PING/SPING Particulate, Iodine and Noble Gas Monitor Detector Systems Technical Specification

A DIVISION OF

Eberline

Thermo Electron CORPORATION

PING/SPING
PARTICULATE IODINE AND NOBLE GAS MONITOR
DETECTOR SYSTEMS
TECHNICAL SPECIFICATION

EBERLINE INSTRUMENT CORPORATION
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A. INTRODUCTION

The purpose of this technical specification is to describe each of the five possible detection channels on the Eberline PING (Particulate, Iodine and Noble Gas Monitor) and SPING (System Level PING) with respect to mechanical design, operational sensitivity, linearity, energy response, range and methods of primary and user calibration. This information will allow the user to determine the applicability of the monitor to meet the requirements of various regulatory requirements for general effluent monitoring.

The final section is devoted to explaining the direct applicability of the SPING-4 monitor to meet the requirements of NUREG 0737 with regard to post accident wide range noble gas monitoring.

The technical specification section for each channel contains the following sections:

1. Detector System: Explains the physical detector system and monitoring environment for the channel including detector type, filter type or monitored gas volume, interfacing electronics, and modes of operation such as threshold settings and typical operating window width where applicable.

2. Primary Calibration Methods: Explains the methods by which the factory calibration was performed and methods of utilizing transfer standards to allow the user to utilize the primary calibration information without the necessity of repeating the primary calibration.

3. Detector System Sensitivity: Lists the sensitivity of the monitoring channel in terms of counts/min per activity concentration and the effects of external background sources on the monitoring channel.

4. Detector System Range: Utilizing the detector sensitivity and background information, the minimum and maximum operating range of the monitoring channel is given.

5. Detector System Linearity: The linearity of the monitoring channel is described.

6. Detector Energy Response: The energy response of the monitoring channel is described as well as the methods by which the energy response was determined.

B. GENERAL MONITOR DESCRIPTION

The PING and SPING monitors are microcomputer based effluent monitors designed to monitor particulates and iodines over the range of 1×10^{-11} to 1×10^{-6} $\mu Ci/cm^3$ and noble gases over a wide range from 1×10^{-7} to 1×10^{2} with the PING-3 and SPING-3 monitors and up to 1×10^{5} $\mu Ci/cm^3$ with the extended range SPING-4 monitor. The microcomputer on the monitor provides the functions of data gathering, alarm posting, system integration (on the SPING) and pump, purge, and check source control.

A built-in gamma area monitor provides for remote indication of the exposure rate at the monitor as well as providing a background compensation signal to the microcomputer.

A solid-state mass flowmeter provides absolute and differential pressure information to the microcomputer. This information is used to calculate mass sample flow and to correct the noble gas channel readings for sample pressure above or below standard atmospheric pressure for which the calibration is based.

Optional motor-driven purging valves allow the operator to place the monitor into a purge mode providing a very useful means of determining what portion of an elevated reading is due to monitor contamination (fixed background) and/or noble gases.

A portable terminal interface on the SPING or a built-in printer and keyboard on the PING allow the operator to locally interface with the monitor and perform normal maintenance, calibration and data request functions. The SPING monitor, when connected in a system with central control terminal(s), can be controlled remotely including such functions as purge and check source.

There are up to nine digital detector channels and two analog input channels used on the PING/SPING monitors. The following is a list of these channels and their function:

CHANNEL	CHANNEL DESCRIPTION
1	- Beta Particulate (Beta Scintillator)
2	- Beta Particulate Bkg. (Diffused Junction Alpha)
3	- Iodine (NaI)
4	- Iodine Background (shared NaI)
5	- Low Range Noble Gas (Beta Scintillator)
6	- Gamma Area Monitor (Energy Comp. G-M)
7	- Mid Range Noble Gas (Energy Comp. G-M)
8	- Noble Gas Bkg. (Imbedded Energy Comp. G-M)
9	- High Range Noble Gas (Energy Comp. G-M) (SPING-4)
14	- Analog Transducer (Absolute Sample Pressure)
15	- Analog Transducer (Mass Sample Flow - Calculated)

C. BETA PARTICULATE CHANNEL

1. Detector System:

The particulate channel utilizes a Model RDA-3A beta scintillation detector connected to a Model IB-2 detector interface box. The RDA-3A is mounted inside a Model SA-13 lead-shielded sampler assembly providing three inches of lead shielding in a four pi configuration to minimize the effects of external gamma sources. A Model CSM-1 motor-driven check source mechanism fitted with a Model CS-17 (approximately 30 μCi ^{137}Cs) source is installed on this channel to provide periodic operational testing of the detector system.

The RDA-3A detector views the back side of a 47 mm diameter membrane type filter on which the sample stream particulates are collected. The front side of the filter is viewed by a solid-state diffused junction alpha detector whose signal is supplied to the microcomputer for the purpose of removing the background from naturally occurring radioactivity from the particulate channel reading.

The RDA-3A uses a 2 inch diameter by 0.010 inch thick Pilot-B plastic scintillator with a 1.6 mg/cm^2 aluminized mylar window. This crystal is coupled to a 2 inch diameter, 10 dynode photomultiplier tube. The outer sleeve of the scintillation detector is made of aluminum. A stainless steel version is available. O-ring seals internal to the sampler assembly provide the air tight seal necessary to prevent ambient air from being drawn into the sample chamber. Lead doors mounted on hinges to allow access to the detector shield the back of the detector assembly.

The IB-2 interface box contains the following plug-in cards:

a. a high voltage card to convert the +12 Vdc power from the microcomputer to the proper high voltage for the RDA-3S

b. an amplifier card to amplify the signal from the photomultiplier tube

c. a combination pulse height discriminator and line driver card which provides pulse height discrimination and a 50 ohm line driver to interface the counting signal (pulses) to the microcomputer.

The IB-2 discriminator card is operated in a gross counting mode (above a 100 keV threshold) with the window switched "out". The output signal from the line driver is a square edged wave which changes TTL state (high or low) at each detector count.

2. Primary Calibration Methods:

Primary calibration of the beta particulate channel is no different from normal calibration. This involves placing a plated 47 mm diameter ^{99}Tc source (or other beta emitting source) which is NBS traceable inside the filter holder behind the filter paper. In this way the beta particles will transverse the filter during calibration just as they do during actual operation. A very realistic primary calibration which is easy for the user to reproduce is obtained in this fashion.

3. Detector System Sensitivity:

^{137}Cs - 5 cpm/h for 1 x 10^{-11} μCi/cm^3
^{90}Sr-^{90}Y - 8.8 cpm/h for 1 x 10^{-11} μCi/cm^3
^{99}Tc - 3.8 cpm/h for 1 x 10^{-11} μCi/cm^3

The above sensitivities are based on a sampling flow rate of 60 liters/min which is the normal sampling rate of this monitor. The sensitivity is expressed in cpm/h since this is the resulting count rate from operating the monitor for one hour in an airborne concentration of the specified isotope at the specified concentration.

The nominal background is approximately 25 cpm fixed detector background plus 10 cpm/mR/h of external ^{137}Cs field.

4. Detector System Range:

The operational range of the beta particulate channel is nominally from 1 x 10^{-11} to 1 x 10^{-6} μCi/cm^3.

The minimum detectable count rate (counts/min) is determined to be two sigma above the non-elevated ambient background count rate. The minimum detectable concentration is determined by dividing the minimum detectable count rate by the channel sensitivity in counts/min per $\mu Ci/cm^3$. The maximum detectable concentration is determined by dividing the maximum count rate allowed by the monitor microcomputer before flagging the channel as high failed (1.02×10^6 counts/min) by the channel sensitivity in counts/min per $\mu Ci/cm^3$.

5. Detector System Linearity:

The scintillation detector used in the particulate channel has a dead time of only a few microseconds resulting in less than 5 percent non-linearity through the high fail count rate of 1.02 million counts/min. A linearity response curve for the RDA-3A detector is included in the appendix.

6. Detector Energy Response:

The energy response of the RDA-3A detector was determined through the use of a set of NBS traceable beta standards. The energy response was first determined (in air) by measuring the response per beta flux versus energy. Energy response relative to measurement of collection filters was then determined by fitting the energy response curve to three points obtained by placing plated sources into the monitor. The energy response is flat (plus or minus 30 percent) from 100 keV to 2 MeV as shown in the RDA-3A energy response curve included in the appendix.

D. IODINE CHANNEL

1. Detector System:

The iodine channel utilizes a Model RDA-2A gamma scintillation detector connected to a Model IB-2 detector interface box. The RDA-2A is mounted in the second position of the Model SA-13 lead-shielded sampler assembly providing three inches of lead shielding in a four pi configuration to minimize the effects of external gamma sources. The RDA-2A detector views a 2 inch diameter by 3/4 inch thick charcoal or silver zeolite iodine collection cartridge through which the sample flows.

A Model CSM-1 motor-driven check source mechanism fitted with a Model CS-18 (approximately 0.5 μCi ^{133}Ba) source is installed on this channel to provide periodic operational testing of the iodine detector system.

The RDA-2S detector is a 2 inch diameter by 2 inch thick thallium activated sodium iodide crystal coupled to a 2 inch, 10 dynode photomultiplier tube. A small ^{241}Am seed is fitted inside the crystal to provide a gain stabilization pulse to the IB-2 stabilization card. The outer sleeve of the scintillation detector is aluminum. A stainless steel version is available. O-ring seals internal to the sampler assembly provide the air tight seal necessary to prevent ambient air from being drawn into the sample chamber. Lead doors mounted on hinges to allow access to the detector shield the back of the detector assembly.

The IB-2 interface box contains the following plug-in cards:

a. a high voltage card to convert the +12 Vdc power from the microcomputer to the proper high voltage for the RDA-3S

b. an amplifier card to amplify the signal from the photomultiplier tube

c. two combination pulse height discriminator and line driver cards which provide pulse height discrimination and a 50 ohm line driver to interface the counting signal (pulses) and background signal to the microcomputer

d. a gain stabilization card to minimize discriminator drift due to aging and/or temperature effects

The IB-2 discriminator cards are operated in a "window" mode with a base level threshold and an adjustable window. The normal set-up of the iodine channel utilizes a 50 keV wide window centered about the 364 keV photon which predominates the ^{131}I photon emissions. A second window of equal width (50 keV) is set up approximately 120 keV above the iodine window to count iodine background. The use of this channel for live background compensation is described below.

The dual channel IB-2 used for the iodine channel outputs two signals to the microcomputer. Each detector signal is a square edged wave, alternating polarity, TTL level signal which changes state (high or low) at each detector count.

2. Primary Calibration Methods:

Tests involving the implantation of ^{131}I into the iodine cartridge have been performed to understand the relation between the use of a plated calibration source and actual iodine within the collection cartridge. Through these tests, Eberline has determined that the detector sensitivity obtained through the use of a plated source in front of the iodine cartridge must be corrected for the average photon attenuation which occurs when iodine is evenly distributed within the collection cartridge. For this correction the sensitivity in cpm/μCi/cm^3 obtained through the use of a plated source is multiplied by 0.71 to correct for the expected 29 percent attenuation.

Transfer calibration of the iodine channel is accomplished with a 47mm diameter plated ^{133}Ba source placed in front of the iodine cartridge which resides in the iodine cartridge holder. The obtained sensitivity is corrected for photon attenuation as previously explained and the difference in photon emissions per disintegration between ^{133}Ba and ^{131}I. The latter correction is made by multiplying the sensitivity by 1.19.

3. Detector System Sensitivity:

The nominal sensitivity of this channel is 3.5 cpm/h for 1 x 10^{-11} μCi/cm^3 of ^{131}I. This sensitivity is based on the recommended operating flow rate of 60 liters/min. The sensitivity is expressed in cpm/h since this is the resulting count rate from operating the monitor for one hour in an airborne concentration at the specified concentration.

The nominal background is 45 cpm plus 15 cpm per mR/h of external ^{137}Cs field.

4. Detector System Range:

The operational range of the iodine channel is nominally from 10^{-11} to 10-6 μCi/cm^3.

The minimum detectable count rate (counts/min) is determined to be two sigma above the non-elevated ambient background count rate. The minimum detectable concentration is determined by dividing the minimum detectable count rate by the channel sensitivity in counts/min per μCi/cm^3. The maximum detectable concentration is determined by dividing the maximum count rate allowed by the monitor microcomputer before flagging the channel as high failed (1.02 x 10^6 counts/min) by the channel sensitivity in counts/min per μCi/cm^3.

5. Detector System Linearity:

The gamma scintillation detector used on the iodine channel has a very short dead time of only a few microseconds resulting in a less than 5 percent non-linearity through the high fail count rate of 1.02 million counts/min. A RDA-2A linearity response curve is included in the appendix.

6. Detector Energy Response:

While NaI scintillation detectors are very energy dependent, the use of pulse height analysis on this channel to define the calibration range prevents this from being a problem.

D. LOW RANGE NOBLE GAS CHANNEL

1. Detector System:

The Low Range Noble Gas channel utilizes a Model RDA-3A beta scintillation detector connected to a Model IB-2 detector interface box. The RDA-3A is mounted in the third position of the Model SA-13 lead shielded sampler assembly providing three inches of lead shielding in a four pi configuration to minimize the effects of external gamma sources. The RDA-3A detector views a 270 cm^3 gas chamber through which the sample flows.

A Model CSM-1 motor-driven check source mechanism fitted with a Model CS-18 (approximately 30 µCi ^{137}Cs) source is installed on the SA-13 to provide periodic operational testing of the detector system.

The RDA-3A uses a 2 inch diameter by 0.010 inch thick Pilot-B plastic scintillator with a 1.6 mg/cm^2 aluminized mylar window. This crystal is coupled to a 2 inch diameter, 10 dynode photomultiplier tube. The outer sleeve of the scintillation detector is made of aluminum. A stainless steel version is available. O-ring seals internal to the sampler assembly provide the air tight seal necessary to prevent ambient air from being drawn into the sample chamber. Lead doors mounted on hinges to allow access to the detector shield the back of the detector assembly.

The IB-2 interface box contains the following plug-in cards:

a. a high voltage card to convert the +12 Vdc power from the microcomputer to the proper high voltage for the RDA-3S

b. an amplifier card to amplify the signal from the photomultiplier tube

c. a combination pulse height discriminator and line driver card which provides pulse height discrimination and a 50 ohm line driver to interface the counting signal (pulses) and background signal to the microcomputer

The IB-2 discriminator card is operated in a gross counting mode (above a 100 keV threshold) with the window switched "out".The output signal from the line driver is a square edged wave which changes TTL state (high or low) at each detector count. Note that since the counting electronics in the microcomputer register a single count with each full wave transition, two counts at the detector correspond to only one count at the microcomputer.

2. Primary Calibration Methods:

The low range noble gas channel primary calibration was performed by introducing known concentrations of several isotopes into the gas sample chamber. At the time of gas calibration, the sensitivity (efficiency) of the detector to a plated ^{99}Tc source was also determined. The user is expected to use the transfer standard method of calibration by utilizing the ^{99}Tc source installed in the beta particulate filter holder. This holder, with the transfer source installed, is inserted in place of the mid range noble gas detector normally facing the low range detector for a highly reproducible geometry. The detector efficiency is then compared to that of the original detector for which the primary calibration data was collected. The ratio of efficiencies between these two detectors provides a direct cross reference to the primary gas calibration.

3. Detector System Sensitivity:

The nominal sensitivity of this channel is 28 cpm for 1×10^{-6} μCi/cm^3 of ^{133}Xe or 41 cpm for the same concentration of ^{85}Kr at atmospheric pressure.

The nominal background is 25 cpm plus 10 cpm per mR/h of external ^{137}Cs field.

4. Detector System Range:

The operational range of the low range noble gas channel is nominally from 10^{-7} to 10^{-2} μCi/cm^3 (^{133}Xe).

The minimum detectable count rate (counts/min) is determined to be two sigma above the non-elevated ambient background count rate. The minimum detectable concentration is determined by dividing the minimum detectable count rate by the channel sensitivity in counts/min per $\mu Ci/cm^3$. The maximum detectable concentration is determined by dividing the maximum count rate allowed by the monitor microcomputer before flagging the channel as high failed (1.02×10^6 counts/min) by the channel sensitivity in counts/min per $\mu Ci/cm^3$.

5. Detector System Linearity:

The scintillation detector used in the low range noble gas channel has a dead time of only a few microseconds resulting in less than 5 percent non-linearity through the high fail count rate of 1.02 million counts/min. A linearity response curve for the RDA-3A detector is included in the appendix.

6. Detector Energy Response:

The energy response of the RDA-3A detector was determined through the use of a set of NBS traceable solid source beta standards. This data was then fitted to several known primary gas calibration points to produce the gas energy response curve for the RDA-3A included in the appendix. The energy response for this detector is flat (plus or minus 30 percent) from 100 keV to 2 MeV.

E. MID RANGE NOBLE GAS CHANNEL

1. Detector System:

The Mid Range Noble Gas channel utilizes a Model NGD-1 detector which is an energy compensated G-M tube mounted within a 233 mg/cm^2 lucite cap. The NGD-1 detector is interfaced to a Model IB-4A detector interface box.

The NGD-1 detector is designed to monitor the photon emissions from the defined gas volume. The use of a lucite cap provides good beta attenuation and because of its low atomic number, has a very low efficiency for bremmstrahlung photon production.

The NGD-1 detector is mounted in the third (right-most) position within the SA-13 lead shielded sampler assembly facing to the front of the monitor. The continuity of the lead shielding in the SA-13 is maintained by the three inch cylindrical lead block which forms the end of the detector. O-ring seals internal to the sampler assembly provide the air tight seal necessary to prevent ambient air from being drawn into the sample chamber.

The IB-4A detector interface box performs the functions of generating the high voltage (from the 12 Vdc supplied by the monitor) needed by the detector and processing of the detector pulses resulting in their output through a 50 ohm line driver. The signal from the line driver is a square edged wave which changes TTL state (high or low) at each detector count.

2. Primary Calibration Methods:

The mid range noble gas channel primary calibration was performed by introducing known concentrations of several isotopes into the gas sample chamber. At the time of gas calibration, the sensitivity (efficiency) of the detector to a known field of ^{137}Cs source was also determined. The user is expected to use the transfer standard method of calibration by placing the detector in a ^{137}Cs gamma field through the use of a stick source, gamma calibrator or a gamma well. The detector efficiency is then compared to that of the original detector for which the primary calibration data was collected. The ratio of efficiencies between these two detectors provides a direct cross reference to the primary gas calibration.

3. Detector System Sensitivity:

The nominal sensitivity of this channel is 685 cpm for 1 $\mu Ci/cm^3$ of ^{133}Xe or 61 cpm for the same concentration of ^{85}Kr at atmospheric pressure.

The nominal background is 0.5 cpm plus 1 cpm per mR/h of external ^{60}Co field.

4. Detector System Range:

The operational range of the mid range noble gas channel is nominally from 10^{-3} to 10^{2} $\mu Ci/cm^3$ (^{133}Xe).

The minimum detectable count rate (counts/min) is determined to be two sigma above the non-elevated ambient background count rate. The minimum detectable concentration is determined by dividing the minimum detectable count rate by the channel sensitivity in counts/min per $\mu Ci/cm^3$. The maximum detectable concentration is determined by dividing the maximum count rate allowed by the monitor microcomputer before flagging the channel as high failed (1.02×10^6 counts/min) by the channel sensitivity in counts/min per $\mu Ci/cm^3$.

5. Detector System Linearity:

The energy compensated G-M detector used in this channel has a fairly large dead time (over 100 usec) which causes noticeable counting losses in the top decade of operation. The counting losses as a result of non-linearity at the top end of operation is approximately 20 percent which should be accounted for when readings are obtained from this decade. A linearity response curve for this detector is included in the appendix.

6. Detector Energy Response:

The energy response of the detector used for this channel is within plus or minus 15 percent of the true field with respect to exposure rate over a range from 40 keV to approximately 3 MeV. An energy response curve for this detector is included in the appendix.

F. HIGH RANGE NOBLE GAS CHANNEL

1. Detector System:

The High Range Noble Gas channel monitor utilizes an energy compensated G-M tube monitoring a section of 0.035 inch thick 1 inch o.d. stainless steel pipe. This detector is interfaced to a Model IB-4A detector interface box. The entire detector assembly including the rotary solenoid check source mechanism is mounted within the SA-9 lead-shielded sampler assembly providing three inches of shielding in a four pi configuration. The check source utilized in this configuration is a 0.7 µCi ^{90}Sr-Y plated to the end of a stainless steel plug.

The High Range detector is designed to monitor the photon emissions from the defined gas volume. Beta particle attenuation in the steel pipe viewed by the detector prevents this channel from being sensitive to beta particles with the exception of some bremmstrahlung production.

The IB-4A detector interface box performs the functions of generating the high voltage (from the 12 Vdc supplied by the monitor) needed by the detector and processing of the detector pulses resulting in their output through a 50 ohm line driver. It also provides the check source control signal to the check source mechanism when the proper signal is received from the microcomputer. The signal from the line driver is a square edged wave which changes TTL state (high or low) at each detector count.

2. Primary Calibration Methods:

Normal calibration of the high range noble gas channel is a primary calibration performed by replacing the sample stream piping with a sealed section of 1 inch o.d. tubing filled with ^{85}Kr. Since this standard utilizes the same sample volume, wall thickness, etc. as the original counting configuration a very accurate calibration is obtained. Eberline has also performed primary calibrations with ^{133}Xe which can be utilized by transferring the detector sensitivity to the ^{85}Kr standard to the ^{133}Xe primary calibration.

3. Detector System Sensitivity:

The nominal sensitivity of this channel is 8.4 cpm for 1 $\mu Ci/cm^3$ of ^{133}Xe or 2.3 cpm for the same concentration of ^{85}Kr at atmospheric pressure.

The nominal background is 0.5 cpm plus 1 cpm per mR/h of external ^{60}Co field.

4. Detector System Range:

The operational range of the beta high range noble gas channel is nominally from 1 to 10^5 $\mu Ci/cm^3$ (^{133}Xe).

The minimum detectable count rate (counts/min) is determined to be two sigma above the non-elevated ambient background count rate. The minimum detectable concentration is determined by dividing the minimum detectable count rate by the channel sensitivity in counts/min per $\mu Ci/cm^3$. The maximum detectable concentration is determined by dividing the maximum count rate allowed by the monitor microcomputer before flagging the channel as high failed (1.02×10^6 counts/min) by the channel sensitivity in counts/min per $\mu Ci/cm^3$.

5. Detector System Linearity:

The energy compensated G-M detector used in this channel has a fairly large dead time (over 100 usec) which causes noticeable counting losses in the top decade of operation. The counting losses as a result of non-linearity at the top end of operation is approximately 20 percent which should be accounted for when readings are obtained from this decade. A linearity response curve for this detector is included in the appendix.

6. Detector Energy Response:

The energy response of the detector used for this channel is within plus or minus 20 percent of the true field with respect to exposure rate over a range from 100 keV to approximately 3 MeV. An energy response curve for this detector is included in the appendix.

G. GAMMA AREA MONITORING CHANNEL

1. Detector System:

The gamma area monitor is a Model DA1-1-CC which utilizes an energy compensated G-M detector with an integral solenoid-driven check source. The check source is a Model CS-19 threaded plug which contains approximately 0.3 μCi of ^{90}Sr-^{90}Y. The range of the DA1-1-CC is from 0.01 to 100 mR/hr. Its G-M tube has a sensitivity of approximately 1200 counts/min per mR/hr.

The DA1-1-CC contains its own high voltage supply, pulse amplifier and line driver. The output signal from the line driver is a square edged wave which changes TTL state (high or low) at each detector count.

H. FLOW AND PRESSURE TRANSDUCER

As part of operating the monitor in derived concentration mode, the microcomputer must have access to information concerning the sample flow rate through the monitor. In addition, the microcomputer automatically performs a pressure correction on the gas monitoring channels to correct for the error caused from operating the monitor at a slight negative pressure when the gas calibration was performed or corrected to atmospheric pressure. A solid-state flow and pressure transducer is mounted on the monitor between the pump and the last monitoring channel to provide the necessary information to the microcomputer.

The sensor measures both the absolute pressure of the sample and the differential pressure across a flow orifice. This information is passed to the microcomputer in the form of two 4-20 mA current loops. The microcomputer takes this information and calculates the sample mass flow rate. Channels 14 (absolute pressure) and 15 (calculated mass flow) are used to display this information on the microcomputer.

I. MONITOR APPLICABILITY TO NUREG 0737 REQUIREMENTS

The following discussion relates directly to the requirements of section II.F.1 and table II.F.1-1 of the November 1980 edition of NUREG 0737, "Clarification of TMI Action Plan Requirements".

1. 0737 Requirement: Noble gas effluent monitoring shall be provided for the total range of concentration extending from normal condition (as low as reasonably achievable) concentrations to a maximum of 10^5 µCi/cm^3 (^{133}Xe). The range capacity of individual monitors should overlap by a factor of ten.

SPING-4 Capability: As shown in the graph included in the appendix labeled "Monitoring Ranges of Three Channel Gas Monitor", a monitor equipped with low, mid and high range noble gas monitoring channels such as the SPING-4 is capable of monitoring ^{133}Xe equivalent concentrations of noble gases from 10^{-7} to 10^5 µCi/cm^3 with at least a one decade overlap between channels.

2. 0737 Requirement: The sampling design criteria shall be per ANSI N13.1

SPING-4 Capability: These monitors are designed per the recommendations of ANSI N13.1 with a minimum of plumbing bends prior to the sample reaching the particulate collection filter to minimize the plate-out of particulate material. Installations utilizing Eberline designed and supplied sampling probes are likewise designed per ANSI N13.1 taking into account the velocity and flow rate of both the sampled stack and the sample stream as well as the diameter of the sample stack. Doing this results in probes with the correct number of sampling points (nozzles) for a representative sample and the correct nozzle diameter for matching the velocity of the stack stream to the sample stream reducing particle size discrimination.

3. 0737 Requirement: Calibrate monitors using gamma detectors to ^{133}Xe equivalent. Calibrate monitors using beta detectors to ^{90}Sr or similar long-lived beta isotope of at least 0.2 MeV.

SPING-4 Capability: As explained in the above sections, the mid and high range detectors are gamma sensitive detectors which are calibrated with ^{133}Xe. The low range beta sensitive detector is calibrated by the user with a transfer standard of ^{99}Tc which has a maximum beta energy of 0.292 MeV and a half-life of 2×10^5 years.

4. 0737 Requirement: Display shall be continuous and recording as equivalent ^{133}Xe concentrations or $\mu Ci/cm^3$ of actual noble gases.

SPING-4 Capability: The SPING-4 monitor is equipped with a front panel digital readout which provides continuous display of the gas concentration for any channel. Each unit will also log ten-minute or hourly detail averages to the system printer in a continuous fashion.

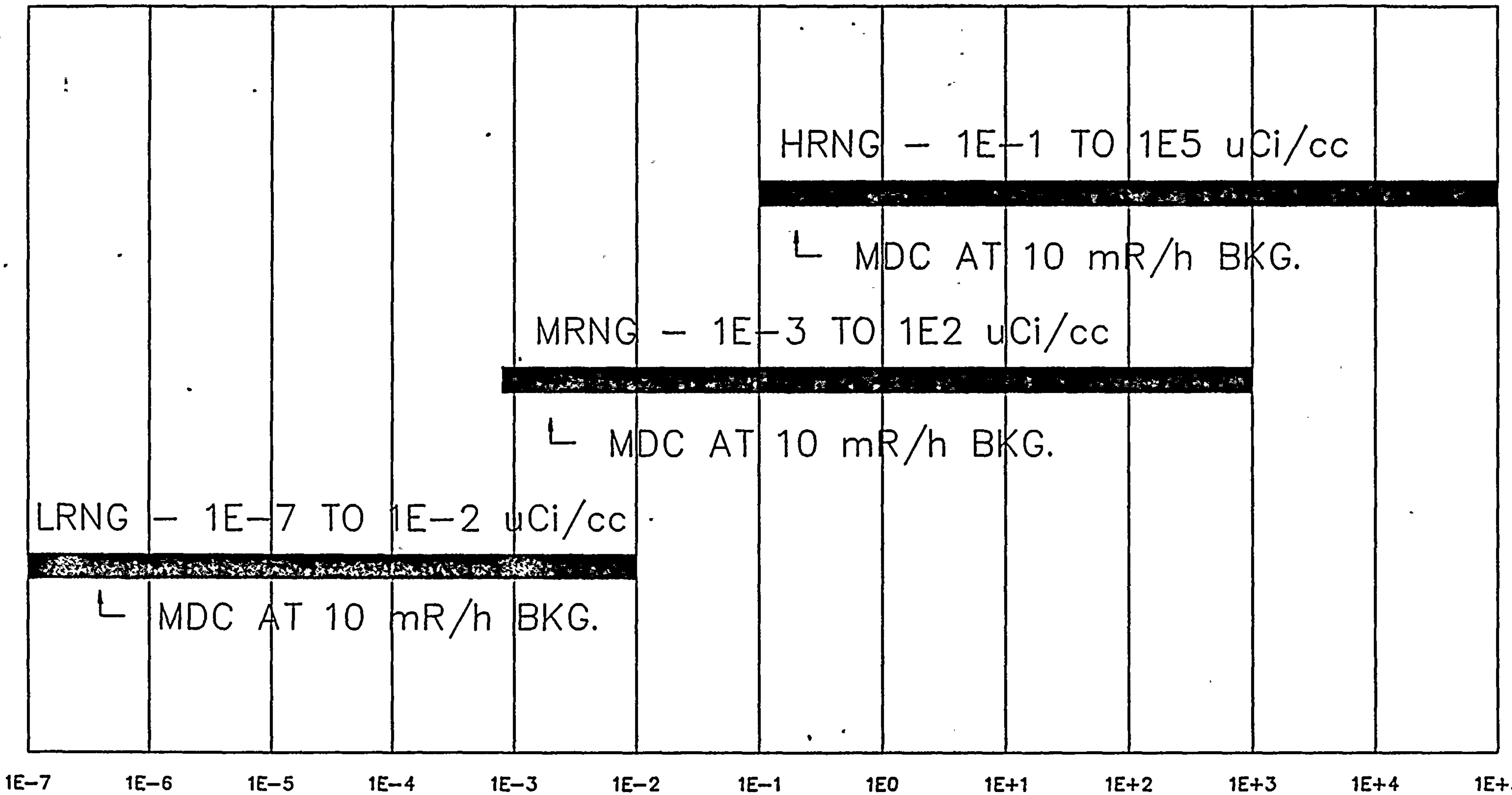
5. 0737 Requirement: The instrument shall provide sufficiently accurate response to perform the intended function in the environment to which they will be exposed during an accident.

SPING-4 Capability: Eberline will consult with the client concerning the environmental range over which the monitor is expected to function to aid in proper location of the monitors resulting in long-term service and reliable operation.

A P P E N D I X

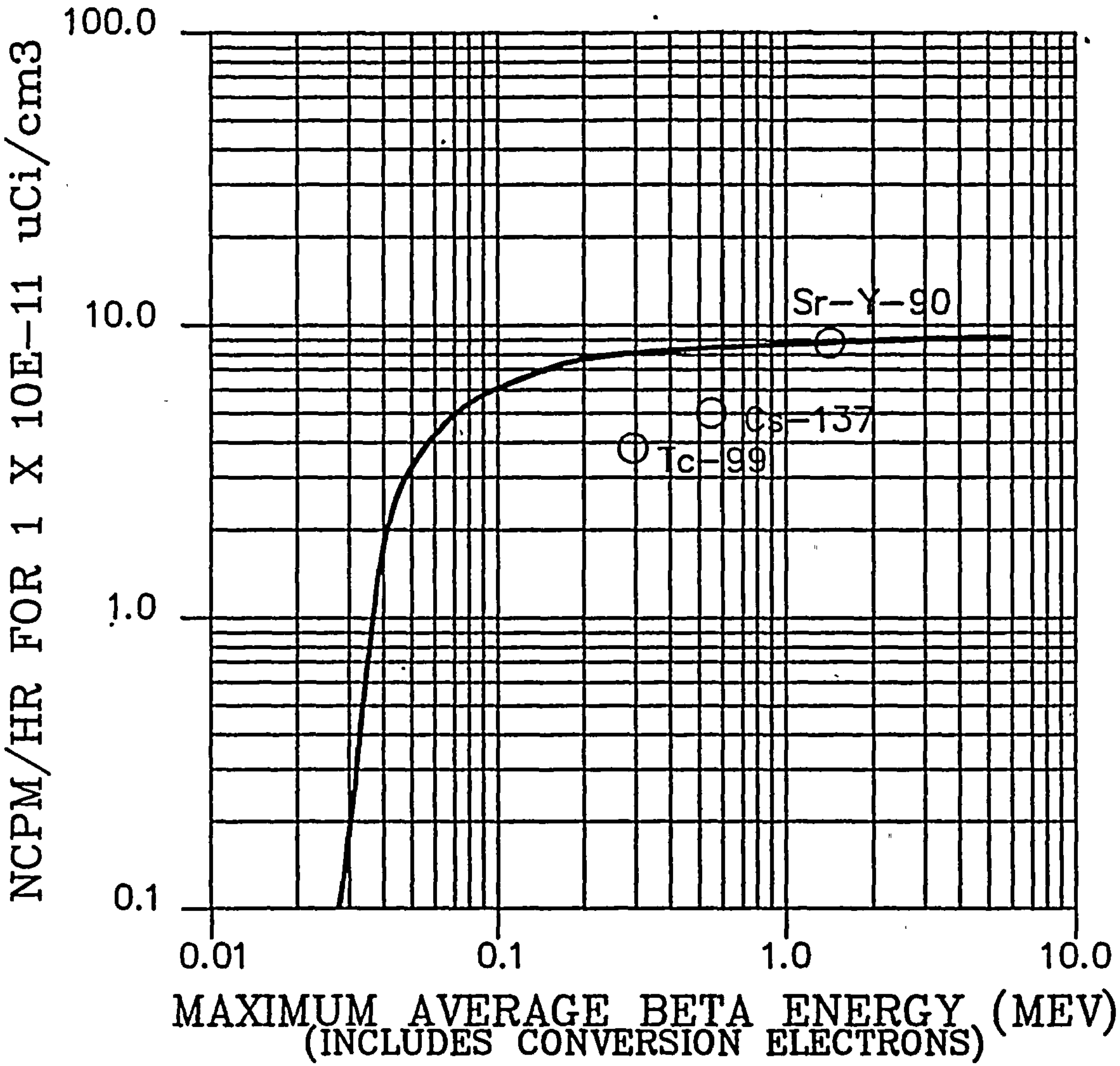
1. MONITORING RANGES OF THREE CHANNEL GAS MONITOR
2. RDA-3X BETA PARTICULATE ENERGY RESPONSE CURVE
3. RDA-3X LOW RANGE NOBLE GAS ENERGY RESPONSE CURVE
4. RDA-3X LINEARITY RESPONSE CURVE
5. RDA-2X LINEARITY RESPONSE CURVE
6. MID AND HIGH RANGE NOBLE GAS ENERGY RESPONSE CURVE
7. MID AND HIGH RANGE NOBLE GAS LINEARITY RESPONSE CURVE
8. PRIMARY CALIBRATION REPORT - LOW RANGE NOBLE GAS
9. PRIMARY CALIBRATION REPORT - MID RANGE NOBLE GAS
10. PRIMARY CALIBRATION REPORT - HIGH RANGE NOBLE GAS

MONITORING RANGES OF
THREE CHANNEL GAS MONITOR

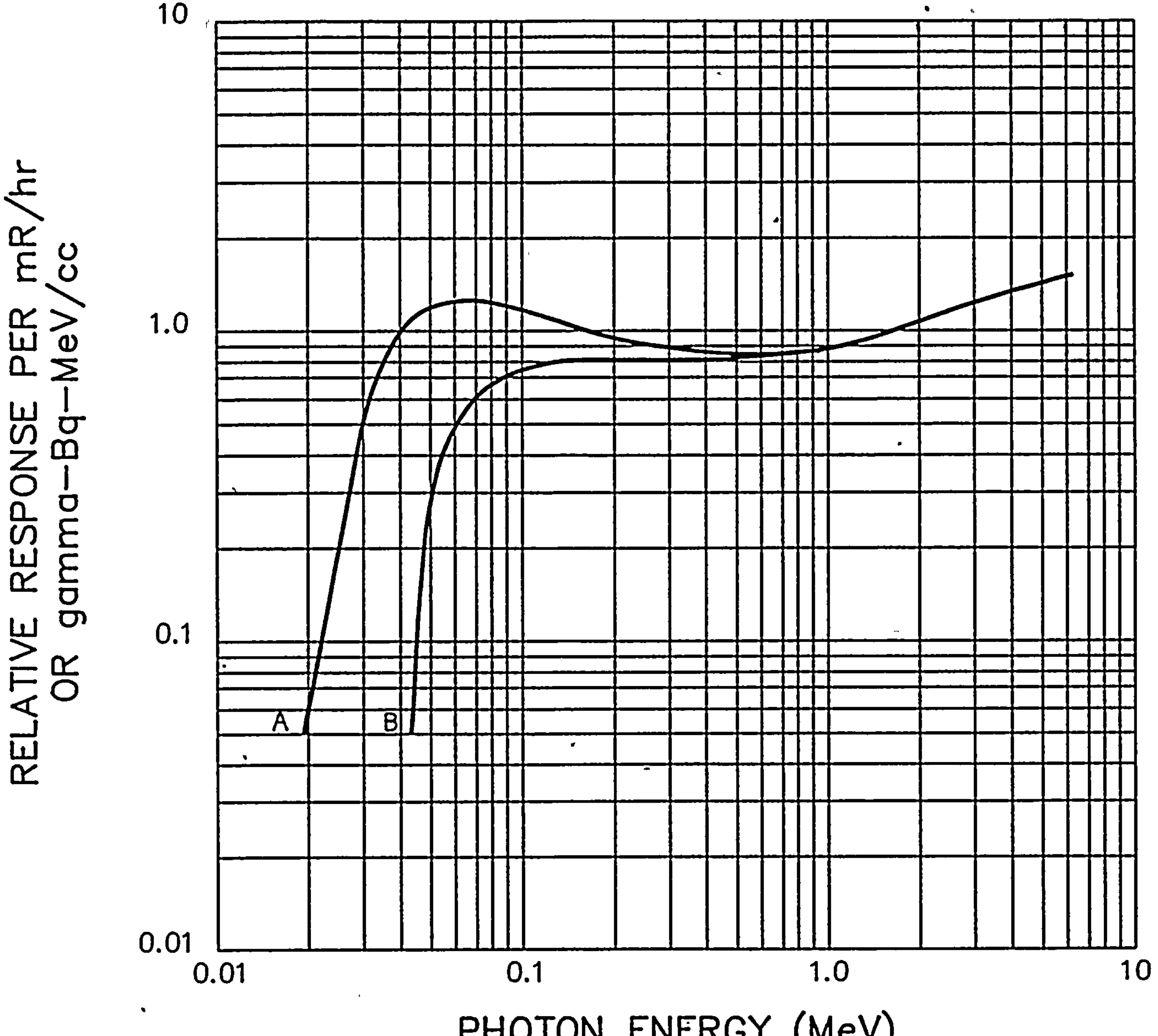


Xe–133 CONCENTRATION (uCi/cc)

ENERGY RESPONSE CURVE
RDA-3X BETA PARTICULATE

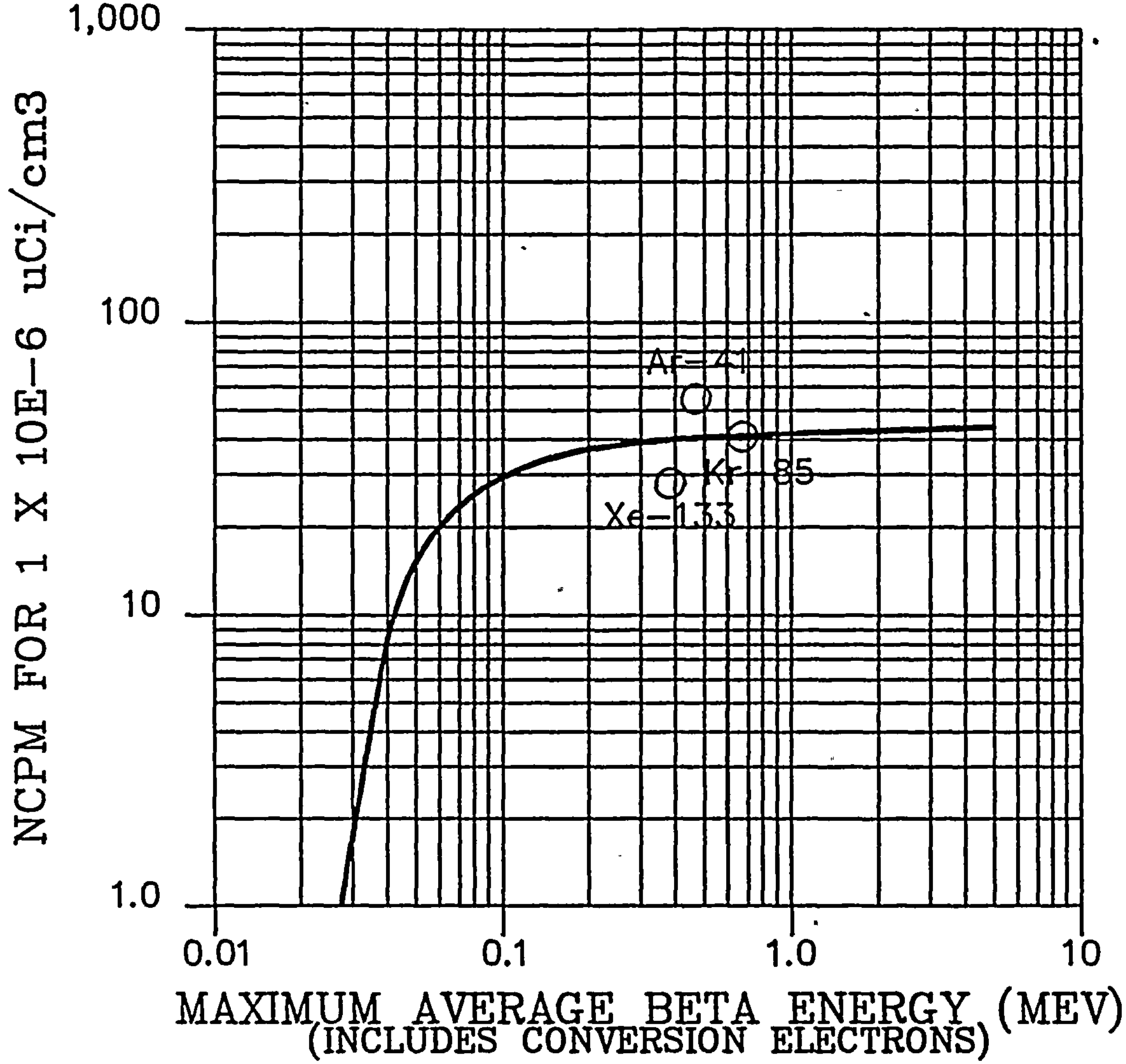


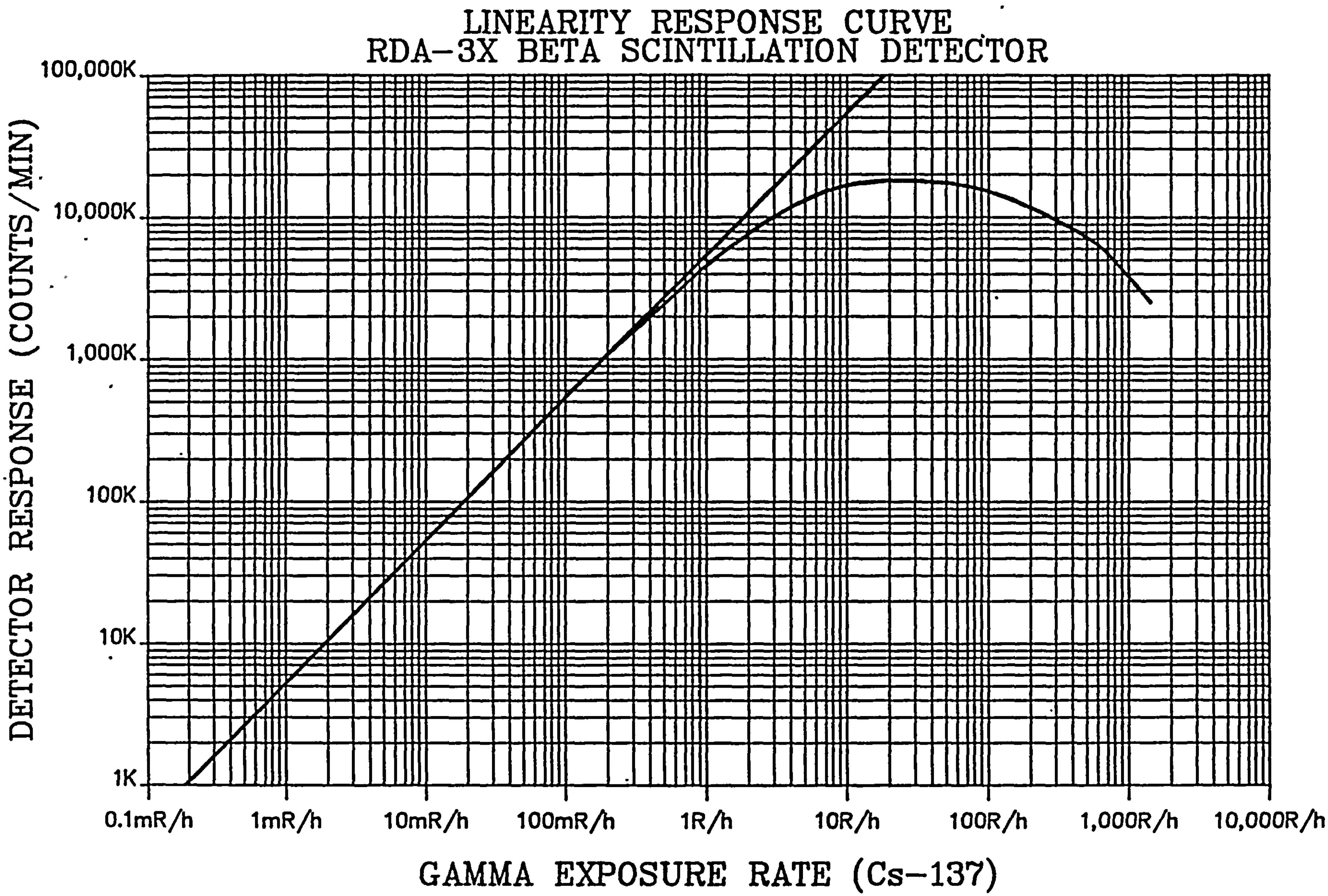
ENERGY RESPONSE CURVE
MID AND HIGH RANGE NOBLE GAS CHANNELS



A – MID RANGE   B – HIGH RANGE

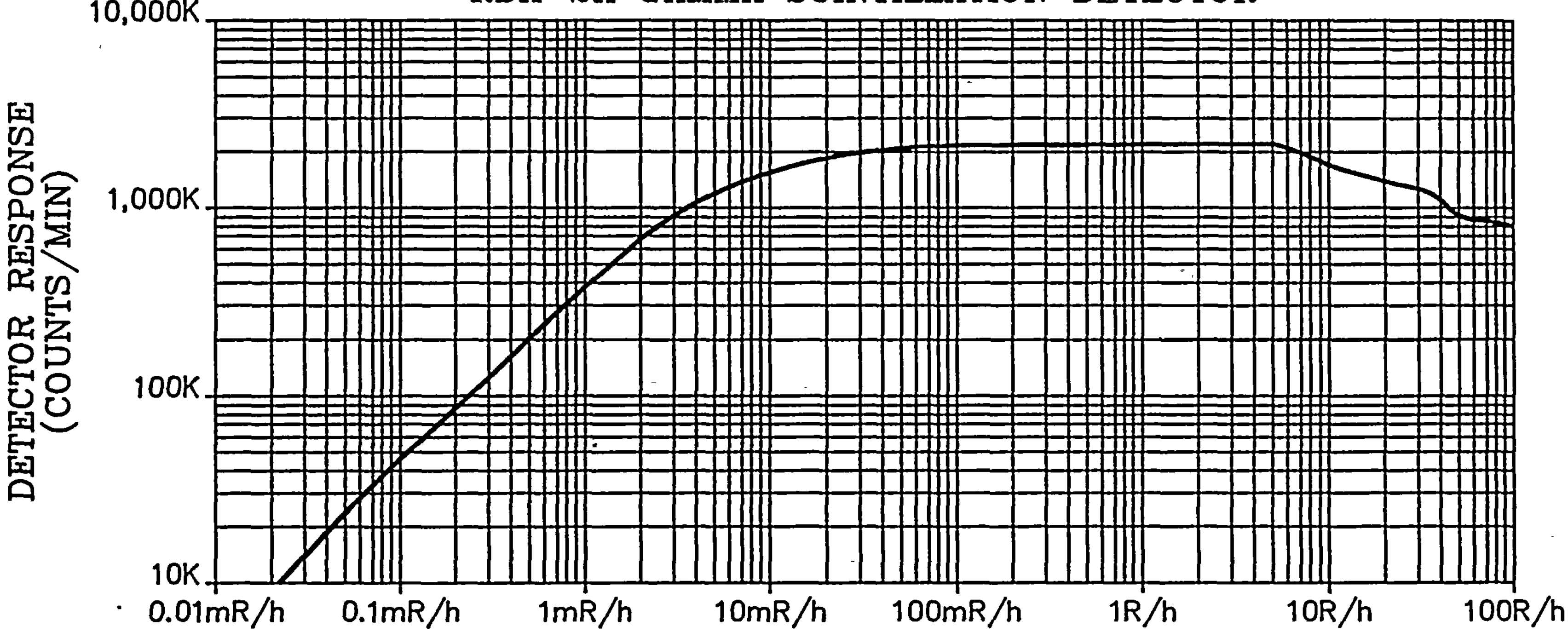
ENERGY RESPONSE CURVE
RDA-3X LOW RANGE NOBLE GAS




LINEARITY RESPONSE CURVE
RDA-3X BETA SCINTILLATION DETECTOR
100,000K
10,000K
1,000K
100K
10K
1K
DETECTOR RESPONSE (COUNTS/MIN)
0.1mR/h
1mR/h
10mR/h
100mR/h
1R/h
10R/h
100R/h
1,000R/h
10,000R/h
GAMMA EXPOSURE RATE (Cs-137)

LINEARITY RESPONSE CURVE

RDA-2X GAMMA SCINTILLATION DETECTOR

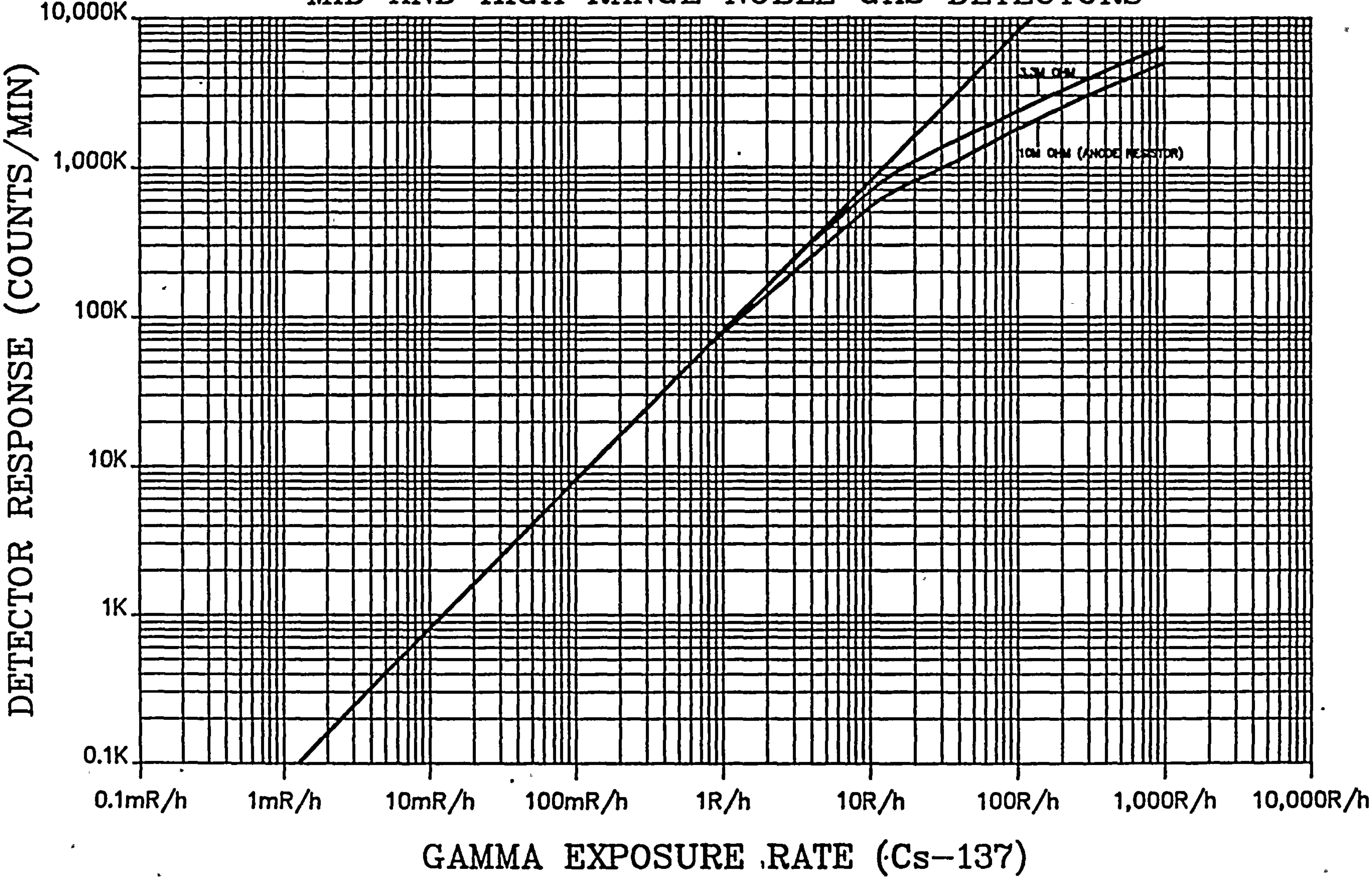


GAMMA EXPOSURE RATE (Cs-137)

THRESHOLD: 335 keV WINDOW: "OUT" Am SEED + BKG COUNT RATE: 58K CPM

DETECTOR RESPONSE HAS SEED AND BKG SUBTRACTED

LINEARITY RESPONSE CURVE
MID AND HIGH RANGE NOBLE GAS DETECTORS



NO.	QUAN.	PER.	DESCRIPTION

CHG.	APP.	DATE	DESCRIPTION	DATE	BY	CH'K
OI-1	[illegible]	1/20/84	miscellaneous Corrections Doc. Number was 12000-21	1/19/84	BC	[illegible]

QA APP. | REV | OT 3-25-82

EBERLINE INSTRUMENT CORPORATION
SANTA FE, NEW MEXICO

DR.	L.D.	3/23/82
CH'K.	[illegible]	3/23/82
PROJ. ENG.	[illegible]	3/23/82
APP.	[illegible]	3/25/82

SA-13 LOW RANGE NOBLE GAS BETA DETECTION

PRIMARY CALIBRATION WITH NOBLE GAS

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FRAC.	DEC.	ANG.
± 1/64	X.XX ± .015 X.XXX ± .005	± 1/2°

ALSO USED ON	EFF. WITH

SCALE

12000-A21 Sheet 1 of 12

ULTRAVEL NO. 490M

SA-13 LOW RANGE NOBLE GAS BETA DETECTOR PRIMARY CALIBRATION WITH NOBLE GAS

A. PURPOSE

To determine the sensitivity of the low range beta detector (model RDA-3A) to ^{133}Xe and ^{85}Kr gas in the SA-13 sampler assembly.

B. MATERIALS AND EQUIPMENT USED

1. SA-13, S.N. 224
2. RDA-3A, S.N. 466
3. IB-2, S.N. 970
4. Absolute Pressure Gauge, Wallace and Tiernan, S.N. FA16-LL09217

   NOTE: The sampler was mounted in an Eberline Model PING-3 Air Monitor. Data was taken using the PING-3 Microcomputer. The calibration constant was 1.00E00. Since the electronics divides the count rate by 2, all data, except that in the conclusion, is one-half the detector value.

C. SOURCES USED

1. ^{137}Cs Stick Source No. EI-119
2. ^{99}Technetium Electroplated Disc Source No. S-2752 (Certificate Enclosed)
3. ^{85}Kr Gaseous Calibration Standard S.N. 65113 (Certificate Enclosed)
4. ^{133}Xe Gaseous Calibration Standard S.N. 65114 (Certificate Enclosed)

   NOTE: All sources used are indirectly traceable to NBS.

D. PROCEDURE

1. The plated ^{99}Tc source was placed in the RDS-1 particulate filter holder and installed in the SA-13 in place of the mid-range Noble Gas Detector (NGD-1). This procedure assures a repeatable geometry between the source and the beta detector. See the data section for results.
2. The RDA-3A was removed from the SA-13 and exposed to various gamma field intensities to verify detector linearity (cpm vs. mR/h). See the data section for results.

3. The sampler was filled via the PING-3 air inlet fitting. The absolute pressure gauge was placed between the regulator output isolation valve and the inlet fitting using a "T" fitting and plastic tubing. An isolation valve was placed between the SA-13 exhaust and the air pump. The air pump exhaust was vented to the roof via plastic tubing.

   The sampler was filled by evacuating the system using the air pump with the regulator isolation valve closed. The system was then filled from the gas bottle by opening the regulator isolation valve. The display was monitored, and when no increase in count rate was observed, the sampler was assumed full of noble gas and the exhaust isolation valve was closed. The system was left filled for approximately one hour while data was collected in the microcomputer history files.

E. DATA

1. The average background of the RDA-3A in the SA-13 (with 4π shielding) was found to be 42.9 cpm.

2. Reference to ^{99}Tc (S-2752)

   a. First data point, 2/24/82: $^{99}Tc = 1.38 \times 10^3$ cpm

   b. Second data point, 2/26/82: $^{99}Tc = 1.41 \times 10^3$ cpm

   c. Average: $^{99}Tc = 1.395 \times 10^3$ cpm

   d. Source Value: $^{99}Tc = 35{,}044$ cpm

   e. Efficiency: $^{99}Tc = 1.395 \times 10^3$ cpm
   $- 42.9$ cpm (BKG)
   1.352×10^3 cpm

   1.352×10^3 cpm divided by 35,044 cpm = 3.86 percent efficient

3. ^{133}Xe, S.N. 65114

   a. Concentration at 1200 PST, 1/29/82: = 0.226 μCi/cm^3 (STP)

   b. Half Life: 5.271 Days

   c. First Data Point, 3/1/82:

$$\frac{I}{I_0} = e^{-0.6931\left(\frac{\text{DAYS}}{\text{Half Life}}\right)} = e^{-0.6931\left(\frac{31\text{ days}}{5.271}\right)} = 1.697 \times 10^{-2}$$

$1.697 \times 10^{-2} \times 0.226\ \mu Ci/cm^3 = 3.834 \times 10^{-3}\ \mu Ci/cm^3$ on 3/1/82.

This concentration ($3.834 \times 10^{-3}\ \mu Ci/cm^3$) yielded a count rate of 4.62×10^4 cpm in the SA-13, when filled to a pressure of of 610 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{4.62 \times 10^4 - 42.9\ \text{cpm}}{3.834 \times 10^{-3}\ \mu ci/cm^3} = 1.204 \times 10^7\ cpm/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760}{610} \times 1.204 \times 10^7\ cpm/\mu Ci/cm^3 = 1.499 \times 10^7 \text{ or } 14.99\ cpm/pCi/cm^3$$

d. Second Data Point, 3/2/82:

$$e^{-0.6931\left(\frac{32\ days}{5.271}\right)} = 1.488 \times 10^{-2}$$

$1.488 \times 10^{-2} \times 0.226\ \mu Ci/cm^3 = 3.362 \times 10^{-3}\ \mu Ci/cm^3$ on 3/2/82.

This concentration ($3.362 \times 10^{-3}\ \mu Ci/cm^3$) yielded a count rate of 3.83×10^4 cpm in the SA-13, when filled to a pressure of 610 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{3.83 \times 10^4 - 42.9\ \text{cpm}}{3.362 \times 10^{-3}\ \mu Ci/cm^3} = 1.138 \times 10^7\ cpm/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760}{610} \times 1.138 \times 10^7\ cpm/\mu Ci/cm^3 = 1.417 \times 10^7 \text{ or } 14.17\ cpm/pCi/cm^3$$

e. Third Data Point, 3/5/82:

$$e^{-0.6931\left(\frac{35\ days}{5.271}\right)} = 1.003 \times 10^{-2}$$

$1.003 \times 10^{-2} \times 0.226\ \mu Ci/cm^3 = 2.266 \times 10^{-3}\ \mu Ci/cm^3$ on 3/5/82.

This concentration ($2.266 \times 10^{-3}\ \mu Ci/cm^3$) yielded a count rate of 2.56×10^4 cpm in the SA-13, when filled to a pressure of 605 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{2.56 \times 10^4 - 42.9 \text{ cpm}}{2.266 \times 10^{-3} \ \mu\text{Ci/cm}^3} = 1.128 \times 10^7 \text{ cpm}/\mu\text{Ci/cm}^3$$

Corrected to standard pressure:

$$\frac{760}{605} \times 1.128 \times 10^7 \text{ cpm}/\mu\text{Ci/cm}^3 = 1.417 \times 10^7 \text{ or } 14.17 \text{ cpm/pCi/cm}^3$$

f. Fourth Data Point, 3/11/82:

$$e^{-0.6931\left(\frac{41 \text{ days}}{5.271}\right)} = 4.555 \times 10^{-3}$$

$4.555 \times 10^{-3} \times 0.226 \ \mu\text{Ci/cm}^3 = 1.029 \times 10^{-3} \ \mu\text{Ci/cm}^3$ on 3/11/82.

This concentration ($1.029 \times 10^{-3} \ \mu\text{Ci/cm}^3$) yielded a count rate of 1.08×10^4 cpm in the SA-13, when filled to a pressure of 605 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{1.08 \times 10^4 - 42.9 \text{ cpm}}{1.029 \times 10^{-3} \ \mu\text{Ci/cm}^3} = 1.045 \times 10^7 \text{ cpm}/\mu\text{Ci/cm}^3$$

Corrected to standard pressure:

$$\frac{760}{605} \times 1.045 \times 10^7 \text{ cpm}/\mu\text{Ci/cm}^3 = 1.313 \times 10^7 \text{ or } 13.13 \text{ cpm/pCi/cm}^3$$

g. The average sensitivity of the RDA-3A to ^{133}Xe is:

Data Point

1. 14.99 cpm/pCi/cm^3 (3/1/82)
2. 14.17 cpm/pCi/cm^3 (3/2/82)
3. 14.17 cpm/pCi/cm^3 (3/5/82)
4. 13.13 cpm/pCi/cm^3 (3/11/82)

Average = 14.11 cpm/pCi/cm^3 .

4. ^{85}Kr, S.N. 65113

a. Concentration on 1/1/82: $= 1.42 \times 10^{-3}$ µCi/cm³ (STP)

b. Half Life: 10.72 Years

c. First Data Point, 2/24/82:

$$\frac{I}{I_0} = e^{-0.6931\left(\frac{\text{Days}}{\text{Half Life} \times 365}\right)} = e^{-0.6931\left(\frac{54\ \text{days}}{10.72 \times 365}\right)} = 0.990$$

$0.990 \times 1.42 \times 10^{-3}\ \mu Ci/cm^3 = 1.406 \times 10^{-3}\ \mu Ci/cm^3$ on 2/24/82.

This concentration ($1.406 \times 10^{-3}\ \mu Ci/cm^3$) yielded a count rate of 2.25×10^4 cpm in the SA-13, when filled to a pressure of 610 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{2.25 \times 10^4 - 42.9\ \text{cpm}}{1.406 \times 10^{-3}\ \mu Ci/cm^3} = 1.597 \times 10^7\ \text{cpm}/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760}{610} \times 1.597 \times 10^7\ \text{cpm}/\mu Ci/cm^3 = 1.989 \times 10^7 \text{ or } 19.89\ \text{cpm}/pCi/cm^3$$

d. Second Data Point, 3/8/82:

$$e^{-0.6931\left(\frac{66\ \text{days}}{365 \times 10.72}\right)} = 0.988$$

$0.988 \times 1.42 \times 10^{-3}\ \mu Ci/cm^3 = 1.404 \times 10^{-3}\ \mu Ci/cm^3$ on 3/8/82.

This concentration ($1.404 \times 10^{-3}\ \mu Ci/cm^3$) yielded a count rate of 2.33×10^4 cpm in the SA-13, when filled to a pressure of 605 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{2.33 \times 10^4 - 42.9\ \text{cpm}}{1.404 \times 10^{-3}\ \mu Ci/cm^3} = 1.657 \times 10^7\ \text{cpm}/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760}{605} \times 1.658 \times 10^7 \text{ cpm/}\mu\text{Ci/cm}^3 = 2.082 \times 10^7 \text{ or } 20.82 \text{ cpm/pCi/cm}^3$$

e. Third Data Point, 3/11/82:

$$e^{-0.6931\left(\frac{69 \text{ days}}{365 \times 10.72}\right)} = 0.988$$

$0.988 \times 1.42 \times 10^{-3}$ μCi/cm^3 = 1.404×10^{-3} μCi/cm^3 on 3/11/82.

This concentration (1.403×10^{-3} μCi/cm^3) yielded a count rate of 2.35×10^4 cpm in the SA-13, when filled to a pressure of 605 mm. Therefore, the sensitivity of the RDA-3A is:

$$\frac{2.35 \times 10^4 - 42.9 \text{ cpm}}{1.404 \times 10^{-3} \ \mu\text{Ci/cm}^3} = 1.671 \times 10^7 \text{ cpm/}\mu\text{Ci/cm}^3$$

Corrected to standard pressure:

$$\frac{760}{605} \times 1.671 \times 10^7 \text{ cpm/}\mu\text{Ci/cm}^3 = 2.099 \times 10^7 \text{ or } 20.99 \text{ cpm/pCi/cm}^3$$

f. The average sensitivity of the RDA-3A to ^{85}Kr is:

Data Point

1. 19.89 cpm/pCi/cm^3 (2/24/82)
2. 20.82 cpm/pCi/cm^3 (3/8/82)
3. 20.99 cpm/pCi/cm^3 (3/11/82)

Average = 20.56 cpm/pCi/cm^3

5. Linearity Check with ^{137}Cs Stick Source

Field Strength	Count Rate	cpm/mR/h
5.00 mR/h	1.66×10^4 cpm	3.32×10^3
10.00 mR/h	3.36×10^4 cpm	3.36×10^3
25.00 mR/h	8.73×10^4 cpm	3.49×10^3
50.00 mR/h	1.75×10^5 cpm	3.50×10^3
100.00 mR/h	3.49×10^5 cpm	3.49×10^3

SA-13 LOW RANGE NOBLE GAS BETA DETECTOR
PRIMARY CALIBRATION WITH NOBLE GAS

NOTE: Because of the binary counting circuitry in the IB-2, actual detector counts are twice the displayed count rate. Therefore this data shows the detector and counting circuitry to be linear to at least 6.98 x 10^5 cpm.

F. CONCLUSION

1. The response of the RDA-3X low range beta detector was found to be:

$^{133}Xe = 14.11$ cpm/pCi/cm^3 (STP)

$^{85}Kr = 20.56$ cpm/pCi/cm^3 (STP)

2. The average background of the RDA-3A was found to be 42.9 cpm in the SA-13 (with 4π shielding).

NOTE: Because of the binary counting circuitry used to collect the above data, all of the detector counts are divided by two. Therefore, actual detector sensitivity is twice that shown above. So:

$^{133}Xe = 28.22$ cpm/pCi/cm^3 (STP)

$^{85}Kr = 41.12$ cpm/pCi/cm^3 (STP)

Background = 85.8 cpm.

APPENDIX A

For applications where there is no mid-range detector (NGD-1) installed in the SA-13 gas volume, there is an increase in beta detector sensitivity due to the increased volume viewed by the beta detector.

Experimental data shows this to be an increase of approximately 13 percent.

DATA SHEET
AND CERTIFICATE OF
RADIOACTIVITY CALIBRATION
FOR GASEOUS STANDARD

Customer: Eberline P.O.# VLSOS W.O.# 9315 Date: 26 Jan 1982

Catalog # Special Container Lecture Bottle: DOT 3E 1800

Isotope: Xe-133 Half Life: 5.271 days

S/N: 65114

Contained Activity: 79.9 mCi Calibration Date: 1200 PST 29 Jan 1982

Concentration (uCi/cc): 0.226 μCi/cc STP

Wt. of Gas: 442.0g

Carrier Gas: Dry N_2

Gauge Reading at Time of Shipment: 2200 PSIG

(x) NBS Traceable (~~directly~~/indirectly) to SRM # 1800-1

Total Error at the 99 % confidence level is 7.5%

Edward C. Benson Jr.
Signature

Chemist
Title

ISOTOPE PRODUCTS LABORATORIES

1800 North Keystone Street, Burbank, California 91504

213-843-7000

DATA SHEET
AND CERTIFICATE OF
RADIOACTIVITY CALIBRATION
FOR GASEOUS STANDARD

Customer: Eberline P.O.# VL505 W.O.# 9315 Date: 26 Jan 1982

Catalog # Special Container Lecture Bottle: DOT 3E 1800

Isotope: Kr-85 Half Life: 10.72 years

S/N: 65113

Contained Activity: 538 µCi Calibration Date: 1 Jan 1982

Concentration (uCi/cc): 1.42×10^{-3} µCi/cc STP

Wt. of Gas: 474.0 g

Carrier Gas: Dry N_2

Gauge Reading at Time of Shipment: 2200 PSIG

(✓) NBS Traceable (~~directly~~/indirectly) to SRM # 4308B-24

Total Error at the 99 % confidence level is 8.2%

Edward C. Bern[illegible]
Signature

Chemist
Title

ISOTOPE PRODUCTS LABORATORIES

1800 North Keystone Street, Burbank, California 91504

213-843-7000

REPORT OF CALIBRATION

Electroplated Beta Source S#S-2752

Description of Source:

Principal radionuclide Technetium 99

Electroplated on polished Stainless Steel disc, approximately 0.79 mm thick.
(type of metal)

Diameter, 4.45 cm active, 4.77 cm total.

Radioactive material permanently fixed to the disc by heat treatment, without any covering over the active surface.

Calibration Date: August 25, 1981

Measurement Method:

The 2π beta emission rate was measured using an internal gas flow proportional chamber. Traceability to NBS has been demonstrated, the most recent intercomparison with NBS being June and July 1974 when the EIC–NBS agreement was within 0.3%.

Measurement Result:

The total number of beta particles emitted from the surface of the disc per minute on the above date was

35,044 ± 1,051

The total disintegration rate, assuming 25 % backscatter of beta particles from the surface of the disc, was

56,070 ± 1,682 (0.0253 uCi)

The uncertainty of the measurement is 3%, which is the sum of random counting error at the 99% confidence level and the estimated upper limit of conceivable systematic error in this measurement.

Information on isotopic composition or radioactive impurities:

Calibrated by: Jimmie Arellano
(please print or type)

(signature)

eberline
Eberline Instrument Corporation
P.O. Box 3874
Albuquerque, New Mexico 87110

These Documents are referred to, but not included in this Document:

1. 12000-A20, Calculation of the Gamma Bequrel MeV/µCi Constant for ^{133}Xe
2. 12000-A22, Shield Scan Data, NGD-1 in an SA-13

NO.	QUAN.	PER.	DESCRIPTION

CHG.	APP.	DATE	DESCRIPTION	DATE	BY	CH'K
B-1	[illegible]	1/20/84	ADDED "A" TO ALL REFERENCES. MINOR CORR. TO CALCULATIONS, SHEET 5	1/19/84	BC	[illegible]
B	ELB	4/30/82 -1842-	Revised, 133 Xe sections, new Cal. Gas Standard, new data, New Sensitivity to 133 Xe	4/21/82	LD	[illegible]
A	[illegible]	2/19/82	COMPLETELY REVISED DATA SECTION, NEW SENS., NEW CALIBRATION CONSTANTS, NEW GAS STANDARD CALIBRATION	2/19/82	[illegible]	[illegible]

Q.A. APP. REV B 4/30/82 [illegible]

EBERLINE INSTRUMENT CORPORATION
SANTA FE, NEW MEXICO

DR.	ds	4-24-80
CH'K.	[illegible]	6/10/80
PROJ. ENG.	[illegible]	6/10/80
APP.	[illegible]	6/10/80

PRIMARY CALIBRATION
SA-12, SA-13 MID RANGE GAS (NGD-1) DETECTOR, DONE 4/16/80

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

ALSO USED ON	EFF. WITH	FRAC.	DEC.	ANG.
		± 1/64	X.XX ± .015 X.XXX ± .005	± 1/2°

SCALE

12000-A03 B

Sheet 1 of 7

SA-13
PRIMARY CALIBRATION - MID RANGE GAS

A. PURPOSE

1. To determine the sensitivity of the NGD-1 Noble Gas Detector to ^{133}Xe and ^{85}Kr gas in the SA-13 Sampler Assembly.

2. To determine detector background in the SA-13 Sampler Assembly.

B. MATERIALS AND EQUIPMENT USED

1. SA-13, SN 224
2. NGD-1, SN 163
3. IB-4A, SN 962
4. Absolute Pressure Gage, SN FA160-LL09217

NOTE: The Sampler was mounted in a PING-3. Data was taken using the PING-3 Microcomputer. Calibration constant was 1.00E00.

C. SOURCES USED

1. ^{137}Cs Stick Source No. EI-120
2. ^{85}Kr Gaseous Calibration Standard SN 65112 (Certificate Enclosed)
3. ^{133}Xe Gaseous Calibration Standard SN 84042 (Certificate Enclosed)

NOTE: All sources used are indirectly traceable to NBS.

D. PROCEDURE

1. The NGD-1 was removed from the SA-13 and exposed to a 10 mR/h ^{137}Cs field to determine a calibration reference point. See the data section for results.

2. The sampler was filled via the PING-3 air inlet fitting. The absolute pressure gauge was placed between the regulator output isolation valve and the inlet fitting using a "T" fitting and plastic tubing. An isolation valve was placed between the SA-13 exhaust and the air pump. The air pump exhaust was vented to the roof via plastic tubing.

   The sampler was filled by evacuating the system using the air pump with the regulator isolation valve closed. The system was then filled from the gas bottle by opening the regulator isolation valve. The display was monitored, and when no increase in count rate was observed after each fill, the sampler was assumed full of noble gas and the exhaust isolation valve was closed. The system was left filled for approximately one hour while data was collected in the microcomputer history files.

E. DATA (All count rates are display values which are one-half detector count rate.)

1. Reference to ^{137}Cs

   a. Background = 3 cpm (open air)

   b. 10 mR/h ^{137}Cs = 455 cpm

   c. Sensitivity = 455 cpm
      -3
      452 cpm

   452 cpm divided by 10 mR/h = 45.2 cpm/mR/h.

2. Average Background of the NGD-1 in the SA-13 is 0.5 cpm.

3. ^{133}Xe, SN 84042

   a. Concentration at 1200 CST, 2 April, 1982 = 0.228 μCi/cm^3 (STP)

   b. Half life 5.271 days

   c. First data point, 04/06/82

$$\frac{I}{I_0} = e^{-0.6931\left(\frac{\text{Days}}{\text{Half Life}}\right)} = e^{-0.6931\left(\frac{4\text{ Days}}{5.271}\right)} = 0.5909$$

0.5909 x 0.228 μCi/cm^3 = 0.1347 μCi/cm^3 on 4/6/82

This concentration (0.1347 μCi/cm^3) yielded a count rate of 36.99 cpm in the SA-13, when filled to a pressure of 605 mm Hg.

Therefore, the sensitivity of the NGD-1 is:

$$\frac{36.99 - 0.5\text{ cpm}}{0.1347\ \mu\text{Ci/cm}^3} = 270.90\ \text{cpm}/\mu\text{Ci/cm}^3$$

Corrected to standard pressure:

$$\frac{760\text{ mm}}{605\text{ mm}} \times 270.90\ \text{cpm}/\mu\text{Ci/cm}^3 = 340.30\ \text{cpm}/\mu\text{Ci/cm}^3$$

The sensitivity in γ·Bq-MeV/cm^3:

$$\frac{340.30\ \text{cpm}/\mu\text{Ci/cm}^3}{1.67 \times 10^3\ \gamma\cdot\text{Bq-MeV}/\mu\text{Ci}(^{133}\text{Xe})} = 0.204\ \text{cpm}/\gamma\cdot\text{Bq-MeV/cm}^3$$

NOTE: See Document No. 12000-A20 for the determination of the γ·Bq-MeV/μCi constant for ^{133}Xe.

d. Second Data Point 04/13/82

$$\frac{I}{I_0} = e^{-0.6931\left(\frac{11\text{ Days}}{5.271}\right)} = 0.2354$$

0.2354 x 0.228 $\mu Ci/cm^3$ = 0.0537 $\mu Ci/cm^3$ on 4/13/82

This concentration (0.0537 $\mu Ci/cm^3$) yielded a count rate of 15.24 cpm in the SA-13, when filled to a pressure of 606 mm.

Therefore, the sensitivity of the NGD-1 is:

$$\frac{15.24 - 0.5\text{ cpm}}{0.0537\ \mu Ci/cm^3} = 274.49\text{ cpm}/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760\text{ mm}}{606\text{ mm}} \times 274.49\text{ cpm}/\mu Ci/cm^3 = 344.24\text{ cpm}/\mu Ci/cm^3$$

The sensitivity in $\gamma \cdot$Bq-MeV/cm^3:

$$\frac{344.24\text{ cpm}/\mu Ci/cm^3}{1.67 \times 10^3\ \gamma \cdot \text{Bq-MeV}/\mu Ci(^{133}Xe)} = 0.206\text{ cpm}/\gamma \cdot \text{Bq-MeV}/cm^3$$

NOTE: See Document No. 12000-A20 for the determination of the $\gamma \cdot$Bq-MeV/μCi constant for ^{133}Xe.

e. The average sensitivity of the NGD-1 to ^{133}Xe is:

$$\frac{0.204 + 0.206}{2} = 0.205\text{ cpm}/\gamma \cdot \text{Bq-MeV}/cm^3$$

4. ^{85}Kr, SN. 65112

a. Concentration on January 1, 1982 = 1.48 $\mu Ci/cm^3$ (STP)

b. Half Life 10.72 years.

c. The first and second data points for ^{85}Kr were taken the same day, 2/12/82.

$$\frac{I}{I_0} = e^{-0.6931\left(\frac{43\text{ Days}}{365 \times 10.72}\right)} = 0.992$$

0.992 x 1.48 $\mu Ci/cm^3$ = 1.469 $\mu Ci/cm^3$ on 2/12/82

This concentration (1.469 $\mu Ci/cm^3$) yielded a count rate of:

First Data Point = 27.9 cpm
Second Data Point = 29.2 cpm

The average of these two points is 28.6 cpm. With the SA-13 filled to a pressure of 610 mm.

Therefore, the sensitivity of the NGD-1 to ^{85}Kr is:

$$\frac{28.6 - 0.5 \text{ cpm}}{1.469\ \mu Ci/cm^3} = 19.13\ cpm/\mu Ci/cm^3$$

Corrected to standard pressure:

$$\frac{760 \text{ mm}}{610 \text{ mm}} \times 19.13\ cpm/\mu Ci/cm^3 = 23.83\ cpm/\mu Ci/cm^3$$

The sensitivity in $\gamma \cdot Bq\text{-}MeV/cm^3$:

$$\frac{23.83\ cpm/\mu Ci/cm^3}{77.97\ \gamma \cdot Bq\text{-}MeV/\mu Ci(^{85}Kr)} = 0.306\ cpm/\gamma \cdot Bq\text{-}MeV/cm^3$$

NOTE: Constant for $\gamma \cdot Bq\text{-}MeV/\mu Ci$ for ^{85}Kr = Gamma abundance x gamma energy x Bq/μCi.

$$0.0041 \times 0.514 \times 3.7 \times 10^4 = 77.97\ \gamma \cdot Bq\text{-}MeV/\mu Ci$$

F. CONCLUSION

1. The response of the NGD-1 compensated G-M tube Noble Gas Detector was found to be:

$^{133}Xe = 0.205\ cpm/\gamma \cdot Bq\text{-}MeV/cm^3$

$^{85}Kr = 0.306\ cpm/\gamma \cdot Bq\text{-}Mev/cm^3$

NOTE: Because of the binary counting circuitry used to collect the above data, all of the detector counts are divided by two. Therefore, actual detector sensitivity is twice that shown above. So:

$^{133}Xe = 0.410\ cpm/\gamma \cdot Bq\text{-}MeV/cm^3$

$^{85}Kr = 0.614\ cpm/\gamma \cdot Bq\text{-}MeV/cm^3$

G. For background data, see 12000-A22; Shield Scan Data/NGD-1 in an SA-13.

DATA SHEET AND CERTIFICATE OF RADIOACTIVITY CALIBRATION FOR GASEOUS STANDARD

Customer: Eberline P.O.# VL796 W.O.# 9525 Date: 1 April 1982

Catalog # GS-133 Container Lecture Bottle: DOT 3E 1800

Isotope: Xe-133 Half Life: 5.271 days

S/N: 84042

Contained Activity: 74.5 mCi Calibration Date: 1200 CST 2 April 1982

Concentration (uCi/cc): 0.228 μCi/cc STP

Wt. of Gas: 408.5 g

Carrier Gas: Dry N_2

Gauge Reading at Time of Shipment: 2000 PSIG

(X) NBS Traceable (~~directly~~/indirectly) to SRM # 1800-1

Total Error at the 99 % confidence level is 7.8%

Edward C. B[illegible]
Signature

Chemist
Title

ISOTOPE PRODUCTS LABORATORIES

1800 North Keystone Street, Burbank, California 91504

213-843-7000

DATA SHEET
AND CERTIFICATE OF
RADIOACTIVITY CALIBRATION
FOR GASEOUS STANDARD

Customer: Eberline P.O.# VL505 W.O.# 9315 Date: 26 Jan 1982

Catalog # Special Container Lecture Bottle: DOT 3E 1800

Isotope: Kr-85 Half Life: 10.72 years

S/N: 65112

Contained Activity: 502.6 mCi Calibration Date: 1 Jan 1982

Concentration (uCi/cc): 1.48 μCi/cc STP

Wt. of Gas: 424.5g

Carrier Gas: Dry N_2

Gauge Reading at Time of Shipment: 2200 PSIG

(✓) NBS Traceable (~~directly~~/indirectly) to SRM # 4308B-24

Total Error at the 99 % confidence level is 6.79%

Signature

Chemist

Title

ISOTOPE PRODUCTS LABORATORIES

1800 North Keystone Street, Burbank, California 91504

213-843-7000

NO.	QUAN.	PER.	DESCRIPTION

CHG.	APP.	DATE	DESCRIPTION	DATE	BY	CH'K
C-2	[illegible]	3/28/85	Added SA-15 reference to pg 8, added display and [illegible] controls designation	3/28/85	[illegible]	[illegible]
C-1	[illegible]	11/30/84	Misc. corrections [illegible]	11/30/84	[illegible]	[illegible]
C	[illegible]	7-14-83 3685	REVISED + REFORMATTED 3685	7/14/83	[illegible]	[illegible]
B	[illegible]	7/12/82	CORRECTED THE CONVERSION, REVISED SHTS [illegible] TO REFLECT THE NEW [illegible] 2403	7/12/82	[illegible]	[illegible]
A	[illegible]	7/28/82	REVISED [illegible]	7/28/82	[illegible]	[illegible]

REV. C 7/15/83

EBERLINE INSTRUMENT CORPORATION

SANTA FE, NEW MEXICO

DR.	ds	5-9-80
CH'K.	[illegible]	6/9/80
PROJ. ENG.	[illegible]	6/9/80
APP.	[illegible]	[illegible]

PRIMARY CALIBRATION SA-15 &

SA-9 HIGH RANGE GAS DETECTOR

DONE 4-15-80

ALSO USED ON	EFF. WITH

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FRAC.	DEC.	ANG.
± 1/64	X.XX ± .015 X.XXX ± .005	± 1/2°

SCALE

12000-A01 C

Sheet 1 of 22 with 3 appendixes

A. PURPOSE

1. To determine the sensitivity of the SA-9 G.M. Tube Detector to ^{133}Xe and ^{85}Kr Gas.

2. To determine the proper G.M. tube geometry for a desired sensitivity.

3. To determine detector background in the sampler assembly.

B. MATERIALS AND EQUIPMENT USED:

1. Prototype SA-9

2. IB-4A P.C. Board connected to the scaler of an MS-2

   a. The IB-4A furnished detector high voltage (500 Vdc) and amplifier. The signal to drive the scaler was taken from the IB-4A Line Driver Output.

3. 2 Two inch spacers and 10 1/2 inch spacers, which were used to change the distance between the G.M. tube and the source.

4. RO-2 Ion Chamber

5. Multichannel Analyzer

C. SOURCES USED

1. ^{137}Cs stick source No. EI-120, ^{60}Co stick source EI-150.

2. EIC gas cylinders per 11058-B04

   a. One cylinder was filled with ^{85}Kr gas, 44.2 mCi at a concentration of 1 mCi/cc. 26 March 1980.

   b. One cylinder was filled with ^{133}Xe gas, 43.9 mCi at a concentration of 1 mCi/cc. Noon PST. 27 March 1980.

   Both cylinders bought on Eberline P.O. No. 827H-270043 (^{133}Xe, Serial No. 41112-1, ^{85}Kr, Serial No. 41111-1)

D. PROCEDURE

1. Data was collected with the following guidelines:

   a. All counting times were 10 minutes, unless otherwise noted.

   b. All raw data is in $\frac{cpm}{2}$ (display) unless otherwise noted.

   c. All distances are from Detector center line to source center line and have units of inches.

The procedure was to gather data for the following:

1. Shield Scan of the SA-9 using an external ^{60}Co source to determine relative effects of background radiation.

2. Response of the detector at various distances to both ^{133}Xe and ^{85}Kr. Used to predict spacing required for desired range of the monitor.

E. DATA (Display Count Rate)

1. Shield Scan - 5 mR/h field

Direction	CPM	CPM/mR/hr
0°	8	1.6
30°	3	.6
60°	3	.6
90°	8	1.6
120°	4	.8
150°	7	1.4
180°	13	2.6
210°	4	.8
240°	3	.6
270°	10	2.0
300°	3	.6
330°	3	.6

a. Source = ^{60}Co no. EI-150

b. Size = 1.19 mCi on 4/80

c. Distance = 23.56"

d. Field = 5 mR/h

See Figure 2 for plot of data.

2. Distance Data

10 minutes counting time, Data x 2 to make detector CPM.

Distance measured between G.M. tube center line and cylinder center line.

Background, Det. Tube in SA-9 = 1.8 CPM (20 min. count)

Date	Distance	^{85}Kr CPM	^{133}Xe CPM
4-9-80	4.0"	629.8	442.0
4-9-80	3.5"	818.0	556.0
4-9-80	3.0"	1,083.8	776.8
4-9-80	2.5"	1,550.6	1,065.6
4-10-80	2.0"	2,254.8	1,336.7
4-10-80	1.5"	3,617.0	2,120.0

F. CALCULATIONS

1. Computation of γBq-MeV/cc values for each source for the three days the source was used. Refer to the Calibration Data sheet for each Gaseous Standard.

a. ^{133}Xe - Serial No. 41112-1

1) Contained activity = 43.9 mCi
2) Cal. Date = Noon PST 3/27/80
3) Corrected concentration

$$\frac{I}{Io} = e^{-.6931\ t/\gamma}$$

where:

t = number of days
γ = half life = 5.27 days
I = Concentration after t days
Io = initial concentration.1 mCi/cc ($10^3\mu$Ci/cc)

Calculating the concentrations

4-8-80 (12 days) = $2.06 \times 10^{-1} \times 10^{3}$ μCi/cc = 2.06×10^{2} μCi/cc

4-8-80 (13 days) = $1.81 \times 10^{-1} \times 10^{3}$ μCi/cc = 1.81×10^{2} μCi/cc

4-10-80 (14 days) = $1.59 \times 10^{-1} \times 10^{3}$ μCi/cc = 1.59×10^{2} μCi/cc

4) Calculation of the γBq-MeV/μCi value for ^{133}Xe.

NOTE: Refer to EIC Document No. 12000-A20 for calculation to obtain these values.

Value is 1.67×10^{3} γBq-MeV/μCi.

5) Converting the concentration to units of γBq-MeV/cc

1.67×10^{3} x concentration = γBq-MeV/cc value.

4-8-80 = 3.44×10^{5} γBq-MeV/cc

4-9-80 = 3.02×10^{5} γBq-MeV/cc

4-10-80 = 2.66×10^{5} γBq-MeV/cc

b. ^{85}Kr - Serial No. 41111-2

1) Contained Activity - 44.2 mCi
2) Cal. Date - 3/26/80
3) Corrected concentration

$$\frac{I}{Io} = e^{-.6931\ t/\gamma}$$

where:

t = number of days
γ = half life = 3972.8 days (10.72 years)
I = corrected concentration
Io = initial concentration 1 mCi/cc (10^{3}μCi/cc)

Calculating the concentrations

4-8-80 (12 days) = $9.979 \times 10^{-1} \times 10^{3}$ μCi/cc = 9.979×10^{2} μCi/cc

4-9-80 (13 days) = $9.977 \times 10^{-1} \times 10^{3}$ μCi/cc = 9.977×10^{2} μCi/cc

4-10-80 (14 days) = $9.975 \times 10^{-1} \times 10^{3}$ μCi/cc = 9.975×10^{2} μCi/cc

4) Calculation of the γBq-MeV/μCi value for ^{85}Kr.

γEnergy (MeV) x percent abundance x 3.7×10^4 = γBq-MeV/μCi

γEnergy ^{85}Kr = .514 MeV

Abundance = .0041

$.514 \times .0041 \times 3.7 \times 10^4 = 77.97$ γBq-MeV/μCi

5) Converting the concentration to units of γBq-MeV/cc

77.97 x concentration = γBq-MeV/cc value

4-8-80 = 7.781×10^4 γBq-MeV/cc

4-9-80 = 7.779×10^4 γBq-MeV/cc

4-10-80 = 7.778×10^4 γBq-MeV/cc

2. Calculation of the sensitivity in units of CPM/γBq-MeV/cc for each gas at each distance in E.2. above.

Sensitivity (cpm/γBq-MeV/cc) =

$$\frac{\text{Observed countrate (cpm) - background countrate (cpm)}}{\text{Concentration* } (\gamma\text{Bq-MeV/cc})}$$

*The concentration is the value for the particular gas on the day that the data was collected.

^{85}Kr

DETECTOR COUNT RATE

Date	Distance inches	Observed countrate cpm	Background countrate cpm	Net countrate cpm	Concentration γBq-MeV/cc	Sensitivity cpm/γBq-MeV/cc
4-9-80	4.0	629.8	1.8	628.0	7.779×10^4	8.07×10^{-3}
4-9-80	3.5	818.0	1.8	816.2	7.779×10^4	1.05×10^{-2}
4-9-80	3.0	1083.8	1.8	1082.0	7.779×10^4	1.39×10^{-2}
4-9-80	2.5	1550.6	1.8	1548.8	7.779×10^4	1.99×10^{-2}
4-10-80	2.0	2254.8	1.8	2253.0	7.778×10^4	2.90×10^{-2}
4-10-80	1.5	3617.0	1.8	3615.2	7.778×10^4	4.65×10^{-2}

^{133}Xe

DETECTOR COUNT RATE

Date	Distance inches	Observed countrate cpm	Background countrate cpm	Net countrate cpm	Concentration γBq-MeV/cc	Sensitivity cpm/γBq-MeV/cc
4-9-80	4.0	442.0	1.8	440.2	3.02×10^5	1.46×10^{-3}
4-9-80	3.5	556.0	1.8	554.2	3.02×10^5	1.84×10^{-3}
4-9-80	3.0	776.8	1.8	775.0	3.02×10^5	2.57×10^{-3}
4-9-80	2.5	1065.8	1.8	1064.0	3.02×10^5	3.52×10^{-3}
4-10-80	2.0	1336.7	1.8	1334.9	2.66×10^5	5.02×10^{-3}
4-10-80	1.5	2120.0	1.8	2118.2	2.66×10^5	7.96×10^{-3}

The values for both gases are plotted in Figure 1.

3. Selecting the spacing for the range of the monitor.

The desired response for the SA-9 is to reach a value 10^5 μCi/cc of ^{133}Xe. Converting this to units of γBq-MeV/cc we multiply by the value 1.67×10^3 γBq-MeV/μCi for ^{133}Xe. This yields 1.67×10^8 γBq-MeV/cc. With an upper limit of 1.024×10^6 cpm on the counting system the sensitivity would be:

$$\frac{1.024 \times 10^6 \text{cpm}}{1.67 \times 10^8 \ \gamma\text{Bq-MeV/cc}} = 6.13 \times 10^{-3} \frac{\text{cpm}}{\gamma\text{Bq-MeV/cc}}$$

Thus the spacing of 2.0 inches was selected. This spacing provides a sensitivity of 5.02×10^{-3} cpm/γBq-MeV/cc and at a ^{133}Xe value of 1.67×10^8 γBq-MeV/cc (10^5 μCi/cc) the SA-9 tube would produce:

$$5.02 \times 10^{-3} \text{ cpm}/\gamma\text{Bq-MeV/cc} \times 1.67 \times 10^8 \ \gamma\text{Bq-MeV/cc} = 8.38 \times 10^5 \text{ cpm}$$

Conclusions:

The two gases selected for use in this calibration were ^{133}Xe and ^{85}Kr. Each has a unique problem which causes the SA-9 to respond in other than a nominal manner. The ^{133}Xe has two primary groups of photons, one centered at 0.081 MeV and the other at 0.030 MeV. These are attenuated by the sample tube wall. Refer to Appendix B for calculations of the measured versus unattenuated (nominal) response.

The ^{85}Kr has a very large beta to gamma emission ratio. The betas cause bremsstrahlung in the tube wall and this increases the net result from ^{85}Kr.

For calculations of the bremsstrahlung contributions refer to appendix A and C.

The measured response to each gas, at 2.0 inch spacing is

^{133}Xe 5.02 x 10^{-3} cpm per γBq-MeV/cc

^{85}Kr 2.90 x 10^{-2} cpm per γBq-MeV/cc

Correcting these values for attenuation and bremsstrahlung respectively, the nominal responses are:

$$^{133}Xe \quad \frac{5.02 \times 10^{-3}\ \text{cpm}/\gamma\text{Bq-MeV/cc}}{0.443} = 1.13 \times 10^{-2}\ \text{cpm}/\gamma\text{Bq-MeV/cc}$$

Detector Count Rate

where 0.443 is the amount of attenuation of the ^{133}Xe photons (refer to Appendix B).

$$^{85}Kr \quad \frac{2.90 \times 10^{-2}\ \text{cpm}/\gamma\text{Bq-MeV/cc}}{2.00} = 1.45 \times 10^{-2}\ \text{cpm}/\gamma\text{Bq-MeV/cc}$$

Detector Count Rate

where 2.00 is the over response due to the bremsstrahlung contribution to the Kr^{85} reading (refer to Appendix C).

Background response from Co^{60} varies from 0.5 to 2.6 CPM per mR/hr, depending on direction, with an average response of approximately 1.2 CPM per mR/hr.

The SA-15 has the same 2.0 inch spacing between the GM tube and sample pipe. It has a 5 inch lead shield which when in a 4π test of 10 mR ^{137}Cs field produced no statistical increase in the background results. The data in section E.1 can still be used as a conservative estimate due to the additional 2 inches of shielding above the SA-9's 3 inches.

PRIMARY CALIBRATION SA-9 FIELD STRENGTH/DISTANCE

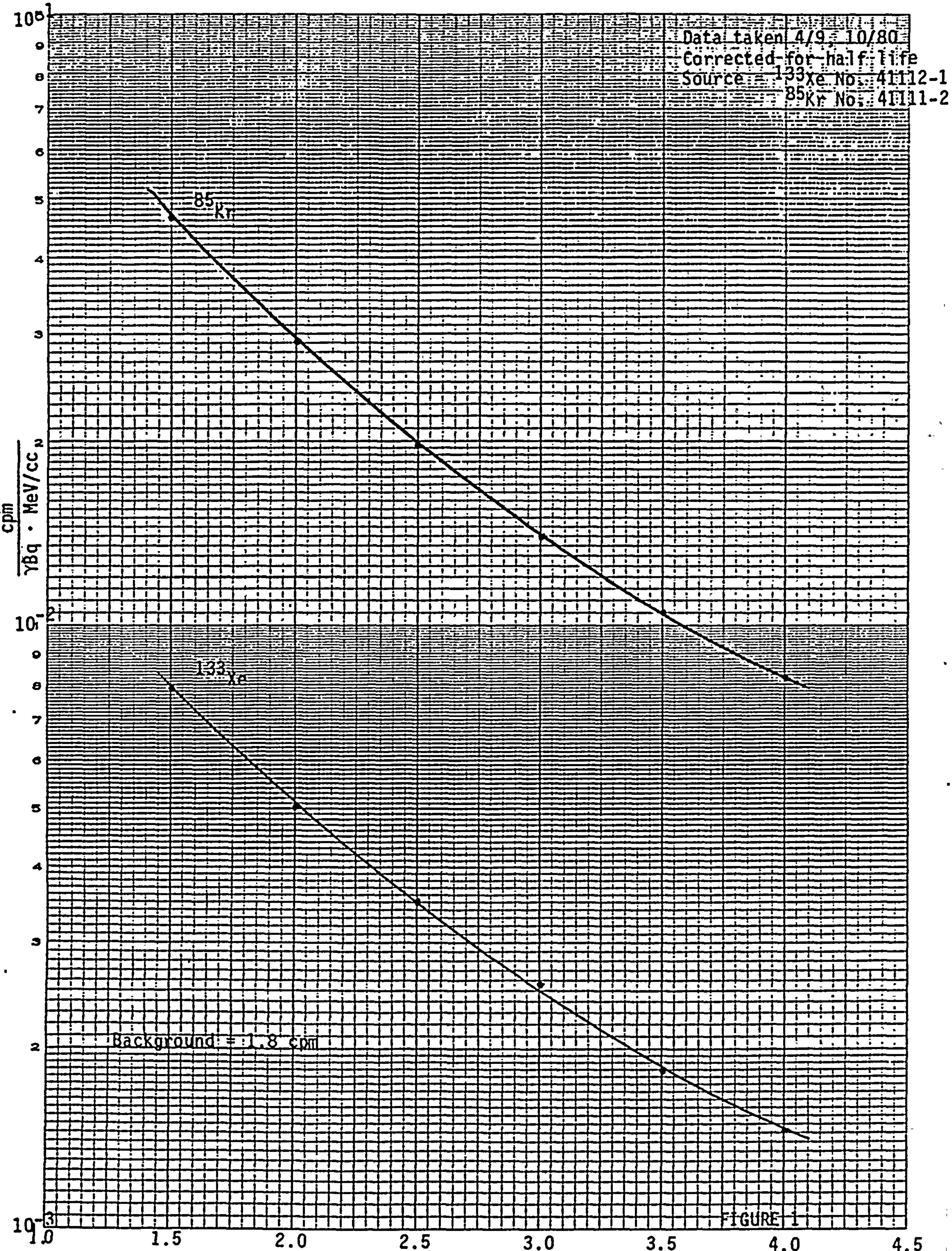
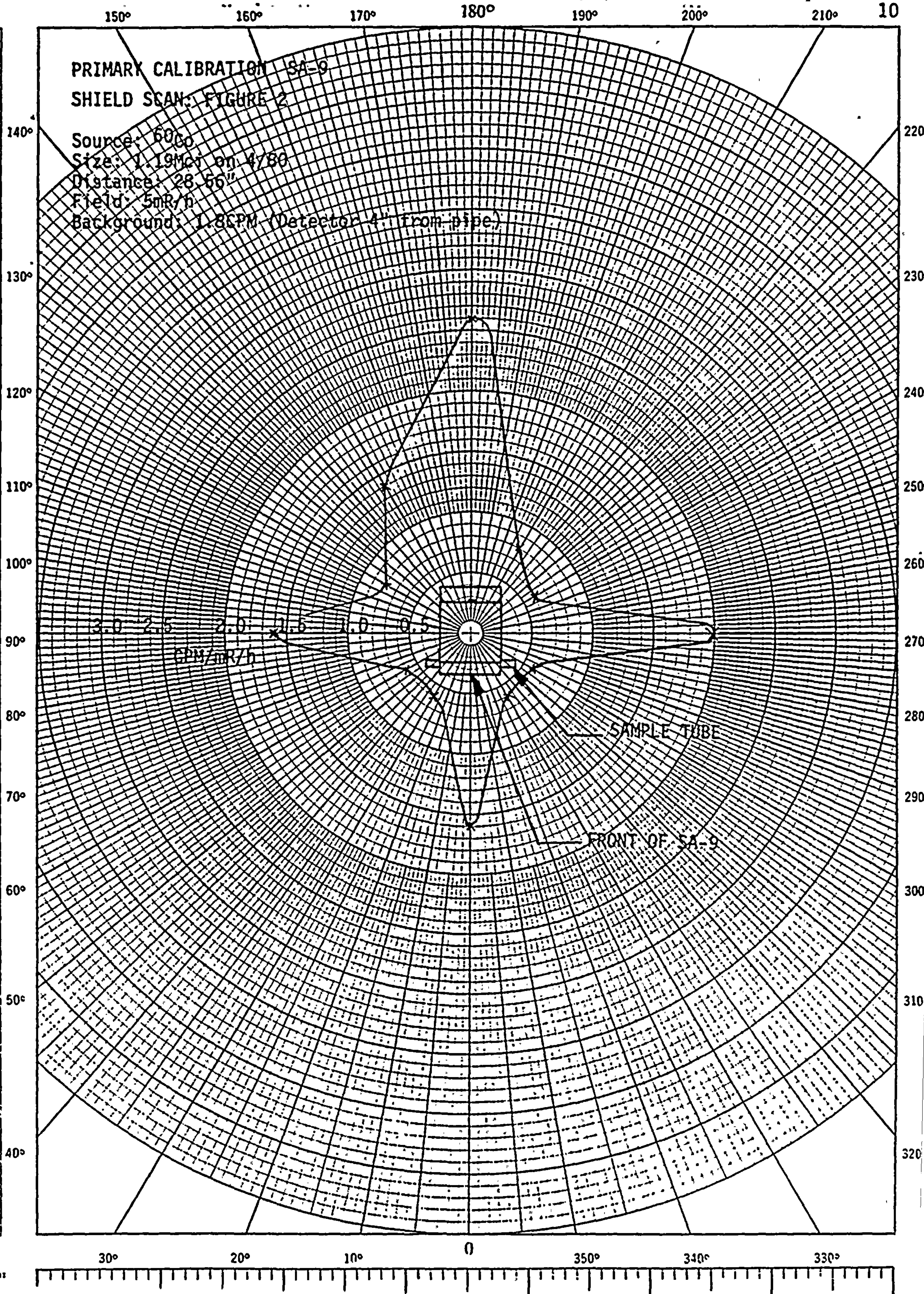


FIGURE 1


PRIMARY CALIBRATION SA-9
SHIELD SCAN: FIGURE 2
Source: ^{60}Co
Size: 1.19Mci on 4/80
Distance: 28.56"
Field: 5mR/h
Background: 1.8CPM (Detector 4" from pipe)
3.0 2.5 2.0 1.5 1.0 0.5
CPM/mR/h
SAMPLE TUBE
FRONT OF SA-9
150° 160° 170° 180° 190° 200° 210°
140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40°
220° 230° 240° 250° 260° 270° 280° 290° 300 310 320
30° 20° 10° 0 350° 340° 330°
Polar

DATA SHEET AND CERTIFICATE OF RADIOACTIVITY CALIBRATION FOR GASEOUS STANDARD

Customer: Eberline P.O.# 830H-27004 W.O.# 7555 Date: 27 March 1980

Catalog # Special Container ~~Lecture Bottle~~: DOT 3E 1800

Isotope: Xe-133 Half Life: 5.27 days

S/N: 41112-1

Contained Activity: 43.9 mCi Calibration Date: Noon PST 27 March 1980

Concentration (uCi/cc): 1 mCi/cc

Wt. of Gas: NA

Carrier Gas: NA

Gauge Reading at Time of Shipment: NA

(X) NBS Traceable (~~directl~~y/indirectly) to SRM # 4307-E-14

Total Error at the 99 % confidence level is ± 10%

Signature

Kenneth Helm
Health Physicist
Title

ISOTOPE PRODUCTS LABORATORIES

1800 North Keystone Street, Burbank, California 91504

213-843-7000

DATA SHEET AND CERTIFICATE OF RADIOACTIVITY CALIBRATION FOR GASEOUS STANDARD

Customer: Eberline P.O.# 827H·27043 W.O.# 7555 Date: 27 March '80

Catalog # Special Container ~~[illegible]~~ DOT 3E 1800

Isotope: Kr 85 Half Life: 10.72 y

S/N: 41111-2

Contained Activity: 44.2 mCi Calibration Date: 26 March 1980

Concentration (uCi/cc): 1 mCi/cc

Wt. of Gas: N/A

Carrier Gas: N/A

Gauge Reading at Time of Shipment: N/A

(X) NBS Traceable (~~directly~~/indirectly) to SRM # 4308B-24

Total Error at the 99 % confidence level is 9.37 %

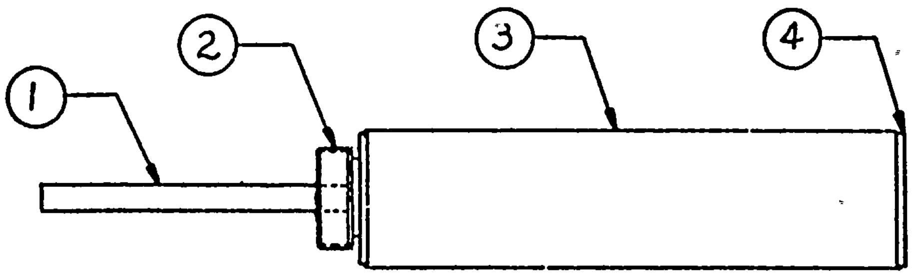
Signature

β_{max} = .67 MeV
γ = .514 MeV, .41%

Kenneth Helm
Health Physicist
Title

ISOTOPE PRODUCTS LABORATORIES
1800 North Keystone Street, Burbank, California 91504
213-843-7000

1	1	ASSY	FILLER TUBE,	11058-A05
2	1	"	PLUG,	11058-A06
3	1	"	SOURCE HOUSING,	11058-A07
4	1	"	END PLUG,	11058-A08
5	AR	"	HARD SILVER SOLDER	



NOTE:
HARD SILVER SOLDER ALL PARTS.

FINISH:
STOCK-UNIFORM TEXTURE

CHG.	APP.	DATE	DESCRIPTION	DATE	BY	CH'K

EBERLINE INSTRUMENT CORPORATION
SANTA FE, NEW MEXICO

DR.	VIARRIAL,V	1/23/80
CH'K.	[illegible]	1/14/80
PROJ. ENG.	[illegible]	3/4/80
APP.	[illegible]	3/4/80

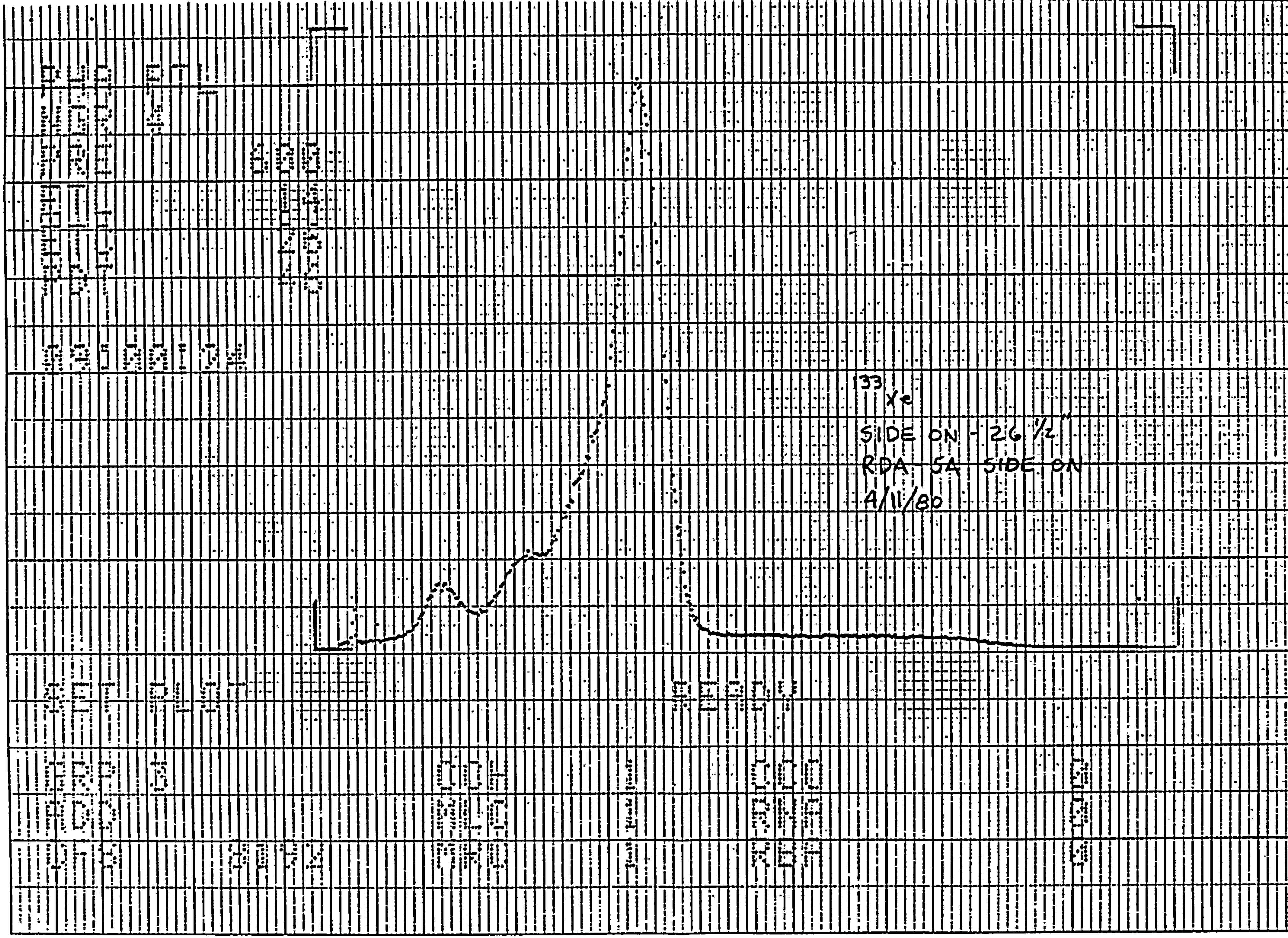
CONTAINER ASS'Y
NOBLE GAS
SOURCE CONTAINER

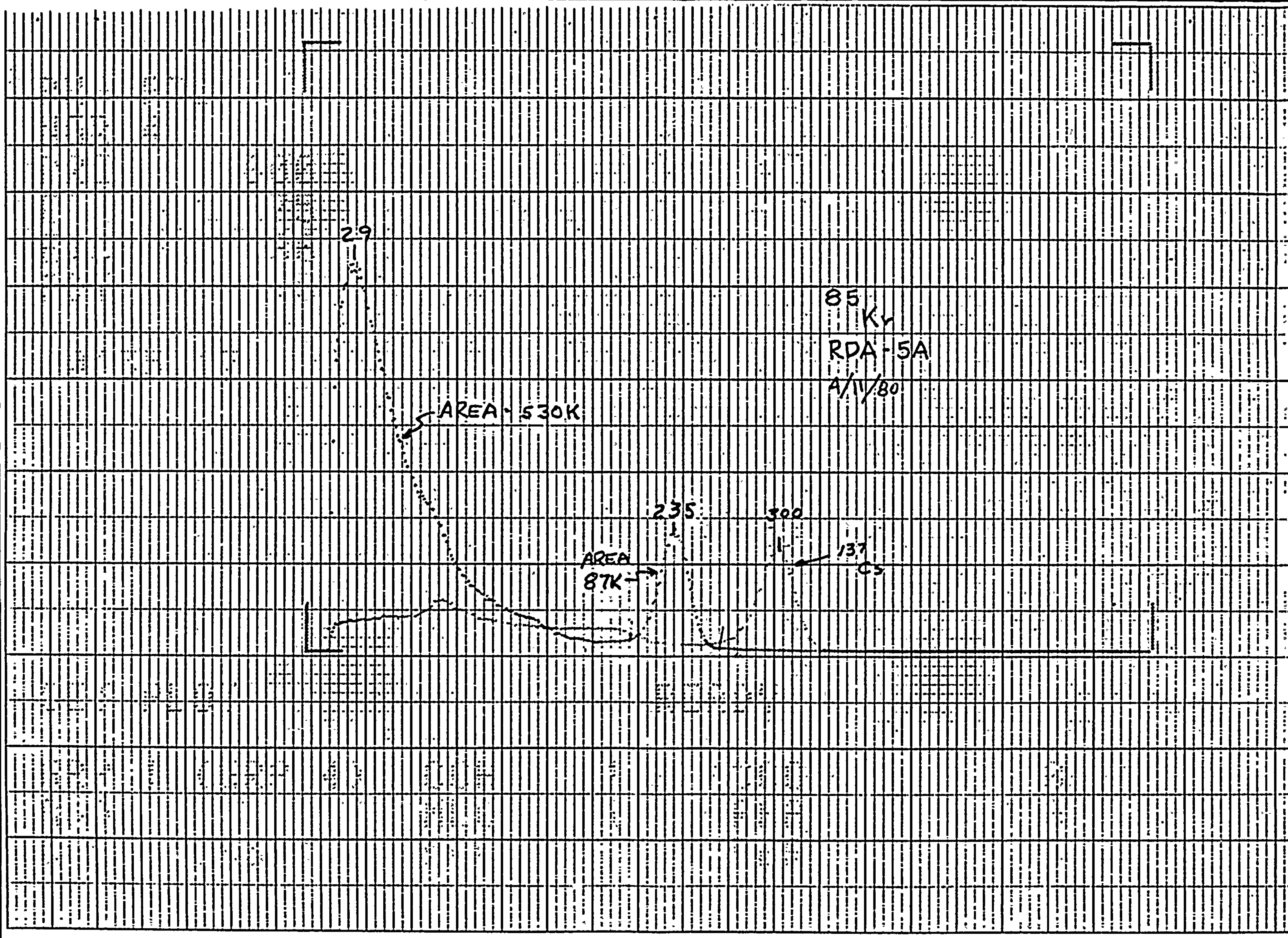
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FRAC.	DEC.	ANG.
± 1/64	.XX ± .015 .XXX ± .005	± 1/2°

SCALE FULL | 11058-B04

ALSO USED ON | EFF. WITH


133 Xe
SIDE ON - 26 ½"
RDA 5A SIDE ON
4/11/80


29
AREA ~ 530K
235
AREA
87K
300
137
Cs
85
Kr
RDA-5A
4/11/80

APPENDIX A

Purpose of Analysis:

To obtain a theoretical basis for the observation of a large, low energy component in the spectrum measured using a detector outside a stainless steel cylinder filled with Kr-85. It was assumed to be due to Bremsstrahlung from the β particles.

The linear energy loss from β particles due to Bremsst. is given by the following equation:

$$\frac{dE}{dX} = \frac{NEZ(Z+1)e^4}{137\, m_0^2 c^4}\left(4 \ln\left[\frac{2E}{m_0 c^2}\right] - \frac{4}{3}\right)$$

(Equation by Bethe - Reference 1, Bethe & Ashkin, "Passage of Rad in Matter", "Exp. Nuclear Physics", 1953, Vol.I, p.166)

where

N = number density of target
Z = atomic number of target
M = electron rest mass
e = electronic charge
c = speed of light
E = β energy

Quantities used (S.S. target)

$Z = 26$ $N = \frac{(7.8\ g/cm^3)(6.023 \times 10^{23})}{55.8\ g/mole} = 8.41 \times 10^{22}\ atom/cm^3$

$e = 4.80 \times 10^{-10}$ esu (esu = $\frac{g^{1/2} cm^{3/2}}{sec}$)

$m_0 = 9.11 \times 10^{-28} g$ $c = 3 \times 10^{10}$ cm/sec

1 erg = $.624 \times 10^6$ MeV erg = g cm^2/sec

E = .6 MeV = 9.62×10^{-7} erg

$$\frac{dE}{dX} = \frac{(8.41 \times 10^{22})(9.62 \times 10^{-7})(26)(27)(4.80 \times 10^{-10} esu)^4}{137\ (9.11 \times 10^{-28})^2\ (3 \times 10^{10})^4}\left(4 \ln\frac{(2)(.6)}{.511} - \frac{4}{3}\right)$$

$\frac{dE}{dX} = 6.81 \times 10^{-8}$ erg/cm $= 4.25 \times 10^{-2}$ MeV/cm

dE = 4.25×10^{-2}(.035 inch x 2.54 cm/inch) = 3.78×10^{-3} MeV

(.035" is wall thickness of S.S. pipe)

Thus the Bremsstrahlung energy emitted per β is 3.78 keV.

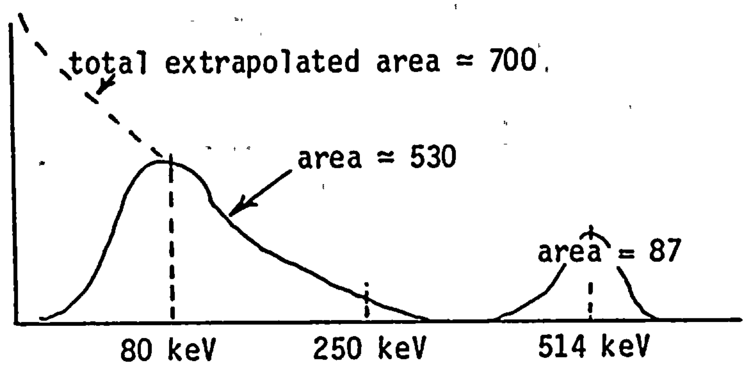
If for each γ there are 250β, the comparison quantity is 3.78 x 250 = 945 keV (cf. .514MeV γ)

Thus for each γ detected, the detector should also detect 865 keV of Bremsstrahlung radiation.

or there should be a ratio of Bremsstrahlung to γ of

$$\frac{\text{Bremsstrahlung}}{\gamma} = \frac{945}{514} = 1.83$$

(this ratio is for total energy, not individual counts)



(this is spectrum obtained from multichannel analyzer)

Bremsstrahlung should be continuously increasing to zero energy, hence, it is extrapolated to zero from cutoff due to detector enclosure to get approximate total area due to Bremsstrahlung.

Energy represented by γ peak = 514 keV x 87 = 4.47×10^4

Energy represented by Bremsstrahlung = $\frac{250 \text{ KeV}}{2} \times 700 = 8.75 \times 10^4$

$$\frac{\text{Bremsstrahlung}}{\gamma} = \frac{8.75}{4.47} = 1.95$$

The 1.83 and 1.95 compare very well considering how approximate the technique used was.

We suspect that the Bremsstrahlung energy is less due to self absorption in the S.S. cylinder which is in line with the above difference.

Errors could be induced by

1) different geometry of γ source and Bremsstrahlung source
2) directional source strength of Bremsstrahlung
3) γ shielding by S.S.

APPENDIX B

Sample Wall Attenuation of ^{133}Xe photons

^{133}Xe correction for the attenuation caused by the sample pipe wall.

The sample pipe wall is 0.035 inch 304 type stainless steel (SS). Which is composed of Carbon (C), Iron (Fe), Chromium (Cr), Nickel (Ni) and Manganese (Mn).

The percentage attenuation for each element is found from the formula

$$\text{Attenuation} = e^{-\mu_n p_n x_n t}$$

where n = represents the five material elements of 304 SS.
μ_n = Mass attenuation coefficient of material at the photon energy of interest, cm^2/g
p_n = density of material, g/cm^3
t = thickness of attenuator, cm
x_n = composition, percentage for each element divided by 100.

The overall attenuation for each energy is the product of the individual attenuations for each element.

The attenuation is then calculated for 0.081 MeV and 0.030 MeV photons.

304 Stainless Steel	Element					
	C	Cr	Fe	Ni	Nm	Reference
Composition x_n*	0.0008	0.190	0.6942	0.095	0.020	1
Density p_n, g/cm^3	2.22	7.10	7.86	8.90	7.20	2
Attenuation coefficient μ_n, cm^2/g 80keV	0.160	0.483	0.594	0.727	0.528	3
Attenuation coefficient μ_n, cm^2/g 30keV	0.250	6.44	8.15	10.3	7.19	3
thickness t	0.035 in x 2.54 cm/in = 0.089 in.					
attenuation 80keV	1.00	.9437	.7494	.9447	.9933	66.36
attenuation 30keV	1.00	.4615	.0191	.4607	.9120	0.37
						Total Attenuation Percentage

*These are the average of the composition limits.

Thus the wall will attenuate the 0.081 MeV to 66.4 percent of the original and the 0.030 MeV to 0.4 percent of the original, a negligible amount.

The 0.081 MeV photons are 66.5 percent of the γBqMeV emissions and the 0.030 MeV photons are 33.5 percent. This is found by summing the product of the gamma abundance (mean number per disintegration) times the energy (mean energy per particle) for all photons from ^{133}Xe.

	Abundance	Energy	γBq-MeV emissions	Percent of Total
.080 MeV complex	0.0061	.0796	0.000486	66.5
	0.3603	.0809	0.02915	
	0.0002	0.3839	0.000077	
.031 MeV complex	0.2552	0.0309	0.007886	33.5
	0.1321	0.0306	0.004042	
	0.0712	0.0349	0.002485	
	0.0150	0.0359	0.000539	
		Total	0.044659	

The composite correction is then

$$\frac{\text{percent attenuation for .080MeV photons}}{100} \times \frac{\text{percent of emissions}}{100} +$$

$$\frac{\text{percent attenuation for .031MeV photons}}{100} \times \frac{\text{percent of emissions}}{100} = \text{correction factor}$$

$$\frac{66.4 \text{ percent}}{100} \times \frac{66.5 \text{ percent}}{100} + \frac{0.4 \text{ percent}}{100} \times \frac{33.5 \text{ precent}}{100} = .443$$

The measured values for ^{133}Xe will be reduced due to this attenuation and thus must be divided by this value to obtain an unattenuated value for ^{133}Xe.

References: 1. Metals Handbook, American Society for Metals page 554, Table 1, Composition Limits of Austenitic Stainless Steels. 2. Periodic Table of the Elements, Central Scientific Company. 3. Photon Cross Sections, Los Alamos Scientific Laboratory, LA-3753

APPENDIX C

Bremsstrahlung from Sample Wall due to ^{85}Kr Beta

Both sources were measured using an Eberline RO-2 air ion chamber instrument with the beta window closed. This was done to predict the additional contribution from the bremsstrahlung to the ^{85}Kr gamma response.

a. ^{133}Xe shield closed = 31 mR/h
b. ^{85}Kr shield closed = 36 mR/h

Data taken 4-9-80. Refer to F.1.a.5) and F.1.b.5) of the Primary Calibration for Concentration Values.

Dividing by Concentration, yields

^{133}Xe Shield Closed $\frac{31}{3.02 \times 10^5} = 1.03 \times 10^{-4} \frac{\text{mR/h}}{\gamma\text{Bq-MeV/cc}}$

Correcting this value due to sample wall attenuation (refer to appendix B).

$$\frac{1.03 \times 10^{-4}}{0.443} = 2.33 \times 10^{-4} \frac{\text{mR/h}}{\gamma\text{Bq-MeV/cc}}$$

^{85}Kr Shield Closed $\frac{36}{7.778 \times 10^4} = 4.63 \times 10^{-4} \frac{\text{mR/h}}{\gamma\text{Bq-MeV/cc}}$

The shield closed data indicates that the ^{85}Kr is emitting about 2.00 times more mR/hr (above 10-20 keV) than it should, relative to the ^{133}Xe.

PRIMARY CALIBRATION SA-9 FIELD STRENGTH/DISTANCE

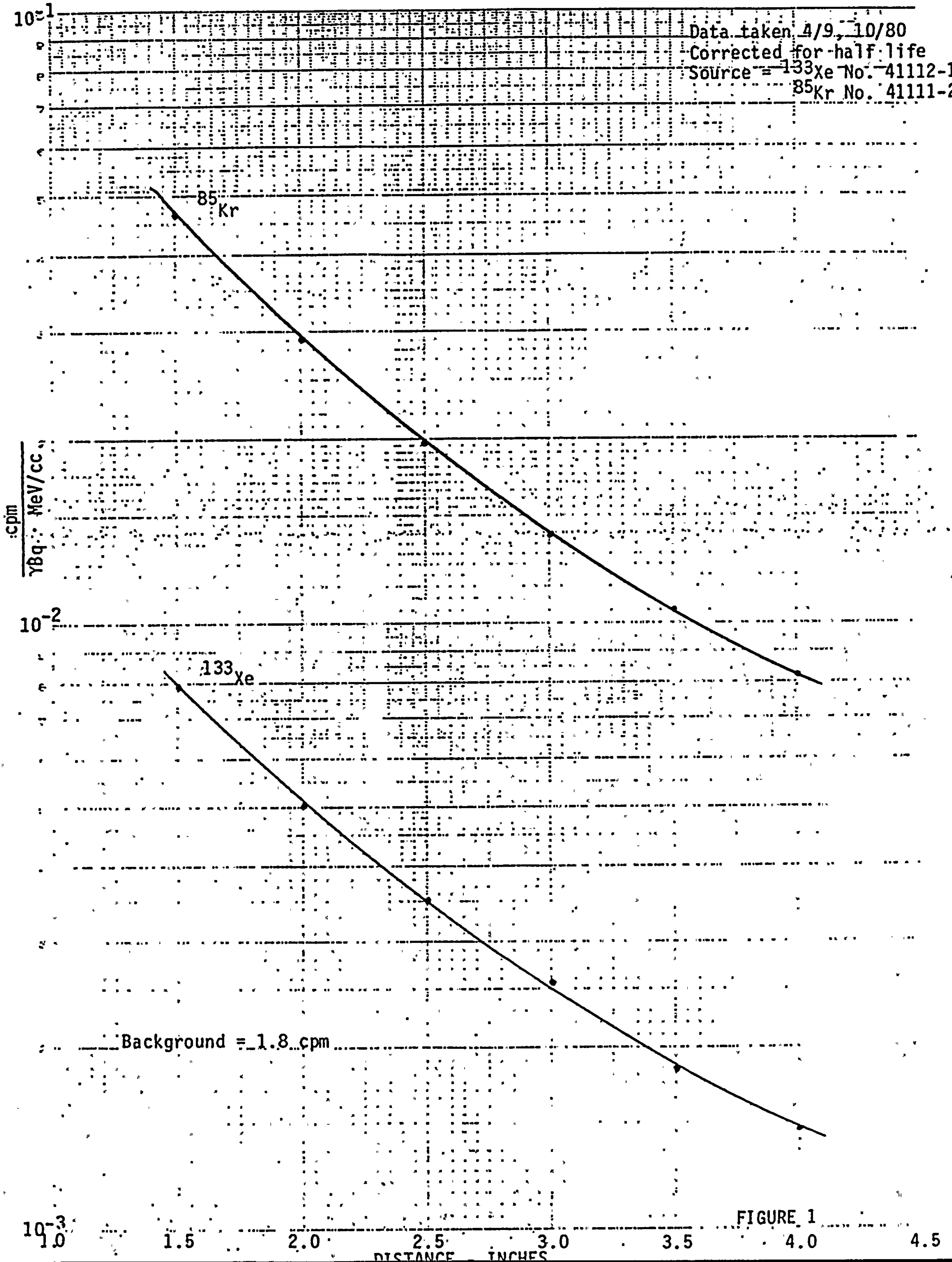
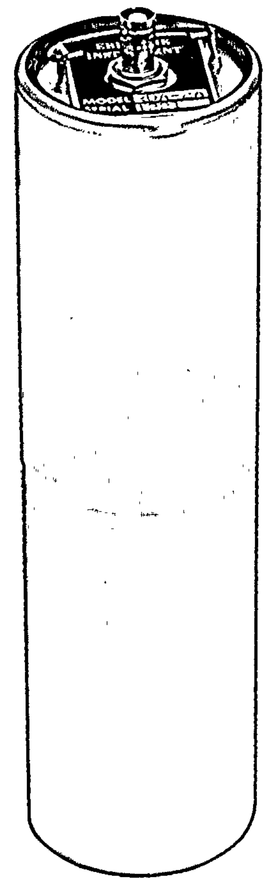


FIGURE 1

Radiation Detector Assembly

Model RDA-XX



- SCINTILLATION DETECTORS
- FOR USE WITH DIGITAL (MICROCOMPUTER) OR ANALOG (RATEMETER AND RECORDER) SYSTEMS
- FOR ALPHA, BETA, AND GAMMA MEASUREMENTS

Eberline

A DIVISION OF Thermo Electron CORPORATION

Model RDA-XX, Radiation Detector Assembly

GENERAL DESCRIPTION

The RDA series of radiation detectors are scintillation-type detectors intended for installation in sampler assemblies for monitoring radiation in installed systems. The -XX in the model number is replaced by a number and a letter defining the type of scintillation crystal and the housing type.

The first X defines the crystal: One for ZnS(Ag) alpha, two for 2-inch x 2-inch NaI(Tl) stabilized gamma, three for plastic beta, four for 2-inch x 2-mm NaI(Tl) stabilized gamma, five for 2-inch x 2-inch NaI(Tl) gamma. Other types are readily available.

The last X defines the housing: A for aluminum, S for stainless steel. Example: RDA-2S is a 2-inch x 2-inch NaI(Tl) stabilized gamma in a stainless-steel housing.

SPECIFICATIONS

Photomultiplier Tube: 2-inch, 10-dynode with S11 photocathode. Selected high resolution type for pulse-height analyzing applications.

High Voltage: Maximum 1800 V, typically in 600 to 1200 V range depending on application.

Current: 120 MΩ resistance requires 10 μA at 1200 V.

Connection: Single MHV coaxial connector supplies high voltage and signal connection.

Magnetic Shield: Included.

Size: 2.625 inches in diameter x 9.25 inches long (6.67 cm x 23.5 cm) excluding connector.

Temperature: 0 °F to 140 °F (-18 °C to 60 °C).

Scintillation Crystal:

Type	Description
1.	2-inch-diameter ZnS(Ag) with 1 mg/cm^2 aluminized Mylar® window.
2.	2-inch x 2-inch NaI(Tl) with ^{241}Am seed imbedded for automatic gain stabilization.
3.	2-inch-diameter x 0.010-inch-thick plastic with 1.6 mg/cm^2 Mylar® window.
4.	2-inch-diameter x 2-mm-thick NaI(Tl) for low energy gamma with ^{241}Am seed imbedded for automatic gain stabilization.
5.	2-inch x 2-inch NaI(Tl).

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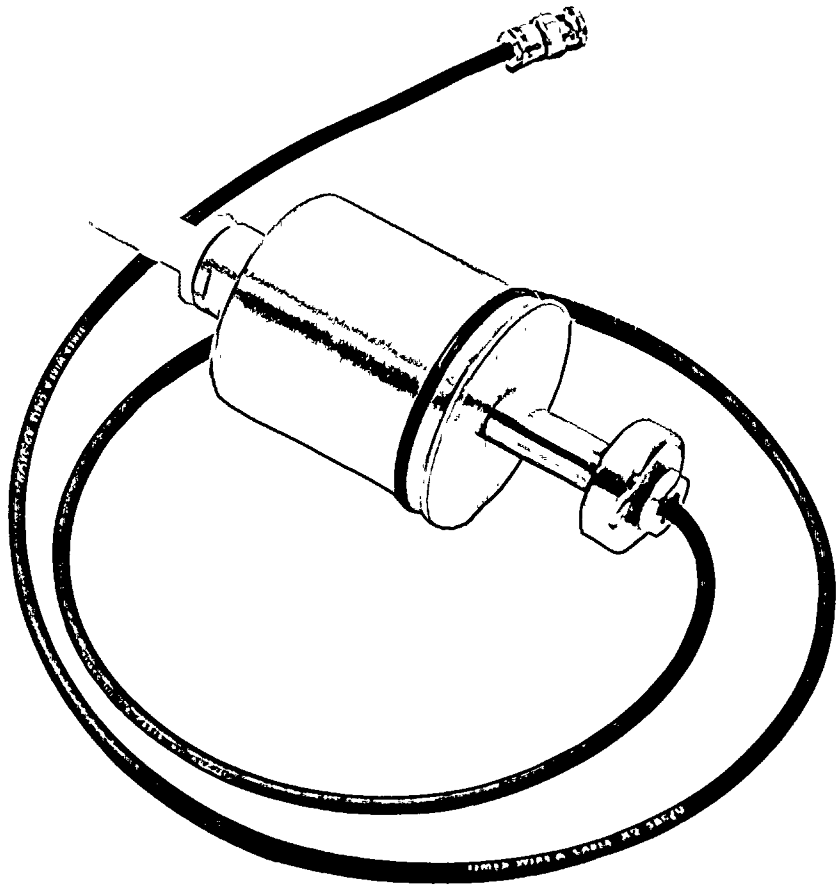
Noble Gas Detector

Model NGD-1



■ FOR USE WITH EBERLINE MODEL SA-X SAMPLER ASSEMBLIES

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CORPORATION

NGD-1

Model NGD-1, Noble Gas Detector

GENERAL DESCRIPTION

The Noble Gas Detector assembly is a gamma detector intended for use in sampler assemblies. The detecting element is an argon-filled, halogen-quenched, Geiger-Mueller (G-M) tube mounted in a holder which forms part of the shield when installed in a sampler. The detector assembly is connected to a microcomputer system or an analog rate meter (EC1-X) via an IB-4A interface box.

SPECIFICATIONS

G-M Tube: Argon-filled, halogen-quenched, energy-compensated.

Operating Voltage: 550 ±50 V

Sensitivity: Approximately 80 cpm per mR/h in a ^{137}Cs field.

Dead Time: Approximately 20 μs.

Plateau: 100 V minimum length with slope approximately 15 percent per 100 V.

Environment: Operating temperature range −40 °F to +167 °F (−40 °C to +75 °C).

Connector: BNC series

Size: 2.75 inch diameter × 8.11 inches long (7.0 cm × 20.6 cm).

Weight: Approximately 6 pounds (2.7 kg).

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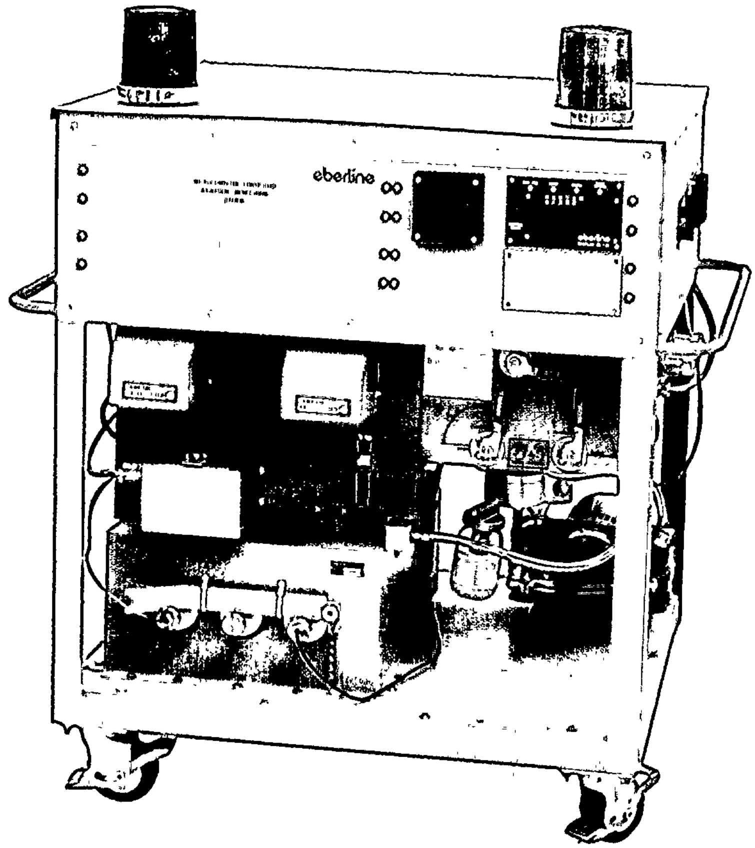
System-Level Particulate, Iodine, and Noble Gas Air Monitor

Model SPING-3A



- MICROCOMPUTER-CONTROLLED MONITOR FOR STACK EFFLUENTS, WORK AREAS, AND DUCTS
- FEATURES INCLUDE: DIGITAL DISPLAYS, BACKGROUND SUBTRACTION, HIGH ACCURACY AND SENSITIVITY, THREE INCHES OF LEAD SHIELDING AROUND DETECTORS (4π CONFIGURATION), SIMPLE TO OPERATE AND MAINTAIN
- CONNECTS TO AN EBERLINE CONTROL TERMINAL TO PROVIDE A READOUT AT A CENTRAL LOCATION

Eberline A DIVISION OF Thermo Electron CORPORATION

SPING-3A

Model SPING-3A, System-Level Particulate, Iodine, and Noble Gas Air Monitor

GENERAL DESCRIPTION

The Model SPING-3A is a microcomputer-based, skid-mounted monitor designed to measure the airborne concentrations or stack emission rates of radioactive particulate, iodine, and noble gas as part of an Eberline Radiation Monitoring System. The microcomputer acquires information from eight channels (SPING-3A) or nine channels (SPING-4A) of detectors and is capable of accepting up to six channels of 4-20 mA analog input.

History files of average net count rate for the past 24 one-minute, ten-minute, one-hour, and one-day periods are stored in the microcomputer memory for transmission and display at the control terminal upon operator request. The SPING-3A microcomputer communicates serially with a central control terminal via a Model CLI-1, Communication Line Isolator, and an individually shielded, twisted-pair cable which enables the control terminal to annunciate, log, and display radiological status and data.

Battery-backed real-time clock/calendar and random access memory enable the SPING-3A to retain channel parameter files and correct time in the event of a complete loss of power to the system.

The distance between the SPING-3A and the control terminal may be extended to 5000 cable feet (1524 meters) using 18-gauge cable. Additional features include stainless-steel plumbing throughout the sampler stages, three inches of lead shielding (4π configuration) with one inch of lead between detectors, solid-state flow sensor, a regulated air pump, a system trouble light, and a high radiation alarm light and horn.

Continuous flow and pressure inputs from a new solid-state flow sensor combined with new software in the microcomputer enable the SPING-3A to perform derived concentration calculations on fixed filter channels resulting in readouts in units of μCi/cm³. Absolute pressure measurements made by the flow sensor allow the microcomputer to correct the noble gas readings for variations in chamber pressures.

A digital display panel visible from the front of the unit provides a rotary switch for selection of one of fifteen possible channels for local display. The format of the data display utilizes three significant mantissa digits with a 1½-digit exponent ($10^{\pm 19}$ maximum). An array of six lights displays current status (normal, maintenance, and fail condition; or trend, alert, and high alarm) of the selected channel. A row of momentary contact switches allows local control of functions such as audible alarm acknowledge, start and stop of pumps and flush mechanisms installed on monitors, and actuation of installed check sources for functional testing of detector channels.

The SPING-3A is one member of a large family of system-level monitors designed to integrate into Eberline's versatile radiation monitoring system.

SPECIFICATIONS

PARTICULATE

Fixed Filter: 47-mm-diameter, Millipore SM recommended.

Detector: Eberline Model RDA-3A, beta scintillation, 2-inch-diameter x 0.010-inch-thick plastic with 1.6 mg/cm² aluminized Mylar® window. The Model RDS-1 solid-state alpha detector is used for radon daughter background subtraction.

Sensitivity (at a flow rate of 60 L/min):
^{137}Cs: 5 cpm/h for 1 x 10^{-11} μCi/cm³,
^{90}Sr-^{90}Y: 8.8 cpm/h for 1 x $10^{-11}$$\mu$Ci/cm³
^{99}Tc: 3.8 cpm/h for 1 x 10^{-11} μCi/cm³; all are nominal.

Range: Approximately 10^{-11} to 10^{-6} μCi/cm³

Background: Approximately 25 cpm (dependent on geographic location) plus 10 cpm per mR/h of external ^{137}Cs field. Two methods of background subtraction are available. A solid-state alpha detector provides a means of subtracting out the build-up of radon daughters on the filter, and the area monitor provides a means of subtracting gamma background. If variable noble gas levels are encountered which interfere with the particulate measurement, the noble gas channel may be selected as a background compensation channel.

IODINE

Cartridge: 2-inch diameter x 3/4-inch-thick metal-cased cartridge containing TEDA impregnated charcoal. (Silver zeolite is optionally available from Eberline. Price fluctuates and is available upon request).

Detector: An Eberline Model RDA-2A, 2-inch x 2-inch NaI(Tl) with a ^{241}Am seed embedded for automatic gain stabilization for drift-free pulse-height analysis.

Sensitivity (at a flow rate of 60 L/min):
^{131}I: 3.5 cpm/h for 1 x 10^{-11} μCi/cm^3.

Range: Approximately 10^{-11} to 10^{-6} μCi/cm^3

Background: 45 cpm (dependent on geographic location) plus 15 cpm per mR/h of ^{137}Cs which is subtracted via an adjacent energy window.

NOBLE GAS (LOW RANGE)

Volume: 2.65-inch-diameter x 3-inch-deep (270 cm^3 volume).

Detector: Eberline Model RDA-3A beta scintillation detector, 2-inch-diameter x 0.010-inch-thick plastic with 1.6 mg/cm^2 aluminized Mylar® window.

Sensitivity:

^{133}Xe = 28 cpm for 1 x 10^{-6} μCi/cm^3 at 14.7 psia.
^{85}Kr = 41 cpm for 1 x 10^{-6} μCi/cm^3 at 14.7 psia.

Range: Approximately 10^{-7} to 10^{-2} μCi/cm^3, ^{133}Xe equivalent

Background: Approximately 25 cpm (dependent on geographic location) plus 10 cpm per mR/h of external ^{137}Cs field. An empirically determined fraction of the area monitor channel is subtracted to correct for gamma background.

NOBLE GAS (INTERMEDIATE RANGE)

Volume: 2.65-inch-diameter x 3-inch-deep (270 cm^3 volume). This is the same volume viewed by the low range noble gas detector.

Detector: Eberline energy-compensated Geiger-Mueller (G-M) tube.

Sensitivity:

^{133}Xe = 0.41 cpm for 1 γBq MeV/cm^3 (5.99 $\times$ 10^{-4} μCi/cm^3) at 14.7 psia,
^{85}Kr = 0.61 cpm for 1 γBq MeV/cm^3, (0.01 μCi/cm^3) at 14.7 psia.

Range: Approximately 10^{-3} to 10^2 μCi/cm^3, ^{133}Xe equivalent (1 to 10^6 γBq MeV/cm^3).

Background: Approximately 0.5 cpm (depending on geographic location) plus 1 cpm per mR/h of external ^{60}Co field. An empirically determined fraction of the background channel (identical detector in the lead shield) is subtracted for background compensation.

MISCELLANEOUS SPECIFICATIONS

Electronics: Eberline Interface Boxes, Models IB-2, IB-3C, and IB-4A, which contain the detector high voltage, signal amplifier, and line driver provide the function of interfacing the detectors to the microcomputer.

Battery Backup: The SPING-3A contains a battery which automatically powers all of the electronics in the event of loss of external power. This insures against information being lost from the microcomputer's memory for 8 hours.

Check Source: A motor-driven check source assembly and check source is provided for each of the channels with the exception of the intermediate range noble gas channel. The check sources used include 30 μCi ^{137}Cs sources for the particulate and low-range noble gas channels, a 0.5 μCi ^{133}Ba source for the iodine channel, and a 0.3 μCi ^{90}Sr-^{90}Y source for the area monitor (NRC license required). All of these sources are completely shielded from the detector when in the retracted position. They can be actuated either individually or as a group by keyboard request at the central control terminal or individually at the SPING-3A's location via the display panel.

Analog Signal Input: The acquisition of an analog signal may be desirable in the event the SPING-3A is used as a stack monitor. A signal can be acquired which is representative of the stack flow rate and used in computations of radioactive effluent release rates. Six channels of analog input are standard with the SPING-3A. Two of the channels are used for input of absolute and differential pressure from the installed transducers with four channels of input available for other signals.

PUMP AND FLOW INDICATION SYSTEM

Pump: Eberline Model RAP-3 with adjustable, regulated flow. Recommended sample flow rate is 60 L/min.

Flow Indicator: The flow measurement system consists of an absolute and differential pressure transducer which will pass information to the microcomputer. This information is then used to calculate the mass flow rate of the monitored air stream. The current absolute sample pressure may be viewed at any time by selecting Channel 14 on the digital display. The current sample flow rate in liters per minute may be viewed at any time by selecting Channel 15 on the digital display. This solid-state flow transducer system is used to correct problems defined by NRC Notice 82-49.

MECHANICAL SPECIFICATIONS

Size: 45 inches wide x 32 inches deep x 49 inches high (1.14 m x 0.81 m x 1.24 m) with skids.

Weight: Approximately 1500 pounds (682 kg). Approximately 2000 pounds (910 kg) with the high range noble gas option.

Operating Temperature: 32 °F to 122 °F (0 °C to 50 °C).

Power Requirements: 115 Vac, 60 Hz at 8 A (operating), 15 A (startup).

Inlet and Outlet Connections: 1-inch-o.d. (2.54 cm) tube compression fittings.

OPTIONS

High Range Noble Gas Detector

An Eberline Model SA-9 detector assembly for monitoring noble gases in the range of 1 to 1 x 10^5 μCi/cm^3 referenced to ^{133}Xe.

Detector: Energy-compensated GM tube with 0.7 μCi ^{90}Sr-^{90}Y check source which views a portion of a 1-inch-o.d. stainless-steel pipe running through the SA-9.

Sensitivity: 0.01 cpm per γBq-MeV/cm^3 at 14.7 psia (1 to 1 x 10^5 μCi/cm^3 of ^{133}Xe).

Background: Background compensation is accomplished by automatically subtracting a portion of the signal from the (GM) detector buried in the SA-13 lead block.

Remote Purge/Grab Sample Plumbing

This option includes the necessary plumbing, software, and a set of motor valves to allow purging of the SPING-3A from the central control terminal as well as locally via a push-button command. Grab sample ports with hose barbs and valves are also supplied.

Analog Signal Output

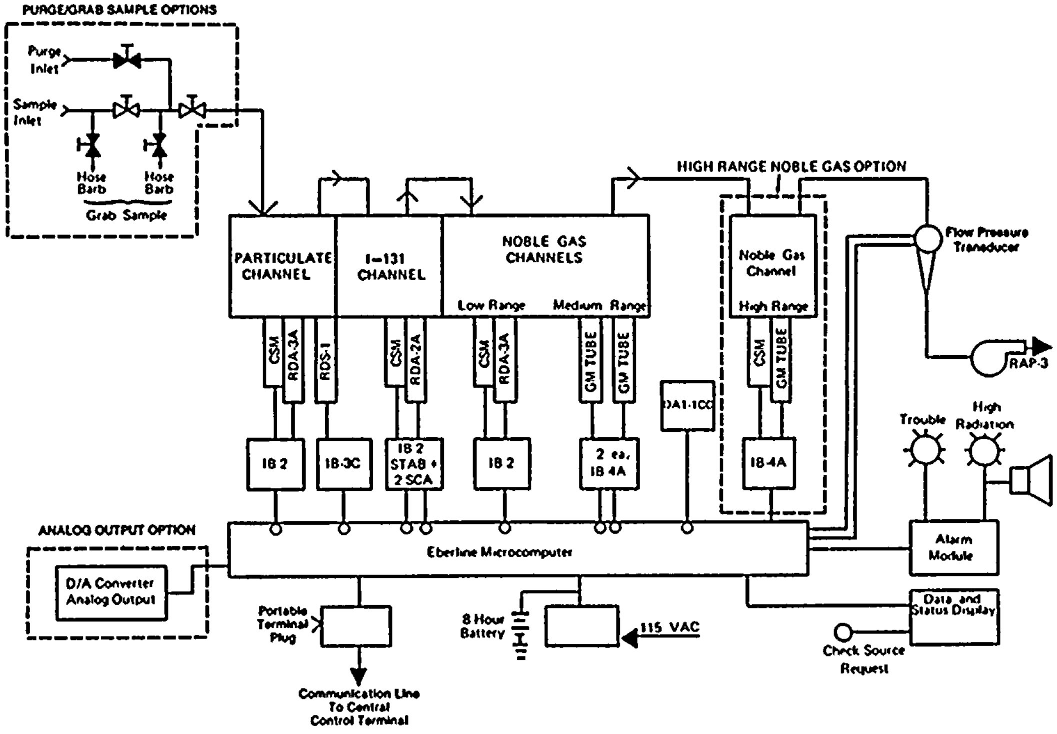
Occasionally it is desirable to output a signal which is representative of the radiation level sensed by a particular detector in the SPING-3A. This is made possible by the analog output option which is a 4 to 20 mA output loop. Any or all of the measurement channels may have this option except Channel 2 (alpha particulate).

Redundant Communication Interface

Eberline central control terminals can be, and often are, configured into a radiation monitoring system so that two control terminals communicate independently to each field microcomputer (SPING-3A, etc.). The redundant communication interface option is needed if communication with two control terminals is intended.

Manual Purge/Grab Sample Plumbing (Stainless Steel)

This option provides the necessary valves and plumbing to allow purging the SPING-3A and to allow grab sampling. All valves included in this option are manually-operated, stainless-steel valves.



SPING-3A Functional Block Diagram

NO.	QUAN.	PER.	DESCRIPTION

This document is for Eberline in-house usage only and is subject to modification at any time. The process described herein is valid only if performed by Eberline personnel at Eberline facilities.

CHG.	APP.	DATE	DESCRIPTION	Q.A.	BY	CH'K

EBERLINE INSTRUMENT CORPORATION
SANTA FE, NEW MEXICO

Q.A. APP. Y. O.I. 2/1/82

DR.	—	—
PROJ. ENG.	[signature]	1/29/82
Q.A.	J. Wells	2/1/82
APP.	[signature]	1/30/82

DIMENSIONAL TOLERANCES
Unless Otherwise Specified

FRAC.	DEC.	ANG.
± 1/64	X.XX±.015 X.XXX±.005	± 1/2°

ALSO USED ON	EFF. WITH

CALCULATION OF THE GAMMA BEQUEREL MeV/μCi CONSTANT FOR ^{133}Xe

SCALE

12000-20

sheet 1 of 2

CALCULATION OF THE GAMMA BEQUEREL MeV/μCi CONSTANT FOR ^{133}Xe

I. Calculation of the γ·Bq·MeV/μCi constant for ^{133}Xe.

- MIRD Pamphlet No. 10 lists the following photons (x and gamma rays) originating from the decay of ^{133}Xe:

RADIATION	PHOTONS/DISINTEGRATION	MEAN ENERGY/PHOTON (MeV)
Gamma	0.0061	0.0796
Gamma	0.3603	0.0809
Gamma	0.0002	0.3839
K Alpha-1 X-Ray	0.2552	0.0309
K Alpha-2 X-Ray	0.1321	0.0306
K Beta-1 X-Ray	0.0712	0.0349
K Beta-2 X-Ray	0.0150	0.0359
L X-Rays	0.0823	0.0043

<u>Note:</u> All the photons emitted in less than 0.01 percent of the disintegrations were omitted.

- The mean photon energy emitted per disintegration is determined by:

$$\sum_{i=1}^{n} (\gamma_i/d)(MeV_i)$$

This value is 0.0450 γ·Mev based on the MIRD photon listing.

- Since a Bequerel (Bq) is one disintegration per second and there are 3.7×10^4 disintegrations per second/μCi, the γ·Bq·Mev/μCi constant for ^{133}Xe [illegible]

$$(0.0450\ \gamma MeV)(3.7 \times 10^4\ Bq/\mu Ci) = 1.67 \times 10^3\ \gamma \cdot Bq \cdot MeV/\mu Ci$$