QUAD ALPHA SPECTROMETER Model 7404

0288

Operator's Manual

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Section 1. Introduction

The Canberra Model 7404 is a four-channel Alpha Spectrometer with built-in power supply, vacuum gauge, detector bias supply, test pulse generator, leakage current monitor, and preamplifier/amplifiers. The 7404 is complete. It interfaces directly to an MCA having a mixer-router input without the need for additional instrumentation to complete a four-channel Alpha Spectrometer System. The 7404 offers unequalled performance in terms of counting geometry, ease-of-use, diagnostic capability, maintainability and versatility.

The 7404 is designed for maximum flexibility in sample size and geometry. The sample holder can be readily adjusted for 0 to 30 mm detector-sample spacing. Spacers are available for a wide variety of sample diameters up to 50 mm (2 in). The sample holder itself can be biased with a dc voltage of 0 to -12 volts to help prevent detector contamination due to recoil. In addition, the sample holder swings out toward the operator for ease of loading samples. It is locked in position beneath the detector when the chamber door is closed to start a counting cycle. The sample holder is fabricated from stainless steel for low background contribution.

A built-in power supply provides ±12 V dc and ±24 V dc power for the internal electronics and for the Model 7404-01 preamplifier/amplifier modules which process signals from the detectors. It also provides 0 to -12 V dc (internally adjustable) bias for the sample holders to help prevent detector contamination due to recoil.

A low noise, four channel, 0 to ±200 V dc power supply is provided for detector bias. The bias voltage for each of the four detectors is independently adjustable by means of front panel screwdriver controls. The bias voltage is monitored by a built-in 3½ digit panel meter. Polarity of the bias voltage is internally selectable. The bias supply is interlocked to the vacuum gauge to ensure that bias is not applied during poor vacuum conditions. Bias is disabled when the pressure inside the chamber is above an internally preset level. A front panel indicator tells the operator when the preset pressure level is reached and bias is applied.

The detector bias rises with an internally selected time constant of 1 to 5 minutes. In case of power failure, or vacuum system malfunction, bias voltage is reduced quickly to avoid possible damage to the detectors due to microplasma breakdown.

The 7404 provides a means for measuring detector leakage current using the built-in 3 1/2 digit panel meter. This exclusive feature allows the user to diagnose detectors and to optimize the performance of detectors in a way never before possible. By measuring their V-I characteristics, the user can select the optimum operating voltage—thereby improving system performance and/or extending the useful life of detectors.

The vacuum chamber of the 7404 is equipped with a thermocouple vacuum-gauge tube which is read out by the digital panel meter. This provides the user with a ready means of determining vacuum conditions within the detector chamber. The vacuum gauge is interlocked to the detector bias circuit to prevent application of bias while vacuum conditions are poor.

The 7404 in conjunction with its complementary 7404-01 Preamplifier/Amplifier provides independently controlled calibrated test signals which can be used to calibrate the detector system without the use of alpha sources. In the test mode, the panel meter displays test signal energy for each of the four channels. By means of front panel and offset controls on the Preamplifier/Amplifier, each channel can be calibrated to the exact energy range desired.

The 7404 vacuum chamber is helium leak tested to 10^{-10} standard cc/sec. The chamber door is equipped with precision hinges which automatically adjust for O-ring compression and hardware tolerances. Vacuum is controlled by means of a stainless steel, three-way, solenoid valve which is interlocked to the bias network and vacuum monitor to prevent accidental damage to detectors. The chamber may be vented to and purged by an inert gas during sample changes to prevent introduction of contaminants such as radon during sample changes.

The 7404 is equipped with a special filter to prevent back-streaming of vacuum pump oil into the detector chamber.

The Model 7404-01 Preamplifier/Amplifier provides signal conditioning and amplification which is optimal for the type of detectors used in Alpha Spectroscopy. It accepts power, bias and test signals from the 7404 by means of a 9-pin connector. Bias and test signals can be monitored as applied also via BNC connectors on the rear panel. The amplifier output is available on a rear BNC and on a front panel test point.

The gain is continuously adjustable for X 1 to X 2.5 by means of a 22-turn screwdriver control on the front panel. The output offset is also adjustable by means of a front panel 22-turn control. The range of dc offset is ±200 mV dc. The sensitivity is 1 V/MeV.

The 7404-01 is a plug-in module which can be removed for bench testing and ready replacement in the field. Critical spares of this sensitive system component are available off-the-shelf.

Section 2.
Specifications

2.1 SYSTEM PERFORMANCE
(Based on use of PD-450-20-100M Detector)
ENERGY RESOLUTION - 20 keV (FWHM)
EFFICIENCY - ≥ 25%
BACKGROUND - ≤ 1 count/hr. above 3 MeV
SAMPLE SIZE - up to 50 mm (2 in.) diameter
SAMPLE SPACING - 1 to 30 mm from detector

2.2 ELECTRONICS
BIAS SUPPLY
RANGE—0 ± 199.9 volts
STABILITY—≤ 50 ppm/°C
NOISE—≤ 5 mv peak-to-peak
DISPLAY RESOLUTION—0.1 volt
CALIBRATION PULSER
STABILITY—≤ 50 ppm/°C
RANGE—0 to 19.99 MeV
DISPLAY RESOLUTION—10 keV
DETECTOR CURRENT MONITOR
RANGE—0 to 19.99 μA
DISPLAY RESOLUTION—0.1 μA
SAMPLE BIAS SUPPLY
RANGE—0 to -12 V dc (internally adjustable)
VACUUM GAUGE
RANGE—0 - 1000 microns (standard)
-0 - 19.99 torr (optional)
Chart provided for converting meter reading to pressure level at extremes of scale.
PREAMPLIFIER/AMPLIFIER (Model 7404-01)
SHAPING—0.5 μsec unipolar, dc restored
NON-LINEARITY—≤ 0.1% of full scale
OUTPUT—0 to 10 volts, positive

2.3 CONTROLS
DISPLAY—Front panel rotary switch selects function displayed: Bias, Leakage, Vacuum, or Test energy.
CHANNEL—Front panel rotary switch selects channel displayed.
BIAS—Front panel screwdriver controls to adjust bias for each of four detectors.
AC VOLTS—Rear panel slide switch to select 115 V ac or 230 V ac operation.
VACUUM INTERLOCK—Rear panel locking toggle switch to enable or disable Vacuum/Bias interlock.
POWER—Rear panel toggle switch enables or disables main power.
TEST—Front panel screwdriver controls to adjust test signal energy for each of four channels.
BIAS ON/OFF—Front panel locking toggle switch enables or disables detector bias.
PUMP/VENT—Front panel locking toggle switch controls solenoid valve to pump or vent sample chamber.
SAMPLE BIAS—Internal control to adjust sample holder bias from 0 to -12 volts dc.
BIAS VOLTAGE RISETIME—Internal control to select 1 or 5 minute time-constant on detector bias.
VACUUM/BIAS INTERLOCK LEVEL—Internal potentiometer adjusts vacuum level at which bias is enabled.
7404-01 AMPLIFIER
GAIN—2 MeV full scale to 10 MeV full scale (10 V)
OFFSET—0 ± 200 mV dc.

2.4 CONNECTORS
7404 CHASSIS (Rear)
SAMPLE BIAS—BNC (factory connected)
VACUUM SOLENOID—Molex 03-06-1031. (Factory connected)
7404-01 PREAMP/AMPLIFIER (Rear)
MULTIFUNCTION—Accepts power, bias and test signals from 7404. Amphenol 17-20090.
HV INPUT—BNC
TEST INPUT—BNC
OUTPUT—BNC

2.5 PHYSICAL
WIDTH - 48.3 cm (19 in.)
HEIGHT - 17.8 cm (7 in.)
DEPTH - 34.3 cm (13.5 in.)
WEIGHT - 8.8 kg (19.5 lb.)

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Section 3A.
Controls and Connectors -7404 Chassis

3A.1 FRONT PANEL:

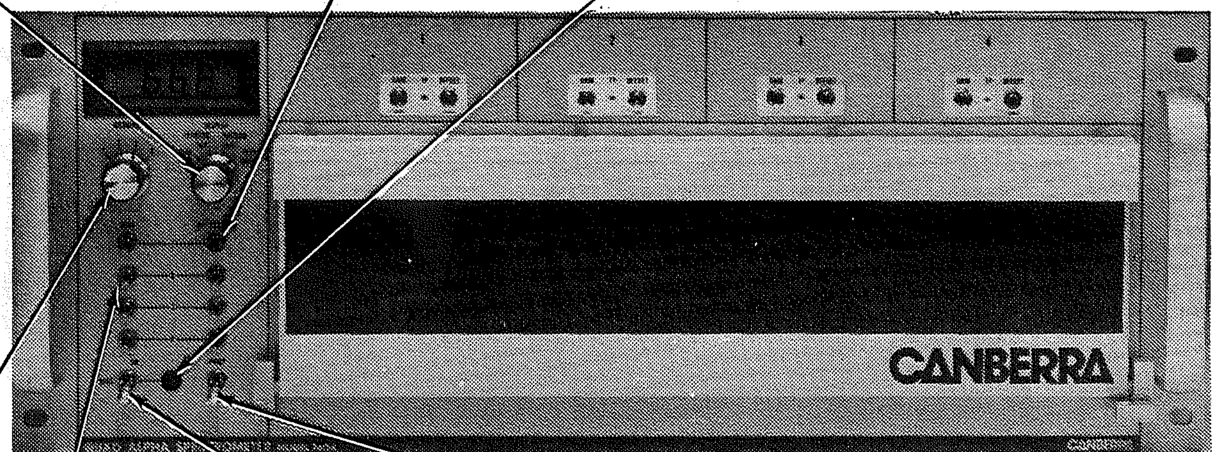


Figure 3A.1
Front Panel

3A.2 SIDE PANEL:

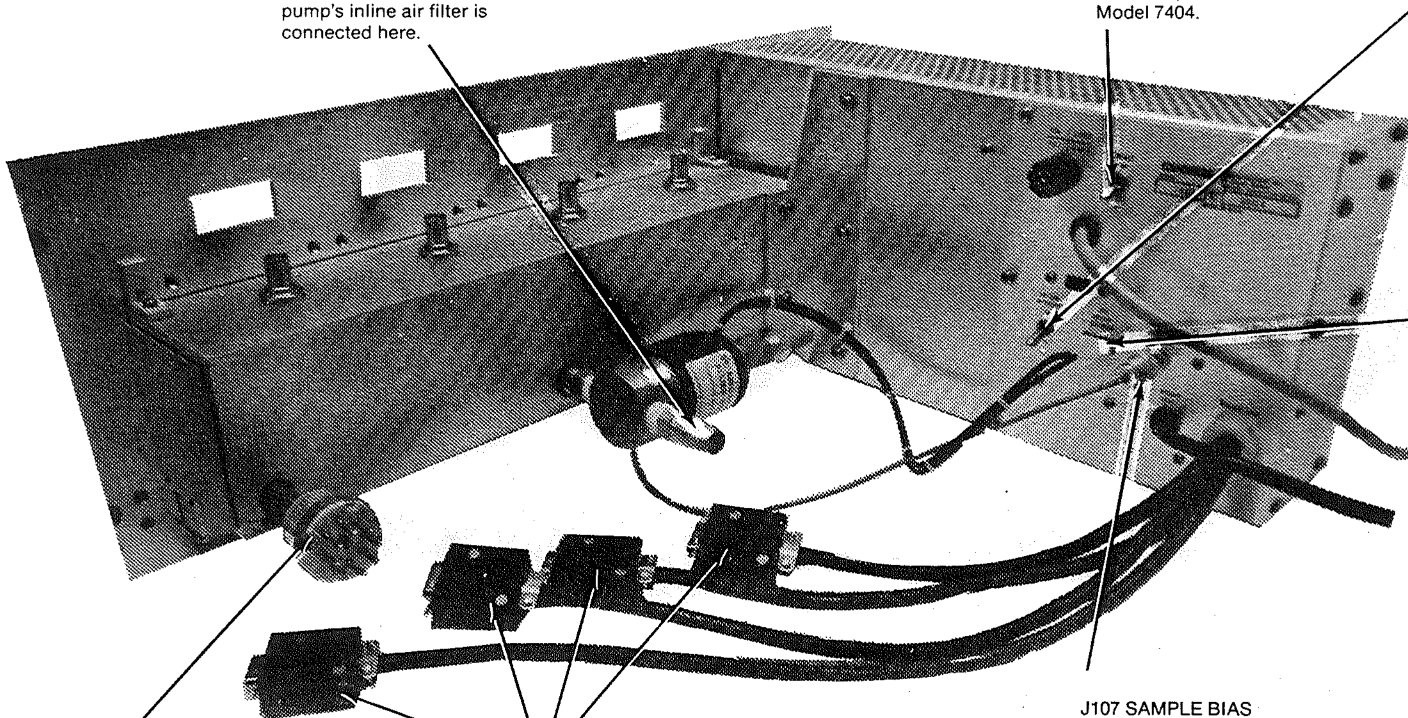


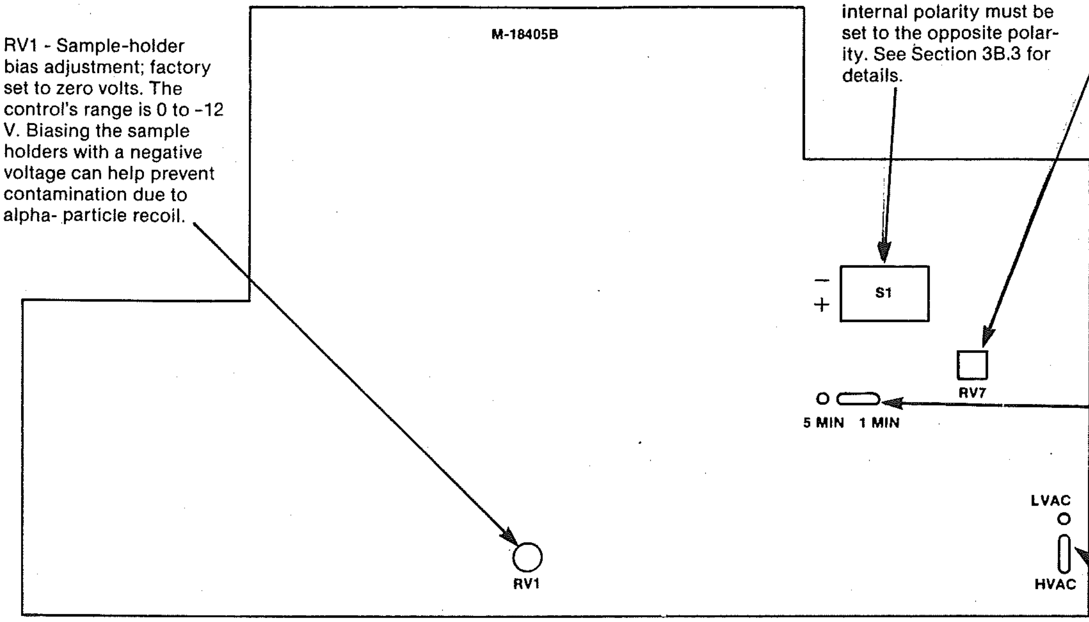
Figure 3A.2
Side Panel

3A.3 INTERNAL CONTROLS:

RV1 - Sample-holder bias adjustment; factory set to zero volts. The control's range is 0 to -12 V. Biasing the sample holders with a negative voltage can help prevent contamination due to alpha- particle recoil.

S1 - Bias Polarity switch; factory set for "+". Note that the Model 7404-01's internal polarity must be set to the opposite polarity. See Section 3B.3 for details.

RV7 - Bias Enable Vacuum Level control. Factory set so that the bias supply can be enabled by the front panel BIAS ON switch when the pressure reaches 100 microns. The control has a range of zero to about one-half of the full pressure range. See Appendix A for further information and adjustment instructions. This circuit is defeated if the side-panel VACUUM INTERLOCK switch is OFF.



BIAS RISETIME - Internal jumper to select 1 or 5 minute time constant on detector bias. Unit is shipped with jumper in the 1 minute position.

H VAC/L VAC - Not a user changeable option. Leave this jumper in the factory set HVAC position.

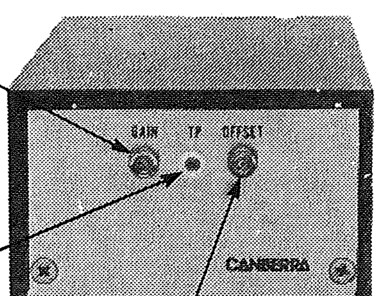
Figure 3A.3
Internal Controls

Section 3B.
Controls and Connectors, 7404-01 Preamp/Amp

3B.1 MODEL 7404-01 FRONT PANEL:

GAIN - Adjusts the amplifier gain from 1 V/MeV to 2.5 V/MeV.

TP - Test Point which allows observation of the amplifier output. Note: a high-impedance probe (a X10 oscilloscope probe) must be used to avoid false readings due to circuit loading.



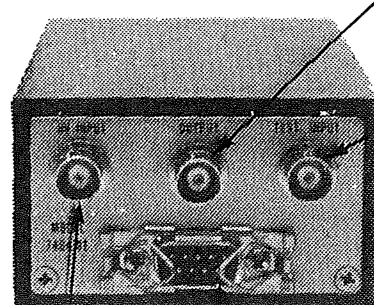
OFFSET - Allows the amplifier dc output level to adjust for ADC and/or mixer router offset. Range: ≥ ± 200 mV.

Figure 3B.1
Front Panel

3B.2 REAR PANEL:

OUTPUT CONNECTOR Used to connect the amplifier output signal to the Mixer/Router or ADC input.

TEST INPUT CONNECTOR - Can be used for external Test Pulser (such as the Model 8210) if the internal Test Pulser is first disconnected. (Can be used to check that correct test signal is present at the 7404-01.)



HV INPUT CONNECTOR Can be used for external detector bias supply if the internal bias supply is first disconnected. (Can be used to check that correct bias is present at the 7404-01).

9-PIN AMPHENOL CONNECTOR - Provides power, detector bias, and test signals from the Model 7404.

Figure 3B.2
Rear Panel

3B.3 POLARITY CONTROL:

In the center of the Model 7404-01 printed circuit board there is a single polarity jumper. This jumper must be set to match the polarity shown on the Digital Panel Meter when the DISPLAY switch is in the TEST position. Note that the negative sign is displayed; the positive sign is not displayed. This sign is set by the position of the Model 7404 bias polarity switch; changing this polarity will change the displayed sign. Be sure to change the Model 7404-01 polarity jumper to match the TEST DISPLAY sign.

Factory set to negative.

Section 4. Operation

4.1 INSTALLING THE DETECTORS

CAUTION - 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.

Avoid microplasma breakdown - Read Appendix B, the SSB Detector Instruction Sheet before installing the detectors.

To install a detector the sample holder must be all the way down on its support rod. To move the holder, loosen the clamp screw and slide the holder down the rod.

Swing the holder out of the chamber and screw the detector (with the plastic cover in place) 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. Now swing the sample holder back into the chamber.

Install all of the remaining detectors in the same way, one at a time.

4.2 CONNECTING THE PUMP

The vacuum pump is connected to the Model 7404 with one-half inch (inner diameter) tubing. The filter should be placed in the vacuum line between the pump and the Model 7404.

4.3 CONNECTING THE MULTICHANNEL ANALYZER

Using 93 ohm cable (type RG-62) connect the output of each 7404-01 to one of the Mixer/Router INPUT connectors.

4.4 SETTING UP THE SYSTEM

With the detectors installed and no samples in the chamber, close the door and check the following control positions.

CONTROL	POSITION
Vacuum Interlock (Rear)	ON
Pump/Vent (Front)	Vent
Display (Front)	Vacuum
Power (Rear)	OFF
Bias (Front)	OFF
Bias Potentiometers (Front)	Fully Counterclockwise (No Stop, 22 turns)

1. Start Vacuum Pump.
2. Turn on rear power switch.
3. Put pump/vent switch in PUMP position. Gurgling sound should stop after a minute or so if there are no big leaks in the vacuum line.
4. Turn on the front panel BIAS switch. Bias will not be applied until vacuum reaches the internally preset level. This may take several minutes. It is dependent on the size and type of vacuum pump and vacuum tubing.

4.5 SETTING BIAS

Starting with the bias at zero, each channel should be increased slowly (turning bias potentiometers clockwise) to the recommended voltage while monitoring the DPM. Refer to Appendix B, the SSB Detector Instruction Sheet, for the method used in applying bias to a new detector. Note that generally 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 1 to 5 minutes when the bias switch is activated, and the vacuum conditions are correct. The time constant is factory set to 1 minute, but may be changed by an internal switch. The bias should always be turned off manually before the chamber is vented, and the door is opened. Also it should be manually turned on only after the door has been closed and the pump down has started.

4.6 SYSTEM CALIBRATION

The purpose of a calibration procedure is to set up the system so that the energy range of interest is correctly acquired by the multichannel analyzer, with the desired resolution. In this process the amplifier and ADC controls will be set to attain a known correspondence between the detected alpha particle energy and the MCA channel number. Throughout the following discussion this relation is referred to as the calibration factor, and is reported in KeV/ch.

The controls used, their influence on the system, and the calibration procedure are described following.

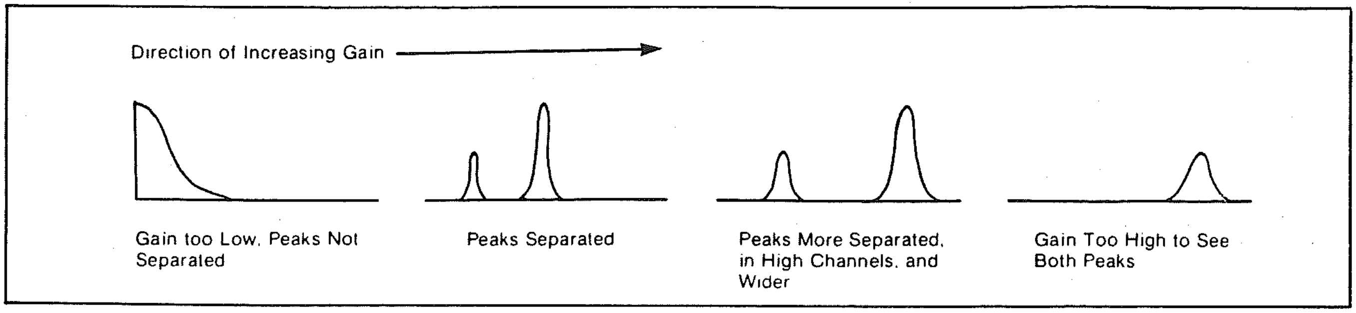


Figure 4.1
Effect of Increasing Amplifier Gain On Peak Position and Width

A. Amplifier Gain Control
One of the functions of the amplifier is to transform a low level pulse from a preamplifier to a higher level pulse more suitable for acceptance by the MCA's ADC. The preamplifier output pulse is in the millivolt range, whereas the ADC requires pulses up to 10 volts. Thus the gain of the amplifier must be set so that the pulses from the detector that correspond to the energy of interest fall within the 0-10 volt range. The diagram below shows the effect of increasing the amplifier gain on the MCA memory. Note that as the gain is increased not only do the peaks move to higher channels, but the distance between the peaks becomes greater, and the peak width is greater. Thus this control affects the calibration factor (i.e. Kev/ch)

B. Amplifier Offset
By adjusting the amplifier offset control, a small amount of dc voltage (±200 mV dc) is added to or subtracted from the amplifier output signal. Its effect on the MCA memory is to move peaks to higher or lower channels.

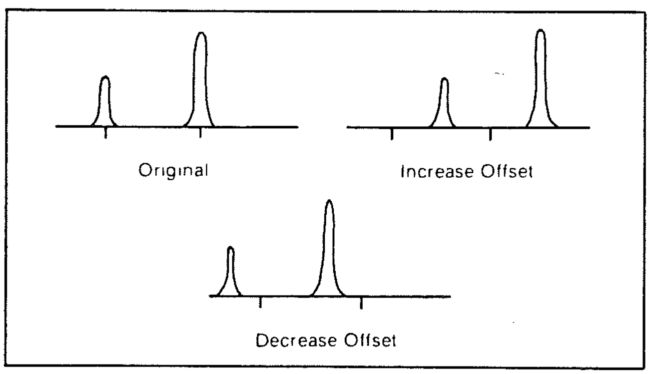


Figure 4.2
Effect of Amplifier offset

In this case only the position of the peaks changes. The distance between peaks and the peak widths remains the same.

C. ADC Gain
The purpose of the ADC is to derive a digital number that is proportional to the amplitude of the pulse presented at its input. This number will correspond to a channel number in the MCA. The gain of the ADC determines the number of parts that the 10 volt input range is divided into. The more parts the better the resolution, until eventually you reach the limits of the detector and front-end electronics. The diagram below shows the effects of ADC gain on resolution.

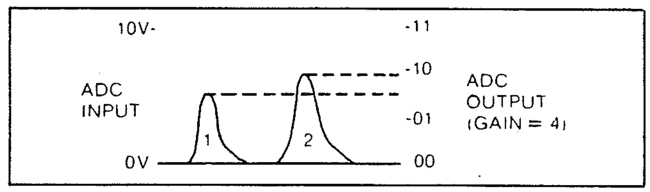


Figure 4,3a
Input Pulses

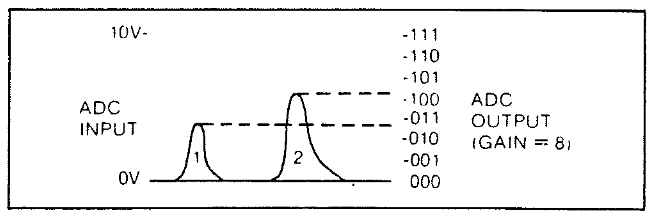


Figure 4.3b
Input Pulses

Note that the low gain ADC of Figure 4.3a cannot discriminate between input pulses one and two, yet they are clearly of different heights. The ADC output for each pulse would be the same, channel number 1.

In Figure 4.3b the ADC gain is higher, and thus it can discriminate between the two pulses. The output from this ADC would be channel number 2 for the first pulse and channel number 4 for the second.

Most MCAs today have gains of at least 1024 channels, and many go to 8192 to take advantage of very high resolution detectors. This means that with 1024 gain each input pulse can be resolved to within 9.8 millivolts. With 8192 gain each pulse is resolved to within 1.2 millivolts.

Changing the ADC gain is similar to changing the amplifier gain. For a specific energy range it will change the peak position, the distance between the peaks (i.e. the calibration factor), and the peak width. See the following diagram of MCA displays.

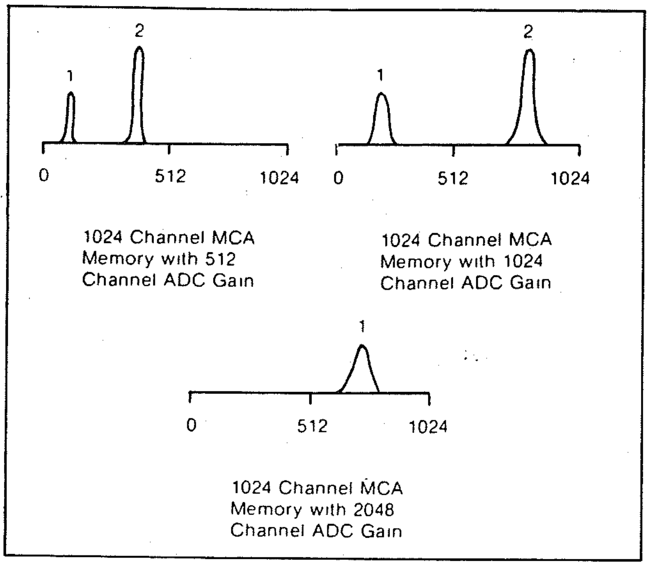


Figure 4.4
Effect of ADC Gain

D. ADC Offset
If the ADC gain is higher than the number of channels available in the MCA, part of the spectrum will be lost. See diagram below.

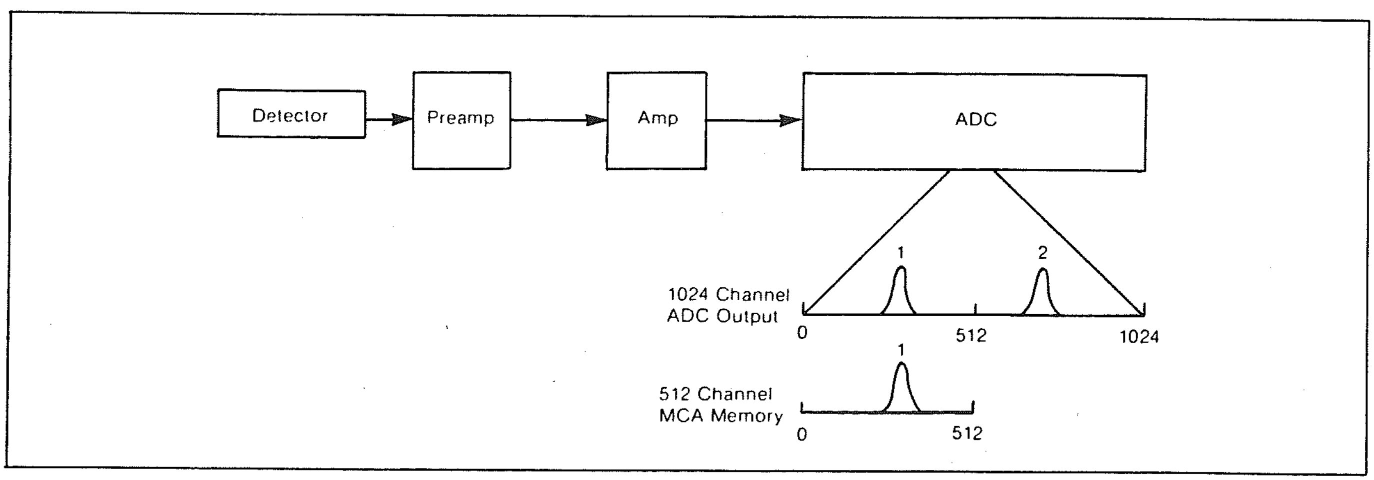


Figure 4.5
Effect of ADC offset

In this case the ADC is dividing the 0-10 volt input from the amplifier into 1024 channels. However, the MCA memory only has 512 channels available. Thus the data in channels 513 to 1024 is lost. This includes peak number 2. If the ADC gain was changed to 512, the entire spectrum would suffer since the 0-10 volt ADC input is now with 1024 channels. If both peaks are to be displayed with 1024 channel resolution, the offset control must be used. This points out the purpose of offset, which is to be able to display a peak with an ADC gain that is higher than the memory size.

For instance, the effect of introducing 512 channels of offset is to display ADC channels 513-1024. See the following diagram.

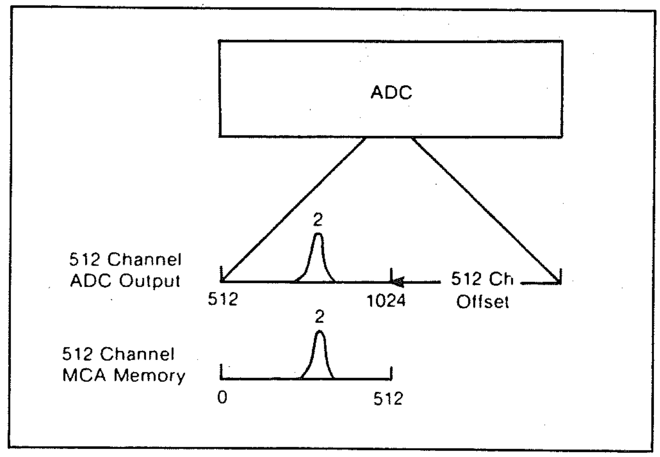


Figure 4.6
Effect of 512 Channel Offset

In this case since both peaks are within 512 channels of each other, both can be simultaneously displayed with 1024 channel resolution by using a 256 channel offset.

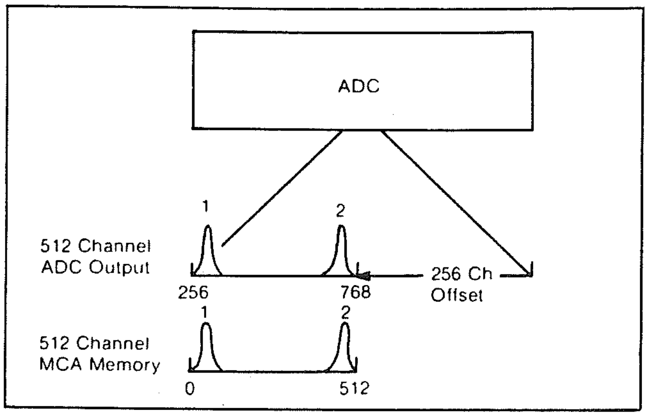


Figure 4.7
Effect of 256 Channel Offset

Note that the offset control changes only the peak position.

E. ADC Zero
This control determines the value of the ADC input voltage at which the ADC starts converting. In most cases this control is set so that the conversion process starts at zero (i.e. zero energy = channel # 0). It has the effect of changing the peak position, but not the distance between peaks or the peak width. To check the ADC zero the distance between two known peaks, both number of channels and energy difference, should be determined. From this the calibration factor (Kev/cH) can be calculated. Dividing the peak energy by this value, and then subtracting this from the peak channel number will give the channel number of zero energy. To put zero energy in channel zero, adjust the ADC zero control so that

$$\text{Peak Channel Number} = \frac{\text{Peak Energy}}{\text{Calibration Factor}}$$

During the process all other controls should remain constant, since they can influence peak position and the calibration factor. However, once the ADC zero control is set, none of the above mentioned controls will affect the zero energy position.

F. Calibrating for a Specific Energy Range
The following procedure assumes that the system has been set up as outlined in sections 4.4 and 4.5, and that the ADC zero has been set to zero.

1. **Determine the Energy Range of Interest**
   The energy range is calculated by subtracting the highest energy of interest from the lowest energy. For instance, if the isotopes of interest are ^{230}Th (4680 keV) and ^{244}Cm (5805 keV), a range larger than 1125 keV (5805-4680=1125) would be required if all of each peak is to be included. In this case a range of 1500 keV from 4500 keV to 6000 keV would be suitable.

2. **Determine the Calibration Factor (keV/ch) to Adequately Acquire the Peaks of Interest**
   The resolution of the detector, and the desired number of channels in the full-width-half-maximum (FWHM) of an energy peak will determine the calibration. The required calibration factor equals the detector resolution divided by the number of channels in the FWHM. A sample calculation would proceed as follows:

   For good resolution the FWHM should be at least 4 channels wide, or more if better resolution is desired. If the detector has a typical resolution of 24 keV, then the necessary calibration factor would be 6 keV/ch (24 keV/4 ch = keV/ch).

3. **Determine the size of the MCA Memory Required**
   The number of memory channels required for each detector can be calculated by using the results of the previous two steps. Simply divide the energy range by the calibration factor. For instance in step 1 the energy range was determined to be 1500 keV and the calibration factor to be 6 keV/ch. Thus the number of channels required is 250 (1500/6 = 250).

   Often MCA memory segments are divided up into binary increments such that the choice of memory could not be exactly 250 channels but one large enough to contain 250 channels. In the case of an MCA having 1024 channels with the provision for dividing the memory in quarters, a 256-channel segment would be chosen for each detector.

4. **Select ADC Gain**
   The ADC gain has to be large enough to include the highest energy peak using the previously selected calibration factor. Dividing the energy of this peak by the calibration factor will determine the lower limit of the ADC gain.

   For example, if the maximum peak energy is 5805 keV and the calibration factor is 6 keV/ch, then the mininum ADC gain is 967 channels (5805/6 = 967). The gain should be chosen to be slightly greater than 967 so that all of the upper peak is included.

   In this case a choice of 1024 channels would be adequate.

5. **Select the ADC Offset**
   By knowing the calibration factor, the channel in which each peak will occur can be calculated (channel number = peak energy/calibration factor). Then the offset required to place these peaks in the available memory can be selected. The highest energy peak will occur in channel number 967 (5805/6 = 967) and the low energy peak in channel number 780 (4680/6 = 780). Since the peaks occur in channels 769 through 1024 of the ADC, an offset of 768 channels (1024-256=768) is required. This calculation is simply the memory size subtracted from the ADC gain. If offset were not used, only channels 0 through 256 would be stored in memory, and these would not contain the desired information.

6. Adjust Amplifier Gain and Offset

The amplifier gain and offset are conveniently adjusted by using the built-in pulser. The gain control is used to set the number of channels between two pulser peaks to equal the energy difference between the peaks divided by the calibration factor.

For example, if the two energies of interest are 5805 keV and 4680 keV than the number of channels between them is 187 ((5805-4680)/6 = 187).

The offset control is then used to place the peaks in the proper channels. The channel number for each peak was determined in the preceding step.

To adjust the amplifier gain and offset proceed as follows:

A. Set the MCA memory size, ADC gain and ADC zero to the value calculated in steps 3, 4, and 5.

B. Set pulser for chamber number one of the 7404 to equal the high energy peak.

C. While collecting into the MCA memory adjust the amplifier gain so that this peak appears in the channel number calculated in step 5.

D. Set pulser for chamber number one of the 7404 to equal the low energy peak, and collect this spectrum into the MCA.

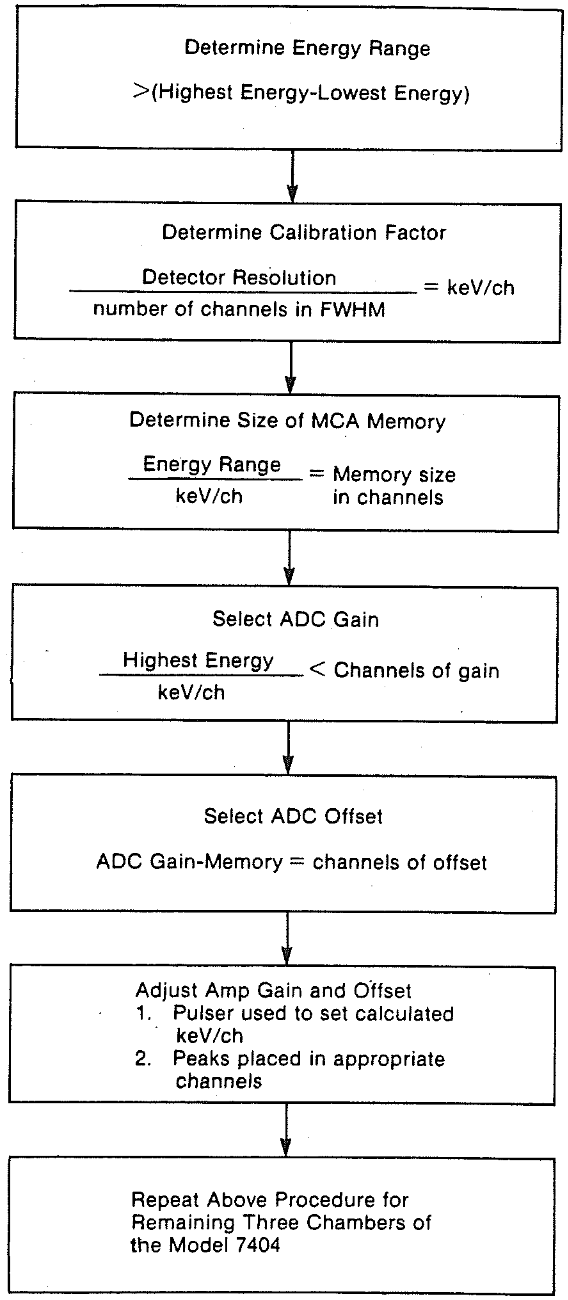
E. By observing the MCA display determine the number of channels between the peaks. If it is lower than expected increase the amplifier gain, if higher decrease the gain.

F. Again set the pulser to the high energy peak and collect the spectrum using the offset control to place the peak in the proper channel.

G. Repeat the above three operations until both the high energy and low energy peaks are collected into the channel numbers that were calculated in step 5. This normally takes several iterations; however, with practice only a few are required.

H. Now that chamber number one of the 7404 is calibrated repeat the above procedure for the remaining three chambers.

7. Summary of the Calibration Procedure



4.7 SAMPLE HOLDER BIAS

Before starting an alpha particle experiment, you may want to set the negative sample-holder bias to prevent alpha particle recoil.

The holders can be biased at any point in the range of zero to -12 volts; the bias is factory set to zero.

To set the bias, remove the left-side cover of the Model 7404 and adjust RV1 while monitoring one of the sample holders with a voltmeter. All sample holders will be biased to the same voltage.

After the bias is set, replace the side cover and all eight screws. The three screws in the middle of the cover must not be left out since they connect the power supply's heat sink to the cover. This connection must be made to provide proper power supply cooling.

4.8 SAMPLE PLACEMENT

With the chamber vented, open the door and set the height of each sample holder as desired. This can easily be done by loosening the clamp screw and moving the holder up or down on its mounting rod, then tightening the screw.

Note that there is a scale at the back of each chamber which can be used as a reference in positioning the holder.

Swing the first holder out and place the sample in the center of the holder, then swing the holder all the way back into the chamber. Repear for each chamber.

When all samples are in place, close the door and move the PUMP/VENT switch to the PUMP position.

When the chamber is pumped down and the Bias voltages have stabilized, data collection may be started.

At the end of the experiment, set the BIAS switch to OFF, move the PUMP/VENT switch to the VENT position, wait for the chamber to vent completely, and open the door to remove or replace the samples.

Section 5. Theory of Operation

5.1 PREAMP/AMP

The Model 7404-01 Preamp-Amp incorporates a 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 Q3, differential amplifier Q1 and Q2, output follower FET Q4, and current sinks Q9 and Q10. This group of devices functions as an inverting feedback amplifier whose closed-loop gain is set by the charge-integrating capacitor C15. Internal bias-currents for FET Q1, 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 R16. This component serves to discharge C15 following each charge integration, and sets the tail-pulse shape of the preamplifier at a nominal 470 μsec decay time constant. Diode D1 provides protection for Q1 from the transient voltages experienced from momentary breakdowns in the detector bias curcuit due to accidental faults.

The test input includes a calibration adjustment potentiometer RV2 which is factory set to allow a controlled voltage-pulse input to generate a shaped output signal that is calibrated to read out in MeV. Thus the user can precalibrate this region of interest without having to use a known open source. All Preamp/Amps are calibrated for identical sensitivity on the test input, and units can be interchanged without compromising the energy calibration derived from the control unit.

Following the charge integrator is a pole/zero compensated differentiator (C5, R20) set for a nominal 0.5 μsec. The now abbreviated tail pulse is amplified by a fixed gain non-inverting feedback amplifier formed by differential pair Q7 and Q8, driver Q5, and push-pull outputs Q6 and Q11. The preset gain of 30 raises the signal level to a more convenient level for the shaping process to follow.

Preliminary integration is provided by R26, L4, and C20 before the signal is fed to the split-load inverter Q12, which permits polarity selection by the internal jumper plug. Q13 buffers the signal before the second integration is realized in R32, L5 and C24. The filtered signal is then amplified again by A1, which incorporates the front-panel-mounted gain control in its feedback path. The signal is usually a positive-going pulse at this point, and D4 limits the excursion by clamping the output of A1 to enhance prompt overload recovery. Capacitor C26 couples the positive pulse into the simple restorer provided by Q15.

This circuit stabilizes the dc reference level for the pulse so as to permit a proper baseline from which the output may be quantized in an ADC or SCA.

Output amplifier A2 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 A2 or output transistor Q14 and insure prompt overload recovery.

The output is a unipolar semi-Gaussian pulse conforming to a nominal 0.5 μsec shape. 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.

5.2 CONTROL UNIT

The control unit which forms the chassis of the Model 7404, includes the power supplies for the detectors and Preamp/Amps, the thermocouple vacuum gauge circuitry, the calibration pulser, and the digital display. As can be seen on the schematic, interlocking, switching, and sensing is necessary for the proper integration of these subsections.

The power supply operates in a conventional manner, using a multiple-secondary power transformer. The primaries are switch-selected in series or parallel by S102 for use with 230 V ac or 115 V ac input respectively. The internal ±12 and ±24 V dc are derived from full-wave rectifiers, capacitor filters, and three terminal regulators. The detector bias is derived from a full-wave rectified, capacitor-filtered level which is controlled by a discrete component series regulator. The output polarity and control signal are selected by a board-mounted toggle switch (S1). The reference voltage is derived from D10 as adjusted by RV8. A time-delay interlock keeps the detector bias regulator cut off until satisfactory chamber vacuum is detected (A4 pin 7 low, and Q12 off to remove the short across D10). Upon activation of this loop, C11 is charged through R8 or R9 until Q10 and Q11 permit D10 to achieve normal bias. This delay and exponential rise permit detector bias to be applied slowly at a controlled rate to prevent damage due to surface breakdown.

The thermocouple vacuum gauge is biased from a controlled ac current source derived from the back-to-back Zener diodes D18 and D19, and through RV11 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. A1, a multiple segment op-amp function generator, reshapes the small thermocouple voltage to an analog representation of the vacuum. The calibration for this is performed during assembly and test so that a reasonable indication of vacuum may be monitored by A4 so that when a preset (usually 100 micron) vacuum is present in the chamber the detector bias-circuit may be enabled. RV7 permits adjustment of this threshold. When A4 is satisfied, it switches off Q12 and drives the front panel BIAS-indicating LED on, to show that the detector bias interlock is enabled.

The calibrated pulser is derived from Zener diodes D25 or D26, as selected by S1. Individual front panel adjustment potentiometers feed their selected dc voltage level to a mercury-wetted relay to charge capacitor C27. The dc level is also divided through R56, RV2 and R55 to drive the front panel digital display. The charge on C27 is switched by the relay to the shaping network R57-C28 to control rise time, and R59 to control decay time before being fed to the test input of the Preamp/Amp selected by the front panel switch (S3).

The digital display is selected to monitor detector bias voltage, detector leakage current, vacuum, or pulser energy calibration for the desired channel. The meter has a liquid crystal 3 1/2 digit display whose decimal point location is automatically moved by the function selection switch (S2). The divided down voltage of the selected channel (RV10 adjustment for calibration), leakage current through a 10 ohm sensing resistor, vacuum reading (R50, R51), or pulser energy equivalent (RV2) are sensed and displayed.

The last feature of note is the pump/vent solenoid. This is controlled by S4, a multiple path switch which also directs the sensing and detector bias interlock. The solenoid is a three-way device which opens the chamber to the external environment in VENT (deactivated coil), or connects the chamber to the vacuum-line filter and external vacuum-pump in the PUMP mode (driven coil). To help overcome the forces of the air-vacuum differential when the PUMP mode is selected, the dc power initially supplied to the coil is from a precharged 330 V dc source (the input rectifier bridge is set by S4a to a line voltage doubler in VENT mode), which decays with discharge of the filter capacitors to 160 V dc nominal. In VENT the reference voltage for the detector-bias supply is directly shorted by S4c to remove voltage from the detectors immediately, and prevent damage to them.

Appendix A.
Setting the Bias-Enable Vacuum Level

The Model 7404 is factory-set to enable the bias supply when the vacuum level falls to 100 microns of pressure. It may be set by the user anywhere in the range zero (one atmosphere) to about one-half of the full vacuum range.

The control for adjusting the bias-enable reference is RV7, located inside the unit. Setting RV7 clockwise will decrease the bias-enable threshold to a higher level of pressure (lower vacuum) and correspondingly, a counterclockwise adjustment will increase the bias-enable threshold to a lower level of pressure (higher vacuum).

While looking at the vacuum shown on the Digital Panel Meter, adjust RV7 so that the front panel BIAS indicator turns on at the desired vacuum level.

The vacuum level shown on the Digital Panel Meter is not exactly equal to the actual vacuum level in the unit at any point above 100 microns. The chart curve shows the relationship between real and displayed vacuum.

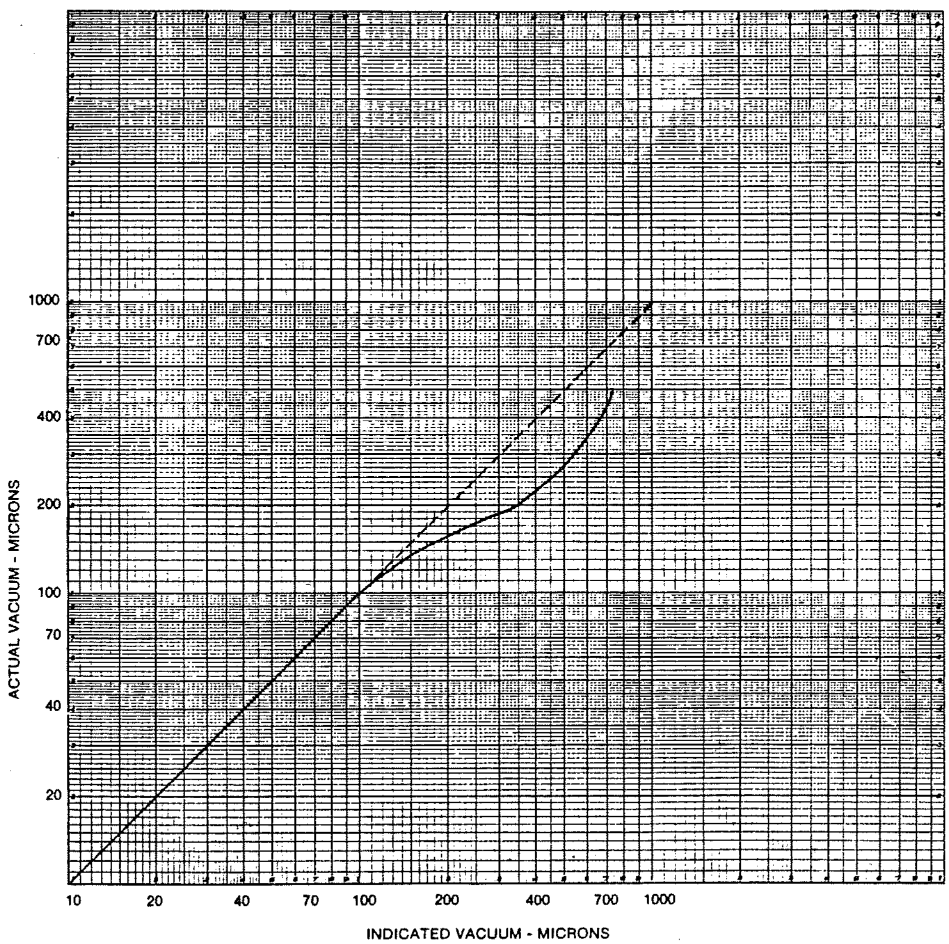


Figure A.1
Indicated vs. Actual Vacuum

APPENDIX B
SSB Detector Instruction Sheet

B.1 PRECAUTIONS IN THE USE AND HANDLING OF SURFACE BARRIER DETECTORS

The following precautions should be observed when handling any surface barrier detector.

1. Avoid mechanical shock.
2. Never allow anything to touch the thin gold electrode on the sensitive surface. Keep the protective cap in place when the detector is not in use. If necessary, use a gentle air stream from a rubber syringe to remove dust or lint. Do not touch the back metal electrode on a transmission mount detector, or the front electrode on light-tight detectors, with anything.
3. The gold electrode on the sensitive surface is not impervious to the passage of large molecules. Therefore, avoid ambients where chemical contamination is present; e.g., mercury vapor, pump oil vapor, organic solvents, ionic salts, acetylene vapors, certain caustic or acid fumes (especially those of a reducing nature), soldering flux fumes, large quantities of water vapor, etc. If the test chamber is cleaned with a solvent such as acetone or alcohol, evacuate the chamber thoroughly several times before installing the detector. If the detector is accidentally exposed to volatile contaminants, thoroughly evacuate the chamber several times with the detector installed, before applying the bias voltage. Where ultimate performance and long term stability are required, it is preferable to use a cold-trapped vacuum system.
4. Monitor the noise level while bias is being applied, especially during the first few times the device is used.
5. Do not apply excessive bias to the detector, nor allow it to operate under breakdown conditions. Unless you are adept at recognizing the onset of microplasma and are willing to risk destroying the diode, do not apply bias in excess of that rated.
6. We recommend that the detector not be removed from its mount. However, if it is necessary to remove it, (e.g., to reverse the polarity of a transmission mount, or in the case of special detectors supplied without a protective can), do not handle the ceramic insulator with your bare hand, since this will leave a low-resistance deposit which can short-circuit the diode or migrate to the diode edge, causing breakdown and/or excessive leakage.
7. When using radioactive sources, avoid unnecessary radiation damage or contamination by closing a shutter in front of the detector when it is not in use. Do not allow high-intensity beams, such as the main proton beam in an accelerator, to fall directly on the detector.
8. To clean detectors that are designed to be decontaminated, use a slightly damp cotton swab or lens tissue; allow the detector to dry thoroughly before applying bias. Contamination acquired from energetic recoils usually cannot be removed because it is driven too deeply into the surface. You may find it expedient to minimize this effect by operating the chamber with a small quantity of residual gas, or by using electrostatic deflection.
9. Do not change the pressure around the diode suddenly while high bias voltage is applied. The preferred procedure is to pump down or let up, slowly, with no bias voltage applied to the detector. If the detector is stored for extended time in vacuum, it is best to leave a small nominal bias applied even when not in use.

B.2 APPLYING BIAS TO THE DETECTOR

After a detector has been stored with no bias applied or after significant changes in ambient, it is sometimes necessary to apply bias quite slowly in order to avoid microplasma breakdown.

Accumulation of moisture and/or ionizable impurities at the junction edge is responsible for this instability, and slow application of bias allows the ionizable imputities to be "drifted" out of the high field region. Avoid applying bias when the device is exposed to the critical pressure region between 1 mm and 50 μ Hg, since this is the pressure region where the problem of surface breakdown on insulators, etc. is most acute. NEVER let up or pump down vacuum system while large bias voltages are applied to the detector. Apply bias only through a large (1 megohm minimum) series resistance. **DO NOT APPLY BIAS IN EXCESS OF THE RATED OPERATING VOLTAGE.** In order to minimize the possibility of destroying the detector by microplasma breakdown, use some means of monitoring the noise, preferably a wideband rms reading voltmeter. If such a meter is not available, qualitative noise measurements may be made with an oscilloscope, or with the discriminator level on a scaler. However, the noise level in many conventional amplifiers and scalers is often too high to allow the latter technique to be used to detect the early onset of microplasma breakdown in the detector.

A meter for monitoring the reverse current is also useful, but observation of the noise is a much more sensitive method for monitoring detector behavior because, near breakdown, the noise increases more rapidly than the reverse current. The reverse current will vary with detector area and from one detector to another, but will usually be in the range of 0.1 to 2 microampere/cm^2.

The following steps should be followed when applying bias to a detector:

1. Apply 10 to 20 volts to the detector. The noise should decrease (assuming a low-noise charge-sensitive amplifier configuration is used).
2. Continue to increase the voltage in small steps, allowing the noise meter to recover from transients to a reasonably steady reading before making further increases in voltage. Frequently, the noise will continue to decrease slowly for a period of several minutes to several hours; this is normal, particularly for detectors which have not been used recently.

3. Sudden momentary increases in the noise pulses are an indication of incipient microplasma. If this phenomenon occurs, proceed very slowly, and if the frequency and/or intensity of noise pulses increase, reduce the bias by approximately 30 percent and allow the detector to "age" (for a time sufficient to permit increases in the bias level without the strong pulsing noise effect) before proceeding.
4. A sudden very large increase in noise, usually accompanied by an increase and/or fluctuations in the reverse current, is an indication of complete microplasma breakdown. Remove the bias voltage immediately in order to minimize irreversible damage to the detector.
5. After the desired bias voltage is attained, observe the noise level for a short time, in order to determine that it is not increasing and that there is no incipient microplasma breakdown.
6. Rated bias for the detector includes the drop accross a 32 megohm bias network. If your bias network is substantially different, you may adjust the applied bias to compensate for the I_L x R drop. Consult your preamplifier manual or schematic for bias network resistor values. The detector leakage current is given on the test data sheet.

Partially depleted detectors usually reach rated thickness way below rated voltage so bias adjustments are usually not required for this type.

WARRANTY

This warranty covers Canberra hardware and software shipped to customers within the United States. For hardware and software shipped outside the United States, a similar warranty is provided by Canberra's local representative.

DOMESTIC WARRANTY

Equipment manufactured by Canberra's Instruments Division, Detector Products Division, and Nuclear Systems Division is warranted against defects in materials and workmanship for one year from the date of shipment.

Canberra warrants proper operation of its software only when used with software and hardware supplied by Canberra and warrants software media to be free from defects for 90 days from the date of shipment.

If defects are discovered within 30 days of the time you receive your order, Canberra will pay transportation costs both ways. After the first 30 days, you will have to pay the transportation costs.

This is the only warranty provided by Canberra; there are no other warranties, expressed or implied. All warranties of merchantability and fitness for an intended purpose are excluded. Canberra shall have no liability for any special, indirect or consequential damages caused by failure of any equipment manufactured by Canberra.

EXCLUSIONS

This warranty does not cover equipment which has been modified without Canberra's written permission or which has been subjected to unusual physical or electrical stress as determined by Canberra's Service Personnel.

Canberra is 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 Canberra personnel without the prior approval of Canberra.

This warranty does not cover detector damage caused by abuse, neutrons, or heavy charged particles.

SHIPPING DAMAGE

Examine shipments carefully when you receive them for evidence of damage caused in transit. If damage is found, notify Canberra and the carrier immediately. Keep all packages, materials and documents, including your freight bill, invoice and packing list. Although Canberra is not responsible for damage sustained in transit, we will be glad to help you in processing your claim.

OUT OF WARRANTY REPAIRS

Any Canberra equipment which is no longer covered by warranty may be returned to Canberra freight prepaid for repair. After the equipment is repaired, it will pass through our normal pre-shipment checkout procedure.

RETURNING EQUIPMENT

Before returning equipment for repair you must contact your Regional Service Center or one of our factories for instructions. For detector repair, contact the Canberra Detector Division in our Meriden, Connecticut, factory for instructions. If you are going to return the equipment to the factory, you must call first to get an Authorized Return Number (ARN).

When you call us, we will be glad to suggest the best way for you to ship the equipment and will expedite the shipment in case it is delayed or lost in transit. Giving you shipping advice does not make us responsible for the equipment while it is in transit.

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