

IRMF intercomparison of calibration of large area reference sources and portable alpha and beta surface contamination monitors 1993/4 - Part 1.

M J Woods¹ and R P Hedley²

(1) Centre for Ionising Radiation and Acoustics
National Physical Laboratory
Teddington, Middlesex TW11 0LW
United Kingdom

(2) Defence Radiological Standards Centre
AWE (A)
Aldermaston, Reading RG7 4PR
United Kingdom

ABSTRACT

During 1993/94 under the auspices of the UK Ionising Radiations Metrology Forum, an intercomparison was conducted amongst UK organisations involved in the calibration of surface contamination monitors and reference sources. The results of that exercise are presented here. The intercomparison has also highlighted several areas of concern which need to be addressed and these are discussed within this report.

© Crown copyright 1996
Reproduced by permission of the Controller of HMSO

ISSN 1361-4053

National Physical Laboratory
Teddington, Middlesex TW11 0LW, UK

No extracts from this report may be reproduced without the written prior consent of the
Managing Director, National Physical Laboratory; the source must be acknowledged.

Approved on behalf of Managing Director, NPL,
by Mr A J Marks, Director, Centre for Ionising Radiation and Acoustics

	Page
1 INTRODUCTION	1
2 MEASUREMENT PROTOCOL	1
3 INSTRUMENTS AND SOURCES	1
4 PROGRESS OF INTERCOMPARISON	2
5 COMPILATION AND CORRECTION OF RESULTS	2
6 DISCUSSION	2
6.1 CONSISTENCY OF REPORTING	2
6.2 CALCULATION OF 2π EFFICIENCY FACTOR	3
6.3 CALCULATION OF CONTAMINATION RESPONSE FACTOR	3
6.4 CALIBRATION SOURCES	4
6.5 UNCERTAINTIES	4
6.6 COMPARISON OF RESULTS	4
7 CONCLUSIONS	4
8 ACKNOWLEDGEMENTS	5
9 REFERENCES	5

TABLES

Table 1	Source-detector separation normalisation functions	6
Table 2	FAG Contamat 111M - 2π efficiency - as initially reported <u>not</u> corrected for source-distance effects	7
Table 3	FAG Contamat 111M - CF_A (cps Bq ⁻¹ cm ²) - as initially reported <u>not</u> corrected for source-distance effects	8
Table 4	Minimonitor EP15 + 900 series ratemeter - 2π efficiency - as initially reported <u>not</u> corrected for source-distance effects	9
Table 5	Minimonitor EP15 + 900 series ratemeter - CF_A (cps Bq ⁻¹ cm ²) - as initially reported - <u>not</u> corrected for source-distance effects	10
Table 6	NE DP6 probe + PCM5/1 ratemeter - 2π efficiency - as initially reported <u>not</u> corrected for source-distance effects	11
Table 7	NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq ⁻¹ cm ²) - as initially reported <u>not</u> corrected for source-distance effects	12
Table 8	Supplementary data	13
Table 9	Linearity test results	14
Table 10	FAG Contamat 111M - 2π efficiency - after resubmissions <u>not</u> corrected for source-distance effects	15
Table 11	FAG Contamat 111M - CF_A (cps Bq ⁻¹ cm ²) - after resubmissions <u>not</u> corrected for source-distance effects	16

Table 12	Minimonitor EP15 + 900 series ratemeter - $\%2\pi$ efficiency - after resubmissions <u>not</u> corrected for source-distance effects	17
Table 13	Minimonitor EP15 + 900 series ratemeter - CF_A (cps Bq ⁻¹ cm ²) - after resubmissions - <u>not</u> corrected for source-distance effects	18
Table 14	NE DP6 probe + PCM5/1 ratemeter - $\%2\pi$ efficiency - after resubmissions <u>not</u> corrected for source-distance effects	19
Table 15	NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq ⁻¹ cm ²) - after resubmissions <u>not</u> corrected for source-distance effects	20
Table 16	Minimonitor EP15 + 900 series ratemeter - $\%2\pi$ efficiency normalised to 3mm for source-distance effects	21
Table 17	Minimonitor EP15 + 900 series ratemeter - CF_A (cps Bq ⁻¹ cm ²) normalised to 3mm for source-distance effects	22
Table 18	NE DP6 probe + PCM5/1 ratemeter - $\%2\pi$ efficiency normalised to 3mm for source-distance effects	23
Table 19	NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq ⁻¹ cm ²) normalised to 3mm for source-distance effects	24
Table 20	Summary of results for recommended radionuclides	25

APPENDICES

APPENDIX 1	Membership of working party	26
APPENDIX 2	Protocols for intercomparison exercises	27
APPENDIX 3	Participants	42

1 INTRODUCTION

The UK Ionising Radiations Metrology Forum (IRMF) was established in 1990 with the aim of facilitating the exchange of information about available UK calibration and testing facilities and their efficient use in the furtherance of compliance with the requirements of current ionising radiations regulations and codes of practice.

In the pursuance of these aims the IRMF has sought to coordinate intercomparisons amongst relevant organisations in order to assess the present level of competence in the calibration of monitors and to provide an insight into those problems whose resolution could be aided by the joint efforts and contributions of IRMF members. Following a successful exercise which concentrated on the calibration of portable gamma-ray dose-rate monitors used for area monitoring, a similar intercomparison was proposed in the field of surface contamination monitoring.

During the latter part of 1992, a Working Party was established to agree the measurement protocol for such an intercomparison. The composition of the Working Party is given in Appendix 1. It was subsequently agreed that representatives from the Atomic Weapons Establishment (AWE) and the National Physical Laboratory (NPL) should coordinate the exercise and establish some benchmark and subsidiary data.

2 MEASUREMENT PROTOCOL

The intercomparison was conducted in two parts. For the instrument-based exercise, a set of instruments covering the principle detector types was circulated and participants were asked to determine their response characteristics using their normal calibration procedures and reference sources. A check source and locating jig accompanied the instruments.

The large area reference standard intercomparison was based on the circulation of three 10 x 15 cm Class 1 Reference sources¹ and participants were asked to calibrate their 2 π alpha or beta emission rates using the methods that they normally applied within their own organisation.

Participants were requested to provide details of their calibrations and their best estimates both of the instrument calibration factors (in terms of %2 π counting efficiency and reading per (activity/unit area)) and of the emission rates of the reference sources.

Reporting sheets were provided together with a written measurement protocol which gave details of the instruments and sources, the relevant setting-up procedures and calibrations required. A copy of the protocol is reproduced in Appendix 2.

3 INSTRUMENTS AND SOURCES

In order to encompass the majority of instrument types in field use, three models were used representing Geiger-Muller detectors (using an EP15 probe), gas-filled proportional counters (Contamat) and scintillation detectors (DP6). These instruments were kindly loaned by instrument suppliers and details are included in the protocol in Appendix 2.

Each instrument was tested at AWE prior to the commencement of the exercise as well as at its conclusion to confirm continuity of performance. In addition, the variation of response with source-detector separation was determined by AWE using large area sources. This was only accomplished for the EP15 and DP6 probes. Since their probe areas were sufficiently smaller than the sources, semi-infinite plane geometry could be maintained: this was not the

case for the Contamat. These variations were determined for sources of ^{238}Pu , ^{241}Am , ^{14}C , ^{147}Pm , ^{36}Cl and ^{90}Sr covering a range of source-detector separations from contact (0 mm) up to 10 mm. Within the accuracies required, the variation for each detector-nuclide combination could be described by a linear relationship. Those relationships are given in Table 1.

The Class 1 reference sources were provided by AWE and NPL (See Appendix 2).

4 PROGRESS OF INTERCOMPARISON

Initially 17 organisations signalled their intention to participate and a schedule was developed to ensure completion during 1993. In practice, slippages occurred for a variety of reasons and several organisations either withdrew from the intercomparison or failed to report their results. The names of the ten laboratories that returned instrument calibration data are listed in Appendix 3. In order to preserve anonymity, each reporting laboratory was given a code letter (A-J) which bears no relation to the order of listing in Appendix 3.

Three organisations returned results for the reference sources, namely B, C and F.

5 COMPILATION AND CORRECTION OF RESULTS

Following the receipt of participants' results, corrections were applied to normalise results to a common source-distance separation of 3 mm. Subsequently, summary tables were produced and participants were invited to submit revised data where mistakes or errors could be identified.

The initial results and other relevant data, as received, are reproduced in Tables 2 to 9. This data was obtained from the standard reporting forms and supplementary data supplied by the participants. In the context of this report, it is not possible to report all of the received data. However, all of the individual reports have been retained by the coordinators and these may be reviewed at a later date to provide additional, useful information. Tables 10 to 19 detail results subsequent to revision and the application of normalisation factors.

6 DISCUSSION

The attempt to conduct an intercomparison of surface emission rate calibrations may have been somewhat optimistic. Although three laboratories reported results and there was good agreement between them, the sources were provided by two of those organisations which in turn have a well-documented traceability between themselves. It has been decided therefore that the results of that exercise should be held back for the moment.

It was disappointing that almost half of those organisations that had indicated their willingness to participate in the instrument-based exercise did not in fact do so or failed to return results. Nevertheless the data that was received has been particularly revealing and is discussed below.

6.1 CONSISTENCY OF REPORTING

Despite the provision of reporting sheets, several participants either replaced the reporting form with their own report, amended the supplied form or completed the form incompletely, incorrectly or ambiguously. Although this resulted, in some cases, in more data being provided, it presented difficulties in making direct comparisons and identifying potential sources of discrepancy.

Comments have been circulated amongst the participants highlighting those areas in which data could be deemed to have shortcomings. A summary would include the following:

Absence of details of reference sources including size, shape, activity/emission rates/traceability, uncertainties

Absence of uncertainties

No breakdown of uncertainties

No indication of confidence level of uncertainties

No indication of method used to calculate response factors

No indication of P-factor(s) used

No indication as to whether the contiguous portions technique was used for the Contamat detector

6.2 CALCULATION OF 2π EFFICIENCY FACTOR

The 2π counting efficiency (2π) is calculated by the following equation:

$$2\pi = (M/B) / (S/A) \times 100\%$$

where M = net instrument indication with respect to the reference source
 B = area of probe
 S = surface emission rate from the reference source
 A = active area of the reference source

The problems here arose principally from arithmetic mistakes. There was also some doubt as to whether the probe area to be used was the nominal value supplied by the manufacturer or some other estimate.

6.3 CALCULATION OF CONTAMINATION RESPONSE FACTOR

The contamination response factor (CF_A) was defined by the following equation:

$$CF_A = M / (N/A)$$

where M = net instrument indication with respect to the reference source
 N = activity of reference source
 A = active area of reference source

There was confusion over the calculation of this response factor which expresses the ratio of the monitor response to the activity per unit area of the calibration source. It is possible to determine this factor either by converting the 2π efficiency using a P-factor or by comparing the monitor readings with the certificated activity (not emission rate) of the calibration source. It was not always clear which method had been used and, in the case of the former, which P-factor had been employed.

The problems with this calibration were compounded by the difference in philosophy between the guidance issued by NAMAS in its document B0824² and that issued by the Health and Safety in its document HS(G)49³.

6.4 CALIBRATION SOURCES

Although details of these sources were not complete, it was clear that a variety of shapes, sizes and types were used. It could be inferred also that many sources had emission rates which were below the minimum level recommended by ISO (i.e. 2000 s^{-1}). The gaps in the data however have mitigated against the possibility of finding any correlations between calibration sources and estimated response factors.

UNCERTAINTIES

The measurement protocol requested participants to provide estimates of overall uncertainty values, at the 68% confidence level, and also to detail the values for the individual components and the method of combining them. The reporting sheets demonstrated a wide variety of response ranging from no information at all to a complete breakdown of all uncertainty components. It is probably fair to say that there was no consistency at all in this area of reporting as well as some significant degree of confusion.

COMPARISON OF RESULTS

The opportunity to reconsider results and submit new data produced a significant improvement in the comparison. A summary of the revised data for the three detectors and the principal radionuclides has been assembled in Table 20. It should be noted that whereas the presented data for the EP15 and DP6 probes have been normalised for source-detector separation that for the Contamat remains un-normalised. Until further work has been performed for the latter detector, it would be unwise to draw any hard conclusions in this case but a cursory examination of the data suggests that the situation is not likely to be significantly different from that for the two other detectors.

The summary shows a clear difference in the spread of results (the difference between the highest and lowest results) between low- and high-energy beta emitters. The HSE guidance contained within HS(G)49 generally requires monitor responses to be within $\pm 30\%$ of their before-use or type-test data. Clearly, the results indicate that if some detectors achieve a "PASS" with some organisations, other organisations must award a "FAIL" for those same instruments. Although the spreads are smaller for the alpha and high-energy beta emitters, this does not rule out the possibility that the same situation could appertain.

7 CONCLUSIONS

It would be possible to highlight other possible causes for concern but these would be minor in comparison with those mentioned above. The general conclusion must be that significant problems exist and that more effort needs to be expended to resolve them. Although the work was completed over a year ago, it is possible that useful evidence still exists which could shed some light on these problems.

In particular, a principal avenue to be examined should be the collection of more definitive data on the calibration sources used. This should cover their physical dimensions, nature (resin/anodised/depth of active layer/etc), traceability, surface emission rate and incorporated activity, uncertainties and date of last calibration.

The other critical examination should be of the calculation process used to determine the response factors from the observed data. This should explore, amongst other factors, the use and magnitude of the P-factors.

It is to be hoped that these further examinations will allow the existing data to be revised such that the discrepancies are significantly reduced; this would be the subject of a supplementary report. The final test however will be whether any lessons learnt are applied in practice and this can only be verified by the conduct of a further intercomparison.

During the present investigation, several related concerns have been aired. Although they do not necessarily bear directly on this intercomparison, they are of importance to the measurement community and to their ability to conduct accurate measurements of surface contamination. These concerns include:

- (a) the need to provide practical advice to the user community on both calibration and interpretation of measurement data,
- (b) the requirement for more definitive data on, and the application of, P-factors
- (c) the need for advice and consensus on the estimation of uncertainties,
- (d) the resolution of differences between NAMAS and HSE advice,
- (e) the requirement to update HS(G)49 and B0824
- (f) an acceptable and practicable means of competency testing
- (g) the need to maintain communications and collaborations, particularly amongst those setting and using international standards

In conclusion, the intercomparison to date has been beneficial not only in identifying measurement problems but also in encouraging the dialogue between the calibration, user and regulatory communities. The investigation of the intercomparison data should continue and a further intercomparison should be conducted. Other related concerns should also be addressed via relevant organisations.

ACKNOWLEDGEMENTS

The authors wish to thank both the members of the working party and the participants for their cooperation and support. They are encouraged by the commitment of the participants to re-examine their data and to provide additional information which may shed light on the reasons for the observed differences.

9 REFERENCES

- 1 International Organisation for Standardization, ISO 8769:1988, *Reference sources for the calibration of surface contamination monitors - Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha emitters.*
- 2 National Measurement Accreditation Service Information Sheet, B0824:1989, *The calibration of radiological protection instruments: surface contamination measuring instruments and sources for their calibration.*
- 3 Health and Safety Executive, HS(G)49:1990, *The examination and testing of portable radiation instruments for external radiations.*

Table Source-detector separation normalisation functions

	% change in response / mm	
Nuclide	EP15	DP6
^{14}C	3.6	2.6
^{147}Pm	3.7	1.7
^{36}Cl	1.4	0.7
^{90}Sr	0.9	1.2
^{241}Am	5.1	3.7

Table 2 FAG Contamat 111M %2 π efficiency - as initially reported
not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	58.1*	72.2*	74.6*	67.7*	-	-	-	-	-	-
B	-	30.8	22.7	53.1	53.4	31.0	42.7	57.2	-	-	-	-
C1	-	44	35	67	64	43	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.344 *	0.660 *	0.666 *	0.368 *	-	0.623 *	-	-	-	-
E	-	21.6	24.2	-	66.3	41.3	-	59.1	56.3	-	-	-
F1	42.8	44.6	36.6	65.5	65.6	37.7	-	-	57.7	6.7	22.2	93.3
F2	36.3	38.0	31.5	62.1	61.7	32.8	-	-	53.4	4.2	14.9	85.2
G	26.8	27.9	22.7	56.6	51.9	24.3	-	-	-	-	-	-
H	-	44.6	-	74.7	75.58	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-	-
J	-	-	33.9	57.8	54.7	-	-	-	-	-	-	-

* data subject to later revision

Table 3 FAG Contamat 111M - CF_A (cps Bq⁻¹ cm²) - as initially reported
not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	22.1	66.3	74.4	34.0	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.0325 *	0.0145 *	0.00721*	0.0403 *	-	0.0227 *	-	-	-	-
E	-	17.96	20.91	-	55.02	34.19	-	49.02	46.75	-	-	-
F1	35.55	37.03	30.35	54.34	54.45	30.43	-	-	47.87	5.52	18.4	77.4
F2	30.11	31.57	26.17	51.51	51.20	27.25	-	-	44.34	3.47	12.40	70.74
G	-	-	-	-	-	-	-	-	-	-	-	-
H	-	0.223 *	-	0.373 *	0.377 *	-	-	-	-	-	-	-
I	35.4	-	26.0	51.2	51.7	32.7	-	-	48.1	-	-	-
J	-	-	0.0847 *	0.283 *	0.274 *	-	-	-	-	-	-	-

* Data subject to later revision

Table 4 Minimonitor EP15 + 900 series ratemeter - %2 π efficiency - as initially reported
not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U
A	-	-	31.2*	59.3*	62.9*	44.6*	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-
C1	-	38	18.5	56	62	30.5	-	-	-	-	-
C2	-	-	19	-	61	-	-	-	-	-	-
D	-	-	0.186 *	0.617 *	0.668 *	0.226 *	-	0.554 *	-	-	-
E	-	34.0	18.6	-	64.8	28.5	-	56.5	48.5	-	-
F1	38.68	39.53	18.28	62.36	65.57	26.84	-	-	51.30	0.90	77.79
F2	34.47	32.95	16.62	56.25	61.89	21.40	-	-	47.43	0.32	56.22
G	28.1	30.7	14.1	60.8	61.5	16.4	-	-	-	-	-
H	-	38.77	-	57.9	52.59	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-
J	-	37.2	21.9	64.4	57.5	-	-	-	-	-	-

* data subject to later revision

Table 5 Minimonitor EP15 + 900 series ratemeter - CF_A (cps $Bq^{-1} cm^2$) - as initially reported
not corrected for source-distance effects

Lab	^{238}Pu	^{241}Am	^{14}C	^{36}Cl	^{90}Sr	^{147}Pm	^{60}Co	^{137}Cs	^{204}Tl	^{63}Ni	Nat.U
A	-	-	1.1	4.9	5.7	2.0	-	-	-	-	-
B	-	1.6	1.3	4.4	4.8	1.8	3.0	5.4	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.665 *	0.172 *	0.0795 *	0.724 *	-	0.197 *	-	-	-
E	-	2.55	1.39	-	4.86	2.14	-	4.24	3.64	-	-
F1	2.59	2.96	1.37	4.68	4.92	2.01	-	-	3.85	0.07	5.83
F2	2.90	2.47	1.25	4.22	4.64	1.60	-	-	3.56	0.02	4.22
G	2.1	2.3	1.05	4.56	4.6	1.23	-	-	-	-	-
H	-	0.1938 *	-	0.289 *	0.2629 *	-	-	-	-	-	-
I	3.2	-	1.6	4.9	6.0	2.1	-	-	4.3	-	-
J	-	*	*	*	*	-	-	-	-	-	-

* data subject to later revision

Table 6 NE DP6 probe + PCM5/1 ratemeter - %2 π efficiency - as initially reported

not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	3.9*	49.6*	51.6*	10.8*	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C1	-	29	2	42	42	9	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.00967	0.395 *	0.463 *	0.0364 *	-	-	-	-	-	-
E	-	37.0	3.2	-	51.9	10.3	-	39.5	34.8	-	-	-
F1	33.7	32.5	3.1	40.0	44.2	6.3	-	-	32.7	0.1	15.2	52.0
F2	28.9	29.6	3.1	38.4	42.8	5.6	-	-	31.5	0.1	9.3	47.2
G	35.8	33.0	1.83	41.9	40.3	4.56	-	-	-	-	-	-
H	-	34.6	-	44.1	39.66 *	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-	-
J	-	-	- *	37.2	36.3	-	-	-	-	-	-	-

data subject to later revision

Table 7 NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq⁻¹ cm²) - as initially reported
not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	0.9	27.5	31.0	3.3	-	-	-	-	-	-
B	-	14.9	0.6	19.1	22.3	2.7	10.3	20.9	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	1.92 *	0.0404 *	0.0172 *	0.676 *	-	-	-	-	-	-
E	-	18.49	1.58	-	25.95	5.13	-	19.76	17.40	-	-	-
F1	16.83	16.24	1.53	20.01	22.11	3.16	-	-	16.37	0.04	7.61	25.98
F2	14.46	14.80	1.55	19.18	21.42	2.82	-	-	15.75	0.04	4.66	23.60
G	17.9	16.5	1.11	20.95	20.15	2.28	-	-	-	-	-	-
H	-	0.173 *	-	0.22 *	0.198 *	-	-	-	-	-	-	-
I	17.5	-	1.5	21.6	22.9	3.8	-	-	16.7	-	-	-
J	-	-	- *	0.182 *	0.182 *	-	-	-	-	-	-	-

* data subject to later revision

Table 8 Supplementary data

	FAG CONTAMAT 111M						MINIMONITOR EP15 + 900 SERIES RATEMETER					NE DP6 PROBE + PCM5/1 RATEMETER				
Lab	Check source		background		source-monitor distance		check source		back-ground	Source-monitor distance		background		EHT (v)	source-monitor distance	
	before	after	α	β	α	β	before	after		α	β	α	β		α	β
A	491	503	-	7.4	-	5	550	550	0.75	-	5	-	6	925	-	5
B	438	455	0	5	3	9	520	520	1	10	10	-	5	925	3	10
C1	497	492	0	6	2	2	495	500	0.5	2	2	-	6	925	2	2
C2	-	-	-	-	-	-	495	500	0.5	-	0	-	-	-	-	-
D	464	473	-	5.9	-	4.7	519	519	0.6	-	4.7	-	4.96	875	-	4.7
E	494	478	0.06	9	11	11	525	525	1	3	3	0	8	950	3	3
F1	494	471	0.01	6.7	0	0	499	499	0.9	0	0	0	5.2	925	0	0
F2	494	471	0.01	6.7	3	3	499	499	0.9	3	3	0	5.2	925	3	3
G	460	438	0.13	4	3	3	550	550	<0.5	3	3	($\alpha + \beta$)	4.5	925	3	3
H	nr	nr	nr	nr	1.5	1.5	nr	nr	1	1.5	1.5	5	5	875	1.5	1.5
I	486	480	0.017	5.58	0	0	550	-	0.6	0	0	0	4.8	940	0	0
J	470	500	-	6	-	4	500	500	0.8	2	*	<1	6	900	-	4

* = used 2 mm separation for ^{14}C and 4 mm separation for ^{36}Cl and ^{90}Sr
 nr = not reported

Table 9 Linearity test results

Lab	Nucl.		FAG CONTAMAT 111M				MINI EP15 + 900 SERIES RATEMETER				NE DP6 PROBE + PCM5/1 RATEMETER				
A	¹³⁷ Cs	c.p.s.	160	909	3620	6255	20	48	130	480	90	250	700	1800	-
		rel.ratio	1.34	0.76	1.01	0.88	1.23	0.98	0.80	0.98	1.01	1.13	1.05	0.81	-
B	³⁶ Cl	c.p.s.	11	76	770	8130	5	29	290	-	6	42	420	4800	-
		rel.ratio	1.01	1.01	1.00	0.96	1.07	0.97	0.93	-	0.95	1.00	1.00	1.03	-
C	²⁴¹ Am	c.p.s.	13	237	1380	-	1.4	24	118	-	6.3	123	600	-	-
		rel.ratio	1.07	0.98	0.96	-	1.17	1.00	0.82	-	1.06	1.06	0.85	-	-
	⁹⁰ Sr	c.p.s.	149	1920	-	-	17	190	-	-	77	840	-	-	-
		rel.ratio	1.12	0.88	-	-	1.19	0.81	-	-	1.21	0.79	-	-	-
D	¹³⁷ Cs	c.p.s.	-	-	-	-	8.9	50	500	-	101	540	4600	-	-
		rel.ratio	-	-	-	-	1.08	1.03	0.89	-	1.01	0.99	1.00	-	-
E	¹³⁷ Cs	c.p.s.	180	520	680	1400	19	55	75	150	200	640	850	1800	-
		rel.ratio	1.03	0.99	0.97	1.00	1.01	0.98	1.00	1.00	0.94	1.00	1.00	1.06	-
F	*	c.p.s.	38-650 (²⁴¹ Am) 220-3350 (⁹⁰ Sr) 106-3146 (¹³⁷ Cs)				30-500 (²⁴¹ Am) too strong (⁹⁰ Sr) 7-400 (¹³⁷ Cs)				20-410 (²⁴¹ Am) 130-2000 (⁹⁰ Sr) 170-4600 (¹³⁷ Cs)				
		rel.ratio	± 1.04% ± 1.69% ± 6.63%				± 3.29% nr ± 9.89%				± 6.83% ± 3.05% ± 4.11%				
G	⁹⁰ Sr	c.p.s.	11	46	330	-	10	47	320	-	7.5	35	245	-	-
		rel.ratio	1.00	0.95	1.05	-	0.94	1.00	1.05	-	0.96	1.00	1.07	-	-
H	nr														
I	¹³⁷ Cs	c.p.s.	55	500	2980	6200	4.2	16	69	270	26	56	210	1200	-
		rel.ratio	1.00	0.98	1.00	1.01	0.97	0.95	0.99	1.08	0.94	1.03	0.98	1.06	-
J	**	c.p.s.	6.3	17.2	28.9	-	7.2	27.2	220	300					
	-	rel.ratio	0.72	1.25	1.03	-	1.03	0.95	1.02	1.00					

* Individual results not reported, only maximum deviation from mean. Number of points measured is not reported.

** ¹²⁹I used for FAG Contamat, ¹³⁷Cs used for Minimonitor EP15 and NE DP6 nr = not reported.

Table 10 FAG Contamat 111M - %2 π efficiency - after resubmissions

not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	28.5	63.5	69.4	36.5	-	-	-	-	-	-
B	-	30.8	22.7	53.1	53.4	31.0	42.7	57.2	-	-	-	-
C1	-	44	35	67	64	43	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	34.4	66.0	66.6	36.8	-	62.3	-	-	-	-
E	-	21.6	24.2	-	66.3	41.3	-	59.1	56.3	-	-	-
F1	42.8	44.6	36.6	65.5	65.6	37.7	-	-	57.7	6.7	22.2	93.3
F2	36.3	38.0	31.5	62.1	61.7	32.8	-	-	53.4	4.2	14.9	85.2
G	26.8	27.9	22.7	56.6	51.9	24.3	-	-	-	-	-	-
H	-	44.6	-	74.7	75.58	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-	-
J	-	-	33.9	57.8	54.7	-	-	-	-	-	-	-

Table 11 FAG Contamat 111M CF_A (cps Bq⁻¹ cm²) - after resubmissionsnot corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	22.1	66.3	74.4	34.0	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	30.8	69.0	68.92	24.8	-	44.1	-	-	-	-
E	-	17.96	20.91	-	55.02	34.19	-	49.02	46.75	-	-	-
F1	35.55	37.03	30.35	54.34	54.45	30.43	-	-	47.87	5.52	18.4	77.4
F2	30.11	31.57	26.17	51.51	51.20	27.25	-	-	44.34	3.47	12.40	70.74
G	-	-	-	-	-	-	-	-	-	-	-	-
H	-	36.8	-	61.55	62.59	-	-	-	-	-	-	-
I	35.4	-	26.0	51.2	51.7	32.7	-	-	48.1	-	-	-
J	-	-	14.05	47.98	45.37	-	-	-	-	-	-	-

Table 12 Minimonitor EP15 + 900 series ratemeter - $\%2\pi$ efficiency - after resubmissions

not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U
A	-	-	15.3	52.6	58.6	24.2	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-
C1	-	38	18.5	56	62	30.5	-	-	-	-	-
C2	-	-	19	-	61	-	-	-	-	-	-
D	-	-	18.6	61.7	66.8	22.6	-	55.4	-	-	-
E	-	34.0	18.6	-	64.8	28.5	-	56.5	48.5	-	-
F1	38.68	39.53	18.28	62.36	65.57	26.84	-	-	51.30	0.90	77.79
F2	34.47	32.95	16.62	56.25	61.89	21.40	-	-	47.43	0.32	56.22
G	28.1	30.7	14.1	60.8	61.5	16.4	-	-	-	-	-
H	-	38.8	-	57.9	62.3	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-
J	-	37.2	21.9	64.4	57.5	-	-	-	-	-	-

Table 13 Minimonitor EP15 + 900 series ratemeter - CF_A (cps $Bq^{-1} cm^2$) - after resubmissionsnot corrected for source-distance effects

Lab	^{238}Pu	^{241}Am	^{14}C	^{36}Cl	^{90}Sr	^{147}Pm	^{60}Co	^{137}Cs	^{204}Tl	^{63}Ni	Nat.U
A	-	-	1.1	4.9	5.7	2.0	-	-	-	-	-
B	-	1.6	1.3	4.4	4.8	1.8	3.0	5.4	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-
D	-	-	1.50	5.81	6.29	1.38	-	5.08	-	-	-
E	-	2.55	1.39	-	4.86	2.14	-	4.24	3.64	-	-
F1	2.59	2.96	1.37	4.68	4.92	2.01	-	-	3.85	0.07	5.83
F2	2.90	2.47	1.25	4.22	4.64	1.60	-	-	3.56	0.02	4.22
G	2.1	2.3	1.05	4.56	4.6	1.23	-	-	-	-	-
H	-	3.24	-	4.83	5.22	-	-	-	-	-	-
I	3.2	-	1.6	4.9	6.0	2.1	-	-	4.3	-	-
J	-	1.39	0.82	4.83	4.31	-	-	-	-	-	-

Table 14 NE DP6 probe + PCM5/1 ratemeter - %2 π efficiency - after resubmissions

not corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	1.9	44.0	48.3	5.8	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C1	-	29	2	42	42	9	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.967	39.5	46.3	3.64	-	-	-	-	-	-
E	-	37.0	3.2	-	51.9	10.3	-	39.5	34.8	-	-	-
F1	33.7	32.5	3.1	40.0	44.2	6.3	-	-	32.7	0.1	15.2	52.0
F2	28.9	29.6	3.1	38.4	42.8	5.6	-	-	31.5	0.1	9.3	47.2
G	35.8	33.0	1.83	41.9	40.3	4.56	-	-	-	-	-	-
H	-	34.6	-	44.1	47	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-	-
J	-	-	1.75	37.2	36.3	-	-	-	-	-	-	-

Table 15 NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq⁻¹ cm²) - after resubmissionsnot corrected for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U(α)	Nat.U(β)
A	-	-	0.9	27.5	31.0	3.3	-	-	-	-	-	-
B	-	14.9	0.6	19.1	22.3	2.7	10.3	20.9	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.52	24.8	29.02	1.48	-	-	-	-	-	-
E	-	18.49	1.58	-	25.95	5.13	-	19.76	17.40	-	-	-
F1	16.83	16.24	1.53	20.01	22.11	3.16	-	-	16.37	0.04	7.61	25.98
F2	14.46	14.80	1.55	19.18	21.42	2.82	-	-	15.75	0.04	4.66	23.60
G	17.9	16.5	1.11	20.95	20.15	2.28	-	-	-	-	-	-
H	-	17.3	-	22.0	23.5	-	-	-	-	-	-	-
I	17.5	-	1.5	21.6	22.9	3.8	-	-	16.7	-	-	-
J	-	-	0.436	18.60	18.16	-	-	-	-	-	-	-

Table 16 Minimonitor EP15 + 900 series ratemeter - $\%2\pi$ efficiency
normalised to 3mm for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U
A	-	-	16.6	54.2	59.8	26.4	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-
C1	-	35.8	17.8	55	61.4	-	-	-	-	-	-
C2	-	-	17	-	59.3	-	-	-	-	-	-
D	-	-	20.0	63.3	67.9	24.3	-	-	-	-	-
E	-	34.0	18.6	-	64.8	28.5	-	-	-	-	-
F1	-	33.5	16.32	59.7	63.7	23.87	-	-	-	-	-
F2	-	32.95	16.62	56.25	61.89	21.4	-	-	-	-	-
G	-	30.7	14.1	60.8	61.5	16.4	-	-	-	-	-
H	-	35.5	-	56.6	61.5	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-
J	-	35.1	21.1	65.3	58.0	-	-	-	-	-	-
Mean		33.9	17.6	58.9	62.0	23.5					
Max. dev. from mean		10%	20%	11%	10%	30%					

Table 17 Minimonitor EP15 + 900 series ratemeter - CF_A (cps Bq⁻¹ cm²)
normalised to 3mm for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U
A	-	-	1.2	5.05	5.8	2.2	-	-	-	-	-
B	-	2.8	1.8	4.9	5.2	2.5	-	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-
D	-	-	1.40	5.68	6.18	1.28	-	-	-	-	-
E	-	2.55	1.39	-	4.86	2.14	-	-	-	-	-
F1	-	2.51	1.22	4.48	4.78	1.79	-	-	-	-	-
F2	-	2.47	1.25	4.22	4.64	1.60	-	-	-	-	-
G	-	2.3	1.05	4.46	4.6	1.23	-	-	-	-	-
H	-	2.97	-	4.73	5.14	-	-	-	-	-	-
I	-	-	1.4	4.7	5.8	1.9	-	-	-	-	-
J	-	1.31	0.79	4.90	4.35	-	-	-	-	-	-
Mean		2.42	1.28	4.79	5.14	1.83					
Max. dev from mean		46%	41%	19%	20%	37%					

Table 18 NE DP6 probe + PCM5/1 ratemeter - $\%2\pi$ efficiency
normalised to 3mm for source-distance effects

Lab	^{238}Pu	^{241}Am	^{14}C	^{36}Cl	^{90}Sr	^{147}Pm	^{60}Co	^{137}Cs	^{204}Tl	^{63}Ni	Nat.U
A	-	-	2.0	44.7	49.6	6.0	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-	-
C1	-	27.7	1.95	41.7	41.4	8.8	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-
D	-	-	1.05	40.0	47.3	3.75	-	-	-	-	-
E	-	37.0	3.2	-	51.9	10.3	-	-	-	-	-
F1	-	28.8	2.9	39.1	42.5	6.0	-	-	-	-	-
F2	-	29.6	3.1	38.4	42.8	5.6	-	-	-	-	-
G	-	33.0	1.83	41.9	40.3	4.56	-	-	-	-	-
H	-	32.4	-	43.6	46.2	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-
J	-	-	1.80	37.5	36.8	-	-	-	-	-	-
Mean		31.4	2.23	40.9	44.3	6.43					
Max. dev. from mean		18%	53%	10%	17%	60%					

Table 19 NE DP6 probe + PCM5/1 ratemeter - CF_A (cps Bq⁻¹ cm²)

normalised to 3mm for source-distance effects

Lab	²³⁸ Pu	²⁴¹ Am	¹⁴ C	³⁶ Cl	⁹⁰ Sr	¹⁴⁷ Pm	⁶⁰ Co	¹³⁷ Cs	²⁰⁴ Tl	⁶³ Ni	Nat.U
A	-	-	0.95	27.9	31.8	3.4	-	-	-	-	-
B	-	14.9	0.75	20.1	24.5	3.1	-	-	-	-	-
C1	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-
D	-	-	0.50	24.4	28.4	1.43	-	-	-	-	-
E	-	18.49	1.58	-	25.95	5.13	-	-	-	-	-
F1	-	14.4	1.41	19.58	21.28	3.00	-	-	-	-	-
F2	-	14.80	1.55	19.18	21.42	2.82	-	-	-	-	-
G	-	16.5	1.11	20.95	20.15	2.28	-	-	-	-	-
H	-	16.2	-	21.8	23.1	-	-	-	-	-	-
I	-	-	1.4	21.1	22.0	3.6	-	-	-	-	-
J	-	-	0.448	18.74	18.40	-	-	-	-	-	-
Mean		15.9	1.08	21.5	23.7	3.10					
Max. dev. from mean		16%	59%	30%	34%	65%					

Table 20 Summary of results for recommended radionuclides

Instrument		CONTAMAT			EP15			DP6		
Nuclide		No of results	Max. dev.	Spread ^(a)	No of results	Max. dev.	Spread ^(a)	No of results	Max. dev.	Spread ^(a)
¹⁴ C	%2 π	9	24%	47%	9	20%	40%	8	53%	97%
	CF _A	7	42%	41%	9	41%	79%	9	59%	105%
¹⁴⁷ Pm	%2 π	8	32%	53%	6	30%	43%	7	60%	102%
	CF _A	6	19%	33%	8	37%	69%	8	65%	120%
³⁶ Cl	%2 π	9	19%	35%	8	11%	19%	8	10%	18%
	CF _A	7	20%	31%	9	19%	30%	9	30%	43%
⁹⁰ Sr	%2 π	10	20%	38%	10	10%	16%	9	17%	34%
	CF _A	8	28%	40%	10	20%	36%	10	34%	57%
²³⁸ Pu	%2 π	3	24%	45%	0	-	-	0	-	-
	CF _A	3	9%	16%	0	-	-	0	-	-
²⁴¹ Am	%2 π	7	40%	64%	7	10%	15%	6	18%	30%
	CF _A	4	42%	62%	7	46%	69%	6	16%	26%

(a) Spread = 100% x (highest value - lowest value)/mean value

APPENDIX 1

Membership of working party

Mike Woods (Chairman)	National Physical Laboratory
John Sephton (Secretary)	National Physical Laboratory
Richard Hedley	Atomic Weapons Establishment, Aldermaston
Duncan McClure	National Radiological Protection Board, Chilton
Jock Playle	Nuclear Electric, Berkeley
Tony Richards	Radiation Protection Service, University of Leeds
John Simpson	AEA Technology, Winfrith
Ian Thomson	Consultant, Southern Scientific Instruments

APPENDIX 2

IONISING RADIATION METROLOGY FORUM PROTOCOLS FOR INTERCOMPARISON EXERCISES

- (1) PORTABLE ALPHA/BETA SURFACE CONTAMINATION MONITORS
- (2) LARGE AREA ALPHA/BETA EMISSION RATE STANDARDS

IRMF FEB 1993

IRMF INTERCOMPARISON OF CALIBRATION OF LARGE AREA REFERENCE
SOURCES
AND PORTABLE ALPHA AND BETA SURFACE CONTAMINATION MONITORS

1. INTRODUCTION

1.1 The Ionising Radiation Metrology Forum (IRMF) has agreed to follow up the successful portable gamma ray dose rate monitor calibration. The aims of this intercomparison are to again assess the present situation within the United Kingdom and to increase confidence in the ability of participants to perform such calibrations, highlighting the need for traceability.

1.2 Additionally, a reference standard intercomparison exercise is to be undertaken, alongside but separate from the contamination monitor intercomparison. This will enable assessment of the accuracy of standard transfer of the radiological quantities alpha or beta 2π surface emission rate. It is hoped that useful data will be yielded in the importance of spectral differences between the UK nuclear industry secondary standards, variations in counting threshold and standard transfer instrumentation, etc., on the accuracy of calibration.

1.3 The instrument based intercomparison will involve the circulation of three commercially available instruments, two of which will have been set up according to the manufacturer's specifications. The third will be circulated with its high voltage supply set at zero; participants will be asked to determine the optimum operational voltage prior to testing. Participants in all three cases will be requested to report their contamination responses, both in terms of % 2π counting efficiency and cps Bq⁻¹ cm², to a range of standard nuclides. Again, to ensure that the exercise and its conclusions are realistic, it is essential that participants employ exactly the same techniques and methods to calibrate the three standard transfer instruments as routinely used within their own organisations. Finally, an optional linearity test will be requested, as this is one of the more important routine annual test items specified in HS(G)49. Instruments must be tested as dedicated probe-ratemeter combinations; no concession is given in the protocol for independent ratemeter tests.

1.4 The large area reference standard intercomparison exercise will be based on circulation of three 10 x 15 cm planar, Amersham anodised alpha/beta Class 1 Reference Standards. The nuclides selected are ¹⁴C, ⁹⁰Sr+⁹⁰Y and ²⁴¹Am, and participants will be invited to calibrate their 2π alpha or beta surface emission rate as appropriate, using techniques and methods they normally apply within their own organisation.

2. ORGANISATION OF THE INTERCOMPARISONS

2.1 The intercomparisons are scheduled for the period April to December 1993. The transfer instruments, associated check source jig and emission rate standards will be initially calibrated at DraStac AWE(A) and NPL (reference sources). As before, it is intended to send the set of transfer instruments and emission rate standards to each participant over successive weekends to despatch Friday (pm) from one participant to the next, ready for use the following Monday (am). The hope is that a minimum of three participants will complete their measurement each calendar month. Those participants not intending to undertake the emission rate standard intercomparison will still receive the standards, as it is vital that the artefact package remains unseparated for logistics reasons. Participants are advised to use the following carriers:

SECURICOR OMEGA EXPRESS
 RADIAC DEPARTMENT
 TECHNO 2
 HUGHENDEN AVENUE
 HIGH WYCOMBE
 BUCKINGHAMSHIRE HP13 5SG

Telephone: 01494 472727, Ext 222

Ask for: Ron Hatcher or Steve Lloyd

2.2 The shipping information must include an appropriately authorised and completed shippers' certificate meeting the requirements of UK road transport regulations, as per the attached "Guide" example. The invitation to participate will be made at the next full IRMF meeting, scheduled for Wednesday, 24th March 1993. At the same time participants will be asked to suggest a week during which they will be able to carry out the necessary measurements, in order that the coordinators can finalise the overall time table. It is envisaged that participants in the source calibration exercise will have to contribute £530/X to the cost of the reference standard calibration, where X is the number of participants, excluding NPL. There will be no charge for the main surface contamination monitor intercomparison; participants are responsible for carrier fee.

3. INSTRUMENT INTERCOMPARISON

The following instruments are being used as transfer instruments for this intercomparison.

(a) Mini-monitor 900 series ratemeter with EP15 halogen quenched geiger-muller

Kindly on loan from Mini Instruments (Mr Roy Sheppard). Instructions for use of the monitor are detailed below; the manufacturer's manual is also to be supplied.

FIG 1 Before the instrument is used, it should be tested using the check source jig supplied. The probe should be accurately placed in contact with the jig surface, at the reference position marked C. The instrument should be battery checked and simply switched on. It should read 550 counts per second after subtracting background.

If the reading is different from this by more than $\pm 10\%$ please contact in the first instance:

Richard Hedley, DraStac AWE(A) 01734 814111, Ext 7478.

You will be advised to return the instrument to DraStac or the manufacturer.

The EP15 probe should be response calibrated using your normal technique, method and reference standards (not those supplied for the reference standard intercomparison exercise).

As many of the following nuclides should be used as possible: ^{238}Pu or ^{241}Am , ^{14}C , ^{36}Cl , $^{90}\text{Sr}+\text{Y}$, ^{147}Pm . Additional nuclides, eg ^{60}Co , ^{137}Cs or any others that are routinely used, are acceptable; appropriate columns are available on the reporting sheets for these additional "other" sources.

Background measurements must also be made, recorded and used to correct the gross cps, previously derived. The net response (cps) must then be used to derive the $\% 2\pi$, and/or the contamination response expressed in terms of $\text{cps Bq}^{-1} \text{cm}^{-2}$. Detailed information

on emission rate to Bq conversion, measurement geometry (i.e. semi infinite plane, distance, etc), emission rate standards used, will be requested later.

The method to be used for defining source surface to detector distance is illustrated at Figure 2. An appropriate reporting form is also attached. Please estimate the overall uncertainty associated with your calibration; record in the column headed U. Uncertainties should be estimated at 1σ (68.3% CL); a detailed breakdown of component uncertainties should be listed on the relevant uncertainty proforma attached.

The optional linearity test must be undertaken using your routine method (or your proposed method to meet this requirement of HS(G)49). If the response linearity is tested with gamma radiation, care must be taken not to test above full-scale deflection. Linearity response must be reported as the ratio of instrument count rate (net) per incident dose or emission rate of standards. Additionally, the mean ratio for all test points should be calculated and reported. Again an appropriate reporting form is attached.

(b) FAG Contamat 111M with Butane filled gas proportional counter

Kindly on loan from Alrad Instruments (Mr I Alderton). Instructions are detailed below for use of this more complex instrument which take advantage of its long term response integration capability. Manufacturers' manuals will accompany the instrument for more complete details on its use.

Before use the instrument must be charged with butane from the supplied cylinder (it is vital that no substitutes - e.g. lighter fuel - are used), using the following procedure.

Remove the protective cover from the gas cartridge. Hold the monitor with the detector in a vertical position, with the gas inlet to the top. Invert the gas cartridge and push it into the left-hand side gas inlet. Initially four 5-second charges of gas are needed.

Allow five minutes between charges and, during the pauses, rest the monitor with the detector face down. Note the time of the final gas charge. Allow half an hour between the final gas charge and check source measurement.

Switch on the monitor using the  button.

Depress the  button to select the "count rate" option.

Depress the  button to select the "counter" mode.

The radiation type $\beta+\gamma$ is the default condition at this stage and will be indicated by the symbol $\beta+\gamma$ on the display. On selection of the "counter" mode above the display will show a continuously updated value of the $\beta+\gamma$ background and the elapsed time (maximum 999 s). The displayed value will stabilise as elapsed time increases. Report the $\beta+\gamma$ background after a suitable elapsed time (~ 100s) has allowed response to stabilise. The $\beta+\gamma$ background value should be between 3-8 cps, depending upon location.

FIG 1

Place the monitor in contact with the surface of the test jig at the reference position marked A. Again in $\beta+\gamma$ "counter" mode record the monitor response after a suitable elapsed time.

Background correct this response, which should be 480 cps after background correction.

If the response is different from this by more than $\pm 5\%$, please contact in the first instance:

Richard Hedley, DRaStac AWE(A) 01734 8141111, Ext 7478

You will be advised to return the instrument to DraStac or Alrad Ltd.

The FAG contammat should be response calibrated using your normal technique, method and reference standards as before. The counter will be in $\beta+\gamma$ mode at this stage and the following nuclides should be used: ^{14}C , ^{36}Cl , $^{90}\text{Sr}+\text{Y}$, ^{147}Pm , plus any other(s) you routinely use.

Again, record and report the response data in the same format as for the Minimonitor calibration, again quoting responses in terms of $\% 2\pi$ efficiency and/or cps $\text{Bq}^{-1} \text{cm}^{-2}$, using the proforma attached.

With the monitor again in "counter" mode depress the

$\frac{\alpha}{\beta+\gamma}$ key to select the α channel. Correct selection will be indicated by

the display of an α symbol.

Record and report the alpha background value. This will be α 1 cps and will require a long elapsed time.

Again response calibrate the FAG contammat, this time using ^{238}Pu and/or ^{241}Am and your normal techniques, etc.

Record and report responses, as before, on the proforma attached. Please estimate the overall uncertainty and record in the column headed U and fill in the more detailed component uncertainty proforma. The optional linearity test must be performed in the manner previously described for the minimonitor. It is likely that the use of either α or β emission rate standards will be the most convenient method. Record and report results using the appropriate proforma attached.

On completion of all tests record the elapsed time since gas charge and repeat the check jig measurement again reporting on the attached proforma.

(c) NE Technology PCM 5/1 with DP6 probe

Kindly on loan from NE Technology (Mr Clive Dray). This probe will be received essentially out of calibration, with the EHT setting at zero volts. Participants will be required to set the monitor to the required operational voltage, using the supplied manufacturers' procedures, as embodied in both PCM5/1 and DP6 probe manuals, for dual α and β operation. There is no check source measurement for this calibration.

Once the instrument has been set up by the participant the light sensitivity of the probe should be checked; satisfactory performance will be indicated by a background count rate of < 10 cps in the β channel.

The DP6 should then be response calibrated using your normal techniques, methods and standards. Please retain and copy the plateau plot utilised in the setting up procedure with your results. Again, record and report results with the relevant proforma, as before, listing component uncertainties, etc.

The optional linearity test should be performed in the manner previously described. Again record and report the results using the relevant attached proforma.

On completion of all tests the voltage must be re-zeroed before transport to the next participant.

4. COLLATION OF RESULTS

4.1 The coordinators of this exercise are Michael Woods (NPL 0181-943 6425) and Richard Hedley (AWE 01734 814111, Ext 7478). Participants should send their results, proformas etc to the coordinators within four weeks of completion of their measurements. Each laboratory will be assigned and subsequently referred to by a letter known only to the coordinators and the participants themselves. A summary report will be prepared and distributed to all participants, prior to the holding of a "summary meeting" to finalise the report and agree conclusions to be drawn from the intercomparisons. Consideration will again be given to publishing a brief report in open literature.

5. Information required from participants in the Instrument Intercomparison exercise.

(a) Please give the dimensions of all reference standards used for the instrument tests, including a brief sketch showing dimensions of any recess for non-planar sources. Specify the active deposit dimensions, substrate, e.g. anodised aluminium or ion exchange resin, backing materials ($\text{mg}\cdot\text{cm}^{-2}$), emission rate, etc.

(b) What is the basis of reference source/emission standard traceability, i.e. secondary NPL calibrated standard, NAMAS, or in-house calibrated. What is the basis of your conversion from emission rate to activity for emission rate standards, i.e. $\alpha \text{ S}^{-1} \text{ cm}^{-2}$ to Bq cm^{-2} .

(c) Please give details of how reference source activity/emission rate over the probe area is calculated for probe efficiency determination, i.e. define how you calculated the probe area. Give details of any positioning jig(s) used, providing a sketch if possible.

(d) Uncertainty: component breakdown

Please give your estimates for perceived uncertainties at the 1σ 68.3% confidence level, e.g. error in meter reading, positioning of instrument, uncertainty in reference standard emission rate, etc. Please show how you have combined those uncertainties to produce the overall uncertainty value.

6. EMISSION RATE STANDARD COMPARISON

6.1 Three large area (10 x 15 cms) planar, Amersham anodised type emission rate standards (^{241}Am , ^{14}C , $^{90}\text{Sr}+\text{Y}$) are to be circulated for this intercomparison.

These should be emission rate calibrated as appropriate, quoting the surface emission rate of the relevant particulate radiation into the forward 2π steradians.

6.2 The calibration must be undertaken using your established technique and standard transfer emission rate standards. The emission rate you derive for each source should be reported on the attached proforma with its reference time and date (GMT). Additionally, please report the estimated overall uncertainty at the 1σ (68.3% C1), in the column marked U. A more detailed uncertainty breakdown will be requested later.

7. COLLATION OF RESULTS

7.1 The coordinators will again coordinate and report results to participants, as per the instrument intercomparison. The purpose of this exercise is largely to gain data on the significance of standards transfer instrumentation, technique, traceability, reference source characteristics, etc., on the accuracy of tertiary standard emission rate calibration. Therefore please answer the following questions as accurately as possible.

8. Information required from participants in the emission rate standard intercomparison exercise:

(a) Standard transfer instrumentation

Counter/instrument type:

Counter dimensions:

Window dimensions:

Window/thickness/areal density/material (e.g. mg cm^{-2} Al Mylar):

Counting gas (e.g. P-10):

Counting gas flow rate/operational pressure:

Anode wire/diameter (e.g. $40\text{ }\mu\text{m}$ tungsten):

NIMS electronics used:

Plateau length and slope

Alpha:

Beta:

Operational voltage

Alpha:

Beta:

Background cps

Alpha:

Beta:

Threshold setting

Alpha:

Beta:

Deadtime correction method:

Calibration geometry:

(b) Emission rate standards used in calibration:

Traceability:

Date of last calibration:

Nuclides:

Format and dimensions:

Active substrate (e.g. anodised, ion exchange resin):

Inactive substrate (e.g. backing plate mg cm² or composition):

Half life value used for emission rate corrections:

Emission rate at time of intercomparison:

(c) Uncertainty: component breakdown

Please give your estimates perceived uncertainties at the 1 σ , 68.3% confidence level, e.g. emission rate uncertainty for standards used, deadtime correction uncertainty, positional uncertainty, etc. Please show how you have combined these uncertainties to produce the overall uncertainty value.

IRMF SURFACE CONTAMINATION: INSTRUMENTATION
INTERCOMPARISON

PARTICIPANT _____ LAB REF _____ TEMP °C _____
INSTRUMENT TYPE: MINIMONITOR EP15 PROBE CHECK SOURCE CPS B/G CORRECTED
BEFORE: _____ AFTER: _____

NUCLIDE	SOURCE TO DETECTOR DISTANCE mm	CPS GROSS	CPS NET	2 π EFFICIENCY % B/G CORRECTED	U (1 σ)	CPS Bq ⁻¹ cm ⁻² B/G CORRECTED	U (1 σ)	OFFICIAL USE ONLY
²³⁸ Pu								
²⁶¹ Am								
¹⁴ C								
³⁶ Cl								
⁹⁰ Sr + ⁹⁰ Y								
¹⁴⁷ Pm								
* OTHER								
* OTHER								

Comments:

Date:

Signature:

*Specify other nuclides used

IRMF SURFACE CONTAMINATION: INSTRUMENTATION
INTERCOMPARISON

PARTICIPANT
INSTRUMENT TYPE: FAG CONTAMAT 111M
TIME INTERVAL OF TESTS AFTER GAS INJECTION

LAB REF

TEMP °C
CHECK SOURCE CPS B/G CORRECTED
BEFORE: AFTER:

CIRA/EXT/002

NUCLIDE	SOURCE TO DETECTOR DISTANCE mm	CPS GROSS	CPS NET	2 π EFFICIENCY % B/G CORRECTED	U (1 σ)	CPS Bq ⁻¹ cm ⁻² B/G CORRECTED	U (1 σ)	OFFICIAL USE ONLY
²³⁸ Pu								
²⁶¹ Am								
¹⁴ C								
³⁶ Cl								
⁹⁰ Sr + ⁹⁰ Y								
¹⁴⁷ Pm								
* OTHER								
* OTHER								

Comments:

Date:

Signature:

*Specify other nuclides used

IRMF SURFACE CONTAMINATION: INSTRUMENTATION
INTERCOMPARISON

PARTICIPANT
INSTRUMENT TYPE: NE TECHNOLOGY PCM5/1 DP6 PROBE
OPERATIONAL VOLTAGE: ALPHA : BETA

LAB REF

TEMP °C
BETA BACKGROUND AMBIENT LIGHT
CPS:

NUCLIDE	SOURCE TO DETECTOR DISTANCE	CPS GROSS	CPS NET	2 π EFFICIENCY % B/G CORRECTED	U (1 σ)	CPS Bq ⁻¹ cm ⁻² B/G CORRECTED	U (1 σ)	OFFICIAL USE ONLY
²³⁸ Pu								
²⁴¹ Am								
¹⁴ C								
³⁶ Cl								
⁹⁰ Sr + ⁹⁰ Y								
¹⁴⁷ Pm								
* OTHER								
* OTHER								

Comments:

Date:

Signature:

*Specify other nuclides used

**IMRF SURFACE CONTAMINATION INTERCOMPARISON: INSTRUMENTATION
LINEARITY TEST (OPTIONAL)**

PARTICIPANT:
LAB REF:

**CHECK SOURCE READING CPS B/G CORRECTED
BEFORE: AFTER:**

CONTAMAT

EP15

INSTRUMENT	INCIDENT RADIATION		INSTRUMENT READING B/G CORRECTED cps	INSTRUMENT READING RATIO cps/μSv h ⁻¹ cps/αβS ⁻¹	MEAN RATIO	OFFICIAL USE
	DOSE RATE ENERGY	ALPHA/BETA EMISSION RATE NUCLIDE				
FAG CONTAMAT 111M						
MINIMONITOR 900 EP15 PROBE						
NE TECHNOLOGY PCM5/1 WITH DP6 PROBE						

Comments

Date:

Signature:

IRMF SURFACE CONTAMINATION; REFERENCE STANDARDS
INTERCOMPARISON

Participant:

Lab Ref:

REFERENCE STANDARD	2π ALPHA/BETA SURFACE EMISSION RATE	U (1 σ)	REFERENCE TIME (GMT) DATE	OFFICIAL USE ONLY

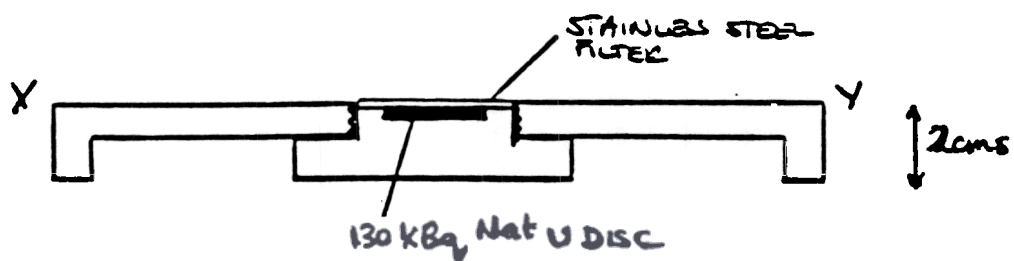
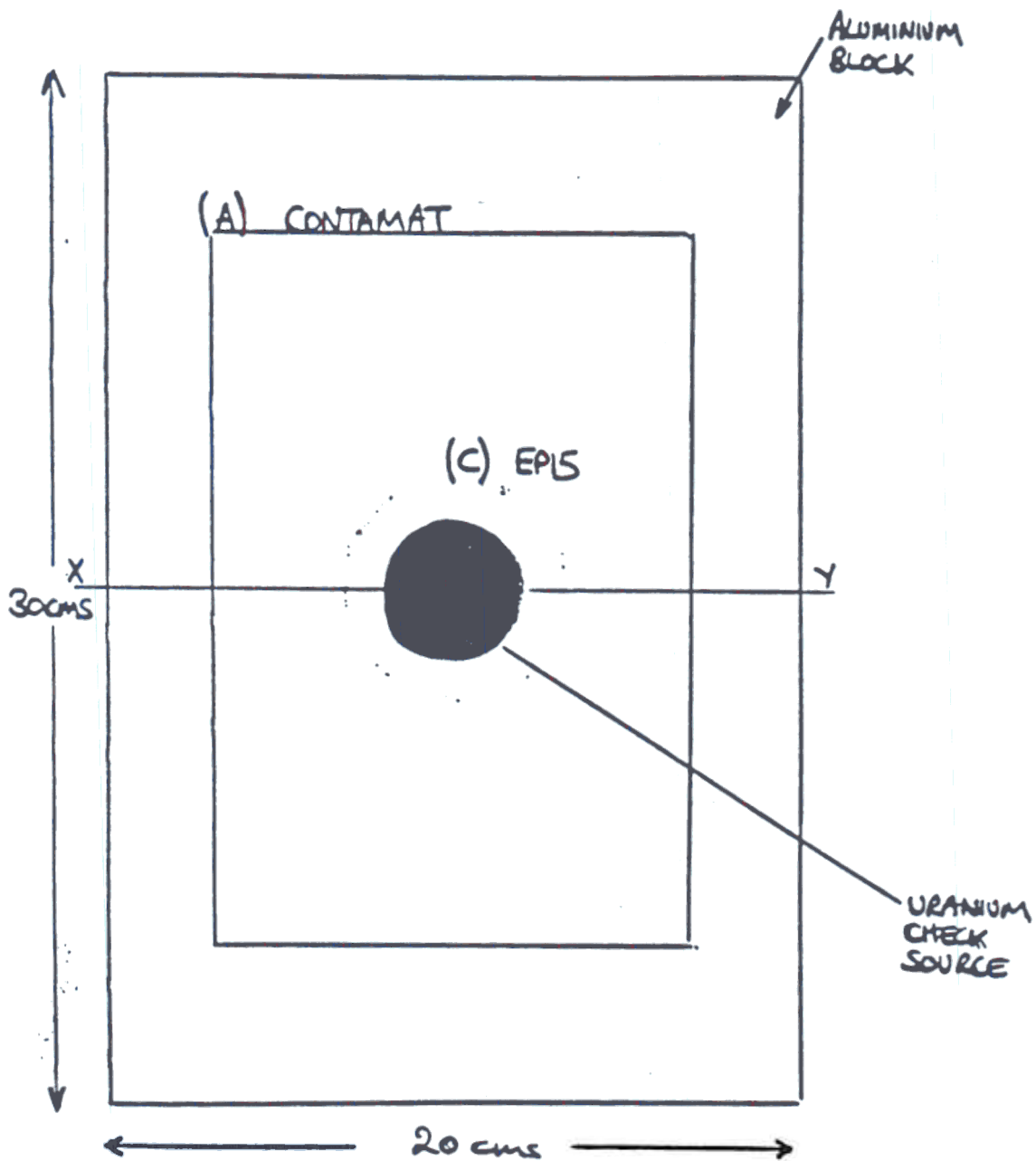
Comments:

Date:
Signature:

IRMF SURFACE CONTAMINATION INTERCOMPARISON
(INSTRUMENTATION)

FIG 1

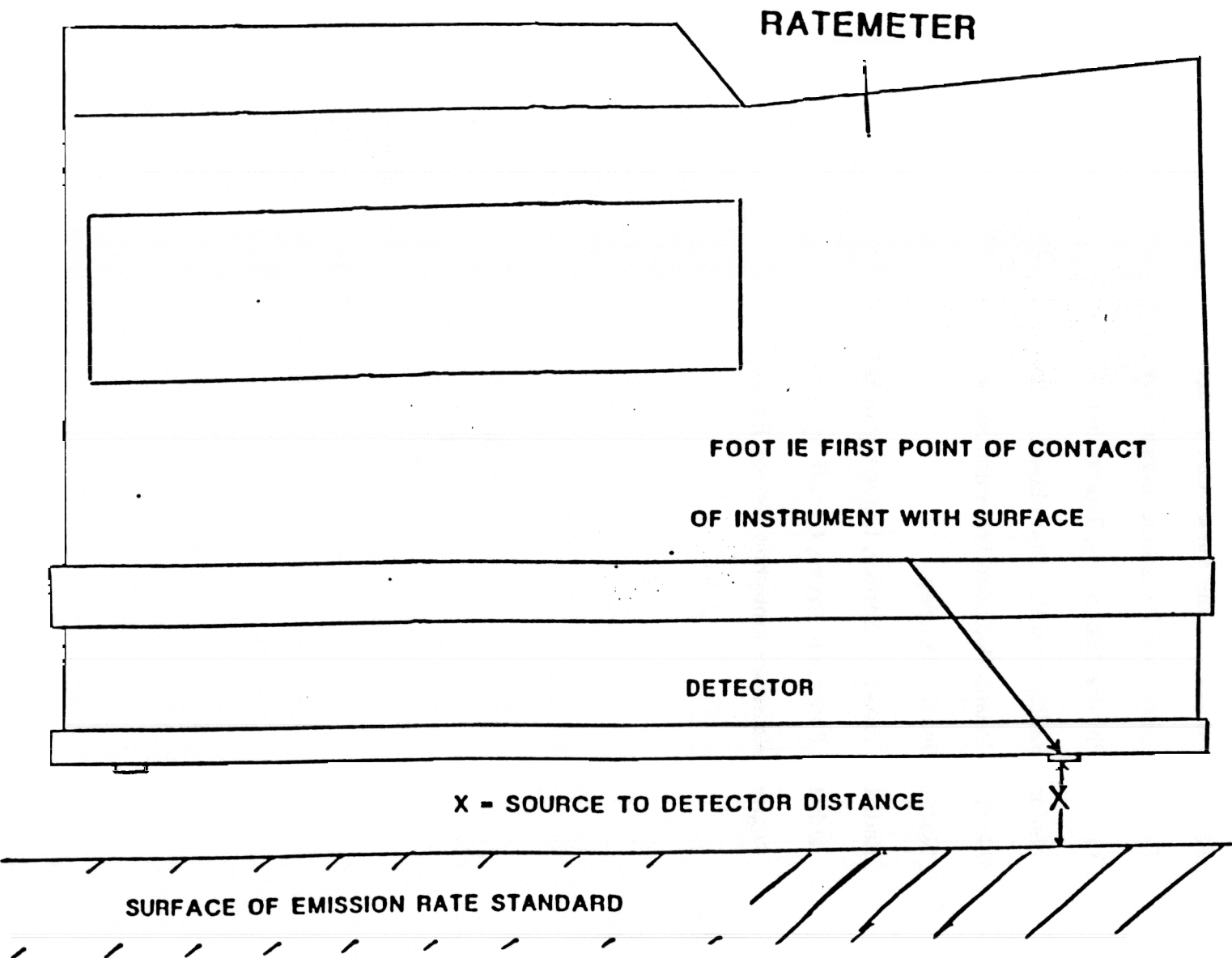
INSTRUMENT CHECK JIG LOCATIONS



IRMF SURFACE CONTAMINATION INTERCOMPARISON (INSTRUMENTATION)

DEFINITION OF SOURCE TO DETECTOR DISTANCE FOR THIS EXERCISE (EG FAG CONTAMAT

FIG 2



APPENDIX 3

Participants

Atomic Energy Authority, Dounreay

Atomic Weapons Establishment, Aldermaston

Defence Radiological Protection Service, Alverstoke

National Physical Laboratory, Teddington

National Radiological Protection Board, Chilton

Northern Ireland Radiation Protection Service, Belfast

Nuclear Electric, Berkeley

Radiation Protection Service, University of Leeds

Radiation Protection Service, Cardiff

Regional Radiation Protection Service, Birmingham