

Germanium Detectors

9231358G

User's Manual



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Important Safety Considerations

Read Carefully

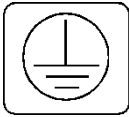
General Safety



Indicates warning of mains or high voltage present at output labeled HV.
Risk of electrical shock if covers are removed.



Caution – risk of danger. Refer to documentation for detailed explanation of caution symbol wherever marked.



Earth tree symbol – indicates the connection point for the primary earth (ground) supply.



Product complies with appropriate current EU directives (Low Voltage & EMC).



Product complies with appropriate current FCC /UL /CSA 61010-1 directives (Low Voltage & EMC).

Personal Safety: Protective gear is required.



Environmental Safety: Caution surfaces hot/cold.



Manufacturer's Address

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Important Operation Consideration

The following potential hazards can occur when using and handling of Ge detectors that must be recognized and properly dealt with to avoid the risk of personal injury.

High Voltage



Ge detectors may operate at bias voltages of 5000 V dc or more. Always be sure that detectors are properly grounded (through the SHV coaxial cable ground to a properly grounded Power Supply/NIM Bin). Also use extreme caution when adjusting internal preamplifier controls to avoid contact with the high voltage circuit.

Liquid Nitrogen Precaution



LN₂ can cause frostbite if not handled properly. Avoid skin contact with LN₂ or with surfaces cooled by LN₂. Read *Handling Liquid Nitrogen* starting on page 36 for more detailed instruction on LN₂ hazards.

Vacuum failure / Over-pressurization



When a cryostat exhibits signs of catastrophic vacuum failure, such as heavy moisture or ice formation on the surfaces, extremely high LN₂ loss rate, and so forth, the adsorber (molecular sieves or charcoal), which normally maintains vacuum, may be virtually saturated.

When allowed to warm up, the adsorber will outgas and the pressure in the cryostat will rise. Cryostats and Dewars sold by Mirion Technologies have a pressure relieving seal-off valve which is designed to prevent dangerous levels of pressurization.

The pressure rise, however, can be high enough to break or break loose beryllium windows and/or end-caps. A frozen or ice clogged seal-off valve may fail to relieve pressure, resulting in dangerous levels of pressurization.

Precautions

For these reasons use extreme caution in handling cryostats with symptoms of catastrophic vacuum failure. When you do have to handle them, take the following precautions:

1. Stop using the failed unit immediately. Do not allow it to warm up until additional steps are taken to prevent damage or injury due to over-pressurization.
2. Drape a heavy towel or blanket over the end-cap and point the end-cap away from personnel and equipment. If the unit is in a shield, close the shield door.
3. Call the factory for further instructions if the incident occurs during working hours.
4. If it is impractical to keep the unit cold until advice is available from the factory, keep the end-cap covered with a heavy towel or blanket and place the unit in a restricted area in a container (corrugated cardboard, for example). If the unit is in a shield, let it warm up in the shield with the door closed.
5. After the unit has warmed up, cautiously check for over-pressurization (outwardly bulging end-caps or windows). If there are no signs of pressure, the unit may be shipped to the factory for repair. Consult the factory for shipping information.

1. Introduction

Germanium detectors are semiconductor diodes having a P-I-N structure in which the Intrinsic (I) region is sensitive to ionizing radiation, particularly X-rays and gamma rays. Under reverse bias, an electric field extends across the intrinsic or depleted region. When photons interact with the material within the depleted volume of a detector, charge carriers (holes and electrons) are produced and are swept by the electric field to the P and N electrodes. This charge, which is in proportion to the energy deposited in the detector by the incoming photon, is converted into a voltage pulse by an integral charge-sensitive preamplifier.

Because germanium has a relatively low band gap, these detectors must be cooled in order to reduce the thermal generation of charge carriers (thus reverse leakage current) to an acceptable level. Otherwise, leakage current induced noise destroys the energy resolution of the detector. Liquid nitrogen, which has a temperature of 77 °K, is the common cooling medium for such detectors. The detector is mounted in a vacuum chamber which is attached to or inserted into a LN₂ Dewar. The sensitive detector surfaces are thus protected from moisture and other contaminants.

Although Ge detectors can be warmed up when not in use, the lithium-diffused N+ contact is not perfectly stable at room temperature. For this reason it is best to avoid extended warm time, especially for standard-electrode coaxes where the Li contact affects low energy response.

Types of Ge Detectors

Mirion Technologies makes a wide variety of detector types which are described in this instruction manual. The first figure illustrates the various detector geometries that are available from Mirion Technologies, and the energy range they cover. Figure 2 depicts their significant performance characteristics. Consult the chapter, *Detector Descriptions* on page 7, for detailed descriptions and performance ranges of each type.

Chapter 1 Introduction

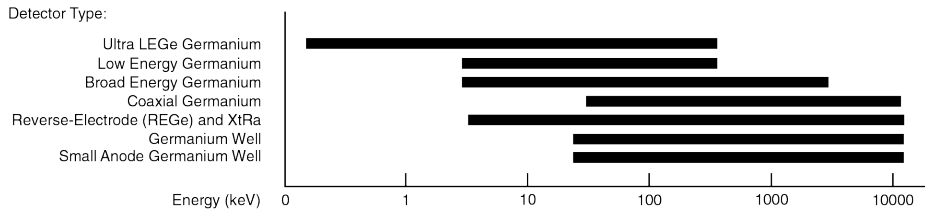
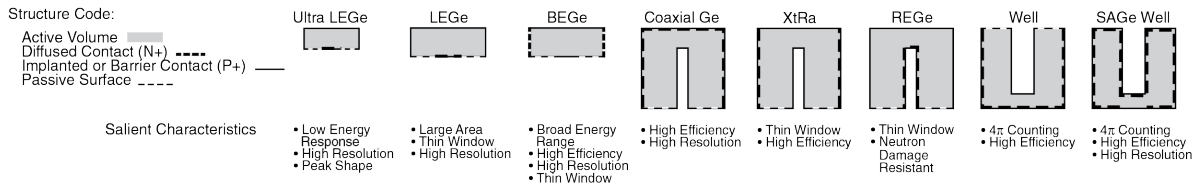
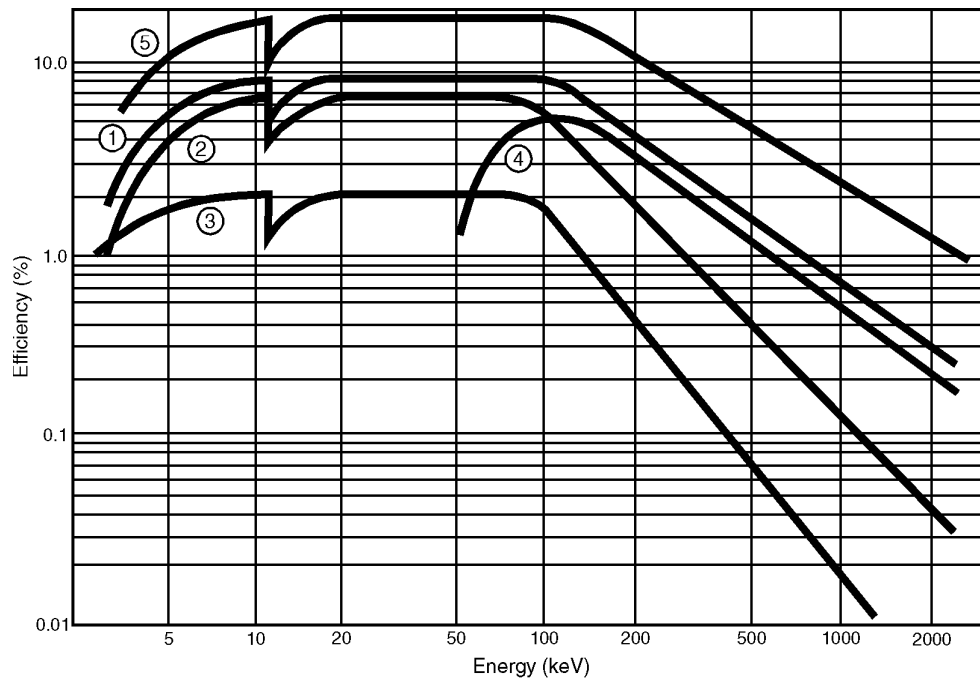


Figure 1 Detector Geometries



Typical absolute efficiency curves for various Ge detectors with 2.5 cm source to end-cap spacing

- Code: ① REGe, 15% Relative Efficiency XtRa, 15% Relative Efficiency ③ LEGe, 200 mm² x 10 mm thick
- ② LEGe, 10 cm² x 15 mm thick ④ Coaxial Ge, 10% Relative Efficiency
- ⑤ BEGe, 5000 mm² x 30 mm thick

Figure 2 Typical Absolute Efficiency Curves

The notch in the efficiency curves at 11 keV is caused by excitation of the Ge K-shell by incoming photons and subsequent escape of a significant percentage of the K-shell X-rays.

Cryostats

A cryostat consists of a vacuum chamber which houses the detector element plus a Dewar (double wall vacuum-insulated vessel) for the liquid nitrogen cryogen. In some cases, the detector chamber and Dewar are permanently connected. These are called “integral” cryostats. “Dipstick” cryostats have a detector vacuum chamber with a dipstick-like cold finger which is inserted into the neck of the Dewar.

The detector element is held in place by a holder, which is electrically isolated from but thermally connected to a copper cold finger. The cold finger transfers heat from the detector assembly to the liquid nitrogen reservoir. The detector holder is held in place by an anti-microphonic stabilizer. The detector holder as well as the outer vacuum jacket or “end-cap” is thin to avoid attenuation of low energy photons. The holder is generally made of aluminum and is typically 0.8 mm thick. The end-cap, is also generally made of aluminum. It is typically 1.5 mm thick. The detector element face is located typically 5 mm from the end-cap so caution should be used to avoid pushing the end-cap in against the detector assembly. The 7500SL cryostat is illustrated in the Figure 3.

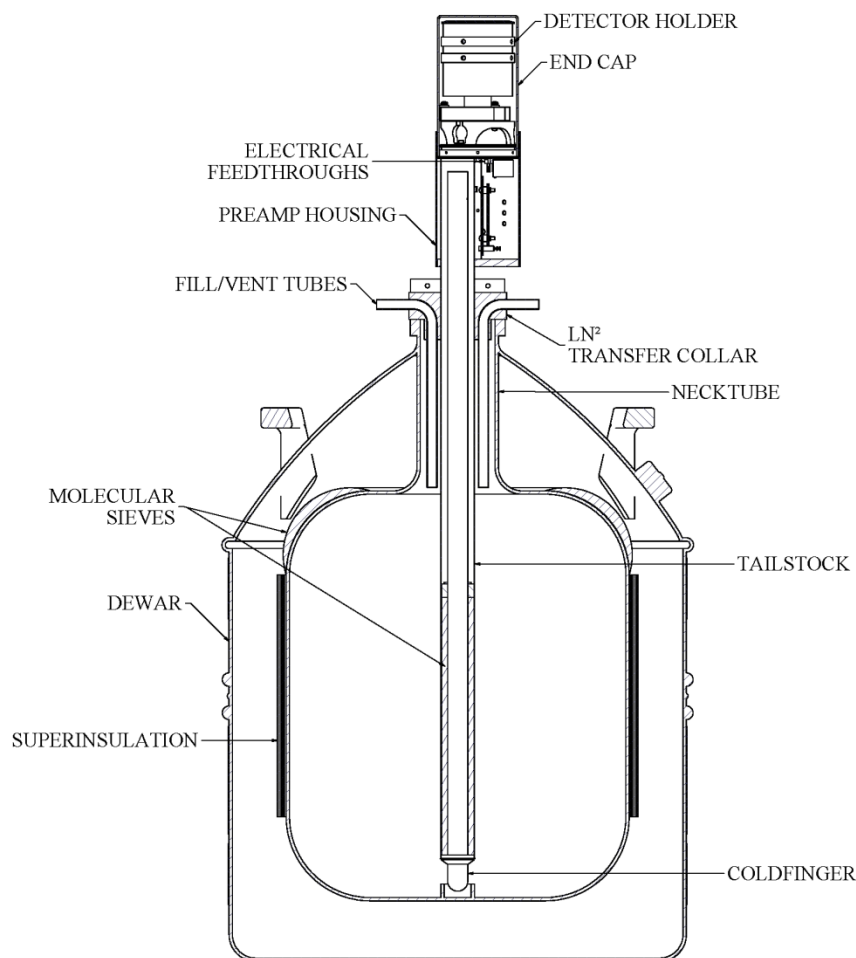


Figure 3 Model 7500SL Cryostat

Preamplifier Description

There are two basic types of preamplifiers in use on Ge detectors. These are charge sensitive preamplifiers that employ either dynamic charge restoration (RC feedback) or transistor reset charge-restoration methods to discharge the integrator.

RC Feedback

The block diagram in Figure 4 describes the conventional RC feedback preamplifier. Charge from the detector is collected on the input node, unbalancing the first stage amplifier which has a capacitor as the feedback element (with a resistor in parallel). The amplifier balance is restored when the output changes by the amount necessary to inject the opposite charge on node A through the feedback capacitor. The transfer function is thus:

$$V_0 = \frac{Q_{in}}{C_f}$$

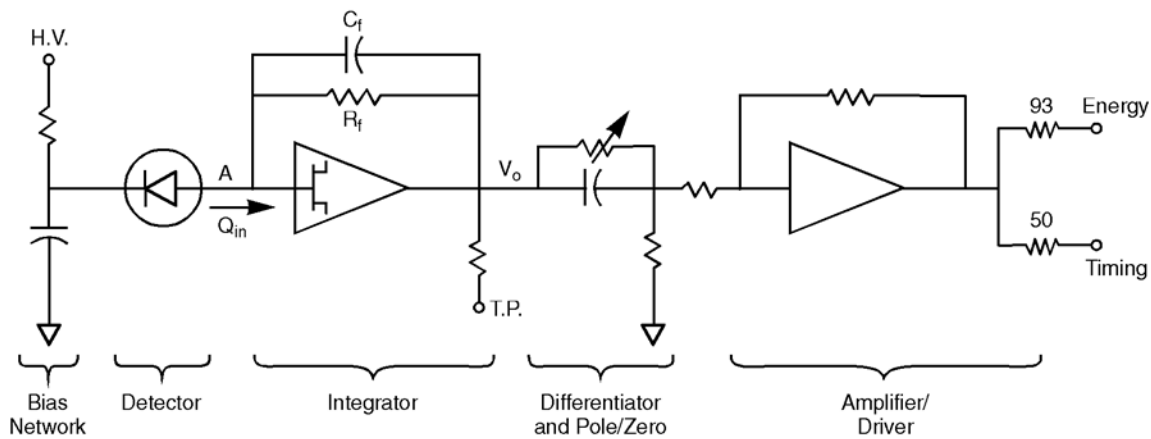


Figure 4 Typical RC Feedback Circuit

The high value resistor (R_f) discharges the feedback capacitor (C_f) with time constant $R_f C_f$. The energy rate limit of the preamplifier is inversely proportional to feedback resistor value as shown in Figure 5.

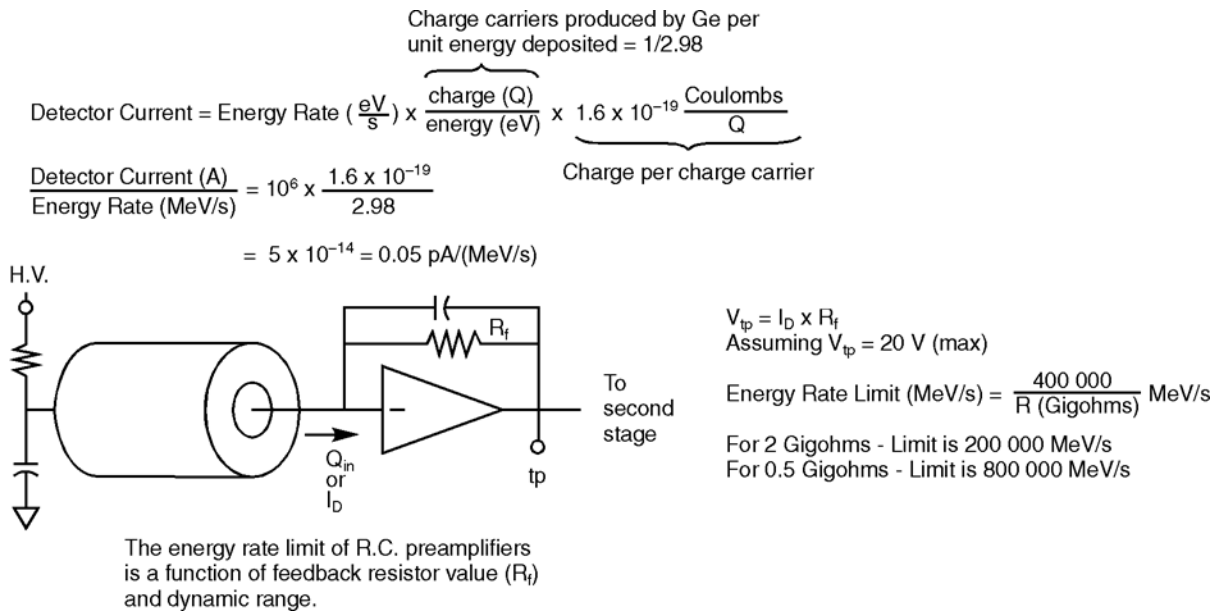


Figure 5 Preamplifier Rate Limit

The output from the integrator is differentiated and passed along to an amplifier/driver which has selectable gain. The output is split and sourced with 50 and 93 ohms for the Timing and Energy outputs, respectively.

Transistor Reset Preamplifiers (TRP)

RC preamps can lock up when they are operated at high energy rates (see Figure 5). The transistor reset preamp (TRP) virtually eliminates lock-up since it is capable of discharging the integrator quickly (< 2 ms) and without long-term transients following reset. Transistor reset preamps can be used with coaxial detectors and special versions of TRPs can be used with low energy detectors.

Warm Up Sensor and HV Inhibit

Detectors are equipped with an internal temperature sensor and associated circuitry which can be used to disable the bias supply in case of accidental warm up of the detector. This function is also provided by a separate LN₂ monitor.

In either case, the reason for having such protection is as follows: When a detector warms up, the molecular sieves, which normally acts as a vacuum pump or adsorber, will release the gases that it accumulated or pumped when cold. The resultant pressure rise can lead to an electrical discharge in the high voltage circuitry within the cryostat and thus damage the FET in the preamplifier.

An additional LN₂ sensor senses the liquid nitrogen level in the Dewar and provides an advance warning so that LN₂ can be replenished before the detector begins to warm up. The internal sensor cannot react until it warms up, so while this affords adequate protection to the FET, it may not prevent down time should a refill not take place immediately.

Environmental Considerations

Germanium detectors are designed and manufactured for use indoors and for use outdoors under limited conditions, as described in the individual detector's specifications sheet. The detectors conform to Installation Category I and Pollution Degree II standards.

Temperature Range

The environmental temperature range for LN₂ cooled detectors is 5 °C to 40 °C, except for SAGe Well where the temperature range is restricted to 10-30 °C. Electrically cooled detectors may be subject to other limits. See the user manual or specification sheets of these electrically cooled cryostats for these limitations.

Humidity Range

Up to 95% relative humidity for non-Well type detectors and up to 50% relative humidity for Well type detectors – non-condensing. Note that Be and polymer windows are readily damaged by moisture condensation. Humidity must be controlled so that moisture does not condense on windows.

2. Detector Description

This chapter will describe the characteristics of the major types of germanium detectors:

- The Ultra-LEGe Detector
- The Low Energy (LEGe) Detector
- The Coaxial (Standard Electrode) Germanium Detector (SEGe)
- The Reverse Electrode (REGe) Detector
- The Extended Range (XtRa) Germanium Detector
- The Small Anode Germanium (SAGe) Well Detector
- The Ge Well Detector
- The Broad Energy Germanium (BEGe) Detector

Ultra-LEGe Detector

The Canberra Ultra-LEGe detector extends the performance range of Ge detectors down to a few hundred electron volts, providing resolution, peak shape, and peak-to-background ratios once thought to be unattainable with semiconductor detectors. The Ultra-LEGe retains the high-energy efficiency intrinsic to germanium detectors because of the high atomic number (Z) and thus covers a wider range of energies than any single-photon detector on the market.

To take full advantage of the low energy response of the Ultra-LEGe, Mirion Technologies offers the option of a polymer film cryostat window. This polymer window is a multilayer film which is supported by a ribbed silicon support structure. The film spans silicon ribs that are about 100 microns apart and 0.3 mm thick and act as a collimator accordingly. On horizontal cryostats, the support rib orientation can be chosen by designating the appropriate window model-number suffix: V for vertical ribs and H for horizontal ribs. The support structure is 80% open so the effective detector area is reduced by 20% from the total area. The total film thickness is about 3400 Å, 400 Å of which is an aluminum layer which reduces sensitivity to ambient light. Detectors having polymer windows must be operated in a darkened environment, nevertheless.

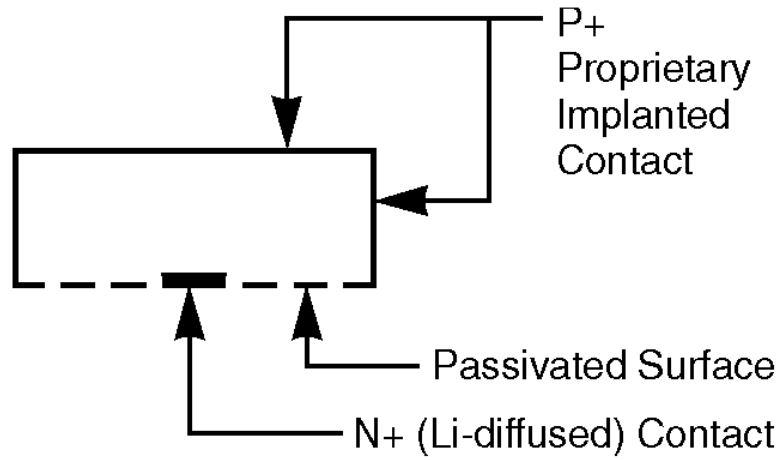


Figure 6 Ultra-LEGe Detector Cross Section

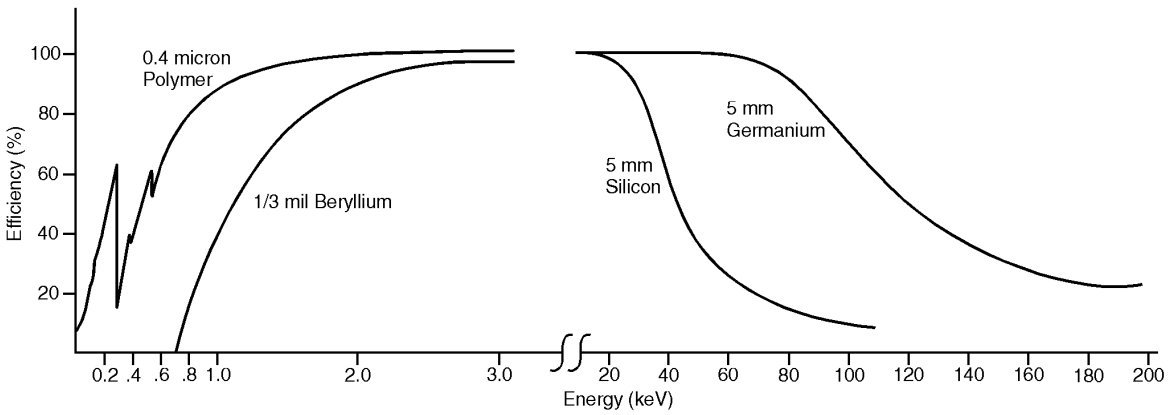


Figure 7 Comparison of Window Transmission and Detector Efficiency

Low Energy Ge Detector (LEGe)

The Low Energy Germanium Detector (LEGe) offers major advantages over conventional planar or coaxial detectors in many applications. The LEGe detector is fabricated with a thin contact on the front face. The rear is of less than full area (Figure 8). Thus the capacitance of the detector is less than that of a planar device of similar size.

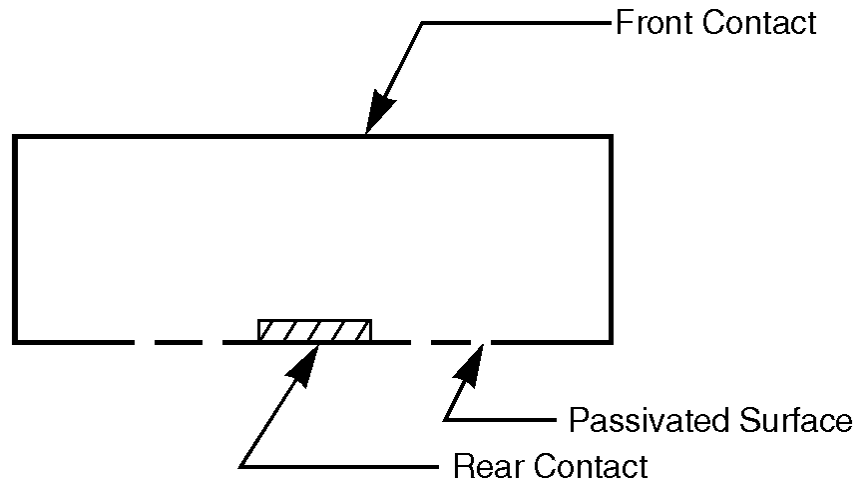


Figure 8 LEGe Detector Cross Section

Since preamplifier noise is a function of detector capacitance, the LEGe affords lower noise and consequently better resolution at low and moderate energies than any other detector geometry. Unlike grooved planar detectors, there is virtually no dead germanium beyond the active region. This, and the fact that the side surface is charge collecting rather than insulating, results in fewer long-rise time pulses with improved count rate performance and peak-to-background ratios.

The LEGe detector is available with active areas from 50 mm² to 2000 mm² or more and with thicknesses ranging from 5 to 20 mm. The efficiency curve given in Figure 9 illustrates the performance of a typical LEGe detector.

To take full advantage of the low energy response of this intrinsically thin window detector, the LEGe is usually equipped with a thin Be window.

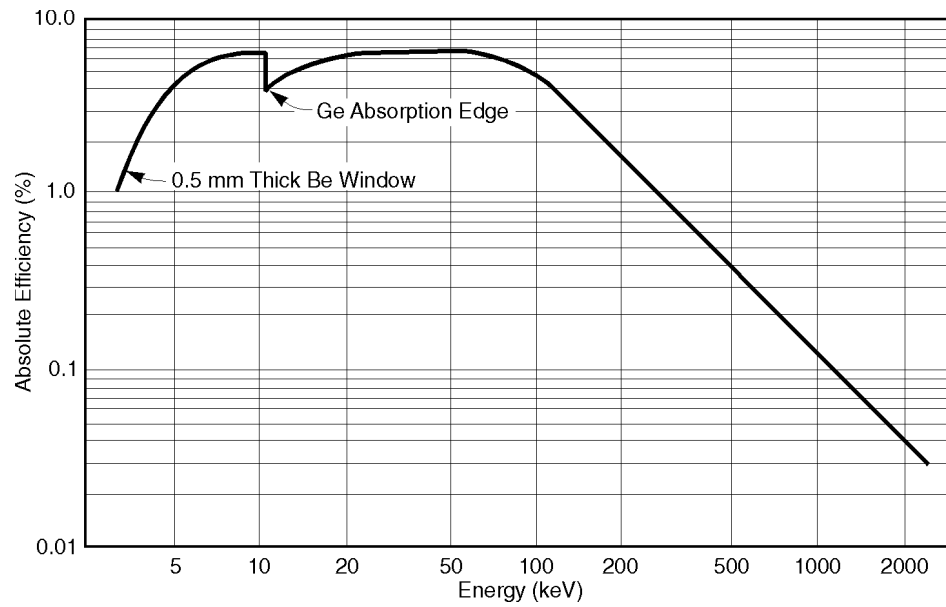


Figure 9 Model GL1015 LEGe Detector Efficiency Curve with 2.5 cm Detector-Source Spacing

Coaxial Standard Electrode Ge Detector

The conventional coaxial germanium detector is often referred to as Pure Ge, HPGe, Intrinsic Ge, or Hyper-pure Ge. Regardless of the superlative used, the detector is basically a cylinder of germanium with an n-type contact on the outer surface, and a p-type contact on the surface of an axial well (Figure 10).

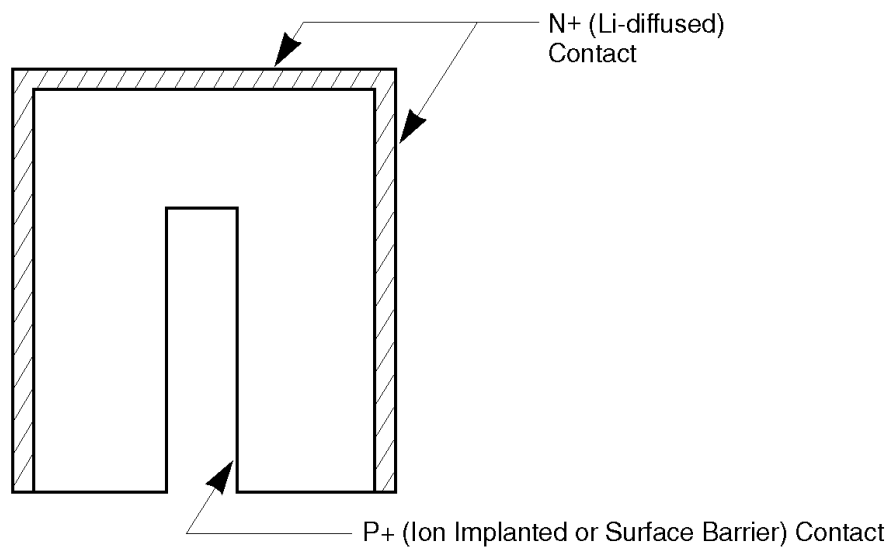


Figure 10 Coaxial Ge Detector Cross Section

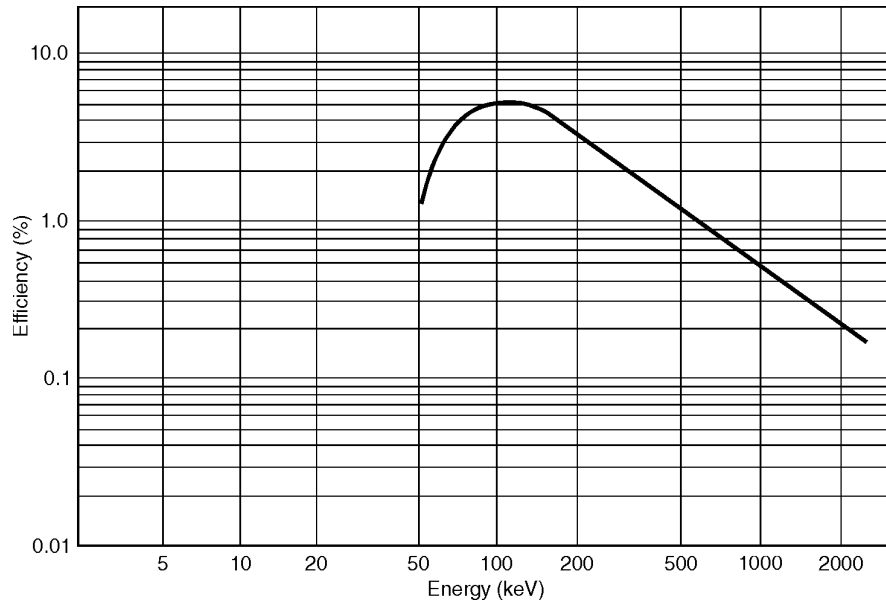


Figure 11 Model GC1020 Coaxial Detector Efficiency Curve with 2.5 Detector-Source Spacing

The germanium has a net impurity level of only about 10^{10} atoms/cc so that with moderate reverse bias, the entire volume between the electrodes is depleted, and an electric field extends across this active region. Photon interaction within this region produces charge carriers which are swept by the electric field to their collecting electrodes where a charge sensitive preamplifier converts this charge into a voltage pulse proportional to the energy deposited in the detector.

The n and p contacts or electrodes are typically diffused lithium and implanted boron respectively. The outer n-type diffused lithium contact is about 0.5 mm thick. The inner contact is about 0.3 microns thick. A surface barrier may be substituted for the ion-implanted contact with equal results.

The Canberra Coaxial Ge detector can be shipped and stored without cooling. Like all germanium detectors, however, it must be cooled when it is used to avoid excessive thermally generated leakage current. Furthermore, the lithium diffused outer contact will increase in thickness if the detector is kept warm for extended periods (months or years). This will affect the efficiency of the detector, particularly at low energies.

Reverse-Electrode Ge Detector

The Reverse-Electrode detector (REGe) is similar in geometry to other coaxial germanium detectors with one important difference. The electrodes of the REGe are opposite from the conventional coaxial detector in that the p-type electrode (ion-implanted boron) is on the outside, and the n-type contact (diffused lithium) is on the inside (Figure 12). There are two advantages to this electrode arrangement – window thickness and radiation damage resistance.

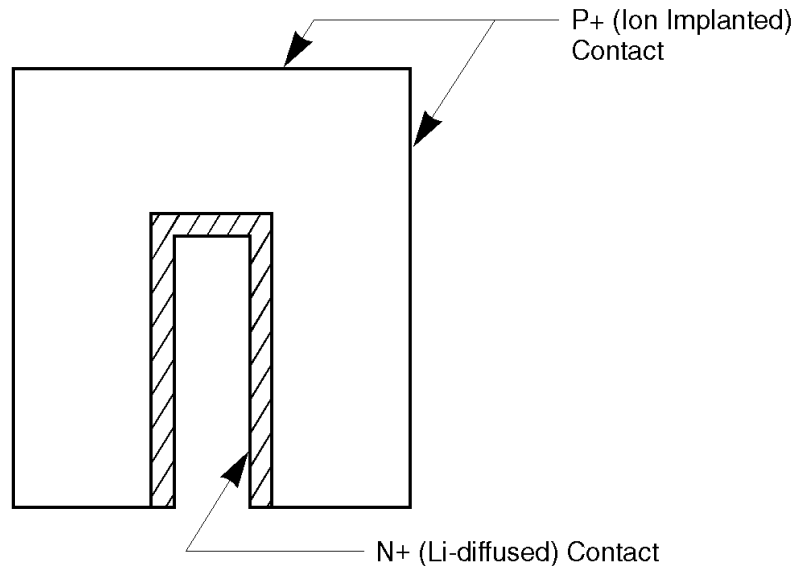


Figure 12 REGe Detector Cross Section

The ion-implanted outside contact is extremely thin ($0.3 \mu\text{m}$) compared to a lithium-diffused contact. This, in conjunction with a thin 0.6 mm carbon epoxy cryostat window, extends the energy response down to about 5 keV , giving this detector a dynamic range of 2000:1. Needless to say, this dynamic range exceeds the 100:1 offered by most analysis systems so the detector is unlikely to be covering the range of 5 keV to 10 MeV at once.

The radiation damage resistance properties of the REGe detector come about for the following reason. It has been found that radiation damage, principally due to neutrons or charged particles, causes hole trapping in germanium. Unlike the case of the conventional coaxial detector, holes are collected by the outside electrode of the REGe detector.

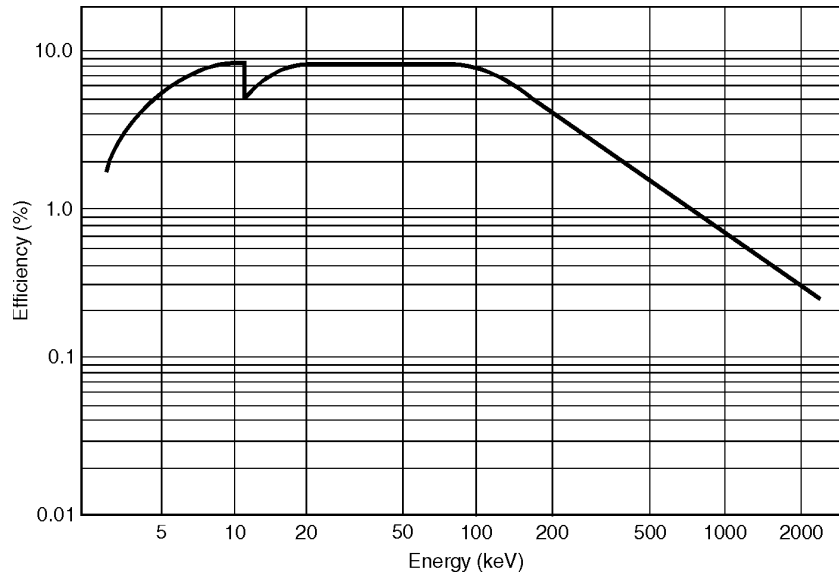


Figure 13 Model GR1520 REGe Detector Efficiency Curve with 2.5 cm Detector-Source Spacing

Since a much greater amount of the active detector volume is situated within a given distance of the outside contact than of the inside contact, it follows that, on average, holes have less distance to travel if they are attracted to the outside contact than if they are attracted to the inside contact. With less distance to travel, they are less likely to be trapped in radiation damaged material. The extent of the improved resistance to radiation damage depends on other factors, of course, but experimental evidence suggests that the REGe detector may be 10 (ten) times as resistant to damage as conventional Coaxial Ge detectors.

Extended Range Ge Detector

The CANBEERA XtRa is a coaxial germanium detector having a proprietary thin-window contact on the front surface which extends the useful energy range down to 5 keV. Conventional coaxial detectors have a lithium-diffused contact typically between 0.3 and 1.0 mm thick (Figure 14).

This dead layer stops most photons below 40 keV or so, rendering the detector virtually worthless at low energies. The XtRa detector, with its exclusive thin entrance window and with a beryllium cryostat window, offers all the advantages of conventional standard coaxial detectors such as high efficiency, good resolution, and moderate cost along with the energy response of the more expensive Reverse Electrode Ge (REGe) detector.

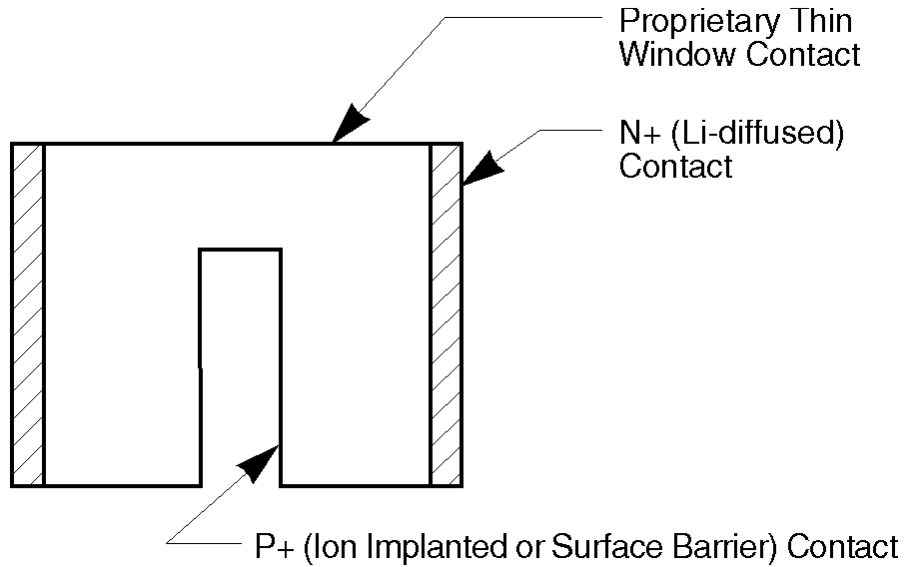


Figure 14 XtRa Detector Cross Section

The response curves (Figure 15) illustrate the efficiency of the XtRa detector compared to a conventional Ge detector. The effective window thickness can be determined experimentally by comparing the intensities of the 22 keV and 88 keV peaks from ^{109}Cd . With the standard 0.6 mm carbon epoxy window, the XtRa detector is guaranteed to give a 22 to 88 keV intensity ratio of greater than 20:1.

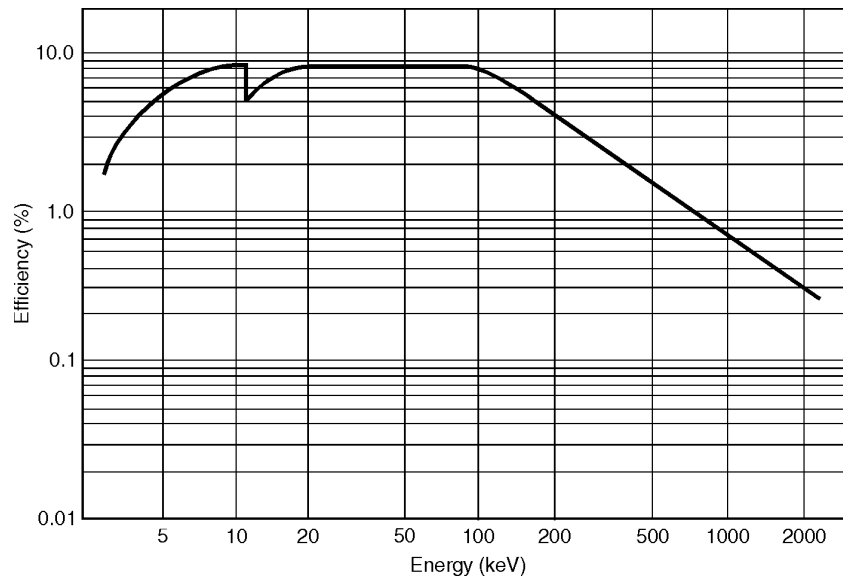


Figure 15 Model GX1520 XtRa Detector Efficiency Curve with 2.5 cm Detector-Source Spacing

Small Anode Germanium (SAGe) Well Detector

The Canberra SAGe™ Well Detector combines excellent energy resolution at low and high energies with maximum efficiency for small samples. Like Traditional Well Detectors, the SAGe Well is fabricated with a blind hole, leaving at least 20 mm of active detector thickness at the bottom of the well. The counting geometry therefore approaches 4π .

The low detector capacitance associated with the small anode technology (similar to what is used on Canberra BEGe detectors) gives the SAGe Well superior low and medium-energy resolution performance compared to Traditional Well or Coaxial Detectors, as well as excellent resolution for higher energy gamma rays.

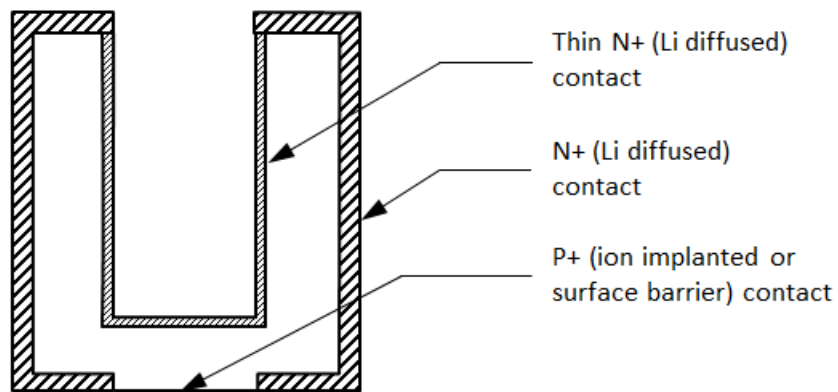


Figure 16 SAGe Well Detector Cross Section

Care and maintenance

In addition to the normal care and maintenance for a HPGe, it is important to note that SAGe Well Detectors are best always kept cooled to LN₂ temperature in order to preserve the low energy sensitivity inside the well. As indicated in the sketch above the N+ contact inside the well consists of a thin Li diffused layer (typically 50 μm). As Li-atoms are mobile in the Ge crystal lattice at room temperatures, the dead layer formed by this N+ contact will grow thicker when the detector is not cooled down.

As this dead layer growth is not a rapid process (occurs over months), the guaranteed low-energy sensitivity inside the well (>5% transmission at 20 keV) will not be impacted by normal periods of warm storage required for shipping and installation. However, long delays (in the order of several weeks) like those that occur during sea freight or prolonged storage in a warehouse should be avoided.

Preamplifier

In contrast to the majority of germanium detectors using RC preamplifiers, SAGE Well uses an AC-coupled preamplifier instead of a DC-coupled preamplifier. In the case of AC coupling, no DC current flows from the detector to the input of the preamplifier as can be seen in Figure 17. Detector leakage current cannot be measured with an AC-coupled preamplifier when the first stage is inside the cryostat. Since the detector bias voltage is being applied through the signal electrode of the detector the bias polarity is opposite for AC vs. DC coupling. The SAGE Well uses negative high voltage detector bias. At equilibrium, the test point of the AC-coupled preamplifier remains at 0 V and is therefore not indicative of energy rate or leakage current. During transients such as application of bias voltage, the test point shifts in a manner similar to the DC-coupled preamplifier and returns to near zero volts at equilibrium.

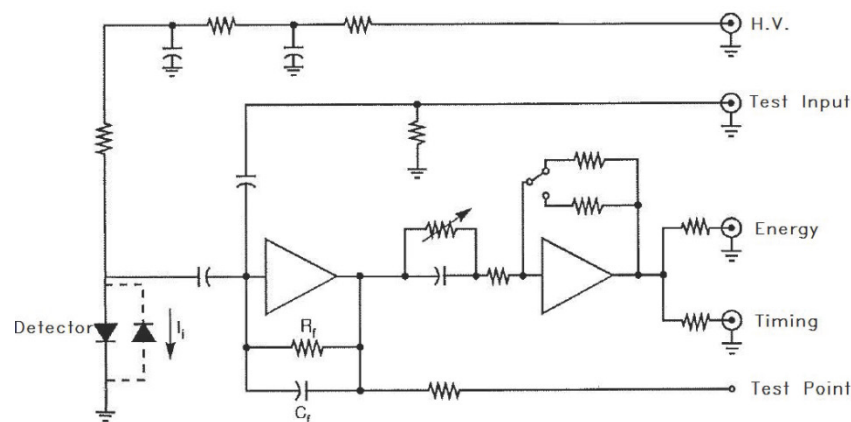


Figure 17 AC-coupled RC Preamplifier

Traditional Well Detector

The Canberra Germanium Well Detector (Figure 18) provides maximum efficiency for small samples because the sample is virtually surrounded by active detector material. The Canberra Well detector is fabricated with a blind hole rather than a through hole, leaving at least 5 mm of active detector thickness at the bottom of the well. The counting geometry therefore approaches 4π .

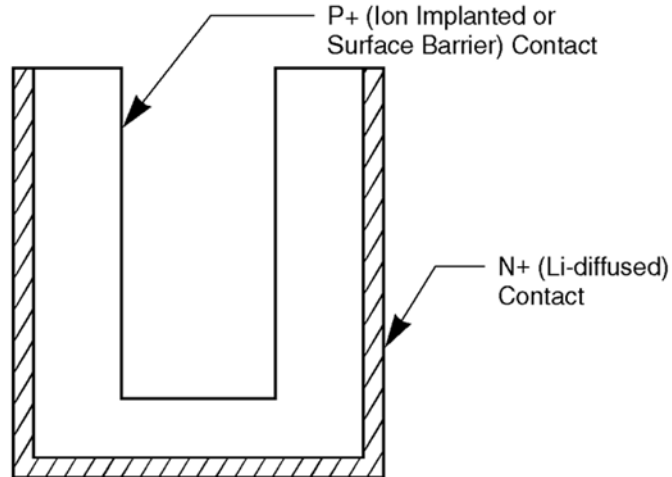


Figure 18 Ge Well Detector Cross Section

Germanium Well Detectors are made from high-purity germanium and can therefore be shipped and stored at room temperature without harm. Unlike lithium-drifted detectors, high-purity germanium detectors may be cycled repeatedly between LN₂ and room temperature with no compromise in performance.

The cryostat end cap and well are fabricated from aluminum with a thickness of 0.5 mm in the vicinity of the well. The ion-implanted or surface barrier contact on the detector element is negligibly thin compared to 0.5 mm of aluminum so these detectors have intrinsically good low energy response.

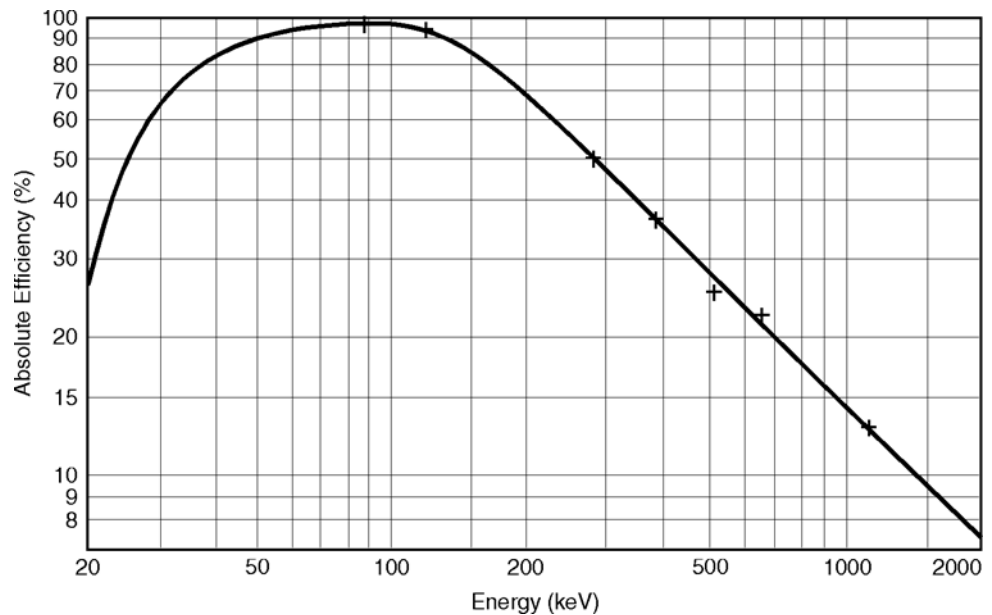


Figure 19 Model GCW2522 Ge Well Detector Efficiency

Broad Energy Ge Detector (BEGe)

The Canberra Broad Energy Ge (BEGe) Detector (Figure 20) covers the energy range of 3 keV to 3 MeV. The resolution at low energies is equivalent to that of our Low Energy Ge (LEGe) Detector and the resolution at high energy is comparable to that of good quality coaxial detectors.

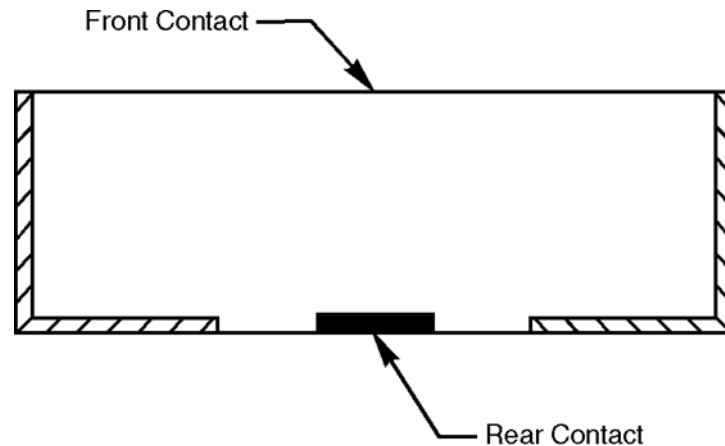


Figure 20 BEGe Detector Cross Section

Most importantly, the BEGe has a short, fat shape which greatly enhances the efficiency below 1 MeV for typical sample geometries. This shape is chosen for optimum efficiency for real samples in the energy range that is most important for routine gamma analysis.

In addition to higher efficiency for typical samples, the BEGe exhibits lower background than typical coaxial detectors because it is more transparent to high energy cosmogenic background radiation that permeates above ground laboratories and to high energy gammas from naturally occurring radioisotopes such as ^{40}K and ^{208}Tl (Thallium).

In addition to routine sample counting, there are many applications in which the BEGe Detector really excels. In internal dosimetry the BEGe gives the high resolution and low background need for actinide lung burden analysis and the efficiency and resolution at high energy for whole body counting. The same is true of certain waste assay systems particularly those involving special nuclear materials.

The BEGe detector and associated preamplifier are normally optimized for energy rates of less than 60 000 MeV/sec. Charge collection times prohibit the use of short amplifier shaping time constants. Resolution is specified with shaping time constants of 4-6 microseconds typically.

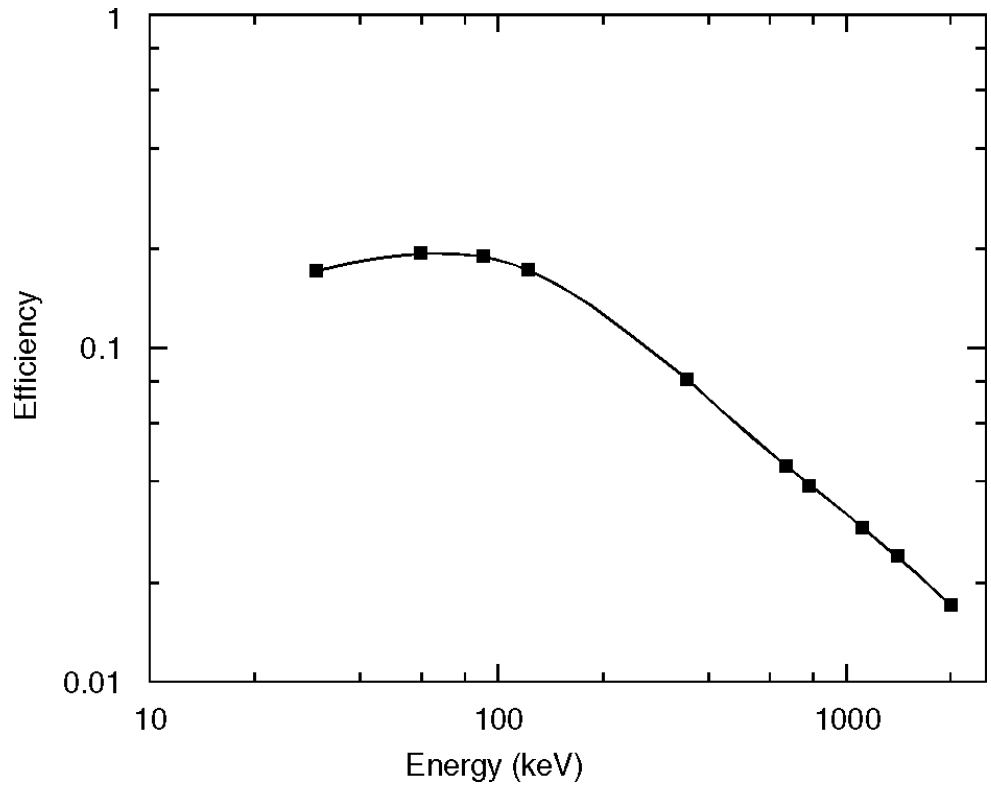


Figure 21 Absolute Efficiency of BE5030 for a Source Measuring 74 mm Diameter by 21 mm Thick Located on the Detector End Cap

3. Cryostat Descriptions

There are three types of cryostats in three basic styles and in many sizes. This variety can be broken down as follows:

- Types: Dipstick, Integral, Electrically Cooled
- Styles: Flanged (traditional), Slimline, U-style
- Sizes: From 1 to 50 liter capacity
- Orientations: Horizontal, Vertical, Variable

In addition, special cryostats or variations on the above are available. Instructions for these units are covered in supplements to this manual if they are necessary.

The section below contains basic information and instructions on care and handling for Canberra cryostats. For detailed information and dimensional data, please refer to the specification sheets in the product section on the Mirion Technologies website www.canberra.com. For electrical coolers a dedicated User's Manual is supplied with these instruments.



Precaution: Most cryostats are equipped with Viton O-ring Seals that are permeable to light gases such as helium. Helium is not pumped effectively by the molecular sieves or charcoal adsorber used to maintain vacuum. The epoxy used to bond beryllium, carbon composite, and polymer windows is also permeable. While permeability (as opposed to leaks) is not generally a problem (the atmospheric abundance of helium is quite low) care should be taken to avoid exposing cryostats to high concentrations of helium for extended periods.

Dipstick Cryostat

Dipstick cryostats consist of a detector chamber having a dipstick-like cold finger which is inserted into a liquid nitrogen Dewar for cooling. The Dewar and the detector chamber have separate vacuum systems including adsorber material which help maintain good vacuum in both over the lifetime of the product. A basic dipstick cryostat is illustrated in Figure 22.

Dipstick Dewar

Most dipstick cryostats use a 30 liter Dewar. The loss rate of the Dewar alone is typically 0.5 to 0.7 liters/day. Faulty Dewars of this type cannot be repaired but can be replaced in the field at moderate cost.

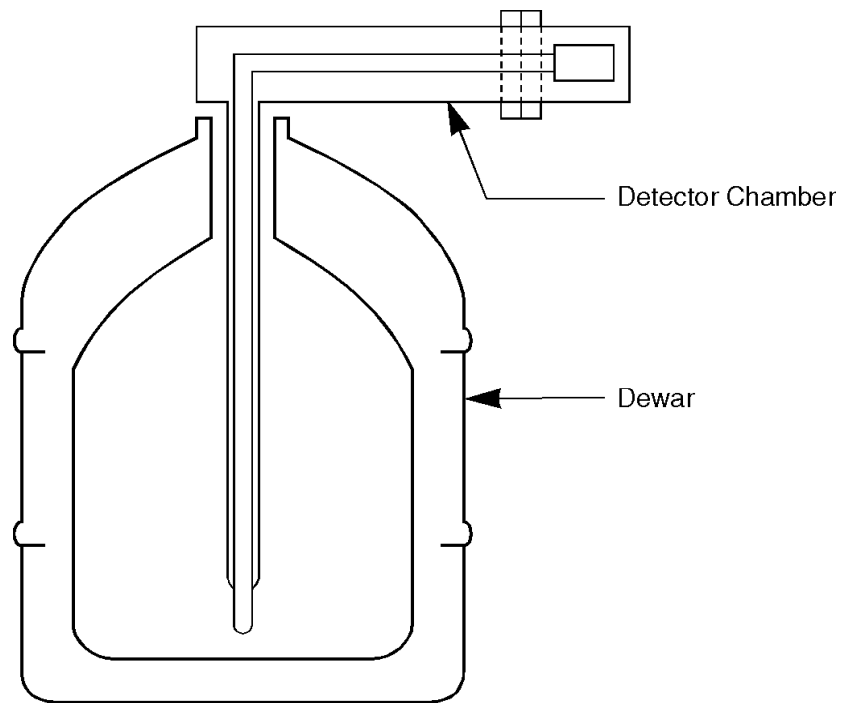


Figure 22 Typical Dipstick Cryostat Cross Section

Fill and Vent Collars

Dipstick cryostats are equipped with a silicone rubber collar which holds the dipstick in place in the Dewar neck. This collar has interchangeable tubes for fill and vent and has provisions for an LN₂ sensor of the type used with LN₂ monitors, such as the Canberra Model 7170. A clamp ring is used on some dipstick cryostats to provide mechanical stability. The clamp ring is attached to the Dewar neck by means of three screws. Two screws in the clamp ring tighten it on the dipstick. Use these screws to change the position of the dipstick. A 7/64 in. hex key wrench is supplied for this purpose.

Integral Cryostat

Integral cryostats have a common vacuum chamber for the Dewar and detector. Unlike the dipstick type, the detector chamber and Dewar cannot be separated without breaking vacuum. A basic integral cryostat is shown in Figure 23.

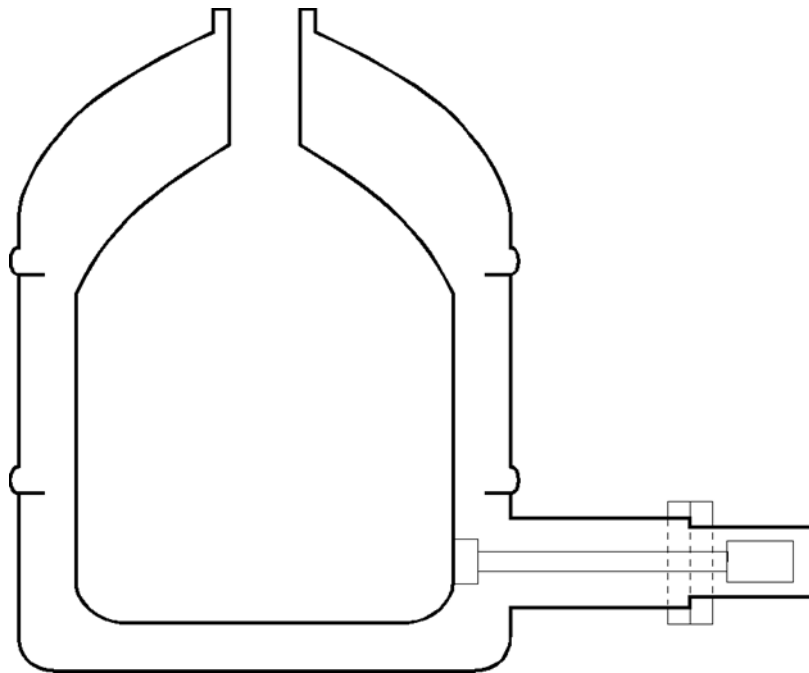


Figure 23 Typical Integral Cryostat Cross Section

Multi-Attitude Cryostat (MAC)

The standard Canberra portable multi-attitude cryostats have twin fill/vent ports which allow the units to operate in any orientation. The arrangement of the fill and vent ports is illustrated in Figure 24. These units are available in several sizes, with holding times of one to five days.

With the detector horizontal, either tube can vent. With the detector facing down, tube one vents. With the detector facing up, tube two vents. See *Multi-Attitude Cryostats (MACs)* on page 40 for more information on the MAC.

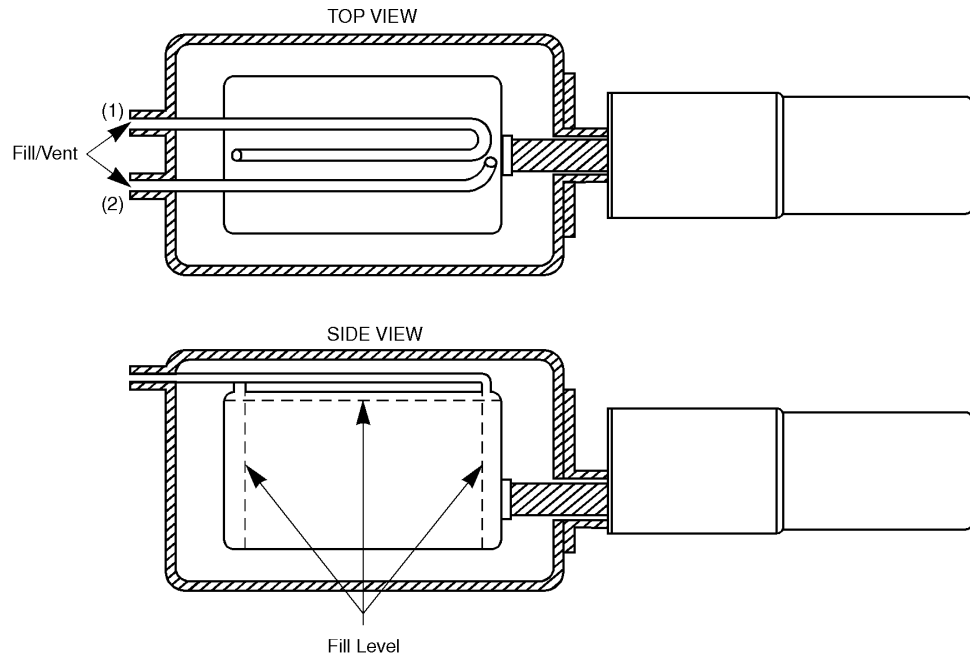


Figure 24 Typical Multi-Attitude (MAC) Cryostat Cross Section

Single Port Portable Cryostats

Portable all-attitude cryostats may also have a single port. These units have a neck tube that extends to the center of the Dewar and as long as the liquid level remains below the end of the tube (i.e., half-full maximum) the port can vent and the cryostat will work normally. For a given overall Dewar size, this type of cryostat has about one half the holding time of the standard MAC. See the figure below for details.

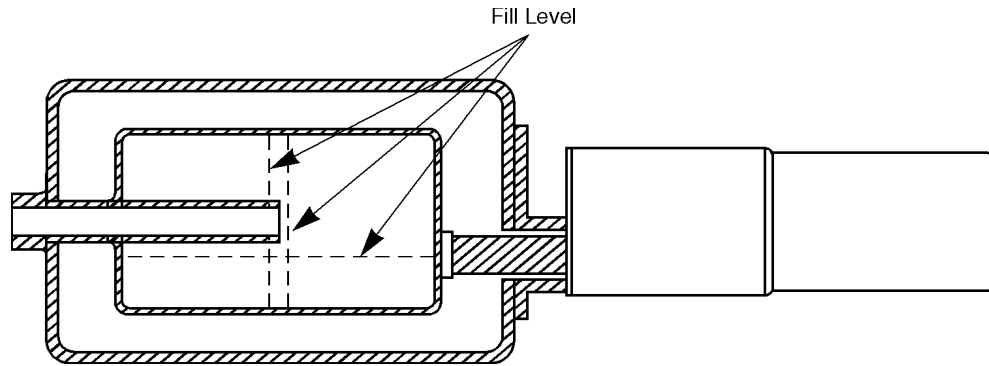


Figure 25 Typical Single Port MAC Cross Section

Detachable Cradle Assembly

The MAC is shipped with a carrying cradle which can be removed if the unit is to be installed in a fixed apparatus for any reason. To detach the cradle, remove the screws holding the rear plate to the handle and to the base, then remove the rear plate and slide the detector backwards taking care to feed the cables through the front plate along with the snout. Refer to Figure 26.

The detector cradle is equipped with a cableway fore and aft, so that the pigtail cables from the preamplifier and the extender cables supplied separately may be retained in a convenient and safe orientation. The cable retainer is a split grommet made of plastic.

To install the cables, the grommet must first be removed from the cableway. The grommet is snapped over the cable bundle and the cables are inserted in the cableway. The grommet is then pressed into the cableway with the split facing the inside.

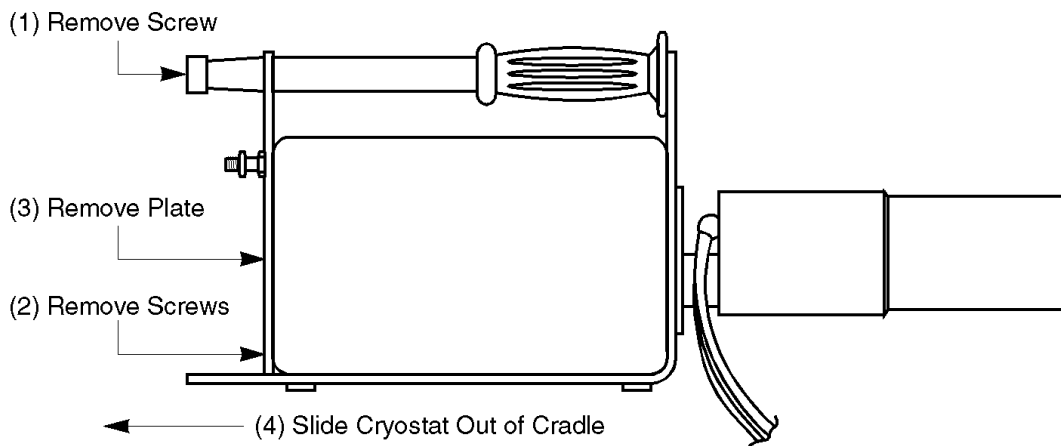


Figure 26 Cradle Assembly

The MAC cradle is also equipped with a clamp to secure the extender cable, so that they will not stress the smaller pigtail cables. This clamp, or some other means, must be employed to prevent damage to the miniature coaxial cables in the pigtail cable assembly.

Flanged versions of the MAC have a conventional (non slimline) preamplifier with bulkhead connectors which do not require strain relief.

Cryo-Pulse® 5 plus Cryostat

The Cryo-Pulse 5 Plus (CP5-plus) is an electrically refrigerated cryostat for use with HPGe radiation detectors. The heart of the cryostat is a 5 Watt pulse tube cooler. Detectors equipped with this type of cryostat do not require liquid nitrogen or other supplemental refrigerants to achieve the appropriate operating temperatures for the germanium.

The cooler is integrated in a compact assembly which is directly attached to the detector housing. The unit can operate in all orientations. The assembly is connected to a bench-top power controller that produces the necessary output voltage to drive the compressor. The controller also contains the logic to operate the CP5-plus in a safe and reliable way. For more information on the operation of CP5-plus, consult the *Cryo-Pulse® 5 plus Electrically Refrigerated Cryostat User's Manual*.

Cryo-Cycle™ II Hybrid Cryostat

The Cryo-Cycle II is a hybrid cryostat having a self-contained LN₂ reservoir connected to an electrically powered cryocooler that condenses the boil-off vapor from warming to liquid to maintain the LN₂ supply indefinitely. The Cryo-Cycle II is designed to accommodate both dipstick cryostats and integral configurations. For detectors equipped with this cryostat consult the *Cryo-Cycle™ II Hybrid Cryostat User's Manual* for operational information.

Cryostat Options

There are wide varieties of cryostat options and features, the most common of which are described below.

Optional Windows

Mirion Technologies equips its SEGe detectors with a standard aluminum endcap (± 1.5 mm thickness). On XtRa, BEGe and REGe detectors, the default is a 0.6 mm thick carbon composite window, which provides good transmission for low-energy photons (to below 10 keV), is ideally suited for Ultra-Low Background applications and is very durable. Finally, beryllium is the default window material on LEGe and Ultra-LEGe detectors. Beryllium is a low Z element, so it has an even better low-energy transmission than carbon composite. Curves showing the transmission characteristics of the various windows are shown in Figure 27

Depending on the detector type and application, it can make sense to select a different window material than the default choice. In addition to the materials mentioned in the previous paragraph, also a 0.5 mm aluminum window, a thinner beryllium or a polymer window are available.

Beryllium and polymer windows are very fragile and require special care and handling, as described below.

Be Window – Care and Handling

Thin Be windows may be damaged easily. Windows of 0.25 mm (10 mils) thickness, or less, should not be touched. The window can be damaged by moisture condensation; keep it clean and dry at all times.

The detector should not be stored or operated in a humid environment. If moisture condenses on the Be window during normal operation, either the humidity is too high or the detector has a vacuum problem.

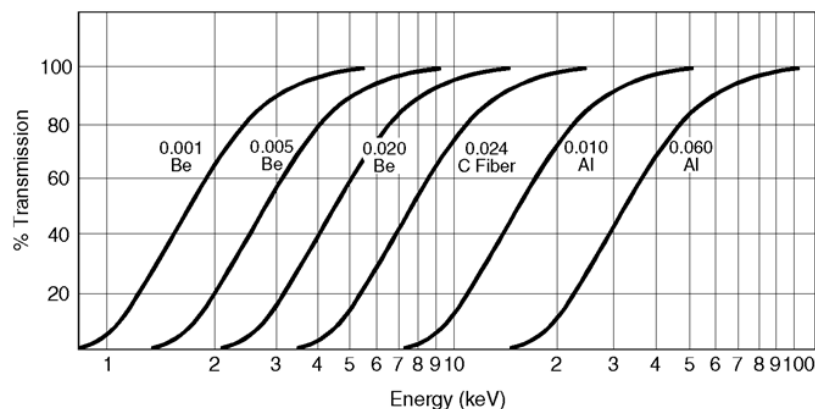


Figure 27 Window Transmission Characteristics (Thickness in inches)

During cool-down or warm-up cycles when the molecular sieves outgas, some condensation may appear. This is normal. It should go away as soon as the molecular sieves re-pump the system.

Note: Damage to Be windows caused by physical abuse or harsh environments is not covered by the warranty.

Polymer Window – Care and Handling

Description:

The Canberra polymer window is only 3400 Å thick including 400 Å of aluminum. Considering that the polymer window is only about 1/25th as thick as 1/3 mil beryllium, it is an amazing device as it withstands atmospheric pressure and is helium leak tight. Not surprisingly, however, the window can be damaged easily if it is not handled properly and protected from the environment. Listed below are characteristics of the window as well as precautionary measures which should be taken to protect it.

The polymer window is a multilayer film supported by a ribbed silicon support structure. The film spans thin silicon ribs which are about 100 mm apart and about 0.3 mm thick. Therefore, the window exhibits a fairly tight collimation effect for photons entering at angles which are not parallel to the ribs. Also the window area is not oversized compared to the detector area so additional collimation is involved here. The ribs are about 20 mm wide so the window has about 80% “open” area.

The aluminum layer is not thick enough to block all light so the detector should be operated in the dark or in very subdued lighting. Ge detectors are very sensitive to infrared radiation and they may show effects of IR even without the presence of visible light.



Precautions:

1. Do not touch the window surface with anything, not even a cotton swab or soft brush. Physical abrasion can easily cause damage to the aluminum layer. It is also good to protect the window from dust and other small particles. Under certain circumstances they can abrade the surface and cause leaks.
2. Always avoid applying pressure to the ribbed side of the window (back pressure). The window is very strong when pressure is applied to the film side but very weak if pressure is applied to the ribbed side.
3. When evacuating a detector on which the window is mounted, it is best to pump down slowly to reduce the shock to the window. When venting a vacuum chamber on which the detector is mounted, you should vent very slowly to prevent flying particles from hitting and damaging the window.
4. Avoid any physical shock to the window, such as bumping or jarring the detector.
5. Never subject the window to temperatures higher than 35 °C.

6. Protect the window from moisture and from exposure to corrosive atmosphere. The aluminum layer is attacked by moisture and by acid fumes.
7. Keep the protective cover on the window whenever the detector is not in use, especially when the detector is being moved or when someone is working around the detector. Be very careful when placing test sources near the detector. This is the most common way of breaking windows in our experience.
8. If (or when) a window breaks, warm up the detector immediately and allow the inside of the detector to defrost and dry out before returning the detector to the factory for repair. This can be facilitated by removing the end cap.

Note: Damage to polymer windows is not covered by warranty.

Remote Detector Chambers (RDC)

The remote detector chamber (RDC) option provides for external shielding just behind the detector element. The diameter and length of the neck joining the RDC to the cryostat vary depending on the application. A typical RDC configuration is shown in Figure 28.

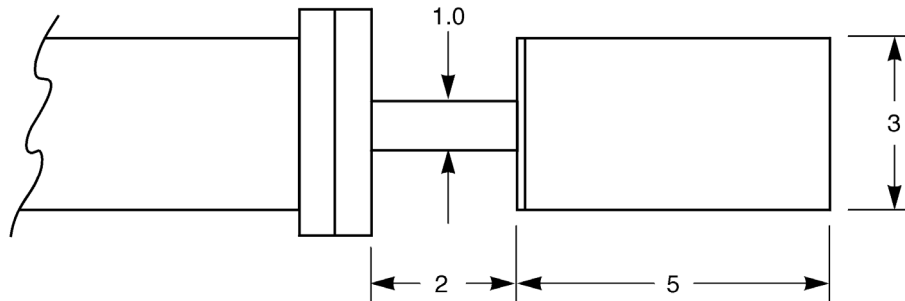


Figure 28 Typical RDC Configuration – Dimensions in inches

Cold Finger Extension

Standard Dipstick Detectors may be equipped with a cold-finger extension up to 10 cm in length. This allows the dipstick to be inserted through the floor of a shield between the detector chamber and the Dewar without sacrificing working volume of the Dewar. Such an arrangement is shown in Figure 29.

Standard Detectors are not designed to be elevated more than 10 cm (4 in.) from the Dewar neck, so the Dewar must be moved up as close as possible to the bottom of the shield.

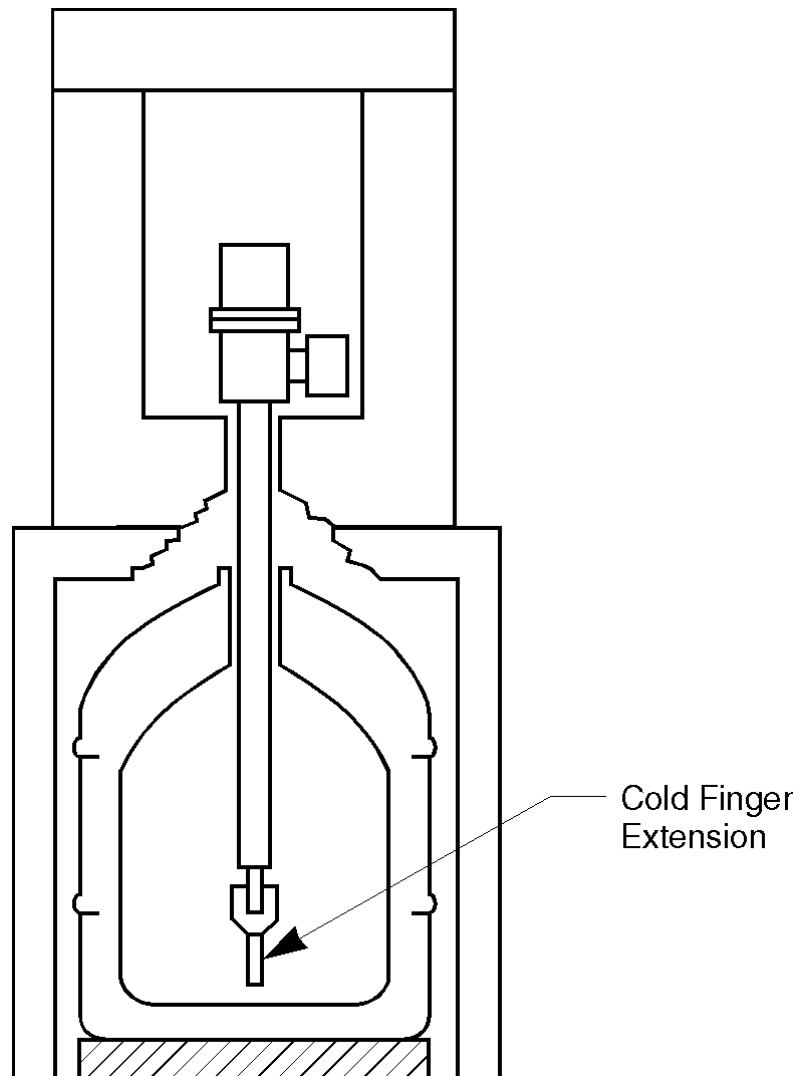


Figure 29 Cold Finger Extension

Special Preamp Hardware

To fit detectors having flanged cryostats into shields of moderate size, special preamp hardware can be used. This hardware generally provides a means of attaching the preamp to the cryostat so that the preamp protrudes a minimum amount from the detector axis.

Ultra-Low Background Materials

Although the materials used in cryostats are checked for abnormal levels of radioactive impurities, the hardware contribution to background can be improved by careful, time-consuming selection of expensive, often exotic materials. The normal materials used in cryostat construction are classified as low background. Materials that are specially selected or chosen optionally are classified as ultra-low background materials. This choice is usually negotiated with the end-user for each application.

Care and maintenance of Ge Array Detectors

General:

Ge Array detectors are very complex and delicate instruments that require proper care and maintenance to obtain reliable long-term performance. Below you will find suggestions for the proper care and maintenance of Array detectors.

Detector Storage:

Ge Array detectors are capable of being warmed up and stored at room temperature. We have found, however, the performance of these detectors is best preserved by keeping them cold. Short warm up periods will not affect detector performance, but extended periods of time at room temperature can cause subtle changes in the electrical characteristics of the detector that will ultimately affect the energy resolution and operating characteristics of the array.

Therefore, we strongly recommend that this detector be cooled down and kept at liquid nitrogen temperature from the time that it is received.

Operating and Storage Environment:

The detector should be used and stored in a clean, dry environment free of any unusual levels of light gases such as helium that can diffuse through vacuum seals spoiling the cryostat vacuum.

Ion Pumps:

Some Ge Array detectors are equipped with ion pumps. These pumps are intended to assist maintaining cryostat vacuum. We recommend that the ion pump be turned on only periodically to monitor and to maintain cryostat vacuum.

However, it is essential that the ion pump never be energized when the detector is cooling down, warming up, or at room temperature. Failure to disable the ion pump during any of these conditions will damage the detector elements. Damage to the array caused by ion pump sputtering from improper use is not covered by warranty.

Be Cryostat Window:

Thin Beryllium windows can be damaged easily. Windows of 0.25 mm (10 mils) thickness, or less, should not be touched. The window can be damaged by by moisture condensation, so keep the window clean and dry at all times.

The detector should not be stored or operated in a humid environment. If moisture condenses on the Be window during normal operation, either the humidity is too high or the detector may have a vacuum problem.

During cool-down or warm-up cycles when the molecular sieves outgas, some condensation may appear. This is normal. It should go away as soon as the molecular Sieves re-pump the system.

NOTE: Damage to Be windows caused by physical abuse or harsh environments is not covered by the warranty.

High Voltage and Preamplifier Power:

Never apply high voltage or preamplifier power until the Array detector has cooled down for the proper time period specified on the detector serial number tag and specification sheet. High voltage and preamplifier power should always be turned off any time that the Array detector is not in use. Also, never allow the Array detector to warm-up to room temperature with high voltage or preamplifier power applied.

Premature application of high voltage and preamplifier power will cause damage to the Array detector. Likewise, failure to disable high voltage and preamplifier power during warm-up to room temperature will also cause damage to the Array.

Filling With Liquid Nitrogen:

The Array detector should be filled from a suitable source of liquid nitrogen that is free from debris and ice crystals. When using a pressurized source of liquid nitrogen the supply pressure should never exceed 25 psig. Over flow of liquid nitrogen and cold nitrogen gas must be diverted away from the cryostat to avoid freezing of the cryostat vacuum seal that will otherwise cause a cryostat vacuum problem.

Please feel free to contact the Mirion Technologies Detector Products Division should you have any questions regarding the proper care and maintenance of your Array detector.

4. Preamplifier Description

There are several types and models of preamplifiers in use depending on the application. The typical usage is given in “Preamp Features” below.

The Preamplifier manual included in the back of this manual has information on the specific preamp used with this detector.

Preamp Features

Preamp Models	Significant Features	Detector Types
iPA-10, iPA-SL10	Low Noise Warm up/HV Inhibit Key Parameter Data Logging Digital Interface	SEGe, BEGe, REGe, XtRa, LEGe, Well, SAGe Well
2002C, 2002CSL	Cooled FET Warm up/HV Inhibit	SEGe, BEGe, REGe, XtRa, LEGe, Well, SAGe Well
ITRP	Integrated Transistor Reset	Ultra-LEGe, LEGe
iPA-P10, iPA-PSL10	Intelligent PreAmp for low capacitance detectors	LEGe
2002CP, 2002CPSL	Set up for low capacitance detectors	LEGe
2101P, 2101PSL	Transistor Reset	SEGe, XTRa
2101N, 2101NSL	Transistor Reset	REGe

Note on iPA output polarity

The output polarity of the Energy and Time signal pulses of the Intelligent Preamplifier (iPA) is inverted with respect to the input pulse polarity. This is in contrast to the 2002C model preamp which is non-inverting. Consult the table below for the typical output polarity of the iPA and 2002C preamps based on detector type. It is important to know the Preamp output polarity in order to appropriately set the Digital Signal Analyzer (DSA) or Amplifier input polarity.

Detector Type	Preamplifier Output Polarity	
	iPA models	2002C models
SEGe, BEGe, XtRa, Well, and SAGe Well	Negative	Positive
REGe, LEGe	Positive	Negative

H.V. Inhibit Circuit Adjustment

If the H.V. Inhibit circuit trips and there are no other symptoms indicating a fault (low LN₂, high loss rate, coolness of cryostat, moisture accumulation, low compressor pressure (off), or high detector leakage current), the circuit may need adjustment. Portable detectors should be vertically upright for this adjustment.

Refer to LN Monitor Board Schematic Diagram.

With H.V. off, measure the voltage between pins 5 and 6 on comparator A1B. Adjust RV1 until the yellow LED comes on, then turn RV1 in the opposite direction until the green LED comes on. Continue until the voltage between pins 5 and 6 is 50 mV.

For iPA model preamplifiers, the H.V. Inhibit is set through the digital interface which is accessible via a USB connection to the preamplifier. Consult the *Model iPA Intelligent Preamplifier for HPGe Detector User's Manual* for more information.

5. Unpacking and Repacking

When you first receive your detector, please follow the instructions in *Unpacking* for unpacking the detector. Be sure to save all packing materials for possible reshipment.

If you should ever need to return the detector to Mirion Technologies for service, please repack the detector for shipment following the instructions in *Packing for Re-Shipment*.

Unpacking

Remove the cryostat from the box by lifting it vertically by the Dewar handle(s). If the detector has been transported in a cold environment, allow it two hours to come to room temperature before proceeding. This will prevent undue moisture accumulation on sensitive parts of the system.

Remove the cord holding the dipstick to the Dewar and/or holding the plastic bag to the detector chamber. Remove the plastic bag covering the detector chamber and inspect the entire detector system for mechanical damage.

If there is evidence of shipping damage contact the carrier, file a claim for damages, and notify Mirion Technologies of the nature and extent of the damage.

Horizontal dipstick cryostats have a plastic foam pillow which cradles the horizontal detector chamber to prevent bending of the dipstick during shipment. This pillow can be removed by cutting the cord or tape securing it to the Dewar's neck.

Packing for Re-shipment

Keep all of the packing materials with the original shipping container in case the detector should be shipped to the factory for service or elsewhere for use. We cannot be responsible for shipping damage incurred after initial delivery of the detector or if a detector is returned for in warranty service with improper packing.

Detectors properly prepared for shipment are shown in the figure "Detectors Prepared for Shipment" located in the next section.

Dipstick cryostats may be returned to the factory without a Dewar. In this case the dipstick must be packed carefully so it will not be damaged in shipment. Even then there is a greater chance of shipping damage because the smaller packages tend to be handled with less care, and the preferred upright orientation will not be respected.

Pack Detectors Warm

Allow detectors to warm up completely before packing in well-insulated containers. Foam in-place packing material is an excellent insulator. Cold detectors packed in this material are so well insulated that the external cryostat hardware including the sensitive vacuum seals may be cooled to a very low temperature as heat is transferred to the cold inner hardware. If the packing container is well ventilated, this should not be a problem.

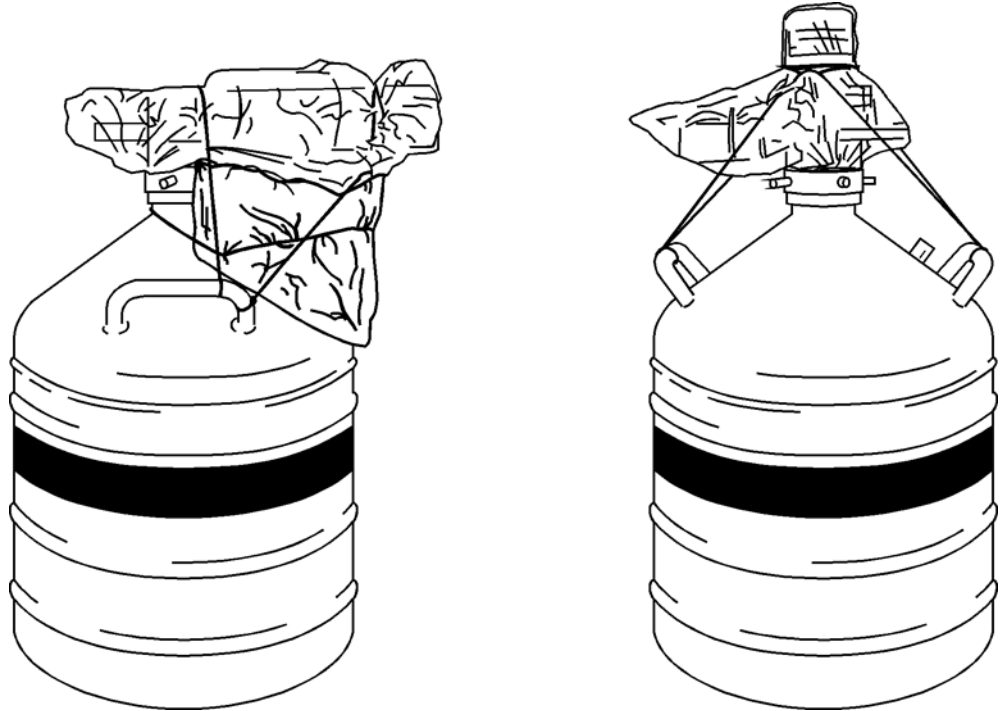


Figure 30 Detectors Prepared for Shipment

6. Filling with Liquid Nitrogen (LN₂)

Before attempting to fill your detector with liquid nitrogen, be sure to read and follow the Warnings and Cautionary Statements listed in *Handling Liquid Nitrogen*, below.

The remaining subsections deal with filling a specific type of cryostat, refer to:

- Dipstick Cryostats – refer to page 38
- Integral Cryostats – refer to page 39
- Multi-Attitude Cryostats – refer to page 23

The section *Temperature Cycling* on page 43 describes the precautions to be taken if it becomes necessary to temperature cycle your detector.

Handling Liquid Nitrogen

Always handle liquid nitrogen carefully! Its extremely low temperature can produce frostbite!



WARNING: Liquid nitrogen's temperature is minus 196 °C (77 °K).
Contact with exposed skin can cause severe frostbite!

When spilled on a surface, the LN₂ tends to cover the surface completely therefore to rapidly cooling a large area.

Protect Your Eyes



The gas issuing from the liquid nitrogen is also extremely cold and can produce frostbite. Delicate tissues such as those of the eyes can be damaged by an exposure to these cold gases which is too brief to affect the skin of the hands or face.

Stand clear of boiling and splashing liquid and its issuing gas. Boiling and splashing always occur when charging a warm container or when inserting warm objects into the liquid. Always perform these operations slowly to minimize boiling and splashing.

Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing liquefied nitrogen: the extremely cold metal may stick fast and tear the flesh when you attempt to pull away from it.

Use tongs to withdraw objects immersed in liquid and handle the tongs and the object carefully. In addition to the hazard of frostbite or skin sticking to cold materials, objects that are soft and pliable at room temperatures usually become very hard and brittle at the temperatures of these liquids and are very easily broken.

Wear Protective Clothing



Protect your eyes with a face shield or safety goggles (safety spectacles without side shields do not give adequate protection).



Always wear gloves when handling anything that is, or may have been, in contact with liquid. Insulated gloves are recommended but leather gloves may also be used. The gloves should fit loosely so that they can be thrown off quickly if liquid should spill or splash into them.

When handling liquids in open containers, it is advisable to wear high-top shoes. Trousers (which should be cuffless if possible) should be worn outside the shoes.

Ventilate the Area

Always handle liquid nitrogen in well-ventilated areas to prevent excessive concentrations of gas.



WARNING: High concentrations of nitrogen gas in an enclosed area can cause suffocation!
Handle liquid nitrogen only in a well-ventilated area.

Never dispose of liquid in confined areas or places where others may enter. Excessive amounts of nitrogen gas in the air reduce the concentration of oxygen and can cause suffocation. The gas being colorless, odorless and tasteless cannot be detected by the human senses and will be inhaled as if it were air.

Cloudy Vapor

The cloudy vapor that appears when the cold LN₂ gas contacts the air is condensed moisture, not the gas itself; LN₂ gas is invisible.

Dipstick Cryostats

Canberra dipstick cryostats are equipped with a fill and vent collar which enables them to be filled without moving the detector chamber. The modern version of this collar is made of silicone rubber which forms a gas-tight seal between the Dewar and detector chamber. The collar is fitted with two identical, thin wall, 9.5 mm (in.) diameter stainless steel tubes, either of which may be used for filling from a storage Dewar at medium pressure, 40-80 kPa (gage) (6-12 psig). The unused tube serves as a vent for N₂ gas that is evaporated during the filling operation. This tube can be fitted with a hose to direct the gas away from the sensitive preamplifier and electrical feedthrough area.

The collar is also equipped with a port for an LN₂ level sensor.

Transfer of LN₂ from a Dewar to a cryostat by means of a low pressure withdrawal device is illustrated in Figure 31.

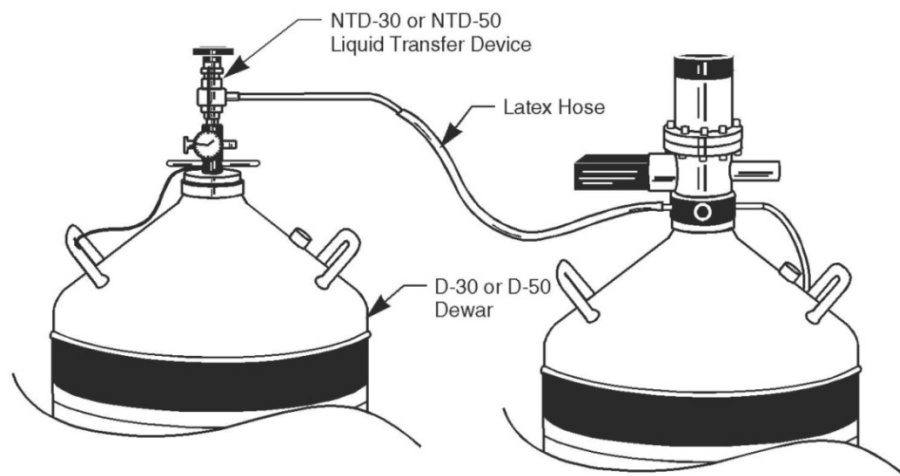


Figure 31 LN₂ Transfer

Warming Up the Dipstick Detector

Should a dipstick detector require a warm up cycle, it is best to remove the dipstick from the Dewar. Loosen the clamp ring if the cryostat is so equipped and slide the dipstick carefully upward. Keep the dipstick either vertically upright or horizontal at all times. Never invert a dipstick cryostat.

If the Dewar is to be emptied, first remove the silicone rubber collar and then pour the contents of the Dewar into another LN₂ container.

Check for and remove any water that may appear in the bottom of the Dewar after it warms to room temperature. The Dewar will warm much more quickly if it is turned on its side to establish convection currents.

A dipstick detector will usually warm up in 12-16 hours (overnight) if it is removed from its Dewar first.

Integral Cryostats

Integral cryostats generally have an open neck tube of 40-65 mm (1.5 to 2.5 in.) diameter. Liquid nitrogen can thus be poured directly into these cryostats or can be pumped in from a pressurized container. Be careful not to spill LN₂ on the detector chamber or the preamplifier as components therein may be damaged by the extreme cold temperatures. A much more preferred way to fill integral cryostat Dewars is to use an optional fill/vent collar, similar to what is shown in Figure 31 for dipstick cryostats.

The neck-plug should be replaced immediately after refilling as it will prevent ice formation in the neck tube, it will keep foreign matter from falling in, and it will increase LN₂ holding time by forcing the cold LN₂ boil-off gases to the neck-tube surface, thereby reducing heat loss by neck-tube conduction.

If an external LN₂ monitor is used with a integral cryostat, the sensor is usually wired to a BNC connector located in the neck plug. A check on the LN₂ monitor can be made by holding the LN₂ sensor tip just above liquid level until a response is obtained. The monitor must react with the sensor inside the Dewar – pulling it out to verify operation cannot guarantee proper operation because of the extreme difference in temperatures.

Warming Up the Integral Detector

Integral cryostats may be warmed up by first pouring the contents into another LN₂ container and then turning the Dewar on its side without the neck plug. In this orientation most integrals will warm up within 24 hours.

Check carefully and remove any water that may appear in the bottom of the warm Dewar. If allowed to remain, the resultant ice can cause hissing and noise in the detector system.

Multi-Attitude Cryostats (MACs)

The MAC should be filled from a source of LN₂ which is at low pressure: 165 kPa (gage) (24 psig). A D-50 Dewar equipped with a low pressure withdrawal device (Model NTD-50) is available from Mirion Technologies for this purpose. Standalone 180 liter pressurized Dewars are also available.

If liquid at high pressure is used, the vaporization that occurs when the pressure is reduced to atmospheric (flash-off) will cause a substantial amount of LN₂ to be blown through the MAC and it will be difficult if not impossible to fill it to capacity. In addition, the Dewar inner could be damaged by high pressure transfer of LN₂.

Fill and Vent Connections

Dual Port Models

The fill and vent connections are 1/8 NPT male fittings. See Figure 32. While hard fittings can be used to transfer the LN₂, it is more convenient to use flexible latex hose which simply stretches over the fittings. The hose can be forced over the hex nut and secured on both sides of the hex nut by a nylon tie-wrap or cord. The hose must not cover the entire nipple as this can lead to excess cooling of the Dewar external hardware.



CAUTION: The Fill and Vent Ports can be damaged by excessive force when attaching or detaching hoses with metal fittings.

Always use a wrench to prevent excess torque on the nipple. See Figure 32.

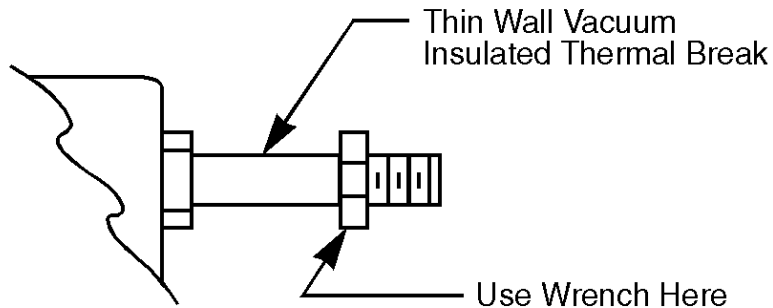


Figure 32 Fill/Vent Port Connector

The transfer line should be as short as practical, no more than 1 m (3 feet) is ideal. It should be kept away from the detector and preamplifier chamber to prevent moisture accumulation on these delicate parts. The transfer line should be insulated for the same reasons.

The vent line should be directed away from personnel to avoid injury. It should be sufficiently long to vaporize any liquid blow-by or overflow, or it should be directed into a reservoir which can contain it safely. A Dewar is a satisfactory reservoir.

Filling Orientation

The fill and vent ports exchange roles depending on the orientation of the detector. The given designators apply to the unit when it is oriented horizontally, which is recommended. When the fill and vent ports are pointing downward, the given designations also apply. However, when the ports point upward, the roles are reversed, i.e., the port designated vent is the fill port and vice versa. See Figure 33 for construction details.

Please note that the MAC does not have exactly the same LN₂ capacity in every orientation, so some spillage can occur when the unit is filled in one orientation and changed to another. This is normal.

The capacity is usually greater when the MAC is horizontal. If filled in this orientation, you can expect to lose some liquid when changing to uplooking or downlooking orientations.

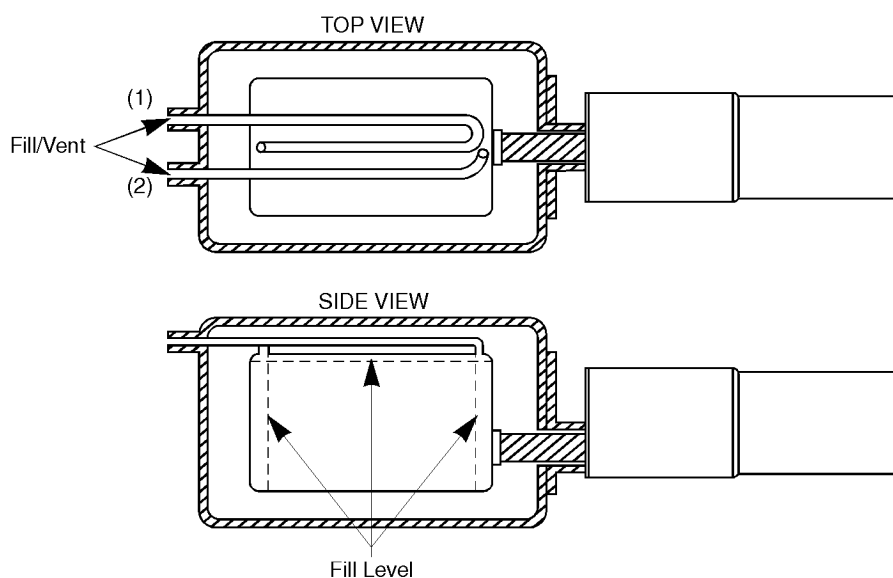


Figure 33 MAC Port Construction

Port Cover

Another effect to be aware of is percolation, which can occur if the MAC is jarred or shaken. To reduce this effect and to decrease the LN₂ loss rate in some orientations, MACs are equipped with a port cover which blocks the fill port. The cover also directs the vent gas away from the vent port, thus preventing snow or ice formation on the vent port. The right hand port should be blocked when the detector is down looking and the left hand port should be blocked when the detector is up looking. A nipple and hose are provided to direct nitrogen gas and spillover liquid away from the user.

Install the cover in the appropriate orientation when the detector is horizontal, then change the orientation. Spillage and loss rate will be minimized if you do this properly.

Single Port Models

Refer to *Typical Single Port MAC Cross Section* on page 24 for an illustration of a single port cryostat. A single neck tube provides both fill and vent functions for this model. The cryostat includes a plug having a pressure relief valve. A secondary fixed pressure relief valve is located on the port boss.

Single port models can be pressure filled by using a 1/4 - 3/8 (6 - 9 mm) diameter tube inserted a depth of about one-half the Dewar length. An optional fill adapter is available from Mirion Technologies.

Mirion Technologies also offers a 30 liter Gravity- Feed supply Dewar for single port MACs and Big MACs. This unit provides a convenient means of keeping detectors filled and ready for use.

Cool-Down Time

Typical detectors will cool down sufficiently within 2-6 hours of filling. The LN₂ loss rate will be extraordinarily high during the cool-down period so the MAC should be topped off with LN₂ a few hours after the initial filling.

Warming Up

Dual Port MAC

A MAC can be emptied quickly by orienting it with the end-cap pointing upwards and blocking the vent port. Under this condition the boil-off gases cannot escape and will thus force most of the LN₂ out of the fill port. Use a hose to direct the LN₂ into another LN₂ container.

Because the MAC cannot be emptied as readily as can an open-mouth Dewar, the natural time required for complete warm up is quite long. To ensure that the detector undergoes a complete warm-up cycle once warm up has begun, purge the detector with dry nitrogen gas.

Do *not* purge with air or with N₂ having significant water vapor content.



To do this, the same considerations should be given to the fill and vent ports as outlined in Fill and Vent Connection. However, the dry nitrogen gas should be forced into the vent port rather than the fill port. An overnight purge at 3 to 5 liters/minute should be sufficient to complete the warm-up cycle. Without a purge warm up may take up to 48 hours.

Single Port MAC

The single port MAC cannot be emptied quickly because the LN₂ will not flow out regardless of the orientation. It can be forced out by inserting a 1/4 - 3/8 inch diameter tube to the full depth of the Dewar and sealing the joint between the tube and the port with the port facing upward. The pressure build-up will force the LN₂ out of the Dewar. Consult the factory for a custom-made device if needed.

Temperature Cycling

High-Purity Ge detectors can withstand repeated and prolonged periods of room temperature storage. While it is only reasonable to expect a detector to last longer if it is kept cold at all times, with certain specific and important precautions, no serious compromise in life time will result from temperature cycling.

Temperature cycling can even be a remedy for certain problems that may occur in the use of Ge detectors. The important precautions are given below.

Turn Bias Off During Warm Up

A detector should not be allowed to warm up with bias applied. When a detector warms up, the molecular sieves outgas and pressure within the cryostat rises. If electrical discharge occurs as a result of this increased pressure, the sensitive detector surfaces and the preamplifier can be damaged. A Canberra Model 7170 LN₂ Monitor can be used to disable the bias supply when the LN₂ drops below a satisfactory level. Detectors equipped with an iPA model preamp can also be used with the appropriate capacitance probes to monitor LN₂ levels and disable the bias at a defined low level alarm. Some detectors are equipped with a built-in Warmup Sensor/HV Inhibit circuit which provides an inhibit signal to the HV power supply.

Complete Warm Up

It can take more than 24 hours for a detector to warm up completely and several hours to cool down thoroughly. When a warm-up cycle has begun, the detector should be allowed to warm up fully before being cooled down again. Otherwise some of the residual gases that are absorbed by the detector surfaces may be frozen there. If the detector warms up completely, the molecular sieves will tend to pump the system clean when the detector is re-cooled. If a detector is inadvertently cooled after partial warm up, a full warm up cycle will likely restore any lost performance. A complete temperature cycle is often prescribed as a fix for performance problems.

Dipstick cryostats (removed from Dewar), Integral cryostats (on side without neck plug), and electrically cooled cryostats (power off) will warm up in 12-24 hours. MACs may take longer, especially if the LN₂ is not purged completely at the start.

Prevent Moisture Accumulation

As noted in *Turn Bias Off During Warm Up* on page 43, when a detector warms up, the molecular sieves which maintain vacuum in the cryostat outgas and pressure within the cryostat rises. Under this condition, the outside of the cryostat will be cooled by the internal hardware until it, too, reaches room temperature. Therefore, it is normal for a cryostat to be cold during warm up and to a lesser extent upon cool down (on cool down the molecular sieves usually get cold and begin pumping before the internal hardware cools down fully).

Moisture which accumulates during temperature cycling should be removed. If humidity in the environment is excessive, moisture may accumulate during normal operation. Environmental humidity should be decreased to prevent both the short term (leakage current in HV circuit/feedthrough) and long term (corrosion) effects of moisture accumulation.

Precautions – Vacuum Failure



When a cryostat exhibits signs of catastrophic vacuum failure, such as heavy moisture or ice formation on the surfaces, extremely high LN₂ loss rate, and so forth, the adsorber (molecular sieves or charcoal), which normally maintains vacuum, may be virtually saturated.

When allowed to warm up, the adsorber will outgas and the pressure in the cryostat will rise. Cryostats and Dewars sold by Mirion Technologies have a pressure relieving seal-off valve which is designed to prevent dangerous levels of pressurization.

The pressure rise, however, can be high enough to break or break loose beryllium windows and/or end-caps. A frozen or ice clogged seal-off valve may fail to relieve pressure, resulting in dangerous levels of pressurization.

Precautions



For these reasons use extreme caution in handling cryostats with symptoms of catastrophic vacuum failure. When you do have to handle them, take the following precautions:

1. Stop using the failed unit immediately. Do not allow it to warm up until additional steps are taken to prevent damage or injury due to over-pressurization.
2. Drape a heavy towel or blanket over the end-cap and point the end-cap away from personnel and equipment. If the unit is in a shield, close the shield door.
3. Call the factory for further instructions if the incident occurs during working hours.

4. If it is impractical to keep the unit cold until advice is available from the factory, keep the end-cap covered with a heavy towel or blanket and place the unit in a restricted area in a container (corrugated cardboard, for example). If the unit is in a shield, let it warm up in the shield with the door closed.
5. After the unit has warmed up, cautiously check for over-pressurization (outwardly bulging end-caps or windows). If there are no signs of pressure, the unit may be shipped to the factory for repair. Consult the factory for shipping information.

7. Setup and Test

The significant specifications of Ge detectors are few in number, and detectors are not complex instruments, so it is possible to verify the performance of a detector with relative ease – provided that the proper equipment is available and correct procedures are used. The equipment used in conjunction with a Ge detector must be of the right type and in good working order to ensure good system performance. Likewise, the procedures must reflect the standards of the manufacturer or there will be unexplained differences in performance between tests in the factory and in the field. The information provided in this section is consistent with the procedures used to generate the energy and efficiency data presented in the detector test data sheet. This is a procedure that uses digital electronics. Procedures with analog electronics are presented in Appendix (Setup and Test with Analog Electronics) on page 62 of this manual.

Equipment Required

The Setup and Test section assumes that the test equipment listed here is available. For efficiency measurements, the ^{60}Co source should be calibrated and traceable to national or international radiological standards.

- Ge Detector, Cryostat, and Preamplifier
- Digital Signal Analyzer (DSA) – Model Lynx[®], DSA-LX[®], or equivalent.
- Computer with Spectroscopy Software Installed – Genie[™] 2000 Gamma Acquisition and Analysis, or equivalent.
- Voltmeter (Analog or 3-1/2 digit)
- Oscilloscope – 50 MHz bandwidth, 5 mV/div.
- Sources as in Table 1

Detector Type	^{60}Co	^{57}Co	^{55}Fe	^{109}Cd
SEGe	P	S		
REGe	P	S		S
XtRa	P	S		S
LEGe		S	P	
Ultra-LEGe		S	P	
Well/SAGe Well	P	S	P	
BEGe	P	S	S	
Where P = Primary source and S = Secondary source				

Test Configuration

Connect the equipment as shown in the Figure 34. Use the same electrical circuit for all AC power for the DSA and Acquisition Computer to avoid ground loops. The connections are typically done with a labeled cable bundle. While there may be more connections options available only the following are needed for validating the test data on the detector data sheet:

- Power – A multi-pin D-type connector to provide low voltage power for the preamplifier.
- HV IN – An SHV connector to provide high voltage bias to the detector.
Note: the connector on the DSA side must be plugged into the appropriate HV polarity as indicated on the detector data sheet.
- HV INH – A BNC connector to provide signal to disable HV bias in the event of a detector warm up.
- ENERGY – A BNC connector with the primary signal from the preamp.
- INHIBIT (TRP only) – A BNC connector to provide a gate signal during the reset period of the Transistor Reset Preamp.

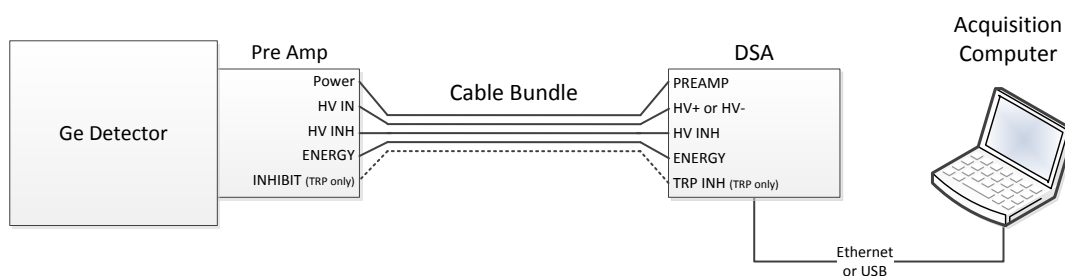


Figure 34 Test Equipment Setup

Instrument Setting

Refer to Table 2 for typical test setup settings for measuring the resolution of various detector types. DSA rise time and flat top time constants for particular detectors may differ from those suggested here. Consult the detector test data sheet for the specific settings.

Table 2 Test Setup for Resolution Measurements								
Detector Type	Typical Preamp	Peak Energy of interest	H.V. Polar.	Input* Polar.	Time Constants (μ s) **		DSA Input Channels	Channel setting for peak of Interest
					RT	FT		
Small LEGe	ITRP	5.9 keV	Neg	Pos	22.6	0.8	2048	842
Small LEGe	RC	5.9 keV	Neg	Pos	5.6	0.8	2048	842
Ultra LEGe	ITRP	5.9 keV	Neg	Pos	22.6	0.8	2048	842
LEGe	ITRP	122 keV	Neg	Pos	22.6	0.8	8192	2260
Small LEGe	RC	122 keV	Neg	Pos	5.6	0.8	8192	2260
Large LEGe	RC	5.9 keV	Neg	Pos	5.6	0.8	2048	842
Large LEGe	RC	122 keV	Neg	Pos	5.6	0.8	8192	2260
Coaxial	RC	122 keV	Pos	Neg	7.2	0.8	8192	1340
Coaxial	RC	1332 keV	Pos	Neg	7.2	0.8	8192	8170
REGe	RC	122 keV	Neg	Pos	7.2	0.8	8192	1340
REGe	RC	1332 keV	Neg	Pos	7.2	0.8	8192	8170
XtRa	RC	22/88 keV	Pos	Neg	7.2	0.8	8192	1340
XtRa	RC	1332 keV	Pos	Neg	7.2	0.8	8192	8170
Well	RC	122 keV	Pos	Neg	7.2	0.8	8192	1340
Well	RC	1332 keV	Pos	Neg	7.2	0.8	8192	8170
BEGe	RC	5.9 keV	Pos	Neg	5.6	0.8	2048	842
BEGe	RC	122 keV	Pos	Neg	5.6	0.8	8192	2260
BEGe	RC	1332 keV	Pos	Neg	5.6	0.8	8192	8170
SAGe Well	RC	122 keV	Neg	Neg	5.6	1.6	8192	1340
SAGe Well	RC	1332 keV	Neg	Neg	5.6	1.6	8192	8170

* Detectors with 2002C preamps have opposite polarity to those listed.

** The time constants listed here are typical settings only. Consult the detector test data sheet for the settings used with the specific detector.

Applying the Bias Voltage

Ensure the high voltage bias cable is plugged into the proper polarity connection on the DSA. While typical detector HV polarities are listed in Table 2, the user should consult the detector data sheet for confirmation of the proper polarity. It should be noted that some older (or non-Canberra) DSA's only have a single HV input connection. For these DSA's the polarity is typically set by an internal jumper. Consult the appropriate DSA manual for setting and verifying the HV polarity.

While not strictly necessary, it is recommended to observe preamplifier ENERGY output with the oscilloscope during the biasing process. For RC-style preamps (e.g. iPA and 2002C), with the preamp powered up, but no detector bias applied, one should observe noise on the ENERGY output that is a few hundred millivolts peak to peak. If this noise is observed on the preamp output, and the detector is fully cooled the detector is safe to apply HV bias on the detector. Note that reset preamplifiers (e.g. 2101 or iTRP models) have a very different behavior as observed on the oscilloscope. See the note below regarding assessing a detector with a reset preamplifier.

The high voltage setting to be applied to the detector is set programmatically in the DSA. Consult the DSA manual regarding making this setting. The appropriate voltage setting is indicated on the detector data sheet. Once properly configured, the bias is typically applied by selecting a single button in the DSA/Spectroscopy software. The bias from DSA is ramped up smoothly to prevent damage to the internal electronics. This ramping period will take several seconds, and during the period the ENERGY output of a RC preamp will be flat offset by several volts for DC-coupled preamps) or near zero for AC-coupled preamps).

When the HV ramping is complete, signal on the ENERGY output should settle to be close zero, and the noise as observed on an oscilloscope should be on a few millivolt peak-to-peak (for RC preamps). One should also be able to observe occasional "spikes" due to background events in the detector.

Note 1: Test Point on RC-style Preamplifiers

In addition to monitoring the ENERGY output on an oscilloscope, one can also monitor the test point Voltage on the preamplifier. For the 2002C the test point is on the rear panel of the preamplifier and is measured with the voltmeter. For the iPA the test point can be monitored through USB in the iPA Graphical User Interface.

With no bias on the detector the test point voltage should read approximately minus (-) 1 to minus (-) 2 volts dc. When bias is applied the test point voltage will go negative for detectors with positive bias. Alternatively, test point voltage will go positive for detectors with negative bias. When bias is fully applied and the detector settles, the test point voltage should return to close to the initial value. The voltage at the test point should approximate that given on the detector data sheet.

Note 2: Reset Preamplifier Signals

The ENERGY output on reset-type preamplifiers (e.g. 2101 and iTRP) look significantly different than RC-style signal output. With no detector bias applied (the preamp output should be about minus (-) 6 to minus (-) 12 volts for detectors

requiring negative bias and plus (+) 6 to plus (+) 12 volts for detectors requiring positive bias. Within these ranges it will have a sawtooth pattern. As bias is applied to the detector the sawtooth pattern will remain but the period of the pulse will stretch out to be a second or more. Figure 35 shows the output signal for detectors having negative bias. The sawtooth is inverted for detectors requiring positive bias and for certain other preamplifier types.



Figure 35 Sawtooth Output Signal

Once fully biased, the period of the sawtooth can be compared to the value shown on the test data sheet.

DSA signal settings

There are many potential settings that can be adjusted on a DSA to fine tune the acquisition and signal processing. For validating the detector test measurements only a few important parameters need to be set:

- Number of input channels
- Rise Time and Flat Top values
- Pole/Zero
- Gain Setting

DSA's can be configured to digitize the input energy signal up to 32768 channels ,in the case of the Lynx DSA. When making spectroscopic measurements it is generally good practice perform measurements with the highest number of channels, as this gives maximum fidelity of the measured data. In the case of the detector data sheet measurements the DSA is set up to fewer channels. This is done to maintain backwards compatibility with historical analog to digital converter settings as well as optimize the number of channels in the measured peak. The number of channels used for each detector type and source measurement is presented in Table 2.

Rise Time and Flat Top values are settings that are used in the DSA's trapezoidal shaping algorithm to optimize the pulse height reading of each event. These settings are analogous to the single shaping time used for semi-Gaussian shaping in analog amplifiers. The settings presented in Table 2 are typical settings, but the values presented on the detector test data sheet are the values used to generate the corresponding energy resolution and efficiency values on the same sheet.

For RC-type preamps it is necessary optimize the pole/zero. Most DSA's have an automatic pole/zero algorithm. It is recommended to follow the auto pole/zero procedure in the respective DSA manual. Note it may be necessary to set the gain of the input signal such that there will be sufficient counts in the spectral range to perform the optimization. The pole/zero process will change the channel positions of the peaks so it will nevertheless be necessary to optimize the gain setting after pole/zero adjustment. Detectors with reset preamplifiers do not require a pole/zero adjustment.

Following pole/zero one should set the gain of the DSA for each measurement such that peak energy of interest appears in the approximate channel location as indicated in Table 2. The choice of the particular channel location in case is chosen such that Full Width at Half Maximum (FWHM) of the peak of interest will be approximately 10 to 15 channels wide. This provides an optimum number of channels for this measurement.

Accumulating the Spectrum

After gain adjustments are complete, clear the spectral memory in the DSA control software (e.g. the embedded acquisition software, or other external packages such as S501 Genie 2000 Gamma Acquisition and Analysis), and accumulate a spectrum with approximately 10 000 counts in the highest channel of the peak of interest.

Calculating Resolution

Table 3 lists the peak energies of radioisotopes commonly used in calculating detector energy resolution.

Table 3 Test Sources			
Isotope	Peak Energies (keV)		ΔE
⁵⁵ Fe	5.894	6.489	595.0 eV
⁵⁷ Co	6.489	14.44	
	122.06	136.47	14.44 keV
¹⁰⁹ Cd	22.1	88.0	65.9 keV
⁶⁰ Co	1173.2	1332.5	159.30 keV

To determine the detector's energy resolution, collect several thousand counts in the 1332 keV peak of ⁶⁰Co. A good rule of thumb is to collect data until there are 10,000 counts in the highest channel of the peak of interest. The procedure is identical for other radioisotopes and lines.

Energy resolution is computed as the full width at half maximum (FWHM) or tenth maximum (FWTM) in units of energy (typically keV). As such the spectral data must be calibration. Consult the spectroscopy software user's manual for performing a spectral energy calibration. DSA's have a very linear response and for the analyses presented here a one or two point energy calibration is typically sufficient.

For the FWHM and FWTM on the detector test data sheet, the values are computed using the algorithms in the Canberra *Genie™ 2000 Gamma Spectroscopy Software*. To extract the FWHM, FWTM, and peak area values for the peak of interest, a region of interest (ROI) is placed to encompass the full peak. The region just outside the ROI (both left and right) will be used to compute the background, so one should ensure that these outer regions are background. The ROI should also not be too much wider than the peak because this could bias the statistical analysis. After the ROI is

placed the FWHM, FWTM, and area can be read off the marker information window. For information on the algorithm used in this computation, consult the *Genie™ 2000 Gamma Spectroscopy Software Customization Tools Manual*.

Other spectroscopy packages could be used as well to extract the energy resolution. In these cases, one should be sure to follow the vendors recommendation for setting up the ROI's, as well as, understand any limitations regarding the peak analysis algorithm. If in doubt one can perform a manual peak energy resolution analysis as described in Section 9 of this document.

Peak/Compton Calculation

Coaxial detectors have Peak-to-Compton (P/C) specifications which are dependent on resolution and efficiency as well as peak/shape, active to inactive material, charge collection, aspect ratio, etc.

The P/C measurement must be made under the same conditions as the resolution measurements, since it uses peak height, not peak area in determining the value. The Compton Region used for P/C calculations has been defined in IEEE Standard 325 for ⁶⁰Co as 1040 keV to 1096 keV. Therefore the formula for P/C is as follows:

$$P/C = \frac{\text{Number of counts in highest channel of 1.33 MeV peak}}{\text{Average counts per channel (1040 keV and 1096 keV)}}$$

Efficiency Measurement

Procedure

Place the source 25 cm away from the end-cap of the detector. The source should be on the end cap axis and no extraneous materials should be between the source and the detector. Appropriate allowances should be made for sources of substantial thickness. Setup the DSA and Spectroscopy System with the same settings as the 1332 keV energy resolution measurement.

Prior to the efficiency measurement, make sure there are no other sources in the area that could disturb the number of counts in the 1332 keV peak. Collect a spectrum until there are at least 10,000 counts in the peak area (i.e. 1% statistical uncertainty). When complete, note the system live time.

Calculation

The relative efficiency is then obtained by the following formula.

$$\text{Relative efficiency} = \frac{N}{T} \times \frac{1}{R_s} \times \frac{1}{1.2 \times 10^{-3}} \times 100\%$$

Where:

N = Number of counts in 1.33 MeV peak

T = Preset Live Time

R_s = Source strength in Gamma-rays per second

1.2×10^{-3} = Efficiency of 3 by 3 NaI detector at 25 cm.

Source Calibration

NIST sources are calibrated in terms of nuclear transformations per second (NT/s) and for ^{60}Co , there is one 1.33 MeV photon emitted per nuclear transformation.

The source emission rate must be corrected for decay at least monthly, because the half life of ^{60}Co (5.27 years) implies a rate decrease of approximately 1.1% per month. Use the following formula to correct for source decay:

$$N_p = N_o \cdot e^{-(0.603)t / \tau}$$

Where:

N_p = present rate of emission

N_o = original rate of emission

t = elapsed time

T = half-life (5.27 years for ^{60}Co)

With a 3 in. x 3 in. NaI(Tl) Detector

If no NIST or other suitable calibrated source is available, a 3 in. x 3 in. detector may be used for direct side-by-side comparisons of Ge detector efficiency.

If this approach is used, it is best to integrate the upper half of the 1.33 MeV peak and multiply by two to determine peak intensity for the NaI(Tl) detector. This reduces the influence of the 1.17 MeV gamma rays on the 1.33 MeV peak.

8. Troubleshooting

There are a very limited number of Ge detector failure modes, the most common being cryostat vacuum loss. The numbers of things which can contribute to loss of resolution are almost limitless, however, and this is where careful diagnosis is most important.

The most important indication of the condition of a Ge detector itself, exclusive of preamplifier and other electronics problems, is reverse leakage current. The first stage of the preamplifier can be used as an electrometer to measure the leakage current of a detector. Note that this is only possible on detectors with a DC-couple preamplifier (most standard detector models), but it is not possible to measure leakage current on AC-coupled preamplifiers.

Leakage Current must be measured as a first step in diagnosing detector performance problems!

Leakage Current Measurement

The most important indication of the condition of a Ge detector element is reverse leakage current. The so-called V-I curve can be determined by using the first stage of the preamplifier as an electrometer. A typical V-I curve for a coaxial detector is illustrated in Figure 38. The leakage current is relatively flat up to the recommended operating bias. The chart also shows the capacitance vs. bias curve, which flattens out as depletion is reached.

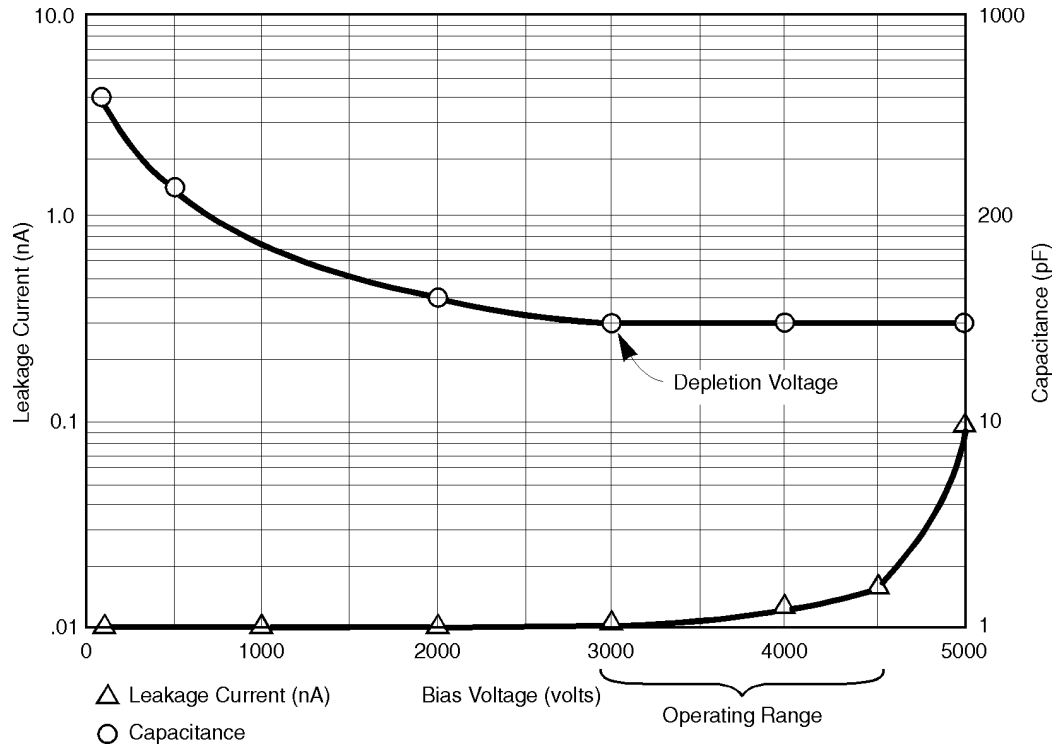


Figure 36 Typical Coaxial I-V and C-V Curves

Although the capacitance cannot be measured readily, you can observe reduced noise at the amplifier output as the capacitance is reduced with increasing bias. The noise should flatten at the point the detector becomes fully depleted provided that the leakage current is still flat at that voltage.

Resistive Feedback Preamplifier

The DC voltage at the rear panel test point is normally in the range of -0.5 to -2.0 volts. In addition to this offset, detector leakage current will cause the test point voltage to shift positive for detectors using negative bias and negative for detectors using positive bias. The transfer function is determined by the feedback resistor value. Figure 39 shows the block diagram for the RC Preamp.

Typical values and corresponding transfer functions are given below:

Detector Type	R_f (typ)	V_{tp} / I_1 (nA)
Small LGe	1×10^{11}	100 volts/nA
Large LGe	5×10^{10}	50 volts/nA
Coaxial	2×10^9	2 volts/nA

The feedback resistor value may be selected for high energy rates (lower value) or lower noise (higher value) so the above values can vary greatly from one detector to another.

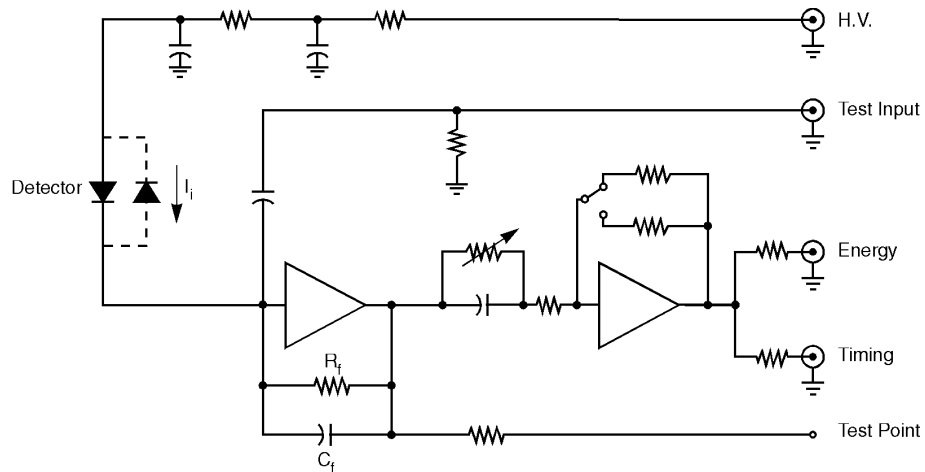


Figure 37 RC Preamplifier Block Diagram

Detected radiation results in detector current, so measurements of leakage current should be done with no radioactive sources in the presence of the detector.

The transient response to increments of voltage is momentary high current (charging the detector capacitance) returning to the normal value. This transient is greatest on the high slope part of the capacitance and observation of the transient tells a great deal about the detector. For example, no or small transient response may indicate an open HV circuit or broken contact to the detector.

Reset Preamplifier

With a reset-type preamplifier, leakage current determines the quiescent (no sources present) preamplifier reset rate. The reset period ranges from roughly 0.1 second to 1.0 second depending on the size of the detector and on other factors, including the absolute temperature, the FET leakage current, the infrared heat load on the detector element, etc. The reset rate must be measured by using an oscilloscope on the preamplifier output. **Error! Reference source not found.**40 shows the block diagram for either a Pulsed Optical (PO) or a Transistor Reset (TRP) preamplifier.

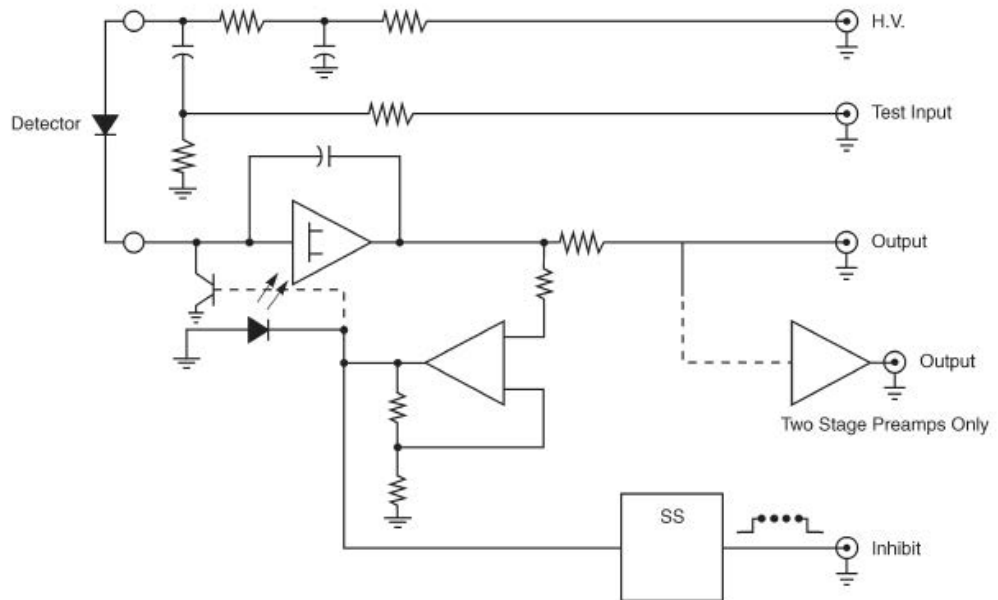


Figure 38 Reset Preamplifier Block Diagram

The transient response to movements of bias is high charging current or high momentary reset rates as indicated in Figure 41, which shows a typical transient response for detectors requiring negative bias. Sawtooth is inverted for detectors requiring positive bias or s for units having a second stage amplification.

Again, detected radiation will increase the leakage current and reset rate so make V-I measurements with no sources present.



Figure 41 Typical Transient Response

Troubleshooting Symptoms and Suggestions

Most of the oscilloscope observations called for in this section are more meaningful at the amplifier output rather than at the preamplifier output. A Schottky clamp may be useful in preventing oscilloscope overload for the observation of low level signals in the presence of large signals. See *Fine Tuning the Amplifier* on page 50 for details.

No Output

- Check Power Supply Voltages.
- Check system cabling.
- Check V-I characteristics.

High Leakage Current

- Try lower bias. Detector may operate OK at lower bias.
- Detector may have been subjected to incomplete warm up cycle. Warm up completely (24 hrs) and cool down again.

Erratic Leakage Current

- Check for voltage breakdown in Preamp HV network, in the bias supply and in the HV cable.
- Dry the electrical feedthroughs with a heat gun (remove the preamplifier first to avoid damaging its components).

Poor Resolution

- Check V-I characteristic by measuring the TP voltage or reset rate as a function of detector bias.
- Check for electrical interference (periodic signals on amp output) from other equipment.
- Check ground loops (50-60 Hz noise).

To prevent ground loop noise from entering the system, the H.V. Input and H.V. Inhibit Output grounds are isolated. To maintain this isolation on 2002CC and 2002CSL preamps, slip the flexible sleeving included with the preamp over the BNC and SHV connector shells after connecting the cables.

Microphonic Noise

- Use symmetrical restorer mode and shorter time constants to minimize effects of microphonic noise.
- Isolate the Dewar from the floor with some insulating material such as rubberized hair, foam, etc.
- Check dipstick orientation to make sure bottom of dipstick does not touch the Dewar inside. Dipstick elevation can be changed by loosening the screws in the clamp ring. These screws are recessed. A 7/64 in. hex key wrench is required.

Low Frequency Noise

- Check for Ground Loops. Make sure whole system is powered from the same electrical outlet or circuit.

High Frequency Noise

- Bias Supply typically uses 5 kHz to 20 kHz DC-DC converter. Change bias supplies if converter frequency appears as noise on preamplifier or amp output.

Peak Tailing

- Check Pole/Zero setting.
- Check HV cables and circuits. Detector may not be getting rated bias.
- Has detector been exposed to neutrons? Radiation damage causes charge collection problems.

Moisture Accumulation

- Indicates poor vacuum unless accumulation on Detector Chamber occurs only when detector is temperature cycled. Measure weight loss in 24 or 48 hour period to determine LN₂ loss rate. LN₂ weighs 0.81 kg (1.78 lb) per liter.

High LN₂ Loss Rate

- See Moisture Accumulation, above. For dipstick type detectors, substitute another Dewar and check loss rate again. Dipstick Dewars may be replaced in the field at moderate cost.

Poor Resolution at High Energy

- Neutron damage affects resolution at high energy to a greater degree than at low energy. As degradation increases, peaks develop asymmetry. Warmup following damage usually makes the resolution worse.

Noise Spikes (same polarity as signal)

- Likely caused by detector surface leakage current. Do complete thermal cycle and retest.

Noise Spikes (opposite polarity from signal)

- Breakdown in HV network, in HV feedthrough or in HVPS, cabling, etc. Check components on another system to verify. Remove preamp to dry electrical feedthrough with heat gun or clean with methanol and then dry thoroughly before reinstalling.

Peak Instability

- Most gain drift problems are associated with the main amplifier or ADC. If drift is greater than that expected from the temperature range experienced by the electronics, substitute amplifier and ADC.
- Wiring problems between detector and preamp can cause discrete peak shifts. Tap gently on detector and preamplifier assembly to induce shifts. Inspect and clean contacts between preamp and cryostat if problem exists.

Poor Resolution at High Rates

- Check amplifier Pole/Zero.
- Use appropriate amplifier shaping time constant.
- Adjust preamplifier Pole/Zero by observing amplifier output with high count rate. Set preamp P/Z for most stable baseline after first properly Pole/Zeroing the main amplifier.

Intermittent Output (pulsed-optical preamp)

- HV breakdown in cables. Unstable HV Power supply. Moisture on feedthrough HV network. All the above can cause pulsed optical preamps to lock up with output at minus (-) 6 to minus (-) 10 volts except when HV is increased momentarily.

LN₂ Siphoning from MAC

- Plug the unused port (the port not venting) with a cover.

Radiation Damage (Tailing)

- Consult factory. Radiation damage repair usually requires annealing at the factory.

Self-generated Microphonics

- Clean dipstick copper surface with abrasives. Check integral Dewars for ice crystals. Warm up and dry them thoroughly.

Noise Pickup

- Keep cables together and away from CRTs, printers, and other electrically noisy equipment.

Erratic Baseline or Amplifier Output (reset preamp)

- Be sure amplifier Pole/Zero is out: Fully counter-clockwise.

H.V. Inhibit

- If the H.V. Inhibit Indicator is on in the absence of symptoms of warm-up or poor vacuum (excessive loss rate or leakage current), the circuit may need adjustment. See *H.V. Inhibit Circuit Adjustment* on page32.

9. Appendix (Setup and Test with Analog Electronics)

The significant specifications of Ge detectors are few in number, and detectors are not complex instruments, so it is possible to verify the performance of a detector with relative ease – provided that the proper equipment is available and correct procedures are used. The equipment used in conjunction with a Ge detector must be of the right type and in good working order to ensure good system performance. Likewise, the procedures must reflect the standards of the manufacturer or there will be unexplained differences in performance between tests in the factory and in the field. The information provided in this section is consistent with the procedures used to generate the energy and efficiency data presented in the detector specification sheet. This is a procedure that uses digital electronics.

Equipment Required

The Setup and Test section assumes that the test equipment listed here is available. For efficiency measurements, the ^{60}Co source should be calibrated to NIST standards.

- Ge Detector, Cryostat, and Preamplifier
- NIM Bin and Power Supply – Model 2000 or Equivalent
- Amplifier – Model 2026 or Equivalent
- MCA – with 8192 ADC Range, 4096 Memory, and Digital Readout
- Detector Bias Supply – Model 3106D, or Equivalent or Model 3102D for bias of 2000 volts or less.
- Voltmeter (Analog or 3-1/2 digit)
- Oscilloscope – 50 MHz bandwidth, 5 mV/div.
- Sources as in Table 1

Detector Type	^{60}Co	^{57}Co	^{55}Fe	^{109}Cd
SEGe	P	S		
REGe	P	S		S
XtRa	P	S		S
LEGe		S	P	
Ultra-LEGe		S	P	
Well/SAGe Well	P	S	P	
BEGe	P	S	S	

Where P = Primary source and S = Secondary source

Test Configuration

Connect the equipment as shown in the Figure 34. Use the same electrical circuit for all AC power to the system to avoid ground loops. The Bias Supply and Amplifier should be located at opposite ends of the NIM Bin, if possible, to minimize cross talk between them. Use the amplifier rear panel output (Unipolar) if the cable between Amplifier and MCA is more than 1 m (3 ft) long. The front panel output may be used with long cables only if the cable is terminated at the MCA with a 93 ohm load. Otherwise, it may oscillate.

To prevent ground loop noise from entering the system, the H.V. Input and H.V. Inhibit Output grounds are isolated. To maintain this isolation on 2002C and 2002CSL preamps, slip the flexible sleeving included with the preamp over the BNC and SHV connector shells after connecting the cables.

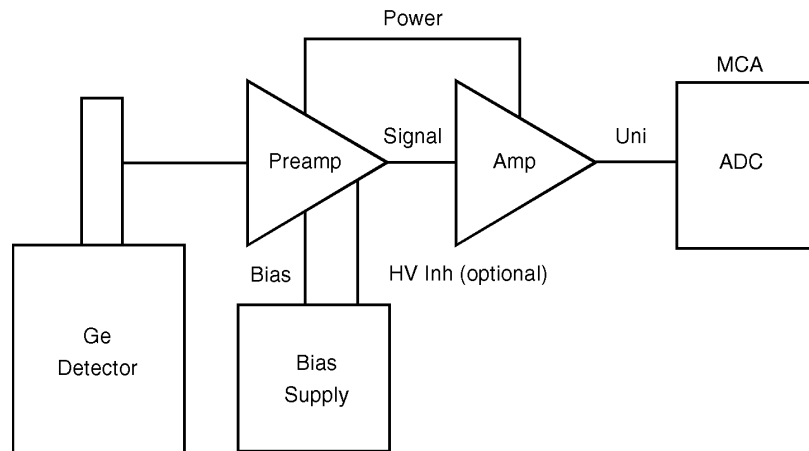


Figure 39 Test Equipment Setup

Instrument Setting

Refer to Table 2 for typical test setup settings for measuring the resolution of various detector types. Amplifier time constants for particular detectors may differ from those suggested here. Consult the detector test data sheet for specifics.

Restorer controls are normally set alike for all detector types, as follows:

Rate - AUTO
Mode - SYM
Threshold - AUTO

Consult the Amplifier Instruction Manual for further information.

Table 5 Test Setup for Resolution Measurements							
Detector Type	Typical Preamp	Peak Energy	H.V. Polar.	Input* Polar.	Time** Constant	ADC Gain	Approx. Energy/ Channel
Small LEGe	ITRP	5.9 keV	Neg	Pos	12 μ s	2048	7 eV
Small LEGe	RC	5.9 keV	Neg	Pos	4 μ s	2048	7 eV
Ultra LEGe	ITRP	5.9 keV	Neg	Pos	12 μ s	2048	7 eV
LEGe	ITRP	122 keV	Neg	Pos	12 μ s	8192	54 eV
Small LEGe	RC	122 keV	Neg	Pos	4 μ s	8192	54 eV
Large LEGe	RC	5.9 keV	Neg	Pos	4 μ s	2048	7 eV
Large LEGe	RC	122 keV	Neg	Pos	4 μ s	8192	54 eV
Coaxial	RC	122 keV	Pos	Neg	4-6 μ s	8192	91 eV
Coaxial	RC	1332 keV	Pos	Neg	4-6 μ s	8192	163 eV
REGe	RC	122 keV	Neg	Pos	4-6 μ s	8192	91 eV
REGe	RC	1332 keV	Neg	Pos	4-6 μ s	8192	163 eV
XtRa	RC	22/88 keV	Pos	Neg	4-6 μ s	8192	91 eV
XtRa	RC	1332 keV	Pos	Neg	4-6 μ s	8192	163 eV
Well	RC	122 keV	Pos	Neg	2-6 μ s	8192	91 eV
Well	RC	1332 keV	Pos	Neg	2-6 μ s	8192	163 eV
BEGe	RC	5.9 keV	Pos	Neg	4-8 μ s	2048	7 eV
BEGe	RC	122 keV	Pos	Neg	4-8 μ s	8192	54 eV
BEGe	RC	1332 keV	Pos	Neg	4-8 μ s	8192	163 eV
SAGe Well	RC	122 keV	Neg	Neg	N/A	8192	91 eV
SAGe Well	RC	1332 keV	Neg	Neg	N/A	8192	163 eV

* Detectors with 2002C preamps use opposite polarity.

** Or equivalent digital shaping.

*** SAGe Well Detectors require digital signal processing for optimum performance. Recommended settings for Rise Time and Flat top are indicated on the specification sheet included in the detector shipment.

Applying the Bias Voltage (RC Preamplifier)

Observe the amplifier output with the oscilloscope. The noise should be several hundred millivolts peak to peak, with no detector bias applied. (Use the cable that normally goes to the MCA rather than an oscilloscope probe).

Monitor the test point on the rear panel of the preamplifier with the voltmeter. It should read approximately minus (-) 1 to minus (-) 2 volts dc. Do not confuse the test input (BNC) with the test point. For AC-coupled preamplifiers, the quiescent test point voltage should be near 0 V.

Increase bias to 100 volts. The noise at the amplifier output should decrease somewhat, and the voltmeter should momentarily change before returning to its initial reading. For Detectors using positive bias, the Test Point voltage change will go negative and for detectors using negative bias, the Test Point voltage will go positive. Increase the bias now to 500 volts. The noise should be further reduced and the voltmeter should respond exactly as before.

Increase the bias in 500 volt steps to the recommended value, observing the behavior of the amplifier signal and voltmeter after each increment. The noise should remain constant after the depletion voltage is reached. The voltage at the test point should approximate that given on the test data sheet in the front of the manual.

Applying the Bias Voltage (Reset Preamplifier)

Observe the preamplifier output with the oscilloscope. If the preamplifier output is connected to the rear amplifier input, the front panel input can be connected to the oscilloscope.

With no bias applied (HV supply off), the preamp output should be about minus (–) 6 to minus (–) 12 volts for detectors requiring negative bias and plus (+) 6 to plus (+) 12 volts for detectors requiring positive bias.

Apply about 50 volts bias. The preamp output should be a sawtooth pattern, with a period stretching gradually to a second or more. Figure 35 shows the output signal for detectors having negative bias. The sawtooth is inverted for detectors requiring positive bias and for certain other preamplifier types.



Figure 40 Sawtooth Output Signal

Increase bias gradually to the recommended operating voltage. The sawtooth pattern should repeat itself after every increment of bias. Compare the period of the sawtooth to the value shown on the test data sheet.

Fine Tuning the Amplifier

Using the amplifier settings given in Table 2 on page 48, introduce the source to the detector with the protective plastic cap removed. Observe the test voltage change if the preamp is RC type. If the preamp is the reset type, the sawtooth frequency will increase. Adjust the amplifier's coarse and fine gains to give approximately 8 volt pulses at the output.

The Pole/Zero control must be fully CCW for reset preamplifiers. With an RC preamplifier, adjust the Pole/Zero control to give the pulse shape illustrated in **Error! Reference source not found.**

Many oscilloscopes exhibit overload recovery problems when they are used with the high gain necessary to set Pole/Zero correctly. A Schottky clamp (Model LB1502) is available from Mirion Technologies to prevent this problem. The Schottky clamp is built into the Model 1510 Integrated Signal Processor and the Models 2025 and 2026 Spectroscopy Amplifiers.

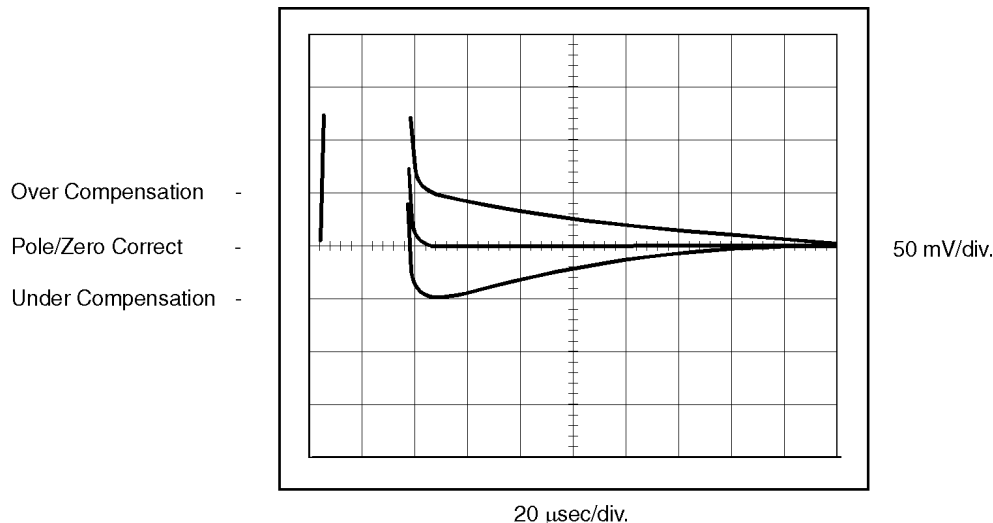


Figure 41 Pole/Zero Compensation

The Schottky clamp circuit is shown in **Error! Reference source not found.** for those who want to make their own.

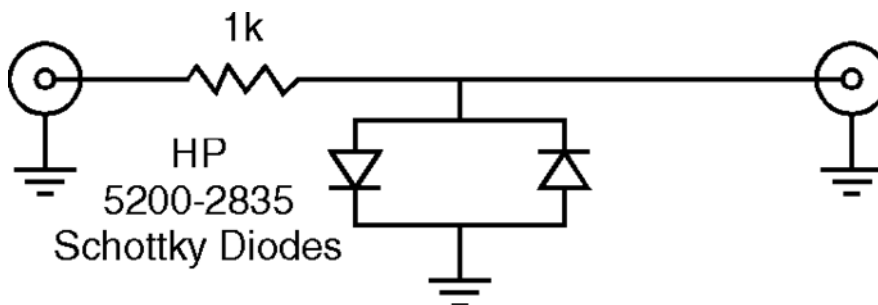


Figure 42 Schottky Clamp Circuit

Accumulating the Spectrum

With the amplifier and ADC settings, as shown in Table 2 on page 48, start a collect cycle in the MCA. Adjust the amplifier gain so that the peaks of interest are to the far right of the display (within 100 channels of the top of the memory group displayed).

After gain adjustments are complete, clear the MCA memory and accumulate a spectrum with approximately 10 000 counts in the peak channel of the peak of interest.

Calculating Resolution

Table 3 lists the peak energies of radioisotopes commonly used in calculating detector resolution.

Table 6 Test Sources			
Isotope	Peak Energies (keV)		ΔE
⁵⁵ Fe	5.894	6.489	595.0 eV
⁵⁷ Co	6.489	14.44	
	122.06	136.47	14.44 keV
¹⁰⁹ Cd	22.1	88.0	65.9 keV
⁶⁰ Co	1173.2	1332.5	159.30 keV

To determine the detector's resolution, collect several thousand counts in the 1332 keV peak of ⁶⁰Co. The procedure is identical for other radioisotopes and lines.

To determine the conversion factor, the energy per channel, find the peak centroids of the 1173.2 keV and 1332.5 keV peaks by expanding each region individually, placing the cursor by eye and recording the center channel of each peak.

Then divide the difference in keV between the two peaks by the number of channels between the peaks:

$$\frac{(1332.5 - 1173.2) \text{ keV}}{\text{Separation in channels (N)}} = \frac{159.3 \text{ keV}}{\text{N channel}}$$

Using the setting for the ADC previously described, the conversion factor should be in the range of 0.16 keV/channel. If it isn't, then something is set up improperly.

In this example N = 977 channels, so the conversion factor is (159.3/977) = 0.163 eV/channel, which is in the proper range.

Expand or print out the 1332 keV peak and determine the number of channels FWHM and FWTM (Full Width at Half Maximum, and Full Width at Tenth Maximum) as in **Error! Reference source not found.**

The peak is at channel 2011, with 8512 counts. Thus Half Maximum (HM) of the peak is 8512/2 = 4256 counts; but it's not likely that there will be a channel with exactly 4256 counts in it. Therefore, it will be necessary to interpolate the data, using the following information:

- The peak channel. That is, the channel with 8512 counts.
- The counts in the channel just below the FWHM point on the left side of the peak (counts < 4256).
- The counts in the channel at or just above the FWHM point on the left side of the peak (counts ≥ 4256).
- The number of the channel in 'c' (just above FWHM on the left side of the peak).
- The counts in the channel at or just above the FWHM point on the right side of the peak (counts ≥ 4256).
- The number of the channel in 'e' (just above FWHM on the right side of the peak).
- The counts in the channel just below the FWHM point on the right side of the peak (counts < 4256).

With this data, calculate the FWHM resolution as a decimal fraction using:

$$(f - d) + \frac{c - \text{HM}}{e - g} + \frac{e - \text{HM}}{e - g} \times 0.163 \text{ keV per channel (the conversion factor)}$$

Table 7 1.33 MeV Peak Data							
Channel	Data						
1992	44	51	39	61	101	239	423
2000	631	923	1384	1961	2898	4766	5759
2008	6790	7569	8072	8512	8176	6935	6152
2016	5081	4206	3305	2555	1742	1012	691
2024	507	54	233	157	122	57	

To calculate:

$$\text{Half Maximum} = 8512 / 2 = 4256$$

$$FWHM = 10 + \frac{4766 - 4256}{4766 - 3460} + \frac{5081 - 4256}{5081 - 4206} = 11.39 \text{ channels}$$

$$FWHM = 11.39 \text{ channels} \times 0.163 \text{ keV/channel} = 1.686 \text{ keV}$$

Tenth maximum is determined using the value:

$$FWHM = 10 + \frac{923 - 851}{923 - 3631} + \frac{1012 - 851}{1012 - 691} = 21.75 \text{ channels}$$

$$FWTM = 21.75 \text{ channels} \times 0.163 \text{ keV per channel} = 3.55 \text{ keV.}$$

Peak/Compton Calculation

Coaxial detectors have Peak-to-Compton (P/C) specifications which are dependent on resolution and efficiency as well as peak/shape, active to inactive material, charge collection, aspect ratio, etc.

The P/C measurement must be made under the same conditions as the resolution measurements, since it uses peak height, not peak area in determining the value. The Compton Region used for P/C calculations has been defined in IEEE Standard 325 for ^{60}Co as 1040 keV to 1096 keV. Therefore the formula for P/C is as follows:

$$P/C = \frac{\text{Number of counts in highest channel of 1.33 MeV peak}}{\text{Average counts per channel (1040 keV and 1096 keV)}}$$

Efficiency Measurement

The efficiency measurement is done with the simplest, most straightforward MCA settings so as to minimize the ADC dead time (and attendant questions of live time correction) and effort required to integrate the peaks (if the MCA does not have such arithmetic capability). For these reasons, we use the 1024-channel range and memory size and no digital offset for this measurement.

Procedure

Place the source 25 cm away from the end-cap of the detector. The source should be on the end cap axis and no extraneous materials should be between the source and the detector. Appropriate allowances should be made for sources of substantial thickness.

Adjust the amplifier gain so that the 1332 keV peak is storing in the upper half of the 1024 channel memory group.

Collect a spectrum for 1000 seconds of live time. When collection is complete, integrate a symmetrical region around the 1.33 MeV peak about 10 channels wide.

Calculation

The relative efficiency is then obtained by the following formula.

$$\text{Relative efficiency} = \frac{N}{T} \times \frac{1}{R_s} \times \frac{1}{1.2 \times 10^{-3}} \times 100\%$$

Where:

N = Number of counts in 1.33 MeV peak

T = Preset Live Time

R_s = Source strength in Gamma-rays per second

1.2×10^{-3} = Efficiency of 3 by 3 NaI detector at 25 cm.

Background Spectrum

In conditions where background is high and might contribute to an error in the efficiency measurement a second spectrum should be accumulated in the absence of the calibrated source. The integral of background in the same region of interest about 1.33 MeV should be subtracted from the former integral before calculating the relative efficiency.

Source Calibration

NIST sources are calibrated in terms of nuclear transformations per second (NT/s) and for ^{60}Co , there is one 1.33 MeV photon emitted per nuclear transformation.

The source emission rate must be corrected for decay at least monthly, because the half life of ^{60}Co (5.27 years) implies a rate decrease of approximately 1.1% per month. Use the following formula to correct for source decay:

$$N_p = N_o \cdot e^{-(0.603)t/\tau}$$

Where:

N_p = present rate of emission

N_o = original rate of emission

t = elapsed time

T = half-life (5.27 years for ^{60}Co)

With a 3 in. x 3 in. NaI(Tl) Detector

If no NIST or other suitable calibrated source is available, a 3 in. x 3 in. detector may be used for direct side-by-side comparisons of Ge detector efficiency.

If this approach is used, it is best to integrate the upper half of the 1.33 MeV peak and multiply by two to determine peak intensity for the NaI(Tl) detector. This reduces the influence of the 1.17 MeV gamma rays on the 1.33 MeV peak.

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Warranty

Mirion Technologies (Canberra), Inc. (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 on a return to factory basis or replace the software or equipment, or (B) in the case of defective services, reperform such services.

LIMITATIONS

EXCEPT AS SET FORTH HEREIN, NO OTHER WARRANTIES OR REMEDIES, WHETHER STATUTORY, WRITTEN, ORAL, EXPRESSED, IMPLIED (INCLUDING WITHOUT LIMITATION, THE WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE) OR OTHERWISE, SHALL APPLY. IN NO EVENT SHALL WE HAVE ANY LIABILITY FOR ANY SPECIAL, EXEMPLARY, PUNITIVE, INDIRECT OR CONSEQUENTIAL LOSSES OR DAMAGES OF ANY NATURE WHATSOEVER, WHETHER AS A RESULT OF BREACH OF CONTRACT, TORT LIABILITY (INCLUDING NEGLIGENCE), STRICT LIABILITY OR OTHERWISE. REPAIR OR REPLACEMENT OF THE SOFTWARE OR EQUIPMENT DURING THE APPLICABLE WARRANTY PERIOD AT OUR COST, OR, IN THE CASE OF DEFECTIVE SERVICES, REPERFORMANCE AT OUR COST, IS YOUR SOLE AND EXCLUSIVE REMEDY UNDER THIS WARRANTY.

EXCLUSIONS

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.