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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

THE PHOTON ENERGY RESPONSE OF SEVERAL IONIZATION CHAMBER INSTRUMENTS

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THE PHOTON ENERGY RESPONSE OF SEVERAL IONIZATION CHAMBER INSTRUMENTS

by

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ABSTRACT

The photon energy response of several radiation survey meters and pocket dosimeters was measured over an energy range of 8 to 1250 kev. Measurements were also taken with the meters in different orientations and with open and closed shield. The devices selected for these measurements are all ionization chamber instruments in routine or special use at the Los Alamos Scientific Laboratory.

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INTRODUCTION

The purpose of this report is to present the photon energy response of several radiation survey meters and pocket dosimeters routinely or specially used at the Los Alamos Scientific Laboratory. The response was measured over an energy range from 8 to 1250 kev; sources were made as monochromatic as possible. The sensitivity between 8 and 242 kev of each device was determined by comparing its reading at each energy with that of a free-air ionization chamber. At 1250 kev the sensitivity is the ratio of the response to that of a Victoreen r-chamber. The results of these measurements are intended to serve as a basis for determining the instruments best suited to a specific monitoring job.

SOURCES

A 300-kv constant-potential Norelco x-ray unit was used as the primary source to measure the response of the instruments to energies between 8 and 242 kev. Fluorescent K radiation, obtained by placing foils of different atomic number in the x-ray beam, covered an energy range from 8 to 100 kev. The direct x-ray beam at various kilovoltages was used with thick amounts of filtration to cover the energy range from

84 to 242 kev. The response to 1250-kev gamma rays was measured with Co^{60} as the source.

A. Fluorescent Sources

For fluorescent radiation, the x-ray tube, except for the window, was encased in a 1-inch-thick lead housing to prevent radiation leakage. A 1.5-inch-thick lead diaphragm that had a tapered conical hole was placed over the window of the x-ray tube to reduce the size of the beam. A lead-lined brass cylinder was placed against the diaphragm to serve as the radiator holder. The radiator was 15 cm from the x-ray target and at an angle of 45 degrees to the central ray of the primary x rays. A 0.75-inch-diameter hole in the radiator holder provided an exit for the fluorescent radiation. The primary beam was absorbed by a second lead-lined brass cylinder which was attached to the radiator holder. An aluminum filter was used with each radiator to absorb the L lines.

Table I gives the energies of fluorescent K radiation obtained with radiators of different material and atomic number. The amount of scattered radiation was determined by absorption and x-ray spectrometer measurements. The exposure rates were measured with a free-air ionization chamber.

B. Heavily Filtered Direct X-Ray Sources

The direct x-ray beam was used to cover an energy range from 84 to 242 kev. Large amounts of filtration were employed to obtain as

TABLE I

Characteristics of the Fluorescent Sources

Atomic number	Radiator material	Radiator thickness* (g/cm^2)	$K\alpha_1$ (kev)	$K\alpha_2$ (kev)	$K\beta_1$ (kev)	$K\beta_2$ (kev)	Weighted average energy** (kev)	Aluminum L-line filter thickness (g/cm^2)	Scattered radiation in fluorescent source (per cent)	Exposure rate at 50 cm*** (mr/min)
29	Cu	0.014	8.047	8.027	8.904	8.976	8.19	0.006	4	18
40	Zr	0.045	15.774	15.690	17.666	17.969	16.07	0.055	2	47
47	Ag	0.074	22.162	21.988	24.942	25.454	22.59	0.103	2	60
56	Ba	0.13	32.191	31.815	36.376	37.255	32.81	0.103	4	55
64	Gd_2O_3	0.23	42.983	42.280	48.718	49.961	43.78	0.103	4	43
70	Yb_2O_3	0.35	52.360	51.326	59.352	60.959	53.28	0.441	7	24
77	Ir	0.55	64.886	63.278	73.549	75.605	65.94	0.441	12	19
82	Pb	0.72	74.957	72.794	84.922	87.343	76.08	0.441	13	18
90	Th	1.50	93.334	89.942	105.592	108.671	94.52	1.446	~15	12

*For the oxides only the mass of the rare earth is included.

**Assuming relative intensities of 1.0, 0.5, 0.25, and 0.05 kev for $K\alpha_1$, $K\alpha_2$, $K\beta_1$, and $K\beta_2$, respectively.

***Primary x-ray source at 300 kv and 15 ma.

narrow a spectrum band as possible. The amount of filtration, or the degree of monochromaticity that was achieved, was limited by the practical necessity of obtaining intensities that were sufficiently large to calibrate the instruments. A rectangular aluminum box was mounted to the lead diaphragm in the x-ray tube window to hold the thick filters.

Table II gives the kilovoltages, the currents, and the types and thicknesses of filters used with the direct x-ray beam to obtain effective energies of 84, 108, 135, 162, 205, and 242 kev. Effective energies were determined by absorption measurements. A description of the method of measuring the spectrum purity, beam uniformity, and exposure rates of the fluorescent and heavily filtered sources will be given in a later report. Table II also gives the spectral peak and the spectral width at half-height measured by an x-ray spectrometer. Exposure rates were again measured with a free-air ionization chamber.

C. Co^{60} Source

All instruments were calibrated to Co^{60} radiation by LASL Group P-4 who employed their routine calibration procedure. Immediately before the energy response measurements, the Co^{60} calibration of the instruments was checked. The exposure rate of the source used for this check was measured with a "high energy" Victoreen r-chamber, which had been calibrated by the National Bureau of Standards.

TABLE II

Characteristics of the Heavily Filtered X-Ray Sources

Exciting potential (kv)	X-ray current (ma)	Primary filter* (g/cm^2)	Effective energy (kev)	Spectral peak (kev)	Spectral width at half-height (kev)	Exposure rate at 50 cm (mr/min)
100	15	2.0 Mo	84	86	24	70
130	15	4.0 Mo	108	108	30	67
170	15	8.0 Mo	135	140	36	95
200	15	9.0 Sn	162	164	39	72
250	10	15.0 Sn	205	205	46	73
300	10	8.0 Pb	242	247	60	68

*Filters placed between two 1/32-inch-thick aluminum sheets.

METHOD OF MEASUREMENT

The x-ray tube with its lead housing was mounted in such a way that it could be rotated. This allowed either the direct beam or the fluorescent source beam to be oriented horizontally above and parallel to the surface of the instrument table, which was located in front of the x-ray tube. Two sets of tracks were mounted on the table top, one set for each beam. The x-ray tube could be positioned so that each beam was directed above and along the center of its set of tracks. A pointer could be placed on either set of tracks and adjusted to the beam center as a convenient reference for lateral and vertical positioning of devices to be placed in the beam. The instruments were laid on or clamped to the top of a scissors-type laboratory jack which was placed on the table and positioned with the aid of the pointer.

The two beams had been calibrated with photographic films for size and uniformity. Care was taken to insure that the entire chamber of each device was within the uniform portion of the beam.

The survey meters were read with a telescope. In some cases it was necessary to use a mirror to see the meter scales. Readings were taken with the survey meters in different positions and with open and closed shield. Where necessary, the zero set on the survey meters was adjusted to compensate for shift caused by the change in position. These instrument positions, with respect to the beams, are illustrated at the end of this report in Figs. 1 to 12, which show the energy response results.

Extracameral effects (i.e., effects on parts of the instrument other than the chamber) of the survey meters were measured at 242 kev by placing the ionization chamber of the instrument in the beam while shielding the electronics, then placing the electronics in the beam and shielding the chamber. This effect was 10 per cent or less in each case.

All the instruments had been serviced and calibrated to Co^{60} radiation within 2 weeks before the measurements. Most of the survey meters were serviced and calibrated by Group P-4, and the dosimeters by photodosimetry personnel of Group H-1. On the day the measurements were taken, the survey meters were allowed to warm up for 1/2 hour and were given an operational check before any readings were taken.

RESULTS

Table III lists the instruments for which energy responses were measured. Except for the 656A pocket dosimeter, the response of only one device of each type was measured. The 656A pocket dosimeter measurements indicate that there may be differences in the response of presumably identical instruments.

The results of the energy response measurements are given in Figs. 1 through 12, in which the sensitivity is plotted versus the energy in kev. In the energy region from 8 to 242 kev, sensitivity means the ratio of the survey meter or dosimeter reading to the free-

TABLE III

List of Instruments

Type or model number	Manufacturer
Type N596	EKCO Electronics, Ltd.
Model SU-1B	Tracerlab, Inc.
Model SU-10 (AN/PDR T-1B)	Tracerlab, Inc.
Model 414	Baird-Atomic, Inc.
Model D-1	Raychronix, Radioactive Products, Inc.
Model CP3D	El Tronics, Inc.
Model AGB-50B-SR	The Victoreen Instrument Co.
Model 656/A (0.5 r direct-reading pocket dosimeter)	The Victoreen Instrument Co.
Model 440	The Victoreen Instrument Co.
Model 61720 (fallout detector)	The Victoreen Instrument Co.
Model M-100 (Minirad survey meter)	The Victoreen Instrument Co.
Model CD V-736 (dosimeter ratemeter)	The Bendix Corp.

air ionization chamber reading. At 1250 kev, sensitivity means the ratio of the survey meter or dosimeter reading to the Victoreen r-chamber reading. The curves give a direct indication of the energy response of each instrument compared to a standard chamber. To correct an instrument reading at a given energy the reading must be divided by the sensitivity or multiplied by the reciprocal of the sensitivity at the energy of interest.

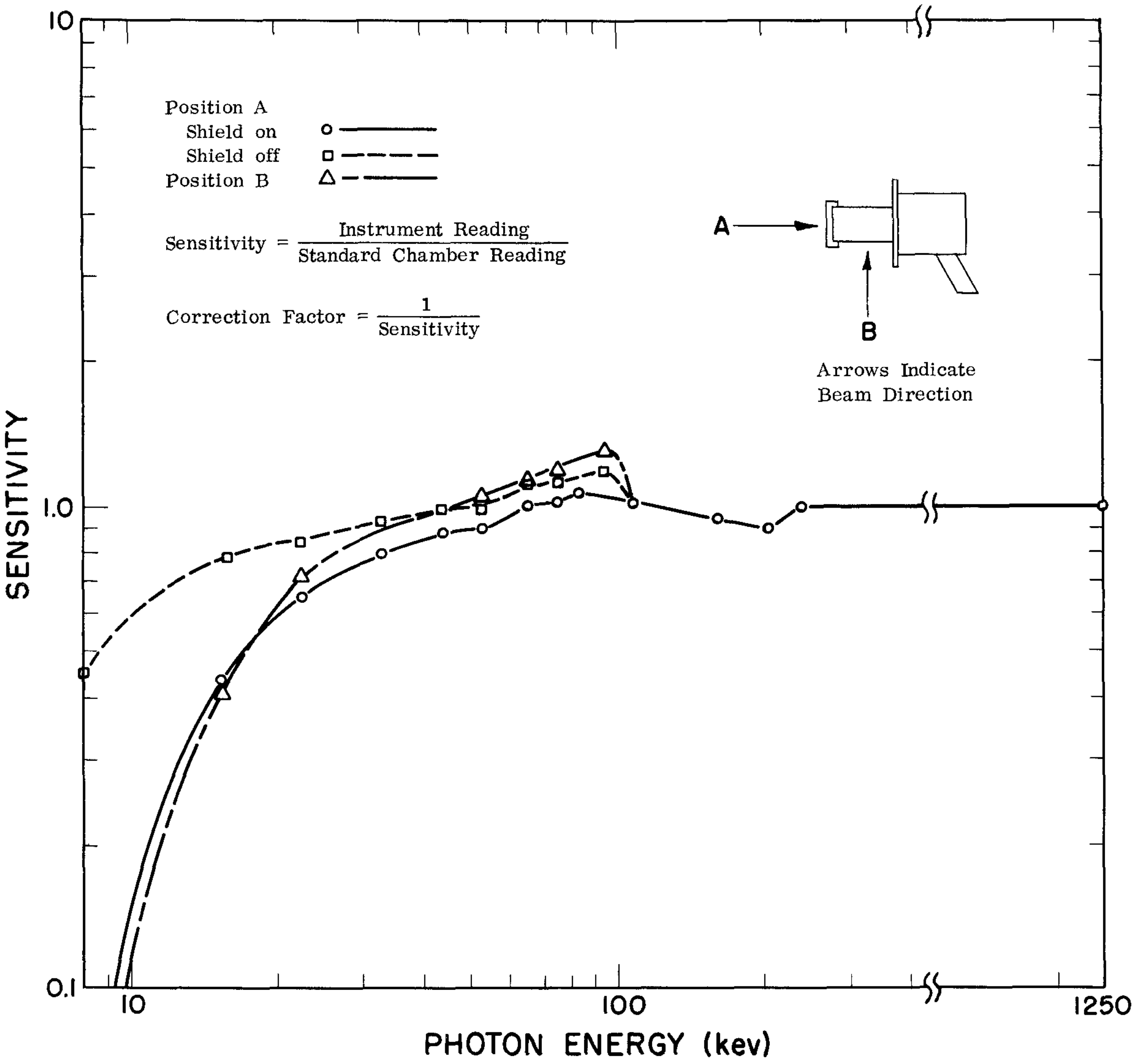

Fig. 1. Type N596, EKCO Electronics, Ltd.

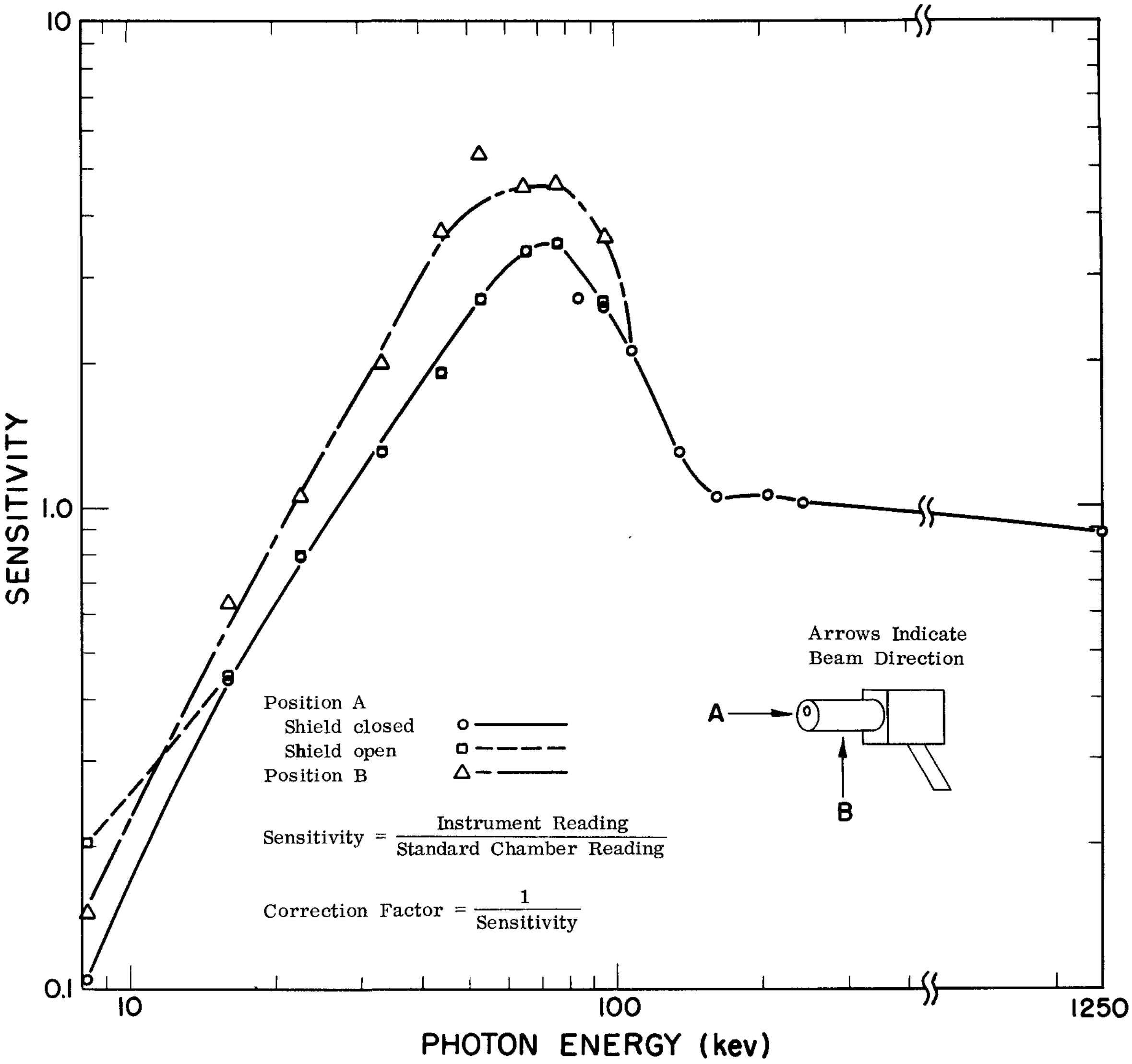

Fig. 2. Model SU-1B, Tracerlab, Inc.

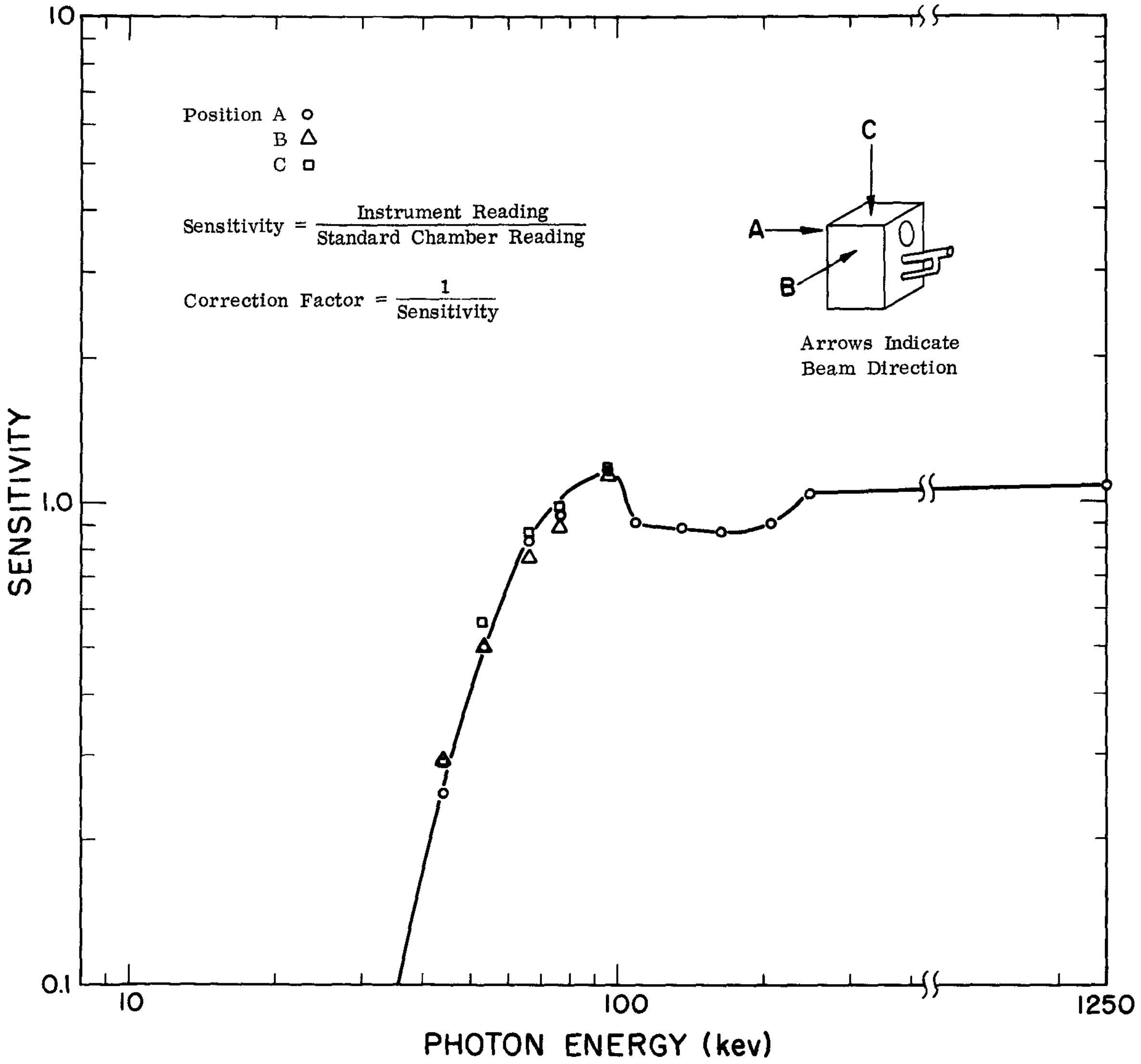

Fig. 3. Model SU-10 (AN/PDR T-1B), Tracerlab, Inc.

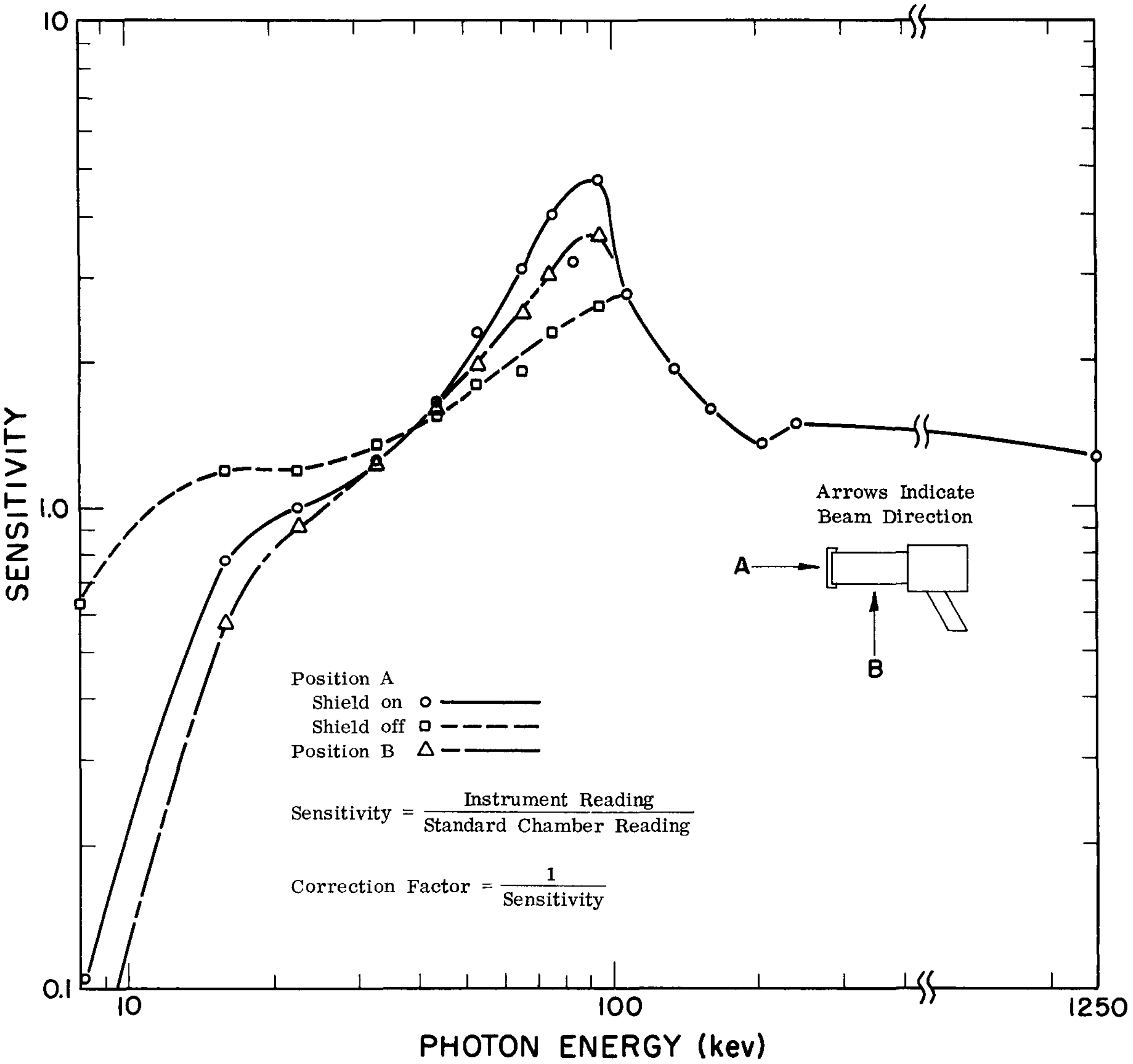

Fig. 4. Model 414, Baird-Atomic, Inc.

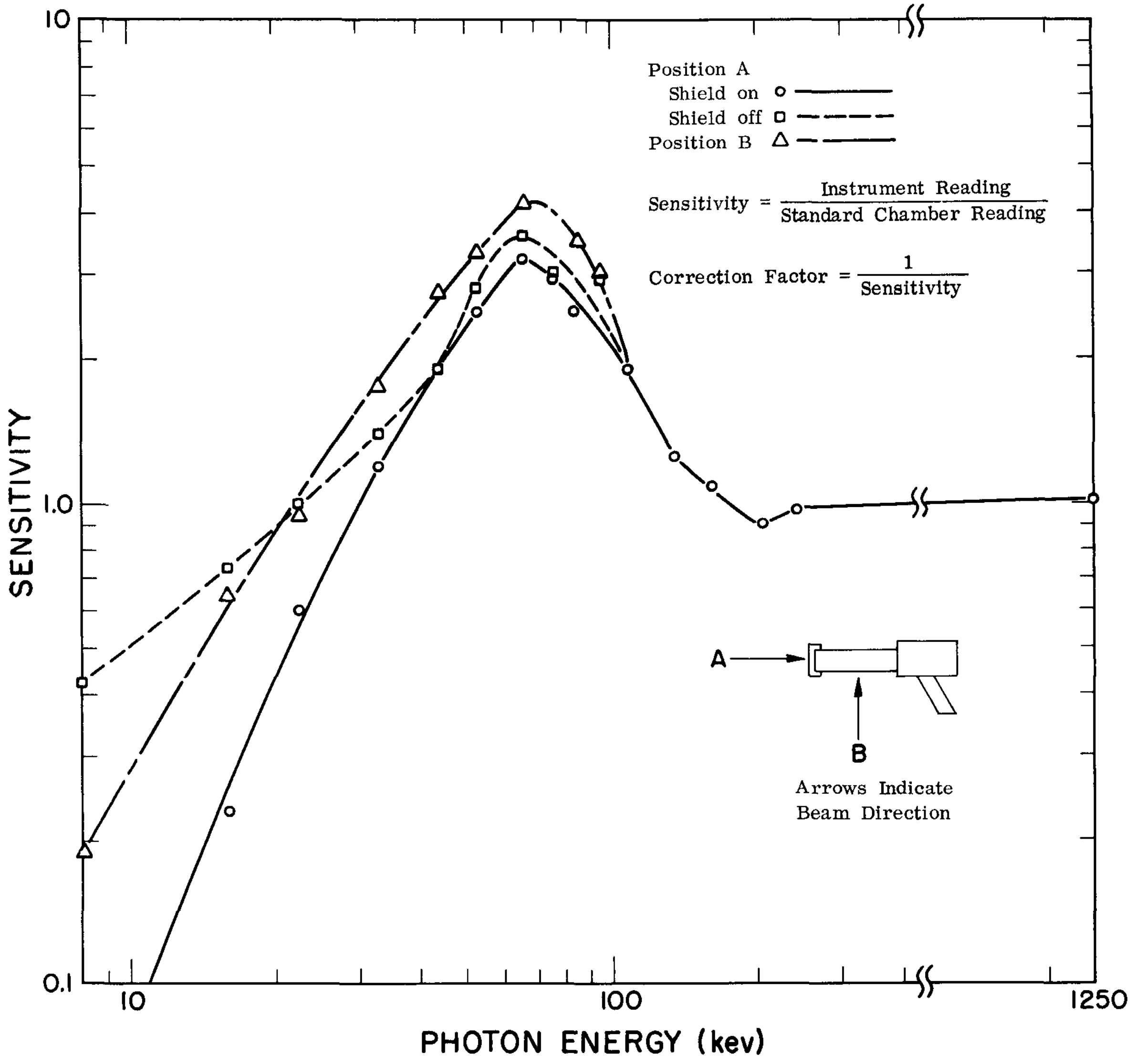

Fig. 5. Model D-1, Raychronix, Radioactive Products, Inc.

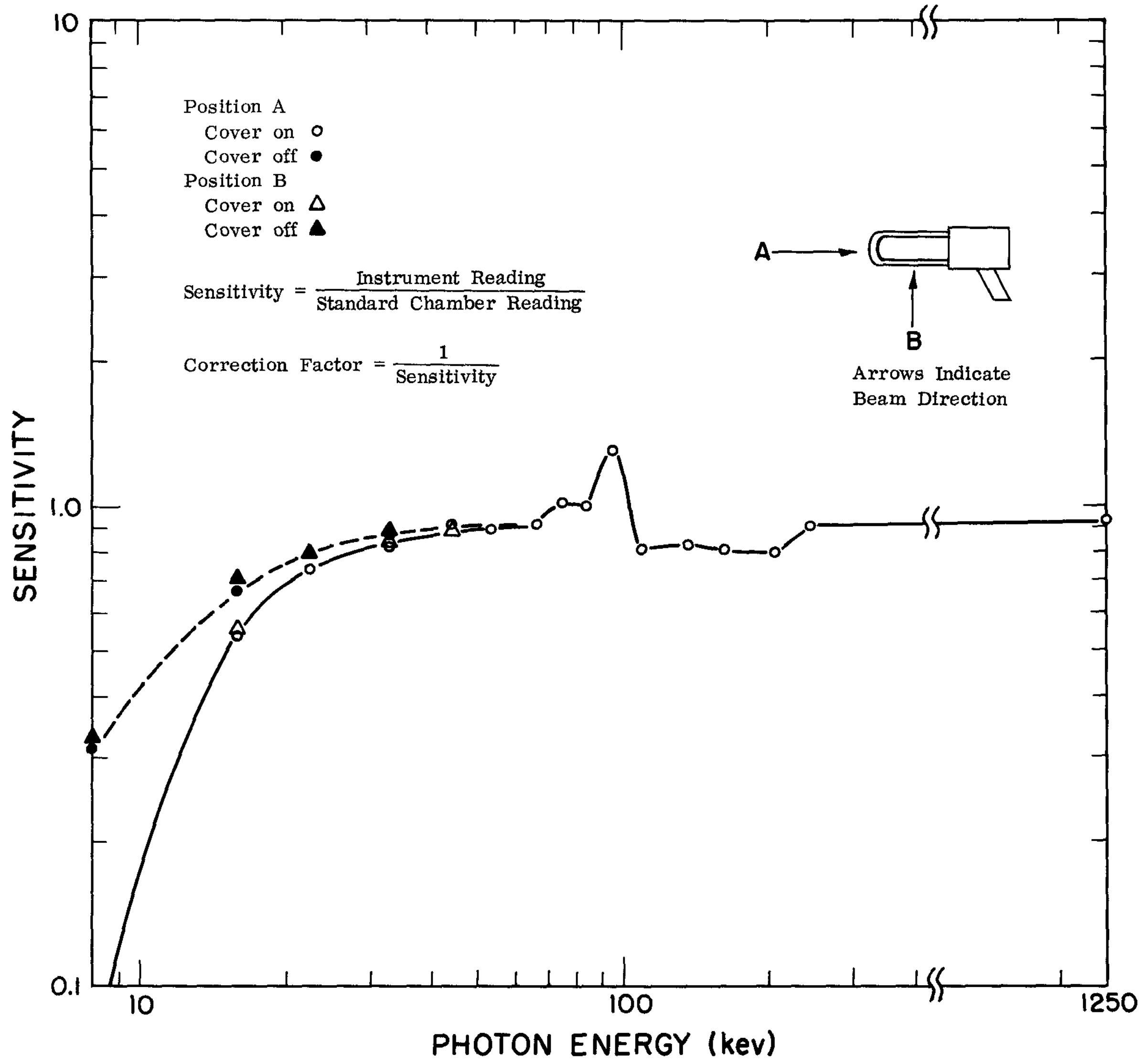

Fig. 6. Model CP3D, El Tronics, Inc.

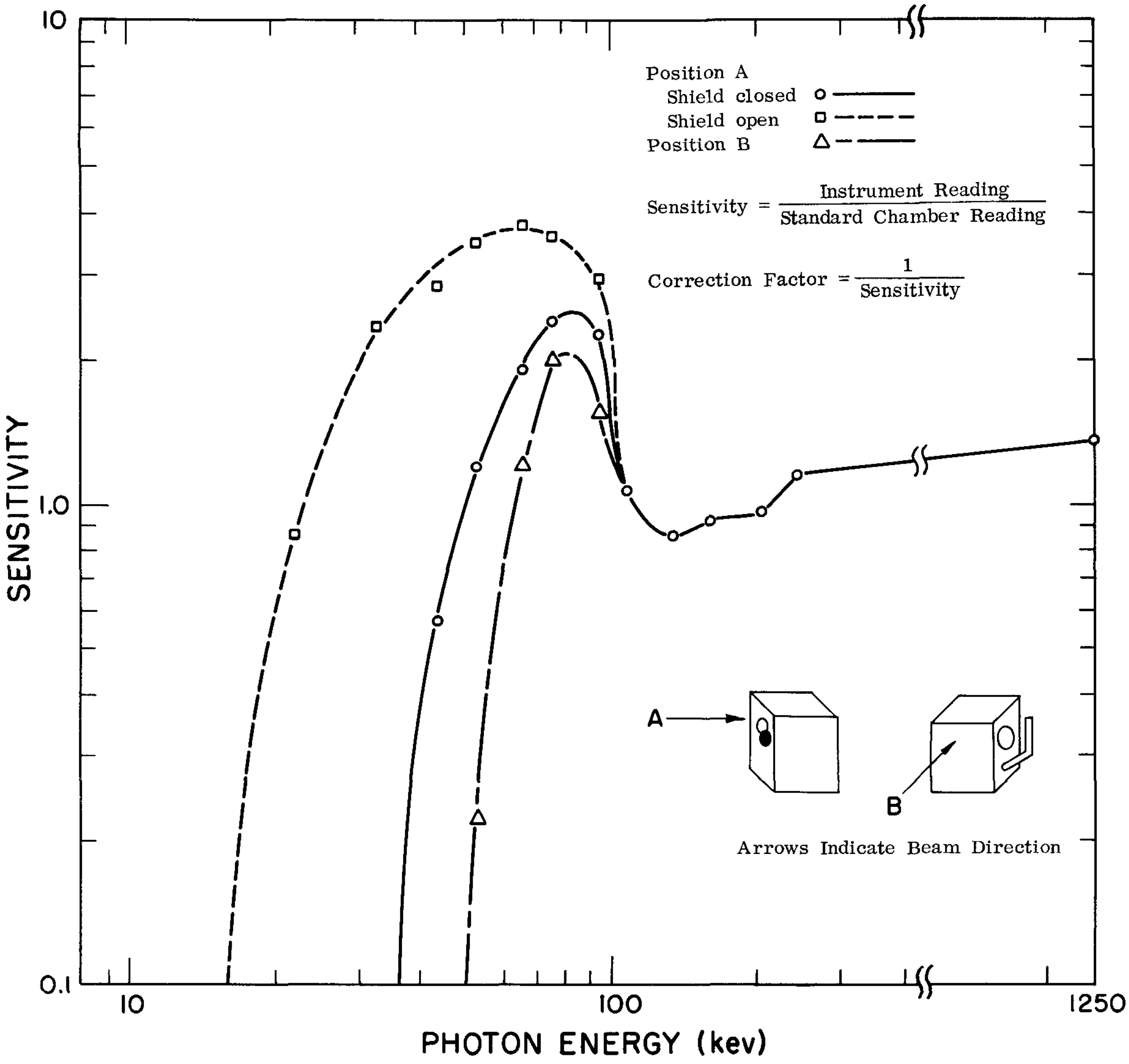

Fig. 7. Model AGB-50B-SR, The Victoreen Instrument Co.

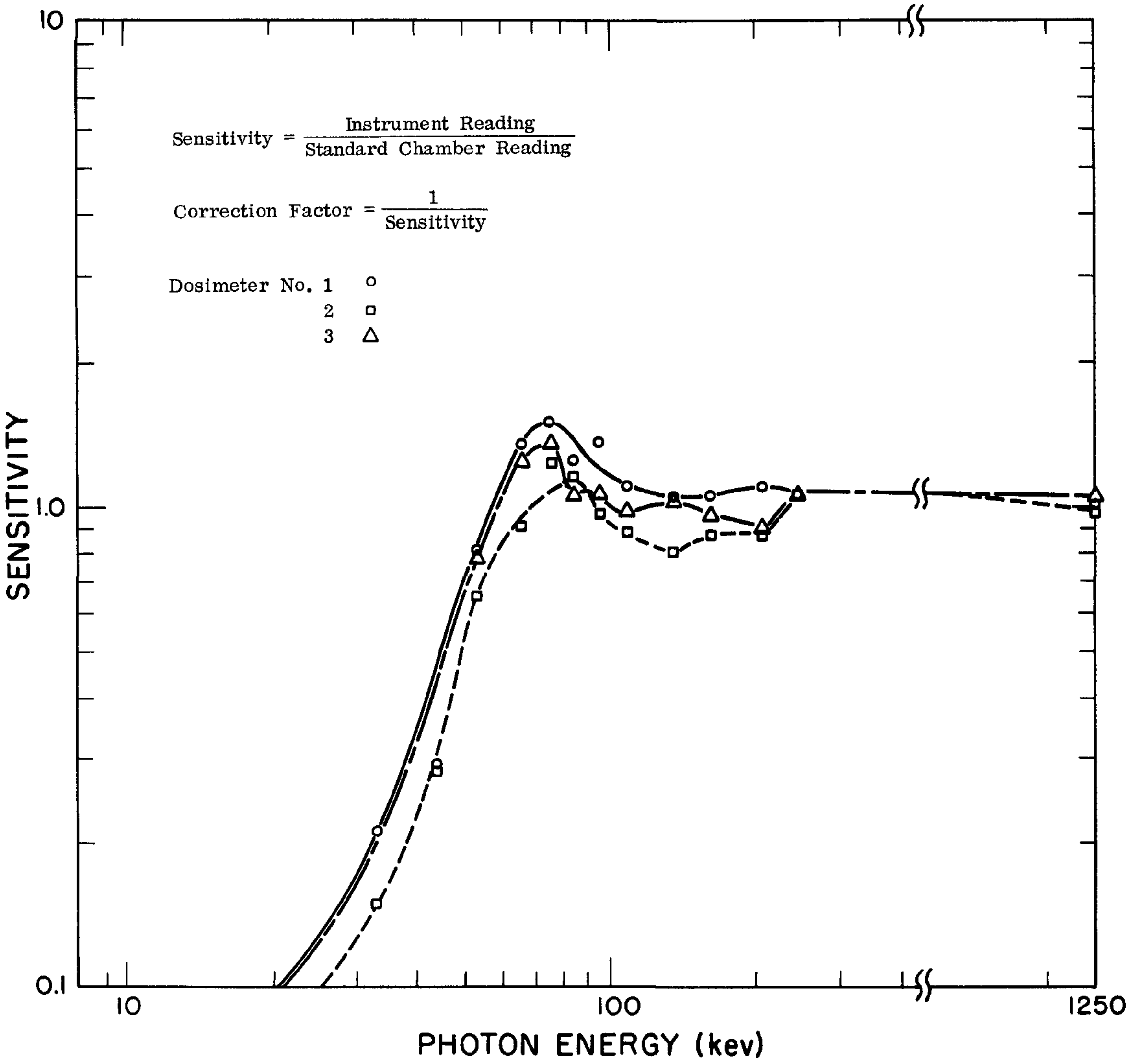

Fig. 8. Model 656/A (0.5 r direct-reading pocket dosimeter), The Victoreen Instrument Co.

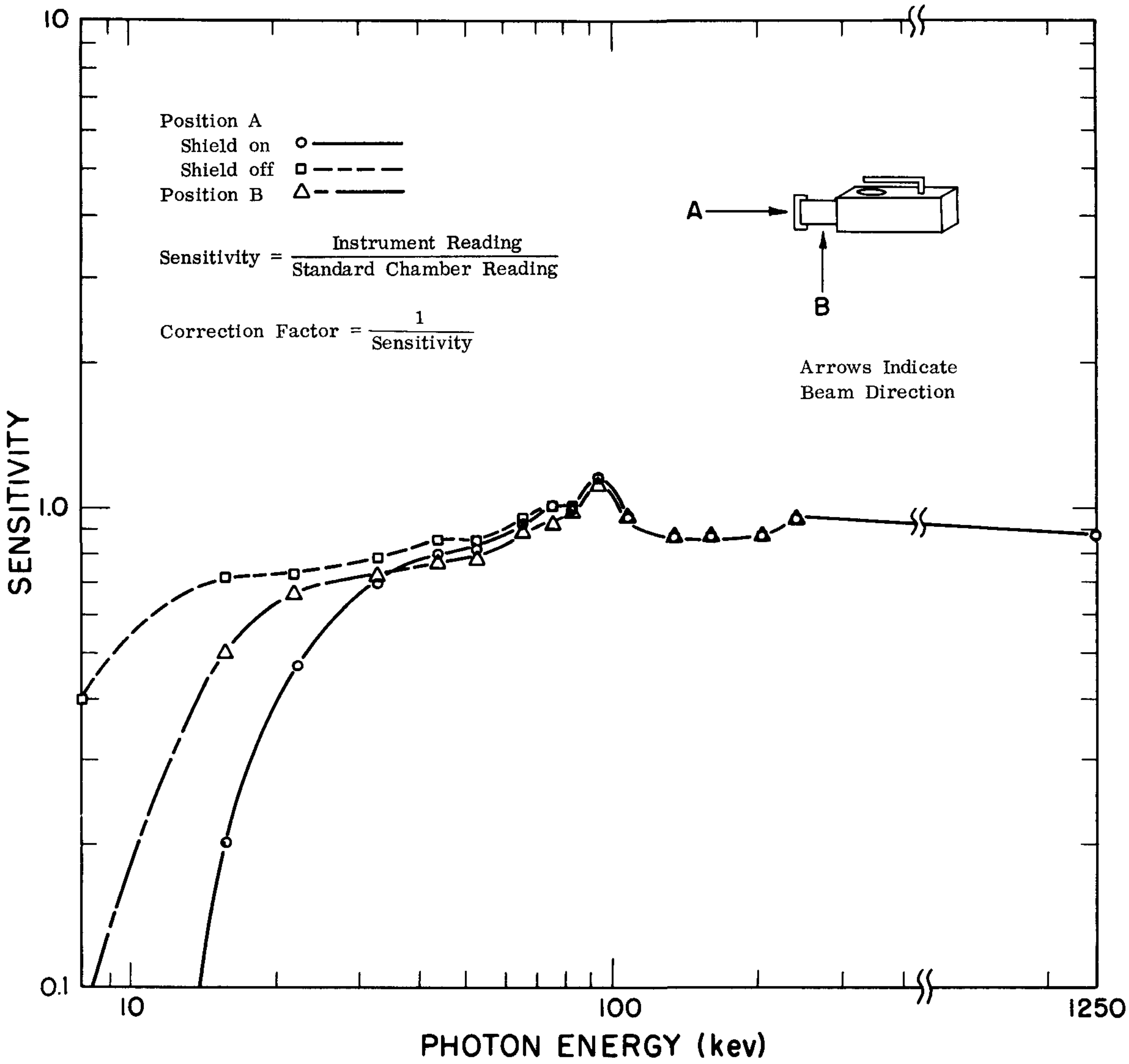

Fig. 9. Model 440, The Victoreen Instrument Co.

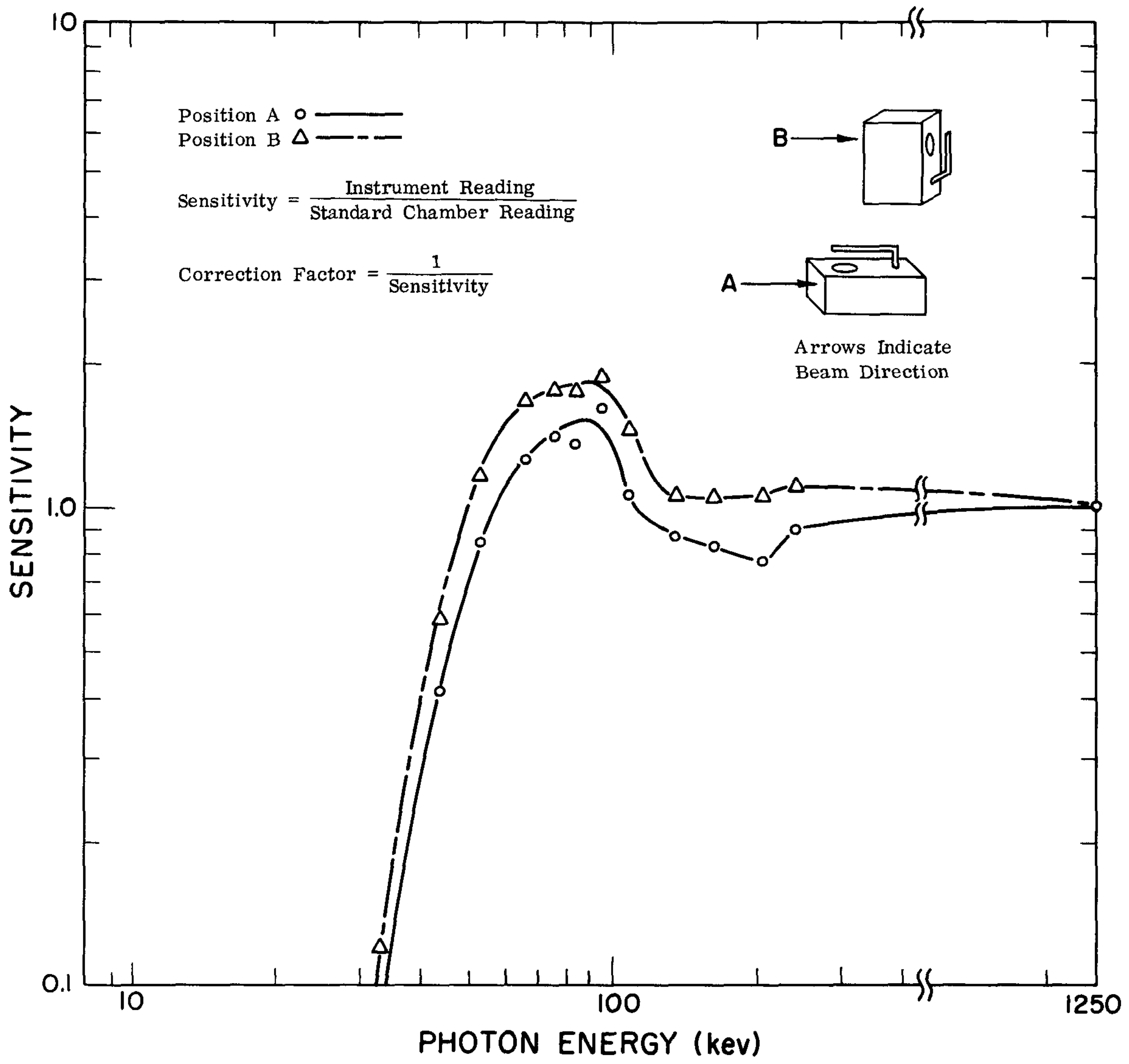

Fig. 10. Model 61720 (fallout detector), The Victoreen Instrument Co.

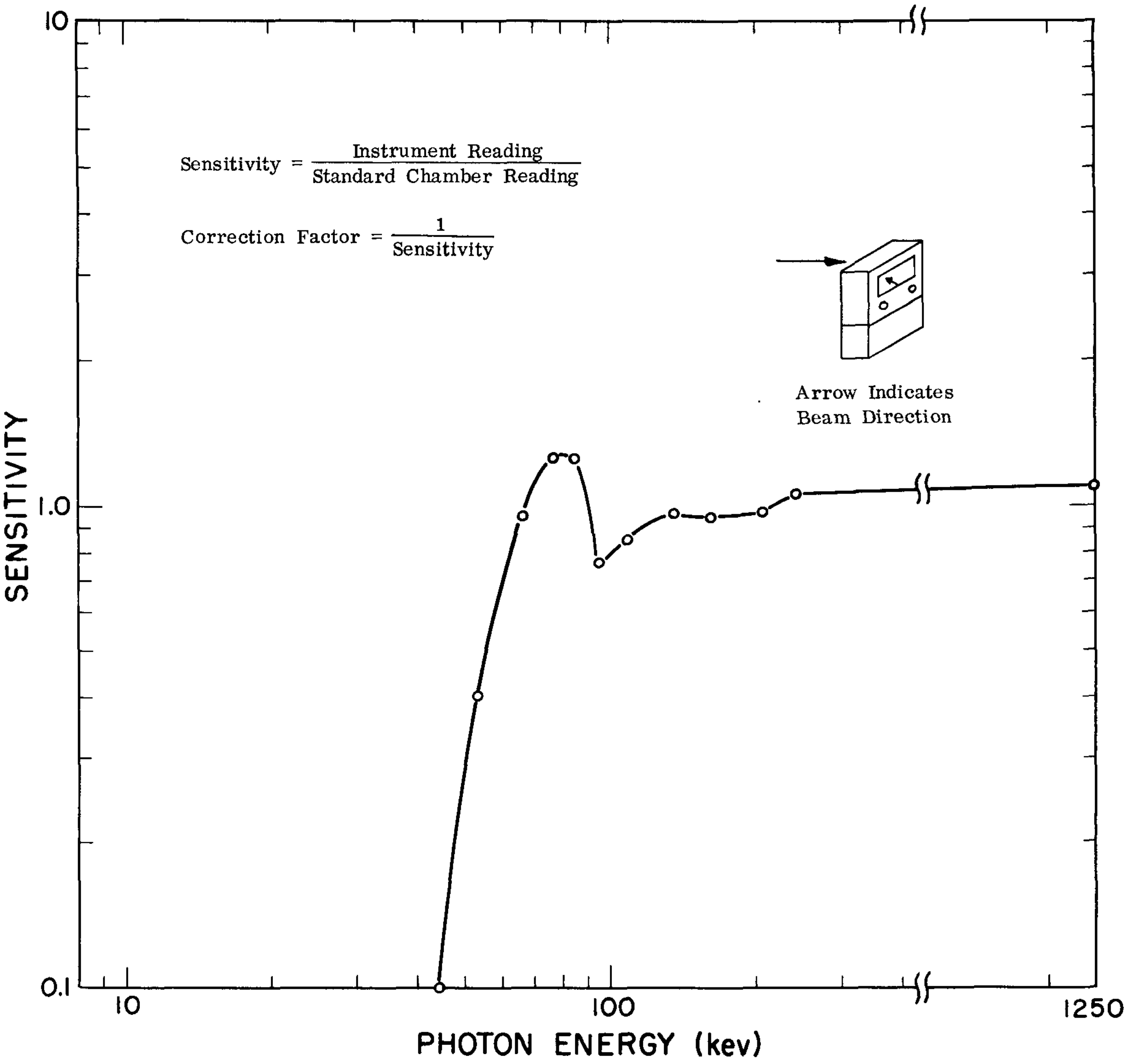

Fig. 11. Model M-100 (Minirad survey meter),
The Victoreen Instrument Co.

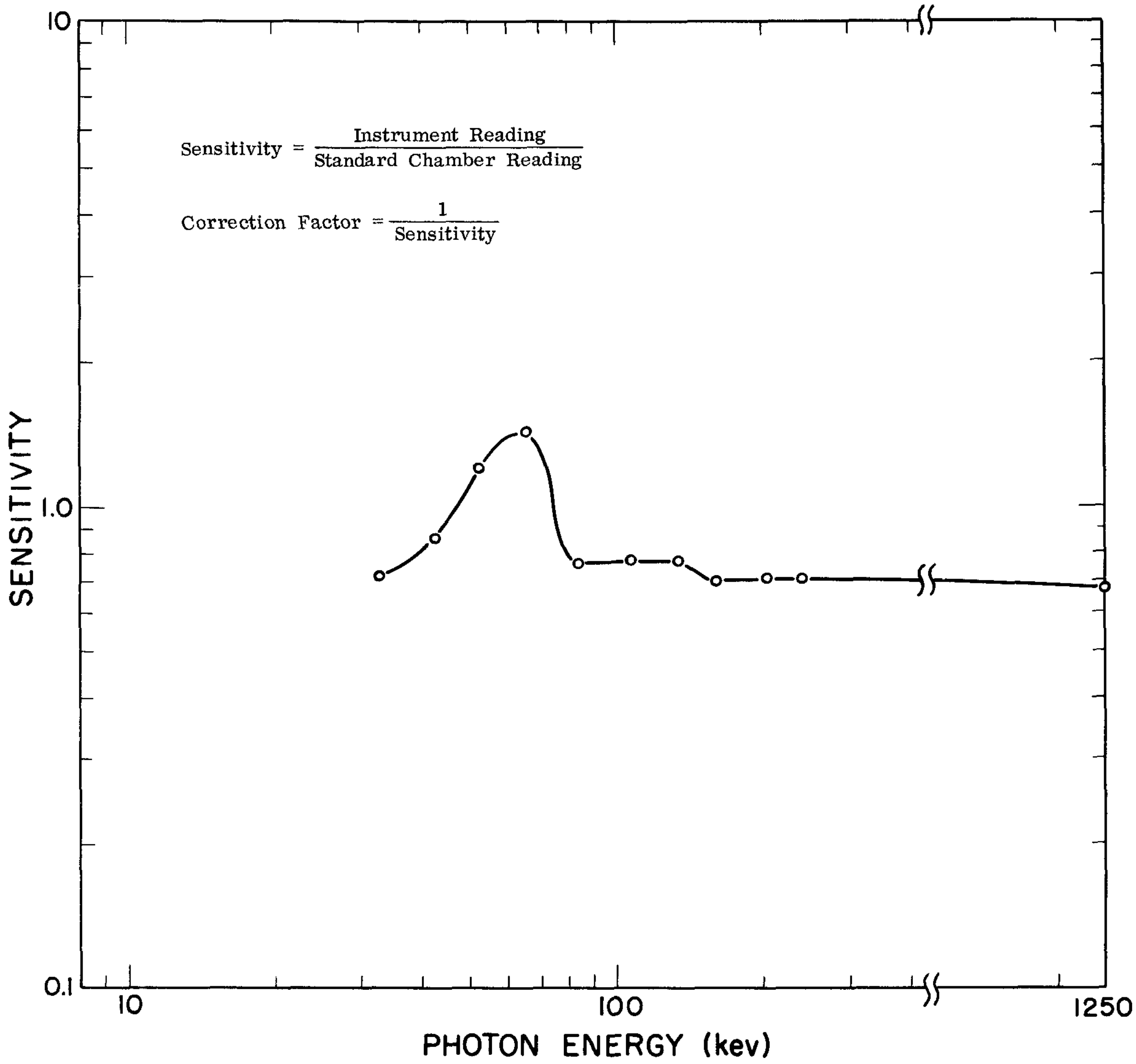

Fig. 12. Model CD V-736 (dosimeter ratemeter), The Bendix Corp.