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SensaVac® Series 421
Cold Cathode Ionization
Vacuum Gauge System
Instruction Manual

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2 SPECIFICATIONS

2.1 CONTROLLER:

Measurement Range	1.0×10^{-10} to 1.0×10^{-2} Torr 1.3×10^{-10} to 1.3×10^{-2} mbar 1.3×10^{-8} to 1.3 Pascal
Max Operating Voltage	4 KV
Max Tube Current	133 uA
Gas Calibration	Air/nitrogen
Units of Measure	Torr, Pascal, and mbar (selectable inside controller)
Reproducibility	5% of indicated pressure
Resolution	1% of indicated decade (above 10^{-9} Torr) 5% of indicated decade (below 10^{-9} Torr)
Operating Temperature	0 to 50° C
Operating Humidity	95% noncondensing maximum
Power Requirement	100, 120, 220, or 240 Vac, 50 or 60 Hz, 20 Watts (selectable inside the controller)
Process Set Points	Two nonvolatile, independently set, pressure dependent set points standard with relays, SPDT contacts, 2 Amps @ 230 Vac resistive load
Process Set Point Response	70 to 200 msec. dependent upon range
Process Set Point Range	2.0×10^{-10} to 9.5×10^{-3} Torr. 2.5×10^{-10} to 9.5×10^{-3} mbar 2.5×10^{-8} to 9.5×10^{-1} Pascal
Gauge Cable Connections	One sheath with both high voltage coax and ion current cables; High voltage coax cable uses SHV bayonet-type connectors on each end; Ion current is low leakage and low noise with threaded SMA type connectors at each end; Maximum length 500 feet
Analog Output	Voltage proportional to Log_{10} of pressure, 1 V per decade (0 - 8 V); 1 V offset (selectable inside controller)
Leak Test	Relative logarithmic bar graph and variable tate audio signal.
Display	Liquid crystal with 2 digit mantissa, 1½ digit exponent. 14 mm (0.55 in.) digit height ±30° viewing angle. Updated four times per second at 60 Hz line frequency, three times per second at 50 Hz. Leak test bar graph. Display indicators for leak test mode, diagnostics, unit of measure.
Controller weight	4.0 lbs. (1.8 Kg)
Front Panel	Functions selectable by rotary switch. Other operations controlled by two push buttons
Operating Functions	ON, LEAK TEST, Self TEST, Set Point 1 Adjust, Set Point 2 Adjust. HV supply externally deactivated by grounding a pin on the accessory connector (ON and LEAK TEST modes only)
Controller Service	Field repairable by replacing P.C. boards

2.2 TUBE

Configuration	Isolated collector inverted magnetron

Construction	Demountable, metal seal, cables connected via bayonet and threaded type coaxial connectors
Materials in Vacuum	Stainless steel, silver-copper brazing alloy, alumina ceramics, aluminum AL 6061, Elgiloy®, OFHC® copper
Operating Temperature	0 to 50° C
Bakeout Temperature	250° C with connectors removed, magnet attached. 125° C with connectors attached, magnet attached
Vacuum Connection	2 ¾" CF, NW 25 ISO-KF, NW 40 ISO-KF, VCR®-F, 1" OD tubulation
Tube weight	2.4 lbs. (1.1 Kg) with 2 ¾" CF flange
Tube Service	Field demountable, cleanable, and replaceable parts.

3 SAFETY WARNING

*** WARNING ***

THE HPS SENSAVAC® SERIES 421 CONTROLLER CONTAINS LETHAL VOLTAGES WITHIN THE ENCLOSURE. To avoid the danger of electric shock, the power line must be disconnected before opening the controller enclosure.

4 UNPACKING INSTRUCTIONS

A complete HPS SensaVac Series® 421 system contains the following components:

HPS SensaVac Series 421 Microcontroller
HPS SensaVac Series 421 gauge tube
Cold Cathode Gauge Cable
10 foot USA power cable
Panel mounting kit
Accessory connector kit
Instruction manual

If you ordered a complete system, please ensure that your shipment contains all of the above items. If any shortages are noted, please notify the Customer Service Department, HPS Division of MKS Instruments, Inc. in Boulder, Colorado, USA, or your nearest MKS/HPS sales office. If your equipment has been damaged in shipment, notify the carrier within 15 days of receipt. Hold all shipping materials and packing for claim verification.

5 TYPICAL APPLICATIONS

- measurement of high vacuum chamber base and process pressures
- control of high vacuum system and process sequencing by use of the set point controls
- sensing abnormal pressure situations and initiating appropriate security measures by use of the set point controls
- process control, including pressure control, using an automatic pressure control system
- measurement of the pressures of backfill gases
- leak testing
- use in fields such as:

electron beam welding
ion milling
vacuum evaporation coating
vacuum tube processing

vacuum metallization
vacuum furnaces
electron microscopy
analytical instruments
laser production
space simulation chambers
vacuum metallurgy
lithography
ion plating
ion implantation
high energy physics
sputtering

6 DESCRIPTION

6.1 The SensaVac® Gauges

The HPS SensaVac® Series 421 Cold Cathode Ionization Vacuum Gauge System is part of the MKS/HPS SensaVac® family of vacuum gauges for industrial and research use. The SensaVac® vacuum gauges cover the pressure range from atmosphere to 10^{-11} Torr. They include digital and analog Pirani gauges, thermocouple gauges, hot and cold cathode ionization gauges, and the unique MODUCELL® Pressure Sensor/Vacuum Switch. Features included in some of the units are simple to use controls with front panel access, exclusive leak detection mode with audio and bar graph, liquid crystal, LED, and analog meter displays, user selectable units of measure, adjustable process control set points, analog outputs, and operation on all common line voltages and frequencies. The SensaVac® gauge tubes are rugged and may be mountedin any position. They are interchangeable without user calibration.

6.2 Summary of Features

The SensaVac® Series 421 Cold Cathode Ionization High Vacuum Gauge System features include:

- wide pressure range 10^{-10} to 10^{-2} Torr
- operates in harsh and dirty environments
- demountable tube makes cleaning easy
- microprocessor based controller with all operating functions accessible from the front panel
- cold cathode ionization gauge has no filaments to burn out
- two standard nonvolatile set points provide fast system control
- user selectable units of Torr, mbar, or Pascal
- Liquid crystal display with large digits is easy to read
- inverted magnetron design increases range
- isolated collector makes sensor tube less susceptible to contamination
- leak test function has bar graph and audio

may be mounted in ¼ DIN cutout or used free standing

The SensaVac® Series 421 Cold Cathode Ionization Gauge controller is microprocessor based for versatility and added functions. Color coding relates switch position to the functions of the two push button switches making most of the operation of the controller self-evident.

The liquid crystal display (LCD) makes possible the presentation of more information than a typical luminescent display. It is visible in a wide range of lighting situations and over a wide viewing angle. Depending upon the function selected, it shows pressure in exponential notation, the units of measure in use, a 30 segment zero center bargraph for leak detection, status of the two set points, and diagnostic information. The display is updated four times per second when the controller is operated on 60 Hz power.

Two independently adjustable set points are standard. The set points are nonvolatile and remain unchanged after turn-off or power failure. They are set within their operating range by turning the rotary switch to the desired set point, 1 or 2, which displays the pressure value at which the respective set point is activated. The UP and DOWN push buttons are used to adjust this value. This provides an unambiguous and repeatable method of adjusting set points.

The controller provides an analog output signal accessible at a rear panel connector. The 0 to 8 Volt (1 Volt per decade) signal is proportional to the Log_{10} of pressure. To enable a computer to distinguish between vacuum with zero

output, and the case where the analog output is zero because the power is off or the unit is defective, a one volt offset can be selected if desired, using a DIP switch inside the controller. This makes the analog output at and below 1.0×10^{-10} Torr equal to one.

Every time the unit is turned on or switched to TEST, it performs a sequence of tests to verify correct operation. Certain malfunctions and controller faults are shown by an error code. The correct operation of all elements of the display is also tested.

The side panels are black anodized extruded aluminum. The rear panel, and top and bottom, are black anodized aluminum. With the molded, high-strength, black plastic front bezel, this gives an attractive package, which harmonizes with other equipment, and provides good shielding from outside electrical interference. The ¼ DIN enclosure is easy to mount in a panel cutout using the hardware provided. No tools are required for fastening in the cutout, and only rear access is necessary. Side clearance space is not required.

The gauge may be operated on cables up to 500 feet (150 meters) long without loss of accuracy or change of calibration.

On the rear of the control unit are a 9 pin D-sub, SHV, and SMA connectors. The D-sub connector is for the pressure output signal and process relays, while the SHV and SMA connect the high voltage and ion current signal to the tube, respectively.

6.3 Principles of the Cold Cathode Ionization Gauge

Cold cathode ionization gauges have a number of inherent advantages. Among these are the fact that they have no filaments to burn out, which makes them immune to inrushes of air and relatively insensitive to damage by vibration. Also there is no x-ray limit for lower pressure measurement as is found with hot cathode ionization gauges. No adjustments such as emission current or filament voltage are necessary. They are extremely rugged and can operate in harsh and dirty environments with little detrimental effect. Since there is no heating, and degassing is not required, there is little effect on the system. Properly designed sensor tubes can be cleaned and reused almost indefinitely. The control circuit is simple and quite reliable with only one current loop, as opposed to a hot cathode gauge which has three.

Penning developed the cold cathode ionization vacuum gauge in the 1930s to eliminate some of the limitations of the then prevalent hot cathode ionization gauge. His design used a wire anode loop at a potential of 2 to 10 KV with two grounded cathodes. A 1,000 to 2,000 Gauss magnet was placed around the tube.

The cold cathode magnetic discharge gauge sensor consists of a cathode and anode with a potential difference of several kilovolts. The electrodes are surrounded by a magnetic field, so arranged that the magnetic field is essentially perpendicular to the electric field. The crossed electric and magnetic fields cause the electrons to follow long spiral trajectories, which increases their likelihood of colliding with gas molecules, thereby providing a significant increase in ionization efficiency relative to a hot cathode gauge. In operation a near constant circulating electron current is trapped by the crossed fields. Collisions of electrons with residual gas molecules produce ions, which are collected by the cathode. The gauge current as a function of pressure obeys the relationship:

$$i_{(gauge)} = k P^n$$

where
k is a constant
P the pressure
n constant usually in the range of 1.00 to 1.15

This equation is valid for the pressure range from 10^{-8} Torr to an upper limit of about 10^{-3} Torr depending upon the series resistor used. Sensitivities of 1 to 10 Amps/Torr are not unusual.

Starting a cold cathode gauge depends upon some chance event such as field emission or a cosmic ray producing the first electron. This produces additional electron/ion pairs during its transit between the electrodes, and the discharge soon builds up to a stable value. Starting of the discharge normally requires a very short time at 10^{-6} Torr or above, a few minutes at 10^{-8} Torr, and longer times at lower pressures. An IgniTorr™ cold cathode starting device can significantly decrease starting times.

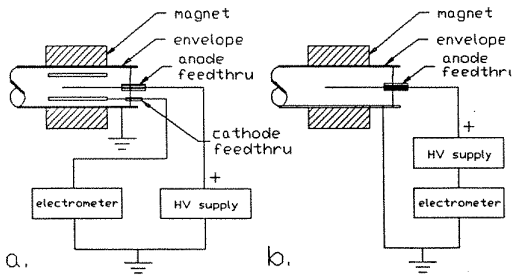
If the series resistor is small, e.g. one megohm, the current at high pressures becomes large and sputtering of the cathode can be a problem. Using a larger series resistor reduces the importance of sputtering, and causes the voltage

across the tube to be pressure dependent for the range of 10^{-4} to 10^{-2} Torr. This permits extending the range of the cold cathode to 10^{-2} Torr.

Because of the difficulty in maintaining the discharge at low pressures, gauges of the loop anode design do not work well below about 10^{-6} Torr. One way of reducing this problem is with a design which uses a cylindrical anode, cathode plates at each end, and a cylindrical magnet. During the 1950s, the inverted magnetron gauge was developed, which used auxiliary cathodes, and was able to measure pressures below 10^{-12} Torr.

Many electrode arrangements have been used in cold cathode gauges. Single feedthrough cold cathode gauges often suffer from spurious currents due to insulator leakage and field emission, which mask the small pressure dependent ionization currents. HPS' SensaVac® Series 421 gauge utilizes an inverted magnetron gauge tube designed to reduce these problems by using separate feedthroughs for the anode high voltage and the cathode current. This geometry uses a cylindrical cathode, a central wire anode, and external cylindrical magnet which provides an axial field. The cathode is insulated from the grounded metal housing.

The inverted magnetron geometry has a characteristic current vs. pressure characteristic which is more reproducible than the other arrangements, and also works well to low pressures without risk of the discharge goingout. This, combined with the patented voltage/current ratio method, gives the gauge a measuring range from 10^{-2} to 10^{-10} Torr. Even long periods of operation at relatively high pressures does not cause a change in calibration. The gauge has the additional advantage of short starting times at low pressures.



Cold Cathode Tube Designs

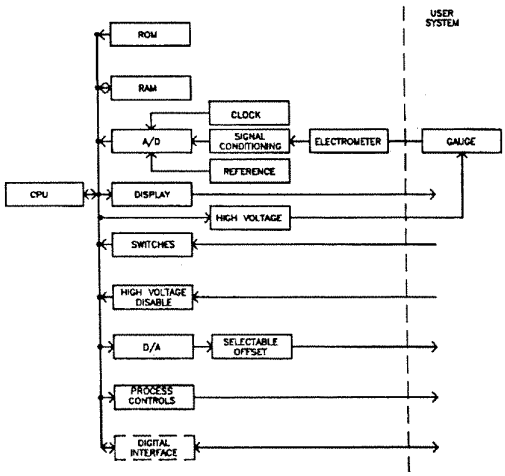
Figure 1

Figure 1 shows (a) the HPS design with separate feedthroughs for anode and cathode and (b) the usual arrangement of a cold cathode gauge tube with a single anode feedthrough. In the latter, any cable or feedthrough insulator leakage to ground is indistinguishable from gauge current, while the HPS design suffers no such shortcoming.

Gauge tubes are interchangeable without calibration. They contain only ultra high vacuum compatible materials and are rugged. The gauge tube is demountable for easy cleaning. Under appropriate conditions, they can be cleaned and reused indefinitely. To accommodate most applications, they are available with a variety of vacuum connections.

The HPS SensaVac® Series 421 uses the cold cathode gauge's inherent sensitivity to gas type to advantage in the leak detection mode. Allowing a gas different than the system gas to enter a system through a leak will change the amount of ionization. Maximum sensitivity is achieved by using a probe gas with an ionization probability which is much different than that of the system gas.

Sensitivity of the cold cathode gauge to gas leaks is also pressure dependent due to the complex nature of the ionization process and the electronic design of the Series 421. Leak test sensitivity can be affected by gauge location, pumping speed, chamber volume, and other system parameters. The HPS SensaVac® Series 421 is useful in locating leaks in high vacuum chambers and lines. The minimum detectable leak is a function of pressure range and can be as low as 10^{-8} Torr-liters/second under ideal conditions.



COLD CATHODE BLOCK DIAGRAM

Figure 2

7 CIRCUIT DESCRIPTION

This chapter is intended to give the reader an overview of the internal workings of the HPS SensaVac® Series 421 Microcontroller. This manual does not provide detail to allow component level troubleshooting of the instrument. Please refer to figure 2, the controller block diagram while reading this section.

The HPS SensaVac® Series 421 is a microprocessor based instrument that controls the cold cathode gauge tube and uses signals from the gauge to display pressure, operate the process control

relays, supply analog voltage vs. pressure outputs, and provide leak test capability.

7.1 CPU and Memory

The controller contains an eight bit Central Processing Unit (CPU) operating at a 5 MHz clock rate. It utilizes a bus architecture to permit control of many tasks with a minimum of interconnections, affording streamlined design and a high degree of operational flexibility and reliability. The CPU receives its operating instructions from Read Only Memory (ROM), an Integrated Circuit (IC) that is programmed at the factory. The CPU uses another type of memory, Random Access Memory (RAM), as temporary storage in performing computations. RAM within the SensaVac® Series 421 is equipped with a battery. This allows the RAM to retain the stored information even when power is removed. This allows the CPU to store calibration constants and set point information, avoiding the inconvenience of recalibrating and reentering set points each time the power is turned off. The battery is a 3 Volt lithium cell with an expected lifetime of ten years.

7.2 Electrometer, High Voltage Measurement, and A/D

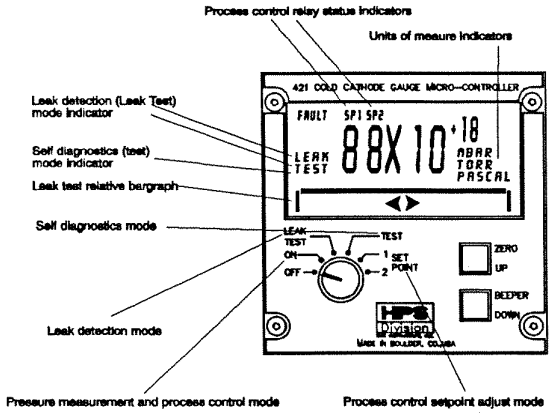
The CPU generates pressure information from the SensaVac® Series 421 gauge by measuring the collector current or the collector current and tube voltage, depending on pressure range. The collector current is converted to a voltage via an electrometer. These two voltages signals are alternately switched to the A/D converter through a high speed analog switch. The A/D converts the voltages into a set of digital words which the CPU then converts to pressure. For pressures below about 10^{-6} Torr, the CPU uses only the electrometer voltage to determine pressure. Above about 10^{-6} Torr, the CPU uses both the tube voltage and the electrometer voltage to calculate a ratio (tube voltage/electrometer voltage) to determine pressure. The conversion accuracy is dependent only upon the accuracy of the input signal and the stability of the independent reference diode. This reference has been selected to maximize initial accuracy while minimizing long term and temperature related drift. The A/D used in the HPS SensaVac® Series 421 utilizes a dual slope integrating conversion technique. This method minimizes the effects of external noise and unintended offsets on the signal by synchronizing the conversion with the period of the AC line voltage.

7.3 High Voltage Supply

The high voltage is generated from low voltage DC with a blocking oscillator type power converter which drives a six stage voltage multiplier. The output voltage is closed loop controlled to a stable voltage reference providing the accurate voltage required to perform the voltage/current ratio.

7.4 Display Driver and Display

The pressure, process control status, unit of measure, bar graph, error codes and test indicator are shown on the custom LCD display (Refer to figure 3). The information displayed is sent from the CPU in a serial data stream to the LCD driver once for every four A/D conversions. The driver chip stores the data in an internal RAM organized in an array of four backplanes by twenty four bits. This data is then used to drive the multiplexed display with the driver chip handling the refresh function.



Front Panel
Figure 3

7.5 Switches

The front panel switches are monitored by the CPU by polling the buffers which interface the switches to the data bus.

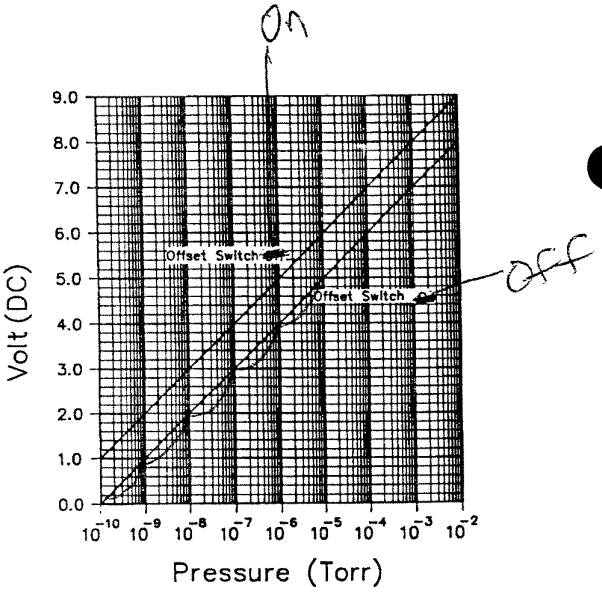
7.6 D/A

The SensaVac® Series 421 Microcontroller provides the user with a logarithmic voltage vs. pressure signal for use in recording or controlling the system pressure. Refer to figure 4, a graph of the logarithmic analog output. Since the signals from the gauge tube follow a nonlinear curve, the CPU processes the A/D output to produce the output signal. The processor then writes the digital equivalent to the digital to analog converter (D/A) which performs the conversion to an

analog signal. A follower amplifier scales the signal to one volt per decade of pressure. A one volt positive offset can be added to the logarithmic analog output by setting the appropriate switch within the controller, thus summing a constant voltage with the D/A output. This offset is useful in automated control systems to verify that the HPS SensaVac® Series 421 controller is operational.

7.7 Process Control Relays and Audio Signal

The process control relays and the audio signal are also controlled by the CPU via the data bus. Data sent to these devices is written to a digital latch which holds the information until overwritten. This data is written following every other A/D conversion providing a response time of approximately 134 milliseconds at 60 Hz line frequency. The output of the latch goes to a driver chip which switches the current to the corresponding relays or the audio signal. The relays used in the SensaVac® Series 421 controller provide the user with reliable switching for loads ranging from logic inputs to solenoids and relays.



Logarithmic Analog Output vs. Pressure
Figure 4

Figure 4

8 INSTALLATION

8.1 Gauge Location and Orientation

In selecting the location and orientation of the gauge, consideration should be given to sources of contamination which might affect the tube interior. As an example, mounting the gauge directly in line with an evaporation source or where particulate material will fall into the tube could affect operation. Mounting the gauge with the vacuum port facing downward is most desirable since it reduces particulates and liquids falling or flowing into the gauge. If particulates in the system are common, it is necessary to restrict these from entering the gauge using a screen or porous filter at the port. In such applications, the HPS centering ring with screen may be useful. The location of the gauge tube in the system should be chosen carefully so that the pressure measured is that of the chamber or manifold. In general, placing the gauge tube away from pumps and gas sources will result in the most representative pressure indication. The HPS SensaVac® Series 421 gauge tube was designed to allow operation in any position without compromising accuracy.

8.2 Vacuum Gauge Connection

The HPS SensaVac® Series 421 gauge tube is offered in four different vacuum connection configurations, NW 25 ISO-KF, NW 40 ISO-KF, 2¾" CF, VCR® and 1" tubulation for use with compression fittings. The KF connections require no special mounting precautions, except where a screening function is desired as mentioned previously. Care must be taken to provide a solid electrical connection between the gauge tubulation and the grounded vacuum system. This is required to effect the shielding of the tube element from external radiation sources.

8.3 Gauge Electrical Connection

CAUTION

THE CONTROLLER MUST BE TURNED OFF BEFORE CONNECTING OR REMOVING THE GAUGE CABLES FROM THE GAUGE TUBE OR CONTROLLER.

The SensaVac® Series 421 gauge tube is connected to the controller via coax cables with SHV and SMA connectors. These socket and connector combinations obviate the need for strain relief in most applications. In situations where stress could be applied to the cable, separate strain relief devices should be used to avoid damage to the gauge or the controller. Cables are available from the factory in standard lengths of 10, 25, 50 and 100 feet, and in custom lengths up to 500 feet.

The cable from the gauge tube are connected to the controller with SHV and SMA connectors labeled "HIGH VOLTAGE" and "ION CURRENT", respectively.

Some applications may require the use of special cables, such as where the connection must be routed through restrictive barriers or through conduit. Custom cables may be fabricated by the user for these situations using the information provided in figure 5. The maximum length of the gauge cable is 500 feet. Please note that SHV and SMA connectors should be used for all applications.

8.4 Controller Switch Settings

BEFORE THE CONTROLLER IS MOUNTED OR PLUGGED INTO A LINE POWER OUTLET, several switches must be set to accommodate the application. These switches select: line voltage, line frequency, unit of measure for the readout, and offset for the logarithmic voltage output. The line voltage switch is located in the AC power connector on the rear panel. The line frequency, unit of measure, and output offset switches are located within the controller on the main circuit board.

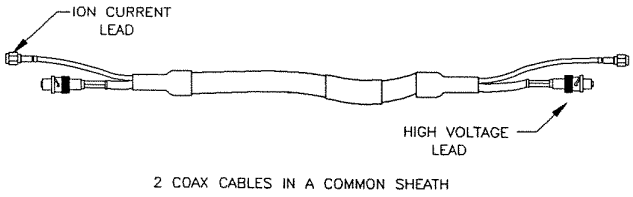


Figure 5

8.5 Line Voltage Selection and Power Fuse Replacement

The HPS 421 Microcontroller is shipped from the factory with line voltage set for 120 Volt, 60 Hz operation, unless specified otherwise by the purchaser. If the power source is different than this, change the voltage selector on the rear panel and/or the line frequency switch within the controller. The HPS SensaVac® Series 421 will operate using the following line voltages.

Nominal Voltage	Voltage Range	Fuse
100	90 to 100	3AG-.75 Amp, S.B.
120	110 to 130	3AG-.60 Amp, S.B.
220	210 to 230	3AG-.25 Amp, S.B.
240	230 to 250	3AG-.25 Amp, S.B.

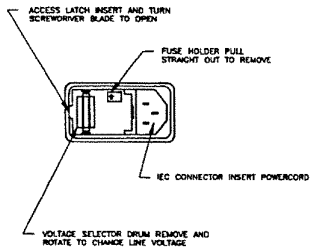


Figure 6

The AC line voltage must be either 50 or 60 Hz AC, ±2 Hz. Refer to paragraph 8.6 to set the line frequency switch. To change the voltage selector setting or fuse, refer to figure 6.

First, ***REMOVE THE POWER CORD FROM THE CONTROLLER.*** Insert a screwdriver blade under the tab to the left of the voltage display on the line input connector and twist the screwdriver. The connector will open exposing the voltage selector drum and the fuse holder. To change the line voltage selector, remove the selector drum and rotate it until the proper nominal line voltage faces you. Insert the drum into its proper location. To change the fuse, remove the fuse holder by pulling the holder (marked with a white arrow) straight out. Remove the fuse, install the correct value fuse (refer to the table above) and insert the fuse holder back into the proper location in the power connector. Close the door of the power connector.

8.6 Line Frequency, Unit of Measure, and Offset Selection

The HPS SensaVac® Series 421 controller can be configured for use at either 50 or 60 Hz line frequency to conform to power sources worldwide. The unit of measure of the displayed pressure can also be selected as Torr, millibar or Pascal. Additionally, the controller can be set to provide a one volt offset to the linearized analog output. This offset is useful in system applications to determine that the HPS SensaVac® Series 421 is powered on and functional.

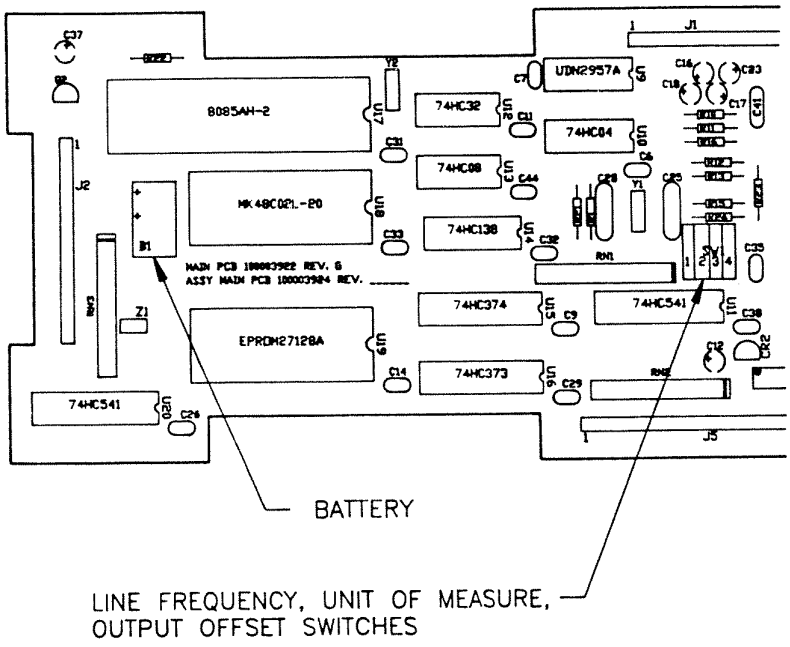
The controller is shipped from the factory set to operate at a line frequency of 60 Hertz, display pressure in Torr, and provide zero volts at a pressure of 1.0×10^{-10} Torr at the logarithmic analog output, unless specified otherwise by the

purchaser. If your application requires that any of these parameters be different than the factory setting, you must change the positions of the switches located within the controller on the main circuit board.

***** CAUTION *****

ALWAYS REMOVE THE POWER CABLE FROM THE CONTROLLER BEFORE PERFORMING ANY DISASSEMBLY. LETHAL VOLTAGES ARE PRESENT IN THE UNIT WHEN POWER IS APPLIED.

To access the selector switches for these functions, refer to figure 7 and the following instructions. Looking at the front of the controller, lay it on its right side and remove the two 5/64 drive flat head hexscrews from the front and the two Phillips head screws from the rear. Lift off the left side cover. Note the set of four switches on the main circuit board (the main board is the one at the top of the controller). These switches are labeled 1 through 4 and one position is labeled ON. As shipped from the factory switches 2, 3, and 4 are all in the OFF position, while switch 1 is in the ON position, unless specified otherwise by the purchaser. The definitions of these switches are:



Selector Switch and Battery Location

Figure 7

Switch #4	Switch #3	Unit Of Measure
OFF	OFF	Torr
OFF	ON	millibar
ON	OFF	Pascal
ON	ON	Illegal combination

Switch #1	ON	Analog output is 0 volt at 1.0 X 10^{-10} Torr
	OFF	Analog output is 1 volt at 1.0 X 10^{-10} Torr
Switch #2	ON	60 Hz line frequency
	OFF	50 Hz line frequency

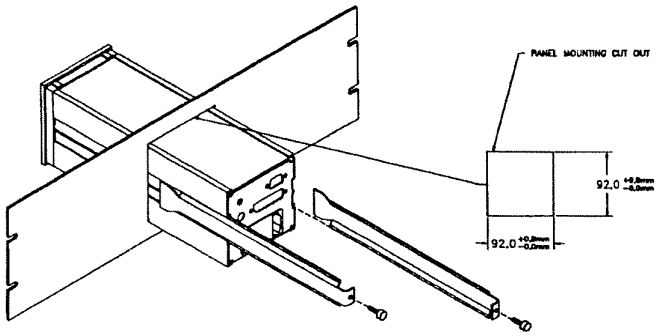
Wrong !

50 ON
60 OFF

8.7 Controller Mounting

The HPS 421 controller is designed to be either mounted in a panel or to stand alone. Adhesive backed rubber feet, which can be attached to the bottom of the unit, are provided for bench top use. To install the rubber feet, remove the protective paper from the mounting surface on each of the rubber feet. Place one of the rubber feet in each of the four corners of the perforated aluminum bottom cover. The controller is also provided with all required hardware for panel mounting into a standard ¼ DIN cutout in a panel up to 3⁄16" thick. A dimensioned illustration of the required cutout is figure 8. The controller requires a minimum of 12 inches of depth behind the panel face to accommodate the connectors

and some clearance for cables. To mount the controller into the panel, insert the instrument through the cutout from the front. Slide the panel mounting brackets into the slots on either side of the controller from the rear, and secure them in place using the thumbscrews provided. Figure 8 illustrates the panel mounting system.



Panel Mounting Cut Out and Panel Mounting Hardware

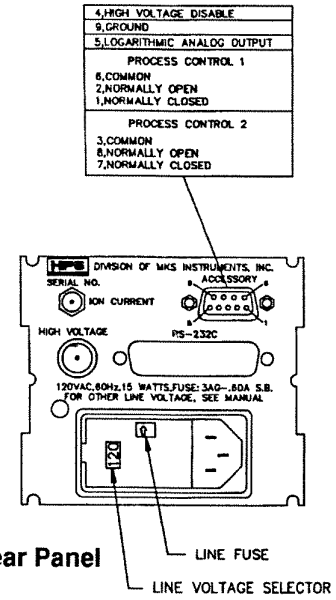
Figure 8

8.8 AC Power Cord

The HPS SensaVac® Series 421 is supplied with a standard powercord terminated in a female IEC connector at the instrument and in a plug for 120 Vac, 60 Hz at the supply end, unless otherwise specified by the purchaser. If the power source is different than this, refer to the above paragraphs concerning line voltage and line frequency selection. Power cords for standard power outlets are generally available at local electrical supply stores. A power cord with no male plug is available from HPS.

8.9 Accessory Connector

Some of the standard features of the HPS SensaVac® Series 421 controller are accessed through the "ACCESSORY" connector on the rear panel. These features are: process control relay contacts, logarithmic analog output, and high voltage disable. A connector kit to mate with the ACCESSORY connector is provided with the HPS SensaVac® Series 421 system. Figure 9 shows the pin-out of the ACCESSORY connector. Care should be taken to avoid inadvertently short circuiting process control relay terminations to the analog output or to the high voltage disable input. Note: If the process control relays are used to switch inductive loads, e.g. solenoids, relays, transformers, etc., arcing of the relaycontacts may interfere with controller operation and/or reduce relay contact life. Under these conditions an arc suppression network, shown schematically in figure 10, is recommended. The values of R and C can be calculated by the equations:



Rear Panel

Figure 9

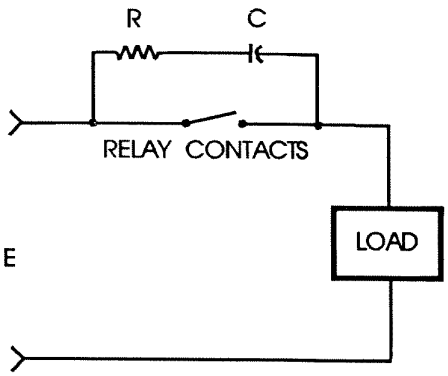
$$C = \frac{I^2}{1X10^7} \text{ and } R = \frac{E}{I^x}$$

where

C is in Farads
R is in Ohms
I is DC or AC_{peak} load current in Amps
E is DC or AC_{peak} source voltage in Volts

$$x = 1 + \frac{50}{E}$$

Note, however, that $R_{minimum} = 0.5$ Ohms and $C_{minimum} = 0.001$ microFarads. If both the analog output and the high voltage disable are being used, use separate ground wires for each and connect them only at the accessory connector as shown in figure 11. Otherwise, the analog voltage may be incorrect.



Process Control Realy Arc Suppression Network Schematic

Figure 10

9 OPERATION

The HPS SensaVac® Series 421 features operating modes for pressure measurement, leak detection, set point specification, and



Accessory Connector

Figure 11

controller self-diagnostics. The operating mode of the controller is selected by the front panel rotary switch and readout is via the LCD display. This chapter explains each operating mode and related accessory features.

*** CAUTION ***

BEFORE APPLYING POWER TO THE HPS SENSAVAC® SERIES 421 CONTROLLER, LINE VOLTAGE AND LINE FREQUENCY MUST BE SET TO MATCH THE USER'S POWER SOURCE.

9.1 ON Mode

Once the gauge and controller have been properly installed, the unit is ready for operation. ***THE GAUGE TUBE MUST BE CONNECTED TO THE CONTROLLER BEFORE THE UNIT IS TURNED ON.***

To measure pressure, set the rotary switch to the ON position. All pressures are displayed in scientific notation (two digit mantissa with a signed exponent) with resolution of one percent of a decade. Above and below range indications are shown as "HI" and "LO", respectively. When the high voltage is disabled with the accessory connector, "HI" is displayed. In the ON mode the LCD display provides the user with information in addition to the pressure and unit of measure. The SP1 and SP2 indicators advise the user that the associated set point relays are energized. The FAULT annunciator indicates that an error has been detected by the unit's self-diagnostic software. Along with the FAULT annunciator, an error code will be displayed in the pressure display to advise the operator of the malfunction. The setpoint relays are operational and the logarithmic analog output is valid in the ON mode.

9.2 LEAK TEST Mode

Leaks in vacuum systems are often difficult to locate and often require the use of mass spectrometer leak detectors and skilled operators. While the SensaVac® Series 421 is not intended to replace mass spectrometer leak detectors, it offers an ideal, inexpensive, and simple method for locating leaks in high vacuum systems. The leak test sensitivity depends on the pumping system and the location of the sensor with respect to the leak, as well as the difference in ionization probability between the probe gas and the system background gas.

Since the indicated pressure of a cold cathode gauge is dependent upon the type of gas being measured, introducing a probe gas through the leak into a steady state system will change the indication. The HPS SensaVac® Series 421 controller uses a zero centered bar graph display with increased sensitivity to indicate gas leaks in high vacuum systems.

This is activated when the control is switched to the leak test mode. The pressure indication remains visible and the set point relays operational. Audible indication of leak signals is user selectable from the front panel. While the leak test sensitivity varies with the pressure range, in the best case, it is as low as 10^{-8} Torr-liters/second.

To use the Leak Test function of the HPS Series 421, pump the system to its base pressure then set the rotary switch to the LEAK TEST position. Note that the pressure is indicated on the display and that a thirty segment, center zero bar graph is activated at the bottom of the display. An audio indicator emits beeps with a repetition rate proportional to the amplitude of the leak signal. The audio indicator can be silenced or reactivated by pressing the BEEPER pushbutton. A probe gas entering the gauge through a leak will cause segments to appear on one side of the center zero marker. The resolution of the bar graph is nonlinear with the first segment more sensitive and subsequent segments less sensitive. The

bar graph can be rezeroed to compensate for system pressure drift or residual search gas by pressing the ZERO pushbutton.

To locate a leak in the vacuum system, probe the suspect areas with a search gas which has an ionization probability different than the system gas. Helium, argon or Freon® gas are suitable for probing a system pumping air or nitrogen. The probing should be done slowly and methodically with a small amount ofsearch gas. Flooding the leak with gas or moving the gas source quickly past the leak can confuse the search, since system time lags may be significant. While probing the suspect components, observe the bar graph display. The maximum deflection of the graph from the zero point indicates that the search gas is nearest the leak location. Once the leak location is determined, repeat the test to confirm.

As with any leak testing, many factors can influence the sensitivity of the test. These factors include system volume, system pressure, search gas, type of vacuum pump, location of the gauge, location of the pump, and size of tubulation in the system. Reducing the search area by minimizing the chamber volume will increase the efficiency of the test. Placement of the gauge and the pump in relation to the leak can also be a major factor in optimizing the sensitivity of the leak detection. Placing the pump away from the suspected leaksource and placing the gauge between the leak and the pump will reduce the gauge response time allowing most accurate pinpointing of the leak location. Tubulation between the suspected leak and the gauge tube should be as short and wide as possible to minimize the time required for the search gas to reach the gauge. The HPS SensaVac® Series 421 LEAK TEST mode is sensitive to any gas either with a lower or higher ionization probability than the gas in the user's system, however for optimal sensitivity, the search gas should be selected to maximize the difference between its ionization probability and that of the system gas. Always use a search gas in small quantity to aid in pinpointing the leak. Gases with a lower ionization probability give controller response on the left side of the bar graph at low pressures. In general, the sensitivity of the leak test is greater for lower system pressures.

The type of vacuum pump used can also affect the accuracy of the leak test operation. For moderate size leaks, it is best to have the system pumped by a high vacuum pump such as a diffusion pump (ion pumps are not recommended). The LEAK TEST mode will work with pumping from a mechanical type pump, however, these pumps may cause cyclical variations in pressure with rotation of the vanes. This is displayed as a large background noise signal possibly masking the leak signal.

If the leak test method outlined above fails to indicate the location of a leak, consider that unexpected high pressures may be caused by a virtual leak, that is, outgassing of a system component.

The HPS SensaVac® Series 421 can be used effectively to locate outgassing parts or "virtual leaks" as well as true gas leaks using the "rate of pressure rise" method. With the gauge controller in the ON or LEAK TEST mode, the system is pumped down to a base pressure. Then the pump is valved off. The rise of the pressure indication over a time interval is then measured. By valving off or removing suspect components from the system and repeating this procedure, the leaking component is isolated.

9.3 TEST Mode

Selecting the TEST mode of the HPS SensaVac® Series 421 controller causes the instrument to perform two diagnostic functions which verify that the controller is working properly. One test is also performed when power is turned on. If the tests give correct results, the unit will indicate `0E` on the LCD display telling the operator that zero errors were found and that the unit is working correctly.

The first test verifies the Nonvolatile Random Access Memory (NVRAM in the controller). This memory device is used to store set point values and operational status of the controller. The CPU performs an error detection/correction procedure on the data in the NVRAM. If no uncorrectable errors are detected, the NVRAM is functioning correctly. A failure in this test is indicated by error code `E1` and indicates that some or all of the NV memory is corrupted. An `E1` error is not necessarily fatal to the instrument. To use the SensaVac® Series 421 controller when an `E1` error is shown, press the UP pushbutton. This acknowledges that the operator is aware that a problem exists. Once the error is acknowledged, the set point values should be inspected. If error `E1` is indicated each time the controller power is turned on or set to TEST mode, it is likely the 3 Volt lithium battery needs to be replaced.

The final test in the TEST mode is the display test. All segments of the display are on for three seconds during which time the user should verify that the display is fully functional by comparing it with figure 3. A failure in the display test indicates a problem with the display, the connector to the display or the display PC Board.

In TEST mode, the set point relays are not operational. They are in the deenergized (high pressure) state. The logarithmic analog output is set at the last value latched while in the ON or LEAK TEST modes.

9.4 Set Point 1 and 2 Modes

The SET PT. 1 and 2 modes are used to read and set the switching pressures of the two set point relays. The relay contacts are accessible through the rear panel ACCESSORY connector. To read the set point pressure, set the rotary switch to the appropriate SET PT position. The pressure displayed is the pressure at and below which the corresponding set point relay will be energized, i.e. the normally open (N.O.) terminal will be in contact with the common (C) terminal. The set point relays are operable only when the mode switch is in the ON or LEAK TEST positions. The status of each set point relay is indicated on the display; the SP1 or SP2 annunciator is on when the corresponding relay is energized. The set points may be programmed to values between:

2.0×10^{-10} and 9.5×10^{-3} Torr or
2.5×10^{-10} to 9.5×10^{-3} mbar or
2.5×10^{-8} to 9.5×10^{-1} Pascal

The set point pressures are easily changed by pressing the UP or DOWN pushbuttons, while the rotary switch is set to the corresponding setpoint.

1. To increment the set point pressure by one least significant digit, press and release the UP pushbutton.
2. To rapidly increment the set point pressure, press and hold the UP button.
3. To decrement the set point pressure by one least significant digit, press and release the DOWN pushbutton.
4. To rapidly decrement the set point pressure, press and hold the DOWN button.
5. To enable a newly programmed set point, turn the rotary switch to another position. The new pressure will be entered in nonvolatile memory and retained until reprogrammed. (Note: The newly programmed value will not be entered if power is removed from the controller before the switch is turned from the setpoint mode.)

Hysteresis - To prevent the relays from oscillating when the pressure passes through a set point pressure, the relays deenergize at a pressure above where they energize. In most cases the relays deenergize at a pressure which is five least significant digits above the set point value. This is equivalent to a hysteresis of 5 percent of the set point pressure decade. The exceptions to the general rule are setpoint values with mantissas of 9.6, 9.7, 9.8, and 9.9. If the set point is 9.6×10^N or 9.7×10^N, the relay will deenergize at a pressure of $1.0 \times 10^{(N+1)}$. If the setpoint is 9.8×10^N or 9.9×10^N, the relay will deenergize at a pressure of $1.1 \times 10^{(N+1)}$.

9.5 Accessory Connector

In addition to the set point relay contacts, the HPS SensaVac® Series 421 controller offers several standard inputs and outputs to enhance its usefulness in system and laboratory applications. These inputs and outputs, described below, are accessed through the ACCESSORY connector on the rear panel of the instrument. Refer to figure 9 for connection information. Available with the SensaVac® Series 421 system is a connector kit for mating with the ACCESSORY connector.

9.6 High Voltage Disable

Because large amounts of sputtering can take place inside the gauge tube at high pressures, it is desirable to have the high voltage disabled at pressures above 10^{-2} Torr. This can be done by connecting pin 4 to pin 9 of the accessory connector with an external manual switch or a process control relay from a gauge that operates between atmosphere and 10^{-2} Torr, such as HPS SensaVac® Series 315 or 917 Pirani gauge controllers or Series 325 MODUCELL® Pressure Sensor/Vacuum Switch.

9.7 Logarithmic Analog Output

The logarithmic analog output provides the user with a one volt per decade logarithmic analog signal which is useful for data recording as well as for input to an automatic pressure controller. A graph showing voltage versus pressure for the logarithmic analog output is figure 4. The logarithmic analog output is valid only when the controller is in the ON and LEAK TEST Modes. In other modes of operation, the output is held at the last value latched in the ON mode. The

logarithmic analog output is updated every 16.7 milliseconds at 60 Hertz line frequency or every 20 milliseconds at 50 Hertz. As delivered from the factory, the logarithmic analog output gives an output of zero volts at 1.0×10^{-10} Torr indication. The user can offset the output by +1.0 volt by setting an internal switch, so that at and below pressures of 1.0×10^{-10} Torr, the output is +1.0 Volt. This feature may be useful to some system users who need to recognize when the SensaVac® Series 421 controller has no power. The pressure may be determined from the output voltage by the equation:

$P(\text{Torr}) = 1 \times 10^{-10} \times 10^{Vo}$ (1.0 Volt offset OFF)

$P(\text{Torr}) = 1 \times 10^{-10} \times 10^{Vo-1}$ (1.0 Volt offset ON)

where P is the pressure in Torr and Vo is the output voltage.

10 USE WITH GASES OTHER THAN AIR/NITROGEN

In a cold cathode ionization gauge the degree of ionization, hence the pressure indication, is dependent upon the gas type. The SensaVac® Series 421 is calibrated to give direct pressure readout for air or nitrogen. For gases other than air or nitrogen, the SensaVac® Series 421 will display a pressure which corresponds to the equivalent degree of ionization from the sensor by nitrogen. This is the "nitrogen equivalent" pressure of the gas. The nitrogen equivalent pressure may be higher or lower than the true gas pressure depending upon the ionization characteristics of the gas at that pressure. Air calibration is indistinguishable from nitrogen. To determine the nitrogen equivalent of gases, it is necessary calibrate the Series 421 with the gas to be measured. This calibration requires a gas independent gauge such as a capacitance manometer or spinning rotor gauge to act as the calibration standard. The fact that the calibration of a cold cathode ionization gauge is dependent upon the gas is both an advantage and a disadvantage. The dependence makes it possible to use the cold cathode gauge as a leak detector. On the other hand, the pressure indications of a cold cathode gauge change with the gas by up to a factor of five or more. Note that the HPS SensaVac® Series 421 controller cannot be recalibrated to directly indicate pressures of gases other than air or nitrogen. Also calibration factors, or relative sensitivity factors, for cold cathode gauges are not the same as those for hot cathode gauges.

11 CONTROLLER AND GAUGE TUBE MAINTENANCE

11.1 Controller Service

The HPS SensaVac® Series 421 controller is designed to be maintenance free under normal operation. Should a problem occur, this chapter provides information which may be used to localize the cause to one of the circuit boards and to replace the faulty board. Due to the complex nature of a microprocessor based instrument, component level troubleshooting of the circuitry is impractical without special test equipment and software. For this reason, HPS offers a PC Board exchange service for the customer who wishes to repair the instrument by removing and installing boards. Factory repair service is also available.

11.2 Cleaning the Front Panel

The front panel of the HPS SensaVac® Series 421 controller is designed to be resistant to most laboratory solvents. The front panel can be cleaned with water, alcohol, trichloroethylene or Freon®. ***DO NOT USE ACETONE ON THE FRONT PANEL.***

11.3 TEST Mode

The HPS 421 controller contains several built in diagnostic functions. These are exercised at power up and when the TEST mode is selected.

11.4 User Troubleshooting

This section lists symptoms and possible causes, in order of likelihood. Problems which fall outside the scope of this troubleshooting guide are generally not serviceable by the user and the faulty unit should be returned to the factory or a MKS/HPS Service Center for repair.

Symptom	Possible Cause
Display does not light	1. Controller is not plugged into proper power source (Paragraph 8.5) 2. Mode selector switch is in OFF position (Paragraph 9.1) 3. Power fuse **F1** is blown (Paragraph 8.5)
E1 error is displayed	1. RAM memory is corrupted. Push up button to clear. Reset setpoints. (Paragraph 9.4) 2. If error E1 is indicted each time the controller power is turned on or set to TEST mode, it is likely the 3 Volt lithium battery needs to be replaced (Paragraph 11.11)
LO pressure or alternates between LO and 10^{-10}	1. Pressure is out of range 2. Discharge not started (Paragraph 6.3) 3. Gauge cables disconnected (Paragraph 8.3)
Incorrectly reading low and fluctuates	1. Gauge tube dirty (Paragraph 11.14)
HI pressure	1. Pressure is out of range

11.5 Unit Disassembly

The HPS 421 controller has been designed for easy assembly and disassembly to allow the user to service his instrument to the PC Board level. To remove or install a circuit board follow the appropriate step by step procedure below. Refer to figure 12 for an illustration of the disassembled unit.

***** CAUTION *****

ALWAYS REMOVE THE POWER CABLE FROM THE CONTROLLER BEFORE PERFORMING ANY DISASSEMBLY. LETHAL VOLTAGES ARE PRESENT IN THE UNIT WHEN POWER IS APPLIED.

***** CAUTION *****

Static sensitive parts are used on the circuit boards of the cold cathode Microcontroller. In handling these boards or any of the components, ground yourself to earth potential. Do not place the circuit boards or components on an insulating surface. Violation of these simple rules could cause component damage.

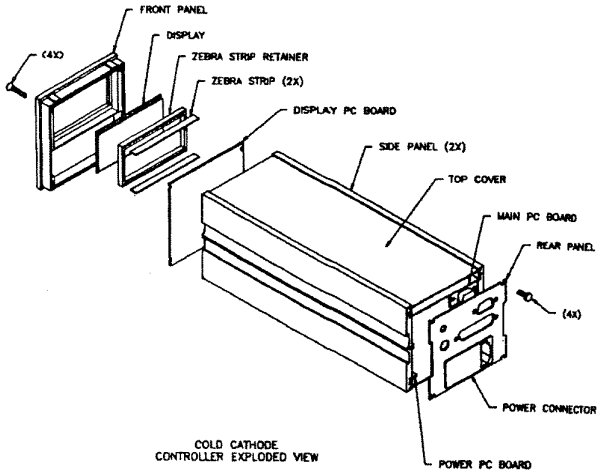


Figure 12

11.6 Removing the Main and Power PC Boards

1. Remove the power cable from the controller.
2. Unscrew the 3/16 inch drive hex standoffs which hold the D-sub connector to the rear panel.
3. Remove the four Phillips head cap screws (one in each corner) from the rear panel.
4. Remove the top and bottom covers of the controller by sliding them out through the rear of the controller.
5. Remove the push-on connectors from the back of the power line connector. Note that each wire is labeled with the letter designator of the terminal to which it is connected.
6. Unsolder the small coaxial cable from the ion current bulkhead SMA connector on the rear panel.

7. Unsolder the high voltage lead wire from the SHV bulkhead connector on the rear panel.
8. Remove the 1/4" drive nut from the mounting stud on the rear panel and remove the ground wire connected to the power supply board.
9. Slide the main and power supply PC Boards out of the case together.
10. The main and power supply boards can now be separated by unplugging the connecting ribbon cable.

11.7 Installing the Main and Power PC Boards

1. After connecting together with the ribbon cable, fold the main and power supply PC Boards together so that the components face the center of the case. Slide the boards into the case together using the slots just inside of the cover slots. Be certain to fully seat the connector between the main board and the display board.
2. Connect the labeled cables from the transformer and the power switch to the power connector. The wires are labeled with the letter designators of their respective tabs. Refer to figure 13 for an illustration of the terminals of the power connector.
3. Solder the center conductor of the small coax cable from the main board to the SMA bulk head connector on the rear panel.

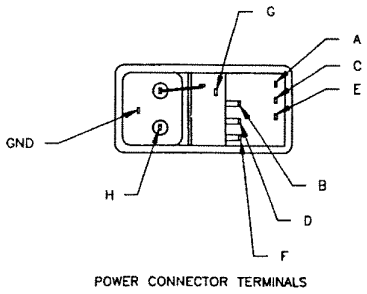


Figure 13

4. Solder the high voltage lead wire from the power supply board to the SHV bulkhead connector on the rear panel. Be sure to replace the insulating tubing over the back of the SHV connector.
5. Slide the top and bottom covers into the outermost slots of the side panels.
6. Install the rear panel and secure it to the side panels using the four Phillips head cap screws.
7. Secure the D-sub connectors to the rear panel using the 3/16 inch drive hex standoffs and #4 washers.

11.8 Removing the Display PC Board

1. Remove the power cable from the controller.
2. Unscrew the 3/16 inch drive hex standoffs which hold the D-sub connectors to the rear panel.
3. Remove the four Phillips head cap screws (one in each corner) from the rear panel.
4. Remove the push-on connectors from the back of the power line connector. Note that each wire is labeled with the letter designator of the terminal to which it is connected.
5. Remove the front panel, display, and display PC Board from the case by removing the four 5/64 inch drive flat head cap screws from the front panel.
6. Hold the front panel assembly together with your hand. Remove the knob from the rotary switch by prying off the cap using a small flat blade screwdriver, then loosening the revealed Phillips/slotted drive screw. It is not necessary to remove the screw completely.
7. Place the front panel assembly face down on the table and lift the display PC Board out of the panel. The display can be removed from the front panel by taking out the "zebra strip" connector with its retainer, then the LCD display.

11.9 Installing the Display PC Board

1. Into the rear of the front panel insert the display, the "zebra strip" retainer, and then the "zebra strips" into the slots of the retainer. Be certain that the display is oriented correctly with the silvered side to the rear and the bar graph near the bottom.
2. Insert the display PC Board into the rear of the front panel. Fasten the side panels to the front panel with the four 5/64 inch drive flat head cap screws through the front. The display board will be sandwiched between the front panel and the side panels.

3. Install the rotary switch knob by putting it on the shaft allowing clearance to the front panel, then tightening the retaining screw with the knob indicator in the correct position. Press on the cap.
4. Connect the labeled wires from the power switch to the power connector. The connectors are labeled with the letter designators of their respective tabs. Refer to figure 13 for an illustration of the rear of the power connector.
5. Install the rear panel and secure it to the side panels using the four Phillips head screws.
6. Secure the D-sub connectors to the rear panel using the 3⁄16 inch drive hex standoffs and #4 washers.

11.10 Replacing the Power Connector

The HPS SensaVac® Series 421 controller uses a power connector with integral line filter, voltage selector, and fuse holder. To replace the power connector follow this step by step procedure:

1. Remove the power cable from the controller.
2. Unscrew the 3⁄16 inch drive hex standoffs which hold the D-sub connector to the rear panel.
3. Remove the four Phillips head screws (one in each corner) from the rear panel.
4. Remove the push-on connectors from the back of the power connector. Note that each wire is labeled with the letter designator of the terminal to which it is connected.
5. Remove the power connector from the rear panel by releasing the four snap-in tabs one at a time using a small slotted screwdriver.
6. Press the new power connector into the rear panel, making certain that it snaps securely in place.
7. Connect the labeled cables from the transformer and the power switch to the power connector. The wires are labeled with the letter designators of their respective tabs. Refer to figure 13 for an illustration of the terminals of the power connector.
8. Install the rear panel and secure it to the side panels using the four Phillips head screws.
9. Secure the D-sub connector to the rear panel using the 3⁄16 inch drive hex standoffs and #4 washers.

11.11 Battery Replacement

To replace the battery, lay the unit on its left side, as seen from the front, and remove the two 5/64 drive hex flat head screws from the front and the two Phillips head screws from the rear. Lift off the right side panel and lift out the perforated top panel. The main printed circuit board is located at the top of the controller. The battery (labeled **B1** on the circuit board) is located near the front of the main board. See figure 7. The battery should be replaced with a vertical P.C. mount 3 Volt lithium battery. These can be obtained from HPS or through many electronics components distributors. When soldering the new battery onto the circuit board, be careful not to overheat the battery or reduced battery life may result. Reassemble in the reverse order.

11.12 Gauge Tube Testing

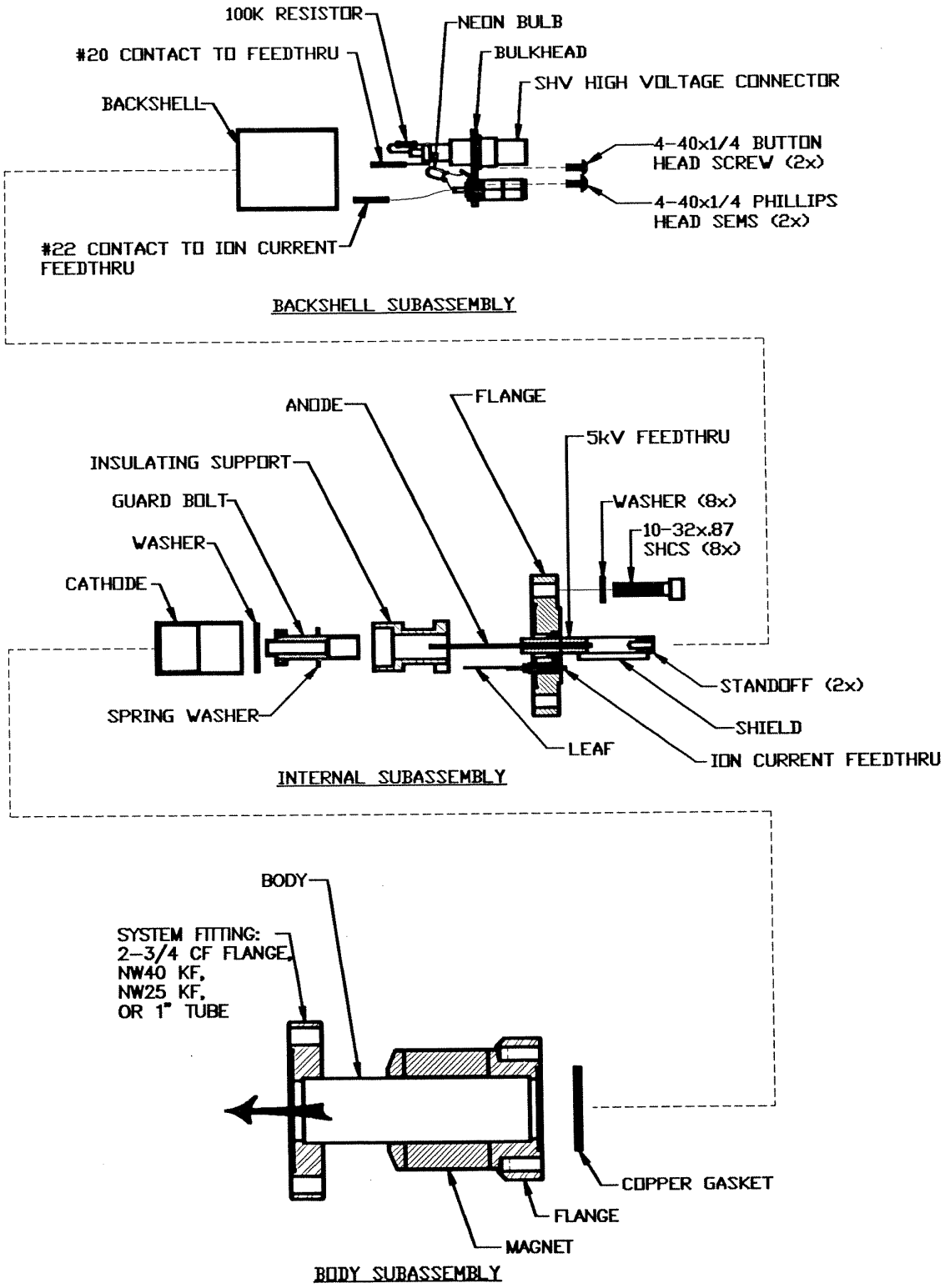
The HPS 421 cold cathode gauge tube contains the anode and cathode (collector) electrodes. The gauge can be easily tested using an ohmmeter. There should be no shorts between the electrodes or to ground.

11.13 Gauge Tube Disassembly

The gauge is easily broken down into three subassemblies. These are shown in figure 14 as the backshell subassembly, internal subassembly, and the body subassembly. Only the internal and body subassemblies are exposed to system vacuum.

To disassemble, first remove the backshell subassembly as follows:

1. Remove two 4-40 x 1⁄4 Phillips head SEMS screws and slide the backshell off the gauge.
2. Remove two 4-40 x 1⁄4 button head screws.
3. Pull the #22 contact off of the ion current feedthrough using standard needle nose pliers.



COLD CATHODE GAUGE TUBE EXPLODED VIEW

Figure 14

4. Again, using needle nose pliers, pull the #20 contact off of the 5kV feedthrough taking the entire bulkhead and connectors with it. There is no need to remove the SHV and SMA connectors from the bulkhead. This completes the normal extent of disassembly required of the backshell subassembly.

   The internal parts are now ready for disassembly.

5. Remove eight 10-32 x .87 socket head cap screws and pull the back flange free. Note that these screws are silver plated for lubricity and should be used only once. However, they can be relubricated with a dry lubricant such as molybdenum disulfide. We recommend that new silver plated replacement screws be used. The copper gasket should be replaced and not reused.

   The cathode and anode assemblies are attached to the flange. Here the disassembly generally proceeds from left to right with respect to figure 14.

6. Remove the cathode by releasing the two integral spring loaded ears hooked over the shoulder of the ceramic insulating support. This is done by gently pulling up on the ear until it just clears the outer diameter of the ceramic.

7. Slide the cathode and washer off the ceramic. Note the position of the small Elgiloy® leaf used to connect the ion current feedthrough to the cathode. Rotational position of the cathode with respect to the leaf is not critical, but some care should be taken not to bend the leaf.

8. The ceramic insulating support is captured by the guard bolt. Remove with a spanner wrench (available from HPS) and unscrew the guard bolt from the flange. Note the presence of the small curved spring washer located under the head of the guard bolt. The spring washer holds the insulating support tight, preloads the guard bolt to resist unscrewing due to possible system vibration, and provides compliance allowing for differential thermal expansion during bakeout.

10.14 Gauge Tube Cleaning

The extent and type of cleaning will vary depending upon your particular system and process requirements. Note that the anode is not removable as it is integral with the welded 5kV high voltage feedthrough and requires care not to bend. Make sure that no cleaning solvents or acids remain in the weld crevices of the feedthroughs. Their presence may corrode the gauge over time, as well as be a source of outgassing later. The body subassembly is ready for cleaning as is and requires no further disassembly. The internal parts are now ready for cleaning.

A Freon® vapor degreasing is sufficient for many applications. However, if the gauge has been exposed to a "dirty" or corrosive atmosphere, the following cleaning procedure can be used. The aluminum parts, i.e. cathode, washer, and guard bolt can be cleaned using a 5% to 20% sodium hydroxide solution at room temperature for one minute, followed by deionized water rinse, 50 - 70% nitric acid dip, also at room temperature, for approximately 5 minutes to remove smut, and finally several deionized water rinses. The anode can be cleaned using 50 - 70% nitric acid, preferably dipping only the anode and not the entire flange in the acid. Then rinse thoroughly in deionized water.

Only the body internal diameter and the flange faces are exposed to vacuum. Again, the choice and extent of cleaning will depend upon the particular application.

11.15 Gauge Tube Assembly

To reassemble, just reverse the order used during disassembly. Especially note the following tightening procedure of the guard bolt. The bolt has a 3/8-40 thread which is delicate. The bolt should be tightened to compress the spring washer about 80%. Do not over tighten as this will remove all compliance from the spring washer and possibly damage the aluminum 3/8-40 thread.

It is important to verify that the anode is well centered within the bore of the guard bolt. If it is off center, just bend it back into position and continue with the assembly.

11.16 Gauge Tube Bakeout

The gauge can be prepared for a 125° C bakeout simply by removing the high voltage and ion current cables.

A higher, 250° C temperature bakeout can also be done but first requires the removal of the backshell subassembly. Refer to figure 14.

1. Remove two 4-40 x ¼ Phillips head SEMS screws and slide the backshell off the gauge.
2. Remove two 4-40 x ¼ button head screws.
3. Pull the #22 contact off of the ion current feedthrough using standard needle nose pliers.
4. Using needle nose pliers, pull the #20 contact off of the 5kV feedthrough taking the entire bulkhead and connectors with it. There is no need to remove the SHV and SMA connectors from the bulkhead. The gauge is now ready for bakeout.

11.17 Parts Ordering Information

Replacement parts and subassemblies for the HPS SensaVac® Series 421 Cold Cathode Gauge System may be obtained from HPS Division of MKS Instruments, Inc. in Boulder, CO. or any MKS Instruments, Inc./HPS Sales Office. Orders for replacements should include the serial number and flange type. A complete SensaVac® Series 421 Cold Cathode Ionization Gauge System requires one controller, one cold cathode cable, and one sensor tube.

421 Controllers with power cord, accessory connector kit, installation hardware and instruction manual.

Part Number	*Voltage/Frequency*
104210101	120V/60 Hz
104210102	100V/50 Hz
104210103	100V/60 Hz
104210104	120V/50 Hz
104210105	220V/50 Hz
104210106	220V/60 Hz
104210107	240V/50 Hz
104210108	240V/60 Hz

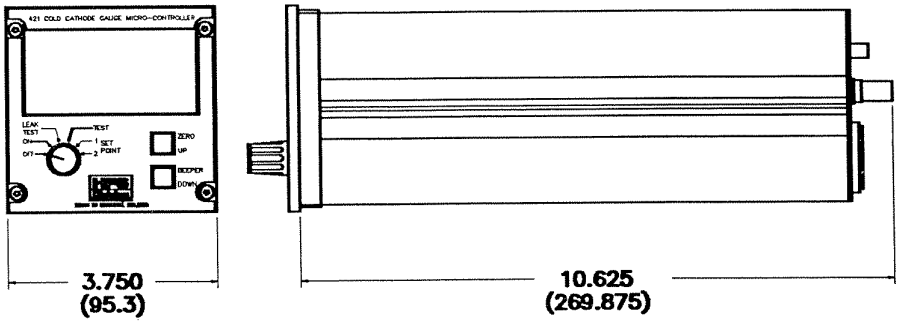


Figure 15

Sensor Cables

Part Number	*Length*
100006171	10 ft. (3.0 m)
100006172	25 ft. (7.6 m)
100006173	50 ft. (15.2 m)
100006174	100 ft. (30.5 m)
100006175	Custom

Sensor Tubes

Part Number	*Vacuum Connection*
104210004	NW 25 KF
104210001	NW 40 KF
104210002	2¾" CF
104210003	1" tube
104210005	½" VCR®-F

Cold Cathode Tube Dimensions inches (mm)

Size	A
NW 25 KF	6.72 (171)
NW 40 KF	6.32 (161)
2 3/4" CF	6.27 (159)
1" Tube	6.22 (158)
1/2" VCR®-F	7.59 (193)

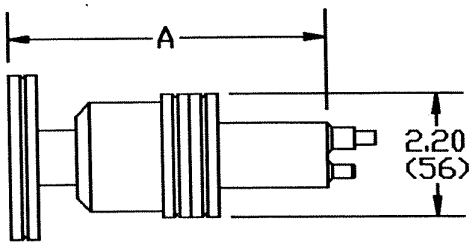


Figure 16

Accessories and Replacement Parts

Part Number	*Description*
100006850	IgniTorr™ Cold Cathode Starting Device
100006734	Cold Cathode Rebuild Kit, includes guard bolt, cathode, washer, 2-1/8" copper seal, abrasive paper, silver plated screws (6), spanner wrench

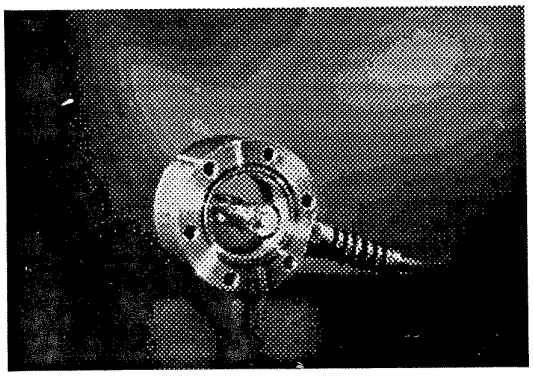


Figure 17
IgniTorr™

103150001	USA power cable
103150002	Power cable without male plug
104210009	Output connector kit
103150004	Mounting hardware kit
104210019	Instruction manual

100003924	Assembly main & power PCB
100003939	Assembly power supply PCB
100003895	Assembly display PCB
100003585	Fuse .60A SB 3AG
100003427	Knob rotary switch
100003219	LCD display
100003342	Power connector controller
100003425	Zebra strip connector
100003920	3 Volt lithium battery
100889001	Tube copper gasket
100005106	Tube silver plated screws
100001422	Washers 5mm
100003965	Insulating support
100004014	Guard bolt
100004062	Spring washer
100004063	Washer
100004085	Cathode
100005040	#22 contact
100005208	#20 contact
100004061	Neon bulb
100003403	100 kOhm resistor
100004084	Bulkhead
100003921	SHV connector
100003954	SMA connector

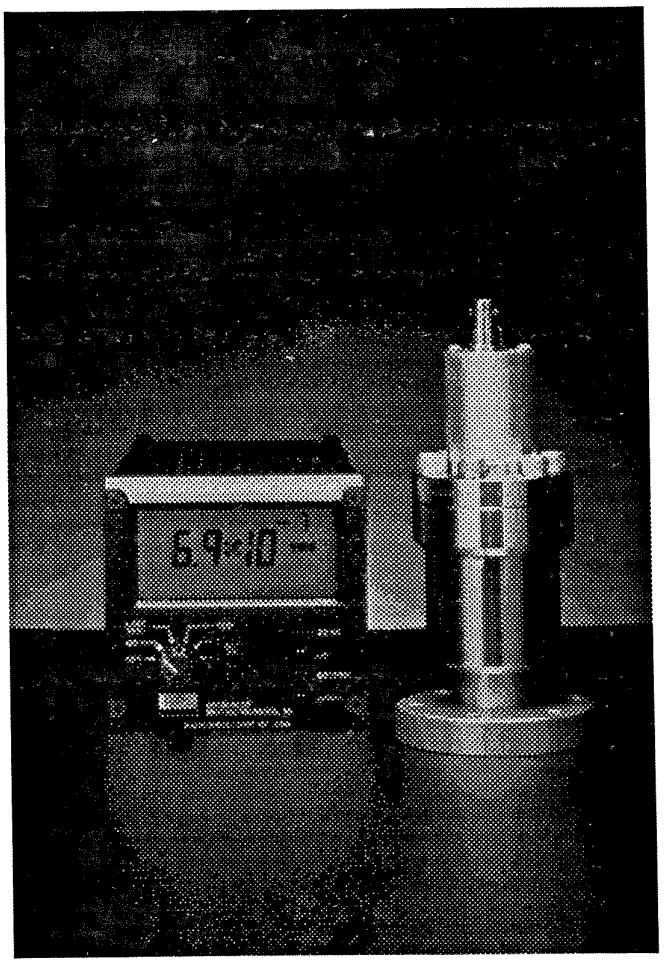


Figure 18

100005039	4-40x1/4 Phillips SEMS screws
100005043	4-40x1/4 Button head screws
100004083	Backshell
100005279	Tube spanner wrench

HPS products are available exclusively through MKS Instruments, Inc./HPS sales offices and distribution centers located throughout the world. To obtain price, delivery, technical, or applications information, contact your nearest MKS/HPS office or HPS directly in Boulder, Colorado.

12 WARRANTY

12.1 Scope of Coverage

HPS Division of MKS Instruments, Inc. ("HPS") warrants the SensaVac® Series 421 Cold Cathode Gauge System and accessories to be free from defects in materials and workmanship for a period of ONE YEAR from date of shipment by HPS or authorized representative to the original purchaser ("Purchaser"). Any product or parts of the product repaired or replaced by HPS under this warranty are warranted only for the remaining unexpired portion of the one year original warranty period applicable to the product which has been repaired or replaced. After expiration of the applicable warranty period, the Purchaser shall be charged HPS' current prices for parts and labor, plus any transportation for any repairs or replacement.

11.2 Repairs

The obligations of HPS under this warranty shall be at its option: (1) to repair, replace or adjust the product so that it meets applicable product specifications published by HPS; or (2) to refund the purchase price.

12.3 Warranty Performance

To obtain warranty satisfaction, contact the following: HPS Division of MKS Instruments, Inc., 5330 Sterling Drive, Boulder Colorado, 80301, USA, Phone (303)449-9861.

12.4 What Is Not Covered

The above warranties do not apply:

a. To damages or malfunctions due to failure to provide reasonable and necessary maintenance in accordance with HPS operating instructions.

b. To damages or malfunctions due to chemical or electrolytic influences or use of the product in working environments outside the specification.

c. To fuses and all expendable items which by their nature or limited lifetime may not function for a year. If such items fail to give reasonable service for a reasonable period of time within the warranty period of the product they will, at the option of HPS, be repaired or replaced.

d. To defects or damages caused by modifications and repairs effected by the original purchaser or third parties not authorized in the repair manual.

12.5 Other Rights and Remedies

a. These remedies are exclusive. HPS SHALL NOT BE LIABLE FOR CONSEQUENTIAL DAMAGES, FOR ANTICIPATED OR LOST PROFITS, INCIDENTAL DAMAGES OR LOSS OF TIME OR OTHER LOSSES INCURRED BY THE PURCHASER OR BY ANY THIRD PARTY IN CONNECTION WITH THE PRODUCT COVERED BY THIS WARRANTY, OR OTHERWISE. SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THE ABOVE LIMITATION OR EXCLUSION MAY NOT APPLY TO PURCHASER. ANY IMPLIED WARRANTY ON THESE PRODUCTS SHALL BE LIMITED TO ONE YEAR FROM DATE OF SHIPMENT TO

PURCHASER. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS SO THE ABOVE LIMITATIONS MAY NOT APPLY TO PURCHASER.

b. Unless otherwise explicitly agreed in writing, it is understood that these are the only written warranties given by HPS. Any statements made by any persons including representatives of HPS which are inconsistent or in conflict with the terms of the warranty shall not be binding on HPS unless reduced to writing and approved by an authorized officer of HPS.

c. This warranty gives PURCHASER specific legal rights, and PURCHASER may also have other rights which vary from state to state.

PI 10/14/88

LAR 10/12/93

For more information or literature contact:

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October 1993

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