Master w/Notes

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SERIES 270

IONIZATION

GAUGE CONTROLLER

INSTRUCTION MANUAL

GRANVILLE-PHILLIPS

SERIES 270

IONIZATION

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INSTRUCTION MANUAL

IT IS VERY IMPORTANT FOR YOU TO READ AND UNDERSTAND THE CONTENTS OF THIS MANUAL AS IT PERTAINS TO YOUR PARTICULAR INSTRUMENT BEFORE YOU ATTEMPT TO INSTALL OR USE YOUR INSTRUMENT.

This manual is to be used only with the following Series 270 Controller part numbers. See Section 1.3 for part number explanations.

270001 004	270019 003	270045 101	270056 100	270067 100
270002 004	270020 003	270048 100	270057 100	270068 100
270003 003	270021 003	270050 100	270058 100	
270004 003	270022 003	270051 100	270059 100	
270014 003	270038 002	270052 100	270060 100	
270015 003	270039 001	270053 100	270061 100	
270016 003	270043 101	270054 100	270062 100	
270017 003	270044 101	270055 100	270066 100	

Instruction Manual P/N 270046 100
Granville-Phillips Co.
5675 E. Arapahoe Ave.
Boulder, CO 80303
(303)443-7660
Revised March 1988

CERTIFICATION

Granville-Phillips Company certifies that this product meets its published specifications at the time of shipment from the factory.

LIMITED WARRANTY

This Granville-Phillips Company product is warranted against defects in materials and workmanship for one year from the date of shipment provided the installation and preventive maintenance procedures specified in this instruction manual have been followed. Granville-Phillips Company will, at its option, repair or replace or refund the selling price of an item which proves to be defective during the warranty period provided the item is returned to Granville-Phillips Company together with a written statement of the problem.

Defects resulting from or repairs necessitated by misuse of the equipment or any cause other than defective materials or workmanship are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. GRANVILLE-PHILLIPS COMPANY IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

SECTION I

GENERAL INFORMATION

1.1 Description

The 270 ionization gauge controller is a precision instrument designed to indicate vacuum pressures from 1 Torr to 10^{-8} Torr, 1 mbar to 10^{-8} mbar, or 100 Pascal to 10^{-6} Pascal, air equivalent. The basic unit is comprised of a power supply, electrometer, emission controller, and ion gauge meter. Dual thermocouple gauge capability and process controls on the ion gauge and thermocouple gauges are included on some models. Recorder outputs provide capability for remote indication as well as continuous monitoring.

In the basic controller the 270 will display pressure data in five linear decades, 10^{-4} to 10^{-8} Torr. The range of readable data is from 0.3×10^{-8} to 12×10^{-4} Torr. The controller is designed to utilize a Bayard-Alpert type transducer with sensitivity ranging from 10/Torr to 25/Torr. The unit is shipped pre-adjusted for directly indicating pressure of a gauge having a sensitivity of 10/Torr, corresponding to an emission current of 2 mAdc.

Degas is provided by conventional resistive (I^2R) heating of the grid surfaces with a nominal 80 watts of power. Ion gauge pressure measurements are not possible during degas.

Ion gauge process controls, when included, provide two independent set points which operate individual SPDT relay contacts. Set point adjustment over the entire measurement range is by means of recessed front panel controls. Interlocks are provided to allow operation only during autorange operation when the filament is on and the gauge has had sufficient time to stabilize.

The thermocouple section is comprised of two independent measuring circuits and, when included, extend the measurement range of the controller to 1 Torr or 1 mbar. Indication is provided by two 1½ inch taut band ruggedized meters. Recorder outputs are also provided for each of the thermocouple circuits. The thermocouple circuitry is designed to operate with Granville-Phillips 270006 or comparable transducers.

Thermocouple process controls, when included, provide an individual SPDT relay contact set point for each thermocouple gauge. Set point adjustment over the thermocouple's measurement range is adjustable by means of recessed front panel controls. The controller is wired such that the set point for thermocouple No. 2 can be used to switch the ion gauge filament on and off, thus allowing fully automatic operation.

All Series 270 controllers come with an automatic ranging feature which can be defeated placing the controller in a manual ranging mode. Autoranging points are preset to occur at $.95 \times 10^{-X}$ and 11.7×10^{-X}. While in the manual mode the controller is capable of readings from 0.0×10^{-X} to 12.0×10^{-X}. Autoranging eliminates troublesome range changing in a variable system and prevents unnecessary shutdowns due to momentary pressure bursts. The manual/auto range function is selected via a front panel switch.

The 270 ion gauge controller provides direct ion gauge pressure readout in either Torr, mbar or Pascal. The unit of measure is selectable by means of a jumper plug inside the controller and appropriate front panel labeling. The pressure signal is converted and displayed in the desired format, thus eliminating cumbersome conversion tables or calculations.

Recorder Output, Ion Gauge		1) 0 to -2.4V corresponding to front panel meter indication of 0 to 12 x 10^{-X}. Output impedance is 2 Kohm. 2) 0 to -5V corresponding to 1V/decade of pressure. Output impedance is 2 Kohms.
Recorder Output, Thermocouple		0 to 2V corresponding to 0 to 1 Torr (0 to 1.33 mbar) of air; output impedance is 1.86 Kohms ± 1%.
Automatic ranging	up down	117% FS 9.5% FS
Electrical Power Requirement		
Customer specified preset at factory via selector switch		105 to 125 VAC, 50-60 Hz, 100W 210 to 250 VAC, 50-60 Hz, 100W 90 to 110 VAC, 50-60 Hz, 100W
Electrical Characteristics		
Collector voltage to ground		0V
Grid voltage to ground		+180V nominal
Filament voltage to ground		+30V nominal
Filament power available		6 VAC, 6A
Degas power available		8 VAC, 10A (12A max)
Process control range, ionization gauge (each of 2)		3×10^{-9} Torr to 10×10^{-4} Torr 3×10^{-9} mbar to 10×10^{-4} mbar 3×10^{-7} Pa to 10×10^{-2} Pa
Process control range, thermocouple gauge (each of 2)		1×10^{-3} Torr to 1 Torr 1×10^{-3} mbar to 1 mbar 1×10^{-1} Pa to 100 Pa
Process control relay contact rating		SPDT, 4A at 115VAC, 2A at 230VAC, resistive load
Filament status relay contact rating		SPDT, 2A at 115VAC, 1A at 230VAC, resistive load
Thermocouple gauge mounting		1/8" NPT or .410 in. compression quick-connect or suitable weld connection.
Compatible Thermocouple Gauges		Hastings-Radist DV-6M, DV-6R, DV-36, and DV-20
Physical:		
Height		89 mm (3.5 in.)
Width		483 mm (19 in.) to fit standard 19 in. relay rack
Depth		292 mm (11.5 in.) required for mounting
Weight		5.3 kg (11.5 lb)
Shipping weight		7.5kg (16.5 lb)
Mounting Hardware Supplied		Four 10-32x½ in. screws and four nylon washers

SECTION II

INSPECTION

2.1 Receiving Inspection

Prior to using your controller for the first time, remove the two screws of the upper corners of the rear panel and take off the top cover. Visually inspect the unit for shipment damage. Especially check to see that all relays are seated in their sockets properly, that the relay retaining straps are in place, that the inter-connect cable between the two P.C. boards is properly seated, that the line voltage selector switches are in the proper position and finally that the proper fuse is provided. Following these preliminary inspection steps may save substantial time delays in putting your new unit into operation in the event of shipping damage or human error.

2.2 Domestic Shipments

Confirm that your shipment includes all material and options ordered. If materials are missing or damaged the carrier that made the delivery must be notified within 15 days of delivery in accordance with Interstate Commerce regulations in order to file a valid claim with the carrier. Any damaged material including all containers and packing should be held for carrier inspection. Contact our Customer Service Department, 5675 East Arapahoe Avenue, Boulder, Colorado 80303, (303) 443-7660 if your shipment is not correct for reasons other than shipping damage.

2.3 International Shipments

If items are missing or damaged the carrier making delivery to the customs broker must be notified within 15 days of delivery.

Example:

If an airfreight forwarder handles the shipment and their agent delivers the shipment to customs the claim must be filed with the airfreight forwarder.

If an airfreight forwarder delivers the shipment to a specific airline and the airline delivers the shipment to customs the claim must be filed with the airline, not the freight forwarder.

Any damaged material including all containers and packaging should be held for carrier inspection. Contact our Customer Service Department, 5675 East Arapahoe Avenue, Boulder, Colorado 80303, U.S.A. Telex 045 791 GPVAC Bldr or telephone (303) 443-7660 if your shipment is not correct for reasons other than shipping damage.

This procedure uses a conventional Volt-Ohm Meter (VOM) and Resistor (10 ohm, 10 watt)

1. With the gauge controller turned off, test for both DC and AC voltages between the metal parts of the vacuum chamber and the gauge controller chassis.

2. If no voltages exist, measure resistance. The resistance should not exceed 2 ohms. Two ohms, or less, implies commonality of these grounds that should prevent the plasma from creating a dangerous voltage between them. This test does not prove that either connection is earth ground, only that they are the same. If more than 2 ohms is indicated, check with your electrician.

3. If AC or DC voltages exist and are less than 10 volts, shunt the meter with a 10 ohm, 10 watt resistor. Repeat the voltage measurement. With the shunt in place across the meter, if the voltage remains at 83% or more of the unshunted value, commonality of the grounds is implied. Repeat the measurements several times to be sure that the voltage ratio is not changing with time. If

$$\frac{\text{Voltage (shunted)}}{\text{Voltage (unshunted)}} = .83 \text{ or more,}$$

this should prevent the plasma from creating a dangerous voltage between these grounds. If more than 10 volts exists between grounds, check with your electrician.

4. If the voltage change in #3 is greater than 17% due to the placement of the shunt, it complicates the measurement. The commonality of the grounds may be satisfactory and the coupling poor, or the commonality could be poor! Your electrician should be asked to check the electrical continuity between these two ground systems.

Electric Power

The line power supplied the Series 270 controller should be one of the following:

100V with a 1.25 amp fuse
115V with a 1.25 amp fuse
230V with a .5 amp fuse

50 - 60 Hz single phase. Voltage selection switches, as shown in Fig. 3-1, are located inside the instrument next to the power transformer and must be set to correspond to the available supply voltage. Check to see that the power switch is turned to off. Connect the power cable to the controller and to an appropriate source of A.C. power. Use only a three wire grounded receptacle.

Figure 3-2 shows the configuration the tube elements must have if the tube is to mate directly to a standard cable assembly. Granville-Phillips catalog numbers 270007, 270008 and 270040 are standard cable assemblies with tube connection as shown in Fig. 3-2. These cables are designed to be used with gauges similar to the series 274 tubulated gauges, with either single or dual filaments. If one of these cables is to be used, connect the tube to the 7 contact connector. Be sure to provide strain relief for the tube connector and cable assembly so that the glass envelope will not break due to pin movement. Plug the plastic collector socket on the collector pin at the opposite end of the tube. Then plug the 6 pin connector into the rear of the controller marked "gauge". Connect the BNC plug into the jack marked "collector". Both are on the rear of the controller.

WARNING

REMOVE OR TURN OFF AC POWER WHEN MAKING GAUGE CONNECTIONS. 180 VOLTS IS APPLIED TO THE ION GAUGE GRID CONNECTIONS WHENEVER THE CONTROLLER POWER IS ON, EVEN WHEN FILAMENT IS OFF. THEREFORE, TO ELIMINATE POSSIBILITY OF ELECTRICAL SHOCK, MAKE GAUGE CONNECTIONS FIRST.

Gauge cable assemblies with catalog numbers 270009, 270010 and 270041 are designed to be used with gauges which do not have the standard base. If you are using one of these cables, connect the individual labeled sockets to the corresponding gauge pins. Connect the sockets labeled "pin cover" to any unused gauge tube pins. Now, plug the 6-pin connector of the gauge cable into the connector on the rear of the controller marked "gauge". Connect the BNC plug of the collector cable to the connector on the rear of the controller marked "collector".

Both of the above cable types may be obtained in lengths up to a maximum of 40 ft if desired. Refer to the data sheet for added information.

If the controller is to be used with gauges other than those supplied by Granville-Phillips, refer to the specifications section located in the front of this manual to assure that your tube specifications are compatible with the controller.

IG Accessory Connector (Refer to Fig. 3-3)

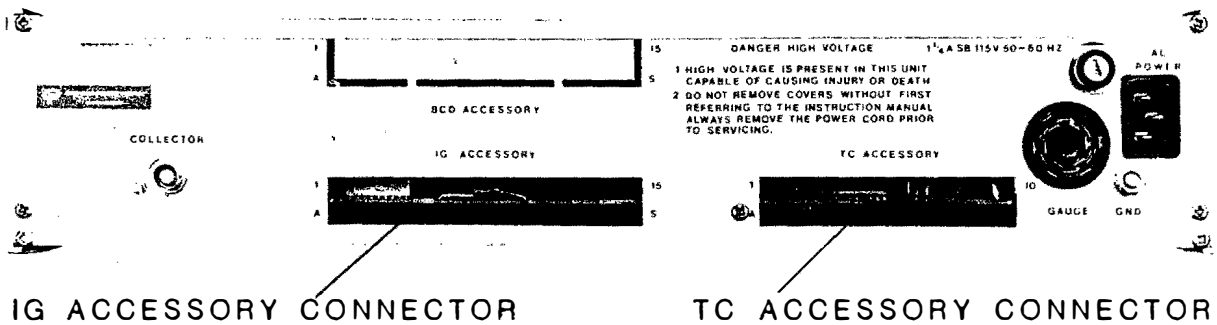


FIG. 3-3 SHOWING ACCESSORY CONNECTORS

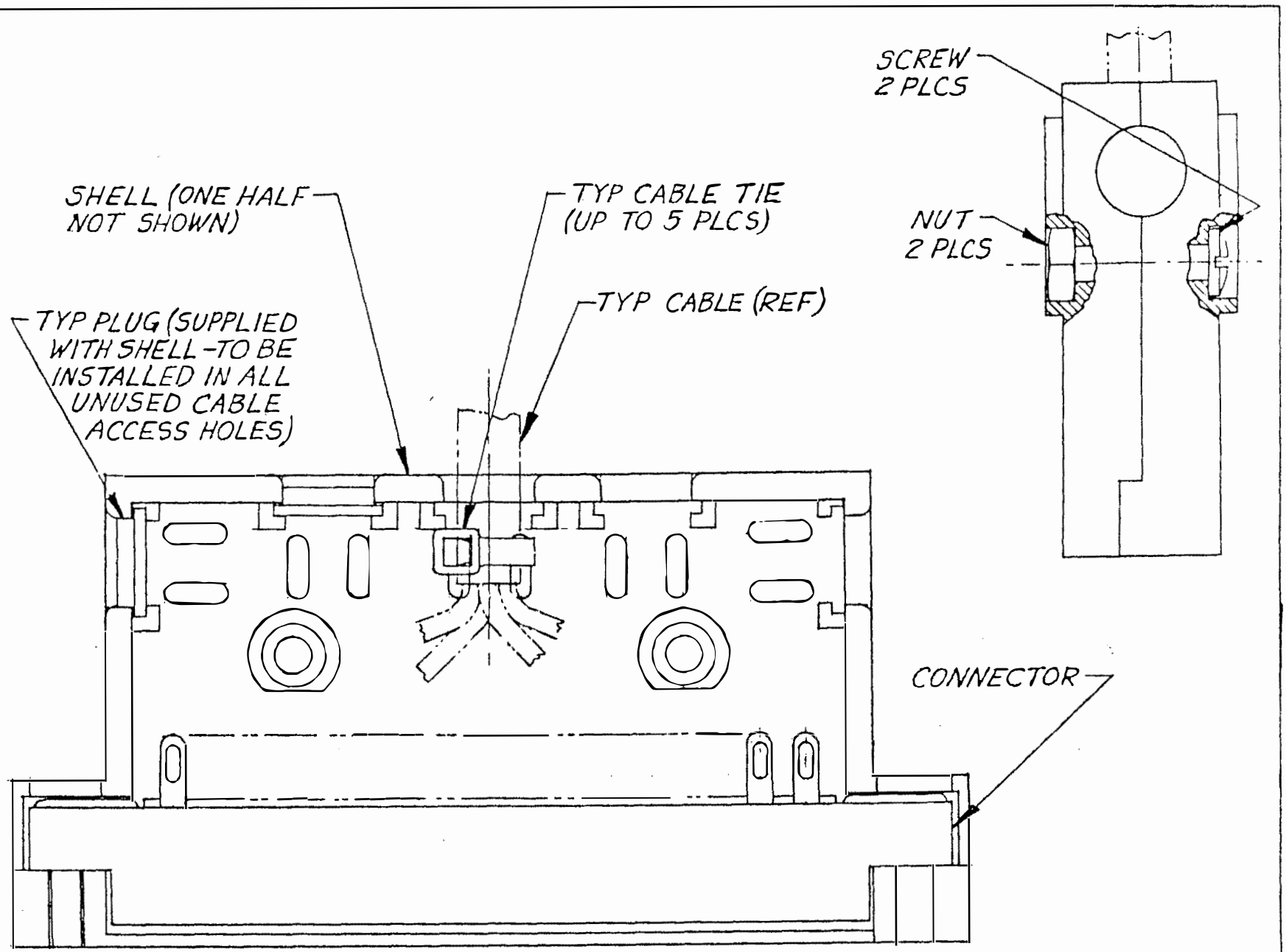


FIG. 3-3A CONNECTOR PICTORIAL

3.5 Units of Measure Selection, Ion Gauge

The ion gauge is capable of providing direct readout in Torr, mbar and Pascal units. To switch units, refer to Fig. 3-5 for proper location of the jumper plug. The jumper plug is located on the main printed circuit board directly behind the ion gauge panel meter (see Fig. 6-1). Place the appropriate label (supplied) over the range units lettering on the front panel between the range indicator LED's and the panel meter.

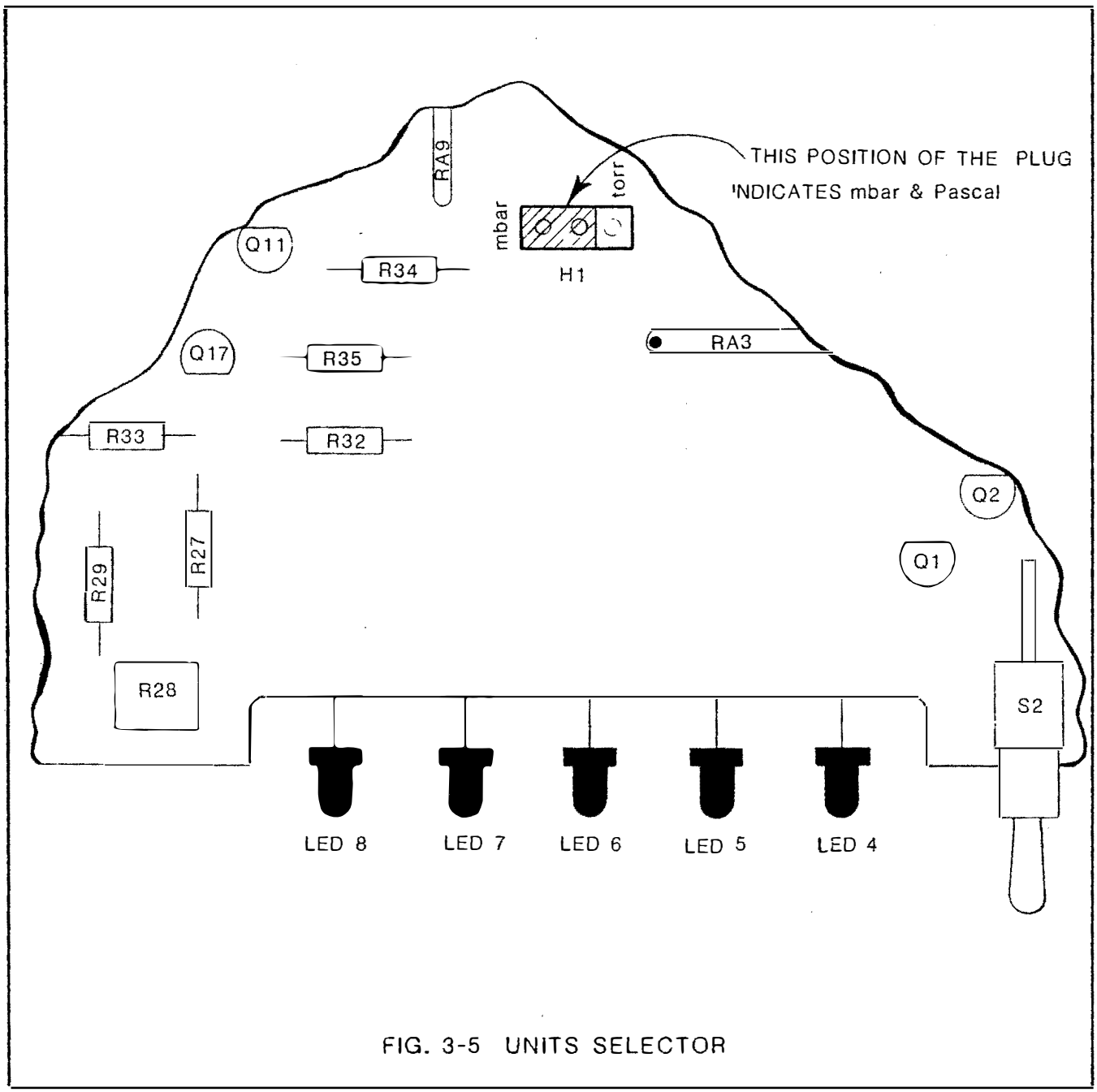


FIG. 3-5 UNITS SELECTOR

007050 100

SECTION IV

OPERATION INSTRUCTIONS

NOTE: It is desirable to read these instructions if full use is to be made of the many features designed into this controller.

4.1 Purpose of Controls (Left to right) (Refer to Fig. 4-1)

Power Switch - Supplies power to the entire unit when switch is placed in the on position.

Power-On Indicator - indicates the status of the power

TC #1 Set - recessed pot for adjusting the set point where the TC #1 process relay energizes.

TC #1 Zero - recessed pot for adjusting the TC #1 zero.

TC #2 Zero - recessed pot for adjust the TC #2 zero.

TC #2 Set - recessed pot for adjusting the set point where the TC #2 process relay energizes and/or the ion gauge filament on/off circuit is controlled.

Degas Light - indicates the status of the degas power.

Degas Switch - switches the degas power to the gauge tube grid.

PC Set #1 - recessed pot for adjusting the set point corresponding to decade and meter reading where the IG process relay #1 energizes.

PC Set #2 - recessed pot for adjusting the set point corresponding to decade and meter reading where the IG process relay #2 energizes.

Filament Switch (270004, 270017, 270022) - three position switch that controls filament status.

1. Auto On (down) - control of the filament is by use of the TC #2 process set point.
2. Center - intermediate position.
3. On/Off (up)- spring loaded position which reverses filament state each time toggled.

Filament Switch (all other models) - spring loaded switch that changes the filament state each time toggled.

Filament Light - indicates the status of the filament.

Emission Switch - spring loaded switch that in the adjust position displays a reading corresponding to the emission current on the ion gauge meter.

Emission Adjust - recessed pot used to adjust the emission current to the recommended value depending upon gauge tube sensitivity.

Decade Lights - indicates pressure decade.

1. Complete the previous section on thermocouple zero.

2. Rotate the TC #2 set pot full CCW.

3. Place the filament switch in the preset position if auto filament control is to be used.

4. Set the system pressure for the desired trip point.

5. Slowly rotate the TC #2 set pot CW until the filament light turns on and/or the #2 process relay energizes.

4.4 Electrometer Zero (check)

1. Make certain the installation described in section 3 has been completed.

2. Turn the power switch on. The power on indicator should be on.

3. Place the auto range switch to the off position and the filament switch to off.

4. Depress the range switch to the down position until a reading in the 10^{-8} range is achieved.

5. Observe that the ion gauge meter reads zero 1/2 small division. If not, use a small screwdriver to slowly adjust the electrometer zero located between the range and autorange switches until a meter zero is obtained.

6. Check the remaining ranges to assure a zero in all ranges.

4.5 Ion Gauge Process Control Set Point Adjustment

The IG process control feature provides relay operation that can be used to control external devices as a function of system pressure as measured on the ionization gauge. Two completely independent relay circuits are provided which can be adjusted to operate anywhere over the pressure range.

1. IG Set Point Adjust (power off)

It is possible to approximate the set point by visually positioning the screwdriver adjust slot of the pot to a degree reading as follows:

Slot fully CCW - 0×10^{-8} (not used)

Slot rotated CW to a horizontal position - 7×10^{-8} Torr or mbar

Slot rotated CW to a 45° point above horizontal - 7×10^{-7} Torr or mbar

Slot rotated CW to a vertical position - 5×10^{-6} Torr or mbar

Slot rotated CW to a 45° point past vertical - 5×10^{-5} Torr or mbar

Slot rotated CW to a horizontal position - 5×10^{-4} Torr or mbar

Slot rotated full CW - 1.2×10^{-3} Torr or mbar

2. IG Set Point Adjust (power on)

1. Rotate the set point pot fully CCW.

2. Allow pressure in the system to stabilize at the desired control point.

3. Slowly rotate the pot CW until the process relay energizes.

The process control relays on the ionization gauge are interlocked in the following manner:

1. Operation is only possible when the autorange switch is in the on position.

2. The filament relay must be energized for a period of two seconds to allow for filament turn on and to create an electrometer output.

Pin information for the IG process relay output is given in Section 3. In order to prevent oscillation around the trip point there is a built-in hysteresis effect amounting to approximately 15% of a decade. For example, if a set point is established to pull in a relay at 5×10^{-6} it will not drop out until the pressure rises above 6.5×10^{-6}.

The process control relays may be used separately or together to suit your specific application. Two examples are shown in Fig. 4-2 and Fig. 4-3.

Fig. 4-2 can be used to allow a process to operate over a specific pressure band. In the example shown the process would only be allowed if the system pressure is between 5×10^{-7} Torr.

Fig. 4-3 can be used to control a process where a large pressure rise is expected once the process is initiated. In the example shown the process would begin when the pressure decreased to 5×10^{-7} Torr and remain on as long as the pressure remained below 5×10^{-6} Torr.

4.6 Filament Operation

Starting the Filament (Manual Mode)

CAUTION: Gauges with tungsten filaments may be damaged by attempting to operate the filament in active gas atmospheres at pressures greater than about 1×10^{-3} Torr.

1. When operating the controller for the first time or with a system at an unknown pressure, set the autorange switch either to on or to off in 10^{-4} range.

2. Momentarily toggle the filament switch to the on/off position and observe the following events.

3. The ionization gauge filament should glow. Note that the tungsten filament glows much brighter than a thoria coated iridium filament when operated at the same emission current.

4. The red filament LED should come on and stay on. NOTE: The filament LED will not stay on if the required electron emission current is not attained within approximately 1 second after the filament switch is depressed. Common causes of no emission are:

   A. Gauge cable not connected
   B. Pressure in tube is too high
   C. Open filament in tube
   D. Grid shorted

For example, if your tube has a sensitivity of 25/Torr, then the meter reading during calibration to make the controller direct reading is:

$$\text{Meter reading} = \frac{10/\text{Torr}}{25/\text{Torr}} \times 10 = 4$$

2. To set the emission current, proceed as follows. Establish the necessary meter reading as described in the previous section. Toggle the spring loaded emission switch to the adjust position. Use a small screwdriver to rotate the emission adjust pot until the desired meter reading is obtained. Read the number in the digital ion gauge display, ignoring the range exponent.

4.8 Reading Pressure

The gauge tube pressure is indicated on the front panel meter. This is a direct reading of pressure in the units indicated below the meter, multiplied by the lighted decade light.

4.9 Automatic Ranging

The controller can be operated with the autorange switch either on or off. When it is off, the range switch is used to select the desired decade. When the autorange switch is on, the autorange circuit is preset to select a range which will give a meter reading between 9.5 and 117 percent of full scale. Process control is operational only when the autorange switch is on.

During autorange operation the electrometer will always return to the 10^{-4} decade any time the filament relay de-energizes.

4.10 Degassing the Gauge Tube

Degassing of the tube is accomplished by resistance heating of the grid structure. To utilize this feature, place the degas switch to the on position. If the filaments were on they will turn off after approximately one second. It is not possible to monitor pressure in the system during degas. When degassing is complete turn off the degas switch and start the filament by toggling the filament switch once to the on/off position.

If, while in degas, the autorange switch is turned off and the 10^{-8} pressure decade selected, an electrometer reading will be observed. This is due to ion desorption from the grid.

4.11 Recorder Outputs

1. Thermocouple - The output of both TC's is available at the TC accessory connector (refer to Section 2 for pin information). This is a 0-2V dc signal corresponding to the meter scale with a source impedance of 1860 ohms. This allows a remote thermocouple meter (see parts list) to be directly driven if remote indication is desired. A graphical plot of output voltage versus pressure is shown in Fig. 4-4.

4.12 Long Cable Operation

The controller is capable of supplying rated filament power to a tube with up to a 40 foot gauge cable. A longer cable can be used if the filament and grid wire size is increased to maintain a line resistance of less than .06 ohms per lead. Consult Granville-Phillips for long cables.

Degas power of 80 watts nominal is available using a 10 foot cable. The degas power at the tube will decrease with longer cable lengths. This will result in a longer period of time being required to degas the tube when long cables are used.

SECTION V

THEORY OF OPERATION

5.1 General Theory of Operation of Ion Gauge Tube and Controller

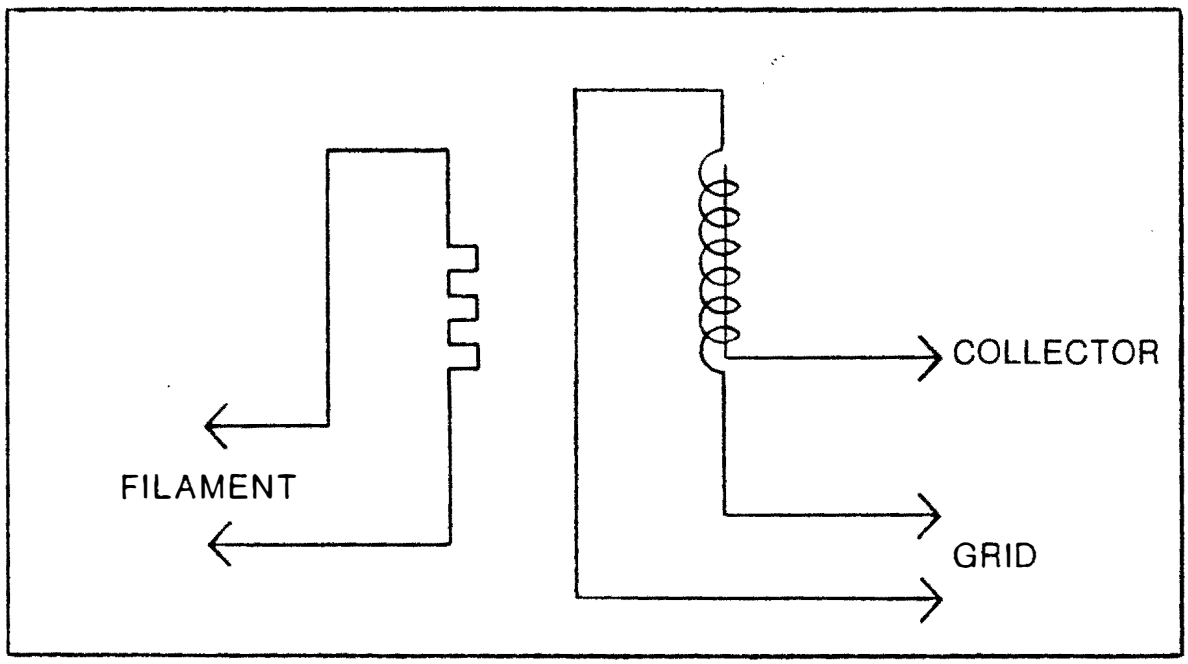


FIG. 5-1 SCHEMATIC OF COMMON IG TUBE

The pressure indication of a Bayard-Alpert gauge is based on the ionization of gas molecules by a constant flow of electrons. The functional parts of the gauge, shown schematically in Fig. 5-1, are the filament, the grid, and the collector. In ionization gauge tubes as well as some electronic vacuum tubes the filament serves as the cathode (hot cathode) or emitter. It's purpose is to emit a stream of electrons. This is accomplished by heating and thereby imparting energy to the molecules thus causing electrons to be boiled off. The rate at which electrons move from the cathode is dependent on the filament temperature and grid potential which must both be highly controlled by the filament power supply and the grid bias supply.

The grid (anode) serves to control the electron beam or more accurately the speed of the electron. In the ion gauge tube the grid is placed at a positive voltage such that most of the electrons emitted at the filament are accelerated through the grid structure and into a drift or interaction region which is the volume surrounding the collector, enclosed by the grid.

Since the ion gauge is open to the vacuum system and since vacuum is the measure of gas particles absence or presence there will be a varying density of gas particles in the electron interaction region depending on the vacuum pressure. The electrons emitted from the cathode will now collide with the gas particles dislodging electrons and producing ions in numbers that are proportional to the gas density. The collector is at a negative potential and thus the positive ions are attracted to it and a current (i^+) is produced also being proportional to gas density. The electrons being negative particles are attracted to the grid structure, this current is noted as I^-. It is these two currents I^+ and I^- which allows the precise measurement of the vacuum. Through electronic detection and control, currents are monitored and vacuum pressure indicated.

5.4 Filament On-Off (Refer to Fig. 5-4)

Transistor Q14 and filament relay K3 control the power to the filament. During manual operation the base of Q14 is turned on by the +10V signal applied from C7 when the filament switch is momentarily toggled to the on/off position. This energizes K3 establishing a holding path through R26 and R24. The voltage at test point V then drops to -12V dc. Momentarily toggling S1 again to the on/off position applies the negative signal to the base of Q14 turning it off causing relay K3 to de-energize. In the auto on position of switch S1 the output of TC #2 process control voltage comparator IC 13-A whose output is either in negative or positive saturation is used, instead, to control the base of Q14.

Remote operation can be performed at any time by use of the IG accessory connector. A momentary short between J3-7, H and J3-9, K will turn on the filament and between J3-8, J and J3-9, K will turn off the filament.

Once energized there are two automatic sources which will result in a filament shutdown. If the output of the emission control amplifier exceeds -6V dc the base of Q14 will be turned off causing the filament relay to de-energize. In addition when not in the auto on mode of filament operation, should the ion current rise to a level corresponding to 3×10^{-3} Torr, transistor Q9 turns on removing the +12V to relay K3, pin 6, removing the source of base current for Q14.

5.5 Emission Control (Refer to Fig. 5-4)

The emission control circuit consists of: An emission reference supply, an emission sensing resistor RA9-4, a high-gain amplifier IC10-A, a synchronized pulse generator composed of Q11, Q17 and T1, and a triac SCR-1 in series with the filament. The output of IC10-A is shorted to its input through contacts 14 and 15 of K3 until the filament circuit is turned on. When the filament circuit is energized, the positive input from the emission reference supply (0.3 to 1.2 volts depending upon the setting of the emission adjust potentiometer R28) to pin 2 of IC10-A results in a negative going output from IC10-A. This increases the output of the current source Q11, which in turn fires unijunction Q17 at earlier and earlier times in the power line cycle. Pulses from Q17 are coupled to the triac, SCR-1, through transformer T1. These pulses cause SCR-1 to conduct for the remainder of the half cycle producing current through the filament. As IC10-A output becomes more negative, the filament is turned on for a larger fraction of the half cycle. The resulting heating of the filament generates the emission current through emission sensing resistor RA9-4. The resulting emission signal voltage serves as a feedback signal to IC10-A, closing the control loop. The signals which synchronize the pulses from Q6 with the power line are obtained from the sync signal generator.

5.6 Emission Sensing Amplifier (Refer to Fig. 5-4)

IC10-B and its associated components form a conventional inverting amplifier with a gain of two and are used to drive the ion gauge meter when the emission switch is held in the adjust position.

5.7 Electrometer Circuit (Refer to Fig. 5-5)

A high gain negative feedback type amplifier consisting of Q20 and IC9-A is used so that the collector electrode is normally maintained within millivolts of ground potential. Due to the high input impedance of Q20, essentially all of the ions from the collector electrode must flow through the feedback resistor, R_f, of Fig. 5-2. Since the amplifier input is maintained at ground potential by the high loop gain, the output voltage is the product of the ion current times the feedback resistance. This output is used to supply information to the recorder output, converter, and autoranging circuit. The collector lead is attached to the gate of one side of the dual JFET Q20 through a protection network consisting of a surge voltage protector, C1, R4, CR4 and CR36. The other gate is grounded. The JFET is used as a source follower and is coupled to operational amplifier IC9-A's differential input. The loop is

IC6-A and IC6-B are voltage comparators having as their inputs a voltage corresponding to the desired set point and the output of the pressure amplifier. When the pressure is lower than the set points selected the amplifier switches from positive saturation to negative saturation turning on the relay driver transistor and energizing the relay. Each comparator has regenerative feedback which causes hysteresis of approximately 15% of a decade.

5.11 Thermocouple Circuit (Refer to Fig. 5-8)

The thermocouple circuit consists of a transducer power supply, two identical amplifiers IC11 and IC12, and meter circuits. Only one circuit will be discussed since operation is identical.

Power to heat the filament of the GPC 270006 transducer is regulated by a pair of back to back zeners, CR31 and CR32, whose output signal is an approximate square wave as shown in Fig. 5-8. This signal is coupled to the thermocouple by transformer T2. R49 is used to adjust the output of the thermocouple to 10 mV dc when the pressure at the thermocouple is less than 1×10^{-3} Torr. Amplifier IC11 is a low drift, inverting amplifier with a DC gain of 200. Initial adjustment of the amplifier is made by adjusting R54 for an output of +2.0V dc with the 270006 transducer at atmosphere. At a pressure of 1×10^{-3} Torr or lower the output of the amplifier is reduced to zero due to the +10 mV input from the thermocouple. The amplifier output is used to power the meter.

5.12 Thermocouple Process Control (Refer to Fig. 5-9)

The thermocouple process control circuit consists of two identical voltage comparators IC13-A and IC13-B, and relay drivers Q21 and Q22. Again only one channel will be discussed since they are identical. The output of the thermocouple amplifier is compared with the output of the set pot through resistors RA12-1 and RA12-2. Voltage comparator IC13-A is at negative saturation when the pressure is above the desired set point. When the pressure input decreases to the desired set point the output of the amplifier switches to positive saturation turning on the relay driver and energizing the relay. The comparator has regenerative feedback which provides hysteresis operation.

The output of IC13-A is also used to control the filament relay (refer to Fig. 5-9).

SECTION VI

MAINTENANCE

6.1 General Information

Although this instrument was designed using as many commonly available components as possible, thus allowing easy service, it is still recommended that only qualified technical personnel attempt repairs.

Should difficulties be encountered in the use of your controller, the following list of symptoms and remedies, along with the circuit descriptions of Section 5, the schematics, and the parts location diagrams can prove useful in quickly getting back into operation.

The warranty on this instrument provides for free service at the factory for the first full year after delivery, and at a reasonable service charge thereafter. However, since the majority of parts are readily available at your local electronics supply stores, it may, in some cases, prove most expedient for you to repair minor troubles should they occur.

If the prescribed remedies do not correct the troubles, or if additional assistance or special parts are required, contact the Technical Service Department, Granville-Phillips Company, 5675 East Arapahoe Avenue, Boulder, Colorado, 80303. Telephone: 303-443-7660. Repairs properly made with equivalent electronic parts and rosin core solder, which do not damage other portions of the unit, do not represent a violation of the warranty. A desoldering tool is required for satisfactory removal of components from the circuit boards.

Check the following list for the observed symptoms. This listing of symptoms and remedies is not complete, but should be sufficient to solve most problems. All possible causes of failure should be thoroughly explored before attempting any component replacement.

DANGER HIGH VOLTAGE

HIGH VOLTAGE IS PRESENT WITHIN THIS UNIT CAPABLE OF CAUSING INJURY OF DEATH. DO NOT TOUCH CABLE CONNECTIONS OR INSIDE OF THE CONTROLLER WHEN POWER IS APPLIED. FOLLOW SAFE PROCEDURES WHEN OPERATING AND WORKING ON THE EQUIPMENT TO AVOID SHOCK HAZARDS.

CAUTION: It is necessary to use extreme caution when troubleshooting to prevent damage to the CMOS logic elements.

6.2 Guidelines for Troubleshooting

The following guidelines are manufacturer recommended when performing troubleshooting involving these components.

1. Avoid placing static charges on any component.
2. Use a conductive grounded work surface.
3. Use a grounded type of soldering iron.
4. Use conductive envelopes to store or ship CMOS devices.

6.3 Input Power Problems

Problem	Possible Cause	Cure
1. Power light will not light (all functions inoperative.) Refer to Fig. 5-3.	1. Power cord not plugged in.	Plug in power cord.
	2. No power to receptacle.	Restore power to receptacle.
	3. Controller fuse F1 blown.	Replace fuse with correct type and value; 1-1/4A slo blo for 100V operation, and 115V operation, 1/2A slo blo for 230V operation.
	4. Defective transformer T4. Check for continuity of primary winding.	Replace T4 if defective.
	5. Switch S5 defective.	Replace S5.
2. Controller power fuse F1 blows as soon as the power switch is turned on. Refer to Fig. 5-3.	1. Incorrect power source. Check power source vs. controller requirements.	Connect controller to proper source of power or reset selector switching as shown in Fig. 4-2.
	2. Incorrect fuse rating.	Use correct fuse. A 1-1/4 or 1.25A "slo blo" for 100V operation and 115V operation, 1/2A "slo blo" for 230V operation.
	3. Defective component of power supply P.C. board. Remove gauge cable, interconnect cable to main board and thermocouple gauge cable. If problem remains, trouble is with T4, CR26, C19, C20, C27, C21.	Locate defective component and replace.

6.4 Power Supply Problems (Refer to Fig. 5-3 and Fig. 6-2)

Whenever a problem persists after elimination of possible external causes by removing all cables but the power cable, and thus appears to be in the controller, the power supplies should be checked first. Use a standard DVM to check the labeled points on Fig. 6-1 and 6-2 for the following outputs with respect to ground:

Problem	Possible Cause	Cure
	7. IC10-A or associated component defective. Using an oscilloscope, verify that the waveform present on pin 1 of IC10-A is as shown on Fig. 5-4 when the filament light is on.	Troubleshoot and repair
	8. Verify that the waveform present at the junction of R33 and C10 is as shown on Fig. 5-3 when the filament light is off. If not CR28, R33 or C10 is defective.	Troubleshoot and repair as necessary.
	9. Attempt to turn on the filament and check for pulses riding on the above waveshape during the time the filament light is on. If not present, check Q11, Q17 and associated components.	Troubleshoot and repair as necessary.
	10. Defective triac SCR1 or pulse transformer T1. Using an oscilloscope check for firing pulses on SCR1 gate to anode 1 (across C23) during period when light is on. If pulses are present, the triac is defective. If pulses are not present, check for shorts across SCR1, C23 or T1.	Troubleshoot and repair.
	11. Defective degas switch, S6, or 9 and 10 of transformer, T4.	Troubleshoot and repair.
2. Gauge tube filament will not light when filament switch is toggled (filament indicator light does not light even momentarily).	1. Incorrect input applied from remote input.	Correct source of remote input. Must be momentary type of input.
	2. Power supply voltage problem.	Refer to Power Supply Problems.
	3. Defective relay K3.	Replace relay.
	4. Defective circuit components R21, R22, C7, CR5, K3 or no input from electrometer circuit.	Troubleshoot and repair.

Problem	Possible Causes	Cure
4. Gauge tube filament turns on as soon as ac power is turned on. Filament light is not on. Filament glows very brightly indicating high emission current.	1. Shorted triac SCR1, Fig. 5-4. Apply a short from gate to anode 1 (across C23).	Replace triac.
	2. Defective synchronous pulse generator.	Troubleshoot and repair.
5. Gauge tube filament turns on as soon as power is applied. (Emission normal with filament light on.)	1. Transistor Q14 shorted, Fig. 5-4.	Replace relay.
	2. Relay K3 pins 6 to pin 7 shorted.	Replace relay.
	3. External filament remote control applying a ground to J3-7 or J3-H.	Correct external remote control circuit. It must be a momentary type of input.
6. Gauge tube filament turns on as soon as power is applied. (Emission normal with filament light off.)	1. Defective relay K3. (Pins 14 and 15 open.	Replace relay K3.
7. Erroneous indication of emission current on meter but operation of the filament appears normal.	1. Defective emission current amplifier IC10-B or related circuit component, Fig. 5-4.	Troubleshoot and repair.

6.6 Electrometer Circuit (Refer to Fig. 5-5 and Fig. 6-1)

1. Zero meter indication in any range. (Emission normal.)	1. Collector cable not connected to gauge tube and/or controller.	Connect cable to controller.
	2. Collector cable open. Check continuity of collector cable.	Repair or replace as necessary.
2. With only the power switch on, the electrometer will not zero in any range.	1. Defect in collector cable.	Repair or replace gauge cable.
	2. Power supply problem.	Refer to section on power supplies and repair same.
	3. Defect in electrometer circuit. Check Q20, IC9 or related circuit component.	Replace or repair as necessary.

Problem	Possible Causes	Cure
6. Manual or autoranging only operates in down-range direction.	1. Defective up range comparator IC7-B or associated comparator defective. Check voltage at test point D for 0V dc when the manual switch is depressed to the up position.	Troubleshoot and repair.
7. Range changing continues with erratic sequence of digits below 10 range.	1. Lock out signal from IC5 through IC14 missing.	Troubleshoot and repair.
8. Unit does not change ranges automatically. Manual ranging is okay.	1. Defective K3 relay contact.	Replace K3 relay.

6.8 Ion Gauge Process Control (Refer to Fig. 5-7 and Fig. 6-1)

1. Both process control circuits inoperative.	1. Normal operation. Autoranging switch is in the manual position.	Place switch in auto position.
	2. Defective delay circuit component Q16, Q15, R36, R37 or C13. Check for -23V dc on Q15 collector after filament is turned on.	Troubleshoot and repair.
	3. Defective pressure amplifier IC8, or associated component (Refer to Fig. 5-5). Measure the output at test point H for the following output: 10^{-8} range 0V to -1V dc corresponding to the meter reading 10^{-7} range -1V dc to -2V dc corresponding to the meter reading 10^{-6} range -2V dc to -3V dc corresponding to the meter reading 10^{-5} range -3V dc to -4V dc corresponding to the meter reading 10^{-4} range -4V dc to -5V dc corresponding to the meter reading	Troubleshoot and repair.
2. One process control circuit inoperative.	1. Defective circuit component IC6, RA7, RA8, Q13, Q12, K1 or K2.	Troubleshoot and repair.

Problem	Possible Causes	Cure
	5. Defective op amp or associated circuit component. Check that the amplifier has a DC gain of 200. Ein: 0 mV, 5 mV, 10 mV Eout: 2V dc, 1V dc, 0V dc	Troubleshoot and repair.
5. Meter pegged hard against either stop.	1. Defective amplifier or associated component.	Troubleshoot and repair.

6.10 Thermocouple Process Control (Refer to Fig. 5-9 and Fig. 6-2)

1. One P.C. circuit will not energize its associated relay.	1. Defective amplifier IC13-A or B, or associated component. Check the voltage at test point W or X to determine if the problem is with the amplifier or relay driver.	Troubleshoot and repair.
2. One P.C. circuit will not de-energize its associated relay.	1. Defective amplifier IC13-A or B, or associated component. Check the voltage at test point W or X to determine if the problem is with the amplifier or relay driver.	Troubleshoot and repair.
3. Both P.C. circuits cannot be set.	1. Defective -5.1V dc supply component R54 or CR33.	Troubleshoot and repair.

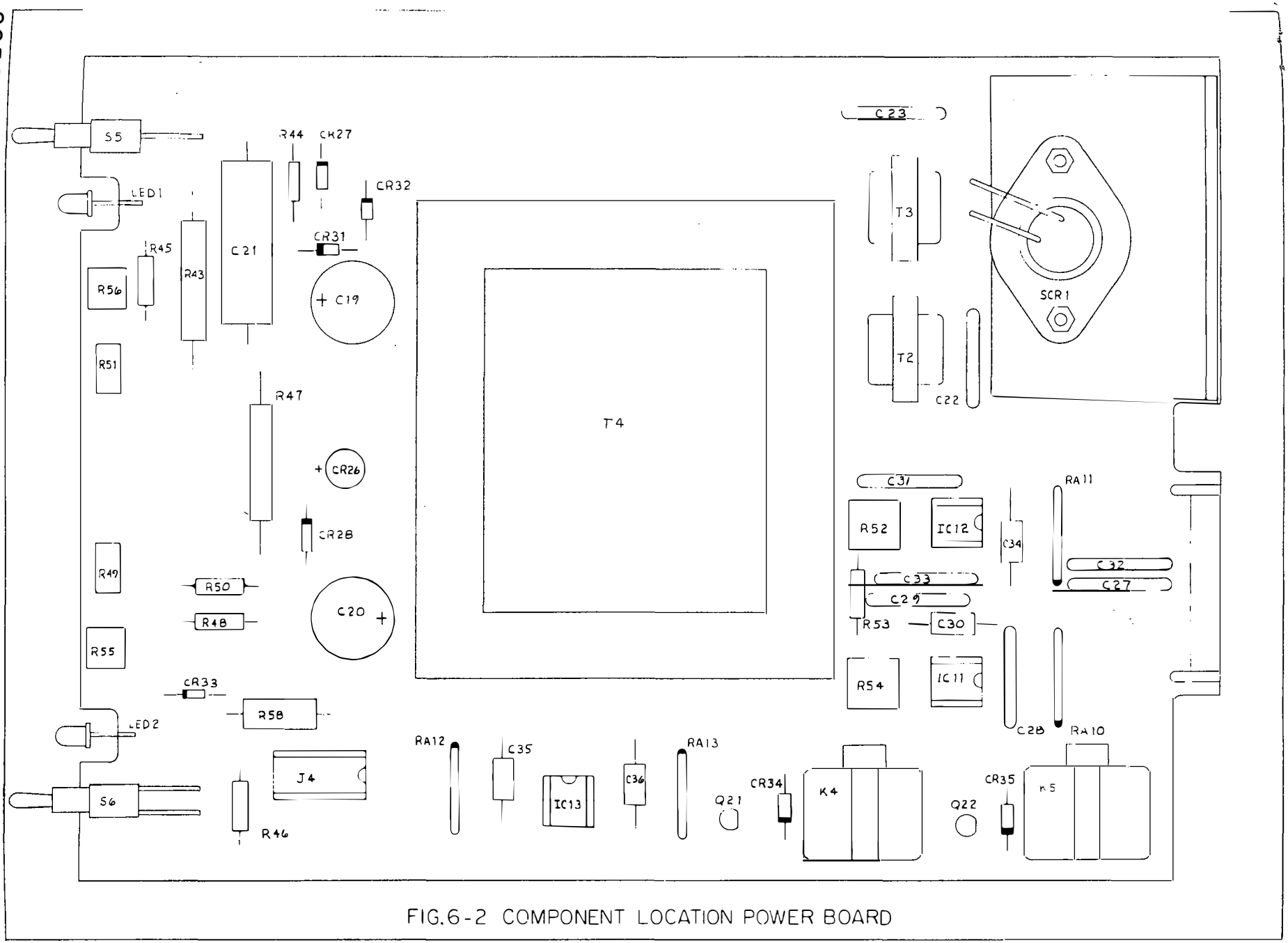


FIG.6-2 COMPONENT LOCATION POWER BOARD

7.2 Main Circuit Board Parts List (Refer to Fig. 6-1)

Circuit Designation	Description	G-P Part Number
	Integrated Circuits	
IC1 thru IC4	Quad 2-input nand 4011UB	004697 101
IC5	Binary up/dn counter 4516B	004696 100
IC6 thru IC8	Dual Operational amp MC1458, Motorola	007509 002
IC9	Dual Operational amp RC4558DN	005406 100
IC10	Dual Operational amp MC1458, Motorola	007509 002
IC14	Quad 2-input NAND 4011UB	004697 101
	Transistors	
Q1 thru Q8	Transistor 2N3906 PNP Si	001881 100
Q9	Transistor Darlington NPN Si General Electric GES5308	003880 101
Q10	Field effect transistor, Siliconix J112	004794 100
Q11 thru Q13	Transistor 2N3906 PNP Si	001881 100
Q14, Q15	Transistor Darlington NPN Si General Electric GES5308	003880 100
Q16	Transistor 2N3906 PNP Si	001881 100
Q17	Unijunction 2N4871, Motorola	004403 001
Q18, Q19	Field effect transistor, Selected 2N4118A Motorola SFE-1359	006004 100*
Q20	Field effect transistor, Selected U235	007644 100*
Q23	Protector Surge Voltage RCA SGT03U13	009095 100
	Diodes	
CR1, CR2	Zener diode 12V 1.0W, IN4742A	007649 100
CR3	Zener diode 6.0V 1.0W, 1% Schauer SZ6.0-1%- 10 mA	004240 100
CR4	Zener, modified D38W14	004836 101*
CR5 thru CR9, CR39	Signal diode IN4007 Si	001896 100
CR15	Zener diode 30.0V 1.0W IN4751	005787 001
CR16	Signal diode IN4007 Si	001896 100
CR18	Zener diode 5.1V 1.0W IN4733A	005228 002
CR20 thru CR25	Signal diode IN4007 Si	001896 100
CR36	Zener, modified D38W14	004836 101*
CR37, CR38	Signal diode IN3064 Si	004563 002
SVP	Protector surge voltage Siemens B1-C90/3	003574 102
LED3 thru LED8	Diode light emitting red Dialight 521-9200	003378 100
	Capacitors	
C1, C2, C3	Capacitor 4700 pf 500V polystyrene Centralab CPR-4700J	001459 101
C4	Capacitor 100p 500V polystyrene Centralab CPR-100J	001462 101
C5	Capacitor 0.1uf 100V mylar Cornell Dubilier WMF 1P1	004571 001
C6	Capacitor 10.0 uf 16V electrolytic Sprague 500D106G016BA7	005785 001

Circuit Designation	Description	G-P Part Number
R23	Resistor 510.0 Kohm 5.0% 0.5W carbon	005691 001
R24	Resistor 100.0 Kohm 5.0% 0.5W carbon	000292 100
R25	Resistor 20.0 Kohm 5.0% 0.5W carbon	001022 100
R26	Resistor 100.0 Kohm 5.0% 0.5W carbon	000292 100
R27	Resistor 1.3 Kohm 5.0% 0.5W carbon	007024 100
R28	Pot 500.0 ohm 20.0% 0.5W	006480 100
R29	Resistor 20 ohm 5.0% 0.5W	001845 100
R30	Resistor 2.0 Mohm 5.0% 0.5W carbon	004774 100
R31	Resistor 2.0 Kohm 5.0% 0.5W carbon	001108 100
R32	Resistor 2.26 Kohm 1.0% 0.5W metal film	006085 001
R33	Resistor 1.0 Kohm 5.0% 0.5W carbon	000462 100
R34	Resistor 2.0 Kohm 5.0% 0.5W carbon	001108 100
R35	Resistor 100.0 ohm 5.0% 0.5W	000379 100
R36	Resistor 510.0 Kohm 5.0% 0.5W carbon	005691 001
R37	Resistor 100.0 Kohm 5.0% 0.5W carbon	000292 100
R38, R39	Pot 5.0 Kohm 20.0% 0.5W	006479 100
R40	Resistor 1.0 Mohm 5.0% 0.5W carbon	000296 100
R41, R42	Resistor 2.0 Mohm 5.0% 0.5W carbon	004774 100
R57	Resistor 10.0 Kohm 5.0% 0.5W carbon	000464 100
R59	Resistor 1.50 Kohm 1.0% 0.1W metal film	005791 100
R60	Resistor 1.0 Mohm 5.0% 0.5W carbon	000296 100
RA1	Resistor Array	004685 101*
RA2	Resistor Array	004683 101*
RA3	Resistor Array	007635 100*
RA4	Resistor Array	004665 102*
RA5	Resistor Array	004667 102*
RA6	Resistor Array	004666 102*
RA7, RA8	Resistor Array	004671 102*
RA9	Resistor Array	004668 102*
R61	Pot, 10.0 Kohm, 20%, 1.0W	003277 101
	Switches	
S1 (man)	Switch, fil. control, man., SPDT, on-x-mom C & K 7108SAV-2B 7108 SD9AV 2BE	004787 100
S1 (auto)	Switch, fil. control, auto., DPDT on-off-mom C & K 7207SAV-2B 7207 SD9 AV 2 BE	004788 102
S2	Switch, up/down, SPDT mom-off-mom C & K 7105SAV-2B 7105 SD9 AV 2 BE	004040 103
S3	Switch, autoranging, DPDT on-x-on C & K 7201SAV-2B 7201 SD9 AV2BE	004785 102
S4	Switch, emission, SPDT on-x-mom C & K 7108SAV-2B 7108 SD9AU 2BE	004787 102
	Connectors and Sockets	
J1	Connector BNC female Amphenol UG1094-U	000608 100
XK1, XK2	Socket Relay 10 contact PCB mtg.	001165 103
XK3	Socket Relay 16 contact PCB mtg.	001166 103
H1	Jumper Plug Berg 65474-001	006891 100

Circuit Designation	Description	G-P Part Number

Resistors and Potentiometers

Circuit Designation	Description	G-P Part Number
R43	Resistor 10 Kohm 5.0% 5.0W	004780 100
R44	Resistor 510 Kohm 5.0% 0.5W	005691 001
R46	Resistor 200 ohm 5.0% 0.5W	004773 100
R47	Resistor 500 ohm 5.0% 5.0W	004781 100
R48	Resistor 200 ohm 5.0% 0.5W	004773 100
R49	Pot 1 Kohm 20.0% 0.5W Bourns 3386P	006481 100 12F168
R50	Resistor 200 ohm 5.0% 0.5W	004773 100
R51	Pot 1 Kohm 20.0% 0.5W Bourns 3386P	006481 100 12F166
R52	Pot 100 ohm 20.0% 1.0W Bourns 3386F	007247 100 13F015
R53	Resistor 10 Kohm 5.0% 0.5W	000464 100
R54	Pot 100 ohm 20.0% 1.0W Bourns 3386F	007247 100 13F015
R55, R56	Pot 500 ohm 20.0% 0.5W Bourns 3386P	006480 100 New 12F168
R58	Resistor 680 ohm 5.0% 1.0W	000463 100

Light Emitting Diodes

Circuit Designation	Description	G-P Part Number
LED1, LED2	Diode, light emitting, red Dialight 521-9200 1.9V 20 ma Newark 25F-1460	003378 100

Relays

Circuit Designation	Description	G-P Part Number
K4, K5	Relay 5.8 mA 2500 ohm 2PDT 3A con. American Zettler AZ420-C56-4HUS	006513 100

Switches

Circuit Designation	Description	G-P Part Number
S5A, S5B	Assembly, Switch, Line Selector	006890 100*
S5	Switch, power, SPDT, PCV sil on-x-on C & K 7101SAV-2Q 7101/SD9AV 2QE	004784 102
S6	Switch, degas, DPDT, PCV sil on-x-on C & K 7201SAV-2Q 7201 SD9 AV 2QE	004786 102
S7	C+K 7101 SD9 AV 2BE	

Fuses

Circuit Designation	Description	G-P Part Number
F1 (100,115V)	Fuse, 1.25 Amp, 250V, slow blow (English) Littelfuse 3AG 313 1.25	004966 100
F1 (230V)	Fuse, 0.5 Amp, 250V, slow blow (Metric) Littelfuse 213.500	006967 100

Connectors and Sockets

Circuit Designation	Description	G-P Part Number
	Socket, Relay, 10 contacts, PCB Mt Potter Brumfield ALL-10	001165 103
	Insert cap, metric fuse Schurter FEV 031.1653	006910 100
	Insert cap, English fuse Schurter FEK 031.1666	006966 100
	Connector, female, 6 pin Amphenol 78-56-071	001318 100
	Connector, power, 3 blade recessed Switchcraft EAC-301	006443 100

Miscellaneous

Circuit Designation	Description	G-P Part Number
	Shield, Transformer	007536 001*
SUP	Surge Voltage Protector	003574 102

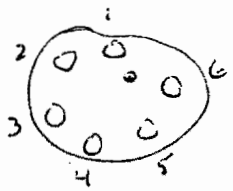
Notes.

1. Electrometer Zero adjustment in adjacent ranges

check CR1 + CR2 switching Diodes
S/B ∞ in reverse

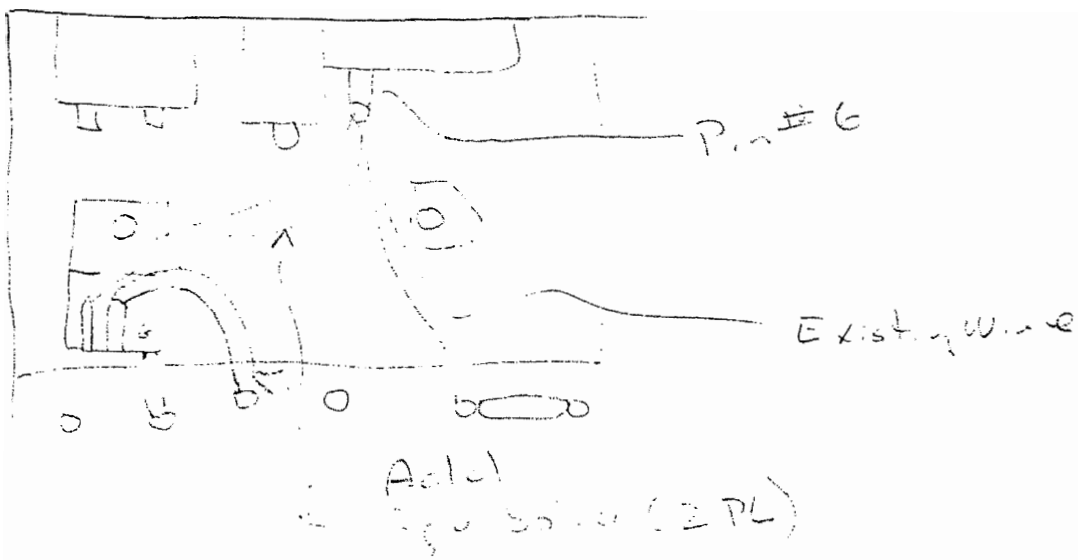
2. Auto ranging oscillation (✓ Range display in manual first)

3. 6 Pin Plug : Key at 2:00 (Viewed from rear)



4. Buzz on no F.I Tune on
✓ C7

5. TRIAC Replacement 200V/15A Isolated
ECG 5645
MOT MAC15A4 FP (Newark



① IS connection. Relocate ground wire to right screw

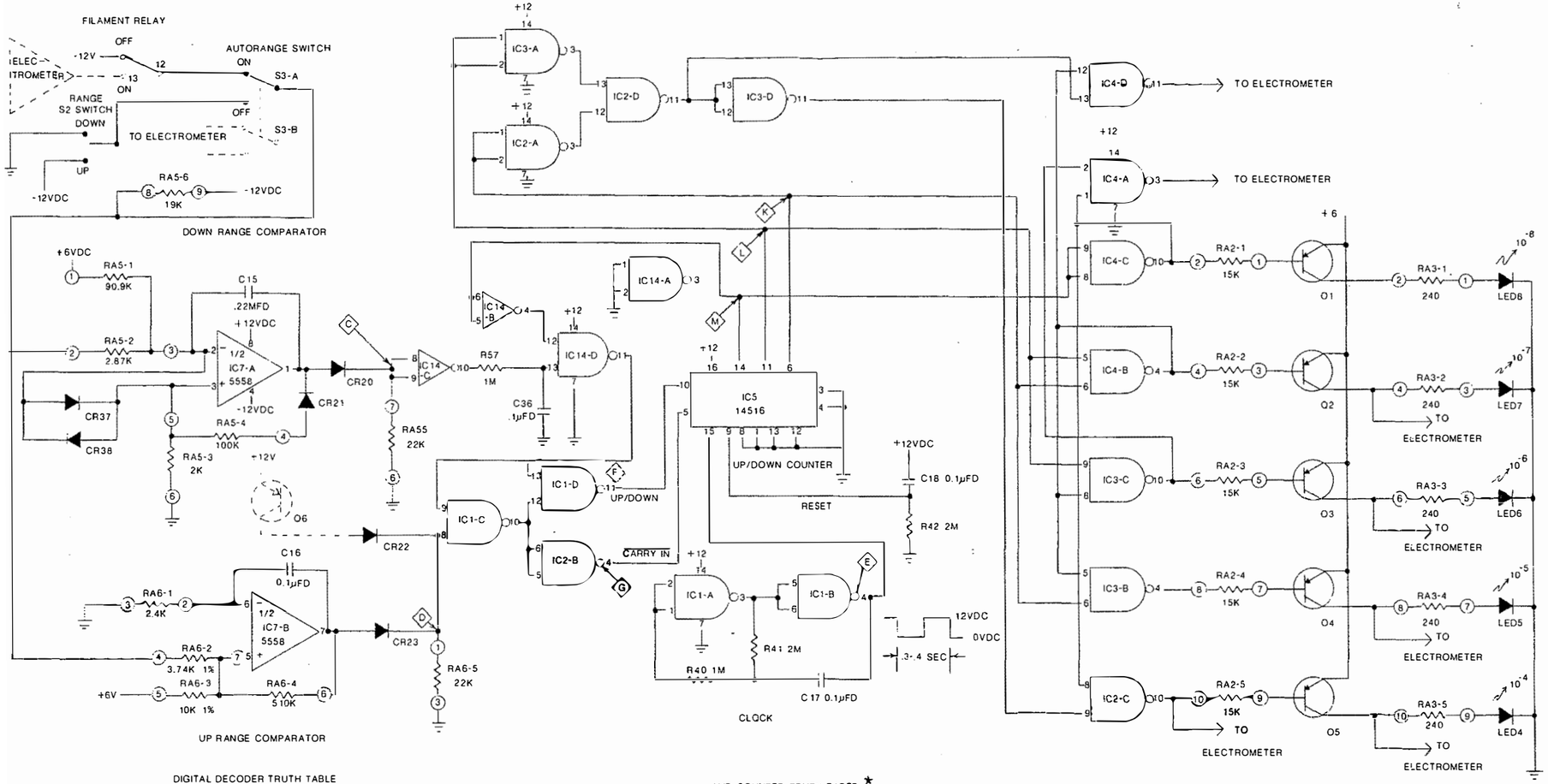
② Heat sink - become insulated to left screw

DECADE	SWITCH O18	SWITCH O19	SWITCH O10	EQUIVALENT R F
10^{-4}	ON	OFF	ON	100K
10^{-5}	OFF	ON	ON	1M
10^{-6}	OFF	ON	OFF	10M
10^{-7}	OFF	OFF	ON	100M
10^{-8}	OFF	OFF	OFF	1000M

NOTES:
1. ALL RESISTORS IN OHMS, .5W,5% UNLESS OTHERWISE NOTED
2. RESISTOR ARRAYS (RA TYPES) 1/8W
3. ⏚ DENOTES SIGNAL GROUND
4. ⏚ DENOTES CHASSIS GROUND
5. ◇ DENOTES TEST POINTS

CONNECTOR IDENTIFICATION
J1 COLLECTOR INPUT
J3 IG ACCESSORY

FIG. 5-5
ELECTROMETER SCHEMATIC



DIGITAL DECODER TRUTH TABLE

	IC5			IC2			IC3				IC4			
DECADE	M	L	K	PIN 3	PIN 10	PIN 11	PIN 3	PIN 4	PIN 10	PIN 11	PIN 3	PIN 4	PIN 10	PIN 11
10^{-4}	0	0	0	1	0	0	1	1	1	1	0	1	1	1
10^{-5}	0	0	1	0	1	1	1	0	1	0	0	1	1	0
10^{-6}	0	1	0	1	1	1	0	1	0	0	1	1	1	0
10^{-7}	0	1	1	0	1	1	0	1	1	0	0	0		1
10^{-8}	1	0	0	1	1	0	1	1	1	1	1	1	0	1

U/D COUNTER TRUTH TABLE ★

ELECTROMETER OUTPUT	C	D	IC1 PIN 10	F	G	ACTION
GREATER THAN -.19VDC	0	1	1	1	0	COUNT DOWN
LESS THAN -.19VDC AND GREATER THAN -2.34 VDC	1	1	0	1	1	STEADY STATE
LESS THAN -2.34VDC	1	0	1	0	0	COUNT UP

NOTES:
1. ALL RESISTORS ARE IN OHMS, .5W, ±5% UNLESS OTHERWISE SPECIFIED
2. RESISTOR ARRAYS (RA TYPES) ARE 1/8W
3. ⏚ DENOTES SIGNAL GROUND
4. ALL QUAD NAND GATES ARE 14011 TYPE
5. ⁄ DENOTES TEST POINT

FIG. 5-6
AUTORANGING SCHEMATIC

AUTORANGING SCHEMATIC

FIG. 5-6

007056 100

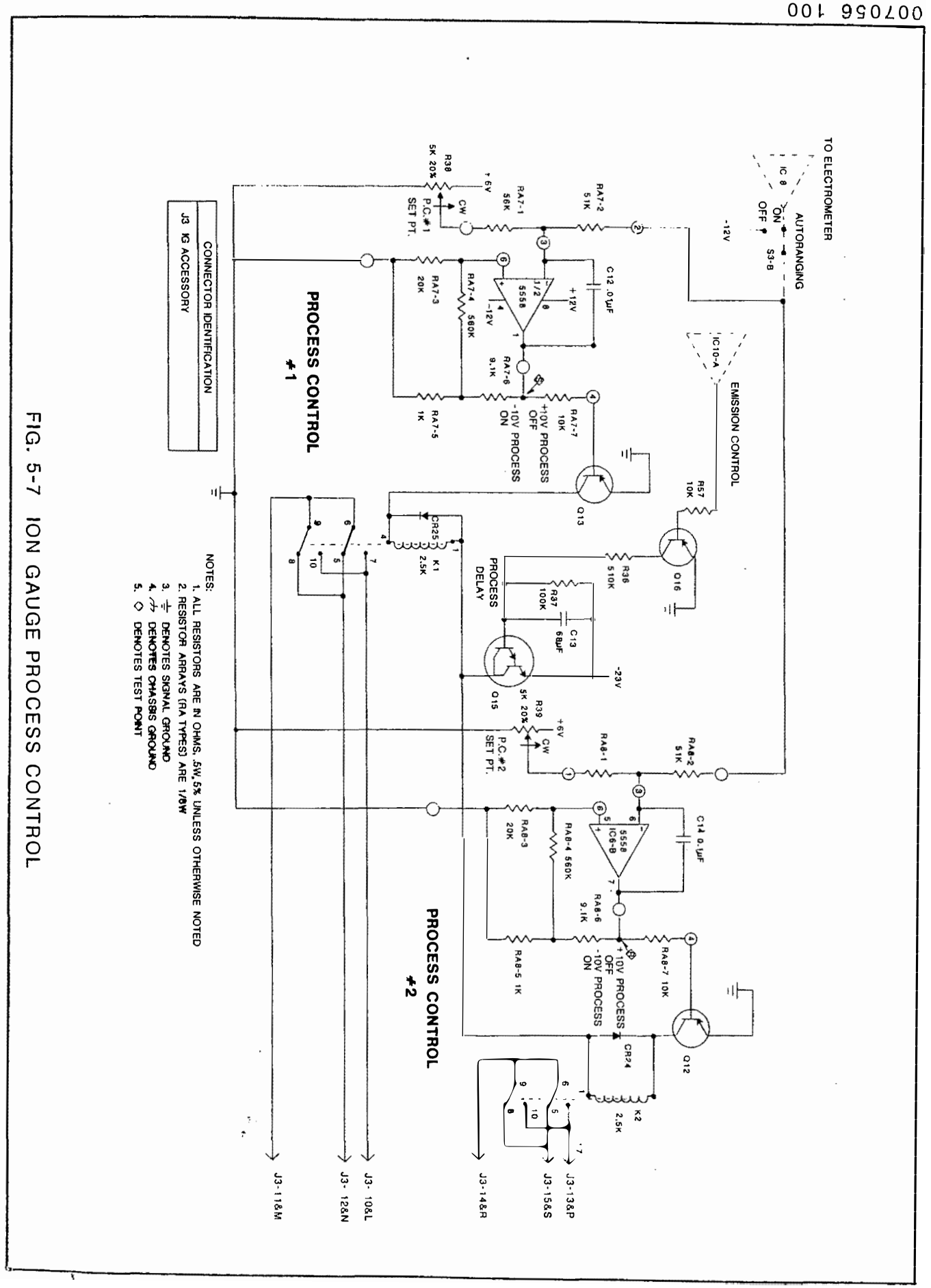
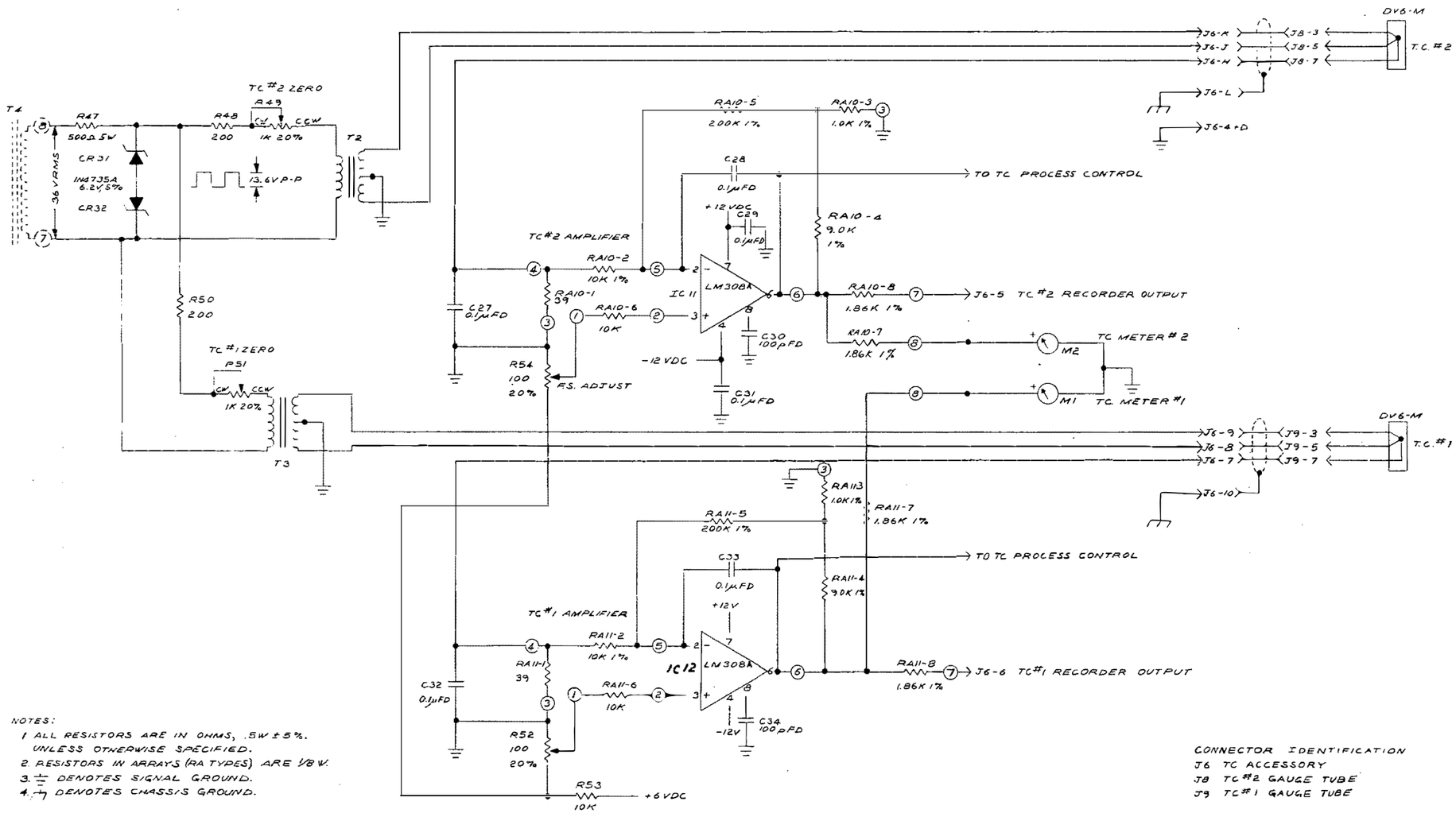


FIG. 5-7 ION GAUGE PROCESS CONTROL



NOTES:
1. ALL RESISTORS ARE IN OHMS, .5W ± 5%. UNLESS OTHERWISE SPECIFIED.
2. RESISTORS IN ARRAYS (RA TYPES) ARE 1/8 W.
3. ⏚ DENOTES SIGNAL GROUND.
4. ⏚ DENOTES CHASSIS GROUND.

CONNECTOR IDENTIFICATION
J6 TC ACCESSORY
J8 TC #2 GAUGE TUBE
J9 TC #1 GAUGE TUBE

FIG. 5-8
THERMOCOUPLE SCHEMATIC

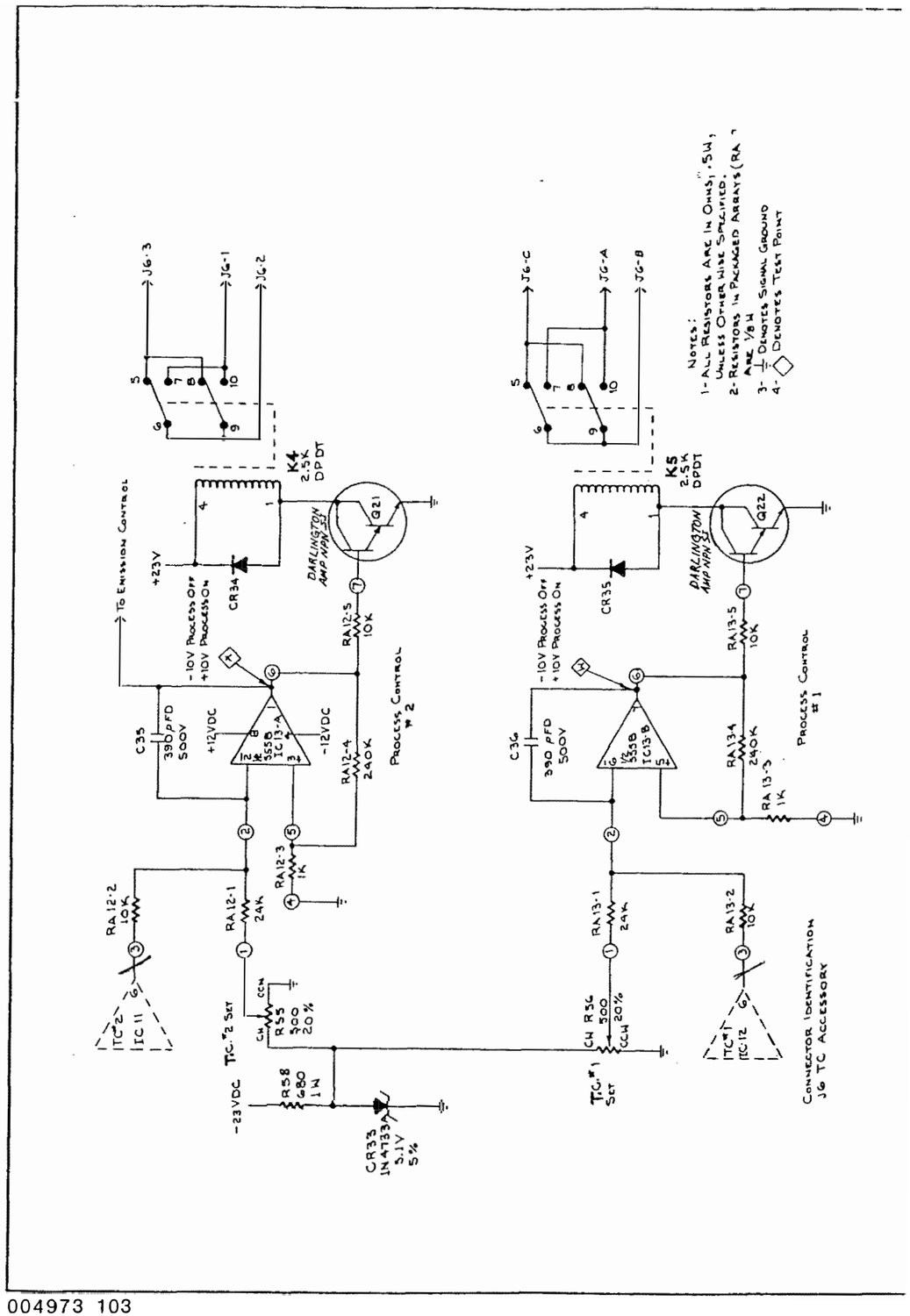


FIG. 5-8

THERMOCOUPLE SCHEMATIC

004973 103