STUDIES ON THE POCKET DOSIMETER FOR PREVENTION OF RADIATION INJURIES

1. BASIC TESTS OF THE POCKET CONDENSER CHAMBER

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In order to prevent radiation injuries, it is necessary for persons handling radioactive substances and X-rays to be constantly accurately informed on the radiation doses they are exposed to while working, so that he can keep it reduced to the smallest possible level or at least below the tolerance doses as clinically established at the present time.[1) 2) 3)] It is, however, very difficult to measure the radiation doses during operation owing to the fact that most of the radiation to which the operator is exposed is composed of scattering rays, particularly in X-ray treatment.

Hitherto the dosimetry method which measures radiation dose by optical density of films or photographic papers has been the subject of considerable fundamental studies [4)] and practical application.[5)6)7)] However, an accurate measurement of radiation dose for every radiation quality can be conducted with considerable difficulty owing to the dependence of photosensitive emulsions upon waves lenghths, and to the difficulty of preparing standard optical densities. For the purpose of minimizing the technical error in the measurement of the optical density of films, we have once adopted a method of preparing numerous test pieces out of one sheet of X-ray film measuring 10 × 12 inches which, we expected, would give us a uniformity of emulsion sensitivity and by which we read the optical density of developed films directly with photoelectric densitophotometer. In the mean time the method of measurement of radiation dose by using the ionization chamber was already reported in 1938 [8)], and more recently dosimetry by pocket ionization chamber or pocket dosimeter has become popularized [9)]. We have therefore tested the pocket condenser chamber (hereafter to be called simply pocked chamber) made by Toshiba Electric Co., for several of its fundamental properties. It must be admitted that the pocket chamber has a number of limitations in its construction as compared with large sized ionization chamber in order to meet the requirements of its purpose [10)]. The knowledge of such limitations and special properties of the pocket chamber would be pertinent in using it. This report deals with results of our tests of the pocket chamber.

Method and Equipments

As sources of radiation for capacity range between 45 to 60 kVp., a diagnostic X-ray apparatus was used, for that between 70 to 160 kVp., a deep therapy apparatus, and for high energy source a therapeutic dose of γ-ray of radium was employed. At first we measured exact doses of X-ray by means of Küstner's Standard Dosimeter (Eichstandgerät) (hereafter called E.S.G.), and then irradiated nine pocked chambers with various qualities of X-ray at a fixed dosage. In order to cancel the effect of scattering rays from walls of the room, the nine pocket chambers were set near the center of a wide room, parallelly and closely to become vertical against the center flux of incident ray. The distance from the focus to the pocket chambers was 120 cm. At this distance, it was supposed that the effect of the low of inverse-square was not operative between the central and the terminal chambers, and our preliminary test did not show signs of mutual interaction of scattering ray among respective chambers. The character of the pocket chambers was studied with varied radiation qualities to be realised by changing the tube voltages and filters either separately or together. We further compared the indication -rate of the pocket chambers with the optical density several film badges irradiated simultaneously.

Results and Discussion

1. *Natural Discharge.*

The prime requisite for a pocket chamber is the after-charge stability of potential. Natural discharge of pocket chamber is shown in Table I and II. From these tables it is seen that the majority of the chamber purchased in February 1953 became useless after several months owing to the increase in natural discharge. It is thus clear that every pocket chamber should be tested at appropriate intervals for its natural discharge.

Table I

Natural discharge of pocket chambers purchased Feb. 1953.

Date	Period of test	Chamber number						
		10	11	12	13	14	15	16
1953 IV 14	24 hours	3	0	14	4	10	0	0
〃 IV 25	24 〃	13	2	15	5	45	1	2
〃 VI 12	8 〃	12	0	8	3	over	1	4

TABLE II

Natural discharge of pocket chambers purchased Oct. 1953. Values are shown in graduation.

Date	Period of test	Chamber number								
		1	2	3	4	5	6	7	8	9
1953 II 1	24 hours	−1	0	−0.5	0	0	0	−1	−1	−1
〃 〃 2	8 〃	−1	0	0	0	0	0	−1	0	0
〃 IV 20	8 〃	0	1.0	0.5	0	over	0	over	0.5	0
1954 VIII 3	24 〃	4.5	3.5	13.0	3.0	over	1.5	over	2.0	16.0
〃 〃 6	24 〃	2.0	3.0	2.0	2.5	over	0.5	over	1.0	8.0
〃 〃 7	8 〃	1.5	2.0	1.5	1.5	over	0	over	1.0	20.0
〃 〃 9	8 〃	2.0	1.5	1.0	1.0	over	0	over*	0.5	dam.**

* "over" means over the scaling out.
** "dam." devotes.

Since the handling unit of a pocket chamber is usually the duty hours of a day at the longest, it is advisable to test the natural discharge of the pocket chamber for eight hours; an examination lasting longer than 24 hours would hardly be of practical value.

In Table II, negative values of natural discharge were effected by a mechanical shock of the chamber or a fluctuation of charger potential, they should have been zero, or positive at least.

2. *Indication-rate and correction factor.*

Owing to its construction the pocket chamber shows a wave-length dependence, but if we express the "indication-rate" with the value indicated by the pocket chamber in per cent of the doses measured with E.S.G., :

$$\text{Indication-rate} = \frac{\text{Value indicated by pocket chamber}}{\text{Dose measured with E.S.G.}} \times 100\,(\%),$$

the indication-rate depends not only upon the tube voltage but also upon the thickness and sorts of filters used. The results are shown in Table III and IV. Table III shows indication-rate obtained by using one and the same filter (0.3 mm Cu + 1.0 mm Al) with the tube voltage ranging from 60 kVp. to 160 kVp.. Table IV lists the indication-rate obtained by varying the filter for each voltage and for radium γ-ray.

Table III illustrates that the indication-rate changes continuously with the variation of the tube voltage to approach 100 % with the rise of the tube voltages which means that the beam becomes progressively harder.

TABLE III

Indication-rates as measured with the same filter (0.3 mm Cu+1.0 mm Al) through out the voltage range tested. Figures are listed in percentual value given by the formula:

$$\text{Indication-rate} = \frac{\text{Value indicated by pocket condenser chamber}}{\text{Dose measured with E.S.G.}} \times 100\,\%$$

Tube Voltage	Chamber number								
	1	2	3	4	5	6	7	8	9
60 kVp.	200	198	233	218	233	229	260	224	233
80 〃	264	230	277	264	271	284	277	277	284
100 〃	214	189	232	229	218	224	238	207	218
120 〃	179	163	193	185	182	196	201	176	189
140 〃	146	133	152	149	149	154	163	146	154
160 〃	141	133	148	144	134	148	151	134	157

TABLE IV

Indication-rates as obtained by varying the filter for different tube voltages. Figures listed are in percentual value as indicated in Table III.

Tube voltage	Filter	Chamber number								
		1	2	3	4	5	6	7	8	9
45 kVp.	0.5 Al mm	152	150	167	167	167	173	188	173	173
50 〃	〃 〃	137	135	145	149	150	155	160	150	155
60 〃	〃 〃	115	108	128	122	115	130	130	122	130
80 〃	1.0 Al	152	142	164	155	157	175	196	164	172
100 〃	2.0 Al	137	123	151	140	135	151	154	137	152
120 〃	0.1 Cu+1.0 Al	144	142	163	157	150	163	172	146	162
140 〃	0.3 Cu+1.0 Al	146	133	152	149	149	154	163	146	154
160 〃	0.5 Cu+1.6 Al	141	127	141	143	136	144	149	130	141
Ra-γ	$0.2 P_t + I_r$	123	125	128	143	128	125	127	124	133

Now we shall tentatively designate the ratio of the value of E.S.G. to that indicated by the pocket chamber as the "correction factor":

$$\text{Correction factor} = \frac{\text{Dose measured with E.S.G.}}{\text{Value indicated by pocket chamber}}\,.$$

Correction factor for cases where filter is fixed and variable are shown in Table V and VI respectively.

If we wish to obtain an exact value of the dose measured by the pocket chamber by employing the correction factor, we should use a table like the ones listed in Table V or IV. Let us now compare corresponding columns for the same tube voltage in Table III and IV. For example, at 60 kVp. tube voltage, a filter of 0.3 mm Cu + 1.0 mm

Al has been used in Table III, while in Table IV that of 0.5 mm Al. In spite of the same tube voltage used in both tables, the indication-rate is 198 %-260 % in Table III, whereas in Table IV it is 108 %-130 %. Likewise, at 80 kVp., 100 kVp., 120 kVp. and 160 kVp. there are also differences between Table III and IV.

In short, despite the peak tube voltage is of the same value, the radiation quality changes with the filter employed, resulting in variation of the indication-rate of pocket chamber. It follows, as seen from Table V and VI, that the correction factor varies even at the same tube voltage according to the difference of filter used. Thus a strict qualification of radiation is required for the use of correction factor.

TABLE V

Correction factors obtained with a filter (0.3 mm Cu+1.0 mm Al) fixed for different voltages. Figures listed obtained by the formula:

$$\text{Correction factor} = \frac{\text{Dose measured with E.S.G.}}{\text{Value indicated by pocket chamber}}$$

Tube voltage	Chamber number								
	1	2	3	4	5	6	7	8	9
60 kVp.	0.50	0.51	0.43	0.46	0.43	0.44	0.38	0.45	0.43
80 〃	0.38	0.43	0.36	0.38	0.37	0.35	0.36	0.36	0.35
100 〃	0.47	0.53	0.43	0.44	0.46	0.45	0.52	0.48	0.46
120 〃	0.56	0.61	0.52	0.54	0.55	0.51	0.50	0.57	0.53
140 〃	0.68	0.75	0.66	0.67	0.69	0.65	0.61	0.69	0.65
160 〃	0.71	0.75	0.67	0.70	0.75	0.67	0.66	0.75	0.64

TABLE VI

Correction factors obtained with different filters for different tube voltages. Figures listed are obtained by the same formula as using Table V.

Tube voltage	Filter	Chamber number								
		1	2	3	4	5	6	7	8	9
45kVp.	0.5 Al mm	0.66	0.67	0.60	0.60	0.60	0.58	0.54	0.58	0.58
50 〃	〃	0.73	0.74	0.68	0.67	0.66	0.64	0.63	0·66	0.64
60 〃	〃	0.80	0.92	0.78	0.82	0.86	0.77	0.77	0.82	0.77
80 〃	1.0 Al	0.66	0.70	0.61	0.65	0.54	0.57	0.51	0.61	0.58
100 〃	2.0 Al	0.73	0.81	0.70	0.72	0.74	0.66	0.65	0.73	0.66
120 〃	0.1 Cu+1.0 Al	0.69	0.71	0.61	0.64	0.66	0.61	0.58	0.69	0.62
140 〃	0.3 Cu+1.0 Al	0.68	0.75	0.66	0.67	0.67	0.65	0.61	0.69	0.65
160 〃	0.5 Cu+1.0 Al	0.71	0.79	0.71	0.70	0.74	0.69	0.67	0.77	0.71
Ra-γ	$0.2P_t+I_r$	0.81	0.80	0.78	0.70	0.78	0.80	0.78	0.80	0.75

3. *Difference of individual chambers.*

An inspection of different columns of Table III or IV immediately reveals the difference in the indication-rate of individual chambers in spite of the concurrent irradiation. Every chamber is thus subject to individuality. Therefore, a correction using a list like Table V or VI requires the correction factor for each chamber. Tables VII and VIII show the indication-rate in per cent of the mathematical mean of individual column to demonstrate clearly the differences in indication-rate among different chambers given in different columns.

TABLE VII

Individuality of pocket chambers as expressed in per cent of mean indication-rate calculated from the data of Table V.

Tube voltage	Chamber number									
	1	2	3	4	5	6	7	8	9	Mean
60 kVp.	89	88	103	97	103	102	116	99	103	100
80 〃	98	85	103	98	100	105	103	103	105	100
100 〃	98	86	106	104	100	102	109	95	100	100
120 〃	97	88	104	100	99	106	109	95	102	100
140 〃	97	89	101	100	100	103	109	98	103	100
160 〃	98	93	103	100	94	103	106	94	102	100
Mean in Row	96.2	88.2	103.3	99.8	99.3	103.5	108.7	97.3	103.7	100.0

TABLE VIII

Individuality of pocket chambers as expressed in per cent of mean indication-rate calculated from the data of Table VI.

Tube voltage	Chamber number									
	1	2	3	4	5	6	7	8	9	Mean
45 kVp.	90	89	100	100	100	103	112	103	103	100
50 〃	93	91	98	100	101	104	108	101	104	100
60 〃	94	89	105	100	94	106	106	100	106	100
80 〃	93	86	100	94	96	107	119	100	105	100
100 〃	97	87	106	98	95	106	108	97	106	100
120 〃	93	91	105	101	96	105	111	94	104	100
140 〃	98	89	101	100	100	103	109	97	103	100
160 〃	101	92	102	102	98	104	107	94	101	100
Ra-γ	95	97	100	112	100	97	99	96	104	100
Mean in Row	94.9	90.1	101.7	100.8	97.8	103.9	108.8	98.0	104.0	100.0

4. *Comparison of the optical density of film emulsion and performance of pocket chamber for wavelength dependence.*

The pocket chambers and X-ray films were irradiated concurrently at the dose of 0.1 r with a variety of the tube voltage to compare their wave-length dependence. The results of comparing the indication-rate of the pocket chamber with the optical density of the film are shown in Table IX. The filter used was 1.0 mm Al throughout the voltage tested. Optical density was read directly with photoelectric densito-photometer. The observation suggests that in the range of our experimentation, the optical density of the film is subject to fluctuation due to the change in tube voltage to a lesser extent than the indication-rate of the pocket chamber.

TABLE IX

Comparison of the pocket chamber indication-rate and the optical density of film badges for wavelength dependence. A filter of 1.0 mm Al was used throughout the voltages tested.

Tube voltage	Indication-rate									Optical density of Film Badge
	Chamber number									
	1	2	3	4	5	6	7	8	9	
64 kVp.	146	132	152	143	—	155	—	140	149	1.35
90 〃	166	146	180	155	—	160	—	160	166	1.35
100 〃	169	143	180	158	—	175	—	163	175	1.40
110 〃	175	149	175	163	—	172	—	169	180	1.40
120 〃	183	160	186	180	—	172	—	175	177	1.40
130 〃	155	143	169	160	—	155	—	155	160	1.25
140 〃	135	132	146	138	—	146	—	143	132	1.20
150 〃	143	143	158	152	—	163	—	149	146	1.22
160 〃	160	152	177	163	—	172	—	138	166	1.22

COMMENT AND CONCLUSION

The wavelength dependence of the pocket condenser chamber are of a fairly considerable extent; especially at tube voltages employed for diagnostic purpose the indication-rate amounts to over 200 %. For the scattering ray, which represents an assembly of radiations of different qualities, the pocket chambers may well indicate a value different from the actual dose. Accordingly X-ray operators should take into account of this fact when measuring scattering X-ray doses they have suffered with pocket condenser chambers. But if the correction factors for all the radiation qualities are obtained in advance, the use of pocket chambers for dosimetry would be relevant to a certain extent. But even in such cases it should be kept in mind that there are differences in indication-rate among different chambers. Further it may be suggested that the utility of the film optical density method is by no means inferior to the pocket chamber method if employed appropriately. In addition, it should be pointed out that examinations of natural discharge at appropriate intervals is of great importance.

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