RESULTS OF THE 1996–1998 IAEA CO-ORDINATED RESEARCH PROJECT ON INTERCOMPARISON FOR INDIVIDUAL MONITORING OF EXTERNAL EXPOSURE TO PHOTON RADIATION

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Abstract

This paper presents the conclusions drawn at the end of the intercomparison, the purpose of which was to examine the performance of the dosimetry systems in radiation fields similar to those encountered in practical routine monitoring. These fields included, for a range of doses, mixed normally incident and wide angle fields of simulated direct source and room scatter radiation for some typical energy distributions and high-energy photons (6-7 MeV) with and without secondary electron equilibrium. Almost all of the participating services satisfied the evaluation criteria on overall accuracy for all fields.

1. INTRODUCTION

The results reported here stem from the Phase III of the IAEA Co-ordinated Research Project. Phase II was concluded in June 1998 with a Research Co-ordination Meeting (RCM) in Braunschweig, Germany.

The results are presented here in a form allowing conclusions to be drawn, while preserving the anonymity of the participants. The whole evaluation procedure was computer-assisted.

2. CHARACTERIZATION OF THE PARTICIPANTS' DOSIMETRY SYSTEMS

Before the irradiations, participants received a questionnaire to be filled in to provide information on their dosimetry system. The data obtained were used to prepare a table with all relevant details. Participants were given the opportunity to amend this table during the RCM in Braunschweig. The corrected data are summarized in the Appendix.

Sixteen participants used only thermoluminescence (TL) detectors, four participants used only films, and three participants used a film-TL detector combination. The TL materials are LiF:Mg,Ti - LiF-N:Mg,Ti - $Li_2B_4O_7$, Si - LiF_7 - LiF_6 - CaF_2 - Al_2O_3. The films are from different manufacturers.

3. EVALUATION OF THE SUBMITTED DATA

The dosimeters of each participant's dosimetry system were irradiated according to the irradiation plan described in this TECDOC.

For every irradiation, the participant was informed of the irradiation date, but no information was provided about the radiation quality or the angle of incidence.

As the dosimeters of every participant had to be divided into groups to enable dosimeter irradiation to be carried out at three different institutes, three dosimeters from each group were preserved unirradiated for background corrections.

Each group was composed of 4 dosimeters, for irradiations at different radiation qualities and/or different dose levels. In total, 12 results had to be reported by each participant.

Participants were requested to report their results on a prepared data-sheet, according to the following instructions:

- all results corrected for background,
- dose values given in term of $H_p(10)$
- mean energy and angle of incidence to be completed, if the dosimetry system permits to provide such data.

An example of an individual result sheet is given in Table I.

Seven participants provided mean energy and angle of incidence, one participant provided the mean energy only, 15 participants did not provide any additional information besides the dose values.

Details of the irradiation conditions are given in Table II of [1]

TABLE I. EXAMPLE OF INDIVIDUAL DATA SHEET

Results for the Individual Dosimetry System 1 - Film

Dos N°	Irradiation data given by the IAEA				Irradiation data given by the participant				Quotient
	Radiation Quality	$H_p(10)$ mSv	Irradiation date	Angle deg	Mean energy keV	$H_p(10)$ mSv	Angle	Remarks	Quotient
1	Ir-192	9.83	23/7/98	±80	400	9.05	0°	ROT	0.92
2	Ir-192	9.99	28/7/98	0 (50%) ±80 (50%)	400	9.66	0°	ROT	0.97
3	Ir-192	1.00	16/7/98	0	400	1.05	0°	AP	1.05
4	Ir-192	41	6/7/98	0	400	39	0°	AP	0.95
8	S-Co+W-80	3.09	17/7/98	0 (50%) ±80 (50%)	100	3.08	0°	ROT	1.00
9	S-Co+W-80	80.35	20/7/98	0 (20%) ±80 (80%)	200	83.3	0°	ROT	1.04
10	S-Co+W-80	1.52	15/7/98	0 (80%) ±80 (20%)	130	1.55	0°	ROT	1.02
11	W-80	0.43	16/7/98	±80	60	0.4	0°	ROT	0.94
15	R-F+W-300	7.25	22/06/98 + 14/07/98	0 (50%) ±80 (50%)	600	7.71	0°	ROT	1.06
16	R-F+W-300	1.1	22/06/98 +15/07/98	0 (50%) ±80 (50%)	1000	1.15	0°	ROT	1.05
17	R-F	1.03	22/06/98	0	6000	0.99	0°	AP	0.96
18	R-F (*)	1.29	23/06/98	0	6000	1.27	0°	AP	0.98

(*) Without electronic equilibrium

4. GRAPHICAL REPRESENTATION OF THE RESULTS OF EVERY PARTICIPANT

The results of each participant are arranged in a set of two diagrams aiming to facilitate comparison of the data sets of the participants. The data-sheet table is given together with these two diagrams in the Appendix, for every participant.

The first diagram illustrates the values of the response in the various radiation fields. The response is the quotient of measured value and the conventionally true value of $H_p(10)$.

The second diagram shows the location of the response values in relation to the "trumpet".

Details of the diagrams

In the diagram of Figure 1, where the participant is identified by the laboratory number and the type of dosimeter used is indicated, each of the 12 response values is represented by a box providing a visual indication as to whether the assessment by the dosimetry system is an overestimate or an underestimate. All Q values in the range of 2.0 are indicated.

For each radiation quality, the Q value is the mean of the values reported by the participant.

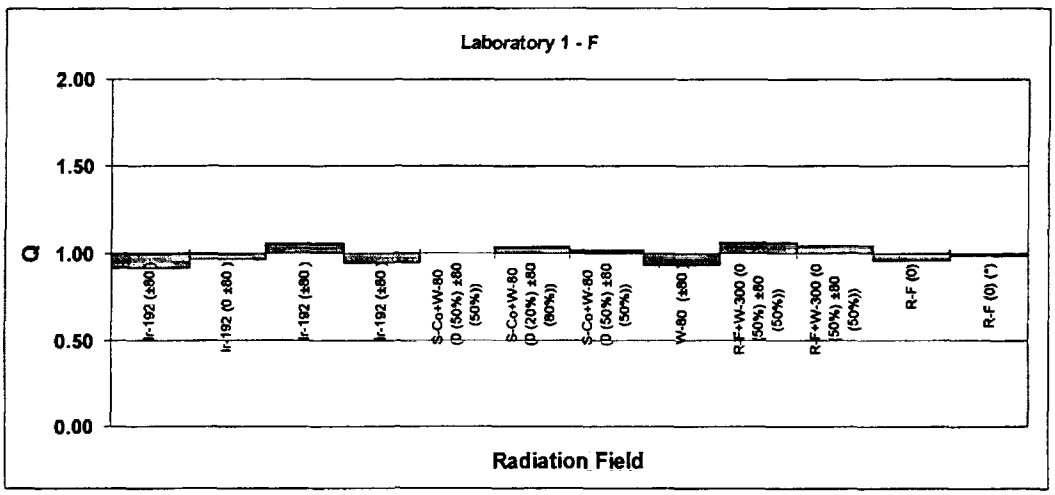

FIG. 1. Response (Q) in various fields (here the Laboratory 1, with a film dosimetry system).

In the second diagram (Figure 2) also identified by the laboratory number and the type of dosimeter, each response value in the range of 0 to 2 is indicated by a dot, together with so-called trumpet curves as given in [2]:

$$\text{high} : H_{ul} = 1.5[1 + H_o/2Ho + H_l)]$$

$$\text{low} : H_{ll} = (1/1.5)[1\text{-}2H_o/(H_0 + H_l)]$$

with H_0 taken as equal to 0.08 mSv.

Q values above 2.0 are separately indicated.

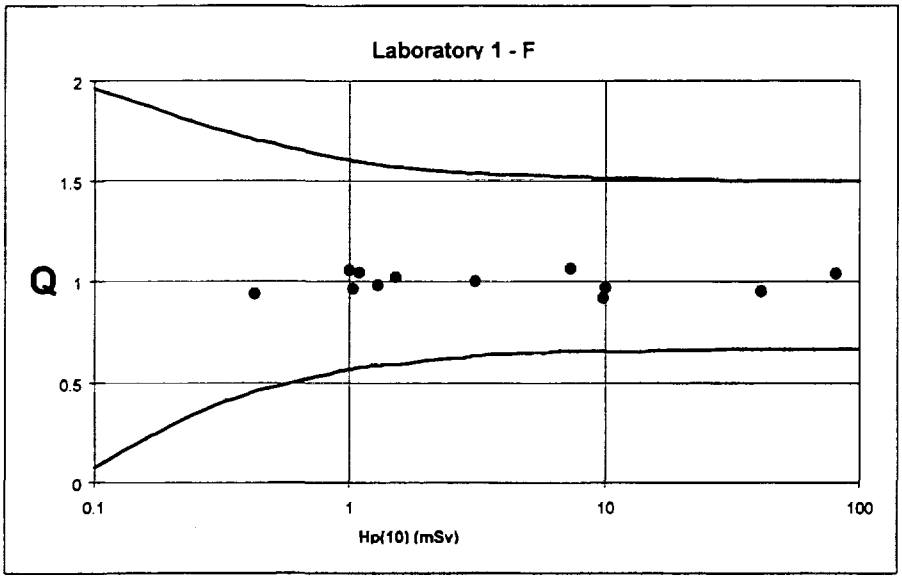

FIG. 2. Example of trumpet curve.

5. GENERAL SURVEY OF THE RESULTS FOR ALL DOSIMETRY SYSTEMS

Table 2 compiles the results obtained with all the participants' dosimetry systems, giving the following data:

- mean value R of all responses Q

- standard deviation, υ, belonging to R

- numbers of outliers *O*, i.e. the number of quotients which lie outside the ICRP interval.

The table is sub-divided into film dosimetry systems, TL dosimetry systems and others (film + TLD, phosphate dosimetry systems), and the results in every subsection are arranged according to the value of υ for $H_p(10)$ beginning with the smallest value. The number of outliers (*O*) outside the trumpet is given in the last column. Table II illustrates the great variety of the results reflecting the different performances of the dosimetry systems for the measurand $H_p(10)$.

6. FREQUENCY DISTRIBUTIONS OF THE Q VALUES AND OF THE VARIATION COEFFICIENT

The frequency distribution of all Q values is given in Figure 4.

TABLE II. GENERAL SURVEY OF THE RESULTS FOR ALL DOSIMETRY SYSTEMS

System Type	R	v in %	O
Film	0.99	5	0
	0.97	11	0
	1.23	28	0
	1.30	40	4
TLD	0.99	7	0
	1.16	8	0
	1.05	10	0
	0.99	15	0
	0.99	15	0
	1.05	16	0
	0.98	17	0
	0.93	18	0
	1.01	18	0
	1.08	20	0
	1.16	21	1
	0.94	23	0
	1.21	29	2
	1.25	29	2
	1.14	34	1
Other	1.11	15	1
	1.11	15	1
	1.08	20	0
	1.14	24	0
	1.20	43	4

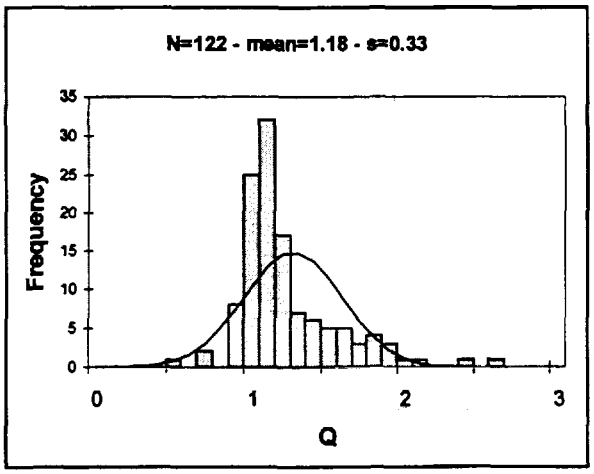

FIG. 4. Frequency distribution of all Q values.

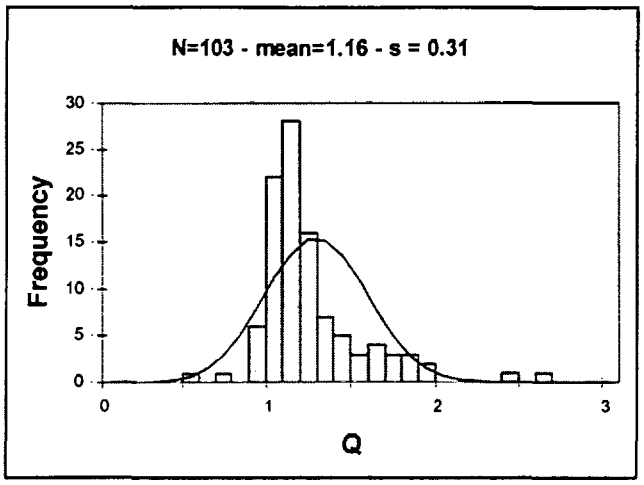

FIG. 5. Frequency distribution of Q values without dosimeter 18 (R-F without electronic equilibrium).

The frequency distribution of the variation coefficient υ is given in Figure 6.

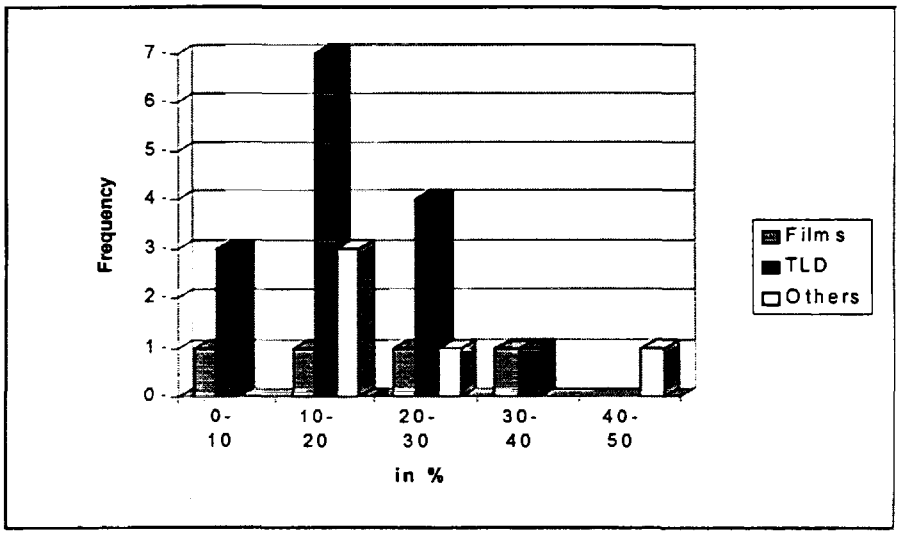

FIG. 6. Frequency distribution of all the υ values.

7. FREQUENCY DISTRIBUTION OF THE OUTLIERS

An impression of the irradiation conditions under which the doses have been most difficult to measure can be obtained from the frequency of the outliers for the various irradiations.

Figure 7 shows the frequency distribution for all the dosimetry systems for the measurand Hp(10). The radiation qualities given in the abscisse are the same as in Figure 1.

From this diagram, one can see that the radiation qualities Ir-192, S-Co+W-80 and R-F can be measured quite well by all the participants. But for W-80, R-F+W-300, R-F at low level and R-F without electronic equilibrium, there are, respectively, 3, 2, 5 and 6 outliers.

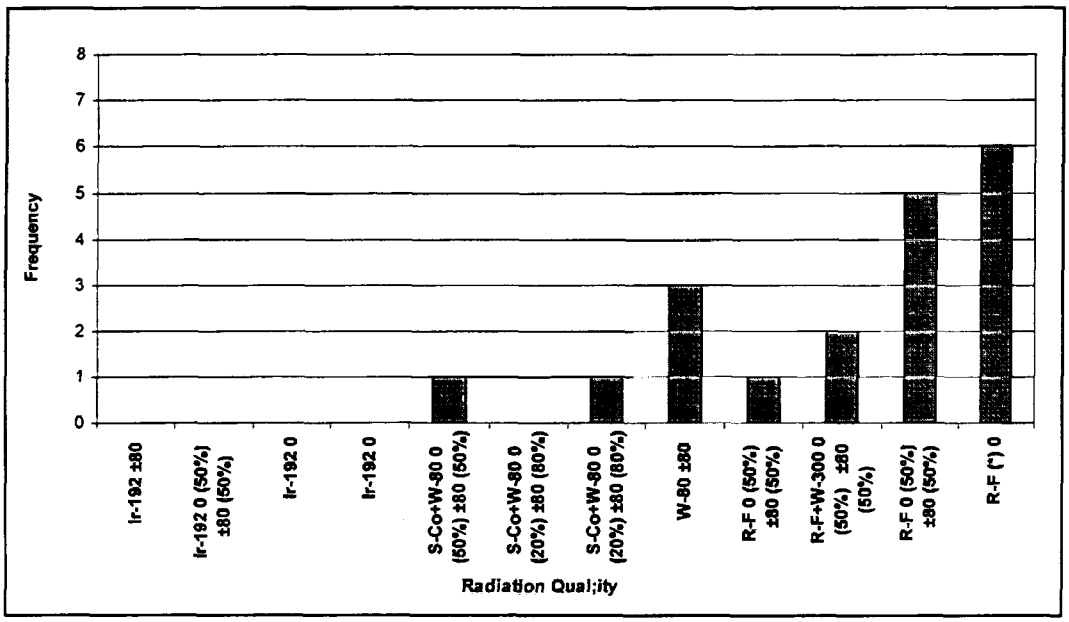

FIG. 7. Frequency distribution of all the outliers for all dosimetry systems.

Another question is how many dosimetry systems in this intercomparison fulfill the ICRP requirement, that is results for which at most one quotient lies within the trumpet curves. This is answered in Table III.

TABLE III. RELATIVE NUMBER OF DOSIMETRY SYSTEMS FOR WHICH AT MOST ONE QUOTIENT LIES BETWEEN 1/1.5 AND 1.5.

Dosimetry system	Percentage
TLD	62.5 %
Film	75 %
Others	100 %

8. CONCLUSIONS

The overall objective of the IAEA Occupational Protection Programme is to promote an internationally harmonized approach for optimizing occupational radiation protection through the development of standards and the provision for the application of these standards. This Co-ordinated Research Project had the aim to further both these objectives. In particular, this CRP gave participating dosimetry services from IAEA Member States in Eastern Europe, the opportunity to assess the recommendation of the IAEA to use the operational quantity personal dose equivalent, $H_p(10)$, and to evaluate the performance of their dosimetry systems. The intercomparison of systems was limited to whole body photon dosimeters in this instance, and examined the performance in simulated workplace fields. The use of such fields was to allow the assessment of the dosimetry systems under actual working conditions, at least in part.

The Workshop, attended by all the participants, gave information on the philosophy underlying the development and adoption of the operational quantities; on calibration procedures; on photon workplace fields energy and angle distributions; and on dosimeter characteristics. The participants were actively involved in the discussions and gave details of their services and dosimeters.

The "mini type test" enabled the participants to adjust, where necessary, their energy and angle response characteristic data, calibration and normalization factors to be in terms of personal dose equivalent. The discussion meeting which followed, clarified many aspects of the use of the new quantities. The "mini type test" had the second purpose of assisting in the harmonization of procedures at secondary standards laboratories in Eastern European States to type test in terms of $H_p(10)$. In addition a check was carried out of the dosimetry of the participating irradiating laboratories including PTB, ARCS and NRPB. The check demonstrated the agreement of the irradiation facilities in providing a given magnitude of $H_p(10)$, on phantom, within about 3%.

The intercomparison had 23 participating dosimetry services. The purpose of the intercomparison was to examine the performance of the dosimetry systems in radiation fields which were similar to those encountered in practical routine monitoring. These fields included, for a range of doses, mixed normally incident and wide angle fields of simulated direct source and room scatter radiation for some typical energy distributions and high-energy photons (6-7 MeV) with and without secondary electron equilibrium. Almost all of the services satisfied the evaluation criteria on overall accuracy for all fields.

The CRP was carried out successfully in every regard. Furthermore, the participating dosimetry services demonstrated a satisfactory proficiency to assess personal dose equivalent, $H_p(10)$, the quantity recommended by the IAEA to assess the occupational whole body exposure to photons.

REFERENCES

[1] V.E. ALEINIKOV, P. AMBROSI, D. BARTLETT, L. BÜERMANN, D.R. MCLURE, I. CSETE, V. FOMINYKH, H. STADTMANN. Dosimeter Irradiations for the IAEA 1996-1998 Co-ordinated Research Project on Intercomparison of Individual Monitoring (This TECDOC)

[2] P. AMBROSI, D. BARTLETT. Dosimeter characteristics and service performance requirements (this TECDOC)

APPENDIX

List of participants' dosimetry systems

Note : The participants are responsible for the technical information given.

Parti. Number	Quantity routinely measured	Photon energy range (keV)	Nominal dose range	Detector	Filter front		Filter back		Pre-irradiation procedure	Post-irradiation procedure	Read-out procedure
					Material	Thickness ($mg.cm^{-2}$)	Material	Thickness ($mg.cm^{-2}$)			
1	Hp(10)	50 - 1500	0.1 mSv - 1 Sv	Film	Plastic Cu Cu Sn (437) + Pb (227) Cd	150 45 715 664 690	Plastic Cu Cu Sn (437) + Pb (227) Cd	150 45 715 664 690	None	Single development	Densitometer Melico
2		50 - 3000	0.1 - 50 mSv	Film	Cu Pb Cu Cu Forsan	 150	Cu Pb Cu CU Forsan	 150	None		Densitometer TRD 04
3	Hp	10 - 1250	0.5 mSv - 2 Sv	F + TLD	Plastic Plastic Cu Cu Cu Sn + Pb Plastic Plastic	50 300 45 446 1338 436.8/340. 2 10 500	Plastic Plastic Cu Cu Cu Sn + Pb Plastic Plastic	50 300 45 446 1338 436.8/340. 2 600 100	Film: none TLD: anneal at 400°C for 1 h followed by 100 °C for 2h	Film TLD: anneal at 100 °C for 20 min	Film: manual optical density measurement with Victoreen 07-440 TLD: Harshaw 2000 AB
4	Exposure	15 - 1300	0.1 mSv - 1 Sv	TLD	Al	214	Plastic Plastic	106 130	80 °C for 1 h	Time annealing	Radose RF-1
5	Exposure	30 - 3000	5 μR - 1000 R	TLD	Plastic	480			Annealing 400 °C for 5-7 min	Li2B4O7: preheating for 1.5 s and heating for 10.5 s at 300 °C LiF: Pre-heating for 1.5 s and heating for 8 s at 300 °C	RADOS

Parti. Number	Quantity routinely measured	Photon energy range (keV)	Nominal dose range	Detector	Filter front		Filter back		Pre-irradiation procedure	Post-irradiation procedure	Read-out procedure
					Material	Thickness ($mg.cm^{-2}$)	Material	Thickness ($mg.cm^{-2}$)			
6	Hp	20 - 10000	0.01 mSv - 10 Sv	TLD	Al (241) Plastic (130) Al (241) Plastic (130) Al (241) Plastic (130) Mylar	371 371 371	Plastic Plastic Plastic Plastic	306 306 306 306	Annealing 300 °C for 12 s	24 h waiting time	RADOS
7	Exposure	30 - 1250	0.1 mSv - 1 Sv	TLD	Dural (230) Plastic (800)	1030	Plastic	30	Annealing	None	DTU-01
8	Hp	20 - 10000	0.05 mSv - 20 Sv	TLD	ABS (242) + Cu (91) ABS + PTFE Mylar ABS	333 1000 13 300	Plastic Plastic Plastic Plastic	50 50 50			
9	Hp(10) Hp(0.07) HE	15 - 6000	0.15 mSv - 2 Sv	Film	Cu Cu Cu Pb Plastic	45 445 1427 565 150	Plastic Cu Cu Cu Pb Plastic	300 45 445 1427 565 150			Densitometer
10	Absorbed dose i n air	20 - 1300	0.04 mGy - 6 Gy	Film + TLD	Plastic Plastic Dural Sn + Pb + Cd In Plastic + PFTE Mylar	50 300	Plastic Dural Sn + Pb + Cd Plastic Plastic	50	Film : none TLD: automated internal annealing	Film TLD heating 150 °C for 15 s	Film: densitometer Parry DR 1105 TLD: Harshaw 6600
11	Hp(10)	40 - 1256	0.1 mSv - 10 Sv	TLD	PVC (18) ABS (242) Cu (91) PTFE (7) PVC (18) Teflon (1000) PTFE (7) PVC (18) Mylar (17) PTFE (7) PVC (18) ABS (300) PTFE (7)	358 1025 42 345	PVC (18) ABS (166) PTFE (7) PVC (18) ABS (166) PTFE PVC (18) ABS (166) PTFE PVC (18) ABS (166) PTFE	191 184 184 184	None	Pre-heating 150 °C for 10 s	Harshaw 6600
12	Exposure	50 - 1500	0.2 mSv - 5 mSv	TLD	Open Al (214) Plastic (130)	374	BPO (106) Plastic (130) BPO (106) Plastic (130)	236 236	Annealing at 320 °C	Time annealing for 24 h	RADOS

Parti. Number	Quantity routinely measured	Photon energy range (keV)	Nominal dose range	Detector	Filter front		Filter back		Pre-irradiation procedure	Post-irradiation procedure	Read-out procedure
					Material	Thickness ($mg.cm^{-2}$)	Material	Thickness ($mg.cm^{-2}$)			
14	Hp	50 - 1300	0.01 mSv - 1 Sv	TLD	Plastic	75	Plastic	75	Annealing 30 mn at 350 °C	None	Home built
15	Hp(10)	100-3000	0.1 mSv - 1 Sv	TLD	ABS (242) Cu (91) ABS () PTE (1000) Mylar ABS	333 1000 17 300	ABS ABS ABS ABS	173 173 173 173	None	None	Harshaw 8800
16	Hp(10)	50 - 1300	0.1 mSv - 1 Sv	TLD	ABS	1000	Plastic	50	Annealing 1 h at 400 °C followed by 2 h at 100 °C	0.5 h at 100 °C	Harshaw 6600
18	Exposure	60 - 1250	0.01 R - 1000 R	TLD	Plastic	254	Plastic	413	Annealing 15 mn at 400 °C (if dose > 15 R)	15 s at 115 °C - 25 s at 220 °C - 20 s at 270 °C	KDT-02M
19	Exposure	20 - 1250	2 mR - 200 R	TLD	Sn Al Al Al	2 mm 1 mm 1 mm 10	Al Al Al Al	1 mm 1 mm 1 mm 1 mm	Annealing 10 min at 350 °C	None	PROTECTA
20	Dose equivalent	50 - 1500	0.1 mSv - 0. 1 Sv	Film	Open window Cu Cu Cu Pb	 0.05 mm 0.5 mm 1.5 mm 1.0 mm	Open window Cu Cu Cu Pb	 0.05 mm 0.5 mm 1.5 mm 1.0 mm	None	Manual development	VICTOREEN 07-440
23	Hp(10) Hp(0.07)	15 - 10000	0.05 mSv - 3 Sv	TLD	Open window Polypropylene Al	 6 mm 0.7 mm	Polypropylene Polypropylene	2 mm 2 mm	Annealing 2 h 300°C + 16 h 80°C		Vinten 802
24	Exposure	50 - 2000	5 - 200 mrem	Pen	Al	0.8 mm					