STUDIES ON THE POCKET DOSIMETER FOR PREVENTION OF RADIATION INJURIES

III. THE BASIC TEST OF SOME RATE METERS

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Though filmbadge or pocket chamber is used in measuring the quantity of radiation which an individual engaged in handling the radiological apparatus in exposed, the use of dose rate meter or counting rate meter is gradually gaining popularity in lightly determining the space doses under certain conditions at a given location or to survey a degree of contamination by radioactive substances. Since, however, these meters show errors which are attributable to causes either idenitcal to or different from the pocket chamber, it is highly dangerous to accept the figures shown by them as completely reliable. We have reported, in Parts I and II of this series of investigation, on the errors to which the pocket chambers and the filmbadges are liable. In the present paper we shall report on the results gained by our studies with three dose rate meters and a counting rate meter.

When using the dose rate meters or the counting rate meters, their wavelength dependence arises by the same mechanism as in the case of pocket chamber, are ammeter methods with D.C. amplifier circuit. So we must take into considerration such error as those which may be caused by their electric circuit. Thus the causes of errors which may arise with the mechanism of the rate meters are as follows:

1. Wavelength dependence
2. Geometrical dependence
3. Quantity dependence
4. Stability of range changing
5. Accuracy of standard source for calibration.

Reliability (quantity dependence) of the index of radiation quantity denotes the degree of accuracy of the indication of the radiation quantity on the meter from the minimum (0) to the maximum (full scale) on its graduation. One may use the them "linearity" in place of quantity dependence when the graduation is uniform. Stability of range changing means that the indication value of the higher magnification and that of the lower magnification correspond correctly (or not) when the range (resistance) is changed, since these meters are capable of changing the range of indication by selection of the resistance of the grid circuit within the extent of approximately $10^9 \sim 10^{11}$ ohm in order to expand the scope of measurement[1)2)]. Next, as these meters have sensitive electric circuits it is necessary that the indications of the meters be periodically calibrated by an equipment with a known radiation quantity which these meters are provided with. The radiation source often calibrator must possess on accurately known quantity for the following reasons; As ordinarilly employed, and the radiation quantity of 1 mg of radium in 0.5mm platinum filter as commonly used has been determined to be 0.84 mr/hr at 100cm distance. This value, however, holds only when 0.5mm platinum is used. The radium which is readily available at most hospitals is supplied for therapuitic purposes, and comes therefore encased in platinum of thickness of 0.2mm, 0.5mm, or 1.0mm according to the requirements of different theraputic purposes. To attach the value of 0.84 mr/hr for each milligram of radium for all purposes is obviously not appropsiate. It is, therefore, imperative that we make an accurate estimation of radiation quantity of radium before using it as a calibration source.

It is on these quetion that we have conducted the studies in the succeeding pages.

THE MEASURING INSTRUMENTS STUDIED

The meters which we selected as objects for our examinations were Models

TABLE I.

Outline of the meters construction

Subject \ Meter	DR-1 Meter*	Model 2585	Model 2610 A
Type	Ionization chamber	Ionization chamber	Geiger-Müller tube
Electric source	A.C. 100 Volt	D.C. 22.5 × 3Volt	D.C. 300 × 3Volt
Calibration	Possible	Possible	Possible
Correction table for radiation quantity	in explanation	no	in explanation
Graduation and Range	25 × 100 mr/hr 25 × 10 〃 25 × 1 〃	50 × 100 mr/hr 50 × 10 〃 50 × 1 〃	20mr/hr (60 × 1000c/m) 2mr/hr (60 × 100c/m) 0.2mr/hr (60 × 10c/m)
Filter	Gamma-& X-rays: +bakelite Beta-rays: mica window	Same as DR-1	Hard gamma-ray: metal cover Soft rays: cover open
Measurement center of meter	5cm fro front (chamber length 18cm)	Geometrical center (chamber length 15cm)	Geometrical center

* DR-2 is improved type of DR-1, and μr meter is added for reading the roentgen second of instantaneous exposure.

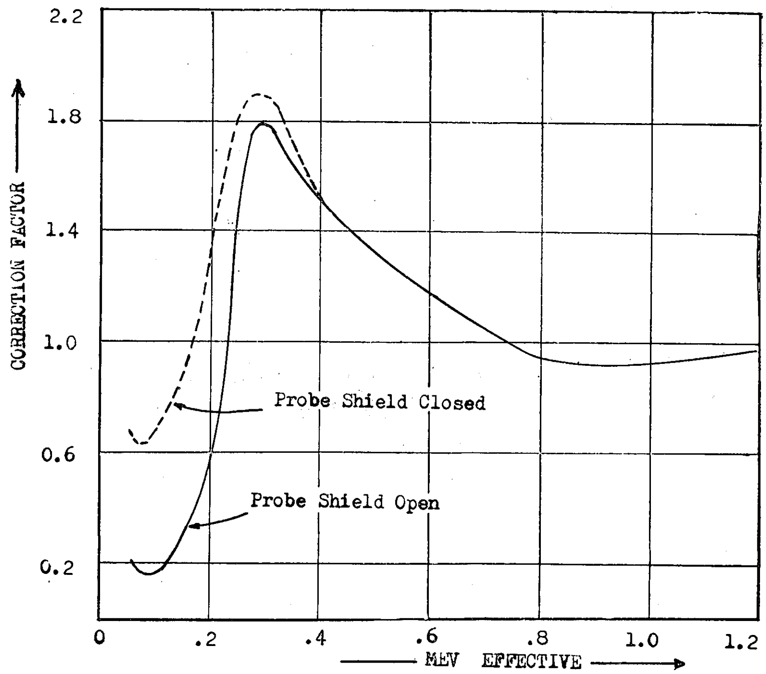

Fig. 1 Correction curve of Model 2610A for radiation quantities (Reproduced from the pamphlet accompanying apparatus)

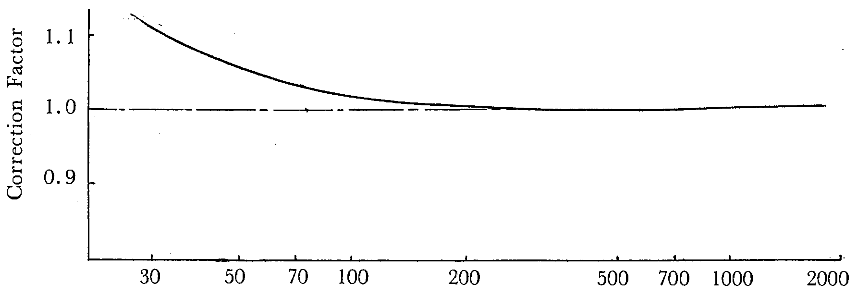

Fig. 2 Correction curve of DR-1 for wavelength dependence (Reproduced from the pamphlet accompanying apparatus)

2585 and 2610A (made by Nuclear Chicago), DR-1, and its mode DR-2 meter (made by Kobe Kogyo Co. Ltd.). Table I shows the outline of their constructions. DR-1, DR-2 and Model 2585 are ionization chambers, and Model 2610A is counting rate meter by Geiger-Müller tube. As a reference, we have reproduced in Fig. 1 and 2 the wavelength dependence of the Model 2610A and the DR-1 which are shown in the pamphlet accomdanying the apparatuses.

PROCEDURES

We used the radium gamma-rays for radiation source to examine these meters. In these cases, we used filters that are thicker than the equivalent of changing 0.5mm Pt in order to exclude the beta-rays. The radiation quantities were varied by changing the distance between the radiation source and the instruments to be tested. We used 1mg of radium Pt 0.2mm + brass 1.5mm filter for Model 2610A, and three tubes of 1mm platinum filter containing 10mg each for Model 2585 and DR-1 and DR-2. The radiation quantity of the former was determined by experimentation to be 0.8mr/hr at 100cm (the result 3 given elsewhere in the present paper), and for the latter we adapted the value of 7.5 r/hr at 1cm from Yamakawa's data[3]. Inactual testing in order to prevent the backscatering, these meters were kept as far as possible from the surrounding walls and the sundry fixtures. But Eto and others have reported that there were not so large an influence from these environmental circmferences[4]. For the center points of these chambers and the counter, we adapted the points 5cm from the front of the chamber for DR-1 and DR-2, and the geometrical center for Models 2610A and 2585, following the directions given in the reference panphlets accampanying the meters.

RESULTS

1.a) As a result of our examination on the DR-1, it seemed to us that the stabilization of the indication was good. If we assume that the "indication rate" are obtained by the next equation, then the indication rate is comparatively stable in regard to the quantity variation.

$$\text{indication rate} = \frac{\text{indicated quantity}}{\text{calculated quantity}} \times 100\ (\%)$$

The results obtained when the chamber axis coincided with the incident beam flux, and when the chamber axix is set vertical to the incident beam flux, are shown in Table II. And in each division, the upper row numbers indicate values and the figures in brackets are show the indication rate. In Table III are shown the results of our examination on the error which is caused by alteration of the range. These results demonstrate that the measurement at the both ends of gradation is unreliable.

1.b) In Table IV are shown the results of our examinations on the DR-2 meter. So far as these examinations are concerned no better results can be expected of DR-2 than DR-1.

1.c) The results of our examinations on the Model 2585 are shown in Table V. In this case, we corrected the indication of the needle, at the outset,

TABLE II

DR-1 indication values (in bracket are indication rates)

Condition	Range \ Distance / Calcurated doses	22 cm 465mr/hr	47 cm 101.8mr/hr	72 cm 43.4mr/hr	97 cm 23.9mr/hr	147 cm 10.4mr/hr
Chamber axis parallel with beam flux	25×100	500mr/hr (108%)				
	25× 10		105 (103)	45 (104)		
	25× 1				23.5 (98)	10.5 (101)
Condition	Range \ Distance / Calcurated osesd	25 cm 360mr/hr	50 cm 90.0mr/hr	75 cm 40.0mr/hr	100 cm 22.5mr/hr	150 cm 10.0mr/hr
Chamber axis vertical to beam flux	25×100	400mr/hr (111%)				
	25× 10		90 (100)	45 (113)		
	25× 1				24.5 (109)	9.0 (90)

TABLE III

The error due to range changing of DR-1; Source: 10mg Radium 3 tubes, Adjusted in "zero set" Position

Distance \ Range	× 1	× 10	× 100
130 cm	13.0*	1.5	
100 〃	23.0	3.0	
75 〃		5.0	0.3
50 〃		12.0	1.0
25 〃			4.5
15 〃			10.5

* Numbers are shown in graduation

so as to make it correspond to calculated doses at 100cm, and the indication rate on this condition was calibrated 100%. We believe that the major cause for an unusually pronounced differences in the indication rate with the variation in the radiation quantity is due to the error of taking the geometrical center

TABLE IV

DR-2 indication values (in bracket are indication rates)

Condition	Range \ Distance / Calcurated doses	40cm	50cm	75cm	100cm	125cm	150cm	175cm	200cm
		mr/hr 141	mr/hr 90.0	mr/hr 40.0	mr/hr 22.5	mr/hr 14.4	mr/hr 10.0	mr/hr 7.4	mr/hr 4.5
Chamber axis parallel with Beam flux	25×100	150 (106%)	100 (111)	30 (75)					
	25×10	182 (129)	85 (94)	38 (95)	20 (89)	14 (97)	8 (80)	7 (95)	
	25×1				20.2 (90)	12.4 (86)	8.5 (85)	6.3 (85)	5.0 (111)
Chamber axis vertical to beam flux	25×100		100 (111)	50 (125)					
	25×10		92 (102)	43 (108)	24 (106)	18 (125)	12 (120)		
	25×1				22.1 (98)	14.6 (101)	9.7 (97)		

TABLE V

Model 2585 indication values (in bracket are indication rates)

Condition	Range \ Distance / Calcurated doses	25 cm	50 cm	75 cm	100cm	125cm	150cm
		360mr/hr	90.0mr/hr	40.0mr/hr	22.5mr/hr	14.4mr/hr	10.0mr/hr
Chamber axis parallel with beam flux	50×100	270mr/hr (75%)	120 (133)	100 (250)			
	50×10	286 (79)	73 (81)	40 (100)	25 (111)	23 (160)	
	50×1			37.4 (94)	22.5 (100)	17.0 (118)	13.0 (130)

for effective (measuring) center. More-over, the difference of the indication rate arises as the result of the change of the range is so large that the reliability because very law, especially when the indicating needle approaches the highest end of the scale.

1.d) In testing on the Model 2610A, we made the indication at 100 cm correspond to calculated doses, and regard this value as 100%. One side of the G–M tube of this meter has a window which can be opened or closed by a metal cover. It is used closed for hard beam, and opened for soft beam. The results

TABLE VI

Indication values and indication rates of the Model 2610A
The upper row are indication values in mr/hr
The lower row are indication rates in %

Condition	Shield	Range \ Distance	25 cm	75 cm	100cm	150cm	290cm
		Calculated doses	mr/hr 12.8	mr/hr 1.42	mr/hr 0.80	mr/hr 0.35	mr/hr 0.095
Radiation flux incidents upon window side is vertical to G-M tube axis	Open	20	13.2 (102)				
		2		1.65 (116)	0.95 (119)	0.45 (128)	
		0.2					0.12 (126)
	Closed	20	11.0 (86)				
		2		1.40 (98)	0.80 (100)	0.35 (100)	
		0.2					0.10 (105)
Radiation flux corresponds with G-M tube axis	Open	20	7.0 (55)				
		2		0.75 (53)	0.45 (56)		
		0.2				0.18 (52)	0.055 (58)
	Closed	20	7.0 (55)				
		2		0.70 (49)	0.40 (50)		
		0.2				0.18 (52)	0.055 (58)
Radiation flux incidents upon the back of window is parallel to G-M tube axis	Open	20	10.0 (78)				
		2		1.15 (81)	0.70 (87)	0.35 (100)	
		0.2					0.090 (95)
	Closed	20	11.0 (86)				
		2		1.25 (88)	0.80 (100)	0.40 (114)	
		0.2					0.10 (105)

of the examination on their radiation conditions with the cover either opened or closed, are shown in Table VI. The difierence due to range changing is not very large, but we must notice the fact that the wavelength dependence is large (see the Fig. 1).

2) When the incident quantity is small, for the large time-constant is adopted in this instrument, we need a considerable time to get the accurate and stabilized indication. Our observation on DR-1 meter showed clearly that it requires more than 30 seconds before the indication is stabilized, and that it

showed a larger fluctuation than 1 division eveo afterwards (25 division full scale) (see Fig. 3). It seems, therefore, that pretty difficult to make an accurate meassurement in shorter time. In Fig. 4 is shown the result of the same examination on DR-2 meter. It shows that DR-2 is more stable than DR-1.

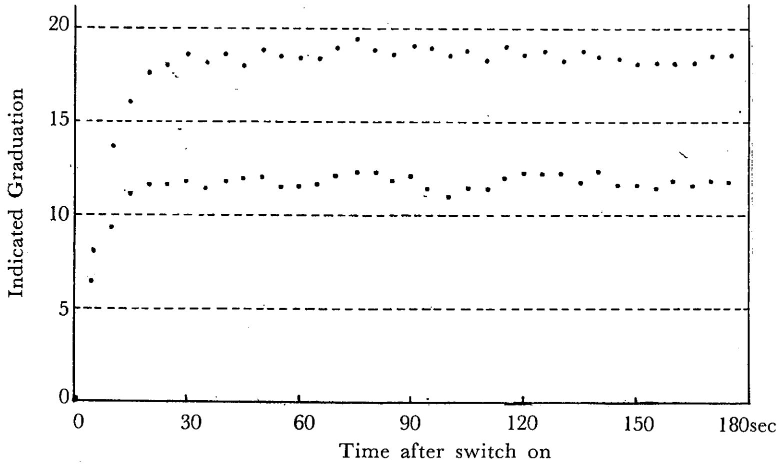

Fig. 3 Stability of indication of DR-1
Source: A Ra tube of 10mg with Pt 1.0mm filter
■ : Distance 60cm
● : Distance 75cm

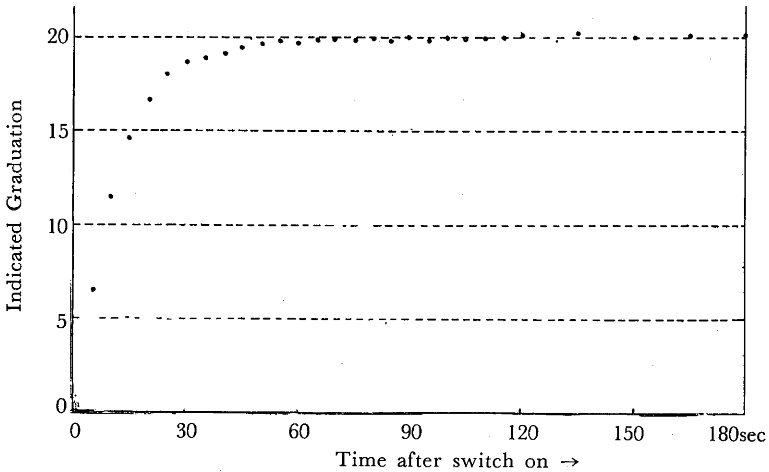

Fig. 4 Stability of indication of DR-2
Source: 3 tubes of Ra 10mg with Pt 1.0mm filter
Distance: 100cm

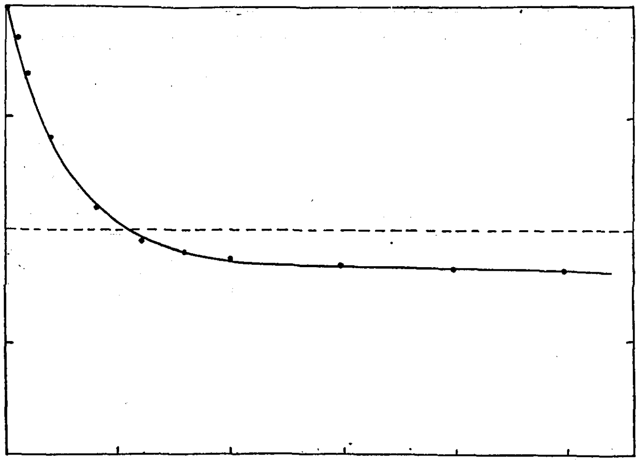

Fig. 5 The reduction of Ra γ-ray by Cu filter
Measured with Lauritsen electrscope, source is Ra 1 mg of Pt 0.2mm shell and set to 100% the radioactivity of bare shell.

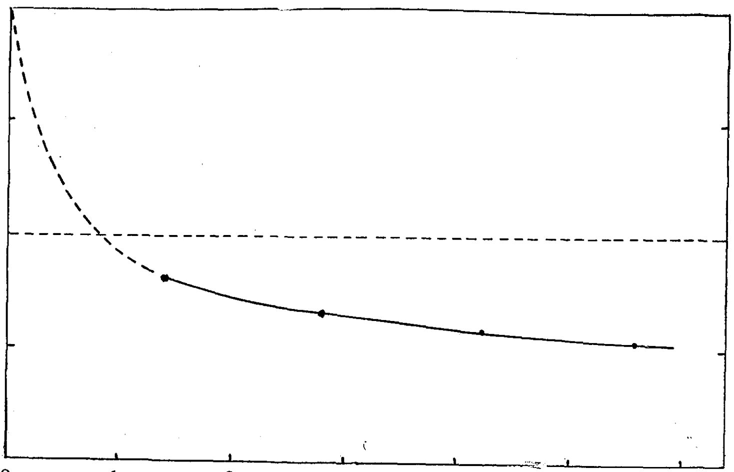

Fig. 6 The reduction of Ra γ-ray by Pb filter
Measured with Lauritsen electroscope, source is Ra 1 mg of Pt 0.2mm shell and set to 100% this radioactivity.

3) The radiation quantity of 1 mg radium has been evaluated 0.84 mr/hr at 100 cm, when 0.5 mm platinum filter is used. The radium which we use in our experiments is mostly the ones prepered for therapeutic purposes, and the

filters are of thickness varying as 0.2, 0.5, 1.0mm, etc., and is shaped as either as shells, needles, or tubes. Therefore, we think that it is not proper to apply uniformly 0.84 mr/hr for every 1 mg of radium at 100cm.

We used 1 mg shell of radium with the 0.2mm Pt filter as radiation source, and as the intermediary filters the Cu plates and Pb plates were used. And by the method in which the thickness of these intermediary filters is varied, we measured with Lauritsen's electroscope the ionization by penetrating radiation, and examined how these filters weaken the radiation. The distance between the radiation source and the window of the chamber is 34.1cm, and the filter was set at 2cm from the source.

The relation of the decrease of the ionization quantity with the increase in of the thickness of Cu plate as filter are shown in Fig. 5. We can observe that the ionization decreases with the increase of the filter thickness, even when it becomes thickness than Pt 0.2mm + Cu 1.0mm, at which thickness the beta-rays and the soft gamma-rays are expected to have been almost completely absorbed. The curve of reduction of ionization with the increased thickness of the Pb filter is given in Fig. 6. In Fig. 5 and 6, the numbers in brackets of the horizontal axis show the thickness of Pt which is equivalent to the thickness each of the Cu or the Pb filters[3) *Yamakawa*]. The ionizing intensity of the filter equivalent to Pt 0.5mm shows 50% of Pt 0.2mm which contains the soft gamma-rays and beta-rays. When the filter is equivalent to Pt 1.0mm, the decrease of 10% is observed for the equivalent thickness to Pt 0.5mm. From this result, it is clear that the radiation quantity of radium is influenced by the cover filter. Therefore, when using the radium gamma-rays for the standard radiation source, its true radiation quantity should have been cleared previously.

CONCLUSION

On the four meters, DR-1 and DR-2 meters (Kobe Kogyo Co. Ltd.), Model 2585 and Model 2610A (Nuclear Chicago), we have conducted a series studies on the errors which are liable to occur in their use, and obtained the following results:

1) Both ends of the graduation have poor linearity.

2) All the four meters are provided with the apparatus of the range changing, but in connection with the conclusion 1, we must pay a special attention to the peculiar behavior of the indication accompanying the range changing.

3) Since the time required for stabilization of the indication is long when the radiation quantity is small, it is necessary that a longer time be spent in each measurement.

4) For calibration, we must use the standard radiation source of which the

quantity has previously been accurately known. Even though the weight of the radium is constant, the radiation quantity varies according to the thickness of its container when one uses the gamma-rays of radium for this purpose.

It is our fervent wish that through continuous efforts of those men engaged in the manufacture of the meters the differences in the performance of the apparatuses be eliminated and an accurate and uniform indication quantity become avoilable to the common aim of service to humanity.

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REFERENCES

1) ROSSI. B. B. and STAUB, H. H.: Ionization Chambers and Counters. McGraw-Hill, New York, 1949.
2) WILKINSON, D. H.: Ionization Chambers and Counters. Cambridge, the University Press, 1950.
3) YAMAKAWA, H.: Clinic of Radium Therapy, Nanzando, Tokyo, 1938.
4) ETO, H., et al: On the Practical Methods of Testing the Characteristics of the Monitoring Meters I. Pocket-mters. *Radioisotopes*. **3**: 55～57, 1954.
5) ETO, H. et al; On the Practical Meods of Testing the Characteristics of the Monitoring Meters II. Radiation Survey Meter. *Radioisotopes*. **3**: 59～62, 1954.