Calibration of Low-Energy Photon Emitting Irradiator Systems

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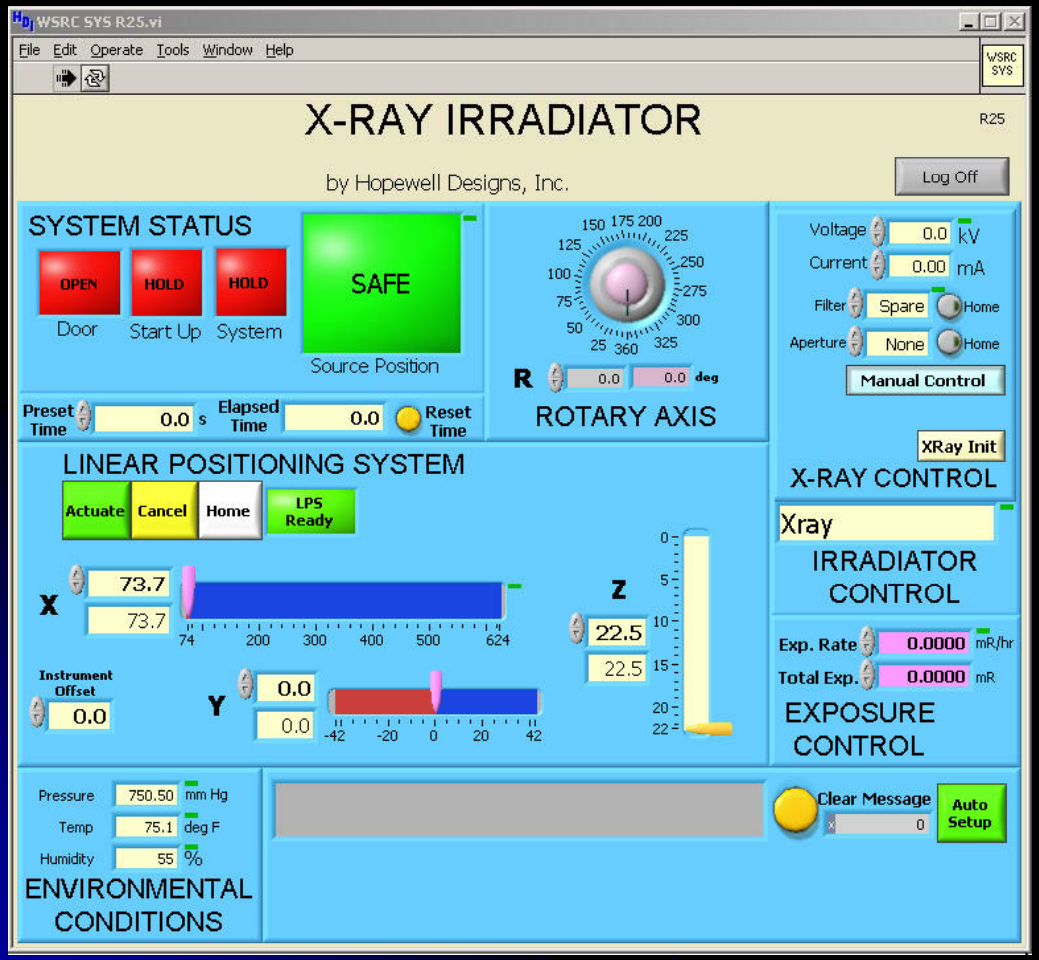
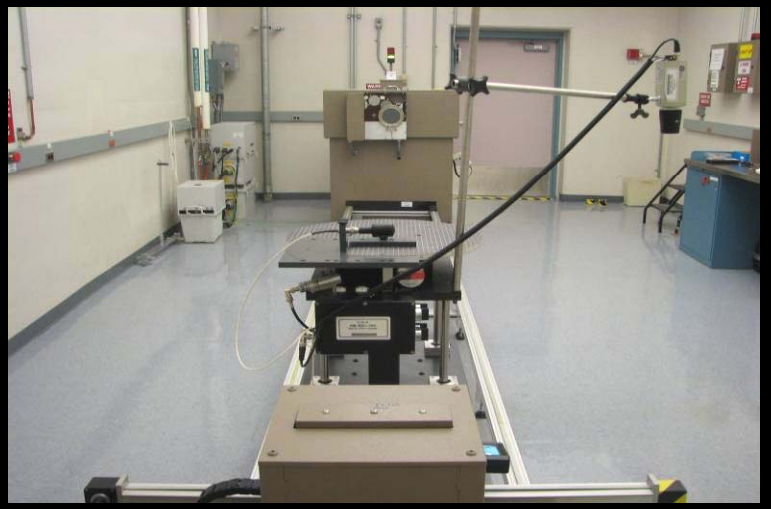
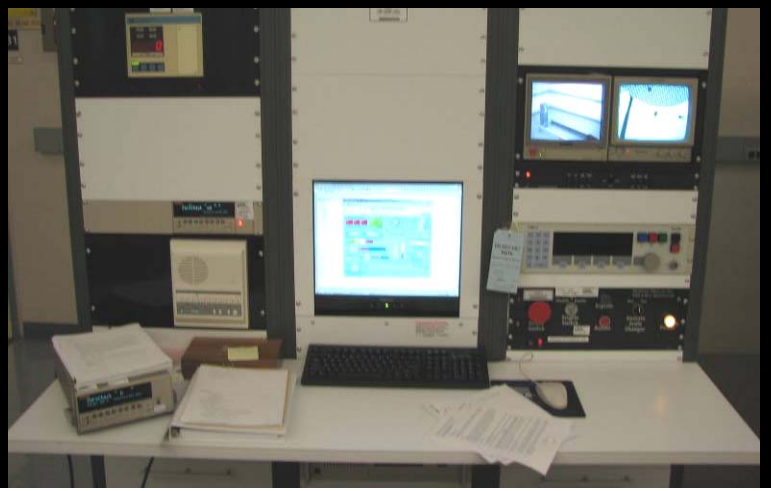
Irradiator Systems

- Primarily used for calibrating radiation monitoring equipment and experimental studies

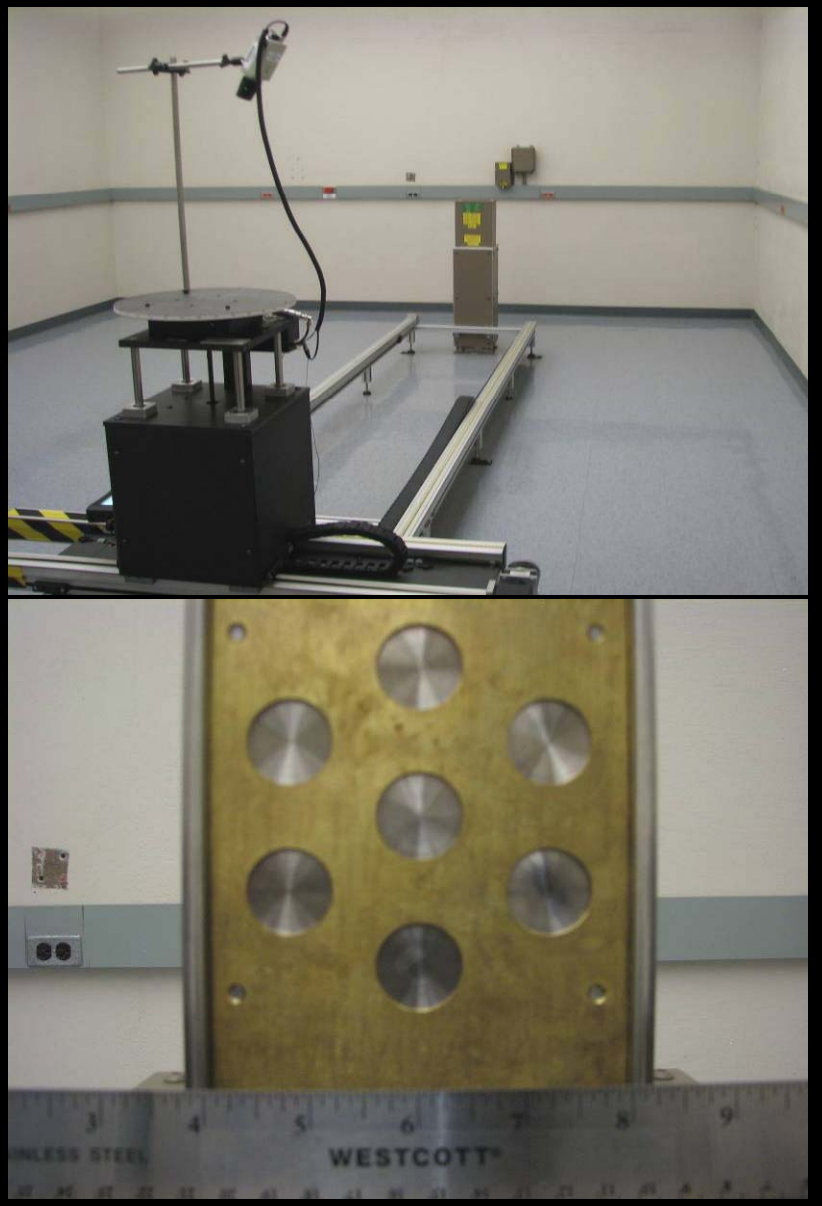




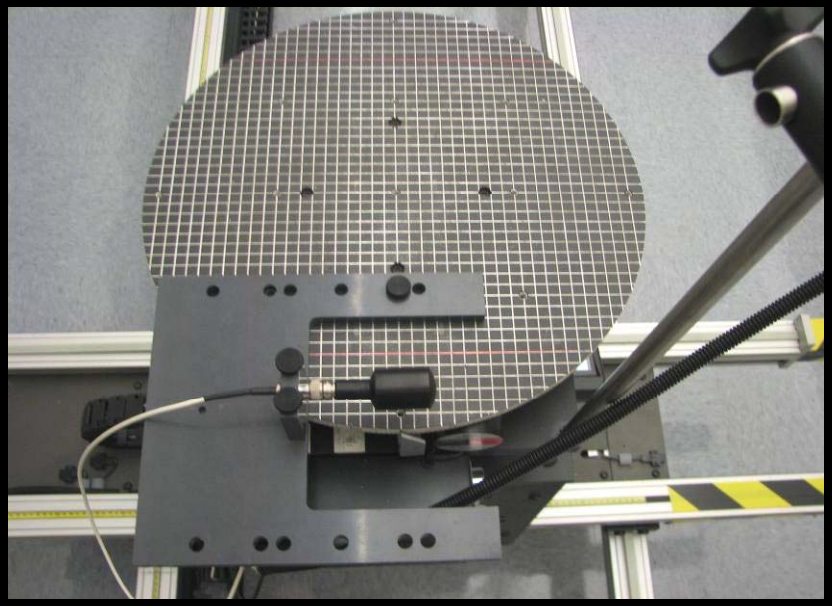


Americium-241 Irradiator

- 7 – 1Ci Am-241 sources
  - Sealed in stainless steel
  - 30mm diameter
- Low-energy gamma-ray (59.5 keV) is of interest
- Calibration
  - Exposure and Dose rates as a function of distance



Measurement Process



- Capintec PM-30 Ion Chamber
  - Air equivalent walls
  - Calibrated by NIST
- Keithley Electrometer
  - Provides -300V bias
  - Measures electrical current created by ionizing radiation
- Recorded electrical current from 30cm to 100cm in ≈5cm increments

Deriving Exposure Rate From Electrical Current

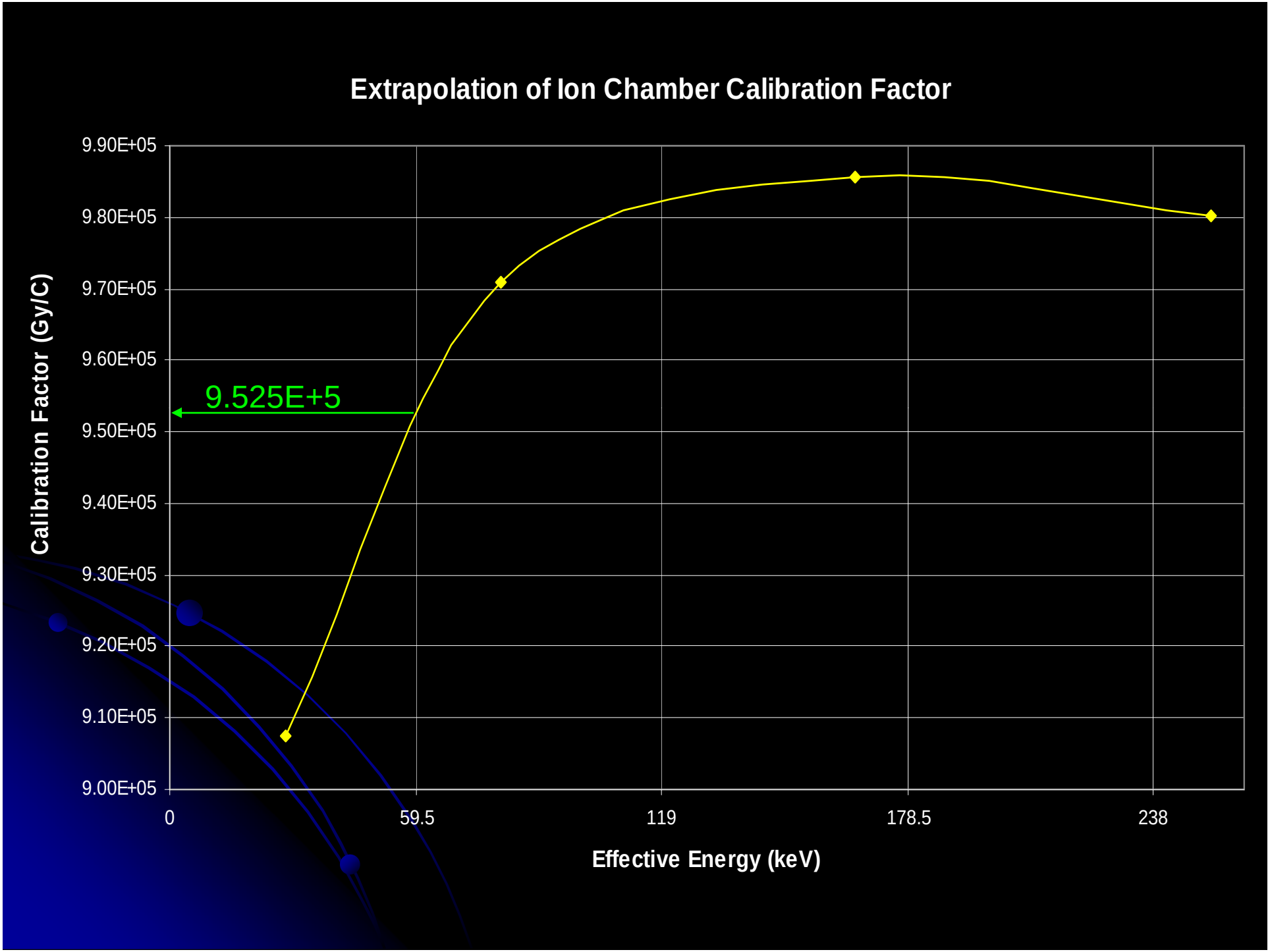
Where: I = electrical current
Q = electrical charge (nC)
t = time (s)

Where: $TP_{cor.fac.}$ = standard temperature and pressure correction factor
T_m = measured temperature (°C)
P_m = measured pressure (mmHg)

Where: X = exposure rate (mR/hr)
CF = ion chamber calibration factor

NO CALIBRATION FACTOR FOR AMERICIUM 241 EXISTS!

NOT EVEN FROM NIST!


Extrapolation of Ion Chamber Calibration Factor
Calibration Factor (Gy/C)
9.90E+05
9.80E+05
9.70E+05
9.60E+05
9.525E+5
9.50E+05
9.40E+05
9.30E+05
9.20E+05
9.10E+05
9.00E+05
0
59.5
119
178.5
238
Effective Energy (keV)

Results of Calibration

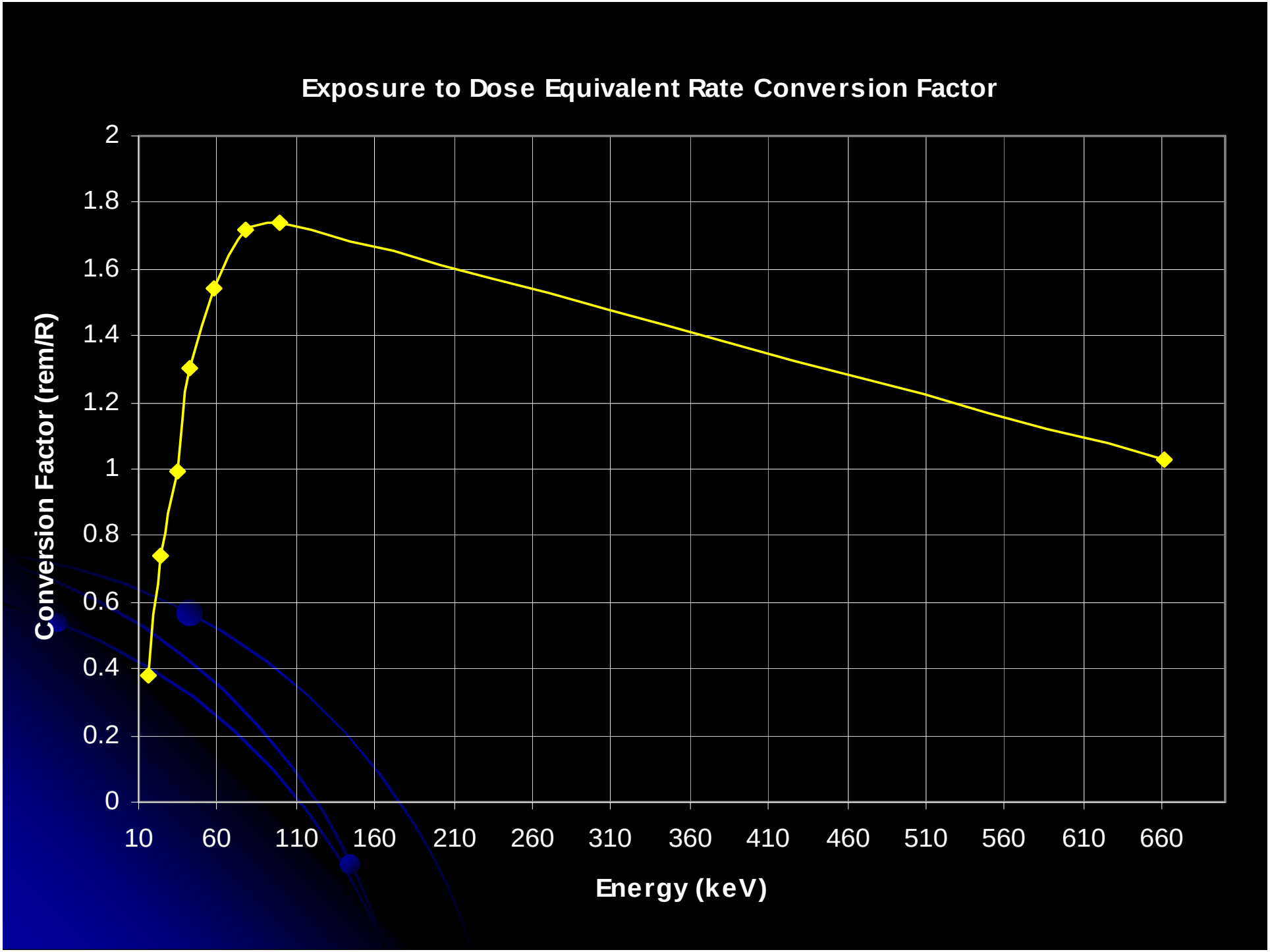
- Plotted results in Table Curve to obtain a simple equation for the irradiator computer to interpret
  - Distance vs. Exposure rate
  - Exposure rate vs. Distance

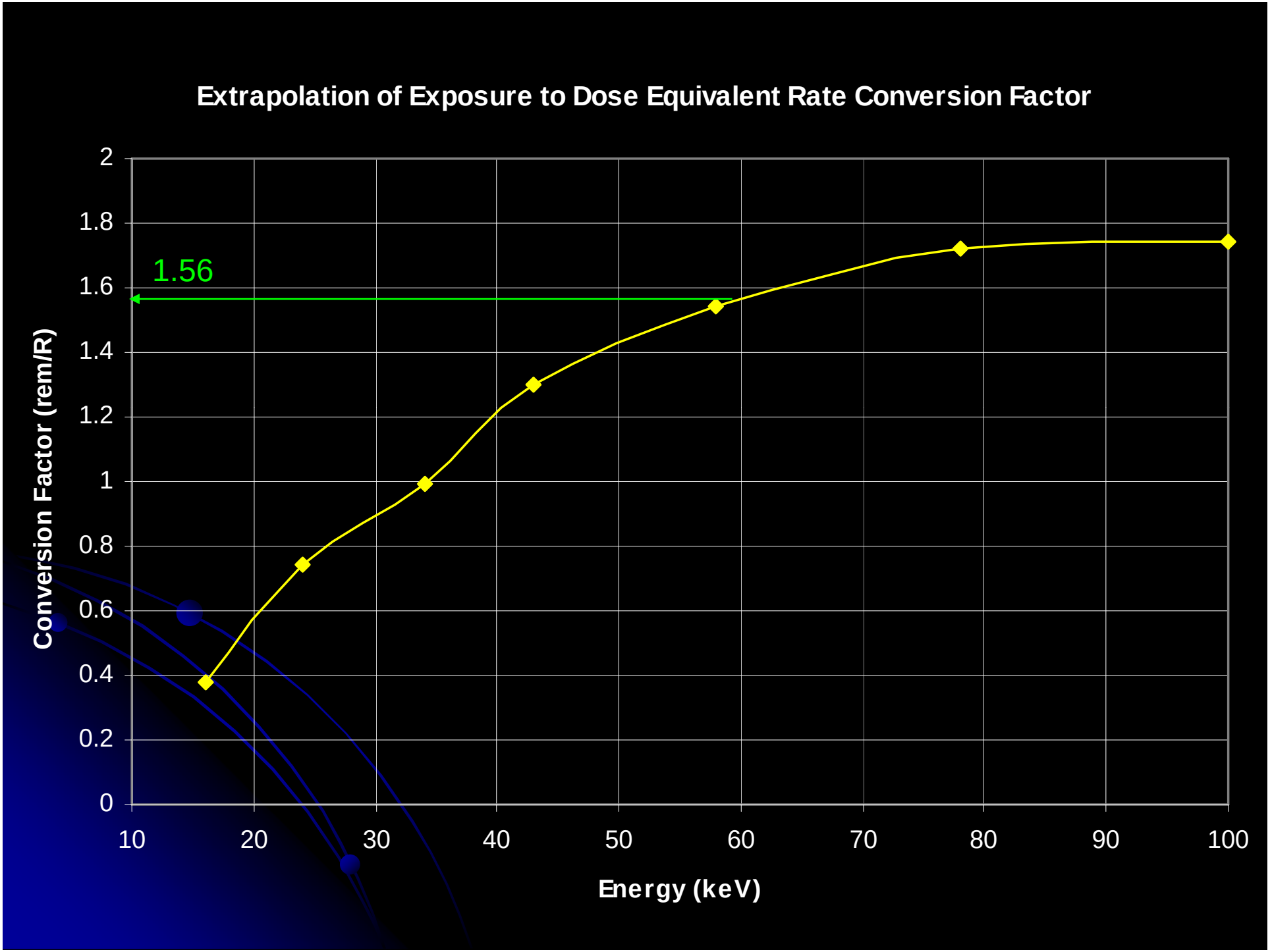
Distance from Source (cm)	Exposure Rate (mR/hr)
30	549
35	408
40	313
45	247
50	200
55	165
60	137
65	118
70	99
75	86
85	68
100	48

The Disagreement

- Portable *calibrated* instruments appear to over respond by 50+%!!
- EPD's and TLD's are calibrated to Am-241
  - These instruments measure dose equivalent
  - There must be another factor!

Distance from Source (cm)	Exposure Rate (mR/hr)	Ro-20	Teletector	Panasonic 802 TLD	EPD
30	549				
35	408	530			
40	313	408			
45	247	322			
50	200	269	300	315	
55	165	225	255		
60	137	190	205		
65	118	170	180		
70	99	149	155		157
75	86	130	130		
85	68	102	100		
100	48	78	75		


Exposure to Dose Equivalent Rate Conversion Factor
Conversion Factor (rem/R)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
60
110
160
210
260
310
360
410
460
510
560
610
660
Energy (keV)


Extrapolation of Exposure to Dose Equivalent Rate Conversion Factor
Conversion Factor (rem/R)
Energy (keV)
1.56
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
70
80
90
100

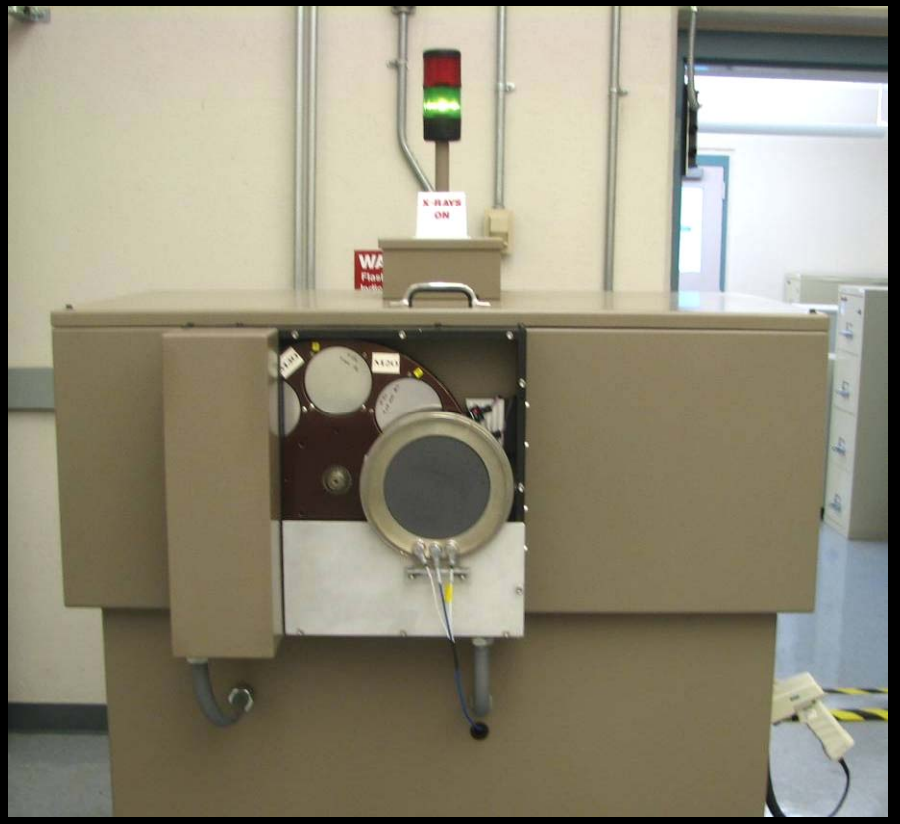
Results of Calibration (again)

- Plotted results in Table Curve to obtain a simple equation for the irradiator computer to interpret
  - Distance vs. Dose Equivalent rate
  - Dose Equivalent rate vs. Distance

Distance from Source (cm)	Dose Equivalent Rate (mrem/hr)	Ro-20	Teletector	Panasonic 802 TLD	EPD
30	856				
35	636	530			
40	488	408			
45	385	322			
50	311	269	300	315	
55	258	225	255		
60	213	190	205		
65	184	170	180		
70	155	149	155		157
75	134	130	130		
85	106	102	100		
100	75	78	75		

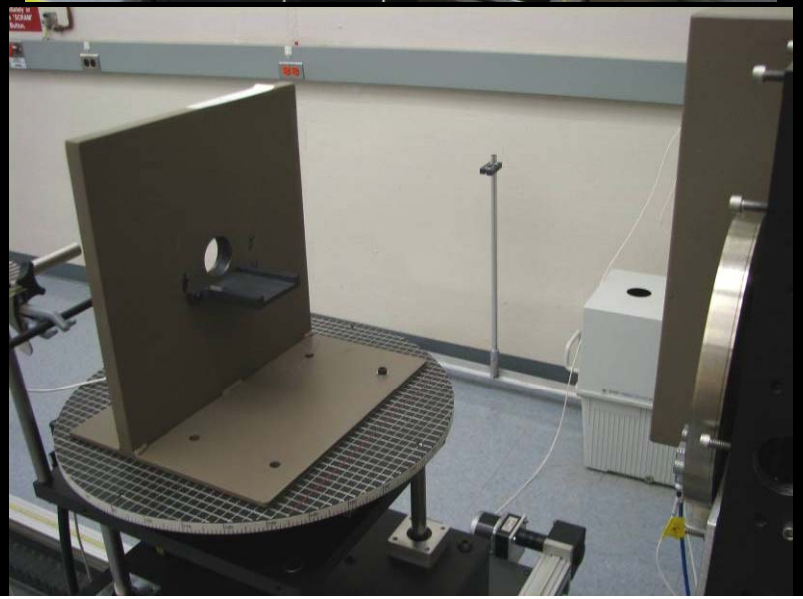
X-Ray Irradiator

- Industrial grade Tungsten anode x-ray machine
  - High stability constant potential
  - Capable of 17 to 300keV x-rays
- Available beam codes:
  - M30, H40, H50, H100, H150, H200, H250, H300
- Calibration
  - Verify 1st and 2nd half-value layers and homogeneity coefficient are within tolerances supplied by NIST



Measurement Process

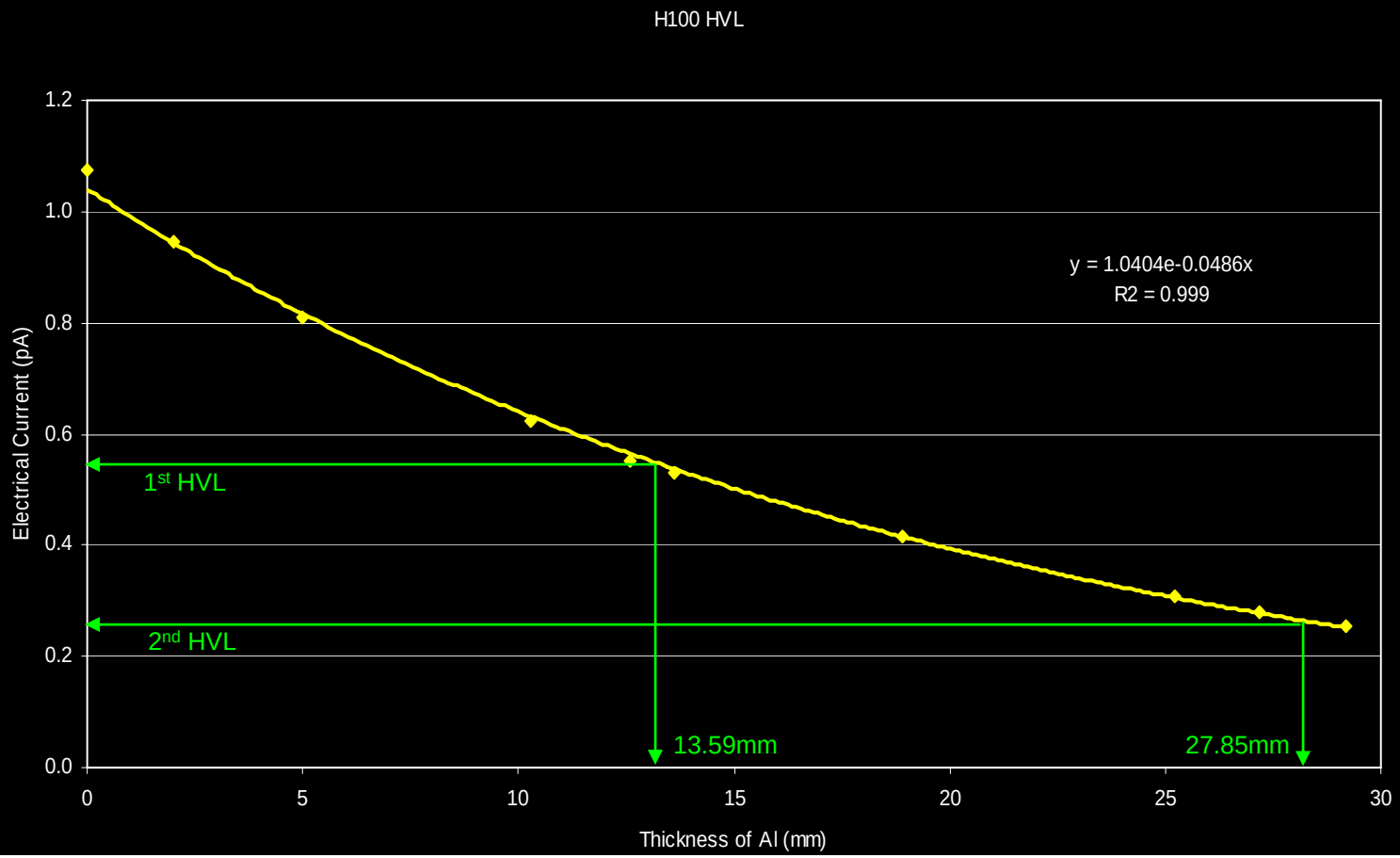
- Exradin A3 Ion Chamber
  - Shonka-Wyckoff design
  - Air equivalent walls
- Keithley Electrometer
  - Provides -300V bias
  - Measures electrical current created by ionizing radiation
- Current measurements were taken as the thickness of aluminum shielding was increased; until both HVL's were exceeded
  - HVL's must be within ±5% of NIST values
  - Homogeneity coefficient must be within ±7% of NIST values



Determination of HVL's

Where: I = electrical current
Q = electrical charge (nC)
t = time (s)

Where: hc = homogeneity coefficient
HVL = half-value layer



Calibrated Beam Codes

		Measured	NIST Standard	Percent Difference
H40	1st HVL (mm)	2.88	2.9	0.5%
	2nd HVL (mm)	2.96	3.09	4.1%
	Homogeneity Coefficient	97.4	94	3.6%
H50	1st HVL (mm)	4.34	4.2	3.4%
	2nd HVL (mm)	4.40	4.52	2.6%
	Homogeneity Coefficient	98.8	93	6.1%
H100	1st HVL (mm)	13.59	13.4	1.4%
	2nd HVL (mm)	14.26	13.81	3.3%
	Homogeneity Coefficient	95.3	97	1.8%

Results of Calibration

- H40, H50, and H100 beam codes were within calibration limits
- H150 did not have correct filter
  - Correct filter will be needed before proper calibration
- Other beam codes were very close (≈+7% of NIST values)
  - If the high voltage was turned down these beam codes may fall within the NIST tolerances (by shifting the energy spectrum)

References

- Dennis Hadlock
- Fred Ogden
- DOE Standard for the Performance Testing of Personal Dosimetry Systems (EH-0027)
- National Institute of Standards and Technology, *NIST Calibration Conditions for X- and Gamma-Ray Measuring Instruments*