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Intercomparison of ^{131}I solution and capsule source in UK Hospitals, 1999

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ABSTRACT

As part of the ongoing programme, supported by the National Measurement System Policy Unit of the Department of Trade and Industry, the National Physical Laboratory is conducting a new series of intercomparisons and workshops.

Recent concerns have been raised within the nuclear medicine field about the apparent discrepancies between the AEA Technology plc nominal activity for ^{131}I capsules and the corresponding activity measurements made in hospitals.

To assess the accuracy of clinical measurements of the activity of ^{131}I solutions and capsules and to determine the reason for the above disagreement, an intercomparison exercise was conducted between the National Physical Laboratory (NPL), AEA Technology plc (AEA), Nycomed-Amersham (NA) and the UK hospital physics community.

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1. INTRODUCTION

A wide variety of radioactive materials are routinely used in UK Hospitals for diagnostic and therapeutic purposes. The activity of the particular radionuclide should be accurately determined prior to administration to a patient. Radionuclide calibrators are the most common instruments used for this purpose. Their principle of operation is relatively simple and, used correctly via a quality assurance system, they can achieve the desired accuracy of the administered activities. A protocol for establishing and maintaining a quality system has been recommended for use in UK hospitals [1].

As part of the ongoing programme, supported by the National Measurement System Policy Unit of the Department of Trade and Industry, the National Physical Laboratory is conducting a new series of intercomparisons and workshops. This continues the very well-subscribed intercomparisons conducted in previous years [2-6]. The aim is to determine the overall level of performance in the UK hospitals, to identify and discuss problems and to facilitate the exchange of information.

Recent concerns have been raised within the nuclear medicine field about the accuracy of measurements of ^{131}I capsules. The capsules are routinely used in over 80 centres around the UK and the great majority are supplied by AEA Technology plc. Numerous hospitals have reported differences of up to + (10 - 15) % from the "nominal" activities quoted by the AEA Technology plc, causing concerns about potentially overestimating the activity prior to administration.

To assess the accuracy of clinical measurements of the activity of ^{131}I solutions and capsules and to determine the reason for the above discrepancies, an intercomparison exercise was conducted between the National Physical Laboratory (NPL), AEA Technology plc (AEA), Nycomed-Amersham (NA) and the UK hospital physics community.

2. PARTICIPANTS

Participation was open to all UK hospitals and the exercise was publicised via the contact mailing lists maintained by AEA, NA and NPL.

A total of 45 participants received a capsule sample: 16 of those also opted for a solution sample. Several participants took the opportunity to share their samples by circulating them amongst other hospital departments in their region.

A list of the participants is given in Appendix 1.

3. INTERCOMPARISON SAMPLES

The solution samples were supplied by NA from a stock solution of ^{131}I, which was accurately sub-divided into a series of 4 ml aliquots in P6 vials. Two aliquots from the same solution, in P6 vials, were also despatched to NPL for activity assay. At 12:00 GMT on 17 March 1999, the activity concentration in each vial was approximately 4.1 MBq g^{-1}. The chemistry of the solution samples was not specified.

The ^{131}I capsule samples were supplied by AEA, along with the standard AEA plastic applicator. Three of these capsules were despatched to NPL for activity assay. The capsule samples comprised ^{131}I as sodium chloride adsorbed in salt. The typical activity content of a capsule was in the region of 75 MBq at the reference time.

4. INTERNATIONAL EQUIVALENCE OF NPL PRIMARY STANDARDS

The accuracy of NPL's primary standardisation of ^{131}I has been confirmed by the submission of ampoules of this particular radionuclide to the International Reference System (SIR) of the International Bureau of Weights and Measures (BIPM) in Paris. This system allows comparisons to be made between the primary standards of national standards laboratories across the world. NPL values have been compared against the values submitted by the national metrology institutes of 10 other countries and the data are presented in Table 1 and Figure 1. It will be seen that all of the NMI values agree within ± 0.3% and that the median uncertainty quoted by any individual NMIs is again ± 0.3%. The conclusions that are drawn from these results are that the NPL primary standard is in good agreement with other national standards and that the uncertainty on the NPL standard is reasonable.

5. NPL MEASUREMENTS OF INTERCOMPARISON SAMPLES

The solution and capsule samples sent to NPL were assayed using a sealed, high-pressure, re-entrant ionisation chamber - the NPL secondary standard radionuclide calibrator. This system is also known as the 671/271 and the ISOCAL IV. This chamber had been previously calibrated for ^{131}I solutions in such a way that direct traceability was maintained to the absolute standards of ^{131}I using the primary standardisation facilities and techniques available at NPL.

The presence of any radioactive impurities in the solution and capsule samples was checked by gamma spectrometry. No gamma emitting contaminants were identified.

In addition to the existing calibration factor for ^{131}I solution in a P6 vial, a calibration factor had also been previously derived for the NPL secondary standard radionuclide calibrator for an ^{131}I capsule in a P6 vial. This had been accomplished by first assaying the capsule in a P6 vial in the calibrator and then re-assaying it after it had been dissolved [7].

The transfer of the primary standard values mentioned previously to the NPL secondary standard ionization chambers introduces additional uncertainties but these

are relatively small. The standard uncertainty on the NPL measurements of activities was ± 0.355% for the solution samples and ± 0.55% for the capsule samples, at the 68% confidence level.

For each of the solutions and capsules that were despatched to participants, certificates of measurement were provided to NPL by AEA and NA respectively. The samples provided to NPL were assayed as described previously and these results were compared to those on the measurement certificates. This allowed comparisons to be made between the activity values declared by the three institutes and, if necessary, for the NA and AEA values to be normalised to the primary standards. From the NA and AEA certificates of calibration, the corresponding uncertainty on the solution activities was ± 0.70% and ± 1.5% on the capsule activities, at the 68% confidence level.

For the activity concentrations of the two solution samples supplied to NPL, the ratios of the NA results to those of NPL were 1.002 and 1.003. These differences are statistically insignificant given that the combined NPL and NA uncertainty on the activity measurements is ± 0.79%. For the three capsule samples sent to NPL, the corresponding ratios were 1.011, 0.999 and 0.996. Given that the combined NPL and AEA uncertainty on these activity measurements is ± 1.60%, then the conclusion again is that there is no significant difference between the NPL and AEA results.

For the purpose of this intercomparison exercise, each of the three capsules was transferred into the plastic applicator provided which was, in turn, placed in the standard container jig supplied with the NPL chamber for P6 vial assays. Measurements of the chamber output showed an increase in response of 0.6% compared with that obtained with the capsule in a P6 vial.

The solution from each vial was also re-dispensed accurately into 2 ml and 5 ml BS ampoules and then measured using the NPL secondary standard radionuclide calibrator. The activity concentration of the transferred solution confirmed the initial activity in each P6 vial as well as establishing that there had been no adsorption of activity to the walls of the P6 vials.

Details of the containers, their nominal volumes and wall thicknesses, are given in Table 2.

6. CAPINTEC ARC 120 MEASUREMENTS AT NPL

Given that the majority of radionuclide calibrators in use in the UK are manufactured by Capintec, it made sense to conduct some exploratory measurements on the ARC 120 model held at NPL. Solution samples in P6 vials were assayed in the ARC 120 using the recommended Calibration Setting (pre-set and 151 dial setting) and the indicated activities were compared against those obtained from the traceable NPL ISOCAL IV system. For the capsules, a similar exercise was conducted with the samples being measured both in P6 vials and in the plastic applicator: the same Calibration Setting was used as for the solutions.

The measurements of both solutions and capsules in P6 vials showed a small variation of up to 1% from the known activities. When the capsules were assayed in the plastic applicator, a larger variation was observed - of the order of 3.7% from the known activities. There was only a minimal variation in response due to the two different Calibration Setting options. The results of these comparisons are shown in Figure 2.

7. MEASUREMENT AND REPORTING PROTOCOL

Participants were invited to assay their capsule (no particular container type was suggested for capsule assay) and their solution in P6 vial samples, where available, in each of their radionuclide calibrators and to report their results directly to NPL.

When the participants received their samples, the only information they received were the nominal activities: the significance of this is discussed later. Once participants had reported their measurements to NPL, the NA and AEA certificates of calibration for their individual solution and capsule samples were sent to them. Participants were also informed of the traceable activity content of their solution sample based on the NPL standardisation.

Participants were encouraged to provide additional information for this exercise by making measurements using both pre-set facilities and manual settings, where available. There were also asked to transfer the solution samples to other containers (such as syringes) and the capsules to P6 vials or other containers suggested in their calibrator manual and to report their results on these. Estimates of measurement uncertainties were also sought. A standard reporting form was provided.

8. CONFIDENTIALITY

All results were reported directly to NPL. Each result was given a code by NPL, consisting of a capital letter indicating the sample type (“C” for capsule and “S” for solution), a number indicating the individual participating hospital and a small letter indicating the particular calibrator in that hospital. This code system both preserves the anonymity of individual participants and allows the comparison of results of solution and capsule measurements in the same calibrator.

All results included in this report are tabulated against those codes and the correlation between code and calibrator (and hence participant) remains confidential to NPL.

9. ANALYSIS OF RESULTS

A total of 243 capsule results, representing measurements on some 148 calibrators in over 50 hospitals, were received from 42 of the possible 45 participants; 14 of these participants also reported 145 solution results, from measurements made on 64 calibrators in 19 hospitals.

All solution results have been decayed to the same reference time of 12:00 GMT on 17 March 1999. The results from the initial batch of capsules, sent to the majority of the participants, have been decayed to the reference time of 12:00 GMT on 18 March 1999. The results from the additional batch have been decayed to the reference time of 12:00 GMT on 24 June 1999. The half-life used was 8.04 days [8].

For each original solution sample, the activity content was determined from the activity concentration measurements made by NPL, together with the masses of solution dispensed by NA. For those samples which were subsequently transferred by the participants to different container types (e.g. syringes), the activities were determined on the basis of the participants declared dispensings and the NPL measured activity concentrations. The reported solution activities were then compared to these NPL calculations. The results have been tabulated as ratios of reported activity to the NPL-determined value and are presented in Table 3.

The reported capsule activities were compared to the AEA activities quoted on the individual certificates of calibration. The good agreement between NPL and AEA activity measurements of the three capsule samples sent to NPL as part of this exercise, confirmed the accuracy and traceability of the AEA measurements. The capsule results, therefore, have been tabulated as ratios of reported activities to the AEA certificated value and are shown in Table 4.

One asterisk(*) in the setting column in Tables 3 and 4 indicates that the participant applied a self-determined correction factor or a self-derived dial factor; two astericks (**) show that the correction applied was derived from a previous direct intercomparison between that hospital and NPL.

None of the participants reported any evidence of contaminant checks.

A summarised breakdown of the results by container, setting type and calibrator type used are given in Table 5, for solution samples, and in Table 6, for capsules. In the breakdown by calibrator, for the reported solution results, only the original vial results were considered. All reported results were used in the summary by calibrator for capsules. The results are also selectively displayed in histogram form in Figures 3 to11.
The reported uncertainties are presented in Table 7 for the solution results and in Table 8 for the capsule results.

10. DISCUSSION

The aim of this exercise was to assess the accuracy of ^{131}I capsule and solution activity measurements, using typical radionuclide calibrators available in UK hospitals, and also to provide the participants with a traceable standard to check and review their calibration factors for this particular radionuclide. It also provided a good opportunity to investigate the apparent differences reported by some users between the activities quoted by AEA for the capsules they supply and the corresponding activity measurements made in the hospitals.

From all the solution reported results, some of the residue measurements need to be regarded with some reservation. It is clear from the results that the estimation of the mass remaining after transfer is not always accurate and this could lead to a distortion of the related results. The discussion, as it relates to containers, is confined to those solution results for the original P6 vials and for syringes.

10.1 CAPINTEC ARC 120 MEASUREMENTS

It is useful to discuss these results first in that they provide some insight which may provide some explanations for the observed results (and discrepancies). To put these results into context, there are three significant points that should be noted in relation to the User Manual [9] for this calibrator, namely:

(a) the User Manual states that "the Calibration Setting Numbers are given for approximately 5 grams of radioactive solution in a standard source ampoule made of about 0.6 mm thick borosilicate glass. The standard radioactive source in the ampoule is, however, a good approximation for a radiopharmaceutical in a plastic syringe or a glass syringe (wall thickness of about 1.2 mm) for most radioisotopes";

(b) no correction factor is suggested for syringes;

(c) there is no Calibration Setting available for ^{131}I in the capsule form.

In respect of syringes, the reported measurements suggest that a correction factor of the order of 6% may be indicated. For the other formats, it is clear that the Calibration Setting is designed for a container which is never used in practice in the medical community. The discrepancies seen for these formats may well be attributable, in part at least, to this fact and it begs the question of whether users should take steps to determine the appropriate Calibration Settings and effectively recalibrate in their standard measurement format.

10.2 CAPSULE RESULTS

Most hospitals in the UK procure their ^{131}I capsules from AEA Technology plc. Unless a standardised source is requested, each capsule is delivered with a packing note and a provisional certificate, both stating the product code, the "nominal" activity of the sample and the reference time. In the absence of any recommendation (except for the NPL ISOCAL IV [7]) for an appropriate ^{131}I capsule calibration factor (for a specified container type) for individual calibrators, hospitals have been assaying capsules using calibration figures which are intended for solutions in a different container. These results have then been compared against the AEA "nominal" activity values. Some hospitals have sent copies of their records, showing differences of up to 10% or more, suggesting potential under- or over-dose situations.

It is important to note that the "nominal" value is indeed just that. It is there for two purposes. The first is to indicate to the production department producing these capsules that the true activity should be within ± 10% of the "nominal"

value. Second, it is required to allow the correct radiological protection and transport measures to be adopted. It cannot be stressed too strongly that the "nominal" value is not a traceable activity value and must not be used for calibration purposes or to check the performance of a calibrator.

As already mentioned in this report, the measurements made at NPL have confirmed the accuracy of both the AEA and NA activity measurement capabilities for ^{131}I capsules and solutions.

This intercomparison exercise aimed to get a true reflection of the accuracy of capsule activity measurements and to identify possible sources of errors. The overall capsule data, see Figure 3 and Table 6, shows that all results agreed within ± 10% of the AEA value. Figure 4 also reveals that for this exercise, most of the participants chose to measure their capsules in the plastic applicator provided. Although the results all fall within the ± 10% bounds, the results also indicate that there is a tendency to overestimate the activity, as Figure 3 shows, with about 84% of the results being higher than the true value and only 16% lower.

There are several possible reasons for this tendency to over-estimate, such as:

errors in the manufacturers calibration figures;

use of containers for which the recommended calibration figures do not apply;

changes in wall thicknesses of routine containers.

variations between the users calibrator and that with which the calibration figures were derived.

It is important to know what the traceability route is for the manufacturers calibration figures. For example, have they been produced in collaboration with the national metrology institute and under an independently accredited quality system? Have the international standards for these radionuclides changed since these figures were produced? It is partly for these reasons that the UK protocol for maintaining the quality of radionuclide calibrator performance [1] recommends that calibration figures should be checked at installation and then on a regular basis.

The effects of using non-standard containers have been illustrated in the measurements presented earlier in this report. In this particular instance, it is likely that this is the principal cause of the skewed distribution of results. Again, unless the manufacturers provide specific guidance on this (such as the published factors for capsules in P6 vials for the ISOCAL IV [7]), users will need to conduct their own re-calibration exercise.

The third possible reason suggested above is something which has the largest effect on radionuclides which emit predominantly low-energy photons.

A previous intercomparison with ^{123}I illustrated this [5]. In the case of P6 vials, for example, there are many variants of this and it is often not possible to distinguish one from another.

The fourth reason suggested here is illustrated in several of the tables and figures. Some hospitals have more than one calibrator of the same type yet there is no guarantee that results from each will be the same and, indeed, whether they show the same differences between different container types. For example, one of the participants measured his capsule in a plastic applicator and in a P6 vial, using two different Capintec CRC 15 calibrators (see results C3[a] and C3[b]). The variation in response with container type is about 1.3% difference for system [a] and about 2.1% for system [b].

In consideration of these possible errors, some participants have applied either self-determined capsule correction factors or correction factors derived from an NPL calibration. Figure 3 shows the distribution of all the capsule results received (white columns), with overlays indicating those results which are based on self-correction factors (grey) and on the results of an NPL calibration (black). The self-correction results, show an improvement in the overall spread but with a tendency to now underestimate. The “NPL calibration” results show even better improvements although the numbers of results are admittedly small.

Although some hospitals have noticed differences between the “dial” and “preset” results for particular calibrators, this exercise had revealed no systematic differences between the two settings. The same tendency to overestimate the activity for both setting types is illustrated in Figure 5, with about 92% of the “preset” results and about 80% of the “dial” results being higher than the AEA value.

10.3 SOLUTIONS IN P6 VIAL RESULTS

The overall solution in P6 vial results, as shown in Figure 8 and Table 5, are relatively good, with about 90% of them centrally distributed within ± 4% of the NPL value.

Similar distributions of results can be noticed for both “preset “ and “dial” settings, as displayed in Figure 9. No significant differences in response between the two setting types were noticed for individual calibrators.

When the capsule and solution results are differentiated between individual calibrators, some interesting contrasts are revealed.

10.4. VARIATIONS BETWEEN CALIBRATOR TYPES

10.4.1 CAPINTEC - Capsules

Capintec chambers provide results (see Figure 6) which show the same trend as all the reported values, with the an average of about 78% results up to 6% higher than the true value.

In the light of the statements in the User Manual and the experimental evidence presented here, the reason for the general tendency to overestimate the activity seems to be the recommended Calibration Setting Number, which is for ^{131}I in liquid form, in a container not used in practice for routine assay. Another contributory factor could be the variation in wall thickness of the internal well between these individual calibrators Although details of the production tolerances are not known, evidence from previous intercomparisons [2-6] suggest that this factor should not be overlooked.

10.4.2 CAPINTEC - Solutions

For solution samples, Capintec systems produce results that are very acceptable. Figure 10 shows an overall spread of not greater than ± 6%, with around 90% of the results lying within 4% of the true value.

10.4.3 ISOCAL IV - Capsules

The ISOCAL IV is the NPL secondary standard radionuclide calibrator. This system was calibrated by NPL for capsules in P6 vials and the design tolerances are sufficiently strict to ensure that the variation in response between chambers is minimised. This is evidenced by the spread of results of up to 4% from the AEA value, as displayed in Figure 7. Based on recent measurements at NPL, an increase in response of about 0.6% is expected for capsule measurements in the plastic applicator.

10.4.4 ISOCAL IV - Solutions

All the solution results for ISOCAL IV systems are within ± 4% of the NPL value, with the exception of a single extreme outliner, which deserves some attention. This suggests that the performance of these calibrators in the assay of ^{131}I solution is, generally, good.

10.4.5 ISOCAL III - Capsules

Only 4 capsule results were reported for these systems and they are uniformly distributed within 4% of the AEA value (see Figure 7).

10.4.6 ISOCAL II/PITMAN 238 - Capsules

Since these chambers are unsealed and therefore subject to pressure and temperature variations and because of suspected errors in the initial calibration procedures, these systems had repeatedly shown problems in previous exercises.
As expected, the results for these systems have a wider spread of about 6% from the true value (see Figure 7). Considering the added errors in the assay of

^{131}I capsules, users of these systems are well advised to check their calibrations.

10.4.7 ISOCAL II/PITMAN 238 - Solutions

The spread of results for the ISOCAL II systems seems to also be within ± 4% of the true value, but the small number of data available makes it difficult to asses the accuracy of the existing calibration factors for these calibrators.

10.4.8 Other systems - Capsules

The performance of the other systems (see Table 6) is similar to that of the Capintec systems, with most of the capsule results about 6% higher than the true value. A better distribution of results, of about 4% from the AEA value is noticeable for Atomlab systems. However, with only very few reported results, it is difficult to draw any conclusions about the performance of these calibrators.

10.4.9 Other systems - Solutions

The other systems used seem to perform reasonably well, but, again, because of the insufficient number of solution results reported, it is difficult to have a clear understanding of their individual performances. The majority of these results are within 4% of the true value (see Table 5).

10.5 SYRINGE DATA - solution transfer

Only a total number of 7 syringe results were reported, with 4 of them for Capintec systems and 3 for Isocal II/Pitman 238. These are pictorially displayed in Figure 8. No distinction was made between those results which have been obtained using the manufacturers recommended calibration factors and those using factors resulting from user-recalibrations.

The spread of results is not significantly different from that for solutions in P6 vials.

10.6 CAPSULE/SOLUTION RATIOS FOR INDIVIDUAL CALIBRATORS

Since some of the participants reported data on both capsule and solution samples, it is possible to compare the performance of individual calibrators for ^{131}I between the liquid (in P6 vials) and capsule (in plastic applicator) forms. No distinction has been made between those results (for either capsules or solution) which have been obtained using the manufacturers recommended calibration factors and those using factors resulting from user-recalibrations. This analysis is shown in Figure 12 with the vertical lines marking the results from a particular hospital.

Figure 12 shows the narrow spread of solution results (of about ± 4% from the true value), with the mean value only 0.6% higher than the true value. In contrast, most of the capsule results centre about 4% high, with the overall mean value about 3% higher than the true value.

To get a better picture, the results of some of the participating hospitals are individually displayed in Figure 13 (participant no. 18) and Figure 14 (participant no. 25). The values from participant no. 18 are from measurements made on 6 different CAPINTEC type calibrators, with the first capsule and solution result for each calibrator made on "preset" mode and the second one on "dial" setting. Similarly, the results from participant no. 25 are from measurements on 5 different CAPINTEC type calibrators, one ISOCAL IV and one ISOCAL II system.

The capsule results are invariably higher than the solution results as would be expected from the discussion above. Interestingly though, the differences between the two formats are not constant, varying between 1% and almost 12%. The smallest difference of 1% corresponds to result 25(d) which is an ISOCAL IV.

For participant 18, the differences range from about 2% to 12% whilst the spread of results between either capsules or solutions is of the order of 7%. It would be hoped that a good quality assurance regime would have identified these differences and instituted some corrective actions to bring the individual calibrators into better agreement with one another. To a lesser extent, the same comments can apply to participant 25.

11. UNCERTAINTIES

The response to the request for estimates of uncertainty produced far less contributions than the previous exercises and the same comments apply as before: the methods of estimation and combination of individual contributions shows no consistency. For some of the reported results, the estimated uncertainties were simply the uncertainties quoted in the User Manual, or the limit on the overall accuracy required for radionuclide calibrators used in hospitals. The question of uncertainties will be addressed at the radionuclide calibrator workshop which follows this intercomparison.

12. CONCLUSION

This exercise has proved opportune in enabling current concerns about the accuracy of calibrations for ^{131}I capsules to be examined. In particular, it has highlighted the misunderstanding about the purpose and validity of the "nominal" activity values provided by the supplier. The authors propose the following conclusions.

a) the accuracy and traceability of Nycomed-Amersham and AEA Technology plc measurements of ^{131}I are confirmed;

b) the recommended calibration factors and format of measurements for capsules for many calibrator systems (except the ISOCAL IV) generally overestimate the activity and recalibrations are required;

c) recalibrations must be conducted using traceable standards.

d) the nominal activities quoted by the supplier must not be used to check the performance of a calibrator;

e) suppliers should seek ways of ensuring that the status of "nominal" values are more easily understood;

f) syringe factors should be checked in the same way as solution and capsule factors;

g) users should ensure that quality assurance procedures are established and maintained on a regular basis;

h) the reporting and understanding of uncertainties is poor. Considering the significance of this, NPL will provide advice on this subject;

i) the programme of intercomparison exercises should be continued..

13. ACKNOWLEDGEMENTS

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(9) *Radioisotope Calibrator Owner's Manual for Models CRC-7, CRC-12 and CRC-120.*

Capintec, Inc. Pittsburgh, PA 15238, U.S.A. (1983).

Table 1

Comparison of primary standards from National Metrology Institutes (NMIs) via BIPM SIR system

Country	NMI Acronym	NMI value/Mean value	Uncertainty (%)
Switzerland	IRA	0.998	± 0.005
France	LMRI	0.999	± 0.002
UK	NPL	0.999	± 0.003
Japan	ETL	0.999	± 0.003
Slovakia	UVVVR	0.999	± 0.003
Hungary	OMH	0.999	± 0.003
India	BARC	1.000	± 0.004
Germany	PTB	1.001	± 0.002
Australia	ANSTO	1.001	± 0.009
South Africa	NAC	1.002	± 0.005
U.S.A.	NIST	1.004	± 0.004

Table 2

Details of containers used in experimental work at NPL

Container	Nominal volume (ml)	Wall thickness (mm)
BS glass ampoule	2	0.45
BS glass ampoule	5	0.55
NBS glass ampoule	5	0.6
P6 glass vial	10	1.2
Capsule plastic applicator	not known	not known

Table 3

^{131}I solution reported results.

Solution Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	NPL Activity (MBq)	Reported/NPL
S1[a]	VINTEN	ISOCAL IV	dial 11060	16.36	16.395	0.998
S1[b]	SIEL	BIC-1	^{131}I preset	16.28	16.395	0.993
	”	”	dial 199	16.28	16.395	0.993
S1[c]	CAPINTEC	CRC-15R	^{131}I preset	16.46	16.395	1.004
	”	”	dial 151	16.47	16.395	1.004
S1[d]	VEENSTRA	VDC 202	^{131}I preset	16.58	16.395	1.011
	”	”	dial 412	17.17	16.395	1.047
S1[e]	CAPINTEC	ARC-120	^{131}I preset	17.18	16.395	1.048
	”	”	dial 151	17.21	16.395	1.049
S5[a]	CAPINTEC	CRC-35R	^{131}I preset	16.66	16.409	1.015
	”	2 ml syringe	^{131}I preset	8.74	8.238	1.061
	”	residue	^{131}I preset	8.34	8.171	1.021
S5[b]	PITMAN	238	dial 0567	17.28	16.409	1.053
	”	2 ml syringe	dial 0567	8.71	8.238	1.057
	”	residue	dial 0617	8.61	8.171	1.054
S5[c]	VINTEN	ISOCAL II	dial 1293	16.36	16.409	0.997
	”	2 ml syringe	dial 1203	8.15	8.238	0.990
	”	residue	dial 1297	8.16	8.171	0.999
S5[d]	CAPINTEC	CRC-10Beta	^{131}I preset	15.62	16.409	0.952
	”	2 ml syringe	^{131}I preset	7.70	8.238	0.935
	”	residue	^{131}I preset	7.71	8.171	0.944
S7[a]	VINTEN	ISOCAL III	dial 1190	16.33	16.363	0.998
S7[b]	VINTEN	ISOCAL IV	dial 1200	15.92	16.363	0.973
S7[c]	CAPINTEC	CRC-15R	^{131}I preset	16.45	16.363	1.006
S7[d]	VINTEN	ISOCAL II	^{131}I preset	15.80	16.363	0.965
S7[e]	CAPINTEC	CRC-35R	^{131}I preset	16.64	16.363	1.017
S7[f]	CAPINTEC	CRC-35R	^{131}I preset	16.41	16.363	1.003
S7[g]	CAPINTEC	CRC-15R	^{131}I preset	16.64	16.363	1.017
S7[h]	CAPINTEC	CRC-15R	^{131}I preset	16.40	16.363	1.002
S7[i]	CAPINTEC	CRC-15R	^{131}I preset	16.41	16.363	1.003
	”	”	^{131}I preset *	16.41	16.363	1.003
	”	”	dial 151	16.34	16.363	0.999
S7[j]	CAPINTEC	CRC-10RB	^{131}I preset	16.87	16.363	1.031
	”	”	^{131}I preset *	16.19	16.363	0.990
	”	”	dial 151	16.68	16.363	1.020
S7[k]	AMERSHAM	ARC-120	^{131}I preset	16.54	16.363	1.011
	”	”	^{131}I preset *	16.38	16.363	1.001
	”	”	dial 151	16.55	16.363	1.012
S18[a]	CAPINTEC	CRC-15 Beta	^{131}I preset	16.13	16.306	0.989

Solution Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	NPL Activity (MBq)	Reported/NPL
	(Pb shield)					
	”	”	dial 151	16.13	16.306	0.989
S18[b]	CAPINTEC	CRC-120R	^{131}I preset	16.38	16.306	1.004
	”	”	dial 151	16.38	16.306	1.005
S18[c]	CAPINTEC	CRC-15R	^{131}I preset	16.58	16.306	1.017
	”	”	dial 18.2	16.58	16.306	1.017
S18[d]	CAPINTEC	CRC-15R	^{131}I preset	15.68	16.306	0.962
	”	”	dial 151	15.59	16.306	0.956
S18[e]	CAPINTEC	CRC-15R	^{131}I preset	16.15	16.306	0.990
	”	”	dial 151	16.24	16.306	0.996
S18[f]	CAPINTEC (Pb shield)	CRC-15R	^{131}I preset	16.25	16.306	0.996
	”	”	dial 151	16.25	16.306	0.996
S18[g]	VINTEN	ISOCAL II	dial 1278	16.15	16.306	0.990
S18[h]	CAPINTEC (Pb shield)	CRC-15R	^{131}I preset	16.29	16.306	0.999
	”	”	dial 151	16.20	16.306	0.993
S22[a]	CAPINTEC	CRC-15R	^{131}I preset	16.65	16.397	1.016
S22[b]	CAPINTEC	CRC-15R	^{131}I preset	16.30	16.397	0.994
S22[c]	VINTEN	ISOCAL IV	^{131}I preset	17.99	16.397	1.097
S22[d]	CAPINTEC	CRC-15R	^{131}I preset	16.62	16.397	1.014
S22[e]	CAPINTEC	CRC-15R	^{131}I preset	16.53	16.397	1.008
S22[f]	CAPINTEC	CRC-15R	^{131}I preset	16.27	16.397	0.992
S22[g]	CAPINTEC	CRC-15R	^{131}I preset	16.31	16.397	0.995
S22[h]	CAPINTEC	CRC-15R	^{131}I preset	16.32	16.397	0.995
S24[a]	NE TECHNOLOGY	ISOCAL IV	^{131}I preset	16.55	16.416	1.008
	(Pb shield)	”	^{131}I preset	16.80	16.416	1.023
	”	”	dial 1200	16.61	16.416	1.012
	(Pb shield)	”	dial 1200	16.85	16.416	1.026
	”	25 ml vial	^{131}I preset	16.72	16.216	1.031
S24[b]	VEENSTRA	VDC 304	dial 447	16.38	16.416	0.998
S25[a]	CAPINTEC	CRC-15R	^{131}I preset	16.59	16.175	1.025
S25[b]	AMERSHAM	ARC-120R	^{131}I preset	16.10	16.175	0.995
	”	”	dial 151	16.08	16.175	0.994
S25[c]	CAPINTEC	CRC-15R	^{131}I preset	16.47	16.175	1.018
S25[d]	SOUTHERN SCIENTIFIC	NPL-CRC	^{131}I preset	16.21	16.175	1.002
S25[e]	VINTEN	ISOCAL II	dial 1308	15.98	16.175	0.988
S25[f]	CAPINTEC	CRC-10BC	^{131}I preset	16.32	16.175	1.009
	”	”	dial 151	16.44	16.175	1.017
S25[g]	CAPINTEC	CRC-10B	^{131}I preset	16.18	16.175	1.000
	”	”	dial 151	16.21	16.175	1.002
S26[a]	CAPINTEC	CRC-10R	^{131}I preset	16.28	16.165	1.007
S26[b]	ATOMLAB	100 PLUS	^{131}I preset	15.87	16.165	0.982
S27[a]	CAPINTEC	CRC-120	^{131}I preset	17.13	16.371	1.047
	”	”	dial 151	16.77	16.371	1.024
S27[b]	CAPINTEC	CRC-15R	dial 151	16.76	16.371	1.024
S27[c]	CAPINTEC	CRC-120	^{131}I preset	16.86	16.371	1.030
	”	”	dial 151	17.04	16.371	1.041

Solution Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	NPL Activity (MBq)	Reported/NPL
S27[d]	CAPINTEC	CRC-15R	dial 151	16.74	16.371	1.023
S28[a]	CAPINTEC	CRC-15R	dial 151	16.80	16.278	1.032
	”	”	^{131}I preset	16.77	16.278	1.030
	”	”	dial 151	16.72	16.278	1.027
	”	”	^{131}I preset	16.72	16.278	1.027
	”	”	dial 151	16.55	16.278	1.017
	”	”	^{131}I preset	15.86	16.278	0.974
	”	”	dial 151	16.52	16.278	1.015
	”	”	^{131}I preset	16.60	16.278	1.020
S28[b]	AMERSHAM	ARC-120	dial 151	16.54	16.278	1.016
	”	”	^{131}I preset	16.43	16.278	1.010
	”	”	dial 151	16.52	16.278	1.015
	”	”	^{131}I preset	16.30	16.278	1.001
	”	”	dial 151	16.35	16.278	1.004
	”	”	^{131}I preset	16.35	16.278	1.004
	”	”	dial 151	16.48	16.278	1.012
	”	”	^{131}I preset	16.41	16.278	1.008
S28[c]	AMERSHAM	ARC-120	dial 151	16.56	16.278	1.018
	”	”	^{131}I preset	15.88	16.278	0.976
	”	”	dial 151	16.57	16.278	1.018
	”	”	^{131}I preset	15.90	16.278	0.977
	”	”	dial 151	16.55	16.278	1.017
	”	”	^{131}I preset	15.86	16.278	0.974
	”	”	dial 151	16.54	16.278	1.016
	”	”	^{131}I preset	15.84	16.278	0.973
	”	”	dial 151	16.53	16.278	1.016
	”	”	^{131}I preset	15.86	16.278	0.974
S29	ATOMLAB	100	^{131}I preset	15.87	16.515	0.961
	”	”	dial 22.2	15.41	16.515	0.933
S30	VINTEN	ISOCAL IV	dial 11060	16.24	16.246	1.000
S33[a]	CAPINTEC	CRC-15R	^{131}I preset	15.99	16.180	0.988
	”	”	dial 151	15.99	16.180	0.988
S33[b]	CAPINTEC	CRC-15R	^{131}I preset	16.21	16.180	1.002
	”	”	dial 151	16.21	16.180	1.002
S33[c]	AMERSHAM	ARC-120	^{131}I preset	16.38	16.180	1.012
	”	”	dial 151	16.36	16.180	1.011
S33[d]	BIODEX	ATOMLAB 100	^{131}I preset	16.26	16.180	1.005
	”	”	dial 22.2	16.26	16.180	1.005
S34[a]	AMERSHAM	ARC-120	^{131}I preset	16.47	16.330	1.009
	”	”	dial 151	16.48	16.330	1.009
		universal container	^{131}I preset	16.13	15.000	1.075
		universal container	dial 151	16.15	15.000	1.077
S34[b]	CAPINTEC	CRC-15R	^{131}I preset	16.64	16.330	1.019
	”	”	dial 151	16.65	16.330	1.020
S34[c]	AMERSHAM	ARC-120	^{131}I preset	16.41	16.330	1.005
	”	”	dial 151	16.48	16.330	1.009
S34[d]	CAPINTEC	CRC-15R	^{131}I preset	16.77	16.330	1.027

Solution Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	NPL Activity (MBq)	Reported/NPL
	”	”	dial 151	16.83	16.330	1.031
	”	universal container	^{131}I preset	16.38	15.000	1.092
	”	universal container	dial 151	16.45	15.000	1.096
S35[a]	CAPINTEC	CRC-15 β	dial 151	16.36	16.271	1.005
	”	”	dial 151	16.36	16.271	1.005
	”	syringe	dial 151	8.53	8.513	1.001
	”	residue	dial 151	7.65	7.758	0.987
S35[b]	CAPINTEC	ARC-120R	dial 151	15.01	16.271	0.922
	”	”	dial 151	15.33	16.271	0.942
	”	syringe	dial 151	8.81	8.513	1.035
S35[c]	VINTEN	ISOCAL II	dial 1308	16.63	16.271	1.022
	”	”	dial 1308	16.53	16.271	1.016
	”	syringe	dial 1308	9.09	8.513	1.068
	”	residue	dial 1308	7.51	7.758	0.968

Table 4

^{131}I capsule reported results

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
C1[a]	VINTEN	ISOCAL IV	dial 11070	77.90	77.6	1.004
	”	”	dial 11060	78.41	77.6	1.010
C1[b]	SIEL	BIC-1	^{131}I preset	78.44	77.6	1.011
	”	”	dial 199	78.44	77.6	1.011
C1[c]	CAPINTEC	CRC-15R	^{131}I preset	80.17	77.6	1.033
	”	”	dial 151	80.38	77.6	1.036
C1[d]	VEENSTRA	VDC 202	^{131}I preset	78.36	77.6	1.010
	”	”	dial 412	80.95	77.6	1.043
C1[e]	CAPINTEC	ARC-120	dial 170	77.39	77.6	0.997
	”	”	^{131}I preset	83.13	77.6	1.071
C2	VINTEN	ISOCAL II	dial 1301 *	78.02	75.7	1.031
C3[a]	CAPINTEC	CRC-15R	^{131}I preset	77.07	75.1	1.026
	”	”	dial 151	77.07	75.1	1.026
	”	”	^{131}I preset	76.05	75.1	1.013
	”	”	dial 151	76.05	75.1	1.013
C3[b]	CAPINTEC	CRC-15R	^{131}I preset	78.71	75.1	1.048
	”	”	dial 151	78.71	75.1	1.048
	”	”	^{131}I preset	77.06	75.1	1.026
	”	”	dial-151	77.07	75.1	1.026
C4[a]	CAPINTEC	CRC-15R	^{131}I preset	79.66	75.2	1.059
	”	”	dial 151	79.66	75.2	1.059
	”	”	dial 151 **	75.69	75.2	1.007
C4[b]	CAPINTEC	CRC-10B	^{131}I preset	80.30	75.2	1.068
	”	”	dial 151	82.03	75.2	1.091
	”	”	dial 151 **	77.05	75.2	1.025
C5[a]	CAPINTEC	CRC-35R	^{131}I preset	81.45	78.4	1.039
C5[b]	PITMAN	238	dial 536	75.73	78.4	0.966
C5[c]	VINTEN	ISOCAL II	dial 1301	80.30	78.4	1.024
C6	SIEL	BIC-1 (Pb shield)	^{131}I preset	77.98	75.6	1.032
	”	”	dial 199	77.55	75.6	1.026
C7[a]	VINTEN	ISOCAL III	dial 1190	76.82	75.1	1.023
C7[c]	CAPINTEC	CRC-15R	^{131}I preset	77.73	75.1	1.035
C7[d]	VINTEN	ISOCAL II	dial 1308	76.23	75.1	1.015
C7[e]	CAPINTEC	CRC-35R	^{131}I preset	78.79	75.1	1.049
C7[f]	CAPINTEC	CRC-35R	^{131}I preset	78.01	75.1	1.039
C7[g]	CAPINTEC	CRC-15R	^{131}I preset	78.63	75.1	1.047
C7[h]	CAPINTEC	CRC-15R	^{131}I preset	78.62	75.1	1.047
C7[i]	CAPINTEC	CRC-15R	^{131}I preset	77.94	75.1	1.038
C7[j]	CAPINTEC	CRC-10RB	^{131}I preset	80.27	75.1	1.069

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
	”	”	dial 151	79.19	75.1	1.054
C7[k]	AMERSHAM	ARC-120	^{131}I preset	78.75	75.1	1.049
	”	”	dial 151	78.75	75.1	1.049
C8[a]	CAPINTEC	CRC-15R	^{131}I preset	77.40	75.2	1.029
	”	”	dial 160	74.48	75.2	0.990
C8[b]	VINTEN	ISOCAL II	^{131}I preset	75.56	75.2	1.005
C8[c]	VINTEN	OPEN CHAMBER	^{131}I preset	73.47	75.2	0.977
C8[d]	ATOMLAB	200	^{131}I preset	75.01	75.2	0.997
C8[e]	CAPINTEC	CRC-15R	^{131}I preset	79.84	75.2	1.062
	”	”	dial 160	77.01	75.2	1.024
	”	”	dial 170	73.97	75.2	0.984
	”	”	dial 182	70.60	75.2	0.939
C8[f]	SIEL	BK-1	^{131}I preset	76.19	75.2	1.013
C8[g]	AMERSHAM	ARC-120	^{131}I preset	78.89	75.2	1.049
C8[h]	CAPINTEC	CRC-15R	^{131}I preset	77.98	75.2	1.037
C8[I]	CAPINTEC	C-11	^{131}I preset	76.52	75.2	1.018
C8[j]	VINTEN	ISOCAL II	dial 1328	78.30	75.2	1.041
C8[k]	VINTEN	ISOCAL II	dial 1328	76.83	75.2	1.022
C8[l]	VINTEN	ISOCAL II	dial 1328	77.16	75.2	1.026
C8[m]	ATOMIC PRODUCTS	”	^{131}I preset	79.17	75.2	1.053
C9[a]	AMERSHAM	ARC-120	^{131}I preset	76.64	74.4	1.030
	”	”	dial 151	76.86	74.4	1.033
C9[b]	CAPINTEC	CRC-15R	dial 151	76.92	74.4	1.034
C10	CAPINTEC	CRC-15R	dial 151	78.74	74.4	1.058
	”	”	dial 151	78.75	74.4	1.059
	”	”	dial 182 *	69.42	74.4	0.933
C11[a]	NE TECHNOLOY	ISOCAL III	dial 1200 (P6 vial)	80.82	80.7	1.002
	”	”	dial 1209 (5 ml vial)	80.23	80.7	0.994
	”	”	dial 1235 (2 ml vial)	78.53	80.7	0.973
C11[b]	NE TECHNOLOY	ISOCAL III	dial 1200 (P6 vial)	81.43	80.7	1.009
	”	”	dial 1209 (5 ml vial)	80.70	80.7	1.000
	”	”	dial 1235 (2 ml vial)	78.95	80.7	0.978
C12	VINTEN	ISOCAL II (Pb shield)	dial 1308	72.59	74.8	0.970
C13	ATOMLAB	200	^{131}I preset **	75.40	75	1.005
	”	”	dial 22.8 **	75.40	75	1.005
C14	SIEL	BIC-1	^{131}I preset	72.61	73.3	0.991
C15[a]	CAPINTEC	CRC-10BC	163 preset *	76.47	76	1.006
	”	”	dial 163 *	76.38	76	1.005
	”	”	dial 151	81.01	76	1.066
C15[b]	CAPINTEC	CRC-15R	dial 162 *	75.77	76	0.997
	”	”	dial 151	79.30	76	1.043
C15[c]	VINTEN	ISOCAL IV	dial 1225 *	76.85	76	1.011

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
	”	”	dial 1200	78.51	76	1.033
C15[d]	CAPINTEC	CRC-15R	dial 163 *	75.98	76	1.000
	”	”	dial 151	79.85	76	1.051
C15[e]	CAPINTEC	ARC-120	dial 158 *	76.73	76	1.010
	”	”	dial 158 *	76.40	76	1.005
	”	”	dial 151	78.82	76	1.037
C15 [f]	CAPINTEC	CRC-120	dial 164 *	74.89	76	0.985
C15[g]	CAPINTEC	CRC-12	dial 156 *	76.71	76	1.009
C16	CAPINTEC	CRC-15R	dial 151	80.73	75.3	1.072
	CAPINTEC	CRC-15R	dial 151	78.71	75.3	1.045
C17[a]	CAPINTEC	CRC-15R	^{131}I preset	78.01	76.6	1.018
C17[b]	VINTEN	ISOCAL II	dial 1308	78.21	76.6	1.021
C17[c]	VINTEN	ISOCAL II	dial 1472	78.23	76.6	1.021
C17[d]	ATOMLAB	100	^{131}I preset	75.07	76.6	0.980
	”	”	dial 22.2	75.07	76.6	0.980
C18[a]	CAPINTEC	CRC-15Beta	^{131}I preset	77.43	75.6	1.024
	”	”	dial 151	77.32	75.6	1.023
C18[b]	CAPINTEC	CRC-120R	^{131}I preset	78.78	75.6	1.042
	”	”	dial 151	78.68	75.6	1.041
C18[c]	CAPINTEC	CRC-15R	^{131}I preset	78.60	75.6	1.040
	”	”	dial 151	78.72	75.6	1.041
C18[d]	CAPINTEC	CRC-15R	^{131}I preset	80.94	75.6	1.071
	”	”	dial 151	80.83	75.6	1.069
C18[e]	CAPINTEC	CRC-15R	^{131}I preset	77.16	75.6	1.021
	”	”	dial 151	77.27	75.6	1.022
C18[f]	CAPINTEC	CRC-15R	^{131}I preset	77.08	75.6	1.020
	”	”	dial 151	77.30	75.6	1.022
C19[a]	PITMAN	270	dial 10550	77.86	75.3	1.034
C19[b]	CAPINTEC	CRC-120R	^{131}I preset	74.99	75.3	0.996
	”	”	dial 151	75.87	75.3	1.008
C19[c]	CAPINTEC	CRC-15R	^{131}I preset	76.90	75.3	1.021
	”	”	dial 151	76.58	75.3	1.017
C20	CAPINTEC	CRC-10B	^{131}I preset	74.88	71.8	1.043
	”	”	dial 151	74.40	71.8	1.036
C21[a]	CAPINTEC	CRC-15R	dial 151	84.79	81.9	1.035
C21[b]	CAPINTEC	CRC-15R	dial 151	84.53	81.9	1.032
C21[c]	CAPINTEC	CRC-15R	dial 151	84.49	81.9	1.032
C22[a]	CAPINTEC	CRC-15R	dial 164 *	75.30	76.4	0.986
C22[b]	CAPINTEC	CRC-15R	dial 164 *	74.21	76.4	0.971
C22[c]	VINTEN	ISOCAL IV	^{131}I preset	80.96	76.4	1.060
C22[d]	CAPINTEC	CRC-15R	dial 166 *	74.68	76.4	0.977
C22[e]	CAPINTEC	CRC-15R	dial 166 *	73.95	76.4	0.968
C22[f]	CAPINTEC	CRC-15R	dial 162 *	74.63	76.4	0.977
C22[g]	CAPINTEC	CRC-15R	dial 158 *	76.03	76.4	0.995
C22[h]	CAPINTEC	CRC-15R	dial 158 *	76.11	76.4	0.996
C23[a]	CAPINTEC	CRC-15R	^{131}I preset	79.82	75.9	1.052
	”	”	dial 151	79.73	75.9	1.050
C23[b]	CAPINTEC	CRC-15R	^{131}I preset	78.57	75.9	1.035
	”	”	dial 151	78.57	75.9	1.035

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
C23[c]	CAPINTEC	CRC-15R	^{131}I preset	78.75	75.9	1.038
	”	”	dial 151	78.75	75.9	1.038
C24[a]	NE TECHNOLOY	ISOCAL IV	^{131}I preset	78.18	76.8	1.018
	”	” (Pb shield)	^{131}I preset	79.47	76.8	1.035
	”	”	dial 1200	77.97	76.8	1.015
	”	” (Pb shield)	dial 1200	79.18	76.8	1.031
C25[a]	CAPINTEC	CRC-15R	^{131}I preset	81.02	77.3	1.048
C25[b]	AMERSHAM	ARC-120R	^{131}I preset	79.62	77.3	1.030
	”	”	dial 151	79.37	77.3	1.027
C25[c]	CAPINTEC	CRC-15R	^{131}I preset	79.83	77.3	1.033
C25[d]	SOUTHERN SCIENTIFIC	NPL-CRC	^{131}I preset **	78.38	77.3	1.014
C25[e]	VINTEN	ISOCAL II	dial 1308	78.23	77.3	1.012
C25[f]	CAPINTEC	CRC-10BC	^{131}I preset	80.06	77.3	1.036
	”	”	dial 151	79.89	77.3	1.034
C25[g]	CAPINTEC	CRC-10B	^{131}I preset	79.42	77.3	1.027
	”	”	dial 151	79.59	77.3	1.030
C26[a]	CAPINTEC	CRC-10R	^{131}I preset	78.36	76.7	1.022
C26[b]	ATOMLAB	100 PLUS	^{131}I preset	77.56	76.7	1.011
C27[a]	CAPINTEC	CRC-120	^{131}I preset	79.60	73.8	1.079
	”	”	dial 151	78.52	73.8	1.064
C27[b]	CAPINTEC	CRC-15R	dial 151	77.49	73.8	1.050
C27[c]	CAPINTEC	CRC-120	^{131}I preset	77.77	73.8	1.054
	”	”	dial 151	76.79	73.8	1.041
C27[d]	CAPINTEC	CRC-15R	dial 151	77.41	73.8	1.049
C28[a]	CAPINTEC	CRC-15R	dial 151	78.07	73.9	1.056
	”	”	^{131}I preset	78.07	73.9	1.056
	”	”	dial 151	78.11	73.9	1.057
	”	”	^{131}I preset	78.11	73.9	1.057
	”	”	dial 151	77.94	73.9	1.055
	”	”	^{131}I preset	77.95	73.9	1.055
	”	”	dial 151	78.17	73.9	1.058
	”	”	^{131}I preset	78.17	73.9	1.058
C28[b]	AMERSHAM	ARC-120	dial 151	77.88	73.9	1.054
	”	”	^{131}I preset	76.89	73.9	1.040
	”	”	dial 151	77.09	73.9	1.043
	”	”	^{131}I preset	76.57	73.9	1.036
	”	”	dial 151	77.39	73.9	1.047
	”	”	^{131}I preset	77.39	73.9	1.047
	”	”	dial 151	75.98	73.9	1.028
	”	”	^{131}I preset	75.77	73.9	1.025
C28[c]	AMERSHAM	ARC-120	dial 151	77.98	73.9	1.055
	”	”	^{131}I preset	74.02	73.9	1.002
	”	”	dial 151	77.54	73.9	1.049
	”	”	^{131}I preset	73.96	73.9	1.001
	”	”	dial 151	78.10	73.9	1.057
	”	”	^{131}I preset	74.52	73.9	1.008
	”	”	dial 151	78.78	73.9	1.066
	”	”	^{131}I preset	75.41	73.9	1.020

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
	”	”	dial 151	77.79	73.9	1.053
C29	ATOMLAB	100	^{131}I preset	73.90	74.6	0.991
	”	”	dial 22.2	72.05	74.6	0.966
C30	VINTEN	ISOCAL IV	dial 11091	75.21	75.4	0.998
C31	CAPINTEC	CRC-15R	^{131}I preset	77.75	75.1	1.035
C32[a]	CAPINTEC	CRC-12	^{131}I preset	75.38	74.1	1.017
	”	”	dial 151	75.70	74.1	1.022
C32[b]	CAPINTEC	CRC-15R	^{131}I preset	77.31	74.1	1.043
	”	”	dial 151	77.32	74.1	1.043
C33[a]	CAPINTEC	CRC-15R	^{131}I preset	75.10	74.4	1.009
	”	”	dial 151	75.10	74.4	1.009
C33[b]	CAPINTEC	CRC-15R	^{131}I preset	76.55	74.4	1.029
	”	”	dial 151	76.55	74.4	1.029
C33[c]	AMERSHAM	ARC-120	^{131}I preset	77.28	74.4	1.039
	”	”	dial 151	76.95	74.4	1.034
C33[d]	BIODEX	ATOMLAB 100	^{131}I preset	76.56	74.4	1.029
	”	”	dial 22.2	76.56	74.4	1.029
C34[a]	AMERSHAM	ARC-120	^{131}I preset	79.04	75.1	1.053
	”	”	dial 151	78.72	75.1	1.048
C34[b]	CAPINTEC	CRC-15R	^{131}I preset	79.90	75.1	1.064
	”	”	dial 151	80.04	75.1	1.066
C34[c]	AMERSHAM	ARC-120	^{131}I preset	78.03	75.1	1.039
	”	”	dial 151	78.41	75.1	1.044
C34[d]	CAPINTEC	CRC-15R	^{131}I preset	79.12	75.1	1.054
	”	”	dial 151	79.52	75.1	1.059
C35[a]	CAPINTEC	CRC-15BETA	dial 151 *	71.11	75.6	0.941
C35[b]	AMERSHAM	ARC-120	^{131}I preset	69.84	75.6	0.924
	”	”	dial 151	71.61	75.6	0.947
C35[c]	VINTEN	ISOCAL II	dial 1308	80.78	75.6	1.069
C36[a]	VINTEN	ISOCAL IV	dial 2650	75.40	74.7	1.009
C36[b]	CAPINTEC	CRC-120	dial 158	76.94	74.7	1.030
C36[c]	CAPINTEC	CRC-12	dial 158	75.22	74.7	1.007
C36[d]	VINTEN	ISOCAL IV	dial 1200	77.17	74.7	1.033
C36[e]	VEENSTRA	”	dial 447	76.32	74.7	1.022
C36[f]	CAPINTEC	CRC-35R	dial 160	75.32	74.7	1.008
C36[g]	AMERSHAM	ARC-120	dial 160	75.08	74.7	1.005
C36[h]	AMERSHAM	ARC-120	dial 156	76.10	74.7	1.019
C36[i]	AMERSHAM	ARC-120	dial 156	76.38	74.7	1.022
C36[j]	CAPINTEC	CRC-15R	dial 151	78.41	74.7	1.050
C36[k]	CAPINTEC	CRC-15R	dial 151	79.02	74.7	1.058
C36[l]	CAPINTEC	CRC-15R	dial 158	75.73	74.7	1.014
C36[m]	CAPINTEC	CRC-15R	dial 159	75.15	74.7	1.006
C36[n]	CAPINTEC	CRC-15R	dial 159	75.59	74.7	1.012
C36[o]	CAPINTEC	CRC-15R	dial 159	75.56	74.7	1.011
C36[p]	CAPINTEC	CRC-15R	dial 160	75.22	74.7	1.007
C36[q]	CAPINTEC	CRC-15R	dial 165	74.14	74.7	0.993
C36[r]	CAPINTEC	CRC-15R	dial 165	74.11	74.7	0.992
C36[s]	CAPINTEC	CRC-12	^{131}I preset	77.62	74.7	1.039

Capsule Code	Calibrator Manufacturer	Model	Settings	Reported Activity (MBq)	AEA Activity (MBq)	Reported/AEA
C36[t]	CAPINTEC	CRC-12	^{131}I preset	78.51	74.7	1.051
C36[u]	PITMAN	270	^{131}I preset	78.68	74.7	1.053
C36[v]	VINTEN	ISOCAL II	dial 1324	75.38	74.7	1.009
C41	CAPINTEC	CRC-15R	dial 160 *	74.49	75.2	0.991
	”	”	^{131}I preset	77.31	75.2	1.028
C37	SIEL	BIC-1	^{131}I preset	77.14	75.1	1.027
	”	”	dial 199	76.96	75.1	1.025
C38	CAPINTEC	CRC-15R	dial 151	77.13	74.5	1.035
C39[a]	CAPINTEC	CRC-15R	^{131}I preset	77.92	77	1.012
C39[b]	AMERSHAM	ARC-120	^{131}I preset	77.36	77	1.005
	”	”	dial 151	78.35	77	1.018
C39[c]	CAPINTEC	CRC-7B	^{131}I preset	78.77	77	1.023
C39[d]	VINTEN	ISOCAL III	^{131}I preset	78.68	77	1.022
C40	CAPINTEC	CRC-15R	dial 151	78.47	75.6	1.038
C42[a]	CAPINTEC	CRC-15R	dial 1308	75.50	74.8	1.009
C42[b]	VINTEN	ISOCAL II	dial 1308	70.54	74.8	0.943
C42[c]	VINTEN	ISOCAL II	dial 1308	72.80	74.8	0.973

Table 5

^{131}I solution results summarised by calibrator and container

^{131}I SOLUTION DATA GROUPS	0.90 to 0.92	0.92 to 0.94	0.94 to 0.96	0.96 to 0.98	0.98 to 1.00	1.00 to 1.02	1.02 to 1.04	1.04 to 1.06	1.06 to 1.08	1.08 to 1.10
ALL DATA (total: 145 results)	0	3	4	11	31	63	18	8	4	3
CONTAINER DATA:										
- P6 VIAL DATA	0	2	3	10	28	62	15	6	0	1
- PRESET DATA	0	0	1	9	13	34	7	2	0	1
- DIAL DATA	0	2	2	1	15	28	8	4	0	0
- SYRINGE DATA	0	1	0	0	1	1	1	1	2	0
- RESIDUE DATA	0	0	1	1	2	0	1	1	0	0
- OTHER CONTAINERS DATA	0	0	0	0	0	0	1	0	2	2
CHAMBER DATA: (P6 vial data)										
- ISOCAL II/PITMAN 238	0	0	0	1	3	1	1	1	0	0
- ISOCAL III	0	0	0	0	1	0	0	0	0	0
- ISOCAL IV	0	0	0	1	2	3	2	0	0	1
- CAPINTEC 120	0	1	1	5	2	24	2	4	0	0
- CAPINTEC 35	0	0	0	0	0	3	0	0	0	0
- CAPINTEC 15	0	0	1	2	15	22	9	0	0	0
- CAPINTEC 10	0	0	1	0	1	6	1	0	0	0
- VEENSTRA	0	0	0	0	1	1	0	1	0	0
- SIEL	0	0	0	0	2	0	0	0	0	0
- ATOMLAB	0	1	0	1	1	2	0	0	0	0

Table 6

^{131}I capsule results summarised by calibrator and container

^{131}I CAPSULE DATA GROUPS	0.90 to 0.92	0.92 to 0.94	0.94 to 0.96	0.96 to 0.98	0.98 to 1.00	1.00 to 1.02	1.02 to 1.04	1.04 to 1.06	1.06 to 1.08	1.08 to 1.10
ALL DATA (total: 243 results)	0	3	3	13	19	52	79	59	14	1
CONTAINER DATA:										
- PLASTIC APPLICATOR DATA	0	3	2	12	19	48	77	59	14	1
- PRESET DATA	0	1	0	2	4	18	35	25	7	0
- DIAL DATA	0	2	2	10	15	30	42	34	7	1
- P6 VIAL DATA	0	0	0	0	0	3	2	0	0	0
- OTHER CONTAINERS DATA	0	0	1	1	0	1	0	0	0	0
CHAMBER DATA: (all data)										
- ISOCAL II/PITMAN 238	0	0	1	4	0	4	6	1	1	0
- ISOCAL III	0	0	0	2	2	2	2	0	0	0
- ISOCAL IV	0	0	0	0	1	7	4	1	0	0
- CAPINTEC 120	0	1	1	0	3	10	14	19	4	0
- CAPINTEC 35	0	0	0	0	0	1	2	1	0	0
- CAPINTEC 15	0	2	1	4	10	15	33	31	6	0
- CAPINTEC 12	0	0	0	0	0	3	2	1	0	0
- CAPINTEC 10	0	0	0	0	0	2	7	2	3	1
- CAPINTEC 11	0	0	0	0	0	1	0	0	0	0
- CAPINTEC 7	0	0	0	0	0	0	1	0	0	0
- PITMAN 270	0	0	0	0	0	0	1	1	0	0
- VEENSTRA	0	0	0	0	0	1	1	1	0	0
- SIEL	0	0	0	0	1	3	4	0	0	0
- ATOMLAB	0	0	0	3	2	3	2	1	0	0

Table 7

^{131}I Solution Results - Reported Uncertainty

Participant	Type A uncertainty (random)	Type B uncertainty (non-random)	Overall uncertainty
S24[a]	1%	1%	2%
S24[b]	1%	1%	2%
S25[a]	0.4%		
S25[b]	0.2%		
S25[c]	0.3%		
S25[d]	0.4%		
S25[e]	1.2%		
S25[f]	0.4%		
S27[a]	10%		
S30	1.63%	negligible	1.63%
S33[a]	0.75%	1.5%	
S33[b]	0.7%	1%	
S34[a]	0.22%	5.66%	5.66%
S34[b]	0.27%		
S34[c]	0.16%		
S34[d]	0.3%	5.69%	5.70%

Table 8

^{131}I Capsule Results - Reported uncertainty

Participant	Type A uncertainty (random)	Type B uncertainty (non-random)	Overall uncertainty
C4[a]	2.0%	2.0%	4.0%
C4[b]	2.0%	2.0%	4.0%
C6	0.6%	-2.0%	
C11[a]			0.07%
C11[b]			0.1%
C15[g]	0.0516%		
C16			10% !!!!
C19[a]	0.7%	5.5%	5.5%
C20			3%
C24	1%	1%	2%
C25[a]	0.1%		
C25[b]	0.2%		
C25[c]	0.2%		
C25[d]	0.4%		
C25[e]	0.5%		
C25[f]	0.2%		
C25[g]	0.2%		
C27[a]	2.0%		
C30	0.6%		
C31	0.5%	5.4%	
C33[a]	0.15%	1.5%	
C33[b]	0.15%	1%	
C33[c]	0.15%	2%	
C33[d]	0.15%	3.5%	
C34[a]	0.4%	5.66%	5.67%
C34[b]	0.1%		
C34[c]	0.5%		
C34[d]	0.1%	5.69%	5.69%
C36[a]			0.6%
C37	5%	0.4%	5.02%
C38	0.1%		
C39[a]	0.12%	0.4%	
C39[b]	0.11%	0.8% - preset 0.2% - dial	
C39[c]	0.17%	2.4%	
C39[d]	0.1%	4.4%	
C40	7%		7%
C41			3%
C42[a]			

Participant	Type A uncertainty (random)	Type B uncertainty (non-random)	Overall uncertainty
C42[b]	1.54%		
C42[c]	2.07%		

Table 9

Distribution of results from past and present intercomparisons
(expressed as percentage of results within given range of NPL value)

		Range	
Year	Nuclide	0.95 - 1.05	0.90 - 1.10
1981	^{125}I	13%	26%
1981	^{57}Co	52%	76%
1986	^{99m}Tc	73%	94%
1986	^{131}I	88%	95%
1996	^{67}Ga	91%	95%
1996	^{123}I	28%	62%
1997	^{111}In	84%	92%
1999	^{131}I solution ^{131}I capsule	90% 79%	100% 100%

Figure 1

Comparison of primary standards from National Metrology Institutes (NMIs) via BIPM SIR system

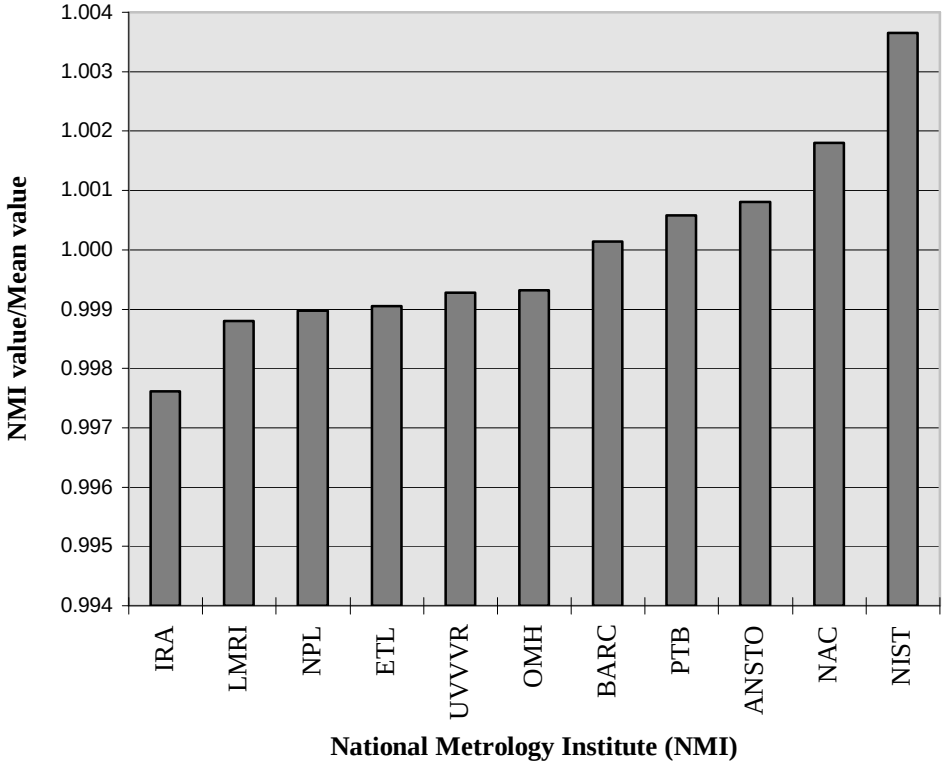


Figure 2 Variation in response with container in Capintec ARC 120 (for solutions and capsules)

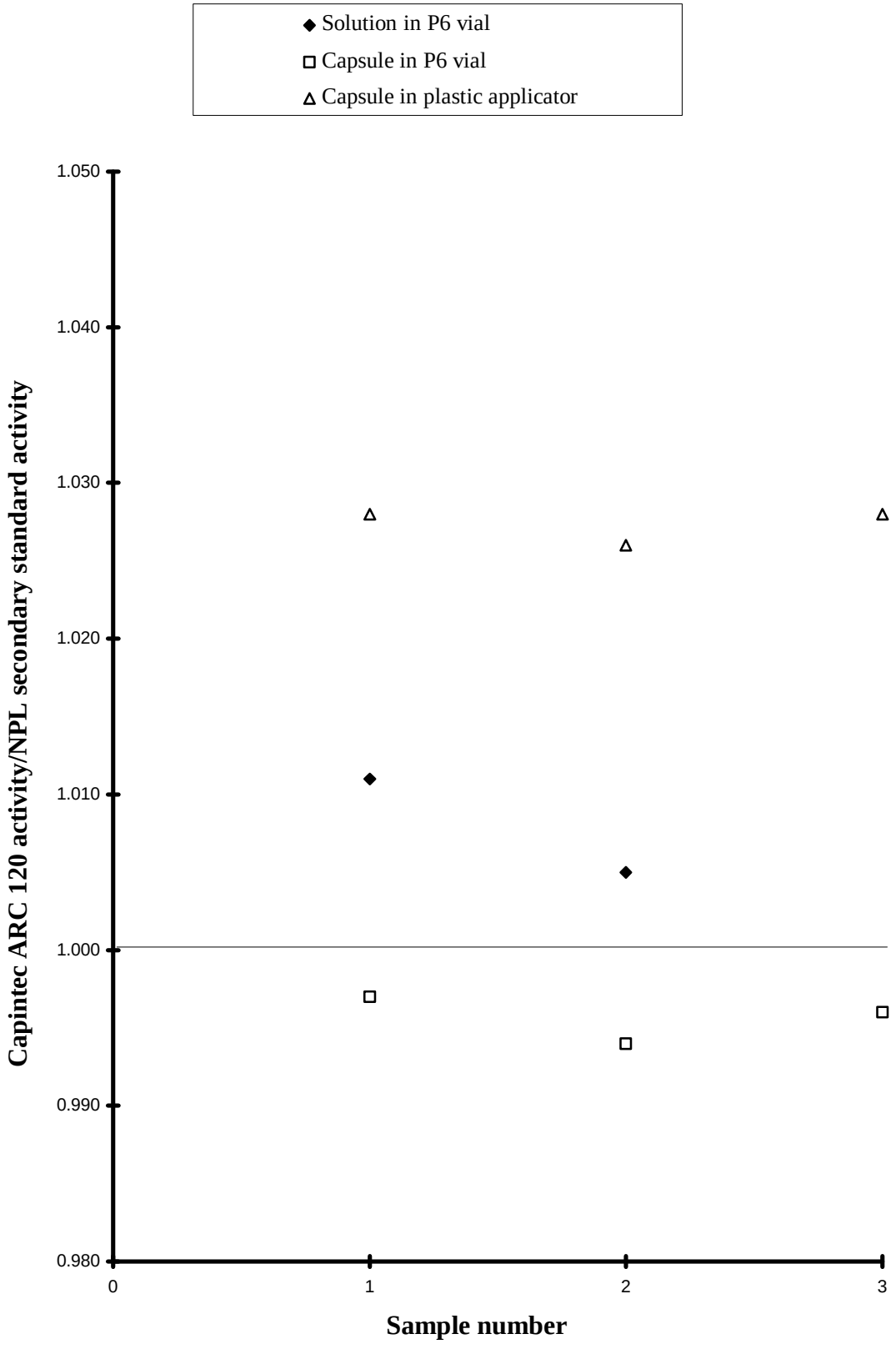


Figure 3 Distribution of ^{131}I capsule results - all systems, all containers

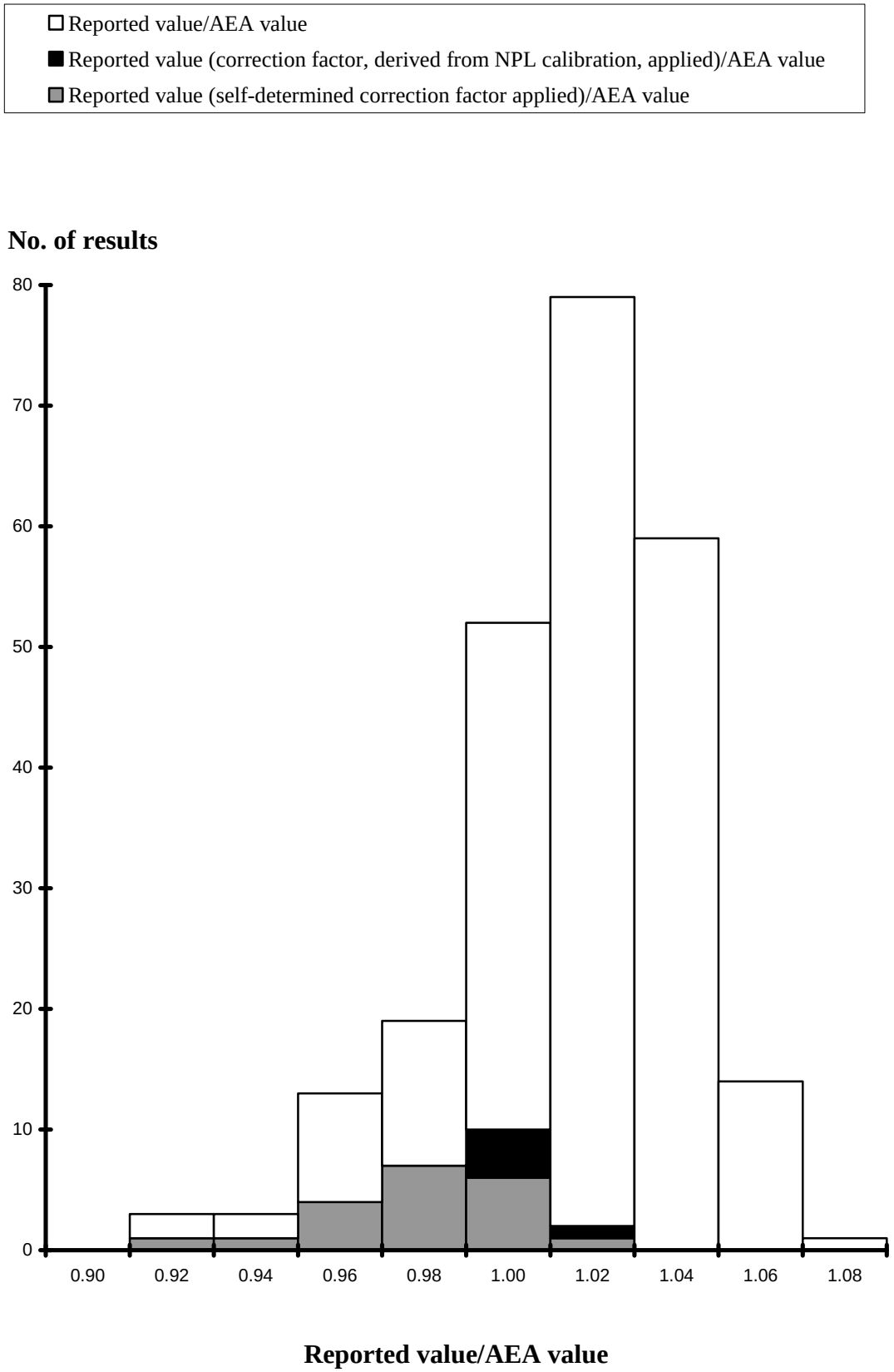


Figure 4 Distribution of ^{131}I capsule results-plastic applicator and P6 vial

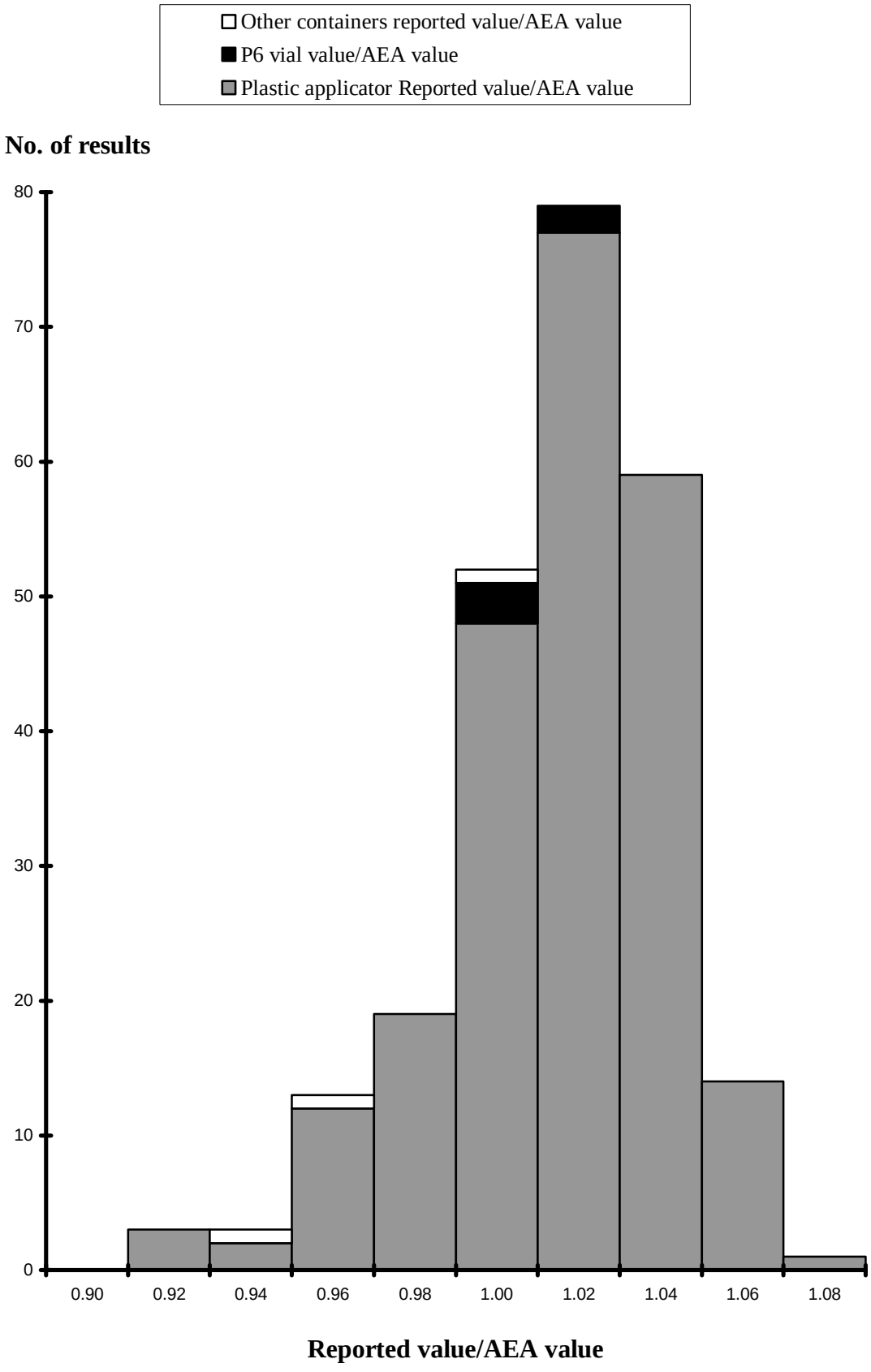


Figure 5 Distribution of ^{131}I capsule results - preset and dial settings (plastic applicator only)

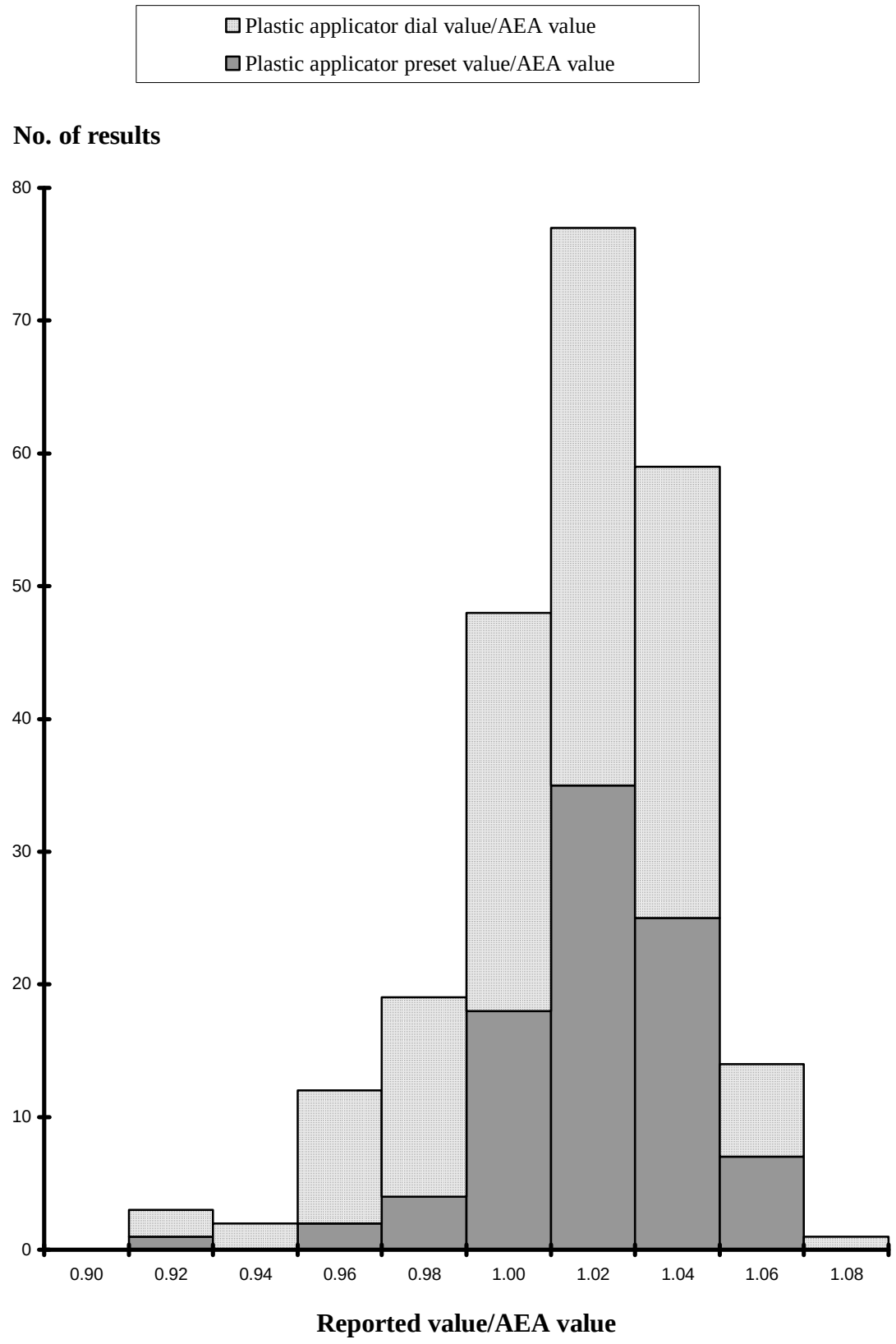


Figure 6 Distribution of ^{131}I capsule results - CAPINTEC systems

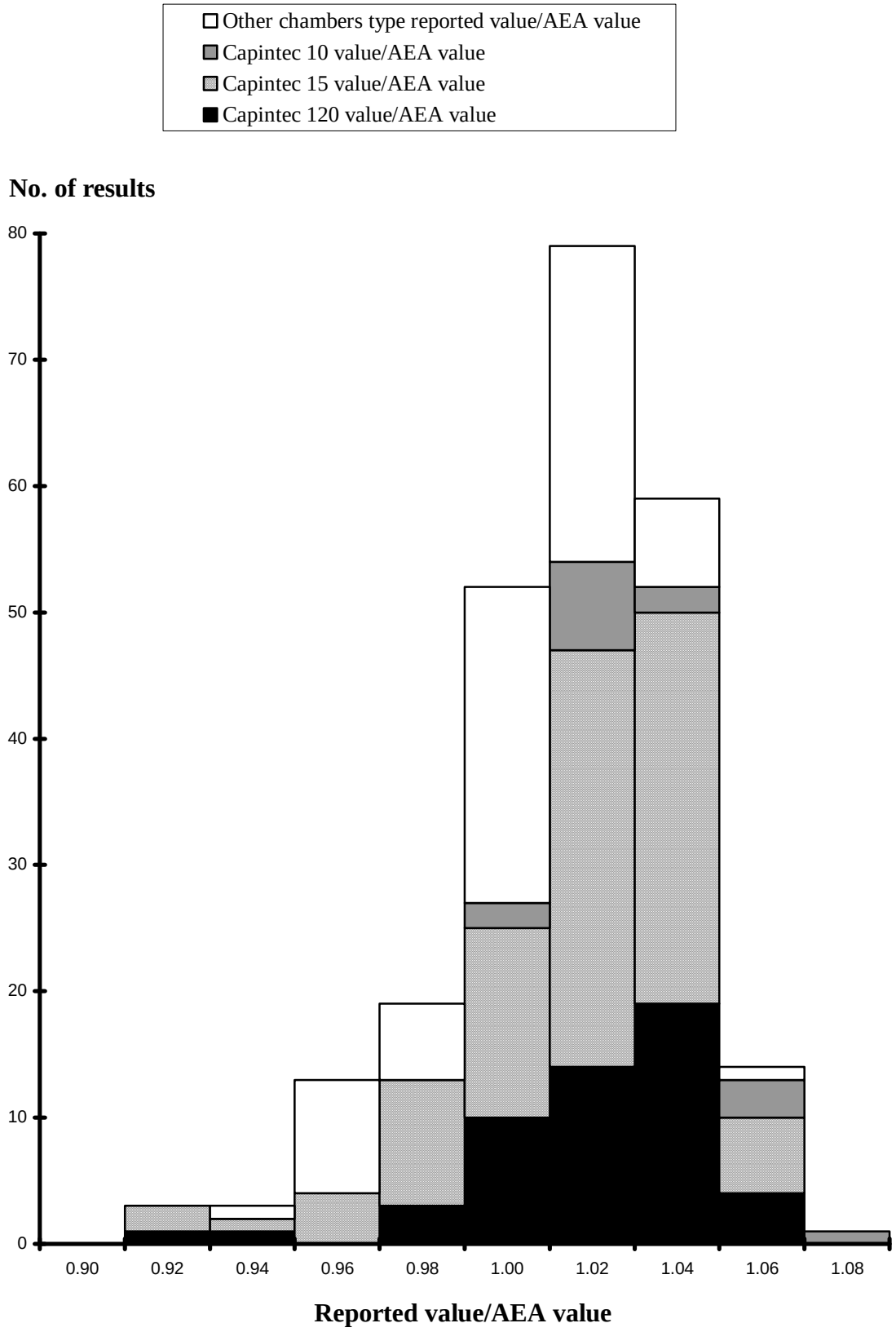


Figure 7 Distribution of ^{131}I capsule results-ISOCAL systems

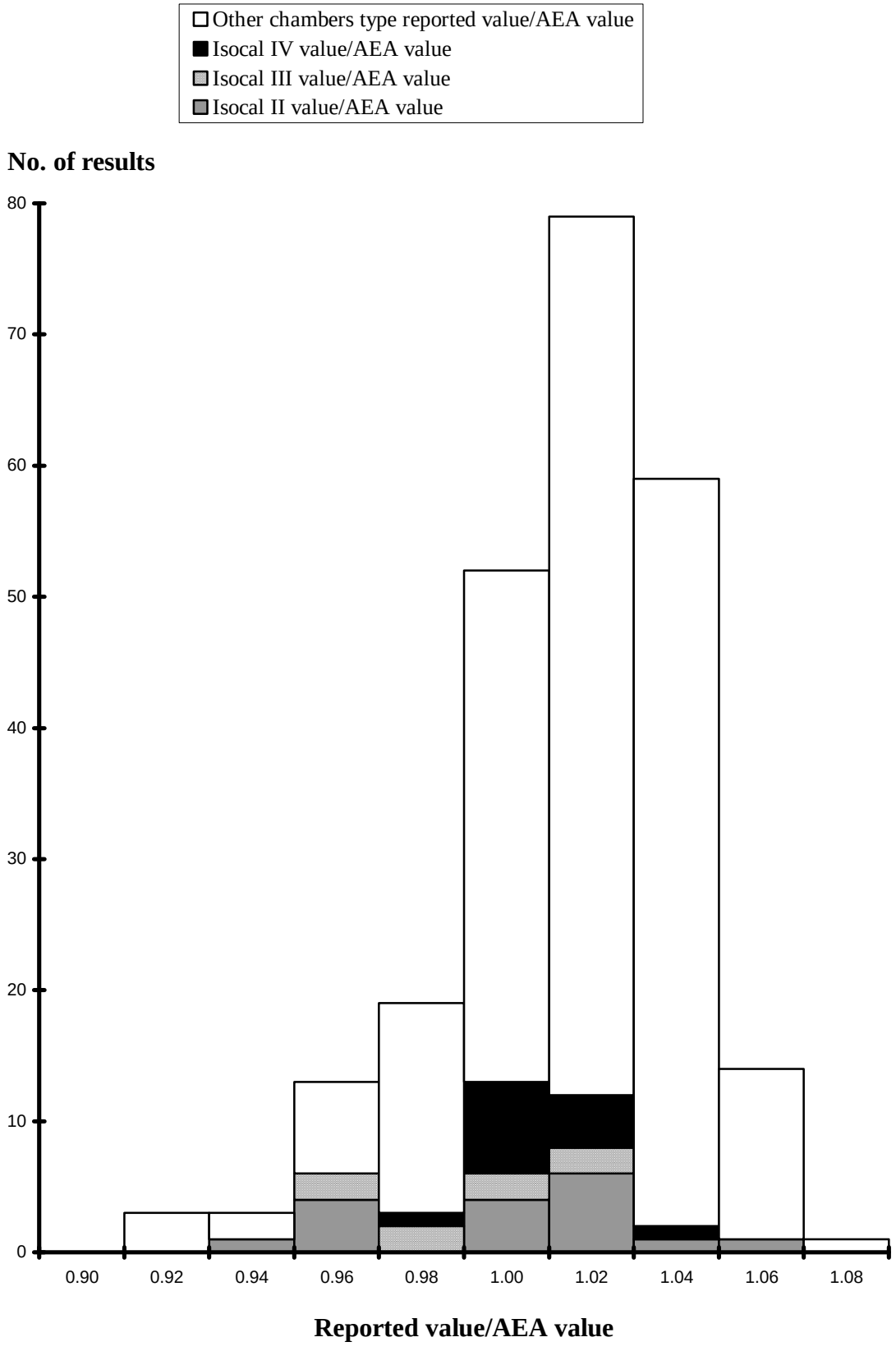


Figure 8 Distribution of ^{131}I solution results - P6 vial and syringe

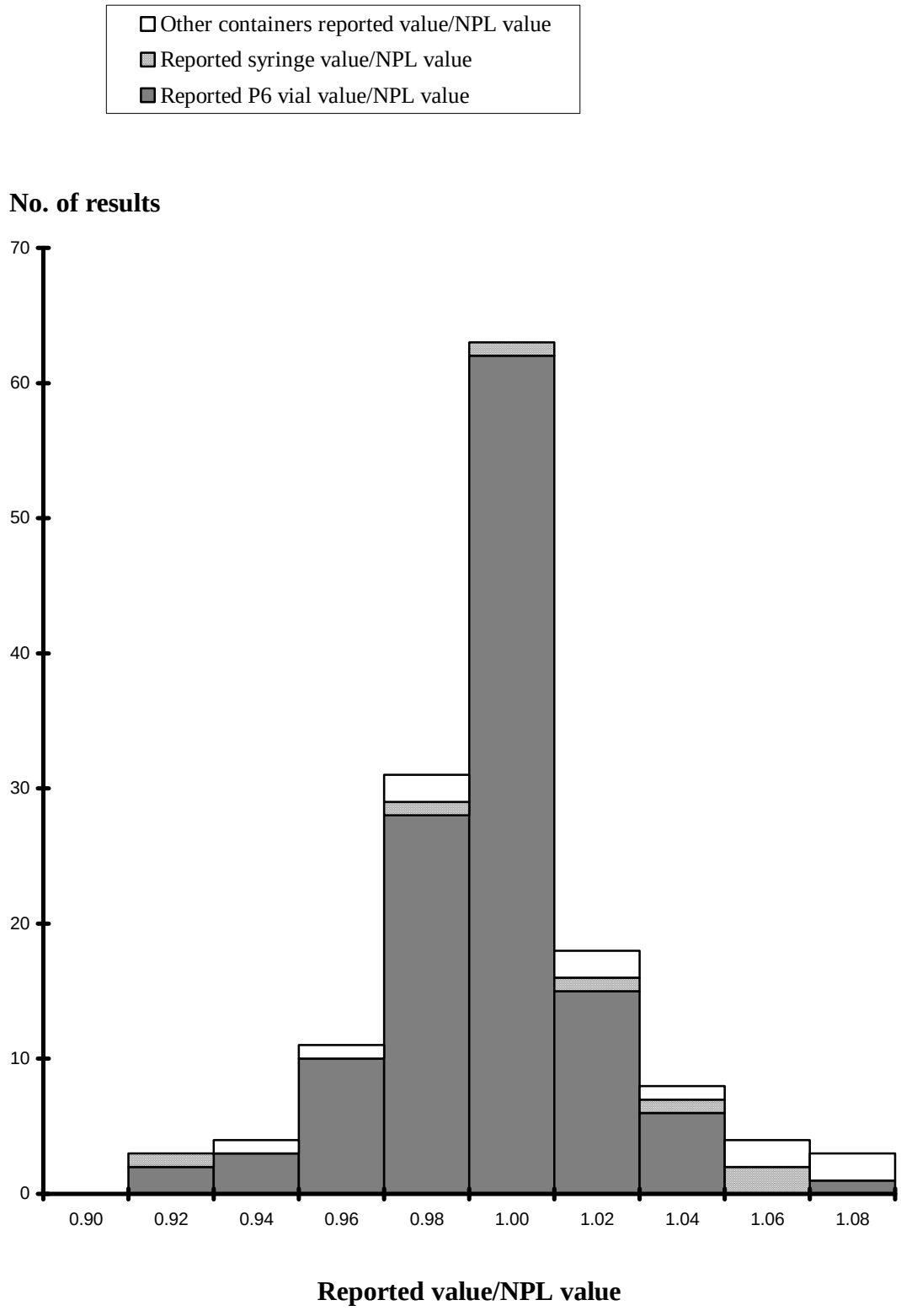


Figure 9 Distribution of ^{131}I solution results - preset and dial settings (P6 vial only)

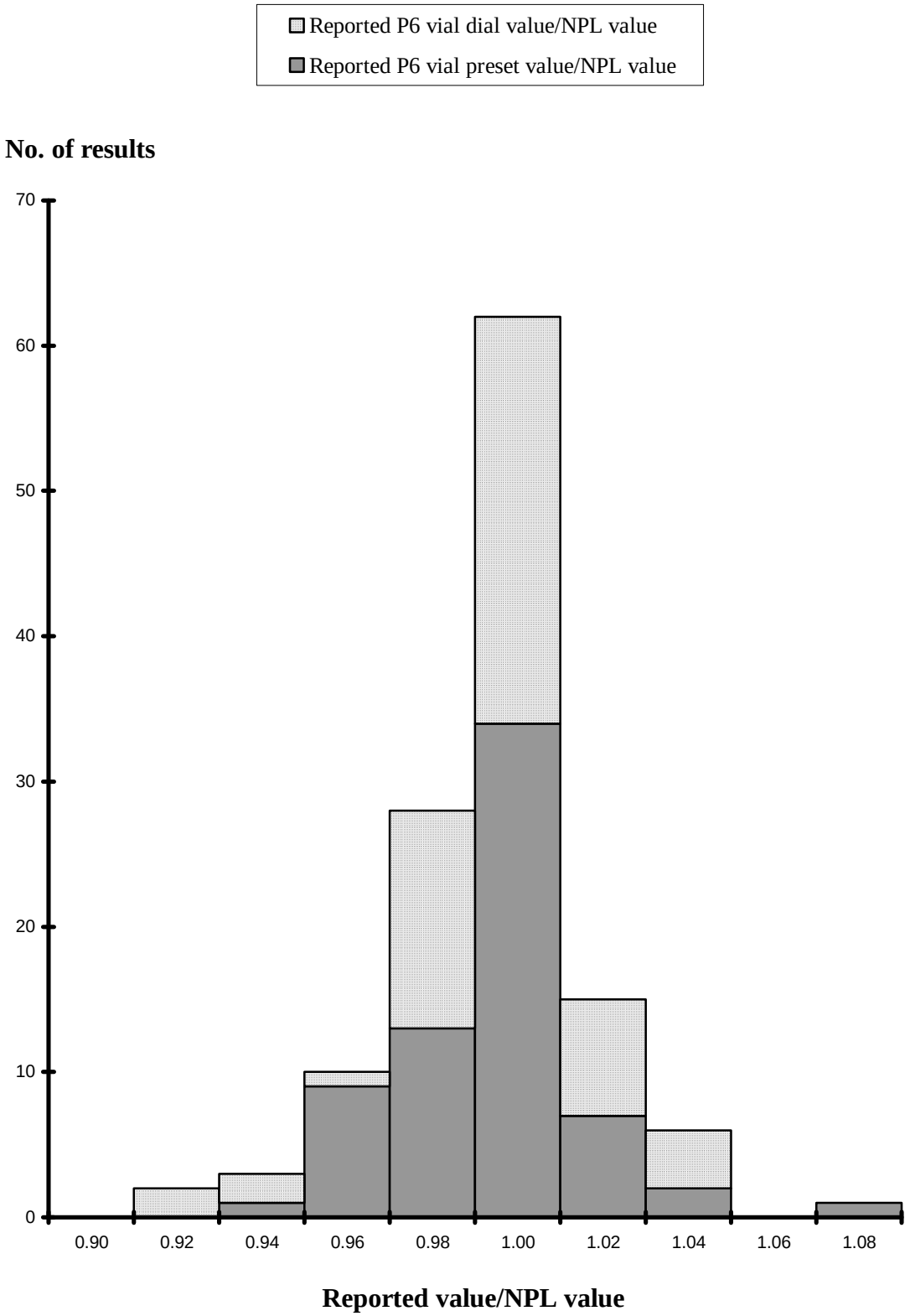


Figure 10 Distribution of ^{131}I solution results - CAPINTEC systems (P6 vials only)

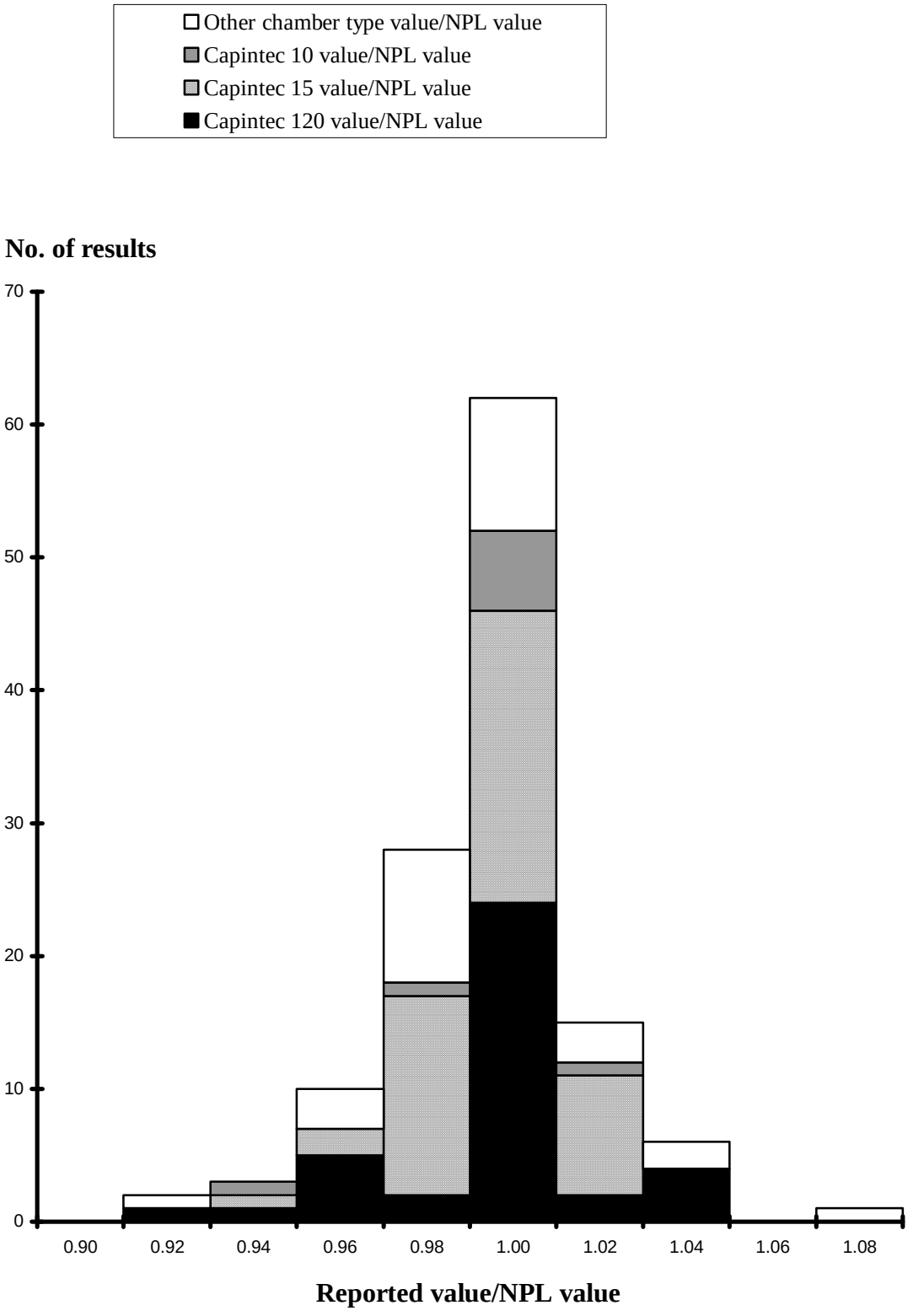


Figure 11 Distribution of ^{131}I solution results - ISOCAL systems (P6 vial only)

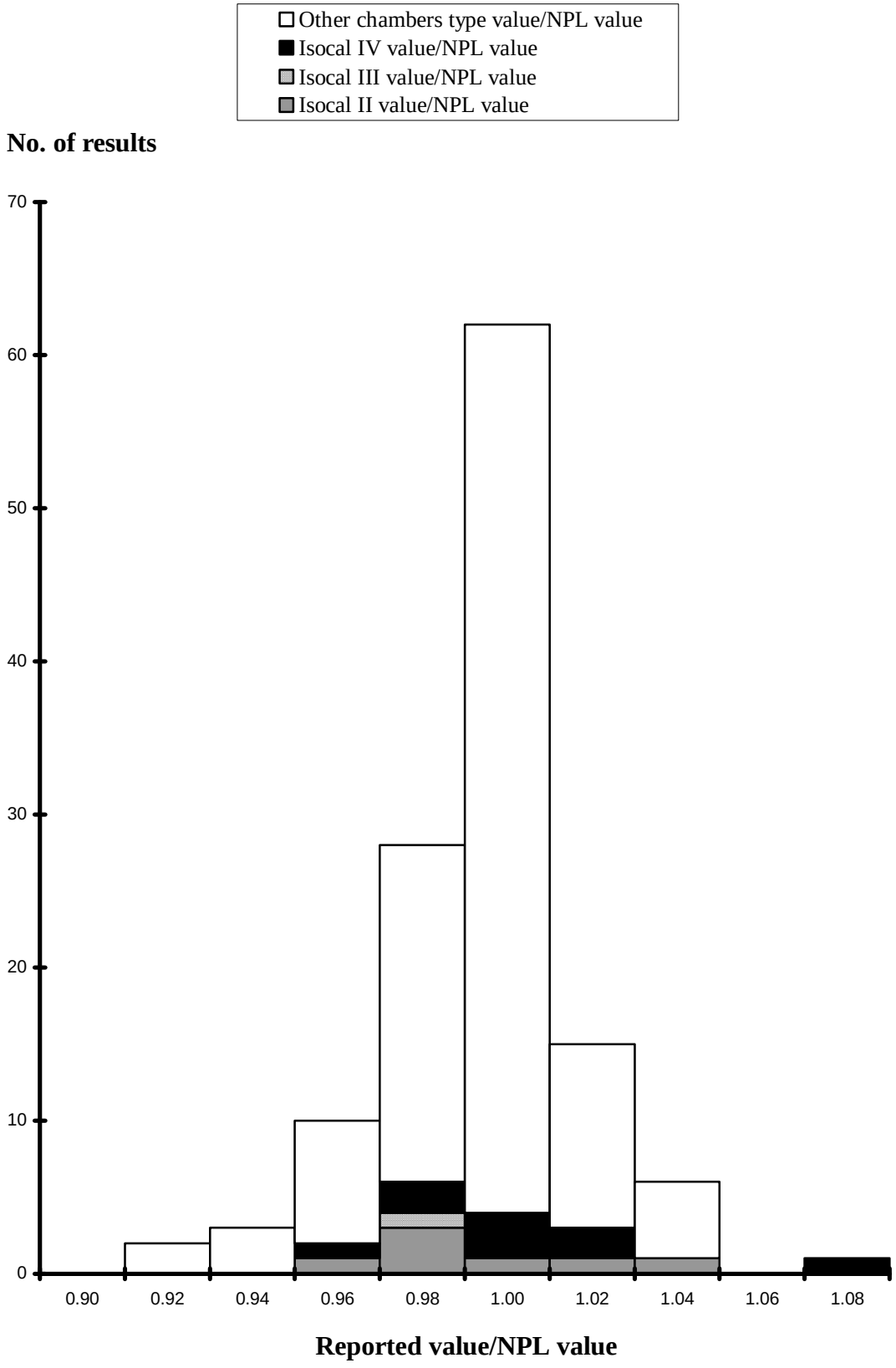


Figure 12 Distribution of ^{131}I solution and capsule results for individual hospitals

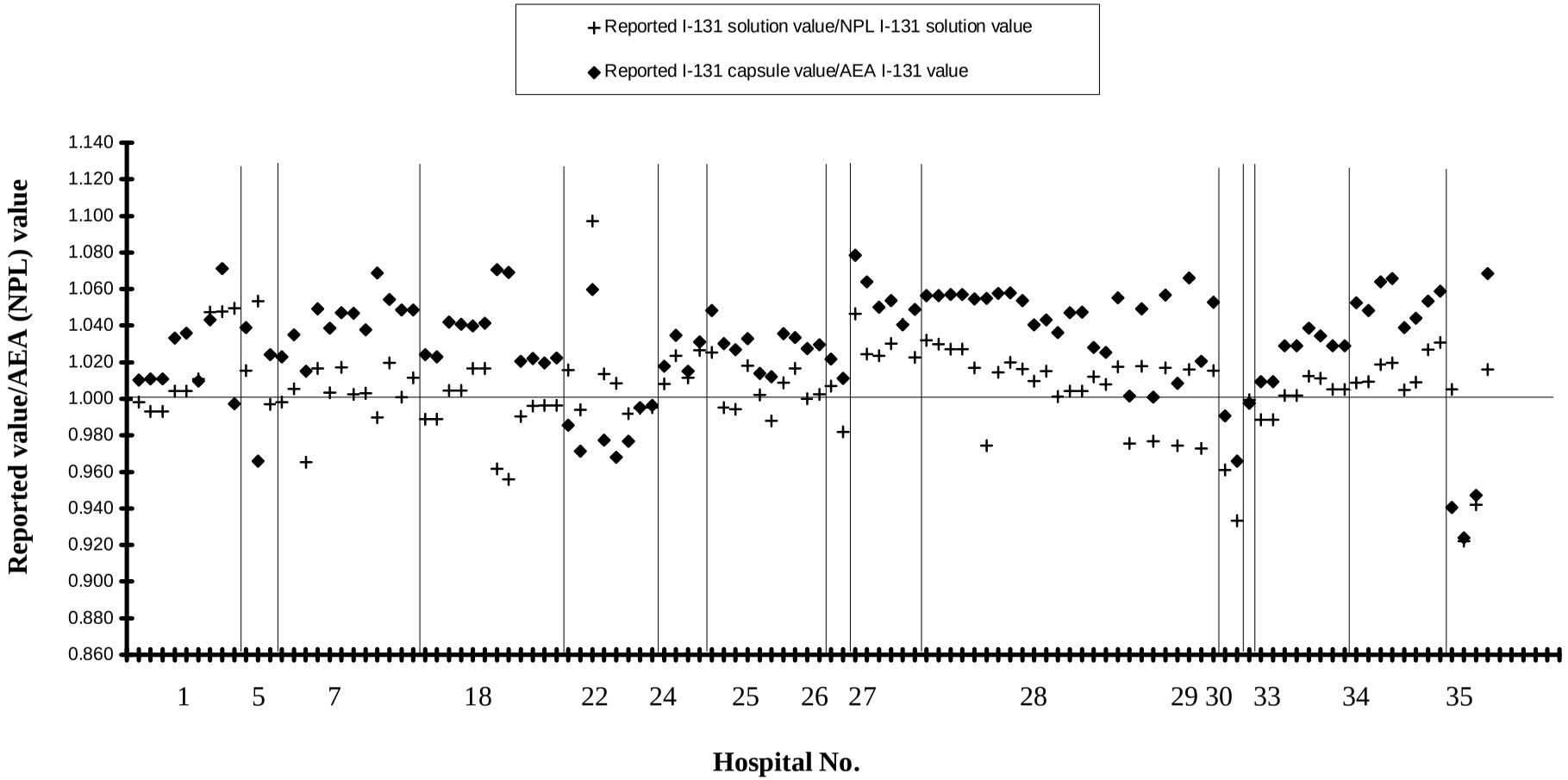


Figure 13 Distribution of solution and capsule results for hospital No 18

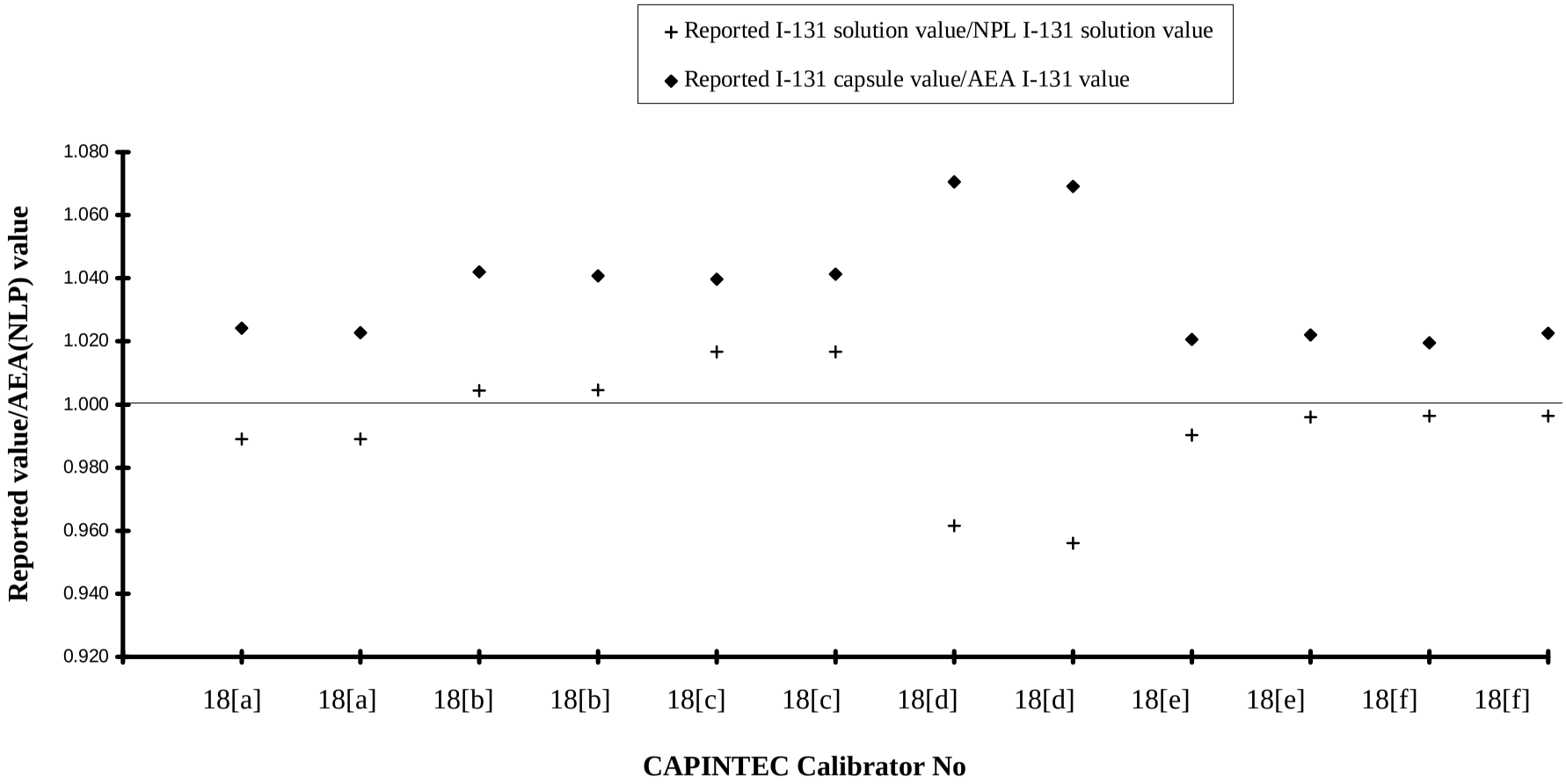
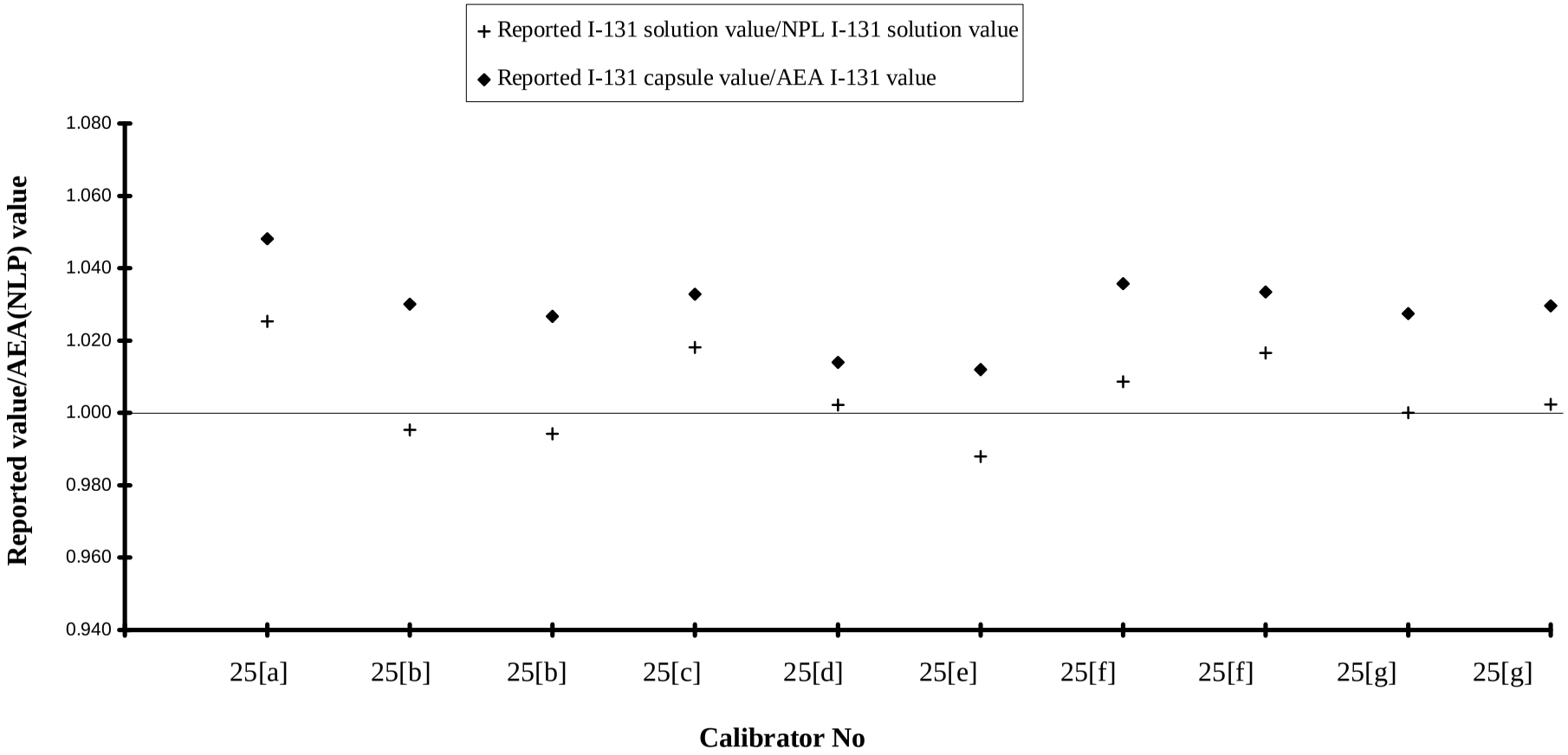


Figure 14 Distribution of solution and capsule results for hospital No 25



APPENDIX 1

PARTICIPANTS

Participants	Hospital
S Hooper	University Hospital, Wales
P Howells	Scarborough Hospital, Scarborough
D Pears	Diana Princess of Wales Hospital, Grimsby
I Belton	Leicester Royal Infirmary, Leicester
M Evans	The Royal Wolverhampton NHS, Wolverhampton
B Baily	Cromwell Hospital, London
I Driver	Cookridge Hospital, Leeds
M Waller	York District Hospital, York
A Smith	Harrogate District Hospital, Harrogate
M Burniston	St James's Hospital, Leeds
R Gadd	North Staffordshire Hospital, Stoke-on-Trent
C Tan	Royal Cornwall Hospital, Cornwall
A Foster	Royal Shrewsbury Hospital, Shrewsbury
J Childs	Maidstone Hospital, Maidstone
T Hosking	North Middlesex Hospital, London
A Millar	Royal Infirmary, Edinburgh
D Brown	St John's Hospital, Livingston
C Sidey	Western General Hospital, Edinburgh
P Davies	UCLH Middlesex Hospital, London
P Hillel	Weston Park, Royal Hallamshire,
P Hillel	Northern General, Chesterfield Royal; Sheffield
B Pratt	Royal Marsden NHS, Sutton
P Waldock	Ipswich Hospital, Ipswich
P Cosgriff	Pilgrim Hospital, Boston
N Boyce	St Mary's Hospital, Portsmouth
J Mac Donald	Glan Clwyd Hospital, Rhyl
P Ormsby	Derriford Hospital, Plymouth
B Gilmore	Belvoir Park Hospital, Belfast
M Fenwick	Ninewells Hospital, Dundee
H Stockdale	Royal Liverpool University Hospital, Liverpool
W Heywood	Poole Hospital, Poole
S Owens	Christie Hospital NHS, Manchester
L Kohler	Raigmore Hospital, Inverness
P Barnes	Royal Sussex County Hospital, Brighton
M Avison	Bradford Royal Infirmary, Bradford
R Smith	Guys Hospital, London
J Ballantyne	Charing Cross Hospital, London
R Blair	Newcastle General Hospital, Newcastle
D Marshall	Medway Maritime Hospital, Gillingham
D Parry-Jones	Addenbrooke's Hospital, Cambridge
Wil Van Der Putten	University Hospital, Galway, Ireland
T Davies	Princess Royal Hospital, Hull
D Simpson	Kent and Canterbury Hospital, Canterbury

T R Elkerton	Royal Devon and Exeter Hospital
Andrew Garton	Royal Marsden Hospital, London
Colin Jennings	Walsgrave Hospital, Coventry
Matt Williamson	Pinderfields Hospitals, Wakefield
T J Watts	North Devon District Hospital, North Devon