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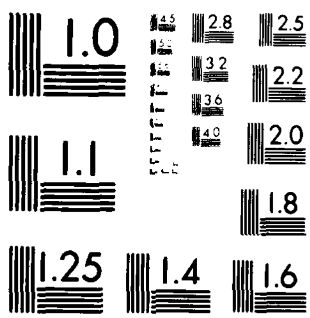

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USAF OEHL TECHNICAL REPORT

LEVEL II

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EVALUATION OF THE USAF RHL PIC-PRD, BENDIX 1200 MR, DCA 005, AND VICTOREEN 541L POCKET PERSONNEL RADIATION DOSIMETERS

MARCH 1980

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William E. Mabson

WILLIAM E. MABSON, Colonel, USAF, BSC
Commander

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(10) Karl L. Prado, William E. ..., Donald ..., Paul E. Love

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The energy and angular dependence exhibited by the Bendix 1200 MR, Victoreen 541L, DCA 005, and USAF PN 7545394 pocket ionization chamber low energy dosimeters has been evaluated. Chambers were exposed to x-rays of 9, 21, 42, 64, 84, 120, and 170 keV effective and their accuracy (measured/actual) computed. All radiations were delivered at 0^o, 45^o, 90^o, 135^o, and 180^o and their angular dependence (response at X^o relative to response at 90^o) reported.

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REPORT NO. 80-17

EVALUATION OF THE USAF RHL

PIC-PRD, BENDIX 1200 MR, DCA 005,

AND VICTOREEN 541L POCKET

PERSONNEL RADIATION DOSIMETERS

MARCH 1980

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I. INTRODUCTION

A. This Laboratory has evaluated the angular and energy dependence exhibited by the following pocket ionization chamber personnel radiation dosimeters:

1. Bendix Model 1200 MR, Serial Number 310; Bendix La Physiotechnique Category 6 Charger, Number 78.

2. Victoreen Model 541L, Serial Numbers 1583A and 1589A; Victoreen Dosimeter Charger Model 2000A, Serial Number 8528.

3. Dosimeter Corporation of America (DCA) Model 005, Serial Numbers 9070183 and 9070184; Victoreen Model 2000A, Serial Number 8528 Charger.

4. USAF Radiological Health Laboratory Pocket Ionization Chamber Personnel Radiation Dosimeter (PIC-PRD), Part Number 7545394 Serial Numbers 01, 02, Y1 and Y2. Part Number 7545406-10 charger reader.

The Bendix, Victoreen and DCA chambers are direct reading, low-energy dosimeters; the PIC-PRD chambers are indirect reading, low-energy dosimeters. All but the PIC-PRD have a range of 0-200 mR full scale. The PIC-PRD has a range of 0-400 mR full scale.

B. The PIC-PRD dosimeters contain a small amount of desiccant (moisture removing material) in the end cap. The PIC-PRD Serial Numbers 01 and 02 contained activated desiccant. Due to the fact that in many instances re-activation (drying) of the desiccant may not be possible in the field, the PIC-PRD Serial Numbers Y1 and Y2 were evaluated with moisture saturated desiccant.

C. The above-mentioned dosimeters were exposed to x-rays possessing effective energies of: 9, 21, 42, 64, 84, 120 and 170 keV effective. The characteristics of the irradiation techniques utilized in this evaluation are summarized in Table 1 (Atch 1). The exposures were delivered at 0^{o}, 45^{o}, 90^{o}, 135^{o} and 180^{o} to the central axis of the chamber as depicted in Atch 2. The exposures were measured at the geometric center of the chamber's sensitive volume.

D. Section II of this report describes the events which have led to this evaluation. In Section III the measurement and evaluation procedures and irradiation methods are discussed. The results of the evaluation are presented in Section IV and conclusions are reached and recommendations made in Section V.

II. BACKGROUND

A. For many years USAF Non-Destructive Inspection (NDI) radiographers used the IM-9 ionization chamber pocket dosimeter as a secondary personnel dosimeter to provide almost all real-time indication of occupational exposure. An evaluation of this dosimeter proved that the IM-9 exhibited very poor energy and directional dependence (reference USAF Radiological Health Laboratory (RHL) Technical Report 70W-36). Dosimeters that were commercially available at that time and were also evaluated faired no better than the IM-9.

B. In 1975, the USAF RHL designed and constructed a low energy, indirect reading pocket dosimeter (the PIC-PRD). This dosimeter is described in the USAF RHL Technical Report 75W-63. The PIC-PRD, which was designed to be an inexpensive, throw-away item requiring no calibration, was built to express better angular and energy dependence.

C. Numerous problems with the PIC-PRD dosimeter and its associated charger reader (Part Number 7545406) have surfaced since they became available for Air Force use:

1. Due to the fact that the dosimeter and the charger reader were fabricated independent of each other they were, in many instances, not compatible.

2. The charger reader exhibited problems with its charging mechanism.

3. Variations in dosimeter performance can be expected due to the fact that the dosimeters were "hand made".

4. The stock of PIC-PRD dosimeters is rather limited. Due to the fact that the dosimeter is not commercially available, it is only a question of time before the stock is depleted.

D. In order to bring this problem to the attention of responsible officials and to present data which may be germain to the decision-making process, this Laboratory has evaluated the PIC-PRD dosimeter and has compared its performance with that of other commercially available low-energy dosimeters.

III. PROCEDURES

A. All chambers were exposed to x-rays generated by a modified orthovoltage therapy unit operable between 20 and 250 kVcp. Effective x-ray energies were 9, 21, 42, 64, 84, 120, and 170 keV effective (Atch 1). The chambers were exposed at 0^o, 45^o, 90^o, 135^o, and 180^o from the incident radiation beam direction (Atch 2) for each of the above mentioned energy levels. The exposure rates varied between 64 MR/min and 475 MR/min due to limitations imposed by added x-ray filtration, attainable milliamperage and source to detector distance.

B. The exposure rate at all energies was determined using Victoreen Intercomparison Standard Ionization Chambers calibrated by the NBS. The Victoreen Model 415A, Serial Number 11, was used for techniques LFD and LFI, and the Victoreen Model 415B, Serial Number 111 was used for techniques MFG, MFI, MFK, HFG, and HFI.

C. The intercomparison standards were used in a charge collection mode; the ionization currents being integrated by a $1X10^{-9}$ Farad Reference Standard Capacitor, General Radio type 1404-A, Serial Number 583. The integrating capacitor was connected in the feedback loop of a Cary Model 471 Vibrating Reed Electrometer, Serial Number 1094, in series with a Keithley Precision Voltage Source, Model 660A, Serial Number 35454. Measurement was effected by manually nulling, with the precision voltage source, the voltage developed across the integrating capacitor.

D. The beam monitor for the x-ray source consisted of a locally fabricated transmission ionization chamber. The ionization currents produced were measured using the same technique as described above. The integration capacitor is of high quality 1% polystyrene specially processed type whose value is $1X10^{-7}$ Farad. The electrometer is a Victoreen Model 475A Dynamic Capacitor Electrometer, Serial Number 206 and the precision voltage source is a Fluke Model 341A, Serial Number 11505.

IV. RESULTS

A. The data obtained during the evaluation are presented in Attachments 3 through 11. In all instances the measured values represent the best estimate of the chamber reading which could be made by two investigators. The actual values were all measured with the Victoreen Intercomparison Standards.

B. Energy dependence was evaluated by plotting relative response (measured exposure divided by actual exposure) at 90° incident radiation (See Atch 2) as a function of photon effective energy. The data are presented in Attachments 12 and 13, and the graphs are contained in Attachments 14 through 18.

C. Angular dependence was evaluated at effective energies of 21, 64, and 120 keV. For the purpose of this report, the results obtained at these energy levels are representative of the angular response exhibited by the dosimeters at low, medium, and high energy x-rays. The data are contained in Attachments 19 through 21, and the graphs are presented in Attachments 22 through 25.

D. Results of Energy Dependence Evaluation:

1. The Bendix dosimeter exhibits a 25% variation in response to x-ray energies between 42 and 170 keV. Below 42 keV, the relative response drops to less than 0.1 at 21 keV and 0.0 at 9 keV (Atch 14).

2. The Victoreen dosimeters exhibit a $\pm$7% variation in response to x-ray energies between 42 and 170 keV. Below 42 keV, the relative response drops to approximately 0.7 at 21 keV and to 0.0 at 9 keV (Atch 15).

3. The DCA dosimeters exhibit a $\pm$5% variation in response between 42 and 170 keV. The relative response below 42 keV remains good being approximately 0.85 at 21 keV and approximately 0.60 at 9 keV (Atch 16).

4. The PIC-PRD dosimeters exhibit as much as 50% variation in response of energies between 42 and 170 keV. Below 42 keV, the relative response remains rather high at approximately 0.7 to 0.9 at 21 keV and at approximately 0.4 to 0.7 at 9 keV (Atchs 17 and 18).

E. Results of Angular Dependence Evaluation:

1. Essentially the Bendix, Victoreen, and DCA dosimeters exhibit the same angular dependence. The relative response drops considerably at 0° and 180°. This is to be expected due to the fact that these dosimeters are direct reading and, therefore, contain non-air equivalent materials at the ends. The Bendix dosimeter exhibits practically no angular dependence between 45° and 135° (Atch 22). The Victoreen dosimeters' response between 45° and 135°

varies between 10% at 21 and 120 keV and 20% at 64 keV (Atch 23). The DCA dosimeters exhibit a variation of approximately 10% at 64 and 120 keV, and of 30% at 21 keV between 45° and 135° (Atch 24).

2. The PIC-PRD dosimeters' response variation between 45° and 135° is approximately 5% at 120 keV, practically 0% at 64 keV, and 20% at 21 keV. The response at 0° and 180° when compared to that at 90° is approximately 80% at all three x-ray energies. Again, this increased sensitivity at 0° and 180° is due to the fact that the PIC-PRD, being an indirect reading dosimeter, contains almost air equivalent materials at the ends.

V. CONCLUSIONS AND RECOMMENDATIONS

A. The PIC-PRD dosimeters do not represent an improvement over low-energy dosimeters which are currently commercially available as far as energy dependence is concerned. The fact is, both the Victoreen and DCA dosimeters exhibit less energy dependence than do the PIC-PRD dosimeters.

B. In terms of angular dependence, the PIC-PRD faired better than the rest. It is important to note, however, that the PIC-PRD dosimeter is an <u>indirect</u> reading dosimeter whereas the remaining dosimeters are <u>direct reading</u> type. Unfortunately, commercially available indirect <u>reading</u> dosimeters were not evaluated at this time, therefore, a comparison cannot be made in this respect.

C. In terms of cost, the PIC-PRD is by far the least expensive of all the dosimeters evaluated. This is because: first, direct reading dosimeters are basically more expensive than indirect reading dosimeters; second, the PIC-PRD was fabricated in-house. However, being that the PIC-PRD was designed as an inexpensive item to be discarded upon poor performance, there is a good reason to suspect that the present stock of PIC-PRD dosimeters will be depleted rather rapidly.

D. Although the evaluation of the PIC-PRD dosimeters did not demonstrate gross differences in response it should be noted that 30% differences were encountered PIC-PRD Serial Number 01 verses Serial Number Y2 at 42 keV, 90° and even greater differences could be expected. The differences observed by these investigators were exhibited primarily by activated-desiccant compared to saturated-desiccant dosimeters.

E. In view of the above mentioned problems it is the opinion of these evaluators that a substitute for the PIC-PRD will soon be required. Very acceptable possible replacements are available commercially. The best of the dosimeters we evaluated was the DCA Model 005. Another possible replacement is the low-range (0-200 MR) dosimeter currently being developed by the Federal Emergency Management Agency, FEMA, (formerly Civil Defense Agency) in conjunction with the Department of the Navy. Production of the FEMA dosimeter was scheduled to begin this year.

25 Attachments

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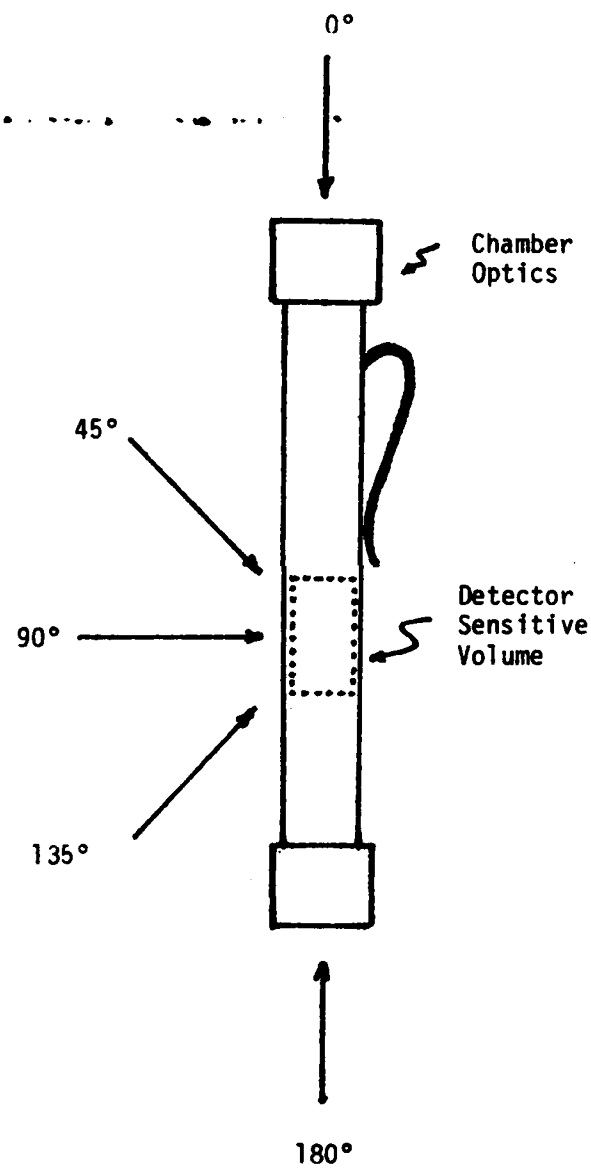
USAF OEHL IRRADIATION TECHNIQUES

TECHNIQUE	KVCP	TOTAL FILTRATION	1st HVL (mm Al)	HOMOGENEITY COEFFICIENT	EFFECTIVE ENERGY
LFD	20	1 mm Be	.078	0.70	9 keV
LFI	50	1 mm Be 1 mm Al	1.03	0.63	21 keV
MFG	100	5 mm Al	4.50	0.76	42 keV
MFI	150	5 mm Al 0.25 mm Cu	9.40	0.81	64 keV
MFK	200	5 mm Al 0.5 mm Cu	12.7	0.95	84 keV
HFG	150	4 mm Al 4 mm Cu 1.5 mm Sn	16.9	N/A	120 keV
HFI	200	4 mm Al 0.6 mm Cu 4 mm Sn 0.7 mm Pb	19.6	N/A	170 keV



Angular Dependence Geometry

Pocket Chambers

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: Bendix Dosimeter SN. 310 DATE: FEB 8[illegible]

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0°	45°	90°	135°	180°
LFD (9 keV)	measured (mr/hr)		78	112	100	0
	actual (mr/hr)		150	150	150	150
LFI (21 keV)	measured (mr/hr)		145	160	155	[illegible]
	actual (mr/hr)		150	150	150	150
MFG (42 keV)	measured (mr/hr)	0	151	156	158	30
	actual (actual)	152	150.1	146.4	149.1	151.2
MFI (64 keV)	measured (mr/hr)	22	171	175	172	50
	actual (mr/hr)	152.2	153.9	151.7	152.4	153.[illegible]
MFK (84 keV	measured (mr/hr)	30	174	180	180	60
	actual (mr/hr	151.8	150.4	150.2	150.2	149.[illegible]
HFG (120 keV)	measured (mr/hr)	42	186	195	191	85
	actual (mr/hr)	148.9	147.9	148	150.1	150.5
HFI (170 keV)	measured (mr/hr)	52	181	185	182	95
	actual (mr/hr)	149.7	149	148.7	151.5	150.2

Atch 3

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: VICTOREEN SN. 1583 A DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0^{o}	45^{o}	90^{o}	135^{o}	180^{o}
LFD (9 keV)	measured (mr/hr)		0	0	18	12
	actual (mr/hr)		150	150	150	150
LFI (21 keV)	measured (mr/hr)		90	110	100	[illegible]
	actual (mr/hr)		150	150	150	150
MFG (42 keV)	measured (mr/hr)	22	152	142	122	22
	actual (actual)	151.1	148	146	148.7	150.5
MFI (64 keV)	measured (mr/hr)	28	151	160	158	OFF SCALE
	actual (mr/hr)	152.3	151.5	153.9	152.8	147.2
MFK (84 keV	measured (mr/hr)	36	151	152	139	32
	actual (mr/hr	150.2	149.1	148	150.4	149.5
HFG (120 keV)	measured (mr/hr)	31	160	152	140	38
	actual (mr/hr)	148.5	148.4	147.2	150	149.9
HFI (170 keV)	measured (mr/hr)	40	136	145	134	39
	actual (mr/hr)	149.3	149.2	148.5	151	150.5

Atch 4

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: VICTOREEN SN. 1589A DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0°	45°	90°	135°	180°
LFD (9 keV)	measured (mr/hr)		2	0	9	9
	actual (mr/hr)		150	150	150	150
LFI (21 keV)	measured (mr/hr)		85	95	90	9
	actual (mr/hr)		150	150	150	150
MFG (42 keV)	measured (mr/hr)	18	128	125	107	29
	actual (actual)	151.1	148	146	148.7	150.5
MFI (64 keV)	measured (mr/hr)	30	130	135	134	25
	actual (mr/hr)	152.3	151.5	150	152.8	147.2
MFK (84 keV	measured (mr/hr)	35	130	130	118	30
	actual (mr/hr	150.2	149.1	148	150.4	149.5
HFG (120 keV)	measured (mr/hr)	40	148	140	137	35
	actual (mr/hr)	148.5	148.4	147.2	150	149.9
HFI (170 keV)	measured (mr/hr)	40	109	110	102	40
	actual (mr/hr)	149.3	149.2	148.5	151	150.5

Atch 5

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: DCA SN. 000 DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0^0	45^0	90^0	135^0	180^0
LFD (9 keV)	measured (mr/hr)		118	219	196	0
	actual (mr/hr)		400	400	400	400
LFI (21 keV)	measured (mr/hr)	30	250	335	330	19
	actual (mr/hr)	400	400	400	400	400
MFG (42 keV)	measured (mr/hr)	OFF SCALE	360	392	350	70
	actual (actual)	398.7	391.7	396.5	402	401.5
MFI (64 keV)	measured (mr/hr)	38	401	400	386	40
	actual (mr/hr)	404.4	404.7	397.1	403.3	394.5
MFK (84 keV	measured (mr/hr)	60	400	400	386	121
	actual (mr/hr	400.5	398.7	399.5	400	400
HFG (120 keV)	measured (mr/hr)	110	390	379	400	178
	actual (mr/hr)	398	397.2	396.9	400	399.7
HFI (170 keV)	measured (mr/hr)	120	362	360	370	OFF SCALE
	actual (mr/hr)	397.1	396	396.3	399.8	398.8

Atch 6

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: DCA SN. 001 DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0°	45°	90°	135°	180°
LFD (9 keV)	measured (mr/hr)		110	182	161	10
	actual (mr/hr)		400	400	400	400
LFI (21 keV)	measured (mr/hr)	20	230	350	340	12
	actual (mr/hr)	400	400	400	400	400
MFG (42 keV)	measured (mr/hr)	36	362	384	320	76
	actual (actual)	398.7	391.7	396.5	402	401.5
MFI (64 keV)	measured (mr/hr)	58	402	402	370	59
	actual (mr/hr)	404.4	404.7	397.1	403.3	394.5
MFK (84 keV	measured (mr/hr)	74	400	400	378	121
	actual (mr/hr	400.5	398.7	399.5	400	400
HFG (120 keV)	measured (mr/hr)	110	438	402	390	160
	actual (mr/hr)	398	397.2	396.9	400	399.7
HFI (170 keV)	measured (mr/hr)	122	284	330	322	160
	actual (mr/hr)	397.1	396	396.3	399.8	398.8

Atch 7

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: PIC-PRD SN. 01 DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0^0	45^0	90^0	135^0	180^0
LFD (9 keV)	measured (mr/hr)		100	158	120	120
	actual (mr/hr)		300	300	300	300
LFI (21 keV)	measured (mr/hr)		270	200	230	160
	actual (mr/hr)		300	300	300	300
MFG (42 keV)	measured (mr/hr)	320	322	339	330	239
	actual (actual)	302.9	301.4	298.6	292.9	302.2
MFI (64 keV)	measured (mr/hr)	270	360	346	350	262
	actual (mr/hr)	304.8	303.4	302.5	304.5	300.5
MFK (84 keV	measured (mr/hr)	284	354	330	348	260
	actual (mr/hr	303.9	301.5	301.4	301.8	300.8
HFG (120 keV)	measured (mr/hr)	298	359	379	376	300
	actual (mr/hr)	297.5	296.9	296.3	300.6	300.4
HFI (170 keV)	measured (mr/hr)	252	342	359	342	298
	actual (mr/hr)	297.7	297.5	296.8	301.2	299.9

Atch 8

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: PIC-PRD SN. 02 DATE: FEB 8[illegible]

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0^o	45^o	90^o	135^o	180^o
LFD (9 keV)	measured (mr/hr)		120	138	120	140
	actual (mr/hr)		300	300	300	300
LFI (21 keV)	measured (mr/hr)		260	220	238	178
	actual (mr/hr)		300	300	300	300
MFG (42 keV)	measured (mr/hr)	242	298	300	288	210
	actual (actual)	302.9	301.4	298.6	292.9	302.2
MFI (64 keV)	measured (mr/hr)	256	326	318	319	242
	actual (mr/hr)	304.8	303.4	302.5	304.5	300.5
MFK (84 keV	measured (mr/hr)	262	322	350	321	252
	actual (mr/hr	303.9	301.5	301.5	301.8	300.8
HFG (120 keV)	measured (mr/hr)	318	390	378	368	302
	actual (mr/hr)	297.5	296.9	296.3	300.6	300.4
HFI (170 keV)	measured (mr/hr)	239	278	290	290	248
	actual (mr/hr)	297.7	297.5	296.8	301.2	300

Atch 9

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: PIC-PRD SN. Y1 DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0°	45°	90°	135°	180°
LFD (9 keV)	measured (mr/hr)		120	118	140	186
	actual (mr/hr)		300	300	300	300
LFI (21 keV)	measured (mr/hr)	210	260	280	270	200
	actual (mr/hr)	300	300	300	300	300
MFG (42 keV)	measured (mr/hr)	260	330	320	320	242
	actual (actual)	296.4	302.4	299.2	299	302.8
MFI (64 keV)	measured (mr/hr)	278	366	358	350	270
	actual (mr/hr)	305.5	304.9	302.4	300	299.6
MFK (84 keV	measured (mr/hr)	310	360	361	359	298
	actual (mr/hr	303.5	302	302.1	301.9	300.9
HFG (120 keV)	measured (mr/hr)	312	260	390	400	330
	actual (mr/hr)	297.5	297.3	295.8	299.8	300
HFI (170 keV)	measured (mr/hr)	330	381	379	390	318
	actual (mr/hr)	297.4	297.1	297.1	300.8	299.9

USAF OEHL/RZE

INSTRUMENT EVALUATION

INSTRUMENT: PIC-PRD SN. Y 2 DATE: FEB 80

RADIATION ENERGY		ANGLE OF INCIDENT RADIATION BEAM				
TECHNIQUE (keV Eff)	MEAS/ACT.	0^{0}	45^{0}	90^{0}	135^{0}	180^{0}
LFD (9 keV)	measured (mr/hr)		200	208	210	120
	actual (mr/hr)		300	300	300	300
LFI (21 keV)	measured (mr/hr)	190	290	240	250	200
	actual (mr/hr)	300	300	300	300	300
MFG (42 keV)	measured (mr/hr)	248	316	318	304	222
	actual (actual)	296.4	302.4	299.2	299	302.8
MFI (64 keV)	measured (mr/hr)	250	339	320	319	244
	actual (mr/hr)	305.5	304.9	302.4	300.1	299.6
MFK (84 keV	measured (mr/hr)	290	321	339	341	259
	actual (mr/hr	303.5	302	302.1	301.9	300.9
HFG (120 keV)	measured (mr/hr)	340	370	378	370	300
	actual (mr/hr)	297.5	297.3	295.8	299.8	300
HFI (170 keV)	measured (mr/hr)	238	298	298	310	258
	actual (mr/hr)	297.2	297.1	297.1	300.8	299.9

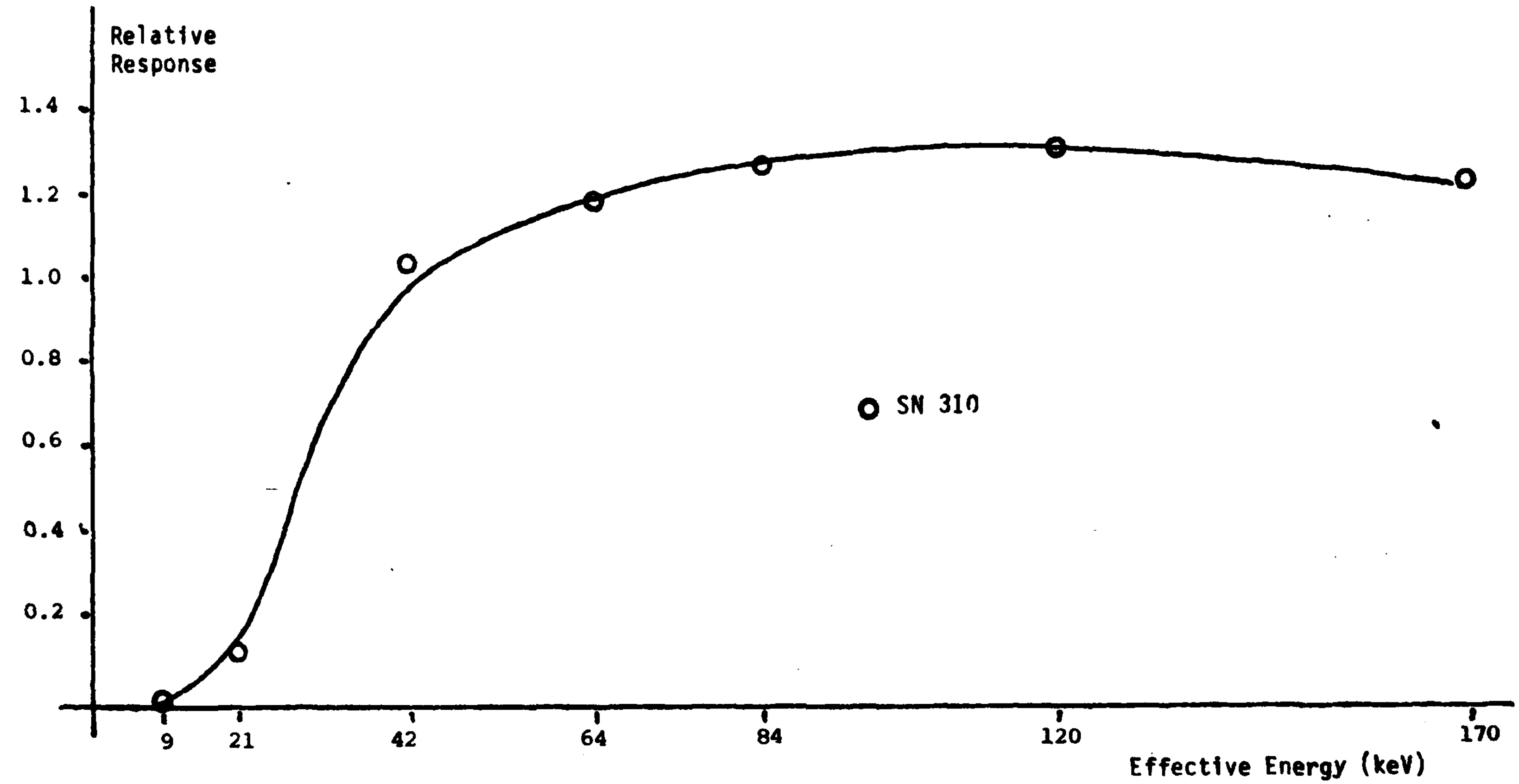
Relative Response (Measured/Actual)

		Bendix 310	Vic 1583A	Vic 1589A	DCA 000	DCA 001
		90°	90°	90°	90°	90°
LFD (9 keV)		0	0	0	0.55	0.66
LFI (21 keV)		0.06	0.73	0.63	0.84	0.88
MFG (42 keV)		1.07	.97	.86	0.99	0.97
MFI (64 keV)		1.15	1.04	.89	1.01	1.01
MFK (84 keV)		1.20	1.03	.88	1.00	1.00
HFG (120 keV)		1.32	1.03	0.95	0.95	1.01
HFI (170 keV)		1.24	0.98	0.74	0.91	0.83

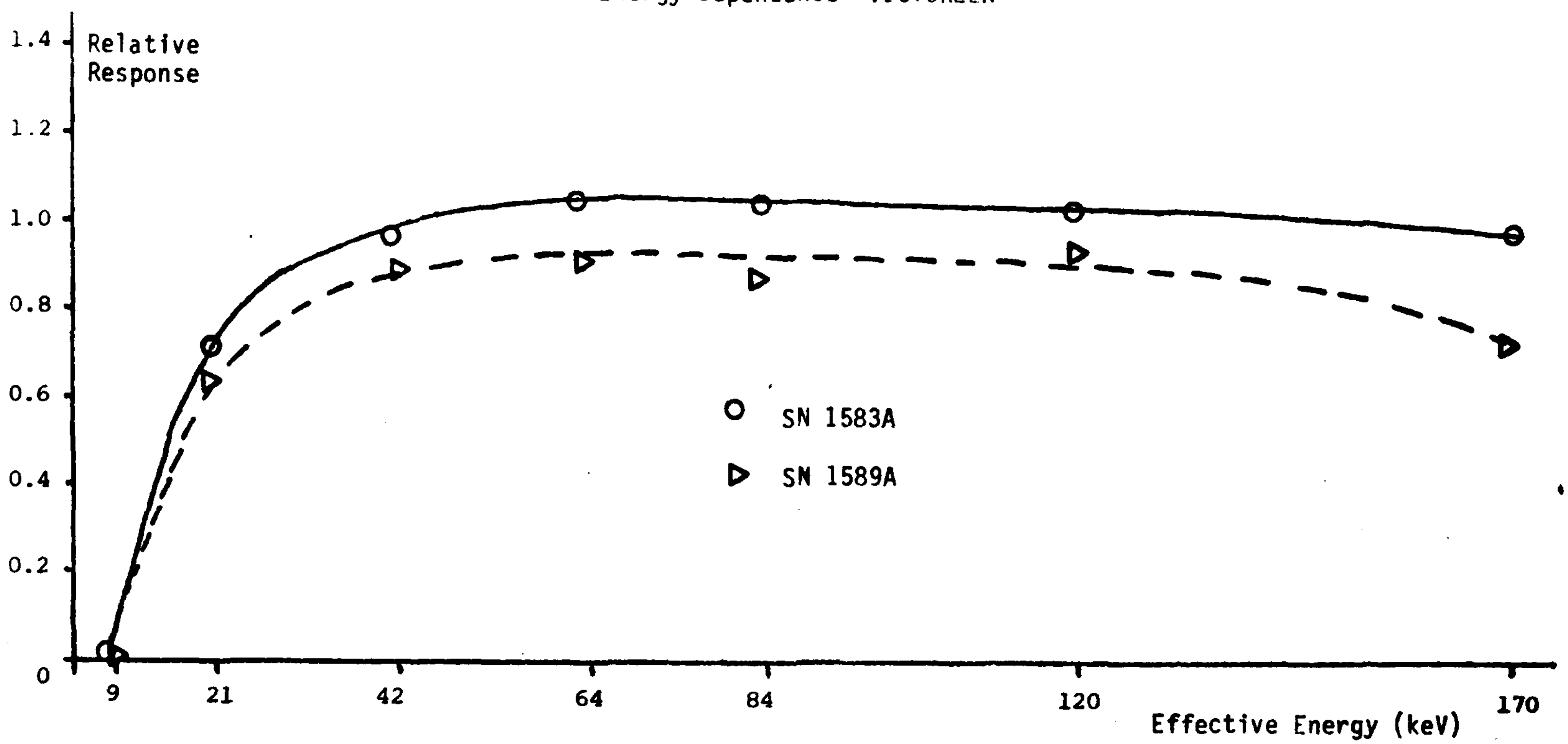
Relative Response (Measured/Actual)

		Pic-Prd 01	Pic-Prd 02	Pic-Prd Y1	Pic-Prd Y2	
		90°	90°	90°	90°	
LFD (9 keV)		0.53	0.46	0.39	0.69	
LFI (21 keV)		0.67	0.73	0.93	0.80	
MFG (42 keV)		1.14	1.00	1.07	1.06	
MFI (64 keV)		1.14	1.05	1.18	1.06	
MFK (84 keV)		1.09	1.16	1.19	1.12	
HFG (120 keV)		1.28	1.28	1.32	1.28	
HFI (170 keV)		1.21	0.98	1.28	1.00	

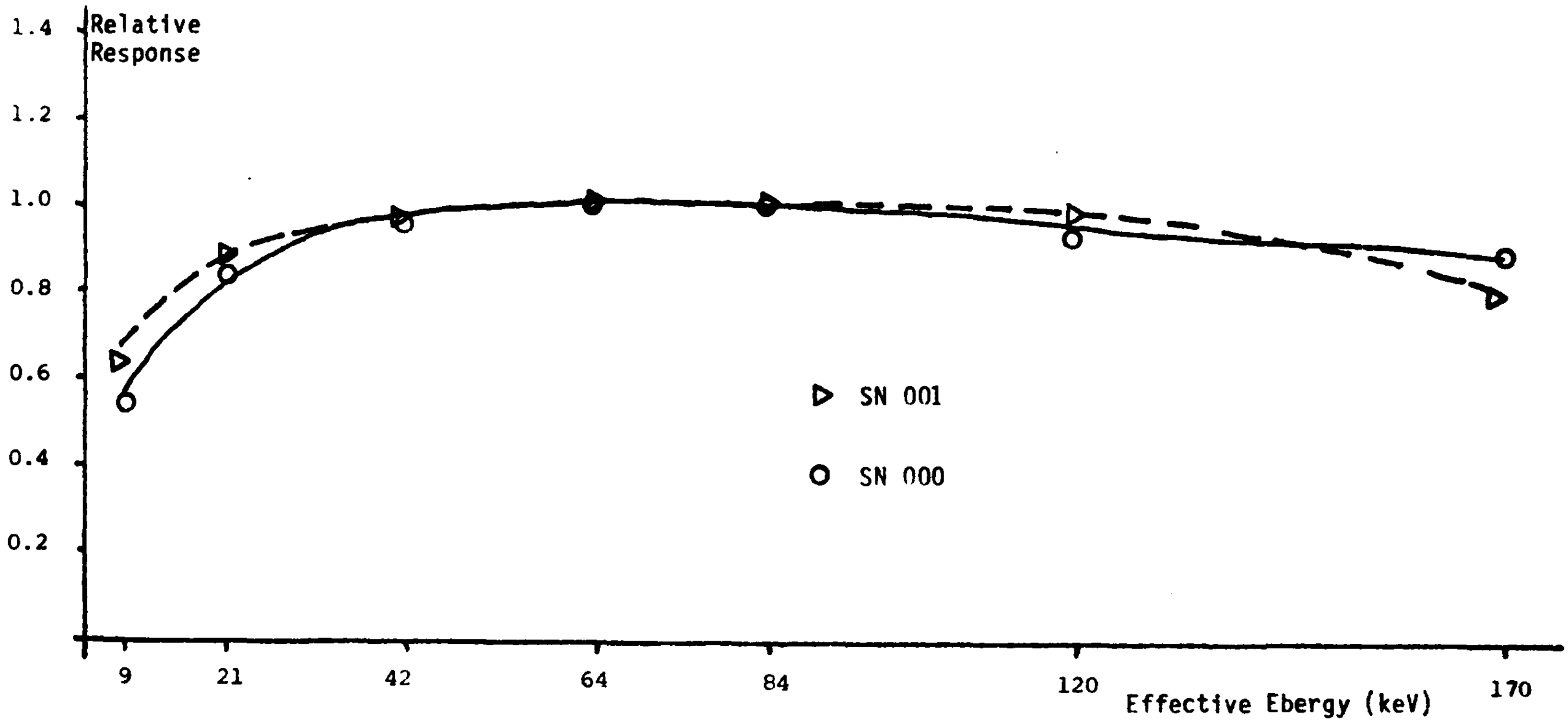
Energy Dependence BENDIX



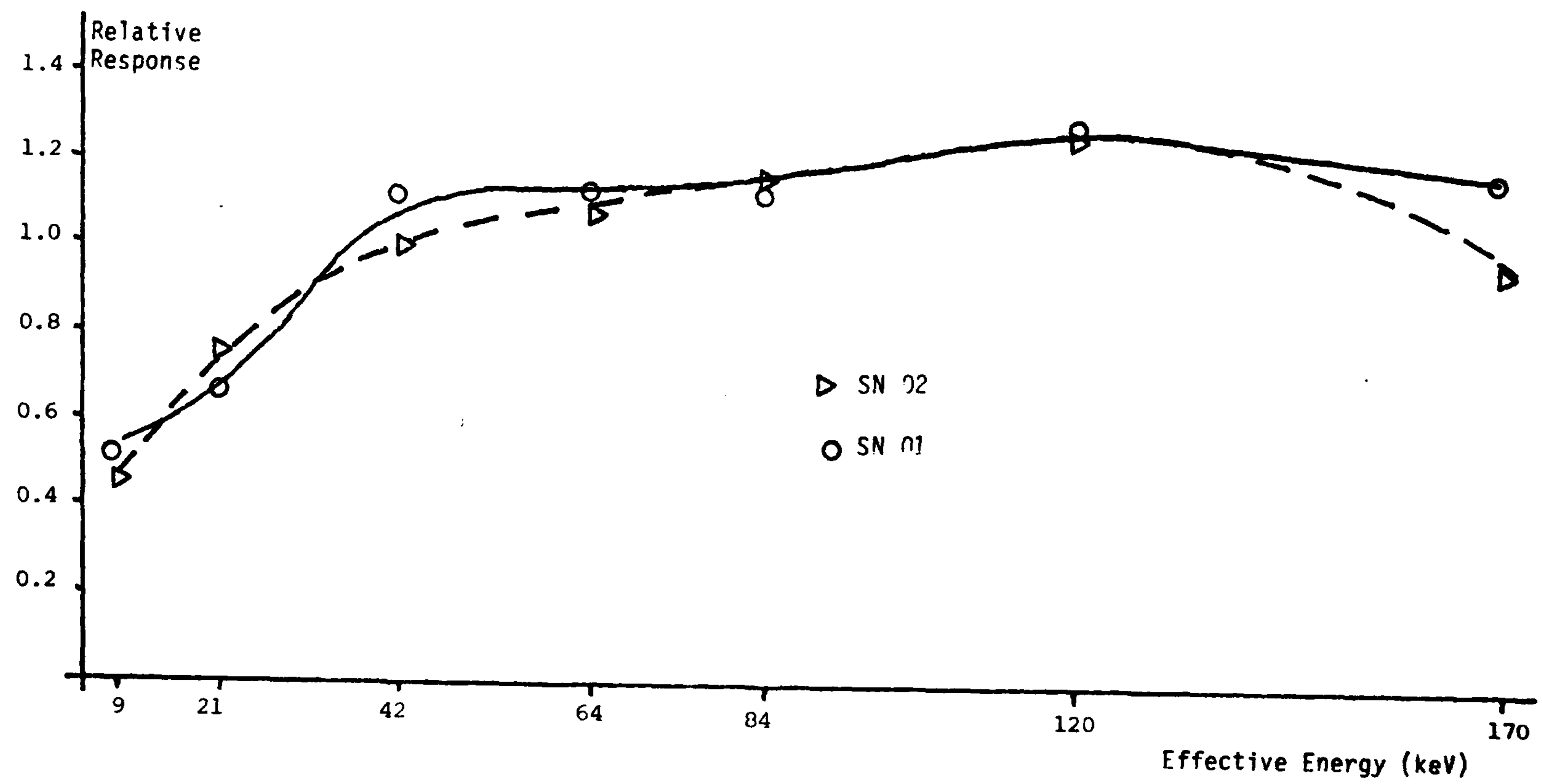
Energy Dependence VICTOREEN



Energy Dependence DCA

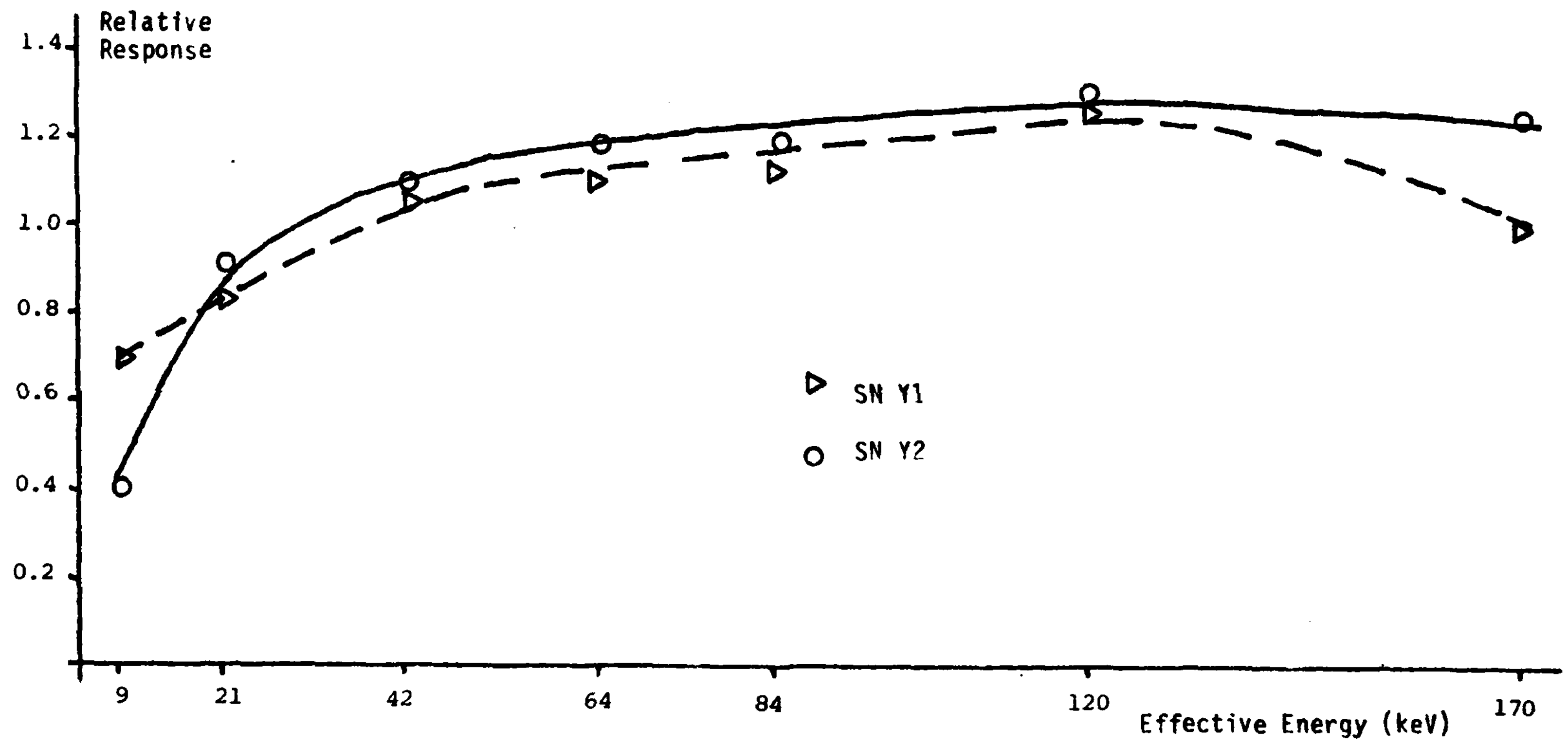


Energy Dependence PIC-PRD



Atch 17

Energy Dependence PIC-PRD



Atch 18

Technique LFI 21 keV

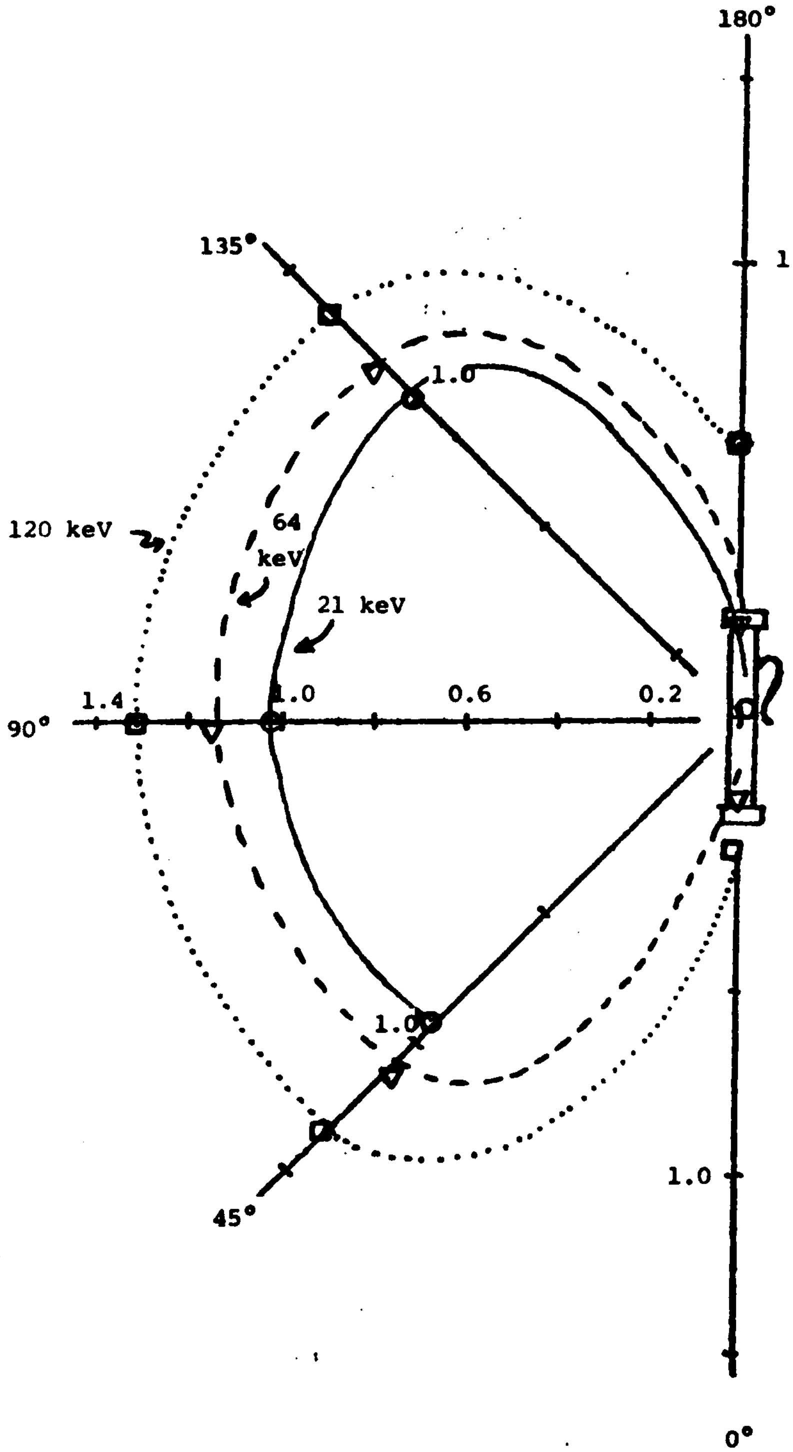
INCIDENT RADIATION ANGLE (DEG)	BENDIX	VICTOREEN	DCA	PIC-PRD
	measured / actual	measured / actual	measured / actual	measured / actual
0			0.06	
45	0.97	0.60	0.60	0.90
90	1.06	0.73	0.85	0.70
135	1.03	0.67	0.84	0.78
180	0.07	0.06	0.04	0.56

Technique MFI 64 keV

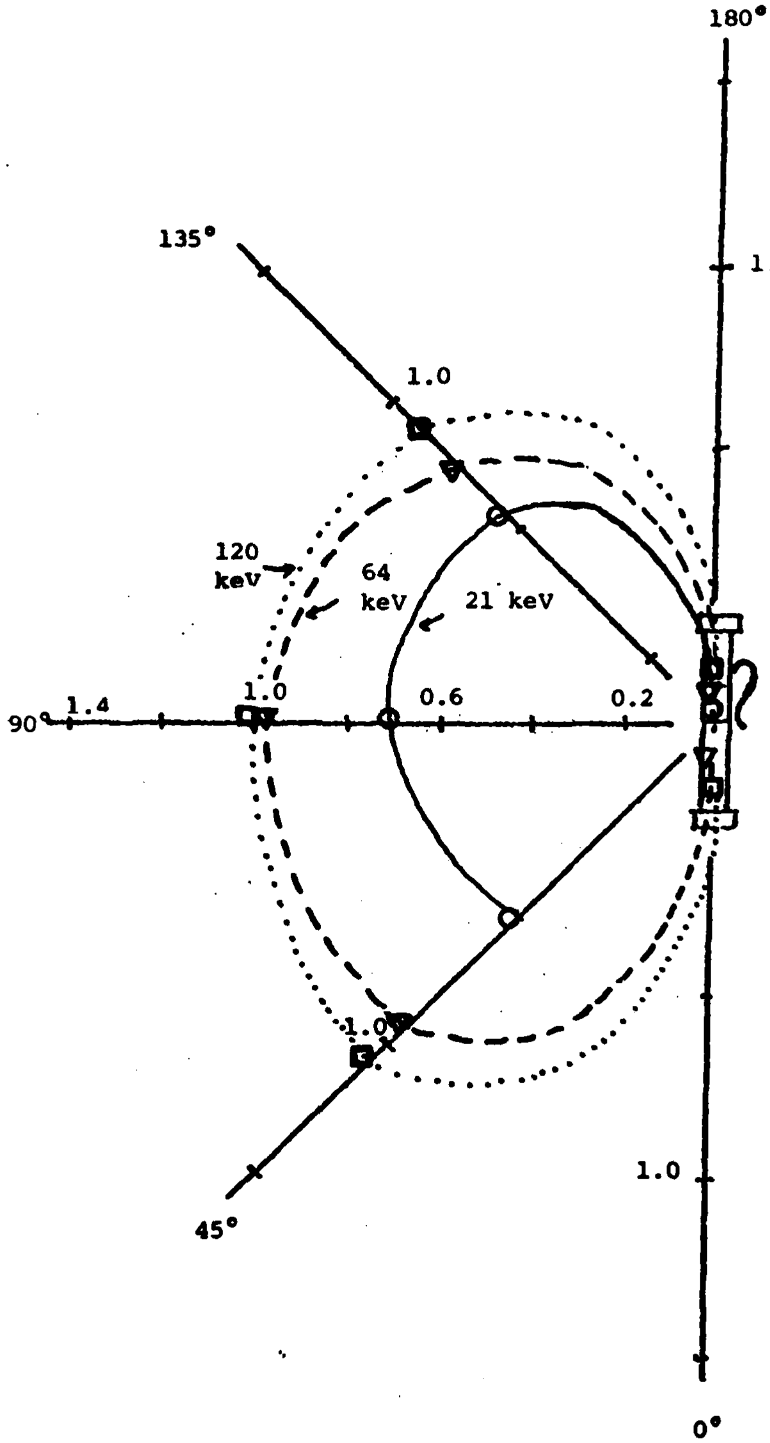
INCIDENT RADIATION ANGLE (DEG)	BENDIX	VICTOREEN	DCA	PIC-PRD
	measured / actual	measured / actual	measured / actual	measured / actual
0	0.14	0.18	0.10	0.85
45	1.12	0.94	1.00	1.10
90	1.16	0.92	1.01	1.10
135	1.13	0.80	0.94	1.10
180	0.33	0.20	0.12	0.85

Technique HFG 120 kev

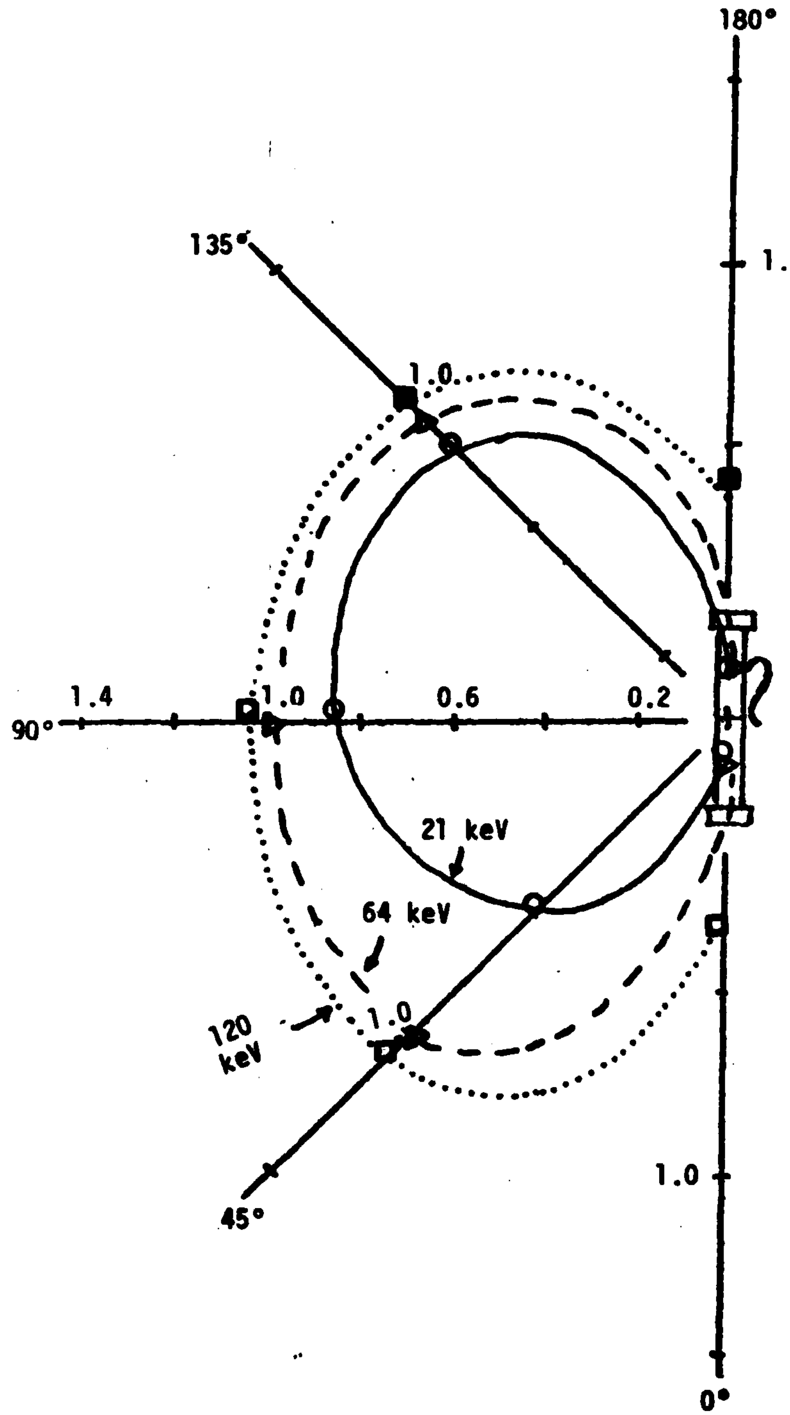
INCIDENT RADIATION ANGLE (DEG)	BENDIX	VICTOREEN	DCA	PIC-PRD
	measured / actual	measured / actual	measured / actual	measured / actual
0	0.28	0.24	0.28	1.04
45	1.26	1.04	1.06	1.27
90	1.32	1.00	1.00	1.28
135	1.27	0.92	0.98	1.25
180	0.57	0.24	0.42	1.00



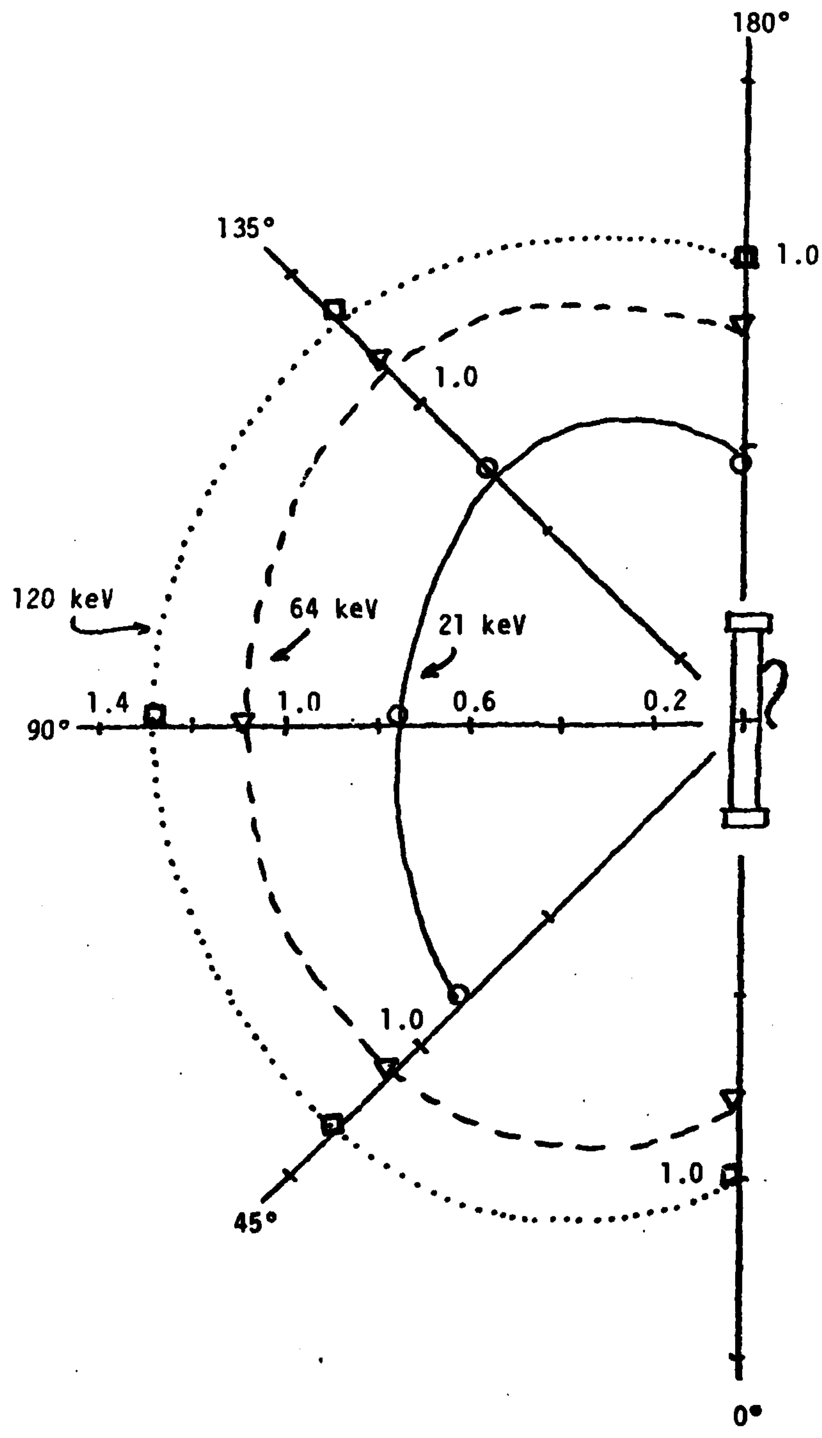
Angular Dependence BENDIX



Angular Dependence VICTOREEN



Angular Dependence DCA



Angular Dependence PIC-PRD

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