User's Manual

Model 320
Temperature Controller

Obsolete Notice:

This manual describes an obsolete Lake Shore product. This manual is a copy from our archives and may not exactly match your instrument. Lake Shore assumes no responsibility for this manual matching your exact hardware revision or operational procedures. Lake Shore is not responsible for any repairs made to the instrument based on information from this manual.

■LakeShore®

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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.

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

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from improper or inadequate maintenance, unauthorized modification or misuse, operation outside of the environmental specifications for any product or part or buyer-supplied software interfacing.

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

CERTIFICATION

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

TRADEMARK ACKNOWLEDGMENT

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.

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CHAPTER 1

INTRODUCTION

1.0 GENERAL

This chapter provides an introduction to the Model 320 Autotuning Temperature Controller. The Model 320 was designed and manufactured in the United States of America by Lake Shore Cryotronics, Inc. The Model 320 Autotuning Temperature Controller is a microprocessor-based instrument with digital control of a variable current output. The Model 320 features including the following:

- Autotuning
- Nonvolatile memory space to store one sensor calibration curve
- Serial Interface (RS-232C Electrical Format) is standard
- Three Models available:
  - Silicon Diode (320-01)
  - 100 Ω Platinum Resistor (320-02)
  - Thermocouple (320-04)
- Eight character alphanumeric LED display for high visibility
- Simple scroll type display with cursor key entry
- Capability of reading sensors with ±0.1 kelvin accuracy or better
- Isolated current source allows true 4-wire sensor readings
- Control Stability to ±0.1 or better in K or °C
- 25 watts of heater power, Variable DC current source output
- Small 1/4 DIN package

If you have just received your new Model 320, please proceed to Chapter 2 and become familiar with the installation instructions. Instrument operational information is contained in Chapter 3. Chapter 4 contains information on Model 320 special features. Details on remote operation using the Serial I/O Interface is contained in Chapter 5. Service and calibration information is provided in Chapter 6. For reference, various appendices are included. Finally, an alphabetical index is included at the end of the manual.

We welcome your comments concerning this manual. Although every effort has been made to keep it free from errors, some may occur. When reporting a specific problem, please describe it briefly and include the appropriate paragraph, figure, table, and page number. Send comments to Lake Shore Cryotronics, Attn: Technical Publications, 64 East Walnut Street, Westerville, Ohio 43081-2099. The material in this manual is subject to change without notice.

Due to Lake Shore's commitment to continuous product improvement, it is reasonable to expect that modifications will be made in the Model 320 software with time. Some of these changes are the result of Customer feedback regarding operation on various cryogenic systems. We encourage you to contact us with any observations or suggestions which you have regarding the use of this controller. Also, *please return your warranty card* to ensure that any software updates are sent to you.

1.1 MODEL 320 TEMPERATURE CONTROLLER SYSTEM DESCRIPTION

The following are some of the major features of the Model 320 Autotuning Temperature Controller.

Input. The Model 320-01 is a silicon diode temperature controller. The Model 320-02 input is configured for a 100 Ω Platinum Thermometer (PRTs). The Model 320-04 Thermocouple controller is usable with several types of thermocouples: 0.07% and 0.03% Ch-AuFe, E, K, and T thermocouples. In addition, the Model 320-04 has electronic room temperature compensation standard.

Sensors. Typical electronic accuracy and resolution specifications for various sensors and temperature ranges are provided in Table 1-1.

Precision. For best precision, individual sensors should be accompanied with the 8001 Precision Calibration Option which programs the instrument with calibration data for a specific sensor. The algorithm within the instrument interpolates between data points to an accuracy which exceeds 50 mK over the entire temperature range of the Precision Option. Therefore the overall system accuracy and that of the calibration itself is reduced to a minimum. (Lake Shore calibrations are typically better than 50 mK below 28K for diode sensors.) See the Lake Shore Product Catalog for additional discussion of calibration accuracy.

Memory. The memory space provided in the Model 320 allows one user response curve to be stored in the instrument. The data for calibrated sensors can be stored in the instrument as an 8001 Precision Option at the factory or by the customer via the Serial interface. There is room for a 99 point curve.

Control Algorithm. The Model 320 offers a simple and inexpensive answer to control needs. The control algorithm provides three-term digital temperature control. Proportional (GAIN), integral (RESET) and derivative (RATE) are individually set via front-panel entry in manual mode or automatically tuned with the Autotune feature.
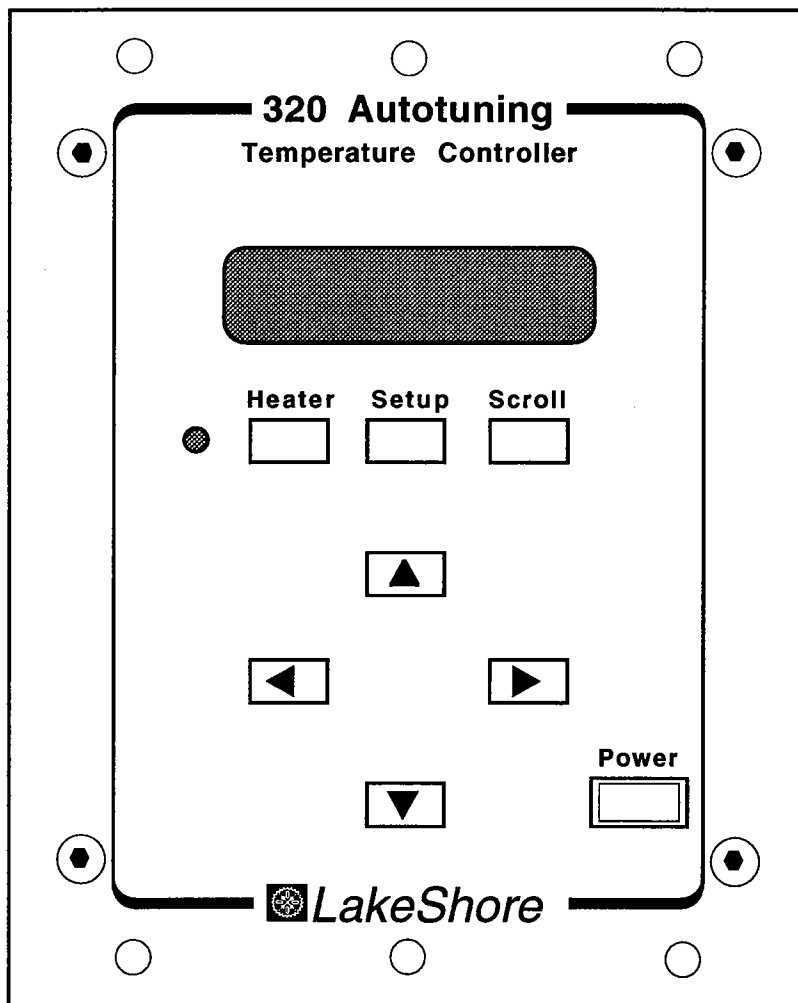
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Figure 1-1. Model 320 Temperature Controller Front Panel

Control Setpoint. The control setpoint is set via the front panel keypad or over the computer interface. The setpoint can be set in temperature to a resolution of 0.1 K or °C.

Heater Power Output. Heater power output of the Model 320 Temperature Controller is a variable DC current source for quiet, stable control. It sources a maximum of 25 watts with a 25Ω heater. The heater display is in percentage of full scale output current. Thus, the user can conveniently monitor heater power applied to the system. (This value is calculated in the Model 320 and is not an actual measurement.)

Interface. A serial interface is standard in the Model 320. It can be used to remotely control most front panel functions and output display data and instrument status.

1.2   HARDWARE OPTIONS AND ACCESSORIES

The options installed in your unit are detailed on the B page of this manual (following the title page). A general list of Model 320 options and accessories is detailed in this paragraph. The standard Model 320 heater output is 25 watts.

Model	Inputs
320-01	Silicon Diode.
320-02	Platinum RTD.
320-04	Thermocouple.

AC Line requirement should be specified at time of order: 100, 120, 220 or 240 VAC; 50 or 60 Hz.

Accessories Included:

1	Detachable 120 VAC line cord (115-006).
1	Sensor mating connectors (106-233).
1	Heater output connector (106-009).
1	Users manual (MAN-320).

Precision Options:

8001	Precision option (requires calibrated sensor).
8002-05	Precision option number if the user already owns a Model 320.

Accessories Available:

2001	RJ11 3 meter (10 feet) Modular RS-232C (Phone) Cord.
2002	RJ11 to DB25 Adapter. Connects RJ11 to a 25-pin RS-232C serial port.
2003	RJ11 to DB9 Adapter. Connects RJ11 to a 9-pin RS-232C serial port.
8271-30	Sensor/heater cable assembly for diode and platinum sensors.
HTR-25	25 Ω Cartridge Heater, 25 W, 1/4 inch diameter by 1 inch long.

Table 1-1. Instrument Electronic Information for Various Sensors and Temperature Ranges

Model No.	320-01	320-02	320-04 *
Sensor Type	Silicon diode	100 Ω Platinum RTD	Thermocouple
Sensor Temp Coefficient	Negative	Positive	Positive
Sensor Units	Volts (V)	Ohms (Ω)	Millivolts (mV)
Input Range	0 - 2.5 V	0 - 300 Ω	±15 mV
Sensor Excitation	10 µA ±0.05% constant current	1 mA ±0.01% constant current	N/A
Example LSCI Sensor	DT-470-C0	PT-103	Ch-AuFe 0.07%
Sensor Temp. Range	1.4 - 475 K	30 - 800 K	1.4 - 325 K
Standard Sensor Curve	LSCI Curve 10	DIN 43760	NBS generated
Typical Sensor Sensitivity	−30 mV/K at 4.2 K −1.9 mV/K at 77 K −2.4 mV/K at 300 K −2.2 mV/K at 475 K	0.19 Ω/K at 30 K 0.42 Ω/K at 77 K 0.39 Ω/K at 300 K 0.33 Ω/K at 800 K	16 µV/K at 4.2 K 20 µV/K at 300 K
Measurement Resolution Sensor Units Temperature Equivalence	0.04 mV 1.3 mK at 4.2 K 21 mK at 77 K 16 mK at 300 K 18 mK at 475 K	5 mΩ 26 mK at 30 K 12 mK at 77 K 13 mK at 300 K 15 mK at 800 K	0.5 µV 31 mK at 4.2 K 25 mK at 300 K
Sensor Unit Display Resolution	0.1 mV to 1 mV	0.01 Ω to 0.1 Ω	1 µV
Measurement Accuracy	±0.2 mV ±0.02% RDG	±20 mΩ ±0.05% RDG	±2 µV ±0.05% RDG
Temperature Accuracy with Calibrated Sensor and Precision Option	±0.1 K at 4.2 K ±0.3 K at 77 K ±0.2 K at 300 K ±0.2 K at 475 K	±0.2 K at 30 K ±0.2 K at 77 K ±0.3 K at 300 K ±0.6 K at 800 K	±0.4 K at 4.2 K ±0.2 K at 300 K
Measurement Temp. Coefficient Sensor Units (%RDG/°C) Temperature Equivalence	±0.01% ±5 mK/C° at 4.2 K ±53 mK/°C at 77 K ±22 mK/°C at 300 K ±40 mK/°C at 475 K	±0.01% ±3 mK/°C at 4.2 K ±5 mK/°C at 77 K ±30 mK/°C at 300 K ±90 mK/°C at 800 K	±0.018% ±75 mK/°C at 30 K ±50 mK/°C at 300 K
Setpoint Display Resolution in Sensor Units	0.1 mV to 1 mV	0.01 Ω to 0.1 Ω	1 µV

* All thermocouple data are for uncompensated inputs.
† No Model 8001 Precision Option is available for thermocouples. Error listed is for the instrument only.

Table 1-2. Model 320 Specifications

Thermometry:

Number of Inputs:	One
Sensor Types:	Model 320-01 – Silicon Diode
	Model 320-02 – Platinum RTD
	Model 320-04 – Thermocouple
Accuracy:	Based on Model and Sensor Type (Refer to Table 1-1)
Update Rate:	1 second
Precision Curve Storage:	One 99 point curve entered via Serial Interface

Control:

Control:	Digital, three term PID with Autotune
Automatic Control Mode:	P, PI, or PID control, user selectable
Manual Control Mode:	Proportional (GAIN) 1-1000, integral (RESET) 1-1000 sec., and derivative (RATE) 0 - 200%
Control Stability:	Better than ± 0.1 K in a properly designed system for diode and platinum sensors
Setpoint Resolution:	0.1 in Temperature (K or °C)
Heater Output Type:	Analog DC Current Source
Heater Setting Resolution:	15 bit
Max Power To Heater:	25 W
Max Current To Heater:	1 A
Heater Output Compliance:	25 V
Heater Load:	20 Ω or greater to operate, 25 Ω required for full power
Heater Noise:	0.005% of full scale power

Front Panel:

Display:	8-digit Alphanumeric LED
Display Units:	Temperature in K or °C. Sensor units in volts (320-01), ohms (320-02), or millivolts (320-04)
Annunciator:	Heater On
Temperature Resolution:	0.1 K or °C
Sensor Units Resolution:	Same as setpoint resolution.
Keypad:	Scrolls through sensor reading, setpoint, and heater current. Setup of units, curve number, manual control settings, tuning selection, filter and BAUD rate

Interface:

Serial Interface:	300 or 1200 baud, RJ11 connector (RS-232C electrical standard)

General:

Ambient Temperature Range:	15-35 °C
Power Requirements:	90-125, or 210-250 VAC, 50 or 60 Hz; 65 watts
Size:	105 mm wide x 132 mm high x 280 mm deep (4.2 x 5.2 x 11 inches).
Weight:	2.7 kilograms (6 pounds)

1.3   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.

1.4   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 over 1000 volts must be so marked).
⏚ or ⏚	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.
⏛ or ⏛	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).
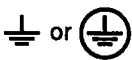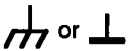
CHAPTER 2

INSTALLATION

2.0 GENERAL

This chapter provides general installation instructions for the Model 320 Autotuning Temperature Controller. Inspection and unpacking instructions are provided in Paragraph 2.1. Repackaging for shipment instructions are provided in Paragraph 2.2. A definition of rear panel controls is provided in Paragraph 2.3. Finally, an initial setup and system checkout procedure is provided in Paragraph 2.4.

2.1 INSPECTION AND UNPACKING

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

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

2.2 REPACKAGING FOR SHIPMENT

If it is necessary to return the Model 320, sensor, or accessories for repair or replacement, a Return Goods Authorization (RGA) number must be obtained from a factory representative before returning the instrument to our service department. Instruments may not be accepted without an RGA number. When returning an instrument for service, the following information must be provided before Lake Shore can attempt any repair.

A. Instrument model and serial number.
B. User name, company, address, and phone number.
C. Malfunction symptoms.
D. Description of system.
E. Returned Goods Authorization (RGA) number.

Wrap instrument in a protective bag and use original spacers to protect controls. Repack the system in the LSCI shipping carton (if available) and seal it with strong paper or nylon tape. Affix shipping labels and FRAGILE warnings. Write the RGA number on the outside of the shipping container or on packing slip.
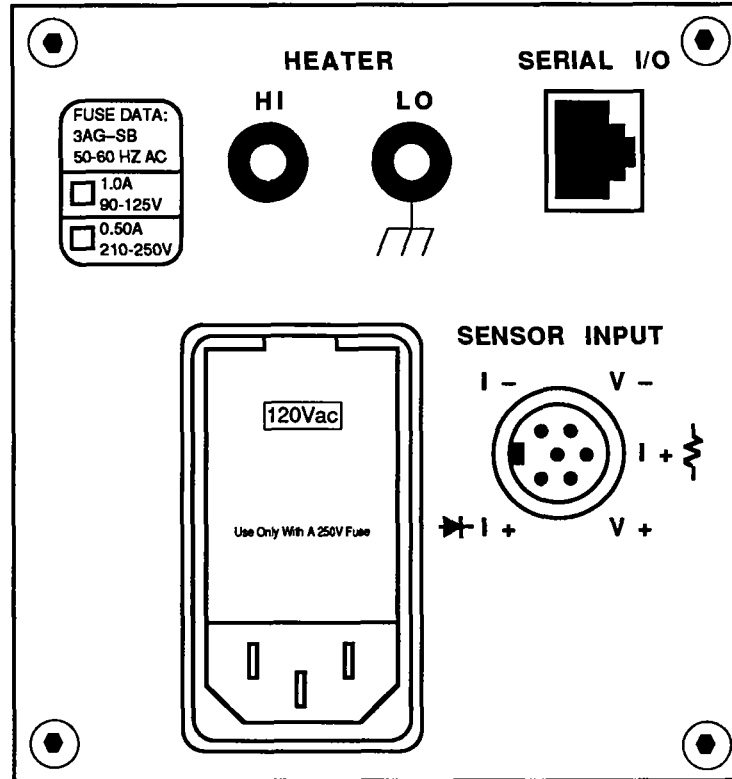
S-320-U-2-1

Figure 2-1. Typical Model 320 Rear Panel

2.3 DEFINITION OF REAR PANEL CONNECTIONS

This paragraph provides a description of the Model 320 rear panel connections. The rear panel consists of the power and fuse assembly, Serial I/O Connector, Sensor Input Connector, and Heater Output Connectors.

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              CAUTION
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Verify that the AC Line Voltage Selection Wheel located on the rear panel of the Model 320 is set to the available AC line voltage and that the proper fuse is installed before inserting the power cord and turning on the instrument.

Power and Fuse Assembly. The power and fuse assembly is the primary entry and control point for AC power to the unit. The assembly consists of two parts: power line jack and the fuse drawer. The line cord is connected to the power line jack. Power to the unit is controlled by the **Power** switch located on the front panel. The fuse drawer contains a 1 A 3AG Slow Blow fuse for 90-125 VAC or a 0.5 A 3AG Slow Blow fuse for 210-250 VAC.

Serial I/O Connector. The Serial I/O (Input/Output) Connector accepts the standard RJ-11 telephone connector. RJ-11 to DB9 or DB25 Adapters are available from Lake Shore that permit connection to the user's computer.

Sensor Input Connector. A sensor input connector is provided for attaching temperature sensor to the unit. Always turn off the instrument before connecting the sensor.

Heater Connectors. Two banana jacks provide heater connections.

2.4 ENVIRONMENTAL REQUIREMENTS

The Model 320 is for laboratory use. In order to meet and maintain specifications, the Model 320 should be operated at an ambient temperature range of 18-28 °C. The unit may be operated within the range of 15-35 °C with reduced accuracy.

WARNING

To prevent electrical fire or shock hazards, do not expose this instrument to rain or excess moisture.

2.5 GROUNDING AND SHIELDING

To protect operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends, and some local codes require, instrument panels and cabinets be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument.

Grounding and shielding of signal lines are major concerns when setting up any precision instrument or system. The Model 320 has included ground isolation of the sensor excitation to allow 4-wire measurement of diode voltage and resistance. Improper grounding of sensor leads and shields can defeat this feature.

Digital logic in the Model 320 is tied directly to earth ground for interface communication. The low side of the heater output is directly connected to earth ground.

NOTE

Do not attach the shield to earth ground at the sensor end.

Shield sensor cables whenever possible. Attach the shields to the shield pin provided in the connector.

2.6 HEATER SETUP

The heater output of the Model 320 is brought out the back panel as a Dual Banana Jack. A mating connector is supplied. Current is driven from the HEATER (HI) connection to the HEATER (LO) connection. Heater LO is connected to earth ground. A resistive heater load of 25 Ω or more should be connected between these two points.

The heater output is a 1 amp current drive and does not have to be fused. The Model 320 is designed to power a 25 Ω heater for maximum heater output. A larger heater resistance may also be used but will result in a lower maximum power output. For example, the output compliance voltage is 25 volts so that a 100 Ω heater resistance allows a maximum power output of 6.25 watts $[(25V)^2/100\Omega]$.

CAUTION

● The instrument has built-in protection to prevent overheating. If the heater load is below approximately 20 Ω or if the heater loads are shorted, the output will turn off. If this occurs, turn the instrument OFF and connect the proper load. If the heater load is less than 20 Ω, add a resistive load in series with the heater so that the total resistance between the HI and LO output terminals is approximately 25 Ω.

● Use care during heater installation to ensure Heater Hi is not shorted to ground. Damage to the instrument can result from improper heater wiring.

Within a cryostat, 30 gauge stranded copper lead wire (ND-30) is recommended for connection to the heater. The heater leads should not run coincident with the sensor leads due to the possibility of capacitive pick-up between the two sets of leads. If the heater leads must be close to the sensor leads, wind (twist) them in such a manner that they cross each other at ninety degrees.

2.7   SENSOR INPUT CONNECTIONS

Diode and platinum connections are defined in Paragraph 2.7.1. Thermocouple connections are described in Paragraph 2.7.2. Finally, thermocouple compensation is discussed in Paragraph 2.7.3.

2.7.1   Diode (Model 320-01)/Platinum (Model 320-02) Connections

The Model 320 has one rear panel 6-pin input connector for diode (Model 320-01) or resistance (Model 320-02) sensors. The lead connection definition for the sensor is shown in Figure 2-2 and Table 2-1.

The use of a four wire connection (Figure 2-2 a, b) is highly recommended for two lead resistive elements and diodes to avoid introducing current/resistive (IR) drops in the voltage sensing pair which translates into a temperature measurement error.

An alternate two line wiring method (Terminals I and V shorted together) may be used for the DT-470 series diodes in less critical applications where lead resistance is small and small readout errors can be tolerated (Figure 2-2 c). Measurement errors due to lead resistance for a two lead hook-up can be calculated using; $T= IR/[dV/dT]$ where I is 10 microamperes, R is the total lead resistance; dV/dT is the diode sensitivity and T is the measurement error. For example, $R = 250$ with $dV/dT = 2.5$ mV/K results in a temperature error of 1 kelvin. Two wire connections are not recommended for platinum.

The Lake Shore Quad-Lead™ 36-Gauge Cryogenic wire is ideal for connections to the sensor since the four leads are run together and color-coded. The wire is Phosphor Bronze with a Formvar™ insulation and Polyvinyl Butryral bonding between the four leads. Color coding is red, green, clear and blue on the four leads which makes it extremely easy to determine one wire from another. For this and other accessories, refer to the Lake Shore Cryogenic Accessories Catalog.

Table 2-1. Diode or Platinum Input Connections

Terminal	Description
1	– Current
2	– Voltage
3	+ Current 1 mA (platinum)
4	+ Voltage
5	+ Current 10 mA (diodes)
6	Shield

(a)
2-Lead Sensor,
4-lead Hook-up
for Diodes

(b)
2-Lead Sensor,
4-lead Hook-up
for Resistors

(c)
2-Lead Sensor,
2-lead Hook-up
for Diodes
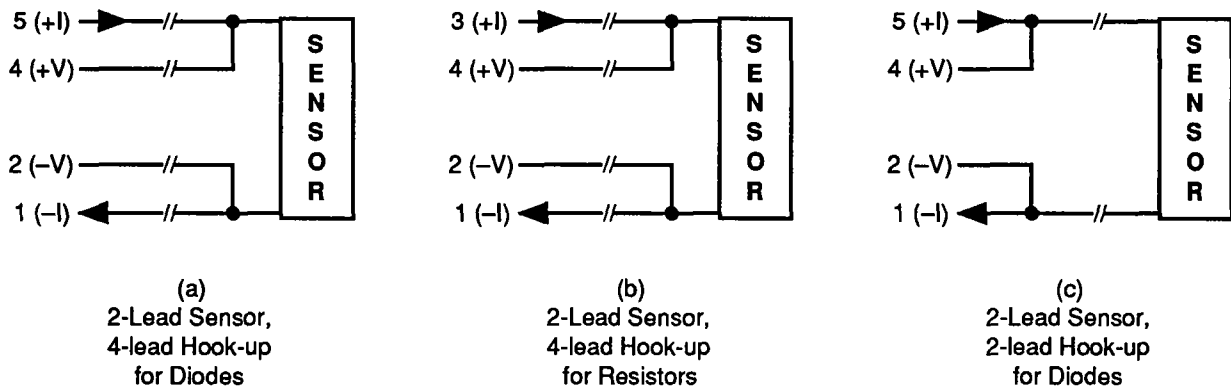
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Figure 2-2. Sensor Connections

2.7.2 Thermocouple (Model 320-04) Connection

┌─────────────────┐
│   CAUTION   │
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Use care during installation of thermocouple sensor to maintain an isolated ground from the sensor back to the instrument. A shorted thermocouple sensor will produce a degraded signal; or even no signal at all.

The thermocouple input has a thermal block for connecting thermocouple wires. The positive and negative terminals correspond to V+ and V– and should match the polarity of the thermocouple used. Be sure to tighten the screw terminals carefully. Loose connections will result in unstable readings and control. For additional information on thermocouple operation, refer to Chapter 4.

2.7.3 Thermocouple Compensation

The thermocouple input has a thermal block for connecting thermocouple wires and for temperature compensation. The thermocouple response curve tables within the instrument are normalized to the ice point of water. Consequently, accurate readings can be obtained by one of two methods. An ice bath with a reference junction can be used with the internal room temperature compensation turned OFF. The more convenient method is to eliminate the reference junction with its associated ice bath and use the internal electronic room temperature compensation by turning the internal compensation ON.

2.8 POWER UP

The power up paragraph consists of a power up sequence in Paragraph 2.8.1, power up configuration in Paragraph 2.8.2, and power up errors in Paragraph 2.8.3.

2.8.1 Power Up Sequence

The following power up sequence occurs at power up.

1. The Display indicates as a test of the display segments.

    ▓ ▓ ▓ ▓ ▓ ▓ ▓ ▓

2. Next, the unit displays
    # LSCI 320

3. Then, the factory set BAUD rate will show.
    # BAUD 300

4. The Model 320-01 then displays
    # SI
    or the Model 320-02 then displays
    # PT
    or the Model 320-04 then displays
    # TC

5. The Model 320 then goes into normal operation.

2.8.2   Power Up Configuration

The instrument will power up in the configuration it was in when the power up feature was turned off. Parameters including heater range, setpoint, gain, reset, rate, units and curve number are stored in non-volatile memory and preserved even when the line cord is disconnected from the unit. To initialize the instrument, do the following.

| CAUTION |

If a precision option is present and the following process is performed, the precision option will be *erased*.

1. Turn the instrument off.

2. Press and hold the Setup key and turn the instrument on. Do not release the Setup key.

3. Continue to hold the Setup key down until the instrument goes in to normal operation.

4. Check the curve number for proper operation. (Refer to Paragraph 2.9.)

2.8.3   Power Up Errors

On power up, the Model 320 does a check of the internal memory. In the event that a problem exists, an error message will be displayed on the instrument front panel.

Er01

on the display, indicates that there is a hardware problem in the instrument memory. This error is not correctable by the user and the factory should be consulted.

Er02

on the display indicates that there is a soft error in the instrument memory. In some situations this error can be user corrected by initializing the Model 320 memory. To reinitialize the memory, please refer to the discussion in Paragraph 2.8.2.

2.9   SENSOR CURVE SELECTION

In order for the instrument to operate accurately in temperature, it is necessary to select the response curve that matches the sensor being used. To determine which curve is selected, press the Setup key repeatedly until the curve number is displayed. An example of what the display may show is displayed below.

Cu 04

To change the curve, press the Up cursor key to increment or the Down cursor key to decrement the display. The curve numbers available are 0 through 11. The standard curves, with their curve number and temperature range, are given in Table 2-2. If a curve with the wrong temperature coefficient slope is selected, the Model 320 will default to the lowest order curve of the correct type.

In addition to the standard curves, Table 2-2 allows room for one user defined curve. This is curve 11. The user defined curve can have up to 97 points plus two end points. These are put into the curve table at the factory or by the user over the remote serial interface. Chapter 5 of this manual describes entry over the serial interface.

When in the curve selection mode, the Left and Right cursor keys are used on the Model 320-04 thermocouple controller to toggle compensation on and off.

Table 2-2. Sensor Curves

Curve No.	Number of Lines	Range (K)	Description
00	31	1 –325	DT-500 DRC Curve D
01	31	1 –325	DT-500 DRC Curve E1
02	31	1 –325	DT-400 Series Sensors Curve 10
03	31	14 –800	Platinum DIN Curve
04	88	2-475	DT-400 Series Sensors Curve 10
05	31	—	Reserved
06	31	1.4 – 325 *	AU 0.07% Fe
07	31	4 – 325 *	AU 0.03% Fe
08	31	3 – 425 *	Type E
09	31	3 – 525 *	Type K
10	31	3 – 485 *	Type T
11	—	—	—

* Values are for thermocouples with compensation. Uncompensated, the thermocouple can use the full ±15 mV range.

2.10 PRECISION OPTIONS (MODELS 8000, 8001, AND 8002-05)

There are three types of precision options available for the Model 320. The Model 8000 Precision Option generates the data table from a Lake Shore calibrated sensor. The maximum number of data points is 99. A typical calibration precision option ranges between 30 and 40 points depending on the sensor type and temperature range of the calibration. The data and accuracy of the fit is supplied to the user as a separate document. This information can be entered by the user over the serial interface.

Prior to shipment, Lake Shore can also generate a custom sensor response curve from the individual sensor calibration as indicated in the above paragraph and store it in the Model 320 via the Model 8001 Precision Option. The data and accuracy of the fit is then supplied to the user as a supplement to this manual.

The Model 8002 Precision Option is used when the customer already owns a Model 320 and wants the additional sensor calibration stored in the instrument. Lake Shore stores the calibration data in a NOVRAM and sends the programmed IC to the customer. The IC is then installed in the instrument by the customer. The user should be prepared to supply the Model 320 serial number at the time of order.

2.11 SERIAL INTERFACE (RS-232C) SETUP

The Serial I/O connector is a standard 6 wire RJ-11 (telephone) jack. Lake Shore offers the Model 2002 RJ-11 to 25-pin adapter and the Model 2001 10 ft. cable which connects the Model 320 and Model 2002. See Figures 2-3 thru 2-5 for Model 2001, 2002, and 2003 wiring information. Refer to Section 4 for information on serial interface commands.

The Model 320 allows for two different BAUD rates (300 and 1200). Press the Setup key repeatedly until the BAUD rate is shown. The Up arrow key will toggle between 300 and 1200 BAUD as indicated on the display. Model 320 Serial Interface specifications and other information is provided in Chapter 5.

2.12 RACK MOUNTING

The Model 320 can be installed in a standard size 1/4 panel EIA rack space.

S-320-U-2-3
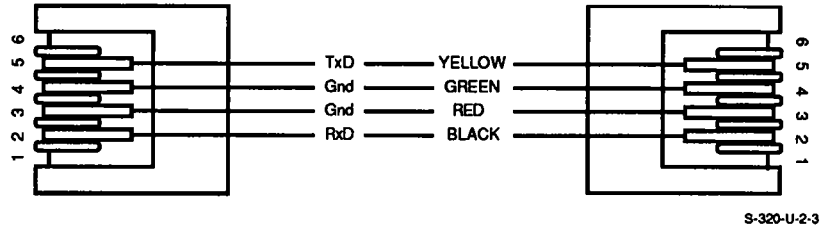
Figure 2-3. Model 2001 RJ11 Cable Assembly Wiring Details

S-320-U-2-4
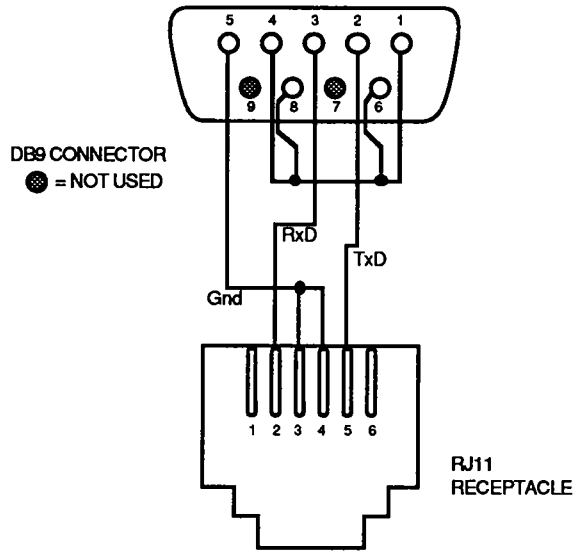
Figure 2-4. Model 2003 RJ11 to DB9 Adapter Wiring Details

S-320-U-2-5
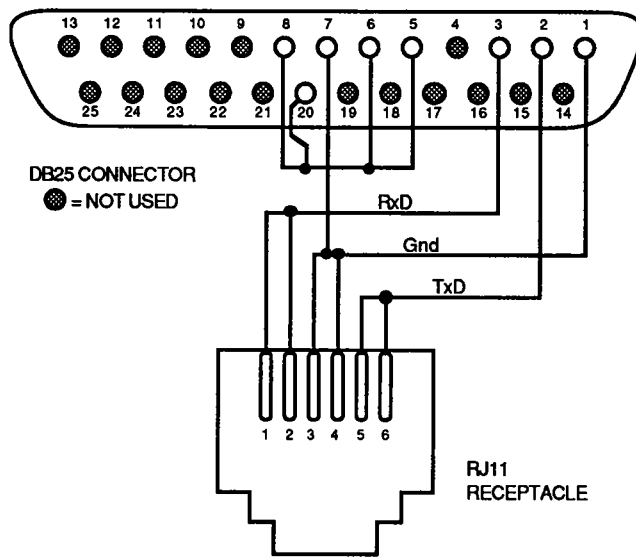
Figure 2-5. Model 2002 RJ11 to DB25 Adapter Wiring Details

CHAPTER 3

OPERATION

3.0   GENERAL

This chapter describes Model 320 Temperature Controller operation. The front panel controls are described in Paragraph 3.1. Sensor control is described in Paragraph 3.2. Control fundamentals are described in Paragraph 3.3. Manual control settings are described in Paragraph 3.4. Finally, manual PID parameter settings are described in Paragraph 3.5.

3.1   DEFINITION OF FRONT PANEL CONTROLS

This paragraph provides a description of the front panel controls on the Model 320. The three function keys on the Model 320 are labeled Scroll, Setup and Heater. These keys are used to select display modes or change modes. The Cursor keys are used to make changes in adjustable parameters in these particular modes when appropriate.

Scroll   The Scroll key is used to scroll through the most often viewed instrument displays. This includes the control sensor reading, and setpoint and heater output current.
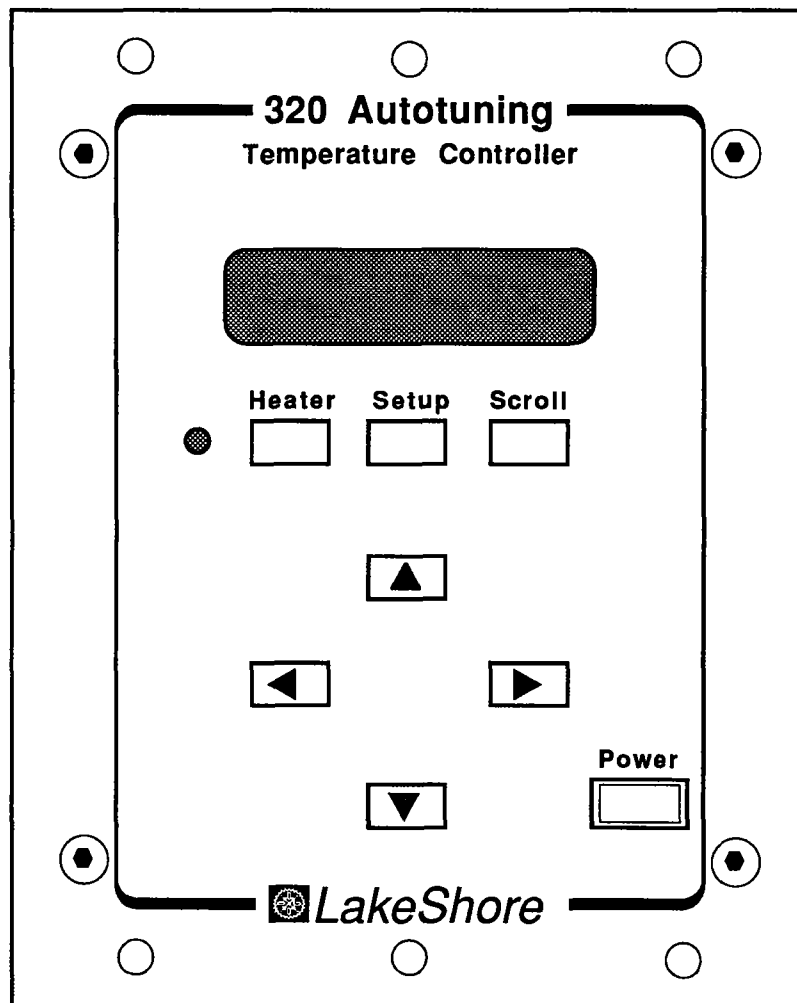
S-320-U-1-1

Figure 3-1. Model 320 Front Panel

Front Panel Keypad Definitions (Continued)

Setup   The Setup key is used to select setup parameters. Each of these parameters can then be configured for individual applications. Units, curve number, Autotuning parameters, manual tuning parameters and Baud can be accessed with this key.

Heater   The sole function of the heater key is to turn the heater on and off.

Cursor   The cursor (or arrow) keys are used with the function keys to make changes in the specific parameters selected on the display. When entering number data (setpoint, control parameters), the Left and Right keys select the digit that will be changed (indicated by the digit flashing). The Up and Down keys change that digit.

Power   The sole function of the power key is to turn the instrument power on and off.

3.2 CONTROL SENSOR

The Control reading can be displayed in temperature (K or °C) or the sensor units associated with the input. The units selected are shared by the Control Sensor and the Setpoint. The control reading is displayed on power up. If it is not shown, press the scroll key repeatedly. The control reading is the value that does not have an "S" or "Heat" in the beginning.

3.2.1 Selecting Control Units

Control units can be changed by the following procedure:

1. Press the Setup key repeatedly until the units are displayed.

2. Press the Up arrow key to toggle units between K, °C or the appropriate sensor units.

NOTE

Setpoint units match control units.

3.2.2 Control Resolution

Temperature Resolution. In temperature mode, the sensor reading is displayed in K or °C with a display resolution of 0.1 degrees.

NOTE

This is display capability and *not* system resolution or accuracy of the reading.

Voltage Resolution (Models 320-01 and 320-04 Only). In voltage mode (V), the display has a resolution of 0.1 millivolt (mV) below 2 volts and 1 mV above 2 volts. For Thermocouple inputs, the millivolt symbol is used to indicate millivolts. The millivolt display resolution is 1 microvolt.

Resistance Resolution (Model 320-02 Only). The Resistance mode is allowed for the Platinum Input configuration. The display resolution, in resistance, is 0.01 Ω below 200 Ω and 0.1 Ω above 200 Ω.

3.2.3 Control Input Errors

If an input signal from the sensor exceeding full scale is applied to the input leads, an overload condition is present and is indicated by "OL" on the display. The heater is then shut off. If no signal or a signal of the wrong polarity is present at the input leads, a Zero Error is indicated by "Er27" on the display and the heater is promptly shut off. The Model 320 will display dashes "- - - -" on the display if there is an internal malfunction.

3.3 CONTROL FUNDAMENTALS

The Model 320 has several outstanding features which will help in temperature control of your cryogenic system. These include standard built-in curves along with the ability to store a 99 point curve, Serial Interface, an isolated current source allowing true four-wire sensor readings, eight-character alphanumeric display for high visibility, simple scroll-type input with cursor key entry, 25 Watt DC current source output with short circuit protection of the output and digital filtering. These and other features are discussed in detail throughout this manual. In addition, the Model 320 (along with the Model 330) is the first cryogenic controller with an Autotuning feature. The Autotuning algorithm determines the settings of controller gain (Proportional), reset (Integral), and rate (Differential) by observing the time response of the system upon changes in setpoint under either P, PI, or PID control. Since this is a digital system, there are two inherent limitations associated with digital control and Autotuning.

First, there is the limitation that any control system is inherently unstable if the sampling rate (frequency) is not greater than twice the system bandwidth (inverse of system time constant). This is known as the Nyquist criterion. With the current technology used in this instrument, i.e., sampling frequency, etc., digital control is possible for cryogenic system with time constants near or greater then one second. Fortunately, almost all cryogenic system which operate above 1 kelvin will have time constants that meet this criteria.

The Autotuning function requires that the system time response be measured as a result of a change in temperature setpoint. In order to get meaningful data for determining the PID parameters, several points on this response curve must be measured. Consequently, for cryogenic systems where step responses are less than ≈5 seconds (where the number of measured points is small), correct determination of the PID parameters is difficult and better temperature control will normally be achieved by manual selection of gain and reset (rate will not normally be required). Fortunately, fast cryogenic systems are not difficult to tune manually.

For slower systems with longer time constants (which can be very difficult to tune manually), Autotuning can obtain enough information on a step change to characterize the system and determine proper values of gain, reset, and rate.

There may be other conditions where you will prefer to stay with manual settings. For example, when a closed cycle refrigerator has very little mass on its second stage and is near its bottom temperature, attempts at Autotuning may give poor results for control settings due to the large inherent temperature fluctuations associated with the cooling cycle. Adding mass to the second stage smoothes out these fluctuations, but lengthens cooldown time.

Lake Shore has simplified the input of the rate time constant in this controller to correspond to a percentage of the reset time constant, i.e., 0 to 200%. Consequently, if you are in the manual mode and you set RATE at 100%, on any change in RESET, the controller will automatically calculate the RESET time constant (999/RESET) and set the RATE time constant at 1/8 of the RESET time constant. This is one-half the conventional Zeigler-Nichols setting for rate and results in a smaller overshoot of a given setpoint. Therefore, once RATE is set as a percent, you do not have to worry about updating its value with setpoint changes resulting in new PI settings. Obviously, if you prefer less RATE, set the rate setting at something less than 100%. Remember, however, in many cryogenic systems, rate will not be required anyway, and is consequently set at 0%.

An application note titled "Fundamentals for Usage of Cryogenic Temperature Controllers" is included with Appendix D. This application note should be read in detail if you are not familiar with cryogenic temperature controllers.

3.3.1   Setpoint

To change the setpoint, press the Scroll key until the setpoint is shown in the display. An "S" will be the first digit. Use the Left and Right cursor keys to move to digits which need to be changed. Flashing will indicate the digit to be changed. The Up and Down cursor keys will change the value of the particular digit. Enter the new setpoint with the cursor keys. Press the Scroll key to complete the operation.

If the setpoint is displayed in degrees Celsius or millivolts (Model 320-04), the Up key can be used to toggle the sign of the set point when it is flashing.

The setpoint is limited in temperature to the range of the curve being used for control. Table 2-2 gives these limitations in kelvin for curves 00 through 04. There is no setpoint limiting for the control channel when controlling in sensor units even if a curve is selected.

3.3.2   Heater

Heater% Display. The heater current is displayed by pressing the Scroll key until it is shown in the display. Units are percent of full scale heater current. If the heater is off, the display will show "Heat OFF." To toggle the heater on or off, simply press the Heater key. The indicator to the left of the Heater key will light when the heater is on.

NOTE

If the heater load drops below approximately 20 Ω, the actual output will turn off. However, the display may still show a % of heater display other than zero.

3.4   MANUAL CONTROL SETTINGS

In manual mode, the instrument will accept Gain, Reset and Rate parameters from the user and provide three term PID control. To put the instrument in Manual Control Mode, press the Setup key until the display shows the tuning selection (P, PI, PID or Manual). Press the Up arrow key until the unit displays "Manual."

3.4.1   Gain (P)

Adjustment of the gain or the proportional (P) part of the control function gives the controller an overall range of 1 to 999.

To enter a gain value, press the Setup key until GAIN is shown. The display will show the current gain setting. Use the Left and Right keys to cursor to the digit to be changed. It will flash to indicate that it can be incremented or decremented with the Up or Down key. When the gain value is set, press the Setup or Scroll key to enter it.

3.4.2   Reset (I)

Adjusts the reset time constant of integrator (I) in the control function. Effective reset time constants, between 999 seconds and 1 second, can be achieved by entering reset settings of 1 - 999. Reset time in seconds is (999/Value Entered). A reset of zero will make the controller proportional only.

To enter a new reset value, press the Setup key until the RESET is shown in the display. The display will show the current reset setting. Use the Left and Right keys to cursor to the digit to be changed. It will flash to indicate that it can be incremented or decremented with the Up or Down key. When the reset value is set, press the Setup or Scroll key to enter it.

For example, if the Reset setting is 20 the reset time in seconds is approximately 50 (999/20=50).

3.4.3   Rate (D)

This adjusts rate time constant of differentiator (D) in the control function. Effective settings are between 0 seconds and 200% of 1/4 the reset time. In manual mode, rate is normally set at 1/4 the reset time in seconds (100%), because larger values may cause system instability.

To enter a new rate, press the Setup key until RATE is shown in the display. The display will show the current rate percentage setting. Use the Left and Right keys to cursor to the digit to be changed. It will flash to indicate that it can be incremented or decremented with the Up or Down key. When the rate value is set, press the Setup or Scroll key to enter it.

3.5   MANUALLY SETTING PID PARAMETERS

The following paragraph on manually setting PID parameters is presented in question and answer format.

Q: How do I determine an appropriate gain setting for my cryogenic system?

A: First, turn off both RESET and RATE. Set in a nominal gain setting of 50. Make sure that the heater turns on; if not, increase the gain setting until the heater turns on. Let the system stabilize. Note that it will stabilize at some point below the set point. Keep increasing the controller gain by factors of two until the system temperature begins to oscillate. Adjust the gain for small sustained oscillations. Measure the period of these oscillations for determining the correct setting for reset. Reduce the gain by a factor of two to three until the temperature again becomes stable with time. Be sure that you allow time at each setting for the system to stabilize if it will. For some systems and cryogenic sensors with low sensitivity, the maximum.

Q: When I enter a reset number, how does that relate to my cryogenic system?

A: The reset number is an industrial control term which in the Model 320 corresponds to the number of repeats (or time constants) per 1000 seconds. The time constant is 1000 divided by this number in seconds. Consequently, a reset number setting of 20 corresponds to a time constant of 50 seconds. A system will normally take several time constants to settle into the set point, e.g. the 50 second time constant, if correct for the system being controlled, would result in a stable set point in a time frame between 5 and 10 minutes.

Q: How do I determine RESET?

A: The oscillation period which you measured in determining the appropriate gain setting is equal to the reset time constant which is desired. Divide this number in seconds into 1000 and set the result into the RESET register. This result is the number of repeats per 1000 seconds. If the system did not oscillate at the highest gain setting, use the following procedure. Stabilize the temperature at a high gain setting. Change the set point downward by one or two degrees and observe the time that it takes for the temperature to change 60% of this excursion. Use this number as the reset time constant; divide it into 1000 and set in the result as the RESET value.

Q: What about RATE?

A: The rate time constant should normally be somewhere between 1/4 and 1/8 the reset time constant if it is used at all. Consequently, you can set it between 0 and 200% of 1/4 the reset time constant. Start with settings of either 0, 50 or 100% and determine which setting gives you the type of control which you desire. Don't be surprised if for your system, the setting you prefer is 0 (OFF). Note that by using a percent of reset time constant, rate scales automatically with changes in the reset value and does not have to be revisited frequently.

Q: How does reset change with temperature?

A: In a normal cryogenic system, the time response of the system slows down as the temperature increases. Consequently, as the temperature rises the time constant will become longer as well. Therefore, if you have determined a valid value of reset at a particular temperature, increasing the temperature will result in a decrease in the reset number, i.e., a longer time constant; conversely decreasing temperature will demand a shorter time constant, i.e., an increase in the reset setting.

Q: For a silicon diode sensor, why does the optimum controller gain value increase by nearly an order of magnitude between 25 K and 35 K?

A: The system gain is a product of the controller gain and the sensor gain, i.e., sensor sensitivity. At 25 K the sensor sensitivity (dV/dT) is approximately an order of magnitude larger than it is at 35 K. If the load parameters have not changed greatly, neither will the system gain. Therefore, the controller gain must be increased to compensate for the reduction in sensor sensitivity.

Q: What happens to the system gain as the temperature increases?

A: It normally increases. Consequently, if the sensor sensitivity is relatively constant, you can normally increase the controller gain with increasing temperature.

CHAPTER 4

SPECIAL FEATURES

4.0 GENERAL

This chapter describes the special features of the Model 320 Temperature Controller. Paragraph 4.1 describes Automatic tuning. Paragraph 4.2 describes Autotuning features. Finally, Paragraph 4.3 describes Model 320-04 Thermocouple Controller Operation.

4.1 AUTOMATIC TUNING

Autotuning is recommended for most control systems. There are three control algorithms available that optimize different control requirements. To observe which of the three algorithms described below is being used, press the Setup key until the tuning selection is shown in the display (P, PI, PID or Manual).

4.1.1 Initial Values of PID Parameters In Autotune Mode

The initial values of the PID parameters in the Autotune mode are set when the controller is changed from Manual to either P, PI or PID control. The initial PID factory settings are 50 and 20 with the controller set for PI control.

4.1.2 Minimum Overshoot

The full three function PID control algorithm is designed to minimize overshoot. It uses GAIN (P), RESET (I), and RATE (D) to bring the system to the control temperature as smoothly as possible.

To select the PID tuning algorithm, press the Setup key until the tuning selection is shown. Now, press the Up arrow key until the display shows "Auto PID."

4.1.3 Minimum Time To Setpoint

The two function PI control algorithm minimizes the time it takes for the system to first reach the setpoint. Some of the damping used in PID control is not present so more overshoot should be expected.

To select the PI tuning algorithm, press the Setup key until the tuning selection is shown. Now, press the Up arrow key until the display shows "Auto PI."

4.1.4 Gain Only

The third control algorithm available on the Model 320 is GAIN (P) only. No time dependent control parameters (other than digital sampling rate) will be initiated by the controller. In this mode, characteristics of the system being controlled are more apparent but there will be a temperature offset from the setpoint.

To select the P tuning algorithm, press the Setup key until the tuning selection is shown. Now, press the Up arrow key until the display shows "Auto P."

4.2   AUTOTUNING FEATURES

The following paragraph on Autotuning features is presented in question and answer format.

Q: The What algorithm or algorithms is Lake Shore using in the Model 320 controller?

A: The procedures used to determine values for gain, rate and reset took us a long time to implement. These procedures are evolving with time and are considered proprietary to the company. It is significantly more difficult to determine automatically these control parameters at cryogenic temperatures because of the differences in cryogenic physical plants and their variation with temperature. It is not uncommon for a cryogenic load to vary by over three orders of magnitude over its useful temperature range. It is also not uncommon for various types of cryogenic loads to be different in thermal properties by several orders of magnitude at the same temperature. Consequently, the algorithm complexity of the problem is much greater than that for well behaved high temperature loads.

Q: Will Autotuning work for all types of systems?

A: There will undoubtedly exist conditions and systems where you are better off using manual control. An example might be an extremely fast cryogenic system load where it is difficult for the controller to characterize the load. Under these conditions manual control should undoubtedly be used.

4.3   MODEL 320-04 THERMOCOUPLE CONTROLLER OPERATION

The Model 320-04 thermocouple controller is designed to accommodate thermocouple sensors. Chromel-AuFe (0.07%), Chromel-AuFe (0.03%), E, K, and T thermocouples are supported with internal curves that enable the controller to operate in temperature units (°C and K) as well as voltage in millivolts.

The Model 320-04 utilizes a secondary temperature sensor to monitor the Reference Junction (room) temperature and provide curve compensation. Thermocouple (Reference Junction) Compensation can be disabled in order for the Model 320-04 to be used with external compensation techniques.

4.3.1   Sensor Attachment

Thermocouple leads are attached to the terminal block by aluminum screws. Be sure to tighten the terminal screws carefully. Loose connections will result in unstable readings and control. The leads must be connected with the proper polarity or the input option will not operate properly. The positive terminal of the terminal block is indicated by the V+ label on the rear panel and should correspond with the positive thermoelement listed for each type of thermocouple.

4.3.2   Thermocouple Curve Selection

To choose a thermocouple curve (6 through 10) listed in Table 2-2 and refer to the instructions for manual curve selection in Paragraph 2.9.

4.3.3   Thermocouple Compensation From Front Panel

To determine whether thermocouple compensation is selected or not, press the Setup key until the curve selection is shown. The display will show on in the right most digits if Thermocouple Compensation is on and off if it is off. To toggle the compensation status, press the Left or Right cursor key.

4.3.4   Thermocouple Compensation From Remote Interface

To select or prevent thermocouple compensation over the remote interface, use the ACOMP command described in Chapter 5.

4.3.5 Internal Offset Adjustment

When a new or different thermocouple is attached to the instrument, it is necessary to adjust the offset to compensate for discrepancies in thermocouple material, leads and connections. An offset adjustment trimpot is provided to allow offset calibration of the thermocouple. The steps below outline the procedure.

1. Place the thermocouple in a reference bath of known temperature (liquid nitrogen, ice etc.). Allow the system to stabilize to the reference temperature.

2. On the front panel of the Model 320-04, select the desired temperature units.

3. Turn on thermocouple compensation.

4. Adjust the offset adjustment trimpot (R8) so that the displays read the reference temperature.

NOTE

The offset adjustment compensates for the thermocouple used in the calibration. If another thermocouple is attached, or the thermocouple has aged, or the configuration of the system is changed, then the offset adjustment must be repeated.

4.3.6 Curve Format

The card is hardware limited to reading input between -15 mV and +15 mV. All curves should be limited in temperature so not to exceed these values. If thermocouple compensation is desired, the thermocouple curve must be normalized to zero in degrees Celsius. Compensation also limits the practical range by approximately the room temperature voltage of the thermocouple used.

The Model 320-04 is designed to operate on sensor curve data in the range of 0.00000 to 3.00000 volts so thermocouple voltage must be converted to this range before it is entered into a user curve table. To obtain the proper table value from a thermocouple voltage, it must be summed with 15 millivolts to make it positive and multiplied by one hundred to shift the resolution.

A -15.0000 millivolt thermocouple voltage will result in a 0.00000 volt table value and +15.0000 millivolts will result in 3.00000 volts.

4.3.7 Thermocouple Wire Types And Recommendations

The following are thermocouple wire types and recommendations for use at cryogenic temperatures. For more information on thermocouples or other sensors, refer to the Lake Shore Product Catalog. Please note that the Chromel-Gold/Iron 0.03% is not currently sold by Lake Shore.

Chromel-Gold/Iron (0.07% & 0.03%*)
Consists of a Gold (Au) - 0.07 and 0.03* at % Iron (Fe) as the negative thermoelement and a Ni-Cr alloy (Chromel) as the positive thermoelement. This thermocouple is more widely used because of its relatively high thermoelectric sensitivity (>15 mV/K above 10K).

Type E
(Chromel-Constantan) Has the highest sensitivity among the three standard thermocouple types typically used at low temperatures - types E, K and T (8.5 mV/K at 20K). The best choice for temperatures down to 40K. Chromel is the positive thermoelement.

Type K
(Chromel-Alumel) Has about one half the sensitivity of Type E at 20K (Type K = 4.1 mV/K). Recommended for continuous use in inert atmospheres. Chromel is the positive thermoelement.

Type T
(Copper-Constantan) For use in vacuum, as well as oxidizing, reducing or inert environments down to 90K. The copper element has high thermal conductivity, making this thermocouple the least usable for cryogenic applications. Sensitivity at 20K (4.6 mV/K) is similar to Type K. Copper is the positive thermoelement.

Chromel-CuFe(0.15%)
Measurable temperature range 4 to 300K. Curve table applied from 4K to 273K. Sensitivity > 11 mV/K @ 4.2K. Lower in cost than Gold-Chromel thermocouples and physically stronger.

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CHAPTER 5

REMOTE OPERATION

5.0   GENERAL

This paragraph provides a description of the SERIAL I/O Interface. RS-232C is a standard of the Electronics Industries Association (EIA) describing of one of the most common interfaces between a computer and electronic equipment. To utilize this interface, a Customer supplied computer is required equipped with a RS-232C Interface port. When a connection is made between the computer and the Model 320, the Serial Interface permits remote monitoring and control of the Model 320 control functions, which in turn controls the operation of the Model 320. See Figure 5-1.

The Serial Interface is capable of bi-directional communication, i.e., it can both transmit and receive information. In transmission (Tx) mode, RS-232C Interface converts parallel information to serial information and sends that information over a cable up to 50 feet long (or longer with proper shielding). In the receiving (Rx) mode, the RS-232C Interface converts the serial information back to parallel information for processing.

5.1   SERIAL INTERFACE DESCRIPTION

The Serial Interface hardware configuration is described in Paragraph 5.1.1. Serial Interface settings are described in Paragraph 5.1.2. A sample BASIC program to establish communications between the computer and the Model 320 is provided in Paragraph 5.1.3. Commands are divided into four types: Display, Channel, Control Process, and Curve. Individual commands are described in Paragraph 5.2.
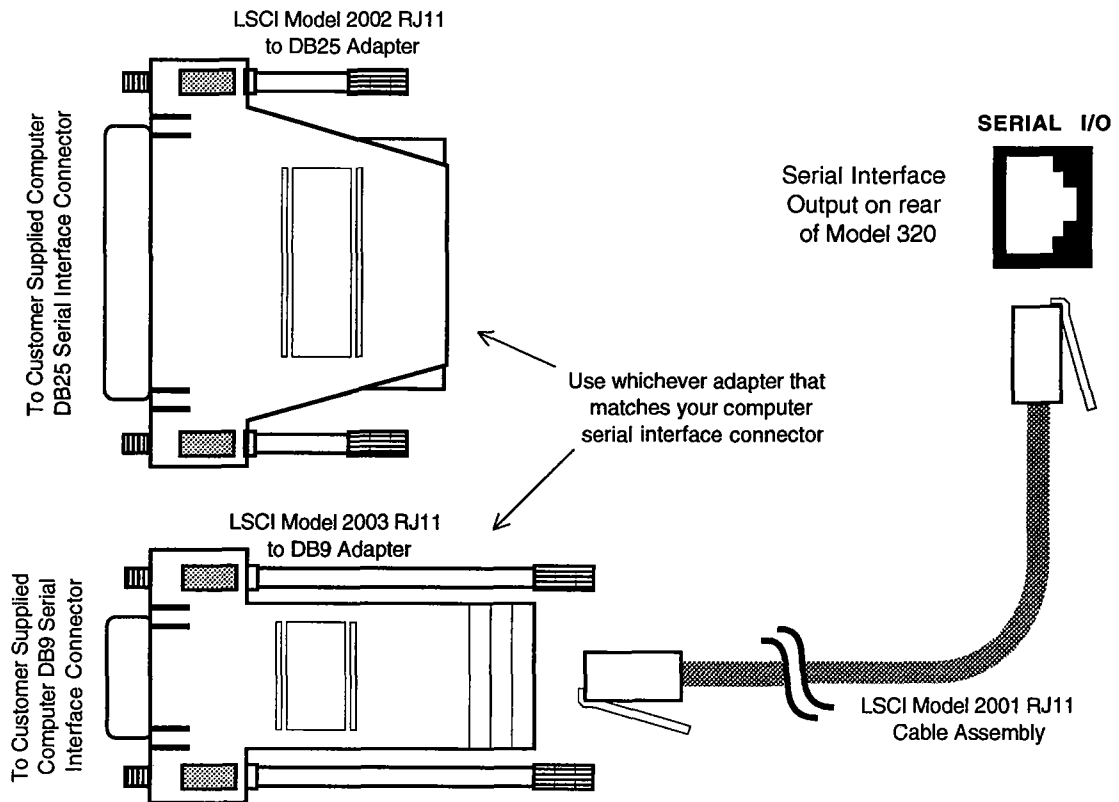
S-320-U-5-1

Figure 5-1. Serial Interface Connections

5.1.1 Serial Interface Configuration

The following is a technical description of the RS-232C Interface configuration. Communication parameters are defined in Table 5-1. Terminators are fixed to carriage return (CR) and Line Feed (LF). A query may be added to the end of a command string if the instrument is required to return information. For example, CUNI K;UNIT? commands the Model 320 to set the temperature units to kelvin followed by a request that the Model 320 return the temperature units to confirm the change had been made.

The connector used for the serial interface is a standard 6-wire RJ-11 (telephone) jack. Lake Shore offers the Model 2001 10-foot Cable Assembly, Model 2002 RJ-11 to DB25 Adapter, and the Model 2003 RJ-11 to DB9 Adapter.

Table 5-1. Serial Interface (RS-232C) Specifications

Transmission:	Three-Wire
Connector:	RJ-11 Modular Socket
Timing Format:	Asynchronous
Transmission Mode:	Half Duplex
Baud Rate:	300 or 1200
Bits per Character:	1 Start, 7 Data, 1 Parity, and 1 Stop
Parity Type:	Odd
Data Interface Levels:	Transmits and Receives Using EIA Voltage Levels
Terminator:	LF (0AH)

5.1.2 Serial Interface Settings

The Model 320 will operate at two different Baud rates: 300 or 1200. Press the **Setup** key until the BAUD rate is displayed. The ▲ key will toggle between the two settings.

5.1.3 Sample BASIC Serial Interface Program

The following is a sample RS-232C Interactive serial poll routine for the Model 320 written in Quick Beginner's All-purpose Symbolic Instruction Code (BASIC).

```
'INTERACTIVE SERIAL POLL ROUTINE FOR 320
'WRITTEN FOR QUICK BASIC

      CLS

'OPEN STATEMENT FOR 300 BAUD

      OPEN "COM1:300,0,7,1,RS" FOR RANDOM AS #1 LEN = 256

L1:   INPUT "ENTER COMMAND";A$        'ENTER COMMAND STRING FROM KB
      PRINT #1,A$+CHR$(13)+CHR$(10);'SEND STRING TO 320 WITH TERM
      IF MID$(A$,LEN(A$),1) <> "?" THEN GO TO L2 'TEST QUERY SENT
      LINE INPUT #1,B$               'INPUT RESPONSE ONLY IF QUERY
      D$=INPUT$(1,1)                  'GET LINEFEED
      PRINT B$                        'OUTPUT TO SCREEN
L2:   PRINT
      GO TO L1                        'GET NEXT COMMAND STRING
```

The following are examples using this BASIC program. (Input provided by the user is shown in **bold** type.)

ENTER COMMAND? **CUNI K**	Set Control Units. Instrument will set unit to kelvin units.
ENTER COMMAND? **CUNI?**	Control Units Query. Instrument will return appropriate unit, where K = kelvin.
K	
ENTER COMMAND? **CDAT?**	Sensor Data Query. Instrument will return appropriate sensor reading.
+77.6	
ENTER COMMAND? **TUNE 3**	Set Autotuning Status. Instrument will set Autotuning to PID.
ENTER COMMAND? **TUNE?**	Autotuning Status Query. Instrument will return appropriate setting, where 0 = Manual, 1 = P, 2 = PI, and 3 = PID.
1	
ENTER COMMAND? **RANG 0;RANG?**	Combination command of setting the heater to off and requesting heater status; where 0 = off and 1 = on.
0	
ENTER COMMAND?	

Query commands end with a "?." The common commands (along with a brief description) recognized by the Model 320 are summarized by function in Paragraph 5.2. Additional notes are as follows:

● Commands may be chained together when separated by a semi-colon (;). Multiple queries cannot be chained.

● Queries have the same syntax as the associated setting command followed by a question mark (?). They should return the same information that is sent.

● Leading zeros and zeros following a decimal point are not needed in a command string, but they will be sent in response to a query. A leading "+" is not required but a leading "–" *is* required.

● If you enter a correctly spelled command without a "?," the command will send all zeros. Incorrectly spelled commands are ignored.

● When the term free field is used, it indicates that the decimal point is a floating entity and can be placed any appropriate place in the string of digits.

● [term] is used when examples are given and indicates where terminating characters should be placed by the user or where they appear on a returning character string from the Model 320.

5.2 SERIAL INTERFACE COMMAND SUMMARY

This paragraph provides a summary of the Serial Interface Commands. The summary is divided into four command groups: Display, Channel, Control Process, and Curve Commands. A detailed list of Display Commands is provided in Paragraph 5.2.1. A detailed list of Channel Commands is provided in Paragraph 5.2.2. A detailed list of Control Process Commands is provided in Paragraph 5.2.3. A detailed list of Channel Commands is provided in Paragraph 5.2.2. A detailed list of Curve Commands is provided in Paragraph 5.2.4. The commands are presented in the same order as shown below. Available command formats are as follows: XXX = Command Only, XXX? = Query Only, and XXX/? = separate Command and Query.

Display Commands

Command	Function
*IDN	Identification Query
CUNI	Set Control Units
CUNI?	Control Units Query
CDAT?	Control Sensor Data Query

Channel Commands

Command	Function
ACUR	Set curve for A
ACUR?	Curve A Query
ACOMP	Set A Compensation
ACOMP?	A Compensation Query
ATYPE?	A Input Type Query

Control Process Commands

Command	Function
TUNE	Tune Status
TUNE?	Tune Query
GAIN	Set Gain
GAIN?	Gain Query
RSET	Set Reset
RSET?	Reset Query
RATE	Set Rate
RATE?	Rate Query
RANG	Set Range
RANG?	Range Query
HEAT?	Heater Query
SETP	Set Setpoint
SETP?	Setpoint Query

Curve Commands

Command	Function
CUID?	Curve Identification Query
ECUR	Edit Curve
KCUR	Curve Deletion
CURV11	Enter User Curve
CURV?	Curve Number Information Query

5.2.1 Display Commands

This paragraph provides a detailed description of each Display Command. The display commands allow the interface to act as a virtual display. Display data, as well as format, can be transferred. An explanation of the command structure is shown below.

Brief Description of Function

Command Name → **CUNI?**   Control Units Query

Syntax of what user must input → **Input:**   CUNI?

Information returned in response to the query → **Returned:**   K, C, V, R, or M

Explanation and definition of returned data → **Remarks:**   Used to query the unit for current control units information. The character returned will be K for kelvin, C for Celsius, V for Volts, R for Ohms, or M for millivolts.

---

*IDN?   Identification Query.

Input: *IDN?

Returned: Manufacturer,model number,0,firmware date

Remarks: Identifies the instrument model and software level. "0" in the returned syntax is in place of the serial number.

Example: LSCI,MODEL320,0,103190[term]

CUNI   Set Control Units Status.

Input: CUNI K, CUNI C, or CUNI S

Returned: Nothing

Remarks: Set units parameter with K for kelvin, C for Celsius, or S for the appropriate sensor units (volts, ohms, or millivolts).

Example: If operating in kelvin with a Model 320-01, CUNI S[term] makes the units volts; being the sensor units for a diode sensor. The Model 320-02 platinum controller has sensor units of ohms, and the Model 320-04 thermocouple controller has sensor units of millivolts.

CUNI?   Control Units Query.

Input: CUNI?

Returned: K, C, V, R, or M

Remarks: Returns current control units setting. The character returned will be K for kelvin, C for Celsius, V for volts, R for Ohms or M for millivolts.

CDAT?   Sensor Data Query.

Input: CDAT?

Returned: +/- 000.00 [term]

Remarks: A free field is active here. The value returned is 7 characters (a sign, 5 digits and a decimal point.

Example: +1.2345 [term]   voltage
                 -123.4 [term]   Celsius
                 +234.5 [term]   kelvin or Celsius

5.2.2 Channel Commands

This paragraph provides a detailed description of each Channel Command. Channel commands set and verify parameters associated with the sensor input channels.

ACUR

Assign Curve Number.

Input: ACUR XX

Returned: Nothing

Remarks: Fill in curve parameter with an integer from 0 through 11 (11 for the user curve.). Refer to Table 2-2 for a listing of sensor curve numbers.

ACUR?

Curve Number Query.

Input: ACUR?

Returned: XX

Remarks: Value returned is an integer from 00 through 11, corresponding to the currently selected sensor curve number. Refer to Table 2-2 for a listing of sensor curve numbers.

ACOMP

Set Room Temperature Compensation (Model 320-04 thermocouple controller only).

Input: ACOMP 0 or ACOMP 1

Returned: Nothing

Remarks: Select temperature compensation parameter with 0 for off or 1 for on.

ACOMP?

Room Temp. Compensation Query (Model 320-04 thermocouple controller only).

Input: ACOMP?

Returned: 0 or 1

Remarks: Returns current room temperature compensation status where 0 = off and 1 = on

---

ATYPE?

Input Type Query.

Input: ATYPE?

Returned: SI, PT, TC, or ER

Remarks: Returns input type where SI = silicon diode, PT = platinum, TC = thermocouple, and ER = improper switch setting (error).

5.2.3 Control Process Commands

This paragraph provides a detailed description of each Control Process Command. These commands allow the interface to change any of the control parameters of the Model 320. Manual mode PID parameters are accessible as well as Autotuning status.

TUNE
Sets Autotuning Status.

Input: TUNE X

Returned: Nothing

Remarks: Set Autotuning status as follows: 0 = Manual, 1 = P, 2 = PI, and 3 = PID. Refer to Paragraph 4.1 for further information on Autotuning settings.

TUNE?
Autotuning Query.

Input: TUNE?

Returned: XX

Remarks: Returns current Autotuning status where 0 = Manual, 1 = P, 2 = PI, and 3 = PID. Refer to Paragraph 4.1 for further information on Autotuning settings.

GAIN
Set Gain While In Manual Control Mode.

Input: GAIN XXX

Returned: Nothing

Remarks: The gain parameter can be filled in with an integer of 0 through 999.

Example: GAIN65 [term] instructs the Model 320 to set a control gain of 65. Gain corresponds to the Proportional (P) portion of the PID Autotuning control algorithm.

GAIN?
Gain Query.

Input: GAIN?

Returned: XXX

Remarks: Returns current gain setting in manual or Autotune mode. The value returned is an integer from 000 through 999. Gain corresponds to the Proportional (P) portion of the PID Autotuning control algorithm.

RSET
Manual Mode Reset Setting.

Input: RSET XXX

Returned: Nothing

Remarks: The reset parameter can be filled in with an integer from 0 through 999. Reset corresponds to the Integral (I) portion of the PID Autotuning control algorithm.

Control Process Commands (Continued)

RSET?
Reset Query.

Input: RSET?

Returned: xxx

Remarks: Returns current reset setting. The value returned is an integer from 000 through 999. Reset corresponds to the Integral (I) portion of the PID Autotuning control algorithm.

RATE
Manual Mode Rate Setting.

Input: RATE xxx

Returned: Nothing

Remarks: The rate parameter can be filled in with an integer from 0 through 100. Rate corresponds to the Differential (D) portion of the PID Autotuning control algorithm.

RATE?
Rate Query.

Input: RATE?

Returned: xxx

Remarks: Returns current rate setting. The value returned is an integer from 0 through 100. Rate corresponds to the Differential (D) portion of the PID Autotuning control algorithm.

RANG
Set Heater Status.

Input: RANG 0 or RANG 1

Returned: Nothing

Remarks: Sets heater status where 0 = off and 1 = on.

RANG?
Heater Status Query.

Input: RANG?

Returned: 0 or 1

Remarks: Returns current heater status where 0 = off and 1 = on.

HEAT?
Heater Power Status Query.

Input: HEAT?

Returned: xxx

Remarks: Returns the percent of full scale heater current, where the returned number represents one percent increments up to 100.

Control Process Commands (Continued)

SETP

Sets Setpoint In Units Chosen For Control.

Input: SETP XXX.X (for temp.), or SETP X.XXX (for voltage)

Returned: Nothing

Remarks: Fill in the setpoint parameter with a value from 0 through 999.9 for temperature or 0 through 2.499 for voltage. Utilizes the free field format for the decimal point.

Example: If in kelvin:
1. SETP77.2[term] will result in the display showing S 77.2 K

2. SETP123[term] will result in the display showing S 123.0 K

If in Celsius:
3. SETP-123[term] will result in the display showing S -123.0 C

4. SETP123.456[term] will result in the display showing S 123.4 C

SETP?

Setpoint Status Query.

Input: SETP?

Returned: ±XXX.X for temp., or ±X.XXX for voltage

Remarks: Returns current set point setting. The value returned will be 6 digits (a sign, 4 digits and a decimal point).

Example: If using the examples above in the SETP command discussion—if in kelvin:
1. SETP?[term] will return +077.2[term]

2. SETP?[term] will return +123.0[term]

If in Celsius:
3. SETP-123[term] will return -123.0[term]

4. SETP123.456[term] will return +123.4[term]

5.2.4 Curve Commands

This paragraph provides a detailed description of each Curve Command. The commands allow the user to verify existing curves added at the factory or enter and delete the user defined curve over the interface.

CUID?

Curve Identification Query.

Input: CUID?

Returned: WW, XXXXXXXXXXXXXXXXXX, Y, ZZ

Remarks: Returns the header lines that identify the curves (standard sensor and user curve) loaded into each curve location. The information lines for the user curve will only be available if it is actually present. Information returned is defined as follows:

W = Curve number: The value given here will be 00 through 11.

X = Curve description: 18 character information line. All 18 character spaces do not have to be used.

Y = Temp. coefficient: N represents a negative temperature coefficient, while P represents a positive one.

Z = Number of points: This value will be the number of points for that particular curve (usually 31, but can be up to 99).

Example: 00, STANDARD DRC-D ,N,31,
01, STANDARD DRC-E1,N,31,
02, STANDARD CRV 10,N,31
03, STANDARD DIN-PT,P,31
etc.

ECUR11

Edit A Data Point In User Curve 11.

Input: ECUR11, X.XXXXX, XXX.X

Returned: Nothing

Remarks: Fill in the point to be edited. It should be the units/temperature combination. If the Model 320 does not recognize either the units value or the temperature value, it will assume that you are inputting an entirely new point and place it in the proper ascending position.

Example: If the point to be edited was input as 0.19083,364.0 and should have been 0.19083,365.0, input the command as follows:

ECUR11,0.19083,365.0[term]

The Model 320 will recognize the units field and replace that data point with the new temperature value.

KCUR11

Delete User Curve 11 Data Command.

Input: KCUR11

Returned: Nothing

Remarks: Will delete all data stored for the User Curve 11.

Curve Commands (Continued)

CURV11

Enter User Curve.

Input: CURV11, XXXXXXXXXXXXXXXXXX, YY*

Returned: Nothing

Remarks: Enters the user curve, where X = 18 characters for curve description (must be at least 1 character), Y = unit/temperature data point in ascending units (must be from 2 to 97 pairs), and the "*" character is at the end of the data string.

The data points are input with the units value first. This value will be voltage or R_{equiv}. The value will have one character before the decimal place and five after it (0.00000). The table below gives the conversion of raw units into the format required. The Model 320 automatically fills in leading and trailing zeros.

The second value is the temperature. It has three character spaces before the decimal point and one after it (000.0). After all points are input, placement of an "*" terminates the sensor curve input.

INPUT TYPE	UNITS	CONVERSION
Silicon Diode	Voltage	Input range is 0.00000 to 6.00000.
Platinum	Resistance	Input range is 0.00 to 299.99 Ω. 0.00 Ω looks like 0.00000 and 299.99 Ω looks like 2.99990 (0.01 times R).
Thermocouple	Millivolts	Input range is −15 to +15. Add 15 mV to make all positive 0-30 mV and multiply by 100 to make look like 0-3.00000 V. For example, a thermocouple voltage of -5.0000 mV would be entered as 1.00000V.

To view a typical output after using this command to input all the information, see the example under the CURV? command. When entering, omit the temperature coefficient, the number of points and endpoints.

The Model 320 determines and stores whether the curve is a positive or negative coefficient curve. Based on temperature coefficient, the Model 320 then stores the curve end points and also adds the number of points.

Curve Commands (Continued)

CURV?

Curve Number Information Query.

Input: CURV? XX

Returned: AA, BBBBBBBBBBBBBBBBBB, C, XX, YYYYYY, ZZZZ

Remarks: User must provide curve number (00 thru 11) with query. The instrument will return header line and all point information for that curve. Information returned is defined as follows:

A = Curve number:	The value will be from 00 to 11.	
B = Curve description:	18 character information line. All 18 characters may not be used.	
C = Temp. coefficient:	N represents negative temperature coefficient, while P represents positive.	
X = Number of points:	The number of data points for that particular curve (usually 31, but can be up to 99).	
Y = Units:	The value will be voltage or R_{equiv}. (Refer to CURV Command). The value will have 1 character before the decimal place and 5 after it (0.00000).	
Z = Temperature:	The value will have 3 places before the decimal point and one after it (000.0).	

Example:
00, STANDARD DRC-D ,N,31,
0.00000,499.9,0.19083,365.0,
0.24739,345.0,0.36397,305.0,
0.42019,285.0,0.47403,265.0,
0.53960,240.0,0.59455,220.0,
0.73582,170.0,0.54606,130.0
0.95327,090.0,1.00460,070.0,
1.04070,055.0,1.07460,040.0,
1.09020,034.0,1.09700,032.0,
1.10580,030.0,1.11160,029.0,
1.11900,028.0,1.13080,027.0,
1.14860,026.0,1.07200,025.0,
1.25070,023.0,1.35050,021.0,
1.63590,017.0,1.76100,015.0,
1.90660,013.0,2.11720,009.0,
2.53660,003.0,2.59840,001.4,
6.55360,000.0[term]

CHAPTER 6

SERVICE AND CALIBRATION

6.0 GENERAL

This chapter describes the service and calibration for the Model 320 Temperature Controller. Paragraph 6.1 provides general maintenance information. Fuse replacement is described in Paragraph 6.2. Line voltage selection is described in Paragraph 6.3. Paragraphs 6.4 thru 6.6 describe calibration for the Model 320-01, -02, and -04, respectively.

6.1 GENERAL MAINTENANCE

To clean the Model 320 periodically to remove dust, grease and other contaminants, perform the following:

1. Clean front/back panels and case with soft cloth dampened with mild detergent and water solution.

NOTE

Do not use aromatic hydrocarbons or chlorinated solvents to clean the Model 320.
They may react with the silk screen printing on the back panel.

2. Clean surface of printed circuit boards (PCBs) using clean, dry air at low pressure.

6.2 FUSE REPLACEMENT

The line fuse is accessible from the rear of the Model 320 without opening the case. Use the following procedure to check and/or replace the fuse:

WARNING

To prevent shock hazard, turn off the instrument and disconnect it from AC line power and all test equipment before replacing the fuse.

1. Set POWER switch to OFF and disconnect power cord from unit. Fuse compartment will not open with power cord in place. Fuse compartment is located just to right of power cord socket in power connector assembly.

2. Open fuse compartment by prying open cover with a small screw driver from right side of assembly.

3. Remove lower fuse holder by sliding it out of its position with aid of small screw driver.

CAUTION

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

4. Replace fuse as follows: 1 A 3AG Slow Blow fuse for 90-125 VAC or a 0.5 A 3AG Slow Blow fuse for 210-250 VAC.

5. Replace fuse holder in lower fuse position, close fuse compartment and connect power cord.

6.3 LINE VOLTAGE SELECTION

The rear-panel, three-pronged line power connector permits the Model 320 to be connected to 100, 120, 220, or 240 VAC line voltages. Use the following procedure to change the line voltage.

WARNING

To prevent shock hazard, turn off the instrument and disconnect it from AC line power and all test equipment before changing the line voltage selection.

1. Open fuse compartment by prying open cover with a small screw driver from right side of assembly.

2. Do not rotate voltage selector wheel while it is in place. Remove voltage selector wheel and replace it with proper voltage facing out. Note that wheel can only be inserted with writing read from left.

3. Install proper fuse as follows: 1 A 3AG Slow Blow fuse for 90-125 VAC or a 0.5 A 3AG Slow Blow fuse for 210-250 VAC.

6.4 MODEL 320-01 CALIBRATION

To calibrate the Model 320-01 requires a digital multimeter (DMM) with a 4-1/2 digit display capable of 4-lead resistance measurement and a test connector wired as follows:
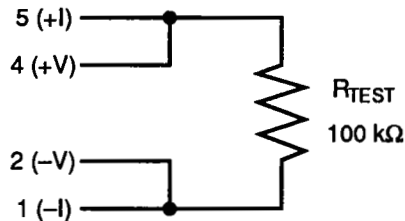
where R_{TEST} should be nominal 100 KΩ and as temperature stable as possible (20-50 ppm/°C).

WARNING

Line voltage is present inside the box. Only qualified personnel should proceed beyond this point.

1. Locate current adjustment R5, zero adjustment R6, and span adjustment R7 on top rear of instrument.
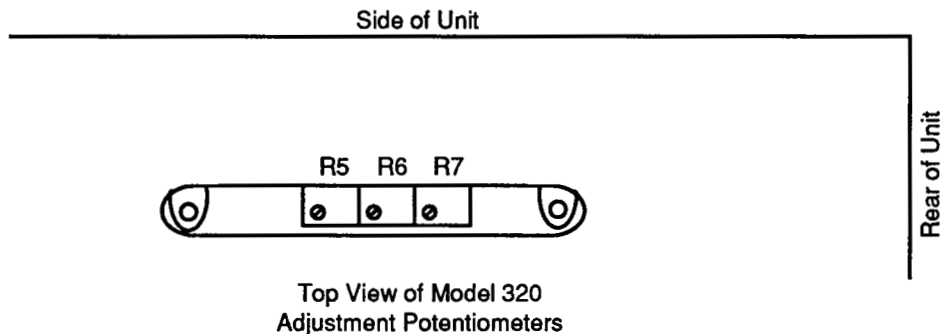
Top View of Model 320
Adjustment Potentiometers

2. Measure resistance of R_{TEST} to 4 1/2 places with a 4-lead measurement. Write down resistance.

3. Attach test connector and put multimeter across R_{TEST}.

4. Plug in instrument and place **Power** switch to on (in) position.

5. Turn heater off.

6. Allow unit to warm up for 1 hour.

7. Adjust current source with R5 until current through R_{TEST} is 10 µA. For a precision 100 KΩ resistor, DMM voltage should read 1.0000 V. For a less accurate resistor, 100.25 KΩ for example, DMM voltage should read 1.0025 V.

8. Remove test connector and place a short between connector pins 2 and 4.

9. Configure unit to display in volts (see Chapter 3).

10. Adjust R6 until display toggles between .0000 and Err27.

11. Remove short between connector pins 2 and 4. Attach test connector and put multimeter across R_{TEST}.

12. Adjust R7 until display reads same as multimeter ($\approx$1 Vdc).

13. Place **Power** switch to off (out) position.

14. Disconnect test connector.

6.5   MODEL 320-02 CALIBRATION

To calibrate the Model 320-02 requires a digital multimeter (DMM) with a 4-1/2 digit display capable of 4-lead resistance measurement and a test connector wired as follows:


where R_{TEST} should be nominal 100 Ω and as temperature stable as possible (20-50 ppm/°C).

| WARNING |

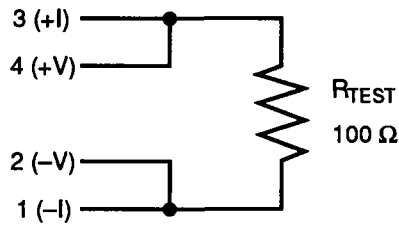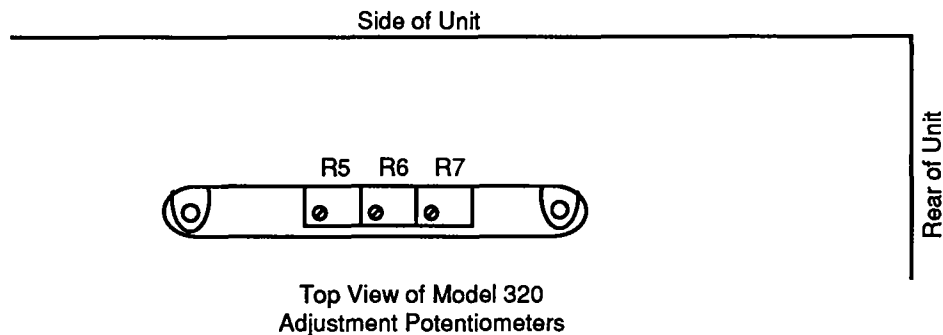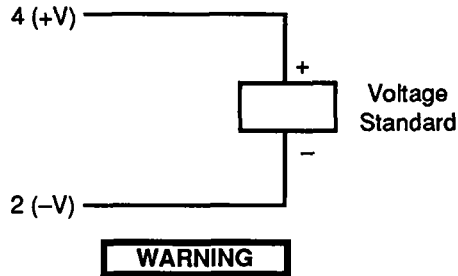Line voltage is present inside the box. Only qualified personnel should proceed beyond this point.

1.   Locate current adjustment R5, zero adjust R6, and span adjustment R7 on top rear of instrument.

Top View of Model 320
Adjustment Potentiometers

2.   Measure resistance of R_{TEST} to 4 1/2 places with a 4-lead measurement. Write down resistance.

3.   Attach test connector and put multimeter across R_{TEST}.

4.   Plug in instrument and place **Power** switch to on (in) position.

5.   Turn heater off.

6.   Allow unit to warm up for 1 hour.

7.   Adjust current source with R5 until current through R_{TEST} is 1 mA. For a precision 100 Ω resistor, DMM voltage should read 1.0000 V. For a less accurate resistor, 100.25 Ω for example, DMM voltage should read 1.0025 V.

8.   Replace 100 Ω resistor with a short.

9.   Adjust R6 until display toggles between 0.00 Ω and Err27.

10.   Replace short with 100 Ω resistor.

11.   Adjust R7 until display reads 100.0 Ω. (For a less accurate resistor, refer to example in Step 7.)

12.   Configure unit to display in ohms. (Refer to Chapter 3.)

13.   Adjust R7 until display reads same as multimeter ($\approx$0.1 Vdc).

14.   Place **Power** switch to off (out) position.

15.   Disconnect test connector.

6.6 MODEL 320-04 CALIBRATION

To calibrate the Model 320-04 requires a Voltage Standard with microvolt resolution and a test connections as follows:

WARNING

Line voltage is present inside the box. Only qualified personnel should proceed beyond this point.

1. Locate zero adjustment R6, span adjustment R7, and offset adjustment R8 on top rear of instrument.

Top View of Model 320
Adjustment Potentiometers
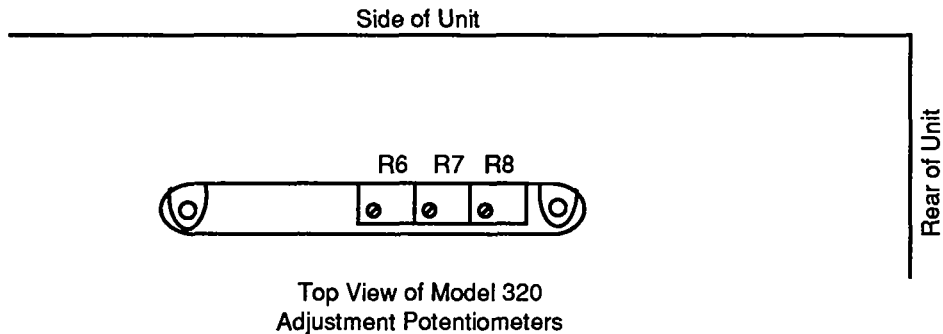
2. Attach voltage standard as shown above. Set voltage standard to zero output.

3. Plug in instrument and place **Power** switch to on (in) position.

4. Turn off heater.

5. Select display units to be in sensor units (millivolts). Select Curve 6 with compensation off.

6. Allow unit to warm up for 1 hour.

7. Adjust R6 to obtain a display reading of 0.000 ±0.001 mV.

8. Change voltage standard output to +14.000 millivolts.

9. Adjust R7 until display reads 14.000 mV.

10. Change voltage standard to −14.000 millivolts. display should read −14.000 ±0.002 mV. If not, check zero input and readjust R6.

11. Place **Power** switch to off (out) position.

12. Disconnect test connector.

When a new or different thermocouple is attached to the instrument, it is necessary to adjust the offset to compensate for discrepancies in thermocouple material, leads and connections. An offset adjustment trimpot is provided to allow offset calibration of the thermocouple. The steps below outline the procedure.

13. Place thermocouple in a reference bath of known temperature (liquid nitrogen, ice etc.). Allow system to stabilize to reference temperature.

14. On front panel of Model 320-04, select desired temperature units.

15. Turn on thermocouple compensation.

16. Adjust offset adjustment trimpot (R8) so that displays read reference temperature.

APPENDIX A
GLOSSARY OF TERMINOLOGY

Absolute Zero – Believed to be the lowest possible temperature; the temperature at which molecular motion stops and at which heat is completely gone. Defined as 0 K, calculated to be –273.15 °C or –459.67 °F.

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:

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

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.

Baud – A unit of signaling speed equal to the number of discrete conditions or signal events per second. A baud as a signal element must be at least one complete cycle in length in order to carry information. Baud and bits per second (bps) are *not* interchangeable. Baud rate indicates how fast signals are being sent, where bps shows the rate at which information is being transferred.

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

Boiling Point – The temperature at which a substance in the liquid phase transforms to the gaseous phase; commonly refers to the boiling point of water which is 100 °C (212 °F) at sea level.

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

CGS System of Units – A coherent system in which the basic units are the centimeter, gram, and second.

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.

Cryostat – A low temperature thermostat.

Decibels (dB) – The standard unit for expressing transmission gain or loss and relative power levels. Decibels indicate the ratio of power output to power input: $dB = 20 \log_{10} V_1/V_2$. The term "dBm" is used when a power of one milliwatt is the reference level.

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.

Dewar – A vacuum bottle used to contain liquid nitrogen and other supercooled gases.

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

Gaussian System (Units) – A system in which centimeter-gram-second units are used for electric and magnetic qualities.

Greek Alphabet – The Greek alphabet is defined as follows:

Alpha	α	A	Iota	ι	I	Rho	ρ	P
Beta	β	B	Kappa	κ	K	Sigma	σ	Σ
Gamma	γ	Γ	Lambda	λ	Λ	Tau	τ	T
Delta	δ	Δ	Mu	μ	M	Upsilon	υ	Y
Epsilon	ε	E	Nu	ν	N	Phi	ϕ	Φ
Zeta	ζ	Z	Xi	ξ	Ξ	Chi	χ	X
Eta	η	H	Omicron	o	O	Psi	ψ	Ψ
Theta	θ	Θ	Pi	π	Π	Omega	ω	Ω

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

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.

International System of Units (SI) – A universal coherent system of units in which the following six units are considered basic: meter, kilogram, second, ampere, Kelvin degree, and candela. The MKSA system of units is a constituent part of this system . The International System of Units, or Système International d'Unités (SI), was promulgated in 1960 by the Eleventh General Conference on Weights and Measures.

Liquid Helium (LHe) – Used for low temperature and superconductivity research: minimum purity 99.998%. Boiling point @ 1 atm = 4.2 K. Latent heat of vaporization = 2.4 Btu/liter. Liquid density = 0.275 lbs/liter.

EPA Hazard Categories: Immediate (Acute)	DOT Label: Nonflammable Gas
Health and Sudden Release of Pressure Hazards	DOT Class: Nonflammable Gas
DOT Name: Helium, Refrigerated Liquid	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 @ 1 atm = 77 K. Latent heat of vaporization = 152 Btu/liter. Liquid density = 0.78 lbs/liter.

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

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.

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).

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

Normally Open – Abbreviation: N.O. A term used for switches and relay contacts. Provides a normally open circuit when actuator is in the free (unenergized) position.

PID – Acronym for Proportional, Integral, and Derivative. A three-mode control action where the controller has time proportioning, integral (auto reset), and derivative action. The integral function, also known as reset, automatically adjusts the temperature at which a system has stabilized back to the set point temperature, thereby eliminating droop in the system. The derivative function, also known as rate, senses the rate at which a system's temperature is either increasing or decreasing and adjusts the cycle time of the controller to minimize overshoot or undershoot.

Pop-off – Another term for relief valve.

Prefixes – Standard International System of Units (SI) prefixes used throughout this manual are as follows:

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	P	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	μ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10^{1}	deka	da	10^{-19}	atto	a

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.

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.

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.

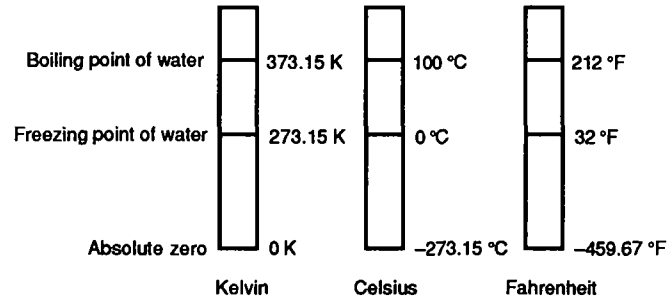**Roman Numerals** – Letters employed in the ancient Roman system of numeration as follows:

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 average of the squares of the values of a periodic quantity taken throughout one complete period. It is the effective value of a periodic quantity

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 – In the use of Lake Shore equipment, susceptibility involves subjecting a 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.

Temperature – 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:

	Kelvin	Celsius	Fahrenheit
Boiling point of water	373.15 K	100 °C	212 °F
Freezing point of water	273.15 K	0 °C	32 °F
Absolute zero	0 K	–273.15 °C	–459.67 °F

APPENDIX B

HANDLING OF LIQUID HELIUM AND NITROGEN

B1.0   GENERAL

Liquid Helium (LHe) and liquid nitrogen (LN$_2$) may be used in conjunction with the Model 320. Although not explosive, the following are safety considerations in the handling of LHe and LN$_2$.

B2.0   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 B-1.

Table B-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

B3.0   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 B-1.
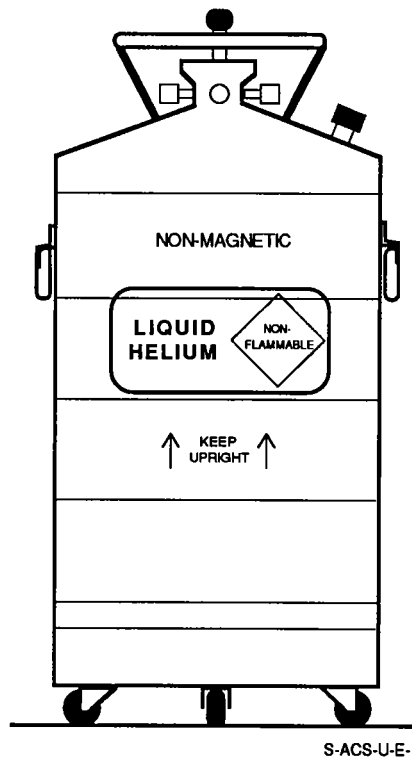

S-ACS-U-E-1

Figure B-1. Typical Cryogenic Storage Dewar

B4.0   LIQUID HELIUM AND NITROGEN SAFETY PRECAUTIONS

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

WARNING

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

● 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, transfers accomplished, and systems 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.

B5.0   RECOMMENDED FIRST AID

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

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

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

References:

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

APPENDIX C

CURVE TABLES

C1.0   GENERAL

The following are curve tables applicable to the Model 320 Autotuning Temperature Controller.

Table C-1. Standard Diode and Platinum Curves

Breakpoint	D CURVE		E1 CURVE		DT-470 CURVE 10		Platinum 100 Ohm	
Number	Temp.(K)	V	Temp.(K)	V	Temp.(K)	V	Temp.(K)	Ω
1	499.9	0.00000	499.9	0.00000	499.9	0.00000	000.0	0.00000
2	365.0	0.19083	330.0	0.28930	475.0	0.09032	030.0	0.03820
3	345.0	0.24739	305.0	0.36220	460.0	0.12536	032.0	0.04235
4	305.0	0.36397	285.0	0.41860	435.0	0.18696	036.0	0.05146
5	285.0	0.42019	265.0	0.47220	390.0	0.29958	038.0	0.05650
6	265.0	0.47403	240.0	0.53770	340.0	0.42238	040.0	0.06170
7	240.0	0.53960	220.0	0.59260	280.0	0.56707	042.0	0.06726
8	220.0	0.59455	170.0	0.73440	230.0	0.68580	046.0	0.07909
9	170.0	0.73582	130.0	0.84490	195.0	0.76717	052.0	0.09924
10	130.0	0.84606	100.0	0.92570	165.0	0.83541	058.0	0.12180
11	090.0	0.95327	075.0	0.99110	140.0	0.89082	065.0	0.15015
12	070.0	1.00460	060.0	1.02840	115.0	0.94455	075.0	0.19223
13	055.0	1.04070	040.0	1.07460	095.0	0.98574	085.0	0.23525
14	040.0	1.07460	036.0	1.08480	077.4	1.02044	105.0	0.32081
15	034.0	1.09020	034.0	1.09090	060.0	1.05277	140.0	0.46648
16	032.0	1.09700	032.0	1.09810	044.0	1.08105	180.0	0.62980
17	030.0	1.10580	030.0	1.10800	036.0	1.09477	210.0	0.75044
18	029.0	1.11160	029.0	1.11500	031.0	1.10465	270.0	0.98784
19	028.0	1.11900	028.0	1.12390	028.0	1.11202	315.0	1.16270
20	027.0	1.13080	027.0	1.13650	027.0	1.11517	355.0	1.31616
21	026.0	1.14860	026.0	1.15590	026.0	1.11896	400.0	1.48652
22	025.0	1.17200	025.0	1.18770	025.0	1.12463	445.0	1.65466
23	023.0	1.25070	024.0	1.23570	024.0	1.13598	490.0	1.82035
24	021.0	1.35050	022.0	1.33170	020.0	1.21555	535.0	1.98386
25	017.0	1.63590	018.0	1.65270	015.5	1.29340	585.0	2.16256
26	015.0	1.76100	013.0	1.96320	012.0	1.36687	630.0	2.32106
27	013.0	1.90660	009.0	2.17840	009.0	1.44850	675.0	2.47712
28	009.0	2.11720	004.0	2.53640	003.8	1.64112	715.0	2.61391
29	003.0	2.53660	003.0	2.59940	002.0	1.68912	760.0	2.76566
30	001.4	2.59840	001.4	2.65910	001.4	1.69808	800.0	2.89830
31	000.0	6.55360	000.0	6.55360	000.0	6.55360	999.9	6.55360

Table C-2. Thermocouple Curves

Breakpoint Number	Chromel vs. Au-0.03 at.% Fe		Chromel vs. Au-0.07 at.% Fe	
	Temp (K)	V_{TC}(mV)	Temp (K)	V_{TC}(mV)
1	0.0	− 15.0000	0.0	− 15.0000
2	3.5	− 4.6676	1.4	− 5.2982
3	8.0	− 4.6067	3.0	− 5.2815
4	13.5	− 4.5259	4.8	− 5.2594
5	18.0	− 4.4571	7.0	− 5.2285
6	24.0	− 4.3703	10.5	− 5.1742
7	30.0	− 4.2869	19.0	− 5.0315
8	52.0	− 3.9928	26.0	− 4.9126
9	60.0	− 3.8830	48.0	− 4.5494
10	65.0	− 3.8126	58.0	− 4.3810
11	70.0	− 3.7411	70.0	− 4.1733
12	80.0	− 3.5948	80.0	− 3.9952
13	90.0	− 3.4436	90.0	− 3.8132
14	105.0	− 3.2026	100.0	− 3.6270
15	115.0	− 3.0374	110.0	− 3.4370
16	125.0	− 2.8689	120.0	− 3.2435
17	135.0	− 2.6957	135.0	− 2.9477
18	145.0	− 2.5184	150.0	− 2.6452
19	160.0	− 2.2468	165.0	− 2.3372
20	170.0	− 2.0615	180.0	− 2.0242
21	180.0	− 1.8725	200.0	− 1.6004
22	195.0	− 1.5839	220.0	− 1.1693
23	210.0	− 1.2905	245.0	− 0.6232
24	225.0	− 0.9912	270.0	− 0.0705
25	240.0	− 0.6847	300.0	+ 0.5986
26	265.0	− 0.1670	305.0	+ 0.7158
27	275.0	+ 0.0378	310.0	+ 0.8431
28	285.0	+ 0.2387	315.0	+ 0.9944
29	305.0	+ 0.6350	320.0	+ 1.1940
30	325.0	+ 1.0387	325.0	+ 1.4841
31	999.9	+15.0010	999.9	+15.0010

Table C-3. Thermocouple Curves

Breakpoint Number	Chromel vs. Constantan		Chromel vs. Alumel		Copper vs. Constantan	
	Temp (K)	E V_{TC}(mV)	Temp (K)	K V_{TC}(mV)	Temp (K)	T V_{TC}(mV)
1	0.0	-15.0000	0.0	-15.0000	0.0	-15.0000
2	3.0	− 9.8355	3.0	− 6.4582	3.0	− 6.2584
3	5.6	− 9.8298	6.0	− 6.4551	6.5	− 6.2523
4	9.0	− 9.8182	10.0	− 6.4486	11.0	− 6.2401
5	13.5	− 9.7956	14.5	− 6.4376	16.5	− 6.2184
6	19.0	− 9.7570	19.5	− 6.4205	22.0	− 6.1888
7	25.0	− 9.7013	25.0	− 6.3951	29.0	− 6.1404
8	32.0	− 9.6204	32.0	− 6.3529	38.0	− 6.0615
9	40.0	− 9.5071	40.0	− 6.2913	48.0	− 5.9535
10	50.0	− 9.3366	48.0	− 6.2149	60.0	− 5.7995
11	60.0	− 9.1345	58.0	− 6.1022	75.0	− 5.5753
12	70.0	− 8.9030	65.0	− 6.0099	90.0	− 5.3204
13	80.0	− 8.6475	75.0	− 5.8634	105.0	− 5.0337
14	90.0	− 8.3673	85.0	− 5.6989	120.0	− 4.7194
15	105.0	− 7.9064	95.0	− 5.5156	135.0	− 4.3767
16	120.0	− 7.3943	105.0	− 5.3166	155.0	− 3.8781
17	135.0	− 6.8386	120.0	− 4.9881	175.0	− 3.3278
18	150.0	− 6.2400	135.0	− 4.6240	195.0	− 2.7342
19	170.0	− 5.3831	150.0	− 4.2267	220.0	− 1.9295
20	190.0	− 4.4564	165.0	− 3.7994	245.0	− 1.0586
21	210.0	− 3.4702	185.0	− 3.1866	270.0	− 0.1254
22	235.0	− 2.1605	205.0	− 2.5259	300.0	+ 1.0616
23	260.0	− 0.7666	230.0	− 1.6463	330.0	+ 2.3247
24	290.0	+ 0.9948	260.0	− 0.5186	360.0	+ 3.6639
25	320.0	+ 2.8428	295.0	+ 0.8688	395.0	+ 5.3095
26	350.0	+ 4.7704	350.0	+ 3.1298	430.0	+ 7.0419
27	385.0	+ 7.1149	395.0	+ 4.9999	470.0	+ 9.1113
28	420.0	+ 9.5570	460.0	+ 7.6164	510.0	+11.2758
29	460.0	+12.4425	510.0	+ 9.6125	555.0	+13.8053
30	475.0	+13.5573	575.0	+12.2790	575.0	+14.9685
31	999.9	+15.0010	999.9	+15.0010	999.9	+15.0010

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APPENDIX D

APPLICATION NOTES

D1.0 GENERAL

The following Lake Shore Applications Notes are included with this manual:

1. Fundamentals For Usage Of Cryogenic Temperature Controllers.

2. DT-470 Series Temperature Sensors Installation and Operation.

3. Measurement System Induced Errors In Diode Thermometry.

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ALPHABETICAL INDEX

The following is an alphabetical index of the headings and major topics contained in the Lake Shore Model 320 Temperature Controller 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 (A1.0). 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.

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LakeShore
C R Y O T R O N I C S , I N C.

64 East Walnut Street, Westerville, Ohio 43081 USA
Telephone: (614) 891-2243
Telex: 245415 CRYOTRON WTVL
Fax: (614) 891-1392

Model 320 Autotuning
Temperature Controller

Autotuning Temperature Control Down to 1.4K
with Control Stability of ± 0.1K or Better

320 Autotuning
Temperature Controller

Heater   Setup   Scroll

Power
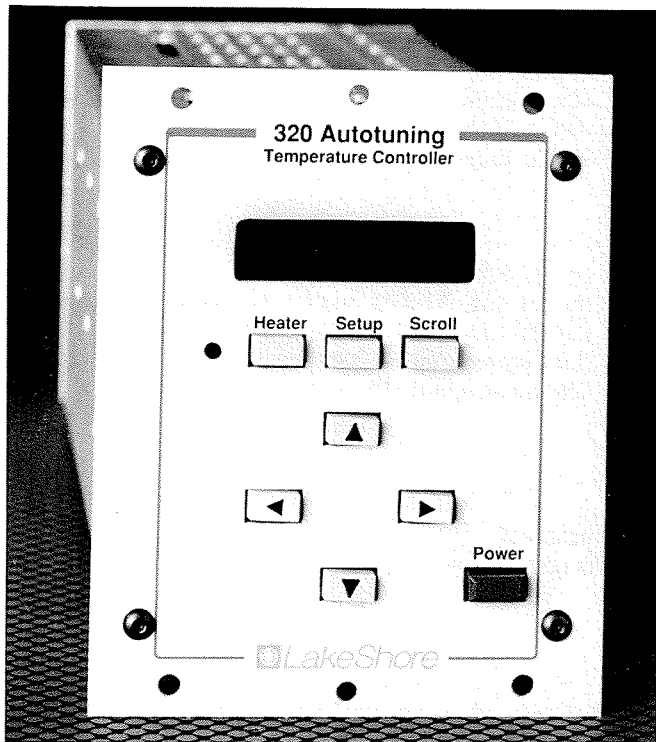
Features

● Autotuning - no need for the user to select PID parameters

● Manual settings of PID parameters via front panel entry

● Three Models: (320-01) Silicon Diodes, (320-02) 100 ohm Platinum Resistors, or (320-04) Thermocouples

● Ability to store one sensor calibration curve

● RS-232C serial interface

● 25 watt DC heater output

● 8 character alphanumeric LED display for high visibility

● Electronic accuracy and control stability to ±0.1 or better in K or °C

● Simple scroll type entry

● Small 1/4 DIN package

● Isolated current source allows true 4-wire sensor readings resulting in high instrument accuracy

What is Autotuning?

Building on the accuracy and convenience of Lake Shore Thermometry, the new Model 320 Autotuning Controller offers a simple, low cost answer to basic control needs. The autotune feature increases the user's efficiency by automatically selecting and adjusting the correct porportional (GAIN), integral (RESET) and derivative (RATE) in virtually minutes. Time spent adjusting or fine-tuning the controller is eliminated, leaving the user with more time to experiment with something other than controller settings!

A cryogenic system is a complex arrangement of thermal resistances and heat capacities which are represented by thermal lags and thermal time constants. The 320 Controller analyzes this system's operating parameters on-line. The controller's "Autotuning" function determines the proper values for gain, rate and reset. Once set, the PID values are only modified when the system characteristics change.

Block Diagram for Diode or Platinum Sensor Input

Lines 2 and 3 represent separate isolated power supplies. They allow "true" 4-wire sensor readings.
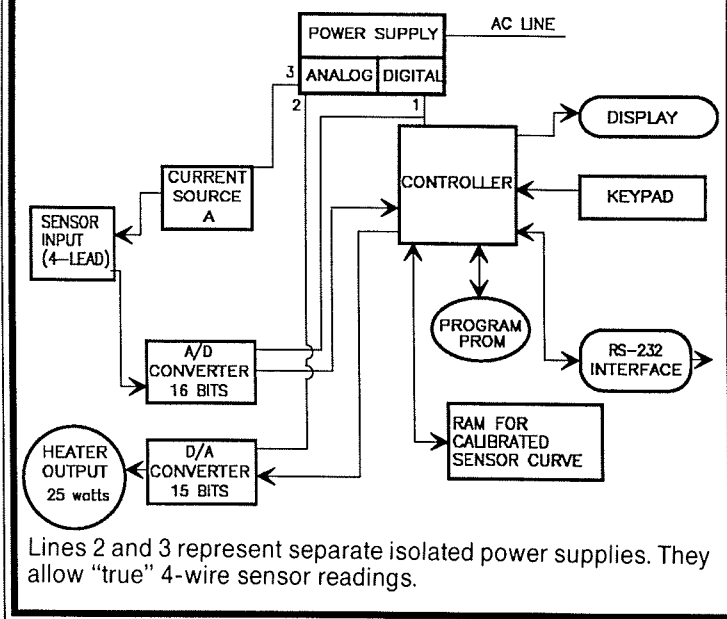
Specifications

Display
Resolution: 0.1 in K or °C
Electronic Accuracy: ±0.1 or better* in K or °C
Temperature Accuracy: Electronic accuracy plus sensor accuracy
Electronic Temperature
Repeatability: ±0.1 or better*in K or °C
Temperature Range:

Silicon Diode	1.4K to 475K	
Platinum	30K to 800K	
Thermocouple		
Ch-AuFe (0.07%)	4K to 325K	
Ch-AuFe (0.03%)	1.4K to 325K	
Ch-CuFe (0.15%)	4K to 273K	
E	40K to 425K	
K	90K to 325K	
T	90K to 485K	

Standard Curves
Standard curves stored in the unit include:

Curve DRC-D	(for DT-500 silicon diodes)
Curve 10	(for DT-450, DT-470, and DT-471 silicon diodes)
DIN Curve 43760	(for PT-100 series 100 ohm platinum sensors)
Thermocouple curves	(for Chromel-AuFe 0.07%, Chromel-AuFe 0.03%, Chromel-CuFe 0.15%, E, K and T)

Temperature Control
Set Point Resolution: 0.1K
Control Stability: ±0.1 or better* in K or °C
Control Repeatability: ±0.1 or better* in K or °C
Control Accuracy: Equivalent to temperature accuracy
Heater Output: 25 watts, 0-1 A with 25 volts compliance
Heater Load: 25 ohm or greater
* Dependent on sensitivity of sensor.

General
Interface: RS-232C - Three wire, half-duplex, asynchronous transmission at 300 or 1200 baud. Connector is RJ-11 modular socket.
    Inputs: Setpoint, Heater On/Off, Curve data
    Outputs: Temperature, Setpoint, Heater %, External curve
Dimensions: 105mm wide x 132mm high x 280mm deep (4.2in. x 5.2in. x 11in.).
Weight: Net Weight: 2.7kg (6 lbs.)
Power: 90-125, or 210-250 VAC (rear panel selectable), 65VA

Accessories Supplied

Users Manual
One Sensor Input Connector (106-233)
One Double Banana Plug for heater output (106-009)

Optional Accessories

2001	RJ11 10ft. (3m) Modular RS-232 Phone Cord
2002	RJ11 to DB25 Adaptor. Connects RJ11 to RS-232 serial port on rear of computer
8271-20	Sensor/Heater Cable Assembly for diode and platinum sensors
106-233	Extra Sensor Input Connector
106-009	Extra Double Banana Plug for heater output

Ordering Information

To order, specify one of the following:

Input Type	Model
Silicon Diode	320-01
Platinum	320-02
Thermocouple	320-04