Series 325

MODUCELL® Pirani Vacuum Sensor/Transducer

Instruction Manual

Instruction manual part number 103250029
Revision B - May 2020

Series 325

MODUCELL® Pirani Vacuum

This instruction manual is for use with Series 325 MODUCELL® Pirani Vacuum Sensor/Transducer.

Customer Service / Technical Support:

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Instruction Manual

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Chapter 1

General Information

1.1 Receiving Inspection

On receipt of the equipment, inspect all material for damage. Confirm that the shipment includes all items ordered. If items are missing or damaged, submit a claim as stated below for a domestic or international shipment, whichever is applicable.

If materials are missing or damaged, the carrier that made the delivery must be notified within 15 days of delivery, or in accordance with Interstate Commerce regulations for the filing of a claim. Any damaged material including all containers and packaging should be held for carrier inspection. Contact MKS Instruments, Inc. Customer Support for assistance if your shipment is not correct for reasons other than shipping damage.

1.2 International Shipment

Inspect all materials received for shipping damage and confirm that the shipment includes all items ordered. If items are missing or damaged, the airfreight forwarder or airline making delivery to the customs broker must be notified within 15 days of delivery. The following illustrates to whom the claim is to be directed.

- 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.

Any damaged material including all containers and packaging should be held for carrier inspection. Contact MKS Customer Support for assistance if your shipment is not correct for reasons other than shipping damage.

1.3 Warranty

MKS Instruments, Inc. provides an eighteen (18) month warranty from the date of shipment for new MKS Products. The MKS Instruments, Inc. General Terms and Conditions of Sale provides the complete and exclusive warranty for MKS products. This document is located on our web site at www.mksinst.com, or may be obtained by contacting an MKS Customer Service Representative.

1.4 Certification

MKS Instruments, Inc. certifies that this product met its published specifications at the time of shipment from the factory.

1.5 Customer Service / Technical Support

Some minor problems are readily corrected on site. If the product requires service, contact the MKS Technical Support Department at +1-833-986-1686. If the product must be returned to the factory for service, request a Return Material Authorization (RMA) from MKS. Do not return products without first obtaining an RMA. In some cases a hazardous materials disclosure form may be required. The MKS Customer Service Representative will advise you if the hazardous materials document is required.

When returning products to MKS, be sure to package the products to prevent shipping damage. Shipping damage on returned products due to inadequate packaging is the Buyer's responsibility.

For Customer Service / Technical Support:
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1.6 Typical Applications for the MODUCELL Pirani Vacuum Sensor/Transducer

- Measuring foreline and roughing pressures generated by mechanical vacuum pumps
- Controlling valves and pumps to automate system pump down using the relay set point
- Sensing abnormal pressure and taking appropriate security measures using the relay set point
- Controlling system pressure using the analog output as input to an automatic pressure controller
- Starting or stopping system processes using the relay set point
- Activating high vacuum sensors in their operating range

Chapter 2
Safety

2.1 Safety Introduction

START BY READING THESE IMPORTANT SAFETY INSTRUCTIONS AND NOTES collected here for your convenience and repeated with additional information at appropriate points throughout this instruction manual.

These safety alert symbols in this manual or on the Product mean caution - personal safety, property damage or danger from electric shock. Read these instructions carefully.

⚠ DANGER	Danger indicates a hazardous situation which, if not avoided, **will result in death or serious injury.**
⚠ WARNING	Warning indicates a hazardous situation which, if not avoided, **could result in death or serious injury**.
⚠ CAUTION	Caution indicates a hazardous situation or unsafe practice which, if not avoided, **may result in minor or moderate personal injury**.
NOTICE	Indicates a situation or unsafe practice which, if not avoided, **may result in equipment damage**.

Notice

These instructions do not and cannot provide for every contingency that may arise in connection with the installation, operation, or maintenance of this product. If you require further assistance, contact MKS.

This product was designed and tested to offer reasonably safe service provided it is installed, operated, and serviced in strict accordance with these safety instructions.

⚠ WARNING

Safety Precautions

Failure to comply with these instructions may result in serious personal injury, including death, or property damage.

Always observe and follow all safety notices that are provided throughout this instruction manual and on the product.

These safety precautions must be observed during all phases of operation, installation, and service of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. MKS disclaims all liability for the customer's failure to comply with these requirements.

- *Read Instructions* – Read all safety and operating instructions before operating the product.
- *Retain Instructions* – Retain the Safety and Operating Instructions for future reference.
- *Heed Warnings* – Adhere to all warnings on the product and in the operating instructions.
- *Follow Instructions* – Follow all operating and maintenance instructions.
- *Accessories – Do not* use accessories not recommended in this manual as they may be hazardous.

WARNING

Electrical Shock or Personal Injury

The service and repair information in this manual is for the use of Qualified Service Personnel. To avoid possible electrical shock or personal injury, do not perform any procedures in this manual or perform any servicing on this product unless you are qualified to do so.

WARNING

Electrical Shock or Fire

To reduce the risk of fire or electric shock, do not expose this product to rain or moisture.

Objects and Liquid Entry - Never push objects of any kind into this product through openings as they may touch dangerous voltage points or short out parts that could result in a fire or electric shock. Be careful not to spill liquid of any kind onto the products.

2.2 Responsibility

It is the responsibility of the Customer to comply with all local, state, and federal ordinances, regulations, and laws applicable to the installation, operation and service of this equipment.

It is the responsibility of the end user to provide sufficient lighting at work to meet local regulations.

Operation and Service of this equipment in strict accordance with the methods and procedures supplied by MKS is the responsibility of the Customer.

MKS assumes no liability, whatsoever, for any personal injuries or damages resulting from the operation or service of this equipment in any manner inconsistent or contrary to the methods supplied in MKS literature including, but not limited to, manuals, instructions, bulletins, communications, and recommendations.

For emergencies and for product safety related matters, contact the MKS Customer Service Department. See Section 1.5 or Section 6.1 for detailed information regarding how to contact MKS Customer Service Representatives.

2.3 Grounding Requirements

See Grounding, Section 4.1 in the Installation chapter for more detailed requirements regarding gauge and system grounding.

WARNING

Proper Grounding

All components of a vacuum system used with this or any similar high voltage product must be maintained at Earth ground for safe operation.

Be aware that grounding this product does not guarantee that other components of the vacuum system are maintained at Earth ground.

Verify that the vacuum port to which the Series 342/343 Mini-Ion Gauge Module is mounted is electrically grounded. It is essential for personnel safety as well as proper operation that the envelope of the gauge be connected to a facility ground. Connect power cords only to properly grounded outlets or sources.

Grounding is very important! Be certain that ground circuits are correctly used on your ion gauge power supplies, gauges, and vacuum chambers, regardless of their manufacturer. Safe operation of vacuum equipment requires grounding of all exposed conductors of the gauges, the controller and the vacuum system. LETHAL VOLTAGES may be established under some operating conditions unless correct grounding is provided.

Ion producing equipment, such as ionization gauges, mass spectrometers, sputtering systems, etc., from many manufacturers may, under some conditions, provide sufficient electrical conduction via a plasma to couple a high voltage electrode potential to the vacuum chamber. If exposed conductive parts of the gauge, controller, and chamber are not properly grounded, they may attain a potential near that of the high voltage electrode during this coupling. Potential fatal electrical shock could then occur because of the high voltage between these exposed conductors and ground.

2.4 High Voltage

High Voltage is present in the unit when electrical power is applied to the electronics enclosure. Hazardous voltages may still be present for some time after disconnecting power to the electronics enclosure. Refer to the Installation and Service chapters for more information.

WARNING

High Voltage

Be aware that when high voltage is present in any vacuum system, a life threatening electrical shock hazard may exist unless all exposed conductors are maintained at Earth ground.

This hazard is not unique to this product.

WARNING

High Voltage

All conductors in, on, or around the vacuum system that are exposed to potential high voltage electrical discharges must either be shielded at all times to protect personnel or must be connected to Earth ground at all times.

WARNING

High Voltage

Be aware that an electrical discharge through a gas may couple dangerous high voltage directly to an ungrounded conductor almost as effectively as would a copper wire connection. A person may be seriously injured or even killed by merely touching an exposed ungrounded conductor at high potential.

This hazard is not unique to this product.

CAUTION

Do not connect or disconnect any electrical connectors while power is applied to the equipment (hot swapping). Doing so may cause damage to the equipment or severe electrical shock to personnel. This hazard is not unique to this product.

2.5 Over Pressure Conditions

WARNING

Explosive Environment

Do not use the Series 325 Sensor in an environment of explosive or combustible gases or gas mixtures. Operation of any electrical instrument in such an environment constitutes a definite safety hazard. Do not use the product to measure the pressure of explosive gases or gas mixtures.

WARNING

Potential Automatic Operation

It is the installer's responsibility to ensure that the automatic signals provided by the product are always used in a safe manner. Carefully check the system programming before switching to automatic operation.

WARNING

Vacuum Chamber High Pressures

Where an equipment malfunction could cause a hazardous situation, always provide for fail-safe operation. As an example, in an automatic backfill operation where a malfunction might cause high internal pressures, provide an appropriate pressure relief device.

Danger of injury to personnel and damage to equipment exists on all vacuum systems that incorporate gas sources or involve processes capable of pressuring the system above the limits it can safely withstand.

For example, danger of explosion in a vacuum system exists during backfilling from pressurized gas cylinders because many vacuum devices such as ionization gauge tubes, glass windows, glass belljars, etc., are not designed to be pressurized.

Install suitable devices that will limit the pressure from external gas sources to the level that the vacuum system can safely withstand. In addition, install suitable pressure relief valves or rupture disks that will release pressure at a level considerably below that pressure which the system can safely withstand.

Suppliers of pressure relief valves and pressure relief disks can be located via an online search. ***Confirm that these safety devices are properly installed before installing and operating the product.***

Ensure the following precautions are complied with at all times:

(1) the proper gas cylinders are installed,

(2) the gas cylinder valve positions are correct on manual systems,

(3) and the automation is correct on automated gas delivery systems.

CAUTION

Vacuum gauges with compression fittings may be forcefully ejected if the vacuum system is pressurized.

2.6 Damage Requiring Service

Disconnect the product from all power sources and refer servicing to Qualified Service Personnel under the following conditions:

- **a.** When any cable or plug is damaged.
- **b.** If any liquid has been spilled onto, or objects have fallen into the product.
- **c.** If the product has been exposed to rain or water.
- **d.** If the product does not operate normally even if you follow the operating instructions. Adjust only those controls that are covered by the operation instructions. Improper adjustment of other controls may result in damage and will often require extensive work by a qualified technician to restore the product to its normal operation.
- **e.** If the product has been dropped or the enclosure has been damaged.
- **f.** When the product exhibits a distinct change in performance. This indicates a need for service.

Notice

Do not substitute parts or modify the instrument.

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to a service facility designated by MKS for service and repair to ensure that safety features are maintained. Do not use this product if it has unauthorized modifications.

Notice

Safety Check - Upon completion of any service or repairs to this product, ask the Qualified Service Person to perform safety checks to determine that the product is in safe operating order.

See Service Guidelines, Section 1.5 for detailed information regarding how to contact MKS Customer Service Representatives.

Chapter 3

Specifications

3.1 General Description

The Series 325 MODUCELL® Pirani Vacuum Sensors are a heat-loss manometer which infers the pressure of a gas by measuring thermal loss from a heated wire. Pirani sensors use the pressure-dependent thermal energy transport from a hot wire to measure pressure.

3.2 Intended Use

The 325 Sensors are for vacuum system pressure measurement. These instruments are to be used only in accordance with the instructions in this operation manual.

3.2.1 Improper Use

- Removal of any factory installed components.
- Modifying any factory installed components.
- Removal of any labeling or warranty seals.
- Operation of this device in any condensing vapor or liquid, or explosive environment.

3.3 Transportation

- Reuse the original shipping container.
- Replace all of the dust caps on all ports prior to shipping.

3.4 Storage

- Store the Sensor indoors between -40 ^{o}C to +70 ^{o}C (-40 ^{0}F to 158 ^{0}F).
- Bag the assembly in a sealed or shrink wrapped bag with desiccant.
- All of the components should be bagged and boxed together along with the instructions for future reference.

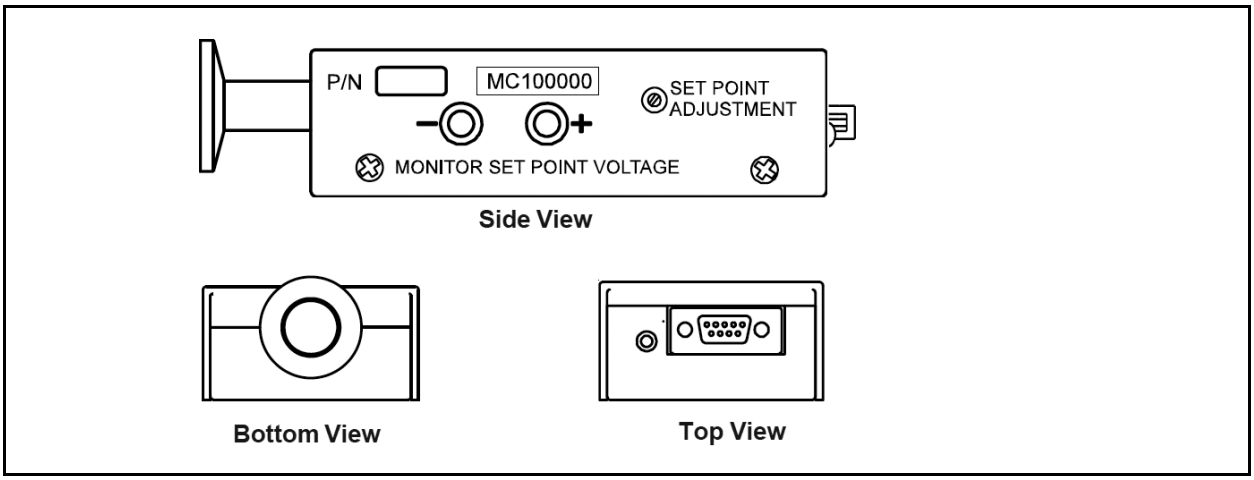

Figure 3-1: Series 325 MODUCELL Sensor

3.5 Specifications

Table 3-1 Specifications for the Series 423 I-Mag Sensor

Parameter	Specification
Performance	
Measurement Range for N_2 / Air (1)	Torr: 1.0 x 10^{-3} to 100 mbar: 1.3 x 10^{-3} to 1.3 x 10^{+2} Pascal:1.3 x 10-^{1} to 1.3 x 10^{+4}
Useful Setpoint Range	Torr: 5.0 x 10^{-3} to 30 mbar: 6.6 x 10^{-3} to 4.0 x 10^{+1} Pascal: 6.6 x 10^{-1} to 4.0 x 10^{+3}
Accuracy	+/- 5% operating
Calibration Gas	Air/nitrogen
Operating Power	15 Vdc, 0.175 A or 24 Vdc, 0.175 A
Output Voltage	0.2 to 3.25 VDC, 1 kW (max) impedance
Physical	
Vacuum Connection	NW40 ISO-KF, .75 in. OD CF, 1 in. OD Tube, or NW25 ISO-KF
Electrical Connection	9 pin sub-miniature “D” type
Relay Contact Rating	2A @ 28 VDC 2A @ 50 VAC, SPDT
Relay Response(2)	15 to 150 msec
Case Material	Aluminum,
Materials exposed to vacuum	SS 304, platinum, alumina ceramic, silverbrazing alloy, nickel200
Weight	0.23 kg (0.5 lb)
Dimensions	60.3 mm x 31.8 mm x 111.1 mm (2.37" x 1.25" x 4.37")
Internal volume	less than 8 cm^3 (0.49 in^3)
Mounting Orientation	Any. However, avoid mounting the gauge directly below the chamber to prevent sputtered material or other debris falling into the gauge.
Operating Temperature	0 ^{o}C to +70 ^{o}C (32 ^{0}F to 158 ^{0}F) ambient, indoor use only, ordinary protection from moisture
Operation Humidity	0 to 90%
Bake out Temperature	85 ^{o}C (185 ^{o}F)
Specifications and dimensions are subject to change without notice.	

(1) Do NOT use this product with flammable or explosive gases.

(2) The fast response (15 msec) is for a quick pressure rise to atmosphere, and the slower response (150 msec) is for smaller pressure changes. Special circuitry allows for this dual response.

Chapter 4
Installation

4.1 Sensor Location

Notice

Install the gauge on the vacuum chamber where it is protected from physical damage and high heat.

See Section 2.5, Over Pressure Conditions, for important safety information before mounting the gauge.

Locate the MODUCELL Sensor where it can measure process chamber or manifold pressure. Install it away from pumps, other vibration sources, and gas sources to give the most representative values.

Locate and orient the Sensor where contamination is least likely. If it is installed directly above a diffusion pump, for example, oil vapor could contaminate the cathode, anode, or other vacuum exposed components, causing the calibration to shift.

The Sensor can be installed with the body set in any direction. Operating position does not affect accuracy. Installing it with the vacuum port facing down is optimal as this helps prevent contaminants falling into it. If particulates in the system are common, it is necessary to keep them from entering the Sensor using a screen or porous filter at the port. A centering ring with a screen, MKS p/n 100318601 is useful.

4.2 Connect the Sensor to the Vacuum System

Mount the Sensor to a grounded vacuum system.

WARNING

Proper Grounding

Improper grounding could cause product failure or personal injury.

- Follow ground network requirements for the facility.
- Maintain all exposed conductors at Earth ground.
- Make sure the vacuum port to which the gauge is mounted is properly grounded.
- See the grounding cautions in Section 2.3.

Connect the MODUCELL to the vacuum system flange using the appropriate gasket and mounting hardware.

Notice

A solid electrical connection between the sensor tube and the grounded vacuum system must be used to shield the tube element from external power sources. In applications where the system may be exposed to large voltage fluctuations, a centering ring (HPSTM part # 100318601) with a screen should be installed, and the screen and tube then grounded.

Orient the MODUCELL to prevent condensation of process vapors on the internal surfaces through line-of-sight access to its interior. If vapor condensation is likely, orient the port downward to help liquids drain out.

CAUTION

Do not use a compression mount/quick connect fitting for positive pressure applications.

For an NW16KF, NW25KF or NW40KF flange:

The NW##KF style flange requires a self-centering O-ring between mating flanges. Use a metal clamp and tighten the clamp to compress the mating flanges together. Do Not use a plastic clamp. See the Grounding Requirements.

Attach the MODUCELL to the mating NW-style connector on the vacuum chamber. Use a new seal and the appropriate tools to tighten the metal clamp.

For an NW16CF (1.33 inch) or NW35CF (2.75 inch) flange:

Attach the MODUCELL to the mating flange on the vacuum chamber. Use a new copper seal between the flanges - do not use a previously used seal. If the flanges have leak test grooves, be sure they are properly aligned.

Finger tighten all 6 bolts. Use the appropriate tools to tighten the 6 bolts. Tighten the bolts in a circular pattern (such as 1, 3, 5, 2, 6, 4, 1, 3, 5, 2, 6, 4) until the flanges are in contact. After contact, torque each bolt to 12 lb ft.

For a VCR-type fitting:

Remove the bead protector cap from the fitting.

Place the gasket into the female nut.

Assemble the components and tighten them to finger-tight.

While holding a back-up wrench stationary, tighten the female nut 1/8 turn past finger-tight on 316 stainless steel or nickel gaskets, or 1/4 turn past finger-tight on copper or aluminum gaskets. Do not twist the gauge to tighten the fitting.

For a NPT-type fitting:

When fitting the MODUCELL with the 1/8" NPT-M thread, do not use the case for tightening; the Sensor's tube has 9/16" hex flats for tightening. A single wrap of thread-sealant tape should be used on the threads of the tube to ensure a leak-free seal.

For an O-ring Compression Seal fitting:

The MODUCELL can also use a ½" O-ring compression seal acting on the tubing above the thread, but the O-ring seal cannot be used for positive pressure applications.

4.3 Electrical Connections

⚠ CAUTION

Do not connect or disconnect any electrical connectors while power is applied to the equipment (hot swapping). Doing so may cause damage to the equipment or severe electrical shock to personnel. This hazard is not unique to this product.

Connect a user-supplied cable to the MODUCELL using a mating 9-pin D-sub connector with strain reliefs to ensure proper electrical connection and to reduce stress on the connectors.

Connect the cable to the Sensor and to the Controller before turning ON the system. Tighten the thumb screw on top of the cable to make sure it is securely in place.

4.3.1 Input/Output Wiring

The following chart and the figure at the right identify the pins in the MODUCELL 9-pin D-sub connector. The user can make a cable using the information from this chart.

The power supply input may range from 12 to 15 Vdc (or 22 to 26 Vdc). The positive side (+) of the power supply is connected to pin 3 and the minus side (-) is connected to pin 4 of the D-sub connector. Damage will occur if the polarity of the power supply input is reversed.

Table 4-1: Power Connections / 9-pin D-sub Connector

Pin #	Description
1	Set point relay - normally open contact
2	Set point relay – normally closed contact
3	Power supply input (+)
4	Power supply input (-)
5	Analog output voltage (+)
6	Set point relay – common
7	Set point relay – disable
8	Analog output voltage (-)
9	Set point relay output voltage

The ground connection to the set point relay in the MODUCELL® is pin 7 of the D-sub connector. If pin 7 is left open, then the MODUCELL®'s set point relay is disabled. The set point relay may also be disabled by setting the set point voltage below 200 mV. Any switching mechanism used to control this line must be capable of handling 50 mA at 15 V (or 30 mA at 24 V).

Do not ground pin 7 to pin 4. Doing this will cause a sudden voltage drop on the ground wire, resulting in a large transient in the analog output voltage. Pin 7 must be grounded at the power supply.

The differential analog outputs are pin 5 (+) and pin 8 (-). They can be connected to a differential input voltmeter or an A/D converter in a system controller.

Note: Do not connect the (-) side of the analog output (pin 8) to the power supply ground (pin 4). This will cause half of the power supply current to flow through this wire. The voltage drop caused by this current will produce very large errors in the measured output voltage. The longer the cable, the worse the error.

The set point voltage (relay trip point) is available on pin 9. This voltage can be measured during a start-up check to be sure that it is adjusted correctly.

⚠ CAUTION

Do not short circuit the set point relay terminals to the analog output.

4.3.2 Inductive Loads and Arc Suppression

If the set point relay is used to switch inductive loads, e.g., solenoids, relays, transformers, etc., the arcing of the relay contacts might interfere with controller operation or reduce relay contact life. Therefore an arc suppression network, shown in figure 1, is recommended. The values of the capacitance C and the resistance R can be calculated by the equations,

$C = I^2/(1 \times 10^7)$ and $R = E/(I^x)$,
where,
C is in farads
R is in ohms
I is DC or AC_{peak} load current in amperes
E is DC or AC_{peak} source voltage in volts
$x = 1 + (50/E)$

Note that:

$R_{min} = 0.5$ W and $C_{min} = 1.0 \times 10^{-9}$ F.

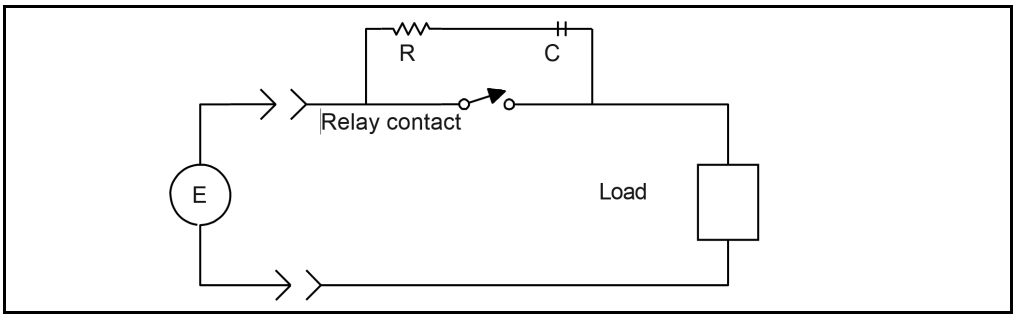

Figure 4-1: Relay Arc Suppression Network

4.3.3 Adjust the Set Point

The set point relay can be adjusted to actuate at a particular pressure, using the MODUCELL's built-in potentiometer.

To adjust the set point relay to a particular pressure, use the data in Figure 5-1 and Figure 5-2 to find the corresponding voltage. Connect a digital voltmeter to the tip jacks on the side of the MODUCELL shown in Figure 4-2. While monitoring the voltage at the tip jacks, adjust the potentiometer next to the tip jacks until the indicated voltage matches that of the graph (Figure 5-1) or Figure 5-2 for the relay activation pressure.

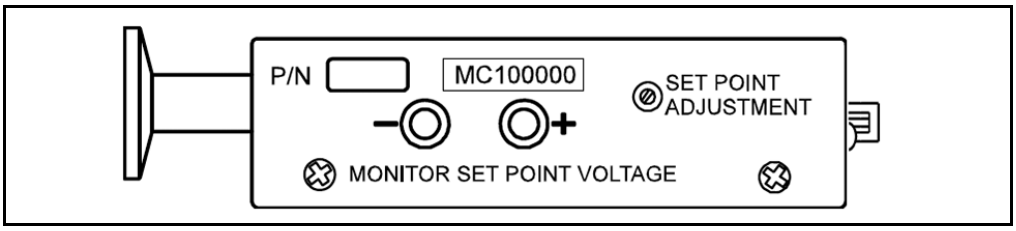

Figure 4-2: MODUCELL Set Point Adjustments

As the measured pressure falls below the set point value, the relay contacts labeled normally open will close, the contacts labeled normally closed will open, and the LED, shown in Figure 4- 3, will turn ON.

As the measured pressure rises above the set point value, the relay contacts labeled normally open will open, the contacts labeled normally closed will close, and the LED will turn OFF.

Power or sensor failure causes the relay to de-energize, creating the same condition as when the pressure is above the set point.

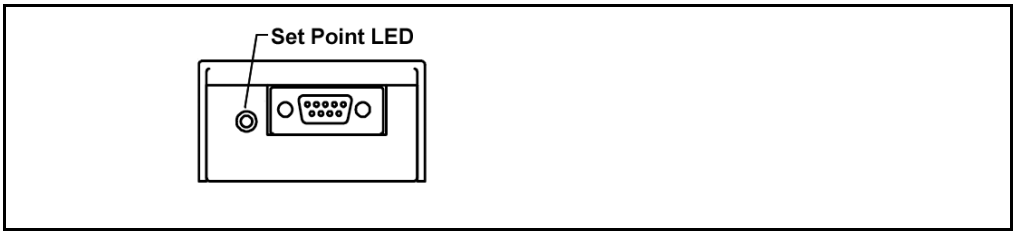

Figure 4-3: Set Point LED on the MODUCELL

Notes:

Chapter 5

Operation

5.1 Theory of Operation

The MODUCELL is a heat-loss manometer which infers the pressure of a gas by measuring thermal loss from a heated wire.

5.1.1 Theory of the Thermal Conductivity Gauge

The MODUCELL uses a wire as one arm of a balanced Wheatstone bridge. The bridge amplifier maintains the sensor wire at a constant temperature, and the amplifier output varies with the energy loss. A hot wire suspended from supports in a partial vacuum loses thermal energy in three ways: (1) thermal energy transport, which is pressure dependent, (2) end loss to the supports, and (3) radiation to surrounding surfaces.

Pirani and thermocouple gauges use the pressure-dependent thermal energy transport from a hot wire to measure pressure. Because the end loss and radiation are constant for a wire at constant temperature, they provide a masking signal which largely determines the low pressure limit of the gauge. Optimizing parameters for the wire length and diameter, thermal emissivity, thermal conductivity, and wire temperature can control these terms but not eliminate them. A Pirani gauge may be operated at constant current, constant voltage, or constant resistance (equivalent to constant temperature) at the sensor wire. The MODUCELL is operated at constant temperature to increase high pressure sensitivity. At constant current or voltage, the wire temperature at high pressure is much less than the temperature value at vacuum, reducing the high pressure sensitivity.

5.1.2 Bridge Amplifier

The bridge amplifier, op amp U3a, operates in a balanced bridge configuration to keep the sensor element temperature constant. Thus, the bridge driving voltage from the amplifier is related to the pressure in the gauge.

This bridge driving voltage is buffered by op amp U3b and is then fed to pin 9 of connector J1 and the comparator circuit.

5.1.3 Voltage Reference

Diode D3 and op amp U1a form a precision adjustable reference that is fed to the comparator circuit. Trimpot R27 can be adjusted to the proper voltage to trigger the set point relay at the desired pressure.

5.1.4 Comparator

Op amp U1b is an analog comparator circuit that compares the voltage from the buffer amplifier (pressure signal) to the reference voltage. When the pressure signal falls below the adjusted reference voltage, transistor Q2 is turned on, energizing the set point relay PCR1 and indicator LED1. Resistor R4 then provides a feedback path around op amp U1b, which increases the set point voltage by approximately 5 mV. This hysteresis provides stable operation even though some noise may be present on the buffered pressure signal.

5.1.5 Open Filament Detector

Op amp U2a acts as a comparator that monitors the filament side of the bridge. If the sensor filament breaks, the inverting input of the op amp falls below the 80 mV reference voltage from R29, turning on transistor Q1 which prevents transistor Q2 from turning on. Thus the set point relay will not energize, making the MODUCELL fail-safe.

5.2 Measuring Pressure

To measure gas pressure with the Series 325 MODUCELL, refer to Figure 5-1and Figure 5-2 which show the voltage output as a function of pressure for nitrogen, argon, or helium.

To use the graph or the table to read the pressure, measure the MODUCELL output voltage with a digital voltmeter or an A/D converter and computer combination.

When using the graph, remember that the pressure scale is logarithmic, and the voltage scale is linear. Equal increments of distance along the pressure scale do not correspond to equal pressure changes.

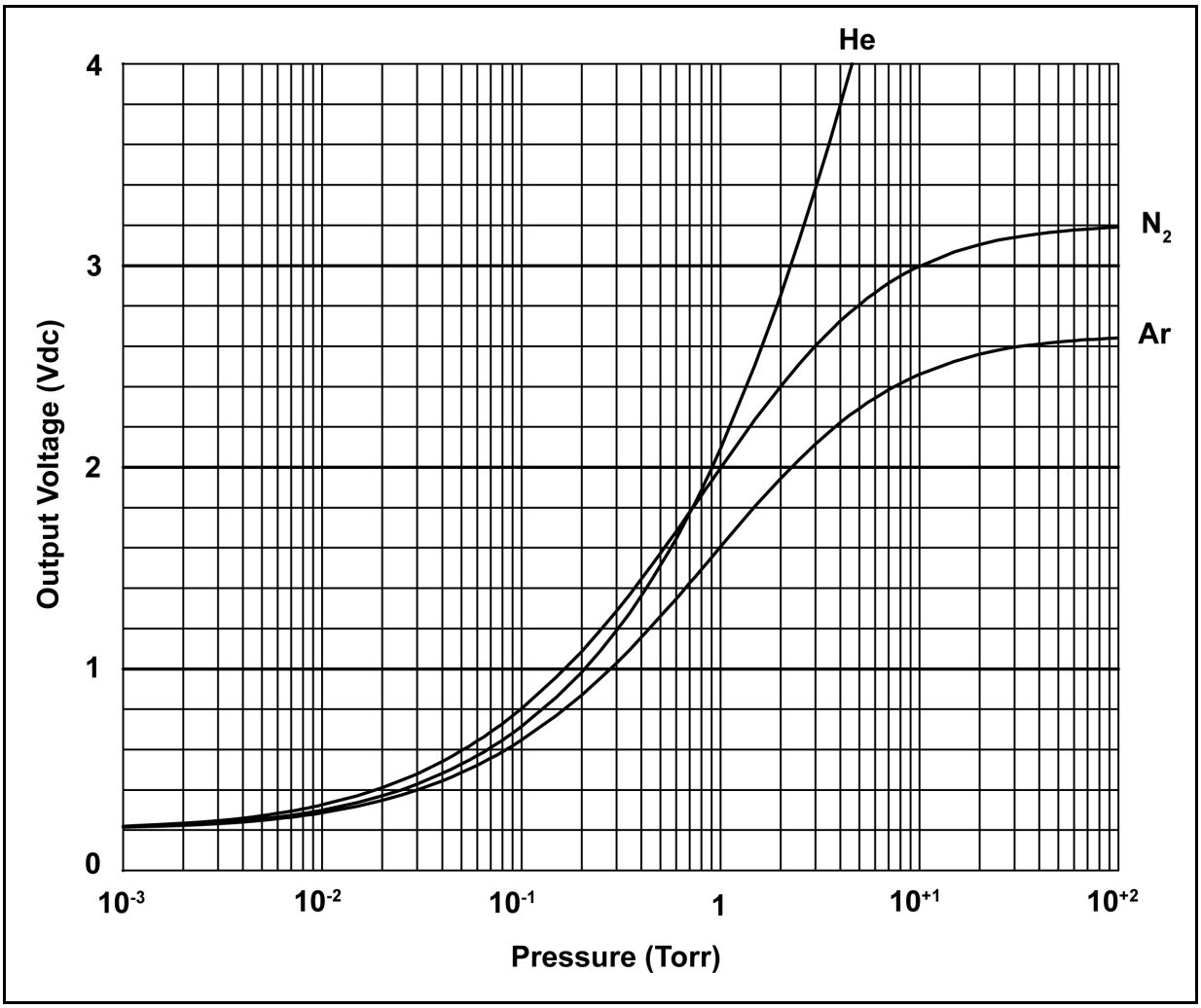

Figure 5-1: Analog Output Chart

MODUCELL Output Voltage vs. Pressure

Torr	Pascal	Voltage			Torr	Pascal	Voltage		
		Nitrogen	Argon	Helium			Nitrogen	Argon	Helium
0.0010	0.1330	0.2209	0.2158	0.2174	0.70	93.1	1.7744	1.4234	1.7686
0.0013	0.1663	0.2246	0.2181	0.2202	0.80	106	1.8564	1.4906	1.8820
0.0015	0.1995	0.2281	0.2204	0.2229	0.90	119	1.9288	1.5503	1.9875
0.0018	0.2328	0.2316	0.2226	0.2256	1.00	133	1.9935	1.6037	2.0863
0.0020	0.2660	0.2351	0.2248	0.2282	1.50	199	2.2364	1.8059	2.5072
0.0025	0.3325	0.2418	0.2292	0.2334	2.00	266	2.3975	1.9415	2.8456
0.0030	0.3990	0.2484	0.2335	0.2385	2.50	332	2.5130	2.0397	3.1305
0.0040	0.5320	0.2610	0.2419	0.2483	3.00	399	2.6002	2.1142	3.3768
0.0050	0.6650	0.2730	0.2499	0.2577	4.00	532	2.7233	2.2202	3.7876
0.0060	0.7980	0.2844	0.2577	0.2668	5.00	665	2.8064	2.2921	4.1213
0.0070	0.9310	0.2954	0.2652	0.2756	6.00	798	2.8663	2.3443	4.4007
0.0080	1.0640	0.3060	0.2726	0.2841	7.00	931	2.9115	2.3838	4.6395
0.0090	1.1970	0.3162	0.2797	0.2923	8.00	1064	2.9469	2.4149	4.8469
0.0100	1.3300	0.3260	0.2866	0.3003	9.00	1197	2.9754	2.4399	5.0292
0.0125	1.6625	0.3494	0.3032	0.3194	9.50	1263	2.9876	2.4507	5.1124
0.0150	1.9950	0.3713	0.3189	0.3374	10.0	1330	2.9988	2.4605	5.1910
0.0175	2.3275	0.3918	0.3338	0.3544	20.0	2660	3.1052	2.5602	6.1836
0.0200	2.6600	0.4112	0.3480	0.3706	30.0	3990	3.1415	2.5964	6.6695
0.0250	3.3250	0.4474	0.3748	0.4011	40.0	5320	3.1597	2.6127	6.9607
0.0300	3.9900	0.4806	0.3995	0.4293	50.0	6650	3.1707	2.6227	7.1553
0.0400	5.3200	0.5405	0.4446	0.4807	60.0	7980	3.1781	2.6295	7.2947
0.0500	6.6500	0.5936	0.4851	0.5269	70.0	9310	3.1834	2.6344	7.3995
0.0600	7.9800	0.6418	0.5220	0.5693	80.0	10640	3.1874	2.6380	7.4813
0.0700	9.3100	0.6861	0.5561	0.6086	90.0	11970	3.1906	2.6409	7.5469
0.0800	10.640	0.7271	0.5879	0.6454	100	13300	3.1931	2.6433	7.6007
0.0900	11.970	0.7656	0.6177	0.6802	500	66500	3.2165	2.6647	
0.1000	13.300	0.8017	0.6458	0.7132	750	99750	3.2217	2.6696	
0.1250	16.625	0.8841	0.7102	0.7894	1000	133,000	3.2261	2.6737	
0.1500	19.950	0.9573	0.7677	0.8585					
0.1750	23.275	1.0234	0.8198	0.9222					
0.2000	26.600	1.0839	0.8676	0.9815					
0.2500	33.300	1.1913	0.9530	1.0897					
0.30	39.9	1.2850	1.0277	1.1874					
0.40	53.2	1.4424	1.1540	1.3599					
0.50	66.5	1.5715	1.2583	1.5106					
0.60	79.8	1.6805	1.3468	1.6456					

Figure 5-2: Pressure vs Output Voltage

5.3 Gas Other than Air or Nitrogen

Before using the MODUCELL to measure pressure of gases other than air or nitrogen, read and understand this section. Contact the MKS Customer Service Department if additional information is needed.

The MODUCELL is designed to give voltage output according to the graph in Figure 5-1 or the table in Figure 5-2 for air or nitrogen. If the MODUCELL is used to read pressure of gases with poorer heat transfer properties than nitrogen, the true system pressure may be much higher than indicated. *This reading error could lead to a dangerous overpressure.*

A vacuum system which is backfilled from a pressurized gas source should have a safety device installed, such as a burst disc.See Section 2.5.

5.3.1 Nitrogen Equivalent Pressure and Voltage

The thermal loss from a heated sensor element is a function of the transporting gas (see page A.1, Theory of the Thermal Conductivity Gauge.) Since the MODUCELL is such a sensor, the voltage output depends upon the gas being measured.

Using the voltage and pressure data in Figure 5-1 or Figure 5-2, the MODUCELL output can be read as pressure using an A/D converter and computer. However, when used with gases other than nitrogen, the system would then read nitrogen equivalent pressure. When a Sensor is set up to read pressure for nitrogen but is used with the gases helium or argon, the data in the graph and table can be used to interpret the readings as true pressure.

5.3.2 Calibrating for Gases Not Shown in the Graph or Table

To determine the voltage/pressure relationship for gases which are not shown in the graph or table, you might need to calibrate the MODUCELL for this gas. This calibration requires a gas type independent gauge such as a capacitance manometer to act as the calibration standard. A curve like that of Figure 5-1can be generated.

5.3.3 Detecting Leaks in the System

The MODUCELL allows the Pirani's inherent gas type sensitivity to be used to detect leaks. A gas different from the system gas entering through a leak will change the thermal energy transfer. Maximum sensitivity is achieved by using a probe gas with a molecular weight much different than the system gas. Note from the E_{gas} equation, in Appendix C, that lighter gases provide increased energy transport while heavy gases reduce the thermal transfer. The MODUCELL is sensitive to leak probe gases either heavier or lighter than the system gas.

5.4 Using the MODUCELL with a Computer

The MODUCELL is designed to operate in highly automated systems, especially those that are controlled by digital computers. It is compatible with many different computers, interfaces, and software programs. This section only illustrates some possibilities for the MODUCELL's use with computers.

5.4.1 Analog-to-Digital Converter

To take full advantage of MODUCELL's capabilities, an A/D converter should be used with an input voltage span of 0 to 5 V. The A/D conversion rate should be at least 6 Hz (150 msec conversion time). A resolution of 12 bits is needed, corresponding to 1.22 mV per bit. The A/D converter must have a differential input.

5.4.2 Equations to Convert Voltage to Pressure

The following equations convert a MODUCELL voltage reading in volts to a pressure reading in Torr. The voltage must be within the domain of the equation or an incorrect pressure reading will result.

$$P = \left[\frac{a}{\frac{b}{V^2 - V_0^2} - 1} \right]^{1/c}$$

Nitrogen
The domain is $0.21 < V < 3.0$,
where $a = 1.6578$, $b = 10.45$, $c = 0.9954$, and $V_0 = 0.2057$.

Argon
The domain is $0.21 < V < 2.6$,
where $a = 1.81$, $b = 7.107$, $c = 0.997$, and $V_0 = 0.2063$.

Helium
The domain is $0.21 < V < 7.7$,
where $a = 14.394$, $b = 66.35$, $c = 0.992$, and $V_0 = 0.2059$.

$$P = \frac{(V-d) + \sqrt{(V-d)^2 - 4fg}}{2f}$$

Nitrogen
The domain is $V > 3.0$,
where $d = 3.2133$, $f = 1.501 \times 10^{-5}$, and $g = -2.168$.

Argon
The domain is $V > 2.6$,
where $d = 2.6617$, $f = 1.4 \times 10^{-5}$, and $g = -1.983$.

Figure 5-3: Equations to Convert Voltage to Pressure

5.5 Energy Transfer and Measurement Limits

5.5.1 The Energy Transfer Equation

The mechanism of energy transfer between the wire and the gas in a heat- loss manometer like the MODUCELL depends upon the pressure range. For pressures below 10-1 Torr, it is possible to derive an equation showing a linear relationship between the thermal energy loss to the gas E and the pressure P, where:

$$E_{gas} = \text{const. } a \frac{1}{4} \frac{(\gamma + 1)}{(\gamma - 1)} \left[\frac{(T_W - T_g)}{\sqrt{MT_g}} \right] P$$

Figure 5-4: Energy Transfer Equation

and for the particular gas,

a is the accommodation coefficient

g is the ratio of the specific heat at constant pressure to that at constant volume

M is the molecular weight of the gas

T_w is the temperature of the wire

T_g is the temperature of the gas

5.5.2 Measurement Limits

At pressures above 100 Torr for nitrogen, and widely differing values for other gases, the gas acts like an insulating layer. At still higher pressures, and in a large enclosure, convection contributes to energy transport.

The pressure range between 10^{-1} Torr and 100 Torr is a transition region, where the slope of the energy loss curve decreases continuously.

Note that the sum of end and radiation losses is about 10 times the gas transport at a pressure of 10^{-3} Torr. This determines the practical lower limit for thermal conductivity gauges. It is possible to measure lower pressures, but long term stability becomes a serious problem.

From the energy loss equation above, it is clear that the signal from a thermal conductivity gauge is not calculable from first principles but depends upon gas type. Because the energy transfer is dependent upon the rate of molecular collisions with the wire surface and upon the energy absorbed by each molecule, the gas transport is dependent upon the molecular weight, the internal degrees of vibrational freedom of the molecule, and the accommodation coefficient of the gas.

Chapter 6

Service & Maintenance

6.1 Customer Service / Technical Support

Some minor problems are readily corrected on site. If the product requires service, contact the MKS Technical Support Department at +1-833-986-1686. If the product must be returned to the factory for service, request a Return Material Authorization (RMA) from MKS. Do not return products without first obtaining an RMA. In some cases a hazardous materials disclosure form may be required. The MKS Customer Service Representative will advise you if the hazardous materials document is required.

When returning products to MKS, be sure to package the products to prevent shipping damage. Shipping damage on returned products as a result of inadequate packaging is the Buyer's responsibility.

For Customer Service / Technical Support:
MKS Global Headquarters
2 Tech Drive, Suite 201
Andover MA, 01810 USA
Phone: +1-833-986-1686
Email: insidesales@mksinst.com
Visit our website at: www.mksinst.com

6.2 Service Guidelines

Some minor difficulties are readily corrected in the field.

Because the product contains static-sensitive electronic parts, the following precautions must be followed when troubleshooting:

- Use a grounded, conductive work surface. Wear a high impedance ground strap for personnel protection.
- Use conductive or static dissipative envelopes to store or ship static sensitive devices or printed circuit boards.
- Do not operate the product with static sensitive devices or other components removed from the product.
- Do not handle static sensitive devices more than absolutely necessary, and only when wearing a ground strap.
- Do not use an ohmmeter for troubleshooting MOS circuits. Rely on voltage measurements.
- Use a grounded, electrostatic discharge safe soldering iron.

NOTE: This product is designed and tested to offer reasonably safe service provided it is installed, operated, and serviced in strict accordance with these safety instructions.

WARNING

High Voltage

High voltages present within the electronics enclosure are capable of causing injury or death. To avoid electric shock, wait 3 minutes after power is removed before touching any component within the electronics enclosure.

The service and repair information in this manual is for the use of Qualified Service Personnel. To avoid shock, do not perform any procedures in this manual or perform any servicing on this product unless you are qualified to do so.

CAUTION

Product Modifications

Do not substitute parts or modify the instrument.

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to a service facility designated by MKS for service and repair to ensure that safety features are maintained. Do not use this product if it has unauthorized modifications.

6.3 Damage Requiring Service

Disconnect this product from all power sources, and refer servicing to Qualified Service Personnel if any the following conditions exist:

- The gauge cable, power-supply cord, or plug is damaged.
- Liquid has been spilled onto, or objects have fallen into, the product.
- The product has been exposed to rain or water.
- The product does not operate normally even if you have followed the Operation Instructions. Adjust only those controls that are covered in the instruction manual. Improper adjustment of other controls may result in damage and require extensive work by a qualified technician to restore the product to its normal operation.
- The product has been dropped or the enclosure has been damaged.
- The product exhibits a distinct change in performance. This may indicate a need for service.

CAUTION

Replacement Parts

When replacement parts are required, be certain to use the replacement parts that are specified by MKS, or that have the same characteristics as the original parts. Unauthorized substitutions may result in fire, electric shock or other hazards.

CAUTION

Safety Check

Upon completion of any service or repairs to this product, ask the Qualified Service Person to perform safety checks to determine that the product is in safe operating order.

6.4 Troubleshooting

A troubleshooting chart for the MODUCELL follows. With this guide, you should be able to locate and remedy the cause of a fault. The problems listed here might occur on the system assembly level. Other faults are usually not serviceable by the user, and the faulty unit should be returned to MKS to be repaired.

Troubleshooting Chart

Symptom	Possible Cause	Remedy
Pressure readings are too high or low.	1. Sensor may be dirty or contaminated.	1. Test and replace if necessary.
No analog output voltage, and no set point voltage.	1. D-sub is disconnected. 2. Power supply turned OFF.	1. Connect D-sub. 2. Turn power ON.
No analog output voltage but set point voltage OK.	1. Broken or shorted filament. 2. Analog output shorted to ground.	1. Test and replace if necessary. 2. Check cable connection at the D-Sub connector.
Set point relay will not operate.	1. Set point voltage incorrectly set. 2. Broken or shorted filament. 3. Pin 7 of D-sub not connected to ground at power supply.	1. Check your set point. 2. Test and replace if necessary. 3. Check any external switches which may be controlling this line.

Figure 6-1: Troubleshooting Chart

CAUTION

Electrostatic Discharge

Use a grounded, conductive work surface. Wear a high impedance ground strap for personnel protection. Circuit boards and electronic components could be damaged by electrostatic discharge.

Use conductive or static dissipative envelopes to store or ship static sensitive devices or printed circuit boards.

Wear cleanroom gloves during all handling and cleaning procedures.

Use clean tools during all handling and cleaning procedures.

6.5 Cleaning the MODUCELL Case and Sensor Tube

The finish on the MODUCELL case is designed to resist many laboratory solvents, but it should be cleaned with water or alcohol.

The tube can be contaminated by roughing pump oils and other fluids condensing or decomposing on the heated filament. Such contamination changes the emissivity of the filament, and the different emissivity can cause the calibration to change, especially with low pressure.

However, it is not advisable to clean the sensor tube. Trying to clean the tube would very likely either deform or break the filament, and the deformed filament would then cause additional error from a shift in the sensor's output.

If the sensor tube has become contaminated, replace it following the procedure given on page 16.

6.5.1 Venting to Atmosphere

Sudden venting of the Sensor at its port can greatly stress the sensor physically and risk damaging its fine heated wire. To avoid damage to the Sensor, vent the vacuum system to atmosphere *before* removing it.

6.6 Testing the Sensor Tube

You can test the function of the MODUCELL® Sensor tube even if improper cleaning or rough handling has damaged the tube slightly and affected calibration.

1. Disconnect the lead from the D-sub connector.
2. Remove the four Phillips head screws from the MODUCELL® sides, and remove the cover.
3. Check the resistance from terminal F1 to F2, the wires leading to the Sensor tube (Figure 6-2). The resistance reading should be approximately 31 W. If the reading is approximately 340 W, the tube filament is broken or burned out.
4. Check the resistance from F1 to the tube body and from F2 to the tube body. With the D-sub disconnected, both readings should show a resistance of more than 20 MW. If the reading is lower, the tube may have an internal short which could be caused by either a damaged filament or some type of contamination on the inside of the tube. In either case, the defect requires that the Sensor tube be replaced.

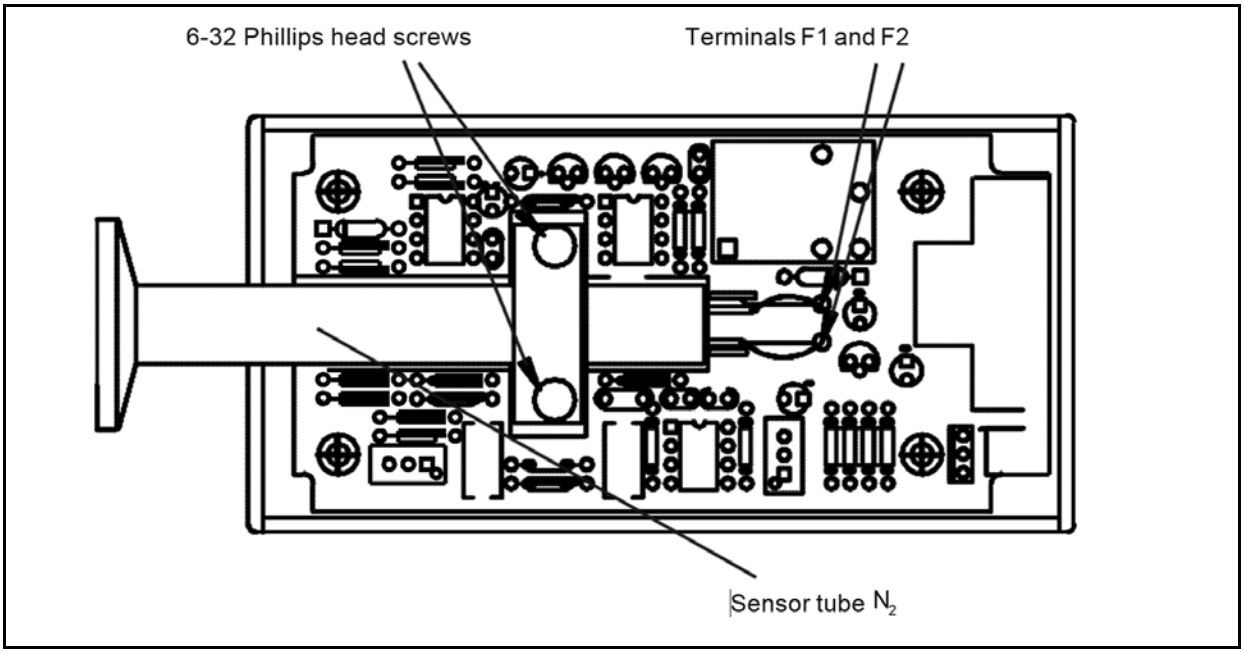

Figure 6-2: Checking Resistance

6.7 Replacing the Sensor Tube

6.7.1 Disassemble the MODUCELL

1. Remove the four Phillips head screws that secure the cover on the sides.
2. With a low wattage soldering iron, de-solder the two wires that connect the tube to terminals F1 and F2 (Figure 6-2).
3. Remove the two 6-32 Phillips head screws that hold the tube in place.
4. Remove the tube by lifting it straight up.

6.7.2 Reassemble the MODUCELL

1. Install a new tube. Place a small amount of silicone heat sink compound between the thermistor (Figure 6-5) and tube, and then place it in position.
   The tube mounting bracket is slightly off-center. Be sure the tube is oriented so its center line is offset toward the board (Figure 6-3).

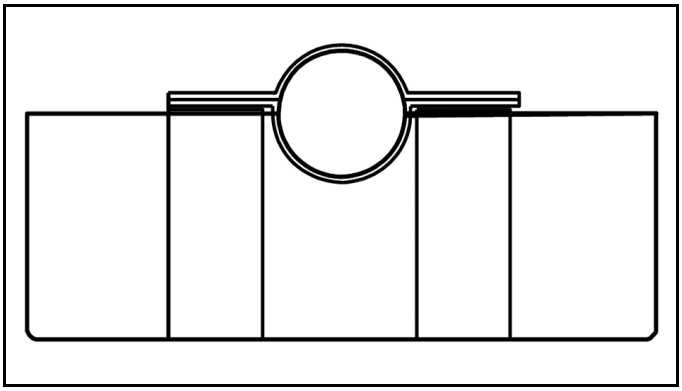

Figure 6-3: End of Tube View

2. Install the two 6-32 Phillips head screws to secure the tube in place.

3. Solder the two wires from the tube to F1 and F2. Clip off any excess wire. Be sure the clippings do not fall into the enclosure.

4. Calibrate the new Sensor tube following the four steps below.

- **a.** Position the MODUCELL so the tube axis is vertical.
- **b.** Operate the unit for at least 20 minutes at atmospheric pressure (nitrogen or air).
- **c.** Attach a voltmeter between pins 5 and 8 of the D-sub connector, (+) to pin 5 and (-) to pin 8.
- **d.** Adjust the potentiometer, R15, (Figure 6-5) for a voltage reading of 3.222 V.

5. Install the cover and the four Phillips head screws.

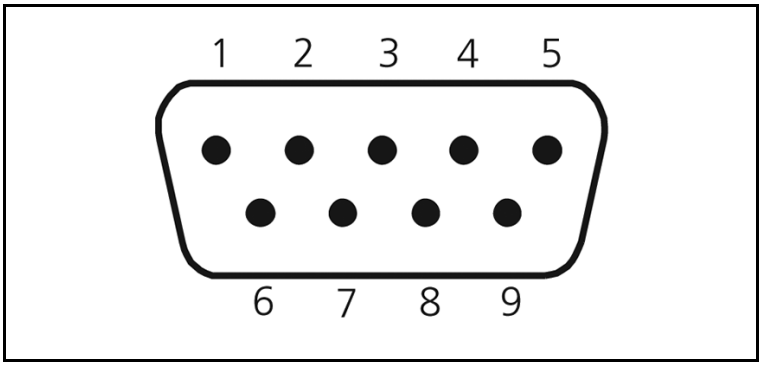

Figure 6-4: 9-Pin Connector

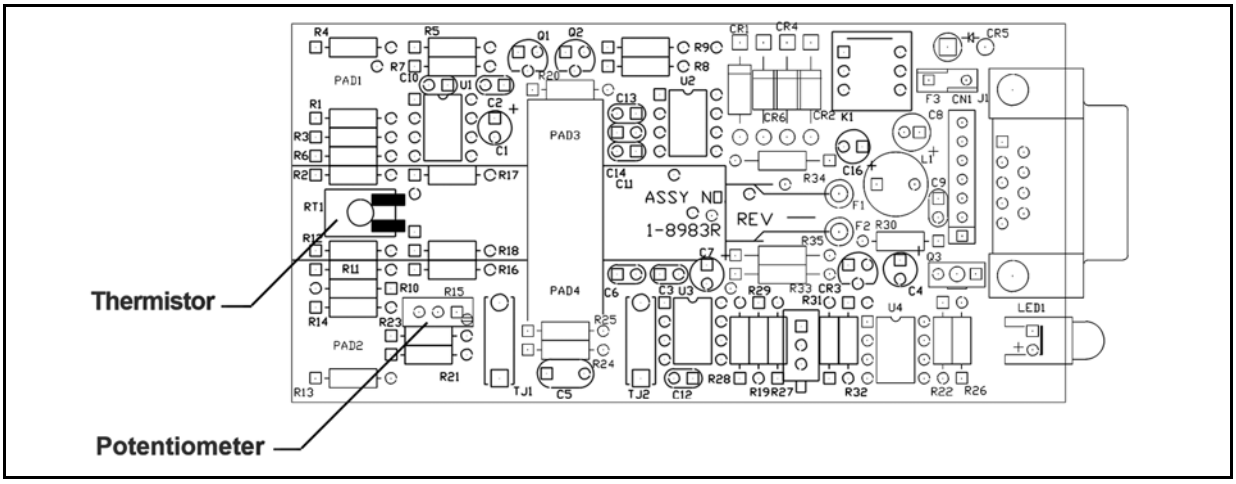

Figure 6-5: PC Board Thermistor and Potentiometer

Series 325

MODUCELL® Pirani Vacuum Sensor/Transducer

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Instruction Manual

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