Model 7401/7401VR Alpha Spectrometer

User's Manual

9231603B

ISO 9001 SYSTEM CERTIFIED

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Table of Contents

Notes

1. Introduction

The Canberra Model 7401 is a complete alpha spectrometer that includes a vacuum chamber, bias supply, preamp/amplifier, pulser, discriminator, counter, and digital display in a versatile double-width NIM. Samples up to two inches in diameter can be analyzed in the chamber, which is made of stainless steel for low background and ease of cleaning. The chamber will accommodate most charged particle detectors, including Canberra's rugged, low background, high resolution PIPS Detectors with active areas up to 1200 mm^2. A stainless steel shelf and sample holder are provided, with reproducible detector/source spacing selectable from 1 to 49 mm, graduated in 4 mm increments.

The functionality of the 7401 is enhanced by use of a microprocessor-managed user interface. Front panel controls allow the user to set and read high voltage bias, calibration pulser energy, and discriminator and preset time settings for the built-in counter. Additionally, the front panel display provides readout of pressure, detector leakage current, counts and elapsed time. When the 7401 is switched off, the high voltage, discriminator and pulser settings are retained in memory. For gross alpha counting, the counter can be started, stopped and reset using the front panel switches, and time readout can be switched from seconds to hours.

The built-in detector bias supply is adjustable to ±198 V dc. To avoid premature application of bias to the detector, a switchable interlock inhibits the bias supply until proper pressure is reached, then the high voltage is slowly increased to its predetermined setting in approximately one minute.

The preamp and amplifier provide optimal pulse shaping and signal conditioning for detectors used in Alpha Spectroscopy. Gain and offset of the amplifier can be adjusted by means of front panel multi-turn controls. The test pulser can be set to mark energies from 0.1 to 10 MeV and can be used to calibrate the spectroscopy system without the use of alpha sources. The calibrated counter discriminator can also be set between 0.1 and 10 MeV and an auxiliary discriminator output is available on the rear panel. An external test pulser can be connected to the rear of the unit. An MCA can easily accommodate multiple 7401 Alpha Spectrometers using suitable Canberra Mixer/Routers and Multiplexers.

Chamber pressure is manually controlled by a three position valve. The stainless steel door is equipped with hinges which automatically adjust for proper gasket compression and the vacuum chamber is helium leak tested to 10^{-10} cc/s. The 7401 has a pressure gauge with a range of 0-1000 µm Hg (0-133 Pa).

Reverse sample bias is available as an option for the 7401 as Model 7401-RSB. The reverse bias is provided by four 3-volt batteries. For those who need to operate at a decreased vacuum, the Model 7401VR Alpha Spectrometer has a pressure gauge range of 0-20 mm Hg (0-2.67 kPa) and includes the 7401-RSB Reverse Sample Bias option.

2. Controls and Connectors

This is a brief description of the 7401's controls and connectors. For more detailed information, refer to Appendix A, Specifications.

Front Panel

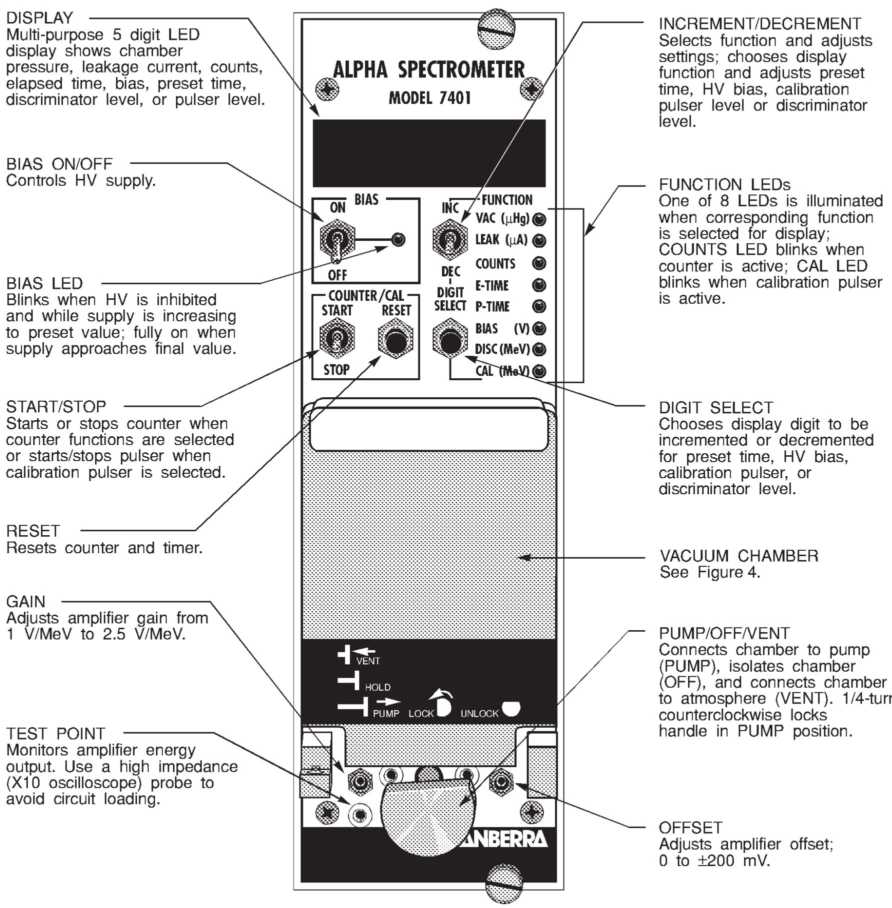

Figure 1 Front Panel Controls

Rear Panel

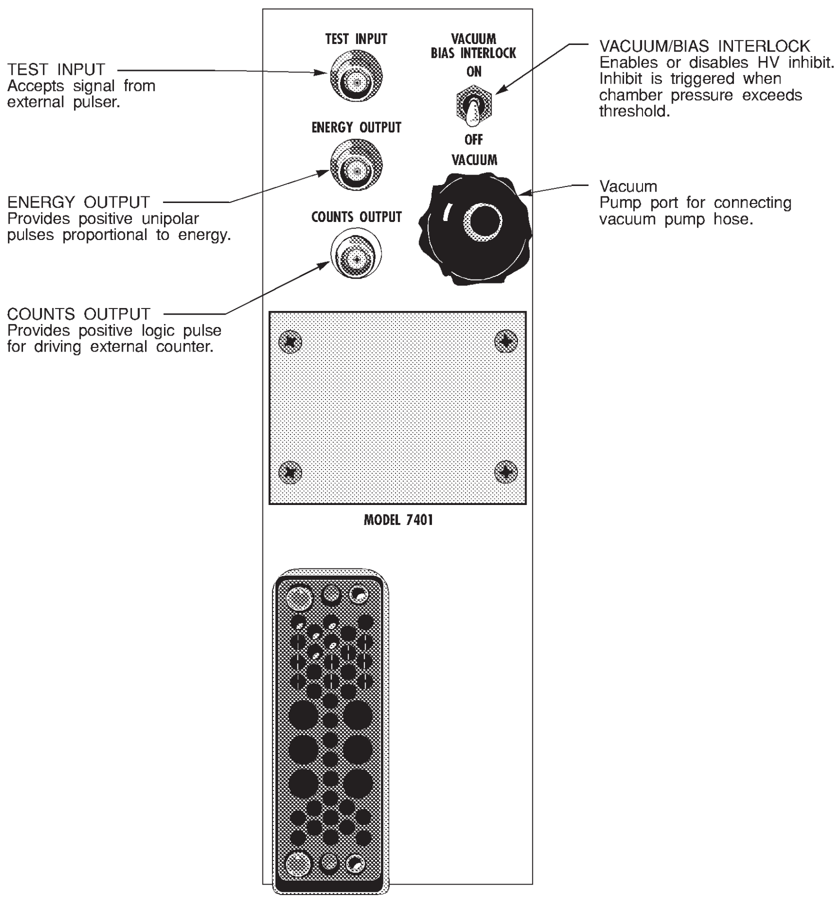

Figure 2 Rear Panel Controls

Internal Controls

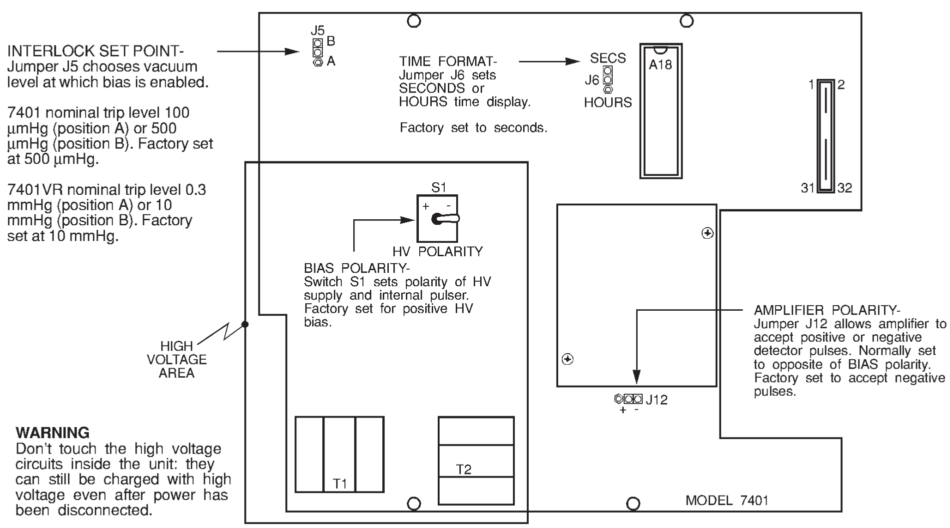

Figure 3 Internal Controls

Vacuum Chamber

Note: For Reverse Sample Bias Kit installation, see drawing B-26491, which can be ordered from Canberra.

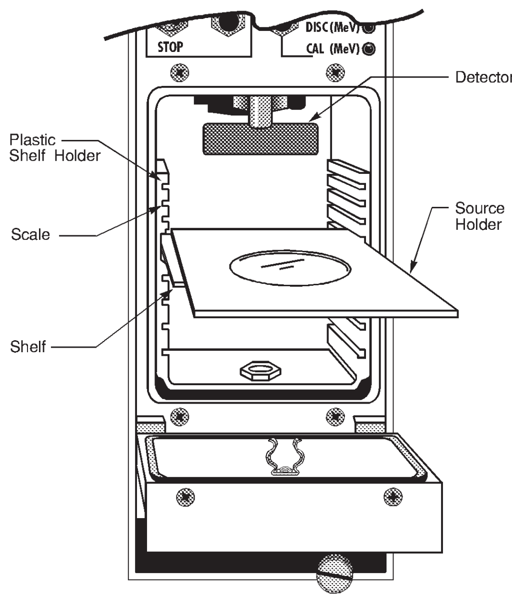

Figure 4 Vacuum Chamber

3. Operating Instructions

The 7401's internal jumpers are factory set for the most common applications, but may have to be changed for a specific need. If you are going to change any jumpers, do it before installing the module in the NIM Bin. To change the jumpers, remove the unit's left-side cover; refer to "Internal Controls" on page 4 for specific information on each jumper.

WARNING Don't touch the high voltage circuits inside the unit: they can still have a high voltage charge, even though the unit's power is off.

Installing The Module

The 7401's power is supplied by Canberra's Model 2000 NIM Bin and Power Supply, or equivalent bin conforming to DOE/ER-00457T. The Bin power and the 7401's Bias Switch should be OFF before installing or removing the unit.

Slide the 7401 into the Bin, making sure that the cover on the right side of the unit is seated in the Bin's top and bottom guide rails. After seating the unit firmly into the Bin's power connector, turn the 7401's front panel captive screws clockwise until finger tight.

The Model 7401 can be operated where the ambient air temperature is between 0 and 50 °C (120 °F, maximum). Perforations in the top and bottom of the 7401 allow cooling air to circulate through the unit.

When the 7401 is rack mounted with other heat generating equipment, be sure to provide adequate clearance to allow for sufficient air flow through the perforations in the NIM Bin's top and bottom covers.

Installing The Detector

CAUTION Turn the BIAS On/Off Switch OFF before installing the detector. Do not turn it on until the unit is ready for operation.

NOTE The detector face must be kept clean and free of contamination for proper performance. Please be sure that the plastic cover is in place when installing or removing the detector. Read the PIPS Detector Information in Appendix B before installing the detectors.

Be sure the sample shelf is in place. It prevents any particles which may be ejected from the valve from hitting the detector. With the plastic cover still in place, install a detector by screwing it into the connector at the top of the chamber. After the detector is screwed firmly into the connector, remove the plastic cover. Be careful not to touch the detector face.

Compared with ruggedized Canberra PIPS detectors, conventional SSB detectors may be very sensitive to conditions causing microplasma breakdown. Be sure to read the detector's instruction sheet before installing and using the detector.

Connecting The Pump

The vacuum pump is connected to the Model 7401 vacuum fitting located on the rear panel. The outside diameter of the fitting is 9.5 mm ($\frac{3}{8}$ in.). Use metal tubing and high quality rubber couplers wherever possible in the vacuum line to minimize outgassing and to ensure a short pumpdown time.

Connecting the MCA

Using 93 ohm cable (type RG-62), connect the ENERGY Output of the 7401 to the ADC input of the multichannel analyzer. If multiple 7401 modules are being used, connect each 7401 ENERGY Output to one of the Mixer/Router Inputs.

Preliminary Setup

With the detector installed and no sample in the chamber, close the door and set the 7401 switches as follows.

Bias On/Off Switch	OFF
Vacuum/Bias Interlock Switch	ON

Turn on the 7401's power by turning on the NIM Bin's power switch.

Operation

CAUTION Do not turn on the BIAS Switch until the proper bias voltage has been set. See Setting Bias the First Time on page 8.

Using the front panel switches you can select any of eight items for display. See Figure 5. Front panel switches also allow you to adjust settings, control the counter/timer and turn the bias voltage on and off.

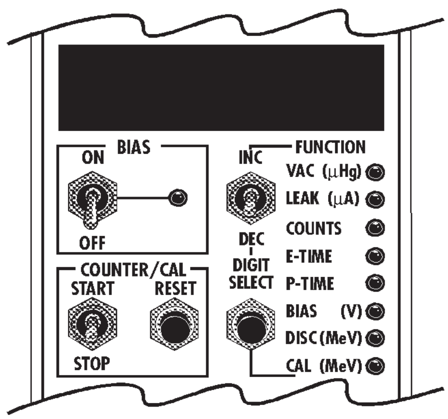

Figure 5 Front Panel Switches

The INCrement/DECrement and DIGIT SELECT Switches are used to control the display function and to change the 7401's settings. To change the display function, first make sure that no single digits are blinking. If a single digit is blinking, press the DIGIT SELECT Switch one or more times until all digits are steadily lit. Then use the INCrement/DECrement Switch to choose a different function. The selected function's LED will turn on.

If all digits on the display are blinking at once, an overrange condition exists. In this case, the function can be changed using the INCrement/DECrement Switch.

Four instrument settings can be adjusted using the front panel controls: Preset Time (P-TIME), BIAS, DISCriminator Energy, and CALibration pulser energy.

To adjust a parameter setting, first make sure that the corresponding LED is lit. Then press the DIGIT SELECT button until the digit that is to be changed blinks. Once the digit is blinking, use the INCrement/DECrement Switch to change the setting.

To advance to the next digit, press the DIGIT SELECT switch again. Repeat this for as many digits as necessary, then press the DIGIT SELECT button one or more times until all digits are steadily lit. Note that either of two digits can be changed when adjusting BIAS voltage and DISCriminator and CALibration pulser energies. Any of five digits can be changed in Preset Time (P-TIME).

The Model 7401's internal memory maintains BIAS, DISCriminator and CALibration pulser settings when the unit's power is turned off. To insure proper memory operation, make sure that all changes to these settings have been completed before turning the 7401's power off.

If the BIAS Function is selected, the display always indicates the voltage applied to the detector bias network. If the BIAS Switch is turned off, the bias will remain close to zero volts. Once the BIAS Switch is turned on, the display will show the detector voltage as it increases to the bias level stored in internal memory.

Initializing The Display

The front panel display is initialized to show the Bias whenever the unit's power is turned off, then on. To aid in testing, it can also be reset and initialized by simultaneously pressing the RESET and DIGIT SELECT push buttons while pressing the INC/DEC Switch to the INC position. When the unit is reset, the stored BIAS, DISCriminator, and CALibrate settings will not be changed.

Applying Vacuum

Applying the vacuum is done in three steps:

1. Set the display to read VACuum.

2. Start the vacuum pump.

3. Pull the valve handle out to the PUMP position and rotate the handle ¼-turn counterclockwise (Figure 6). The gurgling sound should stop in a minute or so if there are no leaks in the vacuum line.

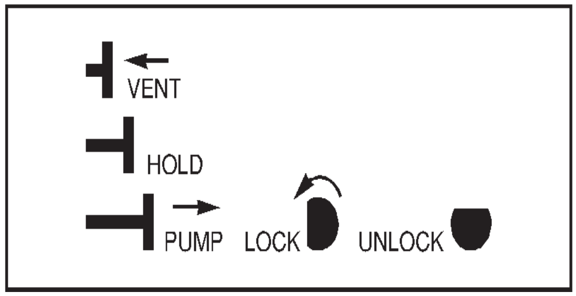

Figure 6 Valve Operation

Setting Bias the First Time

Throughout this operation the display, which is monitoring the voltage applied to the detector bias network, will show a voltage close to zero.

CAUTION The high voltage memory should be reset to zero before turning on the BIAS Switch for the first time, or when changing detectors.

1. Use the INC/DEC Switch to select the BIAS Function; its LED is lit when the function is selected. Now press the DIGIT SELECT pushbutton twice to select the bias voltage tens digit; that digit will blink when it is selected.

   With the tens digit selected, the bias voltage will change by 10 volts each time the INC/DEC Switch is pressed. Press the INC/DEC Switch to the DECrement position 20 times to insure that the voltage setting stored in the internal memory has been reset to zero (0). The display will show a voltage close to zero since it is monitoring the detector bias network.

2. After the high voltage has been reset to approximately zero volts, turn the BIAS Switch on.

CAUTION Avoid applying excess voltage to the detector. Wait approximately one minute after turning on the BIAS Switch (until the BIAS on/off LED stops blinking) before increasing the voltage. This will allow time for the bias voltage to stabilize.

3. Starting with the bias at approximately zero, slowly increment the bias to the recommended voltage while monitoring the voltage display. Refer to the Detector Instruction Sheet for the method used in applying bias to a new detector. When a low leakage detector is being used, it is not necessary to correct for the voltage drop in the bias network.

Once the correct bias has been set, it will automatically be applied with a time constant of approximately one minute when the BIAS Switch is turned on and the vacuum conditions are correct. The bias should always be turned OFF manually before the chamber is vented and the door is opened. The BIAS Switch should be turned ON manually only after the door has been closed and the pump-down has started.

Previous Bias Setting

If the bias has been previously set to the correct voltage, power can be applied to the detector by selecting the BIAS Function and turning on the front panel BIAS Switch. If the rear panel VACUUM/BIAS INTERLOCK Switch is on, bias will not be applied until vacuum reaches the internally preset level. This may take a few minutes and it is dependent on the size and type of vacuum pump and vacuum tubing.

Sample Placement

Before opening the door make sure that the high voltage to the detector has been turned off. Then after pressing the chamber valve to VENT the chamber, open the door and set the shelf height as desired. See Figure 4. Note that the scale on the left side of the plastic shelf holder can be used as a reference in positioning the holder. Insert the sample holder tray holding the sample.

When the sample is in place, close the door, pull the chamber valve to the PUMP position and lock it by rotating the handle ¼-turn counter clockwise (Figure 6).

After the chamber is pumped down and the Bias voltage has stabilized, data collection may be started.

At the end of the experiment, set the BIAS Switch to off, vent the chamber and open the door to remove or replace the sample.

System Calibration

To calibrate the system, insert a known source in the chamber, accumulate a spectrum and use the 7401 gain control to position the isotope peak at the desired MCA channel. Adjustment of the ADC Gain, Range and Digital Offset controls may also be necessary, as well as the ADC Zero.

The 7401 amplifier offset is factory set to zero volts, but may be adjusted to ±200 mV. The amplifier output pulses and offset may be monitored at the front panel TEST POINT using an oscilloscope.

Calibration may also be accomplished using the 7401's Calibration Pulser. To use the pulser first select the CAL Function. Then set the desired energy and turn on the pulser by pressing the START/STOP Switch to the START position. The CAL LED will blink. Adjust the gain control to place the pulser peak at the desired channel of the MCA spectrum. The Calibration Pulser will turn itself off when you leave the CAL Function.

Using the Discriminator Counter/Timer

To use the counter/timer, first determine the lowest energy alpha particles which are to be counted. Then use the front panel controls to display the discriminator level and set the Discriminator to the required energy. Next set the Preset Time by moving to the Preset Time Function (P-TIME) and entering the appropriate setting. Once this is done, turn the counter on by pressing the START/STOP Switch to START. The counter/timer can be started, stopped and reset using the front panel switches, but only when one of the three counter/timer functions is selected: Preset Time (P-TIME), Elapsed Time (E-TIME), or COUNTS.

If Preset Time is set to zero, the counter will continue to count indefinitely. When the Elapsed Time timer has counted beyond 99 999 seconds it will "roll over" to 0 and continue counting; the entire display will blink to indicate that rollover has occurred. The gross alpha counter will not advance beyond 99 999.

The time readout is factory set to display seconds, but an alternate display in hours and hundredths of hours (HHH.HH) can be chosen by moving an internal jumper (refer to "Internal Controls" on page 4) and either turning the power off then on, or by using the front panel switches to initialize the display (see "Initializing the Display" on page 9).

The COUNTS output on the rear panel is available to drive an external counter with the discriminator output.

Multiple 7401s On a Single Pump

A single vacuum pump can be connected to more than one 7401, however the pump down time may increase. To connect more than one unit to the vacuum pump, you must install a fitting or manifold system to expand the number of vacuum lines.

It may be necessary to change samples or otherwise service one chamber while continuing to run an experiment in the remaining chambers. This can be done by using the 7401's three-position valve. In the OFF position, the pump port and the chamber port are both closed. In the PUMP position the pump port is connected to the chamber and the vent is closed. In the VENT position the chamber is connected to the vent and the pump port is closed.

Thus, individual chambers on a manifold may be vented without disturbing the other chambers. However when a chamber which has been vented is pumped down again, there will be a momentary pressure rise in the entire system until the vacuum is re-established.

Three methods are available for servicing a chamber while reducing or avoiding interruptions in the other chambers. Following any of these three methods will allow selected chambers to be off line indefinitely without affecting the others.

NOTE In the HOLD position, valve operation can be affected by large transient pressure changes in the vacuum line.

If a 7401 is to be connected to the same pump as a large-chambered unit, such as the Model 7404 Quad Alpha Spectrometer, and the HOLD function is required, Canberra recommends that an external valved manifold, such as the Model 7400-14 Dual Six-Port Valved Manifold, be installed to switch between the units as detailed in "Method C" on page 15.

Method A – Canberra PIPS Detectors Installed in All Model 7401s.

This method can be used if the 7401 is equipped with a Canberra PIPS detector or other detector which is ruggedized and can tolerate exposure to changing pressure between 500 µm Hg and 700 mm Hg while bias is applied.

1. Set the HV Interlock switch OFF on all 7401's sharing the same vacuum pump.
2. On the unit to be vented, turn the detector BIAS off.
3. Carefully push the chamber valve to the VENT position and open the chamber door. Let the valve return to the HOLD position. See Figure 6. Vacuum in adjacent chambers should not change.
4. After servicing the chamber, firmly close the chamber door.
5. Pull the chamber valve handle to the PUMP position and lock it by rotating the handle ¼-turn counterclockwise (Figure 6). The pressure in adjacent chambers

will momentarily rise, then decrease as the pump removes the air introduced from the serviced chamber.

Method B – Other Detector Types Installed, such as Standard SSB Detectors,.

This method should be used when any of the 7401's are equipped with a detector which might be damaged by exposure to changing pressure between 500 µm Hg and 700 mm Hg while bias is applied.

An additional step has been included here to isolate the chambers which are not serviced from any momentary loss of vacuum.

1. Remove the 7401's side covers and verify that jumper J5, Interlock Set Point, is set to the 500 µm Hg position (position B). Refer to Figure 6 for the jumper's location.

2. Make sure that the VACUUM/BIAS INTERLOCK is enabled on all units.

3. On the unit to be vented, turn the detector BIAS off.

4. Carefully push the chamber valve to the VENT position (Figure 6) and open the chamber door. Let the valve return to the HOLD position. Vacuum in adjacent chambers should not change.

5. After servicing the chamber, firmly close the chamber door.

6. Place the valves on adjacent chambers in the HOLD position.

7. Pull the valve for the chamber which was serviced to the PUMP position and turn on the BIAS Switch. Bias will automatically be applied to the detector when the correct vacuum is reached.

8. When the serviced 7401 chamber attains a vacuum similar to the adjacent chambers, carefully change the valves on the adjacent chambers to the PUMP position.

The loss rate of the chambers on hold is typically 40 to 80 µm Hg per minute. This allows in excess of four minutes to evacuate the vented chamber before the 500 µm Hg vacuum trip point is reached on adjacent chambers. This is more than adequate time to repump the vented chamber.

Method C – Using the 7401 with the Model 7400-14 Dual Manifold,

The Model 7400-14 is a Dual Six-Port Valved Manifold for use with vacuum chambers or Alpha Spectrometers. The 7400-14 makes it possible to service individual chambers without affecting the pressure in other chambers attached to the same pumping system.

The 7400-14 requires one vacuum pump, such as the Model 7400-01 or 7400-02, for each of the unit's two manifolds. The manifolds are connected to the vacuum chambers by means of three-way valves. In this way, the high vacuum manifold can remain at constant pressure while the pump-down manifold experiences the pressure transients associated with pump-down of chambers.

An installation diagram, drawing B-201083, is available from Canberra. Note that two 7400-11 Installation Kits and two 7400-09 Filters are required in addition to the two Model 7400-01 or 7400-02 vacuum pumps.

Keep the length of hose between manifold and vacuum chambers as short as possible.

When a system is first assembled and tested it is important to get the vacuum system operating properly *before* detectors are installed in the vacuum chambers.

1. Seal all manifold ports not being used with the black rubber caps that are provided with the 7400-14.

2. Evacuate the lines and observe pump behavior with all valves in the off position. If the pump's gurgling sound continues after more than a few minutes of operation, it indicates a gross leak.

3. Change one valve to the pump-down position and note that the pressure in the associated spectrometer begins to decrease after a few minutes of pumping. It will take several minutes for the pressure to reach the 1000 µm Hg read-out limit of standard Canberra Spectrometers. When the pressure reaches about 100 µm Hg you will know that this channel and the pump-down manifold are free of gross leaks. Turn the valve to the High-Vacuum position and verify that the pressure on this side is in the same range.

4. If the pressure on either side is not in the right range tighten and or re-lubricate the vacuum line couplings.

5. Repeat step 3 for each of the spectrometers in the system.

Routine Operation of the 7400-14

1. Always evacuate chambers with the valve in the Pump-Down position.

2. When the pressure in the chamber reaches the normal operating range turn the valve to the High Vacuum position.

3. Before opening a chamber turn the associated manifold valve to the pump-down position.

4. Before re-evacuating a chamber check to see that the associated manifold valve is in the pump-down position.

Routine Precautions

1. Never connect an evacuated chamber to a manifold or pump which is not under vacuum. The chamber may draw oil vapor from the pumping system and contaminate detectors.

2. Service vacuum pumps periodically. Do not wait for them to fail. Consult manufacturer's instructions.

3. Replace filters periodically. Oil clogged filters will reduce pumping speed and may allow backstreaming.

4. Circuit Description

The block diagram, Figure 7, summarizes the 7401 circuitry which performs several functions for this integrated module, including analog signal amplification, discrimination, low and high voltage power supply, vacuum gauge signal processing, test pulse generation, analog to digital conversion, digital and display control, and computing.

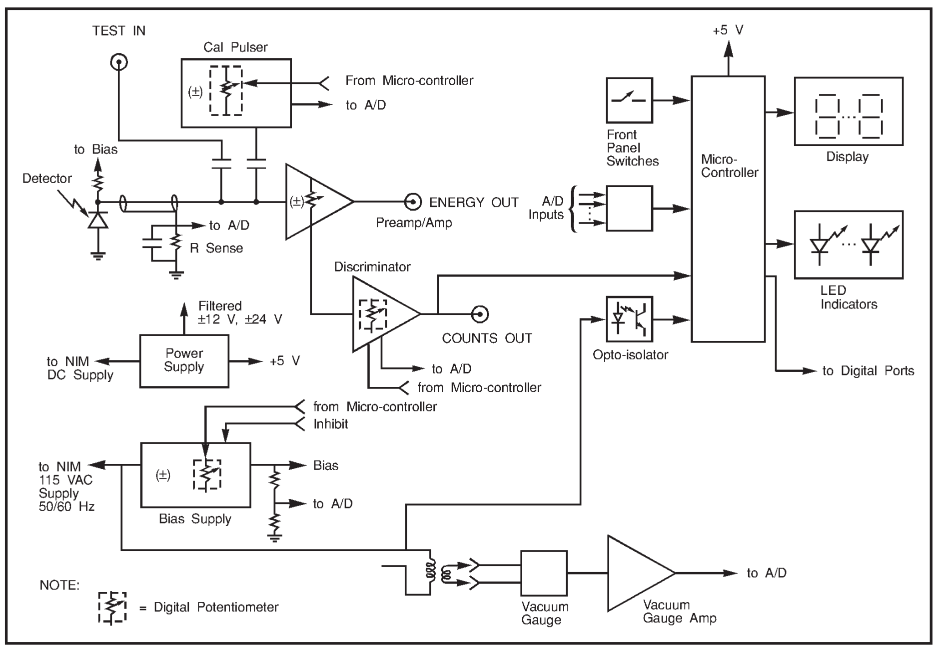

Figure 7 Block Diagram

Preamp/Amp

The Model 7401 incorporates a shielded low-noise charge-sensitive preamplifier and a unipolar output shaping-amplifier which have been optimized for the needs of alpha spectroscopy.

The preamplifier consists of input FET Q14, differential amplifier Q12 and Q11, output follower FET Q13 and current sinks Q20 and Q19. This group of devices functions as an inverting feedback amplifier whose closed-loop gain is set by the charge-integrating capacitor C122. Internal bias-currents for FET Q14, loop gain, and compensation are set to provide best performance for the large area, thin detectors most commonly employed for low-level alpha particle counting. Bias stabilization is provided by the dc feedback path through R15. This component serves to discharge C122 following each charge integration, and sets the tail-pulse shape of the preamplifier at a nominal 470 µs decay time constant. Diode D1 provides protection for Q14 from the transient voltages experienced from momentary breakdowns in the detector bias circuit due to accidental faults.

The calibration pulser input includes potentiometer RV10 which is factory set so that the output pulse amplitude represents the energy displayed in MeV. Thus you can precalibrate a region of interest without having to use an open source.

Detector current is filtered by C39, C301, C302, R1 and C38, then sensed by R191 which generates a voltage that is measured by the A/D. The result is displayed when LEAKage Function has been selected by the front panel controls.

Following the charge integrator is a pole/zero compensated differentiator (C6, R20 and R21) set for a nominal 0.5 µs decay time constant. The time-clipped tail pulse is amplified by a fixed gain non-inverting feedback amplifier formed by differential pair Q17 and Q25, driver Q18 and push-pull outputs Q16 and Q15. The gain of this amplifier stage is fixed at X30.

Preliminary integration is provided by R30, L2, and C21 before the signal is fed to the split-load inverter Q21, which permits polarity selection by the internal jumper plug J12. Q22 buffers the signal before the second integration in R39, L3 and C24. The filtered signal is then amplified again by A25, which incorporates the front-panel-mounted gain control in its feedback path. The signal is a positive-going pulse at this point, and D4 limits the excursion by clamping the output of A25 to enhance prompt overload recovery.

Capacitor C120 couples the positive pulse into the simple restorer provided by Q23. This circuit stabilizes the dc reference level for the pulse in order to maintain a proper baseline from which the output may be quantized in an ADC or SCA.

Output amplifier A26 provides the final stage of gain and permits the introduction of a dc offset/zero-adjust, controlled by a front panel potentiometer. D5 limits the positive excursion to prevent saturation in either A26 or output transistor Q24 and insures prompt overload recovery.

The output is a unipolar semi-Gaussian pulse with a shaping time constant of 0.5 µs. This integration has been found to be nearly optimum for the noise spectrum of typical surface barrier alpha particle detectors to provide the best energy resolution.

Auxiliary Circuits

The auxiliary circuits include the power supplies for the detectors and preamp/amp, the thermocouple vacuum gauge circuitry, the calibration pulser, discriminator and A/D. As can be seen on the schematic, interlocking, switching, and sensing is necessary for the proper integration of these subsections.

Power Supplies

The internal 12 V and 5 V supplies are derived from inductor-capacitor filters, three-terminal regulators and Zener diode regulators. The detector high voltage bias is derived from the 115 V ac supplied by the NIM power supply which is boosted by transformer T1 then full-wave rectified, filtered by capacitor C3, and controlled by a discrete component series regulator. The output polarity is selected by a board-mounted toggle switch (S1). The reference voltage is derived from D6 as adjusted by digital pot A5.

When the VACUUM/BIAS INTERLOCK is enabled by the rear panel switch, a time-delay interlock keeps the detector bias regulator cut off until satisfactory chamber vacuum is detected by comparator A1. When this occurs A1 pin 1 goes low, and Q5 turns off to remove the short across D6. Upon activation of the high voltage section, C38 is charged through R61 until Q4 and Q6 permit D6 to achieve its full Zener voltage. As regulator diode D6 approaches its full voltage, sense transistor Q1 turns on, sending a signal to the microprocessor. This delay and exponential rise permit detector bias to be applied slowly at a controlled rate to prevent detector damage due to surface breakdown.

Amplifier A4 and high voltage transistors Q2 and Q3 provide high voltage regulation. Closed loop dc gain is determined by the ratio of R67 to R66. When set for a positive output voltage, the input at pin 2 of A4 is amplified and output is controlled by Q2 acting as a shunt element and Q3 acting in series between the high voltage and the load.

Vacuum Gauge

The thermocouple vacuum gauge is biased from a controlled ac current source derived from the back-to-back Zener diodes D17 and D18, and through RV15 into a current transformer. The gauge output is a dc voltage representing the temperature of a thermally isolated heater wire as influenced by static air pressure (or vacuum) in the chamber. Amplifier A2 boosts the low level DC signal and sends it to comparator A1 and to the A/D for digitizing and subsequent linearization by the microprocessor.

The calibration for vacuum gauge circuitry is performed during assembly and test so that a reasonable indication of vacuum may be monitored by A1. The detector bias-circuit can be enabled when the chamber reaches the preset vacuum level selected by J5. The 7401's preset level can be either 100 or 500 µm Hg. The 7401VR's preset level can be either 0.3 or 10 mm Hg. RV1 and RV2 adjust the thresholds.

Calibration Pulser

The reference voltage for the calibrated pulser is derived from Zener diodes D15 or D16, as selected by switches S1 and A9. Digital potentiometer A10 feeds a selected dc voltage level to switch A13 to charge capacitor C119. The dc level is also divided through R91 and R92 to provide a voltage for the front panel digital display. Oscillator A11 controls the repetition rate of the pulse generator. The charge on C119 is switched by A13 to shaping components C61 to control rise time, and R170 to control decay time before being fed to the calibration pulser input of the preamp/amp.

Discriminator

The reference voltage for the discriminator is derived from Zener diode D28. Digital potentiometer A22 feeds a selected dc voltage level through divider R57-R56-RV13 to the A/D for display and to one input of comparator A24. Amplifier A23 samples the shaped alpha pulse and supplies the other input to comparator A24. RV20 and RV12 allow adjustment of discriminator offset and gain. The output of the comparator is fed to one-shot A14 and then via buffer A17 to the rear panel BNC COUNTS output. The output of the discriminator one-shot is also connected to the microprocessor's internal counter.

Analog to Digital Converter

The A/D can measure one of eight different dc inputs. Three of the inputs, +12 V, –12 V, and 0 V, available at analog multiplexer A8, are test inputs. The other five inputs are voltages coming from the auxiliary circuits for display. The output of the multiplexer is filtered by R123 and C69 and fed to A/D converter A7, whose output appears on the microprocessor data bus.

Microprocessor and Control Circuits

The microprocessor controls the front panel switch and display functions, the counter/timer and the three digital pots. It also reads the internal A/D converter, scaling and linearizing the data for display.

The processor sends display information to display driver A21, whose power supply is regulated by shunt regulator D32. This regulator prevents excessive low frequency ripple from appearing on the power supply lines. Front panel switch status is passed to the microprocessor by buffer A19.

By reading the power line frequency through opto-isolator A6, the processor establishes an accurate 1 second time base for the counter/timer. If the power line frequency is not within the 50 or 60 Hz specification, the processor uses an internal crystal-controlled counter to generate the time base.

Digital pots A5, A10, and A22 are each controlled by the microprocessor through three control lines. Each digital pot has 100 discrete settings and retains its last setting in internal memory when power is removed.

In order to allow for processor reset without cycling the power, three front panel switches are connected to inverters in package A17, which sends a reset pulse to the microprocessor.

A. Specifications

Input

TEST INPUT - Accepts signal from external pulser; Z_{in} = 93 Ω; gain nominally X 10; rear panel BNC.

Outputs

ENERGY OUTPUT - Provides positive, linear near-Gaussian shaped unipolar pulses proportional to energy, linear to + 10 V; max output 12 V; dc restored; Z_{out} = 10 Ω; short circuit protected; rear panel BNC.

TP (Test Point) - Replica of the energy output signal; isolated by 1 kΩ resistance; front panel mounted pin jack.

COUNTS OUTPUT - NIM-standard positive logic pulse available on rear panel BNC connector for driving external counter; pulse width nominally 3.5 µs for any event above discriminator setting; Z_{out} ≈ 50 Ω, dc coupled.

Display

Multi-purpose 5-digit LED display shows chamber pressure in µm Hg (mm Hg on the 7401VR), detector leakage current (µA), gross counts, elapsed time, preset time, high voltage bias, discriminator level (MeV), and calibration pulser level (MeV); time readout in seconds or hours.

Front Panel Controls and Indicators

BIAS ON/OFF - Toggle switch controls high voltage supply

BIAS LED Indicator - Blinks when high voltage is inhibited and while supply is increasing to preset value; solidly illuminated when supply approaches final value.

FUNCTION LED Indicators - One of eight LEDs is illuminated when corresponding function is selected for display; COUNTS LED blinks when counter is active; CAL LED blinks when calibration pulser is active.

INCREMENT/DECREMENT - Dual purpose momentary toggle switch selects display function and sets preset time, HV bias, calibration pulser level or discriminator level.

DIGIT SELECT - Pushbutton switch chooses display digit to be incremented or decremented; operable when setting preset time, HV bias, calibration pulser, or discriminator level.

START/STOP - Dual purpose momentary toggle switch starts or stops counter when counter functions are selected or starts/stops pulser when calibration pulser is selected.

RESET - Pushbutton resets counter and timer.

GAIN - Screwdriver adjustable multi-turn potentiometer adjusts amplifier gain.

OFFSET - Screwdriver adjustable multi-turn potentiometer adjusts amplifier offset.

PUMP/OFF/VENT - 3-position valve control; PUMP connects vacuum pump to chamber; OFF isolates pump from chamber and chamber from atmosphere; VENT vents chamber to atmosphere and isolates pump. Locks in pump position by turning handle one quarter turn counterclockwise.

Rear Panel Control

VACUUM/BIAS INTERLOCK - Locking toggle switch enables or disables HV inhibit; inhibit is triggered when chamber pressure exceeds threshold.

Internal Controls

VACUUM/BIAS INTERLOCK SET POINT - Dual position jumper chooses vacuum level at which bias is enabled. 7401 nominal trip level is 100 or 500 µm Hg (13 or 67 Pa); factory set to 500 µm Hg (67 Pa). 7401VR nominal trip level is 0.3 mm Hg (0.04 kPa) or 10 mm Hg (1.33 kPa); factory set to 10 mm Hg (1.33 kPa).

BIAS POLARITY - Toggle switch sets polarity of HV supply and internal pulser. Factory set for positive HV bias.

AMPLIFIER POLARITY - Jumper allows amplifier to accept positive or negative detector pulses. Factory set to process negative pulses.

TIME FORMAT - Jumper sets seconds or hours time display. Factory set for seconds display.

System Performance

(Based on use of a 450-20 AM PIPS detector with a good quality ^{241}Am point source.)

Energy Resolution

≤20 keV (FWHM) with a detector-source spacing equal to the detector diameter.

Detector Efficiency

≥25% for detector-source spacing of less than 10 mm.

Background

≤1 count/hr above 3 MeV.

Electronics Performance

OPERATING TEMPERATURE RANGE - 0 to 50 °C.

BIAS SUPPLY

Range - Nominal 1 V to ±198 V dc, adjustable in 2 V steps from 2 V to full voltage.

Stability - Better than 50 ppm/°C.

Noise - ≤5 mV peak-to-peak.

Display Resolution - 0.1 V.

CALIBRATION PULSER

Range - 0.1 to 10 MeV, adjustable in 0.1 MeV steps.

Stability - Better than 50 ppm/°C.

Display Resolution - 10 keV

DISCRIMINATOR

Range - 0.1 to 10 MeV

Display Resolution - 10 keV

DETECTOR CURRENT MONITOR

Range - 0 to 20.00 µA

Display Resolution - 0.01 µA

VACUUM GAUGE

7401 Range - 0 to 1000 µm Hg (0 to 133 Pa)

7401VR Range - 0 to 20 mm Hg (0 to 2.67 kPa)

COUNTER

Count Range - 0 to 99 999 counts.

Time Range - 0 to 99 999 seconds or 0 to 999.99 hours.

Preset Time Range - Same as Time Range.

Time base - 50 Hz or 60 Hz power line frequency or internal crystal, automatically selected.

PREAMPLIFIER/AMPLIFIER

Shaping - 0.5 µs unipolar, dc restored.

Integral Nonlinearity - ≤0.4% of full scale.

Gain Range - 6 MeV to 13 MeV full scale (17 to 40 V/pC, 1 to 2.5 V/MeV).

Gain Drift - ≤200 ppm/°C

DC Drift - ≤±100 µV/°C

Noise - ≤0.12 fC RMS referred to input at 0 pF input capacitance.

Offset range - 0 to ±200 mV

Connectors

TEST INPUT, ENERGY OUTPUT and COUNTS OUTPUT - BNC type UG-1094/U.

VACUUM - 9.5 mm (3⁄8 in.) O.D. aluminum fitting mounted through rear panel.

DETECTOR - Axial microdot

Power Requirements

+12 V dc – 250 mA	+24 V dc – 100 mA
–12 V dc – 50 mA	–24 V dc – 50 mA

Physical

SIZE - Standard double-width NIM module 6.86 X 22.12 cm (2.70 X 8.71 in.) per DOE/ER - 0457 (1990).

NET WEIGHT - 2.5 kg (5.5 lb)

SHIPPING WEIGHT - 3.2 kg (7.0 lb)

VACUUM CHAMBER AND HARDWARE - 8.16 X 6.03 X 6.25 cm (3.25 X 2.375 X 2.5 in.) (height, width, depth). Stainless steel chamber, door, shelf and sample holder.

SAMPLE SIZE - Up to 51 mm (2 in.) diameter

MAXIMUM DETECTOR SIZE - 1200 mm^2

SAMPLE-DETECTOR SPACING - 1 to 49 mm in 4 mm steps

SAMPLE HOLDER - One Model 7401SH-4 sample holder for 25 mm (1 in.) samples is supplied. Other sample holder sizes are available as extra cost options.

Environmental

OPERATING TEMPERATURE – 0 to 50 °C.

RELATIVE HUMIDITY – Up to 80%, non-condensing.

Tested to the environmental conditions specified by EN 61010, Installation Category I, Pollution Degree 2.

Options

MODEL 7401-RSB Reverse Sample Bias - Includes four 3 V batteries mounted on the sample shelf. The average battery life is 8 years.

MODEL 7401VR Alpha Spectrometer - Same as 7401 except the pressure gauge has a range of 0 to 20 mm Hg (0 to 2.67 kPa); also includes Model 7401-RSB Reverse Sample Bias option.

Model 7401SH-3 sample holder for 19 mm (3⁄4 in.) samples.

Model 7401SH-8 sample holder for 51 mm (2 in.) samples.

B. PIPS Detector Information

Handling

The PIPS detector should be handled with care. The implanted face contact, while not as fragile as an evaporated gold contact, is nonetheless very thin, as it must be in order to achieve high efficiency and good resolution for alpha particles. Do not touch the surface with anything that might cause scratches or abrasion.

Operation

The PIPS detector has implanted, passivated contacts which are protected from the environment so there is little risk of microplasma breakdown upon application of bias. However, if the detector has been stored in humid conditions, it should be kept in vacuum for a short while to remove excess condensation before applying bias.

Alpha resolution is measured using a point source at least one detector diameter away from the detector face. Resolution will not be as good with the source closer because of the more acute angle of particle travel through the entrance window.

Alpha sources do not emit monoenergetic alphas, but have an intrinsic line width that contributes to system resolution. Our detectors are tested using good quality sources, such as the NBS 4904G. The use of old or inferior calibration sources may cause resolution problems and can lead to detector contamination due to recoil sputtering.

Cleaning

The PIPS detector can be cleaned with a cotton ball dampened with a good grade of acetone. Avoid excess wetting of the detector assembly, but repeat the cleaning treatment with fresh cotton to eliminate traces of contamination. Blow dry with dry air or dry nitrogen gas and vacuum pump for 15 minutes or so to remove residual moisture before applying bias.

C. Power-On Error Codes

When the 7401 is turned on or reset from the front panel (“Initializing the Display” on page 9), the microprocessor runs several tests. If an error is detected one of the following error codes will be displayed:

E1 RAM test error. RAM is on board the micro-processor.

E2 Checksum error for program code in EPROM on board the microprocessor.

E3 A/D error. No change in A/D status line within a 100 ms time period.

E4 The ac power line was not detected by the module. Module will use internal timer as time base.

E5 The ac power line was detected by the module but the line frequency is not within ± 0.5 Hz of 50 or 60 Hz. Module will use internal timer as time base.

D. Self Tests

CAUTION Avoid detector damage by removing it from the chamber before executing any of the high voltage tests.

The 7401 will execute several internal tests when in the test mode, which is enabled by resetting the module. This is done by cycling power or using the front panel reset switches ("Initializing the Display" on page 9). Immediately after the reset, press the RESET and DIGIT SELECT buttons simultaneously and hold the switches until the software revision level is displayed. Then the numeral "1" will be displayed signifying that the unit is ready to perform test number one. Use the INC/DEC switch to choose a test.

Press the START switch to start the test. The letter "P" will be displayed if the test was passed. The letter "E" indicates an error. After each test is finished, the program returns to the select mode.

NOTE When the self-tests are executed, the digital pot settings for Bias, Calibration pulse level, and Discriminator level will be altered.

After completing the self-tests, resume normal operation by cycling power or using the front panel switches to reset the unit (see "Initializing the Display" on page 9).

Switch Test (Test 1)

This tests all front panel switches. After the START switch is pressed, the number 1.0 will be displayed, meaning press the START switch (again). If the test is passed, the number will increment and the test will wait for the next switch to be pressed.

1.0 – Press the START switch (again).

1.1 – Press the STOP switch.

1.2 – Press the RESET switch.

1.3 – Press the INCREMENT switch.

1.4 – Press the DECREMENT switch.

1.5 – Press the DIGIT SELECT switch.

After the DIGIT SELECT test passes, the program returns to the select mode.

Display Test (Test 2)

When this test is selected and START switch is pressed, 2.0 is displayed. The display then cycles through the display characters and tests the LED indicators. After that the program returns to select mode.

A/D Test (Test 3)

This tests the A/D integrated circuit. If error indicator “E” is displayed, the START switch must be pressed to continue.

E 3.0 – Failure when measuring +12 V.

E 3.1 – Failure when measuring –12 V.

E 3.2 – Failure when measuring 0.0 V.

HV Bias Test (Test 4)

Remove the detector before executing this test, which tests the high voltage bias supply and digital pot. If an error is encountered, START switch must be pressed to continue.

Before starting this test, turn on the bias voltage. If the test is begun with the bias off, the bias on/off LED will blink, reminding you to turn on the bias. It takes about a minute to stabilize the high voltage.

E 4.0 – Pot cannot be set to lowest setting.

E 4.1 – Pot fails mid-point check.

E 4.2 – Pot fails high setting check.

E 4.3 – Pot fails step-size check.

After completing the Bias test, turn off the bias switch.

Calibration Pulser Pot Test (Test 5)

Tests calibration pulser digital pot. If an error is encountered, START switch must be pressed to continue. This test is a long one, please wait for it to finish.

E 5.0 – Pot cannot be set to lowest setting.

E 5.1 – Pot fails mid-point check.

E 5.2 – Pot fails high setting check.

E 5.3 – Pot fails step-size check.

Discriminator Digital Pot Test (Test 6)

Tests discriminator digital pot. If an error is encountered, START switch must be pressed to continue.

E 6.0 – Pot cannot be set to lowest setting.

E 6.1 – Pot fails mid-point check.

E 6.2 – Pot fails high setting check.

E 6.3 – Pot fails step-size check.

Pulser/Amp/Discriminator Test (Test 7)

Checks that test pulser, amplifier and discriminator are calibrated and work correctly as a system.

E 7.0 – No counts detected with discriminator level below pulser level.

E 7.1 – Erroneous counts detected with discriminator level above pulser level.

E. Chamber Cleaning

Before cleaning the chamber, you should remove the detector and the plastic shelf holder insert. To remove the plastic insert, unscrew the nut at the bottom of the chamber using a 13 mm ($\frac{1}{2}$ in.) wrench. When reinstalling the plastic insert, remember that the nut holding the insert also provides the force necessary to seal the valve to the chamber. The nut should be tightened firmly. Since the vacuum is drawn through the bushing at the bottom of the can, be careful to avoid contaminating the vacuum path. Plug the hole if necessary. Also avoid introducing cleaners into the vacuum gauge mounted at the top of the chamber.

If the large detector mounting bushing is removed for any reason or if the detector BNC/Microdot connector is removed from the bushing, care must be taken when re-threading the plastic parts. Care must also be exercised when removing and replacing the rubber gaskets and O-rings. A sharp tool can damage the rubber parts. Nitrile (Buna N) and flourocarbon rubbers are used for the gaskets. If a gasket has been wiped clean, smooth on a light coat of silicone vacuum grease with the fingers before reassembling.

F. Installation Considerations

This unit complies with all applicable European Union requirements.

Compliance testing was performed with application configurations commonly used for this module; i.e. a CE compliant NIM Bin and Power Supply with additional CE compliant application-specific NIM were racked in a floor cabinet to support the module under test.

During the design and assembly of the module, reasonable precautions were taken by the manufacturer to minimize the effects of RFI and EMC on the system. However, care should be taken to maintain full compliance. These considerations include:

- A rack or tabletop enclosure fully closed on all sides with rear door access
- Single point external cable access
- Blank panels to cover open front panel Bin area
- Compliant grounding and safety precautions for any internal power distribution
- The use of CE compliant accessories such as fans, UPS, etc.

Any repairs or maintenance should be performed by a qualified Canberra service representative. Failure to use exact replacement components, or failure to reassemble the unit as delivered, may affect the unit's compliance with the specified EU requirements.

Warranty

Canberra (we, us, our) warrants to the customer (you, your) that for a period of ninety (90) days from the date of shipment, software provided by us in connection with equipment manufactured by us shall operate in accordance with applicable specifications when used with equipment manufactured by us and that the media on which the software is provided shall be free from defects. We also warrant that (A) equipment manufactured by us shall be free from defects in materials and workmanship for a period of one (1) year from the date of shipment of such equipment, and (B) services performed by us in connection with such equipment, such as site supervision and installation services relating to the equipment, shall be free from defects for a period of one (1) year from the date of performance of such services.

If defects in materials or workmanship are discovered within the applicable warranty period as set forth above, we shall, at our option and cost, (A) in the case of defective software or equipment, either repair or replace the software or equipment, or (B) in the case of defective services, reperform such services.

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Our warranty does not cover damage to equipment which has been altered or modified without our written permission or damage which has been caused by abuse, misuse, accident, neglect or unusual physical or electrical stress, as determined by our Service Personnel.

We are under no obligation to provide warranty service if adjustment or repair is required because of damage caused by other than ordinary use or if the equipment is serviced or repaired, or if an attempt is made to service or repair the equipment, by other than our Service Personnel without our prior approval.

Our warranty does not cover detector damage due to neutrons or heavy charged particles. Failure of beryllium, carbon composite, or polymer windows, or of windowless detectors caused by physical or chemical damage from the environment is not covered by warranty.

We are not responsible for damage sustained in transit. You should examine shipments upon receipt for evidence of damage caused in transit. If damage is found, notify us and the carrier immediately. Keep all packages, materials and documents, including the freight bill, invoice and packing list.

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