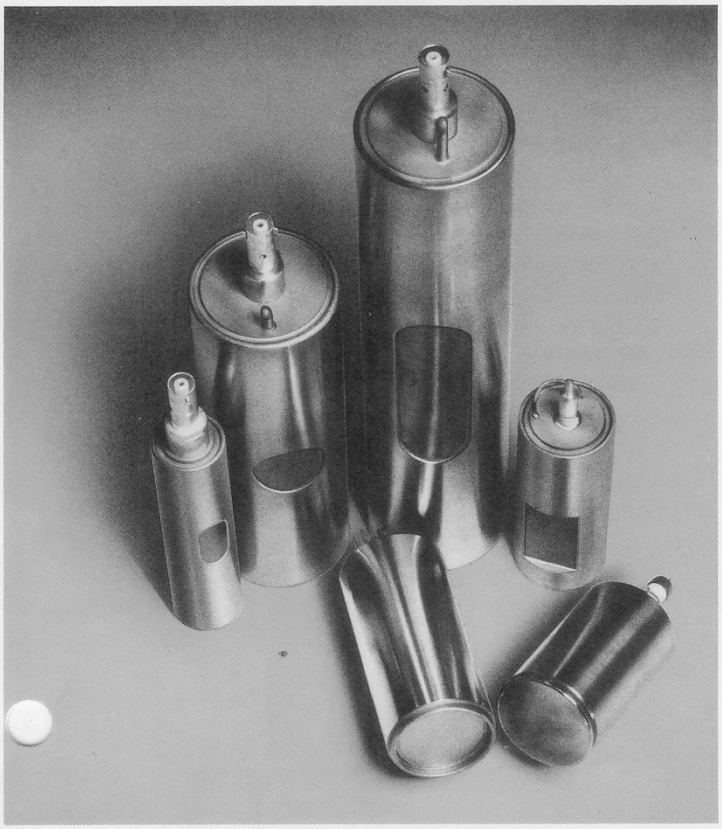
reuter RS stokes

Engineering Data Bulletin 3.00



X-Ray Proportional Counters Performance & Specification Guide

General

Reuter-Stokes manufactures a variety of gas filled proportional counters for detection of low energy X-rays in applications that include:

- X-ray spectrometry and diffraction
- Industrial gaging and process control
- Astrophysics
- Mössbauer-effect studies

In the low energy range, the overall features of gas-filled counters can be of significant advantage over scintillators and solid-state detectors:

- High detection efficiency can be obtained.
- Energy resolution, particularly with the data reduction capability of modern electronics, is more than acceptable for many research and industrial applications.
- The counters are rugged devices capable of operating in hostile environments without special attention; particularly the capability for operation at temperature extremes without performance degradation or need for cooling.
- The counter/electronics combination is frequently the lowest-cost detecting combination.

The main considerations in the selection of an X-ray counter for a specific application are:

- Thickness and composition of the window which transmits the radiation.
- The detection and quench gas
- The operating environment
- The associated electronics

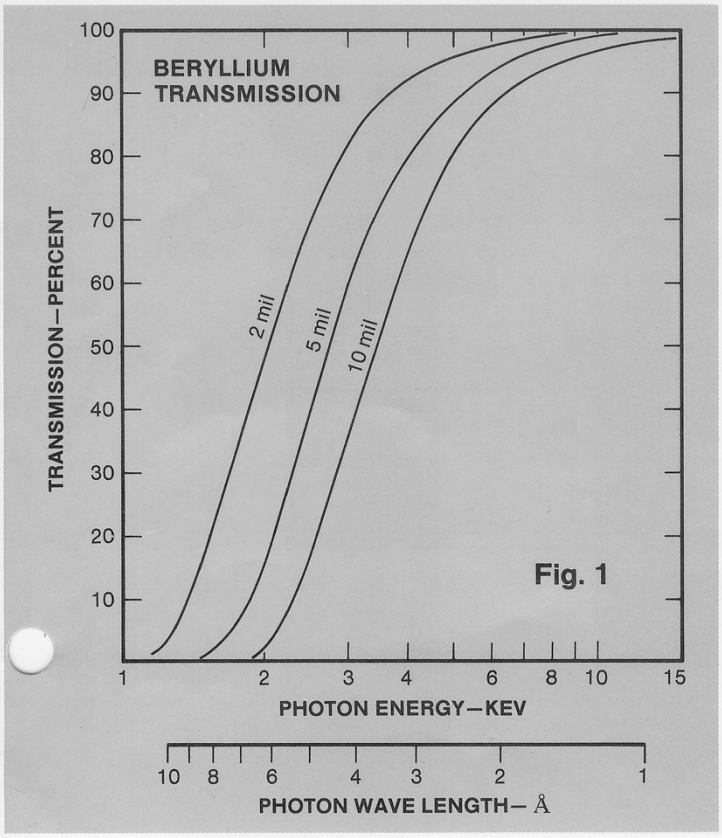


Fig. 1

Thickness and Composition of the Window Material

The window material is selected on the basis of the energy to be transmitted.

As a general rule, the thickest possible window should be used if transmission characteristics are acceptable. (See Figure 1). Five-mil or thicker beryllium can be brazed to the counter body; and as a result, the counter can be processed at the high temperature necessary to optimize performance and lifetime.

X-Ray Proportional Counter Performance

Two-mil thick beryllium windows and organic window materials (such as mylar, polypropolene, formvar, etc) are bonded to the counter body using proprietary epoxy bonding materials and techniques. A two-mil beryllium window, epoxy bonded, provides a rugged envelope in a sealed counter configuration. It is recommended that a counter with a thin film organic window be of a flow counter design because moisture and gas can migrate through these windows.

The primary radiation can also fluoresce the window and counter wall materials. Reuter-Stokes uses beryllium with low iron content to minimize window fluorescence effects. Our use of stainless steel cathode material permits the use of proprietary techniques for brazing the beryllium window to the cathode. This results in internal fluorescence of 6.4 keV. The cathode is normally lined with aluminum to shift internal fluorescence to 1.5 keV. Counters with an all-aluminum cathode and an epoxy-bonded window can also be provided.

In some designs we offer an exit window to allow the unabsorbed radiation to pass out of the counters, reducing unwanted fluorescence.

The Detecting and Quench Gas

The most commonly used X-ray counter gases are high purity xenon, krypton and argon. Gas selection should be based on optimizing the efficiency for, and spectral resolution of, the energies of interest. Gas absorption (efficiency) characteristics are shown on Figures 2, 3 and 4. These characteristics apply specifically to the path length through a 5.08 cm diameter counter at one atmosphere pressure, but they can be used for relative comparison and selection of a gas for any given counter design.

The primary interaction of incident radiation upon counter gas is predominantly photoelectric. Electrons from the primary ionization produce secondary electrons as they are accelerated towards the counter anode. Most of this secondary ionization, or gas multiplication, occurs within a few diameters of the anode wire. The resulting pulse has an energy greater than the ionizing potential of the gas atoms.

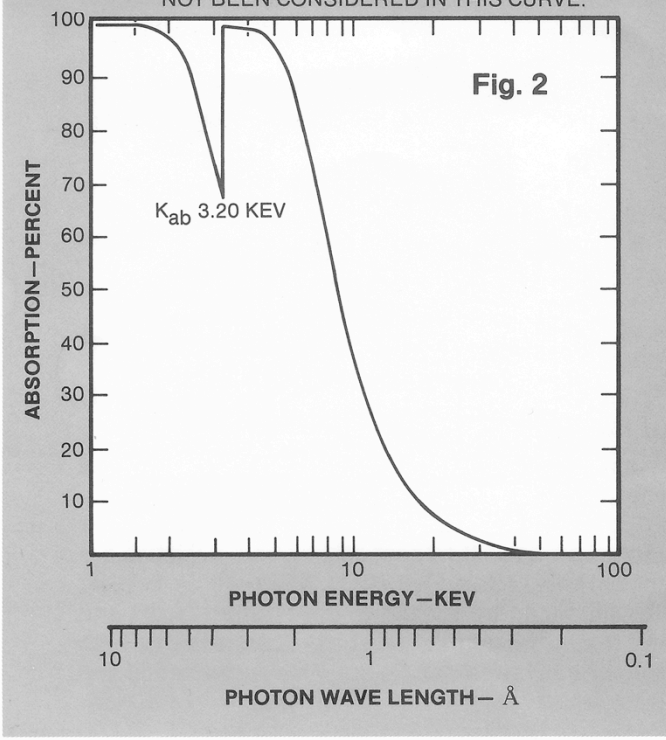
Incident photons exceeding the K_{ab} of the gas cause several secondary processes which result in "escape" peaks characteristic for a given gas. These escape peaks are of the energy: (energy of incident radiation) — (energy of the characteristic X-ray of the detection gas).

Characteristic $\bar{K}\alpha$ X-rays of the various detection gases are:

Xenon	29.7 keV
Krypton	12.6 keV
Argon	2.96 keV

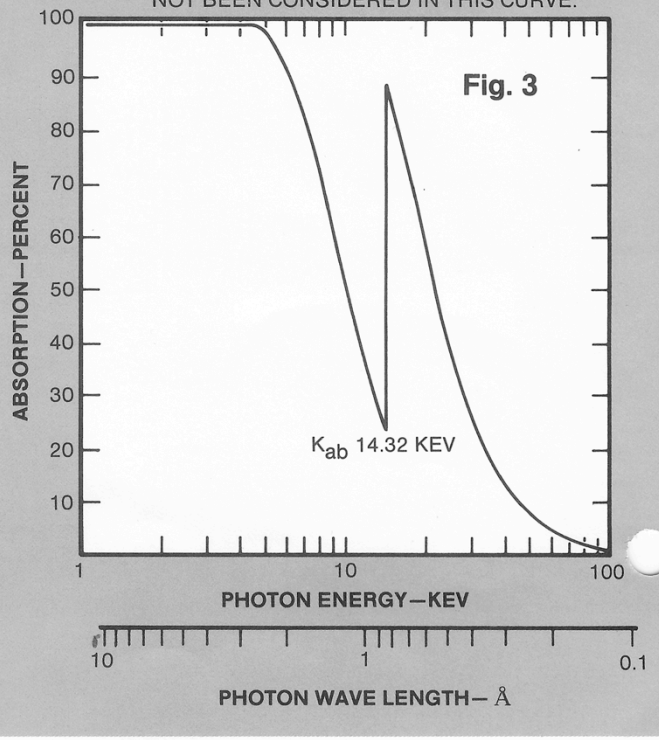
GAS ABSORPTION—97% ARGON—3% CO_2
AT ONE ATMOSPHERE PRESSURE THRU SIDE WINDOW
OF 5.08 CM DIAMETER PROPORTIONAL COUNTER

NOTE: THE EFFECT OF WINDOW TRANSMISSION (ABSORPTION) CHARACTERISTICS HAS NOT BEEN CONSIDERED IN THIS CURVE.



GAS ABSORPTION—97% KRYPTON—3% CO_2
AT ONE ATMOSPHERE PRESSURE THRU SIDE WINDOW
OF 5.08 CM DIAMETER PROPORTIONAL COUNTER

NOTE: THE EFFECT OF WINDOW TRANSMISSION (ABSORPTION) CHARACTERISTICS HAS NOT BEEN CONSIDERED IN THIS CURVE.



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When selecting a counter gas, the location of the escape peak should also be a consideration. For example, the absorption curve for krypton (Figure 3) shows why it is often selected for use with ^{57}Co in studies using its 14.4 keV peak. The sharp drop in efficiency below the K_{ab} edge of the gas causes the 14.4 keV peak to be isolated nicely and the escape peak at 1.8 keV (14.4-12.6) is well away from the primary peak (See Figure 8). There are other reasons for use of krypton with ^{57}Co which relate to its low efficiency for higher energies produced by ^{57}Co and the superior signal/noise ratio for the 14.4 keV peak.

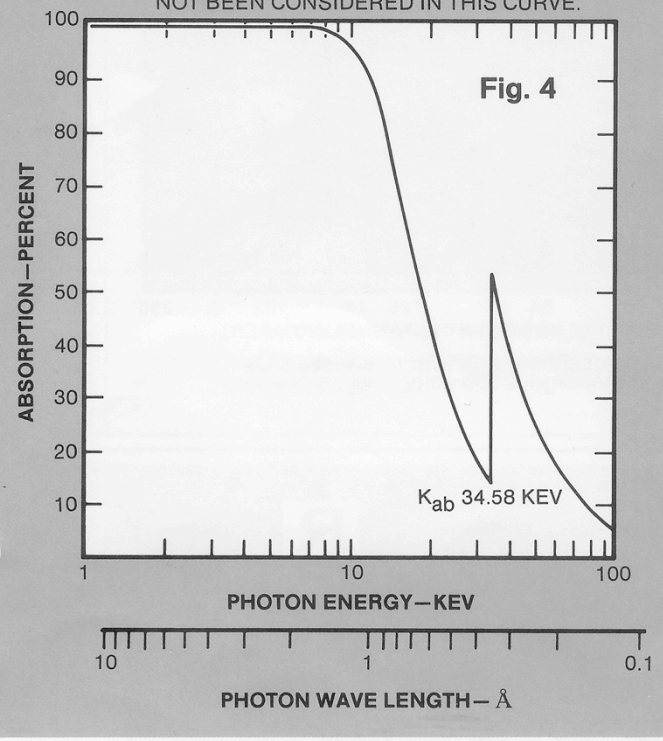
The inert gases are normally used with a small quantity of quench gas. This improves the pulse characteristics of the gas and prevents it from going into continuous discharge, thus shortening counter life. Our quench gas of choice is CO_2 because it provides excellent pulse and lifetime characteristics.

Operating Environment

Except for possible use at high counting rates, most research applications present a laboratory environment which does not subject counters to severe operating conditions, such as high temperature, humidity, etc. The considerations associated with high count rate are discussed in a following section.

GAS ABSORPTION—97% XENON—3% CO_2
AT ONE ATMOSPHERE PRESSURE THRU SIDE WINDOW
OF 5.08 CM DIAMETER PROPORTIONAL COUNTER

NOTE: THE EFFECT OF WINDOW TRANSMISSION (ABSORPTION) CHARACTERISTICS HAS NOT BEEN CONSIDERED IN THIS CURVE.



Industrial applications often require that a counter operate in high temperature and survive in high humidity. Reuter-Stokes' brazed-window counters are capable of operating at temperatures ranging from −25° C to +80° C with less than a 2% temperature-induced gain shift.

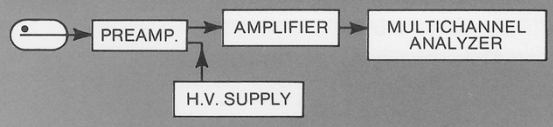
Moisture, particularly moisture containing chlorine, is extremely corrosive to beryllium. Since a protective housing tends to obviate the purpose of a thin window, particular attention must be taken to minimize the exposure of beryllium and organic windows to >65% relative humidity. The greatest protection is offered through use of the thickest acceptable window.

Associated Electronics

X-ray counters generally operate in a voltage range above 1600 volts and below 3000 volts depending on anode and counter diameter, gas pressure, and the amount of quench. Figure 5 shows the charge output per pulse for a variety of gas pressures/mixtures for Reuter-Stokes Model RS-P3-1605-261 using the 5.98 keV X-rays of ^{55}Fe. The shaded area shows the range of charge output (gas gain) over which counters are normally operated.

At high count rate (arbitrarily 2 X 10^4 cps), a reduction in charge output can occur which is caused by a space-charge effect at the counter anode. This gain shift can create an apparent effect of a count rate change if the peak shifts out of the discriminator window. The user should study the output of his counter/electronics combination to determine if it is necessary to compensate for gain shifts. In many industrial applications systems, manufacturers incorporate some form of automatic gain control, and generally, this is a gain adjustment to maintain a specific charge output from a reference pulse. Operating a counter at a lower voltage (reduced charge output) is a means of reducing the tendency for gain shift.

TYPICAL SPECTROMETRY ARRANGEMENT



There is a wide variety of commercially available electronics for use with gas counters. Experiment with the electronics configuration to determine the best settings for the application, keeping in mind that:

1. A charge sensitive preamplifier with a minimum sensitivity of 0.2 volts/pico coulomb is recommended.
2. Shaping time constants of the amplifier should

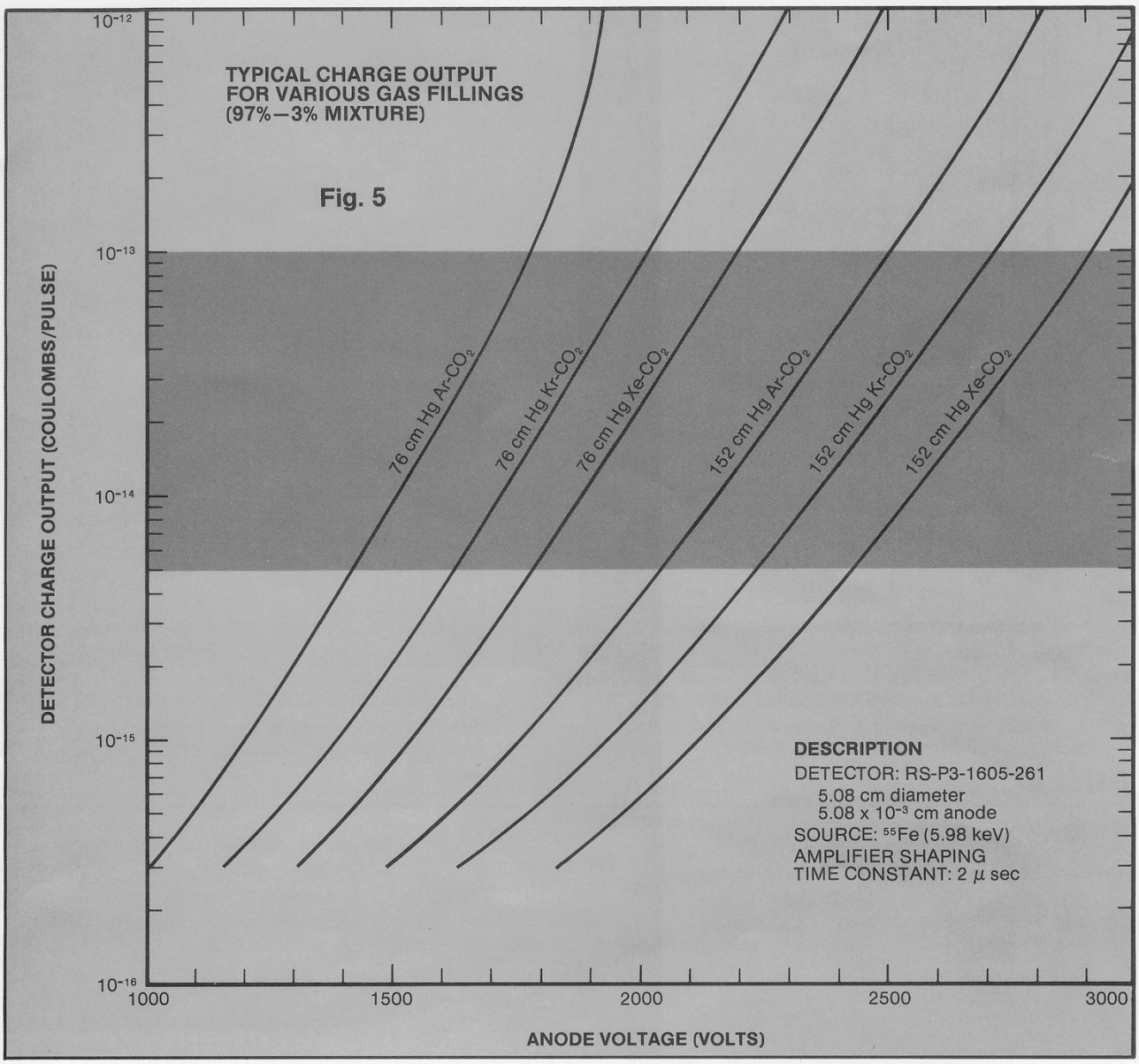
be at least one microsecond to preserve pulse height resolution.

3. There is a fairly wide range of operating voltage over which spectral resolution does not change significantly.
4. Increasing cable length (capacitance) between detector and preamplifier lengthens the pulse rise time; therefore, reducing preamplifier band width.
5. System gain can come from either the counter, by increasing voltage . . . or the electronics, by increasing gain settings. If the counter is required to provide high gain (from increased voltage) it is possible that a shortening of counter lifetime will be a trade off.

Lifetime

All of Reuter-Stokes' standard designs having brazed beryllium windows are specially processed for long life using proprietary techniques. These include special gas purification, cleaning and exhaust/fill techniques which provide a lifetime of GREATER THAN 10^{13} TOTAL COUNTS. Epoxy-bonded, beryllium designs cannot be subjected to the full range of special processes but are nevertheless offered with a lifetime guarantee of GREATER THAN 10^{12} TOTAL COUNTS. Counters having epoxy-bonded organic windows have many potential variables which could affect lifetime.and are offered with $>10^{9}$ total counts capability.

Signs of approaching end of lifetime include double peaking, degradation of spectral resolution, and decrease in charge output.



Specification Guide

Comparative Differential Pulse Height Spectra for RS-P3-1605-261

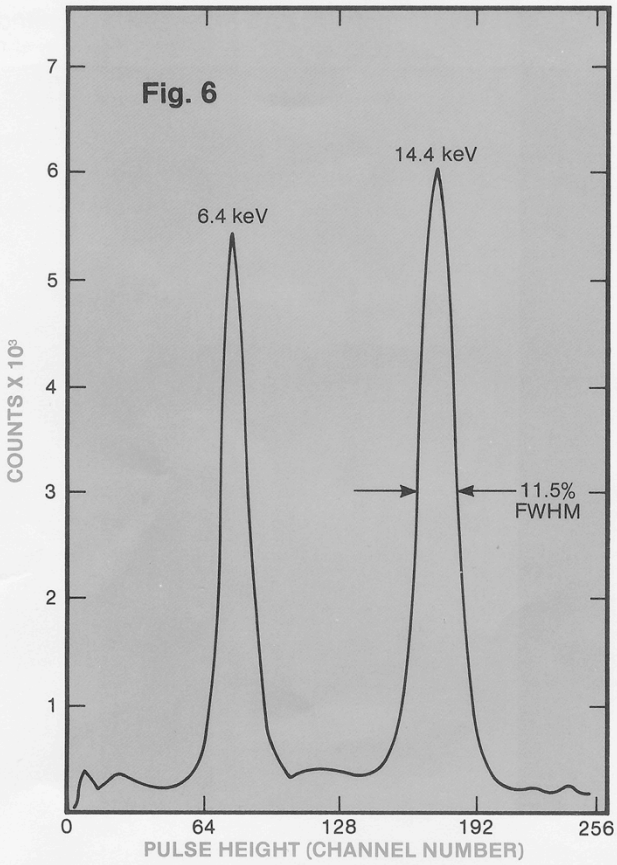
SOURCE:
0.56 microcurie ^{57}Co
with Aluminum filter

LIVE TIME:
300 seconds

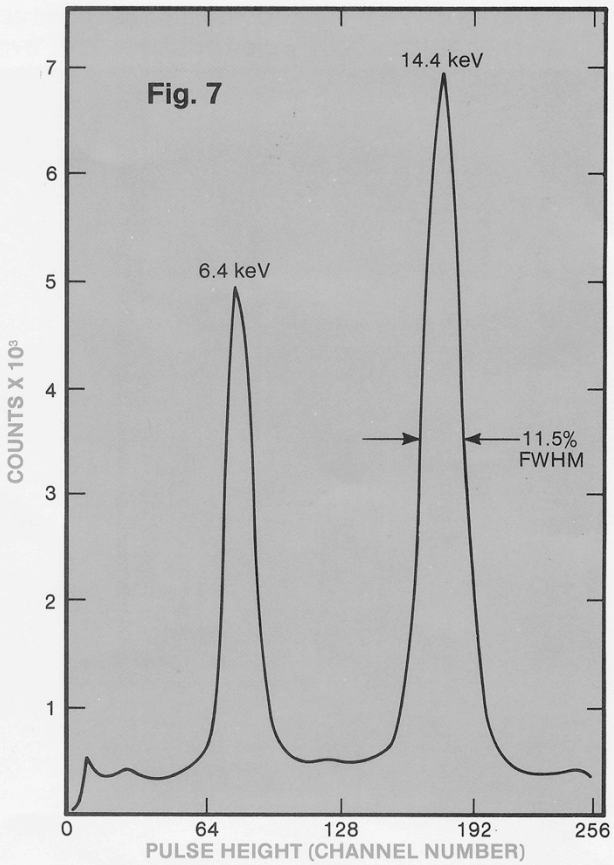
CHARGE OUTPUT:
~5 x 10^{-14} coulombs @ 14.4 keV

SHAPING TIME:
2 μsec

Isotope	TYPICAL X-RAY RESOLUTION		
	Energy (keV)	Line Width (keV)	% FWHM
^{55}Fe	5.98	1.1	18.0
^{57}Co	6.40	1.2	19.0
	14.40	1.7	11.5
^{109}Cd	22.10	1.9	8.5

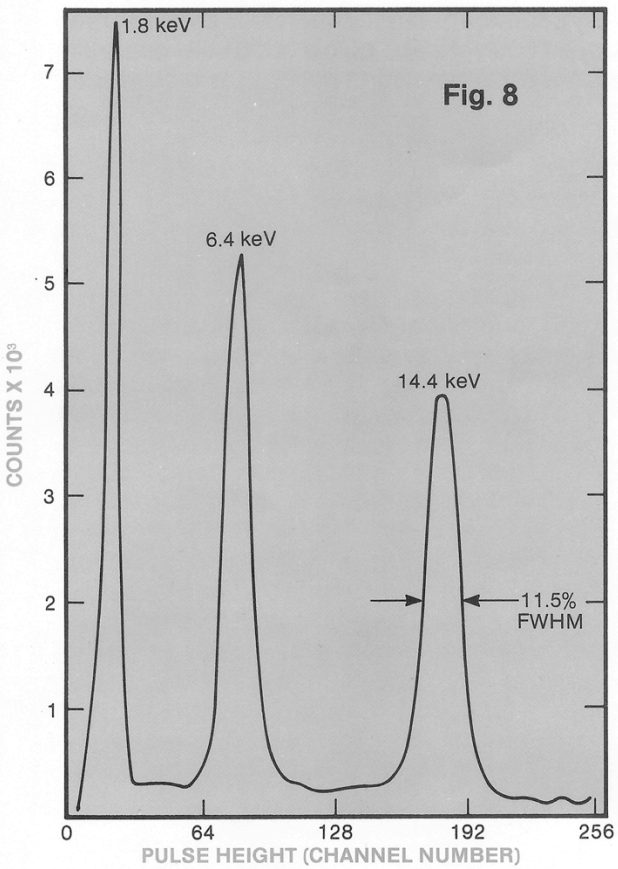


One Atmosphere: 97% xenon—3% CO_2
Anode Voltage: 2000 volts

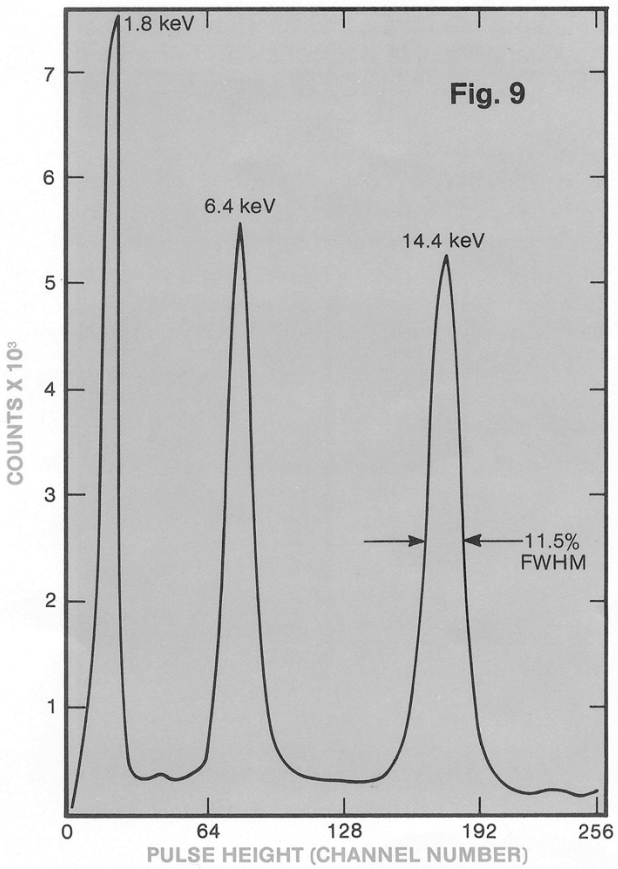


Two Atmospheres: 97% xenon—3% CO_2
Anode Voltage: 2800 volts

Typical X-Ray Resolution
Fill gas: argon, krypton or xenon
Pressure: 76 cm Hg to 152 cm Hg
Shaping time: 2 μsec



One Atmosphere: 97% krypton—3% CO_2
Anode Voltage: 1800 volts



Two Atmospheres: 97% krypton—3% CO_2
Anode Voltage: 2500 volts

reuter RS stokes
18530 South Miles Parkway • Cleveland, Ohio 44128 U.S.A.
Phone (216) ~~475-3434~~ Telex 985253
425-3755 ~~881-9400~~

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