Radiation Physics Note 50

A Comparison of the Victoreen Model 555 Ionization Chamber and NTA Film Responses to ^{137}Cs Gamma Rays

Jack G. Couch

February 1985

Introduction

The large ^{137}Cs beam projector source (135 Ci) and the IMAC ^{137}Cs calibration source No. 5.4 (370 mCi) were used to expose NTA (P1) film badges and the Victoreen Model 555 ionization chamber (integral mode) to various doses. The motivation for these measurements was twofold: First, it is believed that a set of film badge data in the dose range usually encountered for personnel exposures would provide baseline data for comparing future (and previous) measurements connected with the laboratory's film badge testing (quality assurance) program. Such sample data should be a useful guide in designing various types of tests in the future as well.

Second, it is believed that the Victoreen 555 ion chamber is a useful instrument for remote monitoring of doses such as those near uncalibrated sources (e.g., X-ray machines or radiation areas) where film badges or other test measurements are made. (A future radiation physics note will contain just such an application). This instrument may prove particularly suitable for mapping the relative dose vs. position in such areas as the beam projector cage at Site 68.

Some useful calibration information for this particular ion chamber is included in this report.

Victoreen Model 555 Ionization Chamber

Operating instructions and a description of the Victoreen ionization chamber are found in Reference 1. The probe chamber is an unsealed cavity; consequently the signal (and hence dose reading) is proportional to atmospheric air density. For temperatures and pressures other than 22°C and 760 mm Hg, the scale reading must be corrected by the tabulated factor found in the Operating Manual.[1] For convenience, this table is reproduced here as Table 1.

The probe itself is the Type 0.1 DAS. Measurements are made with the side (not the end) of the probe facing the direction of radiation. Meter and scale readings must be corrected by a multiplier of 0.1 when using this probe. For example, a reading of 100 mR corresponds to an actual dose of (0.1) (100) = 10 mR.

An enlargement of a "typical" energy response curve for a V555 with the 0.1 DAS probe was taken from the Operating Manual[1] and is shown as the solid line in Figure 1. The laboratory's V555 system has been calibrated by Victoreen at two points in the keV range using heavily filtered X-rays. The calibration (correction) factors are 1.03 and 0.91 at 50 keV and 150 keV, respectively. An adjustment of the "typical" response curve can be

used to determine a calibration at other energies. The following paragraph is quoted from Page 19 of the Operating Manual.[1]

> Typical energy response curves are available for each probe. These may be used for obtaining a correction factor for energy points other than the energy point at which the probe calibrated. The curves have a standard deviation of 2% to 3% at each of the calibration points, which are used to determine the curve. DO NOT ASSUME that each probe supplied is calibrated at each point. If a point other than the calibration point is to be used, the tolerance of the calibration point must be added to the standard deviation (3%) of the point on the curve to arrive at the accuracy (∿ 6%) of the reading.

The above two calibration points plus one for ^{137}Cs (1.0 at 662 keV) measured in this study are shown as circles in Fig. 1. An adjusted calibration (correction factor) curve based on these three points is shown in the figure as the dashed line. Based on the paragraph quoted above, the dashed curve represents the calibration (± 6%) over the energy range indicated. The curve suggests that an uncertainty of ± 10% or greater would be more appropriate for X- and gamma-rays of unknown energy. It should also be pointed out that the calibration factor for gamma ray energies above that of ^{137}Cs (0.662 MeV) is unknown, and the instrument is likely to under respond at these higher energies.

The accuracy of the instrument at photon energies corresponding to one of the calibration points should be much better (± 3%).

NTA Film

P1 Film Badges supplied by Landauer were used for these measurements. Each batch of badges was sent to Landauer for quick reading and the results were reported as deep and shallow (skin) doses.

Measurements Using the Beam Projector ^{137}Cs Source

A series of irradiations using the 135 Ci ^{137}Cs beam projector were made over the range of 50-700 mR in which the V555 ionization chamber system (integral mode) and NTA film badges were used to measure dose. The badges and chamber were placed at 118.3 cm distance where the dose rate was 20.0 R/hr (0.180 sec/mR) and exposed for a length of time corresponding to the desired dose.

Dose values are tabulated in Table 2A. Ion chamber doses have been corrected by an air density correction of 1.008. Recorded NTA film doses are an average of three badge readings placed at each location. Errors are the standard deviations corresponding to these averages.

The ionization chamber and NTA film readings plotted against the dose delivered by the beam projector are displayed in Figure 2. Linear regression analyses were made for both the ion chamber, and the NTA data. The parameters are shown in Table 2B where r = the correlation coefficient, and a and b are respectively the intercept and slope of the best fit line y = a+bx. In both cases the correlation coefficient r is nearly equal to 1 indicating an excellent fit. The best-fit lines are shown in Fig. 2 as solid and dashed for the ion chamber and NTA film, respectively.

Calibration factors b calibrating the ion chamber and the NTA film to the beam projector are 1.0 and 0.92 respectively. For example, a reported NTA film dose of 100 mrem corresponds approximately to 100/0.92 = 109 mrem as delivered by the beam projector. The absolute accuracy of the dose delivered by the beam projector is not known at this point.

Measurements Using the IMAC ^{137}Cs Calibration Source

A second set of data were taken using the IMAC No. 5.4 (370 mCi) ^{137}Cs source. Both the NTA badges and the ionization chamber were placed at a source position of 39.1 cm where the exposure rate was computed to be 600 mR/hr = 10 mR/min. Only a few data were taken because of the long exposure times required.

The results are recorded in Table 3A. Ion chamber doses contain a 1.02 air density correction. The NTA data are averages from three films placed at each position, and the errors are the corresponding standard deviations. The data and corresponding best-fit lines are shown in Fig. 3, and parameters from the linear regression analysis are listed in Table 3B.

Discussion of Results

The linear relationship between ion chamber dose and ^{137}Cs source dose is exceedingly close in both sets of data, indicating that the random errors are very small in the measurements. This property together with the convenience of use and availability of an integral mode make this instrument a good choice for measuring and comparing relative doses.

The ion chamber calibration factors are 1.0 and 0.97 for the beam projector and IMAC source data, respectively. That is, there is a 3% systematic descrepancy which may be attributable to the difficulty in placing the probe precisely. The magnitude of position-related systematic errors increases with decreasing distance from the source.

The NTA film badge results indicate under responses of 0.92 and 0.90 for the beam projector and IMAC source data, respectively. This under response has been noticed in previous film badge tests.

The use of only three films for each measurement does not, of course, yield a good measure of the spread to be expected in film badge readings. However, the standard deviations of the NTA data do give an indication. These standard deviations are less than 5% for the high dose data but run as high as 15% in the range of 50 mR doses.

Summary

An approximate calibration curve for the Victoreen 555 ion chamber (0.1 DAS probe) is shown which includes a ^{137}Cs calibration point. This device is probably accurate to ± 10% for photons of unknown energy from 0.662 MeV down to a few keV.

Ion chamber and NTA film data from approximately 50- to 700-mR were taken using the large beam projector source. Additional data were taken from 50- to 150- mR using one of the IMAC ^{137}Cs sources. In both cases the ionization chamber results were within 3% of the calculated gamma source doses. However, the NTA film under responded by 8-10%.

The data contained in this report can serve as basis for comparing future quality-assurance test data.

Acknowledgement

The author wishes to thank Darrel Bancroft for his assistance in collecting part of the data.

Reference

1. Instruction Manual for Model 555 Radocon II Intergrating Ratemeter. Victoreen Instrument Division, 10101 Woodland Avenue, Cleveland, Ohio 44104.

TABLE 1

AIR DENSITY CORRECTION TABLE

This instrument is calibrated in International Roentgens corrected to 0°C when used at 22°C and 760 mm mercury (Hg) barometric pressure. For temperatures other than 22°C and pressures other than 760 mm Hg, multiply the scale reading by the factor obtained from the following table.

Inches	Mm.	F. 60.8 C. 16	64.4 18	68.0 20	71.6 22	75.2 24	78.8 26	82.4 28	86.0 30	89.6 32	93.2 34	96.8 36	100.4 38	104.0 40
19.68	500	1.489	1.499	1.509	1.520	1.530	1.541	1.551	1.561	1.571	1.582	1.592	1.602	1.613
20.08	510	1.460	1.469	1.479	1.490	1.499	1.510	1.520	1.530	1.540	1.551	1.561	1.571	1.581
20.47	520	1.431	1.441	1.451	1.461	1.471	1.481	1.491	1.500	1.510	1.520	1.530	1.540	1.550
20.87	530	1.405	1.414	1.424	1.434	1.444	1.453	1.463	1.473	1.482	1.492	1.502	1.512	1.521
21.26	540	1.378	1.388	1.397	1.407	1.416	1.426	1.435	1.445	1.454	1.464	1.474	1.483	1.493
21.65	550	1.354	1.363	1.373	1.382	1.391	1.401	1.410	1.419	1.429	1.438	1.448	1.457	1.466
22.05	560	1.329	1.338	1.348	1.357	1.366	1.375	1.384	1.394	1.403	1.412	1.421	1.431	1.439
22.44	570	1.306	1.315	1.324	1.333	1.342	1.351	1.360	1.369	1.378	1.387	1.396	1.405	1.414
22.83	580	1.283	1.292	1.301	1.310	1.319	1.328	1.337	1.345	1.354	1.363	1.372	1.381	1.389
23.23	590	1.262	1.270	1.279	1.288	1.297	1.305	1.314	1.323	1.331	1.340	1.349	1.358	1.366
23.62	600	1.241	1.249	1.258	1.267	1.275	1.284	1.293	1.301	1.309	1.318	1.327	1.336	1.344
24.02	610	1.220	1.229	1.237	1.246	1.254	1.263	1.271	1.279	1.288	1.297	1.305	1.314	1.322
24.41	620	1.200	1.208	1.217	1.225	1.233	1.242	1.249	1.258	1.266	1.275	1.283	1.292	1.299
24.80	630	1.181	1.189	1.198	1.206	1.214	1.222	1.230	1.239	1.247	1.255	1.263	1.271	1.279
25.20	640	1.164	1.171	1.180	1.188	1.196	1.204	1.212	1.220	1.228	1.236	1.244	1.252	1.260
25.59	650	1.145	1.153	1.161	1.169	1.177	1.185	1.193	1.201	1.208	1.216	1.224	1.232	1.240
25.98	660	1.127	1.135	1.143	1.151	1.159	1.167	1.174	1.182	1.189	1.198	1.206	1.213	1.221
26.38	670	1.111	1.119	1.126	1.134	1.142	1.149	1.157	1.165	1.172	1.180	1.188	1.195	1.203
26.77	680	1.095	1.103	1.110	1.118	1.125	1.133	1.141	1.148	1.156	1.163	1.171	1.179	1.186
27.16	690	1.078	1.086	1.093	1.101	1.108	1.116	1.123	1.131	1.138	1.146	1.153	1.161	1.168
27.56	700	1.064	1.071	1.079	1.086	1.093	1.101	1.108	1.115	1.123	1.130	1.137	1.145	1.152
27.95	710	1.048	1.055	1.063	1.070	1.077	1.084	1.092	1.098	1.106	1.113	1.121	1.128	1.135
28.35	720	1.033	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.091	1.098	1.105	1.112	1.119
28.54	725	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.091	1.098	1.105	1.112
28.74	730	1.019	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.090	1.097	1.105
28.94	735	1.013	1.019	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.090	1.097
29.13	740	1.006	1.013	1.020	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.075	1.083	1.089
29.33	745	.999	1.006	1.013	1.020	1.027	1.034	1.040	1.048	1.054	1.061	1.068	1.075	1.082
29.53	750	.992	.999	1.006	1.013	1.020	1.027	1.033	1.040	1.047	1.054	1.061	1.068	1.075
29.72	755	.986	.993	1.000	1.007	1.014	1.021	1.027	1.034	1.041	1.048	1.055	1.062	1.068
29.92	760	.980	.986	.993	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.047	1.054	1.061
30.12	765	.972	.979	.986	.993	.999	1.006	1.013	1.020	1.026	1.033	1.040	1.047	1.054
30.31	770	.967	.973	.980	.987	.994	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.047
30.51	775	.961	.968	.974	.981	.987	.994	1.001	1.007	1.014	1.021	1.027	1.034	1.041
30.71	780	.954	.961	.967	.974	.980	.987	.994	1.000	1.007	1.014	1.020	1.027	1.033
30.90	785	.948	.955	.961	.968	.974	.981	.988	.994	1.001	1.007	1.014	1.021	1.027
31.10	790	.942	.949	.955	.962	.968	.975	.981	.988	.994	1.001	1.008	1.014	1.021

VICTOREEN

TABLE 2A

Data Using ^{137}Cs Beam Projector

Exposure Time (sec)	Ion Chamber Dose (mR)	^{137}Cs Projector Dose (mR)	NTA Dose (mrem)
9	51	50	47 ± 6
18	100	100	93 ± 6
27	151	150	147 ± 6
36	202	200	193 ± 6
45	252	250	233 ± 12
67.5	388	375	355 ± 13
90	504	500	490 ± 10
122	675	678	613 ± 12

TABLE 2B

Linear Regression Parameters for Beam Projector Data

	r	a	b
Ion Chamber	1.000	1.74	0.998
NTA Film	0.998	6.12	0.921

TABLE 3A

Data Using ^{137}Cs IMAC Source

Exposure Time (min)	Ion Chamber Dose (MR)	^{137}Cs Source Dose (mR)	NTA Dose (mrem)
5	48	50	43 ± 6
10	97	100	80 ± 0
15	145	150	133 ± 6

TABLE 3B

Linear Regression Parameters for IMAC Source Data

	r	a	b
Ion Chamber	1.000	−0.33	0.97
NTA Film	0.994	− 4.7	0.90

FIGURE 1

Calibration curve for V555 Ion Chamber. Circles are calibration points. Solid line is a "Typical" curve from Reference 1. Dashed line is an adjusted average calibration curve based on three calibration points.

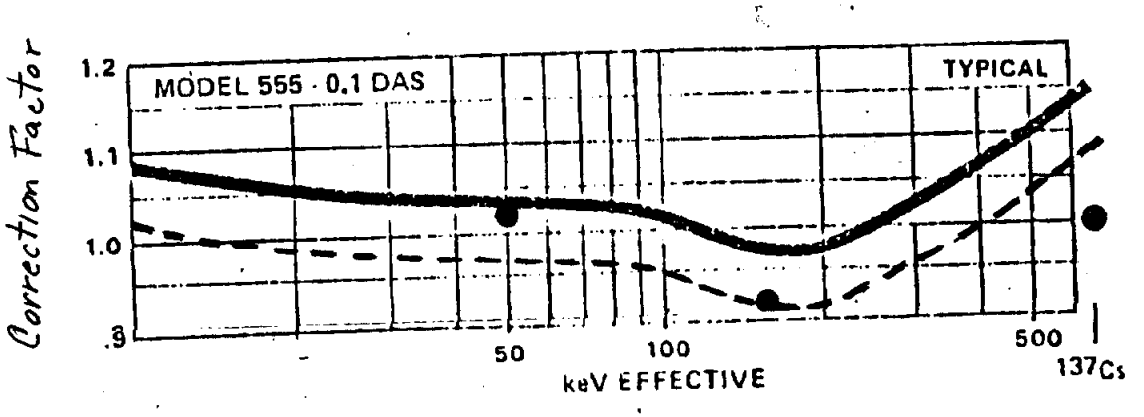


FIGURE 2

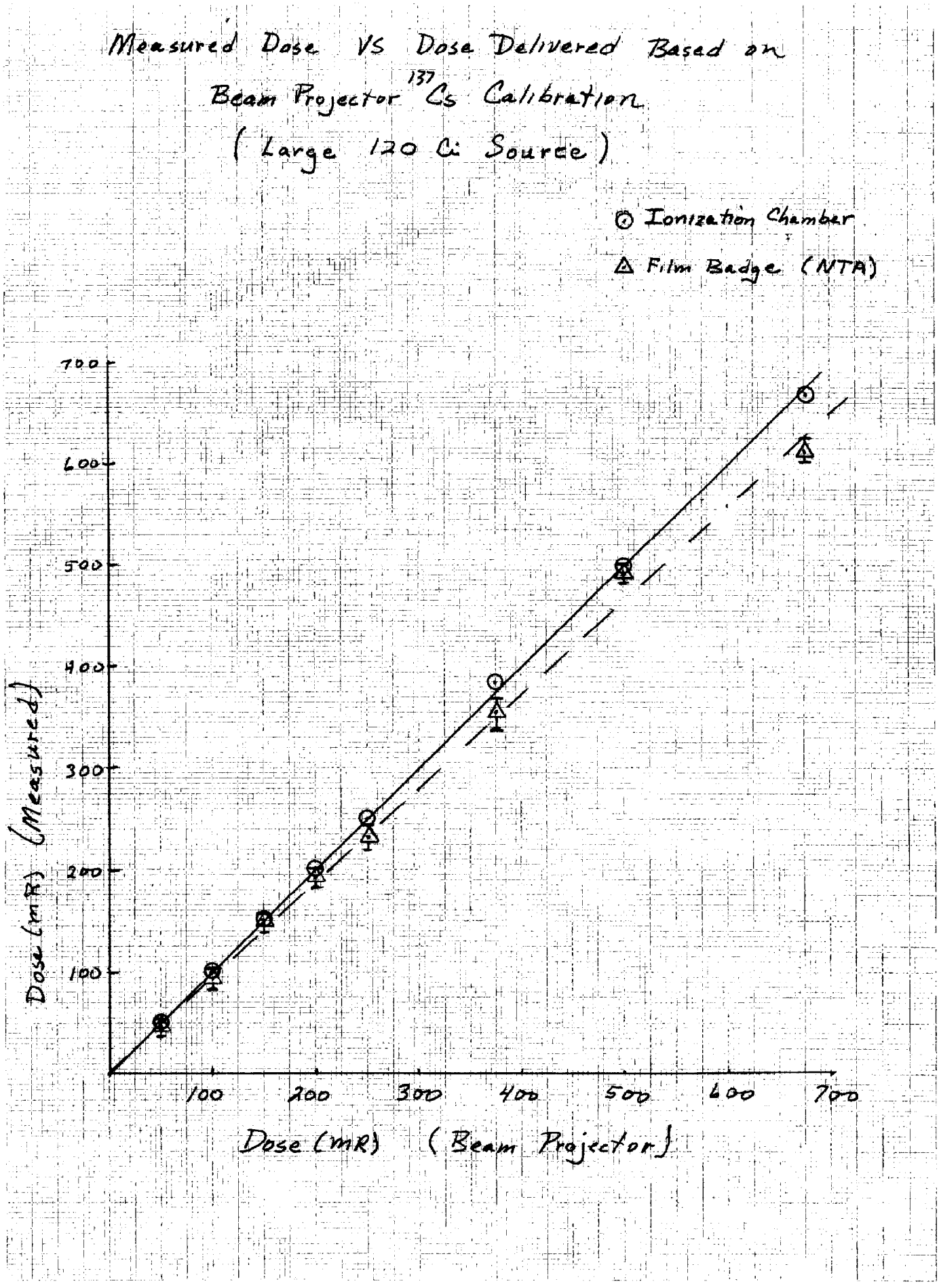
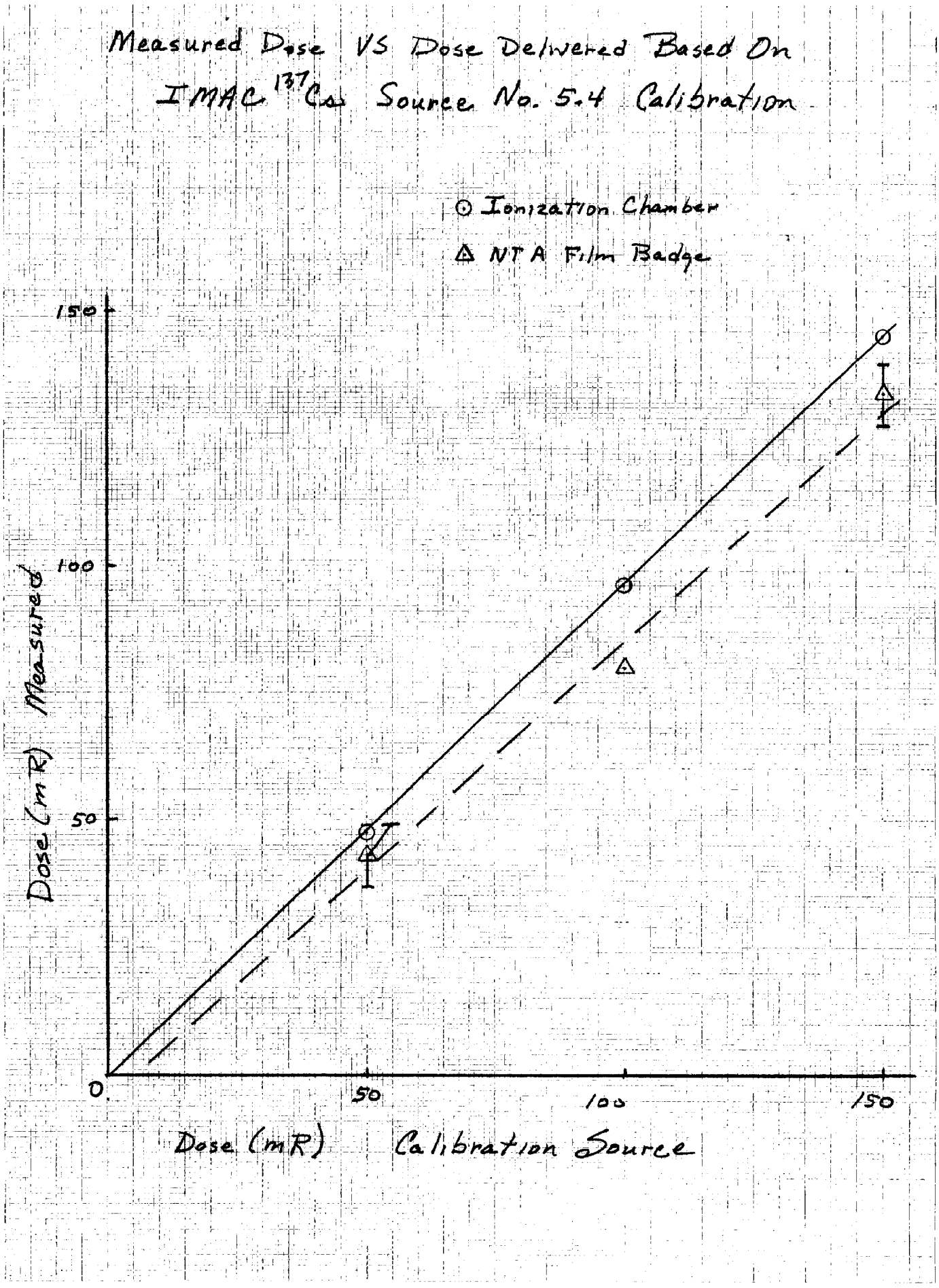

Measured Dose VS Dose Delivered Based on
Beam Projector 137Cs Calibration
(Large 120 Ci Source)
Ionization Chamber
Film Badge (NTA)
Dose (mR) (Measured)
Dose (mR) (Beam Projector)
100
200
300
400
500
600
700

FIGURE 3


Measured Dose VS Dose Delivered Based On IMAC ^{137}Cs Source No. 5.4 Calibration
⊙ Ionization Chamber
△ NTA Film Badge
150
100
50
0
Dose (mR) Measured
50
100
150
Dose (mR) Calibration Source