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STUDIES ON THE POCKET DOSIMETER FOR PREVENTION OF RADIATION INJURIES

IV. ON THE DISTRIBUTION OF SCATTERED RADIATION IN THE OUT CLINIC WORK

KO SAKURAI, HARUMA YOSHINAGA AND TAKAMARU MIKOCHI

Department of Radiology, Yamaguchi Medical School, Ube

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As already described in the preceding sections of this paper, the factor of greatest importance in prevention the radiation injuries is that the person handling radiation apparatuses constantly possesses accurate knowledge of radiation quantity to which he is exposed. Next in importance is that he must exert full efforts to avoid exposure to scattered radiation by first accurately estimating the radiation quantity to which he is exposed by the use of filmbadge, pocket chamber or other forms of portable measuring instrument, or determining the quantity of scattering radiation in the radiation operating rooms with a portable dosage meter.

In parts I, II and III of this paper,[1)2)3)] we have discussed the important factors on which we must bear in mind in using filmbadge, pocket chamber, and dosage rate meter. In the present report, we shall describe our studies on scattered radiation which we meet with in the radiation operating room and to which the persons working there are exposed in the clinical application of radiation.

Concerning the measurement of scattered radiation with pocket chamber the reports by *Kuramoto*,[4)] *Cederlund*[5)] and thus are recorded in the literature, while *Adachi*,[6)] *Eto* and others[7)] have reported on the results of measurement with filmbadge and paperbadge. In addition to these are many studies recorded on distribution of scattered radiation under various conditions of radiation therapy.[8)] Thus *Miya* and others have reported on the quantity of radiation to which was received by worker with protective apron is exposed. Judging from these reports we conclude that the radiation quantities to which workers are exposed are influenced by the capacity of the room in which radiation treatment is given, efficiency of the protective measures taken, and especially throughness with which these protective measures are utilized by the workers themselves.

We have studied the influences if any of attentiveness of workers, environment, and the variety of X-ray work done upon the scattered radiation quantity that we find various X-ray works. In this connection the author makes to apologie

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for his failure to correct the errors in figures of the scattered radiation quantities which we have described as extremely difficult of correction in the first, second

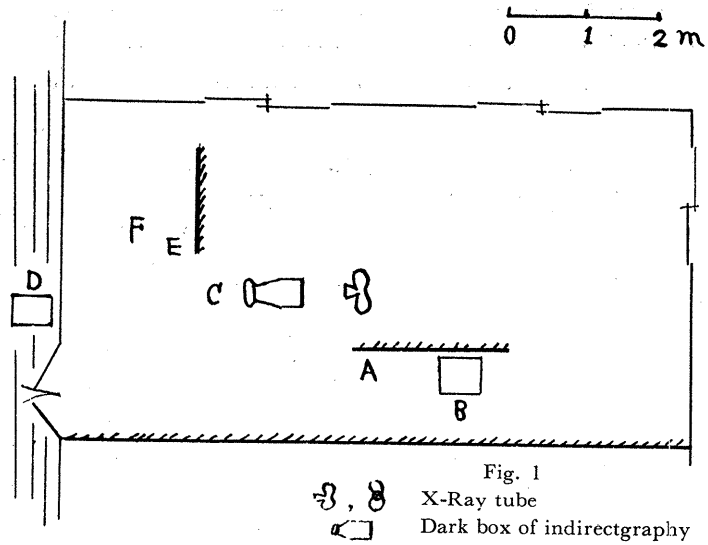

Fig. 1
X-Ray tube
Dark box of indirectgraphy
Protective leadscreen

and third reports of the present study.

For these measurement we have employed pocket chambers made by *Toshiba Electric Co.*, dosage rate meter of *Kobe Kogyo Co.*, and filmbadge made by ourselves.

TABLE I

Exposed doses when operated with precaution in a large room (Condition a)

Number of Patients	Exposed Doses		
	Physician in charge	Technician	Camera man
643	160 (24.8)	61 (9.5)	66 (10.1)
536	128 (23.9)	28 (5.2)	72 (13.4)
265	83 (32.5)	100 (37.8)	56 (21.8)
623	38 (5.9)	28 (4.5)	56 (9.0)
580	128 (22.0)	28 (4.8)	72 (12.4)

The numbers in brackets are doses per 100 patients, unit mr, in all these tables from I to VII.

RESULTS

I. Results with pocket chambers

We have already considered this subject in Part I of the present series.

i) The resuls obtained by quantitative estimation of scattered radiation in mass examination by indirect radiography were classified into 4 groups a, b, c, d, as follows:

a) When the radiation operation is conducted in a large room very cautiously. The only protective measure was the leadlined apron worn by the physician who is charged with placing the patient in appropriate posture. The operator

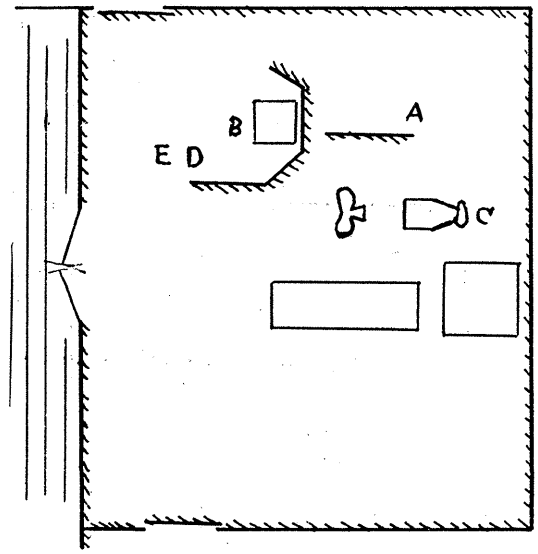

Fig. 2 Referential schema for Table IV

TABLE II

When operated with carelessness in a large room (Condition b)

Number of Patients	Technician		Assisstants and Receptionists											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
80	28 (35)		32 (40)					100 (125)	80 (100)		66 (83)		56 (112)	
50	22 (44)		44 (88)	16 (32)				72 (144)						
641		80 (13)	114 (18)		21 (3)		381 (50)			206 (32)		324 (51)		
578		68 (12)	74 (13)		143 (25)	74 (13)						216 (37)		79 (14)
500		50 (10)	57 (11)		46 (9)	57 (11)	50 (10					103 (21)		162 (32)

and his assistants, however, took special precaution to avoid receiving the scattering rays as far as possible. Table 1 shows the quantities of scattering radiation

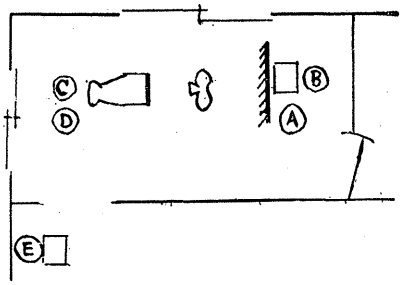

Fig. 3 Referential schema for Table V

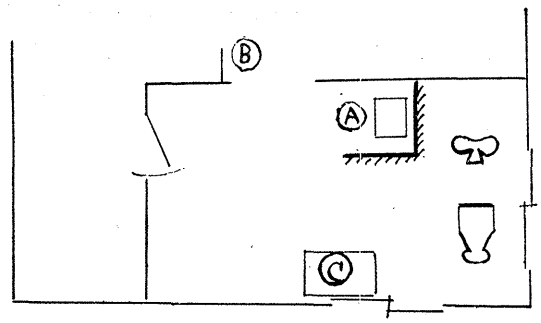

Fig. 4 Referential schema for Table VI

TABLE III

When operated in a small room with protective arrangements (Condition c, i, show Fig. 1)

Number of Patients	Members and Positions					
	A Physician	B Technician	C Camera man	D Receptionist	E Assistant	F Assistant
180	2 (1)	9 (5)	5 (3)	49 (27)	51 (28)	8 (5)

TABLE IV

When operated in a small room with protective arrangements (Condition c, ii, show Fig. 2)

Number of Patients	Members and Positions				
	A Posture Rectify	B Technician	C Camera man	D Assistant	E Assistant
150	34 (23)	5 (3)	5 (3)	11 (7)	
240	15 (7)	9 (4)	17 (7)	29 (12)	45 (19)

received by each member of the operating staff under the conditions above described. The figures in parenthesis represent he quantities of scattering radiation received by each operator for every 100 patients.

b) When radiation operation is conducted under the condition identical to a) with the exception that no particular care was taken by assistants to avoide exposure to the scattering radiation.

Table II shows radiation quantities to which the assistants were exposed. These men were rather inexperienced in handlingthe radiation and consequently lacked proper caution. The room was spacious and the physician in charge kept on

giving them instructions but they were either too slaw or erratic in dodging the scattering radiation and as a result received considerable radiation on their bodies.

c) When operation was conducted in a small room provided with protective arrangement. In Table III are shown the results when lead screen placed in such

TABLE V

When oprated in a small room with protective arrangements
(Condition c, iii, show Fig. 3)

Number of Patients	Members and Positions				
	A Posture Rectify	B Technician	C Camera man	D Assistant	E Assistant
260	16 (6)	16 (6)	21 (8)	28 (11)	28 (11)

TABLE VI

When operated in a small room with protective arrangements
(Condition c, iv, show Fig. 4)

Number of Patients	A Technician	B Assistant	C On the Desk
218	11 (5)	16 (7)	11 (5)
120	11 (9)	16 (13)	28 (23)
152	44 (29)	11 (7)	28 (18)
223	72 (32)	5 (2)	3 (1)
124	22 (18)	28 (23)	22 (18)
221	33 (15)	39 (18)	5 (2)
157	44 (28)	39 (25)	28 (18)
225	28 (12)	11 (5)	33 (15)
261	33 (13)	11 (4)	28 (11)
89	50 (56)	11 (12)	28 (31)
102	39 (38)	11 (11)	22 (22)

a position as illustrated in Fig. 1 was used in a small room. Table IV presents the results obtained under conditions illustrated in Fig. 2, Table V under the

conditions as depicted in Fig. 3. The scattering radiation quantities received by the assistants working in a small X-ray room attached to a dispensary of a factory, as illustrated in Fig. 4, are shown in TablesVI.

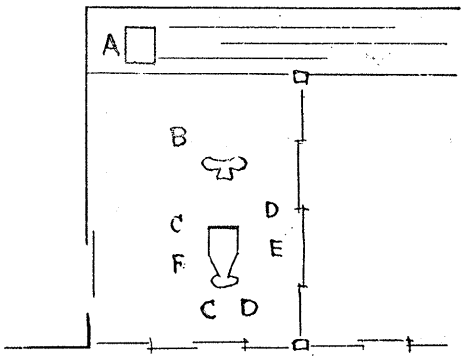

Fig. 5 Referential schema for Table VII. Assistants C and D operated a camera as well as rectified the patients posture

d) When the work was carried out without sufficient caution in small room not provided with protective arrangements.

Table VII shows the radiation quantities to which the operators are exposed during rather careless operation in a small room having not protective arrangements. These operators did not have much experience in radiologic work. Fig.5 represents the results in schema.

TABLE VII

When operated with insufficient precaution in a small room without a protective arrangment (Condition d, show Fig. 5)

Number of Patients	Members and Positions					
	Technician	Posture Rectify	Assistant			
	A	B	C	D	E	F
253	50 (20)	44 (17)	90 (36)	232 (93)	362 (143)	
249	50 (20)	22 (9)	116 (47)	144 (58)		348 (140)

ii) Fluoroscopy

Radiation quantities to which various parts of the body of the examining physicians in gastrointestinal X-ray examination are exposed are shown in Table VIII. Figures in brackets are converted doses for a patient. The radiation doses on the chestwall are measured on the side of tche protective apron adjacent to the chest. The radiation doses reaching the inner surface of the apron was small, but these on the hand palpating the patient were comparatively large. These are however smaller than the maximum tolerance doses 1.5 roentgen per week for the extremities. In these instances the "hand" means the dorsal aspect of the forearm and the "leg" the anterior aspect of the lower leg.

iii) Scattering radiation from therapeutic application of radium

Therapeutic radium fixed in paraffin phantom was used for treatment of skin diseases, and its Scattering radiation quantities received by such parts of the body

as shown by Fig. 6 were determined. The results are as shown in Table IX. The time of exposure was ten minutes, the quantity of radium 20 mg total (4 shells of 5 mg each), and the shells had 0.2 mm filter of platinum.

TABLE VIII

Radiation quantities to which physician is exposed in the gastrointestinal examination

Physician	Nmber of Patients	Exposed Doses				
		Right Hand	Left Hand	Right Leg	Left Leg	Breast
A. K.	6	122 (20)*	226 (38)	16 (3)	90 (15)	50 (8)
A. K.	5	66 (13)	84 (17)	72 (14)	16 (3)	16 (3)
A. K.	5	72 (14)	90 (18)	28 (6)	45 (9)	5 (1)
A. K.	5	28 (6)	66 (13)	22 (4)	38 (8)	5 (1)
T. K.	3	225 (75)	33 (11)	45 (15)	28 (9)	10 (3)
T. K.	5	176 (33)	10 (2)	22 (4)	5 (1)	5 (1)
T. K.	4	172 (43)	22 (6)	56 (14)	44 (11)	5 (1)
Y. M.	4	111 (28)	28 (7)	5 (1)	3)1)	3 (1)
Y. M.	6	106 (18)	6 (1)	78 (13)	100 (17)	11 (2)
Y. M.	6	110 (18)	28 (5)	56 (9)	17 (3)	5 (1)
Y. M.	6	33 (6)	106 (18)	111 (19)	117 (20)	17 (3)

* The numbers in brackets are values per patient.

II. Filmbadge method

i) Individually received radiation quantities of the staff members Radiology Department

The results of filmbadge studies of total radiation quantities to which the members of our Department were exposed during a week of usual routine work are shown in Table X. Although the filmbadge method is suitable for determining the radiation quantities received by a long continued exposure, yet it also has drawbacks of having wavelength dependence and of the fact that the optical density is not in linear correlation with radiation intensity. The two facts which must be born in mind in studying by the filmbadge method. This measurement was made in the following way. As has been stated in part I of the present

constitution, all the test pieces were made from a single sheet of X-ray film 10 × 12 inches in size, some of these were used as standard and were exposed to 80

Fig. 6 Referential schema for Table IX. Shows a form which is handling the radium shells with pocket chambers on his body for measuring the radiation quantities from the radium

TABLE IX

Exposed radiation quantities when therapeutic radium treatment (show Fig. 6)

Measured Part	Exposed Doses	Average Distances from Source
Right Hand	33 mr	20 cm
Left Hand	33	20
Right Side of Venter	11	40
Left Side of Venter	16	40
Head	33	30
Lower Venter	33	40

Treated Radium : 4 shells of 5 mg in 0.2 mm Pt filter
Working Time : about 10 minutes
Working sort : fixed on paraffin brock the radium shells

kVp of the deep therapy apparatus (Greinacher circuit), and the filmbadge test pieces were developed simultaneously with the standard pieces. Optical density of these pieces was measured by photoelectric densitophotometer. An example of the measuring techniques is shown in Fig. 7. By making the radiation operators realize usually the radiation quantities to which they are actually exposed, their concern on prevention of exposure to the scattering radiation has been depened, and the radiation quantities received by them have gradually decreased of late. Classification of the radiation quantities which one is exposed is thus highly effective in prevention of radiation injuries from the scattering radiation.

TABLE X

Individual exposed doses in radiological consultation working *

Member	Date	1952				1953	1955	
		7/VII ~ 12/VII	14/VII ~ 19/VII	21/VII ~ 25/VII	27/VII ~ 2/VIII	2/II ~ 7/II	9/V ~ 14/V	20/VI ~ 25/VI
Physician	A							< 5
	B	190	20	120	20			
	C	15	35	30		17		
	D	30		10	15			
	E	20	20	30		13		< 5
	F						< 5	< 5
	G						10	< 5
Technician	H	50	30	70	80	10		
	I	120	130	26	80			
	J						14	30
	K						8	13
	L						54	26
	M						11	26
	N	20	10	60		16		
	O						8	49
	P	110	10					
Nurse	Q	50	50	260	170	14	10	8
	R	20	25		70			
	S						10	< 5
	T						26	< 5
	U					13		

* Values are shown in milliroentgen, during a week.

tion.

ii) Scattered radiation in the x-ray photographic room. We have used filmbadge method in measuring the scattered radiation quantities in the photographic and therapeutic rooms of our Radiological Department during a week of ordinary routine work. In Fig. 8 we show the measured points, and in Table XI their respection values in milliroentgen, a and b representing the measured by *Yamabe*'s densitometer. The effectiveness of lead protective screen was very clearly demonstrated in this series of tests.

III. Dosage rate meter method

The distribution of scattered radiation in the deep therapy as well as fluoro-

scopy rooms was studied with dosage rate meter, DR-1 (*Kobe Kogyo Co.*). The quantity of scattered radiation in the deep therapy room, the schema of which

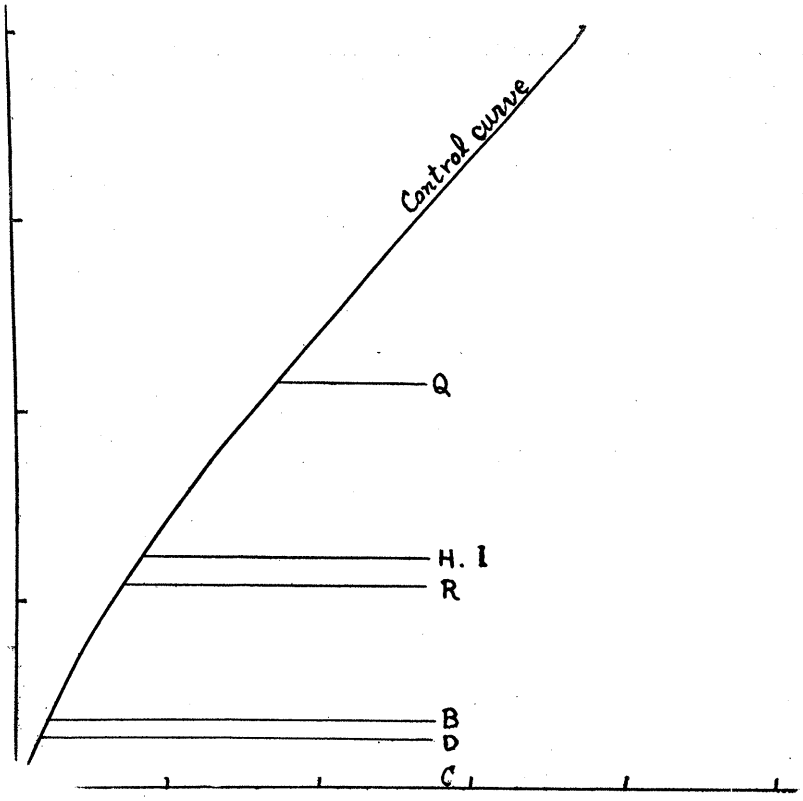

Fig. 7 Referential graph for Table X
The values of horizontal axis from the original point to each vertical foot which let down the crossed points the horizental lines of the optical density of Q, H, I,··· with a control curve, are required doses

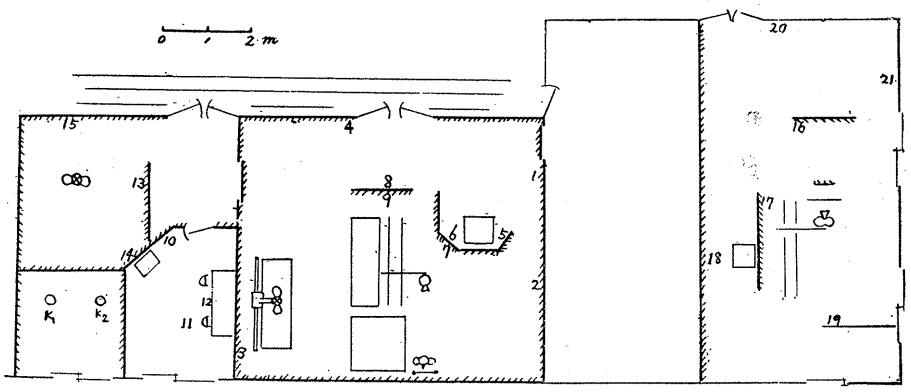

Fig. 8 Referential schema for Table X

is as shown in Fig. 9. during the conduct of deep therapy was determined with DR-1 and is shown in Fig. 9 and 10. The similar quantity variations in the

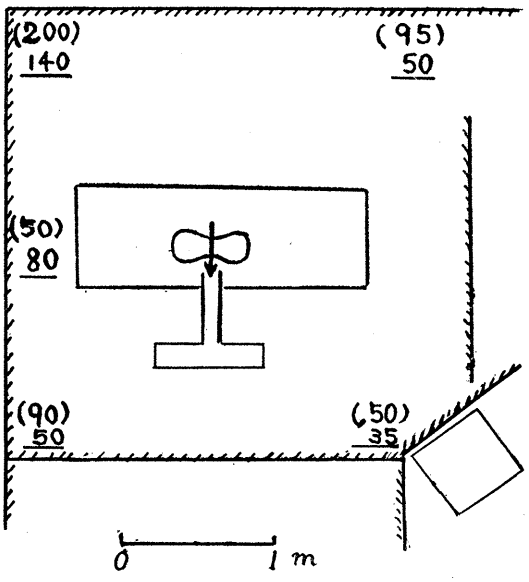

Fig. 9 Measured points and obtained values of a therapeutic room with a dosage rate meter
unit in milli-roentgen per hour
( ) : at 90 cm hight above floor
— : at 25 cm hight above floor
Focus skin distance 23cm, irradiation area 10 × 10cm², 160kVp, Cu 0.5mm + Al 0.5mm filtered, 3mA,
radiation direction 10° to arrow ward from vertical line

TABLE XI

Scattered radiation quantities of radiographic room by means of filmbadge (show Fig. 8)

Measured Points	Obtained Radiation Quantity	
	* a	* b
1	< 5mr	0mr
2	13	0
3	176	0
4	12	17
5	< 5	< 5
6	< 5	0
7	54	200
8	48	49
9	< 5	0
10	9	0
11	0	< 5
12	0	< 5
13	0	< 500
14	0	< 500
15	0	< 566
16	0	< 5
17	0	66
18	0	< 5
19	0	< 5
20	0	< 5
21	0	< 5

* a : May9~14, 1955 b : June 20~25, 1955

fluoroscopy room when the patient is actually fluoroscoped and when he is not, determined by the use of DR-1, are presented in Fig. 11.

Comparative figures obtained under identical conditions with the differences that the measurement was made with pocket chambers are represented in Fig. 12. These figures represent the values obtained by measuring at the altitude of 100cm above the floor in all instances. The irradiation conditions have been as described in the illustrations. As stated in the Parts I and II of the present series, it is important to remember that there are errors in results obtained with both pocket chamber and DR-1 dosimeter, yet in the present study the two instruments gave almost identical values.

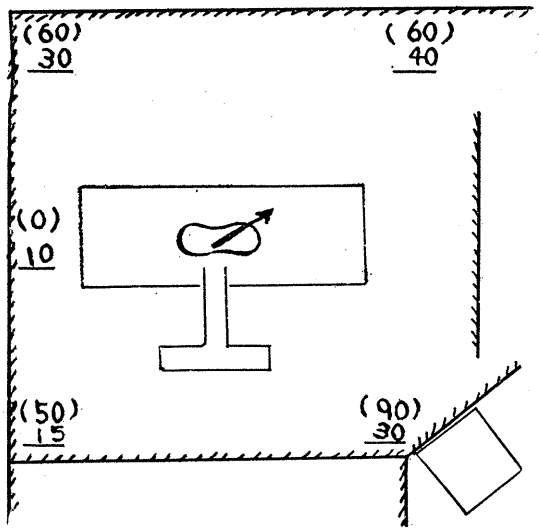

Fig. 10 Measured points and obtained values of a therapeutic room with dosage rate meter unit in milliroetgen
( ) : 90 cm hight, — : 25 cm hight,
focus skin distance 30 cm, irradiation area 8 × 8 cm², 160kVp, Cu 0.5mm + Al 0.5mm, 3 mA,
radiation direction 30° to arrow ward from vertical line

TABLE XII

Scattered radiation quantities of a fluoroscopic room were measured with dosage rate meter DR-1 (show the schema Fig. 11)

Hight above floor / Measured point	150 cm	100 cm	50 cm
1	40.0* (6.0)**	5.0 (0.0)	5.0 (0.0)
2	65.0 (25.0)	130.0 (50.0)	70.0 (20.0)
3	45.0 (25.0)	75.0 (0.0)	0 (0.0)
4	0.5 (0.5)	0.2 (0.0)	0 (0.0)
5	250.0 (40.0)	220.0 (80.0)	100.0 (30.0)
6	70.0 (10.0)	100.0 (40.0)	70.0 (35.0)
7	10.0 (7.0)	23.0 (10.0)	95.0 (120.0)
8	5.0 (1.0)	6.5 (0.0)	6.5 (0.0)
9	0 (0.0)	0 (0.0)	0 (0.0)

* The bare numbers show the scattered radiation quantities when a examining patient is there
** and the values in brackets are a patient is not.
Irradiated condition are as follows, 70 kVp., 2 mA, Al 0.5 mm filtered and the area of irradiating window is 8 cm × 8 cm at the distance of 12 cm from the focus.

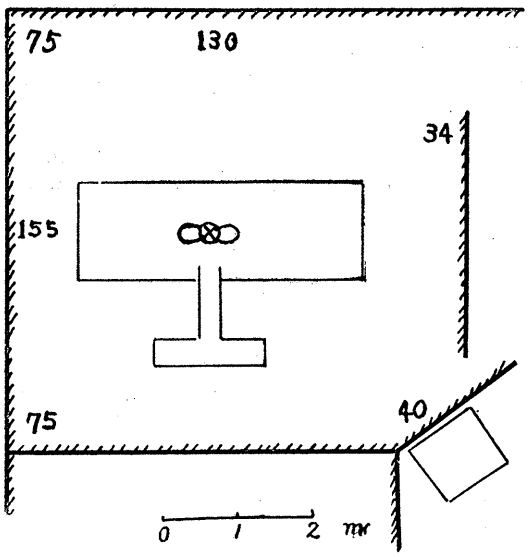

Fig. 11 Referential schema of a fluoroscopic room for Table XII Numbers show measured points corresponding to the numbers on Table XII

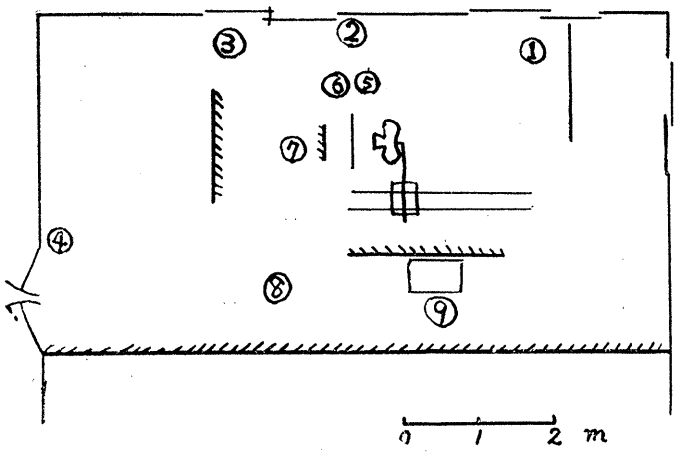

Fig. 12 Measured points and obtained values of a therapuitic room by means of pocket chambers for comparison with dosage rate meter method

SUMMARY

We measured the scatterd radiation encountered in clinical workes with pockd chambers, filmbadges, and a dosage rate meter under variout conditions of irradiation, and presented the results of the study. These resuls may be summarized as follows:

1. To know the quantity of scattered radiation to which each individual worker is highly important to the operators and effective in reducing such radiation quantity.
2. In handling the radiation constant attention and action of the persons

invalid to avoid receiving scattered radiation will markedly diminish the total scattered radiation quantity received by them regardless of whether protective screening is being used or not.

3. If installation of protective arrangements is complete protection of the radiation will be effected with far less efforts.

4. In fluoroscoping patients a pysician in charge should be able to limit the radiation quantity to which he is exposed by a little but continuous caution.

We must point out the fact that figures in the present contribution which were obtained by various methods contain errors that can not easily be corrected as stated in the preceding installments of the presents paper.

In conclusion, for protection of radiological worker himself from radiation injuries, his personal precaution in addion to complete protective equipments is most important.

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