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# CALIBRATION REPORT: ACTIVE RADIATION DETECTOR

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ES62/3-5133

# CALIBRATION OF THE ACTIVE RADIATION DETECTOR FOR SPACELAB-ONE

Annual Report on Contract NAS8-31170

December 1982

Cosmic Ray and Nuclear Instrumentation Laboratory

The University of Alabama in Huntsville

SUMMARY

The flight models of the Active Radiation Detector (ARD) for the ENV-01 environmental monitor* were calibrated using γ-radiation. Measured sensitivities of the ion chambers were:

ARD S/N 1: 6.1 ± 0.3 μ rad per count

ARD S/N 2: 10.4 ± 0.5 μ rad per count.

Both were linear over the measured range 0.10 to 500 m rad hour$^{-1}$. The particle counters (proportional counters) were set to respond to approximately 85% of minimum ionizing particles of unit charge passing through them. These counters were also calibrated in the γ-field.


*This instrument is being developed for the VFI program by the Space Science Laboratory of NASA, MSFC for flight on Space lab 1. A full description of the instrument is not given here.

## ION CHAMBER DOSIMETERS

The tissue-equivalent ion chamber dosimeters (IC's) are designed* to make differential measurement of absorbed dose in a mixed radiation field typical of Spacelab orbits. Each dosimeter consists of a gas-filled ion chamber, electrometer sensor, and pulse generator. When each preset unit of radiation (measured in tissue-rads) is accumulated, a pulse is sent to advance an internal register and reset the electrometer integrator. Preset dose units are in the range of 5 to 10 μ rads per pulse and expected count rates in orbit vary from a low value of a few counts per hour to a few counts per second in the South Atlantic anomaly.

The calibration procedure is designed to measure the sensitivity of the instrument in μ rads per count, and to check the linearity of the system over the expected dose rate range of up to several hundred μ rads per hour.

A view of the ion chamber assembly is shown in Figure 1.

* TEIC I/El, Digital Data Dosimetry, Tulsa, Oklahoma.

## CALIBRATION

### Dose Calculation

$$\text{Energy absorbed per gm} = \frac{\mu}{\rho} \cdot F \qquad \text{ergs g}^{-1}$$

$$= \frac{\mu}{\rho} \cdot \frac{F}{100} \qquad \text{rads} \qquad (1)$$

where $\mu/\rho$ is the energy transfer coefficient (for tables, see Hubbell and Berger, 1965), and

F , the energy flux in ergs $cm^{-2}$,

$$= \frac{3.7 \times 10^{10} \times \text{source strength in Ci} \times E_\gamma \times 1.6 \times 10^{-12} \text{ ergs cm}^{-2}}{4\pi r^2} \qquad (2)$$

where $E_\gamma$ is the proton energy in eV

and $r$ is the source-absorber separation in cm.

Some measured and calculated dose rates of interest are shown in Table 1.

TABLE 1

Some dose rates of interest:

| | |
|---|---|
| Typical sea level background in US: | ∿ 10 μ rad $hour^{-1}$ |
| 10 μ Ci Cs-137 @ 30 cm: | 37 μ rad $hour^{-1}$ |
| 10 μ Ci Cs-137 @ 5 cm: | 1.3 m rad $hour^{-1}$ |
| 100 m Ci Cs-137 @ 50 cm: | 130 m rad $hour^{-1}$ |
| South Atlantic anomaly peak: | ∿ 100 m rad $hour^{-1}$ |

Experimental Arrangement

The setup used in shown in Figure 2. Both source and detector are at a fixed distance ($\sim$ 1 m) from the floor. The source position was unchanged but the detector and shield were on a movable trolley. The source used was a nominal 100 m Ci of Cs-137 (New England Nuclear NER 401 H, serial number CS-315) of actual activity 93.8 ± 5 m Ci on August 8, 1975. At the time of this calibration, its activity was 79.2 m Ci.

The ARD was placed in the $\gamma$-field so that the IC and both PC's were equidistant, d meters, from the source. The number of counts per unit time for each detector was recorded. For the PC's the mean of 17 measurements of counts per second was taken in each case. For the ion chamber, the counting interval was varied depending on the count rate so that the uncertainty in counting was less than 3%. At count rate > 50 per 100 s a counting period of 100 s is adequate. At lower count rates longer interval were used, and at very low rates of a few per 100 s or less, the measurement was made of the intervals between actual counts. This is conveniently done with the GSE since the count register of the ARD is read out and displayed every second by the GSE.

These results for the ion chambers are shown in Figure 3 and 4 for ARDS's 1 and 2 respectively. Plots of PC count rate versus dose rate are shown in Figures 5, 6 and 7.

From this data and equation (2) the sensitivities of the ICs were determined to be:

ARD No. 1 ----- 6.1 ± 0.3 μ rads $(ct)^{-1}$

ARD No. 2 ----- 10.4 ± 0.5 μ rads $(ct)^{-1}$

The IC's are seen to be linear over the range 300 μ rads $hour^{-1}$ to 100 m rads $hour^{-1}$ are probably linear up to an order of magnitude higher in dose rate.

PROPORTIONAL COUNTER RATE METERS (PC'S)

These counters are xenon-filled stainless steel cylinders with aluminum liners (Reuter-Strokes #RS-P3-0803-287). Shown in Figure 8, they are 4 inch long and 1 inch in diameter. There are two PC's in each ARD, one being covered with a copper sleeve 1.27 mm thick for partial discrimination between protons and soft electrons.

Any charged particle intersecting a PC or any photon interacting within a PC will advance the ratemeter for that counter, provided sufficient energy is deposited in the counter to exceed the preset threshold discriminator. For a given radiation field the count rate varies with the system gain and noise and with the discriminator level. This level was set above system noise but low enough to be exceeded by most minimum ionizing singly-charged particles.

Energy Loss Calculation and Discriminator Level Justification

Mean ionization loss for relativistic $z = 1$ particle in Xe = 7.5 keV $cm^{-1}$.

Mean ionization loss across a diameter of the PC = 19.5 keV.

With discriminators set at 8.9 keV, > 90% of all particle trajectories intersecting the PC will exceed this level. Since some particles deposit less than the mean, an overall efficiency of 85% is estimated for relativistic particles. Efficiency is greater for slower particles of sufficient energy.

Consistency of PC Background Count rate with Other Measurements

An experimental measurement of the fast muon flux at Huntsville using the MSFC-UAH cosmic ray instrument gave approximately 0.012 $(cm^2\ sr)^{-1}$. For the effective area of these PC's of 18 $cm^2$ we should expect a fast muon rate of about 0.4 $s^{-1}$. Actual measured background count rates with the ARD PC's were in the range 0.6 to 1.5 $s^{-1}$. Since this includes all background radiation, the AC measurement is in agreement with prediction.

The energy deposit calibration of the PCs was made using low energy photon sources of 5.9 keV (Fe-55) and 14.4 keV (Co-57). The excellent resolution and noise figure of these counters is shown in Figure 9.

Count rates of the PC's in a calibrated γ-field were recorded during the calibration of the ion chambers by the shadow-shield method described below. Plots of count rate versus dose as measured by the ion chambers are shown in Figures 5, 6 and 7.

The proportional counters are not quite linear with dose rate as shown in the figures. In the event of IC failure, however, they will give a reasonable estimate of dose rate. The presence on PC No. 2 of the 1.27 mm thick copper shield did not affect the counting rate greatly compared to PC

No. 1 for 0.66 MeV γ-rays. It will, however, affect the count rate for low energy electrons.

Transfer Calibration and Check Source

During the period between calibration and flight, (approximately one year), checks must be made of the ion chamber (a) to see if it is operating and (b) to check the constancy of the sensitivity (μ rads $ct^{-1}$).

This is effected with a small source placed on a marked spot on the aluminum case of the ARD. The source strength is 10 μ Ci and the effective separation of source and detector is 5 cm. The dose rate is 1.3 m rad $hour^{-1}$, approximately two orders of magnitude above laboratory background and two orders below orbital maximum rate (see Table ). Baseline data using the transfer calibration source and background measurements are given for ARD's No. 1 and 2 in Tables 2 and 3 respectively.

TABLE 2

TRANSFER CALIBRATION/CHECK SOURCE MEASUREMENTS

ARD No. 1

Source on IC Spot

| DATE (1982-1983) | PC 1 | PC 2 | IC time for 1 count (sec) |
|---|---|---|---|
| | counts/sec (mean of 17 measurements) | | |
| December 29 | 7.7 | 19.4 | 16.5 |
| 29 | 8.1 | 20.2 | 16.0 |
| 30 | 9.2 | 19.4 | 16.2 |
| 30 | 9.4 | 17.6 | 15.8 |
| January 2 | 8.9 | 17.0 | 16.1 |
| 2 | 7.6 | 21.0 | 16.2 |
| 2 | 7.8 | 17.9 | 15.9 |
| 2 | 8.5 | 18.7 | 16.1 |
| 5 (post shake) | 9.0 | 21.2 | 14.7 |
| 5 | 8.8 | 19.6 | 14.7 |
| 5 | 10.2 | 20.0 | 14.9 |

Source on PC Spot

| | | | |
|---|---|---|---|
| December 29 | 108 | 107 | ---- |
| 30 | 105 | 109 | ---- |

Room Background

| | | | |
|---|---|---|---|
| December 29 | 1.53 | 1.12 | 1100 |
| 29 | 1.59 | 1.06 | |
| 30 | 1.06 | 0.94 | |

# TABLE 3

## TRANSFER CALIBRATION/CHECK SOURCE MEASUREMENTS

## ARD No. 2

Source on IC Spot

| DATE (1982-1983) | PC 1 | PC 2 | IC time for 1 count (sec) |
|---|---|---|---|
| | counts/sec (mean of 17 measurements) | | |
| December 29 | 7.7 | 17.7 | ---- |
| 29 | 8.1 | 17.3 | ---- |
| 30 | 8.8 | 18.5 | ---- |
| 30 | 8.5 | 18.7 | ---- |
| 30 | 9.5 | 17.5 | ---- |
| January 2 | 8.0 | 16.6 | ---- |
| 2 | 8.1 | 17.1 | ---- |
| 2 | 8.1 | 18.3 | ---- |
| 2 | 7.3 | 19.4 | ---- |
| 8 (reconstituted post shake) | 9.5 | 19.4 | 26.5 |
| | 10.2 | 17.6 | 28.2 |
| | 8.6 | 18.8 | 28.3 |
| | 9.7 | 19.8 | 28.2 |

Source on PC Spot

| | | | |
|---|---|---|---|
| December 29 | 109 | 104 | ---- |
| | 111 | 100 | ---- |
| January 8 | 96 | 114 | ---- |

Background

| | | | |
|---|---|---|---|
| December 29 (in rad. fac.) | 0.7 | 0.6 | 1500 |
| | 0.9 | 0.4 | |
| January 8 (in SSL) | 2.2 | 1.2 | |

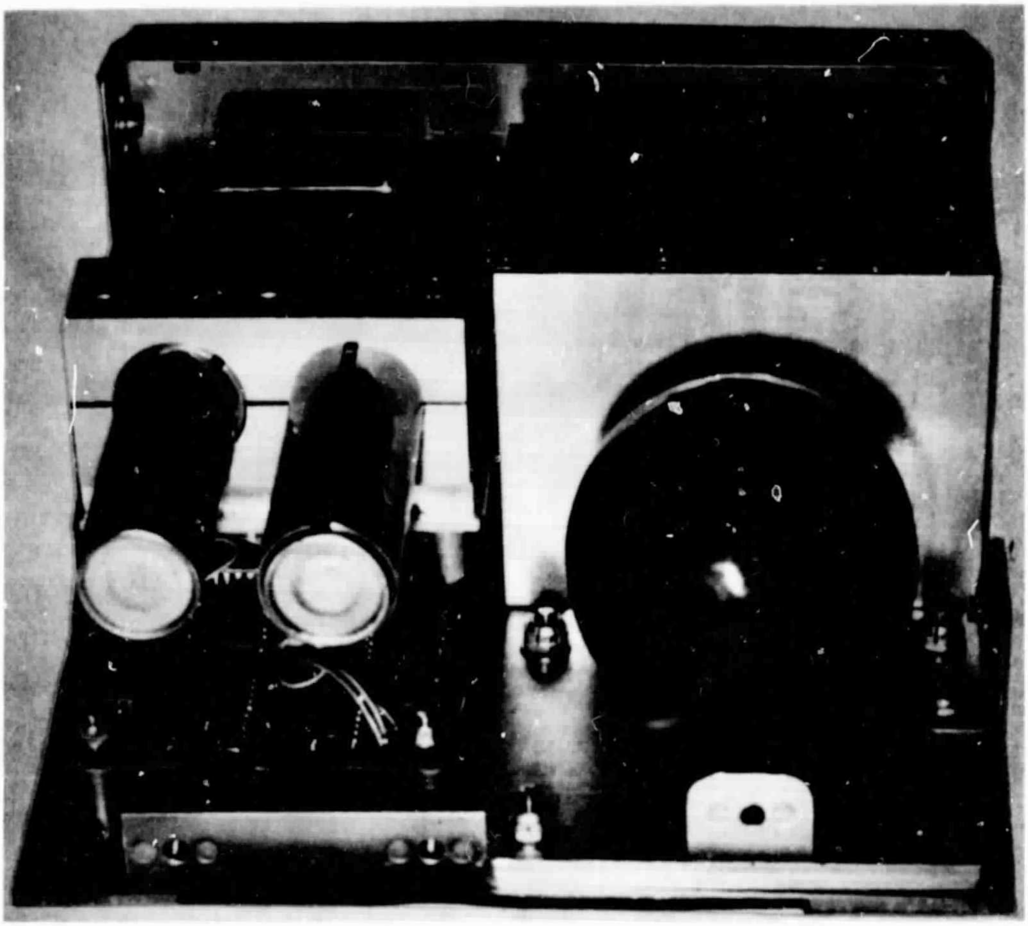
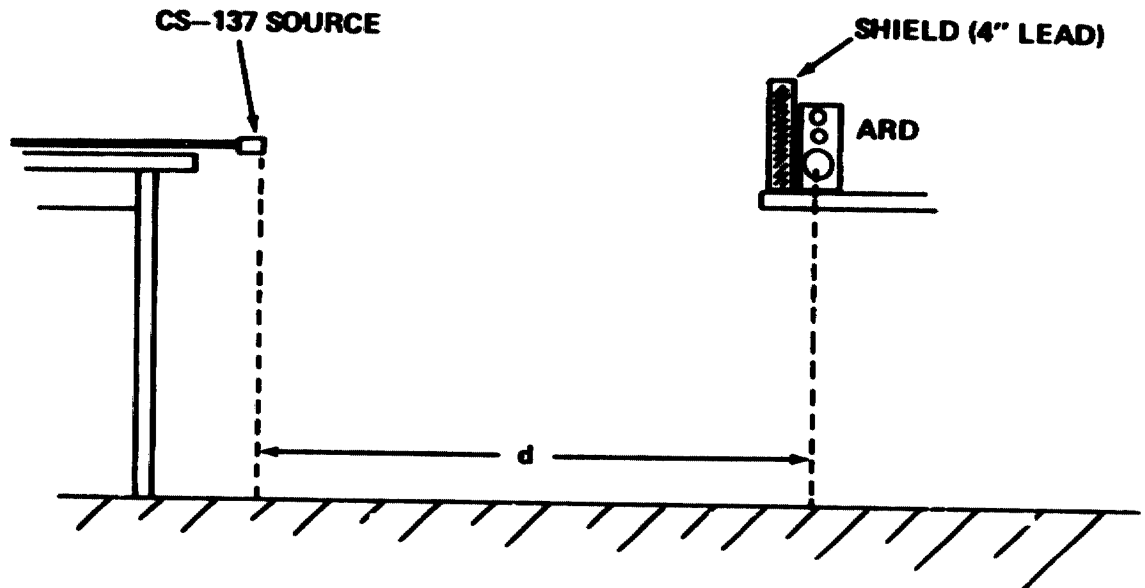


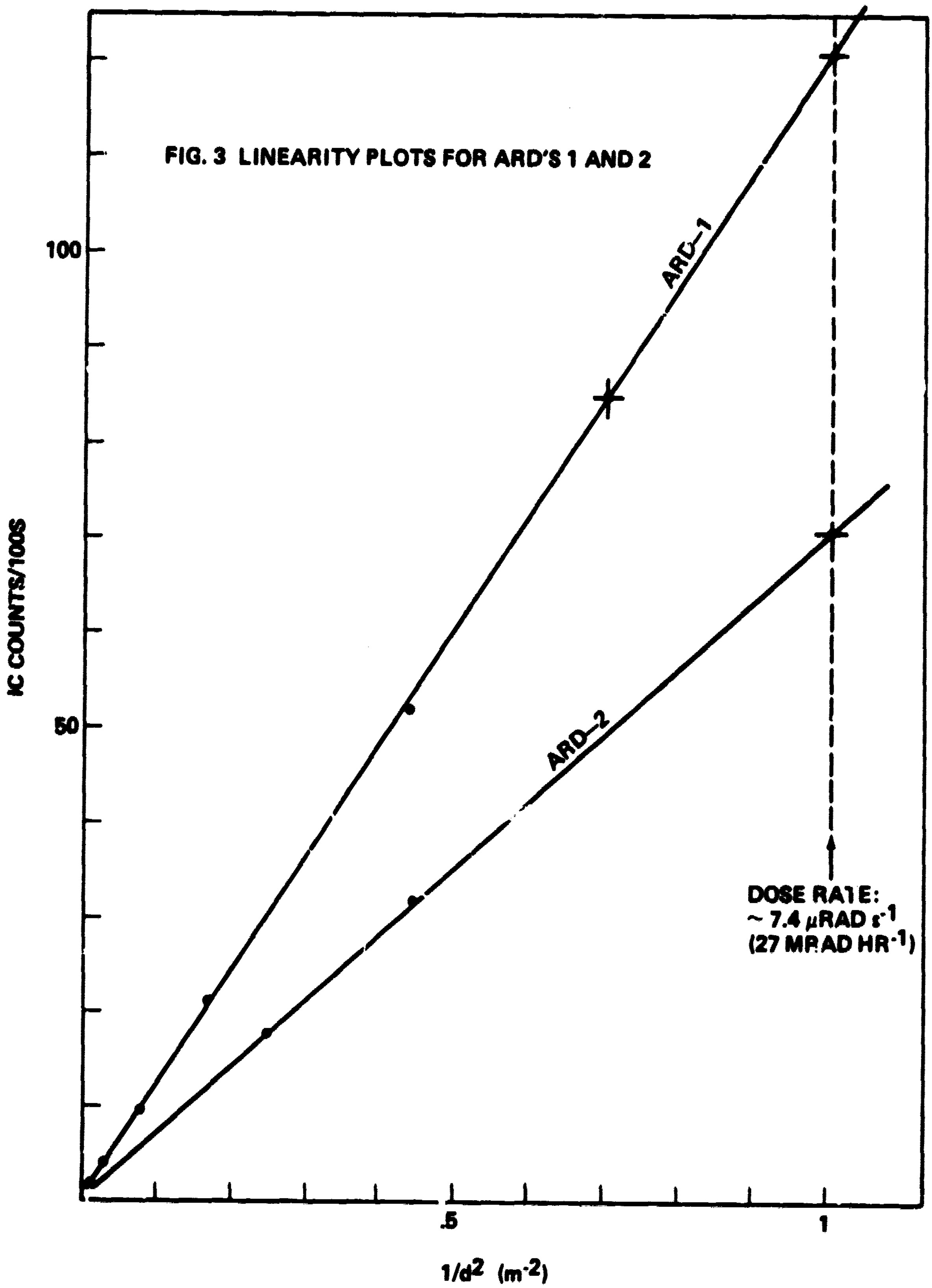
FIGURE 1. ACTIVE RADIATION DETECTOR
(PROTECTIVE COVER REMOVED)




ARD CALIBRATION
EXPERIMENTAL SETUP: SHADOW SHIELD METHOD

FIGURE 2.

ORIGINAL PAGE IS
OF POOR QUALITY



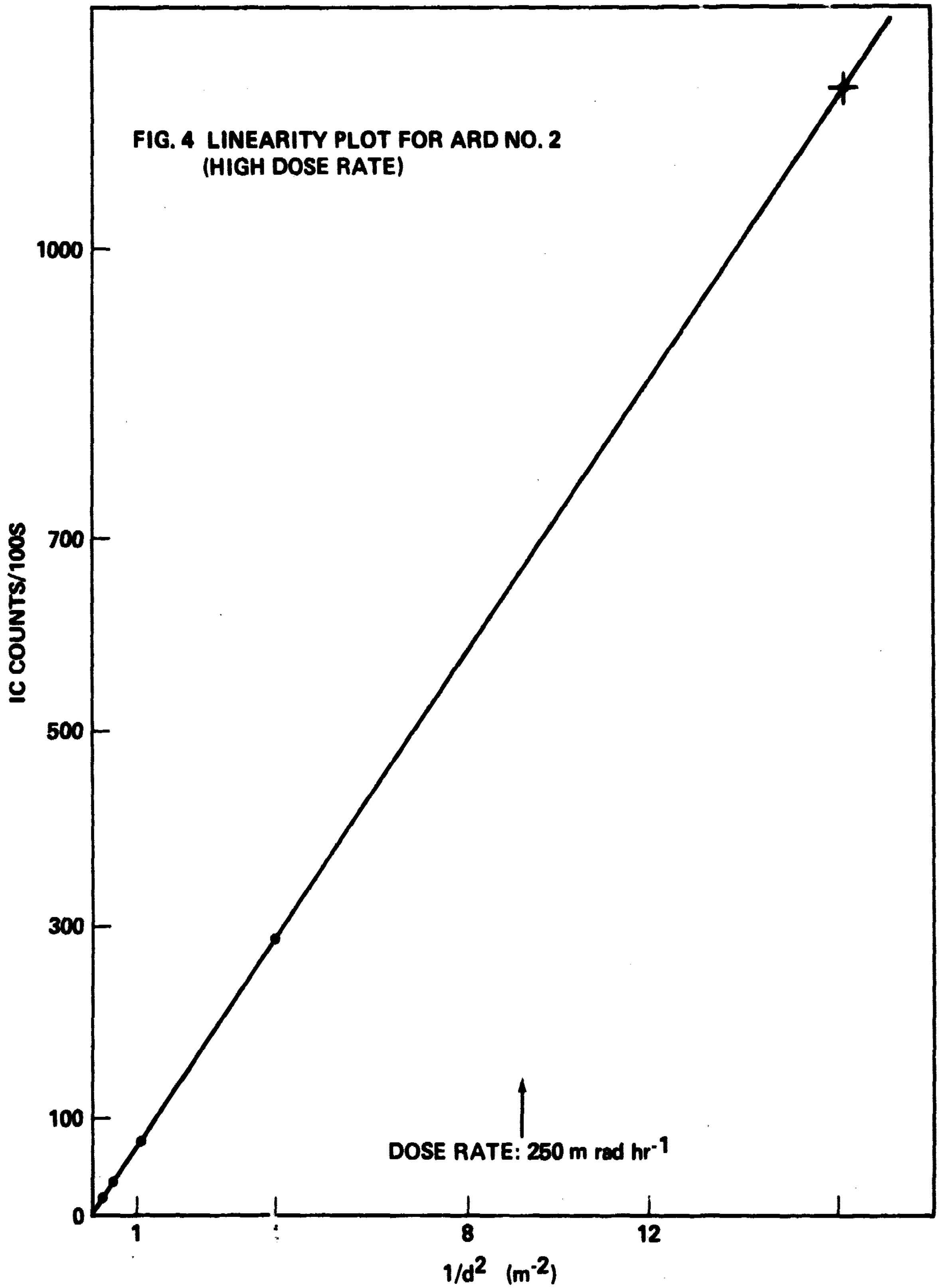


FIG. 4 LINEARITY PLOT FOR ARD NO. 2
(HIGH DOSE RATE)
IC COUNTS/100S
1000
700
500
300
100
0
1
8
12
1/d2 (m-2)
DOSE RATE: 250 m rad hr-1

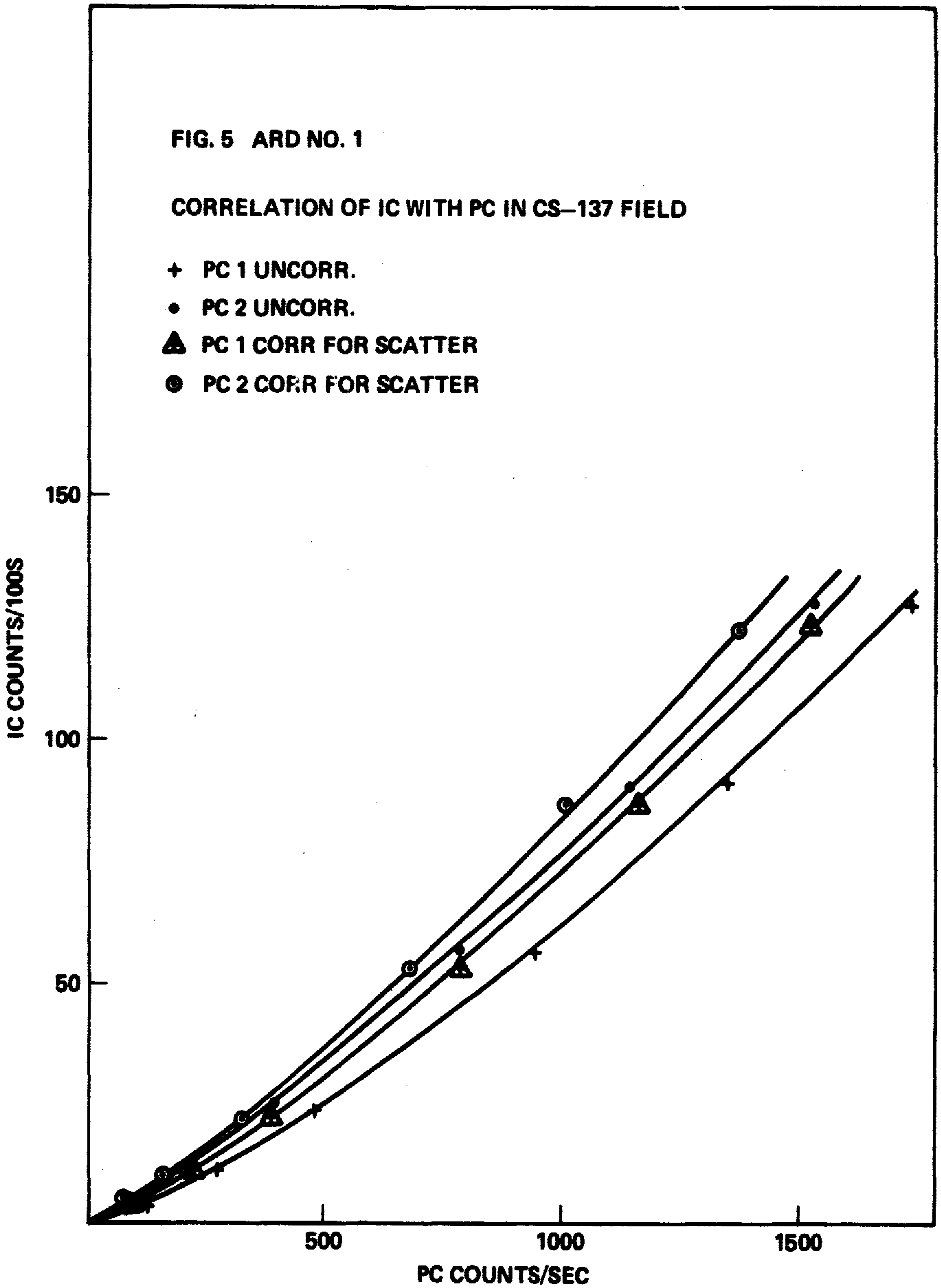


FIG. 5 ARD NO. 1
CORRELATION OF IC WITH PC IN CS–137 FIELD
PC 1 UNCORR.
PC 2 UNCORR.
PC 1 CORR FOR SCATTER
PC 2 CORR FOR SCATTER
150
100
50
IC COUNTS/100S
500
1000
1500
PC COUNTS/SEC

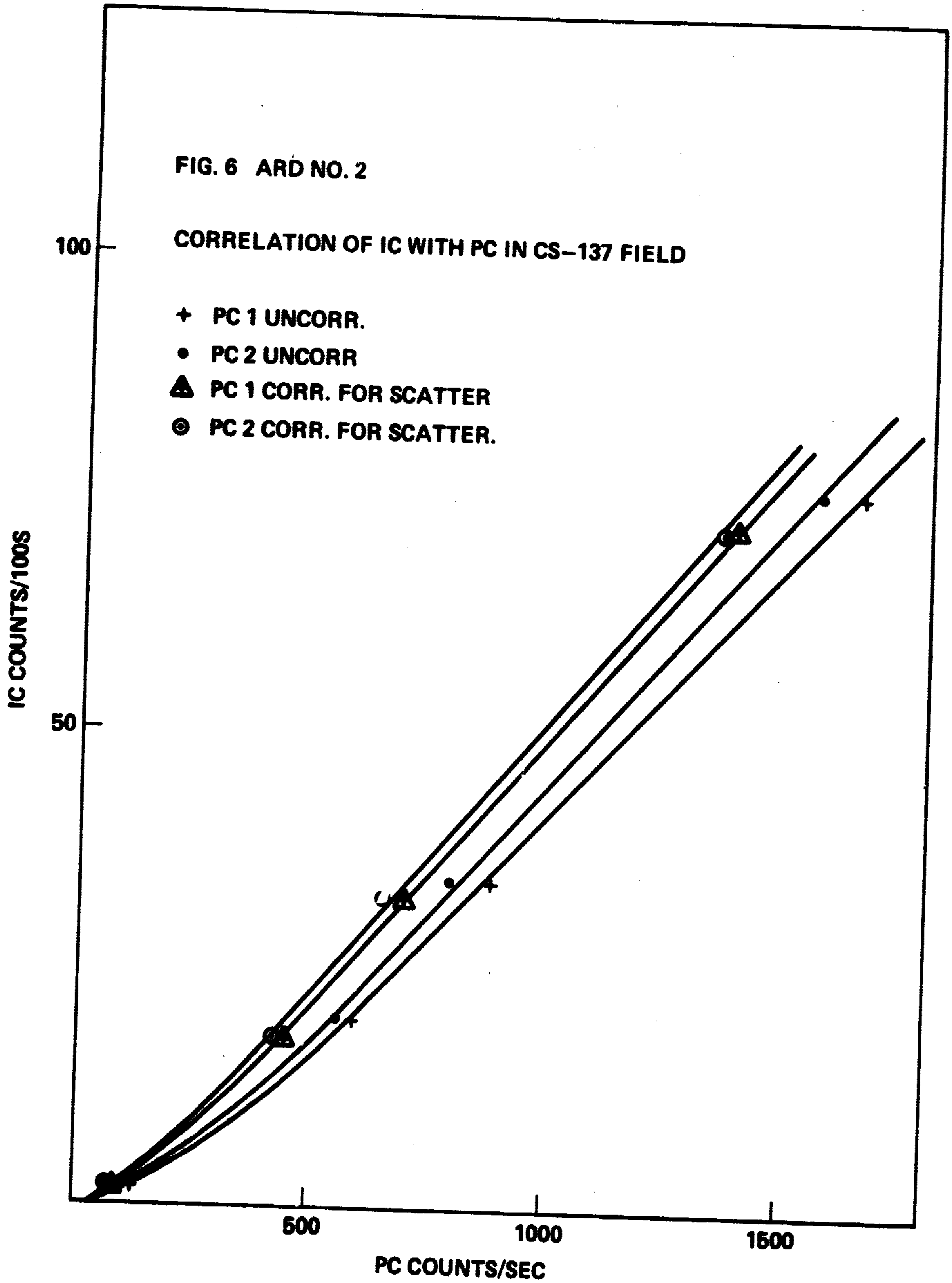



FIG. 6 ARD NO. 2

CORRELATION OF IC WITH PC IN CS–137 FIELD

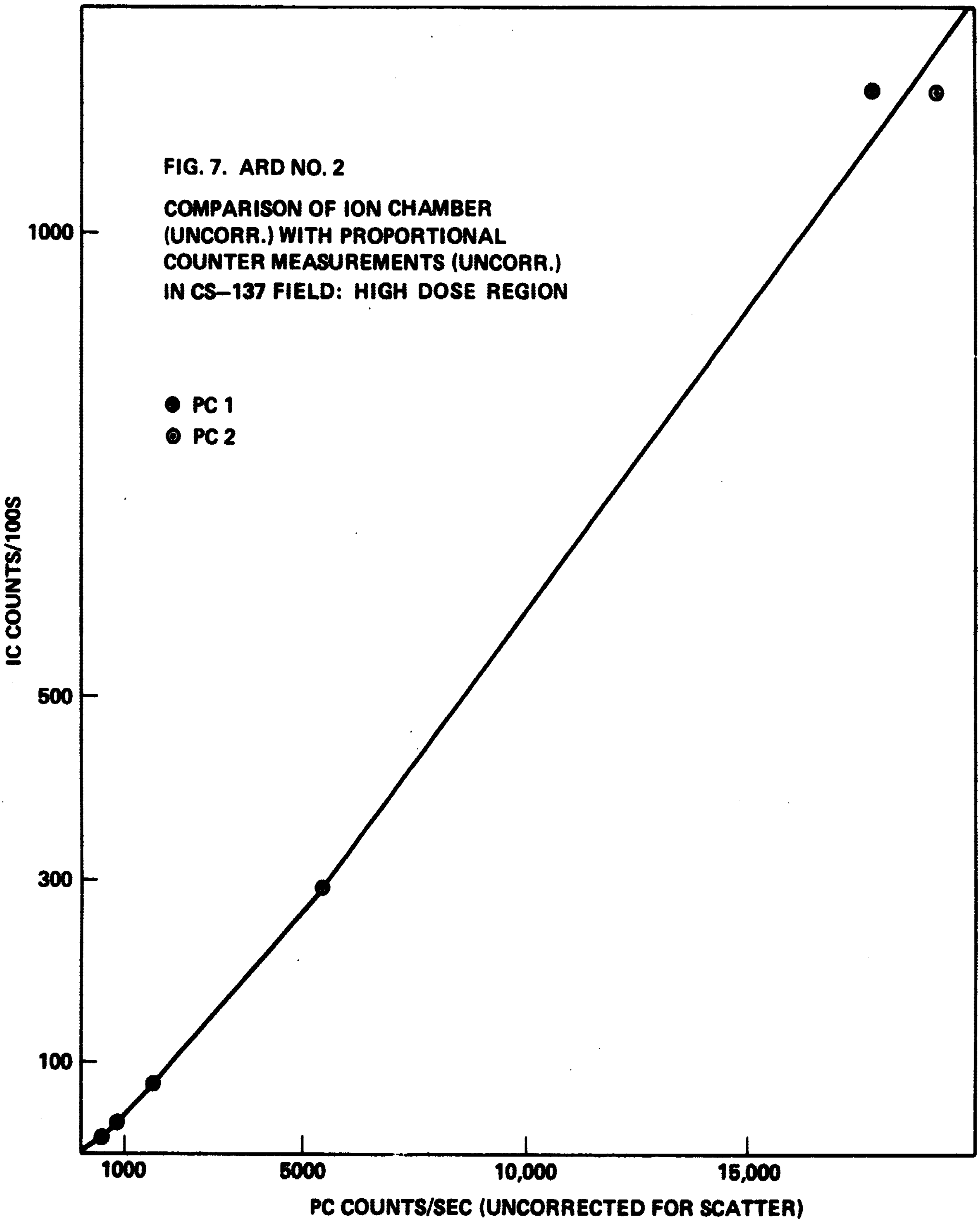
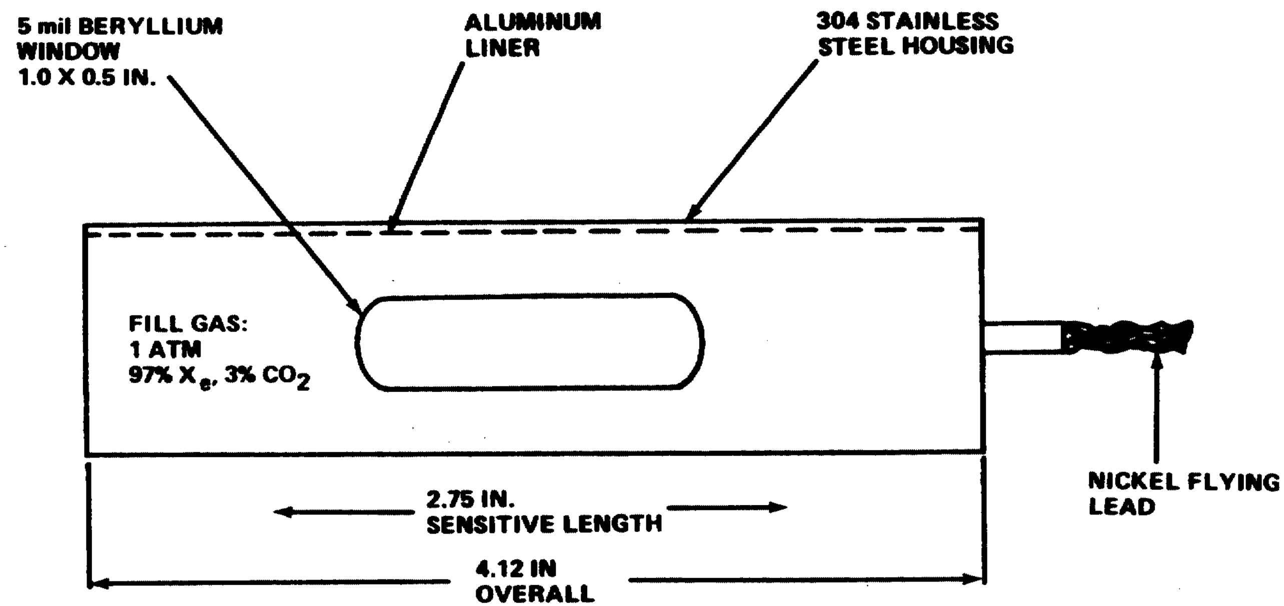


FIG. 7. ARD NO. 2
COMPARISON OF ION CHAMBER (UNCORR.) WITH PROPORTIONAL COUNTER MEASUREMENTS (UNCORR.) IN CS–137 FIELD: HIGH DOSE REGION
PC 1
PC 2
IC COUNTS/100S
1000
500
300
100
1000
5000
10,000
15,000
PC COUNTS/SEC (UNCORRECTED FOR SCATTER)




PROPORTIONAL COUNTER (PC) FOR ARD
(REUTER–STOKES RS–P3–0803–287)

FIGURE 8.

ARD PROPORTIONAL COUNTER ENERGY RESPONSE:

$Co^{57}$ RADIATION

REUTER STOKES RSP 3—0803—287
SERIAL NO.: W—523
VOLTAGE: 2300V

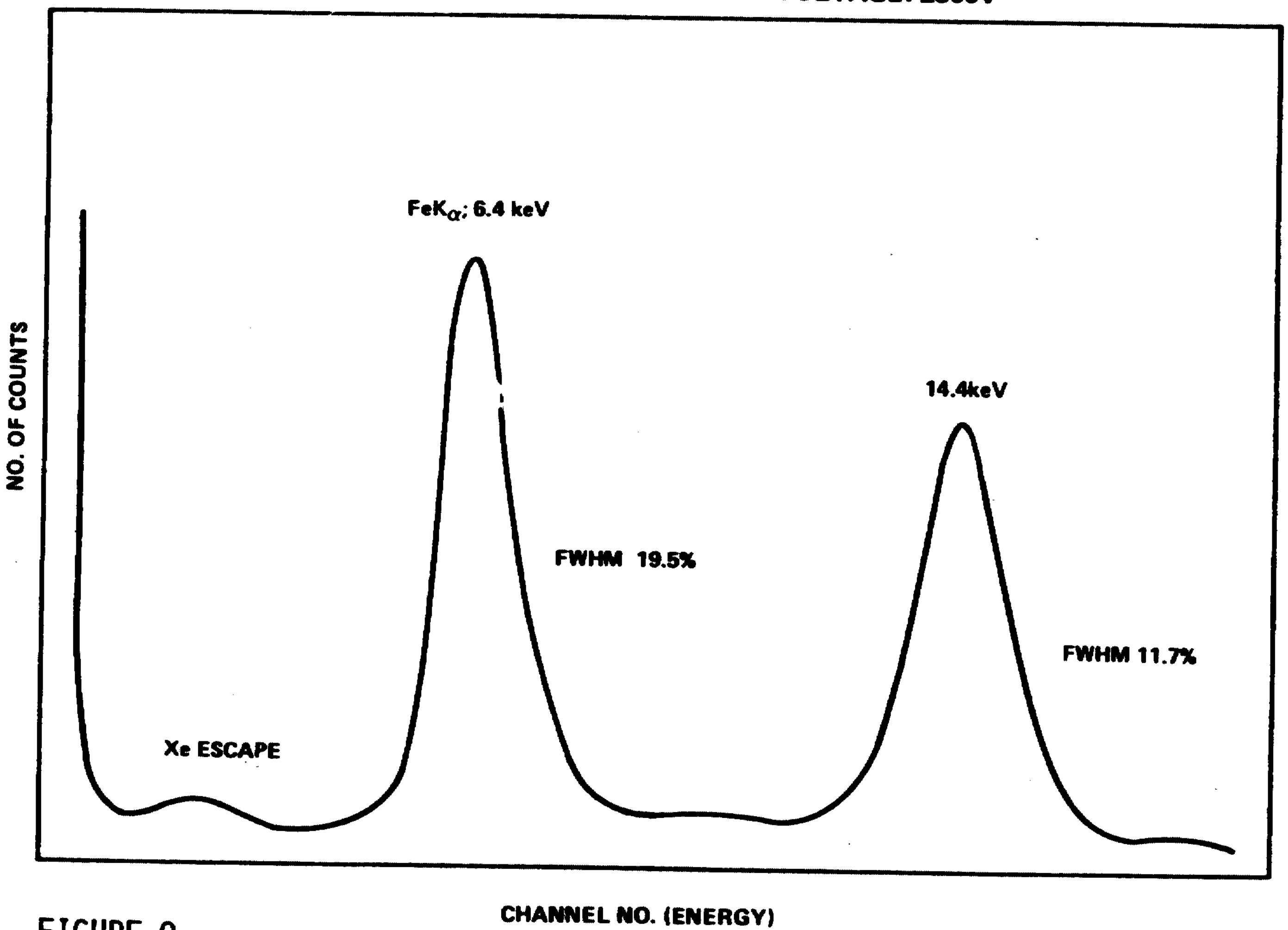



FIGURE 9.