SERIES 260

IONIZATION

GAUGE CONTROLLER

INSTRUCTION MANUAL

GRANVILLE-PHILLIPS

WARNING! - Safe operation of ion producing equipment requires grounding of both the vacuum chamber and the power supply. **LETHAL VOLTAGES** may be established under some operating conditions unless correct grounding is provided.

Research at Granville-Phillips has established that ion producing equipment, such as ionization gauges, mass spectrometers, sputtering systems, etc., from many manufacturers may, under some conditions, provide sufficient conduction via a plasma to couple a high voltage electrode to the vacuum chamber. If conductive parts of the chamber are not grounded, they may attain a potential near that of the high voltage electrode during this coupling. Potentially fatal electrical shock could then occur because of the high voltage between these chamber parts and ground.

During routine pressure measurement using a Granville-Phillips 260 ionization gauge, about 160V may become present on ungrounded chambers at pressures near 10^{-3} Torr. Similar voltages have been measured when testing with controllers from other manufacturers. All isolated or insulated conductive parts of the chamber must be grounded to prevent these voltages from occurring.

Grounding, though simple, is very important! Please be certain that the ground circuits are correctly utilized, both on your gauge controllers and on your vacuum chambers, regardless of their manufacturer, for this phenomenon is not peculiar to Granville-Phillips equipment. Refer to Safety Instructions and Section 3, Installation and Operation, for additional information. If you have questions, or wish additional labels or literature, please contact me or one of our service personnel.

GRANVILLE-PHILLIPS COMPANY
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Senior Scientist
(303)443-7660

007496 100

INSTRUCTION MANUAL

NO. 260014 006

FOR SERIES 260

IONIZATION GAUGE CONTROLLERS

YOU SHOULD READ THIS INSTRUCTION MANUAL BEFORE INSTALLING, USING, OR SERVICING THIS EQUIPMENT.

For use only with Series 260 Ionization Gauge products with the following Part Numbers:

260009	260028	260034
260015	260029	260035
260016	260030	260041
260022	260031	260042
260026	260032	260043
260027	260033	

Granville-Phillips Company
5675 E. Arapahoe Ave.
Boulder, Colorado 80303
(303) 443-7660
Revised January 1988

CERTIFICATION

Granville-Phillips Company certifies that this product met 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.

SPECIFICATIONS

Controller

Pressure Range, Ion Meter	1×10^{-3} to 2×10^{-10} Torr for N_2, with Bayard-Alpert gauge with sensitivity between 10 $Torr^{-1}$ and 100 $Torr^{-1}$. (Upper limit can be extended to 1×10^{-2} Torr with reduced emission current.)
Pressure, Range, Thermo-Gauge	1000 Torr to 10^{-3} Torr, Air
Ambient operating temperature	0 to 50°C
Electrical power requirement	105 to 125 V ac, 210 to 250 V ac, or 90 to 110 V ac depending on model; 50 to 60 Hz, 200 watts.
Ion gauge recorder output	0 to -110 mV, corresponding to front panel meter indication of 0 to 11. 1 Kohm ± 1% output impedance.
Thermo-Gauge recorder output	1.1 to 12V corresponding to pressure indication from vacuum to 1000 Torr. 2.7 Kohm ± 5% output impedance.
Stability of ion current meter zero (for zero current input to electrometer and after 1-minute warm-up).	With time: ± 0.25% FS/50 hrs. With temperature: ± 1% FS,0 to 50°C. With line voltage: ± 0.25%, FS, full voltage range.

Electrical Characteristics:

Filament power available	Lo tap 6A, 8V Hi tap 6A, 14V
Degas power available	9A, 8V, 72 watts
Collector voltage to ground	0V
Grid voltage to ground	+180V nominal
Filament voltage to ground	+30V nominal
Emission current range	100 μA to 10 mA

Automatic ranging:	Down Up	7% of full scale 100% of full scale
Process control range		1×10^{-3} to 1×10^{-9} Torr as indicated
Process control relay contact rating		SPDT, 1A at 115V ac resistive load
Filament status relay contact rating		SPDT, 1A at 115V ac resistive load

Thermo-Gauge

Pressure range	1×10^{-3} Torr to 1000 Torr, air
Mounting	1/8" NPT or ½ in. compression quick connect
Maximum non-operating (bakeout) temperature	100°C

SAFETY INSTRUCTIONS

SAFETY PAYS. THINK BEFORE YOU ACT. UNDERSTAND WHAT YOU ARE GOING TO DO BEFORE YOU DO IT. READ THIS INSTRUCTION MANUAL BEFORE INSTALLING, USING, OR SERVICING THIS EQUIPMENT. IF YOU HAVE ANY DOUBTS ABOUT HOW TO USE THIS EQUIPMENT SAFELY, CONTACT THE GRANVILLE-PHILLIPS PRODUCT MANAGER FOR THIS EQUIPMENT AT THE ADDRESS LISTED ON THIS MANUAL.

Explosive Gases

Do not use Series 260 instruments to measure the pressure of explosive or combustible gases or gas mixtures.

High Pressure Operation

Do not use a compression mount (quick connect) for attaching the gauge tube to the system in applications resulting in positive pressure in the gauge tube. Positive pressures might blow the tube out of a compression fitting and damage equipment or injure personnel.

Chemical

Cleaning solvents, such as trichloroethylene, perchlorethylene, toluene and acetone produce fumes that are toxic and/or flammable. Use only in areas well ventilated to the outdoors and away from electronic equipment or open flames.

IONIZATION GAUGE

Implosion and Explosion

Glass ionization gauges if roughly handled may implode under vacuum causing flying glass which may injure personnel. If pressurized above atmospheric pressure, glass tubes may explode causing dangerous flying glass. A substantial shield should be placed around vacuum glassware to prevent injury to personnel. Avoid attaching gauge connector to gauge tube pins while glass gauge is under vacuum as accidental bending of pins may cause glass to break and implode. Gauge cables, once installed, should be securely clamped or tied to provide adequate strain relief to the gauge tube pins.

Grid Voltage

Be aware that 180V is applied to the grid when the controller is turned on and the gauge tube is connected . Do not touch any gauge tube electrodes while the tube is connected to the controller.

Overpressure

Series 260 instruments containing Thermo-Gauges are furnished calibrated for N_2. They also give the same indication for air within the accuracy of the instrument. Do not attempt to use a Series 260 Thermo-Gauge calibrated for N_2 to measure or control the pressure of other gases such as argon or CO_2, unless accurate conversion data for N_2 to the other gas is properly used. If accurate conversion data is not used or improperly used a potential overpressure explosion hazard can be created under certain conditions.

For example, at 760 Torr of argon gas pressure, the indicated pressure on a Series 260 Thermo-Gauge calibrated for N_2 is about 24 Torr. At an indicated pressure of 50 Torr, the true pressure of argon is considerably above atmospheric pressure. Thus if the indicated pressure is not accurately converted to true pressure, it is possible to overpressure your system. Overpressure may cause glassware such as ionization gauges to shatter dangerously, and if high enough may cause metal parts to rupture, thus damaging the system and possibly injuring personnel. See Section 3 for proper use of conversion data.

High Indicated Pressure

For some gases, be aware the indicated pressure on the Thermo-Gauge will be higher than the true pressure. For example, at a true pressure of 9 Torr for helium the indicated pressure on a Series 260 Thermo-Gauge calibrated for N_2 is 30 Torr. The safe way to operate the gauge is to properly use accurate conversion data. See Section 3 for proper use of conversion data.

Temperature

Do not allow the temperature of the Thermo-Gauge tube to exceed 100°C. The solder can melt, causing gases to leak in or out of your system.

System Grounding

When operating ionization gauges, some relatively common gas discharge conditions have been found to cause currents through the common ground between the vacuum chamber and the ionization gauge controller chassis. If this ground connection is open when the discharge occurs, nearly the full grid voltage (up to 160V) can appear between the ground of the controller chassis and the vacuum system. Human contact could be fatal. In this dangerous condition, the fuses and automatic turn-off circuits in the controller are not usually called to action. Thus, this dangerous voltage could remain between the vacuum system and ground for extended periods of time. Guaranteeing a good common ground for the vacuum chamber and gauge controller chassis can remove these dangers. It appears probable that all brands of gauge tubes and controllers can cause this hazard.

The safety ground on most electronics equipment does not carry continuous current. Thus its potential may differ by several volts from the ground of those vacuum systems which use the power common line as their ground. These two ground systems should have a common junction which is typically at the distribution breaker box. Even though the resistance between these two grounds may be very low, and thus correct, that voltage difference resulting from unbalanced current flow in the common lead complicates the use of the conventional ohmmeter for verifying that low resistance. The placement of a second ground wire between the vacuum chamber and the gauge controller chassis is not a safe answer, for large continuous currents could flow through it as a ground loop.

Refer to the installation instructions for the proper inspection procedure to determine if your system grounding is satisfactory.

INSTALLATION INSTRUCTIONS

Receiving Inspection

Domestic Shipments

Inspect all material received for shipping damage.

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.

International Shipments

Inspect all material received for shipping damage. Confirm that your shipment includes all material and options ordered. 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.

Rack Mounting

Your controller may be rack mounted in a standard 19-inch relay rack using the hardware supplied with each unit. Always provide adequate ventilation so that the ambient temperature will not exceed 50°C. Do not block air flow thru the instrument by mounting it closely against other surfaces.

Electrical Connections

Your controller, as received, is wired for operation from a power source corresponding to the following limits:

Catalog Numbers		Power Source
260015	260033	105-125V*, 50 to 60 Hz, 1 phase, 200W
260016	260035	
260022	260042	
260032	260043	

Catalog Numbers	Power Source
260026, 260027, 260028, 260034, 260041	210-250V, 50 to 60 Hz, 1 phase, 200W
260029, 260030, 260031	90-110V, 50 to 60 Hz, 1 phase, 200W

*The 105-125V controllers can be converted to 210-250V operation by making the wiring changes shown in Fig. 2-1. Replace the power fuse, F1, with a 1A slo-blow fuse rated at 250V. Place the 230-volt decal supplied with these models over the 115-volt rating on the rear panel. If the power connector provided with the unit is not compatible with the power source that is available, the power plug on the cordset supplied with the controller can be removed and replaced by the appropriate type. Wire the new plug according to the following wire insulation color code in order to maintain safe operation:

Black or Brown:	AC Line (Hot)
White or Blue:	AC Neutral
Green or Green/Yellow:	Earth Ground

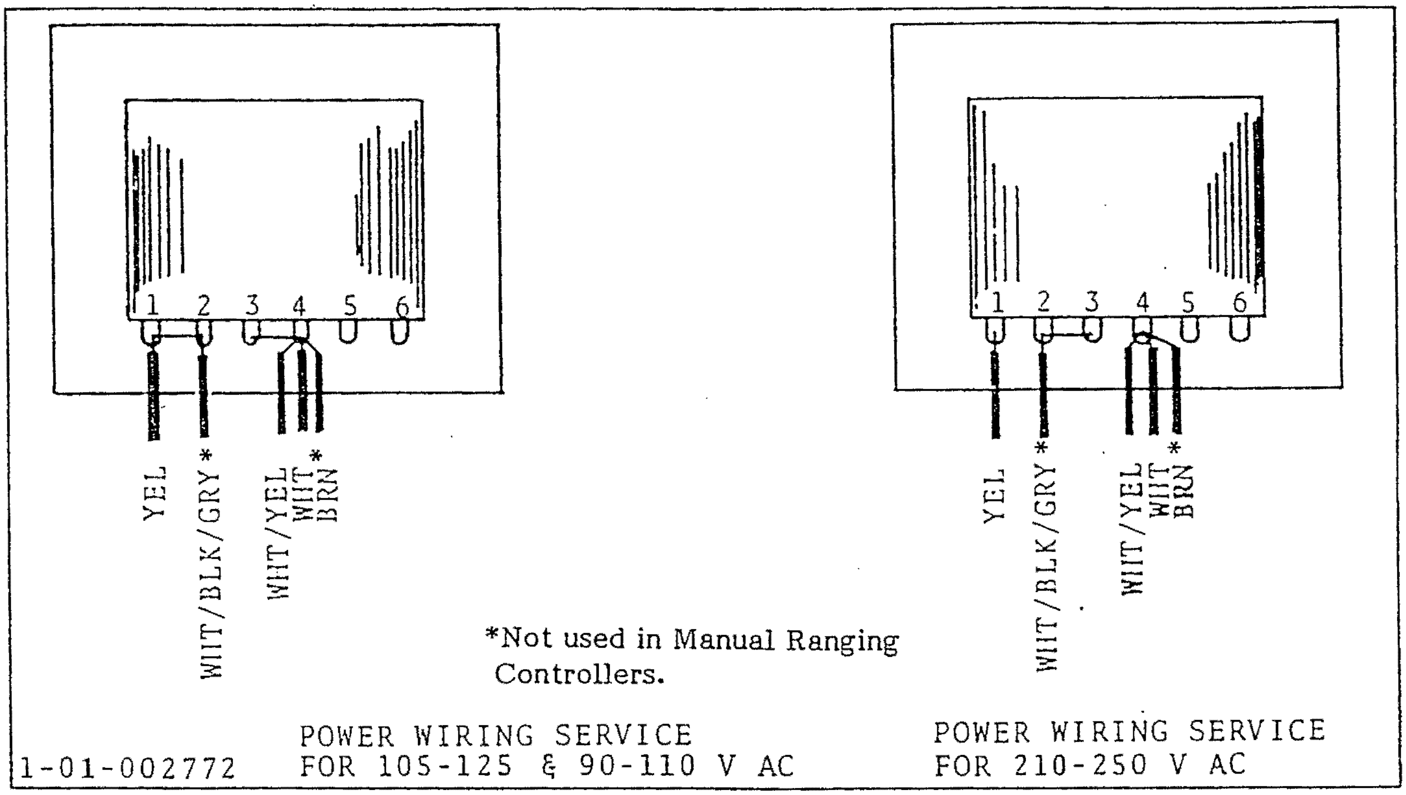

FIG. 2-1 TRANSFORMER WIRING

Ion Gauge Tube

Use caution in handling glass ionization gauge tubes, especially while they are at vacuum. If roughly handled, they may implode, causing serious injury to the operator. If pressurized above atmospheric pressure they may explode causing damage and injury. Always place a substantial shield around vacuum glassware to prevent injury to personnel from implosion or explosion. Avoid attaching cable to gauge tube pins while glass gauge is under vacuum as accidental bending of pins may cause glass to break and implode. Gauge cables once installed should be securely clamped or tied to provide adequate strain relief to the gauge tube pins.

Consideration should be given to where the tube is connected to the system. If placed near the pump, the pressure in the tube may be considerably lower than in the remainder of the system. If placed near a gas inlet or source of contamination, the pressure in the tube may be considerably higher than in the remainder of the system.

When the gauge tube is to be connected to a system where energetic charged particles and/or RF fields may be present in the system, adequate baffling and shielding must be provided by the user. If the gauge tube is not adequately baffled and shielded, controller malfunction or damage may result. The inlet port must be shielded from line of sight transmission of energetic charged particles.

When high RF fields are present in the vacuum chamber such in a sputtering system, an electrostatic shield must be placed in the inlet port of the gauge tube. Several metal discs with staggered small holes, spaced so as to permit gas flow to and from the gauge tube, placed in the inlet port can be effective in preventing RF from affecting the measurement or damaging the controller.

When the gauge tube is used in an RF field external to the system and tube, an RF shield surrounding the gauge tube must be used for proper operation.

Series 260 Ionization Gauge controllers are designed to operate with standard Bayard-Alpert type tubes or other tube types such as the VG1A, whose voltage and current requirements and gauge sensitivity are within the operating range of the controller.

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.

<u>Ion Gauge Cables</u>

Granville-Phillips manufactures two types of cables to go with the Series 260 controller. The gauge cable included with the controller is designed to be used with the Granville-Phillips single filament and dual filament Series 274 tubulated gauges. If you are using this cable, with the controller power switch off, plug the 8 pin connector of the gauge cable into the connector on the rear of the controller marked gauge. Connect the other end of the cable to the gauge. Fig. 2-2 shows what the configuration of the tube elements must be in order to mate directly with the controller using this type of cable. Cables of this type may be obtained in longer lengths up to a maximum of 400 ft. if desired. Refer to the data sheet for added information.

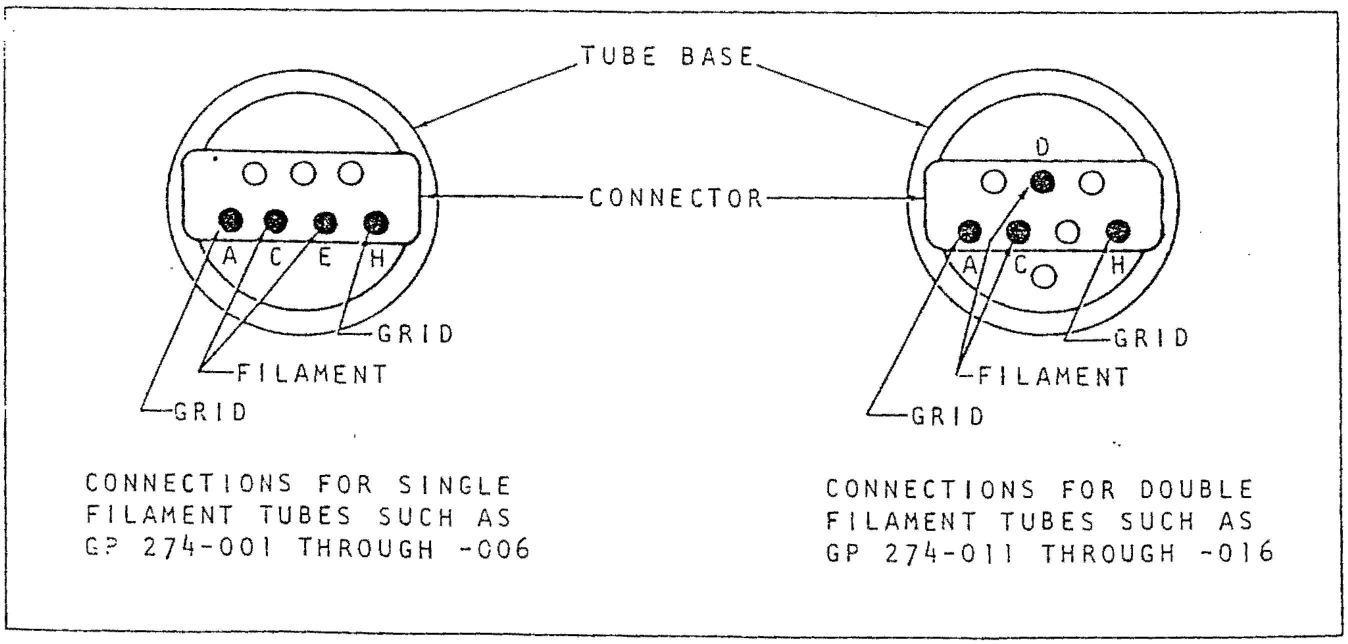

FIG. 2-2 ION GAUGE TUBE CONNECTION

Gauge cable set 260037 is designed to be used with gauges which do not have the standard base such as the Granville-Phillips 274028 nude tube. If you are using this cable, with the controller power switch off, plug the 8 pin connector of the gauge cable into the connector on the rear of the controller marked gauge. Connect the individual labeled sockets to the corresponding gauge pins. As a safety precaution, any unused gauge pin should be connected to the socket labeled "pin cover". This socket has been provided as an insulator for an unused gauge pin.

Gauge Cable Wire Code

Grid	Black
Grid	Brown
Filament	Red
Filament	Green
Collector	Coaxial

Protection of Controller from DC and RF Voltages

The controller is built to withstand shorts between the tube elements. It is absolutely necessary to shield the tube anytime the controller is used on systems where energetic charged particles above 180ev are present. If not shielded, failures are to be expected.

Note also, the use of a high frequency spark coil commonly used for leak testing glass systems can cause damage to the controller. Always disconnect the cables from the tube before leak testing with a spark coil.

Power Cable

Check to see that the ionization gauge tube is at less than 1×10^{-3} Torr or is electrically disconnected before applying power to the controller for the first time. Connect the power cable to the controller and to an appropriate source of ac power. Use only a three-wire grounded receptacle or an adapter plug to ground the controller through the power cable. If the power light is on, turn the controller off by depressing the power switch once. If the degas or auto light is also on, depress the corresponding switch once.

System Ground Test Procedure (Refer to the Safety Instructions for further information)

Procedure: Physically examine the grounding of both the ion gauge controller and the vacuum chamber. Is there an intentional heavy duty ground connection to the vacuum chamber? There should be. Note that a horizontal "O" ring or "L" ring gasket, without metal clamps, can leave the chamber above it electrically isolated. Power can be delivered to mechanical and diffusion pumps without any ground connections to the system frame or chamber. Water line grounds can be lost by a plastic or rubber tube interconnection. What was once a carefully grounded vacuum system can, by innocent failure to reconnect all ground connections, become a very dangerous device. Use the following procedure to test each of your vacuum systems which incorporates an ionization gauge.

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.

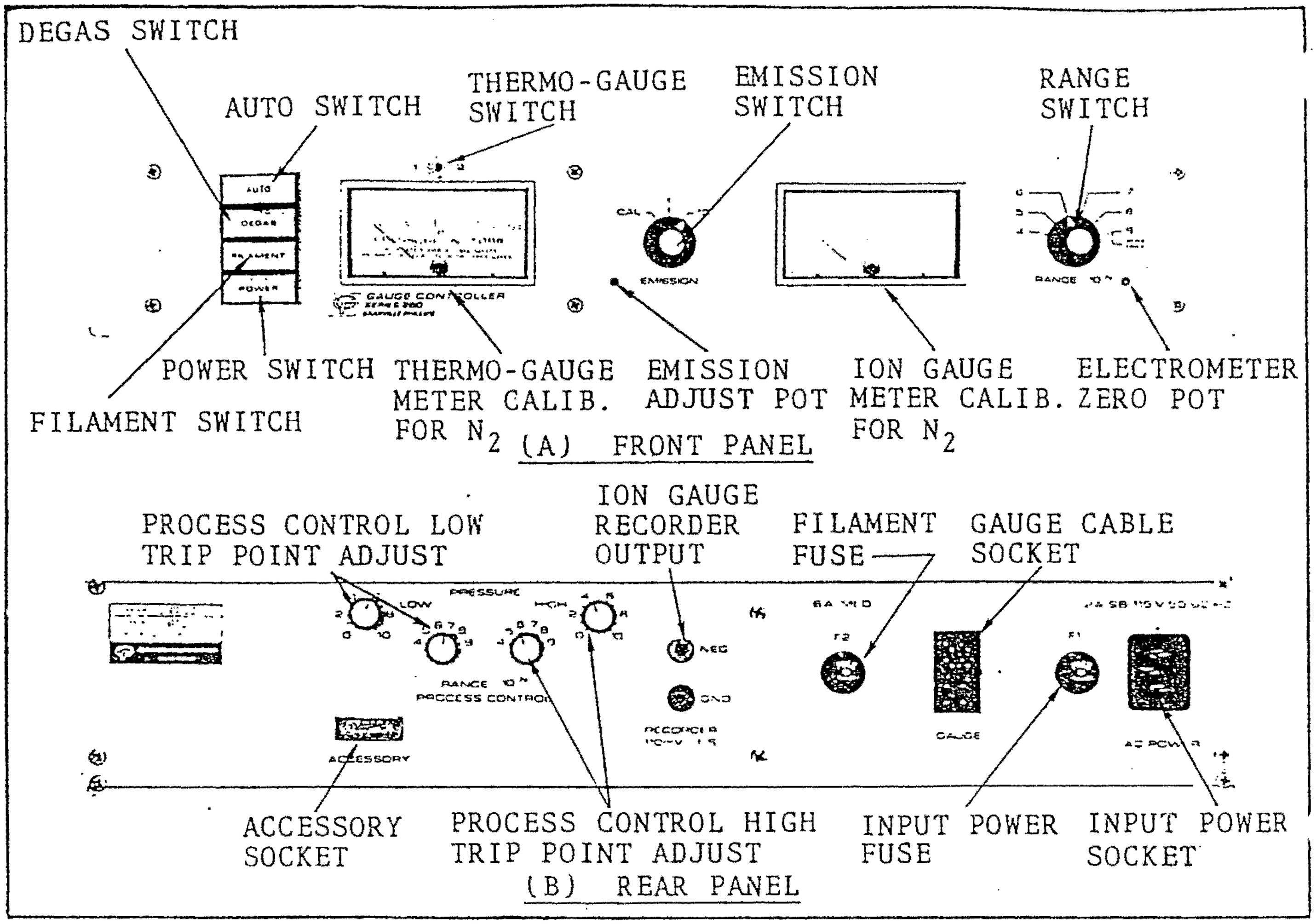

FIG. 2-3 LOCATION OF CONTROLS (FRONT AND REAR PANELS)

IONIZATION GAUGE OPERATION

Checking Electrometer Zero

1. Make certain the installation described in Section 2 has been completed.

2. With the power switch off, check that the ion gauge meter reads zero. If it does not, carefully zero the meter using the adjustment in the center of the meter.

3. Depress the power switch once. The indicator light in the power switch should come on. Depress once any other switch giving an "ON" indication.

4. Turn the emission switch to 10.

5. Rotate the range switch through the six decades and observe that the ion gauge meter reads zero $\pm \frac{1}{2}$ small division in all decades. If adjustment is required, use a small screwdriver to adjust the electrometer zero potentiometer, accessible through a small hole in the front panel near the range switch, until a meter zero is obtained.

Starting the Filament

CAUTION: Some tubes may be damaged by attempting to operate the filament in certain 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 controls as follows:

   Emission switch at 1

   Range switch at 10^{-4}

2. Depress the filament switch once and observe the following events.

3. The ionization gauge tube filament should glow.

4. The filament indicator lamp should come on and stay on. Note that the filament indicator light 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:

   - Gauge tube cable not connected
   - Pressure in tube is too high
   - Grid shorted
   - Tube incapable of supplying sufficient emission

If the filament light comes on briefly and then goes out, refer to Section 5 for guidance.

Establishing Correct Emission Current

1. Your controller has been factory calibrated to be direct reading for N_2 when used with an ionization gauge tube with a sensitivity of 10 per Torr for N_2 when the emission switch is set at either the 1 or 10 mA positions. The controller also gives the same indication for air as for N_2 within the accuracy of the instrument. To make the controller direct reading for other gauge tubes or for gases other than N_2 and air, use Eq. (1) to determine the correct emission current setting.

Eq. 1 $$i_- = \frac{10}{r \times \text{Gauge Tube Sensitivity for } N_2} \times 10 \text{ mA}$$

where r is given in Table 1. Equation 1 is applicable where $10 \leq r \times$ Gauge Tube Sensitivity for $N_2 \leq 100$.

Table 1

Ion gauge sensitivity ratios, r, derived from data obtained by S. Dushman and A. H. Young, Phys. Rev. 68 278 (1945).

Gas	N_2	H_e	N_e	A_r	K_r	X_e	H_2
r	1	0.15	0.24	1.19	1.86	2.73	0.46

Example 1

If your tube has a sensitivity of 25/Torr for N_2, then the emission current to make the controller direct reading for N_2 is

$$i_- = \frac{10}{1 \times 25} \times 10 \text{ mA} = 4 \text{ mA}$$

Example 2

If your tube has a sensitivity of 15/Torr for N_2 and you wish to measure argon pressure, the emission setting to make the controller direct reading for argon is

$$i_- = \frac{10}{1.19 \times 15} \times 10 \text{ mA} = 5.6 \text{ mA}$$

Example 3

Assume you have a tube with a gauge sensitivity of 10/Torr for N_2 and wish to make the controller direct reading for helium. Here Eq. 1 is not applicable for it calls for an emission current beyond the capability of the controller.

$$i_- = \frac{10}{0.15 \times 10} \times 10 \text{ mA} = 66.7 \text{ mA}$$

In such a situation one possibility is to set the emission current at 1/10 of the emission called for by Eq. 1, i.e., 6.7 mA for the assumed case, and remember to increase the indicated reading by a factor of 10. Under these assumptions a reading of 5×10^{-6} Torr for helium corresponds to a pressure of helium of 5×10^{-5} Torr.

2. To set the correct emission current, proceed as follows. Turn the range switch to the 10^{-4} position. Turn the emission switch to the CAL position. Use a small screwdriver to rotate the emission adjust potentiometer, accessible through a hole in the front panel near the emission switch, until the meter reads the desired emission current (10 mA corresponds to 10 on the meter). Thus, if the desired emission current were 4 mA, the meter should read 4 when the emission switch is in the CAL position. The controller would now furnish 4 mA when the emission switch is in the 10 position and 0.4 mA when in the 1 position.

Reading The Pressure

The pressure in the ionization gauge tube can be read only when the emission switch is in the 1 or 10 position. In general, it is preferable to use a low emission current at higher pressures and a high emission current at lower pressures. Turn the range switch until the meter reads on scale. The N_2 equivalent pressure in the tube in Torr is then obtained by multiplying the meter reading by the range switch setting. For example, if the range switch is set on 10^{-5} and the meter meads 5.6, the N_2 equivalent pressure in the tube is 5.6×10^{-5} Torr. The emission and range switches are electrically interlocked so that the N_2 equivalent pressure reading is independent of whether the emission switch is in the 1 or 10 position. The one exception to this is when the emission switch is in the 1 position and the range switch is in the 10^{-9} position. In this case the pressure will read one decade low.

When the emission current is switched between the 1 and 10 position, pressure readings may be different. This is a normal condition dependent upon the outgassing and pumping characteristics of the tube. If the emission is reduced, outgassing and ion pumping in the tube are both reduced. Thus, the pressure in the tube may increase or decrease depending upon whether outgassing or ion pumping is the predominate factor. In a dirty or contaminated tube, the pressure will invariable decrease slightly when the emission current is decreased.

Automatic Ranging

If your controller has the automatic ranging feature, the AUTO switch may be depressed at this time to provide automatic positioning of the range switch. The AUTO light should come on and the controller will automatically select a range to give a meter reading between approximately 7 and 100 percent of full scale.

Extending Pressure Range

It is possible to extend the range of the controller up to 1×10^{-2} Torr for N_2 and air for gauge tubes of 10 per Torr sensitivity by adjusting the emission current to 10 percent of the normal value. To use the 10^{-3} range capability, turn the range switch to the 10^{-4} position, turn the emission switch to CAL and adjust the emission to 1.0 on the meter. Now the controller will furnish 1.0 mA and 0.1 mA when the emission switch is in the 10 and 1 positions, respectively. To compensate for the fact that the emission current is now only 10 percent of the value which makes the controller direct reading, one must mentally multiply each range switch setting by 10. For example, a 10^{-4} reading becomes 10^{-3} and so forth. It is not possible to use this feature on tubes with sensitivities greater than 10 per Torr.

Degassing the Gauge Tube

Degassing the tube is accomplished by resistance heating of the grid structure. It is possible to observe the pressure in the tube during degas. There will normally be a large pressure rise during the initial stages of degassing. If a manual ranging controller is in use, the range switch should be set to a decade reading approximately two or three decades higher in pressure than is present in the system to prevent the filament from turning off. An automatic ranging controller will step through the ranges as required as the pressure rises and then falls during degas.

1. Depress the degas switch and observe that the degas indicator lamp turns on.

2. Observe that the grid structure of the tube starts to glow and that a pressure rise occurs. The system can be left in this mode as long as required to obtain satisfactory outgassing.

3. When degassing is complete, depress the degas switch and observe that the degas lamp turns off.

Ion Gauge Recorder Output

Output jacks on the rear panel supply a signal to either a recorder or pressure controller, such as the Granville-Phillips Series 216 Automatic Pressure Controller. The recorder output is 0 to -110 mV with an output impedance of 1 kΩ.

Long Cable Operation

The controller as received is capable of supplying power to an ion gauge tube with up to a 40-foot gauge cable. A longer cable can be used up to a maximum of 400 feet by rewiring the gauge cable connector as shown in Fig. 3-1, or a long cable suitably wired may be ordered from Granville-Phillips. If you fabricate the long cable, select the conductor for safe insulation and safe wire size and so that line losses are not excessive.

Degas power of 75 watts nominal is available at the controller. The degas power available at the tube will decrease as a function of cable length. This will result in a longer period of time being required to degas the tube when very long cables are used. Under extreme conditions of cable length, it may be necessary to install a separate Variac or transformer to degas the tube.

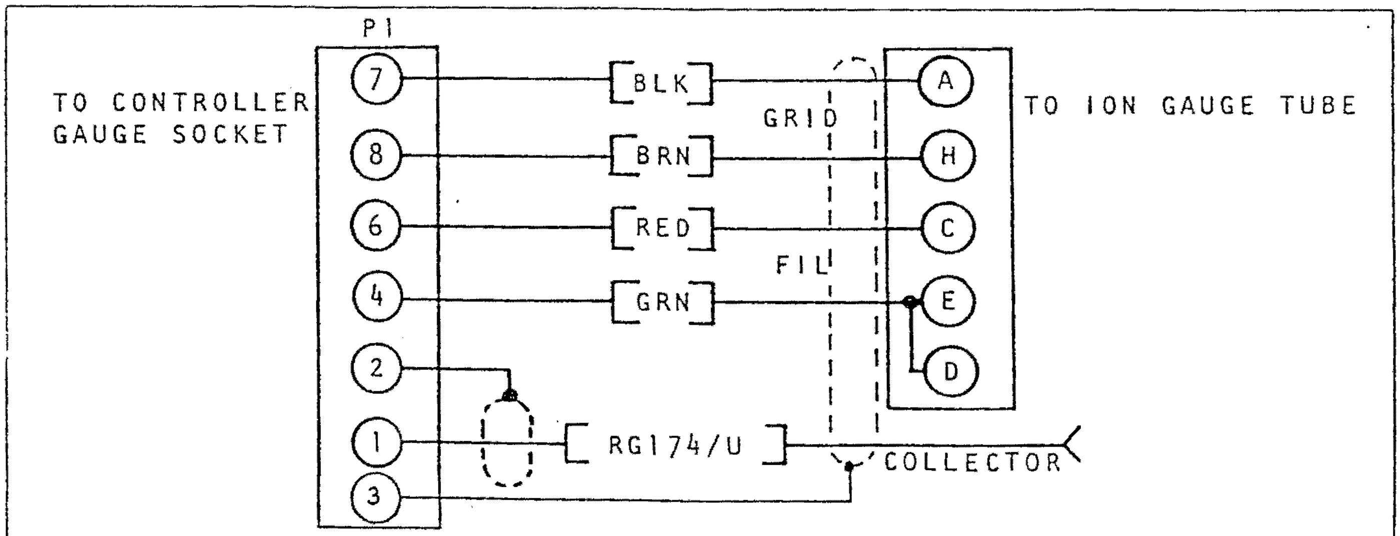

FIG. 3-1 GAUGE CABLE CONNECTIONS FOR LONG CABLES

Ion Gauge Process Control

The process control feature provides relay operations that can be used to control external devices as a function of system pressure as measured on the ionization gauge portion of the controller.

For example, if the controls are set as in Fig. 3-2, the "high" relay shown in Fig. 3-3 will be energized anytime the system pressure is less than 5×10^{-6} Torr. The "low" relay shown in Fig. 3-3 will be energized anytime the system pressure is less than 5×10^{-7} Torr. The trip points can be in the same decade or in different decades.

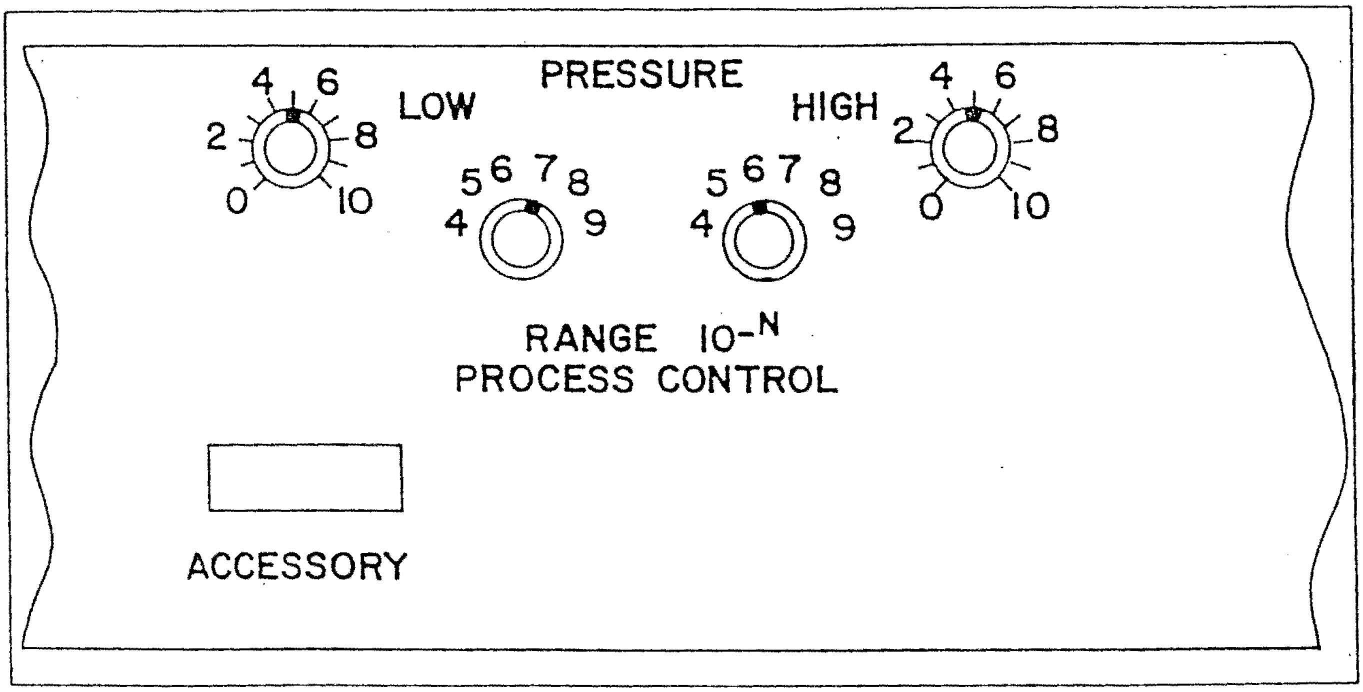

FIG. 3-2 EXAMPLE OF HOW TO SET PROCESS CONTROLS

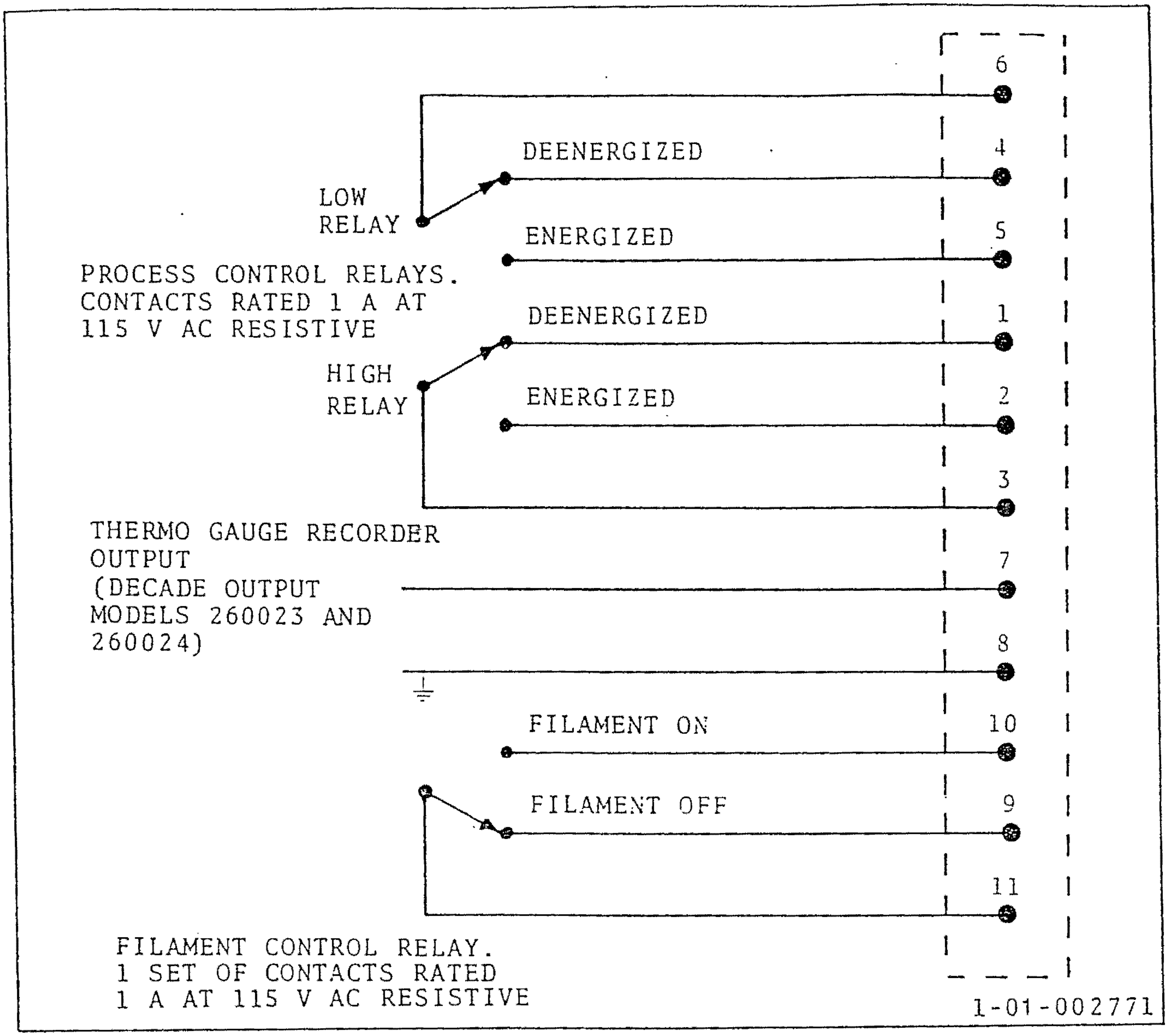

FIG. 3-3 ACCESSORY CONNECTOR

By using the accessory connector to suit your specific application, a variety of control modes can be accomplished. For example, if a pressure band operation is desired, the accessory connector should be wired as shown in Fig. 3-4 with the controls set as in Fig. 3-2. This will result in a closed circuit through the relays only when the pressure is between 5×10^{-7} and 5×10^{-6} Torr.

Another important use is in an application where a pressure rise is expected when the process is turned on. For such an application, it is desirable to turn on the process at a lower pressure and turn off the process if the pressure rises excessively. This can be accomplished by using an auxiliary relay and the circuit shown in Fig. 3-5. With the controls again set as shown in Fig. 3-2, the auxiliary relay will only energize when the pressure decreases to 5×10^{-7} Torr and then will remain energized as long as the pressure remains below 5×10^{-6} Torr. These operations can be used over the entire pressure range of the ionization gauge tube.

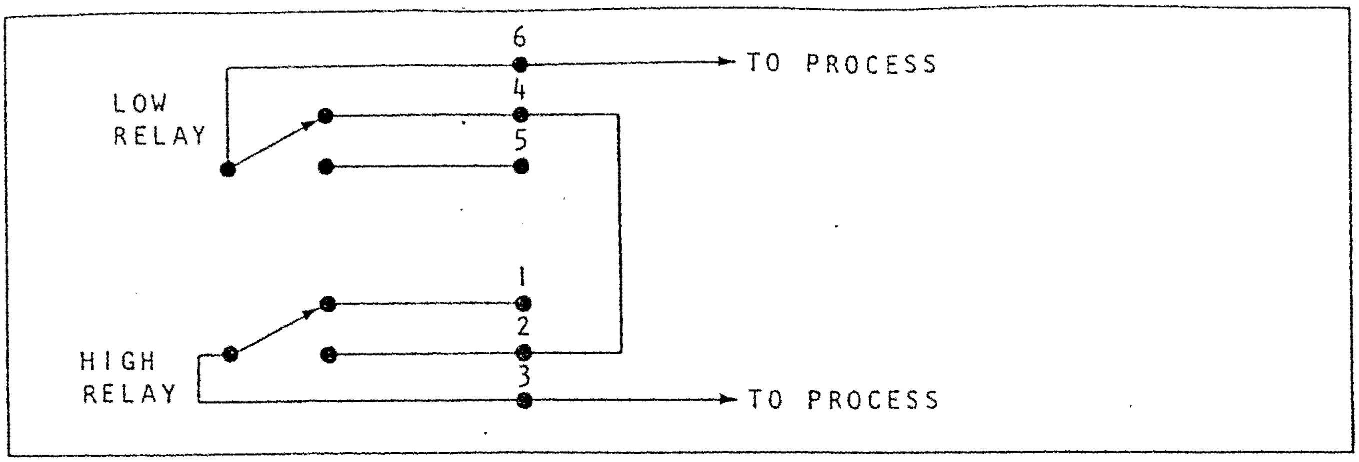

FIG. 3-4 PROCESS CONTROL WITH PRESSURE BAND

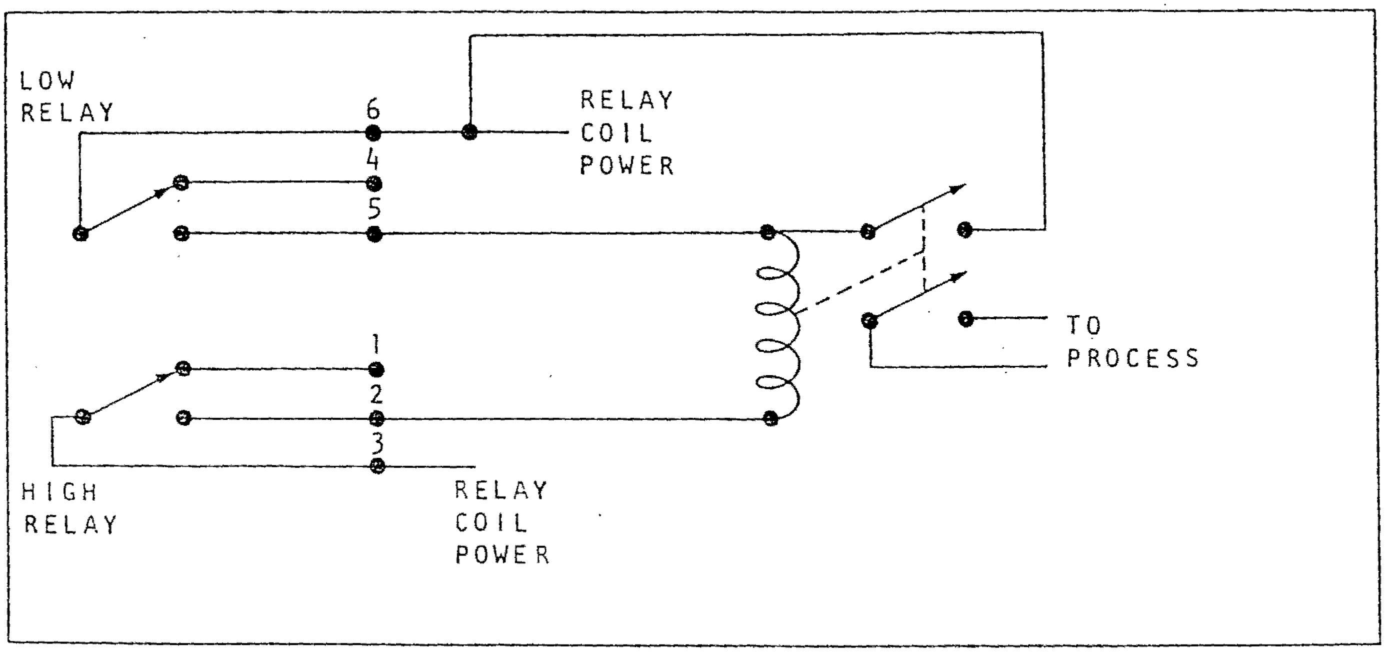

FIG. 3-5 PROCESS CONTROL WITH HYSTERESIS LOOP

Thermo-Gauge

The Thermo-Gauge option consists of a separate meter, a selector switch and necessary circuitry for use with up to two Catalog No. 260009 Thermo-Gauge tubes of the Pirani type. Series 260 Thermo-Gauges are supplied calibrated for N_2. The indicated reading for air is the same as for N_2 within the accuracy of the instrument. With certain safety precautions, the Series 260 Thermo-Gauge may be used to measure the pressure of other gases. See the following pages for safety precautions with other gases.

The Thermo-Gauge may be used at any time independent of the ionization gauge portion of the controller. If no Thermo-Gauge is connected, the meter will read approximately 1000 Torr. Do not under any circumstances attempt to use other types of Pirani gauge tubes with this controller. To do so may be hazardous.

Thermo-Gauge tubes can be installed using a 1/8 NPT connection or with a ½ inch O-ring sealed quick connector available from many manufacturers. For best results, the tubes should be installed in a vertical position above a vacuum line or chamber to prevent particles of contamination from falling into the tube. Tubes should not be installed where they will be exposed to excessive amounts of pump oil or similar fluids.

The Thermo-Gauge tube should be mounted where the ambient temperature range is 0° to 50°C. The maximum non-operating or bakeout temperature is 100°C. Exceeding 100°C may cause the solder used to seal the gauge to melt or cold flow, causing gases to leak in or out of your system. This could be hazardous depending on the resulting gas mixtures.

With the controller power turned off, connect the 8-pin connector labeled 1 to the Thermo-Gauge tube you wish to designate as 1. Connect the remaining 8-pin connector to tube 1 if present. The Thermo-Gauge switch above the Thermo-Gauge meter will now correspond to tubes 1 and 2. Plug the other cable end into the accessory connector on the rear panel. The Thermo-Gauge feature will now be operative whenever the power light is on. To make the Thermo-Gauge meter direct reading for your tubes, it is necessary to adjust two calibration controls on the vertical printed circuit board. Refer to Fig. 3-6.

CAUTION: Dangerous voltages are exposed when cover is removed to make this adjustment. Do not touch any internal components except for the two adjustments shown when power is connected to unit.

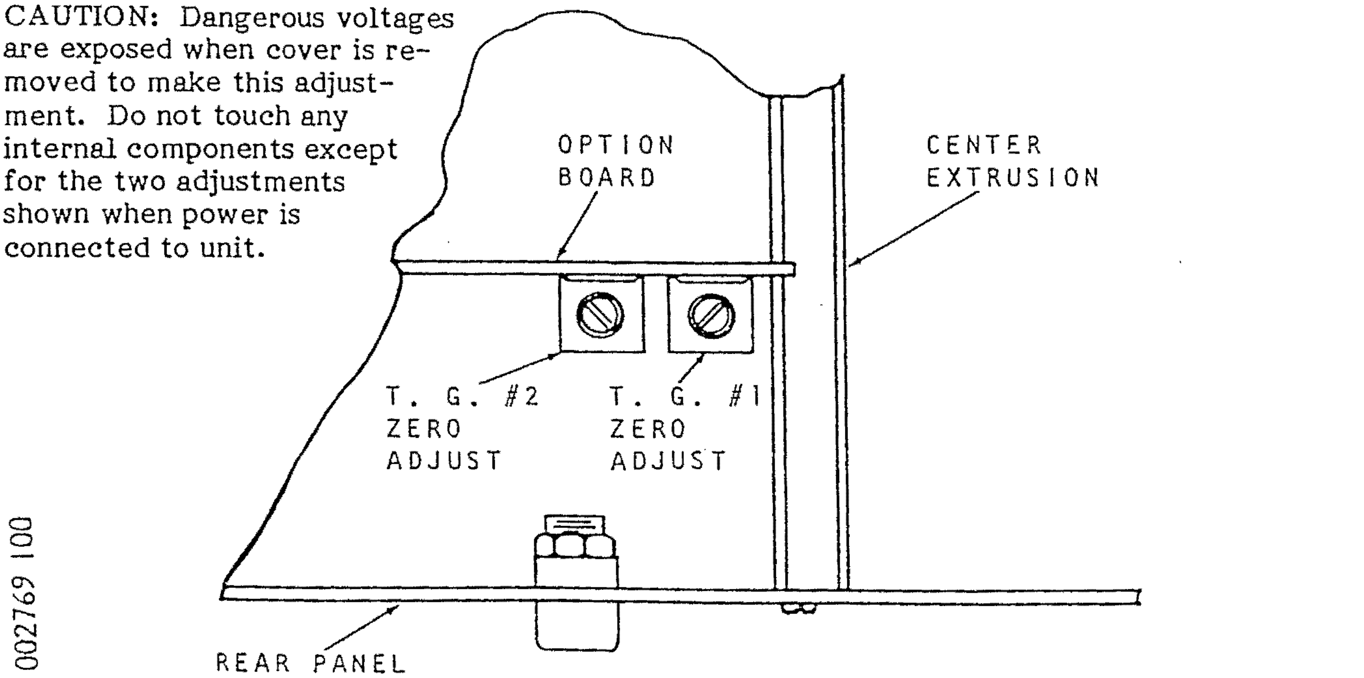

FIG. 3-6 LOCATION OF THERMO-GAUGE CALIBRATION POTENTIOMETERS

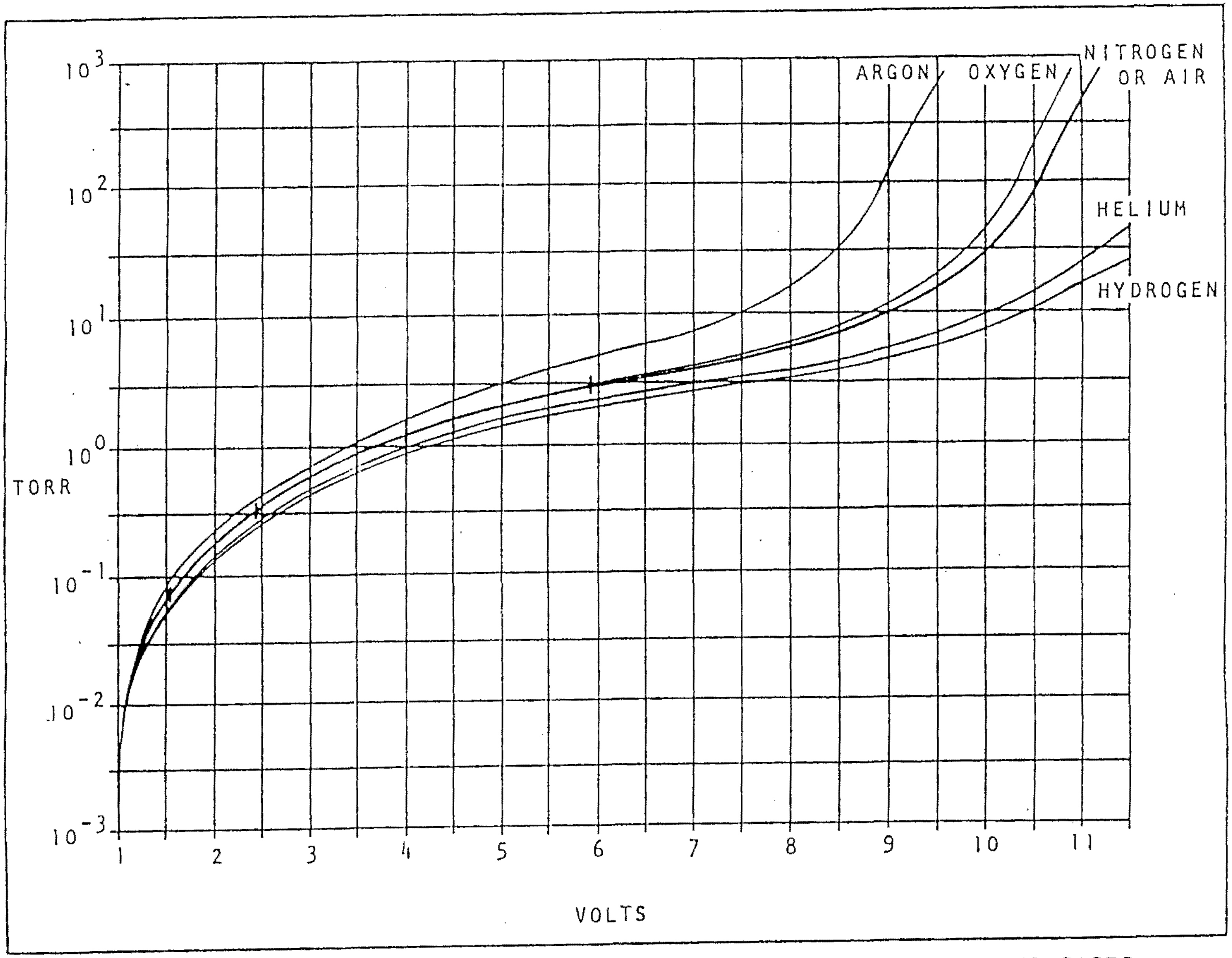

FIG. 3-7 THERMO-GAUGE OUTPUT VOLTAGE VS PRESSURE FOR VARIOUS GASES

The adjustment procedure is as follows:

1. With both Thermo-Gauge tubes exposed to pressures which are known to be less than 1 x 10^{-3} Torr, place the Thermo-Gauge switch in position 1.

2. Using care not to contact live circuits remove the top cover and adjust the No. 1 potentiometer (Fig. 3-6) until the Thermo-Gauge meter reads 10^{-3} Torr.

3. Place the Thermo-Gauge switch in position 2 and adjust the No. 2 potentiometer (Fig. 3-6) until the Thermo-Gauge meter reads 10^{-3} Torr.

4. Replace the cover.

Thermo-Gauge Use With Gases Other Than N_2 and Air

Series 260 Thermo-Gauges are supplied calibrated for N_2. The indicated reading for air is the same as for N_2 within the accuracy of the instrument. With certain safety precautions the Thermo-Gauge may be used to measure the pressure of other gases.

It is important to understand that the indicated pressure on a Thermo-Gauge depends on the type of gas in the tube as well as on the gas pressure in the tube. If you forget this, it is possible to overpressure or underpressure your system which may cause damage to equipment and injury to personnel.

Thermo-Gauge tubes are thermal conductivity gauges of the Pirani type. These gauges transduce gas pressure by measuring the heat loss from a heated sensor wire maintained at constant temperature. For gases other than N_2 and air the heat loss is different at any given true pressure and thus the indicated reading will be different.

Figure 3-7 can be used to determine the true pressure vs. indicated pressure on the Series 260 Thermo-Gauge for six commonly used gases. The curves at higher pressure vary widely from gas to gas because the thermal losses are greatly different for different gases.

If you must measure the pressure of gases other than N_2 or air, you should first use Fig. 3-7 to determine the maximum safe indicated pressure for the other gas as explained below.

Example 1 Maximum safe indicated pressure

Assume a certain vacuum system will withstand an internal pressure just slightly over atmospheric pressure. For safety you wish to limit the internal pressure to a maximum of 300 Torr during backfilling. Assume you wish to fill the system with argon. On Fig. 3-7, locate 300 Torr on the left axis and travel horizontally to the right to intersect the argon curve. Then move downward to intersect the N_2 curve. Then move horizontally to the left-hand scale where you note the pressure is about 12 Torr. Thus, an indicated pressure on the Thermo-Gauge meter of 12 Torr corresponds to about 300 Torr of argon. For safety it is prudent to place a warning label on the instrument face which under the assumed conditions would read "DO NOT EXCEED 12 TORR FOR ARGON".

The following examples serve to illustrate how to use Figure 3-7 to convert indicated pressure to true pressure and vice versa for gases other than N_2 and air.

Example 2 Indicated to true pressure conversion

Assume you wish to determine the true pressure of argon in your system when the Thermo-Gauge is indicating 3 Torr. On Fig. 3-7 locate 3 Torr on the left axis and travel horizontally to the right to the nitrogen curve. Then travel up to the argon curve and then to the left to obtain a true pressure of argon of about 5 Torr. Thus, 5 Torr of argon produces an indication of about 3 Torr (N_2 equivalent) on the Thermo-Gauge meter.

Example 3 True pressure to indicated pressure conversion

Assume you wish to determine what the indicated pressure of argon will be for a true pressure of 5 Torr. On Fig. 3-7 locate 5 Torr on the left scale and travel horizontally to the right to the argon curve. Then travel down to the nitrogen curve and then horizontally to the left to an indicated pressure of 3 Torr (N_2 equivalent).

Thermo-Gauge Recorder Output

The output of the Thermo-Gauge is available at the accessory connector on pins 7 and 8 and can be used either to drive a recorder or a pressure controller, such as the Granville-Phillips Series 216 Automatic Pressure Controller. See Fig. 3-3 for connection information.

The voltage output at the recorder terminal is from 1.1 to 12 V dc corresponding to 1×10^{-3} to 1000 Torr (N_2 equivalent). The output is non-linear and can be related to true pressure by referring to Fig. 3-7. The recorder output impedance is 2.7 kΩ.

SECTION 4

CIRCUIT DESCRIPTION

Operating Principles

The gauge tube (Fig. 4-1) operates as follows: The filament is heated so that it emits electrons. These electrons are accelerated to the grid. Some of these electrons strike gas molecules in the tube forming ions in numbers proportional to the gas density in the tube. These ions are accelerated to the collector electrode where they are collected.

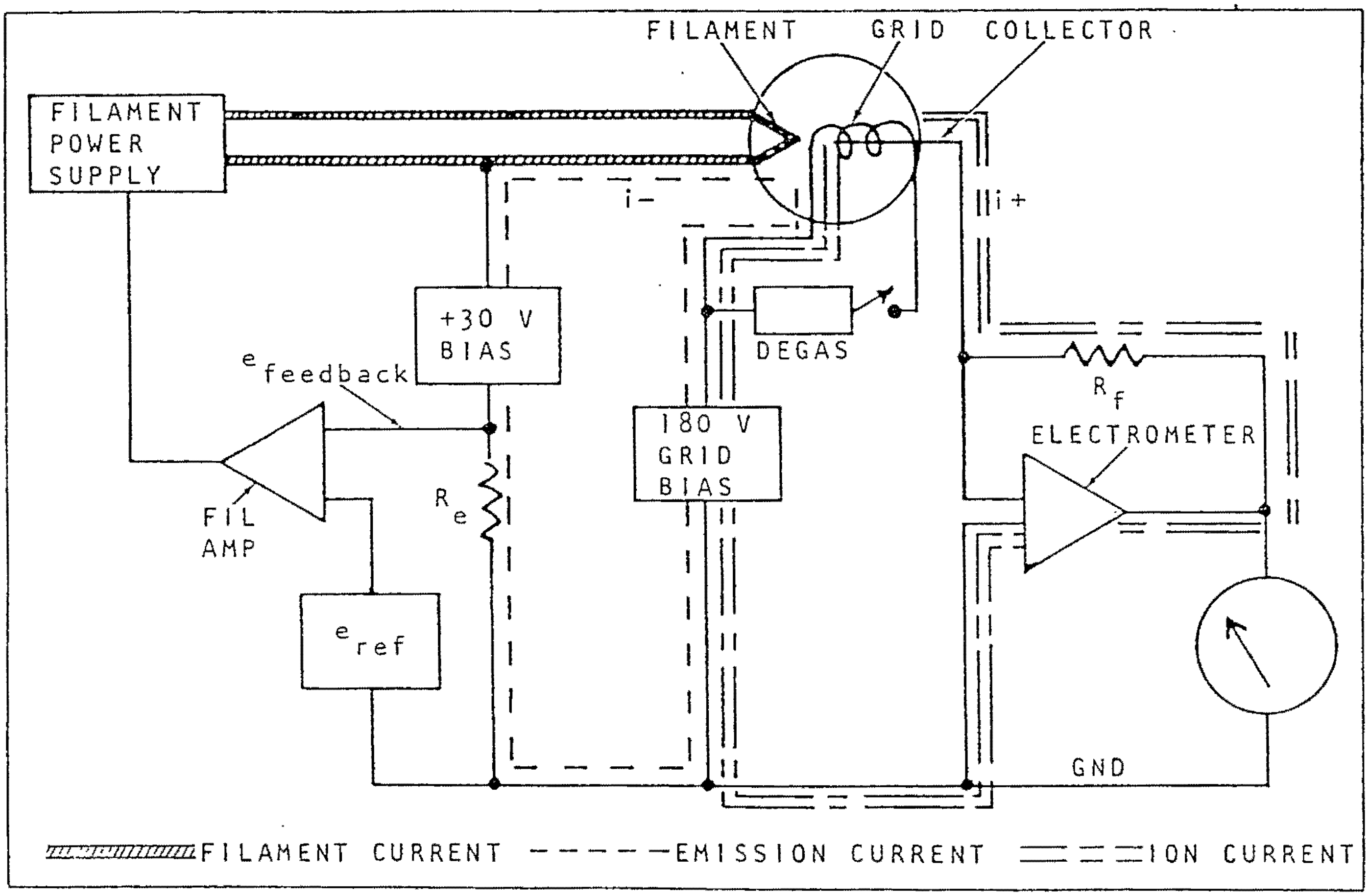

FIG. 4-1 IONIZATION GAUGE CONTROLLER BLOCK DIAGRAM

The ion current, i_+, to the collector depends upon the emission current, i_-. It is therefore necessary to control carefully the emission current at the specified level.

The emission current is regulated by controlling the filament heating power. The basic current paths in the system are shown in Fig. 4-1.

The emission current through resistor R_e results in a voltage drop $e_{feedback}$ across R_e. This voltage is compared with the emission reference voltage e_{ref} by the filament amplifier. The difference is amplified and used to control the filament power supply. The electrometer circuit measures the ion current by forcing charge through an appropriate high resistance, R_f, and displaying the resulting voltage. The necessary operating voltages on the tube electrodes are furnished by power supplies indicated in Fig. 4-1.

180 V Grid Bias Supply (Refer to Fig. 4-2)

Transistor Q3, rectifier assembly CR3, and the associated components form a series regulated, current limited power supply. CR6 is used to regulate the base of Q3 at 180 V. A normal maximum of 10mA is drawn from the grid; however, for faults which could seriously exceed this value, resistor R23 and diodes CR9 and CR10 form a current limiter. At approximately 15 mA, these diodes start to conduct, thereby removing base drive from Q3.

± dc Supplies (Refer to Fig. 4-2)

CR8 is used as two full wave rectifiers, and supplies ± 23 V to filter capacitors C6 and C17. These raw dc voltages are then zener regulated to ± 12 V by CR4 and CR13.

Filament On-Off (Refer to Fig. 4-3)

Transistor Q8 and relay K3 control the power to the filament. This relay is energized by depressing the filament switch, S2, which applies a positive pulse from C2 to the base of Q8, thereby energizing the relay. The relay is then locked in the energized position through contacts 6 and 7 which control the base of Q8. The relay is de-energized by again actuating the filament switch. When the filament is on, C2 is discharged by R7 and the voltage at both leads is -12 volts. Activating the filament switch, S2, then results in a negative signal to the base of Q8, turning it off, and dropping out the relay. In addition, a negative input to the base of Q8 from two other sources will also result in a shutdown. The output of the electrometer is applied through resistor R34 and will turn off Q8 when the output exceeds -7.5V. In addition, the output of the emission circuit will also turn off Q8 when its output exceeds -7 V. This occurs through the path consisting of CR23 and CR24.

Emission Control (Refer to Fig. 4-3)

The emission control circuit consists of: emission reference supply, emission sensing resistors, high-gain amplifier IC2, synchronized pulse generator composed of Q5, Q6 and T2, and a triac CR1 in series with the filament. The output of IC2 is shorted to its input through contacts 11 and 12 of K3 until the filament circuit is turned on. When the filament circuit is energized, the positive input from the emission reference supply (0.1 to 1 volt depending upon the setting of the emission adjust potentiometer R5) to pin 1 of IC2 results in a negative going output from IC2. This increases the output of the current source Q5, which in turn fires unijunction Q6 at earlier and earlier times in the power line cycle. Pulses from Q6 are coupled to the triac, CR1, through transformer T2. These pulses cause CR1 to conduct for the remainder of the half cycle, thereby making possible current through the filament. As IC2 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 either emission sensing resistor R32 or R33, depending upon the emission switch position. The resulting emission signal voltage serves as feedback signal to IC2, closing the control loop. The signals which synchronize the pulses from Q6 with the power line are obtained through CR5 and CR7, and filtered by R18 and C16.

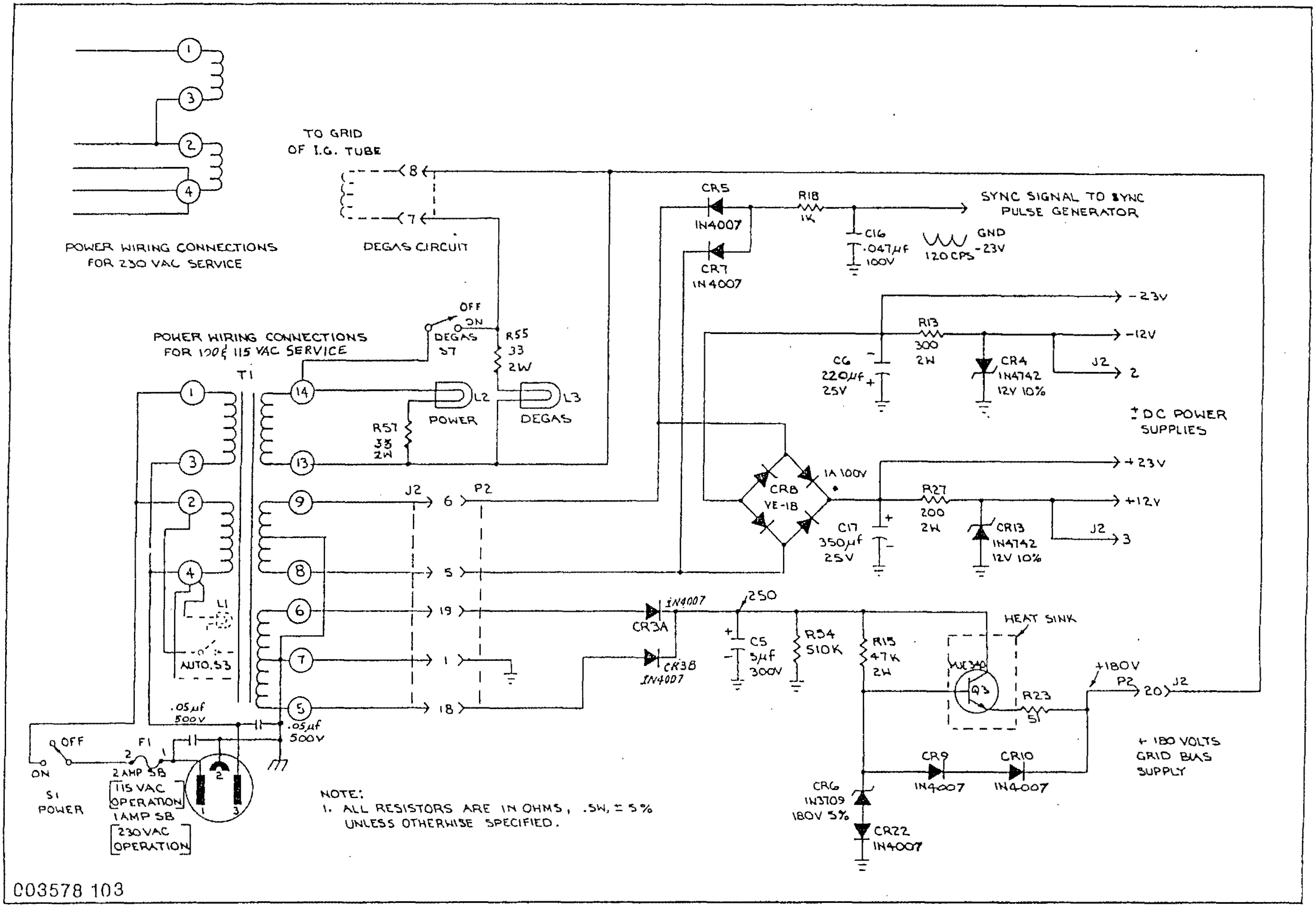

FIG. 4-2 POWER SUPPLY SCHEMATIC

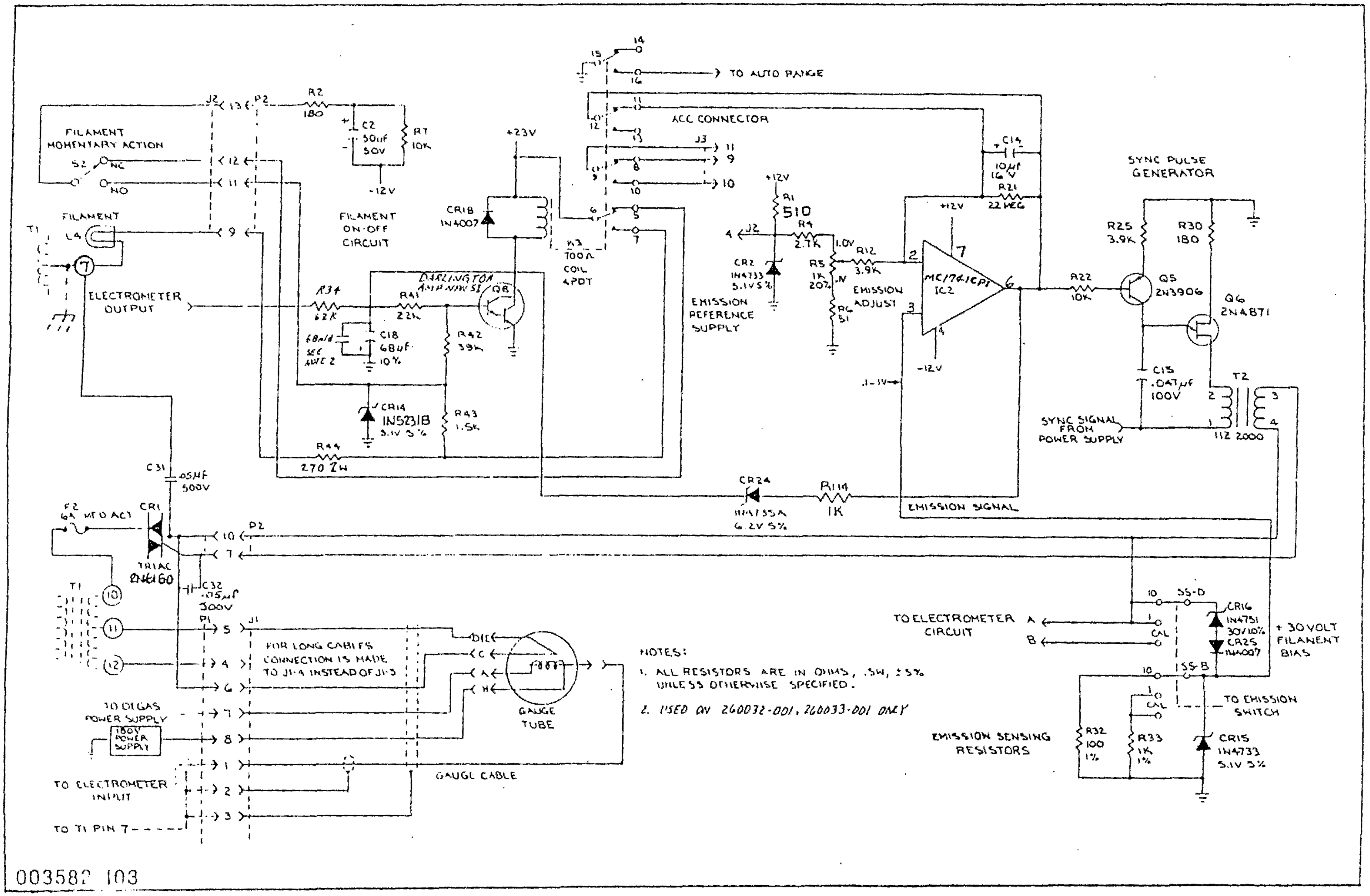

FIG. 4-3 EMISSION CONTROL SCHEMATIC

Electrometer (Refer to Fig. 4-4)

A high gain negative feedback type amplifier consisting of Q1 and IC1 is used so that the collector electrode is normally maintained within a few millivolts of ground potential. Due to the high input impedance of Q1, essentially all of the ions from the collector electrode must flow through the feedback resistor, R_f, of Fig. 4-1. Because the amplifier input is maintained at ground potential, the output voltage is the product of the ion current times the feedback resistance. The amplifier output supplies signal to the ion current meter, process control circuitry, recorder output, filament protection circuitry, and automatic ranging circuitry. Range resistors R35 through R40 are changed as a function of emission switch position and range switch position so that the pressure decade indication is always correct.

The collector lead is attached to the gate of one side of the dual FET Q1. The other gate is grounded. The FET is used as a source follower and is coupled to the input of operational amplifier 1C1, pins 1 and 2 as a differential input. The loop is then closed around the feedback resistor, R35-R40. R10 is the zero adjustment available through the front panel.

Auto Ranging (Refer to Fig. 4-5)

The auto ranging circuit consists of a pair of voltage comparators Q2, Q4 and Q10, Q11, two relay drivers Q7, Q9, two relays K1, K2 and a bi-directional 115 V ac motor with internal gear reduction and clutch.

The output of the electrometer circuit is applied through a filter R8 and C4 to the bases of Q2 and Q10. This voltage is compared with the voltage on the bases of Q4 and Q11. If the electrometer output voltage is more negative than -5.2 V, Q7 turns on, energizing K2. This results in the motor turning the shaft of the range switch counterclockwise (CCW) until the electrometer output is less negative than - 5.2 V. If the electrometer output voltage is less negative than -0.35V, Q9 turns on, energizing K1. This results in the motor turning the shaft on the range switch clockwise (CW) until the electrometer output is more negative than -0.35 V. Diode CR20 prevents further CCW rotation when the range switch is in the 10^{-4} position. Diode CR21 prevents further CW rotation when the range switch is in the 10^{-9} position. The motor is prevented from stopping between range switch positions by current through R53, which supplies base drive to Q7 or Q9, depending upon the direction of rotation.

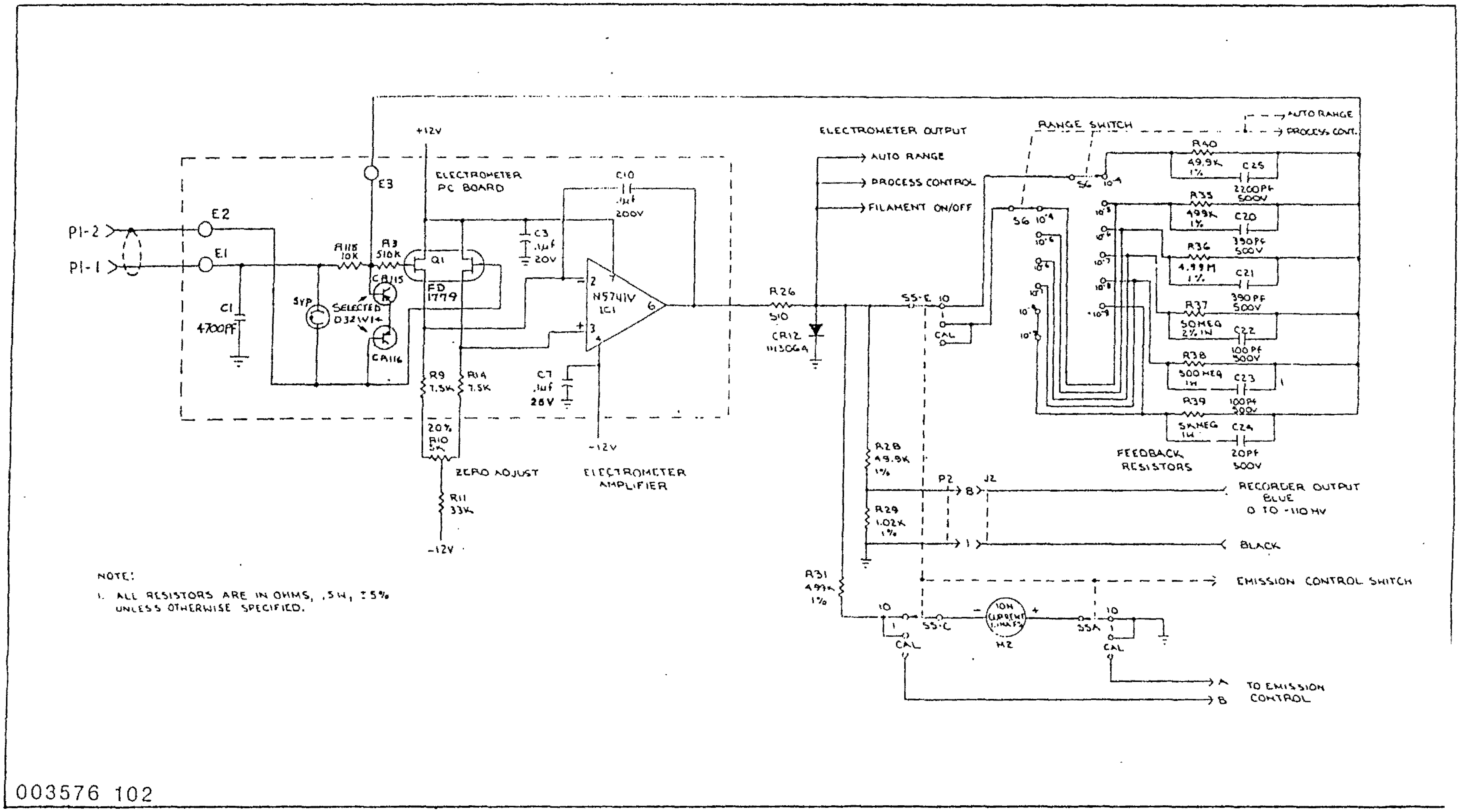

FIG. 4-4 ELECTROMETER SCHEMATIC

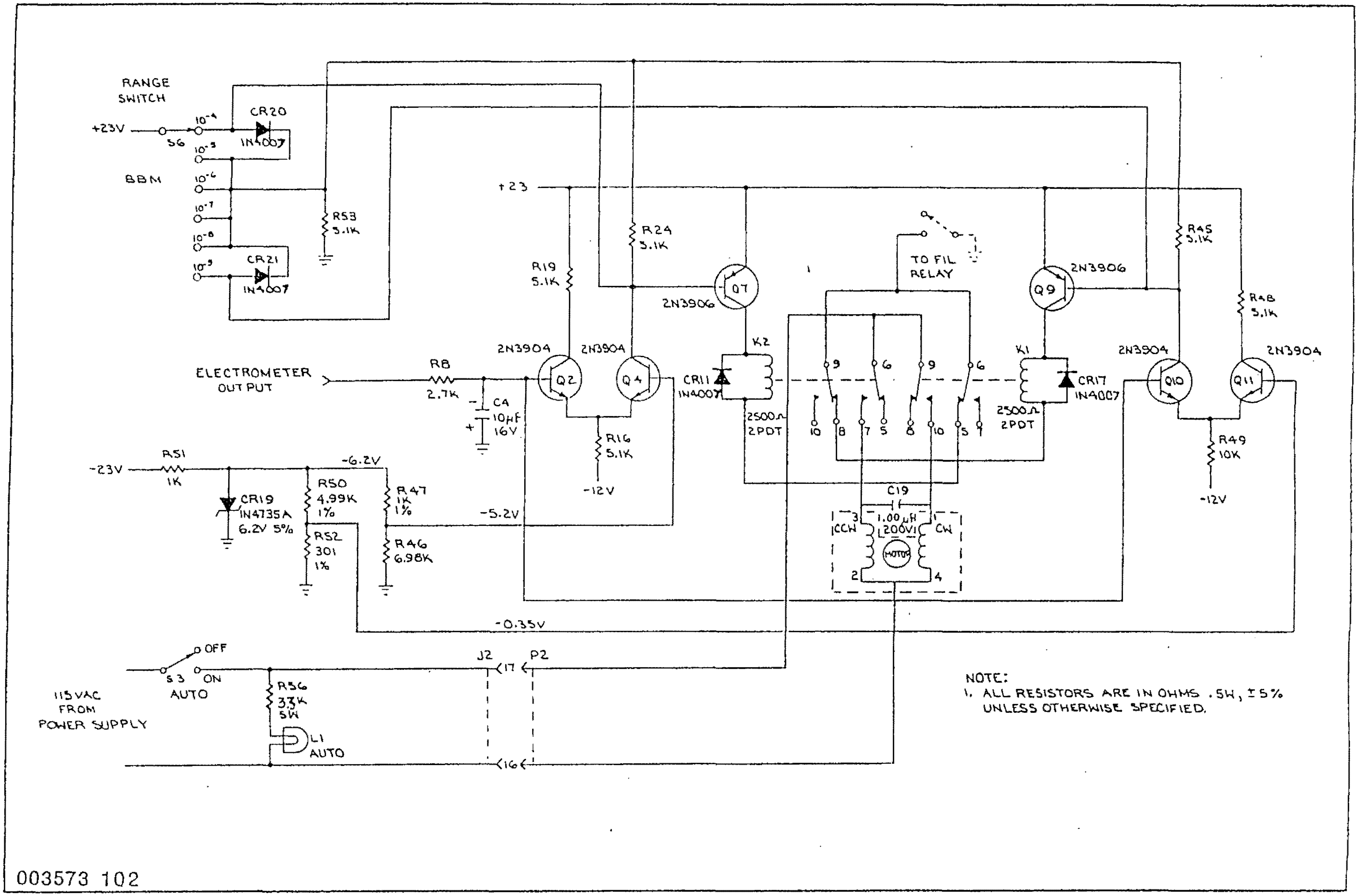

FIG. 4-5 AUTO RANGING SCHEMATIC

Thermo-Gauge (Refer to Fig. 4-6)

The Thermo-Gauge circuit consists of amplifier IC3, bridge driver Q17 and Q18, and a resistance bridge.

Two elements of this bridge, the sensor and the compensator, are in the Thermo-Gauge tube.

The bridge voltage required to attain bridge balance is a function of the pressure in the tube. Amplifier IC3 senses the bridge unbalance, and applies voltage to the bridge so as to reduce this unbalance to essentially zero. The compensator element corrects for the Thermo-Gauge tube ambient temperature. Relay K5 switches Thermo-Gauge tubes into the circuit in response to Thermo-Gauge selector switch S4. R84, R85, R86 and CR37 match the output voltage of the bridge to the meter scale. R78 and R80 are used to set the meter zero for the two Thermo-Gauges at low pressure.

Process Control Without Decade Output (Refer to Fig. 4-7)

The Process Control circuit consists of two relay circuits. The two circuits are identical except for diodes CR38, CR39, CR40 and CR41. These diodes prevent signals from feeding from the high-pressure circuit to the low-pressure circuit. Circuit operation will be given for only one of these circuits. In operation, selector switch S8 and potentiometer R68 are first set for the decade meter reading at which the relay is to energize. Transistor Q12 and Q14 form a voltage comparator which compares the electrometer output against the potentiometer setting selected. When the electrometer output decreases below this setting and there is B+ applied to the comparator, Q14 turns off, resulting in Q16 turning on thus energizing the relay. In addition, Q16 will turn on any time the front panel range switch is at a decade or more lower pressure than the process control decade switch.

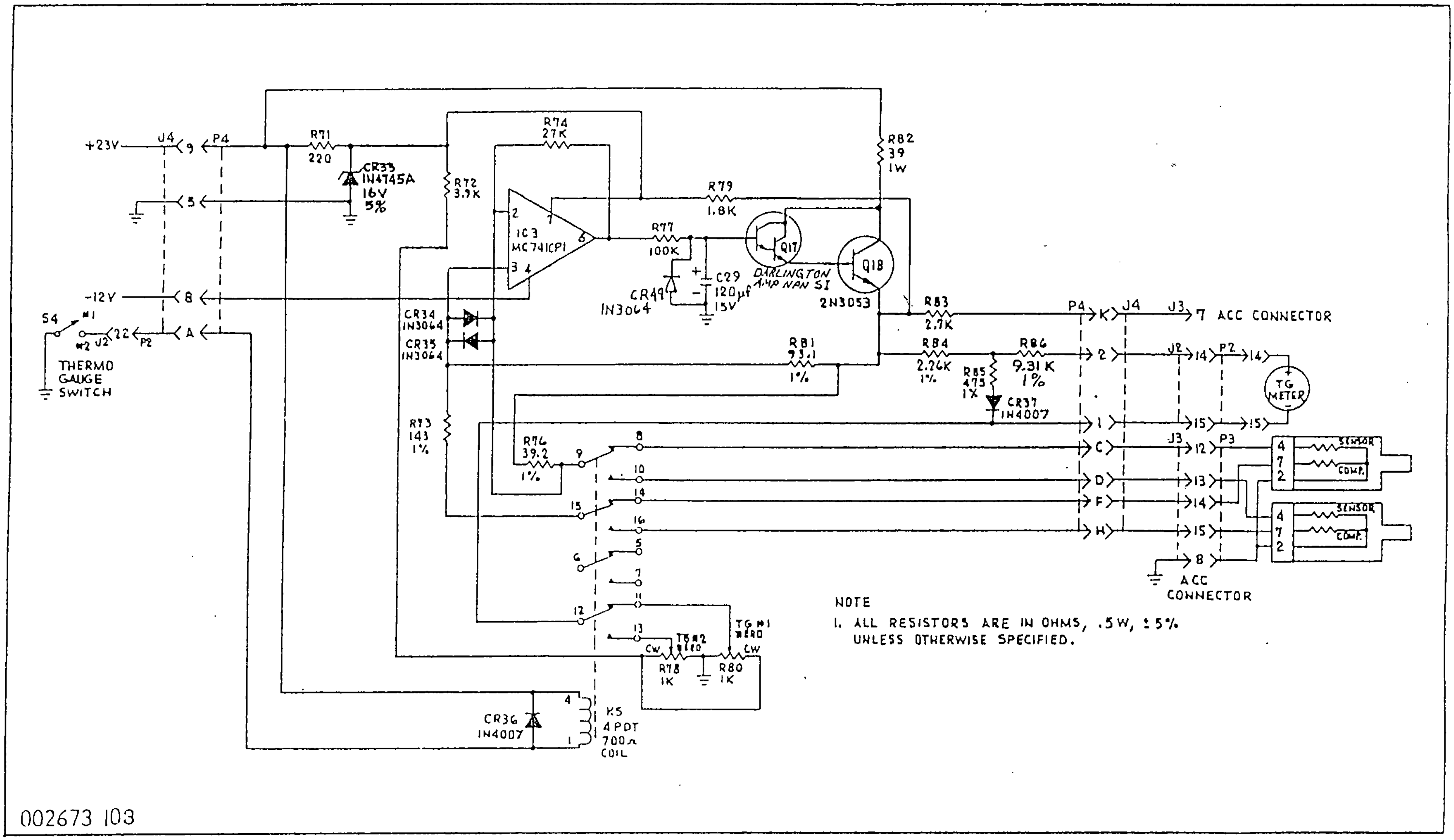

FIG. 4-6 THERMO-GAUGE SCHEMATIC

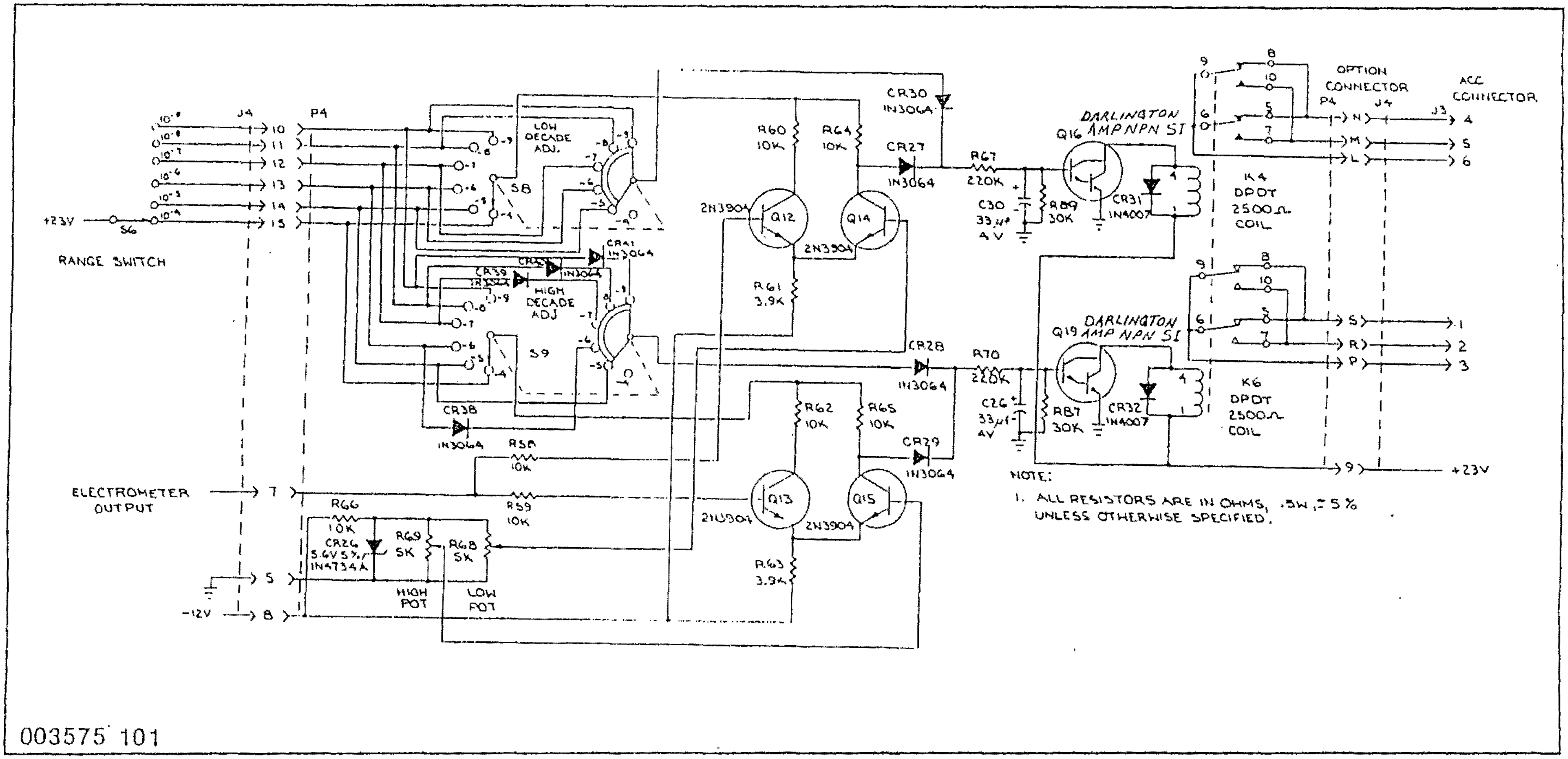

FIG. 4-7 PROCESS CONTROL SCHEMATIC

NOTES

MAINTENANCE AND TROUBLESHOOTING

Should difficulties be encountered in the use of your controller, the following list of symptoms and remedies, along with the circuit descriptions of Section 4, 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 under the conditions stated therein for the first full year after delivery, and at a reasonable service charge thereafter. However, because the circuits are rather simple and the majority of parts are readily available at your local electronics supply stores, it may in some cases prove most expedient for your qualified electronics technician to repair minor troubles, should they occur. Observe all electrical safety precautions in making repairs.

If the prescribed remedies do not correct the troubles, or if additional assistance or special parts are required, contact the Customer Service Department, Granville-Phillips Company, 5675 East Arapahoe Avenue, Boulder, Colorado 80303. Telephone: 303-443-7660. Circuit repairs properly made with equivalent electronic parts and rosin core solder, which do not change the circuit design nor 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.

WARNING

Dangerous voltages are present during operation of this unit. 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.

If it becomes necessary to return your controller to the factory for repair, please include a complete description of the symptoms and documentation of any modifications that have been made.

Symptom	Possible Cause	Remedy
	ac Power and Fuses	
Power light will not light (all functions inoperative).	1. Power cord not Plugged in.	Plug in power cord.
	2. No power to receptable.	Restore power to receptacle.
	3. Controller fuse F1 blown.	Replace fuse with correct fuse type and value. 2 A slo-blo for 115 V operation, 1 A slo-blo for 230 V operation.
	4. Broken wire.	Check power wiring continuity.
	5. Transformer T1 defective.	Replace transformer.
Power light will not light (all other functions operative).	1. Indicator light burned out.	Replace power switch containing light as integral part.
Controller power fuse blows.	1. Incorrect power source.	Check power source vs. controller requirements. Wire transformer connections as shown in Fig. 2-1.
	2. Incorrect F1 fuse rating.	Use correct fuse. 2 A slo-blo for 115 V operation, 1 A slo-blo for 230 V operation.
	3. Shorted rectifier assembly on P.C. Board. Remove connector to board and check if fuse still blows.	Locate defective component on board and replace.
	4. Defective transformer T1.	Replace transformer T1.

Power Supply Problems

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 multimeter to check the labeled points on the P. C. board for the following outputs with respect to ground:

Symptom	Possible Cause	Remedy

Test Point (v)	Reading (V dc)
+ 23	+ 20 to + 25
+ 12	+ 11 to + 13
- 23	- 20 to - 25
- 12	- 11 to - 13
+180	+170 to +190

If the measured voltages do not agree with these readings, it will be necessary to correct this problem before proceeding further. In a great majority of the cases, the location of the fault creating the power supply problem will correct the original problem as well

Symptom	Possible Cause	Remedy
Bias supply output less than less than 170 V dc.	1. Excessive current being drawn from supply, causing current limiting. Determine current by measuring voltage drop across R23.	Locate cause of current drain and correct.
	2. Insufficient voltage across C5. Open secondary pins 5-6 on T1. Open rectifier assembly CR3. Defective capacitor C5.	Replace faulty component.
	3. Defective transistor Q3 or zener CR6.	Replace faulty component.
Bias supply output greater than 190 V dc.	1. Shorted transistor Q3.	Replace transistor.
	2. Open zener CR6.	Replace zener.
	3. Open diode CR22.	Replace diode.

Filament Problems

Symptom	Possible Cause	Remedy
Filament will not light when filament switch is depressed (filament indicator light turns on and then after one second turns off).	1. Gauge tube not connected to gauge cable.	Connect gauge tube.
	2. Gauge cable not connected to controller.	Connect gauge cable.

Symptom	Possible Cause	Remedy
	3. Fuse F2 on controller is open.	Replace fuse with the correct value: 6 A med-act.
	4. Open in gauge cable filament lead.	Repair or replace gauge cable.
	5. Filament in gauge tube open.	Replace gauge tube.
	6. Defect in emission control amplifier or synchronous pulse generator.	Troubleshoot and repair.
	7. Defective triac CR1 or open winding in T1 pins 10, 11 and 12. Check for firing pulses on CR1 gate to anode 1 during period when light is on. If pulses are present, the triac is defective.	Replace triac.
Filament in tube will not light when filament switch is depressed (filament indicator light does not light).	1. Improper power supply voltage. Check ± 12 V supply voltages.	Refer to Power Supply Problems.
	2. Defective relay K3.	Replace relay.
	3. Defective circuit component C2, R2, R7, R43, CR14, R42, R41, Q8, S2.	Replace faulty component.
Filament in tube lights and then turns off after one second.	1. Pressure in tube too high to permit emission.	Decrease system pressure.
	2. Low line voltage.	Connect to line of proper voltage.
	3. Open in gauge cable to grid.	Repair or replace gauge cable.
	4. Grid bias supply shorted by either tube or cable.	Troubleshoot and repair. Refer also to section on bias supply.

Symptom	Possible Cause	Remedy
	5. Degraded filament emissive coating not furnishing required emission.	Replace gauge tube.
	6. Defect in emission control amplifier or synchronous pulse generator.	Troubleshoot and repair.
Filament of tube lights as soon as ac power is turned on.	1. Shorted triac CR1. Apply a short from gate to anode 1 (wires 7 and 26, or the two insulated pins protruding from the top of the triac). If filament remains on, the triac is defective.	Replace triac.
	2. Defective synchronous pulse generator.	Troubleshoot and repair.
	3. Defective relay K3 (pins 11 and 12).	Replace relay.

Emission Control Problems

Because emission is dependent upon filament power, refer also to filament problems to determine location of the problem.

Symptom	Possible Cause	Remedy
Filament power light remains on in the "CAL" and "1" positions of the emission switch, but turns off in the "10" position.	1. Low line voltage.	Connect to line of power voltage.
	2. Poor connection to gauge tube.	Clean pins of gauge tube.
	3. Degraded filament emissive coating not furnishing required emission.	Replace gauge tube.
Emission control potentiometer does not have sufficient range of adjustment.	1. Zener diode CR2 defective.	Replace zener if voltage across diode is below 4.5 V dc.
	2. Defective component in reference source R4, R5 or R6.	Replace defective component.

Electrometer Problems

No meter indications in any range (emission normal).	1.	Collector cable not connected to gauge tube.	Check collector connection.
	2.	Collector cable open.	Check continuity of cable and repair or replace.
Meter indication does not move, but remains fixed at one reading.	1.	Emission switch in "CAL" position.	Turn switch to "1" or "10" position.
With only the power switch on, the electrometer will not zero in any range	1.	Defect in gauge cable to tube. Remove cable to see if problem continues to occur.	Repair or replace gauge cable.
	2.	Power supply problem.	Repair power supply. Refer to section on power supplies.
	3.	Defect in electrometer circuit. Turn off power and remove cover of the electrometer. Visually inspect for opens or shorts.	Correct as required.
	4.	Check to see if problem occurs in both the "1" and "10" positions of the emission switch. If only in one position, check wiring between emission switch and electrometer. Also inspect switch deck.	Repair as required.
	5.	Defective component in vertical electrometer P. C. board.	Repair or replace defective board.
With only the power switch on, the electrometer will not zero in a particular range.	1.	Faulty switch contacts in range switch assembly.	Visually inspect switch and clean with low residue cleaner if necessary.
	2.	Open range resistor R35-R40.	Replace as required.

Auto Range Problems

Auto range completely inoperative (auto range switch and light activated)	1.	Filament not turned on. Auto range only operates when filament is on.	Turn on filament.

Symptom	Possible Cause	Remedy
	2. Power supply problem.	Repair power supply. Refer to section on power supplies.
	3. Excessive friction in motor, gear train or switch. Remove electrometer cover and check for binding in gear train or switch.	Replace device causing drag.
	4. Open motor winding. Check motor continuity.	Replace motor if defective.
Auto range drives to 10^{-9} limit when turned on.	1. Collector lead disconnected from tube or open.	Check cable and repair if necessary.
	2. Relay K1 defective.	Replace relay.
	3. Transistor stages Q9, Q10 or Q11 defective.	Repair as required.
Auto range drives to 10^{-4} limit when turned on.	1. Relay K2 defective.	Replace relay.
	2. Transistor stages Q2, Q4 or Q7 defective.	Repair as required.

Process Control Problems

Symptom	Possible Cause	Remedy
Either process control relay will not energize or de-energize at the set point desired.	1. Defective relay K4 or K5.	Replace relay.
	2. Relay driver stage Q16 or Q19 defective.	Replace transistor.
	3. Voltage comparator stages Q12 and Q14 defective.	Replace transistors.

Thermo-Gauge Problems

Symptom	Possible Cause	Remedy
Thermo-Gauge reading "atmosphere" when pressure is known to be lower.	1. Selector switch on front panel set to read other Thermo-Gauge.	Set selector to proper gauge tube.

Symptom		Possible Cause	Remedy
	2.	Accessory connector not connected at controller end or gauge end.	Insert connector.
	3.	Normal condition for H_2 or He at pressure above about 30 Torr.	See page 3-10 for how to convert indication to true pressure.
	4.	Thermo-Gauge tube defective (Note: Check tube for resistance using an ohmmeter with 1.5V battery only. Do not use a higher voltage ohmmeter.) Pin 2-4 sensor - 58 ohm ±10% Pin 2-7 compensator - 85 ohm ±10% Pin 2-case - infinity	Replace tube.
	5.	Thermo-Gauge circuit inoperative.	Check power supply voltages. If voltages are correct, repair or replace T. G. option board.
Thermo-Gauge reading "10^{-3}" when pressure is known to be higher.	1.	Selector switch on front panel set to read other Thermo-Gauge.	Set selector to proper gauge tube.
	2.	Option board not plugged in.	Remove cover and check option board.
	3.	Thermo-Gauge circuit inoperative.	Remove accessory connector and check that meter reads "atmosphere". Check power supply voltages.
Thermo-Gauge reads below "10^{-3}" at all times regardless of system pressure.	1.	Defective accessory cable or Thermo-Gauge tube.	Check cable for opens or shorts. Check tube for resistance as instructed above.
	2.	Thermo-Gauge circuit inoperative.	Check power supply voltages. If voltages are correct, repair or replace option board.
Thermo-Gauge reads low when pressure is known to be higher.	1.	Normal condition for gases heavier than N_2.	See page 3-10 for how to convert indication to true pressure.

REPLACEMENT PARTS AND REPAIRS

To minimize customer inconvenience caused by down time, the controller has been divided into two major parts by the use of a replaceable printed circuit board containing practically all of the electronic circuitry. In most cases, the parts required to repair your controller can be most easily obtained from your local electronics parts distributor. For any parts that are not obtainable through local sources, contact the Customer Service Department of Granville-Phillips. When requiring assistance, please furnish the catalog number, model number, and serial number of the controller, and the component designation as shown on the schematics in this instruction manual.

Replacement of Main Printed Circuit Board (Refer to Fig. 6-1)

1. Remove top and bottom covers by removing the four sheet metal screws at rear corners of the unit. Slide the covers off.

2. Remove knobs from the emission switch and range switch. Remove nuts holding switches to front panel.

3. Remove the electrometer cover by removing the one 4-40 screw holding the cover to the P. C. board. Gently slide cover off.

4. Unsolder the electrometer input leads from the electrometer board.

5. Remove the two meter leads.

6. Remove the four knobs and two nuts and washers from the process control pots and switches, if applicable.

7. Remove the four remaining sheet metal screws from the rear panel, allowing the panel to drop away from the chassis.

8. Remove the option board, if applicable.

9. Remove the 22-pin rear connector from the P. C. board.

10. Slide the board out of the chassis.

11. To replace the board, reverse steps 1 through 10.

Replacement of Electrometer Assembly

1. Remove the main printed circuit board as outlined above.

2. Use a desoldering tool and carefully remove the solder from the fingers of the front switch deck, which penetrate the main board, and from the fingers of the electrometer board, which penetrate the main board.

3. If the unit is an automatic ranging model, remove the two motor mounting screws and slide the motor back to remove the coupling.

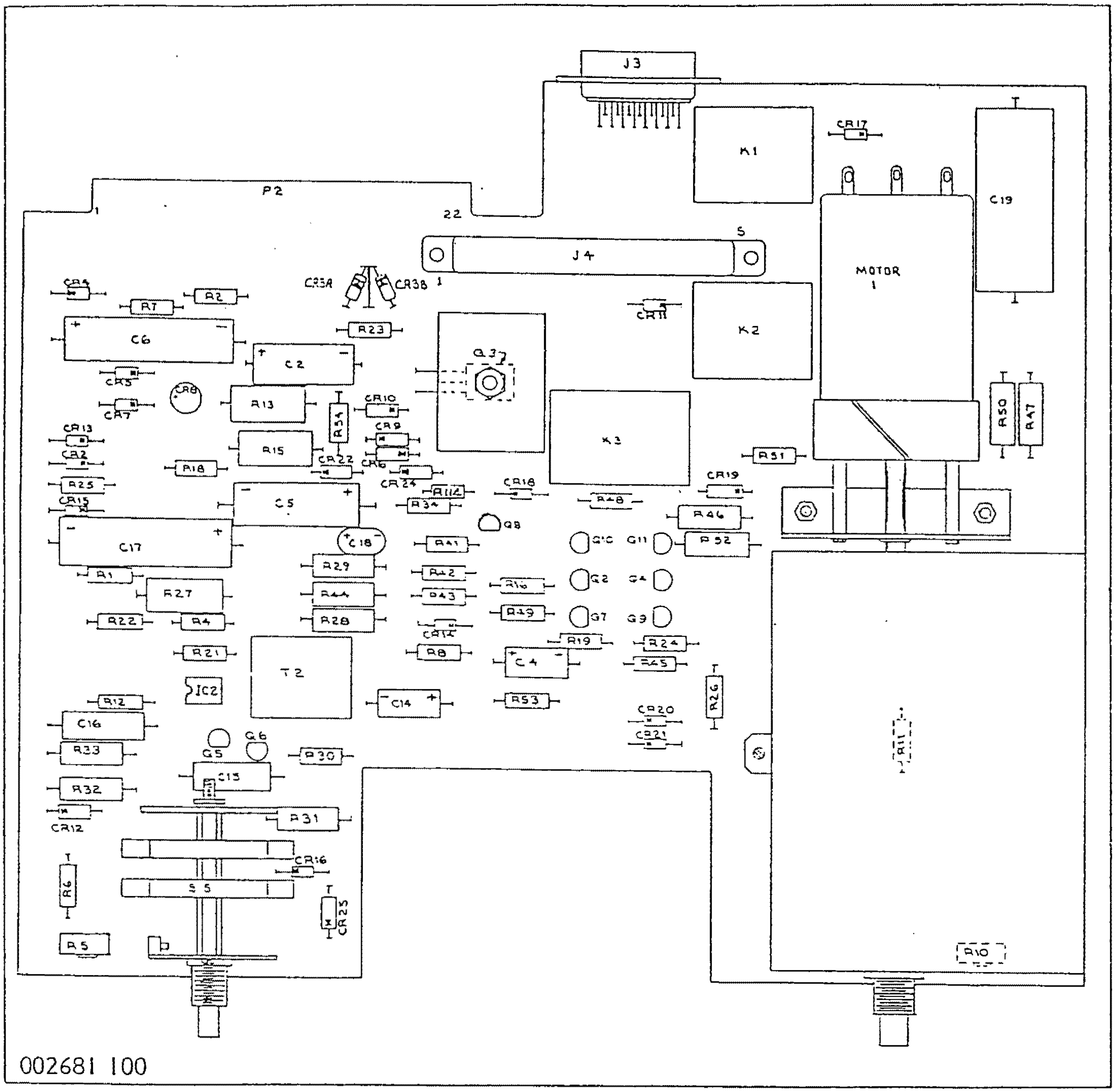

FIG. 6-1 LOCATION OF COMPONENTS ON MAIN PRINTED CIRCUIT BOARD

4. Slowly work the assembly away from the main board.

5. To replace the electrometer assembly, reverse the steps outlined.

Replacement of Electrometer P. C. Board (Refer to Figs. 6-2 and 6-3)

1. Remove the main printed circuit board as outlined above.

2. Remove the one jumper from the range switch assembly to the electrometer board.

3. Remove the motor and coupling.

4. Use a desoldering tool and carefully remove the solder from the fingers of the electrometer board.

5. Remove the two nuts and lockwashers from the switch bolts extending through the electrometer board.

6. Gradually remove the electrometer board from the main board and then slide off of the two bolts.

7. To replace the board, reverse Steps 1 through 6.

Replacement of Option Printed Circuit Board (Refer to Figs. 6-4 and 6-5)

1. Remove top and bottom covers by removing the four sheet metal screws at rear corners of the unit. Slide the covers off.

2. If the option board has only the Thermo-Gauge circuitry, it may be removed by applying an upward pressure, freeing it from the vertical connector.

3. If the option board has the process control option, remove the four knobs and two nuts and washers from the pots and switches.

4. Remove the four remaining sheet metal screws from the rear panel, allowing the panel to drop away from the chassis.

5. Remove the option board.

6. To replace the option board, reverse Steps 1 through 5.

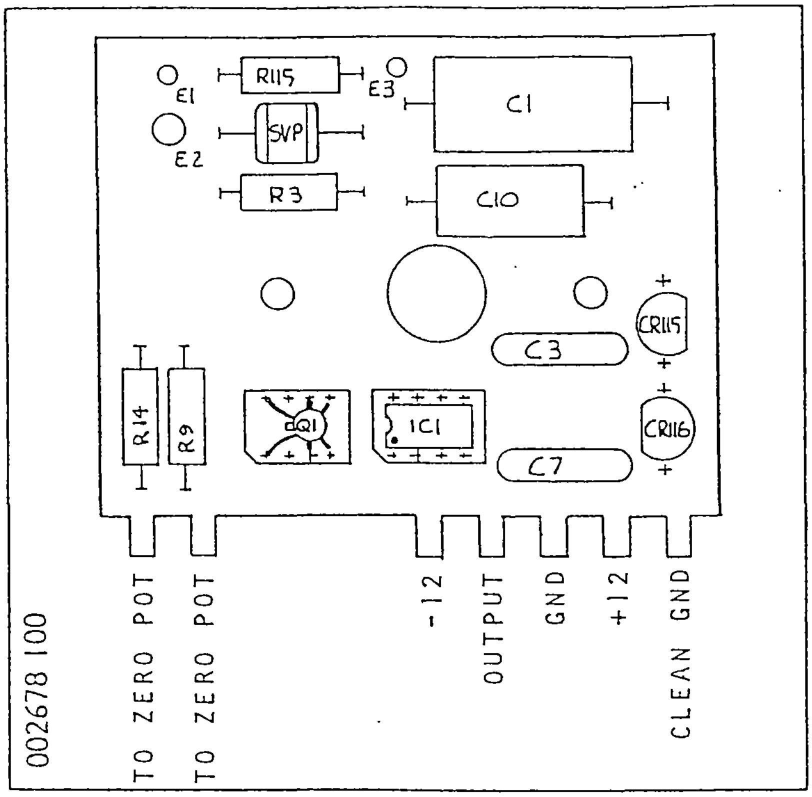

FIG. 6-2 LOCATION OF COMPONENTS ON ELECTROMETER P. C. BOARD

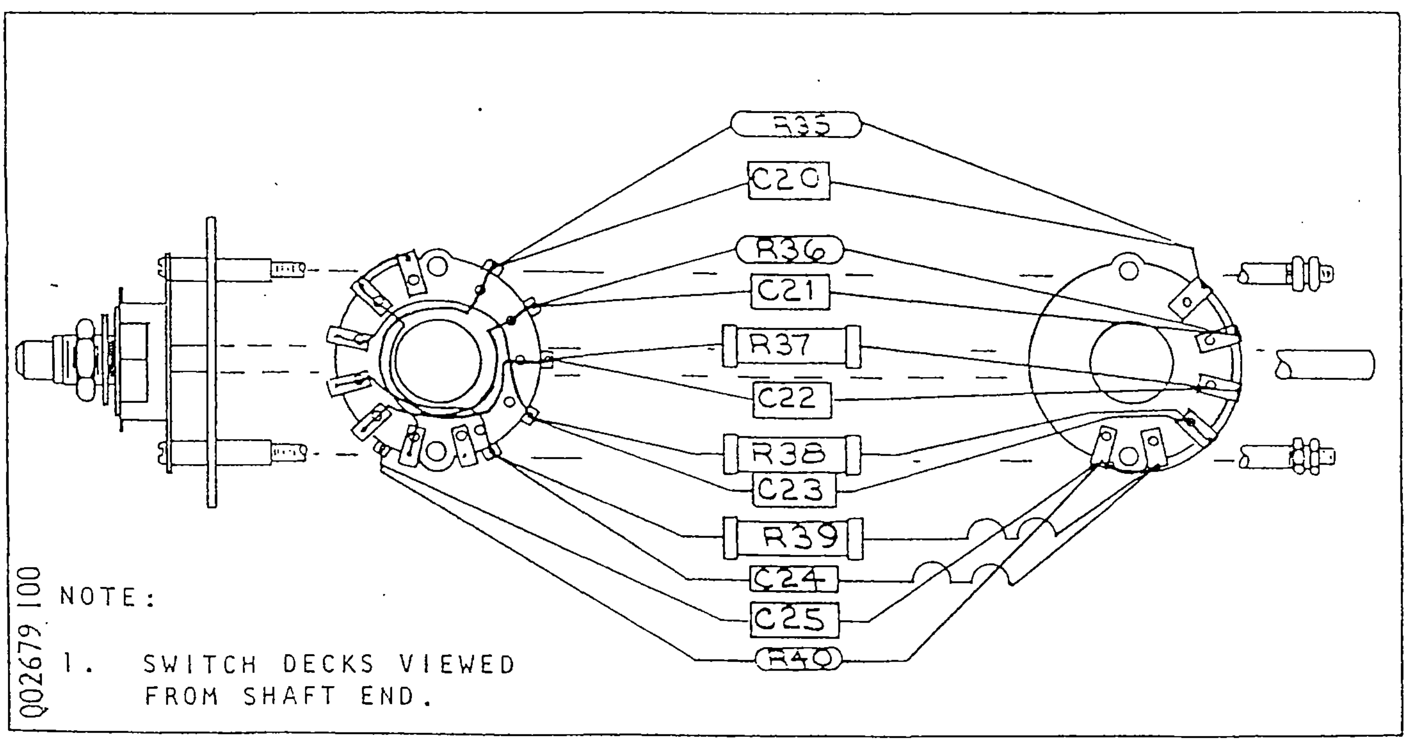

FIG. 6-3 LOCATION OF COMPONENTS ON RANGE SWITCH

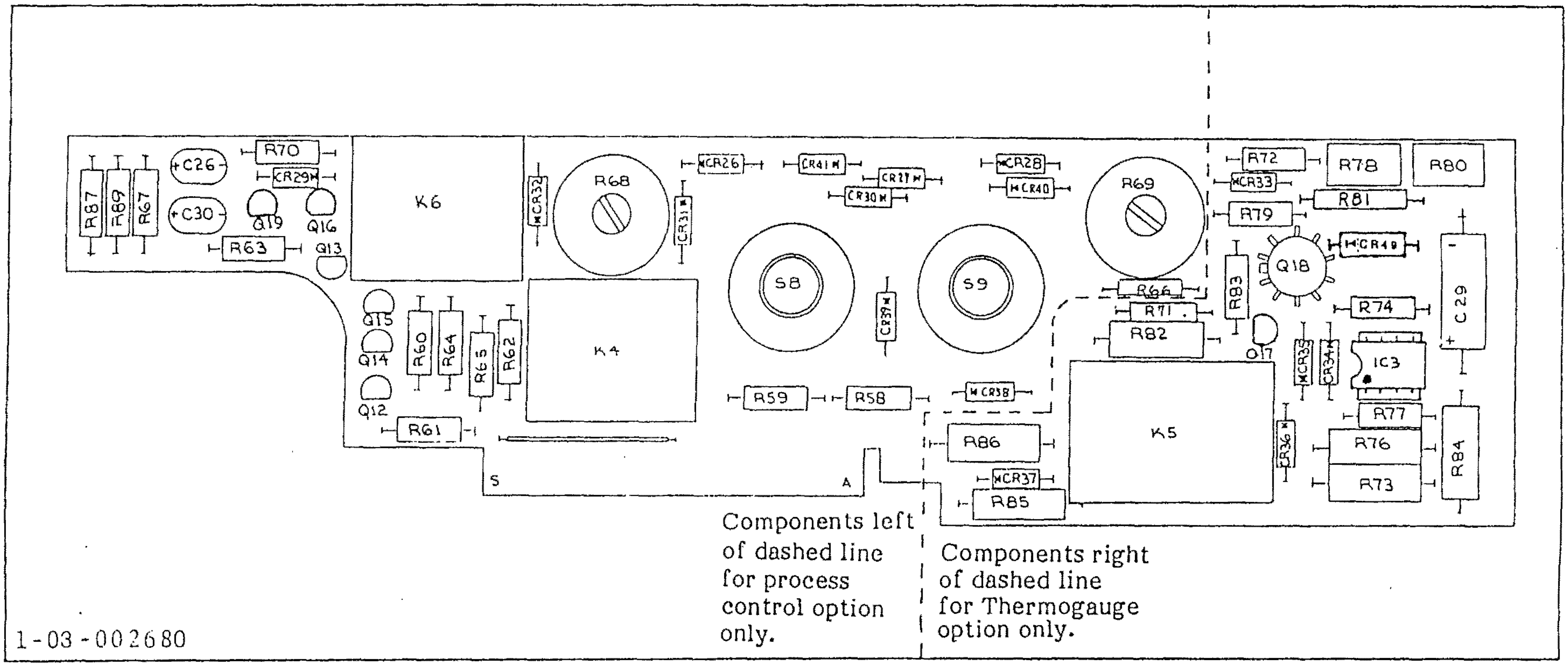

FIG. 6-4 LOCATION OF COMPONENTS ON OPTION PRINTED CIRCUIT BOARD WITH PROCESS CONTROL AND THERMO-GAUGE

NOTES

Series 260 IGC Parts List

TRANSISTORS
UNIJUNCTIONS
FETS

Circuit Designation	Description	GP Part No.
Q1	FET Solitron FD1779	007644 100
Q2, Q4, Q10 thru Q15	Transistor, NPN, Silicon, 2N3904	005822 0 01
Q3	Transistor, NPN, Silicon Motorola MJE340	005232 0 01
Q5, Q7, Q9	Transistor, PNP, Silicon 2N3906	001881 1 00
Q6	Unijunction, 2N4871	004403 0 01
Q8, Q16, Q17, Q19	Transistor, Darlington, NPN, Silicon General Electric GES5308	003880 1 01
Q18	Transistor, NPN, Silicon, 2N3053	001878 1 00

IC's

Circuit Designation	Description	GP Part No.
IC1, IC2, IC3	I. C. Op Amp Motorola MC1741CP1	002897 1 00

DIODES

Circuit Designation	Description	GP Part No.
CR1	Triac Motorola 2N6160	003226 1 03
CR2, CR15	Diode, Zener, 5.1V, 1.0W, 1N4733	005228 0 02
CR4, CR13	Diode, Zener, 12.0V, 1.0W, 1N4742	007649 100
CR5, CR12, CR11, CR17, CR18, CR20 thru CR22, CR25, CR31, CR32, CR36, CR37, CR3,CR9,CR10	Diode, Signal, Silicon, 1N4007	001896 1 00
CR6	Diode, Zener, 180.0V, 0.75W 1N3709B	005794 0 01
CR8	Rectifier Assembly, 100V, 1A Varo VE-18	005226 0 01
CR49, CR27 thru CR30, CR34, CR35, CR38 thru CR47, CR49 CR101, CR102, CR104 thru CR113	Diode, Signal, Silicon, 1N3064	004563 0 01
CR16	Diode, Zener, 30.0V, 1.0W, 1N4751	005787 0 01
CR19, CR24	Diode, Zener, 6.2V, 1.0W, 1N4735A	005995 0 01
CR14	Diode, Zener, 5.1V, 0.5W, 1N5231B	004567 0 01
CR115, CR116	Diode, Zener, Modified D32W14	004836 1 00

Circuit Designation	Description	GP Part No.
CR26, CR103	Diode,Zener, 5.6V, 1.0W, 1N4734A	005997 0 01
CR33	Diode, Zener, 16.0V, 1.0W, 1N4745A	005996 0 03
	CAPACITORS	
C1	Capacitor, 4700 pf, 500V, Polystyrene CRL CPR-4700J	001459 1 00
C2	Capacitor, 50 uf, 50V, Electrolytic Sprague 500D506G050DD7	007023 0 01
C3, C7 thru C9, C28	Capacitor, .1 uf, 25V, Ceramic Centralab Type UK20-104	005945 1 00
C4, C14	Capacitor, 10.0 uf, 16V, Electrolytic Sprague 500D106G016BA7	005785 001
C5	Capacitor, 5 uf, 300V, Electrolytic Sprague 500D505F300DF7	005753 0 01
C10	Capacitor, .1 uf, 200V, Polyester Film Sprague 192P10492	001381 1 00
C11,C12,C13,C27	Capacitor, 56 pf, 1000V, Ceramic Sprague 5GA-Q56	005322 0 01
C15, C16	Capacitor, .047 uf, 100V, Mylar Cornell Dubilier WMF1S47	005756 0 01
C17	Capacitor, 350 uf, 25V, Electrolytic Sprague 500D357G25EH7	005806 0 01
C18	Capacitor, 68 uf, 10V, Tantalum Sprague 196D686X0010FB	005850 0 01
C19	Capacitor, 1.00 uf, 200V, Mylar Cornell Dubilier WMF2P68	005851 0 01
C20, C21	Capacitor, 390 pf, 500V, Polystyrene Centralab CPR-39J	001461 1 00
C22, C23, C24	Capacitor, 100 pf, 500V, Polystyrene Centralab CPR-100J	001462 1 00
C25	Capacitor, 2200 pf, 500V, Polystyrene Centralab CPR-2200J	001460 1 00
C26, C30	Capacitor, 33 uf, 6V, Tantalum Sprague 196D336X0006JE3	006407 0 01
C29	Capacitor, 120 uf, 15V, Tantalum Foil Semcor TSW2K-15-127	005998 0 01
C31, C32	Capacitor, 0.1 uf, 100V, Ceramic Sprague 33C41B6	002606 1 00
C6	Capacitor, 220uf, 25V, EL	005754 0 01
	RESISTORS	
R18,R51,R66	Resistor, 1Kohm, 5%, .5W, Carbon Comp	000462 1 01
R2,R6,R23	Resistor, 51 ohm, 5%, .5W, Carbon Comp	006021 0 01
R3	Resistor, 510Kohm, 5%, .5W, Carbon Comp	005691 0 01
R4,R8,R83	Resistor, 2.7Kohm, 5%, .5W, Carbon Comp	000615 1 00
R5,R78,R80	Pot, 1.0Kohm,20%, 1.0W CTS 360S102B	005908 0 01

Circuit Designation	Description	GP Part No.
R7,R22,R49,R58, R59,R60,R62,R64, R65,R115	Resistor, 10 Kohm, 5%, .5W, Carbon Comp	000464 1 00
R9,R14	Resistor, 7.5 Kohm, 5%, .5W, Carbon Comp	001210 1 00
R10,R68,R69	Pot, 5 Kohm, 20%, 1W CTS 360S502B	005694 0 01
R11	Resistor, 33 Kohm, 5%, .5W, Carbon Comp	001219 1 00
R12,R25,R61,R63, R72	Resistor, 3.9 Kohm, 5%, .5W, Carbon Comp	005700 0 01
R13	Resistor, 300 ohm, 5%, 2W, Carbon Comp	005790 0 01
R15	Resistor, 47.0 Kohm, 5%, 2W, Carbon Comp	005793 0 01
R16,R19,R24,R45, R48,R53	Resistor, 5.1 Kohm 5%, .5W, Carbon Comp	005368 0 01
R17,R20,R75	Resistor, 10 ohm, 5%, .5W, Carbon Comp	000975 1 00
R21	Resistor, 22 Mohm, 5%, .5W, Carbon Comp	001701 1 00
R26,R1	Resistor, 510 ohm, 5%, .5W, Carbon Comp	006027 0 01
R27	Resistor, 200 ohm, 5%, 2W, Carbon Comp	005789 0 01
R28,R40	Resistor, 49.9 Kohm, 1%, .5W, Metal Film	001711 1 00
R29	Resistor, 1.02 Kohm, 1%, .5W, Metal Film	007647 100
R30,R2	Resistor, 180 ohm, 5%, .5W, Carbon Comp	005359 0 01
R31,R50	Resistor, 4.99 Kohm, 1%, .5W, Metal Film	001690 1 00
R32	Resistor, 100 ohm, 1%, .5W, Metal Film	001053 1 00
R33,R47	Resistor, 1 Kohm, 1%, .5W, Metal Film	001831 1 00
R34	Resistor, 62 Kohm, 5%, .5W, Carbon Comp	007645 100
R35	Resistor, 499 Kohm, 1%, .5W, Metal Film	001689 1 00
R36	Resistor, 4.99 Mohm, 1%, .5W, Dep. Carbon	004972 0 01
R37	Resistor, 50 Mohm, 2%, 1W, Dep. Carbon	004971 0 01
R38	Resistor, 500 Mohm, 2%, 1W, Carbon Coated	004970 0 02
R39	Resistor, 5 K Mohm, 2%, 1W, Carbon Coated	004969 0 02
R41	Resistor, 22 Kohm, 5%, .5W, Carbon Comp	001023 1 00
R42	Resistor, 39 Kohm, 5%, .5W, Carbon Comp	001958 1 00
R43	Resistor, 1.5 Kohm, 5%, .5W, Carbon Comp	005374 0 01
R44	Resistor, 270 ohm, 5%, 2W, Carbon Comp	007557 100
R46	Resistor, 6.98 Kohm, 1%, .5W, Metal Film	001684 1 00
R52	Resistor, 301 ohm, 1%, .5W, Metal Film	005576 0 01
R54	Resistor, 510 Kohm, 5%, .5W, Carbon Comp	005691 0 01
R55,R57	Resistor, 33 ohm, 5%, 2W, Carbon Comp	007556 100
R56	Resistor, 3.3 Kohm, 5%, 5W, Wirewound Sprague 243E	007558 100
R67,R70	Resistor, 220 Kohm, 5%, .5W, Carbon Comp	001031 1 00
R71	Resistor, 220 ohm, 5%, .5W, Carbon Comp	000997 1 00
R73	Resistor, 143 ohm, 1%, .5W, Metal Film	001680 1 00
R74	Resistor, 27 Kohm, 5%, .5W, Carbon Comp	001025 1 00
R76	Resistor, 39.2 ohm, 1%, .5W, Metal Film	006086 0 01
R77	Resistor, 100 Kohm, 5%, .5W, Carbon Comp	000292 1 00
R79	Resistor, 1.8 Kohm, 5%, .5W, Carbon Comp	006194 0 01
R81	Resistor, 93.1 ohm, 1%, .5W, Metal Film	006087 0 01
R82	Resistor, 39 ohm, 5%, 1W, Carbon Comp	006088 0 01
R84	Resistor, 2.26 Kohm, 1%, .5W, Metal Film	006085 0 01
R85	Resistor, 475 ohm, 1%, .5W, Metal Film	006193 0 01
R68, R69	Pot, 5 Kohm, 20%, 2W CTS Series 115	005959 001

Circuit Designation	Description	GP Part No.
R86	Resistor, 9.31 Kohm, 1%, .5W, Metal Film	005158 1 00
R87,R89	Resistor, 30 Kohm,5%, .5W, Carbon Comp	007646 100
R101,R104,R106, R108,R110,R112	Resistor, 820 ohm, 5%, .5W, Carbon Comp	007297 0 01
R102	Resistor, 909 ohm, 1%, .5W, Metal Film	001687 1 00
R103	Resistor, 100 ohm, 5%, .5W, Carbon Comp	000379 1 00
R105	Resistor, 1.13 Kohm, 1%, .5W, Metal Film	007303 0 00
R107	Resistor, 1.43 Kohm, 1%, .5W, Metal Film	007307 0 01
R109	Resistor, 1.91 Kohm, 1%, .5W, Metal Film	007306 0 01
R111	Resistor, 2.94 Kohm, 1%, .5W, Metal Film	007305 0 01
R113	Resistor, 5.9 Kohm, 1%, .5W, Metal Film	007304 0 01
	SWITCHES AND LAMPS	
S1-L2	Switch, Power, Lighted Button Molex 1820RL-131-334-428-516-605	005783 0 04
S2-L4	Switch, Filament, Lighted Button Molex 1820RL-125-332-428-516-605	005786 0 04
S3-L1	Switch, Auto, Lighted Button Molex 1820RL-121-331-428-516-605	005808 0 04
L2, L3	Bulb, 6V, .2 Amp Commercial Designation 379	004490 1 00
L4	Bulb, 14V, .08 Amp Commercial Designation 386	004491 1 00
L1	Bulb, 28V,.04 Amp Commercial Designation 388	004492 1 00
S4	Switch, Toggle SPDT Alcoswitch MST-105D	005924 0 01
S5	Switch, Emission	004964 0 01
S6	Switch, Range, IGC	005159 0 01
S7-L3	Switch, Degas, Lighted Button Molex 1820RL-131-334-428-516-605	005784 0 04
S8, S9	Switch, 2 Pol 6 Pos, P. C. Mount	005554 0 01
	CONNECTORS	
J1	Connector, Receptacle F, 8 Contact "Jones" Socket S-308-AB	005207 0 01
P1	Connector, Plug M, 8 contact "Jones" Plug P-308-CCT	004989 0 01
J2	Connector, Receptacle F, 22 contact Viking 22A/1-2	001371 1 00
Gauge Tube Connector	Connector, Plug F, 7 contact Winchester A7SH-28	006457 100 & 006455 100
	Jack, Banana, Blue Donmar 721 Blue	000973 1 00
	Jack, Banana, Black Donmar 721 Black	000972 1 00
J3	Connector, Receptacle M, 15 contact ITT Cannon DA15P-14	005407 0 01

Circuit Designation	Description	GP Part No.
J4	Connector, Receptacle F, 30 contact Viking 2VK15D/4-2	005405 0 01
J5	Connector, Receptacle M, 3 contact(round pin) Switchcraft AC-3G	005410 0 01
J5	Connector, Receptacle M, 3 blade recessed Switchcraft EAC-301	006443 1 00
	RELAYS	
K1,K2,K4,K6	Relay, 2500 ohm, 5.8 mA, 2PDT, 1A con Allied Control #TS154-2C-5.8	001167 1 01
K3,K5	Relay, 24V, 700 ohm, 4PDT, 5A con Allied Control #TF154-4C-24V	002024 1 01
	RELAY SOCKETS	
	Socket, Relay, 16 cont. pin, PCB/Mt Allied Control Co. 30055-4	001166 1 00
	Socket, Relay, 10 cont. pin, PCB/Mt Allied Control Co. 30055-3	001165 1 00
	TRANSFORMERS	
T1	Transformer, Power, IGC Tranex 14-5052	004965 0 04
T2	Transformer, Pulse Sprague 11Z2000 1:1	005792 0 01
	METERS	
M1	Meter, Thermo-Gauge Modutec	006092 0 01
M2	Meter, Ion Current Modutec	004973 0 01
	MOTORS	
Motor 1	Motor, Assy, Gearhead Complete	007226 1 00
	FUSES	
F1	Fuse, 2 Amp Slow Blow Littlefuse 313002	001176 1 00
F2	Fuse, 6 Amp Medium Blow Littlefuse 314006	002278 1 00
	MISC.	
	Holder, Fuse Littlefuse 345001	001077 1 01

Circuit Designation	Description	GP Part No.
	Knob, Round Dial, Skirted Electronic Hardware Corp. PC0F2B	004614 0 01
	Knob, Round, Plain W/Marker Control Knobs, Inc. 5CC2B2	006046 0 01
	Cable, Power (round pin) Belden 17258	005411 0 02
	Power Cord, 3 blade recessed Electro-Cords E1015(8.0) Gray	006444 1 00
	Gauge Cable Assembly	004987 0 04
	Thermo-Gauge Cable Assembly	260040 1 00
	Transformer Shield	005868 0 01
	Main Current Board for Models 260001 and 260015	005946 0 04
	Main Circuit Board for Models 260002 thru 260004 and 260016 thru 260018	006015 0 04
	Main Circuit Board for Models 260005 thru 260008 and 260019 thru 260024	006023 0 04
	Thermo-Gauge Option Circuit Board	006118 0 04
	Thermo-Gauge and Process Control Option Circuit Board	006101 0 03
	Electrometer Circuit Board	005935 0 04
	Surge Voltage Protector (SVP)	003574 1 02

NOTE: The manufacturers part numbers given are for reference only to assist in obtaining parts locally. Parts ordered from G-P may or may not have the listed manufacturer and part number but meet the required G-P part number specification.