LAKE SHORE CRYOTRONICS, INC.
P. O. BOX 214 • HAMBURG, NEW YORK 14075

INSTRUCTION MANUAL

MODEL TGC-100

CRYOGENIC TEMPERATURE CONTROLLER

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Lake Shore Cryotronics, Inc. warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, shipment prepaid, to our factory for that purpose within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by an authorized representative of Lake Shore Cryotronics, Inc.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty likewise shall not apply to any instrument or component not manufactured by others and included in Lake Shore Cryotronics, Inc. equipment; the original manufacturer's warranty is extended to Lake Shore Cryotronics, Inc. customers.

Lake Shore Cryotronics reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

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FIG. 1.1 MODEL TGC-100
CRYOGENIC TEMPERATURE CONTROLLER

SECTION I

General Information

1.1 Introduction

This section contains a description of the Model TGC-100 Cryogenic Temperature Controller, its applications, general specifications, major assemblies supplied and accessory equipment available.

1.2 Description and Applications

The Model TGC-100 Cryogenic Temperature Controller is housed in an aluminum case with standard 19" relay panel front for rack mounting. All connections are at the rear of the case with all normal operating controls on the front panel. The instrument is line operated from either 115 volt or 230 volt mains, 50 or 60 hertz.

The controller is designed to accept a voltage signal from a temperature sensitive transducer (generally a TGC-100 Diode which is not supplied), compare this signal with an internal set point voltage, amplify and process their difference (error signal), and drive an external heating element. An internal precision 10 microampere constant current source is supplied to excite the temperature transducer.

The error processing section of the controller is of the proportional plus integral mode design. Generous amplifier gain ranges have been provided to affect rapid closed loop response times, low steady state temperature offsets and to insure system stability over a wide range of thermal system parameters.

The output power amplifier is capable of supplying 10 Watts of heater power. In view of the high cost of some cryogenic fluids such as helium, cost consciousness suggests that cryostat design and operating strategies be planned to limit heater power requirements to substantially less than ten watts. Power amplifiers are available from the company as accessory equipment if required for special applications.

The principal intended application of the TGC-100 Controller is as a constant temperature regulator for laboratory size cryostats. Its basic design, however, enables it to be used as a general purpose controller for sensors whose raw outputs range between 0.5 and 1.5 volts and whose incremental sensitivities are in the range of tenths of millivolts.

In addition to its use as a closed loop automatic temperature controller, the Model TGC-100 Controller may be used as a precision thermometer. By adjusting the set point voltage so that the error signal is zero, the output voltage of the temperature sensor is accurately obtained. Reference to a voltage versus temperature calibration curve for the transducer in use will then give its temperature.

1.3 General Specifications

The following specifications for the TGC-100 Controller are applicable when used with the TG-100 full range temperature sensitive diode.

General:

Controller Range	- 1^oK to 300^oK nominal
Heater Output	- 10^{-3} to 10 watts, 0-1 Amp, 0-10 Volts
Sensor	- Model TG-100 full range, GaAs temperature sensitive diode, single-ended or floating model
Sensor Input	- four terminal connection, constant current, potentiometric
Sensor Current	- 10 microamperes
Input Line Voltage	- 115V or 220V, 50-60 Hz
Power Consumption	- 30VA
Circuit Design	- Solid State
Weight	- 12 pounds
Dimensions	- 5¼" high, 19" wide, 11½ deep, rack mounting
Gain	- 3 Amps/millivolt into 10 ohm resistor at maximum setting

Temperature Control:

Set Points	- 0.5 to 1.6 Volts Switch - 100 mV per step and 10 turn interpolating potentiometer with 0.1 mV graduations, 0.1% linearity
Repeatability	- ±10 microvolts (0.01^oK or better)
Automatic Reset	- 3 to 100 second variable time constant, or off

Manual Output Control Range	- 10 turn potentiometer control, 0 to
Heater Current Ranges	- 10mA, 30mA, 100mA, 300mA, 1A
Heater Resistance for Max Power	- 10 Ohms
Controller Proportional Gain	- 3 Amps/mV in automatic mode (nominal)

Temperature Readout:

(2 Sensor connections, front panel selectable between control sensor and temperature sensing only sensor)

Accuracy	- equivalent to 100 microvolts (0.1^{o}K worse case) ± calibration error of sensor
Excitation Current	- 10 microamperes
Excitation Current Regulation	- 0.05%
Sensor Calibration Chart	- must be supplied by manufacturer of sensor in use.

1.4 Major Assemblies Supplied

The Model Cryogenic Temperature Controller includes as standard equipment, in addition to the controller proper, the following additional components:

(1) 1, Operating and Service Manual

(2) 2, Five pin plugs for temperature sensor cables

(3) 1, Seven pin plug for remote set point cable

Temperature sensitive diodes are not supplied as part of the Controller.

1.5 Accessory Equipment and Custom Options Available

The following accessory equipment and custom options are available from the factory. Items marked with an asterisk (*) are of a custom nature. The customer should discuss these items with a factory representative before ordering.

(1) Extra 5 and 7 pin connectors.

(2) Multisensor selector panel. (Special low thermal offset switch and cabling for selecting among multiple sensors)*

(3) Remote set point voltage control and programming module.*

(4) Custom modification of sensor current supply value or raw sensor output voltage range.*

(5) TG-100 Gallium Arsenide Temperature Sensitive Diode (Uncalibrated). (See data sheets at end of this manual for nominal operating characteristics and case styles available.)

(6) TG-100 Gallium Arsenide Temperature Sensitive Diode, (Calibrated) Standards laboratory calibration service for correlating diode output voltage with diode temperature. See TG-100 data sheet for additional information.

(7) Power Boosters for heater power requirements in excess of ten watts, or other than ten ohm heater resistances.

SECTION II

Installation

2.1 Introduction

This section contains information and instructions necessary for the installation and shipping of the Model TGC- Cryogenic Temperature Controller. Included are initial inspection instructions, power and grounding requirements, installation information and instructions for repackaging for shipment.

2.2 Initial Inspection

This instrument was electrically and mechanically inspected prior to shipment. It should be free from mars and scratches, and in perfect working order upon receipt. To confirm this, the instrument should be inspected visually for obvious damage upon receipt and tested electrically by use to detect any concealed 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 appropriate claims with the carrier, and/or insurance company. Please advise the company of such filings. In case of parts shortages please advise the company. The standard Lake Shore Cryotronics warranty is given on page ii.

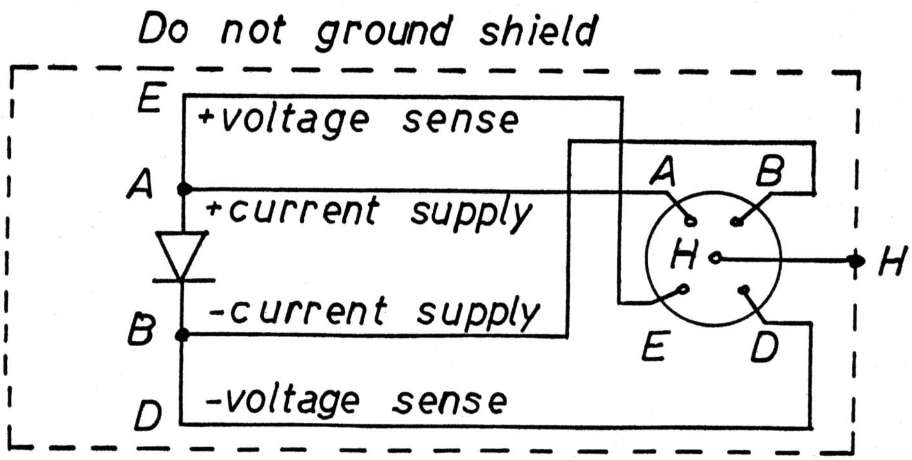
2.3 Power Requirements

Before connecting the power cable to the line, ascertain that the line voltage selector switch (115V or 230V) is in the appropriate position for the line voltage to be used. Examine the power line fuse, FU1, (Key No 13, Page 11) to insure that it is appropriate for the line voltage. (115V = Amp, 230V = 0.4 Amp) Nominal permissible line voltage fluctuation is ±10% at 50 to 60 Hz.

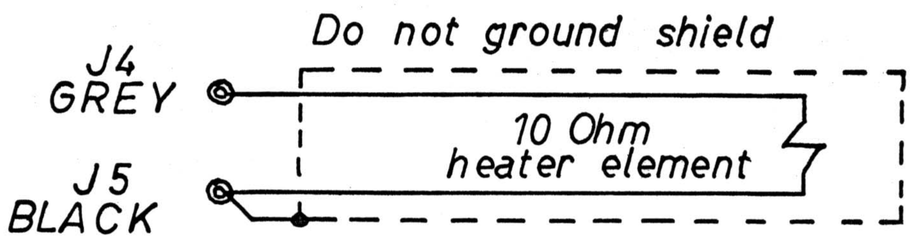
Caution: Disconnect line cord before inspecting or changing line fuse.

2.4 Grounding Requirements

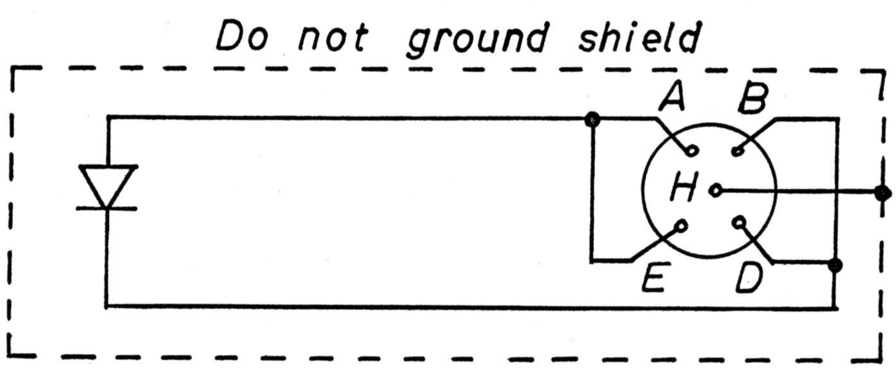
To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends and some local codes require instrument panels and cabinets to be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the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



(A) RECOMMENDED SENSOR CABLE



(B) RECOMMENDED HEATER CABLE



(C) ALTERNATE SENSOR CABLE

FIG. 2.1 SENSOR AND HEATER CABLES

2.5 Installation

The TGC-100 Controller is all solid state and does not generate significant heat. It may therefore be rack mounted in close proximity to other equipment in dead air spaces. However, the heat from such adjacent equipment should not subject the TGC-100 controller to an ambient temperature in excess of 50°C (122°F). As with any precision instrument, it should not be subjected to the shock and vibrations which usually accompany high vacuum pumping systems.

The recommended cable diagrams for the sensor diode and heater element are given in Figure 2.1 (a) and (b). The use of a four wire diode connection is highly recommended to avoid introducing lead IR drops in the voltage sensing pair. The indicated shielding connections are the recommended standard practice to avoid ground loops. If thermal considerations dictate, the alternate wiring scheme shown in Fig. 2.1 (c) may be used for the diode.

The heating element should be floated to preclude the possibility of any of the heater current being conducted into the diode sensor leads. Electrical feedback in addition to the desired thermal feedback, may cause oscillations and certainly erroneous temperature readings.

Inspect the heater element fuse FU2, (Key No. 15, Pg. 11) for proper value. (3 AG, 1.0A, Slow Blow, or smaller current rating if desired.) This fuse protects the output amplifier from damage in case of heater element shorting. Use of a larger fuse may cause damage to the instrument and invalidates the instrument warranty.

2.6 Repackaging for Shipment

Before returning an instrument to the factory for repair, please discuss the malfunction with a factory representative. He may be able to suggest several field tests which will preclude returning a satisfactory instrument to the factory when the malfunction is elsewhere. If it is indicated that the fault is in the instrument after these tests, the representative will send shipping instructions and labels for returning it.

When returning an instrument, please attach a tag securely to the instrument itself (not on the shipping carton) clearly stating:

(1) Owner and address

(2) Instrument Model and Serial Number

(3) Malfunction symptoms

(4) Description of external connections and cryostats.

If the original carton is available, repack instrument in plastic vapor barrier, place in carton using cardboard spacers to protect protruding controls, place protective cardboard sheets on instrument lid and close carton. Seal lid with paper or nylon tape. Affix mailing labels and "FRAGILE" warnings.

If the original carton is not available, wrap the instrument in water proof paper or plastic wrapping material before placing in an inner container. Place shock absorbing material around all sides of the instrument and use cardboard strips to prevent damage to protruding controls. Place the inner container in a second heavy carton and seal with tape. Affix mailing labels and "FRAGILE" warnings.

SECTION III

Operating Instructions

3.1 Introduction

This section contains a description of the operating controls, their adjustment under normal operating conditions, typical controller applications and suggested cryostat adjustment techniques. These instructions are predicated upon the instrument having been installed as outlined in Section II. The diode polarity as shown in Fig. 2.1 (a) in particular must be correct. A calibrated diode is assumed to be connected, as shown in Fig. 2.1 (a), to the "Sensor A" receptacle and a 10 ohm heating element is assumed to be connected to the "Heater" terminals as shown in Fig. 2.1 (b).

3.2 Controls, Indicators and Connectors

The operating controls, indicators and connectors on the instrument's front and rear panels are shown in Figures 3.1 and 3.2. The numbers with leaders to various controls in the figures are keyed to the entries in Table 3.1.

Table 3.1

NO. KEY	NAME	FUNCTION
1	SET POINT - VOLTS 0 - 0.1	Ten turn vernier interpolator potentiometer to continuously adjust set point voltage between switch setting and next higher setting.
2	SET POINT - VOLTS 0.5, to 1.6	Kelvin-Varley divider, selects most significant digits of setpoint voltage.
3	GAIN 1 - 100	Adjusts overall controller gain between 330 and 33,000. (See figure 3.3)
4	AUTO-RESET OFF, MIN. - MAX.	Adjusts gain of amplifier following integrator. (See Fig. 3.3) Effectively determines time constant of integrator between 3 and 100 seconds.
5	AUTO A, MAN. A, MAN. B.	Mode selector switch: AUTO A uses sensor A to automatically control temperature. MAN. A disengages automatic control feature but permits readout of sensor A voltage. MAN. B permits readout of sensor B voltage.

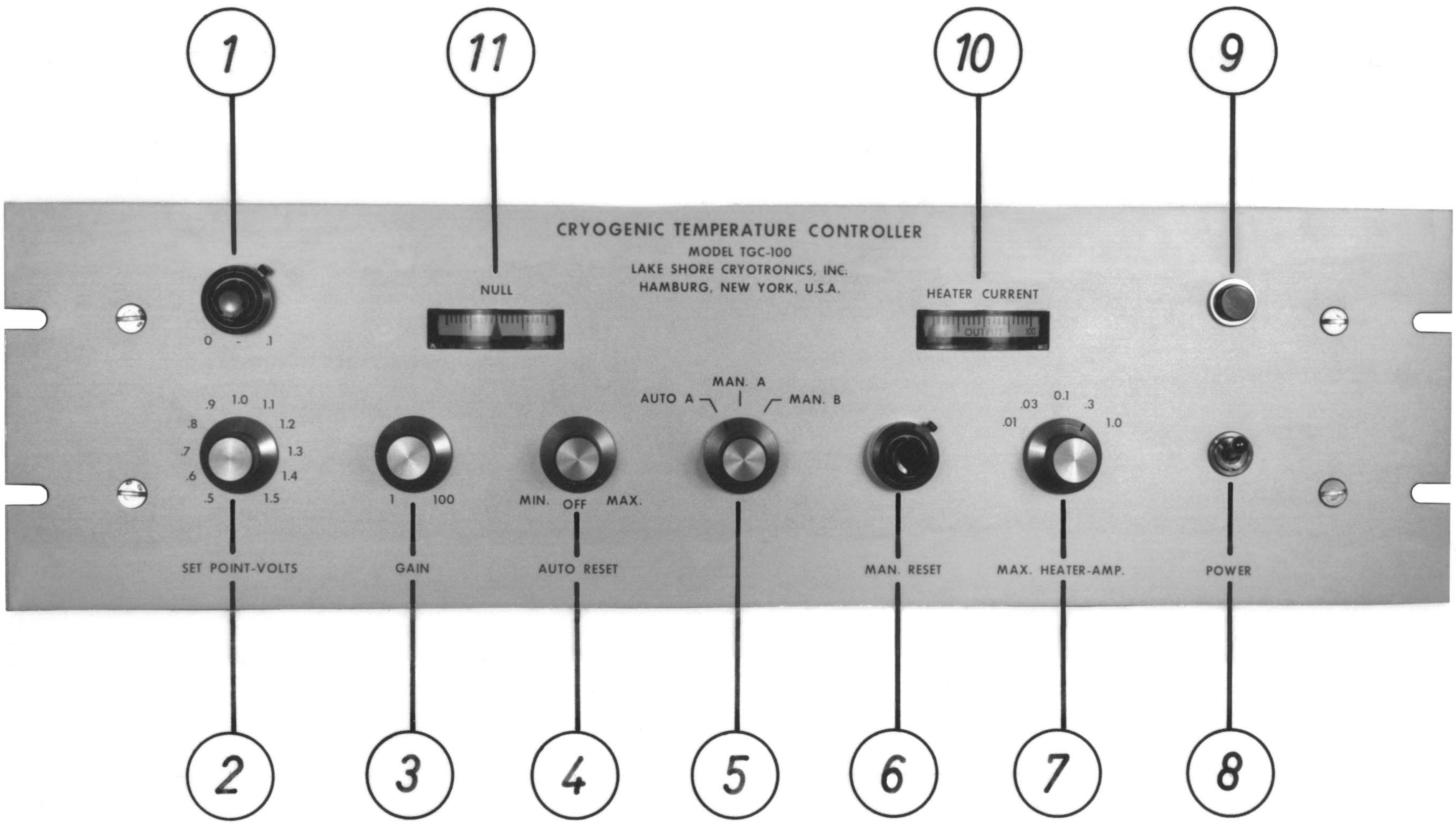


FIG. 3.1 FRONT PANEL

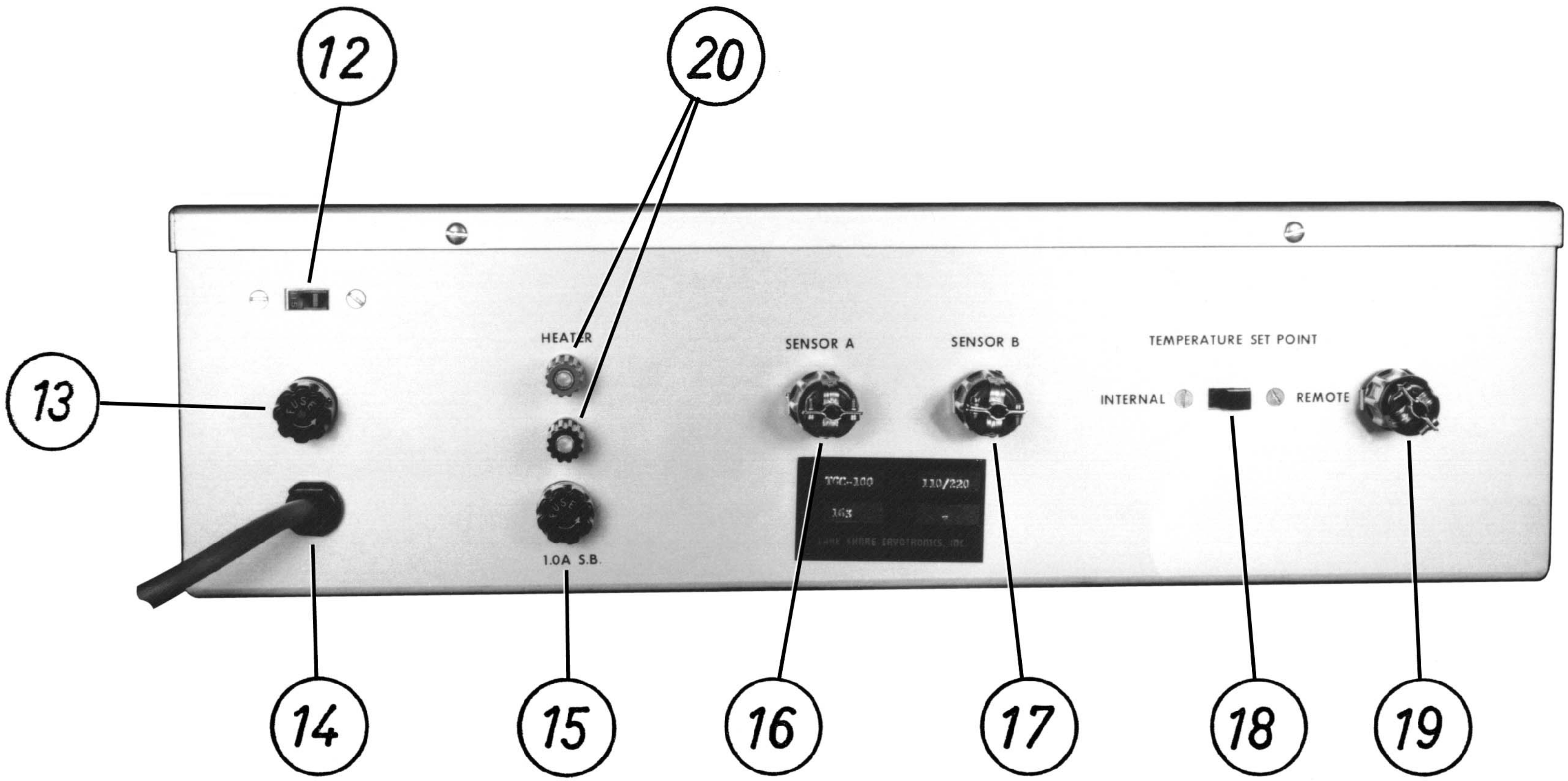


FIG. 3.2 REAR PANEL

Table 3.1 (cont.)

NO. KEY	NAME	FUNCTION
6	MAN. RESET	When mode selector switch (5) is in either MAN. A or MAN. B position, the MAN. RESET ten turn potentiometer permits the user to manually adjust the current to the heater element. (Caution: High settings will quickly boil away cryogenic fluids).
7	MAX. HEATER CURRENT	Switch selected current limiter. Use of a low setting will avoid inadvertent boil-off in setting up system.
8	PWR.	A. C. line switch (ON/OFF)
9	NO LABEL	A. C. line pilot light
10	HEATER CURRENT	Meters heater element current. Full scale deflection corresponds to MAX. HEATER CUR. switch (7) setting.
11	NULL	Measures the voltage difference between the set point voltage and the sensor output voltage. Meter is non-linear for large errors of either sign.
12	NO LABEL	A. C. line voltage selector slide switch
13	NO LABEL	A. C. line fuse (FU1). See para. 2.3
14	NO LABEL	A. C. line cord
15	1.0A, S. B.	Heater element line fuse, 1 AMP., Slow Blow
16	SENSOR A	Sensor A cable receptacle. (Five pin, Amphenol type 126-217 Plug)
17	SENSOR B	Sensor B cable receptacle. (Five pin, Amphenol type 126-217 Plug)
18	TEMP. SET POINT INTERNAL, REMOTE	Selects between internal set point voltage divider and external divider for comparison with sensor voltage. Set point control (1) and (2) are inoperative when switch is in the "REMOTE" position. Be sure this control is set on "INTERNAL" since its location on the rear panel may cause one to overlook its setting when initially checking out the instrument.

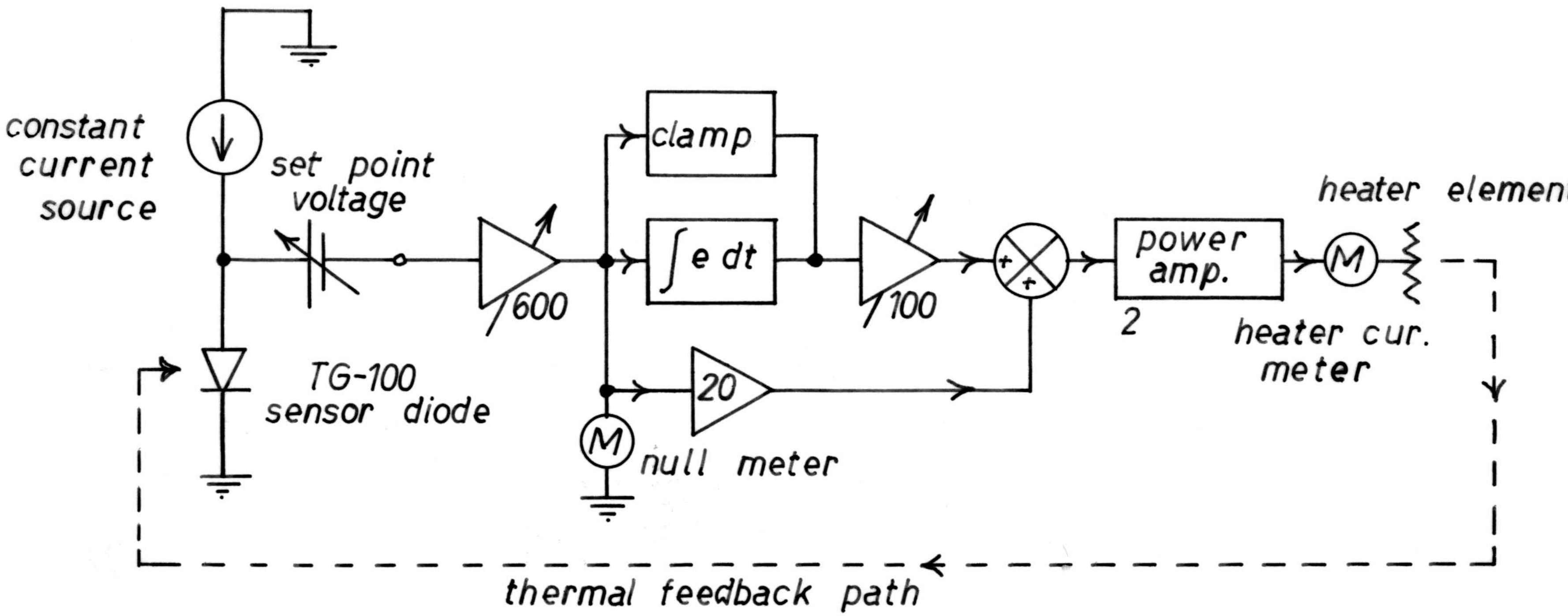


FIG. 3.3 BLOCK DIAGRAM, TGC-100 TEMPERATURE CONTROLLER

Table 3.1 (cont.)

NO. KEY	NAME	FUNCTION
19	NO LABEL	Remote set point voltage divider cable receptacle (Amphenol 126-195 plug).
20	HEATER	Heater element lead terminals (Grey is the high side and Black is the low side.)

3.3 Initial Checks

Initial checks, calibration checks and servicing procedures are described in Section V, MAINTENANCE.

3.4 Temperature Readout Mode

To use the TGC-100 as a cryogenic thermometer to measure the temperature of a calibrated diode connected to SENSOR A terminals, initially position switches and controls as follows:

(1) Temperature set point switch (Key No. 18) to "INTERNAL."

(2) Mode switch (Key No. 5) to "MAN. A."

(3) "MAN. RESET" (Key No. 6) to zero.

(4) "MAX. HEATER-AMP." (Key No. 7) to 0.01.

(5) "GAIN" (Key No. 3) to minimum setting.

(6) "AUTO RESET" (Key No. 4) to off.

(7) "POWER" switch (Key No. 8) to on.

The null meter will probably deflect off scale (either left or right) when the power switch is turned on. If the deflection is to the left, the set point voltage is less than the sensor voltage, if the deflection is to the right, the set point voltage is greater than the sensor voltage.

Adjust the set point voltage until the "NULL" meter is centered while increasing the "gain" towards maximum. Increasing the voltage will move the meter pointer to the right; decreasing the set point voltage will deflect the meter pointer to the left. After centering the meter, read the set point voltage by adding the vernier potentiometer reading (appropriately scaled) to the "SET POINT" switch setting value. The ten turn dial's one thousand divisions correspond to 100 millivolts, so that each dial division corresponds to 0.1 millivolts.

After determining the set point voltage, refer to the diode calibration chart to ascertain the diode temperature.

3.5 Constant Temperature Control Mode

Assume that a calibrated diode is in use as described in paragraph 3.4. To maintain a constant temperature, determine the corresponding set point voltage from the diode calibration chart. Set this voltage on the "SET POINT" switch and vernier.

Position controls as indicated below:

(1) Temperature set point switch (Key No. 18) to "INTERNAL."

(2) Mode switch (Key No. 5) to "AUTO A."

(3) "MAN. RESET" (Key No. 6) to zero.

(4) "MAX. HEATER-AMP" (Key No. 7) to 1.0 AMP.

(5) "GAIN" (Key No. 3) to minimum setting.

(6) "AUTO RESET" (Key No. 4) to off.

(7) "SET POINT VOLTS" switch and potentiometer to voltage corresponding to desired temperature.

(8) "POWER" switch (Key No. *) to on.

If the block or sample holder whose temperature is to be controlled is colder than the set point temperature, the sensor diode voltage will be high and the null meter will deflect to the left. Slowly increase the "GAIN" setting (Key No. 3) in a clockwise direction. The "HEATER CURRENT" meter should show an immediate up scale deflection proportional to the "GAIN" setting. The "NULL" meter should start to come off its full left deflection position as the gain is increased. As the sample holder temperature approaches the set point temperature, the NULL meter will approach center scale and the "HEATER CURRENT" meter will assume a steady value even with a further increase in the gain setting. Continue to increase the gain until an incremental change in gain produces a negligible reduction in the null error, but not so high as to produce oscillations.

To further reduce the null error, rotate the "AUTO RESET" gain control (Key No. 6) out of the detent (off) position in the clockwise direction. As the control is advanced, the null meter should approach the center position with unobservable error. Leave the "AUTO RESET" vernier in the position required to reduce the null error to zero, but below any level which induces oscillations.

Abruptly increase the set point vernier control by ten units. The NULL meter should deflect to the right and the HEATER CURRENT should go to zero immediately. As the sample holder cools, the NULL METER pointer should return towards zero.

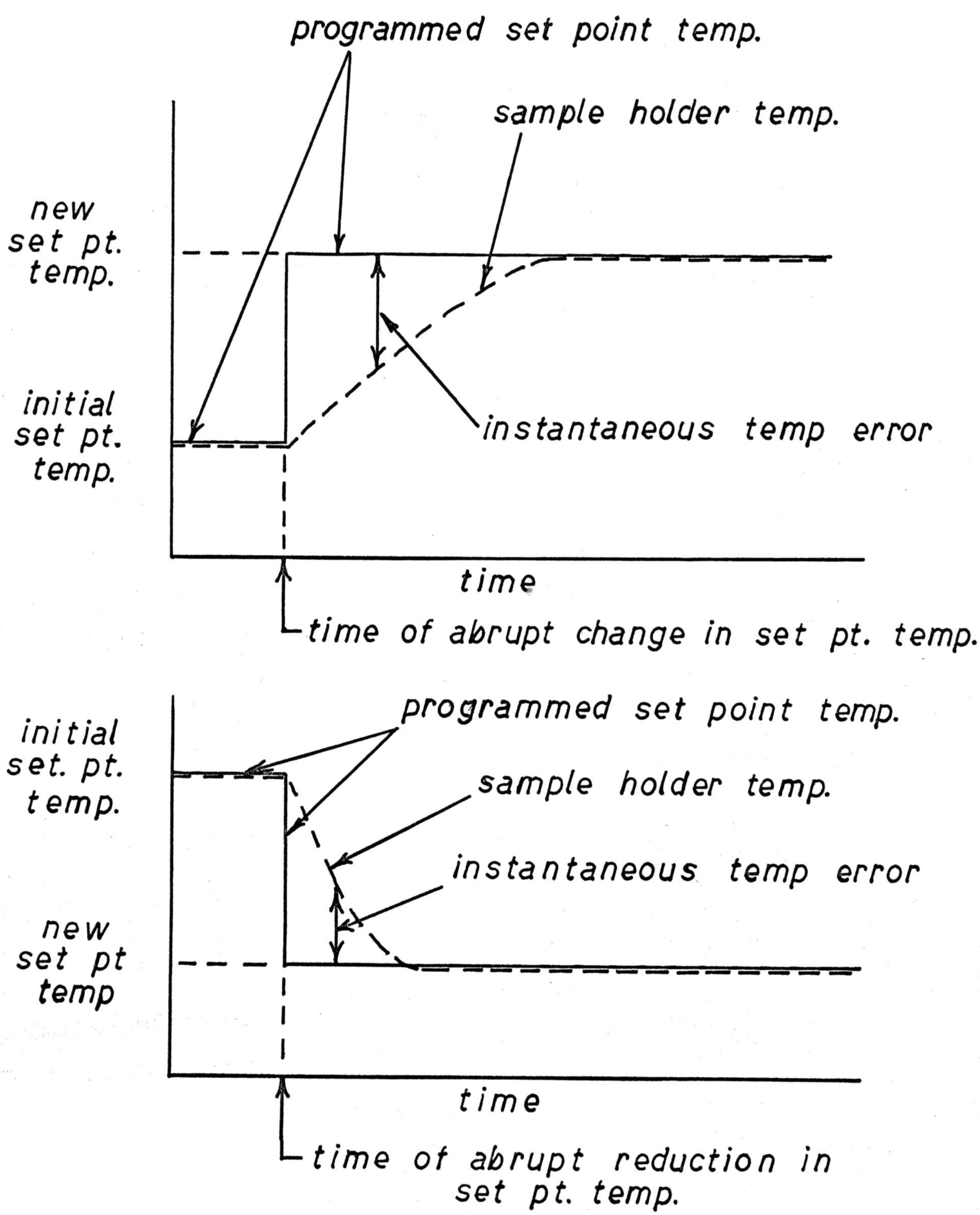


FIG. 3.4 TEMPERATURE VERSUS TIME CHARACTERISTICS OF CONTROLLER

As the NULL METER pointer approaches zero, the HEATER CURRENT will increase from zero to the new steady state value required to maintain the sample at the lower temperature requested. The NULL METER should read zero as the HEATER CURRENT stabilizes at its new value.

Now abruptly decrease the set point vernier control by ten units. The NULL meter should deflect to the left and the HEATER CURRENT meter should deflect toward full scale. As the sample holder heats, the NULL meter pointer will tend to zero and the HEATER CURRENT meter reading will decrease toward its new steady state value. As the NULL meter centers, the HEATER CURRENT should stabilize at the new constant value required to maintain the desired temperature.

A sketch of the temperature versus time pattern described above is given in Figure 3.4. Observe that there is no temperature overshoot or oscillation when the "GAIN" and "AUTO RESET" controls are properly adjusted. (This statement presupposes that the sample holder may be accurately modeled as a simple R-C type time constant circuit.)

If oscillations or overshoot are observed when changing the set point voltage in small increments, reduce the GAIN and AUTO RESET settings until oscillations are no longer observed.

3.6 Manual Heating Mode

By placing the mode selector switch (Key No. 5) in either position MAN A or MAN B, a constant current may be supplied to the heater element. The magnitude of the current is determined by the setting of the MAN. RESET potentiometer (Key No. 6) and the MAX. HEATER AMP. switch (Key No. 7). The current supplied to the heater is indicated on the HEATER CURRENT meter. The full scale reading of the meter corresponds to the MAX. HEATER AMP switch setting.

3.7 Temperature Readout Mode (Sensor B)

In some applications, the temperature is controlled (or regulated) at one physical location while it is desired to measure the temperature at a second location. This requires two sensors, "Sensor A" located at the temperature control point and "Sensor B" at the second point where only the temperature is to be measured. Sensor B must be calibrated.

Assume that the temperature at Sensor A has been stabilized by operating the controller in the constant temperature control mode as described in Section 3.5. By observing the steady HEATER CURRENT reading, one may switch to the MAN A mode as described in Section 3.6 and establish this same current by adjusting the MAN RESET potentiometer. By alternating between the AUTO A and MAN A modes, the MAN RESET potentiometer may be trimmed sufficiently accurately to hold the temperature steady in the MAN A position. Then switch to the MAN B position and quickly adjust the SET POINT VOLT switch and potentiometer to zero the NULL meter. This reading is used to determine the temperature of sensor B. After taking the Sensor B voltage reading, reset the SET POINT VOLT switch and potentiometer to the desired temperature control point and then return to AUTO A control mode.

If there is appreciable null error upon returning to the AUTO A mode of control, the adjustment of the MAN RESET control should be refined and the measurement of the Sensor B voltage repeated.

Since the system is operating "open loop" or is "coasting" in both the MAN A and MAN B mode of control positions, no adjustments or changes should be made in the cryostat system which would introduce transients during this period of time.

3.8 Remote Temperature Programming

Remote temperature control can be achieved by replacing the internal Kelvin-Varley voltage divider with an external resistive divider connected to J_3 and switching the "TEMPERATURE SET POINT" to the "REMOTE" position. To insure maximum accuracy, the total resistance between pins E-D of J should be equal to 515 ohms. The remote set point connection diagram is shown in Figure 3.5.

SECTION IV

Theory of Operation

4.1 Introduction

This section contains the theory of operation of the TGC-100 Controller and a functional characterization of the controller in Laplace transform notation to aid the thermal system designer in system stability analysis.

4.2 General Description

Refer to Figure 3.3 and Figure 5.2 as an aid in the following discussion. With reference to Figure 3.3, a precision constant current source causes 10 microamperes of current to flow through the sensor diode. The set point voltage source (or bucking voltage) is subtracted from the diode voltage and the difference (or error) signal is amplified in a variable gain amplifier stage (operational amplifier A2 in Fig. 5.2). The amplified error is displayed on the NULL meter and also applied to (1) a gain of 20 amplifier, (2) an integrator circuit and (3) a bound or clamping circuit. The bounding circuit disables the integrator for large errors. The output of the integrator is amplified by a variable gain amplifier whose gain is set by the AUTO RESET potentiometer. The gain range is from 1 to 100. The integrator, bounding circuit, post integrator variable gain amplifier and constant gain of 20 amplifier are associated with operational amplifier A3, transistor Q1 and field effect transistor Q2 in Figure 5.2. The processed error signal drives the output power amplifier circuit whose voltage gain is 2. Operational amplifier A4 and transistors Q3 and Q4 in Fig. 5.2 comprise the power amplifier. The output of the power amplifier is metered by the HEATER CURRENT indicator and passed to the heater element. Closed looped control action is achieved by providing a thermal signal path between the heater element and the temperature sensing diode.

To illustrate the automatic temperature control action, suppose the sensing diode is colder than the programmed temperature setting. The diode voltage will be greater than the set point voltage which results in an error voltage. The greatly amplified error signal causes a current to flow in the heating element which raises the diode temperature and reduces its voltage. As the diode temperature approaches the set point temperature, the error signal is reduced and less power is supplied to the heater element. At some small temperature error (or offset) the power supplied to the heater element is just sufficient to heat the sample holder and diode to maintain a steady but slightly lower temperature. The AUTOMATIC RESET feature of the controller is used to reduce this error to zero. The automatic reset circuit integrates the error and this accumulated signal drives the output power amplifier. The integrator signal continues to grow as long as an error exists. The heater current continues to increase in response to the integrator signal. Eventually the error is driven to zero and the integrator signal assumes a constant value. This signal is precisely the value of heater current required to maintain the error at zero. The integrator capacitor stores or "remembers" this signal as the appropriate heater current level to maintain temperature coincidence between the diode and the set point temperature. In control theory* terminology, the AUTO RESET circuit raises the system type number from zero to one.

*"Feedback Control System Analysis and Synthesis" by John J. D'Azzo and Constantine H. Houpis, McGraw-Hill Book Co., New York, 1966, pg. 397.

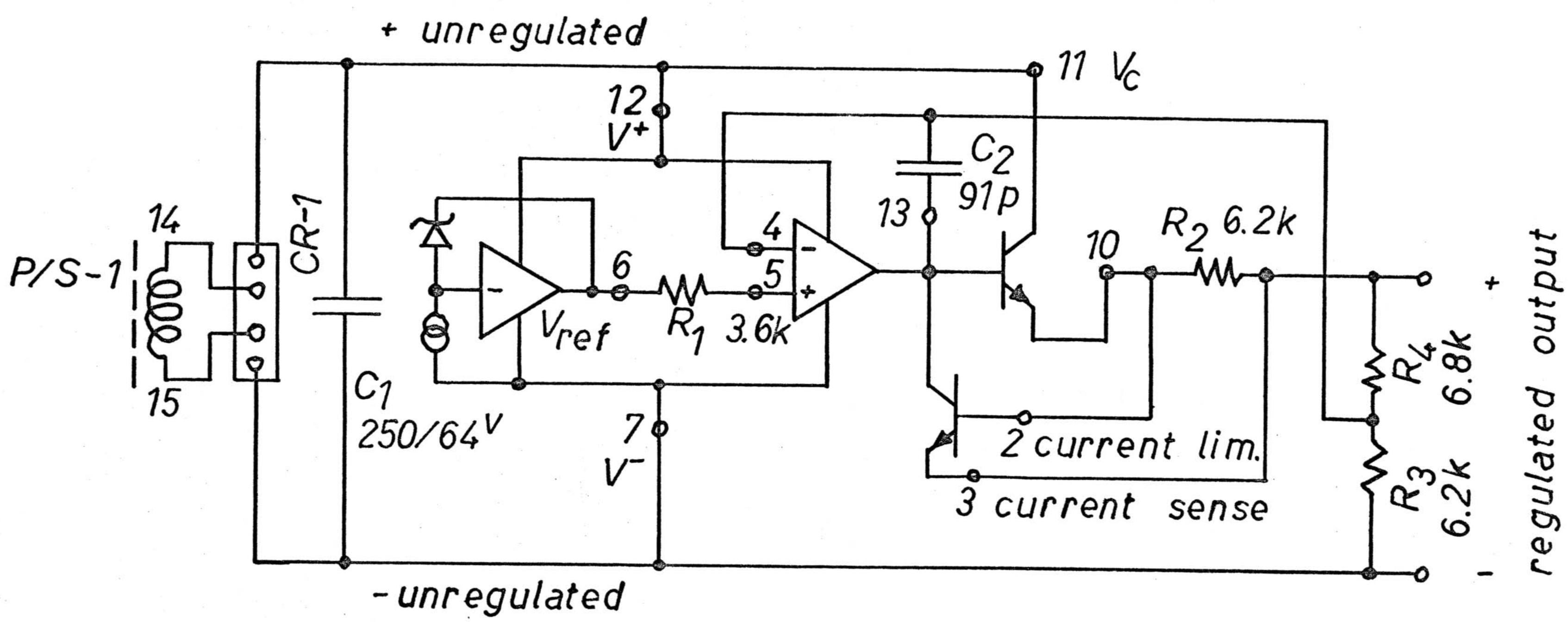


FIG. 4.1 OPERATIONAL POWER SUPPLY CIRCUIT USING A FAIRCHILD μA723 CHIP

4.3 Detailed Description

(a) Regulated Power Supplies

There are five, essentially identical, regulated power supplies in the instrument. They are designated as P/S-1 through P/S-5 in Figure 5.2. Each supply uses a Fairchild uA723 Precision Voltage Regulator as its main component. A detailed drawing of one of the supplies is given in Fig. 4.1. A description of this supply should suffice for all the others.

The secondary voltage of transformer T1 appearing at terminals 14 and 15 is rectified by diode rectifier bridge CR1-4 and filtered by capacitor C1. This unregulated voltage is applied to the Fairchild uA723 power supply leads 12 and 7. The reference voltage op-amp in the uA723 produces a stable, 7.1 volt reference voltage at pin 6. This voltage is externally coupled to the non-inverting input to the regulator op-amp. (pin 5) by resistor R_1. The value of R_1 is chosen to be equal to the parallel combination of R_3 and R_4 to minimize offset errors. Resistors R_3 and R_4 sample a fraction of the output voltage and apply it to the inverting input, pin 4. The regulator op-amp attempts to maintain the potential at pins 4 and 5 equal to one another in spite of variations in the line voltage and load current. The output current is passed through R_2. Automatic current limiting is accomplished by current sampling resistor R_2 and the current shut down transistor connected to pins 2 and 3. If the current through R_2 is excessive, the resulting voltage developed across R_2 causes the transistor to conduct, diverting base current from the series pass transistor.

(b) Diode Constant Current Supply

Referring to Fig. 5.2, power supplies P/S-1 and P/S-2, and operational amplifier A1 constitute the main components in the diode constant current supply. Due to the high input impedance of the operational amplifier A1, the diode current is forced to flow through resistor R26 developing approximately 4.99V at 10 uAmps. The wiper of potentiometer R23 is positioned so that an equal voltage is developed between the wiper of R23 and the junction of CR-22A and R24. With the wiper so adjusted, any variation in the diode current will result in a differential error voltage. When amplified and applied to the cathode of the sensor diode, this signal will be of such a polarity as to drive the diode current back towards its design value of 10 uAmps.

The entire constant current supply system was designed to be fully floating so that the cathode of the sensor diode might be returned to common.

(c) Set Point Voltage Supply and Divider

Floating power supply P/S-3 preregulates the voltage used to supply reference diode CR-13. The doubly regulated voltage appearing between tie point (TP) 5 and the cathode of CR-13 is applied to Kelvin-Varley voltage divider consisting of R30, R31, R101 through R114, R28, R29, R33 and R34. The set point voltage proper consists of the potential developed between tie point 5 and the wiper of potentiometer R28.

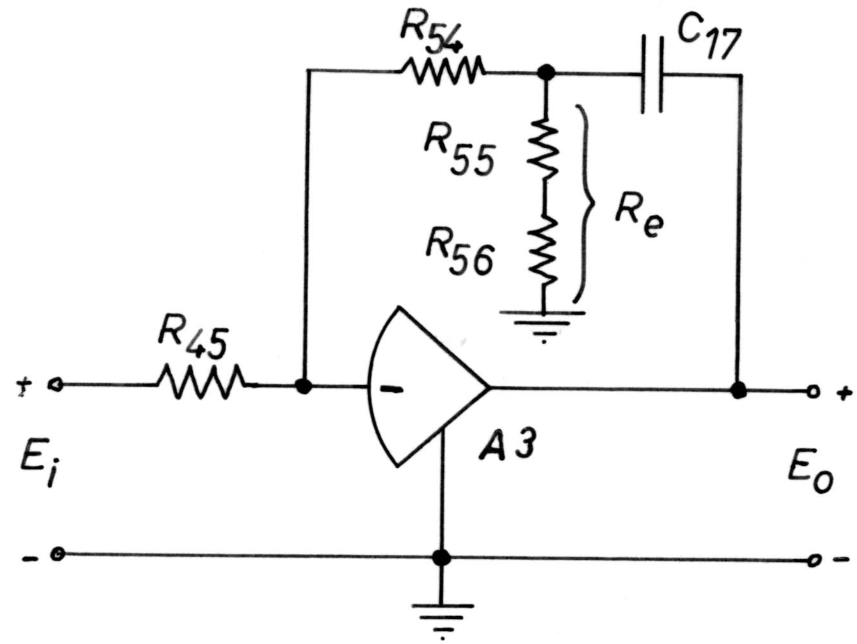
The floating set point voltage power supply and Kelvin-Varley voltage divider constitute a potentiometric loop. When the set point voltage equals the sensor diode voltage, none of the diode constant current supply is diverted from the sensor diode.

(d) Variable Gain Amplifier

The variable gain amplifier shown in Fig. 3.3, with a gain range of 7.5 to 750, is realized by chopper-stabilized operational amplifier A2. The input resistor is R32 and the feedback element consists of R35 and potentiometer R37 and resistors R39, R40 and R41.

Diodes CR-26, 28, 29 and 36 comprise a soft-limiter and amplifier protection circuit. Large signals cause forward biased diodes to conduct which in turn reduces the effective feedback resistance and amplifier gain.

The output of amplifier A2 drives the null meter and subsequent stage A3. For small errors, the meter reading is proportional to the error. As the error amplitude increases, either diode CR-28 or CR-29 conducts reducing the gain of stage and the apparent error. Thus for large errors, the meter reading is logarithmic. Cross-over from linear to non-linear deflection occurs at approximately ±50% of full scale.



$$\frac{E_o}{E_i} = -\left[\frac{R_{54}}{R_{45}} + \frac{1}{SR_{45}C_{17}}\left(1 + \frac{R_{54}}{R_e}\right)\right]$$

FIG. 4.2 SIMPLIFIED EQUIVALENT CIRCUIT OF AUTOMATIC RESET AMPLIFIER

(e) Automatic-Reset Circuit, Bounding Circuit

The bound circuit, integrator, variable gain amplifier (Av of 1 to 100), and the constant gain of 20 amplifier shown in Fig. 3.3 are realized by operational amplifier A3, bipolar transistor Q1 and field effect transistor Q2 in Fig. 5.2. A simplified equivalent circuit of the stage is given in Fig. 4.2.

Application of the principle that the summing junction currents must add to zero yields the overall transfer function of the stage. The constant gain of 20 amplifier in Fig. 3.3 is represented by the term R57/R45 while the variable gain amplifier following the ideal integrator is represented by the term $(1 + R57/Re)/R_{45}C_{20}$ in the equation in Fig. 4.2.

The bounding circuit disables the integrating function for large errors when rapid corrective action is desired. The memory action of integrating capacitor C20 causes the controller to be sluggish in such transient operations. The method of disabling the capacitor depends upon the sign of the error and the polarity of the voltage across C20. If the voltage across capacitor C17 is of such a polarity as to make TP19 positive with respect to TP17, diode CR-33 conducts reducing the effective gain of the stage and discharging the capacitor.

The second mode of bounding occurs if the error signal at the base of Q1 becomes excessively negative. Q1 is normally biased by CR-30 so that field effect transistor Q2 is cut-off (approximately -9^V at the gate). As the base of Q1 becomes more negative, Q1 conducts current, increasing the collector voltage toward zero. The reduced bias on FET Q2 causes its source-drain impedance to act as a shunt resistor across capacitor C20. This shunting effect discharges the capacitor and converts the ideal integrator action to a type zero action.

The switch S3 is open when the AUTO RESET control is out of the detent (off) position.

(f) Output Power Amplifier

The processed error signal appearing at TP18 is greatly amplified in power by the components Q3, Q4 and op-amp A4 before being applied to the heater element. Transistors Q3 and Q4 constitute a Darlington series pass element in a voltage regulator like circuit. They are inside the feedback loop associated with op-amp A4, R65 being the feedback resistor. The input resistor for the op-amp is R62 so that the voltage gain of the power amplifier circuit is R65/R62 or approximately A_V=2. At rated output current of one ampere, the voltage appearing at TP20 is -10 volts. Use of a heater resistance in excess of ten ohms will reduce the available heater current below the rated maximum value of 1 ampere.

Winding 5-6-7 on transformer T1, diodes CR-22 and CR-23 and capacitor C16 constitutes the power supply for the series pass elements Q3 and Q4.

Power supplies P/S-4 and P/S-5 are bus supplies for operational amplifier A3 and A4, transistor Q1 and FET Q2.

(g) Manual Heater Current Control

When the mode selector switch is set to either MAN A or MAN B position, switch secion S1-F connects the input of the power amplifier stage to the wiper of potentiometer R54. Varying the wiper position from zero to its maximum will very the voltage at TP20 from zero to -9 volts. The heater element current is thus varied proportionately to the setting of R54 and the maximum heater current switch (S4) position.

(h) Heater Current Metering and Limiting

The heater element current is measured by the heater current ammeter, shunted by resistor R201 through R205 as appropriate for the current range selected. The full scale output current is determined by the series combination of the heater element resistance and one of the group of resistors R206 through R209. This series combination is connected across the nominal -10 volt output of the power amplifier. Significant deviation of the heater element resistance from its nominal value of 10 ohms will impair meter calibration accuracy only on the 1 amp and 0.3 amp ranges.

Under no circumstances shall the rating of fuse FU2 be increased above one ampere in an attempt to achieve a power dissipation of ten watts in a heater element whose resistance is different from ten ohms. Such a substitution invalidates the instrument warranty and is likely to damage the output power amplifier circuit.

SECTION V

Maintenance and Troubleshooting

5.1 Introduction

This section contains instructions for maintaining and calibrating the controller, nominal voltage values and gains, circuit schematic diagram, printed circuit board component diagram and parts lits.

5.2 Test Equipment and Accessories

An RCA Senior Voltohmit vacuum tube voltmeter or equivalent; a ten ohm, ten watt resistor to simulate the heater element; and a precision 75K resistor connected to simulate the diode in a connector assembly wired according to Fig. 2.1 (c) are normally sufficient for testing and calibrating the TGC-100 Controller.

5.3 General Remarks

Upon initial installation, the single most probable cause of system malfunction is an improperly connected temperature sensing diode. If it is impossible to zero the null meter at any setting of the set point voltage controls, carefully examine the cable/diode assembly to insure that the diode polarity is correct, that the sensor is plugged into the "SENSOR A" receptacle and that the "TEMPERATURE SET POINT/INTERNAL/REMOTE" slide switch at the rear of the case is in the INTERNAL position.

Because of the highly reliable solid state design of the controller, it is most unlikely that the controller will be a source of difficulty. For this reason, it is advisable to examine other portions of the cryogenic system before testing the controller proper. Some suggested checks are:

(1) Open or shorted sensor and heater leads, particularly in the vicinity of the sample holder if it is subject to frequent dis-assembly.

(2) Leakage paths between heater and sensor leads giving rise to electrical feedback in addition to thermal feedback.

(3) Premature loss of cryogenic fluid due to thermal shorts in dewar, ice blocks in lines, sample holder immersed in cryogen, sample holder in vapor whose temperature is above the controller set point temperature, etc.

(4) Excessive thermal path phase lags will cause the control loop to be unstable at high gain settings. Physical separation between the diode and heater, particularly by paths of small thermal cross-section should be avoided.

(5) Examine heater element fuse FU2.

If it is indicated that the controller is malfunctioning after performing the tests to be described below, it is recommended that the instrument be returned to the factory for repair. The computer grade operational amplifiers used in the instrument are costly and may be permanently damaged if subjected to inappropriate test voltages or excessive soldering iron heat. Although premium materials and techniques have been used to fabricate the instrument circuit board, there is always the risk of lifting a connection pad or cracking the board when unsoldering a component.

5.4 Servicing Printed Circuit Boards

It is suggested that components be unsoldered for trouble shooting only as a last resort. Attempt to infer component currents by voltage tests rather than removing a lead and seriesing it with an ammeter. All voltages are available for measurement from the top side of the printed circuit board. Therefore the board need only be removed when it is necessary to replace a component. To remove the printed circuit board, unscrew the eight bolts which attach the board to the stand-off studs mounted on the bottom of the case.

Swing the rear of the board up, using the front edge as a pivot. Be sure to clear the line cord retainer and fuse holders. Be sure to support the board in the raised position. If the board is cantilevered, it may break or develop hairline cracks in the printed wiring.

Use a low heat (25 to 50 watts) small-tip, freshly tinned soldering iron. Use small diameter, rosin core solder. Remove a component lead by applying heat to the lead, observing the solder melt and then pulling the lead through the board from the top side. Never apply tension to printed wiring from the bottom side.

Thoroughly clean all of the old solder from the mounting hole before inserting a new component with the use of a wick or desoldering suction device. Shape the new component and insert in mounting hole. Do not use heat or force to insert the new component. If the leads will not go through the hole, file the lead or clean the hole more thoroughly. Once mounted properly, apply heat to lead and wiring pad simultaneously and resolder. Clean excess flux from the connection and adjoining area with warm water and weak detergent if need be. (Contamination in some areas of the board can seriously degrade the high input impedance of the operational amplifiers.)

5.5 Operational Checks

Replace the sensor diode connector plug with a test plug made up according to Fig. 2.1 (c). Substitute a precision 75K ohm resistor for the sensor diode in the test plug. Remove the heater element leads and place a ten watt, ten ohm resistor across the heater output terminals.

Ten microamperes flowing through the 75K test resistor should develop a potential of 0.75 volts. With the gain set at maximum position and the mode selector switch in position MAN A (assuming the test plug is in SENSOR A receptacle), attempt to null the error with a set point voltage in the vicinity of 0.75 volts. The null meter should swing smoothly as the set point voltage vernier is varied in the vicinity of the null.

While still in the MAN A position, set the MAXIMUM HEATER AMP switch at 1 amp. Vary the MAN. RESET potentiometer from zero towards its maximum. The current meter should increase linearly along with the advance of the MAN RESET control. With the MAN RESET control set to give mid-scale heater current meter deflection, rotate the MAX HEATER AMP switch through all of its positions. The heater current meter indication should remain approximately at midscale in all of the positions.

Zero the null meter with the set point voltage controls. Turn the AUTO RESET and GAIN controls to mid-scale position. Set the MAX HEATER CUR. switch to 1 amp. Position the mode control switch to AUTO A. Abruptly rotate the set point voltage vernier counter clockwise sufficiently to cause a -10 unit deflection of the NULL meter. The heater current meter deflection will consist of two components. The first is a rapid step rise due to the steady null error and a second, gradually rising component due to the AUTO RESET circuit integrating the steady error. The heater current meter will gradually rise towards full scale deflection. The rate at which the heater current rises is determined by the AUTO RESET time constant setting. The rate is a minimum in the counterclockwise position and a maximum in the fully clockwise position.

Abruptly rotate the set point voltage vernier clockwise to cause +10 units deflection of the NULL meter. The HEATER CURRENT meter should gradually decrease from full scale deflection to zero. The rate at which the current meter goes to zero is in part determined by the bounding circuit. Its non-linear behavior accounts for the asymetry in the temperature versus time characteristics as shown in Fig. 3.4.

If the instrument responds to the tests outlined above as indicated, either the trouble lies elsewhere in the system or the malfunction in the controller is of a subtle nature. As an aid in trouble shooting in the latter case, typical voltages and gains under specified conditions are given in Section 5.6.

5.6 Nominal Voltages and Gains

The following voltage measurements were made with an RCA Senior Voltohmist meter. A 1%, 75K resistor was used to simulate the diode and a 10 ohm, 10 watt resistor was used in place of a heater element.

The voltage across the input filter capacitors C1, C4, C7, C10 and C13 in power supplies P/S-1 through P/S-5 nominally 24 volts with 117 VAC line voltage. The output voltage which appears between terminals 3 and 7 of the uA723 integrated circuits is 15 volts. The sampling resistors are proportional so that the potential between pin 4 and pin 7 is approximately 7 volts.

Reference diodes CR-22A and CR-13 are reverse biased at 6.2 volts.

The voltage appearing across capacitor C16 in P/S-6 varies between approximately 14 and 19 volts, depending upon the heater element current. At no load the voltage is 19 volts, decreasing to 14 volts at 1 ampere output.

The emitter of Q1 is biased to +0.5V to compensate for the turn on voltage of Q1.

The NULL meter voltage dropping resistor R46 is chosen so that approximately ±0.25 volts at the output terminal of operational amplifier A2 produces full scale meter deflection. With the mode control set to AUTO A, and both the GAIN and AUTO RESET controls in their maximum clockwise positions, the gate voltage of FET Q2 and the error voltage appearing at the output of op-amp A2 are related as:

NULL METER READING	GATE VOLT. VOLTS
+50	-11.0
0	
-10	-10.7
-20	-10.4
-30	-8.9
-40	-6.4
-50	-3.44
-60	-1.6
-70	+0.24
-80	+0.26

The output power amplifier stage may be checked by placing the mode selector switch in the MAN A position. The potential across R54 (terminals 6 to 7) is 5 volts. The voltage at terminal 20 should be approximately two times the voltage selected between the slider of R51 and ground. The voltage at the output of amplifier A4 is about one volt more negative than the voltage at terminal 20 because of the base emitter drops of Q3 and Q4.

The gain of op-amp stage A2 may be inferred from the set point voltage vernier and the NULL meter. Each 10 units of NULL meter deflection represents 25 millivolts of signal at terminal 12 while each of the 500 divisions (engraved lines) on the set point voltage vernier represents 200 microvolts. The maximum gain of the A2 stage is approximately 750.

With the AUTO RESET control in the off position (in the switch detent) and the MAX HEATER CUR switch in the 1 amp. position, the total voltage gain of amplifiers A3 and A4 may be inferred. The CURRENT METER corresponds to a 10 volt full scale voltmeter if a 10 ohm heater element is used. Comparison of the incremental output voltage change to the corresponding incremental NULL meter error change will yield the gain. The nominal cascade gain of the last two stages is 40.

Gain checks should be performed by first zeroing the NULL meter with the SET POINT VOLTAGE VERNIER. A small voltage change is made in the vernier dial setting and the resulting changes in the NULL meter and CURRENT meters observed.

5.7 Parts List, Component Location Diagram and Schematic

Table 5.1

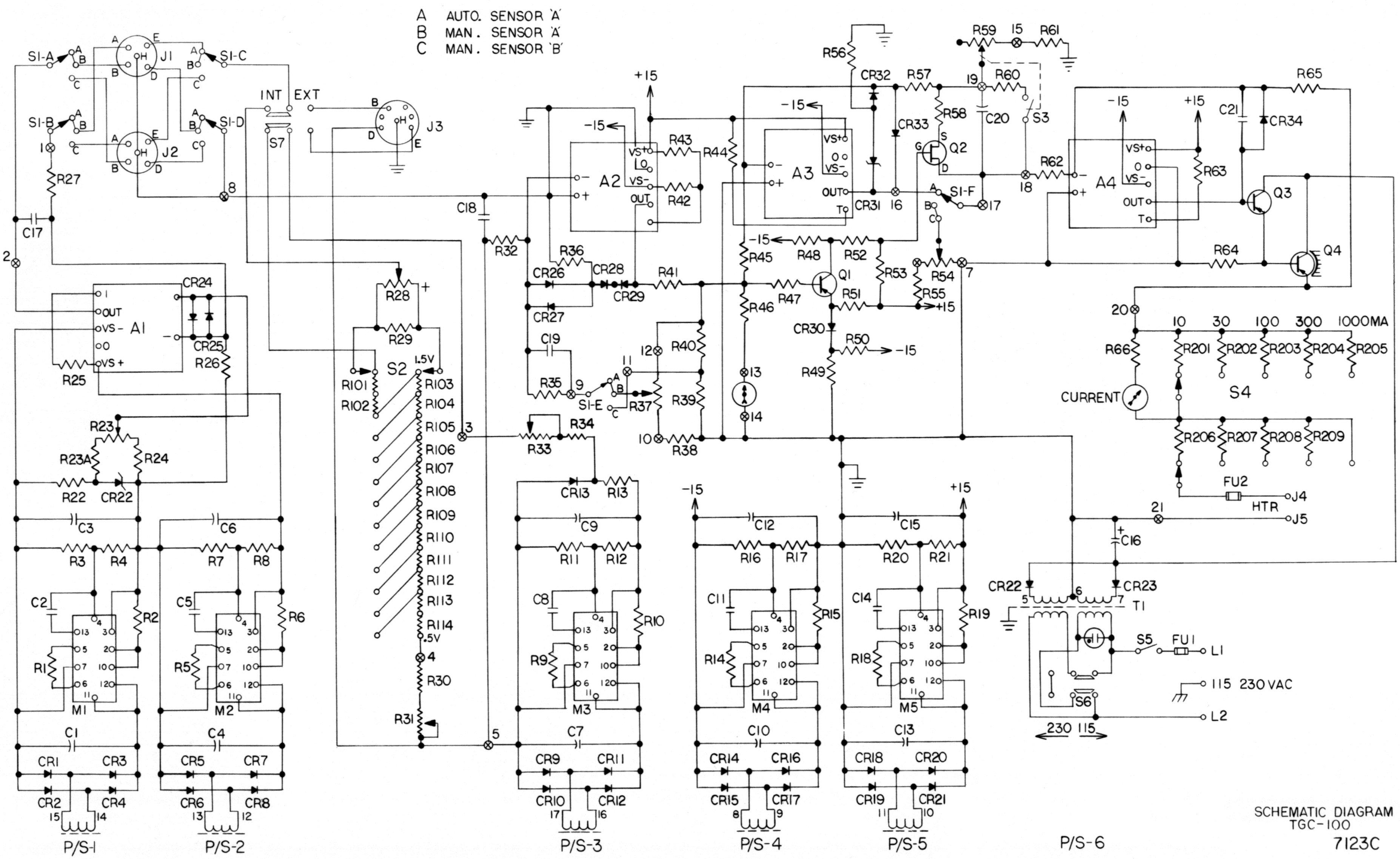
PARTS LIST

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
R1	3.6K, 1/4W, 5%	
R2	6.2K, 1/4W, 5%	
R3	6.2K, 1/8W, 1% (NOMINAL)	
R4	6.8K, 1/8W, 1%	
R5	3.6K 1/4W, 5%	
R6	6.2K, 1/4W, 5%	
R7	6.2K, 1/8W, 1% (NOMINAL)	
R8	6.8K, 1/8W, 1%	
R9	3.6K, 1/4W, 5%	
R10	6.2K, 1/4W, 5%	
R11	6.2K, 1/8W, 1% (NOMINAL)	
R12	6.8K, 1/8W, 1%	
R13	3.6K, 1/4W, 5%	
R14	6.2K, 1/4W, 5%	
R15	6.2K, 1/8W, 1% (NOMINAL)	
R16	6.8K, 1/8W, 1%	
R17	3.6K, 1/4W, 5%	
R18	6.2K, 1/4W, 5%	
R19	6.2K, 1/8W, 1% (NOMINAL)	
R20	6.8K, 1/8W, 1%	
R21	7.5K 1/8W, 1%	
R22A	6.1K, 1/8W, 1%	
R22	5K TRIMPOT, HELIPOT 58PR5000	
R23	21.5K, 1/8W, 1%	
R24	10K to 40K, 1.4W, 1% FACTORY SELECTED	
R25	499K, 1/8W, 0.1%, CEA 1RC	
R26	HELIPOT 7216 R1002.1	
R27	HELIPOT 7216 R1002.1	
R28	248, 1/8W, 0.1%	
R29	HELIPOT 58PR20	
R30	2.94K, 1/8W, 1%	
R31	2,260 1/8W, 0.1%	
R32	HELIPOT 58PR500	
R33	0.56 MEG, 1/4W, 5%	
R34	100K, 1/4W, 5%	
R35	2.7K 1/4W, 5%	
R36	FACTORY SELECTED	
R37	FACTORY SELECTED	
R38	10K, LINEAR TAPER (GAIN CONTROL)	CM38800
R39	100, 1/4W, 5%	
R40	10K, 1/4W, 5%	
R41	100, 1/4W, 5%	
R42	510, 1/8W, 1%	

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
R43	1,000, 1/8W, 1%	
R44	20K, 1/4W, 5%	
R45	51K, 1/4W, 5%	
R46	100K, 1/4W, 5%	
R47	33K, 1/4W, 5%	
R48	15K, 1/4W, 5%	
R49	200, 1/4W, 5%	
R50	9.1K, 1/4W, 5%	
R51	5K, HELIPOT 7216 R5K L.25 (MANUAL RESET CONTROL)	
R52	FACTORY SELECTED	
R53	2K, 1/4W, 5%	
R54	1MEG, 1/4W, 5%	
R55	1MEG POTENTIOMETER (AUTO RESET CONTROL)	CM38799
R56	10K, 1/4W, 5%	
R57	1K, 1/4W, 5%	
R58	33K, 1/4W, 5%	
R59	FACTORY SELECTED	
R60	68K, 1/4W, 5%	
R61	10K, 1/4W 5%	
R101 R114 R200 R209	SEE END OF PARTS LIST	
C1	250 ufd., 64 VDC, AMPEREX	
C2	CM05FD, MALLORY 111J03	
C3	250 ufd., 64 VDC, AMPEREX	
C4	CM05FD, MALLORY 111J03	
C5	250 ufd., 64 VDC, AMPEREX	
C6	CM05FD, MALLORY 111J03	
C7	250 ufd., 64 VDC, AMPEREX	
C8	CM05FD, MALLORY 111J03	
C9	250 ufd., 64 VDC, AMPEREX	
C10	CM05FD, MALLORY 111J03	
C11	2500 ufd., 50 VDC, SPRAGUE 36D262G050AB2A	
C12	RESERVED DESIGNATOR	
C13	0.39 ufd., 100 VDC, PARKTRON	
C14	0.22 ufd., 100 VDC, ELMENCO 1MD-3-224	
C15	RESERVED DESIGNATOR	
C16	RESERVED DESIGNATOR	
C17	0.27 ufd., 15 VDC, TANTULUM	
C18	CM05FD, MALLORY 111J03	
HS1	HEATSINK, WAKEFIELD ENG., MODEL 690-3-BA	
HS2	HEATSINK (CR6), WAKEFIELD ENG., MODEL 695-B	
HS3	HEATSINK (CR7), WAKEFIELD ENG., MODEL 695-B	

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
A1	OPERATIONAL AMPLIFIER	5825
A2	OPERATIONAL AMPLIFIER	5823
A3	OPERATIONAL AMPLIFIER	5825
A4	OPERATIONAL AMPLIFIER	5824
M1	VOLT. REG., FAIRCHILD 6W7723393	
M2	VOLT. REG., FAIRCHILD 6W7723393	
M3	VOLT. REG., FAIRCHILD 6W7723393	
M4	VOLT. REG., FAIRCHILD 6W7723393	
M5	VOLT., REG., FAIRCHILD 6W7728393	
CR1	BRIDGE RECT., MALLORY FWX100	
CR2	BRIDGE RECT., MALLORY FWX100	
CR3	BRIDGE RECT., MALLORY FWX100	
CR4	BRIDGE RECT., MALLORY FWX100	
CR5	BRIDGE RECT., MALLORY FWX100	
CR6	1N1342A, INTERNATIONAL RECT.	
CR7	1N1342A, INTERNATIONAL RECT.	
CR8	1N4571A, REF. DIODE, MOTOROLA	
CR9	SILICON PROTECTION DIODES	411
CR10	SILICON PROTECTION DIODES	411
CR11	SILICON PROTECTION DIODES	411
CR12	SILICON PROTECTION DIODES	411
CR13	1N4571A, REF. DIODE, MOTOROLA	
CR14	1N662, SIL. DIODE	
CR15	1N662, SIL. DIODE	
CR16	1N662, SIL. DIODE	
Q1	2N3638	
Q2	2N5459	
Q3	RCA 39619	
Q4	2N4901, MOTOROLA	
S1	MODE SELECTOR SWITCH	
S2	SET POINT SWITCH ASSEMBLY	
S3	PART OF POTENTIOMETER R55	
S4	HEATER CURRENT METERING SW. ASSEMBLY	
S5	SPST, POWER SW., A.H.&H. 81024-GB	
S6	DPDT, SWITCHCRAFT 46256LF	
S7	DPDT, SWITCHCRAFT 46206L	
FU1	FUSE HOLDER, LITTLEFUSE 342004	
FU2	FUSE HOLDER, LITTLEFUSE 342004	

REF. DESG.	DESCRIPTION				LAKE SHORE PART NO.
J1	5 PIN SENSOR SOCKET, AMPHENOL 126-218				
J2	5 PIN SENSOR SOCKET, AMPHENOL 126-218				
J3	7 PIN REMOTE SET POINT, AMPHENOL 126-198				
J4	HEATER BINDING POST, E.F.JOHNSON, 111-0113-001				
J5	HEATER BINDING POST, E.F.JOHNSON, 111-0103-001				
T1	POWER TRANSFORMER				T-21
PL1	PILOT LIGHT ASSEMBLY, INDUSTRIAL DEVICES 1040A87				
MT1	NULL METER -100-0-100 uAmp.				
MT2	CURRENT METER 0-1 MilliAmp.				
DL1	10 TURN DIAL FOR R26, HELIPOT 2607				
DL2	10 TURN DIAL FOR R27, HELIPOT 2607				
R101	48.7, 0.1%, CEA 1 RC RESISTORS, EA. SET POINT VOLTAGE DIVIDER ASSEMBLY				
R114					
R200	412,	0.1W,	1%		
R201	55,	0.1W,	1%		
R202	17.2	0.1W,	1%	HEATER CURRENT	
R203	5.0,	0.1W,	1%	METERING AND	
R204	1.65,	0.5W,	1%	LIMITING SWITCH	
R205	0.499,	1W,	1%	ASSEMBLY	
R206	1,000,	1/4W,	1%		
R207	330,	1/2W,	1%		
R208	91,	2W,	1%		
R209	24,	5W,	1%		



SCHEMATIC DIAGRAM
TGC-100

7123C

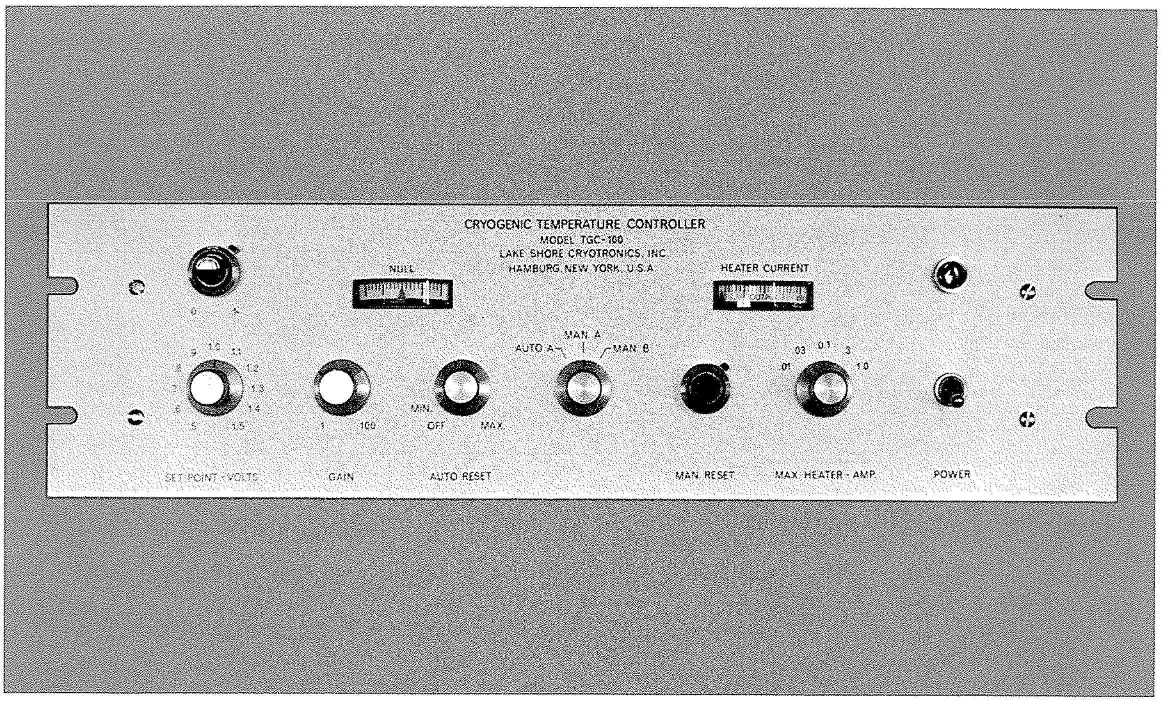
SECTION VI

Appendixes

MODEL TGC-100

CRYOGENIC TEMPERATURE CONTROLLER

1°K TO 300°K



The TGC-100 Cryogenic Temperature Controller has been designed especially for use with the TG-100 full range temperature sensor.

The TGC-100 allows accurate and concurrent temperature control and temperature readout of the control temperature over the range of 1 to 300°K. In addition, a second sensor to measure the sample temperature can be switched into the readout circuit without adversely affecting the controlled temperature. The second sensor is excited during temperature readout only.

SPECIFICATIONS

GENERAL:

Controller Range	– 1 to 300°K nominal
Heater Output	– 10^{-3} to 10 watts, 0-1 amp, 0-10 volts
Sensor	– Gallium Arsenide Diode, Model TG-100 with grounded or ungrounded case
Sensor Input	– 4 terminal connection, constant current potentiometric
Sensor Current	– 10 uA
Voltage Input	– 115V, 220V, 50-60 Hz
Power Consumption	– 30 VA
Construction	– Solid state electronics
Weight	– 10 pounds
Dimensions	– 5¼" high, 19" wide, 11½" deep – rack mounting

TEMPERATURE CONTROL:

Set Points	– .5 to 1.6 V Switch-100 mV per step 10 turn potentiometer – .1 mV smallest division .1% linearity
Repeatability	– ± 10 UV (.01°K or better)
Automatic Reset	– 1 to 30 sec., or OFF
Manual Reset	– 0 to 90% of full output
Auto.-Man. Switch	– For pre-run adjustments or open loop temperature measurements
Heater Current Ranges	– 10 mA, 30 mA, 100 mA, 300 mA, 1 A
Heater Resistance for Max Power	– 10 ohms
Controller Gain	– 3 amps/mV in automatic mode

Remote Temperature Control (set-point)

TEMPERATURE READOUT: 2 Sensor Capability – Control sensor and sample sensor

Accuracy	– equivalent to 100 uV - .1°K worst case
Excitation Current	– 10 uA
Excitation Current Regulation	– .05%
Sensor Calibration	– must be calibrated over desired readout range

APPLICATION DATA:

1. Uncalibrated sensors are acceptable for control mode only. Sensors must be calibrated for temperature readout mode.
2. Sensors can be wired into controller in 2 or 4 lead connection, although 4 lead connection is recommended.
3. Sensor excitation currents greater than 10 uA can be provided on special order.
4. Power cable, sensor leads and Remote Temperature Control are wired into the rear of the chassis.
5. Use of an additional switch (not supplied with the TGC-100) can be used for temperature readout of additional sensors if desired. Input from this switch would be wired into the "Sensor B" input in rear of chassis. Switch should be free of contact resistance and be "shorting" type.
6. Sensors must be ordered separately as they are not included with the TGC-100 as a part of the instrument price.

LAKE SHORE CRYOTRONICS, INC.

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HAMBURG, N. Y. 14075 716–627-2131

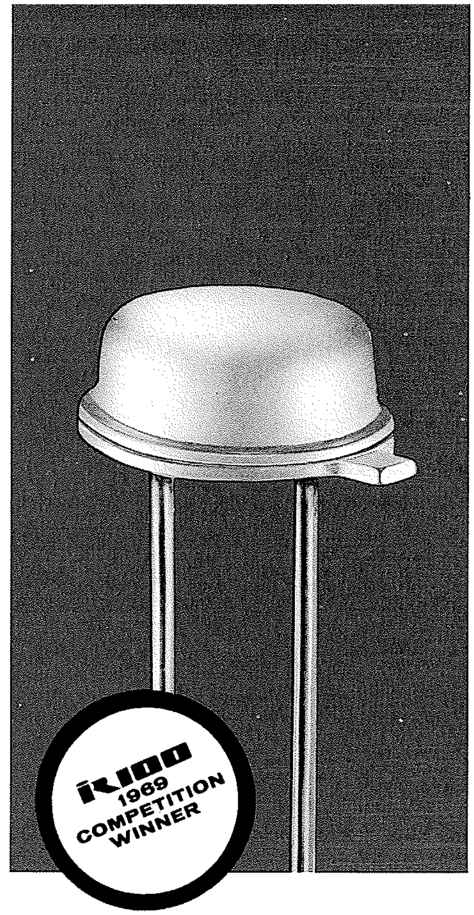
NEW SPECIFICATIONS

TG-100 CRYOGENIC SENSOR

SOLID STATE THERMOMETER

USEFUL RANGE – BELOW 1 K TO 400 K

TG-100 thermometers are manufactured with advanced state of the art techniques to assure surface and contact introduced errors do not exist. These techniques assure that the useful range from 1 K to 400 K will not be degraded with time.



TYPICAL THERMOMETER SPECIFICATIONS

The TG-100 series Cryogenic Sensors are available with either one lead at case potential (negative) and the other isolated (positive), or both leads isolated. Models TG-100K, TG-100K-TO5, TG-100FP always have the negative lead attached to the case. Models TG-100KL and TG-100KL-TO5 always have both leads isolated. Models TG-100P, TG-100P-GR, and TG-100P-TO5 supplied either with negative lead at case potential or isolated, as required.

ACCURACY: Figures 1 and 2 give typical temperature-voltage characteristics at an excitation current of 10 uA. The TG-100 is capable of accuracy to .01 K across the full useful range.

SENSITIVITY: Typical sensitivities at 10 uA excitation currents are shown in Figure 2. At 100 uA the average sensitivity is typically 8% lower.

MATERIAL: Gallium Arsenide diode sensing element.

WEIGHT: Weight of standard models (with 1" leads) is shown on page 4.

PACKAGE: Standard packages are described on page 4. Special configurations are available on request.

LONG TERM STABILITY: No degradation measured over a one year period.

HEAT DISSIPATION: 1.5 x 10^{-5} watts at 4 K with 10 uA excitation current.

MAGNETIC FIELDS EFFECT: Figure 3 shows typical magnetic field induced error data. The relative error induced by the magnetic field $\left(\frac{TH - TO}{TO} \text{ X } 100\%\right)$ decreases with increasing temperature.

METHOD OF ATTACHMENT: Typical materials used include Woods Metal, Indium, GE 7031 varnish, and high conductivity epoxies. Proper electrical isolation between leads is important. Calibrated sensors should have their leads soldered to tempering leads with accessory heat sink clips between the header and solder points.

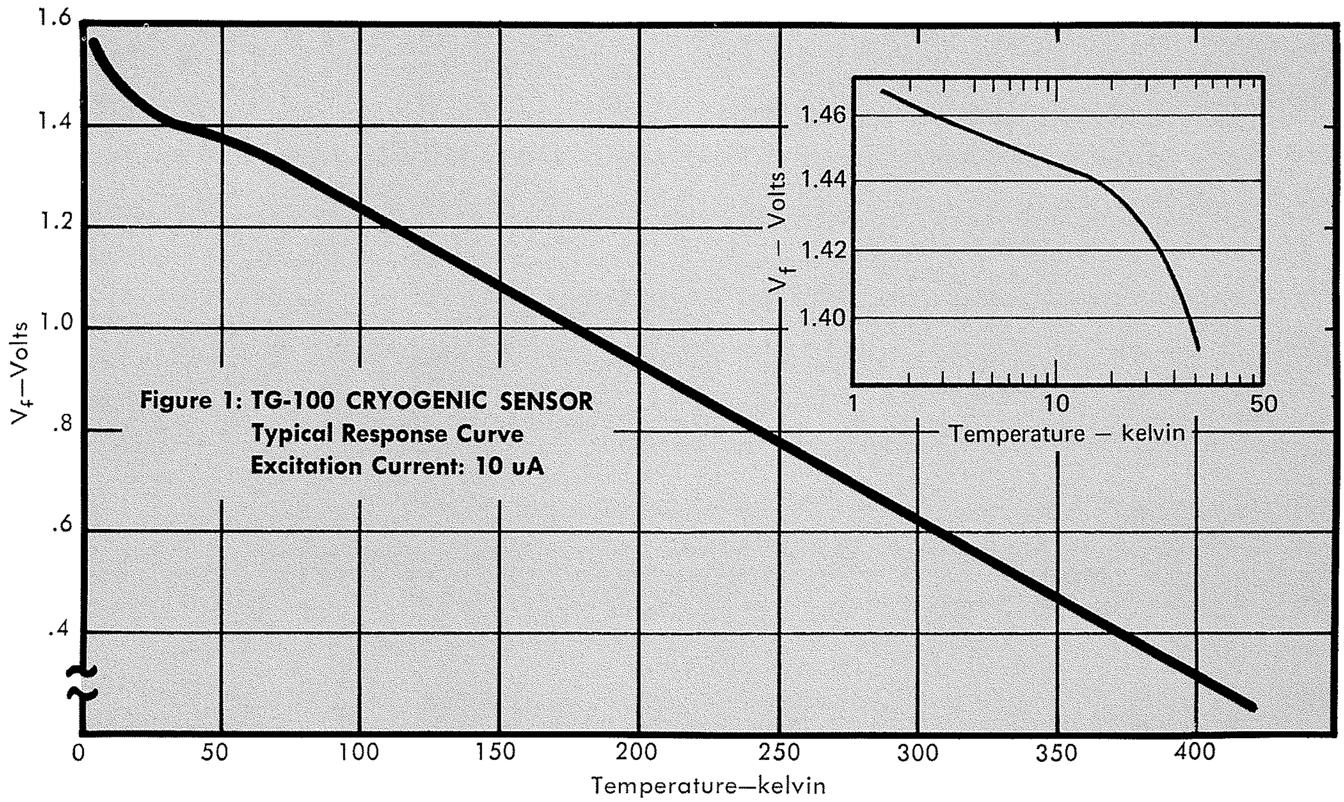


Figure 1: TG-100 CRYOGENIC SENSOR
Typical Response Curve
Excitation Current: 10 uA
V_f—Volts
1.6
1.4
1.2
1.0
.8
.6
.4
0
50
100
150
200
250
300
350
400
Temperature—kelvin
V_f — Volts
1.46
1.44
1.42
1.40
1
10
50
Temperature — kelvin

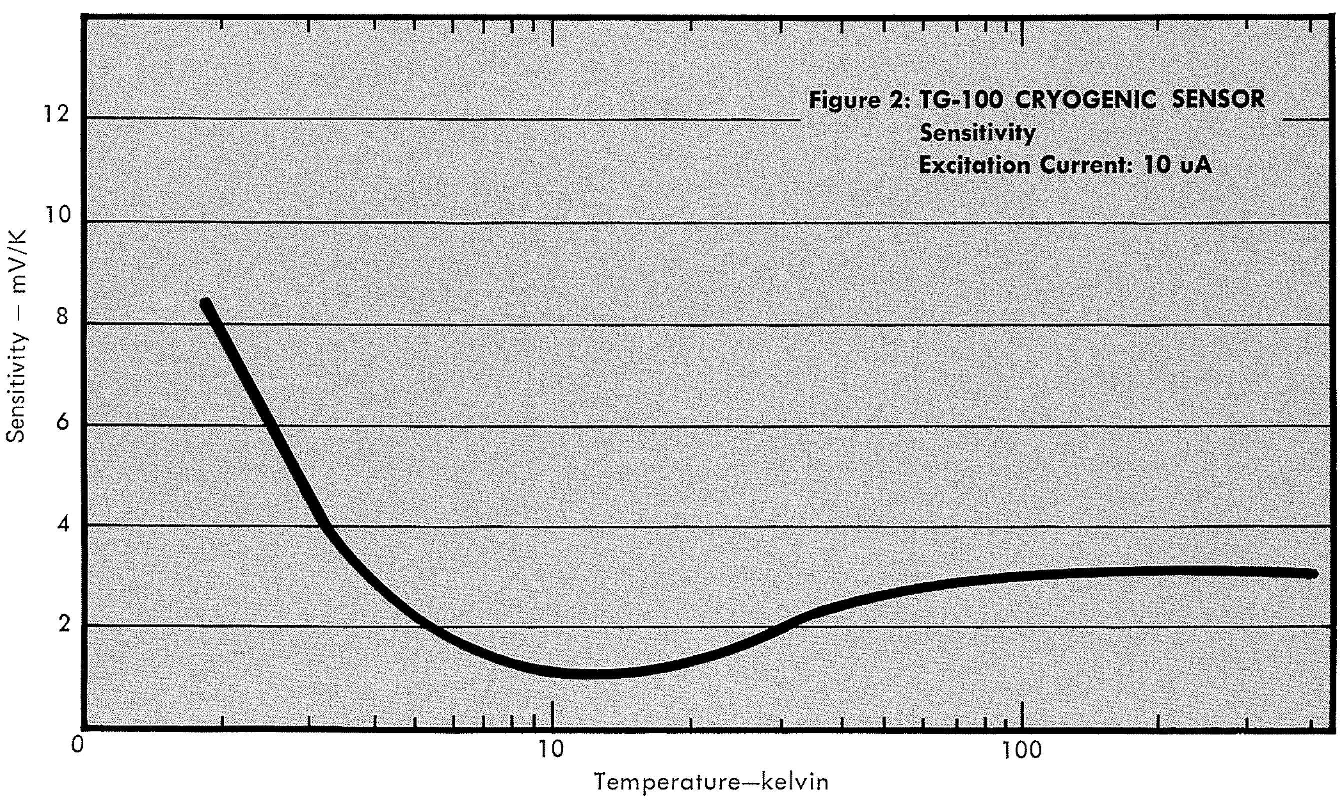
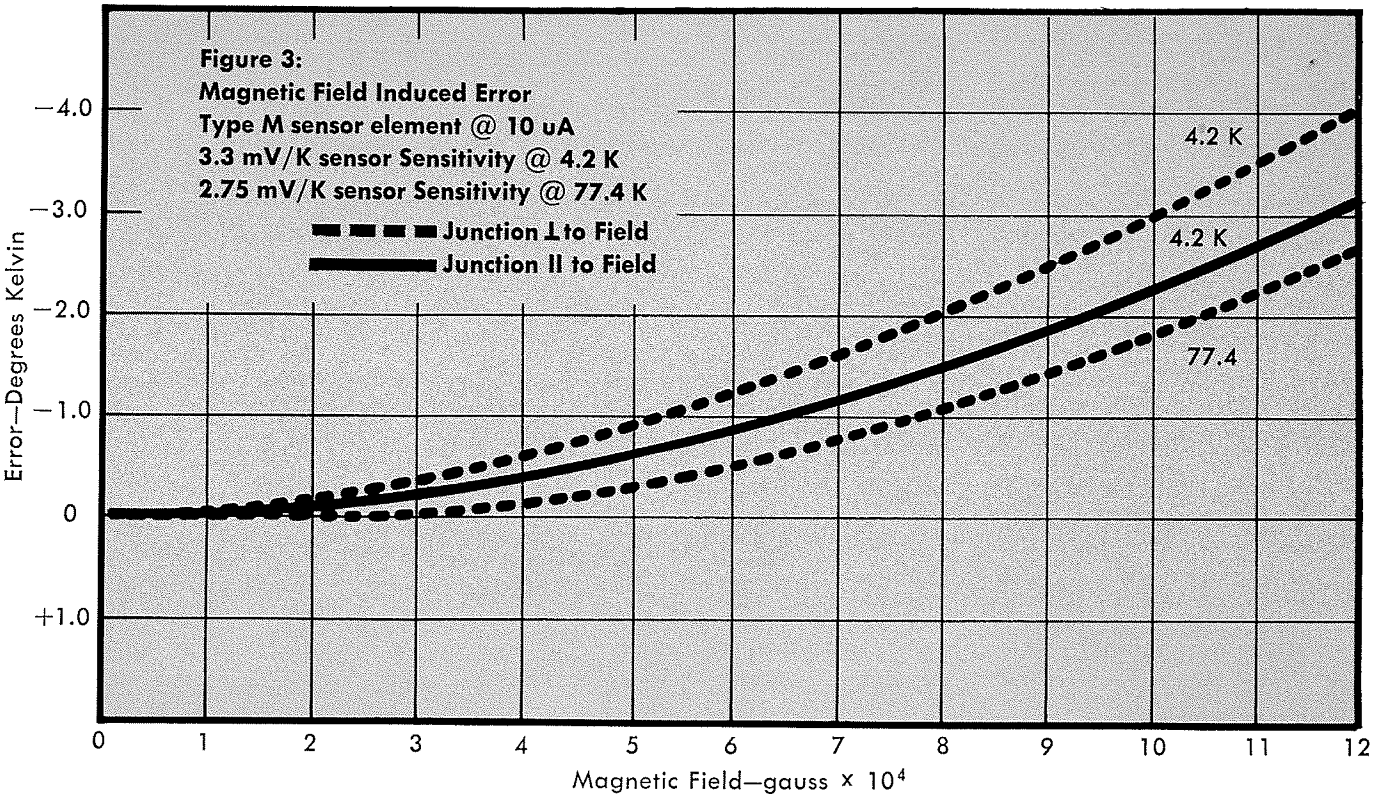


Figure 2: TG-100 CRYOGENIC SENSOR
Sensitivity
Excitation Current: 10 uA
Sensitivity — mV/K
12
10
8
6
4
2
0
10
100
Temperature—kelvin



CALIBRATION SERVICE:

Lake Shore Cryotronics, Inc. offers standard temperature calibration services from 1.5 K to 400 K. Special Calibrations from .3 K to 1.5 K are quoted on request. All readout instruments and standard voltage cells are maintained with NBS traceability. Computer printouts are provided where applicable.

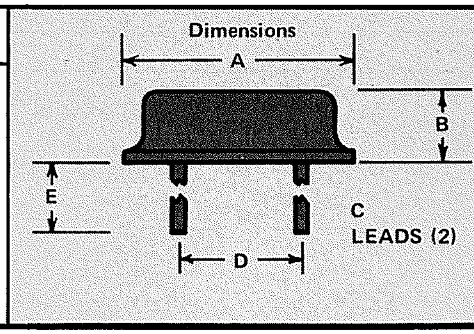
Standard calibrations are supplied according to the following table unless otherwise specified:

Temperature	Maximum Interval	Temperature	Maximum Interval
1.5 to 2.0 K	0.1 K	20 to 40 K	4.0 K
2.0 to 3.0 K	0.2 K	40 to 100 K	5.0 K
3.0 to 5.0 K	0.4 K	100 to 200 K	10.0 K
5.0 to 10 K	1.0 K	200 to 400 K	20.0 K
10 to 20 K	2.0 K		

All calibrations are performed in a 4 wire potentiometric configuration and calibration current is 10 uA unless otherwise specified. The TG-100 sensors are calibrated at 10 uA or 100 uA excitation currents. Calibration voltages are read out to 100 uV (x.xxxx volts) minimum, unless otherwise specified.

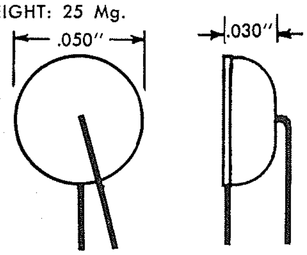
Other temperature sensors can be calibrated in accordance with agreed upon specifications.

DIMENSION	TG-100K	TG-100KL	TG-100P
A	.230"	.230"	.150"
B	.075"	.210"	.065"
C	.019"D	.019"D	.010"D
D	.100"	.070"	.060"
E	.500" Min.	.500" Min.	.500" Min.
Weight	.3 Gram	.5 Gram	.18 Gram
Material	Gold Plated Kovar TO-46 Package	Gold Plated Kovar TO-18 Package	Platinum & Glass



TG-100FP

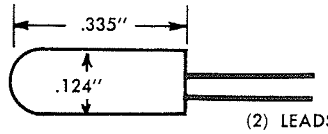
MATERIAL: PLATINUM, GOLD AND EPOXY
WEIGHT: 25 Mg.



2 LEADS .005" D. 1" LONG

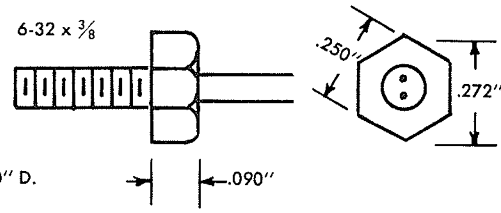
TG100P-GR

MATERIAL: GOLD PLATED COPPER, PLATINUM AND GLASS



(2) LEADS .010" D. 1" LONG

WEIGHT: .42 Gr.



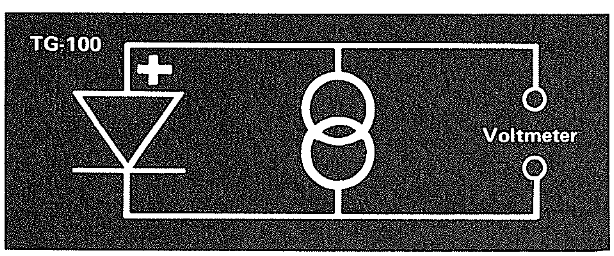
TG100K-TO-5 AND TG100P-TO-5
WEIGHT: 1.24 GR.
THIS CONFIGURATION COMBINES THE TG-100K OR TG-100P WITH A COPPER ALLOY #6-32 HEX HEAD MACHINE SCREW AS A MOUNTING LUG.

APPLICATION NOTES:

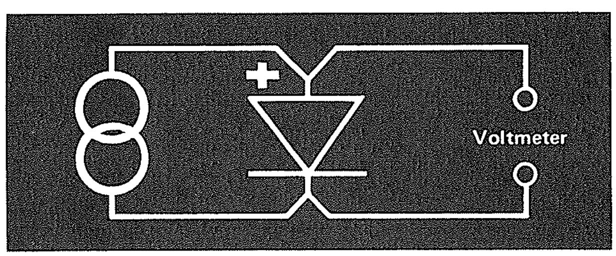
1. The voltage drop across the sensor should be read with a high input impedance voltmeter. The required temperature accuracy vs. Instrumentations current regulation and voltmeter resolution.

Required Temperature Accuracy	Current Source Resolution	Voltmeter Resolution
1.0 K	5%	1 mV
.1 K	.5%	100 uV
.01 K	.05%	10 uV

2. Unless specifically ordered otherwise, the base lead of the TG-100 is attached to the case (the sensor case and base lead are common.) Models TG-100P, TG-100P-GR and the TG-100-T05 series sensors can be supplied with both leads insulated from the case. The TG-100FP can be supplied encapsulated in an insulating epoxy where required.
3. The presence of ferromagnetics in the TG-100K and TG-100K-T05 sensor packages does not appreciably affect the output voltage reading when the sensor is in a magnetic field. However, these models will adversely affect the uniformity of the magnetic field and should not be chosen when magnetic field uniformity is important.
4. See Lake Shore Cryotronics, Inc. bulletin "Installation and Application Notes For Cryogenic Sensors" for a detailed installation guide.
5. Two and four lead (potentiometric) methods of attaching leads to the TG-100 are shown below.



Recommended two-lead system where accuracy requirement does not require lead compensation. Recommended current for optimum usage is 100 ua, or less.



Recommended four-lead system for use when optimum accuracy is desired and lead compensation is required. Recommended current for optimum usage is 100 ua, or less.

LAKE SHORE CRYOTRONICS, INC.

9631 SANDROCK ROAD EDEN, N. Y. 14057
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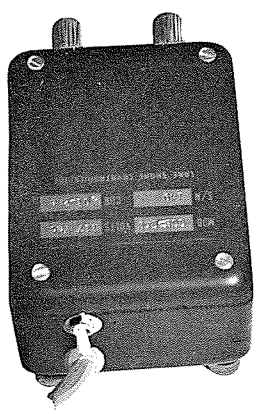
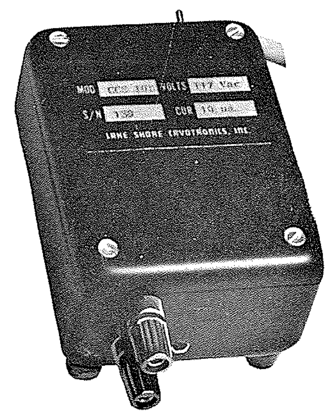
Series CCS Constant Current Sources

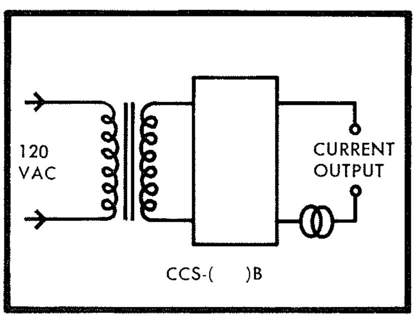


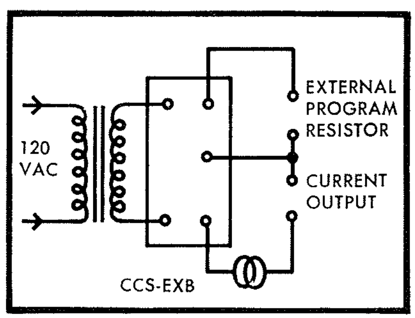


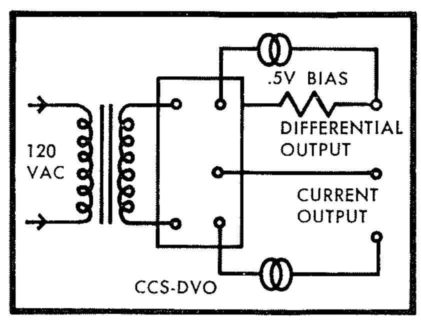
Offered specifically for use with the TG-100 Cryogenic Sensor, the SERIES CCS CONSTANT CURRENT SOURCES have rapidly found their way into a multiplicity of other applications. These power supplies produce a stable DC current output which is isolated from the power line and chassis by a power transformer. The CCS units feature a true constant current regulation mode which results in an instrumentation module that is very stable with changes in environment and time. Either output terminal may be grounded or both may remain floating.

SPECIFICATIONS

1. Nominal Output Current: 5 uA to 2 mA
2. Input Power: 105 to 125 Vac, 1 ph, 60 to 400Hz
3. Output Voltage Compliance: 0 to 15 Vdc at 105 Vac Input
   0 to 20 Vdc at 135 Vac Input
4. Regulation Line Range: ± .005%
5. Temperature Range: −30 to +65°C
6. Temperature Coefficient: ± 0.002% per °C
7. Power Consumption: 5 watts
8. Internal Set Point Control: ± 10%
9. Size: 4" x 2-1/16" x 2-13/16"
10. Weight: 1 lb. Maximum







MODEL DESCRIPTIONS

CCS-( )B These narrow range models are normally supplied in 10 uA or 100 uA configurations. Although factory adjusted, the internal set point control allows a nominal ± 10% adjustment. When ordering, the desired current should be substituted in the brackets of the Model part number; for example, CCS-10B is the 10 uA unit.

CCS-EXB These externally programmable models can be adjusted over the nominal range of 5 uA to 2mA to fit the users needs. Factory set at 5 Vdc output, this model is furnished with external terminals across which a resistance may be connected to adjust the output current anywhere within the nominal output current range.

CCS-DVO Combining the CCS-10B with a .5 Volt bias voltage, this instrument allows 0 to 1 volt bridges and 3 and 4 place DVM's to be used for voltage readout. This capability gives a nominal ¼°K accuracy of temperature measurement over the full useful range of the TG-100 Cryogenic Sensor.

LAKE SHORE CRYOTRONICS, INC.

P. O. BOX 214 • HAMBURG, NEW YORK 14075

50 OHM
ULTRAMINIATURE COAXIAL CABLE

Lake Shore Cryotronics 50 ohm Ultraminiature Coaxial Cable is available in two configurations: Type A has copper plated steel wire; type M has the conductors made from beryllium copper alloy. Type A is recommended for use where low thermal losses are important. Type M is recommended for use in magnetic fields.

Characteristic Impedance:	50 ohms ± 4 ohms @25°C	
Capacitance:	26 picofarads @25°C	
Velocity of Propagation:	79% at 100 MHz @25°C	
Jacket:	Heat fusible Mylar Jacket .013" x .019" Nominal OD	
Shield:	Aluminized Mylar .0011" Thick x 3/16" wide. 50% overlap.	
Dielectric:	Teflon* TFE	
Dielectric Constant:	2.1	
Dissipation Factor @ 1 MHz	.0007	
Overall Diameter over Dielectric	.0070 + .0005"	
	Type A	**Type M**
Center Conductor:	42 AWG Solid Copperweld 40 microinch minimum plating, .0025" diameter	42 AWG BeCu
Drain Wire: placed parallel to center conductor	36 AWG Solid copperweld 40 microinch minimum plating, .005" diameter	36 AWG BeCu
Resistance, ohms/ft @ 25°C: Center Conductor	5.25	.36
Drain Wire	7.54	1.89

Quantity	Price
25 feet	$ 50.00
50	90.00
100	150.00
250	350.00
500	650.00
1000	1200.00

Lake Shore Cryotronics, Inc. Terms and Conditions of Sale Apply.

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