# APTEC GERMANIUM SPECTROMETER

Instruction Manual

INSTRUCTION MANUAL

APTEC GERMANIUM SPECTROMETER

TYPE Planar

MODEL NUMBER PS810-D31C

SERIAL NUMBER #1361

OPTIONS SP-104 Preamp.

Aptec

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# Germanium Spectrometer with a SP104 "AUTOBIAS" Preamplifier

## Contents

# Germanium Spectrometer with a SP104 Preamplifier

## 1. Introduction

### 1.1 General:

The Aptec series of germanium spectrometers has been designed to give the best in proven technology together with performance and reliability. The spectrometer consists of a combination of cryostat, preamplifier, and detector crystal and high voltage supply described in more detail in this manual. The detector crystal itself is a passivated hyperpure germanium device (PHYGE) designed to give long term stability and excellent performance characteristics. The autobias portion of the electronics provides a preset high voltage for the detector together with indicators showing whether operation is normal (green) or abnormal (red).

Liquid nitrogen cooling is required for operation as a spectrometer; storage at room temperature with no deterioration is possible in contrast with the instability of the older lithium drifted devices.

The instrument has been designed for both laboratory and industrial use; however, as high technology equipment, certain precautions must be taken to ensure optimum performance and to avoid the necessity of factory repair. This manual covers operating instructions, performance specifications, principle of operation, circuit description and troubleshooting notes. Also included are the circuit diagrams, parts list, and warranty details.
PLEASE READ THE MANUAL BEFORE STARTING OPERATION.

### 1.2 Receiving and Unpacking

The dipstick cryostats (A - vertical, and B - horizontal) are shipped separately from the liquid nitrogen container, while the integral cryostats (C - down looking and D - sidelooking) are shipped in a single box. Included are a set of cables (power, signal) a manual, and a fill collar (dipstick) or a stopper (integral) and a check list indicating items that were shipped.

a) Visually inspect for shipping damage. IMMEDIATELY NOTIFY THE CARRIER AND APTEC IF DAMAGE IS OBSERVED.
b) Check for receipt of all parts.
c) Unwrap plastic from the cryostat.
d) Unbolt the dewar (integral) from the wooden base.
e) Refer to Section 3.1 for liquid nitrogen cooling instructions.

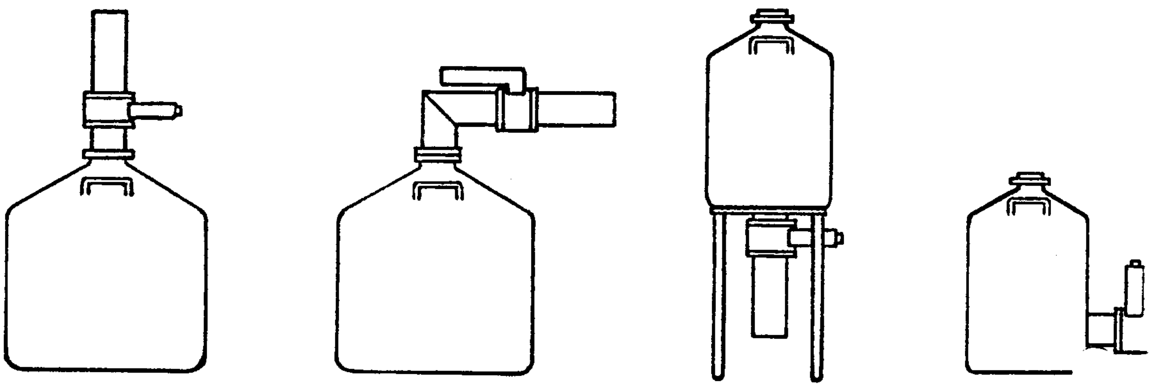
A warranty statement included in Section 7 should be consulted.

# 2. Instrument description

## 2.1 Description

The germanium spectrometer consists of a high purity germanium detector in a high vacuum enclosure (cryostat). The detector is attached by means of a copper or aluminum cold finger to a vessel used to store liquid nitrogen. The vacuum which provides the thermal insulation is maintained by internal cryopumping when the liquid nitrogen is added.

The four basic dewar - cryostat designs are shown below. Further dimensional information is included in Section 8 of the manual.



A B C D

Figure 1

The electronics attached to the cryostat converts the very high impedence charge signal from the Ge detector to a low impedence signal suitable for driving coaxial cables. The circuit consists of a charge sensitive stage followed by a cable driver stage.

The high voltage portion is on the second board and consists of a control circuit and an oscillator - rectifier portion. The output of the high voltage supply is fed to a double RC filter network on the preamplifier board. The high voltage supply is controlled by the OFF-ON switch on the preamplifier panel.

The SP-104 has safety features built in which prevent preamp damage and FET damage if the system is operated under incorrect conditions. The status of the preamplifier is indicated by the red and green status lights. When the green light is illuminated, operation of the spectrometer is normal. When no lights or the red light is illuminated or flashes, spectroscopy is not possible. Conditions which would not allow green light illumination (normal) include lack of liquid nitrogen, excessive radiation fields, detector breakdown, and loss of vacuum by the cryostat.

### 2.1.1 Planar Spectrometers

The planar spectrometer consists of a circular cylinder of Ge with a minimum sensitive thickness in mm and an area in $mm^2$. The position relative to the end-cap and the window is shown schematically below. The window material is normally high purity beryllium metal although thin aluminum is available.

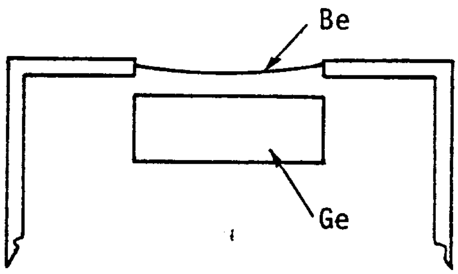



Figure 2.2

The contact of the detector adjacent to the window is a very thin, low Z material with a Ge equivalent thickness of less than 0.1 micron. The opposite detector contact has a thickness of 0.3 to 0.5 mm and is not included as sensitive thickness.

The following table relates detector area to sensitive diameter and Be window thickness. The absorption characteristics of the Be are discussed in Section 4.3.

| MINIMUM Area $mm^2$ | MINIMUM Diameter mm | STANDARD Be window microns (inches) |
|---|---|---|
| 25 | 5.7 | 25 (.001) |
| 80 | 10 | 76 (.003) |
| 200 | 16 | 76 (.003) |
| 300 | 20 | 127 (.005) |
| 500 | 25.5 | 127 (.005) |
| 1000 | 35.8 | 380 (.015) |
| 2000 | 51.0 | 510 (.020) |

## 2.1.2 Coaxial Spectrometer

The coaxial spectrometer consists of a circular cylinder of Ge wit inner and outer electrodes. The position relative to the endcap are shown schematically below for the two types of coaxial spectrometers.

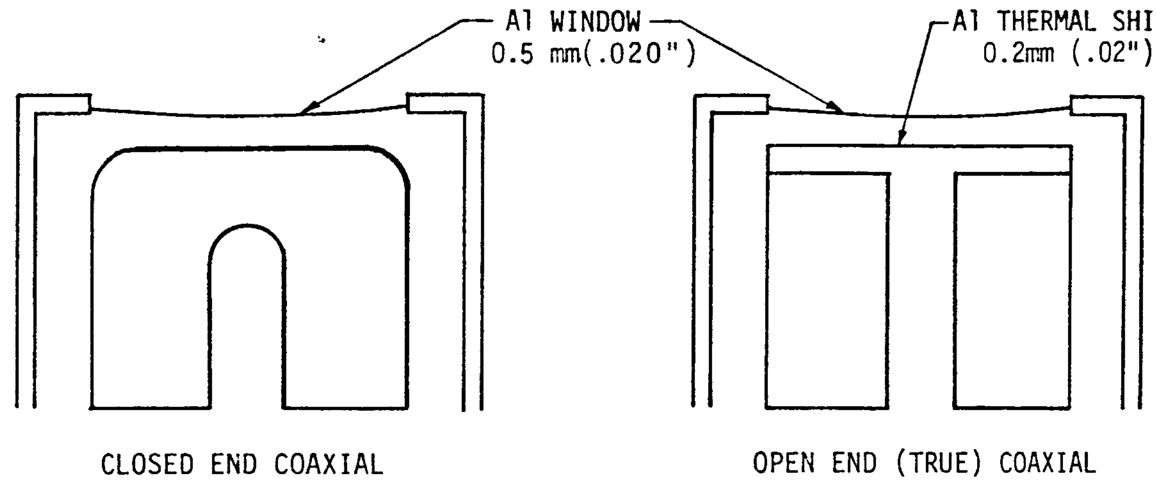



Figure 2.3

The dimensions depend upon the gamma efficiency required for e detector. Better timing and low energy performance are attributed to the true coaxial design, while improved gamma efficiency and energy resolutions are normally attributed to the closed end coaxial design. Actual performance parameters depend upon a number of factors, too numerous and complex for discussion here.

The coaxial spectrometer is normally supplied with a thin Al window, the absorption characteristics of which are given in Section 4.3.

## 2.2 Preamplifier Specifications

Output 1 - Unipolar pulses with risetimes 40 to 250 ns (depend on detector size) and RC decay time constants of 100 microseconds. Output impedence is 93 ohms, series connected. Polarity is negative for planar detectors and positive for coaxial detectors. BNC connector.

Output 2 - As above, except that output impedence is 50

Risetime - Minimum value is 40 ns (10-90%) with detector thickness of 5 mm. Otherwise risetimes vary between 5ns/mm to 10 ns/mm of detector thickness, depending on the location of the photon interaction in the detector.

Test Jack Output - Provides a signal directly from the charge loop with a 10K ohm series resistance. Useful for measuring offset voltages to determine average detector current. A 0.080 inch tip jack.

Charge Sensitivity - Approximately 330 mV/MeV for all coaxials and planars with model numbers PS1010, PS1007, PS1005, and PS505. Approximately 1 V/MeV for all other planar sizes.

| | | |
|---|---|---|
| Power | +24V | 75mA |
| | +12V | 70mA |
| | -12V | 10mA |
| | -24V | 10mA |

Supplied with a 3 meter (10ft) or optional 8 meter (25Ft) power cable terminated with an Amphenol 17-20090 9 pin connector.

Physical - Refer to the dimensional data sheet.

<u>Options</u> - A number of variations of the standard spectrometers are available and are listed below.

| | |
|---|---|
| -01 | Endcap extension of 2 inches (5 cm) |
| -02 | Endcap extension of 6 inches (15 cm) |
| -03 | Endcap extension of 12 inches (30.5 cm) |
| -04 | Endcap extension of 18 inches (46 cm) |
| -05 | Special endcap length (other than 01,02,03,or 04 sizes) |
| -06 | Aluminum window for planar (normally thin Be) |
| -07 | Left side mounted preamplifier (B, D or E Cryostats only) |
| -08 | Right side mounted preamplifier (B,D or E Cryostats only) |
| -09 | Upright preamplifier on horizontal dipstick (B or E Cryostats only) |
| -10 | Edge mounted preamplifier (A, B or E Cryostats only) |
| -11 | Low background cryostat materials (A Cryostats only) |
| -12 | High count rate performance, specified |
| -13 | Resolutions required at nonstandard time constants |
| -14 | True coaxial geometry rather than closed end |
| -15 | Non-standard area or depth - planar |
| -16 | Other performance parameters to be tested |
| -17 | Extended temperature cycling (more than 6) tests |
| -18 | Preamp with built in HV Bias supply |
| -19 | Low absorption window for beta spectroscopy (planar only) |
| -20 | Cable lengths of 25 feet (8 m) |
| -21 | Extended warranty (2 years return-to-factory) |
| -22 | Low profile vertical dipstick |
| -23 | 45 degree dipstick |

## 2.3 Spectrometer Data

### 2.3.1 Spectrometer Information

| | Model | Serial No. |
|---|---|---|
| Spectrometer | PS810-D31C | 1361 |
| Preamplifier | SP104 | 1084-079 |
| Cryostat | INTEGRAL | C9223 |
| Dewar | | |

### 2.3.2 Physical Data

Geometry of Ge crystal PLANAR

Sensitive area (planar) 80 $mm^2$; depth 10 mm

Sensitive volume (coaxial) $cm^3$; diameter cm.

Window material Be ; thickness 0.076 mm (0.003 inch)

Window-Detector distance 2 mm.

Liquid nitrogen capacity 31 liters

Recommended cooling time 24 hrs.

### 2.3.3 Electrical Data

Operating Voltage 1500

Polarity NEGATIVE

Output signal polarity (preamplifier) NEGATIVE

The gamma resolutions were measured using a C.I. 1413 linear amplifier with the baseline restorer on the low setting unless otherwise noted. The multichannel analyser was a Canberra Industries 8180 with a conversion gain of up to 8192.

The procedures for Aptec germanium spectrometers follow the IEEE standard 325 (1970) "Standard Test Procedures for Ge Gamma-Ray Detectors". Copies are available upon request from Aptec.

2.4 Test Data

Offset at operating voltage +0.2 V
(no source present)

| Energy KeV | Count Rate C/S | Time Constant micro sec | FWHM eV | FWTM eV | Notes |
|---|---|---|---|---|---|
| 5.9 | 1K | 8 | 185 | | |
| 122 | 1k | 8 | 490 | 950 | |
| | | | | | |

Efficiency ______% (for 1333 KeV $^{60}Co$ line relative to a 3 x 3 inch NaI, 25 cm source-detector distance).

Peak/Compton ratio ________.

Special Notes:

Tested by B Telb

Date Nov 26/8

Certified by [signature]

Product Manag

# 3. Operating Instructions

## 3.1 Cooling

a) Use liquid nitrogen (preferred), liquid air, liquid oxygen or liquid argon.

b) Allow 2 - 3 hrs. for planars, 4 - 6 hours for coaxial.

c) Overnight cooling is recommended to ensure best stability.

d) Do not apply preamplifier power or HV during cooling.

e) If severe frosting or condensation exists for more than 30 minutes, stop cooling and contact Aptec for further instructions.

### 3.1.1 Dipstick

a) Slip the rubber collar over the dipstick. Wetting with alcohol is sometimes useful.

b) Secure dipstick with three - 6 - 32 by 1.5 inch machine screws; tighten sufficiently to secure the dipstick in place, but do not overtighten.

c) Connect a hose to the fill port and fill as required with liquid nitrogen.

### 3.1.2 Integral Units

a) Obtain a funnel with a tail piece about 10 cm long.

b) Pour in liquid nitrogen, slowly at first. CAUTION: Initial rapid vaporization may spray back liquid nitrogen.

c) Allow 1 to 3 liters for cooling, and enough to allow for usage during the experiment (see 2.3.2.).

Do NOT fill into the dewar neck.

d) When rapid boiling has ceased, insert the dewar stopper.

## 3.2 Locating

The detector should be located in position before power is applied. If moving is required while power is on, sharp drops or bumps should be avoided. If the surface on which the detector sits is noisy (vibration), some isolation by rubber or foam rubber pads is recommended. In high vibration environments, better isolation can be achieved by using a large number of small independent foam (or rubber) supports than by using a single piece of foam.

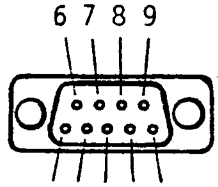
## 3.3 Initial Set-up

Requires
- a linear spectroscopy amplifier
- a power source for the 9 pin preamp power cable (often located on the above amplifier)
- a multichannel analyser with an ADC conversion of at least 1024 channels. (4096 channels is recommended)
- an oscilliscope with a sensitivity 10 mV/div and a bandwidth of greater than 1 MHz.
- gamma or X-ray sources, in the range 0.1 to 100

Optional
- a voltmeter with a sensitivity of ± 0.01 volt to ±25V
- a NIM bin if required for the linear amplifier and/or HVPS
- a square wave or high precision tail pulser.

a) Connect the power cable between the preamplifier and the power source (usually a linear amplifier, multichannel analyzer, or NIM bin). The pin voltages should be as follows

Female




| Pin | |
|---|---|
| 1 | Ground |
| 2 | Ground |
| 4 | +12V |
| 6 | -24V |
| 7 | +24V |
| 9 | -12V |

NOTE

A notable exception is older Tennelec linear amplifiers which may or may not provide the above assignment. If an adapter cable is required, it can be supplied on request by Aptec. D not plug in the preamplifier if other than the above pin voltages are found.

b) Attach a signal cable between output 1 (93 ohm cable, RG62) or output 2 (50 ohm cable, RG59) and the input of the linear amplifier.

c) Adjust the linear amplifier for the correct input and output polarities (negative input for a planar, positive input for a coaxial spectrometer) and the desired time constant (See Test Data in Section 2.3.4).

d) If the power is not already on (NIM bin or MCA), turn it on.

## 3.4 Spectroscopy

a) Attach an oscilloscope to the unipolar output of the linear amplifier. With linear amplifier gain of 100 and scope settings of 50 mV/division and 10 microseconds/division, there should be some noise apparent in the baseline. If not, and if at higher amplifier gains there is nothing present, check all cables and connections.

b) On the preamplifier, turn on the high voltage (HV) by moving the locking switch to the ON position. This should cause the red light to go on an off periodically followed by the green light coming on steadily, while the red light stays off. The start-up period may take from 10 to 60 seconds depending on the size of the spectrometer. Large area of large efficiency spectrometers normally have a longer start-up time.

c) When the green light stays on, observe the gamma pulses on the oscilliscope. Locate the test radiation source at an appropriate distance from the crystal to avoid amplifier saturation. Adjust the gain and pole zero of the linear amplifier for the gamma energy of interest and proceed with setting up the MCA and the remainder of the apparatus.

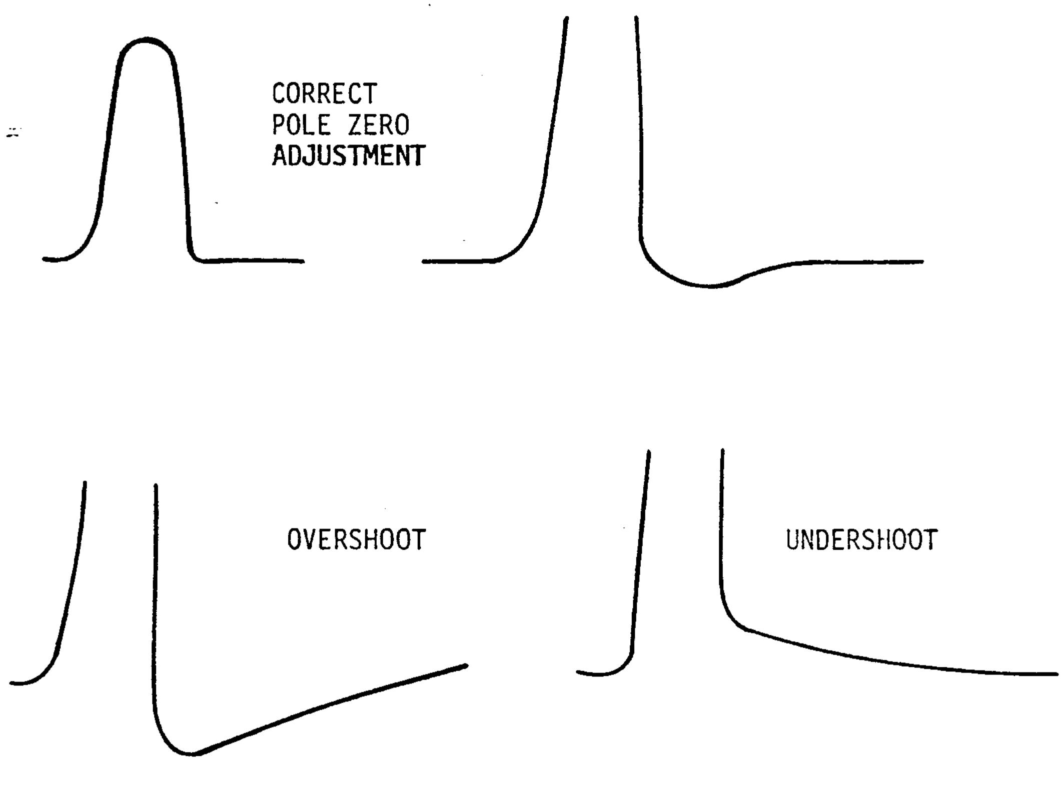



Figure 3.1

d) Switch the BASELINE RESTORER of the linear amplifier into the LO setting.

e) Move the cable carrying the Amplifier output from the oscilloscope to the ADC input.

f) Utilizng the ADC conversion gain and digital offset controls, display the relevent peaks for energy/channel calibration and spectroscopy. To measure resolution accurately, separation of the peaks of interest should be adjusted so that 8 to 20 channels appear between the half maximum points. Adjustment is by linear amplifier gain, conversion gain, and digital offset.

g) For high rate optimization a more detailed procedure is available from Aptec.

3.5 Shut-down

a) Turn off the HV power and the preamplifier power.

b) Re-install the window cover for protection.

c) Disconnect all cables at the Preamplifier panel.

d) If warming up the system, see Section 3.6. on thermal cycling precautions.

3.6 Thermal Cycling

The Aptec spectrometer may have any number of room temperature to liquid nitrogen cycles. The following precautions must be followed to ensure that the detector will retain its original characteristics when cold.

a) If the unit has started warming, either by pouring out the liquid nitrogen, or by removing the dipstick from the dewar, and less than 30 minutes has elapsed, the unit may be recooled and be ready for operation within 1 hour.

b) If the 30 minute warming time is exceeded, the unit MUST be allowed to come to room temperature. The minimum recommended warming time period is 16 hours.

c) Units with end-cap or cold finger extensions may require longer warming and cooling times. If in doubt, contact Aptec for further information.

# 4 Principle of Operation

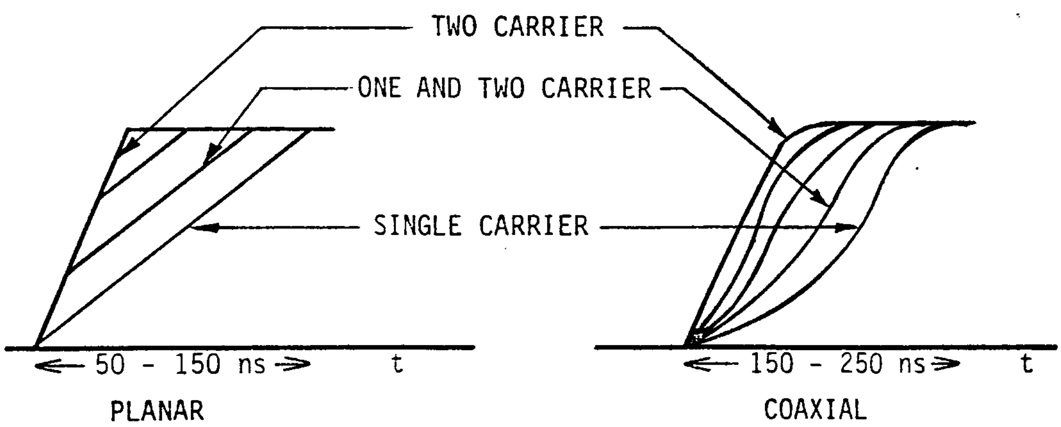
## 4.1 Ge Detector Crystal

The detector consists of a diode made with a high purity germanium. The net ionized impurity concentration of the crystal bulk is about 2 x $10^{10}$ per $cm^3$ or 1/2 part per $10^{12}$. While this material is an intrinsic semiconductor at room temperature, at the temperature of operation the material is either n or p, depending on the majority carrier. When the diode structure is reverse biased, an electric field is required to compensate the remaining net impurity concentration.

This field compensation depends on the contact geometry, the contact separation, and the net ionized impurity concentration. When compensation of all the semiconductor between the contacts is achieved, the corresponding voltage is termed the depletion voltage. Normally the operating voltage is greater than the depletion voltage to ensure rapid collection of the holes and electrons caused by an ionizing event. Below the depletion voltage the sensitive volume is decreased, and the pulse risetimes and gamma resolutions deteriorate.

Electron-hole pairs are produced by an ionizing event at the rate of 335 pairs per KeV of energy at 80K (-193°C). This has a small positive temperature dependence over the allowed operating temperature (20K to 150K) of about 0.02% per K ( °C). Initial separation of the electrons and holes occurs quickly (less than 1ns) for low and moderate ionizing events (electrons, gammas) and the transit to the contacts occurs at the rate of 100ns per cm.

The signal induced on the contacts has a component from hole transit and electron transit and also has a shape influenced by geometry. The various pulse shapes at the preamplifier output are shown schematically in Figure 4.1 for the planar and coaxial geometries.




The signal shapes are of little concern for most gamma spectroscopy, but need to be considered in applications where time information is required. Typical equipment required for timing includes a timing filter amplifier and a constant fraction timing discriminator.

The number of electron-hole pairs produced is linearly proportional to the energy lost by the ionizing particle, X-r a gamma-ray. The amount of charge collected by the electric field of the Ge diode is converted into a pulse by a charge sensitive preamplifier, which is discussed in Section 4.6.

## 4.2 Nuclear Interactions

The X-ray and gamma-rays interact with the Ge crystal to produce electron-hole pairs by photoelectric, Compton, or pair production interactions. A charged particle creates electron-hole pairs directly.

In a photo-electric interaction all of the gamma energy is absorbed and a sharp line is produced in the spectrum, while a Compton interaction, only a fraction of the energy is transferred to electron-hole pairs. This results in a broad continuum from 0 energy up to a maximum energy $E_C$ given by $E_C = E(1 + 255.5/E)^{-1}$ where E is the incident energy in KeV. The remaining energy of the Compton scattered photon may be either fully, partially or not absorbed by the crystal. In a pair production interaction an electron-positron pair is produced.

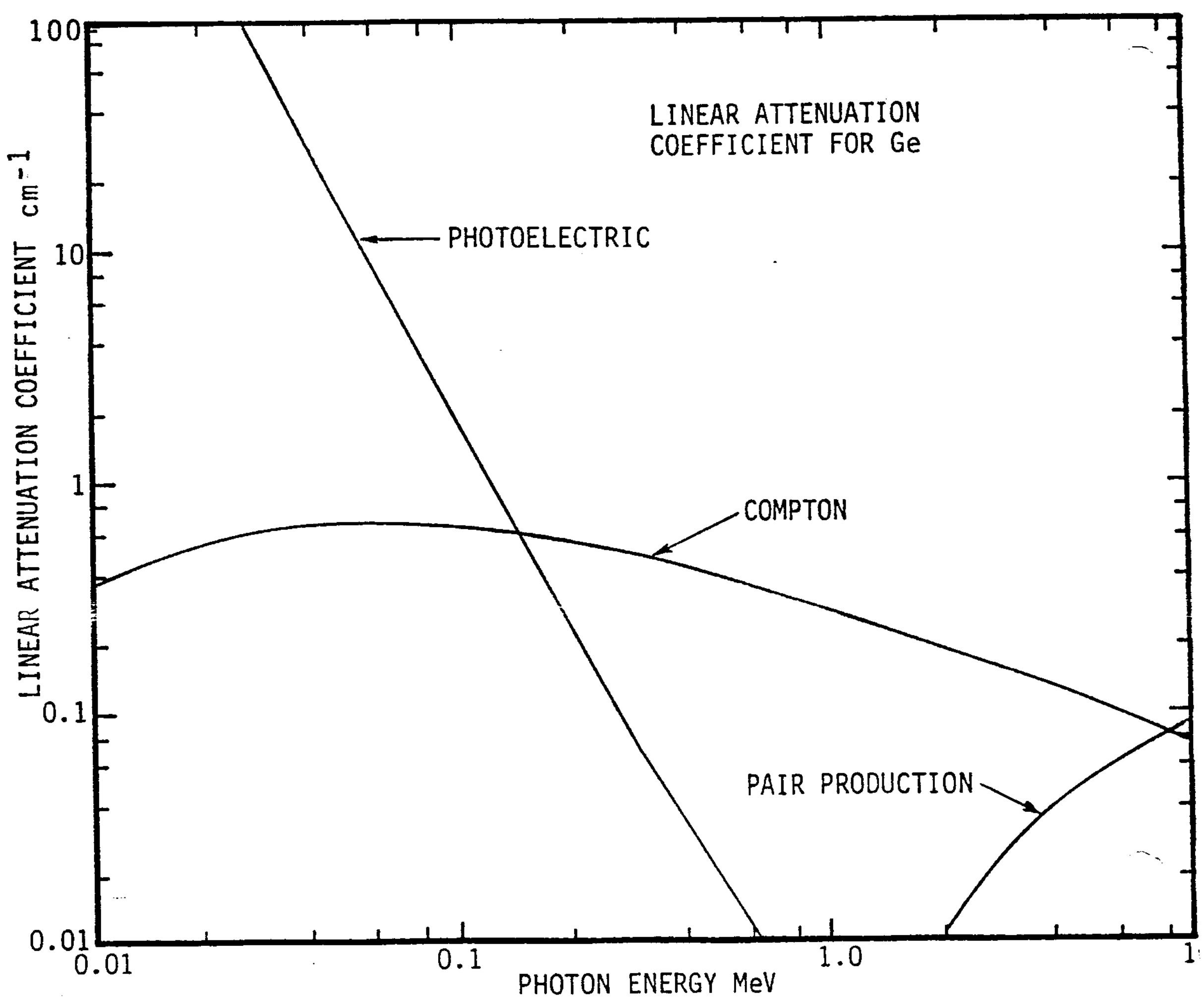



Fig. 4.2

The positron recombines with an electron causing two 511 KeV gamma photons to be emitted in 180° opposite directions. If neither of these photons is absorbed in the crystal, a sharp double escape line shows in the spectrum, if one is fully absorbed a single escape line shows, and if both are absorbed, a full energy line shows. The single escape line normally has poorer resolution than the other lines. The pair production process occurs only for gamma energies greater than 1.022 MeV, and becomes important at energies more than 2 MeV.

The number of incident photons absorbed, N, is given by

$$N = No\ (1-\exp(-ux))$$

where No is the number incident on the crystal, u is the linear interaction coefficient in (centimeters)$^{-1}$, and x is the sensitive crystal thickness in centimeters. The various interaction coefficients are shown in figure 4.2.

Three spectra in Figure 4.3 show various characteristic shapes produced by gamma rays in the various regions.

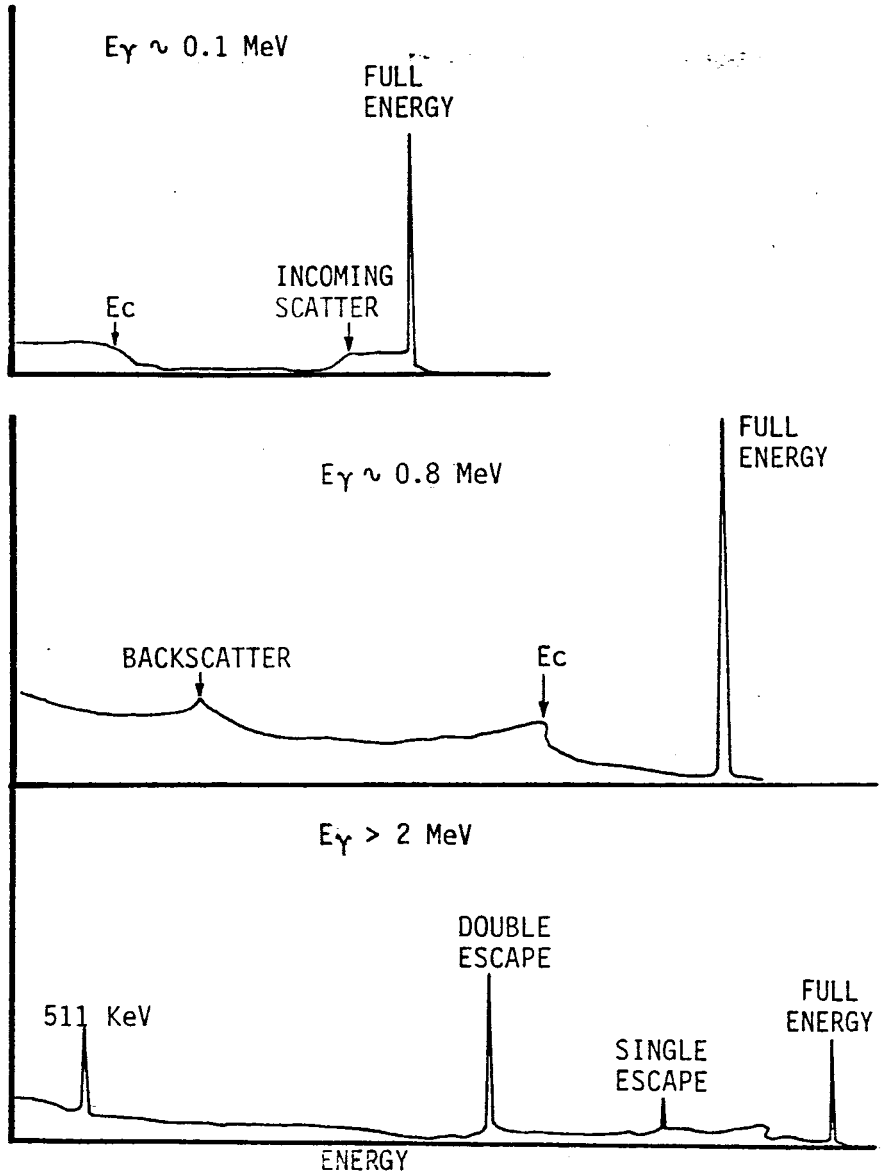



Figure 4.3

## 4.3 Windows

The photons must pass through a window to reach the detector crystal. To minimize aborption the window materials are thin and of low atomic number. The absorption characteristics of the aluminum and beryllium windows are shown in Figure 4.4. Coaxial spectrometers normally have aluminum; planar spectrometers normally have beryllium windows.

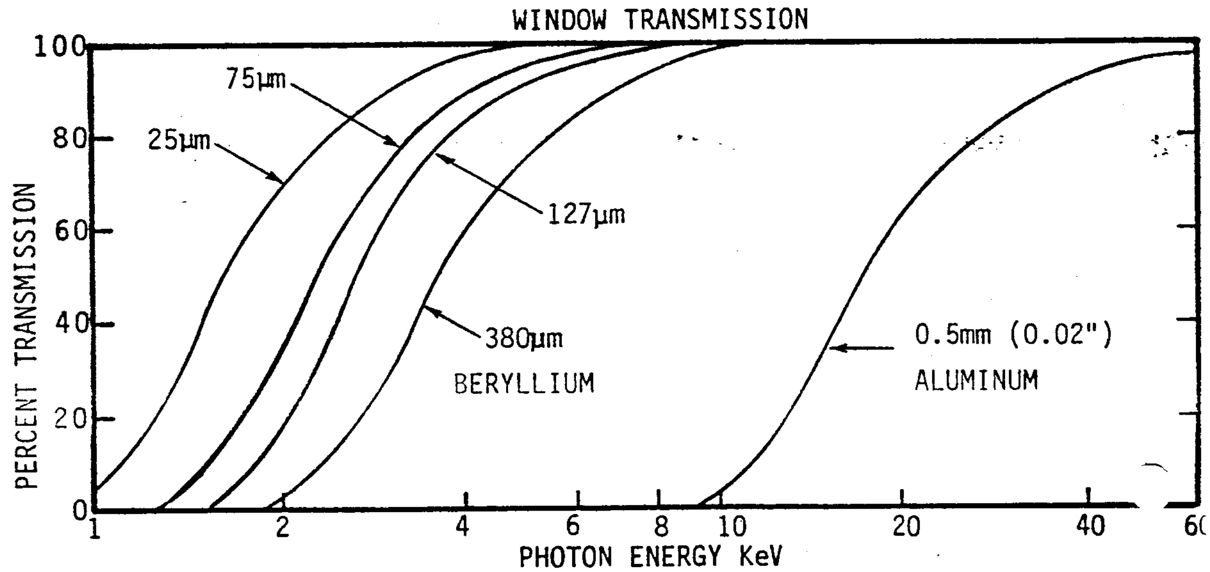



Figure 4.4

## 4.4 Energy Resolution

The gamma energy resolution is normally measured in terms of full width at half maximum (FWHM), and full width at tenth maximum (FWTM) of the peaks as indicated below.

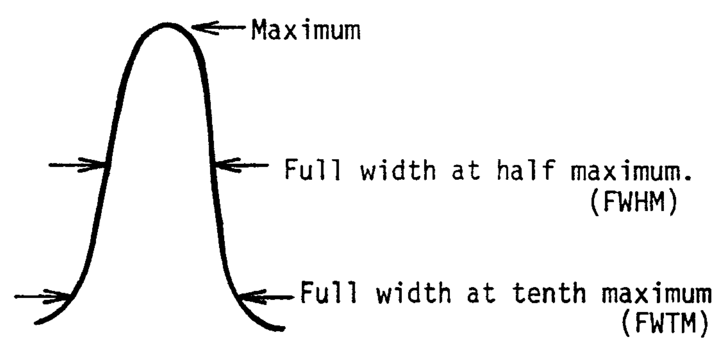



Figure 4.5

Normally the resolution is quoted in terms of eV or KeV. The calibration factor (KeV/channel) is obtained by determining the number of channels between two full energy peaks and dividing this into the energy difference between the two peaks.

Commonly used isotopes and energies are shown below.

| | Energy | Difference |
|---|---|---|
| $^{55}Fe$ | 5.898 eV | |
| | | 592 eV |
| | 6.490 eV | |
| $^{57}Co$ | 14.41 KeV | |
| | | 107.65 KeV |
| | 122.06 KeV | |
| | | 14.4 KeV |
| | 136.48 KeV | |
| $^{60}Co$ | 1173.21 KeV | |
| | | 159.25 KeV |
| | 1332.46 KeV | |

To determine the resolution with reasonable precision, the width at half maximum should be about 10 channels and the number of counts in the peak channel should exceed 2000.

A simple formula exists for estimating resolutions of germanium detectors at intermediate energies if there are two known resolution points measured under similar and properly optimized conditions; same bias, count rate, pole zero, time constant, etc. For details refer to Technical Note #1 available from Aptec.

The energy resolution has contributions from the electronics and the detector itself. The detector contribution (FWHM in KeV) is given approximately by $R_d = 0.043(E)^{1/2}$ where E is the gamma energy in KeV. This is added in quadrature to the contribution from electronic noise. Other contributions which may be present include charge trapping (low energy tailing), high count rate effects, microphonics and other electrical pickup.

The linear amplifier settings and baseline restorer can significantly affect the resolution. At 1000 c/s detectors are normally operated with linear amplifier time constants giving minimum electronic noise. However in some circumstances (high count-rate, high microphonics, high detector current) better resolution may be attained at shorter time constants and high baseline restorer settings.

## 4.5 Detector Efficiency

Efficiency is a very important specification of photon spectometers, but, the many ways of defining efficiency can very often prove confusing. In general, efficiency is quoted as absolute, intrinsic, or relative for the full-energy photopeak or the total spectrum. The following clarifies the terminology.

4.5.1 Absolute Efficiency

The number of recorded counts, A, divided by the number of photons emitted by the source, $A_o$.

$$\text{i.e., } E_a = A/A_o$$

If A is the net photopeak area, then $E_a$ is called the absolute photopeak or absolute full-energy peak efficiency.

4.5.2 Intrinsic Efficiency

The number of recorded counts, A, as above, divided by the number of photons actually striking the detector, $A_d$.

$$\text{i.e., } E_i = A/A_d$$

4.5.3 Relative Efficiency

The number of recorded counts in one detector, $A_1$, divided by the number of recorded counts in a second reference detector $A_r$.

$$\text{i.e., } E_r = A_1/A_r$$

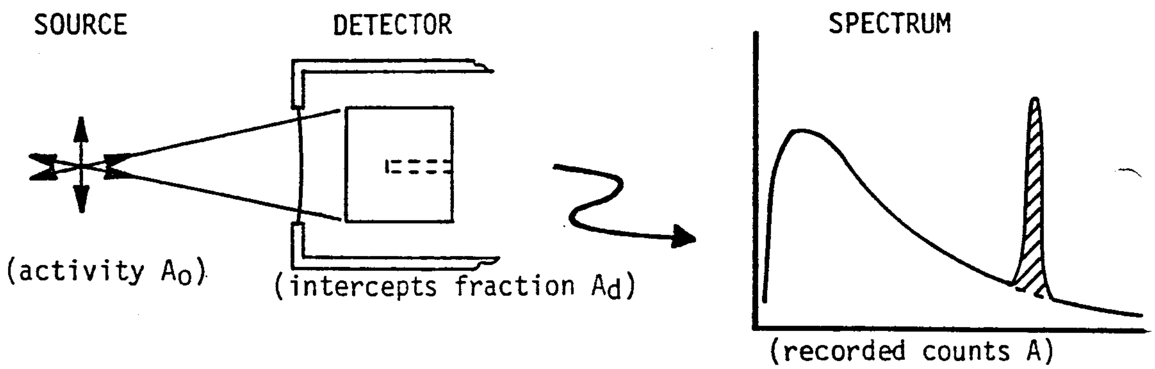



Figure 4.6

The "IEEE Standard Test Procedure for Germanium Gamma-Ray Detector, St. 325-1971" defines the relative efficiency of a germanium spectrometer referenced against a 3" x 3" NaI(Tl) detector, (which has an absolute efficiency of $1.2 \times 10^{-3}$ at 1.33 MeV of $Co^{60}$), where the source to detector distance is 25 cm. A point source is used.

The relative percent efficiency of a germanium spectrometer can also be calculated from the formula

$$E_r = \frac{C \times 100}{t \times 44.4 \times A_{co}}$$

where C = net counts in te 1.33 MeV photopeak,
t = live acquire time of the MCA (seconds),
44.4 = cps from 1 uCi of $Co^{60}$ in a 3" x 3" NaI(Tl) detector at 25 cm, and
$A_{co}$ = source activity in uCi at time of measurement.

Note that the IEEE test procedure for relative efficiency specifies a source to detector distance of 25 cm, not source to end cap distance. The detector to endcap distance is normally 5 mm.

Figure 4.7 is a graph of absolute efficiency for a closed-end coaxial PHYGE detector of 15.4% relative efficiency. The point sources used to produce the absolute efficiency graph were at a distance of 25 cm.

In actual practice sources are seldom placed as in the IEEE test procedures. Users generally place source or samples as close to the detector end cap as possible. As such, each experimental set-up must be individually calibrated as to type and geometry of source, source distance, collimation, shielding, etc.

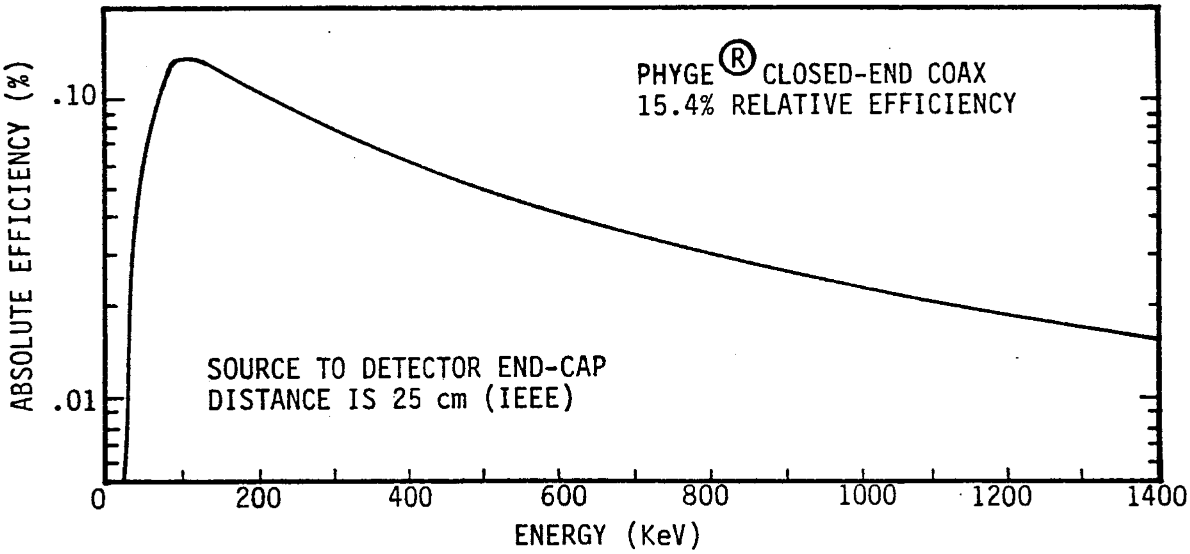



Figure 4.7

## 4.6. Electronics

### 4.6.1 Spectrometer System Description

A spectrometer system for energy spectroscopy, shown schematically Figure 4.8 includes:

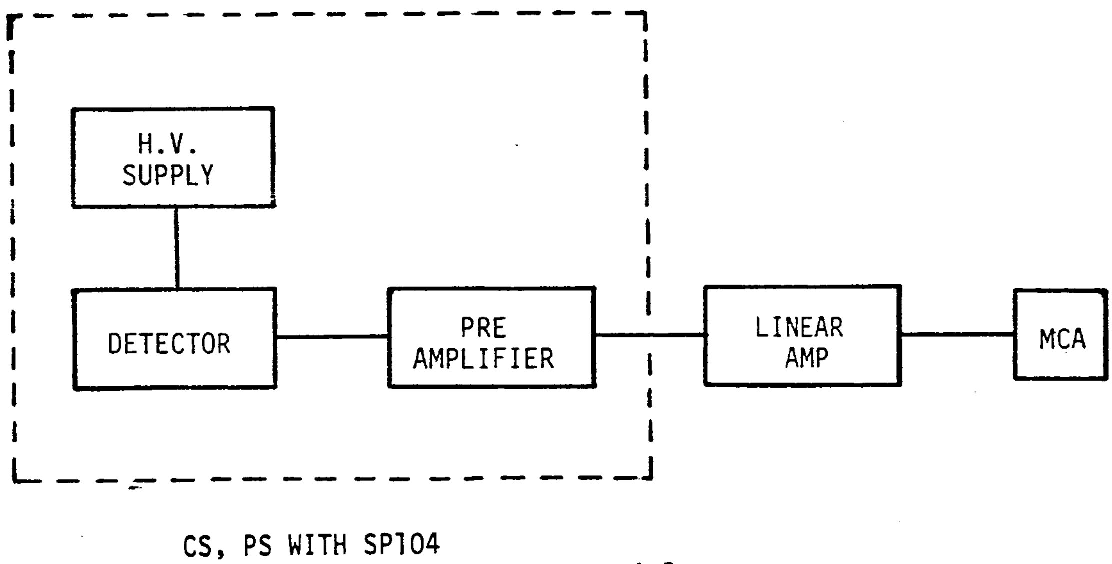



Figure 4.8

a) signal generation (detector-preamplifier, HV supply)
b) signal processing (linear amplifier)
c) signal analysis (multi-channel analyzer).

### 4.6.2 Basic Circuit

Figure 4.9 shows the basic elements of a resistive feedback charge preamplfier with a germanium detector.

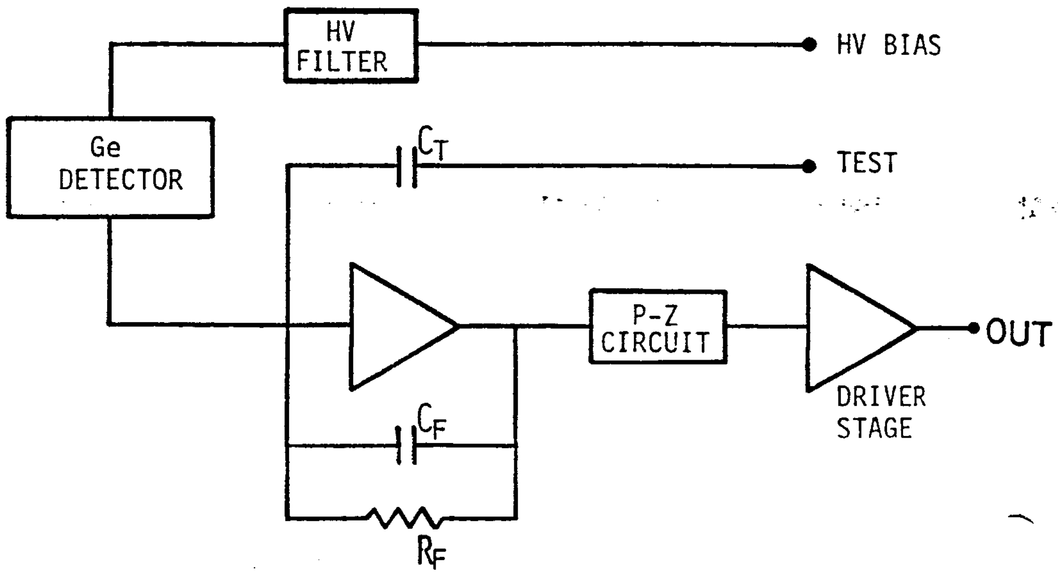



Figure 4.9

A gamma interaction depositing an energy E in the detector generates a transient current carrying a total charge Q given by $Q(E) = 5.37 \times 10^{-20}$ E coulombs where the deposited energy is in electron volts (eV). This charge is momentarily stored in the feedback capacitance $C_f$ of the high-gain wide-b RC feedback preamplifier. This is called a charge sensitive preamplifier since an output step voltage V proportional to the charge and therefore to the deposited energy E is generated.

$$V = 5.37 \times 10^{-20} \frac{E}{C_f}$$

where $C_f$ is in farads. Typical values of $C_f$ are 0.1 to 1 pF. The voltage step decays with a time constant of $R_f C_f$ as the discharges through $R_f$.

The current through the detector from detector leakage, and gamma pulses passes through $R_f$. Hence a measurement of the voltage at the output of the charge sensitive stage can be us to indicate total detector leakage current.

## 4.7 Technical Notes

Further information on specific subjects are available as Technical notes available on request from Aptec.

| Note # | Title |
|---|---|
| 1 | Predicting Resolution for Gamma Peaks from Isotopes Other Than $^{55}Fe$, $^{57}Co$, and $^{60}Co$. |
| 2 | Planar Windows - Al vs. Be. |
| 3 | PHYGE® Planar Spectrometers - In Search of Gold (Interference X-Rays). |
| 4 | Relation Between Size and Efficiency in Coaxial Spectrometers. |
| 5 | Stopping Power - Charged Particle Detectors. |
| 6 | Resolution of Charged Particle Detectors. |
| 7 | Detector Efficiency. |
| 8 | Nitrogen Costs - PHYGE® vs. Ge(Li). |
| 9 | Charged Particle Detector Operating Characteristics. |
| 10 | Annealing of Radiation Damaged PHYGE® Charged Particle Detectors. |
| 11 | Internal Radiation Shielding in a Germanium Spectrometers |
| 12 | Translating Radiation Fields into Total Count Rates. |
| 13 | What is High Purity (Hyperpure, Instrinsic) Germanium? |
| 14 | Window Thickness on Aptec Charged Particle Detectors. |

## 5. Circuit Description

### 5.1 General Features

Figure 5.1 shows the circuit of the SP104 schematically in conjunction with the cryostat. The circuit includes a preamplifier, a high voltage supply and a filter for the high voltage.

### 5.2 Preamplifier

The preamplifier consists of a charge sensitive stage, a pole-z compensation network, and a cable driver stage.

In the charge sensitive stage the input FET, the feedback resis $R_f$, the feedback capacitor $C_f$, and test capacitor are located inside the vacuum cryostat and maintained at an optimum temperature with respect to electronically generated noise. Th input FET is in the common source configuration. This together with a high gain differential amplifier acts as an operational amplifier with feedback components $R_f$ and $C_f$. The test capacit $C_t$ provides a path for injecting pulses from a test pulser to t input of the preamplifier.

The D.C. voltage at the output of the charge sensitive stage is brought to a rear panel test jack for monitoring purposes. Whe the detector HV is off, this voltage is normally -0.3 to -0 V reflects the gate voltage of the FET. The voltage range of the charge loop output is $\pm$ 18V.

The voltage signal from the charge loop with a fall time of several milliseconds is differentiated to give a fall time of l seconds. A pole-zero network is included with the differentiat to remove the undershoot caused by the differentiator. Adjustm is by RV-3, and is set at the factory.

The cable driver consists of an operational amplifier with a ga of 1 or 5 set by a jumper. The jumper is factory set at A-C fo gain of 1. A 5X higher gain is available by selecting the jump position A-B. A push-pull emitter follower output allows an output voltage swing of $\pm$ 10V. Output 1 has a 93 ohm series termination, while output 2 has 50 ohms.

The test input is terminated by 93 ohms and is connected to the test capacitor $C_t$ to allow a test signal to be injected at the input to the preamplifier.

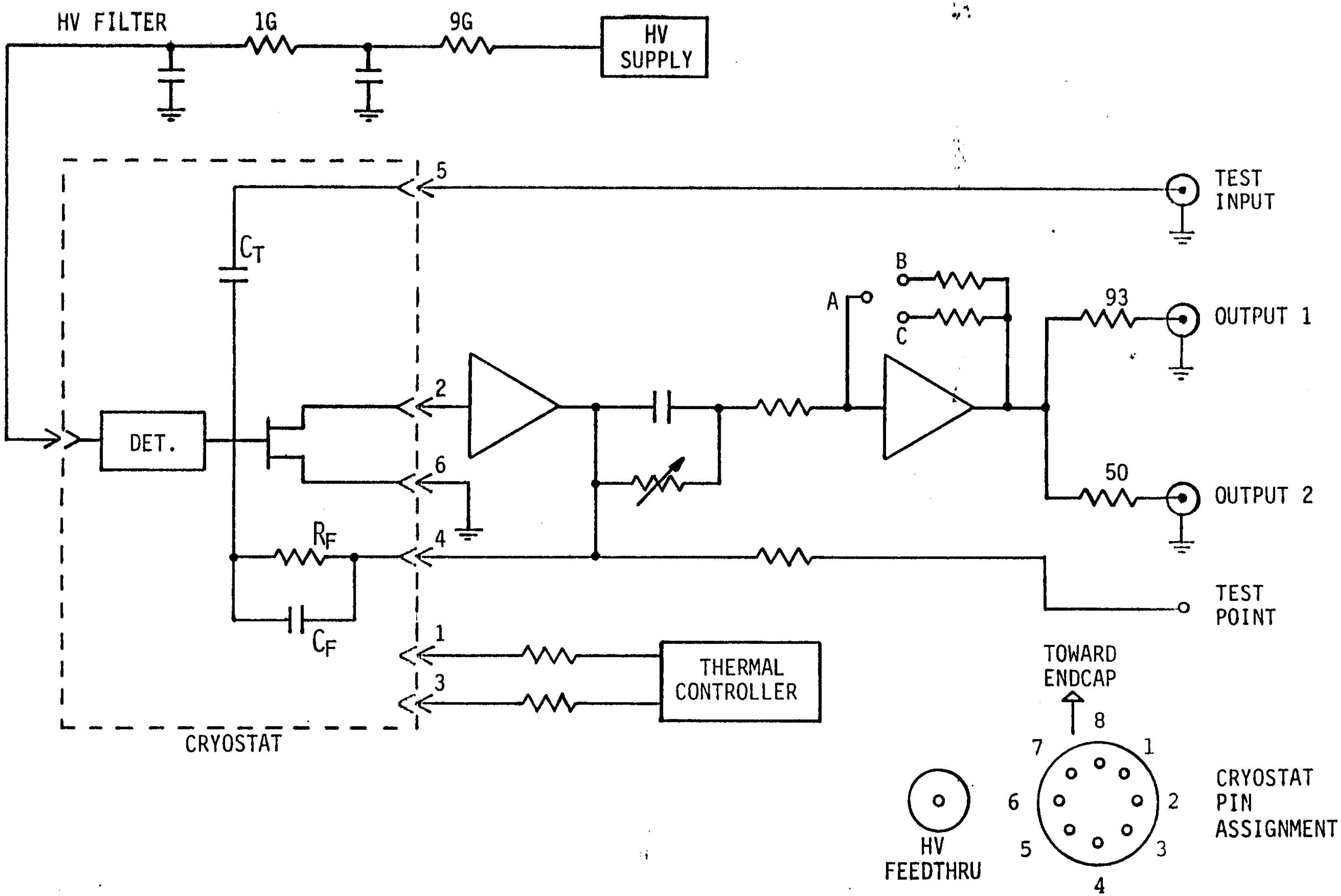



Fig. 5.1 SIMPLIFIED CIRCUIT FOR SPECTROMETER WITH SP104 PREAMPLIFIER, HV SUPPLY.

## 5.3 High Voltage Supply

The high voltage module consists of an epoxy encapsulated oscillator and voltage multiplier. The supply has a voltage feedback to control the voltage and a current limiting feature to avoid the possibility of FET damage.

The value of the HV is controlled by a potentiometer and is preset at the factory to match the operating characteristics of the detector.

## 5.4 High Voltage Filter

This consists of a double RC filter with a time constant of 10 seconds. The components are rated for ± 6000V.

## 5.5 Adjustments

Circuit changes or adjustments, unless authorized by Aptec may void the warranty.

# 6 Troubleshooting

## 6.1 General

Unsatisfactory operation of a system, consisting of a detector, linear electronics, and a multichannel analyser may have many causes. REMEMBER that the detector is only one component of a system and is not the only source of problems.

A good rule in troubleshooting is to CHECK THE SIMPLE THINGS FIRST before going on to diagnosis of complicated problems.

For troubleshooting a voltmeter, oscilliscope, pulser, and test clips are useful.

Step 1 - Check for liquid nitrogen. With dipsticks the copper cold finger should be immersed at least 1 inch (2.5 cm) Refer to Section 3.1.

Step 2 - Check continuity of all cables including power cable; check voltages of power cable at the preamplifier end. See Section 3.3a.

Step 3 - Attach a pulser to the input of the linear amplifier and verify polarity and pulse size. Check that a peak appears on the MCA and is stable with time. Refer to the linear amplifier manual.

Step 4 - Attach a pulser to the test input of the detector preamplifier and verify polarity, amplitude, and appearance on the MCA. Use a positive pulse for coaxial, negative for planar.

Step 5 - Carefully review the set-up procedure outlined in Section 3.3.

Step 6 - Check the voltage of the test point and compare with the test data after a 2 minute stablization period. Small changes (less than 0.5 volt) are likely not significant.

Step 7 - Turn off the HV with the switch on the preamplifier, wait 5 minutes to allow capacitor discharge and open the preamplifier case (HV off). Measure the voltage of the orange wire attached to the multipin feedthrough. The normal value is in the range of 4.2 to 5V.

Step 8 - Refer to the troubleshooting chart if the problem has not been diagnosed.

## 6.2 Troubleshooting Chart

Most types of trouble are indicated by the red light on th preamplifier, once the normal start-up sequence is complete.

| | Symptom | Possible Cause | Actions |
|---|---|---|---|
| a) | No output | Power cable not connected NIM Power OFF Signal cable not connected | Check all connections and pow status. |
| | | Damaged power cable | Remove, check voltages or replace cable. |
| | | Damaged signal cable | Replace. |
| b) | Red light is on except for short off periods (less than .5s) | No nitrogen, or nitrogen level too low | Fill and wait 2-6 hours for cooling. |
| | | Vacuum failure | Check cryostat for frosting o an unusually cold surface— C Aptec Service. |
| | | Excessive radiation incident on the detector | Move source away or reduce radiation field. |
| c) | Red light is on except for longer off (about 1 s) periods | Detector is not fully cooled | Wait if cooling period has be less than 4 hours (6 hrs for horiz dipsticks). |
| | | Excessive radiation incident on the detector | Move source away or reduce radiation field. |
| | | Detector breakdown | Contact Aptec Service. |
| d) | Red light and green light alternate or green light will not stay on | Excessive radiation incident on the detector | Move source away or reduce the radiation field. |
| | | Detector breakdown | Contact Aptec Service. |
| e) | Green light comes on immediately after HV is turned on | Small area detector | Normal. |
| | | HV was recently turned off | Normal. |
| | | HV Oscillator has not started | Turn HV switch OFF and then O |

## 6.2 Troubleshooting Chart

| | Symptom | Possible Cause | Actions |
|---|---|---|---|
| f) | High frequency (more than 1 MHz) oscillation | Poor grounding | Retighten all mounting screws on preamplifier and its case. |
| | | No cable termination | Terminate signal cables (especially those more than 10 ft long) with the characteristic cable impedence. |
| | | Defective preamplifier | Call Aptec. |
| g) | Random pulses of wrong polarity at output of linear amp. | H.V. breakdown | Turn off H.V., wait 5 minutes and open the preamplifier case. If feedthroughs are damp (high humidity) dry with gentle heat. |
| | | Incorrect pole-zero adjust | Adjust linear amplifier pole-zero for minimum overshoot with a $^{60}Co$ source. |
| h) | Baseline disturbances (0.2 to 5 KHz) at output of linear amplifier | Preamplifier defect | Call Aptec. |
| | | Microphonics | Mount on foam pad or pads.<br>Ensure dipstick is not touching dewar walls.<br>Reduce noise.<br>Ensure that the HV is turned on and the green light is on. |
| i) | Poor resolution | Neutron damage | Review exposure history to fast neutrons. Damage likely if fluence exceeds $10^9$ n/cm$^2$. |
| | | Leaky detector | Check test point voltage with no source present. If more positive (planar) or more |

## 6.2 Troubleshooting Chart

| | Symptom | Possible Cause | Actions |
|---|---|---|---|
| | | | negative (coaxial) by more than 2V compared to the test results higher leakage is indicated. |
| | | | Give a 24 hr warmup to room temperature, cool & test again. |
| | | Incorrect pole-zero | Refer to Section 3.4 for correct adjustment. |
| | | Count rate too high | Increase detector source distance. Reduce time constant on linear amplifier and adjust the pole-zero circuit. |
| | | Excessive microphonics | See d)<br>Put baseline restorer in Lo, and symmetric mode. |
| | | Baseline restorer not in | Put in BLR - Lo setting for best resolution at 1000 c/s. |
| | | Gain shifts | Check each component of the system, starting at the MCA, with a stable pulser. |
| | | 60(50)Hz interference | Tie or tape power, and signal cables together. |
| | | | Plug all parts of the system into a single outlet box. |
| j) | Frosting | Poor vacuum | Check for mechanical damage. Contact Aptec. |
| | | Plugged fill or vent tube | Clear of ice, check in high humidity conditions. |

## 7. Warranty

Aptec/NRD warranties the germanium spectrometers to operate to the specifications on the measurement certificate for one year providing proper operating instructions have been followed. Please refer to the attached general warranty concerning Aptec/NRD products.

The germanium spectrometers are specifically not warranted if any of the following is observed in the factory incoming inspection.

1) Mechanical damage to any part of the vacuum enclosure.

2) Evidence of tampering with a vacuum seal or vacuum flange bolt.

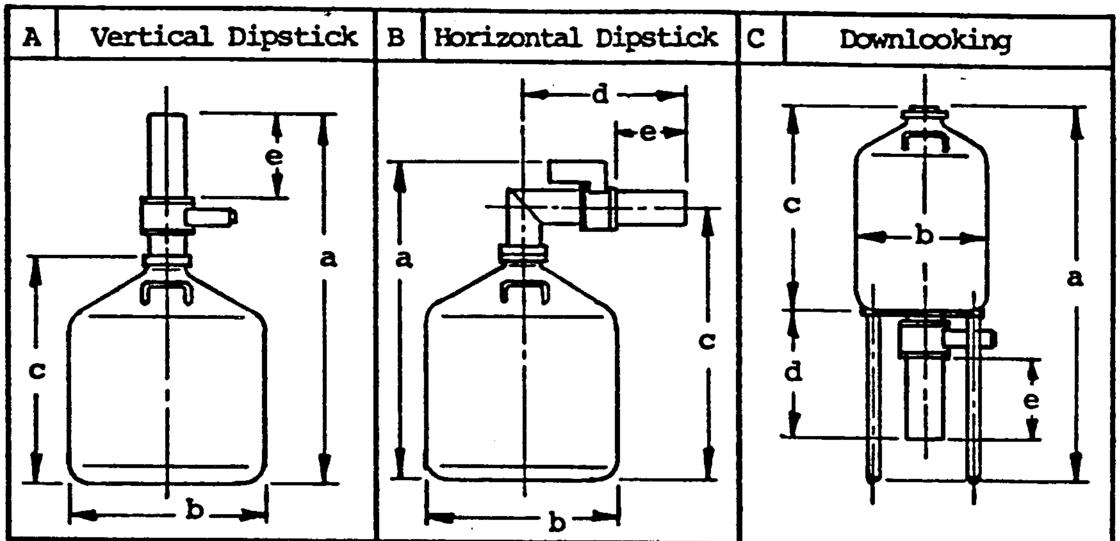
3) Damage to the beryllium window.

4) Radiation damage, as evidenced by an increase of more than 20% in the ratio of the $^{60}Co$ resolution to the $^{57}Co$ resolution at or near the normal operating voltage when compared to the original test data.

8. Dimensional Drawing

APTEC

PS/CS Spectrometers
Dimensional Data




**Metric (cm, l, Kg) Units**

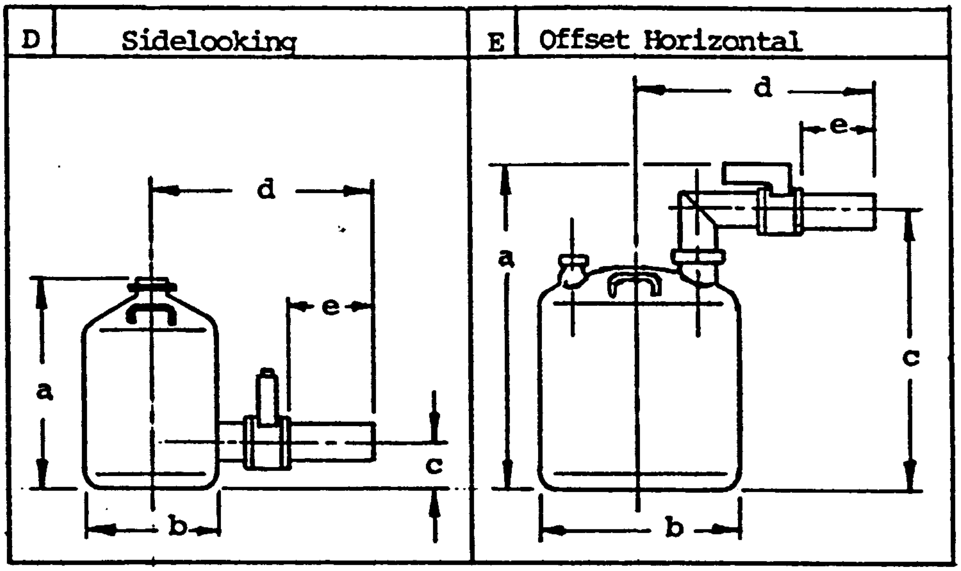
| Cryostat Config. | Capacity in Liters | a† | b | c | d† | Approx. Wt. with LN | Approx. Wt. (I |
|---|---|---|---|---|---|---|---|
| A Vertical | 20 | 87.4 | 36.8 | 56.4 | - | 32 | 18 |
| | 31 | 91.4 | 43.2 | 61.5 | - | 41 | 21 |
| B Horizontal | 20 | 77.5 | 36.8 | 70.1 | 30.0 | 33 | 19 |
| | 31 | 82.5 | 43.2 | 75.2 | 30.0 | 42 | 22 |
| C Downlooking | 5 | 65.0 | 22.1 | 34.5 | 21.8 | 11 | 29 |
| | 7.5 | 76.5 | 22.1 | 46.0 | 21.8 | 14 | 30 |
| | 10 | 74.4 | 28.0 | 43.9 | 21.8 | 17 | 31 |
| | 15 | 87.1 | 28.0 | 56.6 | 21.8 | 21 | 32 |
| | 30 | 83.3 | 41.1 | 52.8 | 21.8 | 38 | 37 |
| D Sidelooking | 1.7 | 28.0 | 17.8 | 7.6 | 31.8 | 5 | 28 |
| | 5 | 34.5 | 22.1 | 7.6 | 33.8 | 10 | 29 |
| | 7.5 | 46.0 | 22.1 | 7.6 | 33.8 | 13 | 30 |
| | 10 | 43.9 | 28.0 | 10.2 | 36.8 | 16 | 31 |
| | 15 | 56.6 | 28.0 | 10.2 | 36.8 | 20 | 32 |
| | 30 | 52.8 | 41.1 | 10.2 | 43.2 | 37 | 37 |
| E Offset | 30 | 83.4 | 43.2 | 75.4 | 42.6 | 42 | 22 |

NOTE: END CAP LENGTH (e) - Planar 10.5 cm.
- Coaxial 14.2, (19.3, 29.5, 44.7 - (special) cm

END CAP DIAMETER - 7.0 cm for PS $\leq$ 1000 mm$^2$; CS $\leq$ 16%
- 8.25 cm for CS $\geq$ 20%

† Dimensions are for planar detectors; for coaxial and/or special endcaps correct according to endcap length (e).
Configurations A, B, and E include a rubber (RTV) collar with $LN_2$ fill and vent tubes. $LN_2$ monitor feedthrough is optional.

**APTEC NUCLEAR INC.** 210 SOUTH 8TH STREET, LEWISTON, NEW YORK 14092 TELEPHONE: (716) 754-7401
**APTEC ENGINEERING LTD.** 4251 STEELES AVE. W., DOWNSVIEW, CANADA, M3N 1V7 TELEPHONE: (416) 661-9722




**Standard (in, l, lb) Units**

| Cryostat Config. | Capacity in Liters | a† | b | c | d† | Approx. Weight with LN | Approx. Shipping Wt. (Dry) |
|---|---|---|---|---|---|---|---|
| A Vertical | 20 | 34.4 | 14.5 | 22.2 | - | 70 | 52 |
| | 31 | 36.0 | 17.0 | 24.2 | - | 95 | 57 |
| B Horizontal | 20 | 30.5 | 14.5 | 27.6 | 11.8 | 72 | 54 |
| | 31 | 32.5 | 17.0 | 29.6 | 11.8 | 97 | 59 |
| C Downlooking | 5 | 25.6 | 8.7 | 13.6 | 8.6 | 24 | 63 |
| | 7.5 | 30.1 | 8.7 | 18.1 | 8.6 | 31 | 65 |
| | 10 | 29.3 | 11.0 | 17.3 | 8.6 | 38 | 67 |
| | 15 | 34.3 | 11.0 | 22.3 | 8.6 | 45 | 69 |
| | 30 | 32.8 | 16.2 | 20.8 | 8.6 | 84 | 80 |
| D Sidelooking | 1.7 | 11.0 | 7.0 | 3.0 | 12.5 | 11 | 60 |
| | 5 | 13.6 | 8.7 | 3.0 | 13.3 | 22 | 63 |
| | 7.5 | 18.1 | 8.7 | 3.0 | 13.3 | 29 | 65 |
| | 10 | 17.3 | 11.0 | 4.0 | 14.5 | 36 | 67 |
| | 15 | 22.3 | 11.0 | 4.0 | 14.5 | 43 | 69 |
| | 30 | 20.8 | 16.2 | 4.0 | 17.0 | 82 | 80 |
| E Offset | 30 | 32.8 | 17.0 | 29.7 | 16.8 | 97 | 59 |

NOTE: END CAP LENGTH (e) - Planar 4.1 inches
- Coaxial 5.6, 7.5, 11.6, 17.6 - (special) inches

END CAP DIAMETER - 2.75 inches for PS $\leq$ 1000 $mm^2$; CS $\leq$ 16%
- 3.25 inches for CS $\geq$ 20%

† Dimensions are for planar detectors; for coaxial and/or special endcaps correct according to endcap length (e).
Configurations A, B, and E include a rubber (RTV) collar with $LN_2$ fill and vent tubes. $LN_2$ monitor feedthrough is optional.

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9. Parts list

The following refers to replacement parts that may be required from Aptec

| Description | Aptec Part Number |
|---|---|
| 31 liter dewar | 755600 |
| 20 liter dewar | 755601 |
| 31 liter 2 port dewar | 755617 |
| Rubber collar for 31 liter dewar | 722802 |
| Rubber collar for 20 liter dewar | 722800 |
| Stopper for integral dewars | 722815 |
| SP104 preamplifier-positive | 730002 |
| SP104 preamplifier-negative | 730003 |
| Power cable. 10 ft (3m) | 730424 |
| BNC-BNC signal cable. 10 ft (3m) | 730420 |
| Valve cover (plastic) | 755006 |
| End-cap cover | 721253 |
| Cold finger extension 4 inch (10 cm) | 721679 |

# WARRANTY

## Aptec Manufactured and/or Supplied Equipment

Equipment purchased from Aptec Engineering Limited has a twelve (12) month return to factory warranty against defects in materials and workmanship provided that the equipment has been used in a proper manner as detailed in the pertinent instruction manual. Repairs or replacements at Aptec's option, will be made without charge **at Aptec's factory** during the warranty period. Shipping expenses to Aptec are to be paid by the customer, shipping expenses to return the repaired equipment to the customer will be paid by Aptec. If the equipment cannot be repaired by Aptec or if special factory calibration is required the equipment will be exported to the principal and returned at Aptec's expense.

This warranty shall not apply to equipment that has been modified, serviced, or tampered in any way by other than Aptec service personnel, or to failures caused by defective equipment not supplied by Aptec.

If the customer orders equipment directly from one of Aptec's suppliers, the customer must communicate directly with the supplier's plant for service, unless previously agreed upon by the customer and Aptec prior to the original equipment order.

## Warranty on Equipment not Represented by Aptec

Although Aptec may frequently supply equipment manufactured by companies we do not represent, the only warranty that shall apply to such equipment, is that warranty offered by the original manufacturer, unless otherwise negotiated at the time of purchase. In most instances, the warranty will **not be** for a period of 12 months, and notably in this area are such items as computers, teletype machines, printers, plotters, and other peripheral devices. In no case, however, will Aptec assume any liability for such equipment other than to pass on to Aptec's customer whatever warranty is available from the original manufacturer.

Aptec will, upon request, state what warranties are offered by the original manufacturer of specific items.

## On-Site Warranty (Option)

The basic Aptec warranty applies to equipment sold by Aptec which is **returned to the factory.** If equipment must be repaired on-site, the actual repair, labour and parts will be provided at no charge during the warranty period. Travel expenses to and from the customer's site and living expenses while on site will be charged to the customer unless an on-site warranty option has been purchased. This option must be purchased prior to shipment of the equipment to the customer.

The on-site warranty option provides for free on-site warranty work with Aptec paying all travel and living expenses, within the first 60 days after delivery of equipment to the customer. If installation is ordered from Aptec, the 60-day period commences upon completion of the initial installation, otherwise it is 60 days after shipment of the equipment from Aptec to the customer. After the initial 60-day period, labour and materials used on site will be covered by the basic warranty but the customer shall pay for all travel and living expenses incurred for any on-site service.

The price of the 60-day on-site warranty option is $300.00 or 2% of the entire system list price, whichever is greater.

After the 60-day on-site warranty period, or after initial installation of the equipment, an annual on-site maintenance contract may be purchased. This may be contracted through Aptec's Service Department.

Installation of equipment purchased from Aptec shall be the **sole responsibility of the customer** unless it is specifically contracted for at the prevailing Aptec field service rates. To ensure timely installation at the receipt of the equipment, it is recommended that installation be contracted for at the time the equipment is ordered.

## Repairs

Any Aptec supplied instrument no longer in its warranty period may be returned, freight prepaid, to our factory for repair and realignment. When returning instruments for repair, either in-warranty or out of warranty, the **customer must contact the factory for shipping instructions** and a 'Returned Goods' number (RG). At the same time, it is understood that all correspondence and discussions concerning repairs shall include a complete description of the item, model number, serial number, the original purchase order upon which the unit was supplied as well as the description of the problem.

Out-of-warranty repairs are guaranteed for three months against the same fault.

For instruments out of warranty, the customer must supply a purchase order number for repair before the unit will be returned.

## Shipping Damage

Shipments should be carefully examined when received for evidence of damage caused by shipping. If damage is found, immediately notify Aptec and the carrier making delivery, as **the carrier is responsible** for damage caused in shipment. Carefully preserve all documentation to establish a claim. Aptec will provide all possible assistance in damage claims.

Aptec – 1980