NPL REPORT CIRM 14

August 1998

First IRMF Intercomparison of Calibrations of Neutron Area Survey Instruments 1995 - 1996

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ABSTRACT

The Ionising Radiations Metrology Forum (IRMF) organised an intercomparison of calibrations of neutron area survey instruments in which five establishments in the UK participated. The exercise involved the circulation of two neutron dose-rate monitors for calibration in the fields produced using ^{252}Cf and ^{241}Am-Be. The instruments used were a Harwell model 0949 and a Studsvik model 2202D.

All results were submitted to the author for analysis. Responses relative to neutron fluence, as stated by the individual participants, were calculated. The results are compared and demonstrate good agreement between establishments.

ISSN 1369-6793

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Approved on behalf of Managing Director, NPL, by
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CONTENTS

1 INTRODUCTION

One of the main aims of the Ionising Radiations Metrology Forum (IRMF) is to encourage good practice in radiological measurements, including the need for traceability to the appropriate national standards, through the organisation of regular intercomparisons. As in the case of the intercomparison of calibrations of gamma-ray monitors [1], the main objective was to assess the ability of calibration laboratories to perform routine calibrations of survey instruments in pursuance of Regulation 24 of the Ionising Radiations Regulations 1985 [2].

The intercomparison involved the circulation of two radiation protection, area survey neutron monitors for participants to calibrate in two neutron fields produced using radionuclide sources and at several dose rates. The participants restricted their measurements to the neutron fields and dose-rates normally used for routine instrument calibrations, employing the same methods to calibrate the two transfer instruments as are routinely used within their organisation.

A further part of the intercomparison was the comparison of calibrations of both monitors for 2.7 MeV neutrons produced using accelerator-based fields. This involved only two participants. Since the results for this part are still under investigation in order to explain observed discrepancies, this report concerns only the calibrations using radionuclide sources.

The calibration quantity for this intercomparison was **neutron fluence**. All results were reported to the author on a standard form for analysis and collation.

The intercomparison was planned by the participants. The analysis was undertaken by the Secretary of the IRMF (V E Lewis, NPL), who was not involved in any of the calibrations carried out at NPL. Instrumentation matters were referred to and dealt with by Graeme Taylor, NPL.

The exercise started in July 1995 and ended in June 1996. The schedule of measurements is shown in Appendix 1.

2 PARTICIPANTS

The establishments (and contact persons) participating in the intercomparison were

AEA Technology (Harwell Laboratory),	Harwell	R Bosley
Defence Radiological Standards Centre,	AWE Aldermaston	P Danyluk
National Physical Laboratory,	Teddington	G C Taylor / D J Thomas
National Radiological Protection Board,	Chilton	D R McClure
VSEL,	Barrow-in-Furness	J R Pople

Prior to the intercomparison it had been decided that participants would not be allowed to withdraw results. The participants chose to identify their results in any presentation or report associated with the exercise.

3 PROTOCOL

A comprehensive protocol for the comparison was produced by D J Thomas and G C Taylor, in consultation with the participants. This provided guidance and included pro forma for reporting various information and the results of measurements to the evaluator. Instructions were given for mounting and operating the instruments correctly. Deviation from the preferred orientation was discouraged unless if it was physically impossible to achieve such an orientation in the facility used.

The protocol, which includes a diagram showing the orientations of the monitors, is reproduced in Annex 1.

4 RADIATION FIELDS

Two types of neutron fields, based on ^{252}Cf and ^{241}Am-Be sources, were selected for this intercomparison. The fields used by individual participants are shown in Appendix 1. All five participants reported results based on ^{241}Am-Be fields and three participants also used ^{252}Cf fields. All participants reported traceability of their fluence rates to national standards.

The participants usually possessed only one or two sources of each radionuclide. A range of distance between source and monitor was therefore used to give a range of dose rates. Overall, a range of neutron dose equivalent rates from about 2 to 1600 μS h^{-1} was covered. The maximum dynamic range for any individual participant was a factor of about 200 between minimum and maximum.

5 INSTRUMENTATION

Two types of routinely-used, neutron dose-equivalent rate monitors, described below, were used as transfer instruments. Both belonged to NPL. The electronics were not deliberately off-set.

5.1 Harwell monitor 0949

The Harwell monitor type 0949 comprises a thermal neutron detector at the centre of a 20 cm diameter spherical polyethylene moderator.

The monitors calibrated by individual participants in the two types of field are shown in Appendix 1. All five participants reported results for the Harwell 0949 in Am-Be fields. Three participants calibrated the Harwell 0949 also in ^{252}Cf fields.

5.2 Studsvik monitor 2202D

The Studsvik monitor 2202D comprises a thermal neutron detector at the centre of a cylindrical polyethylene moderator; one end has rounded edges.

Four of the five participants reported results for the Studsvik 2202D in Am-Be fields; one participant could not calibrate the Studsvik 2202D because they did not calibrate the device routinely and therefore did not know the value of the applicable room-scatter correction (see section 6 below). Two of the three participants using ^{252}Cf fields reported results for the Studsvik 2202D; the third participant did not calibrate the model 2202D routinely.

5.3 Stability checks

In between measurements the instruments were returned to NPL for checks of response to an ^{241}Am-Be source using a fixed geometry. The checks were carried out within one month of the end of the measurements of each participant. The responses to the check source measured over the period of the intercomparison are shown in Figures 1 and 2 for the Studsvik and Harwell monitors respectively. See also Section 8 below.

6 MEASUREMENTS

The two instruments were circulated together to participating laboratories. In order to have a realistic exercise, the participants were asked to employ the same methods to calibrate the instruments as were routinely used within their organisation.

Each participant placed the monitor under calibration at selected distances from the selected radionuclide source and measured the response both in terms of the (pulse) rate of detected events and also as a meter reading. The fluence rate was normally determined from the measured value of the source emission rate, the source anisotropy factor and the distance. An attenuation correction, dependent on the distance between source and front face of the monitor was applied for each position. For each monitor/source/distance configuration, participants reported the fluence rate and corresponding monitor response, using the pro-forma report forms provided with the Protocol (see Section 7 below and Annex).

Participants were also asked to report the magnitude of the correction for neutrons scattered from the air, walls, floor and ceiling of the calibration room. The room-scatter corrections were not usually measured as part of the exercise but were derived from previous (fairly lengthy) measurements made for the specific model of monitor in the field of the selected radionuclide. The correction was in terms of percentage increase of response of monitor relative to response due to direct neutrons - it was not in terms of fluence rate or dose rate. Although the response due to the direct component varied according to an inverse square relation with distance, allowing for air-attenuation, the room scatter component was fairly constant and therefore its effect varied as the square of the distance.

The room-scatter corrections depended markedly on the room dimensions and structural materials. For comparison between participating laboratories, values are shown in Table 1 for a standard distance from source of one metre.

The completed pro-forma report forms were sent to the evaluator for analysis at NPL.

7 INFORMATION REPORTED BY PARTICIPANTS

The following pro-forma (shown in the Annex) were provided:

7.1 Form IRMF NI.1: Calibration measurement details

This form was used for reporting results obtained using the routine calibration technique. The reported data included monitor responses (pulse and dial), fluence rate and scatter correction along with their associated uncertainties. These were sufficient to enable the evaluator to calculate the calibration value. Temperature, pressure and humidity during measurements were reported.

Distance and approximate dose equivalent rate were also reported.

7.2 Form IRMF NI.2: Alternative methods

This form reported essentially the same details as IRMF NI.1 for methods used in addition to the routine calibration technique.

7.3 Form IRMF NI.3: Details of neutron sources

Participants were asked to supply information about their sources including -

emission rate
anisotropy factor
air attenuation factor
encapsulation and dimensional details.

7.4 Form IRMF NI.4 Details of calibration facilities

Participants were asked to supply the following details of calibration rooms -

approximate dimensions of the exposure room,
source height above floor and distance from walls,
source - instrument separation distance,
wall material.

The dimensions of the calibration rooms, given in Table 1, varied considerably

7.5 Form IRMF NI.5 Additional details or comments

This form enabled participants to report anything else of relevance.

8 ANALYSIS AND RESULTS

8.1 Analysis

The calibration values were calculated for each monitor/source/distance configuration. The original intention had been to see if the monitors were sensitive to dose rate effects. However, the major means of varying dose rate was to vary distance between source and monitor, and this produced a change in the room scatter correction that could easily hide any dose rate effect or give the appearance of an effect. In fact, associated measurements in accelerator-produced neutron fields with strengths an order of magnitude higher than those obtained using radionuclide sources indicated that the monitors did not suffer from dose rate effects. It was assumed therefore that any trend with dose rate in the radionuclide fields used was likely to be due to room scatter effects.

No such trends were found. It was therefore assumed that the room scatter corrections used by all participants were consistent over the ranges of distance used. This meant that for each source/monitor configuration the weighted mean values could be calculated for the set of calibration values obtained over the range of distance.

These values are summarised for the pulsed outputs in Table 2. The calibrations are in terms of fluence rather than dose equivalent because the latter is derived from the former simply by using recommended values for the conversion factors for the two radionuclide field; these would be common for all participants.

No results have been withdrawn by any participant. However, a fluence value for one participant was omitted by the evaluator because it yielded results that were 20% below other values in the sets, and was considered to be discrepant.

8.2 Results for ^{241}Am - Be calibrations

All sets of calibration values are shown in Table 2. For convenience the values for each source/monitor combination, normalised to that for NPL, are given in Table 3. (NPL was chosen only because it was one of the two laboratories which had produced results for all four combinations and because some further bi-lateral measurements involving NPL were later carried out - see Section 9.2 below.) Also for convenience, the values are ordered in decreasing magnitude.

There is a clear trend with both NRPB results being 9% higher than NPL and both AEA Technology results being 3% higher. It was known that the NRPB made no correction for source anisotropy and that this would yield high values. Allowing for this effect, which is normally around 4% for the type of source used, would reduce the NRPB values to slightly above those for AEA Technology. This would bring all values but the VSEL value for the Harwell 0949 within the calculated uncertainties. The quotient of the calibration values of the two monitors is the same for all participants except VSEL.

The apparent discrepancy with the VSEL Harwell 0949 value was later found to be due to a fault in the monitor power mechanism which caused a decrease in response over the period of the intercomparison when the monitor was used in the battery mode. This was shown by the check source measurements (see Figure 2). The solid points are those made after each of the participants had made their measurements. This effect was not recognised until after the last participant (VSEL). Investigations of this effect were carried out at NPL and an attempt to apply a correction was made (see Section 9).

There was considered to be no such problem with the Studsvik 2202D because the check source measurements produced a constant count rate throughout the intercomparison, as shown in Figure 1.

8.3 Results for ^{252}Cf calibrations

The values obtained are very consistent but small in number. The three values for the Harwell 0949 agree to within $\pm$ 1%; all three participants used the monitor in the mains supply mode and therefore there were no complications due to a possible battery effect. The two values for the Studsvik 2202D agree to within 0.5% and the quotient of the values for the two monitors is the same for the two participants who calibrated both.

9 FURTHER MEASUREMENTS

9.1 Investigation of battery effects

Altogether, three sets of batteries were used in the Harwell 0949 monitor. The first (existing) set was used only by NPL for measurements in the Am-Be field. A new set was put in just prior to the first check source measurements (at Day zero in Figure 2) made before the monitor was circulated to the other laboratories. The results of measurements made after each participant had made measurements, shown as solid squares, show a linear decrease with time. The NRPB measurements were made just before the second symbol and the VSEL ones were before the last solid square. Both DRaStaC and AEA (Harwell) used mains power.

On observing the extent of this effect, a third set of batteries was put in and further check source measurements were carried out over a period of several months. The results (shown as open squares) show an initial value equal to that observed following the NRPB measurements, followed by a linear decrease with time.

The VSEL value was therefore re-normalised on the assumption that the monitor efficiency had decreased due to the battery effect (Table 2). It was not known how to correct the NPL value and therefore an additional uncertainty of ± 1.5% was introduced.

In further measurements it was observed that the count rate dropped during prolonged continuous use (Figure 3) using a fresh set of batteries. It was not known whether this was a factor in the VSEL measurements, and no further correction could be applied. It is assumed that the VSEL value represented a minimum and it was decided to investigate the discrepancy using indirect means (see 9.2 below).

Finally, the effect of changes in operating voltage were investigated using a mains-powered dc supply with a variable voltage in place of the batteries. No significant change in response was observed between the normal operating voltage of 18 V down to 15 V (Figure 4). The change down to 14 V was a few per cent, with a 10% decrease at 13 V. It was concluded that the measurements using the mains supply mode were not affected by voltage problems.

9.2 Additional calibrations by VSEL

As part of an ongoing QA programme, two MK 7 NRM monitors from VSEL were calibrated in Am-Be fields at NPL and VSEL. The results normalised to values obtained at NPL using NPL sources are shown in Table 4. The values obtained using VSEL sources at NPL are about 1.5% higher; this is consistent within the uncertainties. Those made at VSEL using VSEL sources are a further 1% higher; this is also consistent within the uncertainties. In contrast, the intercomparison result was lower than that of NPL.

This demonstrates that VSEL routine calibrations are consistent with NPL and therefore with the other participants. The low value obtained in the intercomparison for the Harwell 0949 monitor is considered to be entirely due to a battery problem. It has since been pointed out that the type of battery used by NPL was not one that is particularly unsuitable for such use. This type was used because a collaborator in previous work had modified the battery connections, making it impossible to use the recommended type of battery.

10 CONCLUSIONS

The intercomparison showed the desirability of making a correction for the anisotropy of large (physically) radionuclide sources in order to improve the general agreement between calibrating laboratories. This is now done by all laboratories who participated.

This exercise demonstrated the necessity for routine checks of the transfer instrumentation. Although the problem experienced was detected late, it was possible to make some allowance by direct and indirect means. (The problem was found to be confined to the particular unit and type of battery used rather than being generic to that model.)

When allowance is made for known effects the participants' calibration values agree to within ± 3%. The overall accuracy is thus very satisfactory and shows that users could meet the requirements of HS(G)49.

The sensitivities of the monitors used in this exercise (and for other neutron monitors) vary with neutron energy whether expressed in terms of fluence or a dose equivalent quantity. There is some evidence of this variation between Am-Be and ^{252}Cf spectra in Table 2 for the calibrations in terms of fluence. Applying the appropriate conversion factors (see [3]) would in fact yield a larger variation. The uncertainties involved in the calibration of monitors in neutron fields produced by radionuclide sources will generally be much less than those encountered when using the monitors in field measurements on account of spectral effects.

11 ACKNOWLEDGEMENTS

The Ionising Radiations Metrology Forum is supported financially by the National Measurement System Policy Unit of the United Kingdom Department of Trade and Industry.

The help of the participants in the production of this report is gratefully acknowledged.

12 REFERENCES

[1] McClure, D R and Hunt, J B. 1995 *IRMF Intercomparison of Calibrations of Portable Gamma-ray Monitors Used for Area Monitoring.* J Radiological Protection **15** 245 - 252

[2] Ionising Radiation Regulations 1985. **No. 1333** (London HMSO)

[3] Memorandum from the British Committee on Radiation Units and Measurements 1986. *New Quantities in Radiation Protection and Conversion Coefficients.*
British Journal of Radiology **59,** 946 - 950
Journal Soc. Radiological Protection **6,** 131 - 136
Radiation Protection Dosimetry **14,** 4, 334 - 343

APPENDIX 1 SCHEDULE OF MEASUREMENTS

	Am/Be		Cf-252	
	Harwell 0949	Studsvik 2202D	Harwell 0949	Studsvik 2202D
AEA Technology, Harwell	January 96	January 96	January 96	January 96
DRaStaC, Aldermaston	December 95	- - -	December 95	- - -
NPL, Teddington	July 95	September 96	June 96	June 96
NRPB, Chilton	November 95	November 95	- - -	- - -
VSEL, Barrow-in-Furness	March 96	March 96	- - -	- - -

Table 1 **Room dimensions and room scatter corrections**

	Scatter correction normalised to 1 metre distance				
	Dimensions of room	Am/Be		Cf-252	
	Length x width x height (m)	Harwell 0949	Studsvik 2202D	Harwell 0949	Studsvik 2202D
AEA Technology, Harwell	9.4 x 10 x 6	6	6	6	6
DRaStaC, Aldermaston	9.1 x 5.5 x 4.4	19	***	19	***
NPL, Teddington	25 x 18 x 18	7	7.5	7.5	7
NRPB, Chilton *	8 x 5 x 2.5	9.5	6	***	***
VSEL, Barrow-in-Furness **	11.7 x 6.6 x 4.5	12	10	***	***

* "PREMADEX" lining over concrete
** Lightweight roof

The room scatter correction is expressed as percentage of direct field

Table 2 Measured calibration values

Expressed as detected events per unit neutron fluence (cm^2)

Uncertainties (shown in parentheses) apply to the least significant digit(s) and are at a 95% confidence level

	Am - Be			Cf-252			Ratio (Cf-252 / Am-Be)	
	Harwell 0949	Studsvik 2202D	Ratio	Harwell 0949	Studsvik 2202D	Ratio	Harwell 0949	Studsvik 2202D
NRPB, Chilton	0.297 *	0.424 *	1.43	- - - -	- - - -	- - - -	- - - -	- - - -
AEA, Harwell	0.281 (8)	0.401 (12)	1.43	0.310 (9)	0.412 (12)	1.33	1.10	1.03
DRaStaC, Aldermaston	0.274 (8)	- - - -	- - - -	0.305 (8)	- - - -	- - - -	1.11	- - - -
NPL, Teddington	0.273 (4)	0.389 (4)	1.43	0.308 (4)	0.410 (4)	1.33	1.13	1.05
VSEL, Barrow-in-Furness	0.247 (10)	0.395 (15)	1.60	- - - -	- - - -	- - - -	- - - -	- - - -

* Inconsistent value omitted from calculation of mean. Uncertainties were not given.

Table 3 Normalised measured calibration values

	Am-Be		Cf-252	
	Harwell 0949	Studsvik 2202D	Harwell 0949	Studsvik 2202D
NRPB, Chilton	1.088	1.090	----	----
AEA Technology, Harwell	1.029 (28)	1.030 (30)	1.006 (29)	1.005 (30)
DRaStaC, Aldermaston	1.004 (28)	----	0.990 (26)	----
NPL, Teddington re-normalised	1.000 (15) 1.000 (23)	1.000 (11)	1.000 (13)	1.000 (10)
VSEL, Barrow-in-Furness re-normalised	0.905 (37) > 0.945 (37)	1.015 (37)	----	----

Uncertainties (shown in parentheses) apply to the least significant digit(s) and are at a 95% confidence level.

Table 4 **Further measurments by VSEL (normalised values)**

CALIBRATION of Mk 7 NRM MONITORS in Am - Be FIELDS at NPL and VSEL

Source	NPL sources at NPL	VSEL source at NPL	VSEL source at VSEL
Serial number 54	1.000	1.017	1.023
Serial number 234	1.000	1.015	1.025

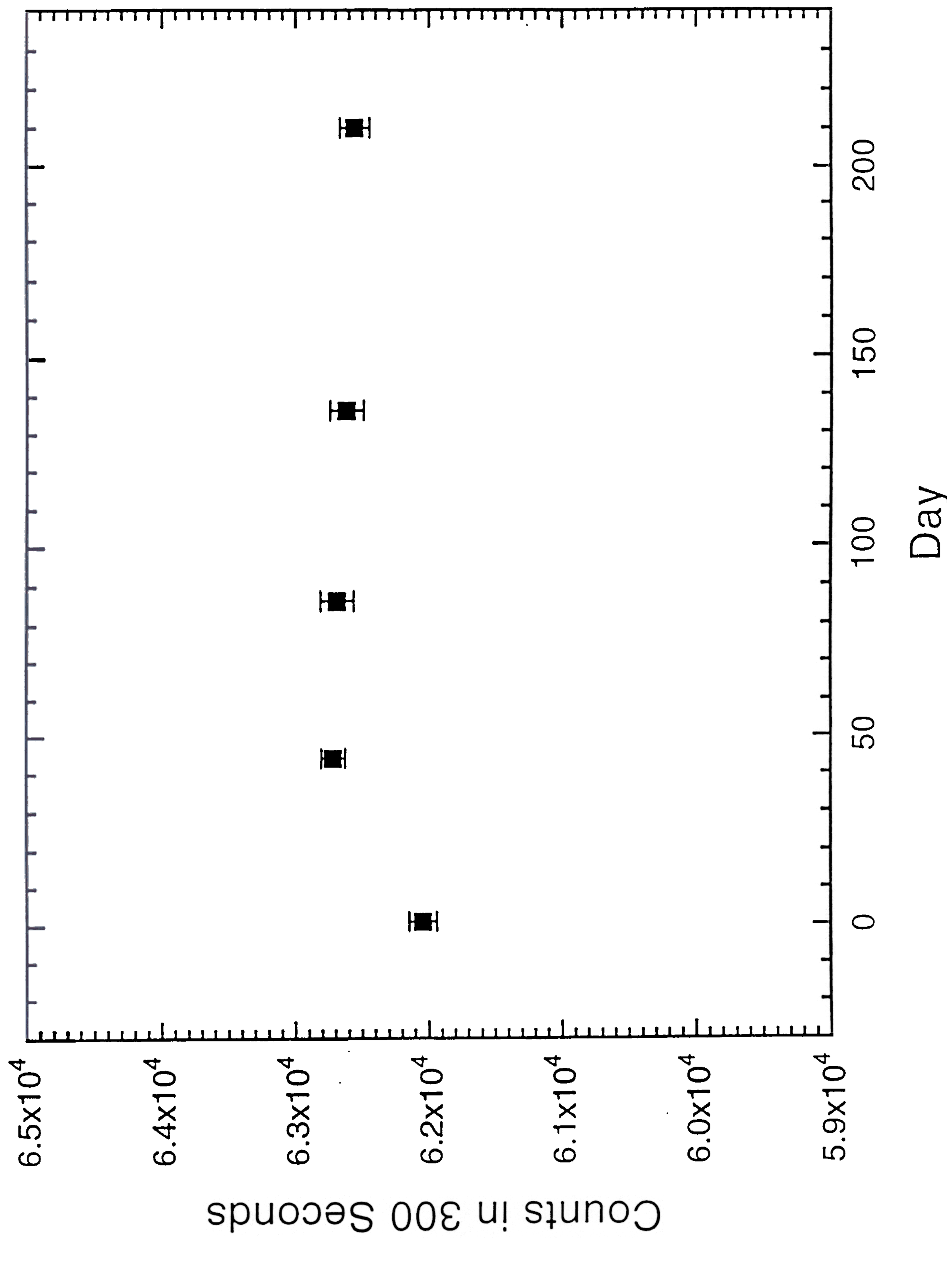

Figure 1 Check source measurements; response of Studsvik 2202D

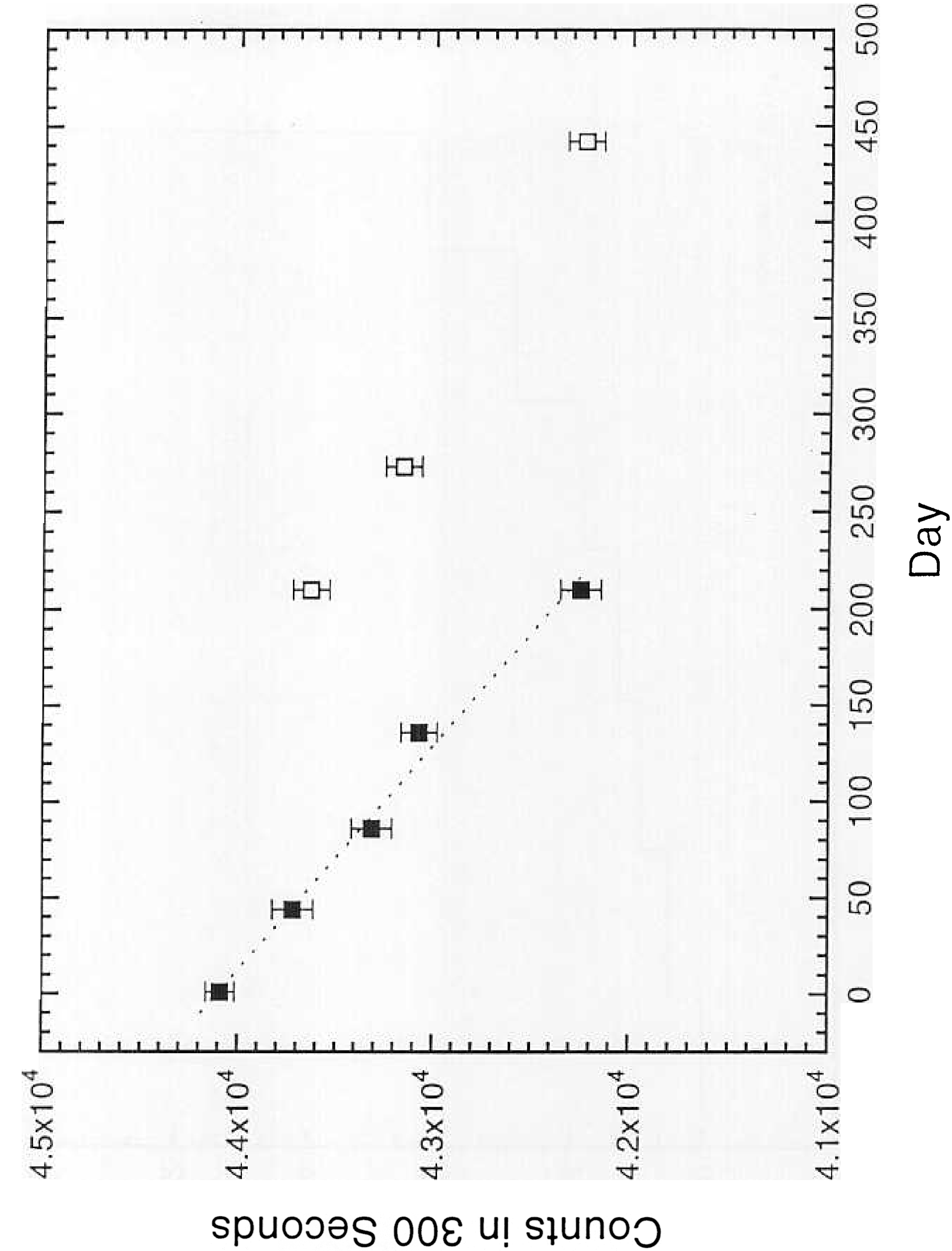

Figure 2 Check source measurements; response of Harwell 0949

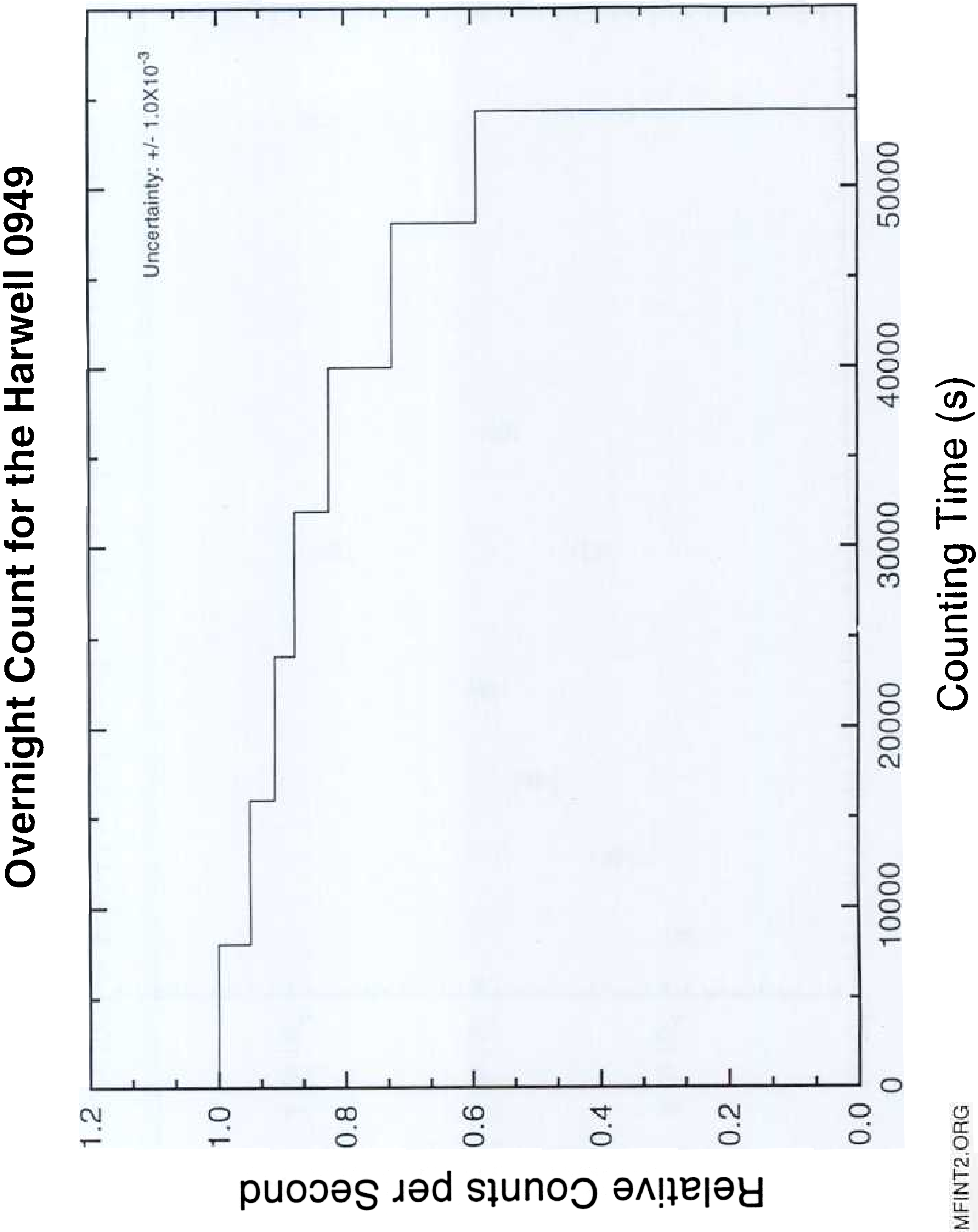

Figure 3 **Check source measurements, response of Harwell 0949; variation of response with prolonged use**

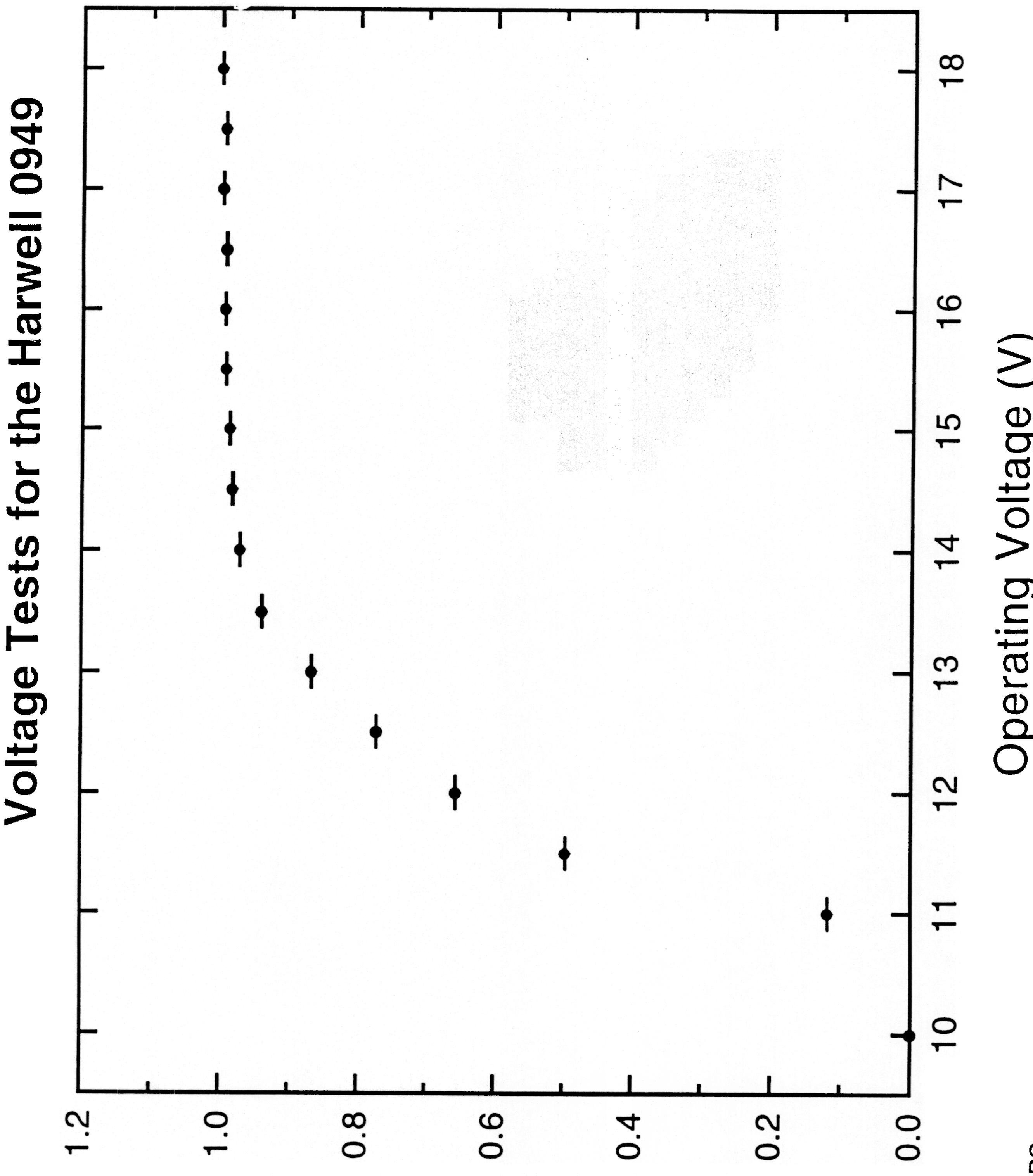

Figure 4 **Check source measurements, response of Harwell 0949; variation of response with supply voltage**

ANNEX 1 PROTOCOL

Contents

IRMF INTERCOMPARISON OF THE CALIBRATION OF NEUTRON AREA SURVEY INSTRUMENTS

PROTOCOL

1. Introduction and aims

The Ionising Radiations Metrology Forum (IRMF) have agreed to undertake an intercomparison of the calibration of neutron area survey dose equivalent monitors. The aim is to assess the present calibration capabilities of the laboratories within the United Kingdom who undertake these measurements. Such an exercise is timely in view of the increasing awareness of the importance of regular instrument checks. This has been stimulated by the publication by HSE of the booklet HS(G)49, *'The examination and testing of portable radiation instruments for external radiations'* which provides guidance on the regular calibration and testing required by the Ionizing Radiations Regulations 1985 for instrumentation used for routine radiation monitoring.

The IRMF intercomparison will involve the circulation of two commercially available instruments, both of which are extensively used in the UK, to the participating laboratories. To keep the exercise as simple as possible and to ensure that a meaningful comparison can be made between results from different laboratories, the quantity measured will be the free-field response of the instruments to neutrons from one of several designated sources. In order that the exercise and its conclusions reflect the routine calibration capabilities it is essential that participants employ exactly the same techniques and methods to calibrate the two transfer instruments as routinely used within their organisations. If laboratories wish to take advantage of the opportunity to make additional measurements this is completely acceptable, provided they do not in any way modify the results obtained using the routine techniques, and provided they do not prejudice the time scales laid down for the overall exercise.

2. Participants

Those who have expressed an interest in participating are:

AEA Technology, Harwell (R Bosley)
DRaStaC, AWE Aldermaston (P Danyluk)
NPL, Teddington (D J Thomas/ G C Taylor)
NRPB, Chilton (D R McClure)
Nuclear Electric plc, Berkeley (M Pottinger/ A Weeks)
VSEL, Barrow-in Furness (J Pople)

3. Instruments

The two area survey instruments to be used in the intercomparison are:

(a) a spherical device, the Harwell 0949 neutron dose equivalent rate monitor, model 95/0949 - 4/6, serial No. 6.

(b) a cylindrical device, the Studsvik neutron dose rate meter, model 2202D, serial No. 0961

Both instruments belong to NPL. <u>They should not be adjusted in any way</u>, and the tape covering the calibration adjustment on the Harwell 0949 should not be removed. Gamma signal rejection should not be a problem for any of the sources employed in the exercise. A user manual/data sheets is included in the transport case with each instrument.

4. Neutron sources

The neutron sources to be used by the participants are:

^{241}Am-Be	(by the majority
^{252}Cf	of participants)
Accelerator D(d,n)	(by Nuclear Electric only)
Accelerator T(p,n)	(by NPL only)

Calibrations should be performed with both the ^{241}Am-Be and the ^{252}Cf sources by all participants if possible.

5. Dose equivalent rate ranges

Five dose equivalent ranges have been specified for the exercise and participants should try to make at least one measurement within each of the five ranges shown below.

	< 10 μSv h^{-1}
2.	10 to 30 μSv h^{-1}
3.	30 to 100 μSv h^{-1}
4.	100 to 300 μSv h^{-1}
5.	> 300 μSv h^{-1}

6. Measurement details

6.1 Quantity measured

The quantity measured, and quoted on forms IRMF NI1.1 and IRMF NI1.2, should be the quotient of the instrument output (pulse count rate or dial reading) by the neutron fluence rate at the position of the effective centre of the instrument. For pulse output the quoted result should thus be count rate per unit fluence rate, which will have the dimensions, cm^2. No attempt should be made to convert to dose equivalent response. This can be done by the evaluator at a later stage in a consistent way for all participants.

The dials of the Harwell instrument and the Studsvik are different. The Studsvik has an analogue dial with a logarithmic scale calibrated in mrem/h. The reported dial response will thus be in mrem/h per unit fluence rate (mrem h^{-1} cm^2 s). For the Harwell instrument the dial is a digital one, and can be set to display either dose equivalent rate in mSv/h, or integral dose equivalent, or integral counts. The quantity to quote for dial reading is the indicated dose equivalent rate, in mSv/h, per unit fluence rate (mSv h^{-1} cm^2 s). Participants may wish to check that the integrated counts as measured by the Harwell instrument dial reading agrees with what they obtain from pulse counting with an external scaler. This, however, requires careful synchronisation to start both systems simultaneously.

The pulse count rate measurement provides much greater precision, and good counting statistics can be acquired, but it was felt to be important to also record the dial reading since this is what the end-user requires. Some participants do not routinely measure the pulse output rate and VSEL have kindly agreed to lend us a small stand-alone scaler system which can be used close to the instrument. (Do not miss the OFF/ON switch on the side of the black box). This can also be used to check participants' own pulse counting system, if they have one, and to investigate effects such as the sensitivity of the instrument to long cables attached to the pulse output.

The main correction will be for the response of the instrument to scattered neutrons, and the technique used to perform these corrections should briefly be described. Some attempt should be made to estimate the uncertainty in: the instrument output, the neutron fluence (or fluence rate) at the instrument, the scatter correction, and the derived response. For the pulse measurements the uncertainty in the instrument output can be derived from counting statistics, for dial readings from repeat readings.

6.2 Instrument adjustments

There will be no deliberate instrument off-set. Since there is no universally recognised 'correct' answer for these instruments, there is not much point doing this. Some calibration laboratories routinely adjust instrument responses on receipt, for example, to ensure complete gamma rejection in all measurement situations. This should not be done in this case, since it would invalidate the exercise as an intercomparison of identical instruments. For the chosen sources there should be no gamma rejection problems.

6.3 Calibration technique

The exercise is meant to be a comparison of results obtained using the calibration techniques routinely employed by each participant. If any other measurements are made, and this is a good opportunity to try out other techniques, the results should be reported separately on form IRMF NI1.2.

6.4 Instrument orientation

The instruments should be mounted as shown in the accompanying Figure. The Harwell 0949 with the electronics on the side away from the source of neutrons, and the Studsvik with the axis of cylindrical symmetry vertical with the electronics on top and the dial facing away from the source.

The effective centre of the Harwell instrument may be assumed to be at the centre of the polyethylene moderating sphere. For the Studsvik the effective centre can be assumed to be on the axis of cylindrical symmetry at a distance of 12.3 cm from the semi-rounded end of the polyethylene moderator (see Figure).

6.5 Power supplies for the instruments

It was originally intended that external power supplies should be distributed with the area survey instruments as an alternative to battery operation. There were, however, difficulties with the Studsvik because the power requirements are +7.5V and -6V, and the cable connection is via a three pole Lemo connector. Rather than delay the exercise any further, this idea has been abandoned for the Studsvik and battery operation should be employed. For the Harwell instrument external power requirements are simply +18V. This can be supplied from a simple stable voltage supply (not supplied). Cables are provided to connect between the supply and the instrument. (For greater distances an additional cable with BNC connectors can be used to connect between the two small cables provided).

7. Organizational details

The two instruments and the associated equipment are contained in two transport containers. These will go to each participant in turn. The keys will be dispatched separately

Between the measurements by the participants the equipment should be returned to NPL for checks of the response using a fixed geometry arrangement and an ^{241}Am-Be source. The measurements by a participant and the subsequent checks at NPL should be completed within one calender month.

A time slot will be agreed with each participant and he is asked to arrange for both collection and despatch of the transport containers from NPL. The address for both pick up and delivery is:

Goods Inwards
National Physical Laboratory
Queens Road
Teddington
Middx, TW11 0LW

The items should be marked: For the attention of D J Thomas, DRSA, Building 47.

8. Information required from participants

A number of pro-forma report sheets will be distributed to each participant detailing the information required when reporting results. Please use these forms as far as possible, completing only those parts marked for participants use, but do feel free to add any information you think necessary.

The first form IRMF NI1.1 is for results obtained using routine calibration techniques. Please use a separate sheet for each neutron source used. Form IRMF NI1.2 is for the results of any subsidiary measurements performed. Form IRMF NI1.3 asks for details about the sources, while IRMF NI1.4 covers the source and detector mounting, and the calibration room size and construction. Finally IRMF NI1.5 has space for any additional details and comments. Please feel free to make additional copies of these forms if required.

For the uncertainties we suggest use of the 67% confidence limit (1σ), but please specify the confidence level assumed, particularly if other than 1σ.

9. Collation of results

The coordinators of this exercise are David Thomas (NPL, 0181 943 6853) and Graeme Taylor (NPL, 0181 943 7087). Participants should send completed pro-forma report sheets to them within six weeks of completing their measurements. Each laboratory will subsequently be referred to by a letter known only to the evaluator (Dr V.E. Lewis) and the particular participants themselves. A summary report will be prepared and distributed to all participants prior to holding a meeting to finalise the report and agree conclusions to be drawn from the intercomparison. Consideration will be given to publishing a brief report in the open literature.

IRMF Neutron area survey instrument intercomparison

nstrument orientation

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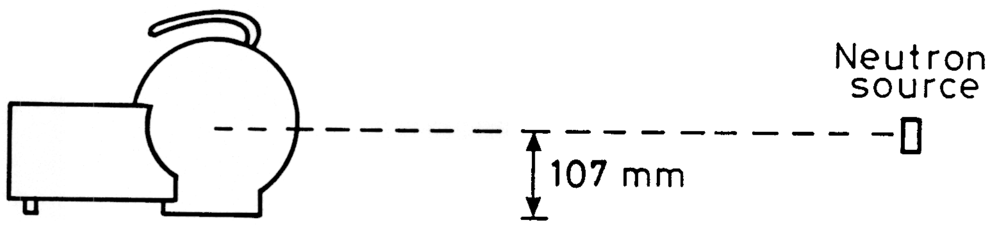

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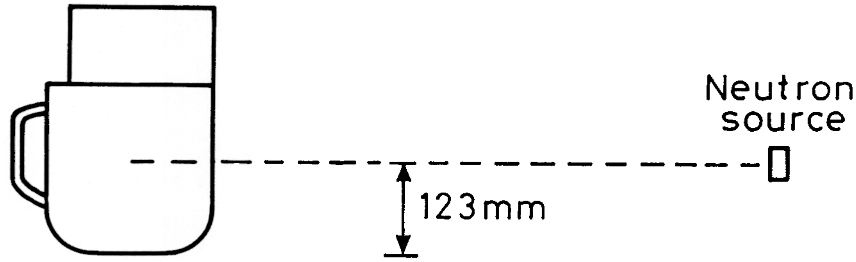

IRMF NEUTRON AREA SURVEY INSTRUMENT INTERCOMPARISON

Please record the calibration results obtained using your **routine** calibration technique (one source per form).

PARTICIPANT..: ____________ LAB REF........ ____________ (PLEASE LEAVE BLANK)

INSTRUMENT...: ____________ N-SOURCE TYPE..: ____________ N-SOURCE IDENTIFIER..: ____________

TEMPERATURE..: ____________ (°C) PRESSURE.......: (kPa) HUMIDITY............: (%)

Date of Measurement	Approx. DE Rate at Instrument (μSv h^{-1})	Dist. from Source to Eff. Centre of Instrument (cm)	Dial or Pulse O/P (**D** or **P**)	Instrument Dial Reading or Count Rate, + uncertainty and units	Fluence Rate at Eff. Centre of Instrument (cm^{-2} s^{-1}) + uncertainty	Fluence Rate Response of Instrument + uncertainty and units	Scatter Correction Assumed (%) + uncertainty

BATTERY/MAINS OPERATED...: ____________ CONFIDENCE LEVEL FOR UNCERTAINTIES...: (%)

TECHNIQUE USED TO DETERMINE SCATTERED NEUTRON COMPONENT...: ____________

PLEASE SPECIFY ANY CORRECTIONS PERFORMED OTHER THAN SCATTER CORRECTIONS...: ____________

IRMF NEUTRON AREA SURVEY INSTRUMENT INTERCOMPARISON

Please record the calibration results obtained using **alternative methods** of calibration (one source per form).

PARTICIPANT..: ____________ LAB REF........: ____________ (PLEASE LEAVE BLANK)

INSTRUMENT...: ____________ N-SOURCE TYPE..: ____________ N-SOURCE IDENTIFIER..: ____________

TEMPERATURE..: ____________ (°C) PRESSURE.......: ____________ (kPa) HUMIDITY............: ____________ (%)

Date of Measurement	Approx. DE Rate at Instrument ($\mu Sv\ h^{-1}$)	Dist. from Source to Eff. Centre of Instrument (cm)	Dial or Pulse O/P (**D** or **P**)	Instrument Dial Reading or Count Rate, + uncertainty and units	Fluence Rate at Eff. Centre of Instrument ($cm^{-2}\ s^{-1}$) + uncertainty	Fluence Rate Response of Instrument + uncertainty and units	Scatter Correction Assumed (%) + uncertainty

BATTERY/MAINS OPERATED...: ____________ CONFIDENCE LEVEL FOR UNCERTAINTIES...: (%)

TECHNIQUE USED TO DETERMINE SCATTERED NEUTRON COMPONENT...: ____________

PLEASE SPECIFY ANY CORRECTIONS PERFORMED OTHER THAN SCATTER CORRECTIONS...: ____________

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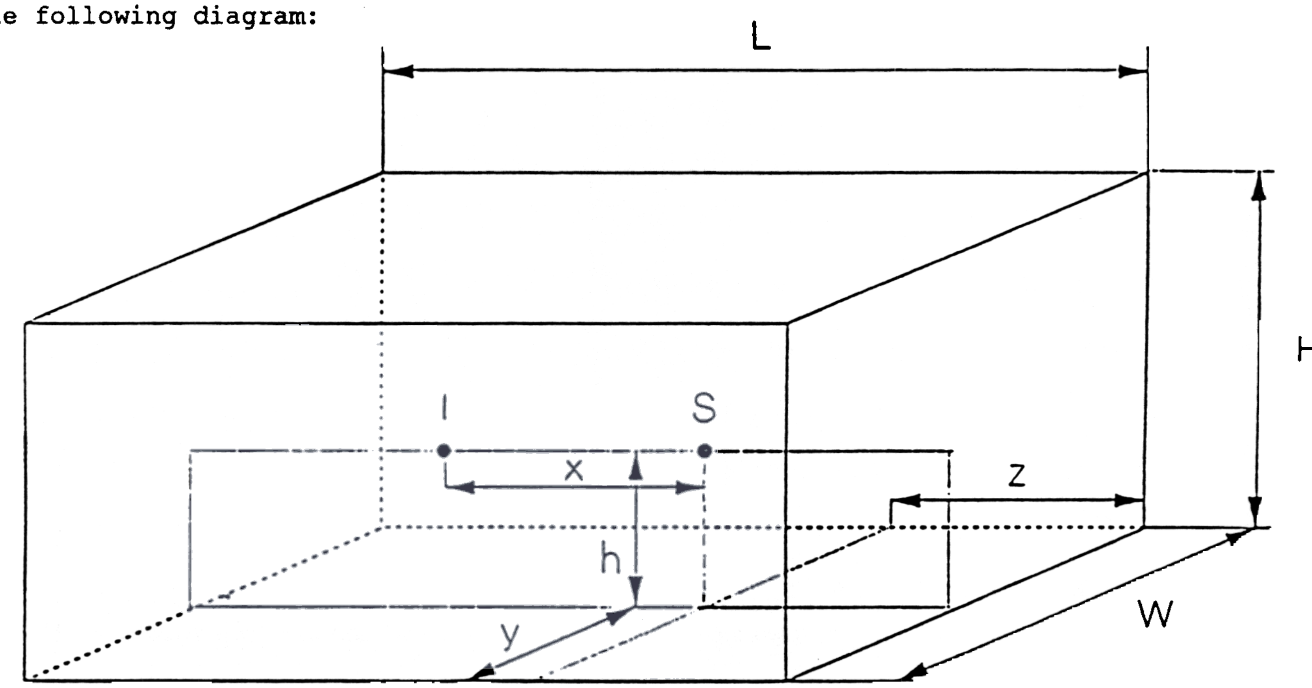
IRMF NEUTRON AREA SURVEY INSTRUMENT INTERCOMPARISON

Please record on this form the details of the calibration room, and of the source/instrument mounting arrangements.

PARTICIPANT..: ____________________ LAB REF: ______ (PLEASE LEAVE BLANK)

(A) CALIBRATION ROOM

Please indicate the approximate dimensions of the calibration room as indicated on the following diagram:



Calibration Room Dimensions (in metres):

Length (L): _________ Width (W): Height (H):

What is the wall material? ____

Source Position Details (in metres):

Irradiation height (h): ________ Distance from walls: (y) (z)

Source/Instrument Separation Distance (in metres):

Minimum X_{min}: ________ Maximum X_{max}: ________

(B) Source and Instrument Mounting

Please give additional details as to how the source and instrument were mounted (or include a photograph): ____

____

____

IRMF NEUTRON AREA SURVEY INSTRUMENT INTERCOMPARISON

Please record on this form any additional details or comments that you think would be helpful.

PARTICIPANT..: ____________________ LAB REF: ______ (PLEASE LEAVE BLANK)

Signature...: Date...:

Please return to:

Dr. D.J. Thomas & Dr. G.C. Taylor
Building 47,
DRSA,
National Physical Laboratory,
Queens Road,
Teddington,
Middlesex,
TW11 OLW

(Tel. 0181 943 6853/7087 Fax: 0181 943 7037)