

DOE Radiological Calibrations Intercomparison Program:  
Fermilab Participation - July 1, 1987

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The purpose of Fermilab's participation in this program was to check the exposure rates of four specified  $^{137}\text{Cs}$  sources and one neutron source used as lab standards against the Battelle, Pacific Northwest Laboratories standards. The Fermilab sources include the 137-6.1-1, the 137-7.1-1, and the 137-8.1-1 sources stored in the beam projector in the basement of Site 68, the 137-5.4 source kept on WH7E and the 238-BE-7.2-1 neutron source kept in the safe at Site 68.

The equipment used for this study was supplied by Battelle, Pacific Northwest Laboratories in Richland, Washington. It included an electrometer to measure integral charge from ionization chamber measurements, a tissue equivalent ionization chamber (FWT-IC-80) for neutron dose rate measurements, a thin-walled ion chamber (PM-30) for photon measurements, a Geiger-Mueller detector and a scaler/counter with high voltage supply which could provide the necessary voltage for all chambers, high voltage and signal cables. The signal cable which was provided produced very high drift values, so a similar Fermilab signal cable which provided drift values on the order of 1 pc/minute was substituted.

A comparison of the calculated sensitivities of the G-M detector, the PM-30 ion chamber and the FWT-IC-80 ion chamber with the PNL values would provide a measure of the accuracy to which the Fermilab 137-5.4(G-M), 137-6.1-1, 137-7.1-1, 137-8.1-1 (PM-30) and the 238-BE-7.2-1 (FWT-IC-80) sources are known.

The G-M detector was exposed to the 137-5.4 source in order to determine its sensitivity  $[D(R)/N \text{ (pulses)}]$ .

Source: 137-5.4	Exposure Rate: 86.224 mR/hr (7/1/87)
Distance: 1.00 m	Exposure: 1.437 mR
Time: 60.0 sec	$D/N = 4.55 \times 10^{-7} \text{ R/pulse}$
$N_{\text{AVG}} = 3,160.8 \text{ pulses}$	

The PM-30 ion chamber was exposed to the sources contained in the source projectors at Site 68. The sensitivity  $[D(R)/Q(c)]$  of the chamber for each source was calculated from the following values.

Temperature:  $22^{\circ}\text{K}$   
 Pressure: 745.8 mm Hg  
 Drift<sub>corrected</sub>:  $1.3 \times 10^{-5} \text{ nc/sec}$   
 Air density correction factor =  $C_{\text{tp}}$   

$$C_{\text{tp}} = \frac{760 (273 + T)}{295 (p)}$$

Source: 137-6.1-1                      Exposure Rate: 0.4971 R/hr (7/1/87)  
 Distance: 92.8 cm                      Exposure:  $1.381 \times 10^{-2}$  R  
 Time: 100 sec                             $D/Q_A = 1.13 \times 10^8$  R/c  
 $Q_{\text{corrected}} = .1233$  nc  
 $Q_A = Q_{\text{corrected}} - \text{DRIFT}_{\text{corrected}} \cdot t$

Source: 137-7.1-1                      Exposure Rate: 3.977 R/hr (7/1/87)  
 Distance: 91.9 cm                      Exposure:  $1.105 \times 10^{-1}$  R  
 Time: 100 sec                             $D/Q_A = 1.11 \times 10^8$  R/c  
 $Q_{\text{corrected}} = 0.9994$  nc

Source: 137-8.1                           Exposure Rate: 29.827 R/hr (7/1/87)  
 Distance: 94.1 cm                      Exposure: 0.8285 R  
 Time: 100 sec                             $D/Q_A = 1.10 \times 10^8$  R/c  
 $Q_{\text{corrected}} = 7.546$  nc

In order to calculate the sensitivity of the FWT-IC-80 ion chamber, it was exposed to a neutron/gamma mixed field under the following conditions.

Temperature:  $28^{\circ}\text{K}$                       Drift: 0.001467 nc/min  
 Pressure: 744.3 mm Hg                      Drift<sub>corrected</sub>: 0.001529 nc/min  
 Voltage: 300 V

Source: 238-BE-7.2-1                      Dose rate:  $2.34 \times 10^{-2}$  rad/hr (7/1/87)  
 Distance: 30.0 cm                      Dose:  $1.17 \times 10^{-2}$  rad  
 Time: 30.0 min  
 $Q_T = .2439$  nc  
 $Q_{T\text{corrected}} = .2541$  nc

The gamma contribution to the field was determined by exposing the G-M detector to the 238-BE-7.2-1 source.

Number of Pulses: 1053  
 Distance: 14.0 cm  
 Time: 60.0 sec

Gamma contribution corrected for time and distance:

$$N_{\gamma} = 1053 \frac{\text{pulses}}{\text{min}} (30 \text{ min}) \left( \frac{14 \text{ cm}}{30 \text{ cm}} \right)^2 = 6880 \text{ pulses}$$

The gamma exposure producing  $N_{\gamma}$  is:

$$E_{\gamma} = (D/N)N_{\gamma} = (4.55 \times 10^{-7} \text{ R/pulse}) (6880 \text{ pulses}) = 3.13 \times 10^{-3} \text{ R}$$

$$\text{rads} = \left( \frac{87.7}{100} \right) \times \left( \frac{\text{mass absorption coeff. of the medium}}{\text{mass absorption coeff. of air}} \right) \times R \quad (1)$$

$$D_{\gamma} = (0.877) \left( \frac{.0326}{.0296} \right) \left( \frac{\text{rad}}{\text{R}} \right) (3.13 \times 10^{-3} \text{ R}) = 3.02 \times 10^{-3} \text{ rads}$$

$$\frac{D_n + D_{\gamma}}{Q_A} = \frac{1.17 \times 10^{-2} \text{ rad} + 3.02 \times 10^{-3} \text{ rad}}{0.2082 \text{ nc}} = 7.07 \times 10^7 \text{ rad/c}$$

$$Q_A = Q_{T\text{corrected}} - \text{DRIFT}_{\text{corrected}} \cdot t$$

$$Q_A = 2.541 \times 10^{-10} \text{ c} - 4.587 \times 10^{-11} \text{ c}$$

The sensitivity of the G-M detector used in conjunction with the 137-5.4 source was calculated to be  $4.55 \times 10^{-7}$  R/pulse. This value may be compared to the value of  $8 \times 10^{-7}$  R/pulse as listed by Pacific Northwest Laboratory. (2)

The sensitivities of the PM-30 ion chamber for the 137-6.1-1, the 137-7.1-1, and the 137-8.1-1 sources were  $1.13 \times 10^8$  R/c,  $1.11 \times 10^8$  R/c, and  $1.10 \times 10^8$  R/c respectively, with a range of  $0.03 \times 10^8$  R/c and a mean of  $1.11 \times 10^8$  R/c. These values can be compared to a listed value of  $1 \times 10^8$  R/c. (2)

The sensitivity of the FWT-IC-80 for the 238-BE-7.2-1 source was calculated to be  $7.07 \times 10^7$  rad/c. The value listed for the FWT-IC-80 chamber is  $4 \times 10^7$  R/c. (2)

## References

1. Cember, H., Introduction to Health Physics, 2nd ed., Pergamon Press, New York, 1983, p. 143.
2. Pacific Northwest Laboratory, letter to Rich Allen, October 13, 1983, p. 2.

## GM-15 MEASUREMENT

Version: January 6, 1987

Counter (s/n) WA 92447  
 Voltage 360 V  
 Scaler (s/n, cal. exp. date)  
A 877G  
 Date of Measurement 6-23-87

Source (ID#) 137-5.4  
 Distance 1m  
 Timer ('internal' or s/n, exp. date)  
internal  
 Operator Rich Allen

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	60	3253	54.22
2	"	3263	54.38
3	"	3151	52.52
4	"	3170	52.83
5	"	3102	51.7
6	"	3040	50.67
7	"	3188	53.13
8	"	3155	52.58
9	"	3215	53.58
10	"	3073	51.22

Ave. Count rate,  $\dot{R} = 52.68 \text{ Pulses/sec}$  Std. Deviation = 1.22

Del. Exp. Rate,  $\dot{X}$  (mR/hr) = ~~36.224~~ 36.224 mR/m

Reported Response

$$4.55 \times 10^{-7} \text{ R/pulse}$$

$$\text{Response} = \dot{X} \times 3600 / \dot{R}$$







## IC-80 IONIZATION CHAMBER MEASUREMENT

Version: January 6, 1987

Chamber (s/n)                       
 Voltage 300V  
 Electrometer (s/n, cal. exp. date)                       
 Elec. Corr. Factor, Ce                       
 Elec. Range                       
 (e.g. nC or  $10^{-10}$  etc.)  
 Humidity (% rel.)                       
 Date of Measurement 07-01-87

Source (ID#) 238-BE-7.2-1  
 Distance 30.0 cm  
 Stop watch (s/n, cal. exp. date)                       
 Temperature (deg-C) 28°  
 Pressure (torr) 744.3  
 Air Density Corr. 1.0418  
 \* Ctp = 760 \* (273 + T) / P / 295 \*  
 Operator Rich Allen

Drift			Irradiation		
Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere	Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere
1200	.0293 nC	$2.44 \times 10^{-14}$	1800	.2439 nC	$1.355 \times 10^{-13}$
Average Drift, $\bar{D} = 1.467 \times 10^{-3} \text{ nC/min}$ Average Current, $\bar{I} = 1.355 \times 10^{-13} \text{ A}$ Signal, $S = (\bar{I} - \bar{D}) * Ctp * Ce$ Delivered Dose Eq. Rate, $\dot{H} = 8.178 \times 10^{-6} \text{ rad/sec}$ Chamber Response $7.07 \times 10^7 \text{ rad/C}$					