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Intercomparison of ^{192}Ir brachytherapy source measurement in UK Hospitals, 1997

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ABSTRACT

An exercise to intercompare the measurement of ^{192}Ir brachytherapy sources has been completed and the results indicate that participants were able to measure the air kerma rate (AKR) of the sources with reasonable accuracy. However, it is noted that; (a) 60% of the results can be unequivocally accepted, 11% are rejected as being definitely discrepant; (b) there is a general low bias on the results; (c) there appears to be no particular instrument bias; (d) there needs to be a fuller consideration of measurement uncertainties by the users; (e) there was a wide range of reference data used; and, (f) calibration of the instrumentation relies in many cases, on manufacturer supplied data.

It is recommended that the exercise is repeated in the near future, and that the use of thick ('hairpin') wires is included in the next exercise.

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1 INTRODUCTION

Radioactive materials are widely used in hospitals for both therapeutic and diagnostic purposes. The assay of patient dose has an important rôle in the correct administration of therapy sources and it should be determined to a high degree of accuracy. Guidelines have been published[1] for the control of dosimetry using brachytherapy sources and this publication specifically addresses the use of low dose rate ^{192}Ir sources and quality control procedures for such sources.

The most common instruments for this purpose are radionuclide calibrators, based on high pressure, re-entrant ionisation chambers. The operation of such instruments is relatively straightforward and, if used correctly in conjunction with a recognised quality assurance system, the relevant levels of accuracy can be achieved. A protocol for such a QA system has been recommended for use in UK hospitals[2].

Some low dose rate (LDR) brachytherapy sources of ^{192}Ir are manufactured in the form of thin wire. These comprise an inner core of platinum/iridium alloy, with an outer sheath of platinum. The wires are irradiated in a neutron flux, activating the iridium to ^{192}Ir. Some minor activation products of iridium and platinum may also be seen but are insignificant in terms of patient dose. High specific activities (>1 MBq mm^{-1}) can be achieved by this technique.

Such sources are particularly effective in the treatment of cancer since;

(i) a high absorbed dose is delivered to the tumour in a short space of time,

(ii) most particulate emissions are effectively absorbed in the platinum sheath, and

(iii) the source is simply administered and removed from the patient, with little generation of active waste.

For the foregoing clinical practice to be effective and safe, the dose from the source has to be accurately known in terms of air kerma rate (AKR) in order to deliver the correct treatment to the patient. In addition, QA requirements should require traceability to national standards. Information about the AKR can be obtained from the manufacturer's documentation and may also be measured on-site using in-house equipment.

Treatments are normally accomplished by the simultaneous insertion, in a predetermined array, of several short lengths of active wire. This treatment array is designed assuming the activity of each wire is both uniformly distributed along it's length and is accurately known. Since wires are normally supplied by the manufacturer in the form of 500 mm coils, and as the irradiation process cannot guarantee a uniform activity distribution, the AKR per unit length is an average value only. The cutting procedure also creates an additional uncertainty on the length of the cut wire. For these reasons, it is not acceptable to rely on the average AKR mm^{-1} supplied by the manufacturer: it is necessary to determine the activities of each individual wire using an in-house facility. That facility is now commonly a well-type ionisation chamber.

Ionisation chambers, typically as the detector component of radionuclide calibrators, have been used for many decades for the measurement of radioactive solutions used in diagnostic nuclear medicine. Calibration factors for solution formats are determined directly by measuring the ionisation chamber response to solutions that have been standardised using absolute methods. For brachytherapy wires, the calibration factors will necessarily be different from those in solution and their derivation is more complex. However, calibration factors have been measured (rather than derived from purely theoretical considerations) for the NPL secondary standard radionuclide calibrator and published in the open literature[3]: these factors have traceability to national primary standards of both activity and air kerma. The traceability of calibration factors for other calibration systems is not known at this stage to the authors.

The level of measurement performance for ^{192}Ir brachytherapy wire sources has been investigated by means of an intercomparison exercise conducted by the National Physical Laboratory (NPL) and the measurement community in the UK.

2 PARTICIPANTS

Participation was open to all UK hospitals. The intercomparison was publicised at the NPL Radiotherapy User's Meeting in 1996. In addition, the exercise was publicised in NPL Newsletters and by Amersham International plc (AI) via their mailing list. A list of participants is given in Appendix 1.

3 INTERCOMPARISON SAMPLES

A stock of 500 mm length ^{192}Ir wires was obtained from AI. They were sub-divided into nominal 10, 30 and 100 mm lengths, placed in nylon tubing and made available for participants. Some of the wires were retained at NPL. The samples were despatched in June 1997, together with a reporting sheet which is reproduced in Appendix 2.

Participants results have been coded but the coding remains known only to NPL.

4 MEASUREMENTS AT NPL

4.1 Ionisation chamber measurements

All of the ^{192}Ir wires used in this work were assayed in the NPL secondary standard ionisation chamber, previously calibrated against absolute standards of radioactivity. As described earlier, these chambers are also calibrated to determine direct measurement of AKR at 1 m. The measurement was achieved using the NPL-designed perspex mounting jig, placed into the P6 vial holder. This arrangement allows accurate and reproducible positioning of the ^{192}Ir brachtherapy sources: the 30 and 100 mm sources were measured in the trough of the jig, rather than in the central position. The data obtained were used to calculate the AKR in μGy h^{-1} at a distance of 1 m and it was these values that were used to compare with the participants data.

4.2 AKR measurements

In addition to the ionisation chamber measurements described above, measurements were also made in NPL's dosimetry facilities to provide an additional confirmation of the ionisation chamber measurements. The measurements were performed in the centre of a room 3 m x 3 m x 7 m . The radiation detector used is a 3.5 dm^3 spherical ionisation chamber and associated electrometer calibrated in terms of AKR annually against the UK national primary standard over a wide range of X- and γ-ray energies. The chamber was placed at 1 m focal distance from the brachytherapy wires which are held in a paper 'V'. The wires were positioned so that the long axis of each wire was parallel to the floor and facing towards the chamber. The materials used in the construction of the chamber and source supports are all low density to minimise the scatter contribution. A measurement of background radiation was performed before and after a set of five readings of five minutes each for every source. The readings were corrected for;

a) the sensitivity of the ionisation chamber for the ^{192}Ir γ-ray spectrum,
b) the size of the chamber,
c) the air density at the time of measurement,
d) the attenuation of the γ-rays due to air,
e) the scatter contribution from the room,
f) the linearity and range factor of the electrometer, and
g) the background contribution.

Further measurements were performed with one source at different focal distances to confirm that the inverse-square law was obeyed within the limits of uncertainty.

4.3 Comparison

The data generated in 4.1 and 4.2 above were used to calculate mean values of ionisation chamber response for a given AKR value and are given in Table 1. It will be seen from the results that the calibration factors obtained from this exercise are not statistically different from those previously determined and published as the definitive factors[(3)].

5) RESULTS

The data reported by the participants are given in Tables 2-4, with a summary in Table 5. The participant's data have been corrected for decay to the NPL reference time of 12:00 on 7 May 1997. The data is also presented graphically in Figures 1 to 4, with the error bars representing the standard uncertainty reported by the participant. The horizontal lines above and below the zero percent deviation value represent the standard uncertainty levels of the NPL value.

There were a number of differing techniques and instruments used by the participants. This data is given in Table 6.

6) DATA ANALYSIS

The participants results were compared with the NPL data in two ways. First, the simple deviation of the participants result from the NPL data was calculated. This approach, however, only provides a simplistic view and does not indicate whether an observed difference is statistically significant or not. In order to do so, it is necessary to use a test which includes the uncertainties on both measurements. A test which is commonly used for this purpose is the 'u-test'[(4)]. The u-statistic is calculated as follows;

$$u = (|A-B|)/(a^2 + b^2)^{1/2}$$

where A is the participants reported value,
a is the uncertainty on A,
B is the NPL value, and
b is the uncertainty on B.

The u-statistic can be interpreted in a number of ways, an example being given in Table 7.

It can be argued that only the results with a u-test value of greater than 3.29 are candidates for rejection. However, given the sensitivity of the public at large about radiation in general and the recent publicity attendant on the incorrect administration of radiotherapy to patients, it is reasonable to assume that ***all*** data where the value of the u-statistic is greater than 1.64 should be treated with some suspicion. For the purposes of this intercomparison, we follow the latter course and assume that, where the u-statistic exceeds 1.64 for a particular result, then that result is deemed discrepant.

7 DISCUSSION

The results obtained show reasonable agreement with the NPL values, although this varies with the length of the wire, with the best set of results recorded for the 30mm wires. Overall the results display a negative bias of 4.1 (± 4.8)%, with the 10mm, 30mm and 100mm wires showing a bias of -4.5 (± 5.4) %, -4.5 (± 4.5) % and -3.3 (± 4.6) % respectively.

7.1 Instrumentation

Most participants used ionisation chambers of various types, although it was not clear if some of the instruments used were ionisation chambers (it is assumed that they are). Given the number of instruments used, there is insufficient evidence to suggest a particular bias associated with any one type of instrument.

7.2 AKR constants

Four participants used an AKR constant of ~0.11 μGy h^{-1} MBq^{-1} m^2 to convert their measured activities to an AKR value and these results (A, B, G, I) appear to show less scatter than the overall set of results. Of the other results, participant E returned the most discrepant data, although these were subsequently revised when it was realised that the calculations used to provide the initial data were unnecessarily complex (and therefore open to error).

7.3 Uncertainties

Most participants made some attempt to estimate the uncertainties associated with their measurements, although participant H did not, pointing out that this was not normally done. The reporting of uncertainties is recommended, since it enables a fair assessment of the performance of the participant to be estimated. In addition, it is (presumably) needed when administering sources to a patient. With the current emphasis on quality assured measurements, the correct estimation of measurement uncertainty is necessary in all fields to enable the operator to demonstrate that their measurements are in agreement with what is required.

For those participants that did estimate the uncertainties, it was notable that the uncertainties reported by participants A (all wires), B (100 mm wire), E (all wires), G (10 and 30 mm wires) and K (all wires) were less than the reported uncertainties derived by NPL for it's chamber calibration. It should also be noted that E only quoted uncertainties due to variation in position: the calibration accuracy of the chamber was not known. In all, excluding the results from E and J before revision and those from H where uncertainties were not quoted, 40% have uncertainties equal to or less than those quoted by NPL.

One must consider all sources of uncertainty when calculating the overall figure and this must necessarily include reference and calibration data itself. For example, the uncertainty achieved in an absolute standardisation of ^{192}Ir solution is ± 0.3%[3], and that for the NPL secondary standard ionisation chamber is ± 0.5%. For the wire sources, the uncertainties on the pA/AKR conversion factors are given as ±1.1% for the 10 mm wires and ± 2.8% for the 30 and 100 mm wires. Although these values apply to the measurements performed at NPL over the years and to the NPL secondary standard calibrators, it is unlikely that other national metrology institutes are able to achieve significantly lower uncertainties. A corollary of underestimating uncertainties is that it will artificially inflate the u-statistic in an intercomparison such as this. This may result in the data appearing to be discrepant when this is not actually the case. This does not mean, however, that inflating uncertainties in order to achieve a lower value of u-statistic is acceptable practice!

7.4 Calibration

It was not clear, in some cases, how the calibrations of individual systems were achieved. In several cases, the manufacturer's settings were used and it has to be said that these data were no worse (or better) than any of the other data. Only two participants (H and J) explicitly stated that they calibrated their chamber against a known source. This did not produce significantly better results.

7.5 Reference data

As stated in various points above, the need to use correct reference data is essential. The measurements made were reported 'at the time of measurement' and decayed to a common reference date by NPL, using a half life of 73.831 (± 0.008) days[5]. It is recognised that sources are usually used shortly after measurement and that this time is short with respect to the half life but it is essential that the correct half life value is used if decay is significant.

This use of reference data also extends to the various calibration factors used which are given in Table 8 and are the currently recommended values[3]. Reading this data in conjunction with Table 7, it is clear that the calibration factors used by participants differ somewhat from those recommended. This being the case, there is the need for the users of such sources to at least check the calibration of their instruments to ensure that they are delivering the correct readings when sources are measured. This in turn suggests that treating measurement devices as 'black boxes' is not recommended practice and that, as far as is possible, one needs to have access to the raw data, *viz.* the pA/source readings.

8 CONCLUSIONS

The exercise to intercompare the measurement of ^{192}Ir brachytherapy source has been successfully completed and the results indicate that, on average, the participants were able to measure the AKR of the sources reasonably accurately. However, some points for concern have come out of this exercise;

i) only 60% of the results can be unequivocally accepted. Of the rest, 11% are rejected as being definitely discrepant,

ii) there is a general low bias on the results of ~4%,

iii) a wide range of measurement devices are in use and it is pleasing to note that there appears to be no particular instrument bias,

iv) there needs to be a fuller consideration of measurement uncertainties by the users,

v) the reference data used is confused, in that almost each participant used their own recipe, in spite of published data being available, and

vi) calibration of the instrumentation relies, in a significant number of cases, on manufacturer supplied data.

It remains for the user community to decide whether the findings of this intercomparison are significant in terms of healthcare delivery; is it acceptable for patient dose, on average to be 4% low, or is this bias insignificant when compared to other aspects of patient care? As metrologists and UKAS assessors, the authors remain to be convinced that the current situation should be allowed to endure and recommend that these points are discussed at the follow up meeting. It is further recommended that the exercise is repeated in the near future, and that the use of thick ('hairpin') wires is included in the next exercise.

9 ACKNOWLEDGEMENTS

The author wish to record their thanks to Steven Judge at Amersham International plc for assisting with publicising the exercise and the participants for the considerable time and effort that they have spent on making this a successful and worthwhile exercise.

10 REFERENCES

(1) Aird, E.G.A., Jones, C.H., Joslin, C.A.F., Klevenhagen, S.C., Rossiter, M.J., Welsh, A.D., Wilkinson, J.M., Woods, M.J. and Wright, S.J.,*'Recommendations for Brachytherapy Dosimetry'*, Joint British Institute of Radiology and Institute for Physical Sciences in Medicine Report, (1993)

(2) Parkin, A., Sephton, J.P., Aird, E.G.A., Hannan, J., Simpson, A.E. and Woods, M.J., *'Protocol for Establishing and Maintaining the Calibration of Medical Radionuclide Calibrators and their Quality Control'*, Proceedings of the joint meeting on Quality Standards in Nuclear Medicine, BIR, London, 1992.

(3) Sephton, J.P., Woods, M.J., Rossiter, M.J., Williams, T.T., Dean, J.C.J., Bass, G.A. and Lucas, S.E.M., *'Calibration of the NPL Secondary Standard Radionuclide Calibrator for ^{192}Ir Brachytherapy sources'*, Phys.Med.Biol., 38, 1157-1164, (1993).

(4) Brookes, C.J., Betteley, I.G. and Loxton, S.M., *'Fundamentals of Mathematics and Statistics'*, Wiley (New York), 369-377, (1979).

(5) Smith, D. And Woods, S.A., *'Recommended Nuclear Decay Data'*, NPL Report RSA(EXT)53, (1995)

Table 1. NPL measurements

Wire length (mm)	Observed calibration factor (OCF) (pA μGy^{-1} h^{-1})	Standard uncertainty (%)	Published calibration factor (PCF) (pA μGy^{-1} h^{-1})	Standard uncertainty (%)	$\frac{(OCF-PCF)}{PCF}$ (%)	u-statistic
10	74.1	2.9	75.2	1.1	-1.5	0.49
30	80.4	1.7	80.3	2.8	0.13	0.04
100	80.7	2.3	80.3	2.8	0.37	0.11

Table 2 - Results for 10mm wires

Code	NPL AKR (μGy h^{-1} @ 1m)		Hospital AKR (μGy h^{-1} @ 1m)				Hospital AKR (μGy h^{-1} @ 1m) at reference time		Deviation (%)	u-statistic
	Value	± %	Value	± %	Date	Time	Value	± %		
A	1.26	1.1	0.82	0.6	24/6/97	10:43	1.29	0.6	1.7	1.37
B	1.37	1.1	0.86	4.8	24/6/97	12:30	1.35	4.8	-1.3	0.27
C	1.64	1.1	0.82	2.9	15/7/97	12:15	1.58	2.9	-4.0	1.34
D	1.61	1.1	0.83	5.9	16/7/97	12:00	1.59	5.9	-1.2	0.20
E	1.55	1.1	0.85	1.0	24/6/97	12:00	1.33	1.0	-13.7	9.84
E*	1.55	1.1	0.96	1.0	24/6/97	12:00	1.51	1.0	-2.6	1.76
F	1.41	1.1	0.86	1.1	24/6/97	15:00	1.36	1.1	-3.6	2.33
G	1.47	1.1	0.88	2.0	25/6/97	11:15	1.39	2.0	-5.6	2.58
H	1.49	1.1	0.86	-	30/6/97	10:50	1.43	-	-3.6	-
I	1.56	1.1	0.86	4.7	8/7/97	12:30	1.53	4.7	-1.6	0.33
J	1.55	1.1	0.65	5.1	18/7/97	13:00	1.29	5.1	-16.9	3.87
J*	1.55	1.1	0.65	7.1	18/7/97	13:00	1.29	7.1	-16.9	2.83
K	1.50	1.1	1.56	0.5	1/5/97	12:00	1.47	0.5	-1.7	1.38

Table 3 - Results for 30mm wires

Code	NPL AKR ($\mu Gy\ h^{-1}$ @ 1m)		Hospital AKR ($\mu Gy\ h^{-1}$ @ 1m)				Hospital AKR ($\mu Gy\ h^{-1}$ @ 1m) at reference time		Deviation (%)	u-statistic
	Value	± %	Value	± %	Date	Time	Value	± %		
A	4.20	2.8	2.76	0.3	24/6/97	10:43	4.33	0.3	3.2	1.12
B	4.36	2.8	2.59	2.9	24/6/97	12:30	4.07	2.9	-6.8	1.76
C	4.19	2.8	2.14	2.9	15/7/97	11:45	4.08	2.9	-2.5	0.62
D	4.36	2.8	2.10	5.9	16/7/97	12:00	4.05	5.9	-7.0	1.14
E	4.71	2.8	2.53	1.6	24/6/97	12:00	3.97	1.6	-15.7	5.04
E*	4.71	2.8	2.89	1.6	24/6/97	12:00	4.54	1.6	-3.7	1.15
F	4.56	2.8	2.74	2.8	24/6/97	15:00	4.30	2.8	-5.7	1.49
G	4.05	2.8	2.46	2.0	25/6/97	11:15	3.90	2.0	-3.6	1.05
H	4.49	2.8	2.61	-	30/6/97	10:55	4.32	-	-3.7	-
I	4.30	2.8	2.34	4.7	8/7/97	12:30	4.19	4.7	-2.6	0.48
J	4.19	2.8	2.03	5.1	18/7/97	13:00	3.99	5.1	-4.9	0.88
K	4.12	2.8	4.34	0.5	1/5/97	12:00	4.10	0.5	-0.4	0.13

Table 4 - Results for 100mm wires

Code	NPL AKR ($\mu Gy\ h^{-1}$ @ 1m)		Hospital AKR ($\mu Gy\ h^{-1}$ @ 1m)				Hospital AKR ($\mu Gy\ h^{-1}$ @ 1m) at reference time		Deviation (%)	u-statistic
	Value	± %	Value	± %	Date	Time	Value	± %		
A	13.6	2.8	9.26	0.2	24/6/97	10:43	14.5	0.3	6.5	2.30
B	14.2	2.8	8.32	2.6	24/6/97	12:30	13.1	2.6	-8.1	2.10
C	14.3	2.8	6.95	2.9	15/7/97	12:00	13.3	2.9	-7.0	1.79
D	14.7	2.8	7.25	5.9	16/7/97	12:00	14.0	5.9	-4.9	0.78
E	14.8	2.8	8.55	2.3	24/6/97	12:00	13.4	2.3	-9.5	2.74
E*	14.8	2.8	9.62	2.3	24/6/97	12:00	15.1	2.3	1.8	0.49
F	13.3	2.8	7.97	2.8	24/6/97	15:00	12.5	2.8	-6.2	1.61
G	15.2	2.8	9.07	2.0	25/6/97	11:15	14.4	2.0	-5.8	1.72
H	14.1	2.8	8.18	-	30/6/97	11:00	13.6	-	-3.4	-
I	14.8	2.8	8.08	4.5	8/7/97	12:30	14.5	4.7	-2.1	0.41
J	14.4	2.8	7.25	5.1	18/7/97	13:00	14.3	5.1	-0.8	0.14
K	14.3	2.8	15.2	0.5	1/5/97	12:00	14.4	0.5	0.6	0.22

* - revised data reported

Table 5 - Summary of u-test results (excluding H; revised participant data in brackets)

Wire length	10 mm	30 mm	100 mm
u<1.64	6(6)	8(9)	5(6)
1.64<u<1.96	0(1)	1(1)	2(2)
1.96<u<2.58	2(2)	0(0)	2(2)
2.58<u<3.29	0(1)	0(0)	1(0)
3.29<u	2(0)	1(0)	0(0)

Table 6 - Other reported data

Code	Instrument	Maker	Type	Comments
A	Ionisation chamber	Capintec	CRC-15β	i) 0.111 µGy h^{-1} MBq^{-1} m^2 used as the AKR constant ii) varied geometries employed
B	Well chamber	PRM	WC2/WCC2	i) 113 µGy GBq^{-1} h^{-1} m^2 used as the AKR constant ii) temperature and pressure corrections made
C	Ionisation chamber	Vinten	ISOCAL-III	Calibration factor of 7.83 pA MBq^{-1} used in conjunction with AKR 'factor' of 0.0974
D	Ionisation chamber	NE Technology	ISOCAL-IV	Several measurements with different operators made
E	Ionisation chamber	-	ISOCAL	i) Integration used to convert measurement to AKR ii) temperature and pressure corrections made
F	Ionisation chamber	NE Technology	ISOCAL-IV	pA reading multiplied by 0.836
G	Well calibrator	Vertec	WC2/WCC2	i) 0.111 µGy h^{-1} MBq^{-1} m^2 used as the AKR constant ii) temperature and pressure corrections made
H	Ionisation chamber	Vinten	ISOCAL	Instrument data given as mR h^{-1} @ 1m using a factor of 1880, obtained from a known ^{137}Cs source.
I	Ionisation chamber	Capintec	CRC-15	Chamber factor set to 408 and AKR constant of 0.111 µGy h^{-1} MBq^{1} m^2 used
J	Well chamber	PTW	077-091	Unit calibrated against known wire of similar AKR
K	Well chamber	Pitman	270 (mark 2)	Manufacturer's setting.

Table 7. u-test interpretation

Condition	Interpretation
u<1.64	The results are not significantly different.
1.64<u<1.96	The results do not probably differ but more information is required to support this conclusion.
1.96<u<2.58	It is not possible to draw a conclusion: thus more data is required.
2.58<u<3.29	The results probably differ but more information is required to support this conclusion.
3.29<u	The results are significantly different

Table 8 - Published calibration factors[3]

Parameter	Wire length	Value	Standard uncertainty
pA MBq^{-1}	10 mm	7.83	± 1.1 %
	30 mm	8.36	± 2.8 %
	100 mm		
μGy h^{-1} MBq^{-1} @ 1m	10 mm	0.104	± 1.6 %
	30 mm		
	100 mm		
pA μGy^{-1} h^{-1} @ 1m	10 mm	75.2	± 1.1 %
	30 mm	80.3	± 2.8 %
	100 mm		

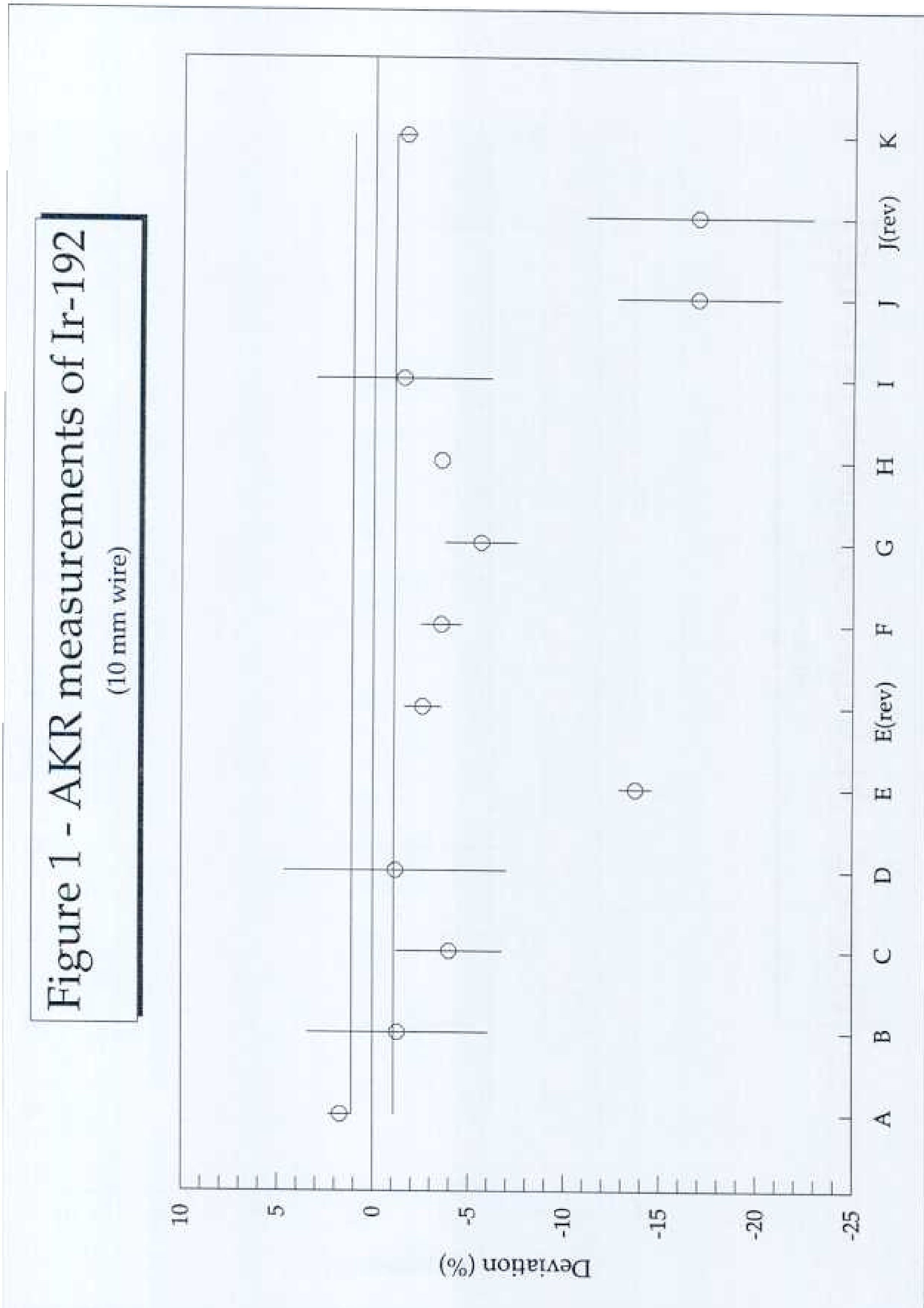

Figure 1 - AKR measurements of Ir-192

(10 mm wire)

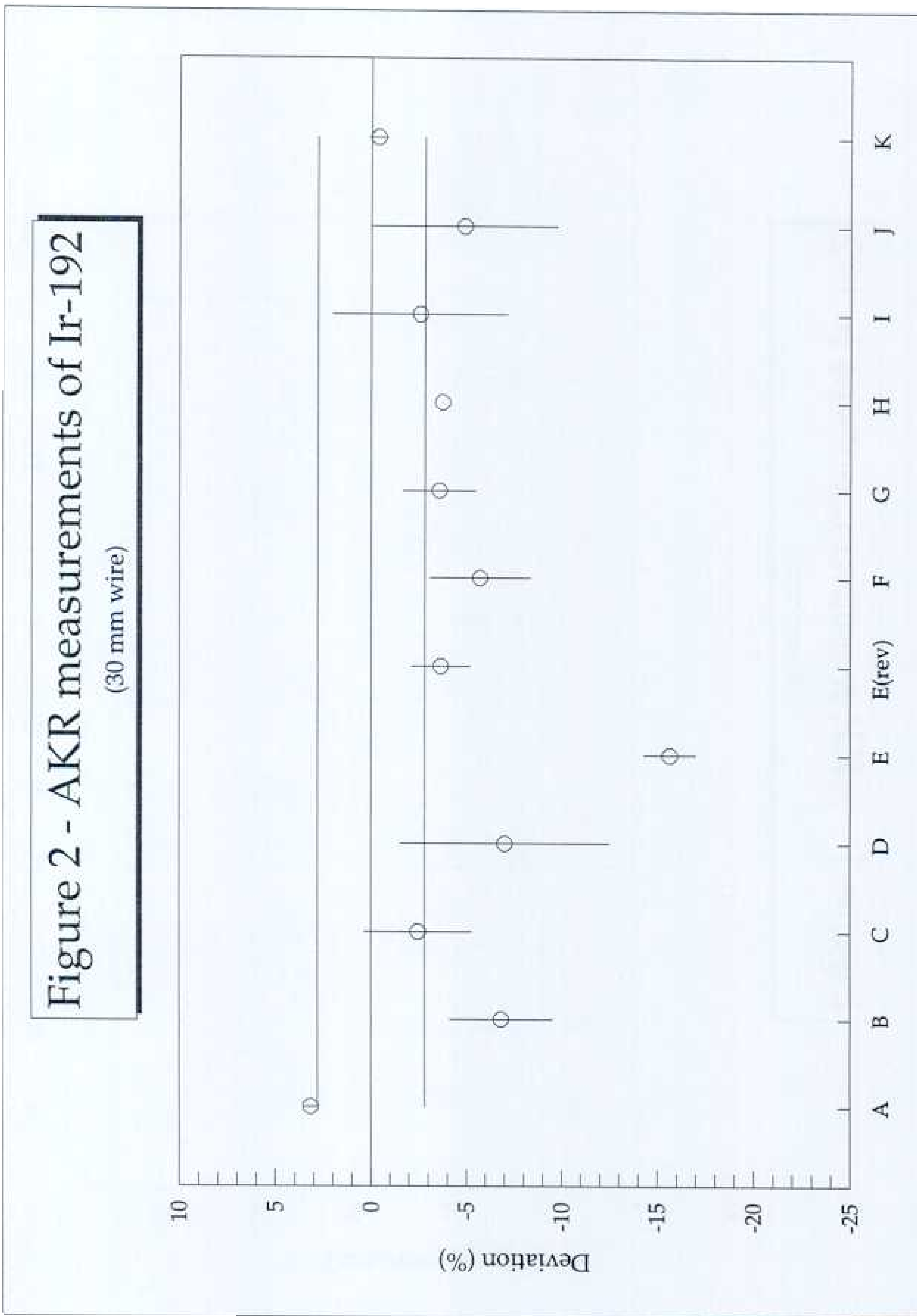

Figure 2 - AKR measurements of Ir-192
(30 mm wire)

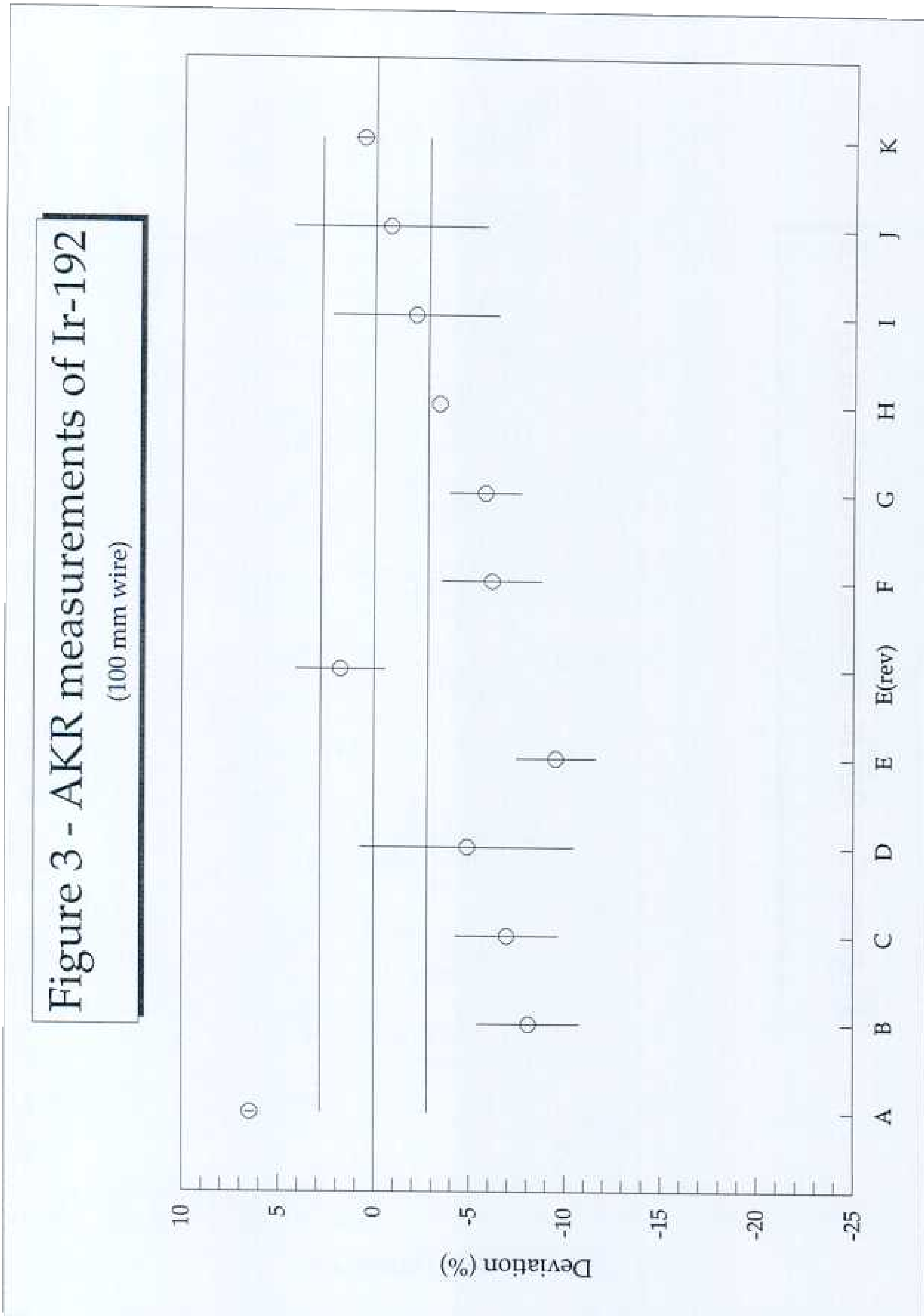

Figure 3 - AKR measurements of Ir-192

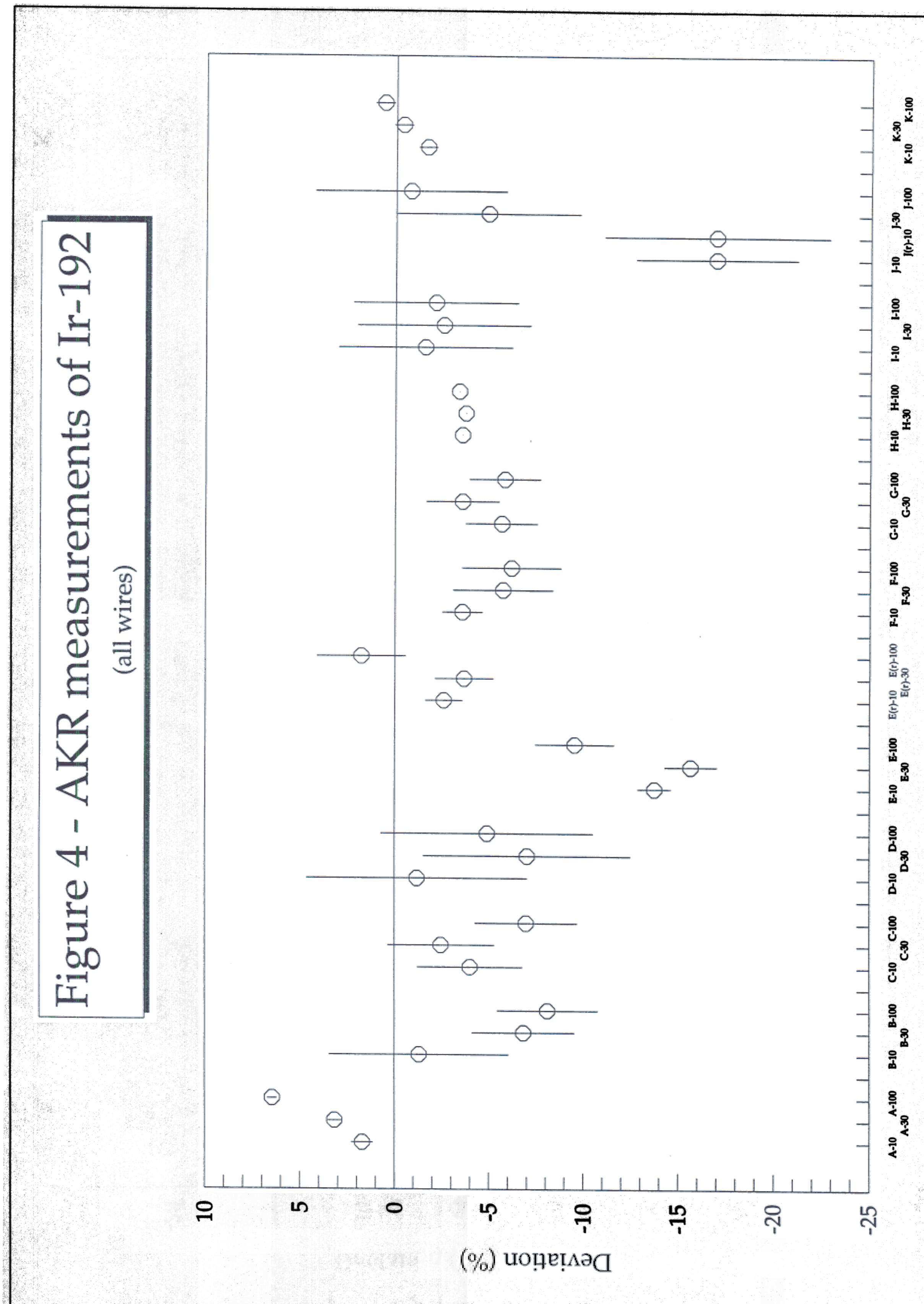

Figure 4 - AKR measurements of Ir-192

(all wires)

APPENDIX 1 - PARTICIPANTS

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APPENDIX 2 - REPORTING SHEET

NPL Iridium-192 Brachytherapy Wire Measurement Intercomparison		
1) Result (10, 30 or 100 mm wire)		
Value		μGy/hr @ 1 metre
Uncertainty (quote at 1 σ - the 68% confidence interval)		[μGy/hr @ 1 metre]/[%]†
Reference time and date	___:___hrs	___/___/___
2) Uncertainties		
Component number	Uncertainty (quote at 1 σ - the 68% confidence interval) [μGy/hr @ 1 metre]/[%]†	Degrees of freedom
(† - delete as appropriate)		
3) Method employed		
4) Equipment used		
5) Corrections/calculations used		
6) Software used		
7) Other information		

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