase and Default is selected, then the raw voltage values will be rotated by the phase (according to the measurement frequency) contained in the ACS.DAT file. If Manual has been selected, the raw voltages will be rotated by the value set prior to logging data (i.e., the value displayed on the screen).

Demag_sample: Path: Collection / Experimental / H_field / Demag_sample

This function is used to demagnetize the system and eliminate any remnant fields which may be present. After the application of a DC field, remnant fields may reside in the system and Demag_sample will reduce this to effectively zero, leaving only the earth's ambient field. When selected, the cycle is performed automatically. The routine steps through a cycle in which the field direction is alternately changed and the field amplitude is decreased with each change. The entire cycle takes approximately five minutes to complete.

NOTE

Whenever operation of the system with the magnet is completed, or prior to using the system, Demag_sample should be used to eliminate any stray fields that may be present.

Derivative: Path: Collection / Temp_ctlr / Derivative

This allows the user to set the Rate value on the DRC-91CA Temperature Controller. When selected, the user will be prompted for an input (0–9.9). After typing a value, press Enter. The default setting for this parameter is 0.

During automated data acquisition, this parameter will be set to 0.

Constants: Edit sub-menu of Main Menu.

This is used to adjust/modify system constants. When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will then be prompted for an input. After typing a value, press Enter again. ESC to exit. The system constants that are displayed and can be modified are:

Field-to-Current Conversion
Calibration Coefficient
MPS field-to-current conversion factor
Maximum allowed current through magnet

NOTE

The only system constant which may need to be adjusted is the calibration coefficient.

Demagnetization: Sample sub-menu of both Analysis and Collection.

This enables you to set a value for the demagnetization factor D. When selected, you will be prompted for an input. Press Enter after typing a value. If mass magnetization had been selected, as opposed to volume magnetization, then you would also be prompted for a sample density.

NOTE

A value for the demagnetization factor can be entered/changed during automatic data acquisition.

Demag_Sample: MPS sub-menu of H Field sub-menu of Experimental Menu.

This function is used to demagnetize the system and eliminate any remnant fields which may be present. After the application of a DC field, remnant fields may reside in the system and **Demag_sample** will reduce this to effectively zero, leaving only the earth's ambient field. When selected, the cycle is performed automatically. The routine steps through a cycle in which the field direction is alternately changed and the field amplitude is decreased with each change. The entire cycle takes approximately five minutes to complete.

NOTE

Whenever operation of the system with the magnet is completed, or prior to using the system, **Demag_sample** should be used to eliminate any stray fields that may be present.

Derivative: Temp Ctlr sub-menu of Collection Menu.

This allows you to set the Rate value on the DRC-91CA temperature controller. When selected, you will be prompted for an input (0–9.9). After typing a value, press Enter. The default setting for this parameter is 0.

During automated data acquisition, this parameter will be set to 0.

Discrete: Path: Collection / Experimental / H_field / Profile / Discrete

This routine enables the user to enter DC field values individually in order to build your own list of DC fields at which data will be recorded during automated data acquisition.

When selected, the user will be prompted for a field input (kAmp/m if SI, kOe if cgs). Input a value and press Enter. A window will be displayed on the screen with this single field value. Continue to enter as many fields as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which fields are entered is the order in which the fields will be set, and data recorded, during data acquisition. ESC when completed to exit.

NOTE

Discrete and Increment can be used together to build a table of discrete field points for fixed point data acquisition.

Display: Path: Collection / Lock-In / Display

Allows the user to set the function that is displayed on the output LCD of the Lock-in Amplifier. When accessed, the following sub-menu is displayed.

Percent: When selected, the output LCD indicates Lock-in Amplifier output in % of full scale for all sensitivities.

Signal: When selected, the output LCD indicates the signal amplitude in voltage. This is the default setting.

Offset: When selected, the output LCD indicates the offset value in effect.

Noise: When selected, the output LCD indicates the rectified output noise in percent of full scale.

Ratio: When selected, the output LCD indicates the ratio of the Lock-in Amplifier's output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Log Ratio: When selected, the output LCD indicates the log of the output described in Ratio.

Signal is the default setting. Regardless of what is chosen in Display when automatic data acquisition (i.e., Auto) is selected, the output LCD will indicate (or be changed to) Signal.

DOS/Windows: Main Menu.

Enables the user to exit to Disk Operating System (DOS) or Windows. When selected, the user will be prompted with the sub-menu "No Yes." Selecting No leaves the user in the Main Menu and selecting Yes exits to DOS or Windows.

Down: Path: Collection / Lock-In / Constant / Down

Decreases time constant setting one unit.

4_Down/Coarse: Path: Collection / Position / 4_Down/Coarse

When selected, the sample will be moved down 0.1 inch (0.254 cm) from its current position.

3_Down/Fine: Path: Collection / Position / 3_Down/Fine

When selected, the sample will be moved down 0.01 inch (0.0254 cm) from its current position.

Calibration Coefficient: Sample sub-menu of Analysis Menu and Sample sub-menu of Collection Menu.

This will enable you to make adjustments to the system calibration constant. The calibration normally will remain constant as supplied by the factory. Slight modifications may be required when the user performs his own independent calibration of the 7000 Series. (Refer to the Lake Shore Application Note "Susceptibility Calibration.") When selected, you will be prompted for an input. After typing a value, press Enter.

Cancel: Analysis Menu and Experimental Menu.

When selected, the **Type-Output** (hard copy device or file specification) will be canceled.

Cancel is also contained in the Addenda sub-menu of the Analysis Menu. When this is selected, a previously selected addenda file will be canceled.

Cancel is also contained in the Temp-Spec. sub-menu of the Experimental Menu. When this is selected, a previously entered temperature specification will be canceled.

Lastly, **Cancel** is also contained in the Array sub-menu of the Experimental Menu. When this is selected, a previously entered array will be canceled.

Collection: Main Menu.

Collection is used to define the experimental parameters that are to be used when logging data for a particular sample or experiment. When selected, the following sub-menu will be presented.

Position: This routine is used to position the sample in one of the secondary coils.

Sample: Allows you to input sample parameters that are to be used in the computation of magnetization from raw data for the real-time feedback feature.

Experimental: Selection of this brings up the experimental set-up menu where experimental parameters are defined for automated data acquisition.

Auto: Acts as a toggle to begin automated data acquisition.

Temp Ctlr: This allows you to interact with the DRC-91CA Temperature Controller through the software.

Lock-In: This allows you to interact with the lock-in amplifier through the software.

Recall: Allows you to input a previously generated configuration file or experimental set-up.

The function of each of these will be described in more detail in preceding or subsequent paragraphs of this manual. ESC to exit.

Constants: Lock-In sub-menu of Collection Menu.

The changing of the time constant setting of the lock-in amplifier is performed here. When selected, the following menu is accessed.

Up: Increases time constant setting one unit.

Down: Decreases time constant setting one unit.

Drift:

Path: Collection / Experimental / Temp_spec / Drift

Specifies that data be logged in drift mode where there is either no active temperature control (e.g., on cooling) or the temperature is being controlled at a user defined value set in Temp_ctlr (e.g., to log data as a function of time).

A default interval between successive measurements, dependent on the defined measurement sequence, will be displayed when this is selected. This value can be changed by entering a new value (default value). Press ESC to use the default interval.

Edit:

Main Menu

This feature allows the user to change/modify system constants/default values contained in ACS.DAT. When selected, the following sub-menu is accessed.

Constants: When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will now be prompted for an input. After typing a value, press Enter. The system constants contained in the window are:

Field-to-Current Conversion
Calibration Coefficient
MPS Field-to-Current Conversion Factor
Maximum allowed current through the superconducting magnet

The calibration coefficient is the only constant that may need to be changed. (Refer to Calibration Coefficient.)

Phase/Frequencies: When selected, a table containing 32 frequencies with their associated phase angles appears in a window. The frequencies listed in this table are the default frequencies which will appear in the selection window used during experimental operation (Refer to Frequency). As supplied, the system is configured with 32 preset frequencies which may be changed to meet required needs. Frequencies can be selected from 1 to 1000 Hz. in 1 Hz. steps and from 1000 to 10,000 Hz in 10 Hz steps.

The phase angle associated with each frequency is used during data acquisition and analysis, so proper specification of the phase angle is required. If single phase data is logged at one of the 32 specified frequencies, the Lock-In Amplifier phase setting will be set to the corresponding phase angle for data acquisition. In dual phase acquisition, data are recorded at both 0 and 90 degree phase settings on the Lock-In Amplifier. The phase angle from the phase/frequency table is then used to process the data to yield the correct phase separation for the real and imaginary components of the susceptibility.

In order to change a particular phase or frequency, move the cursor to that entry and press Enter. A new value can then be input. Esc to exit.

MPS_rates: Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Save: This will save any changes made in either Constants, MPS_rates, or Phases/Frequencies to the ACS.DAT file. When selected, the user will be prompted with "Are the user sure?" Yes saves the new information to the ACS.DAT file and No does not write the new values to the ACS.DAT file.

Auto-Position: Position sub-menu of Collection Menu.

This automatically centers a sample in the bottom secondary coil. When selected, the sample will be moved to the bottom limit switch and then incrementally moved up at 0.1 inch increments (the lock-in voltage being read each time). Once a peak (in absolute value) in the voltage is measured, the sample will continue to move up 3 additional steps. This operation is performed so that a curve can be fit to the voltage vs. position data and a maximum determined. This maximum in voltage vs. position defines the center of the bottom secondary coil and the sample will be automatically moved to that position and the sample position status will indicate "Bottom Coil."

There are safeguards built into the software that are designed to keep the sample from being improperly positioned. There will be instances where the voltage induced by the sample is so small that a maximum cannot be readily determined. In this case, you will be prompted with the statement;

"Failed to find bottom coil position (2). Please find manually."

In this case, it may be necessary to find the center position using an alternate technique. Refer to Paragraph 4.2.4 for sample positioning techniques.

Auto Range: Sequence sub-menu of Experimental Menu.

This allows the autorange feature of the lock-in, which is controlled by the software, to be disabled. It is simply an on/off toggle. Refer to Paragraph 4.2.1 for a description of when and why you might want this feature disabled. ESC to exit.

Auto T: Temp_Ctlr sub-menu of Collection Menu.

Will automatically warm the system up to a user input temperature at a rate of 3 K per minute When selected, you will be prompted for a setpoint. After typing a setpoint and pressing Enter, the control sensor will be read and the setpoint will be set equal to the control sensor temperature reading and the control setpoint will start to increase at a rate of 3 K per minute

Once the setpoint is reached, the temperature will continue to be controlled at that temperature. Pressing the ESC key will cause ramping to cease. The temperature will be controlled at the setpoint determined when the ESC key was pressed.

Begin: Analysis Menu.

When selected, processed data will be printed to a hard copy device or a designated file in an ASCII file format. Begin is also contained in the Auto sub-menu of the Collection menu and Log sub-menu of Experimental. When this Begin is selected automatic data acquisition is initiated. See Auto.

Bottom: Position sub-menu of the Collection Menu

This is a toggle for specifying that the sample is positioned in the bottom secondary coil.

BP: Filter sub-menu of Lock-In sub-menu of Collection Menu.

This selects the Band Pass filter option of the lock-in amplifier. It is simply an on/off toggle.

Build: Addenda sub-menu of Analysis Menu.

An addenda file will be created with the extension .add from whatever file has been specified.

Edit:

Path: Collection / Experimental / H_field / Profile / Edit

This allows the user to edit the field profile specification which was defined using either **Discrete** or **Increment**. When selected, a window of discrete field points will be displayed. Field values can be deleted by moving the cursor to that value and pressing Del. If the user wish to enter fields, move the cursor to the table entry AFTER the desired entry, and press Enter. You will now be prompted for an input. Esc to exit.

Edit:

Path: Collection / Experimental / Temp_spec / Edit

This allows the user to edit the temperature specification that was defined by using either Enter List, Increment, or Sweep in the Temp Spec menu. If Enter List or Increment were used to define the temperature specification, then when Edit is selected the window of discrete temperature points will be displayed. Temperatures can be deleted by moving the cursor to a particular temperature and pressing Enter.

If the temperature specification is a sweep, when Edit is selected, the sweep window will be displayed. Edit allows the user to change sweep rates or nominal temperature spacing. Move the cursor to the rate or spacing the user wish to change and press Enter. You can now enter a new value. Esc to exit.

End:

Path: Collection / Auto / End

This is the only way to terminate an experimental run at any point prior to its completion as defined. When selected, the user will be prompted with "Yes No." If Yes is selected, the file will be closed and the run aborted. If No is selected, the run will continue as defined.

Enter_setpoint: Path: Collection / Temp_ctlr / Setpoint / Enter_setpoint

This routine sets the temperature setpoint on the DRC-91CA Temperature Controller to a user defined value. When selected, the user will be prompted for an input. After typing a value, press Enter.

Experimental: Path: Collection / Experimental

This routine is used to set-up or define the experimental parameters or conditions that are used for an automated data acquisition process. When accessed, the following sub-menu will be displayed:

Frequency: Allows the user to set the frequency of oscillation of the AC field.

H_field: This allows the user to set the amplitude of the AC or DC field. MPS menu items will only appear if the Model 610/612 is included with the system.

Sequence: Defines measurement sequence used when data is recorded. Harmonic menu items only appear if the Harmonic Option is included with the system.

Temp_spec: This is used to define the temperature specifications that are used in automated data acquisition.

Name: This is for entering a file name to which the data will be written.

Move_sample: Toggle for moving sample from the center of one secondary coil to the other.

Log: This will log a single data point as defined in Sequence.

Phase: Used in setting or changing the phase angle from default settings.

Array: This is for defining multiple field/frequency conditions.

These commands are described alphabetically within this section.

Auto:

Collection Menu.

Starts automatic data acquisition. When selected, the following sub-menu is accessed.

Begin: Begins automatic data acquisition process.

End: When selected, you will be prompted with; "**Are you sure? Y/N?**" If "**Y**" is selected the automatic data acquisition process will be terminated. Data recorded up to that point will be saved if a file has been specified. To continue with data acquisition, select "**N**."

Over-ride: During fixed temperature points data acquisition mode, selection of this key will over-ride certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent on the particular temperature range. Upon completion of the WAIT, a DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once this DRIFT/MIN is below 0.1 K per minute the data acquisition/measurement sequence will automatically begin. Selecting **Over-ride** once will over-ride the designated WAIT period and initiate the DRIFT CHECK. Selecting **Over-ride** again will over-ride this as well and data will be recorded immediately.

Real-Time: Selection of this activates real-time feedback of processed magnetization data. When selected, the following sub-menu is accessed.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. Moment: m vs. H, volume magnetism: m(v) vs. H, mass magnetism: m(m) vs. H. ESC to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. Moment: m vs. H, volume magnetism: m(v) vs. H, mass magnetism: m(m) vs. H. Scaling is performed automatically. ESC to exit.

Parm_select: When Parm_select is selected, a window will appear showing the options available contingent on the experimental set-up. Move the cursor to the particular combination you wish to select and press Enter. Parm_select will guide you through all available options in your data set. When done, a window will display the selections which have been made. ESC to exit.

Auto:

Phase sub-menu of Experimental Menu.

This will automatically measure the phase of a particular sample. When selected, the signal due to the sample will be measured in both the top and bottom coil positions at both 0 and 90 degrees. The phase will then be calculated using the following equation:

$$\theta = 90 - \{\tan^{-1} [(v_0^{top} - v_0^{bot})/(v_{90}^{top} - v_{90}^{bot})]\} \text{ (degrees)}$$

where:
v_0^{top} = voltage measured at 0° in the top coil.
v_{90}^{top} = voltage measured at 90° in the top coil.
v_0^{bot} = voltage measured at 0° in the bottom coil.
v_{90}^{bot} = voltage measured at 90° in the bottom coil.

The phase of the lock-in will then be set to this value of θ.

File:

Paths: Analysis / File and Analysis / Output / File

In the Analysis Menu, File is used to load a data file for data processing. When accessed, file names with drive or sub-directory information can be entered and the file will be appropriately accessed. There is no need to specify extensions. If Enter is pressed, the data files contained in the working directory will be displayed in a window. To load a particular file, move the cursor to that file and press Enter. If "a:" is specified, the floppy disk contained in the A drive will be accessed.

In the Output sub-menu, File is used to specify a file to which processed data will be written. When accessed, the user will be prompted for a file name. There is no need to specify extensions. Type a file name and press Enter.

Filter:

Path: Collection / Lock-In / Filter

This enables the user to set the signal channel filters on the Lock-in Amplifier. When accessed the following sub-menu will be displayed.

Flat: No filtering occurs with this selection.

Notch: Provides a stop band with very deep attenuation at f_0 (the reference frequency).

Low-pass: The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on LP.

Band-pass: The band-pass filter attenuates above and below f_0 but with less harmonic rejection than would be provided by LP.

Low-pass is the default filter setting for the fundamental (i.e., n=1) susceptibility. For harmonic susceptibilities (i.e., n>1), Band-pass is the default setting.

Filter_freq:

Path: Collection / Lock-In / Tuning / Filter_freq

When selected, the display will indicate the frequency to which the input filter is tuned. Filter options include Band-pass, Low-pass, or Notch.

Flat:

Path: Collection / Lock-In / Filter / Flat

No filtering occurs with this selection.

Frequency:

Path: Collection / Experimental / Array / Frequency

This routine is designed to specify the frequencies that data is logged at when using multiple fields or frequencies. When selected, the sub-menu "Add Delete" will appear. Selection of Add brings forth the same window of allowed frequencies. To select frequencies, move the cursor to the appropriate frequency value and press Enter. As frequencies are entered, a window of those frequencies will be displayed. Selection of Delete brings forth the window of selected frequencies. To delete certain values, move the cursor to that value and press Enter.

Analysis: Main Menu.

This is the data processing program for processing data contained in data files defined in the Experimental sub-menu of the Collection menu. When selected, the following sub-menu will be displayed.

Begin: Selection of this will either print the processed data to a hard copy device or write the contents to an ASCII file as specified by selecting **Output.**

Cancel: This will abort or cancel selection of **Begin.**

Sample: Allows you to input sample parameters that are used in the computations of magnetization from raw data.

File: Used to input a file name containing data to be processed.

View: This is a toggle for displaying processed data on the screen.

Output: Is for specifying that the processed data be printed to a specified hard copy device or written to an ASCII file. Note that the **Begin** option must be used to actually execute the selection.

Addenda: This allows you to create or select an addenda file to be used when processing data.

Phase Adjust: Allows you to change or modify default phase angles that are used in processing raw voltage values.

Type Output: This allows you to specify how the data is to be processed. Raw data, moment, volume magnetism, or mass magnetism.

The function of each of these subroutines will be described in more detail in subsequent paragraphs. ESC to return to the Main Menu.

Array: Experimental Menu.

Selection of **Array** enables you to enter multiple fields and frequencies at which data will be recorded under automatic operation. The following sub-menu is accessed.

H Field: The following sub-menu is accessed.

- **Add:** When selected, you are prompted for data input (3-digit selectable, 0.10 to 2000 A/m). Each field value input is entered into the field array by pressing Enter. As entries are added to the array, the field values selected will be displayed in a window. ESC to exit.
- **Delete:** When selected the window of selected field values is displayed. To delete a particular field entry, move the cursor to that entry and press Enter. ESC to exit.

Cancel: When selected you are prompted with **"Are you sure? Y/N."** If "Y" is selected the array is canceled. Select **"N"** to exit.

Frequency: Path: Collection / Experimental / Frequency

This allows the selection of the frequency for the applied AC field. A window appears containing the 32 frequency entries which are the default values specified in ACS.DAT. (Refer to the Edit and Phases/Frequencies commands.) To select or change a frequency, move the cursor to that frequency and press ESC. Note that the actual frequency is changed in real-time as the cursor moves through the values in the window.

A red highlight indicates the selected frequency is not compatible with the ac field amplitude and that frequency will not be set. Allowed frequency/field combinations are as follows:

$f < 10$ kHz for $H < 110$ A/m
$f < 2500$ Hz for $H < 1110$ A/m
$f < 1000$ Hz for $H < 2000$ A/m

Field limits are nominal and will vary slightly from system to system. Frequencies not explicitly contained in the window can be manually selected by pressing Enter. A prompt will appear to input the desired frequency and this value will be displayed at the bottom of the frequency window. The allowed frequencies are from 1 to 1000 Hz in 1 Hz steps and 1000 to 10,000 Hz in 10 Hz steps.

NOTE

If proper phase separation is required, always select an operating frequency from the frequency window; i.e., select the frequency by using the cursor key. This automatically accesses the phase angle built into the ACS.DAT file. *Do not use manual entry.* Frequencies entered manually assume a default phase angle of 90 degrees. If proper phase separation is required, the phase must be determined experimentally for the frequency selected.

Gain:

Path: Collection / Temp_ctlr / Gain

Allows the user to change the gain setting of the DRC-91CA Temperature Controller. When selected, the user will be prompted for an input (0–99). After typing a value, press Enter. The default value is 99 and during automated data acquisition the gain will be set/reset to this value.

Graphical:

Paths: Analysis / View / Graphical, Collection / Auto / Real-Time / Graphical, and Collection / Experimental / Log / Graphical

When selected, the processed data will be displayed graphically on the screen. Scaling is handled automatically. Equations entered for X-Axis and Y-Axis under Parm_select will be used to determine the graph. Also, the selection under Susceptibility_display will determine which phase(s) to display. If no equations are entered by the user, then default ones will be used. Esc to exit.

7.4.3 COMMAND BREAKDOWN AND FUNCTIONAL DESCRIPTION

The following is a complete list of ACM7000 Software Commands presented in alphabetical order.

AC:

H Field sub-menu of Experimental Menu.

This sets the amplitude (RMS) of the AC field. When selected, you will be prompted for an input (3-digit selectable, 0.10 to 2000 A/m). After typing a value, press Enter. ESC to exit.

Addenda: Analysis menu

The following sub-menu is accessed.

Select: Prompts for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by **File** in the Analysis menu.

Build: An Addenda file with the extension .add will be created from whatever file has been specified.

Cancel: Cancels a previously selected addenda file.

Addenda: Sample sub-menu of Collection Menu

When selected, you will be prompted for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by **Name** in the Experimental Menu.

All:

View sub-menu of Analysis Menu

This option permits processing all data recorded using multiple temperatures/fields set up in an array. When a file output has been specified, the processed data will be stored in files of the same name but with different extensions: filename.001, filename.002, filename.003, etc. If the temperature/field array had n temperatures and m fields, there would be nm files created. The extension incrementing scheme starts at the lowest temperature, steps through the fields, proceeds to the next temperature and so on until all data is processed. This is illustrated below. When output from only one entry in a temperature/field array is desired, the temperature/field option should be used.

Field \ Temperature					
	.001	.004	.007	.010	.013
	.002	.005	.008	.011	.014
	.003	.006	.009	.012	.015

File extension numbering scheme for a set-up of 3 fields and 5 temperatures

H_field: Path: Collection / Experimental / H_field

This is used to set the amplitude of both the AC and DC magnetic fields. When selected, the following sub-menu will be displayed.

AC: When selected, the user will be prompted to input the amplitude of the AC field.

MPS_field: This is used for setting a single, fixed DC magnetic field of the superconducting magnet.

Profile: This routine enables the user to define a field profile (e.g., for recording data as a function of field) at which data will be recorded during automated data acquisition. When selected, the following sub-menu will be displayed.

- **Discrete:** Build/define a table of discrete field values.
- **Increment:** Build/define a table of discrete field values by selecting a low and high field, and then a field increment.
- **T_change:** Enter a field which will be set after the completion of a field profile sequence, before the temperature is changed.
- **Edit:** Edit a defined field profile. When selected, the window containing the field set-up will be displayed and field entries can be deleted, added, or changed.
- **Maintain:** Define a field that will be set at the completion of an automated data acquisition run.
- **Cancel:** Cancels a previously defined field profile.

Demag_sample: Used to eliminate any remnant fields which may reside in the system after the application of a high DC magnetic field.

Zero_offset: Used to more accurately "zero" the zero current setting of the magnet power supply.

Small_field: Allows setting small DC fields using the ACS control unit and the primary coil.

H_settle: Provides for two options to fine tune settling of magnetic field.

- **Overshoot_ctrl:** An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.
- **Time_dwell:** Enables input of an additional wait period for field stabilization.

H_field: Path: Collection / Experimental / Array / H_field

This is used to set the AC fields that are used when logging data with multiple field or frequency conditions. When selected, the sub-menu "Add Delete" is displayed. If Add is selected, the user are prompted for data input. Input each field value desired and press Enter after each entry. The fields selected will be displayed in a window. Esc to exit. If Delete is selected, the window of selected values will be displayed. To delete a particular entry, move the cursor to that value and press Enter. Esc to exit.

Collection (continued)

Lock-In
Manually set/adjust lock-in control parameters.

Mode
Track/Manual toggle

Filter
Select filter options

- Flat
- Notch
- Low Pass
- Band Pass

Tuning
Select tuning display option

- Phase
- Osc. Freq.
- Level
- Filter Freq.
- Ref. Freq.

Constant
Select time constant

- Up
- Down

Display
Select display mode

- Percent signal
- Signal
- Offset
- Noise
- Ratio
- Log Ratio

Reserve
Select dynamic reserve

- High stability
- Normal
- Reserve

Recall
Load previously defined experimental configuration.

Edit
Modify system defaults (from ACM.DAT).

Constants
Change system constants.

Phases/Freq's
Change system phases and frequencies contained in configuration file.

MPS_rates
Current ramping rates used in charging the superconducting magnet.

Save
Save any changes to configuration file.

Recall
Load previously defined experimental configuration.

Units
Système International d'Unités (SI) or centimeter, gram, second (cgs) toggle.

DOS
Exit to DOS.

H_settle: Path: Collection / Experimental / H_field / H_settle

This routine provides for two options to fine tune the settling of the magnetic field set in the superconducting magnet.

Overshoot_ctrl: An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.

Time_dwell: Permits specifying extra time for the field to settle after each field change.

Esc to exit.

Harmonic: Path: Collection / Experimental / Sequence / Harmonic

Harmonics Option Command. A prompt will appear asking which harmonic (1 through 10) is to be measured and the harmonic selected will be indicated on the display in the Measurement Sequence box. All 10 harmonics are not available for every frequency. The table below indicates the available choices. An error message will be displayed on the screen if an improper selection is made.

HARMONICS	FREQUENCIES
1, 2, 3	All frequencies from 1 – 1 kHz.
1 to 10	f = 5, 6, 8, 10, 12, 15, 16, 20, 24, 25, 30, 32, 40, 48, 60, 75, 80, 100, 120, 125, 150, 160, 200, 240, 250, 300, 375, 400, 500, 600, 750, 800, 1000, 1200, 1500, and 2000

Heater_range: Path: Collection / Temp_ctlr / Heater_range

This allows the user to set or change the heater range setting on the DRC-91CA Temperature Controller. When selected, the following sub-menu is displayed.

MAX: Selection will set the heater range to maximum power.
1_–1: Selection will set the heater range to –1.
2_–2: Selection will set the heater range to –2.
3_–3: Selection will set the heater range to –3.
OFF: Selection will turn the power off.

The heater range is automatically set when in automatic data acquisition mode.

Increment: Path: Collection / Experimental / H_field / Profile / Increment

This allows the user to define discrete field points for fixed field data acquisition by entering them incrementally. When selected, the user will be prompted for a first field value, then a second range value, and finally an increment value (e.g. 0 kOe (or 0 kAmp/m) to 10 kOe (or 800 kAmp/m) in 1 kOe (or 80 kAmp/m) increments). The table of selected values will be displayed on the screen as a window. To input another range, press Enter. To exit, press ESC.

NOTE

Discrete and Increment can be used together to build a table of discrete field points for fixed field point acquisition.

Collection (continued)

Auto	Proceed with automatic data acquisition.
Begin	Begins data acquisition.
End	Ends data acquisition.
Over-ride	Over rides wait period/drift per minute and initiates data taking.
Real Time	Selects real time feedback.
Tabular	Selects tabular mode.
Graphical	Selects graphical mode.
Parm_select	Selects data option; m vs. H, m(v) vs. H, or m(m) vs. H
Temp-Ctlr	Manually set/adjust temperature controller parameters.
Set_Point	Enter temperature set point
1	Increment +10 K.
2	Decrement −10 K.
3	Increment +1 K.
4	Decrement −1 K.
5	Increment +0.1 K.
6	Decrement −0.1 K.
Enter Setpoint	Input set point.
Heater_Range	Select heater power range
Max	Sets to maximum.
1	Sets to −1.
2	Sets to −2.
3	Sets to −3.
Off	Turns off.
Gain	Input gain.
Derivative	Input derivative/rate.
Integral	Input integral/reset.
Auto_T	Input setpoint. Temperature will be automatically adjusted to that setpoint.
Cancel	Cancel and reset to default conditions.

Increment: Path: Collection / Experimental / Temp_spec / Increment

Allows the user to define discrete temperature points for fixed point data acquisition by entering them incrementally. When selected, the user will be prompted for a first value, a second value, and finally an increment. The table of selected values will be displayed on the screen as a window.

If the first temperature is below 30 K, the second temperature maximum is set to 30 K and increments of 0.01 are allowed. If the first temperature is above 30 K, the second temperature maximum is set to 325 K and increments of 0.1 are allowed. Hence, to build a list with increment mode through 30 K requires two input sequences by the user.

NOTE

List and Increment can be used together to build a table of discrete temperature points for fixed point data acquisition.

Integral: Path: Collection / Temp_ctlr / Integral

Allows the user to change the Reset setting of the DRC-91CA Temperature Controller. When accessed, the user will be prompted for an input (0–99). After typing a value, press Enter. The default value is 0 and during automated data acquisition the reset will be set/reset to 0.

Label: Path: Analysis / Output / Label

Allows the user to input a label which will be printed at the head of a hard copy of your processed data or outputted to an ASCII file.

Level: Path: Collection / Lock-In / Tuning / Level

When selected, the display will indicate the amplitude of the oscillator frequency.

List: Path: Collection / Experimental / Temp_spec / List

This routine enables the user to enter temperatures individually in order to build your own list of temperatures at which data will be recorded during automated data acquisition.

When selected, the user will be prompted for a temperature input. Input a value and press Enter. A window will be displayed on the screen with this single temperature value. Continue to input as many temperatures as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which temperatures are entered is important, since the software has the ability to cool or heat to a setpoint. ESC when completed to exit.

NOTE

List and Increment can be used together to build a table of discrete temperature points for fixed point data acquisition.

Lock-In: Path: Collection / Lock-In

This enables the user to change/modify certain parameters/features of the Lock-in Amplifier. When selected, the following sub-menu will be displayed.

Mode	For selection of filter frequency tuning modes of the Lock-in Amplifier.
Filter	Allows selection of the signal channel filter on the Lock-in Amplifier.
Tuning	Used to select the display parameter on the tuning LCD of the Lock-in Amplifier.
Constant	For adjustment of the time constant setting on the Lock-in Amplifier.
Display	For selection of display parameter on the output LCD of the Lock-in Amplifier.
Reserve	Allows adjustment of the dynamic reserve setting of the Lock-in Amplifier.

Collection (continued)

Sample	Input sample specifications.
Magnetization	Select volume or mass magnetization and input sample volume or mass.
Demagnetization	Enter demagnetization factor (& sample density if mass susceptibility selected).
Calibration Coeff.	Modify calibration constant.
Addenda	Enter addenda file name.
Experimental	Set all experimental parameters/manual testing.
Frequency	Select frequency of AC field.
H_field	Select amplitude of AC field, DC field, and DC field of MPS.
AC_field	Select/Set the AC field.
MPS_field	Select/Set the DC magnetic field of the superconducting magnet.
Demag_sample	Selection performs demagnetization cycle for elimination of remnant fields.
Zero_offset	Selection compensates for any MPS zero-drifts.
Sequence	Define measurement sequence.
Phase Increment	Select phase increment.
Movement	Sample movement on/off.
Autorange	Enable/disable lock-in auto-range.
Cycle Select	Select full/half cycle.
Temp Spec.	Define temperature set-up.
List	Enter individual points.
Incremental	Enter low/high & increment.
Edit	Change existing set-up.
Cancel	Cancel existing set-up.
Setpt_Adjust	Fine tune of setpoint on/off.
Name	Enter file name for data storage.
Move Sample	Move sample from one coil position to the other.
Log	Log single data point according the defined measurement sequence.
Begin	Begin logging.
Tabular	Selects tabular mode.
Graphical	Selects graphical mode.
Parm_select	Selects data option; m vs. H, m(v) vs. H, or m(m) vs. H
Cancel	Cancel logging.
Phase	Adjust phase.
Auto	Automatically measures phase for particular sample.
1	Change by +90°.
2	Change by –90°.
3	Change by +10°.
4	Change by –10°.
5	Change by +1°.
6	Change by –1°.
7	Change by +0.1°.
8	Change by –0.1°.
Set	Input phase.
Array	Define field/frequency array.
H Field	Add/delete AC fields.
Cancel	Cancel array.

Log:

Path: Collection / Experimental / Log

Selection of this will record the measurement sequence as defined (sans Temperature specifications), and also, if specified, will execute an array or field profile. These measurements are done at the current temperature. If the user wish to use the temperature specs, then Auto should be used instead of Log. Data can be stored to a file. If no file name is specified, the data will be written to "TEMPFILE.DAT."

Begin: This initiates the data acquisition process and will display the results in the lower right-hand feedback block. Esc to exit.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

Dual Phase:

X-Axis Eq. v' (μV) v'' (μV) Y-Axis' Y-Axis"

or

X-Axis Eq. v' (μV) v'' (μV) Y-Axis magnitude

Single Phase:

X-Axis Eq. v(phase) (μV) Y-Axis Eq.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence and the option chosen for Susceptibility_display. If no display parameters are selected, the program will use the following defaults: if data is logged in single phase, χ' (vertical axis) vs. T (K) (horizontal axis) will be plotted; if data is logged in dual phase, both χ' and χ'' vs. T(K) will be displayed. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a complex matrix of susceptibility data recorded at different fields, frequencies, and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive). Esc to exit.

T:	Temperature	N:	Harmonic	TI:	Time
HAC:	AC field	F:	Frequency		
H:	DC field	χ:	Susceptibility		

Cancel: Terminate the data acquisition.

This data can be written to a file specified using Name. If no file name is specified, it will be written to "TEMPFILE.DAT." To abort the Log sequence, select Cancel.

CAUTION

If Log is used successively, and no file specification is made, the contents of TEMPFILE.DAT will be overwritten.

7.4.2 Menu Breakdown and Functional Description

The following is a text-based representation of the ACM7000 Software configuration.

Analysis	Display the analysis menu.
Begin	Processed data sent to printer or file depending on options selected in Output.
Cancel	Cancel type output, printer, or file depending on options selected in Output.
Sample	Input sample specifications.
Magnetization	Select volume or mass magnetization and input sample volume or mass.
Demagnetization	Enter demagnetization factor (and sample density if processing in terms of mass susceptibility).
Calibration Coeff.	Modify calibration constant.
Label	Input sample label to be printed on printout.
File	Input data file for processing.
View	Display processed data on screen.
Tabular	Displays processed data on screen according to the Type-Output selected.
Graphical	Displays processed data graphically on screen according to the Type-Output selected.
Parm_select	Selects data option to be displayed or processed; m vs. H, m(v) vs. H, m(m) vs. H, or raw data.
All	Processes data for all temperature/field combinations when arrays have been used.
Output	Select type output, printer, or file.
Printer	Prints data to hard copy device. Selects print option.
File	Prints data to file. Selects file output option.
Addenda	Select/create addenda file.
Select	Selects previously created addenda file.
Build	Creates addenda file from data file.
Cancel	Cancels previously selected addenda file.
Phase Adjust	Modify/adjust phase.

Collection	Display the collection menu.
Position	Position sample in top or bottom sensing coil.
Top	Specify top coil position.
Bottom	Specify bottom coil position.
1 - Up Coarse	Moves sample up 0.1 inch.
2 - Up Fine	Moves sample up 0.01 inch.
3 - Down Fine	Moves sample down 0.01 inch.
4 - Down Coarse	Moves sample down 0.1 inch.
Auto_Position	Automatically centers sample in bottom secondary coil.

Log_ratio: Path: Collection / Lock-In / Display / Log_ratio

When selected, the output LCD indicates the log of the output described in Ratio.

Low_pass: Path: Collection / Lock-In / Filter / Low_pass

The low-pass filter gives maximum rejection of the higher harmonics but allows frequencies below f_0 to be passed unattenuated. This is the default filter setting and the filter should, in general, be left on Low_pass.

MAX: Path: Collection / Temp_ctlr / Heater_range / MAX

Selection will set the heater range to maximum power.

Maintain: Path: Collection / Experimental / H_field / Profile / Maintain

This is an on/off toggle. When activated, the last DC field in a profile will be "maintained" at the end of an automatic collection run. When Maintain is off, the DC field will be set to zero at the end of an automatic collection run.

Manual: Path: Collection / Lock-In / Mode / Manual

Selecting this option tells the filter to tune to the frequency set by the PARAMETER ▲ and ▼ keys on the front panel of the Lock-In Amplifier.

Matrix: Path: Collection / Experimental / Array / Matrix

When selected, a field/frequency matrix is displayed. X's mark the field/frequencies which will be used. Individual field/frequency combinations can be deleted or subsequently added to the table by moving the cursor to that element and pressing Enter. Press Esc to exit.

Mode: Path: Collection / Lock-In / Mode

Selects either of two filter frequency tuning modes, Track or Manual. This is an on/off toggle. The default setting is Manual. In this case, the filter tunes to the reference channel operating frequency. If Manual is selected, the frequency is tuned to the frequency set by the PARAMETER keys on the front panel of the Lock-in Amplifier.

Movement: Path: Collection / Experimental / Sequence / Movement

This is an on/off toggle to set sample movement conditions for a measurement sequence. When on, the sample will be automatically moved from the bottom secondary coil to the top secondary coil and back during the logging of a data point. When off, the sample will remain in the secondary coil it was in prior to data acquisition.

Move_sample: Path: Collection / Experimental / Move_sample

Selection of this moves the sample from one secondary coil to the other. The sample must be first positioned in one of the secondary coils before this function can be utilized.

MPS_field: Path: Collection / Experimental / H_field / MPS_field

This command is functional only in systems with a magnet. It sets the DC magnetic field of the 1, 5, or 9 tesla magnet. When selected, the user will be prompted to input a field value. After entering a value, press return. The MPS current will then be automatically adjusted to and stabilized at the selected field.

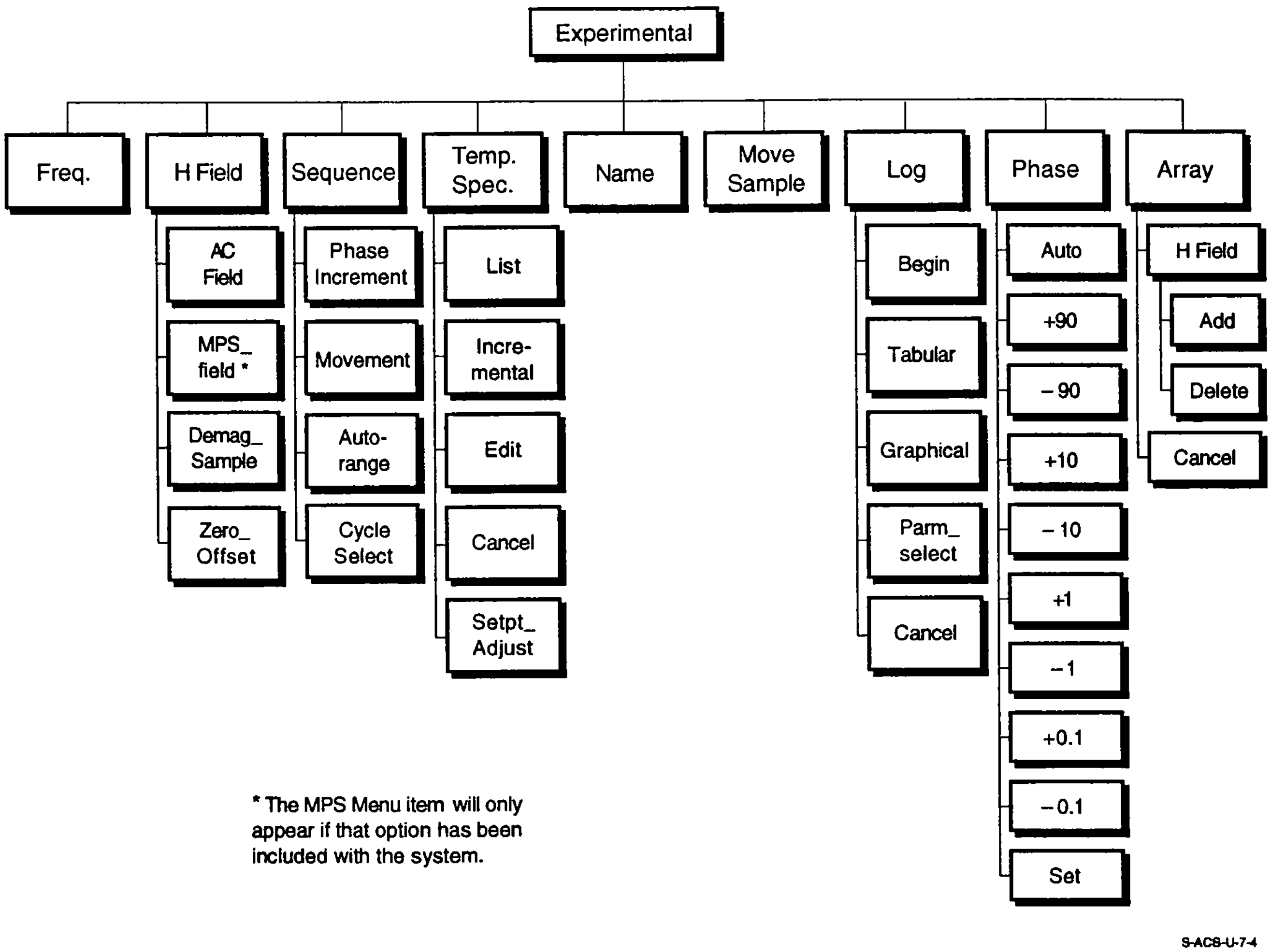


Figure 7-4. Experimental Menu Block Diagram

MPS_rates: Path: Edit / MPS_rates

Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Name: Path: Collection / Experimental / Name

This allows the user to specify a data file to which the data logged will be written. When selected, the user will be prompted for a file name with no extensions. After typing a file name, press Enter.

If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG. If the file name selected already exists, the user will be prompted for a new file name. If a new file name is not specified, the new data will overwrite the data currently contained in the file.

Noise: Path: Collection / Lock-In / Display / Noise

When selected, the output LCD indicates the rectified output noise in percent of full scale.

NORM: Path: Collection / Lock-In / Reserve / NORM

Selection of this gives a FLAT mode dynamic reserve of 40 dB.

Notch: Path: Collection / Lock-In / Filter / Notch

This provides a stop band with very deep attenuation at f_0 (the reference frequency).

OFF: Path: Collection / Temp_ctlr / Heater_range / OFF

Selection will turn the power off.

Offset: Path: Collection / Lock-In / Display / Offset

When selected, the output LCD indicates the offset value in effect.

Osc_freq: Path: Collection / Lock-In / Tuning / Osc_freq

When selected, the display will indicate the set oscillator frequency.

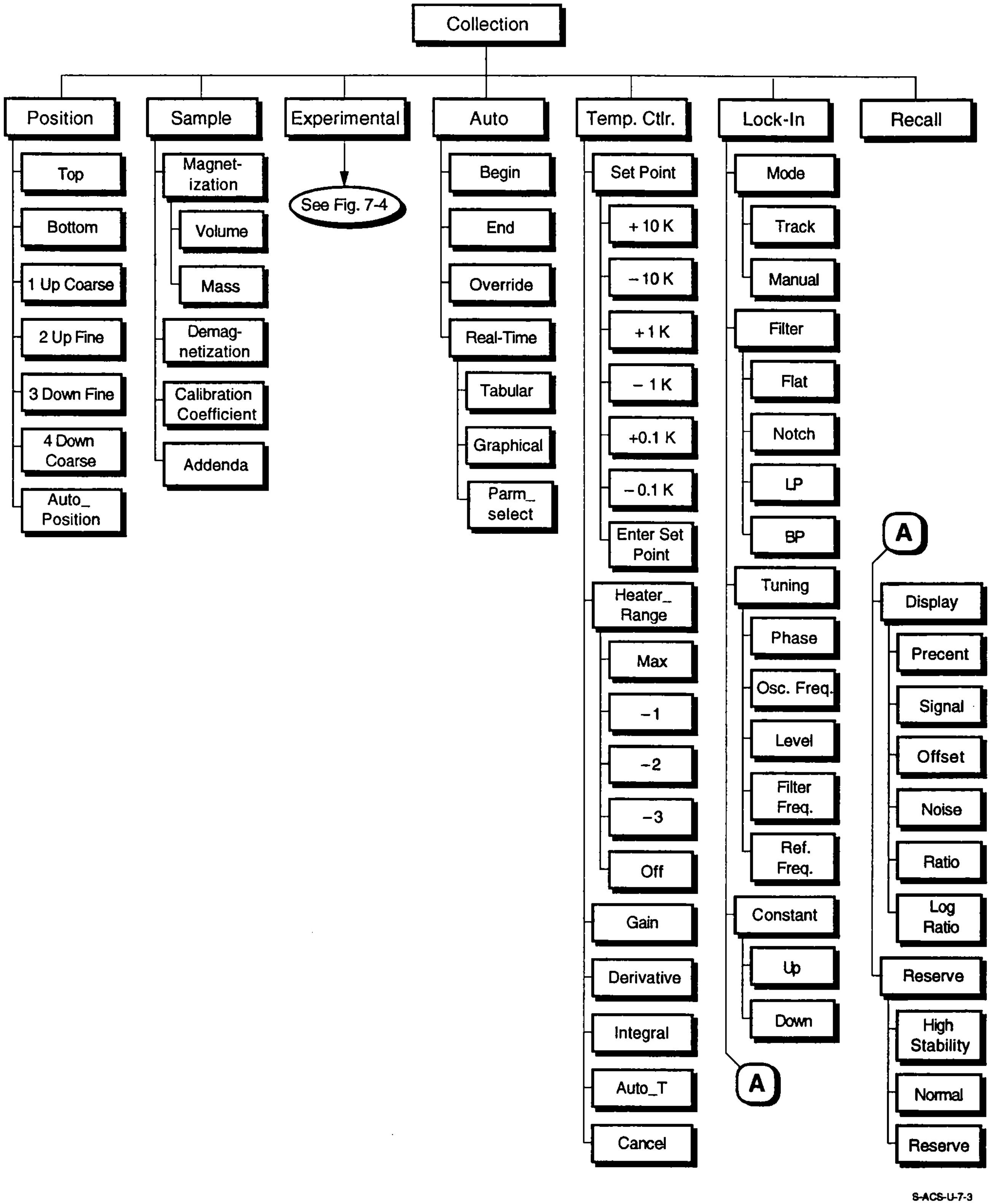


Figure 7-3. Collection Menu Block Diagram

Output: Path: Analysis / Output

This routine allows the user to specify that the processed data be either written to a ACSII file or to a printer. When selected, the following sub-menu is displayed. What is actually written to a file or printer depends on selections made in Parm_select and Data_output.

Printer: On/off toggle.

File: Enter a filename (without extensions). All appropriate data headers will be written to the file or printer (i.e., fixed field, temp, freq values, etc.). The output format is:

Dual Phase:

X-Axis Eq. v' (μV) v'' (μV) Y-Axis' Y-Axis"

or

X-Axis Eq. v' (μV) v'' (μV) Y-Axis magnitude

Single Phase:

X-Axis Eq. v(phase) (μV) Y-Axis Eq.

Or for raw data:

v_0^{bot} v_{90}^{bot} v_0^{top} v_{90}^{top}

where: v_0^{bot} = voltage at 0° in the bottom coil,
v_{90}^{bot} = voltage at 90° in the bottom coil,
v_0^{top} = voltage at 0° in the top coil, and
v_{90}^{top} = voltage at 90° in the top coil.

If data was taken in single phase, then the dual phase column will be zeros.

Label: Allows the user to input a label which will be printed at the head of a hard copy of your processed data or outputted to an ACSII file.

Override: Path: Collection / Auto / Override

During fixed temperature points data acquisition mode, selection of this key will override certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent on the particular temperature range. (Drift/minute and waits are adjustable under Wait_times.) Upon completion of the WAIT, a DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once this DRIFT/MIN is below 0.1 K per minute, the data acquisition/measurement sequence will automatically begin. Selecting Override once will override the designated WAIT period and initiate the DRIFT CHECK. Selecting Override again will override this as well and data will be recorded immediately.

While the temperature is being adjusted from one setpoint to another, Override can be selected to record data at some intermediate temperature. When Override is selected, the temperature ramping will cease and the above mentioned WAIT period will be initiated. In addition to the waits already mentioned, override can override a Begin_time if one was specified under Temp_spec.

Overshoot_ctrl: Path: Collection / Experimental / H_field / H_settle / Overshoot_ctrl

This is an on/off toggle which can be used to activate a special MPS/field control routine used to minimize any field overshoot which may occur on changing fields. The feature functions by pre-settling the field at a value slightly different than the targeted value. After pre-settling, the final field value is set. Activating this feature will add approximately 45 seconds to the time required for field stabilization.

Changing the rates specified for field ramping using the MPS_rates option will also increase or decrease the amount of overshoot depending upon whether the rates are increase or decreased, respectively.

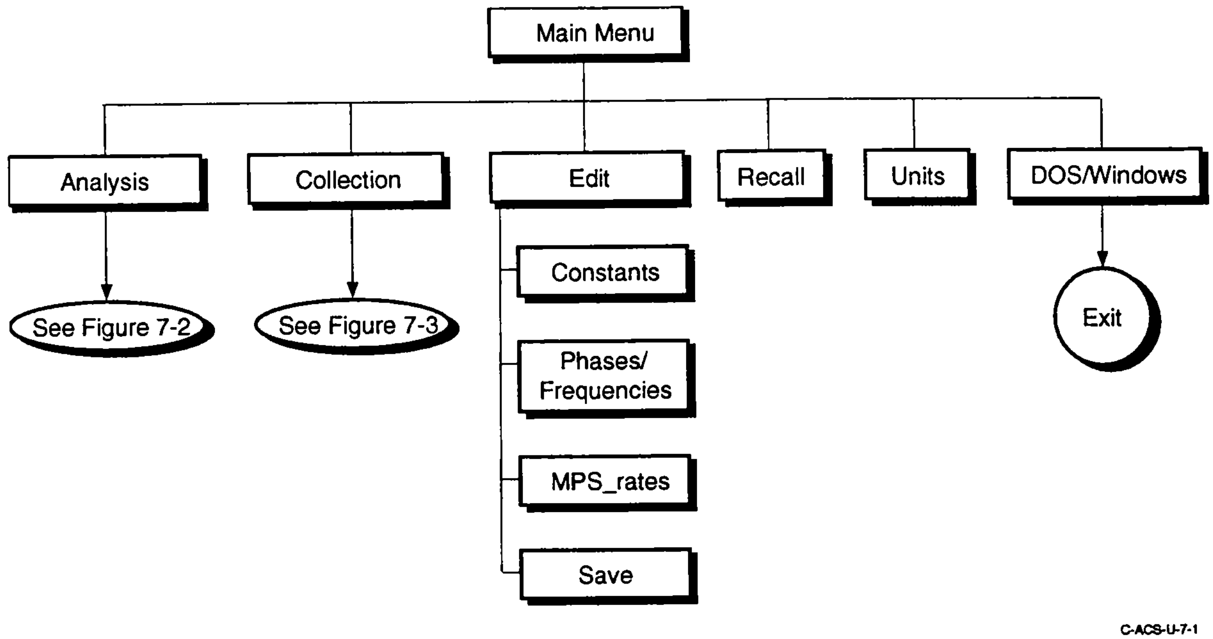


Figure 7-1. Main Menu Block Diagram

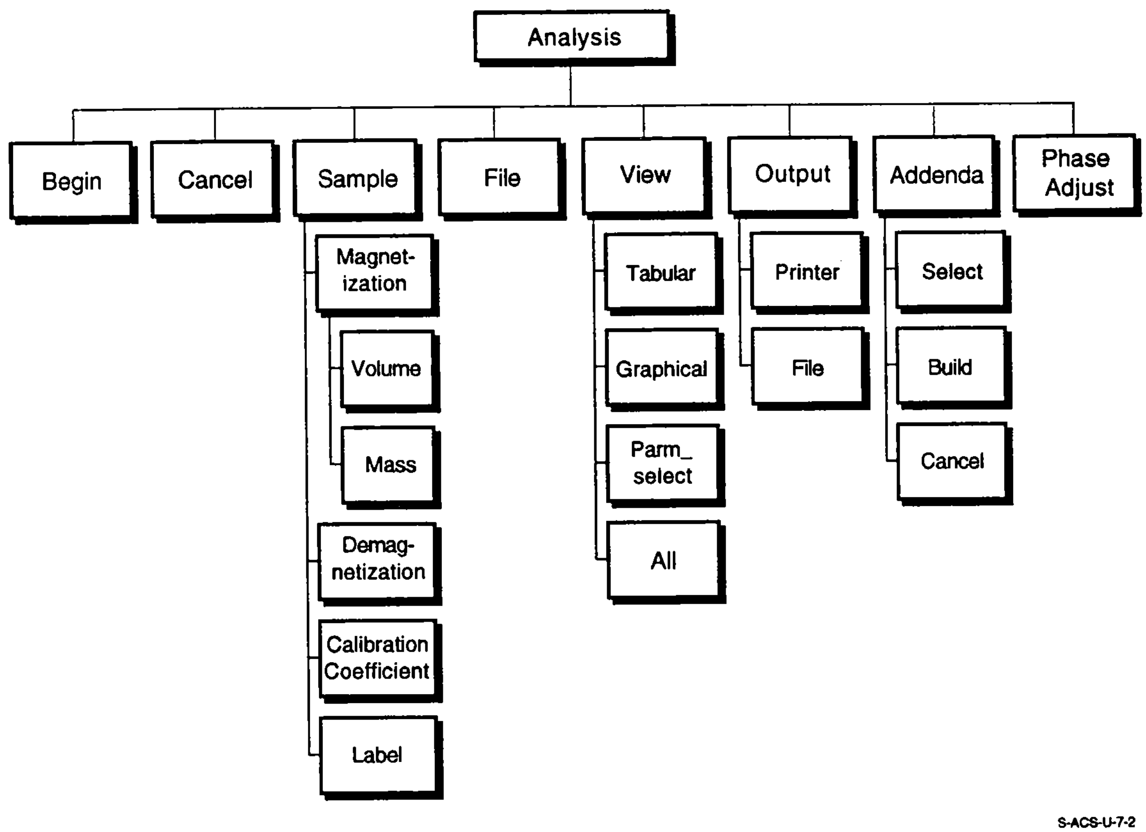


Figure 7-2. Analysis Menu Block Diagram

Parm_select: This command is included in 4 locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. Depending upon the experimental setup, a single acquisition run can yield a complex matrix of susceptibility data recorded at different fields, frequencies, and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T:	Temperature	N:	Harmonic
HAC:	AC field	F:	Frequency
H:	DC field	χ:	Susceptibility
TI:	Time		

Refer to Paragraph 5.2.9.1 for further information. Press Esc to exit.

Percent: Path: Collection / Lock-In / Display / Percent

When selected, the output LCD indicates Lock-in Amplifier output in % of full scale for all sensitivities.

Phase: Path: Collection / Lock-In / Tuning / Phase

When selected, the Lock-in Amplifier LCD display indicates the phase shift introduced either by the software or the user.

Phase: Path: Collection / Experimental / Phase

When this Phase is accessed, the following sub-menu will be displayed.

Auto: This will automatically set the phase for a particular sample under study. When selected, measurements at 0 and 90 degrees in both the top and bottom coil will be performed and the following computation performed.

$$\theta = 90 - \{\tan^{-1} [(v_0^{top} - v_0^{bot})/(v_{90}^{top} - v_{90}^{bot})]\}$$

Where: v_0^{top} = voltage at 0° in top coil.
v_{90}^{top} = voltage at 90° in top coil.
v_0^{bot} = voltage at 0° in bottom coil.
v_{90}^{bot} = voltage at 90° in bottom coil.

The phase of the Lock-in Amplifier will then be set to this value of .

1_+90: Will rotate the phase by +90°.
2_–90: Will rotate the phase by –90°.
3_+10: Will rotate the phase by +10°.
4_–10: Will rotate the phase by –10°.
5_+1: Will rotate the phase by +1°.
6_–1: Will rotate the phase by –1°.
7_+0.1: Will rotate the phase by +0.1°.
8_–0.1: Will rotate the phase by –0.1°.
Set: At the prompt, input the phase value and press Enter.

Phase: Path: Collection / Experimental / Sequence / Phase

This is a toggle between single phase and dual phase data acquisition.

The measurement requires specifying a phase increment ($\Delta\theta$). The system will automatically set the lock-in amplifier phase to ϕ, record the voltage (using sample movement if activated), increment the phase by $\Delta\theta$, record voltage again, and continue this process through a full cycle to ϕ + 360. At each phase angle, the corresponding moment and field is given by the following:

$$m(\theta) = \frac{\sqrt{2}\alpha v(\theta)}{f}$$

$$H(\theta) = \sqrt{2}H_{ac}\,cos(\theta - \phi)$$

The resulting m(H) curve is obtained by plotting this data.

Since the measurement always yields the situation (H,m)=(–H,–m), data can be recorded through only a half cycle (180°) with the remaining part of the loop generated from the first half cycle data.

7.3.3 Addenda

The ACM7000 program permits making addenda corrections to subtract background signals arising from the empty sample holder, substrates, etc.

First, data are recorded with whatever is to be the background using normal operation with sample movement. The temperature range and ac field range should extend slightly beyond the actual range of interest. The number of data points used will depend upon the size of the signal to be corrected and how fine of a grid the user desires. The data file is then processed using the **Build** option in the **Analysis** part of the ACM7000 to create what is called an addenda file. If this file is then specified using either the **Select** option in **Analysis** or the **Addenda** option under **Collection**, the corresponding movement data will be interpolated and subtracted from whatever data is recorded during data acquisition.

The processing of the addenda file assumes the addenda has a linear m vs. H at each temperature. This would occur in most situations and is typical for paramagnetic or diamagnetic background materials. If any unusual type of background is encountered, the built-in addenda feature should not be used.

7.4 ACM7000 PROGRAM DESCRIPTION

ACM7000 is the data acquisition and analysis software which automatically controls all system functions. The software is structured in the same menu driven, easy to use format as the ACS7000 and DCM7000 software. There is provision in the software for recording low-field hysteresis loops with or without an applied dc bias field, at discrete temperatures input by the user. The software features real-time feedback in either tabular or graphical format, and an analysis package for post-processing of previously recorded data.

Since DOSSHELL is no longer included, the ACM7000 software must be run from DOS. At the C prompt, type "cd acm." Once the prompt displays the appropriate directory, type "ACM7000." To return to the main C prompt, type "cd\." To enter the collection mode, the instruments must be turned on first. The analysis mode can be run with the instruments off.

CAUTION

If for any reason an instrument has to be turned off after the program has initialized the instruments, it will be necessary to restart the program ACM.

7.4.1 Menu Breakdown and Option Description

The following information consists of three major portions:

- A flowchart of menu and sub-menu selections.
- A menu and sub-menu breakdown including a brief functional description of each option.
- An alphabetical listing of each of the menu and sub-menu options. Each entry describes in detail where that option is found and how it is used.

Phase_adjust: Path: Analysis / Phase_adjust

This enables the user to input phase values to see the effect of phase changes on the processed susceptibility values. When selected, the user will be prompted for an entry. After typing a value, press Enter.

Phases/Frequencies: Path: Edit / Phases/Frequencies

When selected, a table containing 32 frequencies with their associated phase angles appears in a window. The frequencies listed in this table are the default frequencies which will appear in the selection window used during experimental operation (Refer to the Frequency command.) As supplied, the system is configured with 32 preset frequencies which may be changed to meet required needs. Frequencies can be selected from 1 to 1000 Hz in 1 Hz steps and 1000 to 10,000 Hz. in 10 Hz steps.

The phase angle associated with each frequency is used during data acquisition and analysis, so proper specification of the phase angle is required. If single phase data is logged at one of the 32 specified frequencies, the Lock-in Amplifier phase setting will be set to the corresponding phase angle for data acquisition. In dual phase acquisition, data are recorded at both 0 and 90 degree phase settings on the Lock-in Amplifier. The phase angle from the phase/frequency table is then used to process the data to yield the correct phase separation for the real and imaginary components of the susceptibility.

In order to change a particular phase or frequency, move the cursor to that entry and press Enter. A new value can then be input. Press Esc to exit.

Position: Path: Collection / Position

This routine is used to position the sample in one of the two secondary coils. When accessed, the following sub-menu is displayed.

Top: This toggle specifies the sample is positioned in the top secondary coil.

Bottom: This toggle specifies the sample is positioned in the bottom secondary coil.

1_Up/Coarse: The sample will move up 0.1 inch (0.254 cm) from its current position.

2_Up/Fine: The sample will move up 0.01 inch (0.0254 cm) from its current position.

3_Down/Fine: The sample will move down 0.01 inch (0.0254 cm) from its current position.

4_Down/Coarse: The sample will move down 0.1 inch (0.254 cm) from its current position.

Autoposition: Automatically centers the sample in the bottom secondary coil. When selected, the sample will be automatically moved to the bottom limit switch and then incrementally moved up at 0.1 inch increments, the Lock-in Amplifier voltage will be read each time. Once a peak (in absolute value) in the voltage is measured, the sample will continue to move up 3 additional steps. This operation is performed so that a curve can be fit to the voltage vs. position data and a maximum determined. This maximum in voltage vs. position defines the center of the bottom secondary coil and the sample will be automatically moved to that position and the sample position status will indicate "Bottom Coil."

NOTE

There are safeguards built into the software that are designed to keep the sample from being positioned improperly. There will be instances where the voltage induced by the sample is so small that a maximum cannot be readily determined. In this case, the user will be prompted with the statement "Center position cannot be found." It may be necessary to find the center position using an alternate technique. Refer to Paragraph 5.2.4 for sample positioning techniques.

7.2 ACM7000 SOFTWARE SPECIFICATIONS

Temperature:

Range:	<4.2K to 325K
Accuracy:	±0.2K or ±0.5% of T, whichever is greater
Stability:	±0.1K
Uniformity:	±(0.1K + 0.1% of T)

AC/DC Magnetic Field (Primary Coil):

Range:	3-digit selectable from 0.1 A m^{-1} (0.00125 Oe) to 2000 A m^{-1} (20 Oe) RMS, both AC and DC.
Frequency:	1 Hz to 1 kHz 1 Hz steps, 1 kHz to 10 kHz, 10 Hz steps

Moment Sensitivity: 5 X 10^{-10} A m^2 or 5 X 10^{-7} emu

7.3 ACM7000 PRINCIPLES OF OPERATION

ACM7000 software principles of operation are described in the following three paragraphs. Paragraph 7.3.1 provides definitions. Operational procedures are described in Paragraph 7.3.2. Finally, addenda file information is provided in Paragraph 7.3.3.

7.3.1 Definitions

The following are definitions of symbols used in the ACM7000 principle of operation.

ϕ	System phase angle as contained in acm.dat
θ	Phase angle setting on lock-in amplifier
Hac	RMS ac field amplitude specified from ACM7000
$v(\theta)$	Lock-in voltage recorded at phase angle θ
f	Operating frequency specified from ACM7000
α	AC calibration coefficient
$m(\theta)$	Sample moment measured at phase angle θ
$H(\theta)$	Magnetic field corresponding to phase angle θ

7.3.2 Procedure

During normal operation of the ACM7000 program, the lock-in amplifier uses a low-pass filter to reject higher order harmonics and noise to yield a better measurement of χ' and χ''. However, in order to properly characterize any non-linear m(H) behavior such as occurs in hysteretic samples, the complete signal must be analyzed. During measurements with ACM7000, the low-pass filter is disabled and the lock-in amplifier is set to flat mode of operation.

The system phase angles (ϕ) are determined for each operating frequency as in the ACS7000 software. However, the system must be phased with the lock-in amplifier set to the flat mode of operation since the filter effects the value of the phase angle. The system phase angles contained in ACS.DAT for operation with ACS7000 will not be the same as contained in ACM.DAT for operation with ACM7000. A proper system phase angle is critical in determining the proper shape of the m(H) curve.

Printer:
Path: Analysis / Output / Printer

An on/off toggle for specifying that processed data be printed to a hard copy device.

Profile:
Path: Collection / Experimental / H_Field / Profile

This routine is used to define/set-up the field profile/control that is to be used during an automated data acquisition run. When selected, the following sub-menu will be displayed.

Discrete: Used to input discrete field values for creating a field table where data will be recorded.

Increment: This is for the selection of fields used for creating a field table, entered incrementally, to be used in automated data acquisition.

T_change: Allows you to input a field value that will be set after the completion of a field profile, prior to adjustment of the temperature. The temperature will be adjusted at this field setting.

Edit: Enables you to edit previously defined field control parameters.

Maintain: This is an on/off toggle that will leave the field set to a user defined value after the completion of an automated data acquisition run (e.g., for recording field-cooled magnetization data after the completion of a zero-field-cooled automated data acquisition run).

Cancel: This allows you to cancel a previously defined field profile/control.

Ratio:
Path: Collection / Lock-In / Display / Ratio

When selected, the output LCD indicates the ratio of the Lock-in Amplifier's output to the DC level applied to the rear-panel CH1 ADC AUX INPUT.

Real-time:
Path: Collection / Auto / Real-time

Selection of this activates real-time feedback of data. When selected, the following sub-menu is accessed.

Tabular: When selected, data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

Dual Phase:

X-Axis Eq. v' (μV) v'' (μV) Y-Axis' Y-Axis"

or

X-Axis Eq. v' (μV) v'' (μV) Y-Axis magnitude

Single Phase:

X-Axis Eq. v(phase) (μV) Y-Axis Eq.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence and the options chosen for Susceptibility_display. If no display parameters are selected, the program will use the following defaults: if data is logged in single phase, χ' (vertical axis) vs. T (K) (horizontal axis) will be plotted; if data is logged in dual phase, both χ' and χ'' vs. T(K) will be displayed. Scaling is automatic. Esc to exit.

CHAPTER 7
ACM7000 SOFTWARE OPERATION

7.0 GENERAL

The Model 700ACM AC Moment Measurement Option consists of the ACM7000 Software. The ACM7000 program utilizes a method proposed by Fedor Gömöry[1] which generates an M(H) curve from the ac signal induced in the secondary coils. *This Technique and analysis assumes a M(H) behavior which satisfies the condition such that for every point (M,H), there exists a point (–M, –H). This is true for most hysteretic behavior centered around a zero field.*

Operation and procedures follow the ACS7000 program quite closely and familiarity with this software package is assumed. Hardware operation is identical to standard procedures.

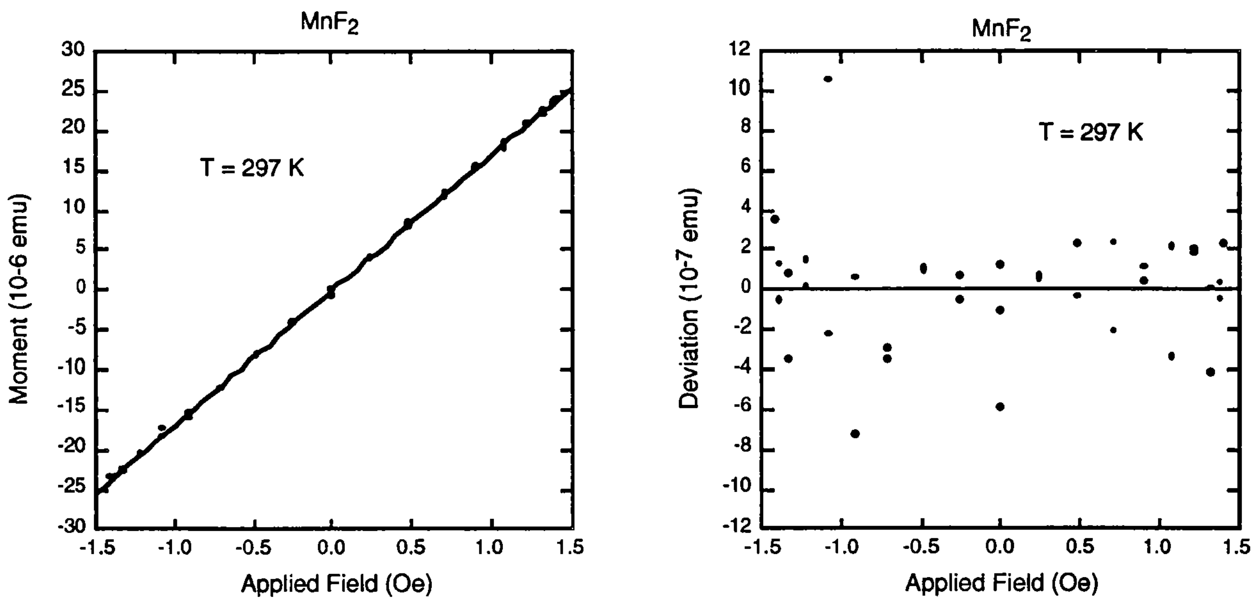
Ref 1. "Use Of A Phase-Sensitive Detector For Measuring Magnetic Hysteresis Loops," Rev. Sci. Instrum. 62, 2019 (1991)

7.1 ACM7000 DESCRIPTION

With this option low-field hysteresis loops (m vs. H) can be generated which realize the magnetic moment precision of the AC measurement technique ($<10^{-10}$ A m^2 or 10^{-7} emu). This procedure uses the phase sensitive detector to analyze the AC pick-up signal and recreate the hysteresis loop. This powerful technique greatly expands the versatility of the AC measurement.

This method is suitable for hysteresis loop measurements on small high T_C samples, and also other magnetic materials. In addition, since it is an AC measurement technique, it permits the study of rate-dependent effects requiring the comparison of magnetization loops obtained at different measurement frequencies.

ACM7000 is the data acquisition and analysis software which automatically controls all system functions. The software is structured in the same menu driven, easy to use format as the ACS7000. There is provision in the software for recording low-field hysteresis loops with or without an applied DC bias field, at discrete temperatures input by the user. The software features real-time feedback in either tabular or graphical format, and an analysis package for post-processing of previously recorded data. The following two illustrations are two examples of results of data collected by the ACM7000 program.



Magnetic moment of a MnF_2 sample at a temperature 297 K. Deviation of the data from the best fit line. The standard deviation of the data is 10^{-7} emu.

Real-time (Continued)

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a complex matrix of susceptibility data recorded at different fields, frequencies, and temperatures. This permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be used when specifying an equation (not case-sensitive):

T:	Temperature	N:	Harmonic	TI:	Time
HAC:	AC field	F:	Frequency		
H:	DC field	χ:	Susceptibility		

Refer to Paragraph 5.2.9.1 for further information. Press Esc to exit.

Recall:

Path: Collection / Recall

Enables the user to load a previously generated configuration file. This is useful when samples are often run using the same experimental conditions or parameters. When selected, the user will be prompted for a file name (no extension). After typing a file name, press Enter. Changes to the experimental configuration can then be made through the software if required. Pressing Enter will display a list of file names.

Ref_freq:

Path: Collection / Lock-In / Tuning / Ref_freq

When selected, the Lock-in Amplifier LCD display will indicate the reference frequency.

Reserve:

Path: Collection / Lock-In / Reserve

Sets the Dynamic Reserve of the Lock-in Amplifier. The following sub-menu will appear.

STAB: High Stability – Selection of this gives a FLAT mode dynamic reserve of 20 dB.

NORM: Normal – Selection of this gives a FLAT mode dynamic reserve of 40 dB.

RES: Reserve – Selection of this gives a FLAT mode dynamic reserve of 60 dB.

The default setting is STAB. During automatic data acquisition, this setting is adjusted automatically if the need arises.

RES:

Path: Collection / Lock-In / Reserve / RES

Selection of this gives a FLAT mode dynamic reserve of 60 dB.

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Sample:

Paths: Analysis / Data_process / Sample and Collection / Data_process / Sample

This enables the user to input sample parameters that enter into the calculations of susceptibility from raw data. When selected, a window is displayed where the user can enter the following.

Volume: Allows the user to enter or adjust the sample volume. Input a value and press Enter.

Mass: Allows the user to enter or adjust the sample mass. After typing a value press Enter.

Demagnetization: Allows the user to enter or adjust a sample demagnetization factor. After typing a value, press Enter.

Density: Allows the user to enter or adjust the sample density. After typing a value, press Enter.

Molecular Weight: Allows the user to enter or adjust a sample molecular weight. After typing a value, press Enter.

NOTE

There are system default values defined that will be used to compute susceptibility from raw data if no specifications are made. They are: SI-units, volume susceptibility with sample volume = 1 cm^3 (1 X 10^{-6} m^3), Demagnetization = 0. These values are arbitrarily assigned and therefore the resulting susceptibility values are arbitrary.

Save:

Path: Edit / Save

This enables the user to save any changes that were made in Constants, MPS_rates, or Phase/ Frequency to the ACS.DAT file. When selected, the user will be prompted with "Are the user sure?" Yes No." If Yes is selected, the new information will be written to ACS.DAT. If No is selected, the new information will not be written to ACS.DAT.

Select:

Path: Analysis / Addenda / Select

This selects the Addenda file to be used in processing the data in Analysis. When selected, the user will be prompted for an Addenda file name (no extension). After typing a valid file name, press Enter.

Set:

Path: Collection / Experimental / Phase / Set

Selection of this allows the user to enter the phase. Upon selecting, the user will be prompted for an input. Input the value and press Enter.

Setpoint:

Path: Collection / Temp_ctlr / Setpoint

This routine enables the user to adjust or change the temperature setpoint of the DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

1_+10: Increments the temperature setpoint +10 K from its current value.
2_–10: Decrements the temperature setpoint –10 K from its current value.
3_+1: Increments the temperature setpoint +1 K from its current value.
4_–1: Decrements the temperature setpoint –1 K from its current value.
5_+0.1: Increments the temperature setpoint +0.1 K from its current value.
6_–0.1: Decrements the temperature setpoint –0.1 K from its current value.
Enter_setpoint: Sets the setpoint at a user defined value. When selected, the user will be prompted for an input. Input a setpoint (selectable to within 0.1 K) and press Enter.

Voltmeter: Path: Collection / Voltmeter

Disable the auto-ranging feature of the voltmeter or adjusts the sensitivity range of the voltmeter. When selected, the following sub-menu will appear.

Autorange: This is an on/off toggle for disabling the auto-ranging feature of the voltmeter.

Select_range: This allows you to choose which sensitivity range is used during automated data acquisition.

Integration_time: Used to set the Digital Voltmeter (DVM) integration time to either 1 power line cycle (PLC) or 100 milliseconds.

These commands are described alphabetically within this section.

Wait_times: Path: Collection / Temp_ctlr / Wait_times

Upon selection, a window will be displayed containing the temperature ranges and the associated wait times (in seconds) the system will wait for a particular setpoint to stabilize. The boundaries for each temperature range are fixed. Also displayed is the drift criteria which must be met for data acquisition to begin. Use the arrow keys to select the temperature range to edit, and press Enter to modify the wait time. Press Esc to exit.

X-Axis_equation: Four locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. When selected, enter the user-defined X-axis equation adhering to the rules discussed under the Parm_select command. Press Esc to exit.

Y-Axis_equation: Four locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. When selected, enter the user-defined Y-axis equation adhering to the rules discussed under the Parm_select command. Press Esc to exit.

Zero_offset: Path: Collection / Experimental / H_field / Zero_offset

This feature is used to adjust the current output of the MPS to account for zero drifts in the power supply output due to fluctuations in the operating environment (e.g., room temperature variations). The "zeroing" is accomplished automatically upon selection.

When using this feature, the output current (at zero current) is read (i.e., I_0) and the current is then set to $-I_0$. In addition, any field that is subsequently set using the MPS is corrected by this I_0. This feature is particularly useful for operation at low fields, and also to obtain the best accuracy in the resultant DC field.

Sequence: Path: Collection / Experimental / Sequence

Used to define the measurement sequence that is used when logging data. When selected, the following sub-menu will be displayed.

Phase: This is a toggle between single phase and dual phase data acquisition.

Default/Manual: This is a toggle for specifying whether the phase that is used either in the voltage rotations or during data acquisition is taken from the phase table in the ACS.DAT file or from a user input value. If Default is selected, the phase is taken from the phase table in the ACS.DAT file according to the measurement frequency used. If data is logged in single phase and Manual has been selected, then data will be recorded at the that was set (i.e., the on the screen) prior to logging data. If data is logged in dual phase and Manual has been selected, then the raw voltage values will be rotated by this .

Movement: On/off toggle for specifying whether or not sample movement is used during a data logging sequence.

Autorange: On/off toggle for specifying whether or not autoranging is performed on the Lock-in Amplifier during data acquisition. The default condition is On. If the autorange is disabled, data will be recorded on the same range of the Lock-in Amplifier (namely the range that it is set prior to logging data).

Harmonic This command will only appear if the Model 700HM Harmonics Measurement Option is included. A prompt will appear asking which harmonic (1 thru 10) is to be measured.

Table This command will only appear if the Model 700HM Harmonics Measurement Option is included. This results in three available options: Add, Delete, and Cancel. Sets up the table used for harmonic data acquisition.

Signal: Path: Collection / Lock-In / Display / Signal

When selected, the output LCD indicates the signal amplitude in voltage. This is the default setting.

Small_field: Path: Collection / Experimental / H_field / Small_field

When selected, the user will be asked to specify a field for the primary coil which will be set by the current source in the Model 140 Control Unit.

STAB: Path: Collection / Lock-In / Reserve / STAB

Selection of this gives a flat mode dynamic reserve of 20 dB (high stability).

Susceptibility_display: This command is included in 4 locations

The command is located in three different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Real-time / Parm_select, and Collection / Experimental / Log / Parm_select. Chooses which phase(s) to display or process.

Time_dwell: Path: Collection / Experimental / H_field / H_Settle / Time_dwell

Used to input a field stabilization time period, in addition to the default time periods contained in the software. When selected, you will be prompted for an input (in seconds). Type in a value and press Enter. Whenever a field change occurs during data acquisition, the system will remain idle for the default wait period plus the Time_dwell. This will allow extra time for field stabilization prior to recording data. The default value of Time_dwell is 0 seconds.

Top: Path: Collection / Experimental / Position / Top

This is a top coil toggle that allows you to specify that the sample is positioned in the top secondary coil.

1_Up/Coarse: Path: Collection / Experimental / Position / 1_Up/Coarse

Selection of this will move the sample up 0.1 inch (0.254 cm) from its current position.

2_Up/Fine: Path: Collection / Experimental / Position / 2_Up/Fine

Selection of this will move the sample up 0.01 inch (0.0254 cm) from its current position.

Units: Main Menu

This is an SI/cgs units toggle.

View: Path: Analysis / View

This enables you to specify whether the processed data is displayed tabularly or graphically on the screen. When selected, the following sub-menu will be displayed on the screen.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

X-Axis equation (*T* (K) by default), & Y-Axis equation (m by default);

or if "Log," default is m vs. H, or if "Auto." default is m vs. T.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. If no display parameters are selected, the program will use the following defaults: if "Log," default is m vs. H, or if "Auto." default is m vs. T. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a matrix of moment data recorded at different fields and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T: Temperature	m: Moment
H: DC field	TI: Time

Refer to Paragraph 6.2.7 for further information. Esc to exit.

Sweep:

Path: Collection / Experimental / Temp_spec / Sweep

This routine enables the user to set the temperature sweep parameters that are used during an automated data acquisition. When selected, the user will be prompted for a lower sweep range, and a higher sweep range and then a sweep rate (0–3 K per minute) [e.g., 10–100 K @ 1 K per minute]. The following information will be displayed in a window on the screen:

Range # Low High Rate Spacing Min. Spacing # pts.

One of the parameters displayed will be "Temperature Spacing." This is the approximate default temperature spacing according to the defined measurement sequence (i.e., Minimum Spacing). The cursor will be on the sweep rate entry If the user desire to change the sweep rate, press Enter and then input a new value. If the user desire to change the temperature spacing, move the cursor to that value and press Enter and then input a new value (with the condition that the new value is greater than or equal to the default value).

The software allows up to three different sweep ranges. If the user only desire one sweep range then Esc to exit. If the user desire a second sweep range (& third), press Enter. Now the user will be prompted for an ending temperature for the second sweep range (the starting temperature of the second sweep range is the ending temperature of the first sweep range), and a sweep rate. The new information will be added to the existing window and changes to the rate or temperature spacing can be made as outlined above. To input a third sweep range, press Enter and continue as outlined above. ESC at any time to exit.

T_change:

Path: Collection / Experimental / H_field / Profile / T_change

Enter the DC field at which the system will be set to after a field profile is completed.

Table:

Path: Collection / Experimental / Sequence / Table

Harmonics Option Command. This results in three available options: Add, Delete, and Cancel. By using the Add or Delete selection, a table of harmonic values (1 through 10) can be set up for use during automatic data acquisition. Measurements will be recorded for each harmonic specified in the table. If the harmonic selection is not consistent with the table below, an error message will be displayed. Cancel will erase any harmonic table which has been set up.

NOTE

When a harmonic table has been set up, an array of multiple fields/frequencies will not be allowed. Only a single field and single frequency is permitted with a harmonic table.

After specifying a harmonic, any subsequent change in the frequency may result in a frequency/harmonic combination not permitted in Table 7-3. When changing frequencies using the frequency window in the Frequency selection, an inconsistent frequency selection is indicated by a *red* highlight (cursor) as the cursor is moved through the available frequencies. Do not set the system to one of these frequencies without going back and altering the harmonic selection.

HARMONICS	FREQUENCIES
1, 2, 3	All frequencies.
4 to 10	f = 1, 2, 3, 4, 5,6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 24, 25, 28, 30, 32, 35, 36, 40, 45, 48, 50, 56, 60, 64, 70, 72, 75, 80, 90, 100, 120, 125, 140, 150, 160, 175, 180, 200, 225, 240, 250, 280, 300, 320, 350, 360, 375, 400, 450, 500, 600, 625, 700, 750, 800, 875, 900, 1000, 1200, 1250, 1400, 1500, 1600, 1750, 1800, 2000, 2250, 2500, 3000, 3500, 4000, 4500, 5000, 6000, 7000, 8000, 9000, 9530

T_change: Path: Collection / Experimental / H_field / Profile / T_change

This routine is used to select a field that will be set at the completion of a measurement profile, before the temperature setpoint is changed or adjusted. When selected, you will be prompted for a value. Input a value, and press Enter. The default value for this is 0-field.

Tabular: Found in three locations

The Tabular command is found in three locations: Analysis / View / Tabular, Collection / Auto / Real-Time / Tabular, and Collection / Experimental / Log / Graphical. The purpose of Tabular is the same in all locations. When selected, the processed data will be displayed on the screen in tabular format according to the defined measurements sequence and the selection made using Parm_select.

Temp_ctlr: Path: Collection / Temp_ctlr

This routine allows you to set, modify, or change parameters on the Lake Shore Model DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

Setpoint: For selection of control setpoint on Temperature Controller.

Heater Range: For selection of heater range on Temperature Controller.

Gain: For selection of gain setting on Temperature Controller.

Derivative: For selection of rate setting on Temperature Controller.

Integral: For selection of reset setting on Temperature Controller.

Auto T: For selection of a setpoint that will then be automatically warmed to at a rate of 3 K/min and subsequently controlled at.

Temp_spec: Path: Collection / Experimental Temp_spec

This routine enables you to define the temperature specifications used during automated data acquisition. When selected, the following sub-menu will be displayed.

List: For selection of individual temperature points used in automated data acquisition.

Increment: This is for selection of temperatures, entered incrementally, to be used in automated data acquisition.

Sweep: Enables user to enter temperature sweep parameters used in automated data acquisition.

Drift: For selection of drift (with no active temperature control or while controlling at user defined temperature point) mode during data acquisition.

Edit: Allows the user to delete temperature from list defined by List or Increment and also for changing sweep rates or temperature spacings in sweep mode.

Cancel: Used to cancel a previously defined temperature specification.

Adjust_setpoint: Used to fine tune the setpoint when exact setpoint values are required.

Begin_times: A time in minutes when the Auto Collection process should start after the Begin key is pressed. The Cancel key under Temp_spec will reset this value.

Tabular: This command is included in 3 locations

The command is located in three different locations: Analysis / View / Tabular, Collection / Auto / Real-time / Tabular, and Collection / Experimental / Log / Tabular. The purpose of Tabular is the same in all locations. When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

Dual Phase:

X-Axis Eq.	v' (μV)	v'' (μV)	Y-Axis'	Y-Axis"
or				
X-Axis Eq.	v' (μV)	v'' (μV)	Y-Axis magnitude	

Single Phase:

X-Axis Eq.	v(phase) (μV)	Y-Axis Eq.

Esc to exit.

Temp_ctlr: Path: Collection / Temp_ctlr

Enables the user to set, change, or modify a number of parameters on the DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

Setpoint: For selection of control setpoint on temperature controller.

Heater_range: For selection of heater range on temperature controller.

Gain: For selection of gain setting on temperature controller.

Derivative: For selection of rate setting on temperature controller.

Integral: For selection of reset setting on temperature controller.

Auto_T: For selection of setpoint that system will then be automatically warmed to at a rate of 3 K per minute and subsequently controlled at.

Wait_times: Adjust the wait period for stabilization associated with each range and drift criteria.

Press Esc to exit.

Temp_spec: Path: Collection / Experimental / Temp_spec

This routine enables the user to define the temperature specification used during automatic data acquisition. When selected, the following sub-menu will be displayed.

List: For selection of individual temperature points used in automated data acquisition.

Increment: This is for selection of temperatures, entered incrementally, to be used in automated data acquisition.

Sweep: Enables the user to select temperature sweep parameters used in automated data acquisition.

Drift: For selection of drift (no active temp. control or while controlling at a user defined temperature point) mode during data acquisition.

Edit: Allows the user to delete temperatures from list defined by Enter List or Increment and also for changing sweep rates or temperature spacings in sweep mode.

Cancel: Used to cancel a previously entered temperature specification.

Adjust_setpoint: Used to fine tune the setpoint when exact setpoint values are required.

Begin_time: Used to set a time to begin the auto-collection routine.

These commands are described alphabetically within this section.

Select_range: Path: Collection / Voltmeter / Select_range

Selection of this allows you to set the range of the voltmeter at which data will be recorded. To leave the voltmeter on this range during automated data acquisition, Autorange must be selected to disable the autoranging feature.

Setpoint: Path: Collection / Temp_ctlr / Setpoint

This routine enables you to adjust or change the temperature setpoint of the DRC-91CA Temperature Controller. When selected, the following sub-menu will be displayed.

1_+10: Increments the temperature setpoint +10 K from its current value.

2_-10: Decrements the temperature setpoint –10 K from its current value.

3_+1: Increments the temperature setpoint +1K from its current value.

4_-1: Decrements the temperature setpoint –1K from its current value.

5_+0.1: Increments the temperature setpoint +0.1K from its current value.

6_-0.1: Decrements the temperature setpoint –0.1K from its current value.

Enter_setpoint: Sets the setpoint at a user defined value. When prompted, input a setpoint (selectable to within 0.1K) and press Enter.

Small_field: Path: Collection / Experimental / H_field / Small_field

Used for setting "small" DC bias fields using the Model 140 ACS Control Unit and the primary coil. When prompted, enter 0 to ±1600 A/m (±20 Oe RMS) and press Enter.

Sweep: Path: Collection / Experimental / Temp_spec / Sweep

This routines allows you to set the temperature sweep parameters that are to be used during an automated data acquisition sequence. When selected, you will be prompted for a lower temperature, a higher temperature, and a temperature sweep rate (0.1 to 3 K/min) (e.g., 10 to 100 K @ 1 K/min). The following information will be displayed on the screen in a window.

Range Number	Low Temp(K)	High Temp(K)	Rate (K/min.)	Spacing (K)	Minimum Spacing	Number of Data Points

One of the parameters displayed will be temperature spacing. This is the approximate default spacing according to the defined measurement sequence (i.e. minimum spacing). The cursor will be on the sweep rate entry. If you desire to change the sweep rate, Simply press Enter and input a new value. If you desire to change the temperature spacing, move the cursor to that value and press Enter and then input a new value (with the condition that the new value be greater than or equal to the default value).

The software provides for up to three different sweep ranges. If you desire only one sweep range, press Esc to exit. If you desire a second sweep range (& third), press Enter. Now you will be prompted for an ending temperature for the second sweep range (the starting temperature of the second sweep range is the ending temperature of the first, & so on), and a sweep rate. The new information will be added to the window, and changes to the rate and spacing can be made as outlined above. To input a third range, press Enter and continue as outlined above. Press Esc at any time to exit.

Time_dwell: Path: Collection / Experimental / H_field / H_settle / Time_dwell

This is used to input a field stabilization time period, in addition to the default time periods contained in the software. When selected, the user will be prompted for an input (in seconds). Type in a value and press Enter. Whenever a field change occurs during data acquisition, the system will remain idle for the default wait period plus the Time_dwell. This will allow extra time for field stabilization prior to recording data. The default value of Time_dwell is 0 seconds.

Top: Path: Collection / Position / Top

This is a top coil toggle which allows the user to specify that the sample is positioned in the top secondary coil.

Track: Path: Collection / Lock-In / Mode / Track

Selecting this option tells the filter to tune to the reference channel operating frequency.

Tuning: Path: Collection / Lock-In / Tuning

Allows the user to specify what parameter is displayed on the tuning display of the Lock-in Amplifier. When selected, the following sub-menu will be displayed.

Phase: When selected, the display indicates the phase shift introduced either by the software or the user.

Osc_freq: When selected, the display will indicate the set oscillator frequency.

Level: When selected, the display will indicate the amplitude of the oscillator freq.

Filter_freq: When selected, the display will indicate the frequency to which the input filter (Band-pass, Low-pass, or Notch) is tuned.

Ref_freq: When selected, the display will indicate the reference frequency.

The default display condition is Ref Freq.

Up: Path: Collection / Lock-In / Constant / Up

Increases time constant setting one unit.

1_Up/Coarse: Path: Collection / Position / 1_Up/Coarse

Selection of this will move the sample up 0.1 inch (0.254 cm) from its current position.

2_Up/Fine: Path: Collection / Position / 2_Up/Fine

Selection of this will move the sample up 0.01 inch (0.0254 cm) from its current position.

Units: Main Menu.

This is a SI/cgs units toggle.

Recall:

Path: Collection / Recall

This routine enables you to load a previously generated configuration file. This is useful when samples are often run using the same experimental conditions or parameters. When selected, you will be prompted for a field name (no extensions). After typing a file name. press Enter. Changes to the experimental configuration can then be made through the software if required.

Sample:

Paths: Analysis / Data_process / Sample and Collection / Data_process / Sample

This enables the user to input sample parameters that enter into the calculations of moment from raw data. When selected, a window is displayed where the user can enter the following.

Volume: Allows the user to enter or adjust the sample volume. Input a value and press Enter.

Mass: Allows the user to enter or adjust the sample mass. After typing a value press Enter.

Demagnetization: Allows the user to enter or adjust a sample demagnetization factor. After typing a value, press Enter.

Density: Allows the user to enter or adjust the sample density. After typing a value, press Enter.

Molecular Weight: Allows the user to enter or adjust a sample molecular weight. After typing a value, press Enter.

Save:

Path: Edit / Save

This enables you to save any changes that were made in Constants or MPS_rates to the DCM.DAT file. When selected, you will be prompted with "Are You Sure? Yes No." If Yes is selected, the new information will be written to DCM.DAT. If No is selected, the new information will not be written to DCM.DAT.

Scan:

Path: Collection / Experimental / Scan

This prompts for the number of scans to be used in the moment measurement. The default is one scan.

Scan:

Path: Collection / Experimental / Position / Scan

This feature is used to position the sample within one of the secondary coils. When selected, a half-scan will be performed and the actual voltage signal will be graphed on the screen. Messages are displayed on the screen which indicate in which position the sample should be moved (i.e. up or down) to make the voltage curve more symmetrical. When the voltage curve is symmetrical, then the sample is properly positioned. Adjust the position of the sample using the coarse and fine up/down keys, and then select Scan again. Repeat this process until the sample has been positioned well enough to yield a symmetric voltage signal.

Select:

Path: Analysis / Addenda / Select

This selects the addenda file to be used in processing the data in Analysis. When selected, you will be prompted for an addenda file name (no extensions). After typing a valid file name, press Enter.

View:

Path: Analysis / View

This enables the user to specify what processed data is viewed on the screen. When selected, the following sub-menu will be displayed.

Tabular: When selected, the data will be displayed on screen in tabular format according to the defined measurement sequence. If data is logged in single phase then the following will be displayed.

Dual Phase:

X-Axis Eq. v' (μV) v'' (μV) Y-Axis' Y-Axis"

or

X-Axis Eq. v' (μV) v'' (μV) Y-Axis magnitude

Single Phase:

X-Axis Eq. v(phase) (μV) Y-Axis Eq.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence and the option chosen for Susceptibility_display. If no display parameters are selected, the program will use the following defaults: if data is logged in single phase, χ' (vertical axis) vs. T (K) (horizontal axis) will be plotted; if data is logged in dual phase, both χ' and χ'' vs. T(K) will be displayed. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a complex matrix of susceptibility data recorded at different fields, frequencies, and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T:	Temperature	N:	Harmonic	TI:	Time
HAC:	AC field	F:	Frequency		
H:	DC field	χ:	Susceptibility		

Refer to Paragraph 5.2.9.1 for further information. Esc to exit.

Config_file: When selected, a window will be displayed containing all the relevant information in the .CFG file. This window allows the user to see the experimental setup without having to jump around to the other menu items. Esc to exit.

Wait_times:

Path: Collection / Temp_ctlr / Wait_times

Upon selection, a window will be displayed containing the temperature ranges and the associated wait times (in seconds) the system will wait for a particular setpoint to stabilize. The boundaries for each temperature range are fixed. Also displayed is the drift criteria which must be met for data acquisition to begin. Use the arrow keys to select the temperature range to edit, and press Enter to modify the wait time. Press Esc to exit.

X-Axis_equation:

Four locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. When selected, enter the user-defined X-axis equation adhering to the rules discussed under the Parm_select command. Press Esc to exit.

Profile:

Path: Collection / Experimental / H_field / Profile

This routine is used to define/set-up the field profile/control that is to be used during an automated data acquisition run. When selected, the following sub-menu will be displayed.

Discrete: This is used to input discrete field values for creating a field table at which data will be recorded.

Increment: This is for the selection of fields used for creating a field table, entered incrementally, to be used in automated data acquisition.

T_change: This allows you to input a field value that will be set after the completion of a field profile, prior to adjustment of the temperature. The temperature will be adjusted at this field setting.

Edit: Enables you to edit previously defined field control parameters.

Maintain: This is an on/off toggle that will leave the field set to a user defined value after the completion of an automated data acquisition run (e.g., for recording field-cooled magnetization data after the completion of a zero-field-cooled automated data acquisition run).

Cancel: This allows you to cancel a previously defined field profile/control.

Real-time:

Path: Collection / Auto / Real-time

Selection of this activates real-time feedback of data. When selected, the following sub-menu is accessed.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

X-Axis equation (*T* (K) by default), & Y-Axis equation (m by default);

or if "Log," default is m vs. H, or if "Auto." default is m vs. T.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. If no display parameters are selected, the program will use the following defaults: if "Log," default is m vs. H, or if "Auto." default is m vs. T. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a matrix of moment data recorded at different fields and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T: Temperature	m: Moment
H: DC field	TI: Time

Refer to Paragraph 6.2.7 for further information. Esc to exit.

Y-Axis_equation: Four locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. When selected, enter the user-defined Y-axis equation adhering to the rules discussed under the Parm_select command. Press Esc to exit.

Zero_offset: Path: Collection / Experimental / H_field / Zero_offset

This feature is used to adjust the current output of the MPS to account for zero drifts in the power supply output due to fluctuations in the operating environment (e.g., room temperature variations). The magnitude of these zero drifts are $<\pm 1$ gauss and utilization of this feature reduces this to the tenth gauss level. The "zeroing" is accomplished automatically upon selection.

When using this feature, the output current (at zero current) is read (i.e., I_0) and the current is then set to $-I_0$. In addition, any field that is then set using MPS_field is corrected by this I_0. This feature is particularly useful for operation at low DC fields and also to obtain the best accuracy in the resultant DC field.

Period (Continued)

During automated data acquisition, the field will be set and the system default waits, and any additional user defined waits (i.e., Time_dwell) will be initiated. After the completion of these waits, the moment will be recorded as a function of time according to the parameters input in Period. If a table of field values has been defined, the field will then be incremented to the next value and the process will start anew. If a table of temperature values has also been defined using either List or Increment, then after the completion of the field profile, the temperature will be adjusted to the next value and after the temperature stabilization period, the process will start anew.

If multiple scans are used to record the moment, then the time interval between measurements extends from the end of one scan sequence to the beginning of the next scan sequence. Esc to exit.

Position: Path: Collection / Experimental / Position

This routine is used to position the sample in one of the two secondary coils. When accessed, the following sub-menu will be displayed.

Top: Toggle that specifies the sample is positioned in the top secondary coil.

Bottom: Toggle that specifies the sample is positioned in the bottom secondary coil.

1_Up/Coarse: Will move the sample up 0.1 inch (0.254 cm.) from its current position.

2_Up/Fine: Will move the sample up 0.01 inch (0.0254 cm.) from its current position.

3_Down/Fine: Will move the sample down 0.01 inch (0.0254 cm.) from its current position.

4_Down/Coarse: Will move the sample down 0.1 inch (0.254 cm.) from its current position.

Scan: Used to position the sample. When selected, a half scan will be performed and the actual voltage signal measured will be graphed on the screen. Messages will appear on the screen which indicate in which direction the sample should be moved (i.e., up or down) to yield a symmetric voltage signal (the voltage signal will be perfectly symmetrical when the sample is properly positioned). Use the coarse and fine adjust keys to move the sample in the proper direction, and initiate the Scan sequence again. Repeat this iteration until the sample is properly positioned (i.e., until a symmetric voltage signal is obtained).

Auto: Autoposition sample in bottom coil.

These commands are described alphabetically within this section.

Printer: Path: Analysis / Output / Printer

This is an on/off toggle. When selected the processed data will be printed to a hard copy device.

CHAPTER 6

DCM7000 SOFTWARE OPERATION

6.0 GENERAL

This chapter provides DCM7000 Software operation. The chapter consists of the following: Basic Information is provided in Paragraph 6.1. Principles of Operation are presented in Paragraph 6.2. Finally, starting the DCM Program is detailed in Paragraph 6.3.

6.1 BASIC INFORMATION

This paragraph provides basic information needed to run the DCM7000 Software Package. First is software installation data in Paragraph 6.1.1. Second is information on the DCM.DAT file in Paragraph 6.1.2. Finally, .DAT and .CFG file conventions are discussed in Paragraph 6.1.3.

6.1.1 Software Installation

NOTE

It is not necessary to run LSINSTAL on systems shipped with a computer, since the computer is per-configured at Lake Shore with all files installed in the proper hard disk directories. LSINSTAL is provided on the backup floppy disk in case of hard disk failure or accidental erasure of crucial files.

Each of Lake Shore's programs is installed in a separate directory on the hard disk of the computer to aid in data file management. DCM7000 is in the DCM directory, ACS7000 is in the ACS directory, and RES7000 is in the RES directory. (Refer to Chapter 5 for further details on ACS7000 software and Chapter 7 for further details on RES7000 software.) The program LSINSTAL.EXE provided with each system will create these directories if they do not already exist and copy all the required files from the floppy disk to the proper directories on the hard disk. LSINSTAL may be run from the floppy disk provided in either the A: or the B: drive.

LSINSTAL checks the files AUTOEXE.BAT and CONFIG.SYS on the default (hard) drive. If they exist, they are checked for compatibility with Lake Shore's software and modified if necessary. (The existing AUTOEXE.BAT and CONFIG.SYS files are first renamed AUTOEXE.OLD and CONFIG.OLD.) If they do not exist, these files are copied from the floppy disk.

Batch command files are provided (ACS.BAT, DCM.BAT, and RES.BAT) for running Lake Shore software from the root directory. A pre-configured GPIB.COM file (the National Instruments GPIB driver file) is copied to the root directory.

Since DOSSHELL is no longer included, the DCM7000 software must be run from DOS. At the C prompt, type "cd dcm." Once the prompt displays the appropriate directory, type "DCM7000." To return to the main C prompt, type "cd\."

Printouts from DCM should be compatible with most popular printers. User changes to the source code will require Microsoft BASIC Version 7.1 or higher. Any changes made to the DCM source code are at the user's risk. Lake Shore will assume no responsibility for damage or errors incurred as result of any changes made to the source code.

Override: Path: Collection / Auto / Override

During fixed temperature points data acquisition mode, selection of this key will override certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent on the particular temperature range. (Drift/minute and waits are adjustable under Wait_times.) Upon completion of the WAIT, a DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once this DRIFT/MIN is below 0.1 K per minute, the data acquisition/measurement sequence will automatically begin. Selecting Override once will override the designated WAIT period and initiate the DRIFT CHECK. Selecting Override again will override this as well and data will be recorded immediately.

While the temperature is being adjusted from one setpoint to another, Override can be selected to record data at some intermediate temperature. When Override is selected, the temperature ramping will cease and the above mentioned WAIT period will be initiated. In addition to the waits already mentioned, override can override a Begin_time if one was specified under Temp_spec.

Parm_select: This command is included in 4 locations

The command is located in four different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. Depending upon the experimental setup, a single acquisition run can yield a matrix of moment data recorded at different fields and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive).

T:	Temperature	m:	Moment
H:	DC field	TI:	Time

Refer to Paragraph 6.2.7 for further information. Press Esc to exit.

Period: Path: Collection / Experimental / H_field / Profile / Period

Permits selection of experimental parameters to be used when recording magnetization data as a function of time. A DC field must first be selected using MPS_field, or a table of discrete fields defined using Discrete or Increment, and a temperature specification must be made using either List or Increment.

When Period is selected, you will be prompted for the number of scan sequences. Note that this is not the number of scans. For example, if up in the scan feature in the Experimental sub-menu of the Collection menu you defined the number of scans (measurement sequence) as 10, then in Period you defined the desired number of scan sequences as 5, you would get 5 scan sequences with each scan sequence performing and averaging over 10 scans.

This is significant because after defining the desired number of scan sequences, you will be prompted for the number of seconds between each. Note that a single scan takes ≈10 seconds. Therefore, 10 scans will take about 60 seconds. This is in addition to the time you will now be defining between each scan sequence.

6.1.2 DCM.DAT File

In order for DCM to run, the file DCM.DAT must reside in the same directory. DCM.DAT contains the coil information specific to each Model 7221 or 7225.

Line 1: Seven entries separated by a comma:

1. "B1" (with quotation marks).
2. Superconducting Magnet Calibration Constant: ratio of the H field (A/m) to the current (A).
3. Primary Coil Calibration Constant: ratio of the H field (A/m) to the current (A).
4. DC Moment Calibration Coefficient.
5. Magnet Power Supply (MPS) Compliance Voltage. Normally set to 5.
6. Maximum allowed output current (A) for MPS. Normally set to 48 for 1 tesla magnet and 72 for 5 tesla magnet.
7. System serial number in quotation marks.

Line 2: These entries specify how the superconducting magnet is to be ramped in current. Four ranges are specified and for each range the ramp rate (A/sec) and upper current limit (A) are required. There are eight entries separated by a comma.

1. Ramp rate for Range 1.
2. Upper current limit for Range 1.
3. Ramp rate for Range 2.
4. Upper current limit for Range 2.
5. Ramp rate for Range 3.
6. Upper current limit for Range 3.
7. Ramp rate for Range 4.
8. Upper current limit for Range 4.

6.1.3 File Conventions

During data acquisition, two files will be created and stored in the DCM directory. These files will have the same name but will have different extensions: .DAT and .CFG. The first contains the actual measurement data while the second contains information concerning the experimental set-up. Both files are required for the data analysis routine.

6.2 PRINCIPLES OF MOMENT MEASUREMENT

The software package DCM is designed to control the 7000 Series instrumentation in both manual and automatic modes of operation. The instruments include the Lake Shore Model DRC-91CA Temperature Controller, Model 140 ACS Control Unit, Model 610/612 Magnet Power Supply, and Keithley Model 182 Sensitive Digital Voltmeter. All instrument functions of relevance are accessible through the keyboard. In addition, DCM logs and records the moment (i.e. voltage), temperature, and DC field measurements during automatic operation. The software was designed for unattended operation.

The measurement of magnetic moment is accomplished through an analysis of the induced voltage generated by moving the sample between the two sensing coils used in the AC susceptibility measurement. This is discussed below in more detail in terms of measurement sequence, temperature control, field control, sample positioning, addenda data and the number of scans. Additional DC information is provided in Paragraph 1.8.

6.2.1 DC Moment Measurement Sequence

In analogy with the AC susceptibility measurement, the DC moment measurement sequence is defined as the process which outputs a single moment measurement. The default measurement sequence consists of a single scan; i.e., the sample is moved from the bottom coil to the top coil and then back to the bottom coil. The recorded voltages are analyzed and a moment value is output.

MPS_field: Path: Collection / Experimental / H_field / MPS_field

This is used for setting the DC magnetic field of the superconducting magnet. When selected, you will be prompted for an input. Enter a value (kOe or kAmp/m), and press Enter. The field will then be automatically adjusted to, and stabilized at the selected field. Esc to exit.

MPS_rates: Path: Edit / MPS_rates

Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. Of only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Name:

Path: Collection / Experimental / Name

This allows you to specify a data file to which the data logged will be written. When selected, you will be prompted for a file name with no extensions. After typing a file name, press Enter.

If no file name is specified, the data will be written to TEMPFILE.DAT and TEMPFILE.CFG. If the file name selected already exists, you will be prompted for another file name. If no new name is specified, the new data will overwrite the data currently contained in the file.

OFF:

Path: Collection / Temp_ctlr / Heater_range / OFF

Selection will turn the heater power off.

Output:

Path: Analysis / Output

This option allows you to specify that the processed data be dumped to a hard copy device or written to a file (ASCII file format). When selected, the following sub-menu appears.

Printer: On/off toggle to specify that the data be printed to a hardcopy device. Depending on the experimental parameters that were used to record data, and the selection made in Sample and Parm_select, the data will be printed out in a two column format (i.e., m versus T, m versus H, χ versus T, etc.) with appropriate headings.

File: When selected, you will be prompted for a file name (no extensions). After typing the file name, press Enter.

Label: Input a label to be printed at the head of a hardcopy of your processed data.

The files are created in ASCII file format and consist of columns separated by a single white space (i.e., m[space]T, m[space]H, χ[space]T, etc.).

Overshoot_ctrl: Path: Collection / Experimental / H_field / H_settle / Overshoot_ctrl

An on/off toggle used to activate a special MPS/field control routine used to minimize any field overshoot which may occur on changing fields. The feature functions by pre-settling the field at a value slightly different than the targeted value. After pre-settling, the final field value is set. Activating this feature will add ≈45 seconds to the time required for field stabilization.

Changing the rates specified for field ramping using the MPS_rates option will also increase or decrease the amount of overshoot depending upon whether the rates are increase or decreased, respectively.

The actual measurement sequence can consist of up to 10 single scans as specified using the SCAN option in the Experimental sub-menu. During this multiple scan measurement, only one value for the moment is output, but this value is the average value for the multiple scans. This mode of operation is useful for measuring samples with low level signals or when extra precision is required.

The time required to complete a moment measurement obviously is dependent on how the measurement sequence is defined. A single scan measurement requires about 11 seconds to execute the measurement sequence. Multiple scans will increase the time up to 70 seconds if 10 scans have been specified. Since the total time required for completing a data acquisition can be dramatically effected by using multiple scans, they should be specified only when required.

6.2.2 Temperature Control

Temperature control and the specification of the desired temperature data points are accessed through DCM. These routines are operationally and functionally identical to that discussed in the ACS program. Refer to Chapter 4 for ACS 7000 Software details.

Automatic data acquisition requiring multiple DC fields or field profiles (e.g. hysteresis curves) is only allowed in fixed point operation in order to maintain temperature control during the field variations.

6.2.3 Field Control

Field control and the specification of the desired field points at which data will be recorded is also accessed through DCM. There are several field control options available through the software.

A. Constant Field: The field can be set and maintained at a single value throughout data acquisition. The field will be turned off at the completion of an automated data acquisition run (e.g., as a function of temperature), or can be changed or turned off by the operator.

B. Field Profiles: Field profiles require fixed point temperature control and cannot be performed in temperature sweep or drift modes of operation.

   1. Field Table: There are provisions in the software for generating a DC field table for which data will be recorded at each point. The individual field points can be entered incrementally or one at a time. The susceptometer/magnetometer automatically steps through each value in the table in order of entry, verifies that it is set to the correct value, and records moment data at each point. Since the field table does not have to be monotonic, hysteresis loops or any other field profile can be created. The field control process proceeds as follows:

      a. The output current of the MPS is automatically ramped to a user defined value, $I_{set} = H_{set}/\beta_2$ where H_{set} is the field selected by the user, and β_2 is the field to current conversion factor for the superconducting magnet.

      b. The current output of the MPS is continually monitored. Once the current is within ±0.1 amps of I_{set}, a 5 second wait is initiated.

      c. At the completion of this 5 second wait period, an additional user defined WAIT is initiated to allow the field to stabilize and reach equilibrium. This WAIT is set in the DCM software (refer to Time_dwell). For most applications, the default values in the software are sufficient for field stabilization. For applications requiring the maximum field stability, the WAIT should be set to ≥30 seconds.

      d. The moment measurement is then performed according to the defined measurement sequence.

      e. After data acquisition is complete, proceed to the next field value in the table according to step **a.** above.

   2. Time: The software provides for recording the magnetic moment as a function of time (e.g., magnetization relaxation in high T_c superconductors) at discrete fields. The software also provides for recording moment as a function of time at one, or multiple DC fields, and allows the user to specify the time duration at a given field, as well as the time between measurements. This is accessed through the Period option.

Log:

Path: Collection / Experimental / Log

Selection of this will record the measurement sequence as defined (sans Temperature specifications), and also, if specified, will execute an array or field profile. These measurements are done at the current temperature. If the user wish to use the temperature specs, then Auto should be used instead of Log. Data can be stored to a file. If no file name is specified, the data will be written to "TEMPFILE.DAT."

Begin: This initiates the data acquisition process and will display the results in the lower right-hand feedback block. Esc to exit.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

X-Axis equation (*T* (K) by default), & Y-Axis equation (m by default);

or if "Log," default is m vs. H, or if "Auto." default is m vs. T.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. If no display parameters are selected, the program will use the following defaults: if "Log," default is m vs. H, or if "Auto." default is m vs. T. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a matrix of moment data recorded at different fields and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T: Temperature	m: Moment
H: DC field	TI: Time

Refer to Paragraph 6.2.7 for further information. Esc to exit.

Cancel: Terminate the data acquisition.

This data can be written to a file specified using Name. If no file name is specified, it will be written to "TEMPFILE.DAT." To abort the Log sequence, select Cancel.

CAUTION

If Log is used successively, and no file specification is made, the contents of TEMPFILE.DAT will be overwritten.

Maintain:

Path: Collection / Experimental / H_field / Profile / Maintain

This is an on/off toggle that will leave the DC field set to whatever value it was set to at the termination of data acquisition. For example, if zero-field-cooled (ZFC) data is being recorded on warming, and after this is completed it is desired to record field-cooled (FC) data, then Maintain will automatically leave the field on at the completion of the run, as the system cools back down.

MAX:

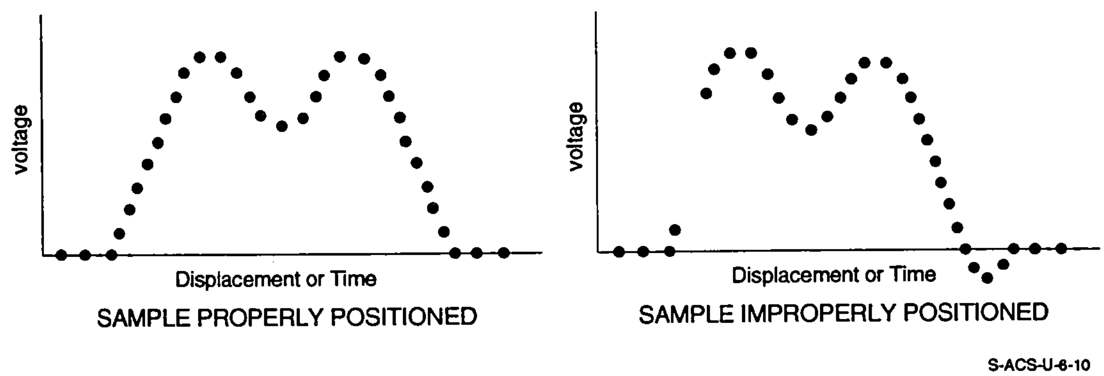
Path: Collection / Temp_ctlr / Heater_range / MAX

Selection will set the heater range to maximum power.

6.2.4 Sample Positioning

Positioning the sample within one of the two secondary coils in the DC measurement mode is different than the AC measurement mode.

The Scan (sub-menu of Position) option in the control software is used to position samples. After loading a sample into the system, set a DC field and select the Position routine in the Experimental Menu. Then specify that the coil is either in the top or bottom secondary coil. This initial designation is arbitrary and should be based on a "best guess." Now select Scan. The sample will be automatically moved from one coil to another, and the voltage signal measured will be graphed on the screen. For a properly positioned sample, the voltage signal peaks will be perfectly symmetrical. Non-symmetric signals indicate the sample is improperly positioned. See figure below.



The sample is positioned by moving the sample up or down as needed. To move the curve to the right, move the sample up. To move the curve to the left, move the sample down. This process is repeated until a symmetric voltage signal is obtained.

For samples with very low signals, this technique will be difficult to use in positioning the sample. When the baseline "scatter" is comparable to the signal due to the sample, try increasing the field strength or increasing the sample size. As a last resort, the following procedure can be used.

A. Find the center of one of the two secondary coils by positioning a small sample with a large output signal, and mark the sample rod with an indelible marker. A convenient place to mark and use for alignment is the top surface of the sample probe seal assembly.

B. Determine the nominal length of the sample to be measured and load it into the system.

C. Move the sample rod to the location determined in step **A** above.

D. Move the sample rod down a distance equal to 1/2 the length of the sample.

E. The sample should now be properly positioned within the secondary coil.

Increment: Path: Collection / Experimental / Temp_spec / Increment

Allows the user to define discrete temperature points for fixed point data acquisition by entering them incrementally. When selected, the user will be prompted for a first value, a second value, and finally an increment. The table of selected values will be displayed on the screen as a window.

If the first temperature is below 30 K, the second temperature maximum is set to 30 K and increments of 0.01 are allowed. If the first temperature is above 30 K, the second temperature maximum is set to 325 K and increments of 0.1 are allowed. Hence, to build a list with increment mode through 30 K requires two input sequences by the user.

NOTE

List and Increment can be used together to build a table of discrete temperature points for fixed temperature point acquisition.

Integral: Path: Collection / Temp_ctlr / Integral

Allows you to change the Reset setting of the DRC-91CA Temperature Controller. When accessed, you will be prompted for an input (0 – 99). After typing a value, press Enter. The default value is 0 and during automated data acquisition the reset will be set/reset to 0.

Integration_time: Path: Collection / Voltmeter / Integration_time

Used to set the Digital Voltmeter (DVM) integration time to either 1 power line cycle (PLC) or 100 milliseconds.

Label: Path: Analysis / Output / Label

Allows you to input a label to be printed at the head of a hardcopy of your processed data.

List: Path: Collection / Experimental / Temp_spec / List

This routine enables you to enter temperatures individually in order to build your own list of temperatures at which data will be recorded during automated data acquisition.

When selected, you will be prompted for a temperature input. Input a value and press Enter. A window will be displayed on the screen with this single temperature value. Continue to input as many temperature as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which temperatures are entered is important, since the software has the ability to cool or heat to a setpoint. ESC when completed to exit.

NOTE

List and Increment can be used together to build a table of discrete temperature points for fixed temperature point data acquisition.

6.2.5 Addenda Data

The addenda is used to describe the empty sample holder, support rod, and anything else which may generate a background signal (e.g., substrate material, etc.) during a moment measurement. The capability for subtracting this background signal from the data being recorded with a sample present is built into the software package.

The addenda data should be recorded using fixed temperature points over an applicable temperature range, and at least two applied fields which span the intended range of use (where one field can be 0 field). A special option in the DCM analysis program processes the addenda data and stores the temperature/field/moment data to a file for later use.

When the addenda file is recalled for use with a data file, the addenda moments are subtracted from the measured sample moments using the following steps:

A. Check the temperature T, and field H at which the sample data was recorded.

B. Use the temperature/field/moment data in the addenda file to determine the addenda moment at temperature T and field H (i.e., a simple 2-dimensional linear interpolation is performed).

C. Subtract the addenda moment from the actual sample moment.

The number of fields and temperatures used in creating the addenda file will depend upon the desired accuracy and materials which may be making up the addenda. The empty sample cup has a moment of approximately 1×10^{-3} emu at 4.2 K and 800 kA/m (i.e., 10 kOe).

When the Series 7000 System is equipped with a superconducting magnet, the data used to create an addenda file must be recorded at multiple DC fields (≥2) and multiple temperatures (≥2). The range of the fields and temperatures should be slightly greater than the range of interest.

6.2.6 Data Acquisition Hierarchy

When setting up an experiment consisting of both temperature data points and a field profile, the following convention is followed.

A. The temperature is first adjusted and controlled at the desired temperature.

B. The field profile is then executed while temperature control is maintained at the setpoint specified in Step A.

C. The next temperature is then selected from the temperature data table and Step A is repeated.

6.2.7 Using Parm_select

The latest version of the DCM7000 software allows the user to enter any equation they wish in order to process the data taken in collection. The equations entered affect the Tabular, Graphical, and Analysis output. In each case where Parm_select appears as a menu item, the information below applies (i.e., under Log, View, Realtime_data, etc., there are no distinctions between each instance of Parm_select.)

Upon choosing Parm_select, the following sub-menu items will appear: X-Axis_equation, Y-Axis_equation, and Data_output, as described in the following paragraphs.

H_field (Continued)

Demag_sample: Used to eliminate any remanant fields which may reside in the system after the application of a high DC magnetic field.

Zero_offset: Used to more accurately "zero" the zero current setting of the magnet power supply.

Small_field: Allows setting small DC fields using the ACS control unit and the primary coil.

H_settle: Provides for two options to fine tune settling of magnetic field.

Overshoot_ctrl: An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.

Time_dwell: Enables input of an additional wait period for field stabilization.

These commands are described alphabetically within this section.

H_settle: Path: Collection / Experimental / H_field / H_settle

This routine provides for two options to fine tune the settling of the magnetic field set in the superconducting magnet.

Overshoot_ctrl: An on/off toggle which accesses a secondary field control routine to minimize any field overshoot which may occur on changing fields.

Time_dwell: Permits specifying extra time for the field to settle after each field change.

These commands are described alphabetically within this section.

Heater_range: Path: Collection / Temp_ctlr / Heater_range

Allows you to set or change the heater range setting on the DRC-91CA Temperature Controller. When selected, the following sub-menu is displayed.

MAX: Selection will set the heater range to maximum power.

1_–1: Selection will set the heater range to –1.

2_–2: Selection will set the heater range to –2.

3_–3: Selection will set the heater range to –3.

OFF: Selection will turn the power off.

The heater range is automatically set when in automatic data acquisition mode.

Increment: Path: Collection / Experimental / H_field / Increment

This allows you to define discrete field points for fixed field data acquisition by entering them incrementally. When selected, you will be prompted for a first field value, then a second range value, and finally an increment value (e.g. 0 kOe (or 0 kAmp/m) to 10 kOe (or 800 kAmp/m) in 1 kOe (or 80 kAmp/m) increments). The table of selected values will be displayed on the screen as a window. To input another range, press Enter. To exit, press Esc.

NOTE

Discrete and Increment can be used together to build a table of discrete field points for fixed field point acquisition.

6.2.7.1 X-Axis_equation and Y-Axis_equation Commands

When entering an equation, the following variables must be used in order to correctly process the equation. Parm_select will flash the error message "Unknown Variable" if it encounters a variable it cannot identify. Parm_select is not case-sensitive.

T	Temperature	TI	Time
H	DC Field	m	Moment

Parm_select also accepts constants, both numerical and in exponential form. Upon entering an equation, Parm_select checks to see if more than one variable has been entered, e.g., T*H. In this case, Parm_select forces the user to decide which variable to "fix." For the example T*H, the user must decide whether to plot all temperatures or all fields; both cannot be plotted. Upon choosing the varying parameter, say T, then the table of fields will appear and the user will be forced to select which frequency to "fix" H at.

Upon entering an equation, the system will ask the user to "fix" any of the remaining variables if necessary. For example, if the user enters "T" as the equation, an arrays of fields exists, a window will appear forcing the user to select at which field to view all temperatures. Note that upon choosing m as the equation, no windows will appear because none are necessary. m is the fixed result of a particular combination of the other parameters (T, H, TI, etc.)

6.2.7.2 Data_output Command

Depending on the available options as dictated by the sample parameters, this option allows the user to choose the type of output they desire: raw moment, Volume χ, Mass χ, Molar χ, Volume Magnetization, Mass Magnetization, Molar Magnetization, or raw data (in Analysis mode only).

6.3 DCM7000 PROGRAM

To start the program, simply type and enter DCM after the prompt C:\>. To enter the collection mode, the instruments must be turned on first. The analysis mode can be run with the instruments off.

CAUTION

If for any reason an instrument has to be turned off after the program has initialized the instruments, it will be necessary to restart the DCM program.

NOTE

An error may be detected by the DCM7000 program if the MPS is turned on and the magnet is not superconducting. If this occurs, simply turn the MPS off and continue with the program. The program will indicate that the MPS is inoperative, but will permit access to all other features of the system. The program should be exited and restarted once the magnet is superconducting and the MPS has been turned on.

6.3.1 Menu Breakdown And Option Description

The following information consists of three major portions:

- A flowchart of menu and sub-menu selections.
- A menu and sub-menu breakdown including a brief functional description of each option.
- An alphabetical listing of each of the menu and sub-menu options. Each entry describes in detail where that option is found and how it is used.

File:

Path: Analysis / File

In the Analysis Menu, File is used to load a data file for data processing. When accessed, file names with drive or sub-directory information can be entered and the file will be appropriately accessed. There is no need to specify extensions. If Enter is pressed, the data files contained in the working directory will be displayed in a window. To load a particular file, move the cursor to that file and press Enter. If "a:" is specified, the floppy disk contained in the A drive will be accessed.

In the Output sub-menu, File is used to specify a file to which processed data will be written. When accessed, you will be prompted for a file name. There is no need to specify extensions. Type a file name and press Enter.

Gain:

Path: Collection / Temp_ctlr / Gain

Allows you to change the gain setting of the DRC-91CA Temperature Controller. When selected, you will be prompted for an input (0 – 99). After typing a value, press Enter. The default value is 99 and during automated data acquisition the gain will be set/reset to this value.

Graphical:

Paths: Analysis / View / Graphical, Collection / Auto / Real_time / Graphical, and Collection / Experimental / Log / Graphical

When selected, the processed data will be displayed graphically on the screen. Scaling is handled automatically. Equations entered for X-Axis and Y-Axis under Parm_select will be used to determine the graph. If no equations are entered by the user, then default ones will be used. Esc to exit.

H_field:

Path: Collection / Experimental / H_field

Used to define the field control that is used during automated data acquisition. When selected, the following sub-menu will be displayed.

MPS_field: This is used for setting a single, fixed DC magnetic field of the superconducting magnet.

Profile: This routine enables you to define a field profile (e.g., for recording data as a function of field) at which data will be recorded during automated data acquisition. When selected, the following sub-menu will be displayed.

- **Discrete:** Allows you to build/define a table of discrete field values.
- **Increment:** Allows you to build/define a table of discrete field values by selecting a low and high field, and then a field increment.
- **Period:** Select the number of data points to be recorded, and time between data points, for recording moment data versus time.
- **T_change:** This allows you to enter a field which will be set after the completion of a field profile sequence, before the temperature is changed.
- **Edit:** This routine enables you to edit a defined field profile. When selected, the window containing the field set-up will be displayed and field entries can be deleted, added, or changed.
- **Maintain:** This enables you to define a field that will be set at the completion of an automated data acquisition run.
- **Cancel:** This cancels a previously defined field profile.

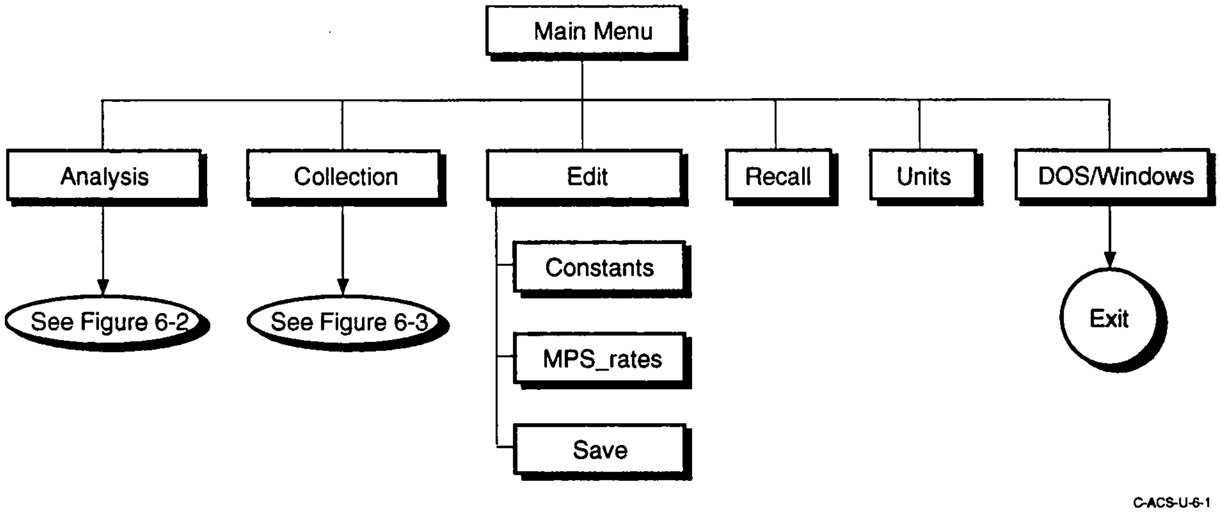


Figure 6-1. Main Menu Block Diagram

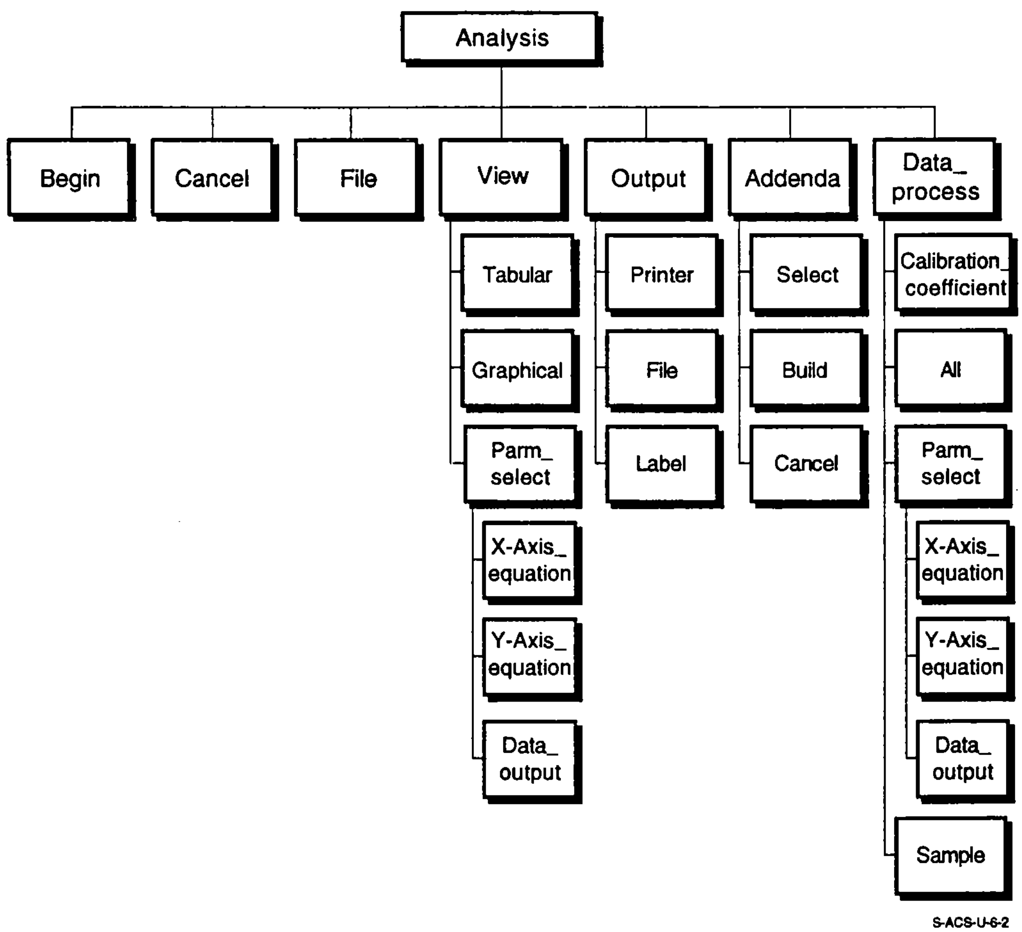


Figure 6-2. Analysis Menu Block Diagram

Edit:

Path: Collection / Experimental / Temp_spec / Edit

This allows you to edit the temperature specification that was defined using either List, Increment, or Sweep under Temp_spec. If List or Increment were used to define the temperature specification, then when Edit is selected the window of discrete temperature points will be displayed. Temperatures can be deleted by moving the cursor to a particular temperature and pressing the Del key.

If the temperature specification is a sweep, when Edit is selected, the sweep window will be displayed. Edit allows you to change sweep rates or nominal temperature spacing. Move the cursor to the rate or spacing you wish to change and press Enter. You can now enter a new value. Esc to exit.

Edit:

Path: Collection / Experimental / H_field / Profile / Edit

This allows you to edit the field profile specification which was defined using either Discrete or Increment. If Discrete or Increment were used to define the field specification, then when Edit is selected, the window of discrete field points will be displayed. Field values can be deleted by moving the cursor to that value and pressing Del. If you wish to enter fields, position the highlight and press INS. You will now be prompted for an input. Esc to exit.

End:

Path: Collection / Auto / End

This is the only way to terminate an experimental run at any point prior to its completion as defined. When selected, you will be prompted with "Yes No." If Yes is selected, the file will be closed and the run aborted. If No is selected, the run will continue as defined.

Enter_setpoint:

Path: Collection / Temp_ctlr / Setpoint / Enter_setpoint

Sets the temperature setpoint on the DRC-91CA Temperature Controller to a user defined value. When selected, you will be prompted for an input. After typing a value, press Enter.

Experimental:

Path: Collection / Experimental

This routine is used to set-up or define the experimental conditions or parameters that are used for an automated data acquisition process. When selected, the following sub-menu will be displayed.

Position: This routine is used to position the sample in one of the secondary coils.

H_field: This allows you to select the options available for setting the DC magnetic field.

Scan: This allows you to select the number of scans that will be performed per measurement sequence when acquiring data.

Temp_spec: This is used to define the temperature specifications that are used in automated data acquisition.

Name: This allows you to input a file name to which the data will be stored.

Log: This will log a single measurement sequence as defined in Experimental (i.e., for a defined field profile at a single temperature selected using Enter_setpoint in Temp_ctlr, or with no active temperature control).

These commands are described alphabetically within this section.

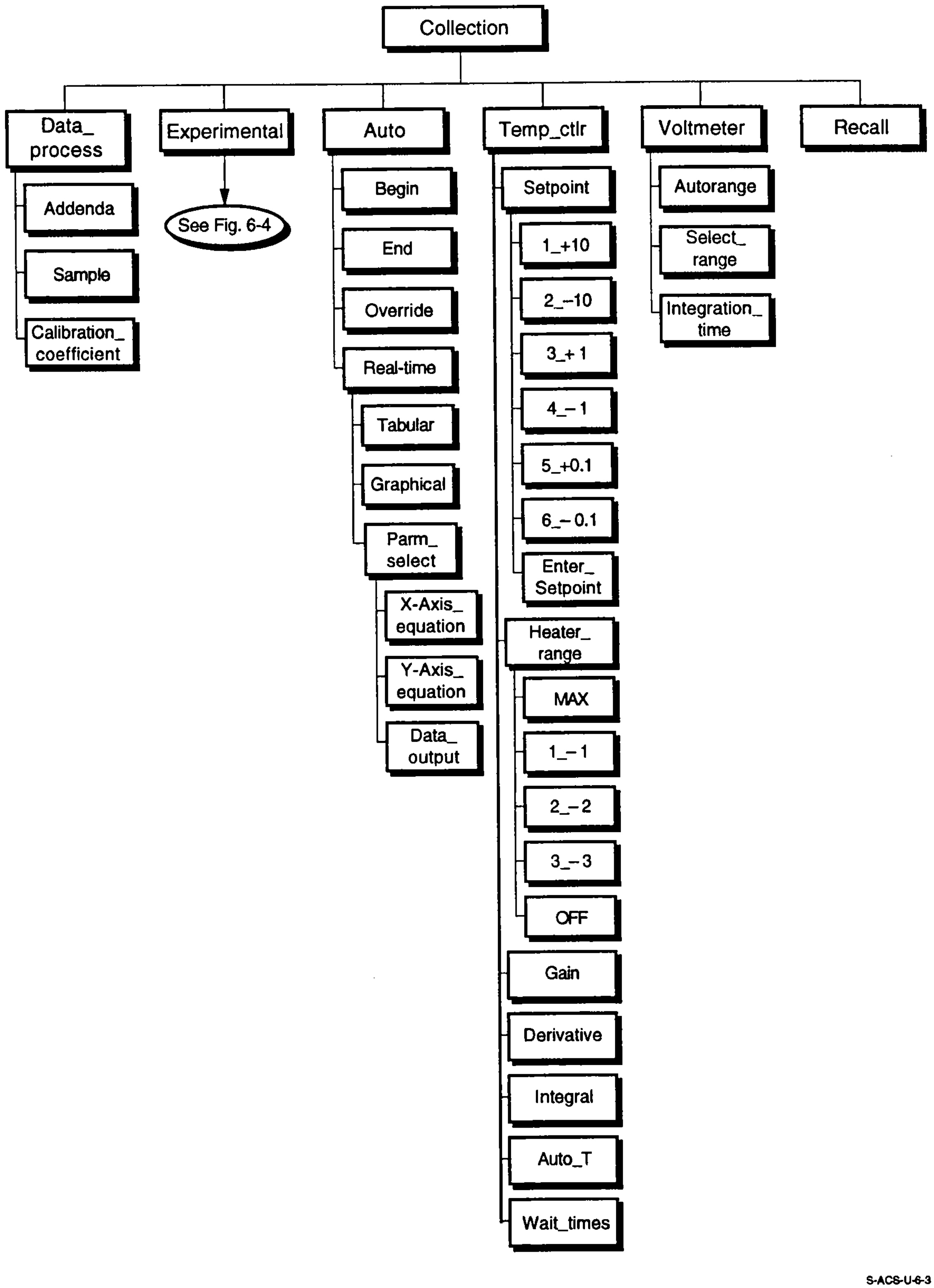


Figure 6-3. Collection Menu Block Diagram

4_Down/Coarse: Path: Collection / Experimental / Position / 4_Down/Coarse

When selected, the sample will be adjusted down 0.1 inch (0.254 cm.) from its current position.

3_Down/Fine: Path: Collection / Experimental / Position / 3_Down/Fine

When selected, the sample will be adjusted down 0.01 inch (0.0254 cm.) from its current position.

Drift:

Path: Collection / Experimental / Temp_spec / Drift

Specifies that data be logged in drift mode where there is no active temperature control (e.g., on cooling), or when the temperature is being controlled at a user defined setpoint selected in Temp_ctlr.

A default interval between successive moment measurements, which depends on the number of scans, will be displayed when this is selected. This value can be changed by entering a new value. Press Esc to use the default value.

Edit:

Main Menu

This feature allows you to change/adjust system constants/default values. When selected the following sub-menu will appear.

Constants: When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will now be prompted for an input. After typing a value, press Enter. The system constants contained in the window are:

Field-to-current conversion factor for primary coil
Calibration Coefficient for moment measurement
MPS maximum allowed current
Field-to-current conversion factor for superconducting magnet

NOTE

The only constant that may need to be changed/adjusted is the calibration coefficient.

MPS_rates: Parameters that control the ramp rates used in charging the superconducting magnet are displayed. Four ranges are indicated and for each range a rate in amperes per second is given to be used up to the specified absolute current value. Both the ramp rate and current limits can be altered. If only one or two ranges are used, the remaining ranges should have a 0 amp/sec rate specified with the current limit set at the maximum current.

CAUTION

MPS parameters are factory set and should not be altered except by personnel experienced with the operation of superconducting magnets. Damage could result.

Save: This will save any changes made in Constants or MPS_rates to the DCM.DAT file. When selected, you will be prompted with "Are you sure?" Yes saves the new information to the DCM.DAT file, and No does not write the new values to the DCM.DAT file.

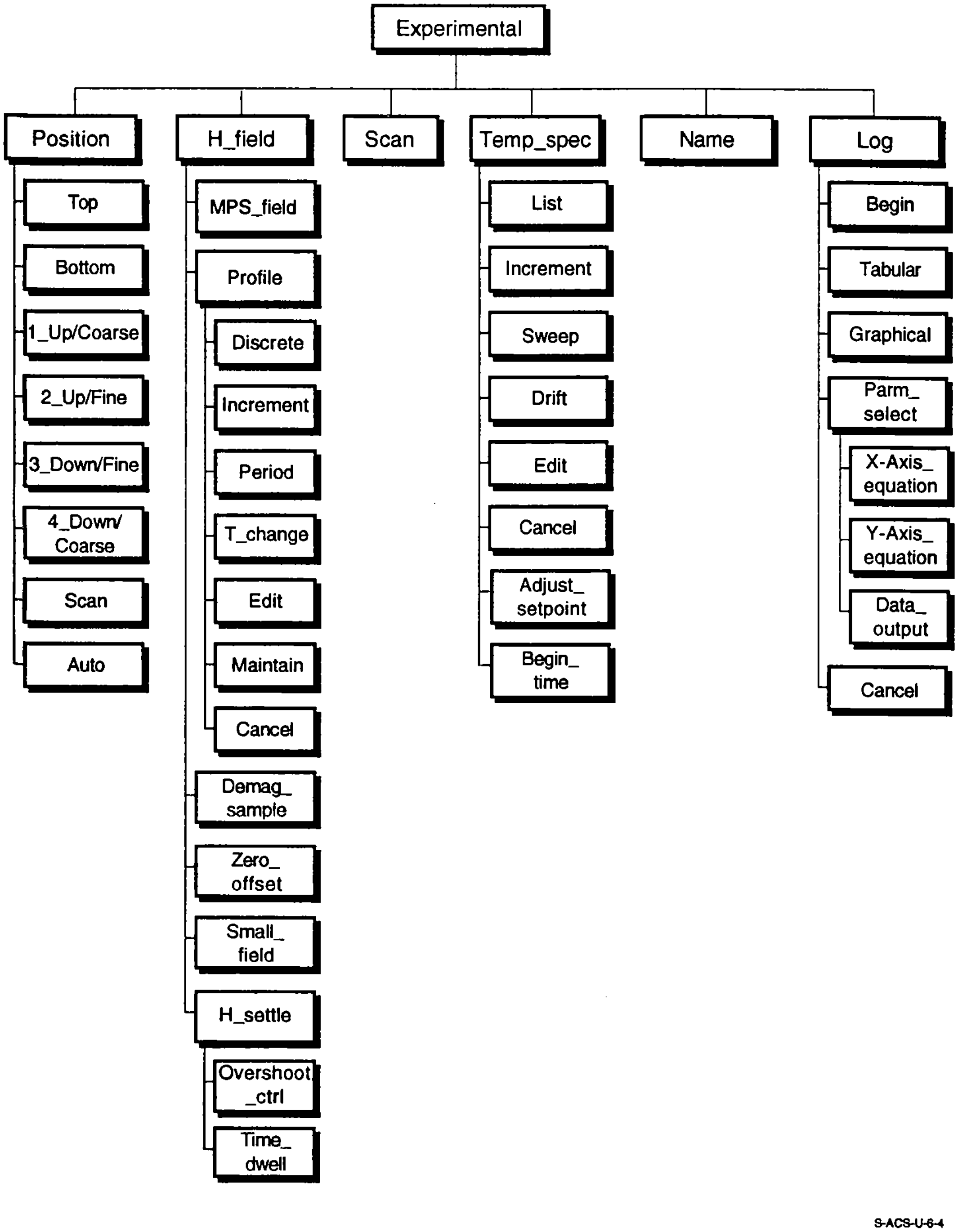


Figure 6-4. Experimental Menu Block Diagram

Data_process: Path: Collection / Data_process

When selected, the following sub-menu will be presented.

Addenda: Select an addenda file to be used when processing data during collection.

Sample: Toggles a window in which the user can enter the sample specs (mass, density, etc.).

Calibration_coefficient: Enter a new value for the calibration coefficient.

Press Esc to exit.

Demag_sample: Path: Collection / Experimental / H_field / Demag_sample

This function is used to demagnetize the system and sample and eliminate any remanant fields which may be present in the magnet. When selected, the cycle is performed automatically. The routine steps through a process in which the field is ramped to its maximum value and then the field direction is alternately changed and the field amplitude is decreased with each cycle down to the lowest selectable field. The entire cycle takes ≈5 minutes to complete.

NOTE

Whenever operation of the system with the magnet is completed, or prior to using the system, Demag_sample should be used to eliminate any stray fields that may be present. Keep in mind that if a sample with "magnetic history" (e.g. a superconductor) is contained in the system when using Demag_sample the sample may be at an unknown point on its hysteresis curve at the completion of the cycle.

Derivative: Path: Collection / Temp_ctlr / Derivative

This allows you to set the Rate value of the DRC-91CA Temperature Controller. When selected you will be prompted for an input (0 – 9.9). After typing a value, press Enter. The default setting for this parameter is 0.

During automatic data acquisition, this parameter will be set to 0.

Discrete: Path: Collection / Experimental / H_field / Profile / Discrete

This routine enables you to enter DC field values individually in order to build your own list of DC fields at which data will be recorded during automated data acquisition.

When selected, you will be prompted for a field input (kAmp/m if SI, kOe if cgs). Input a value and press Enter. A window will be displayed on the screen with this single field value. Continue to enter as many fields as desired (pressing Enter after each entry). Each additional entry will be added to the window. The order in which fields are entered is the order in which the fields will be set, and data recorded, during data acquisition. Esc when completed to exit.

NOTE

Discrete and Increment can be used together to build a table of discrete field points for fixed point data acquisition.

DOS/Windows: Main Menu

Enables you to exit to the Disk Operating System (DOS) or Windows. When selected, you will be prompted with the sub-menu "No Yes." Selecting No leaves you in the Main Menu, and selecting Yes exits to DOS/Windows.

6.3.2 MENU BREAKDOWN AND FUNCTIONAL DESCRIPTION

The following is a text-based representation of the information presented in the menu block diagrams.

Analysis	Display the Analysis menu.
Begin	Processed data sent to printer or file depending on options selected in Output.
Cancel	Input sample specifications.
File	Input data file for processing.
View	Display processed data on screen.
Tabular	Displays processed data tabularly on screen according to the selection made in Parm_select.
Graphical	Displays processed data graphically on screen according to the selection made in Parm_select.
Parm_select	Selects X, Y equations for displaying and processing data.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., m).
Data_output	Select type of moment (mass, volume, molar, etc.)
Output	Select type output: printer or file.
Printer	Prints data to hardcopy device. Selects print option.
File	Prints data to file. Selects file output option.
Label	Input sample label to be printed on printout.
Addenda	Select/create addenda file.
Select	Selects previously generated addenda file.
Build	Creates addenda file from data file.
Cancel	Cancels previously selected addenda file.
Data_process	Define parameters affecting data processing.
Calibration_coefficient	Modify calibration coefficient.
All	Processes data for an array defined by the equations under Parm_select.
Parm_select	Selects X, Y equations for displaying and processing data.
Sample	Input sample specifications.
Collection	Display the Collection menu.
Data_process	Define parameters affecting data processing.
Addenda	Enter addenda file name.
Sample	Input sample specifications.
Calibration–coefficient	Modify/change calibration constant.
Experimental	Set all experimental parameters.
Position	Position sample in secondary coil.
Top	Specify top coil position.
Bottom	Specify bottom coil position.
1_Up/Coarse	Moves sample up 0.1 inch (0.254 cm).
2_Up/Fine	Moves sample up 0.01 inch (0.0254 cm).
3_Down/Fine	Moves sample down 0.01 inch (0.0254 cm).
4_Down/Coarse	Moves sample down 0.1 inch (0.254 cm).
Scan	Moves sample and graphs voltmeter output as a function of time on screen.
Autoposition	Autoposition sample in bottom coil.

Collection: Main Menu

Collection defines the experimental parameters that are to be used when logging data for a particular sample or experiment. When selected, the following sub-menu will be presented.

Data_process: Specifies how the data is processed (i.e., moment as a function of temperature, field, or time).

Experimental: Selection of this brings up the experimental set-up menu where experimental parameters are defined for automated data acquisition.

Auto: Acts as a toggle to begin automated data acquisition.

Temp_ctlr: This allows interact with the DRC-91CA via the software.

Voltmeter: This allows you to interact with the voltmeter through the software.

Recall: Allows input a previously generated configuration file or experimental set-up.

These commands are described alphabetically within this section.

Constants: Path: Edit / Constants

This is used to adjust/modify system constants. When selected, a window of system constants will be displayed. To change a particular system constant, move the cursor to that constant and press Enter. You will then be prompted for an input. After typing a value, press Enter again. Esc to exit.

The system constants that are displayed, and can be changed are:

Field-to-current conversion factor for primary coil.
Calibration coefficient for moment measurement
MPS maximum allowed current
Field-to-current conversion factor for superconducting magnet.

NOTE

Calibration_coefficient is the only constant that may require adjustment.

Data_output: Path: This command is included in 4 locations

The command is located in three different locations: Analysis / View / Parm_select, Analysis / Data_process / Parm_select, Collection / Auto / Parm_select, and Collection / Experimental / Log / Parm_select. Selecting this command will produce a window in which the user chooses the desired moment output (either volume, mass, molar, arbitrary units, or raw data). Raw data can only be displayed under Analysis.

Data_process: Path: Analysis / Data_process

When selected, the following sub-menu will be presented.

Calibration_coefficient: Enter a new value for the calibration coefficient.

All: Toggles the processing of DC field array on/off.

Parm_select: Selects the X, Y equations and data output option for processing data.

Sample: Toggles a window in which the user can enter the sample specs (mass, density, etc.).

Press Esc to exit.

Collection (Continued)

Experimental (Continued)

H_field	Selects DC field setting options.
MPS_field	Select the DC magnetic field of the superconducting magnet.
Profile	Define field profile/control.
Discrete	Enter individual field values.
Increment	Enter low/high and increment.
Period	Select time duration at a given field, and time between successive measurements.
T_change	Select field to be set after the field profile is completed.
Edit	Change existing profile (if present).
Maintain	On/off toggle to leave field on after the completion of automatic data acquisition.
Cancel	Cancel existing setup.
Demag_sample	Selection performs demagnetization cycle for elimination of remanant fields.
Zero_offset	Selection compensates for any MPS zero-drifts.
Small_field	Allows setting small fields with the primary coil/140 current source.
H_Settle	Provides options for controlling settling of the magnetic field.
Overshoot_ctrl	On/off toggle for minimization of field overshoots.
Time_dwell	Select time (in addition to default time settings) for field stabilization.
Scan	Enter number of scans per measurement sequence (default = 1).
Temp_spec	Define temperature setup.
List	Enter individual points.
Increment	Enter first/last and increment.
Sweep	Enter low/high and sweep rate, up to 3 ranges allowed.
Drift	No control, select time between measurements.
Edit	Change existing setup.
Cancel	Cancel existing setup.
Adjust_Setpoint	Fine tune of setpoint on/off.
Begin_time	Enter time (in minutes) to wait before initiating auto-collection.
Name	Enter file name for data storage.
Log	Log data point according to the defined measurement sequence.
Begin	Initiates data acquisition process.
Tabular	Selects tabular display for real-time feedback.
Graphical	Selects graphical display for real-time feedback.
Parm_select	Selects X, Y equations for displaying and processing data.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Data_output	Select type of moment (mass, volume, molar, etc.)
Cancel	Cancels the log sequence.

Auto

Auto	Begin automatic data acquisition (with Temp_spec).
Begin	Begins data acquisition.
End	Ends data acquisition (if in progress).
Override	Over-rides Begin_time, wait period, or drift-per-minute criteria.
Real-time	Selects real-time feedback.
Tabular	Displays real-time feedback in tabular form.
Graphical	Displays real-time feedback in graphical form.
Parm_select	Selects X, Y equations for displaying and processing data.
X-Axis_equation	Enter equation for the X-axis (i.e., T).
Y-Axis_equation	Enter equation for the Y-axis (i.e., χ).
Data_output	Select type of moment (mass, volume, molar, etc.)

Begin:
Path: Collection / Auto / Begin

When Begin is selected, automatic data acquisition is initiated. See Auto.

Begin:
Path: Collection / Experimental / Log / Begin

Initiates data acquisition process and will display the results as they are recorded in the lower left-hand feedback block. Esc to exit.

Begin_time:
Path: Collection / Experimental / Temp_spec / Begin_time

Enter a time in minutes as to when the Auto Collection process should actually start after the Begin key is pressed. Entering zero will reset this value.

Bottom:
Path: Collection / Experimental / Position / Bottom

This is a toggle for specifying that the sample is positioned in the bottom secondary coil.

Build:
Path: Analysis / Addenda / Build

An addenda file will be created with the extension .add from whatever file has been specified. The addenda file can only be created from data logged using fixed temperature points with at least two applied DC fields (where one field can be 0-field).

Calibration_coefficient:
Paths: Analysis / Data_process and Collection / Data_process

This command will enable the user to make adjustments to the system calibration constant. The calibration normally will remain constant as supplied by the factory. Slight modifications may be required when the user performs his own independent calibration of the system.

When selected, the user will be prompted for an input. After typing a value, press Enter.

Cancel:
This option is contained in five different locations.

1. Path: Analysis / Cancel

   Selection of this will cancel a previously selected addenda file.

2. Path: Analysis / Addenda / Cancel

   Selection of this will cancel a previously selected addenda file.

3. Path: Collection / Experimental / H_field / Profile / Cancel

   Selection of this will cancel a previously defined field profile (i.e., discrete fields, etc.).

4. Path: Collection / Experimental / Temp_spec / Cancel

   Selection of this will cancel a previously entered temperature specification.

5. Path: Collection / Experimental / Log / Cancel

   Selection of this will terminate the Log sequence.

Collection (Continued)

Temp_ctrl	Adjust temperature control parameters.
Setpoint	Enter temperature setpoint.
1_+10	Increment +10K.
2_–10	Decrement –10K.
3_+1	Increment +1K.
4_–1	Decrement –1K.
5_+0.1	Increment +0.1K.
6_–0.1	Decrement –0.1K.
Enter_setpoint	Input setpoint.
Heater_range	Select heater power range.
MAX	Sets to maximum.
1_–1	Sets to first range (–1).
2_–2	Sets to second range (–2).
3_–3	Sets to third range (–3).
OFF	Turns off heater range.
Gain	Input gain setting.
Derivative	Input derivative/rate.
Integral	Input integral/reset.
Auto_T	Input setpoint. Temperature will automatically be adjusted to that setpoint (unlike Enter_setpoint).
Wait_times	Adjust the wait period in seconds for each temperature range as well as the drift criteria for those ranges.
Voltmeter	Set/adjust voltmeter control parameters.
Autorange	On/off autoranging toggle.
Select_range	Select range to be used for all data acquisition.
Integration Time	Sets integration on DVM to 1PLC or 100 msec.
Recall	Recall a previously defined experimental configuration.

Edit

Adjust/edit coil parameters and phases contained in DCM.DAT.

Constants	Modify coil parameters contained in DCM.DAT.
MPS_rates	Current ramping rates used in charging the superconducting magnet contained in DCM.DAT.
Save	Save any changes to DCM.DAT.

Recall

Recall a previously defined experimental configuration.

Units

Toggle between Système International d'Unités (SI) or centimeter–gram–second (cgs).

DOS/Windows

Exit to DOS or Windows.

Auto (Continued)

Real-Time: Selection of this activates real-time feedback of data. When selected, the following sub-menu is accessed.

Tabular: When selected, the data will be displayed on the screen in tabular format according to the defined measurement sequence. The following will be displayed:

X-Axis equation (*T* (K) by default), & Y-Axis equation (m by default);

or if "Log," default is m vs. H, or if "Auto." default is m vs. T.

Esc to exit.

Graphical: When selected, the data will be displayed on the screen in graphical format according to the defined measurement sequence. If no display parameters are selected, the program will use the following defaults: if "Log," default is m vs. H, or if "Auto." default is m vs. T. Scaling is performed automatically. Esc to exit.

Parm_select: Depending upon the experimental setup, a single acquisition run can yield a matrix of moment data recorded at different fields and temperatures. This option permits processing the data matrix as user-defined functions which choose a variable parameter while fixing all other possible parameters. The X, Y-Axis equations choose the user-defined function and force the user to pick the variable and fixed parameters. The following naming convention must be adhered to when specifying an equation (not case-sensitive):

T:	Temperature	m:	Moment
H:	DC field	TI:	Time

Refer to Paragraph 6.2.7 for further information. Esc to exit.

Auto:

Path: Collection / Experimental / Position / Auto

Automatically positions a sample in the bottom coil. The positioning routine operates by first moving the sample to the lower limit of the movement assembly. The sample is next moved upward a small increment and a moment measurement (scan) is performed. The sample is then moved upward again and the moment remeasured. This procedure is repeated until a peak in the moment versus position is detected and the sample is loved to that peak moment position. In order to function properly, the sample should have a moment greater than 10^{-5} Am^2 (0.01 emu). Error messages prompt if a proper position could not be achieved.

Autorange:

Path: Collection / Experimental / Voltmeter / Autorange

This is an on/off toggle for enabling/disabling the autoranging feature of the voltmeter.

Begin:

Path: Analysis / Begin

Process data is sent to the printer or a file, depending on the options selected in Output.

6.3.3 COMMAND BREAKDOWN AND FUNCTIONAL DESCRIPTION

The following is a complete list of DCM7000 Software Commands presented in alphabetical order.

Addenda: Path: Analysis / Addenda

The following sub-menu is accessed.

Select: Prompts for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by File in the Analysis menu.

Build: An Addenda file with the extension ".add" will be created from whatever file has been specified. An addenda file can be created only from data recorded using fixed temperature point acquisition with at least two applied fields (where one field can be 0-field).

Cancel: Cancels a previously selected addenda file.

Addenda: Path: Collection / Data_process / Addenda

When selected, you will be prompted for the name of a previously created addenda file to be used in processing whatever data is contained in the data file selected by Name in the Experimental Menu.

Adjust_Setpoint: Path: Collection / Experimental / Temp_spec / Adjust_setpoint

This is an on/off toggle for use with fixed point temperature data acquisition. When this option is active, the system temperature control routines are modified such as to make the actual sample temperature closer to the setpoint values input by the user. Activating this option will increase the data acquisition time by a factor of 1.5 to 2.

This option compensates for the fact that the system contains two temperature sensors. The sample temperature sensor is positioned to optimize both the temperature control and minimize the time required for temperature stabilization. When temperatures are input from the keyboard, these values are control temperature values. The actual sample temperature will vary from the control value depending upon temperature range and system status. The Adjust_setpoint option has a feedback control routine to modify the controller setpoint to bring the sample temperature closer to the input value.

All: Path: Analysis / Data_process / All

This option permits processing all data recorded using multiple fields. When a file output has been specified, the processed data will be stored in files of the same name but with different extensions: filename.001, filename.002, filename.003, etc. Each extension stands for a DC field.

Analysis: Main Menu

This is the processing program for processing data contained in data files defined in the Experimental sub-menu of the Collection menu. When selected, the following sub-menu will be displayed.

Begin: Processed data sent to printer or file depending on options selected in Output.

Cancel: Used to cancel a previously selected addenda file.

File: Used to input a file name containing data to be processed.

View: This is a toggle for displaying processed data on the screen.

Output: is for specifying that the processed data be written to a hard copy device or an ASCII file.

Addenda: This allows you to create or select an addenda file to be used when processing data.

Data_process: Specifies how the data is processed (i.e., moment as a function of temperature, field, or time).

These commands are described alphabetically within this section.

Auto_T: Path: Collection / Temp_ctlr / Auto_T

This will automatically warm the system up to a user input temperature at a rate of 3 K/min. When selected, you will be prompted for a setpoint. After typing a setpoint and pressing Enter, the control sensor will be read and the setpoint will be set equal to the control sensor temperature reading and the control setpoint will start to increase at a rate of 3 K/min.

Once the setpoint is reached, the temperature will continue to be controlled at that temperature. Pressing the Esc key will abort the ramping process, and the temperature will be controlled at the setpoint determined when the Esc key was pressed.

Auto: Path: Collection / Auto

Starts automatic data acquisition. When selected, the following sub menu is accessed.

Begin: Begins automatic data acquisition process.

End: When selected, you will be prompted with; "Are you sure? Y/N?. If "Y" is selected the automatic data acquisition process will be terminated. Data recorded up to that point will be saved if a file has been specified. To continue with data acquisition, select "N".

Override: During fixed temperature points data acquisition mode, selection of this key will over-ride certain WAITS that are built into the software. Specifically, once a certain setpoint is reached, a WAIT period is entered into to allow the temperature to stabilize and reach equilibrium. The exact length of the WAIT is dependent upon the particular temperature range. Upon completion of the WAIT, a temperature DRIFT CHECK is initiated where the temperature drift per minute is automatically monitored. Once the DRIFT/MIN is below 0.1 K/min the data acquisition/measurement sequence will automatically begin. Selecting Override once will over-ride the designated WAIT period and initiate DRIFT CHECK. Selecting Override again will over-ride this as well and data will then be recorded immediately.