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Environmental Radioactivity

Comparison Exercise 2003

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ABSTRACT

The results of the eleventh NPL Environmental Radioactivity Comparison Exercise are reported. In general the level of performance for the nuclides in the α/β mixture has improved but there has been a slight reduction in the level of performance for the nuclides in the β/γ mixture. The reported data does suggest that some analysts are still not making cascade summing corrections. The lack of data returned for many β-emitting nuclides has again made it difficult to assess performance levels.

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CONTENTS

TABLES

ILLUSTRATIONS

APPENDICES

1. INTRODUCTION

This environmental radioactivity comparison was the eleventh in a series of similar exercises[1-12] to have been conducted by NPL since 1989. They have evolved over the years in response to the needs of the radioactivity measurement community in the UK and are now well established as part of the analyst's calendar, being particularly important in support of UKAS accreditation in this field. They have also been instrumental in identifying analytical problems and in providing a regular national forum for discussion and technology transfer in this area.

The exercises have been run approximately once every eighteen months by NPL. The range of sample types available for analysis has been mainly aqueous (dilute nitric or hydrochloric acid) although samples based on matrices such as Kaolin[5] or milk[6] have also been offered. In the 2003 exercise, five samples were available for analysis:

i) a 'high-level' mixture of α-, β-emitting radionuclides (2 – 5 Bq g^{-1} per radionuclide (apart from ^{90}Sr, which was ~ 10 Bq g^{-1}), in dilute nitric acid);
ii) a 'low-level' mixture of α-, β-emitting radionuclides (2 – 5 Bq kg^{-1} per radionuclide (with ^{90}Sr ~ 12 Bq kg^{-1}), in dilute nitric acid);
iii) a high-level mixture of β/γ-emitting radionuclides (1 – 10 Bq g^{-1}, in dilute hydrochloric/oxalic acid);
iv) a 'low-level' mixture of β/γ-emitting radionuclides (2 – 12 Bq kg^{-1}, in dilute hydrochloric/oxalic acid).
v) a mixture of the low energy β-emitting radionuclides (~ 500 Bq kg^{-1}, in very dilute sodium hydroxide);

2. ORGANISATION

2.1. PARTICIPANTS

A total of 32 participants took part in this exercise. The majority of the samples taken were of the β/γ-emitting mixtures, with 22 participants taking the high-level mixture and 23 taking the low-level mixture. Uptake of the α/β-emitting mixtures was 9 for the high-level mixture and 15 for the low-level mixture and uptake of the low energy β-emitting mixture was 17.

The participants came from a wide cross-section of the UK measurement community. A full listing is given in Appendix 1.

2.2. SAMPLES

The samples were given the following identifiers:

i) high-level α-, β-emitting radionuclide mixture - ABHxx/03
ii) low-level α-, β-emitting radionuclide mixture - ABLxx/03
iii) high-level β/γ-emitting radionuclide mixture - BGHxx/03
iv) low-level β/γ-emitting radionuclide mixture - BGLxx/03
v) low energy β-emitting radionuclide mixture - LBxx/03

Tables 1-11 summarise the principal radionuclides in the five sample mixtures made available, along with the impurities present in each mixture.

All the radionuclides used in this exercise are either released by the nuclear industry in the course of normal operations or occur naturally in the environment. The following criteria were looked for when choosing the radionuclides:

(i) that the half-lives were > 50 days;
(ii) that no obscure species were selected (i.e. all could reasonably be found in the environment or in nuclear-licensed site effluent);
(iii) that the α/β-emitter samples contained no radionuclides conventionally used as chemical yield tracers;
(iv) that all the radionuclides were measurable by well-established techniques.

The timescales allowed for analyses were short so, as in previous years, a list of the radionuclides present in the α/β mixture was provided in advance of the exercise to avoid resource wastage. A similar list was not provided for the β/γ-emitting mixtures, since the measurement technique is non-invasive and enables unambiguous identification of the nuclides present, although the following candidate list of possible γ-emitters was provided:

^{7}Be, ^{22}Na, ^{46}Sc, ^{54}Mn, ^{56}Co, ^{57}Co, ^{58}Co, ^{60}Co, ^{65}Zn, ^{85}Sr, ^{88}Y, ^{95}Zr/^{95}Nb, ^{106}Ru/^{106}Rh, ^{109}Cd, ^{110m}Ag, ^{113}Sn, ^{124}Sb, ^{125}Sb, ^{133}Ba, ^{134}Cs, ^{137}Cs, ^{139}Ce, ^{144}Ce, ^{153}Gd, ^{154}Eu, ^{155}Eu, ^{160}Tb, ^{170}Tm, ^{203}Hg and ^{207}Bi.

3. CALIBRATION

3.1. ABSOLUTE CALIBRATION

Traceability of measurement is important to all participants, and all nuclides present in the samples were traceable to primary standards of radioactivity. A primary standard is the highest level standard in any hierarchical measurement system. In most cases, primary standards are also absolute standards.

An absolute standard of radioactivity is one that has been measured directly without reference to any other standard of activity; the activity has been determined from count-rate data alone, without reference to any supplementary data determined from previous experiments. In the case of radioactivity standards, absolute standards are generally derived using the 4π-proportional counter-γ-coincidence counting technique for α/γ and β/γ emitting radionuclides[13]. Those radionuclides decaying by pure α- or pure β-emission can be determined by a variation[14,15] of this technique.

3.2. SECONDARY STANDARDISATION

Absolute counting techniques are labour intensive and this, coupled with the level of operator expertise required, renders it very expensive; also, there is a limit on the lowest amount of activity that can be measured without the associated uncertainties becoming unacceptably high. A simpler, more rapid method is therefore required for routine calibrations, and this is achieved by using an absolutely calibrated solution to calibrate a secondary standard instrument. In the case of α/γ or β/γ emitters and some high energy pure β-emitters, this is usually a well-type ionisation chamber that responds only to the γ-rays emitted (in the case of high-energy pure β-emitters, the ionisation chamber measures the Bremsstrahlung radiation). These instruments are normally very stable; for example, the response of the ionisation chambers maintained at NPL has been found to vary by < 0.1 % over 40 years. Other γ-ray detectors (NaI(Tl) or hyperpure Germanium detectors) are applicable but they do not share the long term stability of ionisation chambers. For pure α-emitters and pure β-emitters, there are no suitable secondary standard instruments that have sufficient long term stability; however, liquid scintillation counters can be used, albeit with counting efficiencies which are dependent on such factors as particle energy, spectral shape, chemical format, etc. Pure β-emitters can also be assayed using an ‘efficiency tracing’ technique[16] using ^{3}H as a tracer nuclide.

4. SOURCE PREPARATION

4.1. PROCUREMENT

The individual radionuclides were obtained from a number of suppliers and have been calibrated at NPL. Table 12 summarises the suppliers, the laboratories responsible for the calibrations and the traceability of the measurements.

4.2. PURITY

Each nuclide was checked for impurities either by α-spectrometry, γ-spectrometry or by reference to the original calibration certificate; the impurity levels are shown in Tables 2, 4, 8 and 11.

4.3. ACTIVITY CONFIRMATION

The activity concentrations of the original individual radionuclide solutions were determined either from the calibration certificates or from measurement at NPL, using either absolute methods or secondary standard instruments as described above.

4.4. PREPARATION

The β/γ-emitting mixtures were prepared by (i) diluting standard solutions of the individual radionuclides to the required activity concentrations, (ii) mixing the individual radionuclides and (iii) diluting the mixture down to the required activity levels. The final activity concentration for each nuclide was determined by dividing the initial single-radionuclide activity concentration by the dilution factors as determined from weighing.

Sets of sources (either single-radionuclide or mixed-radionuclide, depending on the dilution stage) were prepared at each dilution stage, for subsequent counting, in order to derive ‘radiometric’ dilution factors to confirm those derived gravimetrically.

A radiometric dilution factor was determined for each principal radionuclide present. These factors were determined by either γ-ray spectrometry, using a hyperpure Ge γ-ray spectrometer (mixed-radionuclide stage) or by liquid scintillation counting.

The α/β mixtures were prepared in the same way, except some of the single-radionuclide dilutions were checked using liquid scintillation counting and the mixed-radionuclide dilutions were verified, as far as possible, by γ-spectrometric determination of the ^{241}Am component and by liquid scintillation counting of the total activity of the mixture. The low energy β mixed-radionuclide dilutions were verified, as far as possible, by γ-spectrometric determination of the ^{129}I component.

The results showed a good agreement between the gravimetric and radiometric dilution factors. The u-statistic tests (see Chapter 5) were, in all cases, lower than 1.64.

4.4.1. The α/β mixture

Standard solutions of ^{90}Sr, ^{99}Tc, ^{238}Pu, ^{239}Pu and ^{241}Am (either as extant material at a suitable activity concentration level or material prepared from verified dilutions as described above) were combined and diluted to 6.2 kg with carrier. This diluted mixture was used to make:

a) 40 x 100 g samples @ 2 - 5 Bq g^{-1} per nuclide (except for ^{90}Sr, which was present at 10 Bq g^{-1});
b) 1 x dilution bottle (approximately 100 g diluted to 3 kg).

Bottle (b) was used to make:

c) 1 x dilution bottle (approximately 700 g diluted to 20 kg).

Finally, bottle (c) was used to make:

d) 40 x 500 g samples @ 2 - 5 Bq kg^{-1} per nuclide (^{90}Sr present at 12 Bq kg^{-1}).

The carrier used consisted of 2M HNO_3 with 50 μg g^{-1} each of strontium and yttrium as nitrates in 2 M nitric acid. Yttrium may act as a carrier for americium.

4.4.2. The β/γ mixture

The stock solutions of the individual radionuclides were combined and diluted to 7.2 kg with carrier. This was used to make:

a) 50 x 100 g samples @ 1 - 10 Bq g^{-1} per nuclide;

b) 1 x dilution bottle (approximately 100 g diluted to 3 kg).

Bottle (b) was then used to make:

c) 1 x dilution bottle (approximately 1 kg diluted to 25 kg).

Finally, bottle (c) was then used to make:

d) 50 x 500 g @ 2 - 12 Bq kg^{-1}.

The carrier used throughout consisted of 2 M HCl/0.1 M oxalic acid (and 0.0002 M HNO_3) with 50 ppm of Co, Zr, Ru, Cs and Ce and 10 ppm of Rh and Nb.

4.4.3. The low energy β mixture

The stock solutions of the individual radionuclides, were combined and diluted to 3 kg with carrier. This was used to make:

a) 1 x dilution bottle (approximately 700 g diluted to 20 kg).

Bottle (a) was then used to make:

b) 40 x 500 g @ 500 Bq kg^{-1}.

The carrier used throughout consisted of 0.001 M NaOH with 50 ppm of I.

To further validate the overall gravimetric dilution factors, selected customer samples were assayed by γ-ray spectrometry. The radiometric dilution factors were in good agreement with the gravimetric dilution factors.

5. TREATMENT OF DATA

5.1. NUMERICAL DATA

This year, data reporting forms were sent to the participants in an electronic form making the reporting of the data easier and faster. The data returned were used in conjunction with the reference values to calculate two parameters. First, the deviation from the reference value was calculated as a percentage:

$$\text{Deviation (\%)} = \frac{(\text{Analyst's result - Reference value}) \times 100}{\text{Reference value}}$$

The value of the u-statistic[17] was also calculated:

$$\text{u - statistic} = \frac{\left|(\text{Analyst's result - Reference value})\right|}{\sqrt{(\text{Analyst's uncertainty}^2 + \text{Uncertainty on reference value}^2)}}$$

This provides an indication of agreement between the two values. The uncertainty used is the standard uncertainty (with a coverage factor of $k = 1$). This statistic can be interpreted as set out in Table 13.

Note that, throughout this report, the term 'discrepant' is used to describe data yielding a u-statistic > 3.29.

5.2. UNCERTAINTIES

Uncertainties for the reference values have all been estimated in accordance with the internationally-accepted protocols[18,19]. Unless otherwise stated, all the uncertainties in this report are stated as standard uncertainties with a coverage factor of $k = 1$ (i.e. at the 68 % confidence level).

5.3. NUCLEAR DECAY DATA

The data used by the participants are discussed later; the data used by NPL in preparing and validating the samples are all given in Table 14. In each case, the γ-ray emission probabilities, P_γ, are only given if they exceed 1%.

Note: The recommended values stipulated in table 14 have been used for this exercise. CAIR 8[20] is the new NPL recommended reference for half-life data for a selection of isotopes.

5.4. PRESENTATION

The results of all the u-tests carried out are summarised in Tables 15 -17.

The participants' results for the radionuclides included in the samples by NPL are tabulated in Tables 18-45 and are plotted in Figures 1-60. Other radionuclides reported by the participants are given in Table 46.

5.5. CONFIDENTIALITY

As is usual in these exercises, the relationship between the participants and the results remains confidential to NPL.

6. RESULTS FOR α - AND β-EMITTERS

6.1. GENERAL COMMENTS

Following the previous exercise and workshop, the nuclides for inclusion in the α- and β- emitter containing samples was re-assessed. The same activity levels were offered for analysis as in previous exercises, with the exception of the low energy beta emitters where only one level was available. The following nuclides were included in the alpha beta mixtures in both high level samples and low level samples:

^{90}Sr, ^{99}Tc, ^{238}Pu, ^{239}Pu and ^{241}Am

The nuclides ^{14}C and ^{35}S were dropped and the nuclide ^{129}I was mixed with tritium to provide a low energy mixture.

The number of participants has increased together with the overall number of results returned for each nuclide. However the number of results reported for the nuclides contained in the alpha beta mixtures has decreased; this is particularly worrying for ^{90}Sr, where it was anticipated that with the increased time scales, wider participation was expected.

The participants used a variety of radiochemical analysis techniques to separate, purify and measure the individual nuclides in the mixtures. In all cases, traceable measurement standards and yield tracers were employed. The nuclear data sources were from recognized centres, and the wide usage of the Radiochemical Manual[21] was evident.

6.2. ^{3}H

As in previous exercises, participants separated the ^{3}H by distillation, with two laboratories carrying this out at low temperatures and one laboratory using combustion technique. All laboratories measured the ^{3}H by liquid scintillation counting. The overall performance has dropped, with 53% of the results not significantly different from the NPL value against 83% last year. The number of discrepant value (24%) has doubled since the last exercise. This may reflect the fact that the difficulty in the analysis of the tritium has been increased by the presence of ^{129}I in the mixture. There was one clear outlier, and it is not clear from the supplementary data supplied by participants what the reason for this is.

6.3. ^{129}I

The different methods used by the participants include gamma spectrometry of the sample directly, or by removing a measured amount. Many participants separated out the iodine and then measured the resulting solution/precipitate by gamma spectrometry or scintillation counting. One laboratory analysed the sample directly by ICP-MS. Whilst there is a significant spread in the results there is no obvious bias.

6.4. ^{90}Sr

Five results for the high level solution and seven results for the low level solution were reported. Radiochemical separation consisted of purification of strontium, followed by separation of the yttrium daughter. Yttrium-90 was then allowed to 'grow in' to the parent ^{90}Sr solution. After a known ingrowth period, the ^{90}Y was measured, either with a gas flow β counter or a liquid scintillation counter (including Cerenkov counting); one participant (Laboratory 1) used a plastic scintillator – this laboratory also quoted a very low uncertainty that may have been underestimated. Furthermore, one laboratory (Laboratory 48) used γ spectrometry to make the measurement (^{90}Y has a very low abundance γ emission), but this did not produce meaningful data. For both sets of data, there was only one result that was discrepant, and this may be a result of the low uncertainty quoted on their data, the absolute value being in good agreement with other participants.

6.5. ^{99}Tc

Four results were quoted for this nuclide in both solutions. The participants used a variety of separation techniques to purify the technetium that included both ion exchange chromatography and extraction chromatography. Sources were measured by radiometric and mass spectrometric (Laboratories 32 and 47) techniques. Where radiometric separation was employed, both gas flow β counting and liquid scintillation counting were used with one participant (Laboratory 28) employing electrodeposition to prepare a source. There appears to be no significant differences between the various techniques used, although the data set is rather small.

6.6. $^{238}Pu/^{239}Pu$

There were seven results reported for the high level solution and eleven for the low level solution. As with ^{99}Tc, a variety of separation techniques for plutonium purification including ion exchange chromatography and extraction chromatography were used. In all cases the measurement of an electrodeposited source by α-spectrometry was employed for the final assay. The main difference within the data set was the chemical yield tracer used; ^{236}Pu was used by 4 participants (Laboratories 25, 32, 41 and 47) with ^{242}Pu being used by the remainder. There is a suggestion that the results obtained by the laboratories using ^{236}Pu for the high level solution may be slightly lower than those using ^{242}Pu, but the difference is not significant. The results for the low level solution may exhibit a low bias, but, again, this is not significant.

6.7. ^{241}Am

There were thirteen sets of results returned for both levels. This nuclide is interesting as three radically different measurement techniques – α-spectrometry, γ-spectrometry and mass spectrometry – can be used to assay the samples. In this exercise, γ-spectrometry was used by six participants (Laboratories 8c, 15, 17b, 32b, 42 and 48), mass spectrometry by one participant (Laboratory 8b) and the remainder using radiochemical separation, followed by α-spectrometry, using similar techniques as for plutonium, except that ^{243}Am was used as a chemical yield tracer. Some of the uncertainties reported by the participants (Laboratories 1, 32a and 48) were low. In general there is no particular trend that can be observed for these results, and no identifiable cause for some of the outlying results (Laboratories 25 and 38).

7. RESULTS FOR β/γ-EMITTERS

7.1. GENERAL COMMENTS

A total of 32 laboratories took some β/γ samples with 7 opting for high level samples, 11 for low level samples and 14 carrying out the analysis at both levels. A similar mix to last time was adopted, with ^{22}Na and ^{57}Co being dropped and ^{144}Ce being added.

Most participants transferred the sample, without dilution, to a known geometry for γ-ray spectrometry, whilst around one third carried out a dilution or a volume reduction. All participants used semiconductor detectors, with p-type and n-type detectors being equally popular. Commercially-available data-handling software was universally used, with a majority of 'in-house' data libraries. NPL[22] and IAEA[23] nuclear data were the most widely adopted. As previously, most commonly used mixed radionuclide standards were from NPL, Amersham and AEA Technology.

7.2. ^{60}Co

This nuclide is an activation product and is a high-energy calibration point for mixed-radionuclide type standards. The high level results show some improvements with 78% of the data unambiguously correct against 63% for last year. The performance for the low level results has slightly decreased with 74% of the data not significantly different from the NPL value against 81% last year. A slight high level bias is observed.

7.3. ^{95}Zr

^{95}Zr is a fission product. The results for this nuclide are widely spread, with a clear high bias. This reflects the interferences observed with ^{154}Eu, however they should be apparent from the peak ratios. Some analysts still experience problems in analysing ^{95}Zr in the presence of ^{154}Eu.

7.4. ^{106}Ru/^{106}Rh

Ruthenium-106 is a fission product and is a pure β emitter; Rhodium-106 has low abundance γ rays. Ruthenium may be volatile and can therefore be distributed over a wide area, as happened at the Chernobyl accident. The number of discrepant data has increased since the last exercise and the results show a clear low bias of 0.880 ± 0.023. This nuclide exhibits cascade summing effects, but this factor alone cannot explain the bias observed. A satisfactory explanation has not yet been found about the observed large low bias.

7.5. ^{134}Cs

This nuclide is formed by neutron activation of stable caesium, it occurs in nuclear waste and is present in various ecosystems. The performance for this nuclide is similar to the last exercise. For the high level results, the number of discrepant data is equivalent to the number of unambiguously non-discrepant data (44%). Two laboratories have reported smaller uncertainties than NPL, both results are discrepant. The need for cascade summing corrections[24] has been emphasised in the previous exercise but, curiously, the low biases observed suggest that the participants fail to apply any correction.

7.6. ^{137}Cs

^{137}Cs is a fission product and is also used as a calibration nuclide. It occurs widely in the environment. Seventy percent of the data is not significantly different from the NPL value, which one would expect from a calibration nuclide. The number of discrepant data has increased since the last exercise. A slight positive bias is observed.

7.7. ^{144}Ce

This is another fission product. This nuclide had not been included in the environmental comparison exercise since 1993. The measurement of this nuclide is complicated by the fact that it emits low energy γ-rays (133.5 keV) in a part of the spectrum where the rate of change of detector efficiency with energy is large. Most of the results are statistically acceptable, with 76% of the results being indistinguishable from the NPL value. No bias is observed.

7.8. ^{154}Eu

This nuclide is formed by neutron activation of stable europium, and emits γ-rays across the whole γ-ray energy range. It is quite possible to misidentify this nuclide as one of several others, e.g. ^{22}Na, ^{57}Co, ^{95}Zr, ^{124}Sb and ^{152}Eu.

The overall performance has decreased significantly since the last exercise, 48% of the data is unambiguously non-discrepant against 77% for last year. Furthermore, the difficulty in analysing this nuclide has been reduced since the last exercise as the ^{22}Na and ^{57}Co interfering nuclides have been dropped. The results show a wide spread particularly at the lower level, and a small low bias suggesting that cascade summing corrections are not applied.

7.9. ^{155}Eu

This is another fission product with a low fission yield. As for the ^{144}Ce, the measurement of this nuclide is complicated by the fact that it emits low energy γ-rays in an energy range where the rate of change of detector efficiency with energy is large. The performance at the lower level is similar to last time, and performance at the higher level has improved, although the number of discrepant data is higher for both levels. A large spread is observed at low activity level.

8. DISCUSSION

8.1. α-EMITTERS

The level of participation for the α-emitting radionuclides was similar to recent exercises. The overall performance in the exercise is good, with few (~5%) unambiguously discrepant results (u-statistic > 3.29), most (~70%) of the results falling into the non-discrepant zone (u-statistic < 1.64) and the remainder (~25%) in the area where more data is needed to confirm agreement or deviation (1.64 < u-statistic < 3.29). The data does not reveal any differences arising from differing radiochemical analysis techniques, and, as noted for ^{241}Am, none that arise from the measurement technique employed.

8.2. β-EMITTERS

Due to the very low take up of ^{14}C and ^{35}S in the last comparison exercise, both nuclides were dropped and ^{129}I was added to tritium to provide the low energy mixture. ^{90}Sr was again supplied in the α/β mixture. As in the last comparison, the number of results returned was disappointingly low for most of these nuclides (the return for tritium being rather better). However, the measurement of ^{90}Sr and ^{99}Tc is important for the discharge of effluent and the measurement, sentencing and disposal of radioactive waste. The liquid scintillation analysis of ^{90}Sr and ^{99}Tc seems to give very accurate results. No other conclusions can be drawn about the analytical or measurement techniques used, although there appears to be no difference between mass spectrometry and radiometric measurement results for ^{99}Tc. In the light of a low return of data, it is difficult to draw conclusions about countrywide performance.

8.3. β/γ-EMITTERS

It is encouraging to see that the popularity of the β/γ samples is increasing and that all the participants submitted results.

The results seem to show several points:

(i) The overall performance has slightly decreased with 63.8% of the results clearly non-discrepant against 68.2% last year, and the number of clearly discrepant data is 17.5% against 15% last year.

(ii) Interferences between ^{154}Eu and candidate nuclides such as ^{22}Na, ^{57}Co, ^{95}Zr, ^{152}Eu gave rise to discrepant results and/or misidentification of the nuclides; a few participants reported results for ^{22}Na and ^{57}Co.

(iii) Cascade summing effects observed with the measurements of ^{106}Ru, ^{134}Cs and ^{154}Eu still present a problem for many analysts.

(iv) A number of participants reported either very small or very large uncertainties suggesting a need for a better evaluation of the uncertainties.

8.4. GENERAL COMMENTS

8.4.1. Nuclear Decay Data

The wide usage of data from internationally recognised sources continues. The vast majority of data cited for the α- and pure β-emitters was taken from the Radiochemical Manual[21] , but the data for β/γ-emitters was also drawn from other sources, most notably NPL[22], IAEA[23], JEF 2.2[25] and Browne and Firestone. Many participants used 'in-house' data libraries for the assay of the β/γ-emitters. A small number of participants used manufacturers' data, which is acceptable practice provided that the user checks the provenance of the data and makes adjustments as necessary.

The number of laboratories using data that has not come from a properly evaluated and maintained database (or are of unknown origin) is now very small. Analysts having any doubts as to the reliability of their data should consult NPL, who will gladly advise.

8.4.2. Standards

Of those laboratories who cited standards, all used β/γ-emitting standards of the mixed radionuclide type for measuring the β/γ-emitters, with one laboratory supplementing such a calibration with single nuclide standards; for the α/β assays, the standards and chemical yield tracers cited were obtained from NPL, NIST, Amersham or AEA Technology.

9. CONCLUSIONS

There are mixed conclusions to be drawn from this comparison exercise.

On the positive side, fewer discrepant results were submitted for the α/β-emitters than in past exercises. Also the usage of traceable standards and reliable nuclear data remains high. Many participants found the analysis of the low beta mix challenging due to the presence of the ^{129}I.

There are, however, some areas of concern. It seems that cascade summing effects are still evident (i.e. for ^{134}Cs, ^{154}Eu and ^{106}Ru measurements). The results suggest that not all laboratories are correcting efficiently for the interferences between some of the nuclides in the β/γ mixture; in some cases the evaluation of uncertainties has not been done correctly with a few laboratories reporting lower uncertainties than NPL; there has been a slight reduction in the number of unambiguously correct results for the β/γ mixture which was not to be expected as, with the removal of ^{57}Co and ^{22}Na, the mixture contained fewer nuclides which caused interferences than in the last comparison.

10. ACKNOWLEDGEMENTS

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Table 1 – ABH/03/*** - Principal radionuclides

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 ($Bq\ g^{-1}$)	Standard uncertainty ($k = 1$) ($Bq\ g^{-1}$)
^{90}Sr	β^-	9.631	0.018
^{99}Tc	β^-	3.563	0.010
^{238}Pu	α	2.228	0.007
^{239}Pu	α	2.656	0.011
^{241}Am	α/γ	2.466	0.018

Table 2 – ABH/03/*** - Impurities

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 ($Bq\ g^{-1}$)	Standard uncertainty ($k = 1$) ($Bq\ g^{-1}$)
^{241}Pu	β^-	0.018	-
unspecified α-emitters	α	< 0.001	-

Table 3 – ABL/03/*** - Principal radionuclides

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 ($Bq\ kg^{-1}$)	Standard uncertainty ($k = 1$) ($Bq\ kg^{-1}$)
^{90}Sr	β^-	11.942	0.035
^{99}Tc	β^-	4.418	0.017
^{238}Pu	α	2.763	0.011
^{239}Pu	α	3.293	0.016
^{241}Am	α/γ	3.058	0.023

Table 4 – ABL/03/*** - Impurities

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 ($Bq\ kg^{-1}$)	Standard uncertainty ($k = 1$) ($Bq\ kg^{-1}$)
^{241}Pu	β^-	0.022	-
unspecified α-emitters	α	< 0.001	-

Table 5 – LB/03/*** - Principal radionuclides

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 (Bq kg^{-1})	Standard uncertainty (k = 1) (Bq kg^{-1})
^{3}H	β^-	538.7	5.9
^{129}I	β^-	414.3	1.4

Table 6 – BGH/03/*** - Principal radionuclides

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 (Bq g^{-1})	Standard uncertainty (k = 1) (Bq g^{-1})
^{60}Co	β^-/γ	1.808	0.005
^{95}Zr	β^-/γ	4.184	0.036
^{106}Ru	β^-/γ	8.394	0.057
^{134}Cs	β^-/γ	3.168	0.023
^{137}Cs	β^-/γ	2.029	0.016
^{144}Ce	β^-/γ	7.649	0.062
^{154}Eu	β^-/γ	6.662	0.051
^{155}Eu	β^-/γ	4.539	0.051

Table 7 – BGH/03/*** Other nuclides

Radionuclide	Decay mode	Activity concentration @1200 GMT 01/03/04 (Bq g^{-1})	Standard uncertainty (k = 1) (Bq g^{-1})
^{95}Nb	β^-/γ	9.393	0.079

Table 8 – BGH/03/*** Impurities

Radionuclide	Decay mode	Activity concentration @1200 GMT 01/03/04 (Bq g^{-1})	Standard uncertainty (k = 1) (Bq g^{-1})
^{152}Eu	ε, β^-/γ	0.483	0.020
^{65}Zn	ε, β^+/γ	0.0752	0.0007
^{125}Sb	β^-/γ	0.0207	0.0017
^{141}Ce	β^-/γ	0.0035	0.0003
^{103}Ru	β^-/γ	0.0014	0.0004

Table 9 – BGL/03/*** Principal radionuclides

Radionuclide	Decay mode	Activity concentration @ 1200 GMT 01/03/04 (Bq kg^{-1})	Standard uncertainty (k = 1) (Bq kg^{-1})
^{60}Co	β^-/γ	2.247	0.007
^{95}Zr	β^-/γ	5.200	0.045
^{106}Ru	β^-/γ	10.431	0.073
^{134}Cs	β^-/γ	3.937	0.029
^{137}Cs	β^-/γ	2.522	0.021
^{144}Ce	β^-/γ	9.505	0.078
^{154}Eu	β^-/γ	8.279	0.065
^{155}Eu	β^-/γ	5.641	0.064

Table 10 – BGL/03/*** Other nuclides

Radionuclide	Decay mode	Activity concentration @1200 GMT 01/03/04 (Bq kg^{-1})	Standard uncertainty (k = 1) (Bq kg^{-1})
^{95}Nb	β^-/γ	11.673	0.100

Table 11 – BGL/03/*** Impurities

Radionuclide	Decay mode	Activity concentration @1200 GMT 01/03/04 (Bq g^{-1})	Standard uncertainty (k = 1) (Bq g^{-1})
^{152}Eu	ε, β^-/γ	0.601	0.025
^{65}Zn	ε, β^+/γ	0.0935	0.0008
^{125}Sb	β^-/γ	0.0257	0.0021
^{141}Ce	β^-/γ	0.0043	0.0004
^{103}Ru	β^-/γ	0.0018	0.0006

Table 12 – Radionuclide Provenance

Radionuclide	Origin	Calibrating Laboratory	Traceability
Sr-90	NPL, UK	NPL	UK Primary Standard/NPL
Tc-99	NPL, UK	NPL	UK Primary Standard/NPL
Pu-238	TENEX, Russia	NPL	UK Primary Standard/NPL
Pu-239	TENEX, Russia	NPL	UK Primary Standard/NPL
Am-241	NA, UK	NPL	UK Primary Standard/NPL
H-3	NA, UK	NPL	UK Primary Standard/NPL
I-129	NPL, UK	NPL	UK Primary Standard/NPL
Co-60	NA, UK	NPL	UK Primary Standard/NPL
Zr-95	ES, Czech Republic	NPL	UK Primary Standard/NPL
Ru-106	ES, Czech Republic	NPL	UK Primary Standard/NPL
Cs-134	NA, UK	NPL	UK Primary Standard/NPL
Cs-137	NA, UK	NPL	UK Primary Standard/NPL
Ce-144	ES, Czech Republic	NPL	UK Primary Standard/NPL
Eu-154	NA, UK	NPL	UK Primary Standard/NPL
Eu-155	IIR, Czech Republic	NPL	UK Primary Standard/NPL

TENEX: TENEX All-Union Foreign Economic Association Techsnabexport, Russia
NA: Nycomed-Amersham, UK
IIR: Inspektorát pro Ionizující Zåreni, Czech Republic
ES: Eurostandard CZ, Czech Republic

Table 13 – Criteria for u-tests

Value	Conclusion
u < 1.64	The values do not differ significantly
1.64 < u < 1.96	The values probably do not differ significantly but more data are required to confirm this
1.96 < u < 2.58	One cannot say whether there is a significant difference without further data
2.58 < u < 3.29	The values probably differ significantly but more data are required to confirm this
3.29 < u	The values differ significantly

Table 14 – Nuclear decay data

Nuclide	Half life (days)	Eγ (keV)	Pγ (%)	Reference
^{3}H	4504 ± 8	-	-	[25]
^{60}Co	1925.5 ± 0.5	1173.2	99.857 ± 0.022	[23]
		1332.5	99.983 ± 0.006	[23]
^{90}Sr	10460 ± 60	-	-	[23]
^{95}Zr	64.03 ± 0.03	724.199	43.9 ± 0.8	[28]
		756.729	54.5 ± 0.5	[28]
^{99}Tc	(7.718 ± 0.040) x 10^{7}	-	-	[22]
^{106}Ru	368.2 ± 1.2	511.9	20.7 ± 0.6	[23]
		621.8	9.81 ± 0.58	[25]
		1050.4	1.50 ± 0.11	[23]
^{129}I	(5.73 ± 0.15) x 10^{9}	39.6	7.5 ± 0.2	[22]
^{134}Cs	754.28 ± 0.22	475.4	1.49 ± 0.02	[23]
		563.2	8.36 ± 0.03	[23]
		569.3	15.39 ± 0.06	[23]
		604.7	97.63 ± 0.06	[23]
		795.9	85.4 ± 0.3	[23]

Nuclide	Half life (days)	Eγ (keV)	Pγ (%)	Reference
		801.9	8.69 ± 0.03	[23]
		1168.0	1.792 ± 0.007	[23]
		1365.2	3.016 ± 0.011	[23]
^{137}Cs	11020 ± 60	661.7	85.1 ± 0.2	[23]
^{144}Ce	284.9 ± 0.2	80.1	1.36 ± 0.06	[22]
		133.5	11.09 ± 0.20	[22]
		696.5	1.342 ± 0.014	[22]
^{154}Eu	3136.8 ± 2.9	123.1	41.2 ± 0.5	[23]
		247.9	6.95 ± 0.09	[23]
		591.8	4.99 ± 0.06	[23]
		692.4	1.80 ± 0.03	[23]
		723.3	20.2 ± 0.2	[23]
		756.8	4.58 ± 0.06	[23]
		873.2	12.24 ± 0.15	[23]
		996.3	10.48 ± 0.13	[23]
		1004.7	18.2 ± 0.2	[23]
		1274.4	35.0 ± 0.4	[23]
^{155}Eu	1770 ± 50	60.0	1.13 ± 0.05	[23]/[26]
		86.5	30.7 ± 0.7	[27]
		105.3	21.2± 0.5`	[27]
^{238}Pu	32030 ± 110	-	-	[27]
^{239}Pu	(8.806 ± 0.011) x 10^6	-	-	[27]
^{241}Am	(1.5785 ± 0.0024) x 10^5	59.5	36.0 ± 0.4	[23]

Table 15 – Results of u-tests for α/β-emitters

NUCLIDE	LIMITS	NUMBER OF RESULTS HIGH LEVEL	NUMBER OF RESULTS LOW LEVEL
^{90}Sr	< 1.64	4	6
	1.64 - 1.96	0	0
	1.96 - 2.58	0	0
	2.58 - 3.29	0	0
	> 3.29	1	1
^{99}Tc	< 1.64	3	3
	1.64 - 1.96	0	1
	1.96 - 2.58	0	0
	2.58 - 3.29	1	0
	> 3.29	0	0
^{238}Pu	< 1.64	6	6
	1.64 - 1.96	1	3
	1.96 - 2.58	0	0
	2.58 - 3.29	0	2
	> 3.29	0	0
^{239}Pu	< 1.64	5	9
	1.64 - 1.96	0	1
	1.96 - 2.58	1	1
	2.58 - 3.29	0	0
	> 3.29	1	0
^{241}Am	< 1.64	9	10
	1.64 - 1.96	1	0
	1.96 - 2.58	2	0
	2.58 - 3.29	1	1
	> 3.29	0	2

Table 16 – Results of u-tests for low energy β-emitters

NUCLIDE	LIMITS	NUMBER OF RESULTS
^{3}H	< 1.64	9
	1.64 - 1.96	1
	1.96 - 2.58	1
	2.58 - 3.29	2
	> 3.29	4
^{129}I	< 1.64	5
	1.64 - 1.96	0
	1.96 - 2.58	1
	2.58 - 3.29	0
	> 3.29	5

Table 17 – Results of u-tests for β/γ-emitters

NUCLIDE	LIMITS	NUMBER OF RESULTS HIGH LEVEL	NUMBER OF RESULTS LOW LEVEL
^{60}Co	< 1.64	18	17
	1.64 - 1.96	0	2
	1.96 - 2.58	1	1
	2.58 - 3.29	2	0
	> 3.29	2	3
^{95}Zr	< 1.64	11	16
	1.64 - 1.96	2	2
	1.96 - 2.58	3	1
	2.58 - 3.29	1	3
	> 3.29	6	2
^{106}Ru	< 1.64	7	13
	1.64 - 1.96	2	2
	1.96 - 2.58	1	0
	2.58 - 3.29	1	1
	> 3.29	8	3
^{134}Cs	< 1.64	10	15
	1.64 - 1.96	0	2
	1.96 - 2.58	1	3
	2.58 - 3.29	2	2
	> 3.29	10	2
^{137}Cs	< 1.64	16	17
	1.64 - 1.96	1	1
	1.96 - 2.58	2	3
	2.58 - 3.29	3	0
	> 3.29	1	3
^{144}Ce	< 1.64	17	17
	1.64 - 1.96	2	0
	1.96 - 2.58	1	1
	2.58 - 3.29	0	1
	> 3.29	3	3
^{154}Eu	< 1.64	13	9
	1.64 - 1.96	1	4
	1.96 - 2.58	2	2
	2.58 - 3.29	1	2
	> 3.29	6	6
^{155}Eu	< 1.64	17	16
	1.64 - 1.96	1	2
	1.96 - 2.58	0	1
	2.58 - 3.29	1	0
	> 3.29	2	3

Table 18 – Results for ^{90}Sr (ABH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
Lab N°	^{90}Sr Bq g^{-1}	± Bq g^{-1}	^{90}Sr Bq g^{-1}	± Bq g^{-1}		
Lab 1	9.631	0.018	9.3	0.05	-3.44	6.23
Lab 8	9.631	0.018	8.18	1.68	-15.07	0.86
Lab 32	9.631	0.018	9.27	0.49	-3.75	0.74
Lab 35	9.631	0.018	8.5	1	-11.74	1.13
Lab 41	9.631	0.018	9.65	0.6	0.20	0.03

Table 19 – Results for ^{99}Tc (ABH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{99}Tc Bq g^{-1}	± Bq g^{-1}	^{99}Tc Bq g^{-1}	± Bq g^{-1}		
Lab 1	3.563	0.010	3.6	0.4	1.04	0.09
Lab 8	3.563	0.010	3.36	0.35	-5.70	0.58
Lab 32	3.563	0.010	3.05	0.16	-14.40	3.20
Lab 47	3.563	0.010	3.36	0.51	-5.70	0.40

Table 20 – Results for ^{238}Pu (ABH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{238}Pu Bq g^{-1}	± Bq g^{-1}	^{238}Pu Bq g^{-1}	± Bq g^{-1}		
Lab 1	2.228	0.007	2.18	0.05	-2.15	0.95
Lab 8	2.228	0.007	2.22	0.14	-0.36	0.06
Lab 17	2.228	0.007	2.32	0.14	4.13	0.66
Lab 32	2.228	0.007	2.204	0.035	-1.08	0.67
Lab 35	2.228	0.007	2.25	0.56	0.99	0.04
Lab 41	2.228	0.007	2.098	0.068	-5.83	1.90
Lab 47	2.228	0.007	2.16	0.1	-3.05	0.68

Table 21 – Results for ^{239}Pu (ABH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{239}Pu Bq g^{-1}	± Bq g^{-1}	^{239}Pu Bq g^{-1}	± Bq g^{-1}		
Lab 1	2.656	0.011	2.65	0.05	-0.23	0.12
Lab 8	2.656	0.011	2.64	0.16	-0.60	0.10
Lab 17	2.656	0.011	7.5	0.43	182.38	11.26
Lab 32	2.656	0.011	2.625	0.040	-1.17	0.75
Lab 35	2.656	0.011	2.69	0.067	1.28	0.50
Lab 41	2.656	0.011	2.491	0.079	-6.21	2.07
Lab 47	2.656	0.011	2.55	0.13	-3.99	0.81

Table 22 – Results for ^{241}Am (ABH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{241}Am	±	^{241}Am	±		
	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}		
Lab 1	2.466	0.018	2.4	0.03	-2.68	1.89
Lab 8a	2.466	0.018	2.65	0.25	7.46	0.73
Lab 8b	2.466	0.018	2.65	0.27	7.46	0.68
Lab 8c	2.466	0.018	2.4	0.24	-2.68	0.27
Lab 15	2.466	0.018	2.59	0.05	5.03	2.33
Lab 17a	2.466	0.018	2.42	0.12	-1.87	0.38
Lab 17b	2.466	0.018	2.43	0.1	-1.46	0.35
Lab 32a	2.466	0.018	2.380	0.027	-3.49	2.65
Lab 32b	2.466	0.018	2.432	0.056	-1.38	0.58
Lab 35	2.466	0.018	2.65	0.12	7.46	1.52
Lab 41	2.466	0.018	2.253	0.084	-8.64	2.48
Lab 47	2.466	0.018	2.52	0.27	2.19	0.20
Lab 48	2.466	0.018	2.50	0.04	1.38	0.78

Table 23 – Results for ^{90}Sr (ABL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{90}Sr	±	^{90}Sr	±		
	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}		
Lab 1	11.942	0.035	10.7	0.1	-10.40	11.72
Lab 8	11.942	0.035	11.2	1.63	-6.21	0.46
Lab 13	11.942	0.035	11.0	0.695	-7.89	1.35
Lab 25	11.942	0.035	12.12	0.91	1.49	0.20
Lab 28	11.942	0.035	12	1.7	0.49	0.03
Lab 38	11.942	0.035	11.72	0.51	-1.86	0.43
Lab 40	11.942	0.035	11.9	1.64	-0.35	0.03

Table 24 – Results for ^{99}Tc (ABL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{99}Tc Bq kg^{-1}	± Bq kg^{-1}	^{99}Tc Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	4.418	0.017	4.6	0.7	4.12	0.26
Lab 8	4.418	0.017	3.31	0.66	-25.08	1.68
Lab 13	4.418	0.017	3.85	0.46	-12.86	1.23
Lab 28	4.418	0.017	5.5	0.8	24.49	1.35

Table 25 – Results for ^{238}Pu (ABL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{238}Pu Bq kg^{-1}	± Bq kg^{-1}	^{238}Pu Bq kg^{-1}	± Bq kg^{-1}		
Lab 4	2.763	0.011	2.55	0.08	-7.71	2.64
Lab 8	2.763	0.011	2.73	0.25	-1.19	0.13
Lab 13	2.763	0.011	2.65	0.1	-4.09	1.12
Lab 17	2.763	0.011	2.67	0.16	-3.37	0.58
Lab 19	2.763	0.011	2.73	0.1	-1.19	0.33
Lab 25	2.763	0.011	2.31	0.17	-16.40	2.66
Lab 28	2.763	0.011	2.73	0.1	-1.19	0.33
Lab 29	2.763	0.011	3.1	0.2	12.20	1.68
Lab 38	2.763	0.011	2.59	0.10	-6.26	1.72
Lab 40	2.763	0.011	2.797	0.068	1.23	0.49
Lab 47	2.763	0.011	2.56	0.12	-7.35	1.68

Table 26 – Results for ^{239}Pu (ABL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{239}Pu Bq kg^{-1}	± Bq kg^{-1}	^{239}Pu Bq kg^{-1}	± Bq kg^{-1}		
Lab 4	3.293	0.016	3.13	0.09	-4.95	1.78
Lab 8	3.293	0.016	3.32	0.29	0.82	0.09
Lab 13	3.293	0.016	3.25	0.12	-1.31	0.36
Lab 17	3.293	0.016	3.51	0.20	6.59	1.08
Lab 19	3.293	0.016	3.27	0.1	-0.70	0.23
Lab 25	3.293	0.016	3.07	0.22	-6.77	1.01
Lab 28	3.293	0.016	3.15	0.16	-4.34	0.89
Lab 29	3.293	0.016	3.2	0.2	-2.82	0.46
Lab 38	3.293	0.016	3.16	0.12	-4.04	1.10
Lab 40	3.293	0.016	3.477	0.081	5.59	2.23
Lab 47	3.293	0.016	3.25	0.36	-1.31	0.12

Table 27 – Results for ^{241}Am (ABL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{241}Am Bq kg^{-1}	± Bq kg^{-1}	^{241}Am Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	3.058	0.023	2.97	0.4	-2.88	0.22
Lab 8	3.058	0.023	2.95	0.36	-3.53	0.30
Lab 13	3.058	0.023	3.13	0.11	2.35	0.64
Lab 15	3.058	0.023	2.85	0.28	-6.80	0.74
Lab 17	3.058	0.023	2.96	0.21	-3.20	0.46
Lab 25	3.058	0.023	2.37	0.15	-22.50	4.53
Lab 28	3.058	0.023	3.04	0.19	-0.59	0.09
Lab 29	3.058	0.023	2.89	0.15	-5.49	1.11
Lab 38	3.058	0.023	2.37	0.08	-22.50	8.27
Lab 40	3.058	0.023	3.292	0.083	7.65	2.72
Lab 42	3.058	0.023	3.29	0.6	7.59	0.39
Lab 47	3.058	0.023	3.12	0.28	2.03	0.22
Lab 48	3.058	0.023	2.90	0.13	-5.17	1.20

Table 28 – Results for ^{3}H (LB/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{3}H Bq kg^{-1}	± Bq kg^{-1}	^{3}H Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	538.7	5.9	520	10	-3.47	1.61
Lab 4	538.7	5.9	462.1	27.3	-14.22	12.98
Lab 5	538.7	5.9	527	53	-2.17	0.22
Lab 6	538.7	5.9	481.2	1.3	-10.67	9.52
Lab 8	538.7	5.9	567	64	5.25	0.44
Lab 9	538.7	5.9	528.86	22.05	-1.83	0.43
Lab 13	538.7	5.9	540.6	45.9	0.35	0.04
Lab 16	538.7	5.9	569.8	21.48	5.77	1.40
Lab 17	538.7	5.9	566.7	24	5.20	1.13
Lab 19	538.7	5.9	500.0	11	-7.18	3.10
Lab 25	538.7	5.9	611.0	26	13.42	2.71
Lab 28	538.7	5.9	569.0	27	5.62	1.10
Lab 32	538.7	5.9	492	20	-8.67	2.24
Lab 38a	538.7	5.9	491	26	-8.85	1.79
Lab 38b	538.7	5.9	536	42	-0.50	0.06
Lab 40	538.7	5.9	633	20	17.51	4.52
Lab 41	538.7	5.9	907	21.8	68.37	16.31

Table 29 – Results for ^{129}I (LB/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{129}I	±	^{129}I	±		
	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}		
Lab 1	414.3	1.4	471	8	13.69	6.98
Lab 8	414.3	1.4	405	30	-2.24	0.31
Lab 13	414.3	1.4	444.7	22.38	7.34	1.36
Lab 25	414.3	1.4	361	25	-12.87	2.13
Lab 28	414.3	1.4	204	14	-50.76	14.95
Lab 32a	414.3	1.4	490	61	18.27	1.24
Lab 32b	414.3	1.4	500	23	20.69	3.72
Lab 32c	414.3	1.4	468	34	12.96	1.58
Lab 38	414.3	1.4	391	22	-5.62	1.06
Lab 40	414.3	1.4	562.53	20.87	35.78	7.09
Lab 48	414.3	1.4	357	2	-13.83	23.47

Table 30 – Results for ^{60}Co (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co Bq g^{-1}	± Bq g^{-1}	^{60}Co Bq g^{-1}	± Bq g^{-1}		
Lab 1	1.808	0.005	1.84	0.01	1.77	2.86
Lab 3	1.808	0.005	1.9	0.04	5.09	2.28
Lab 4	1.808	0.005	1.9	0.4	5.09	0.23
Lab 5	1.808	0.005	1.86	0.19	2.88	0.27
Lab 6	1.808	0.005	1.82	0.02	0.66	0.58
Lab 7	1.808	0.005	1.87	0.06	3.43	1.03
Lab 8	1.808	0.005	1.81	0.06	0.11	0.03
Lab 9a	1.808	0.005	1.743	0.055	-3.60	1.18
Lab 9b	1.808	0.005	1.747	0.044	-3.37	1.38
Lab 10	1.808	0.005	1.83	0.06	1.22	0.37
Lab 15	1.808	0.005	2.13	0.09	17.81	3.57
Lab 16	1.808	0.005	1.89	0.252	4.54	0.33
Lab 17	1.808	0.005	1.84	0.06	1.77	0.53
Lab 25	1.808	0.005	1.83	0.17	1.22	0.13
Lab 27	1.808	0.005	2.8	0.9	54.87	1.10
Lab 28	1.808	0.005	1.67	0.18	-7.63	0.77
Lab 32	1.808	0.005	1.834	0.025	1.44	1.02
Lab 35	1.808	0.005	1.81	0.05	0.11	0.04
Lab 41	1.808	0.005	1.91	0.0325	5.64	3.10
Lab 45	1.808	0.005	1.719	0.064	-4.92	1.39
Lab 46	1.808	0.005	1.81	0.13	0.11	0.02
Lab 47	1.808	0.005	1.78	0.13	-1.55	0.22
Lab 48	1.808	0.005	1.71	0.01	-5.42	8.77

Table 31 – Results for ^{95}Zr (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{95}Zr Bq g^{-1}	± Bq g^{-1}	^{95}Zr Bq g^{-1}	± Bq g^{-1}		
Lab 1	4.184	0.036	4.29	0.04	2.53	1.97
Lab 3	4.184	0.036	4.22	0.14	0.86	0.25
Lab 4	4.184	0.036	5.6	0.6	33.84	2.36
Lab 5	4.184	0.036	5.19	0.52	24.04	1.93
Lab 6	4.184	0.036	4.68	0.05	11.85	8.05
Lab 7	4.184	0.036	3.4	0.12	-18.74	6.26
Lab 8	4.184	0.036	4.05	0.16	-3.20	0.82
Lab 9a	4.184	0.036	4.718	0.187	12.76	2.80
Lab 9b	4.184	0.036	4.425	0.094	5.76	2.39
Lab 10	4.184	0.036	5.57	0.18	33.13	7.55
Lab 15	4.184	0.036	5.86	0.26	40.06	6.39
Lab 16	4.184	0.036	4.17	0.658	-0.33	0.02
Lab 17	4.184	0.036	5.78	0.21	38.15	7.49
Lab 25	4.184	0.036	4.94	0.47	18.07	1.60
Lab 27	4.184	0.036	6.5	1.7	55.35	1.36
Lab 28	4.184	0.036	3.75	0.39	-10.37	1.11
Lab 32	4.184	0.036	4.345	0.079	3.85	1.85
Lab 35	4.184	0.036	5.39	0.15	28.82	7.82
Lab 41	4.184	0.036	4.01	0.108	-4.16	1.53
Lab 45	4.184	0.036	4.012	0.181	-4.11	0.93
Lab 46	4.184	0.036	4.12	0.42	-1.53	0.15
Lab 47	4.184	0.036	4.04	0.27	-3.44	0.53
Lab 48	4.184	0.036	4.23	0.08	1.10	0.52

Table 32 – Results for ^{106}Ru (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{106}Ru Bq g^{-1}	± Bq g^{-1}	^{106}Ru Bq g^{-1}	± Bq g^{-1}		
Lab 1	8.394	0.057	7.2	0.3	-14.22	3.91
Lab 3	8.394	0.057	6.93	0.21	-17.44	6.73
Lab 4	8.394	0.057	7.1	0.8	-15.42	1.61
Lab 5	8.394	0.057	7.62	0.76	-9.22	1.02
Lab 6	8.394	0.057	7.55	0.12	-10.05	6.35
Lab 7	8.394	0.057	6.54	0.36	-22.09	5.09
Lab 8	8.394	0.057	7.78	0.31	-7.31	1.95
Lab 9a	8.394	0.057	6.807	0.189	-18.91	8.04
Lab 9b	8.394	0.057	7.139	0.189	-14.95	6.36
Lab 10	8.394	0.057	6.84	0.10	-18.51	13.50
Lab 16	8.394	0.057	7.67	0.552	-8.63	1.30
Lab 25	8.394	0.057	7.13	0.67	-15.06	1.88
Lab 27	8.394	0.057	10.5	2.5	25.09	0.84
Lab 28	8.394	0.057	6.64	0.88	-20.90	1.99
Lab 32	8.394	0.057	8.02	0.36	-4.46	1.03
Lab 35	8.394	0.057	7.09	0.46	-15.53	2.81
Lab 46	8.394	0.057	7.87	0.59	-6.24	0.88
Lab 47	8.394	0.057	7.88	0.8	-6.12	0.64
Lab 48	8.394	0.057	6.84	0.06	-18.51	18.78

Table 33 – Results for ^{134}Cs (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{134}Cs Bq g^{-1}	± Bq g^{-1}	^{134}Cs Bq g^{-1}	± Bq g^{-1}		
Lab 1	3.168	0.023	2.91	0.02	-8.14	8.46
Lab 3	3.168	0.023	2.61	0.04	-17.61	12.09
Lab 4	3.168	0.023	3.2	0.4	1.01	0.08
Lab 5	3.168	0.023	2.91	0.29	-8.14	0.89
Lab 6	3.168	0.023	2.95	0.04	-6.88	4.72
Lab 7	3.168	0.023	2.82	0.09	-10.98	3.75
Lab 8	3.168	0.023	3.21	0.1	1.33	0.41
Lab 9a	3.168	0.023	2.726	0.08	-13.95	5.31
Lab 9b	3.168	0.023	2.805	0.071	-11.46	4.86
Lab 10	3.168	0.023	2.97	0.09	-6.25	2.13
Lab 15	3.168	0.023	3.74	0.16	18.06	3.54
Lab 16	3.168	0.023	2.88	0.314	-9.09	0.91
Lab 17	3.168	0.023	3.36	0.13	6.06	1.45
Lab 25	3.168	0.023	2.82	0.26	-10.98	1.33
Lab 27	3.168	0.023	4.3	1	35.73	1.13
Lab 28	3.168	0.023	2.54	0.24	-19.82	2.60
Lab 32	3.168	0.023	3.221	0.060	1.67	0.82
Lab 35	3.168	0.023	2.95	0.08	-6.88	2.62
Lab 41	3.168	0.023	2.85	0.0413	-10.04	6.73
Lab 45	3.168	0.023	2.601	0.152	-17.90	3.69
Lab 46	3.168	0.023	3.13	0.23	-1.20	0.16
Lab 47	3.168	0.023	3.08	0.2	-2.78	0.44
Lab 48	3.168	0.023	2.81	0.02	-11.30	11.75

Table 34 – Results for ^{137}Cs (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{137}Cs	±	^{137}Cs	±		
	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}		
Lab 1	2.029	0.016	2.11	0.02	3.99	3.16
Lab 3	2.029	0.016	2.16	0.07	6.46	1.82
Lab 4	2.029	0.016	2.3	0.3	13.36	0.90
Lab 5	2.029	0.016	2.08	0.21	2.51	0.24
Lab 6	2.029	0.016	2.03	0.03	0.05	0.03
Lab 7	2.029	0.016	2.11	0.07	3.99	1.13
Lab 8	2.029	0.016	1.99	0.06	-1.92	0.63
Lab 9a	2.029	0.016	1.975	0.068	-2.66	0.77
Lab 9b	2.029	0.016	2.036	0.055	0.34	0.12
Lab 10	2.029	0.016	2.18	0.07	7.44	2.10
Lab 15	2.029	0.016	2.47	0.11	21.73	3.97
Lab 16	2.029	0.016	2.22	0.183	9.41	1.04
Lab 17	2.029	0.016	2.24	0.08	10.40	2.59
Lab 25	2.029	0.016	2.06	0.19	1.53	0.16
Lab 27	2.029	0.016	3.3	0.8	62.64	1.59
Lab 28	2.029	0.016	1.88	0.18	-7.34	0.82
Lab 32	2.029	0.016	2.072	0.031	2.12	1.23
Lab 35	2.029	0.016	2.12	0.06	4.48	1.47
Lab 41	2.029	0.016	2.15	0.0354	5.96	3.11
Lab 45	2.029	0.016	2.007	0.064	-1.08	0.33
Lab 46	2.029	0.016	2.05	0.15	1.03	0.14
Lab 47	2.029	0.016	2.01	0.13	-0.94	0.15
Lab 48	2.029	0.016	2.08	0.02	2.51	1.99

Table 35 – Results for ^{144}Ce (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{144}Ce Bq g^{-1}	± Bq g^{-1}	^{144}Ce Bq g^{-1}	± Bq g^{-1}		
Lab 1	7.649	0.062	7.6	0.2	-0.64	0.23
Lab 3	7.649	0.062	7.85	0.38	2.63	0.52
Lab 4	7.649	0.062	6.8	0.8	-11.10	1.06
Lab 5	7.649	0.062	7.05	0.71	-7.83	0.84
Lab 6	7.649	0.062	7.49	0.07	-2.08	1.70
Lab 7	7.649	0.062	7.85	0.26	2.63	0.75
Lab 8	7.649	0.062	7.87	0.23	2.89	0.93
Lab 9a	7.649	0.062	7.438	0.232	-2.76	0.88
Lab 9b	7.649	0.062	7.762	0.215	1.48	0.51
Lab 10	7.649	0.062	8.29	0.26	8.38	2.40
Lab 15	7.649	0.062	9.62	0.41	25.77	4.75
Lab 16	7.649	0.062	8.49	0.637	10.99	1.31
Lab 17	7.649	0.062	8.09	0.3	5.77	1.44
Lab 25	7.649	0.062	7.89	0.74	3.15	0.32
Lab 27	7.649	0.062	9.6	2.5	25.51	0.78
Lab 28	7.649	0.062	7.13	0.68	-6.79	0.76
Lab 32	7.649	0.062	7.30	0.19	-4.56	1.75
Lab 35	7.649	0.062	7.6	0.24	-0.64	0.20
Lab 41	7.649	0.062	8.43	0.204	10.21	3.66
Lab 45	7.649	0.062	7.828	0.968	2.34	0.18
Lab 46	7.649	0.062	7.72	0.56	0.93	0.13
Lab 47	7.649	0.062	7.61	0.49	-0.51	0.08
Lab 48	7.649	0.062	7.18	0.08	-6.13	4.63

Table 36 – Results for ^{154}Eu (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{154}Eu Bq g^{-1}	± Bq g^{-1}	^{154}Eu Bq g^{-1}	± Bq g^{-1}		
Lab 1	6.662	0.051	6.15	0.04	-7.69	7.90
Lab 3	6.662	0.051	6.30	0.07	-5.43	4.18
Lab 4	6.662	0.051	6.8	0.7	2.07	0.20
Lab 5	6.662	0.051	6.55	0.66	-1.68	0.17
Lab 6	6.662	0.051	6.52	0.03	-2.13	2.40
Lab 7	6.662	0.051	6.9	0.25	3.57	0.93
Lab 8	6.662	0.051	6.95	0.27	4.32	1.05
Lab 9a	6.662	0.051	5.793	0.147	-13.04	5.58
Lab 9b	6.662	0.051	6.23	0.145	-6.45	2.80
Lab 10	6.662	0.051	6.47	0.19	-2.88	0.98
Lab 15	6.662	0.051	8.39	0.36	25.94	4.75
Lab 16	6.662	0.051	6.61	0.724	-0.78	0.07
Lab 17	6.662	0.051	6.79	0.25	1.92	0.50
Lab 25	6.662	0.051	5.96	0.56	-10.54	1.25
Lab 27	6.662	0.051	7.3	1.6	9.58	0.40
Lab 28	6.662	0.051	5.5	0.51	-17.44	2.27
Lab 32	6.662	0.051	6.77	0.16	1.62	0.64
Lab 35	6.662	0.051	5.72	0.21	-14.14	4.36
Lab 41	6.662	0.051	6.52	0.118	-2.13	1.10
Lab 45	6.662	0.051	6.079	0.337	-8.75	1.71
Lab 46	6.662	0.051	6.77	0.68	1.62	0.16
Lab 47	6.662	0.051	6.34	0.4	-4.83	0.80
Lab 48	6.662	0.051	5.67	0.05	-14.89	13.89

Table 37 – Results for ^{155}Eu (BGH/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co	±	^{60}Co	±		
	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}	Bq g^{-1}		
Lab 1	4.539	0.051	4.9	0.4	7.95	0.90
Lab 3	4.539	0.051	4.33	0.15	-4.60	1.32
Lab 4	4.539	0.051	4.4	0.5	-3.06	0.28
Lab 5	4.539	0.051	4.94	0.49	8.83	0.81
Lab 6	4.539	0.051	4.92	0.04	8.39	5.88
Lab 7	4.539	0.051	4.82	0.18	6.19	1.50
Lab 8	4.539	0.051	4.6	0.19	1.34	0.31
Lab 9a	4.539	0.051	3.809	0.115	-16.08	5.80
Lab 9b	4.539	0.051	4.347	0.105	-4.23	1.64
Lab 10	4.539	0.051	4.66	0.14	2.67	0.81
Lab 15	4.539	0.051	4.8	0.2	5.75	1.26
Lab 16	4.539	0.051	4.35	0.59	-4.16	0.32
Lab 17	4.539	0.051	4.78	0.18	5.31	1.29
Lab 28	4.539	0.051	4.38	0.47	-3.50	0.34
Lab 32	4.539	0.051	4.44	0.093	-2.18	0.93
Lab 35	4.539	0.051	4.66	0.35	2.67	0.34
Lab 41	4.539	0.051	4.74	0.149	4.43	1.28
Lab 45	4.539	0.051	4.541	0.297	0.04	0.01
Lab 46	4.539	0.051	4.63	0.33	2.00	0.27
Lab 47	4.539	0.051	4.65	0.31	2.45	0.35
Lab 48	4.539	0.051	4.18	0.1	-7.91	3.20

Table 38 – Results for ^{60}Co (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co Bq kg^{-1}	± Bq kg^{-1}	^{60}Co Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	2.247	0.007	1.9	0.2	-15.44	1.73
Lab 3	2.247	0.007	2.28	0.14	1.47	0.24
Lab 5	2.247	0.007	2.49	0.25	10.81	0.97
Lab 7	2.247	0.007	2.63	0.48	17.04	0.80
Lab 8	2.247	0.007	2.38	0.14	5.92	0.95
Lab 10	2.247	0.007	2.32	0.26	3.25	0.28
Lab 13	2.247	0.007	2.08	0.09	-7.43	1.85
Lab 15	2.247	0.007	2.60	0.30	15.71	1.18
Lab 17	2.247	0.007	1.54	0.15	-31.46	4.71
Lab 18	2.247	0.007	2.1	0.3	-6.54	0.49
Lab 19	2.247	0.007	2.3	0.15	2.36	0.35
Lab 23	2.247	0.007	2.4	0.2	6.81	0.76
Lab 27	2.247	0.007	2.8	0.7	24.61	0.79
Lab 28	2.247	0.007	2.03	0.34	-9.66	0.64
Lab 29	2.247	0.007	2.5	0.2	11.26	1.26
Lab 37	2.247	0.007	2.4	0.5	6.81	0.31
Lab 38	2.247	0.007	2.39	0.35	6.36	0.41
Lab 40	2.247	0.007	2.85	0.152	26.84	3.96
Lab 42	2.247	0.007	2.29	0.23	1.91	0.19
Lab 44	2.247	0.007	2.7	0.2	20.16	2.26
Lab 46	2.247	0.007	2.38	0.21	5.92	0.63
Lab 47	2.247	0.007	2.32	0.15	3.25	0.49
Lab 48	2.247	0.007	2.04	0.06	-9.21	3.43

Table 39 – Results for ^{95}Zr (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{95}Zr Bq kg^{-1}	± Bq kg^{-1}	^{95}Zr Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	5.200	0.045	4.5	0.4	-13.46	1.74
Lab 3	5.200	0.045	5.22	0.48	0.38	0.04
Lab 5	5.200	0.045	8.51	0.85	63.65	3.89
Lab 7	5.200	0.045	4.82	0.9	-7.31	0.42
Lab 8	5.200	0.045	5.11	0.28	-1.73	0.32
Lab 10	5.200	0.045	6.87	1.41	32.12	1.18
Lab 13	5.200	0.045	4.60	0.23	-11.54	2.56
Lab 15	5.200	0.045	7.94	0.85	52.69	3.22
Lab 17	5.200	0.045	4.28	0.67	-17.69	1.37
Lab 18	5.200	0.045	5.5	0.6	5.77	0.50
Lab 19	5.200	0.045	5	0.3	-3.85	0.66
Lab 23	5.200	0.045	6.2	1	19.23	1.00
Lab 27	5.200	0.045	7.7	2	48.08	1.25
Lab 28	5.200	0.045	4.48	0.87	-13.85	0.83
Lab 29	5.200	0.045	5.8	0.5	11.54	1.20
Lab 35	5.200	0.045	7.4	0.85	42.31	2.58
Lab 37	5.200	0.045	4.6	1.3	-11.54	0.46
Lab 38	5.200	0.045	3.50	1.50	-32.69	1.13
Lab 40	5.200	0.045	10.5	0.444	101.92	11.88
Lab 42	5.200	0.045	5.23	0.75	0.58	0.04
Lab 44	5.200	0.045	7.1	0.6	36.54	3.16
Lab 46	5.200	0.045	5.90	0.59	13.46	1.18
Lab 47	5.200	0.045	5.63	0.24	8.27	1.76
Lab 48	5.200	0.045	5.34	0.75	2.69	0.19

Table 40 – Results for ^{106}Ru (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{106}Ru Bq kg^{-1}	± Bq kg^{-1}	^{106}Ru Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	10.431	0.073	6.6	0.7	-36.73	5.44
Lab 3	10.431	0.073	10.3	1.8	-1.26	0.07
Lab 5	10.431	0.073	4.86	0.49	-53.41	11.25
Lab 7	10.431	0.073	9.91	5.59	-4.99	0.09
Lab 8	10.431	0.073	8.98	1.08	-13.91	1.34
Lab 10	10.431	0.073	8.16	2.2	-21.77	1.03
Lab 13	10.431	0.073	7.97	0.55	-23.59	4.44
Lab 18	10.431	0.073	7.9	0.8	-24.26	3.15
Lab 19	10.431	0.073	8.7	0.9	-16.59	1.92
Lab 27	10.431	0.073	10.5	3	0.66	0.02
Lab 28	10.431	0.073	7.5	3.2	-28.10	0.92
Lab 29	10.431	0.073	9.2	1.3	-11.80	0.95
Lab 37	10.431	0.073	8.9	1.2	-14.68	1.27
Lab 38	10.431	0.073	11.6	3.6	11.21	0.32
Lab 42	10.431	0.073	10.35	1.7	-0.78	0.05
Lab 44	10.431	0.073	12.6	1.2	20.79	1.80
Lab 46	10.431	0.073	9.60	1.21	-7.97	0.69
Lab 47	10.431	0.073	9.72	0.89	-6.82	0.80
Lab 48	10.431	0.073	10.14	1.16	-2.79	0.25

Table 41 – Results for ^{134}Cs (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{134}Cs Bq kg^{-1}	± Bq kg^{-1}	^{134}Cs Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	3.937	0.029	3.1	0.1	-21.26	8.04
Lab 3	3.937	0.029	3.87	0.15	-1.70	0.44
Lab 5	3.937	0.029	3.34	0.33	-15.16	1.80
Lab 7	3.937	0.029	3.8	0.49	-3.48	0.28
Lab 8	3.937	0.029	4.1	0.13	4.14	1.22
Lab 10	3.937	0.029	3.64	0.29	-7.54	1.02
Lab 13	3.937	0.029	3.92	0.16	-0.43	0.10
Lab 15	3.937	0.029	4.950	0.33	25.73	3.06
Lab 17	3.937	0.029	1.83	0.13	-53.52	15.82
Lab 18	3.937	0.029	4.0	0.4	1.60	0.16
Lab 19	3.937	0.029	3.6	0.2	-8.56	1.67
Lab 23	3.937	0.029	3.5	0.2	-11.10	2.16
Lab 27	3.937	0.029	3.8	1.1	-3.48	0.12
Lab 28	3.937	0.029	3.05	0.34	-22.53	2.60
Lab 29	3.937	0.029	3.7	0.3	-6.02	0.79
Lab 35	3.937	0.029	3.71	0.45	-5.77	0.50
Lab 37	3.937	0.029	4.0	0.6	1.60	0.10
Lab 38	3.937	0.029	3.93	0.35	-0.18	0.02
Lab 40	3.937	0.029	4.40	0.195	11.76	2.35
Lab 42	3.937	0.029	3.38	0.23	-14.15	2.40
Lab 44	3.937	0.029	3.9	0.2	-0.94	0.18
Lab 46	3.937	0.029	4.23	0.32	7.44	0.91
Lab 47	3.937	0.029	4.15	0.15	5.41	1.39
Lab 48	3.937	0.029	4.12	0.21	4.65	0.86

Table 42 – Results for ^{137}Cs (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{137}Cs Bq kg^{-1}	± Bq kg^{-1}	^{137}Cs Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	2.522	0.021	2.3	0.1	-8.80	2.17
Lab 3	2.522	0.021	3.20	0.29	26.88	2.33
Lab 5	2.522	0.021	2.57	0.26	1.90	0.18
Lab 7	2.522	0.021	2.09	0.57	-17.13	0.76
Lab 8	2.522	0.021	2.61	0.11	3.49	0.79
Lab 10	2.522	0.021	2.58	0.27	2.30	0.21
Lab 13	2.522	0.021	2.41	0.10	-4.44	1.10
Lab 15	2.522	0.021	5.21	0.37	106.58	7.25
Lab 17	2.522	0.021	1.26	0.11	-50.04	11.27
Lab 18	2.522	0.021	2.5	0.2	-0.87	0.11
Lab 19	2.522	0.021	2.7	0.2	7.06	0.89
Lab 23	2.522	0.021	2.7	0.2	7.06	0.89
Lab 27	2.522	0.021	3.2	0.8	26.88	0.85
Lab 28	2.522	0.021	2.29	0.5	-9.20	0.46
Lab 29	2.522	0.021	2.5	0.2	-0.87	0.11
Lab 35	2.522	0.021	3.24	0.45	28.47	1.59
Lab 37	2.522	0.021	2.7	0.8	7.06	0.22
Lab 38	2.522	0.021	2.88	0.40	14.20	0.89
Lab 40	2.522	0.021	2.85	0.169	13.01	1.93
Lab 42	2.522	0.021	2.69	0.29	6.66	0.58
Lab 44	2.522	0.021	3.2	0.2	26.88	3.37
Lab 46	2.522	0.021	2.65	0.26	5.08	0.49
Lab 47	2.522	0.021	2.63	0.12	4.28	0.89
Lab 48	2.522	0.021	2.82	0.15	11.82	1.97

Table 43 – Results for ^{144}Ce (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{144}Ce Bq kg^{-1}	± Bq kg^{-1}	^{144}Ce Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	9.505	0.078	7.6	0.4	-20.04	4.67
Lab 3	9.505	0.078	8.45	1.12	-11.10	0.94
Lab 5	9.505	0.078	9.42	0.94	-0.89	0.09
Lab 7	9.505	0.078	10.6	2.94	11.52	0.37
Lab 8	9.505	0.078	9.97	0.85	4.89	0.54
Lab 10	9.505	0.078	10.51	1.13	10.57	0.89
Lab 13	9.505	0.078	9.29	0.44	-2.26	0.48
Lab 15	9.505	0.078	12.55	1.15	32.04	2.64
Lab 17	9.505	0.078	3.81	0.6	-59.92	9.41
Lab 18	9.505	0.078	9.1	0.8	-4.26	0.50
Lab 19	9.505	0.078	9.6	0.6	1.00	0.16
Lab 23	9.505	0.078	9	0.8	-5.31	0.63
Lab 27	9.505	0.078	7.3	2.5	-23.20	0.88
Lab 28	9.505	0.078	9	2.2	-5.31	0.23
Lab 29	9.505	0.078	10.3	1.1	8.36	0.72
Lab 37	9.505	0.078	9.6	2.5	1.00	0.04
Lab 38	9.505	0.078	12.7	2.5	33.61	1.28
Lab 42	9.505	0.078	9.15	1.1	-3.73	0.32
Lab 44	9.505	0.078	12.8	0.7	34.67	4.68
Lab 46	9.505	0.078	10.16	0.89	6.89	0.73
Lab 47	9.505	0.078	9.66	0.44	1.63	0.35
Lab 48	9.505	0.078	8.61	0.34	-9.42	2.57

Table 44 – Results for ^{154}Eu (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{154}Eu Bq kg^{-1}	± Bq kg^{-1}	^{154}Eu Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	8.279	0.065	7	0.2	-15.45	6.08
Lab 3	8.279	0.065	8.47	0.30	2.31	0.62
Lab 5	8.279	0.065	6.63	0.66	-19.92	2.49
Lab 7	8.279	0.065	10.1	1.99	22.00	0.91
Lab 8	8.279	0.065	8.37	0.44	1.10	0.20
Lab 10	8.279	0.065	7.47	0.41	-9.77	1.95
Lab 13	8.279	0.065	7.95	0.33	-3.97	0.98
Lab 15	8.279	0.065	10.85	0.69	31.05	3.71
Lab 17	8.279	0.065	3.2	0.21	-61.35	23.10
Lab 18	8.279	0.065	8.1	0.9	-2.16	0.20
Lab 19	8.279	0.065	7.5	0.3	-9.41	2.54
Lab 23	8.279	0.065	7.1	0.4	-14.24	2.91
Lab 27	8.279	0.065	6.5	2	-21.49	0.89
Lab 28	8.279	0.065	6.8	0.84	-17.86	1.76
Lab 29	8.279	0.065	8.2	1.0	-0.95	0.08
Lab 37	8.279	0.065	8.9	1.0	7.50	0.62
Lab 38	8.279	0.065	11.3	0.8	36.49	3.76
Lab 40	8.279	0.065	10.7	0.645	29.24	3.73
Lab 42	8.279	0.065	7.61	0.37	-8.08	1.78
Lab 44	8.279	0.065	9.6	0.5	15.96	2.62
Lab 46	8.279	0.065	8.33	0.84	0.62	0.06
Lab 47	8.279	0.065	7.7	0.3	-6.99	1.89
Lab 48	8.279	0.065	7.18	0.11	-13.27	8.60

Table 45 – Results for ^{155}Eu (BGL/03/***)

Laboratory Identifier	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{155}Eu Bq kg^{-1}	± Bq kg^{-1}	^{155}Eu Bq kg^{-1}	± Bq kg^{-1}		
Lab 1	5.641	0.064	5.4	0.4	-4.27	0.59
Lab 3	5.641	0.064	6.27	0.43	11.15	1.45
Lab 5	5.641	0.064	5.02	0.5	-11.01	1.23
Lab 7	5.641	0.064	7.97	2.39	41.29	0.97
Lab 8	5.641	0.064	4.94	0.43	-12.43	1.61
Lab 10	5.641	0.064	5.51	0.62	-2.32	0.21
Lab 13	5.641	0.064	5.79	0.25	2.64	0.58
Lab 15	5.641	0.064	6.47	0.49	14.70	1.68
Lab 17	5.641	0.064	2.35	0.21	-58.34	14.99
Lab 18	5.641	0.064	5.9	0.5	4.59	0.51
Lab 19	5.641	0.064	6	0.5	6.36	0.71
Lab 23	5.641	0.064	3.5	0.4	-37.95	5.29
Lab 28	5.641	0.064	5.3	1.1	-6.05	0.31
Lab 29	5.641	0.064	5.5	0.6	-2.50	0.23
Lab 37	5.641	0.064	6.1	1.3	8.14	0.35
Lab 38	5.641	0.064	8.30	1.40	47.14	1.90
Lab 40	5.641	0.064	6.85	0.355	21.43	3.35
Lab 42	5.641	0.064	5.29	0.87	-6.22	0.40
Lab 44	5.641	0.064	5.9	0.3	4.59	0.84
Lab 46	5.641	0.064	6.10	0.45	8.14	1.01
Lab 47	5.641	0.064	5.85	0.25	3.71	0.81
Lab 48	5.641	0.064	5.25	0.16	-6.93	2.27

Table 46 – Other reported radionuclides

Laboratory Identifier	Sample type	Radionuclide	Reported activity concentration	Overall uncertainty
42	ABL/03/***	Gross α measurement	3.55 Bq/kg	0.75 Bq/kg
42	ABL/03/***	Gross β measurement	28.11 Bq/kg	0.56 Bq/kg
44	BGL/03/***	^{170}Tm	7.2 Bq/kg	0.9 Bq/kg

Figure 1: Reported Sr-90 high level results

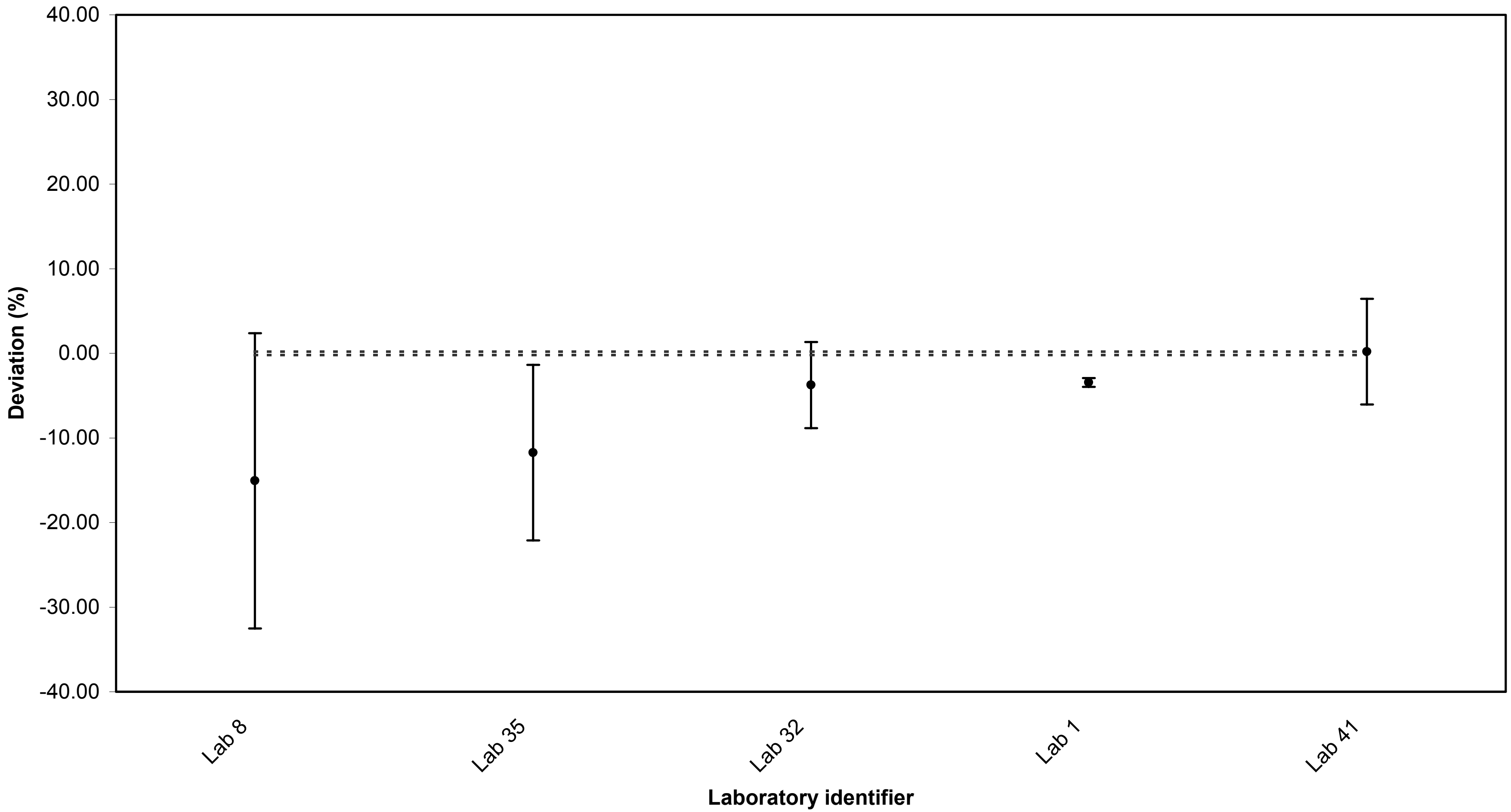


Figure 2 - Sr-90 high level results

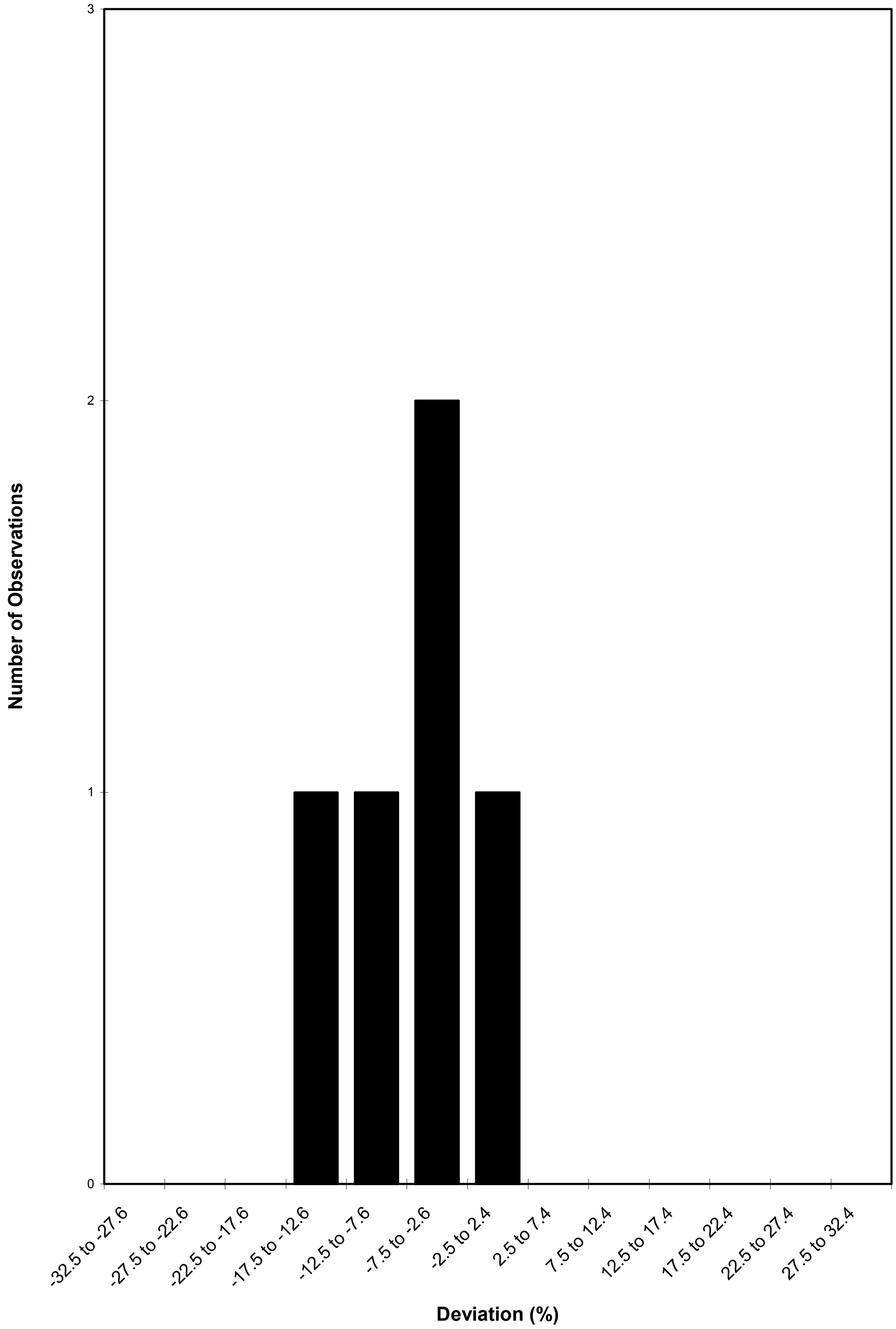


Figure 3 - Reported Tc-99 high level results

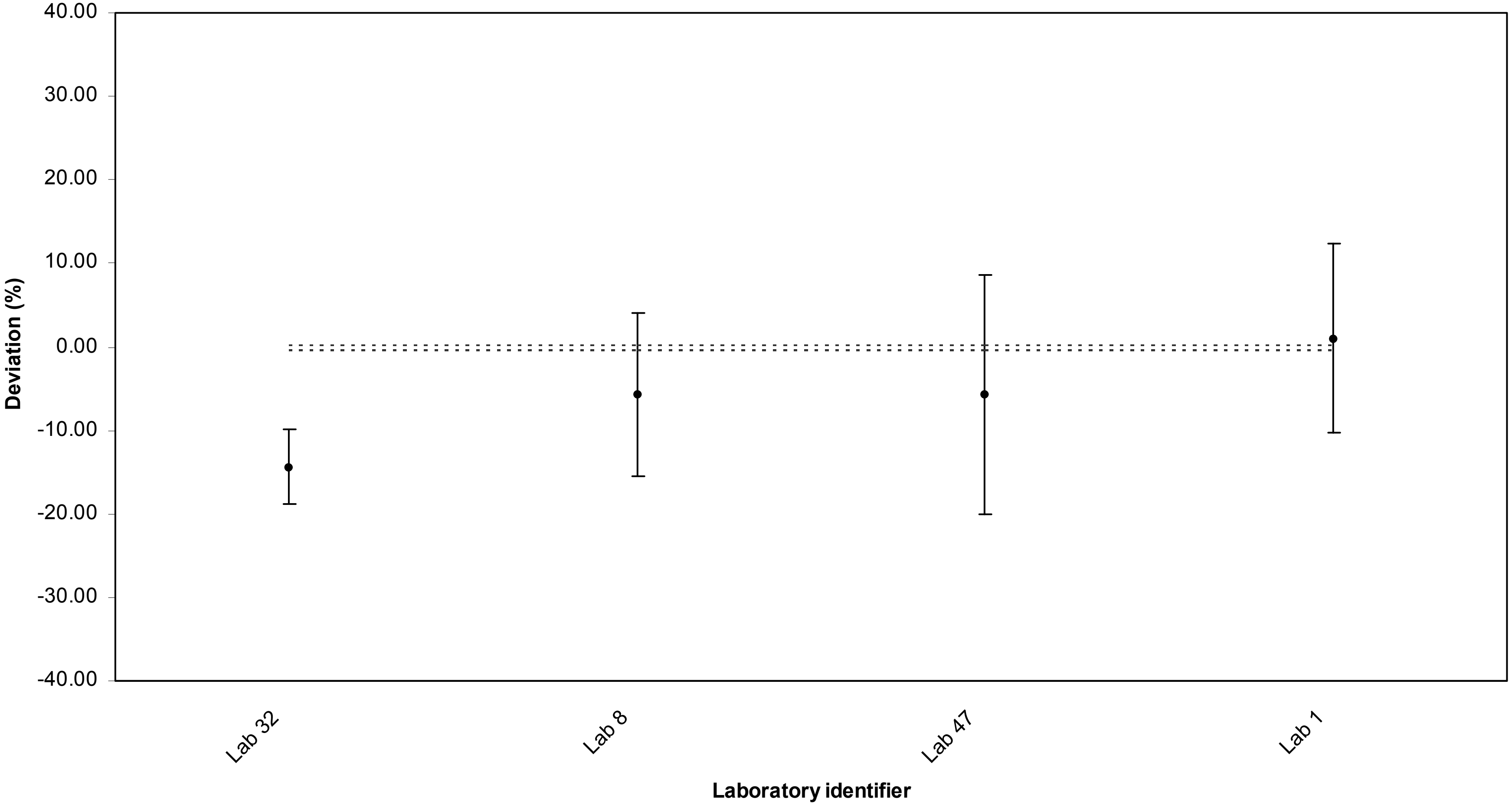


Figure 4 - Tc-99 high level results

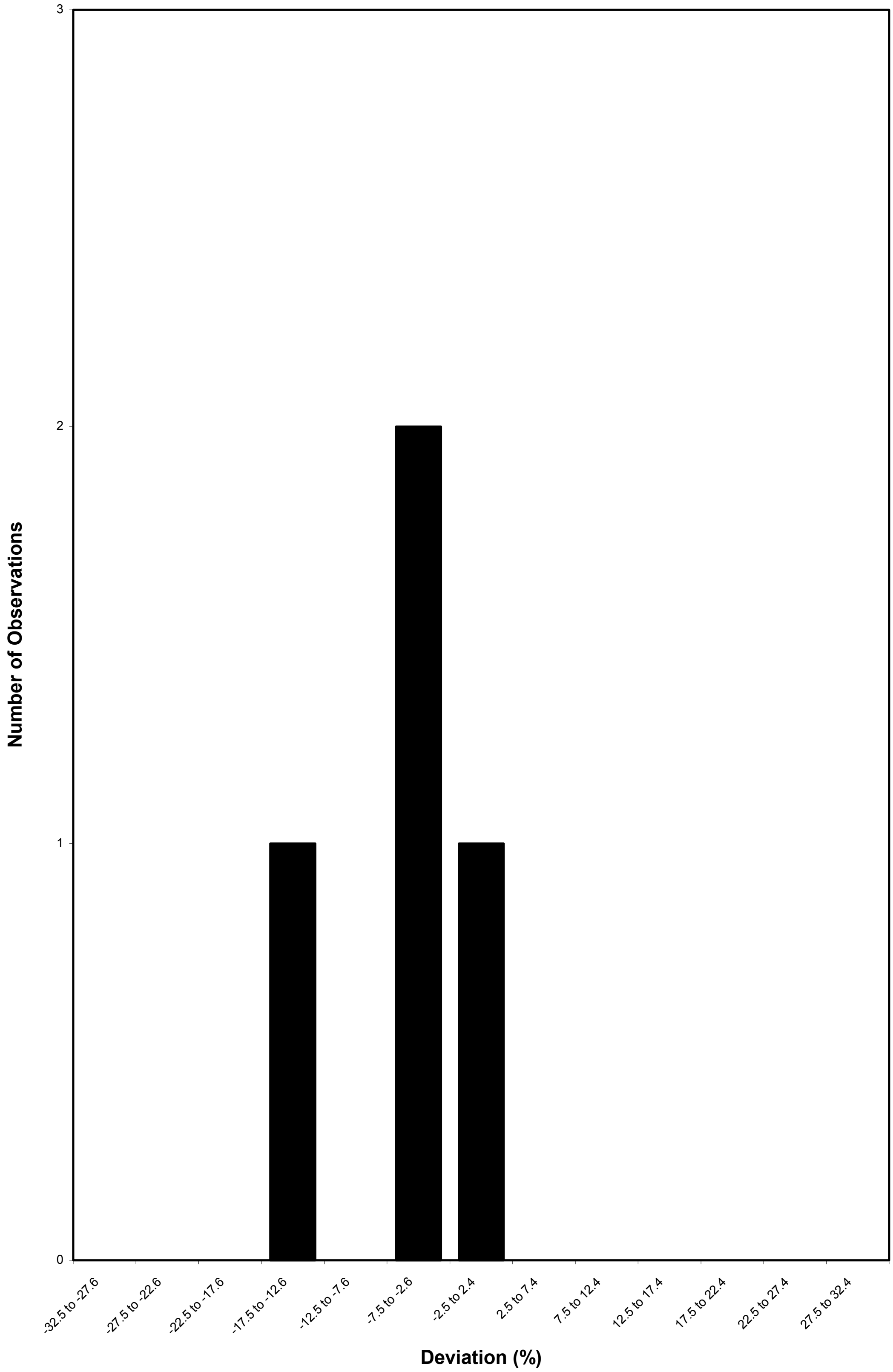


Figure 5 - Reported Pu-238 high level results

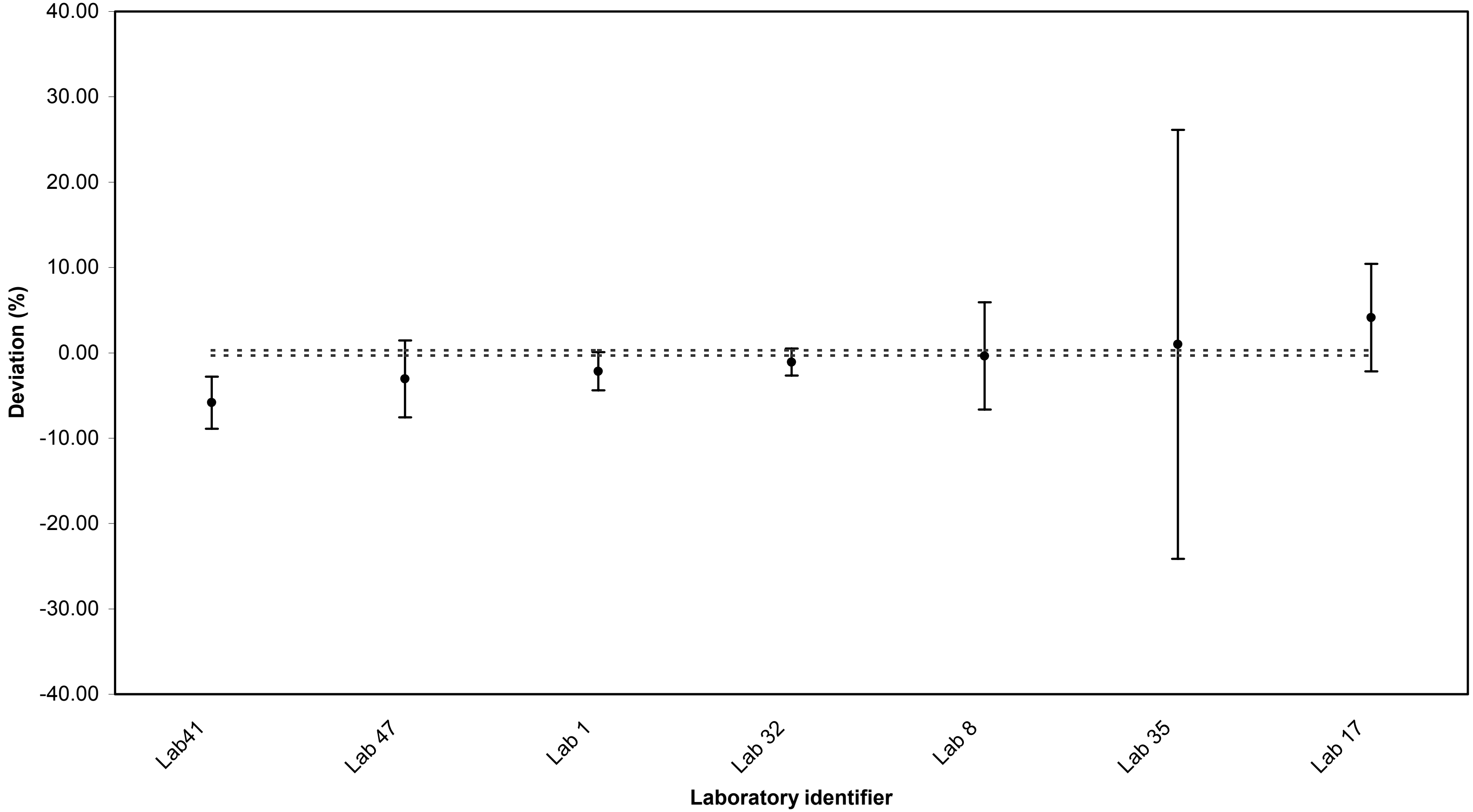


Figure 6 - Pu-238 high level results

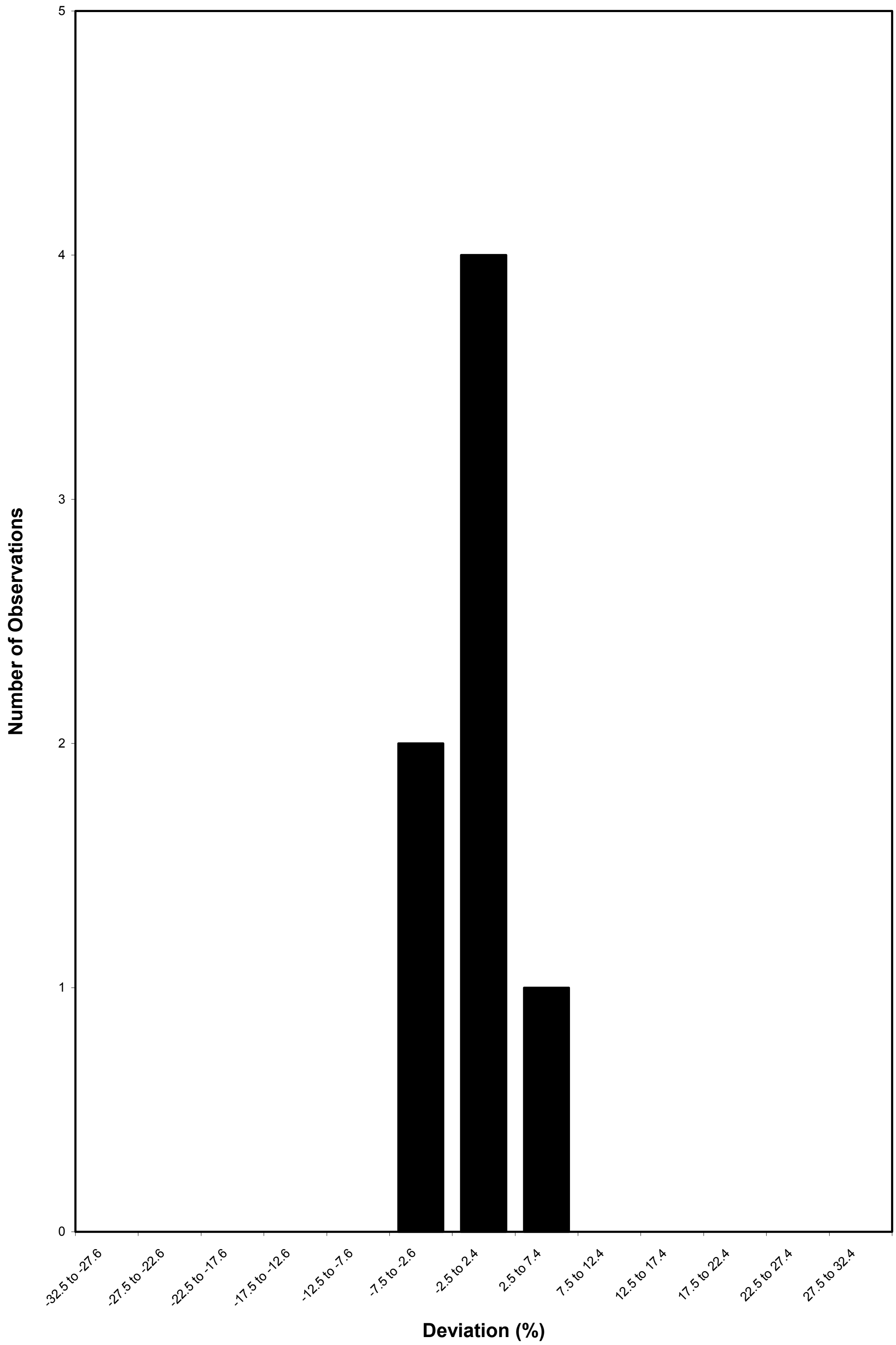


Figure 7- Reported high level Pu-239 results
(One outside limits of plot)

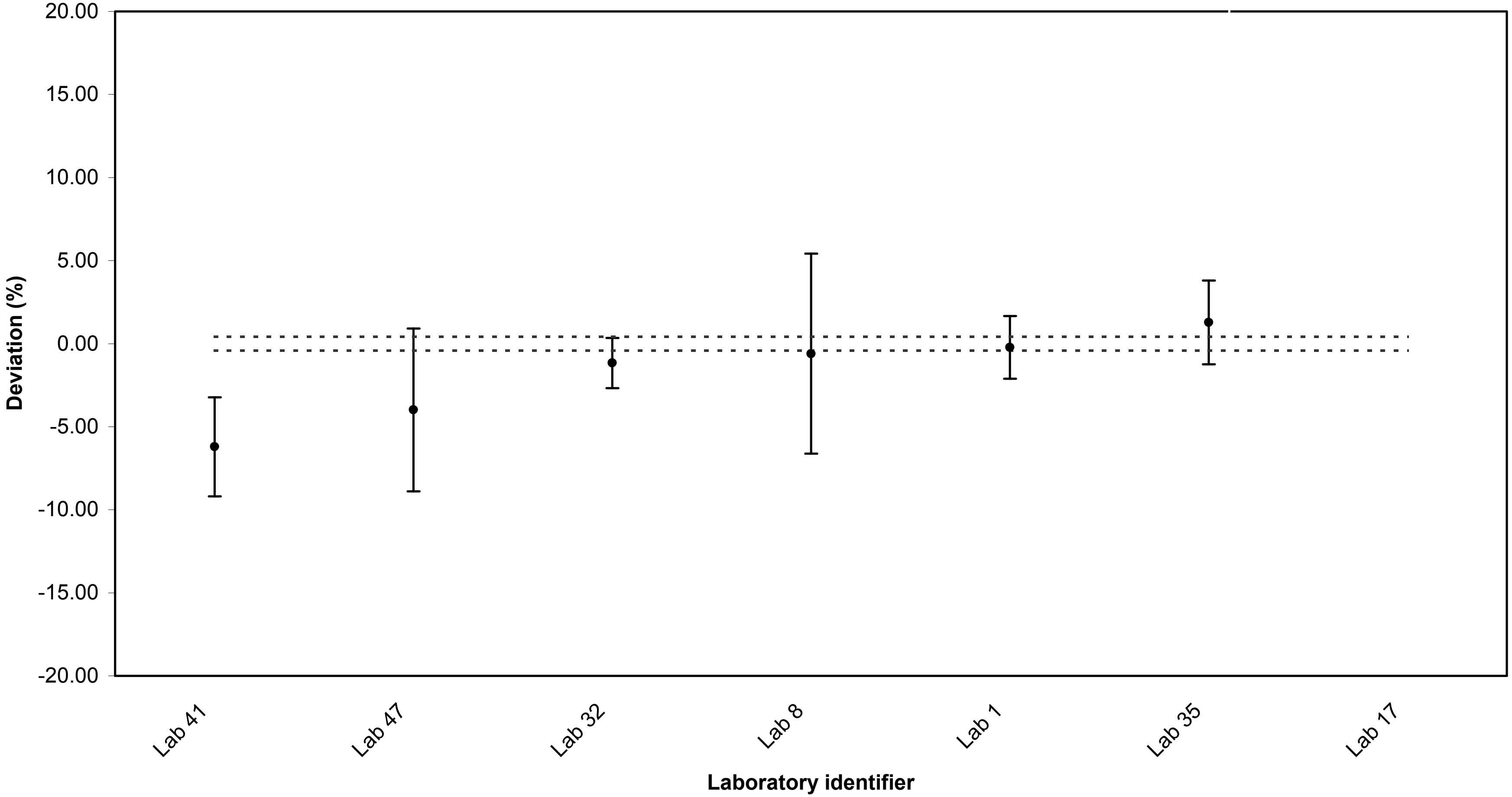


Figure 8 - Pu-239 high level results (One outside limits of plot)

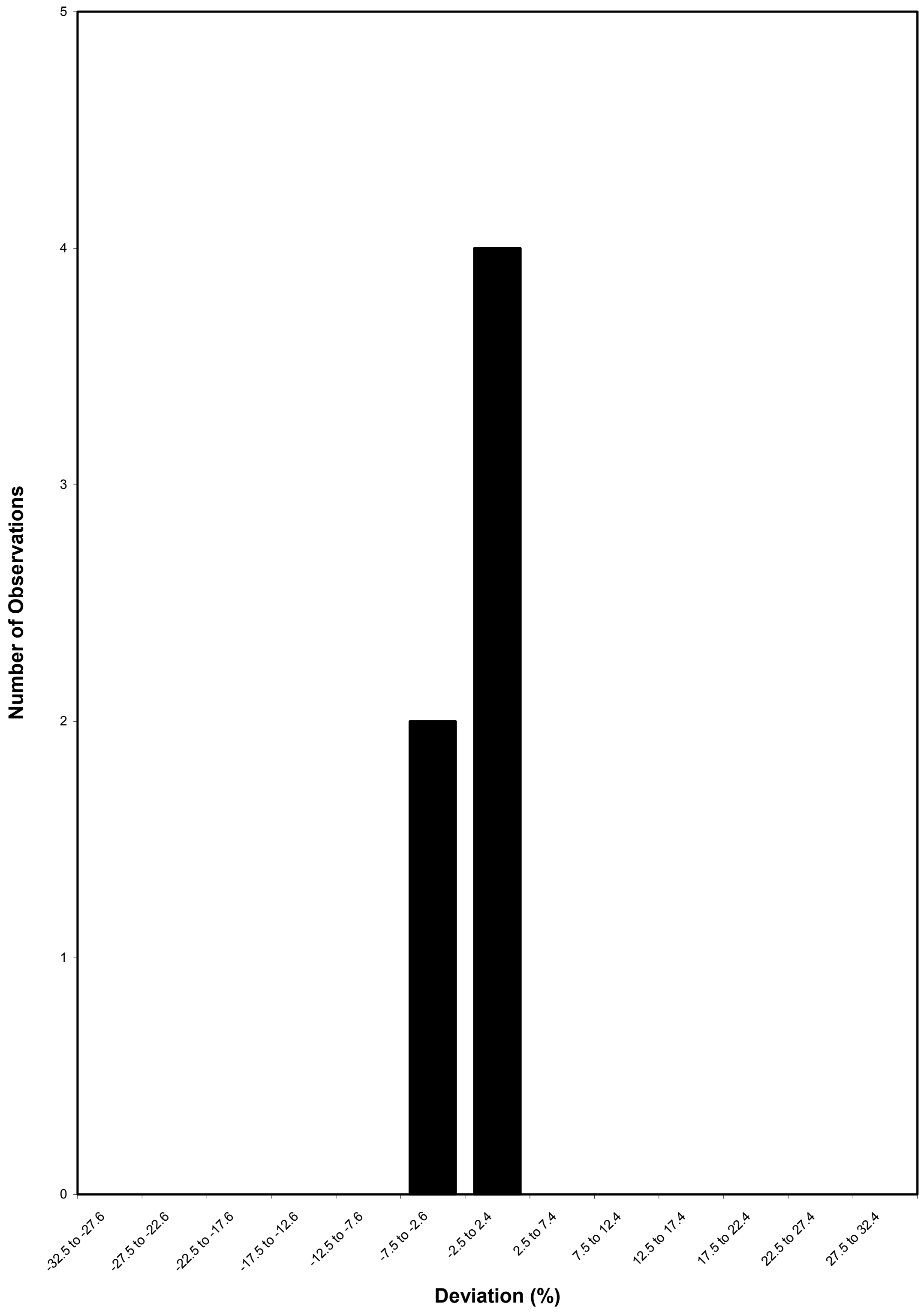


Figure 9 - Reported Am-241 high level results

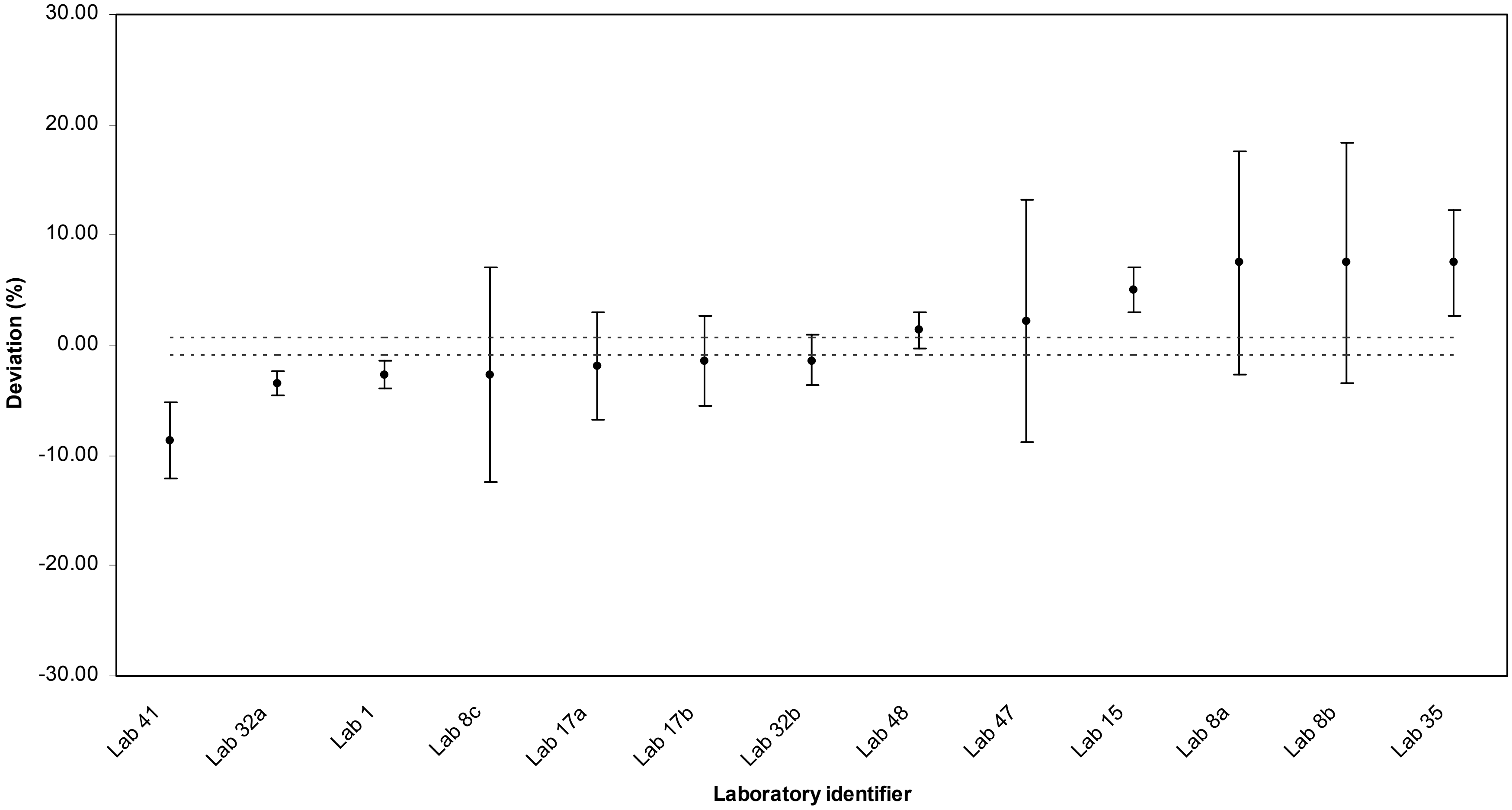


Figure 10 - Am-241 high level results

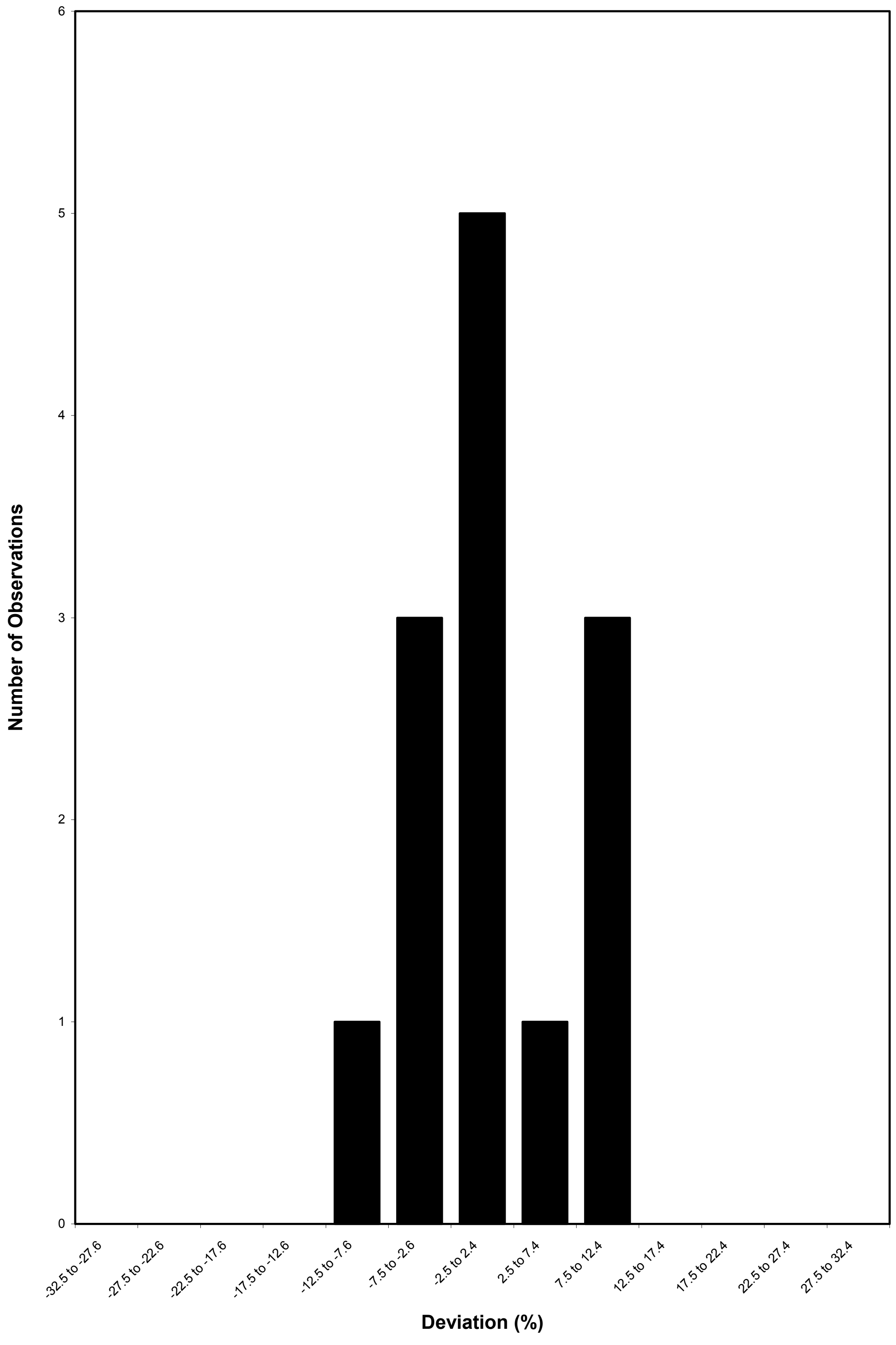


Figure 11 - Reported Sr-90 low level results

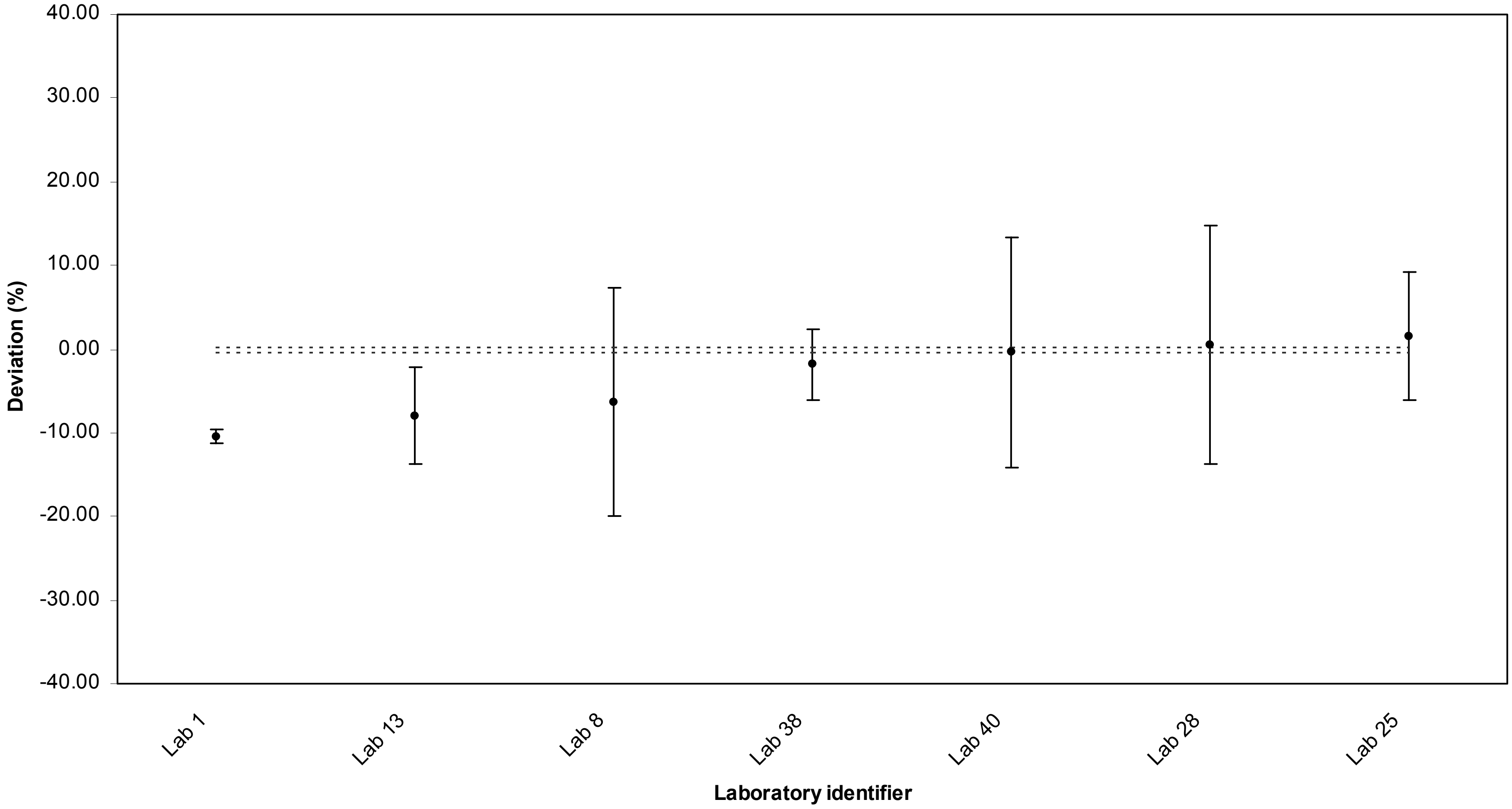


Figure 12 - Sr-90 low level results

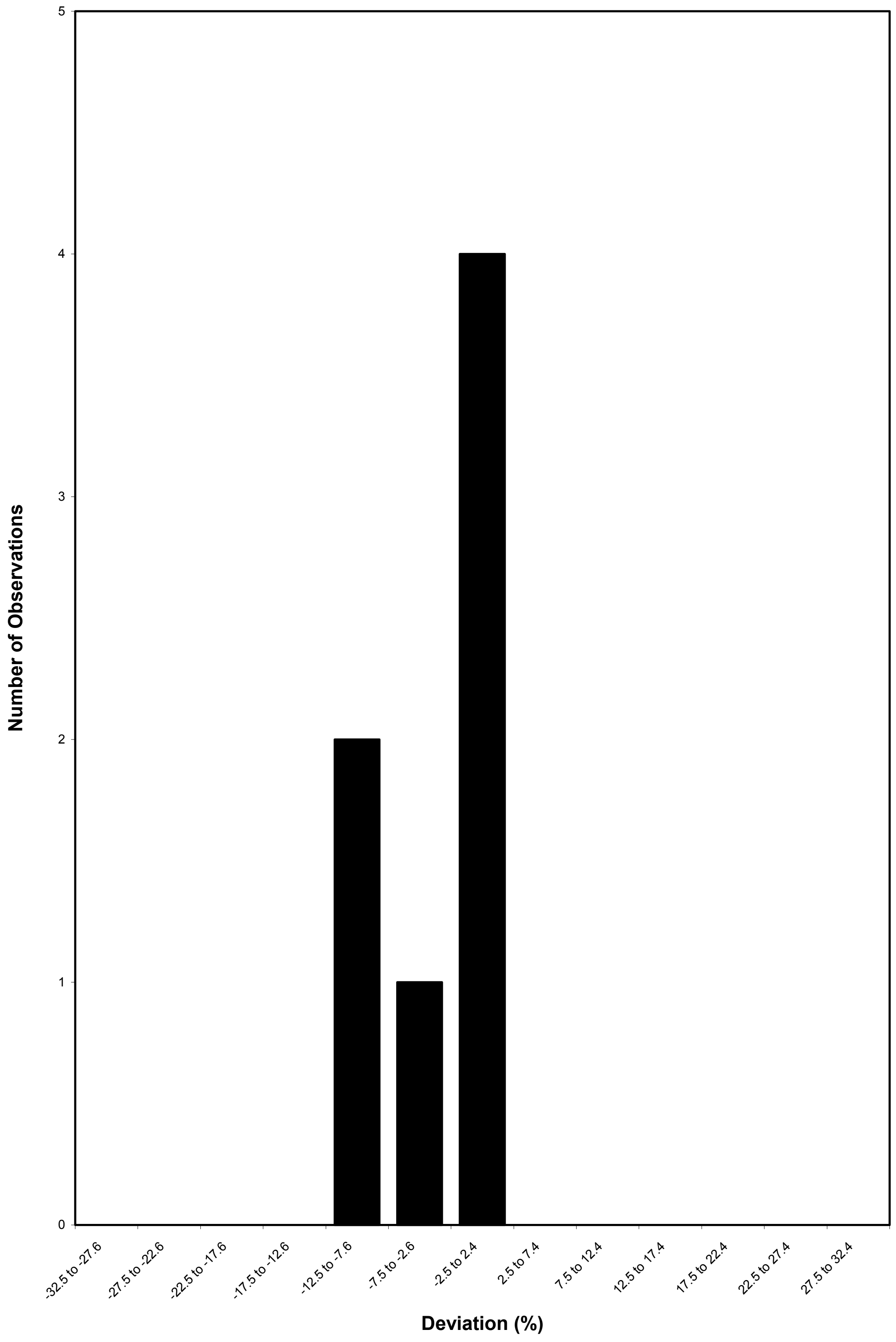


Figure 13 - Reported Tc-99 low level results

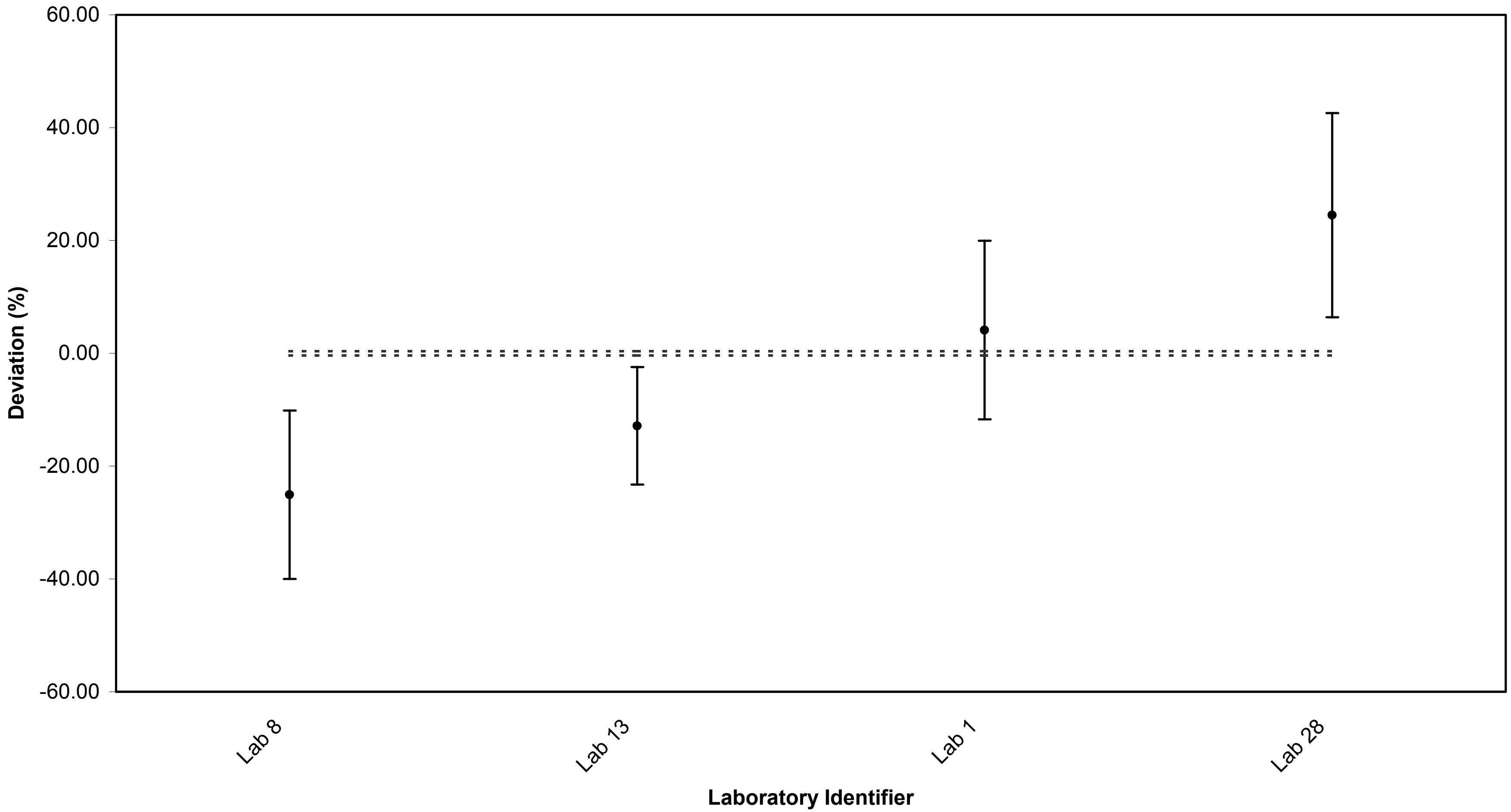


Figure 14 - Tc-99 low level results

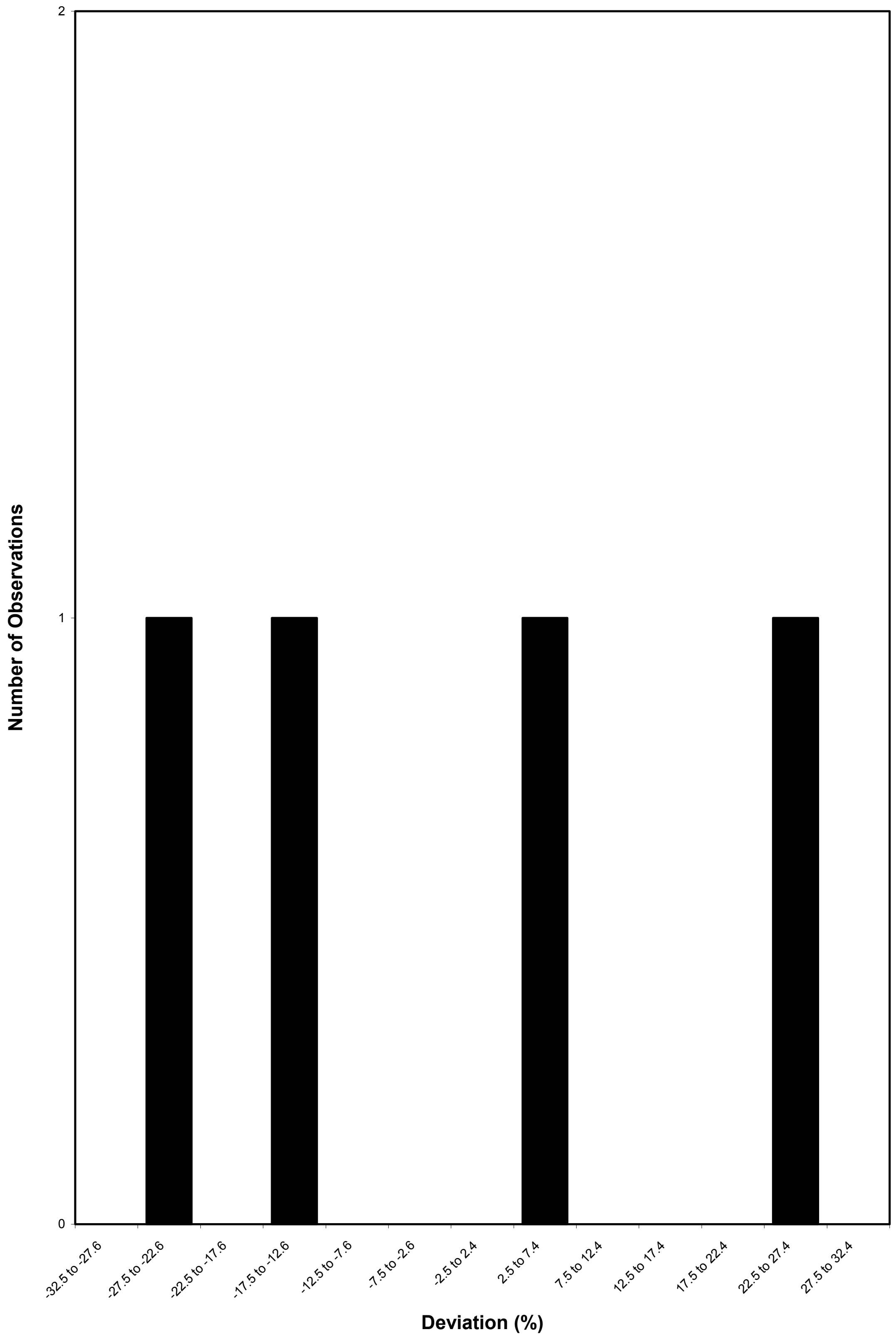


Figure 15 - Reported Pu-238 low level results

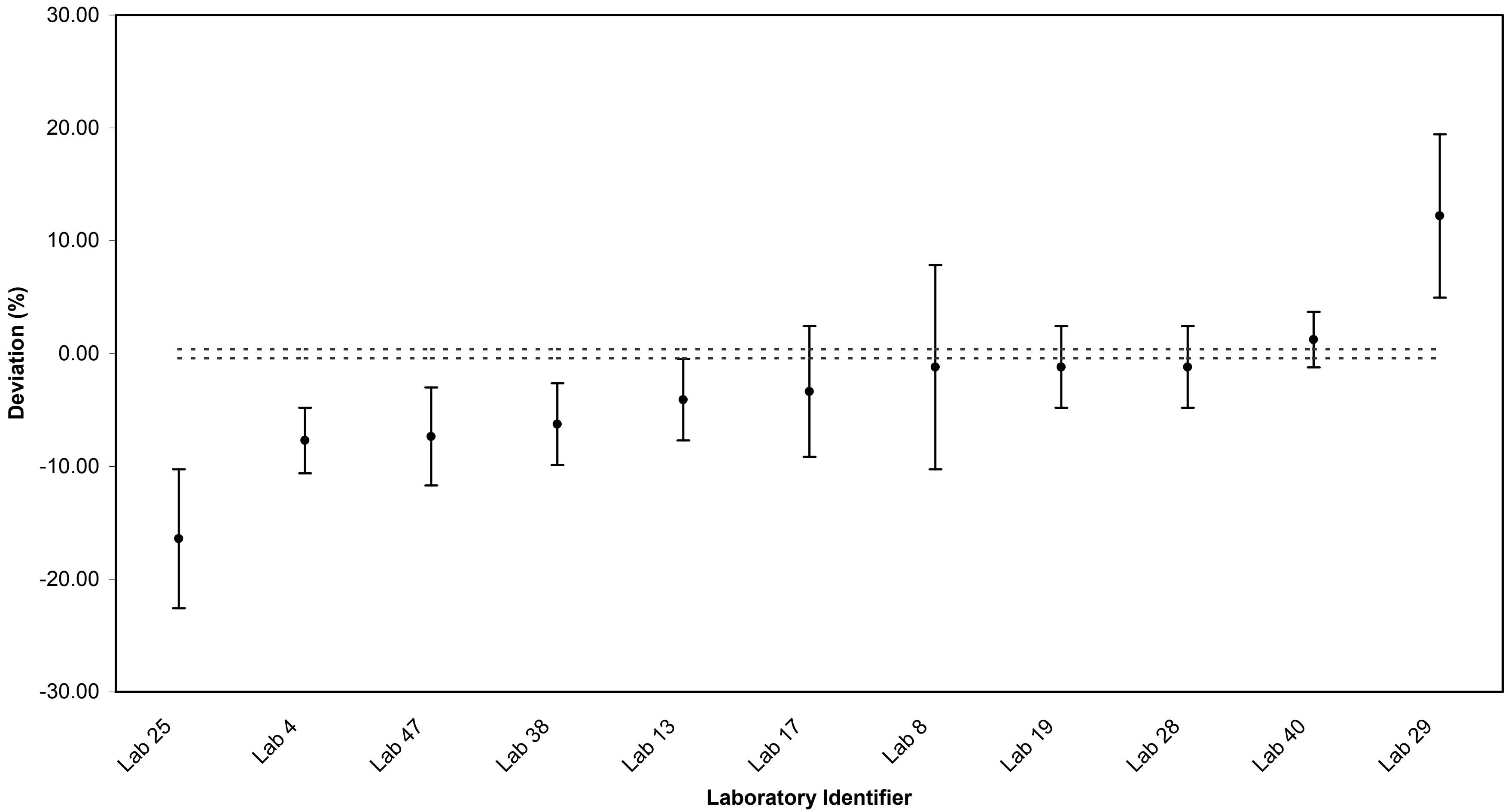


Figure 16 - Pu-238 low level results

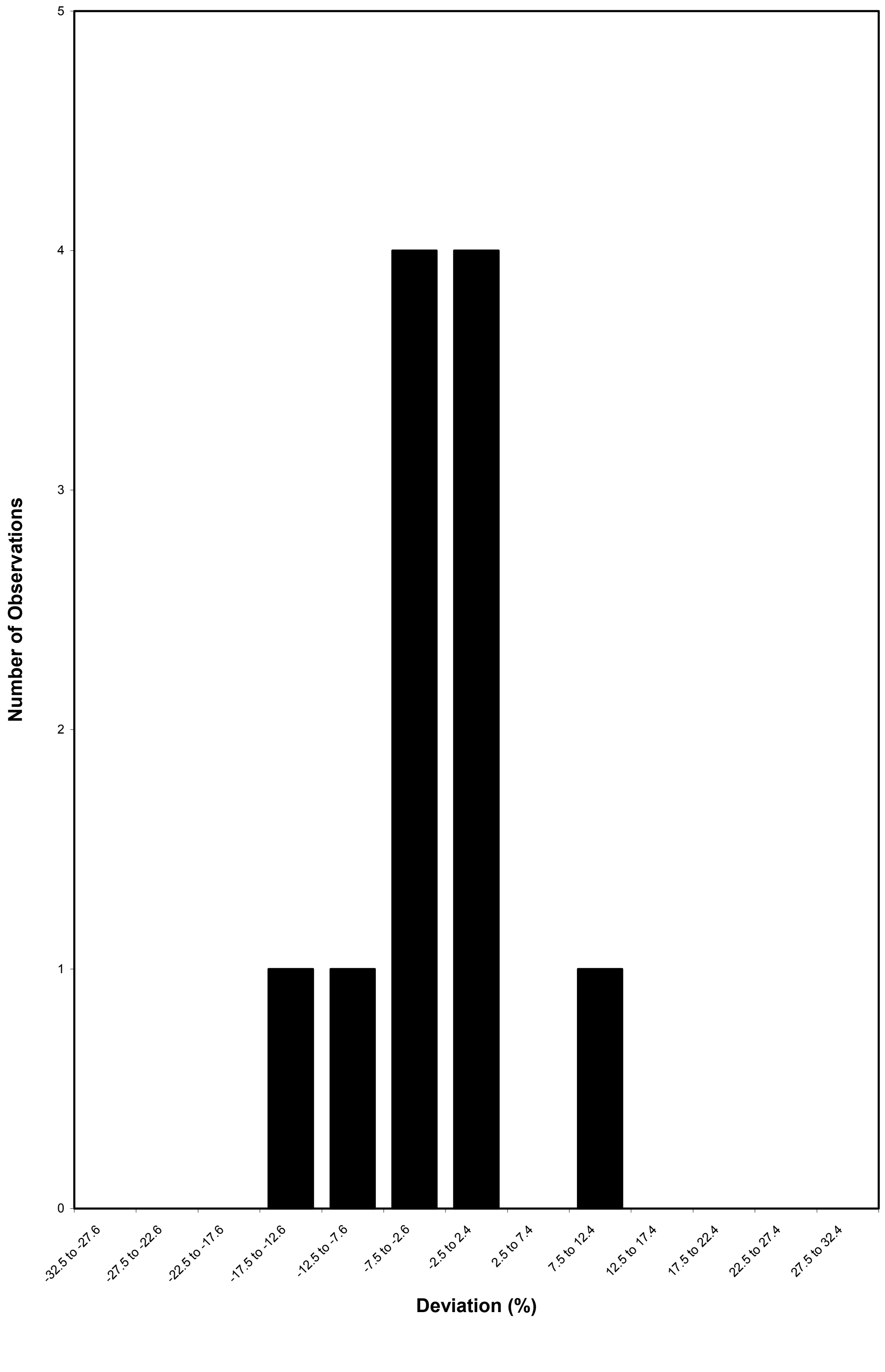


Figure 17- Reported Pu-239 low level results

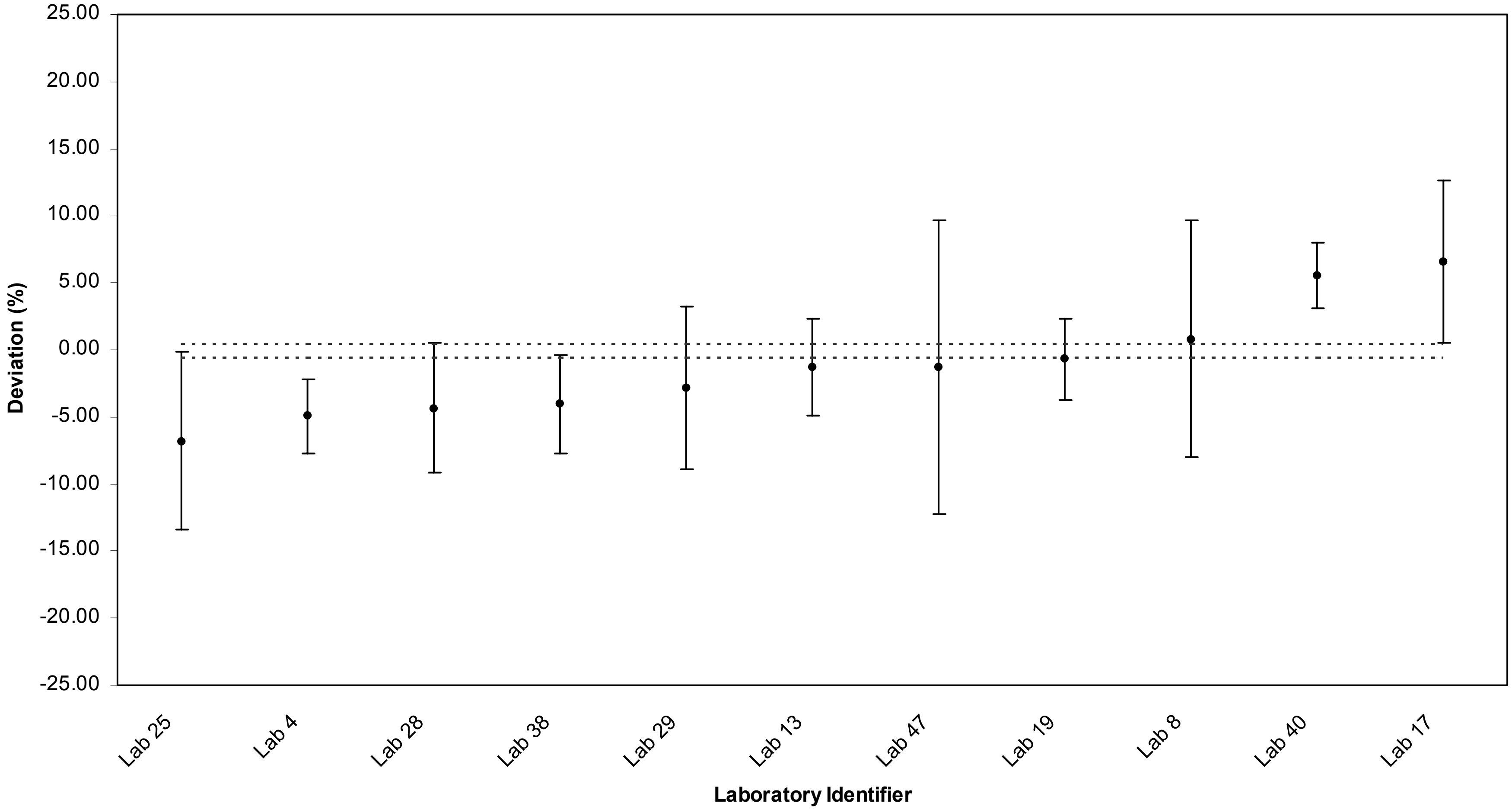


Figure 18 - Pu-239 low level results

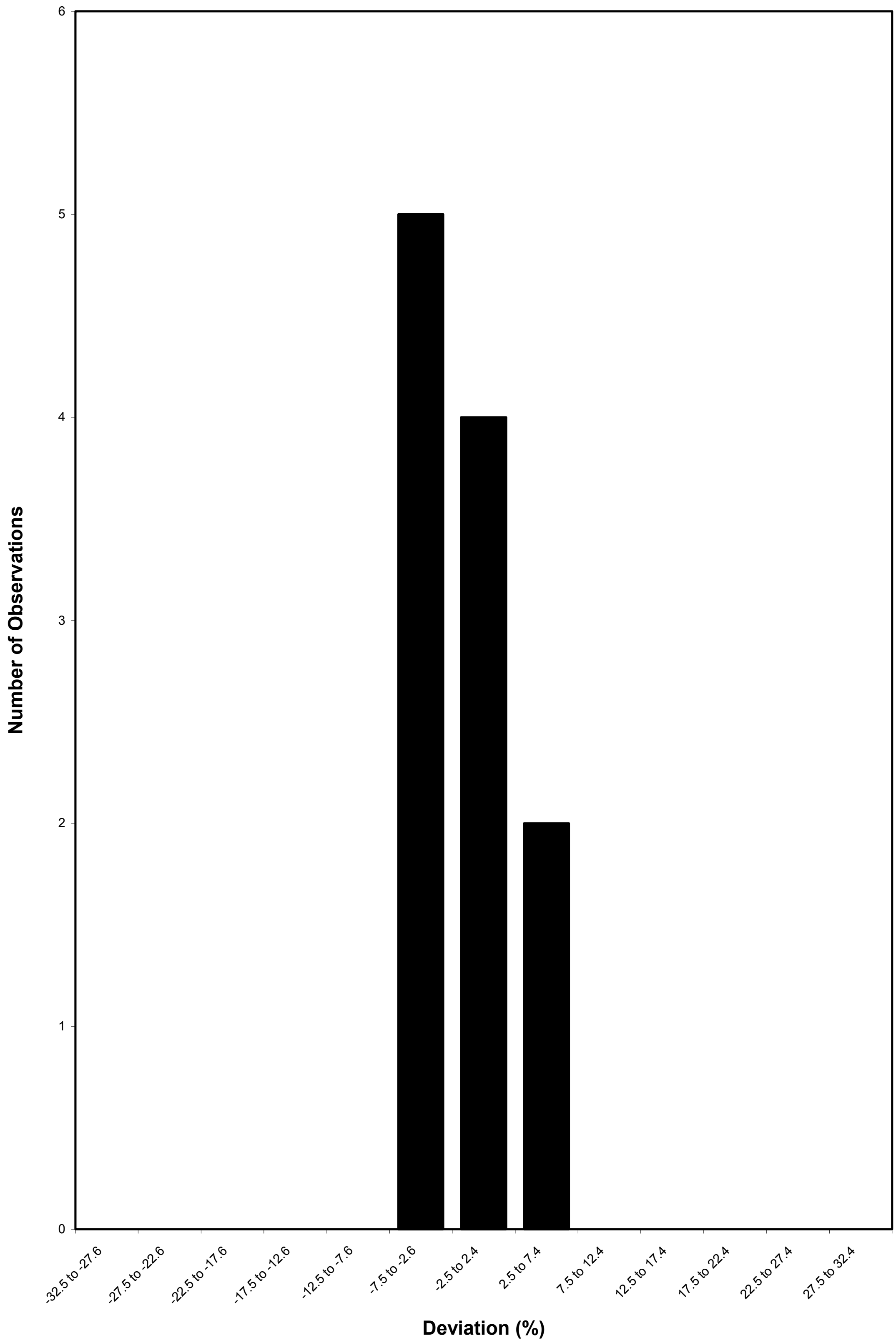


Figure 19 - Reported Am-241 low level results

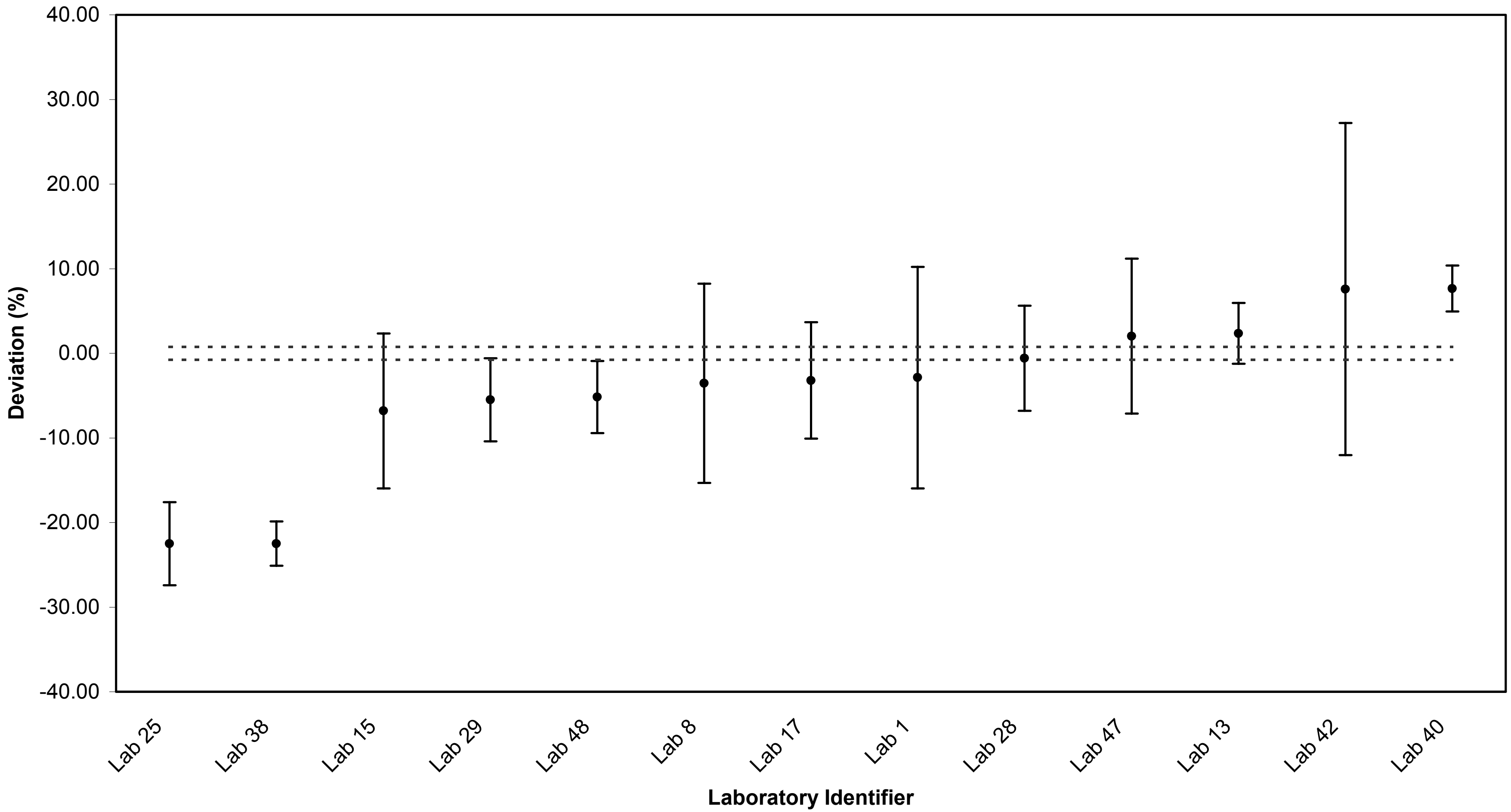


Figure 20 - Am-241 low level results

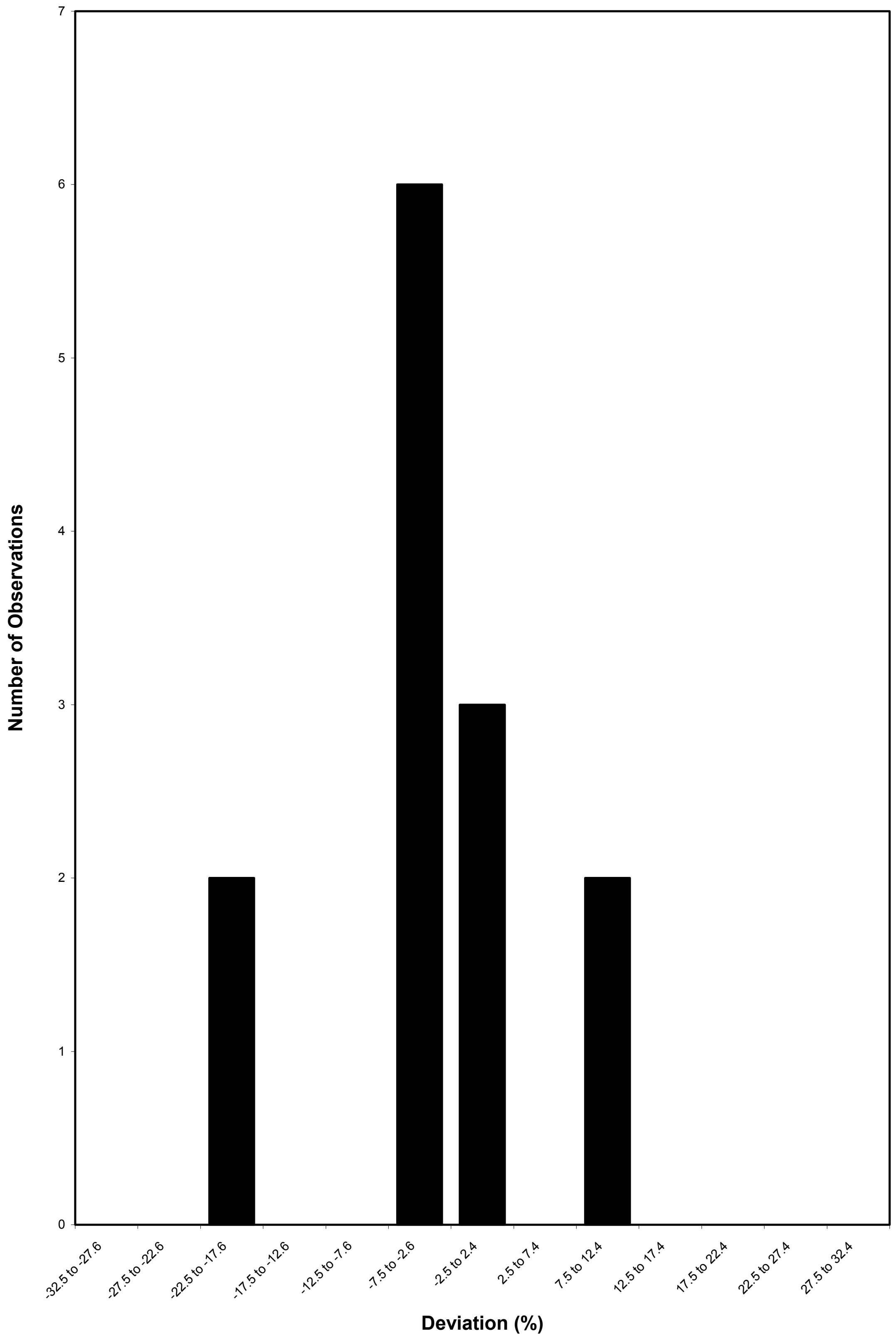


Figure 21 - Reported H-3 results
(One outside limits of plot)

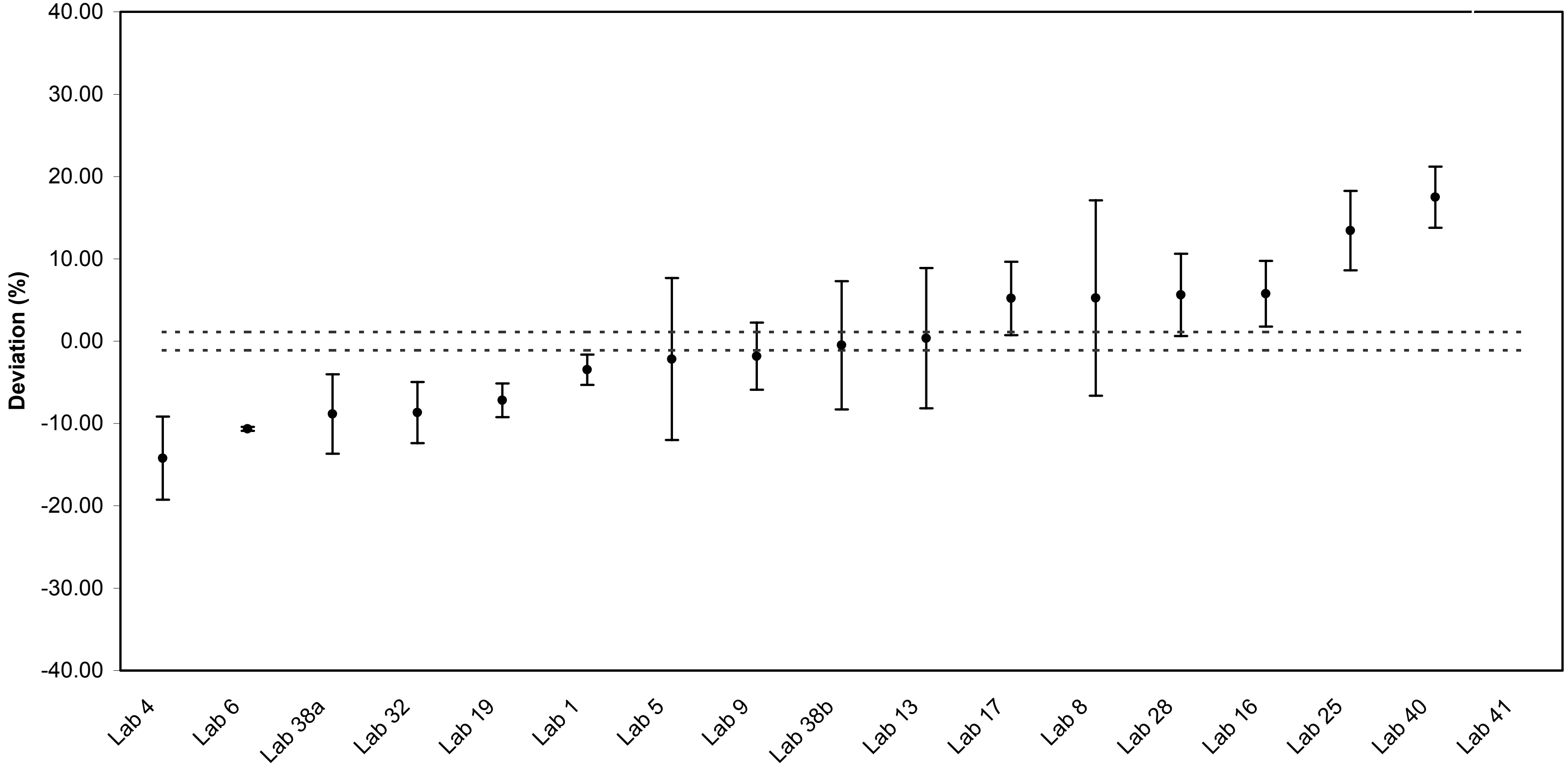


Figure 22 - H-3 results (One outside limits of plot)

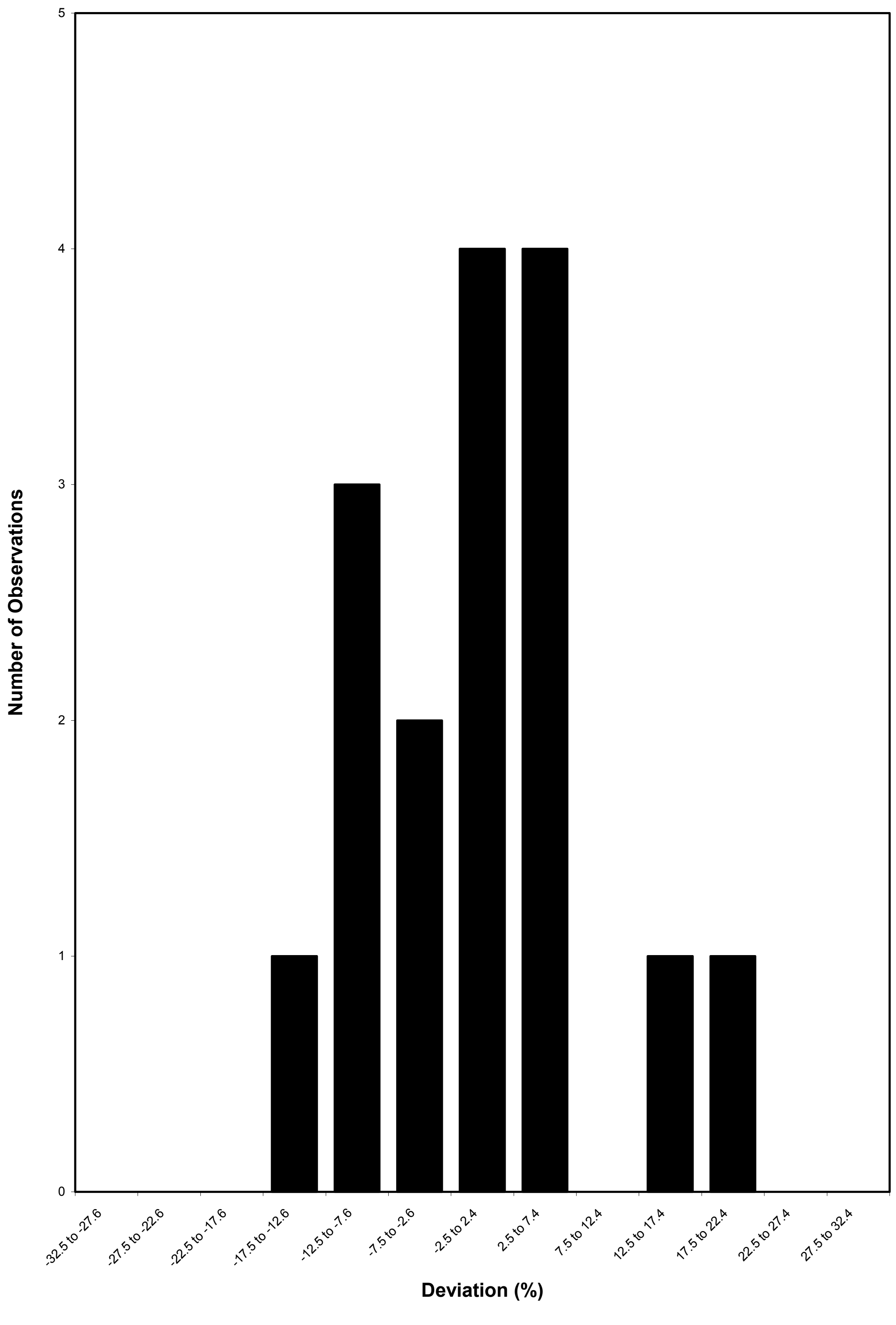


Figure 23 - Reported I-129 results

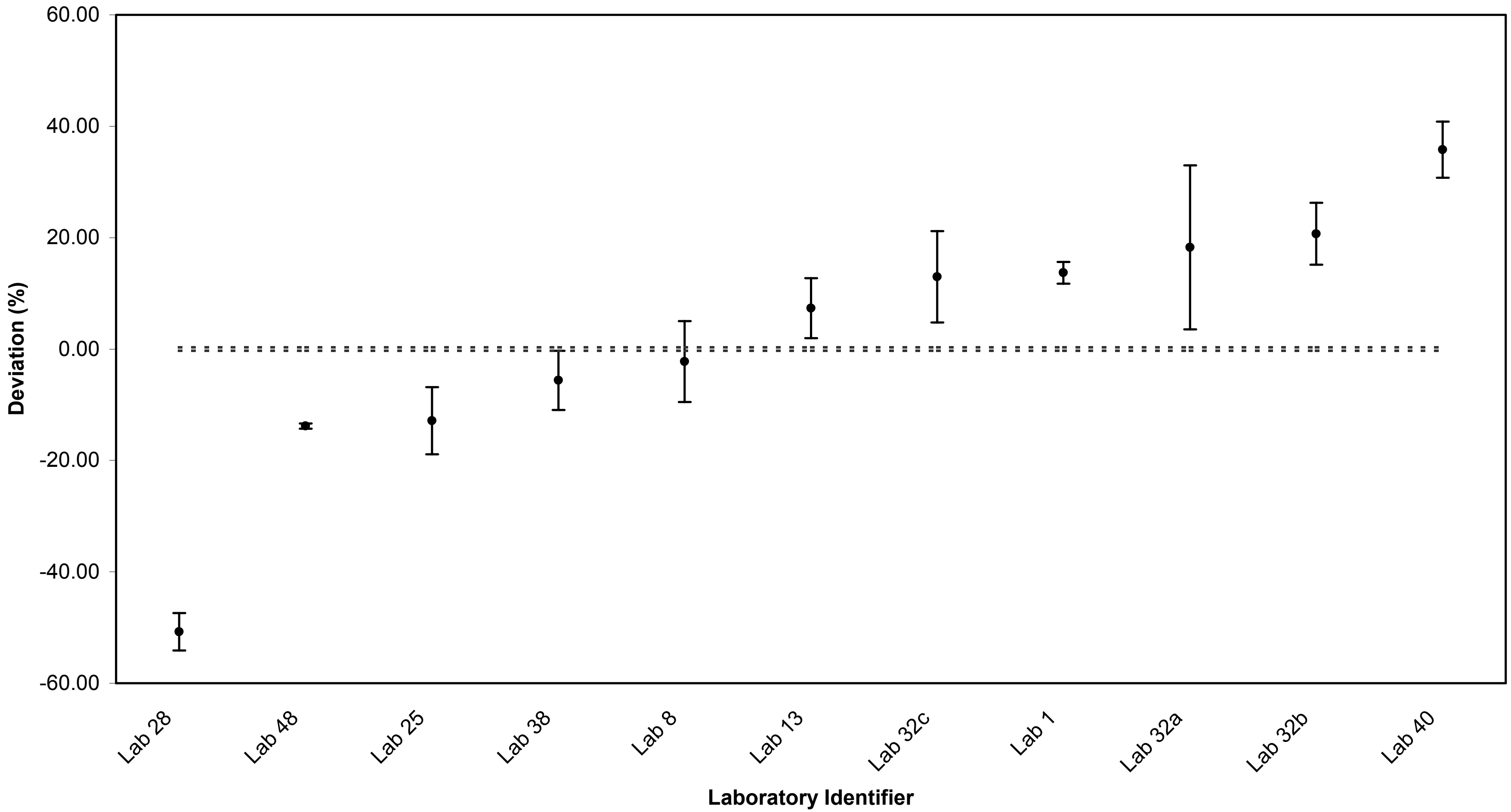


Figure 24 - I-129 results
(Two outside limits of plot)

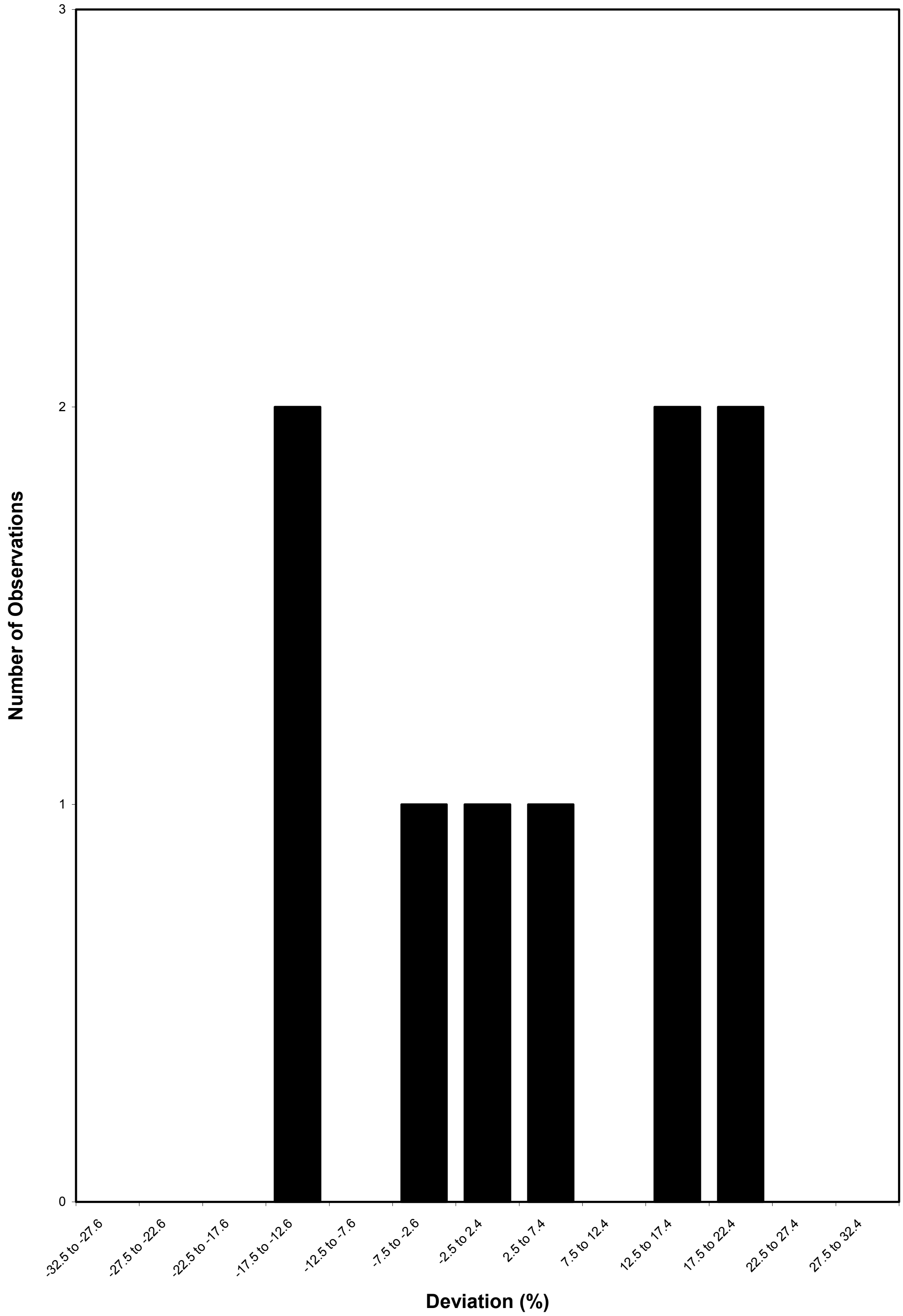


Figure 25 - Reported Co-60 high level results

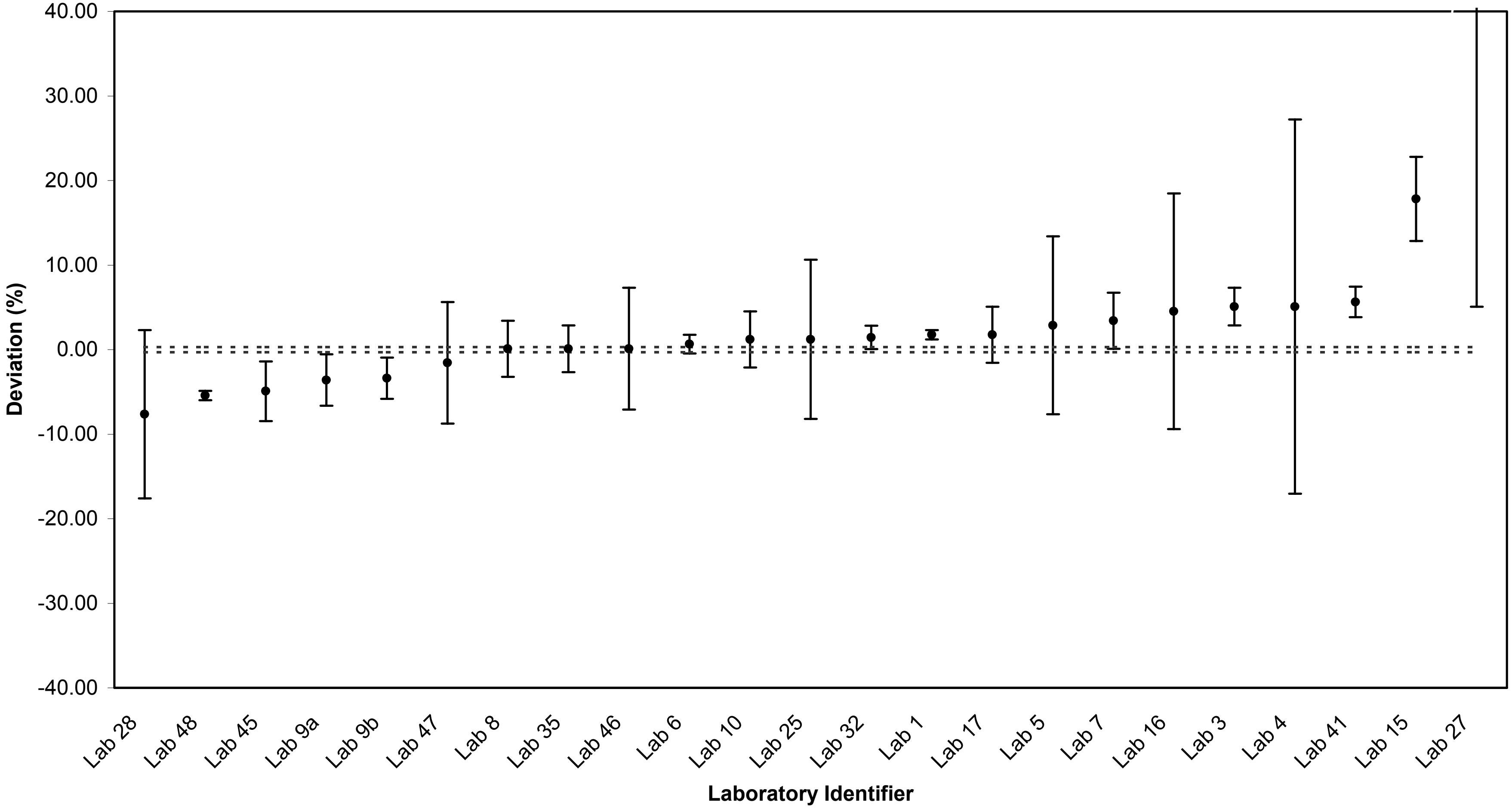


Figure 26 - Co-60 high level results (One outside limits of plot)

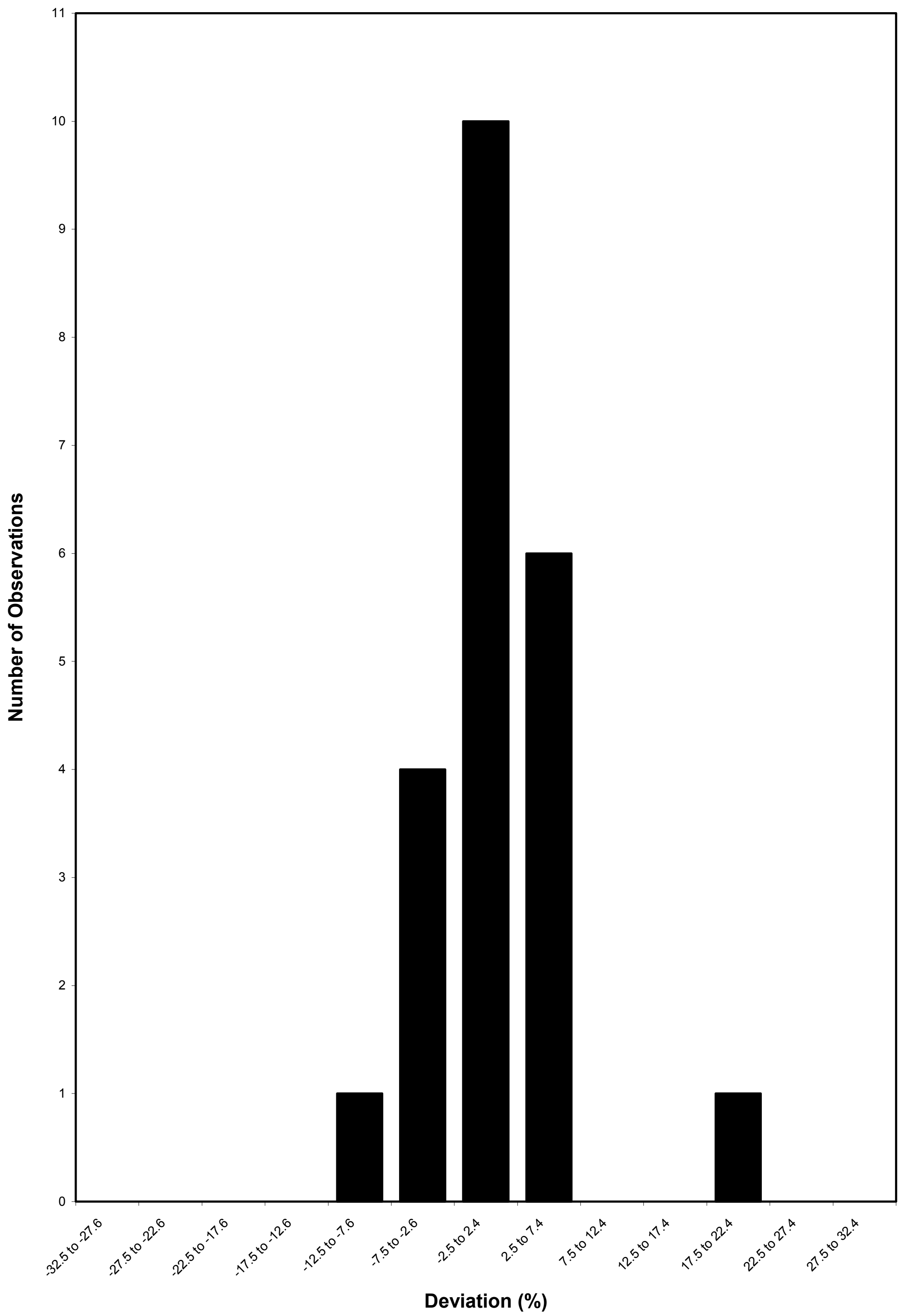


Figure 27 - Reported Zr-95 high level results

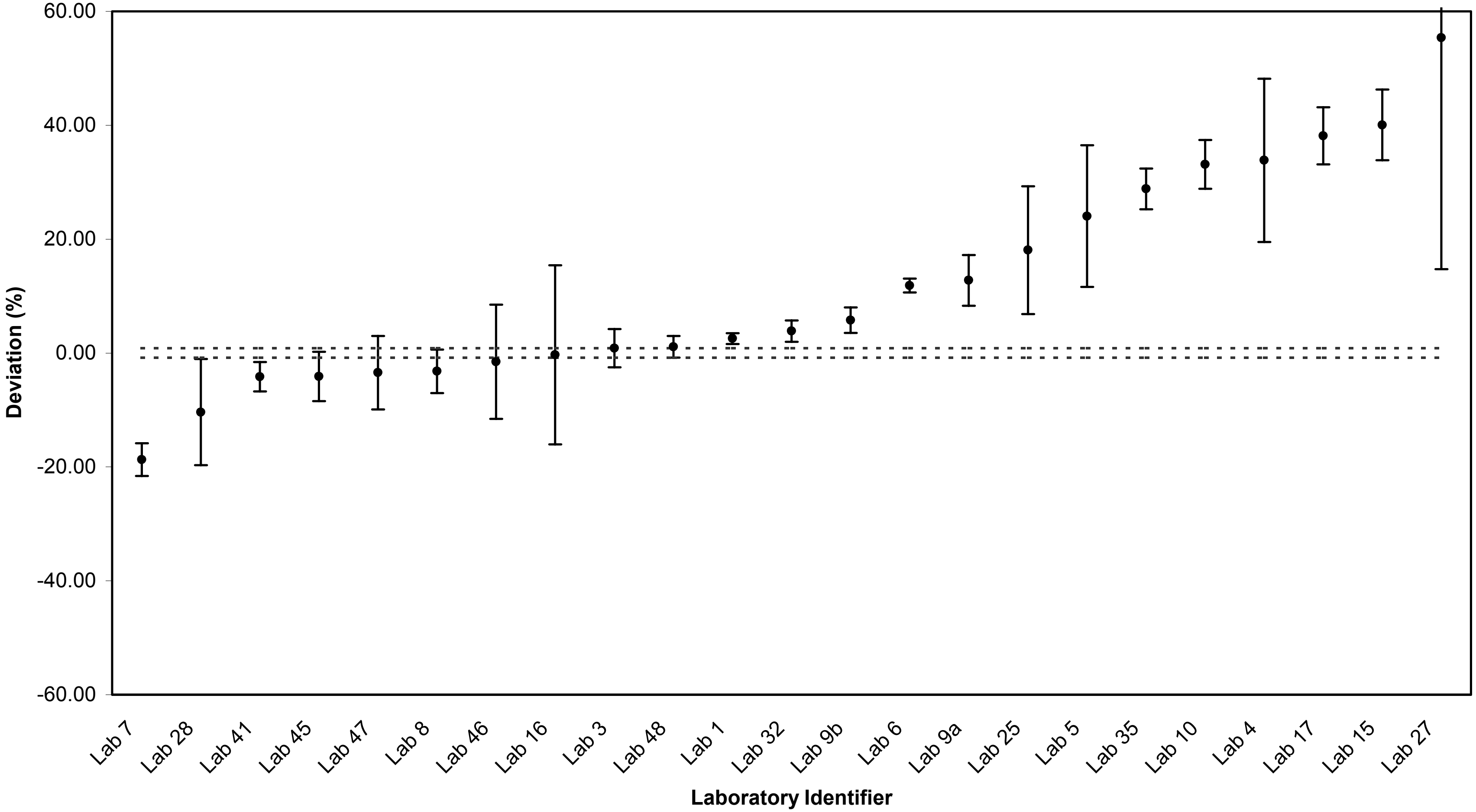


Figure 28 - Zr-95 high level results (Five outside limits of plot)

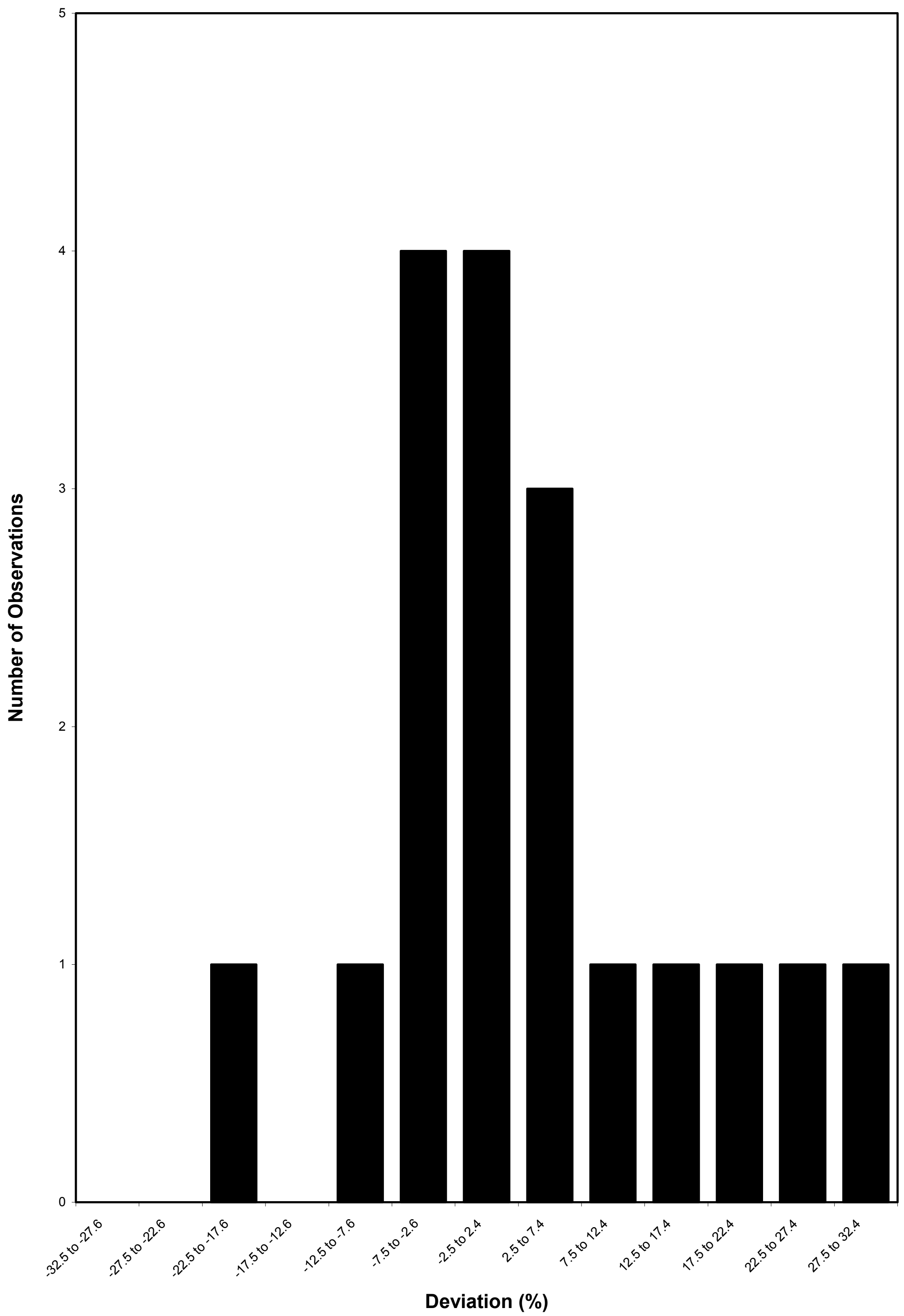


Figure 29 - Reported Ru-106 high level results

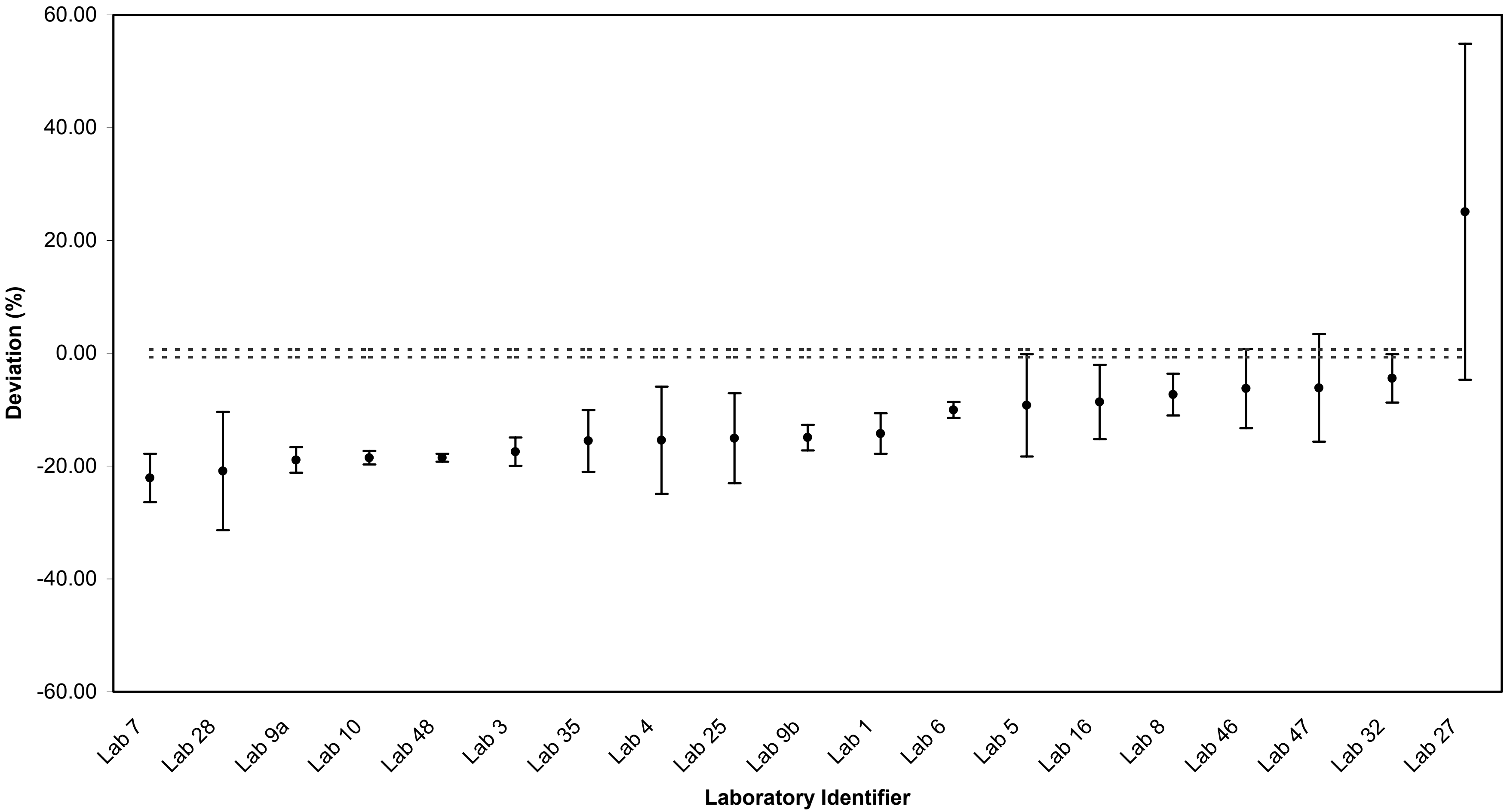


Figure 30 - Ru-106 high level results

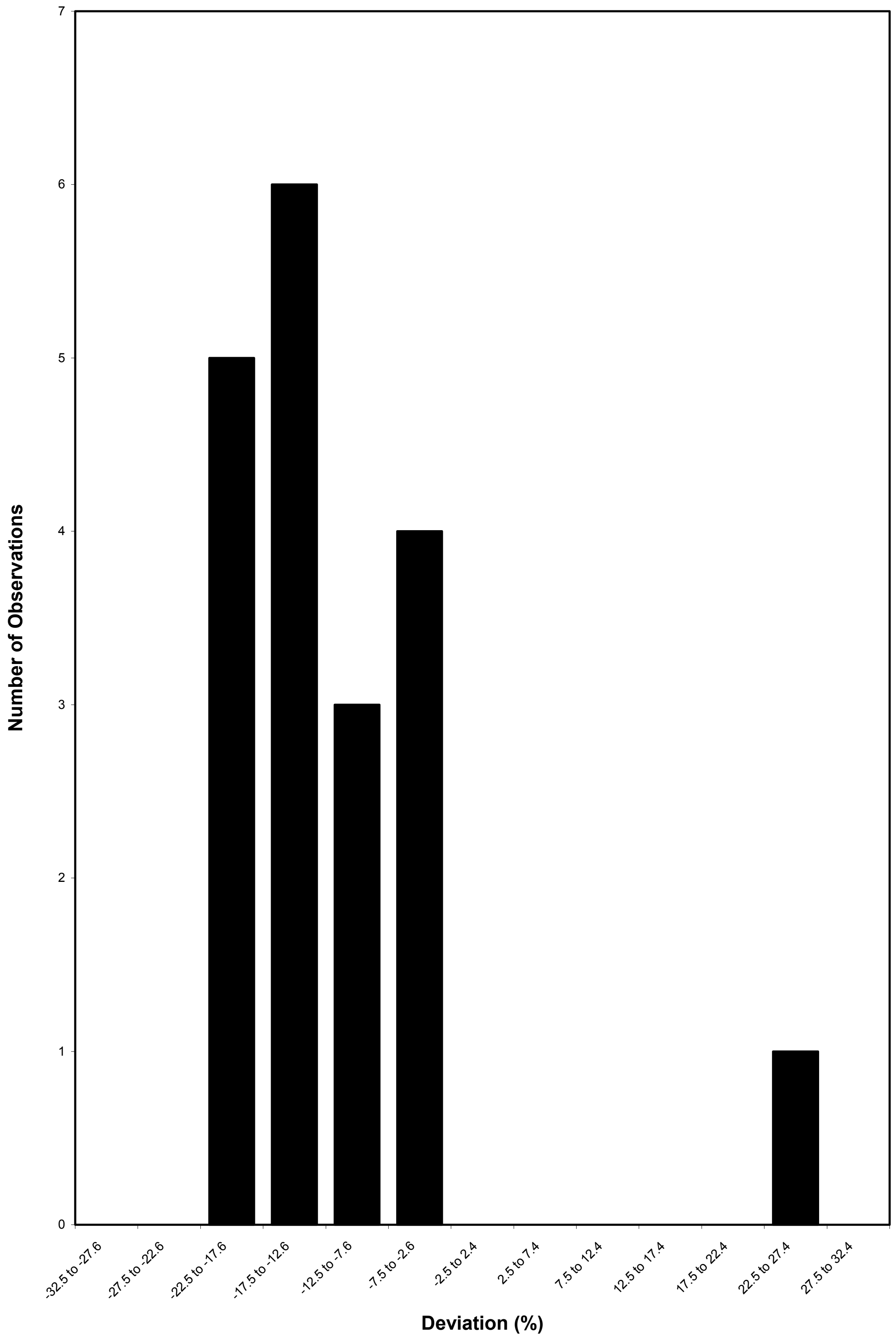


Figure 31 - Reported Cs-134 high level results

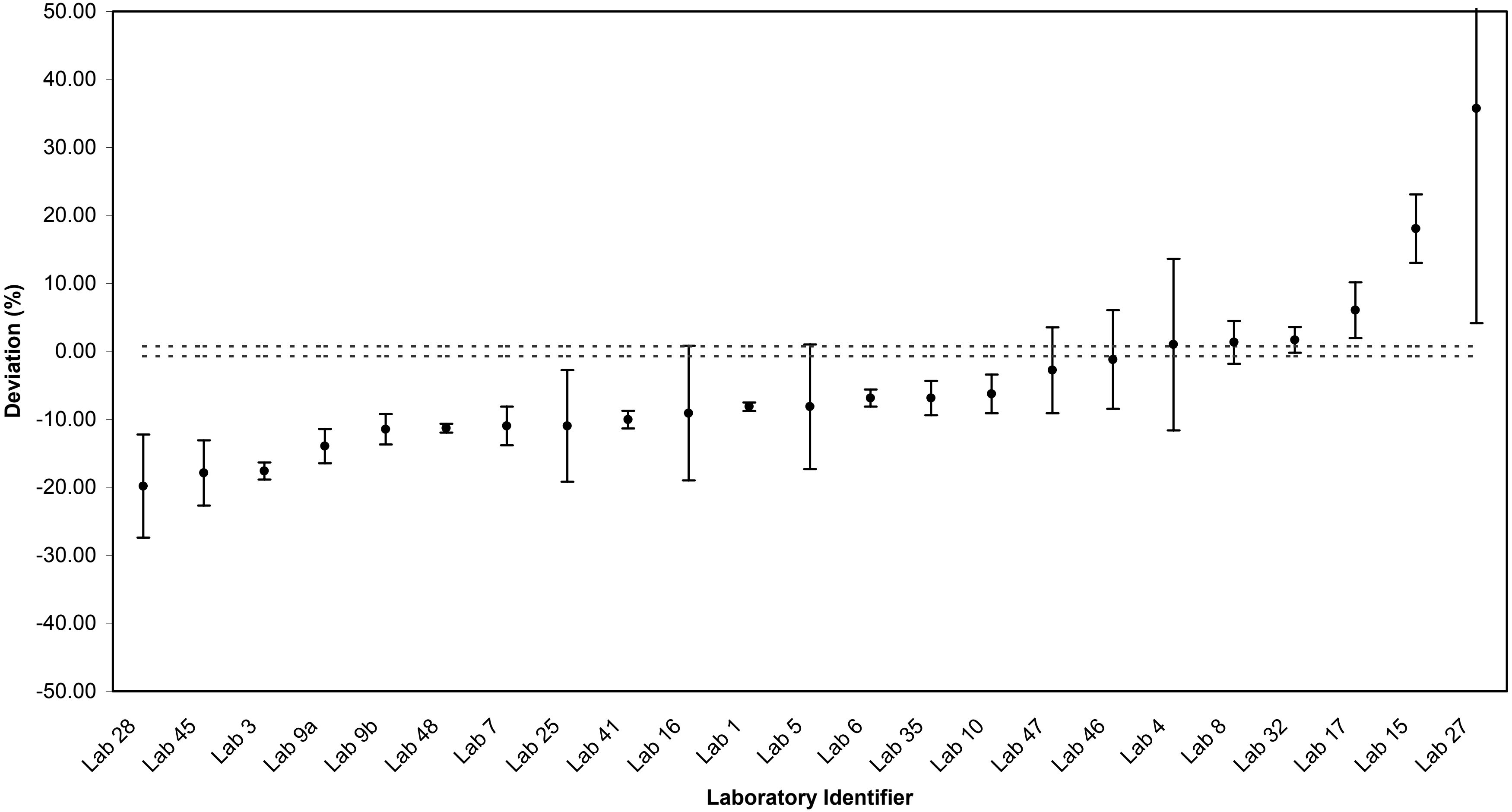


Figure 32 - Cs-134 high level results (One outside limits of plot)

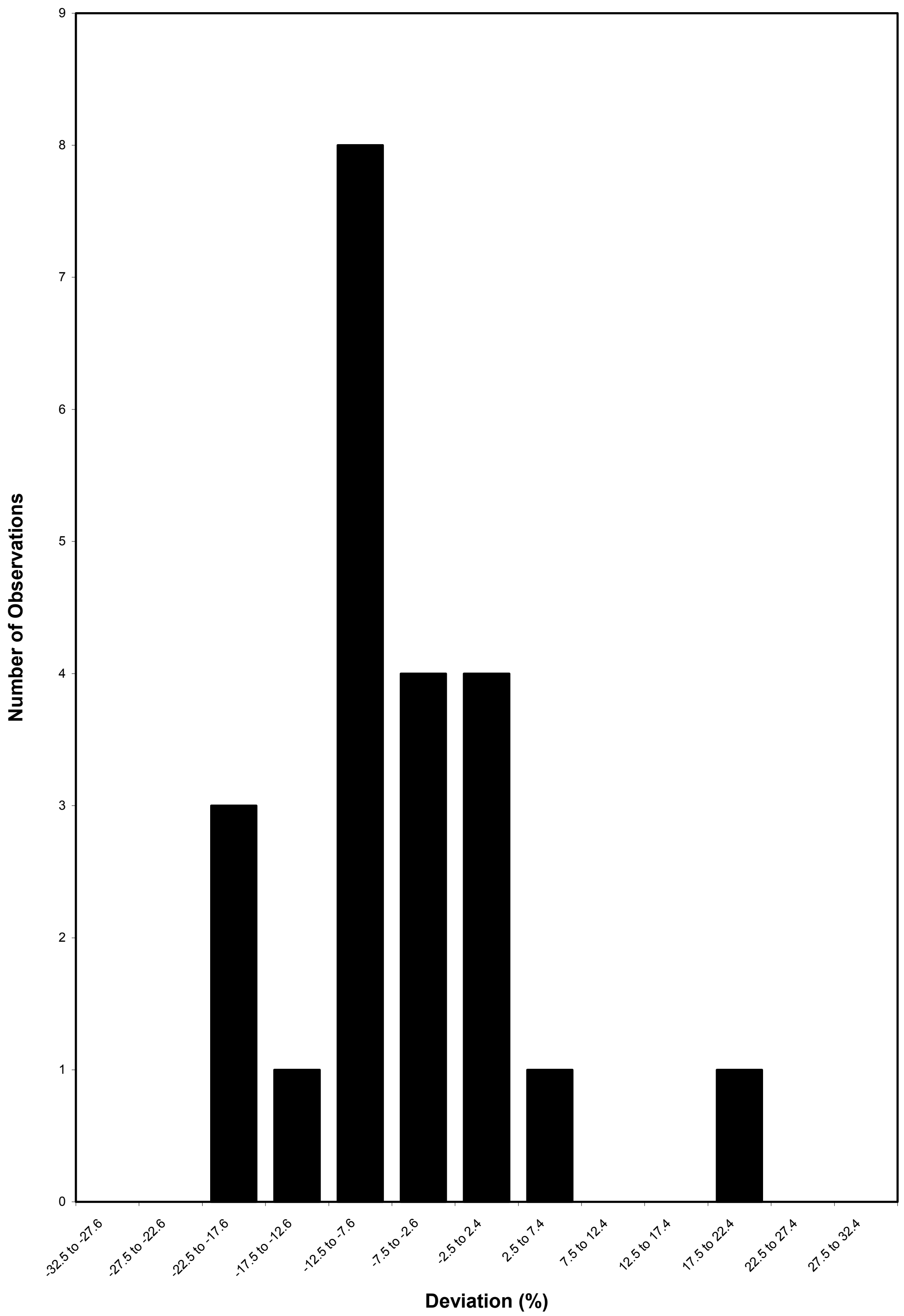


Figure 33 - Reported Cs-137 high level results

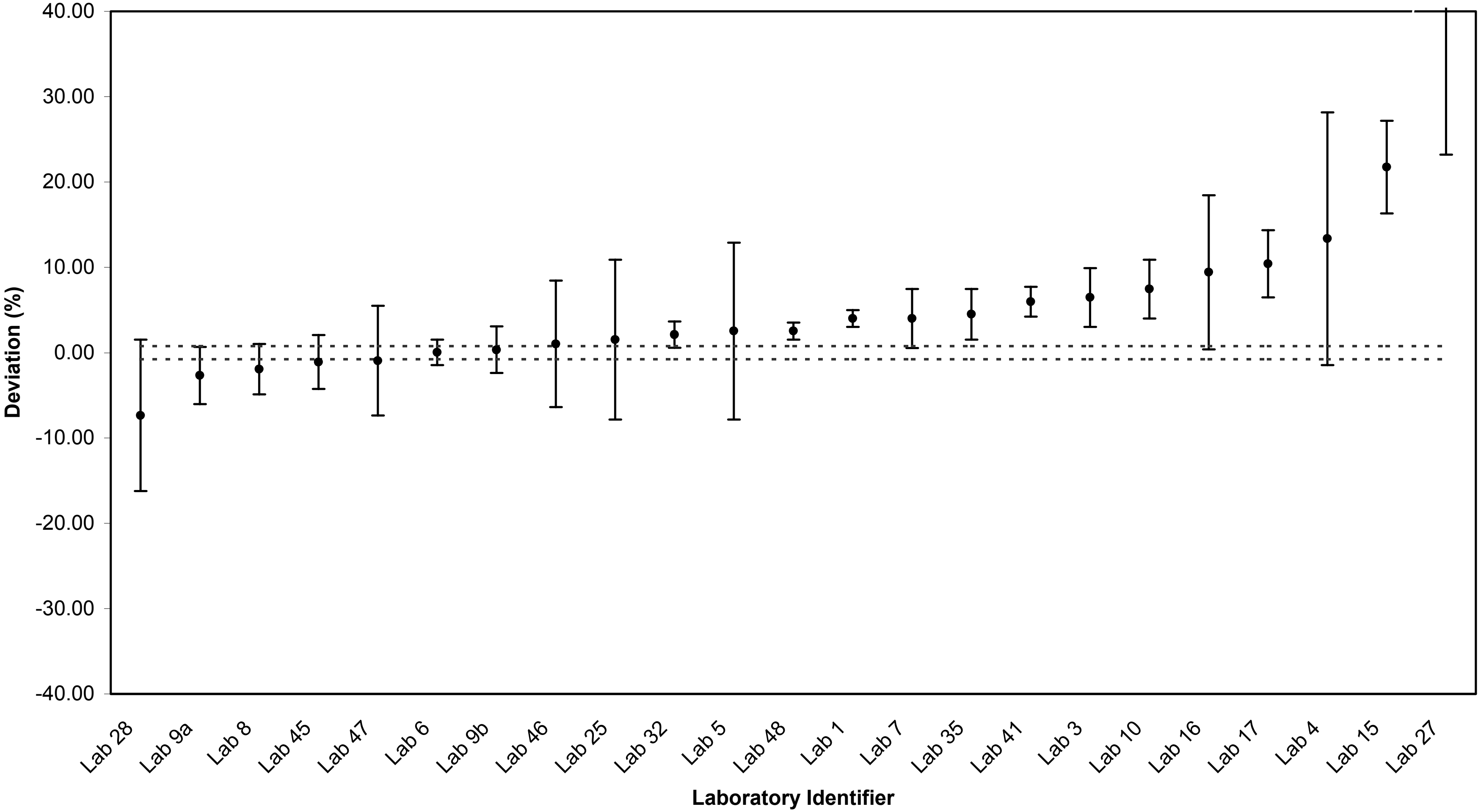


Figure 34 - Cs-137 high level results (One outside limits of plot)

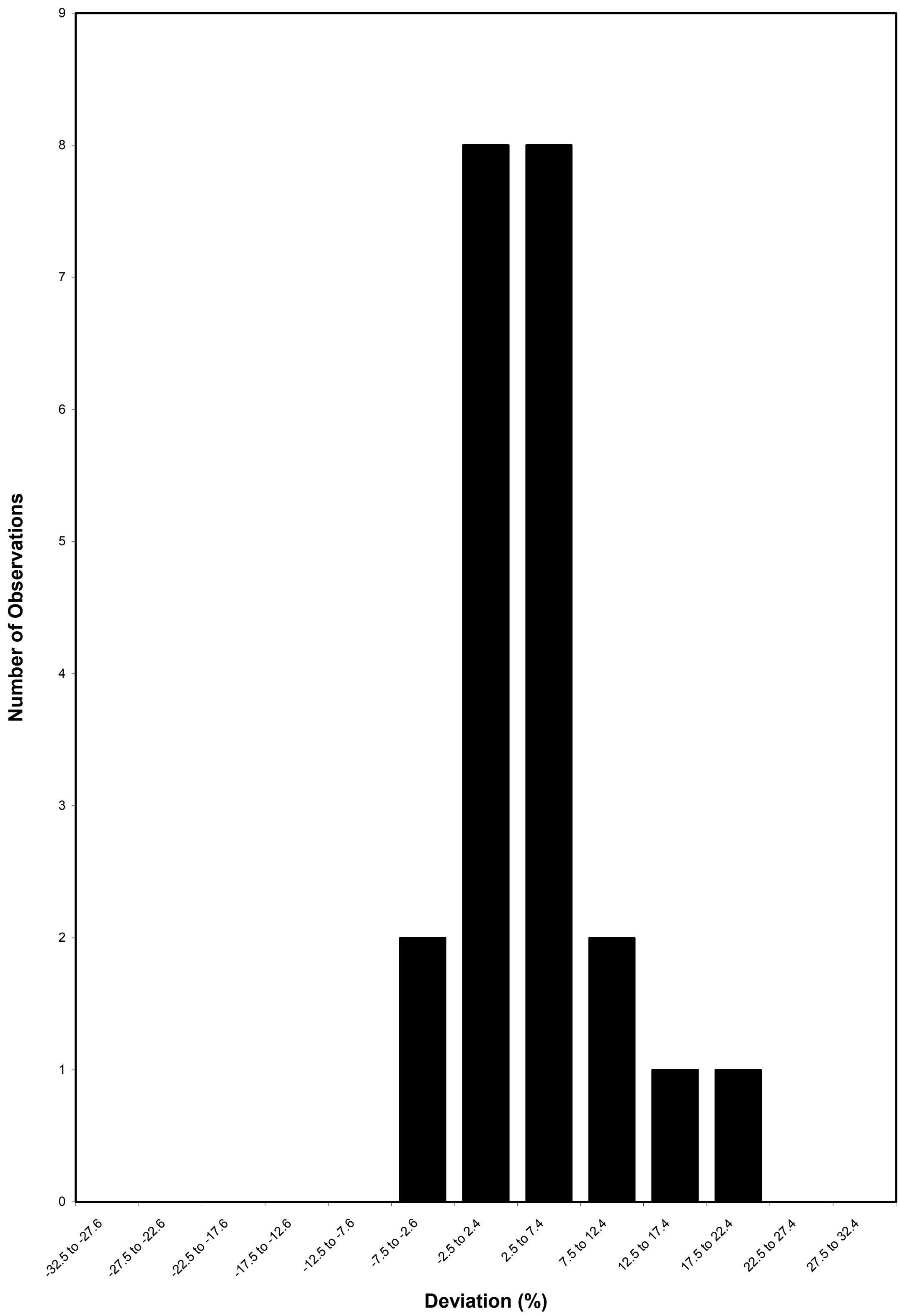


Figure 35 - Reported Ce-144 high level results

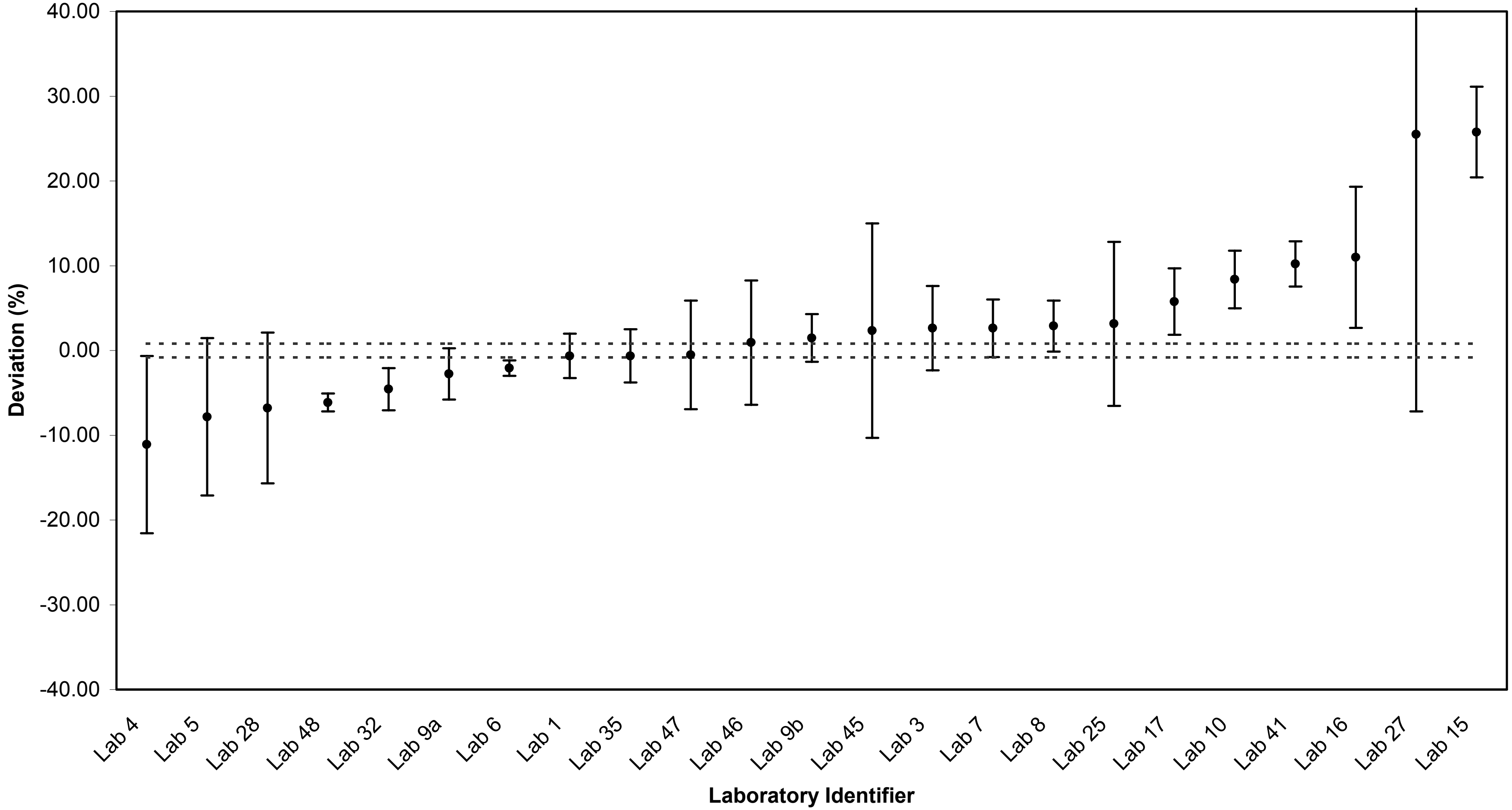


Figure 36 - Ce-144 high level results

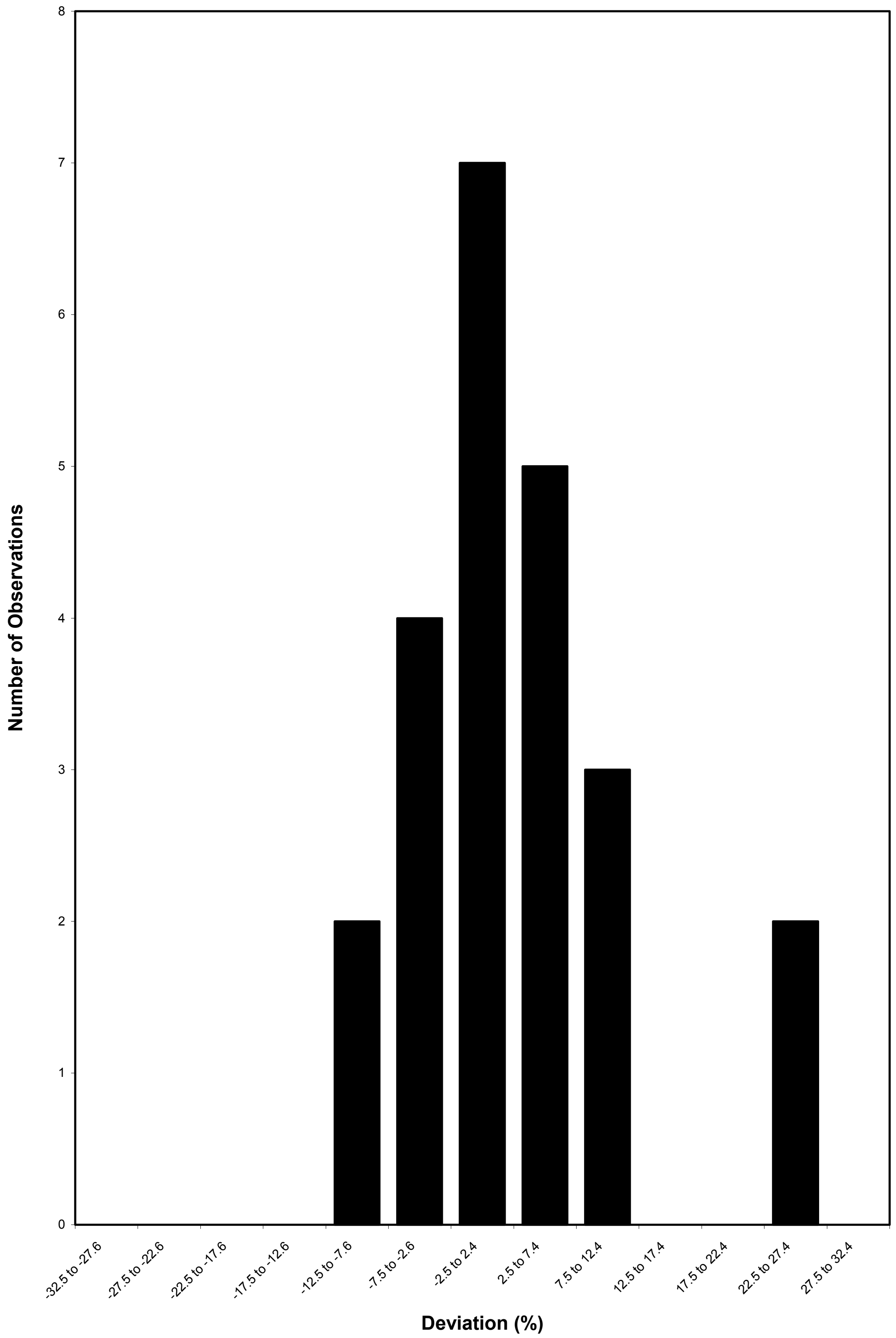


Figure 37 - Reported Eu-154 high level results

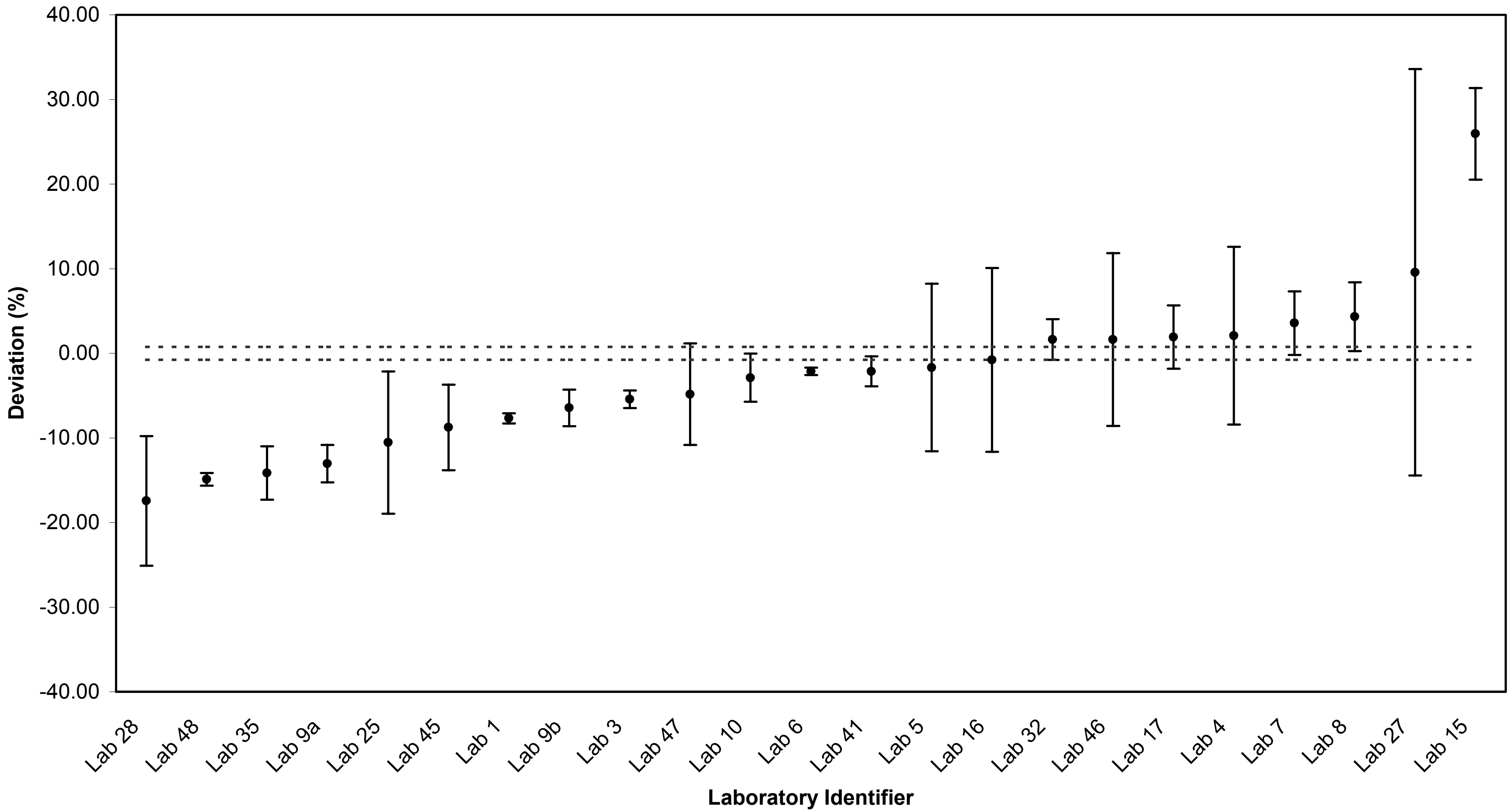


Figure 38 - Eu-154 low level results

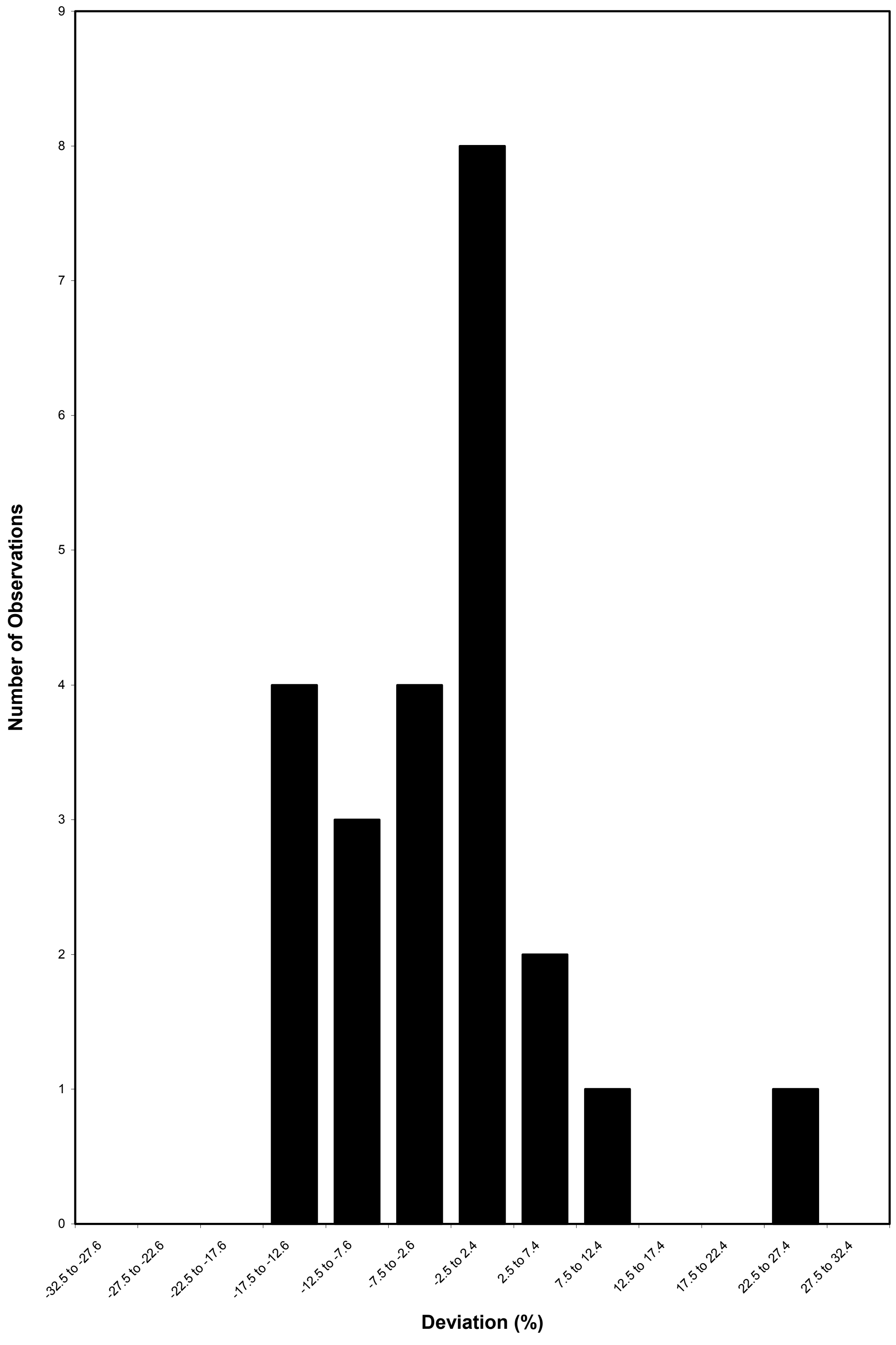


Figure 39 - Reported Eu-155 high level results

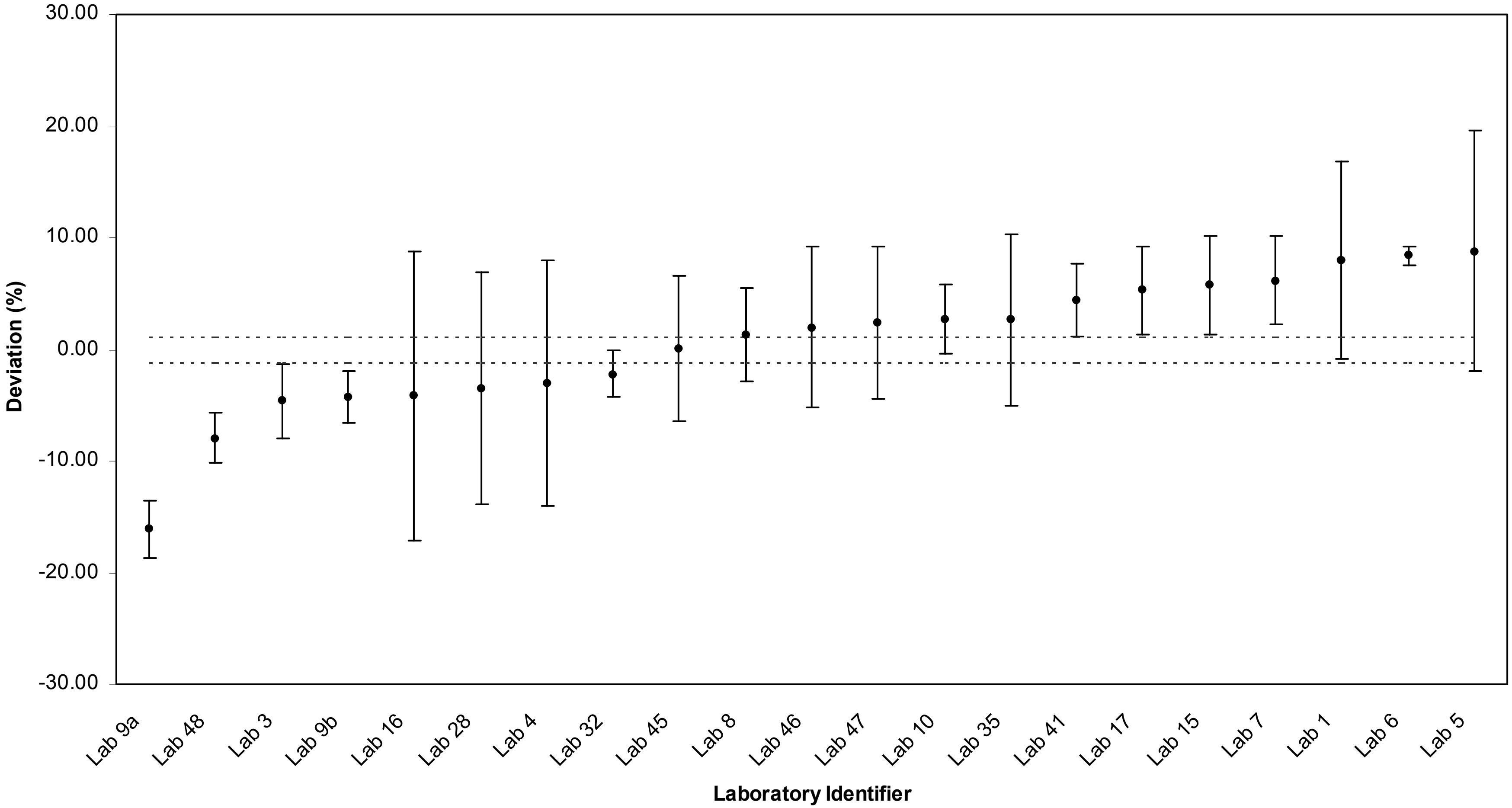


Figure 40 - Eu-155 high level results

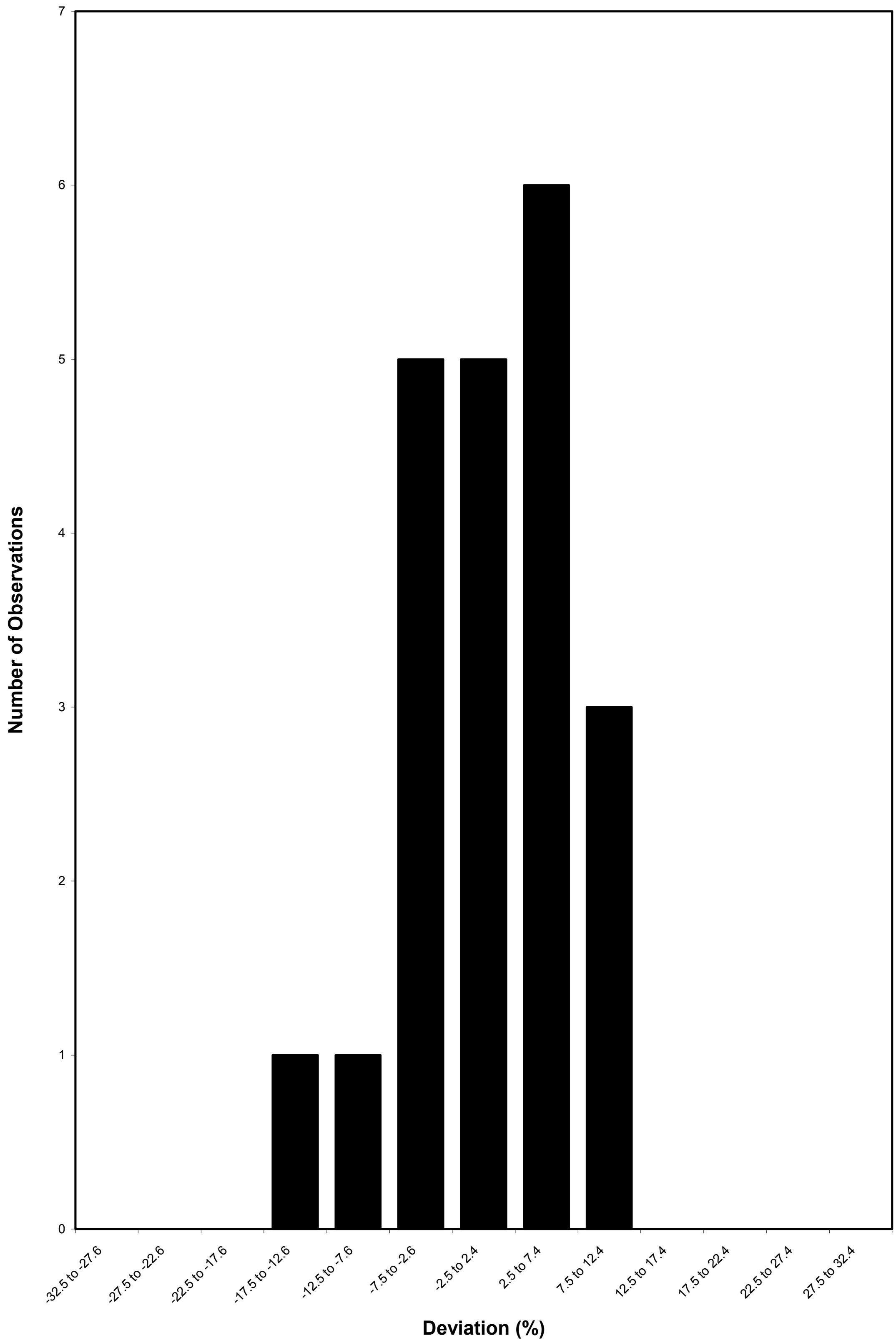


Figure 41 - Reported Co-60 low level results

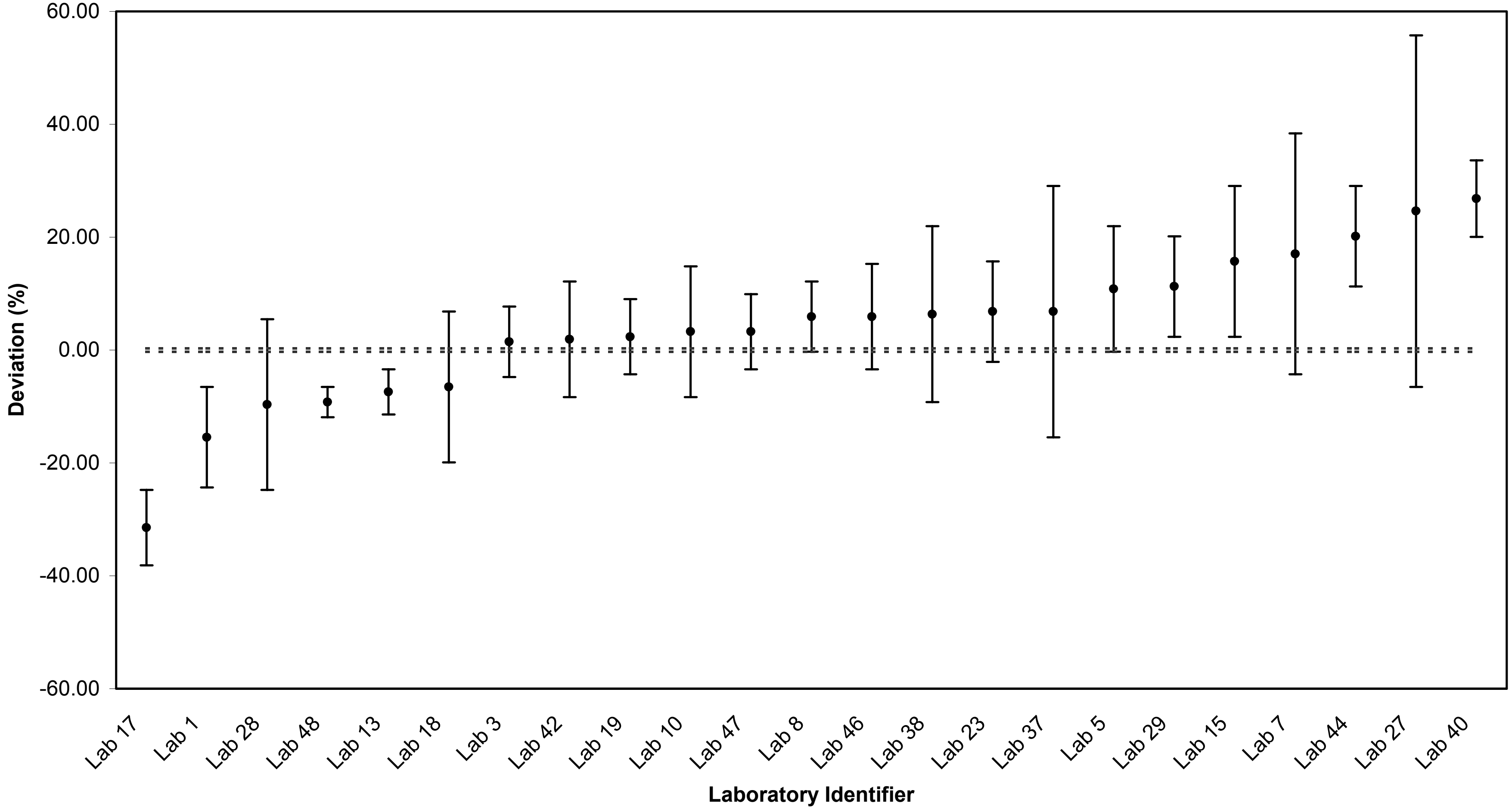


Figure 42 - Co-60 low level results

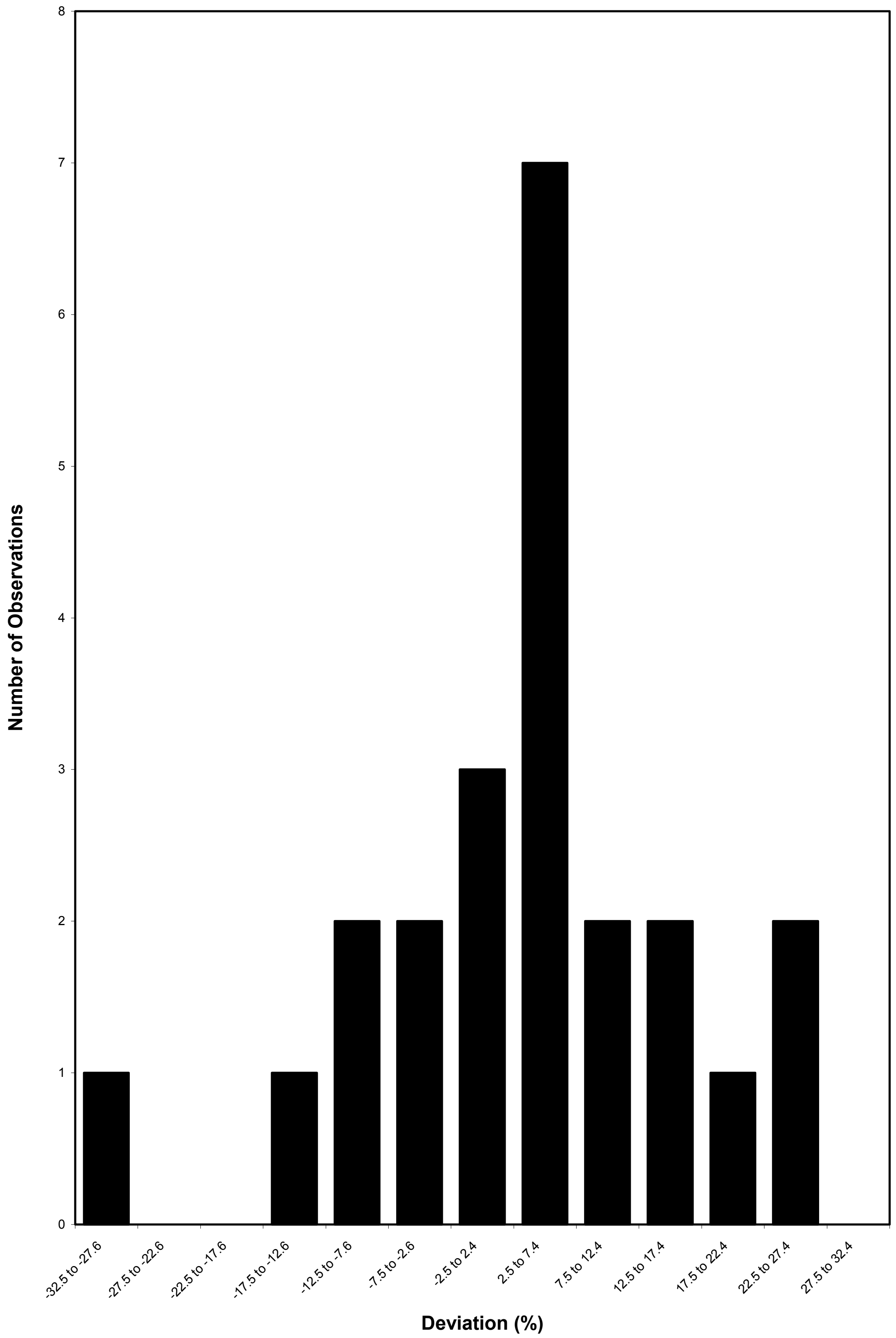


Figure 43 - Reported Zr-95 low level results

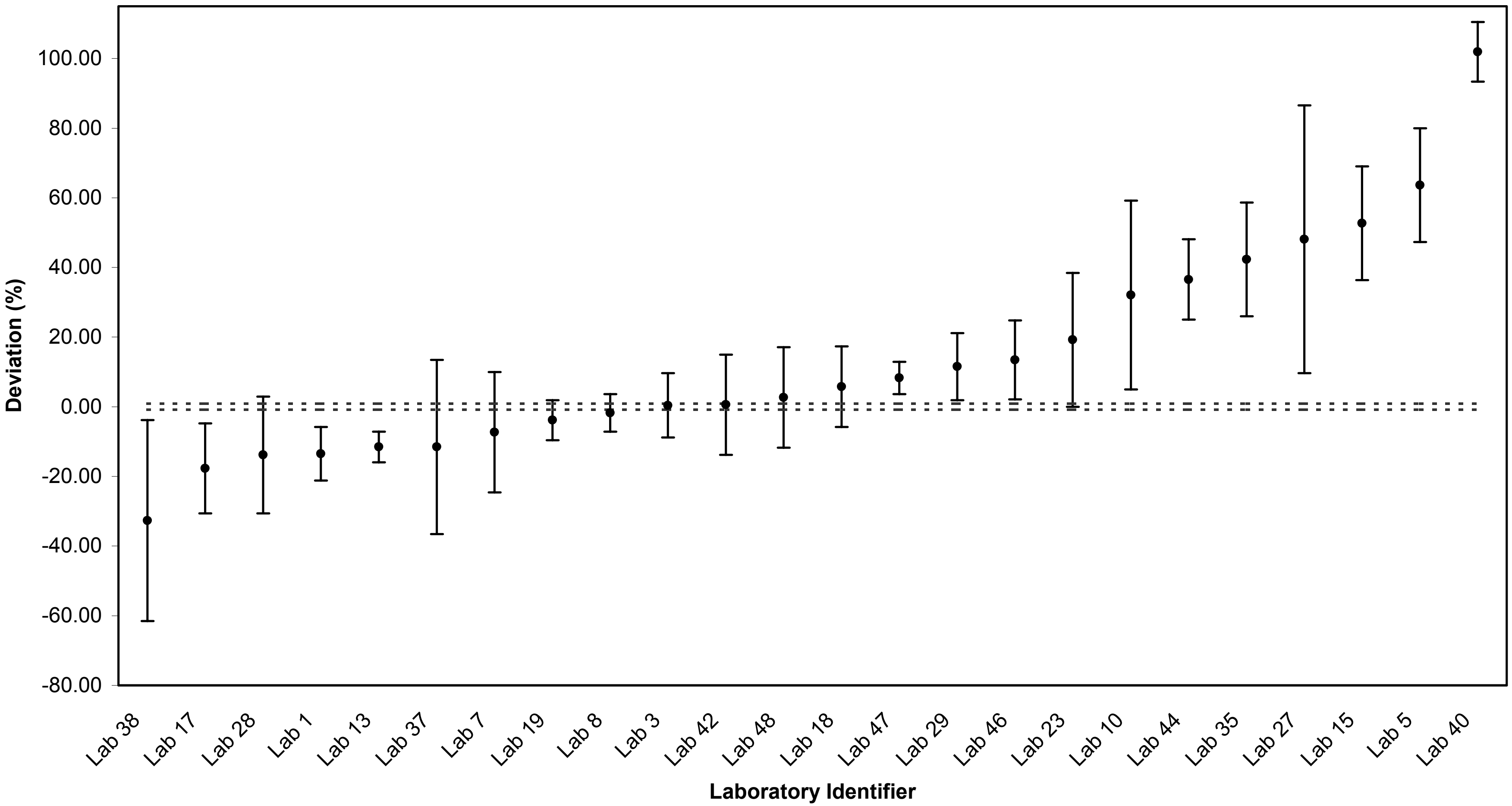


Figure 44 - Zr-95 low level results (Seven outside limits of plot)

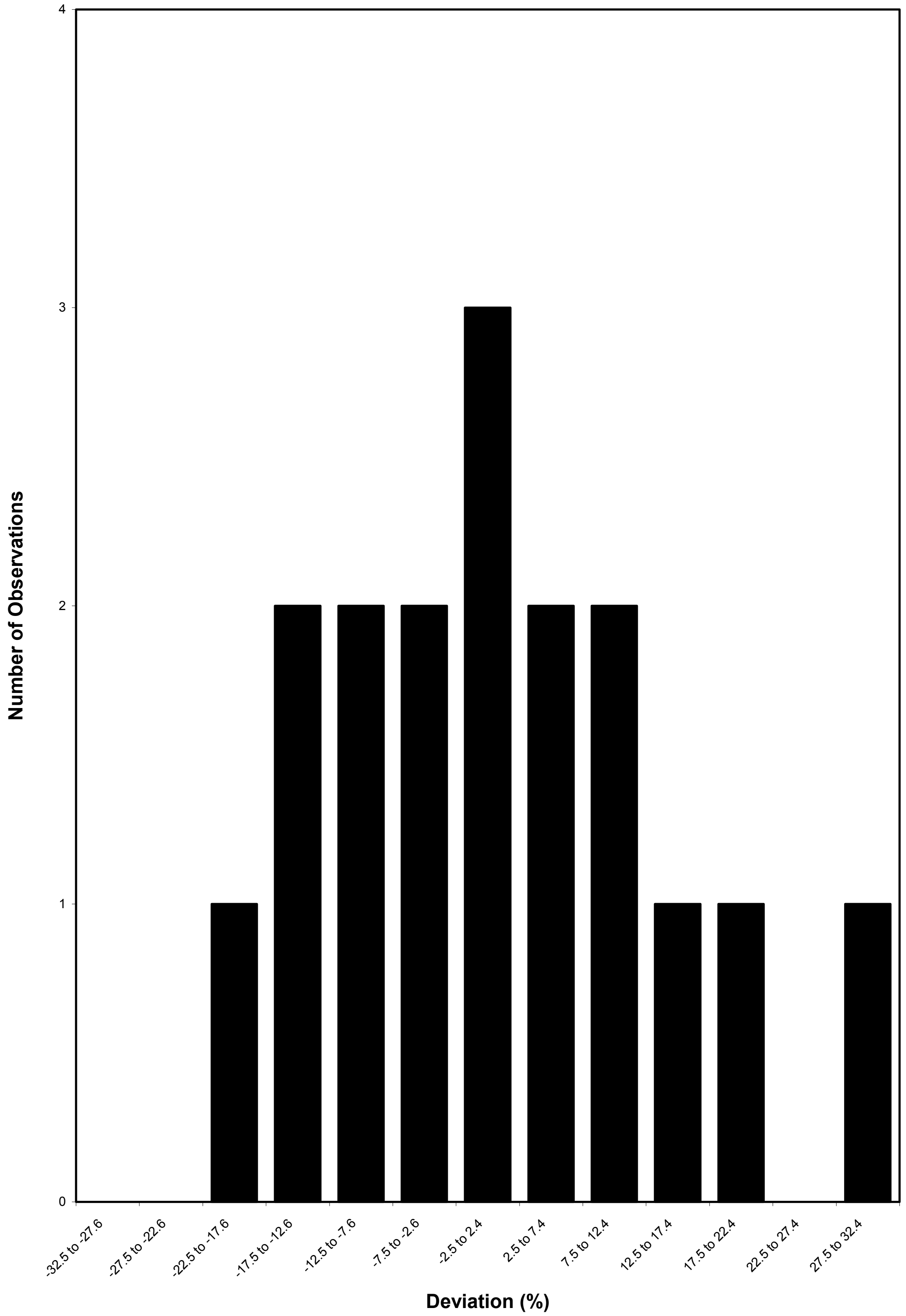


Figure 45 - Reported Ru-106 low level results

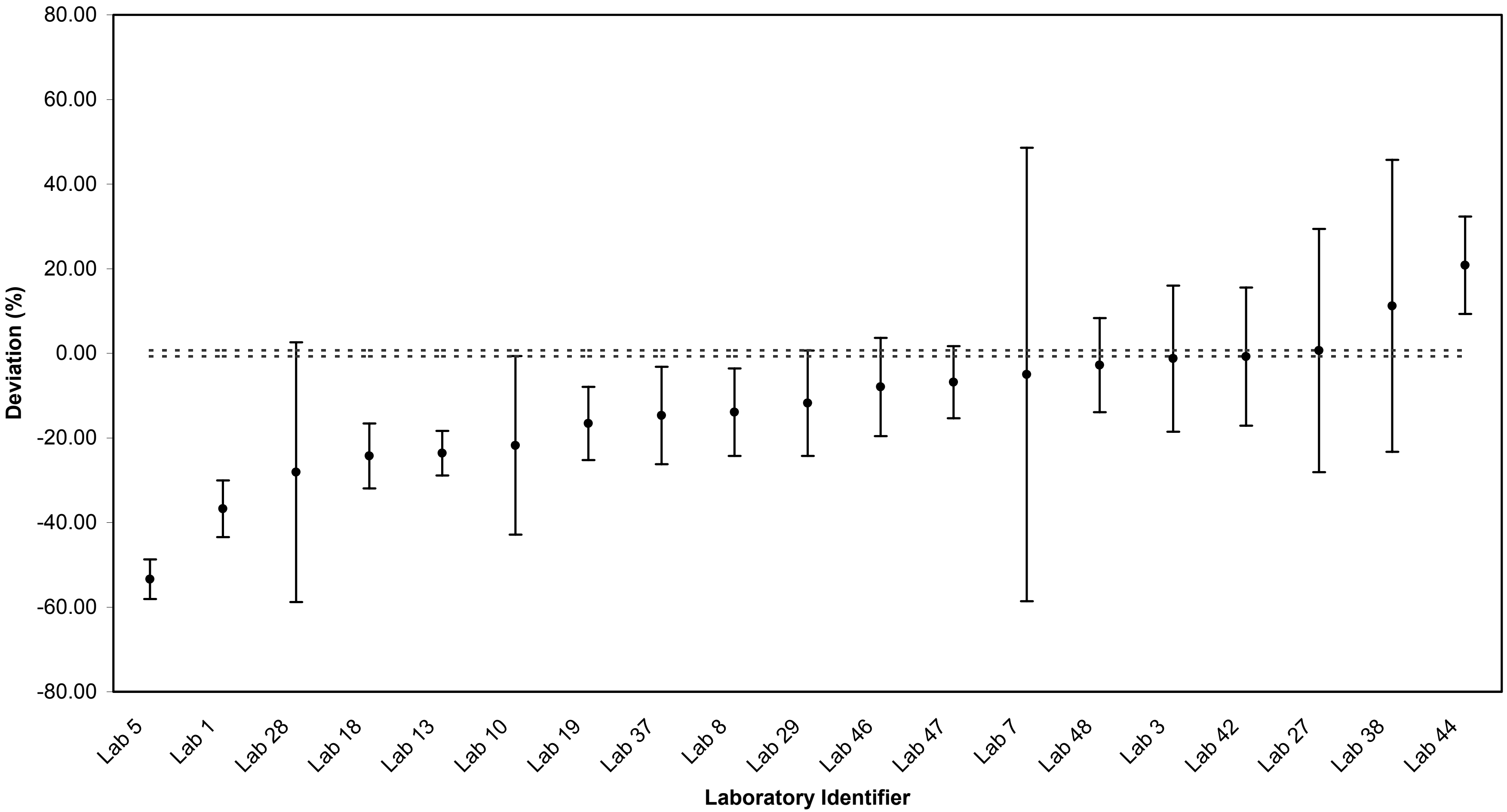


Figure 46 - Ru-106 low level results (Two outside limits of plot)

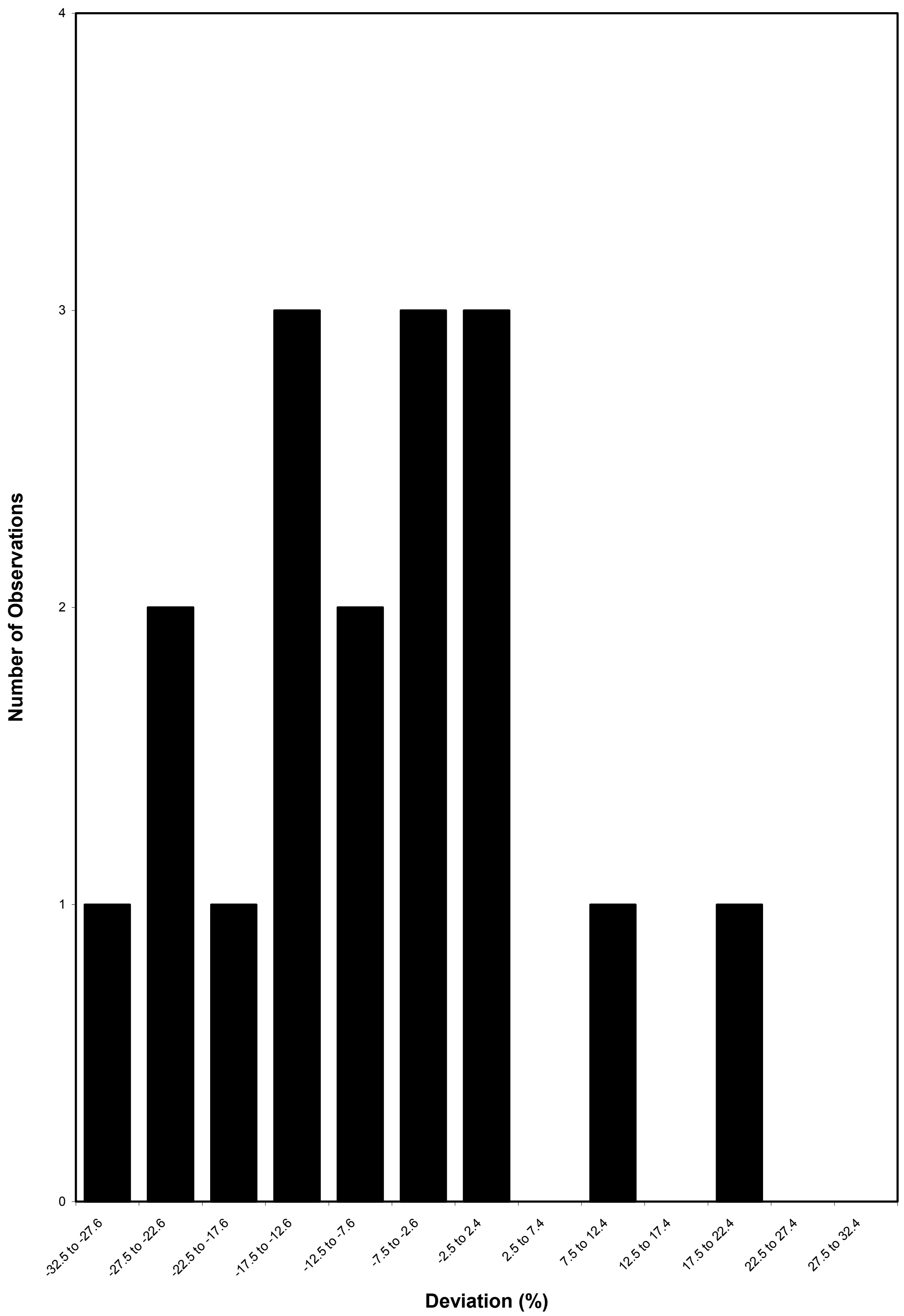


Figure 47 - Reported Cs-134 low level results

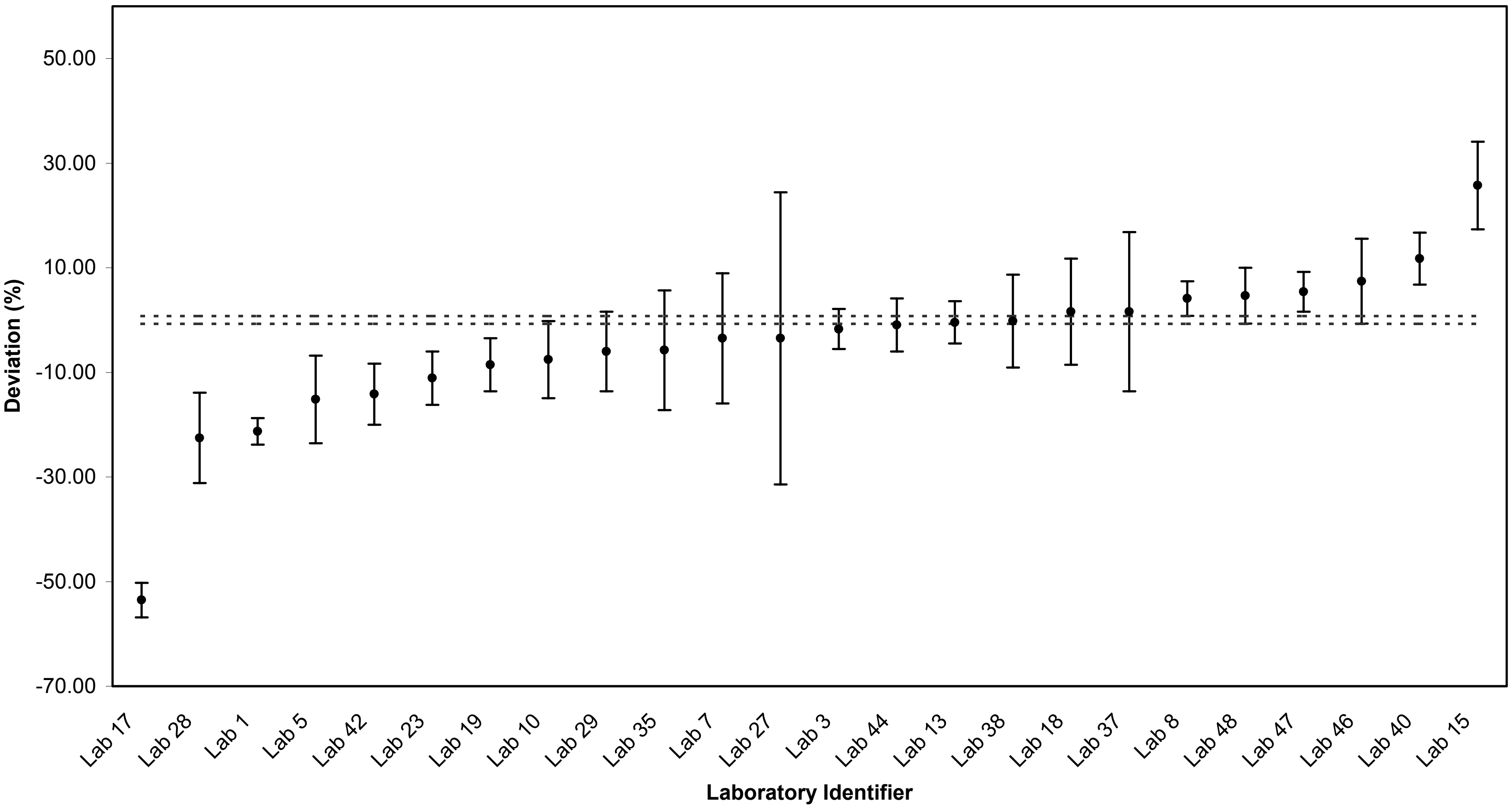


Figure 48 - Cs-134 low level results
(Two outside limits of plot)

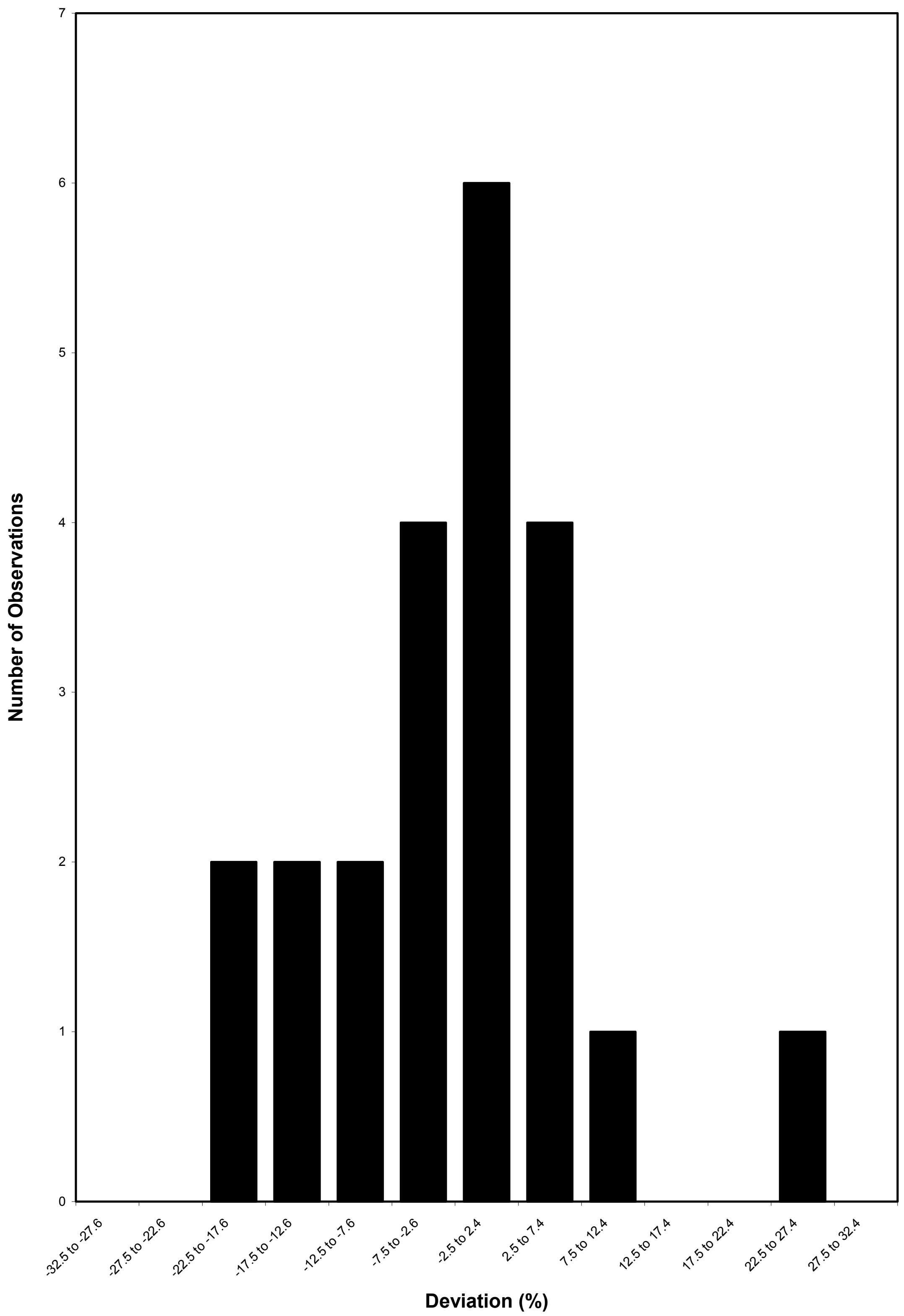


Figure 49 - Reported Cs-137 low level results

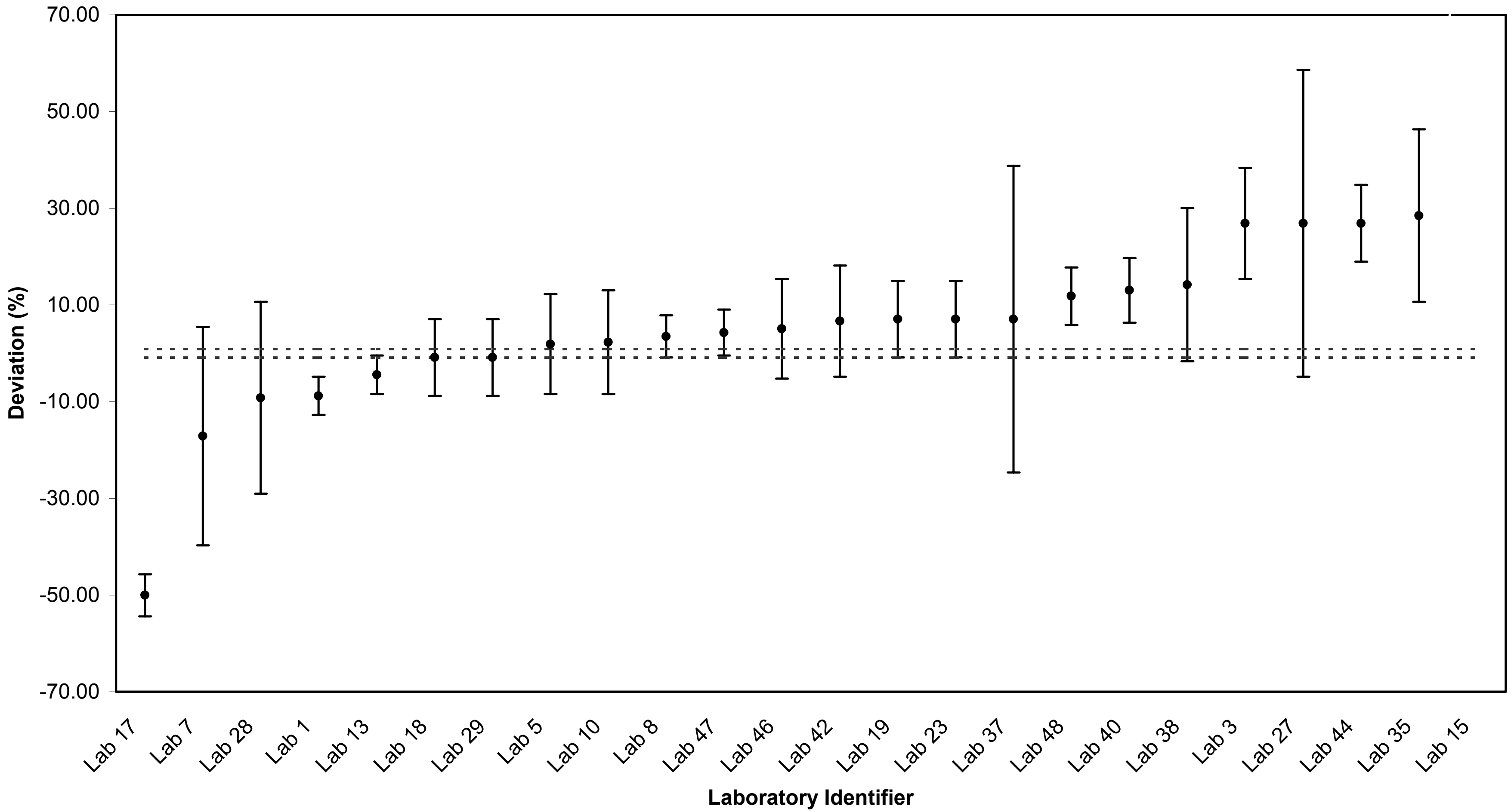


**Figure 50 - Cs-137 low level results
(Two outside limits of plot)**

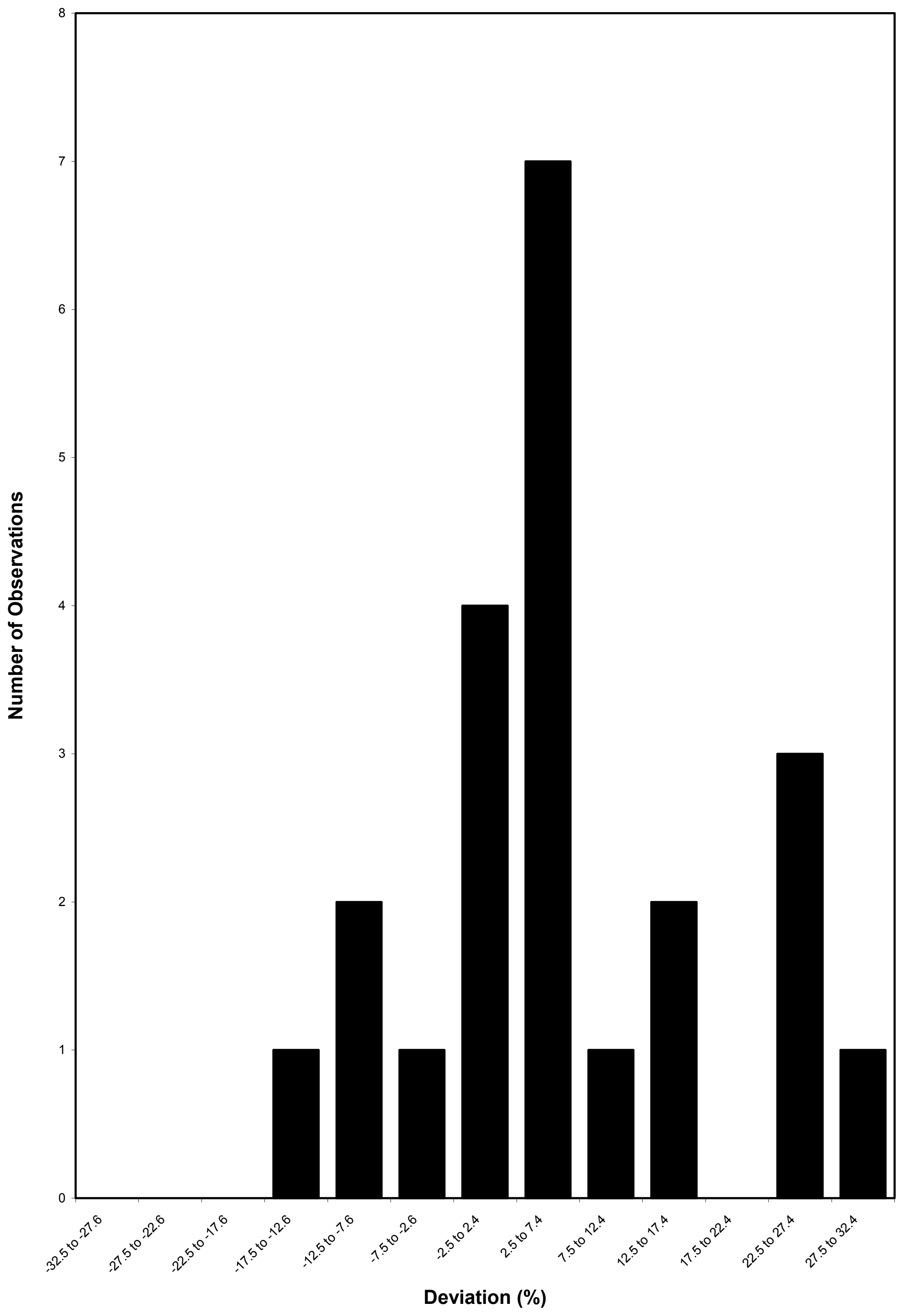


Figure 51 - Reported Ce-144 low level results

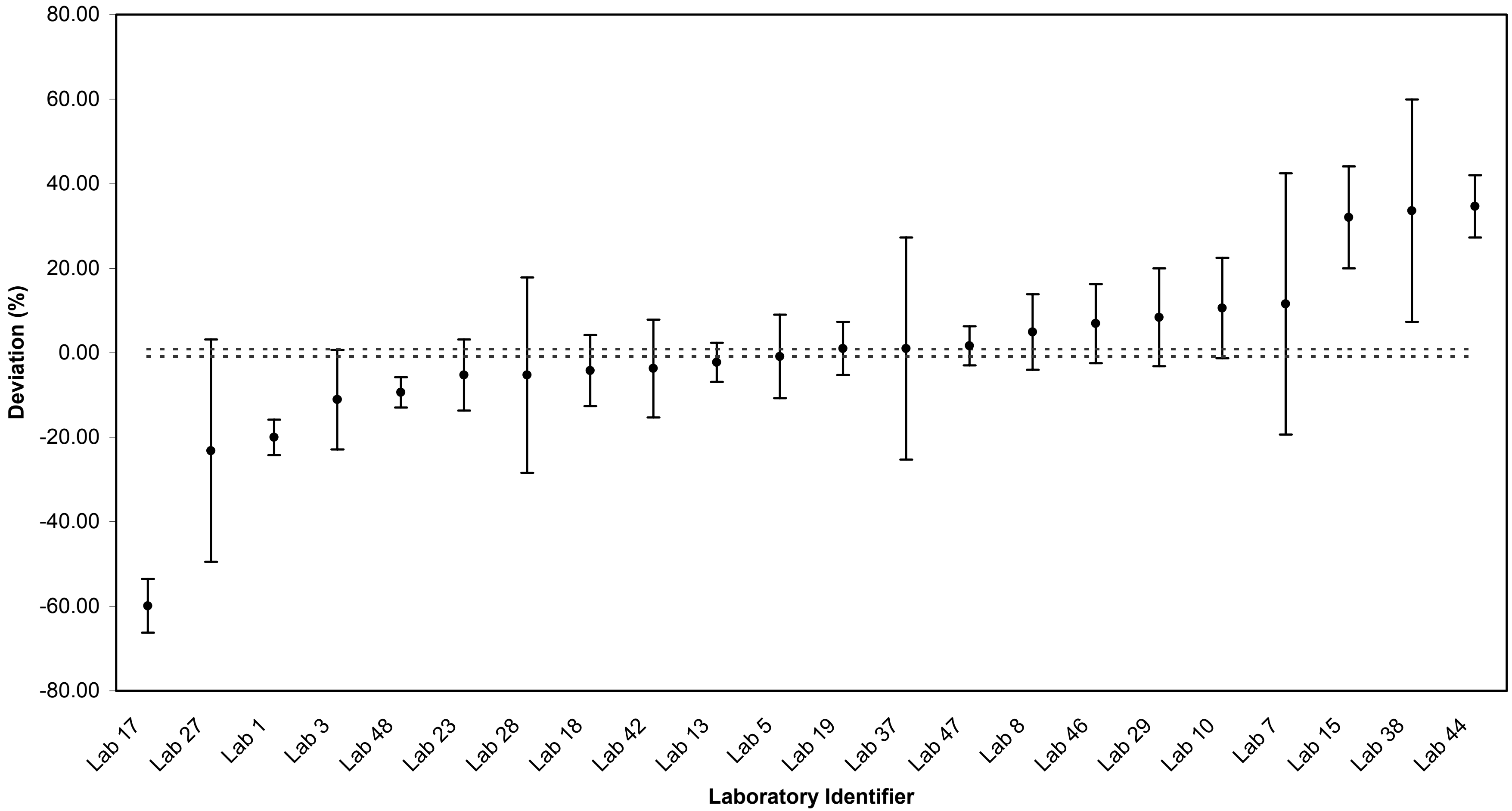


Figure 52 - Ce-144 low level results (Three outside limits of plot)

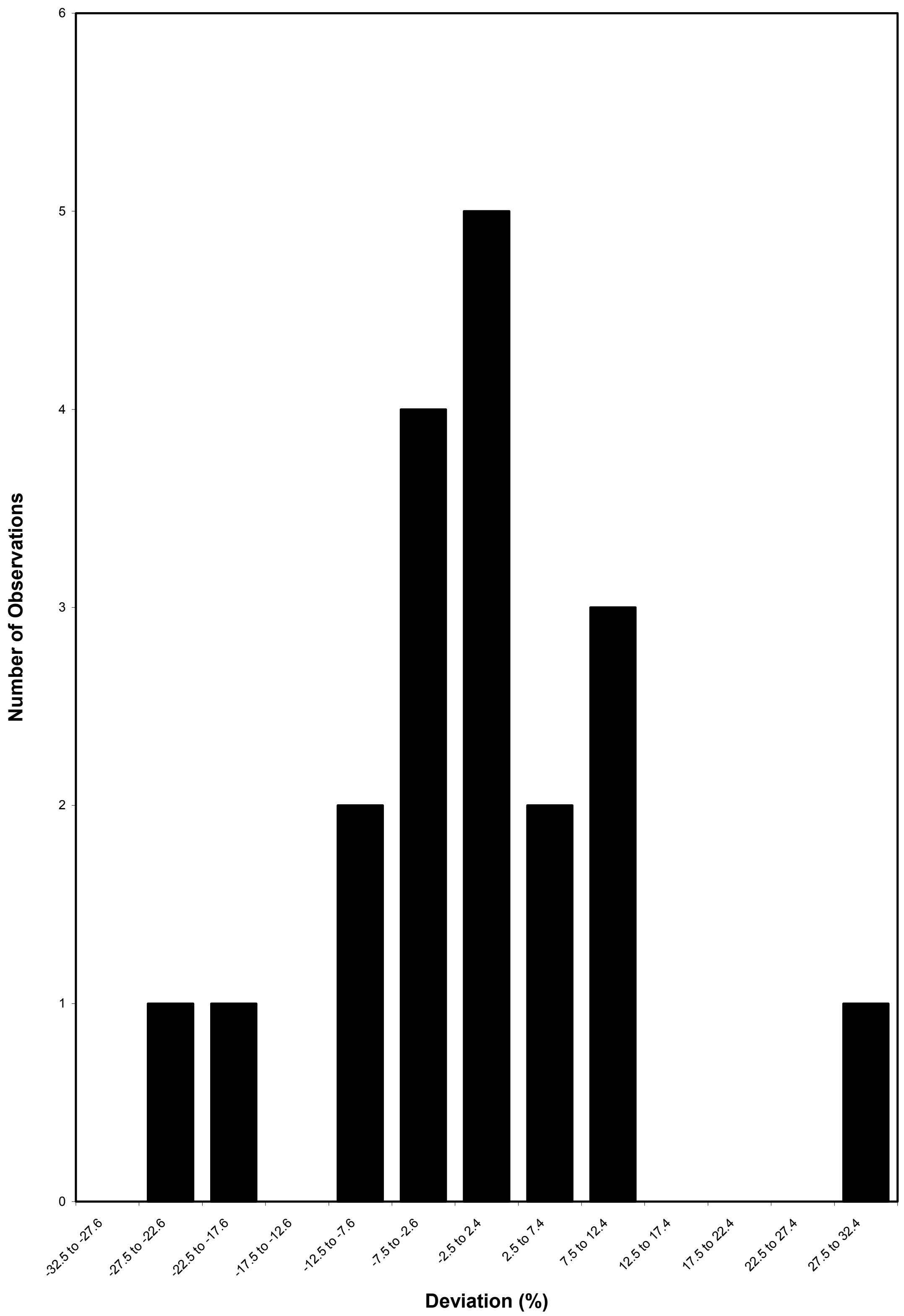


Figure 53 - Reported Eu-154 low level results

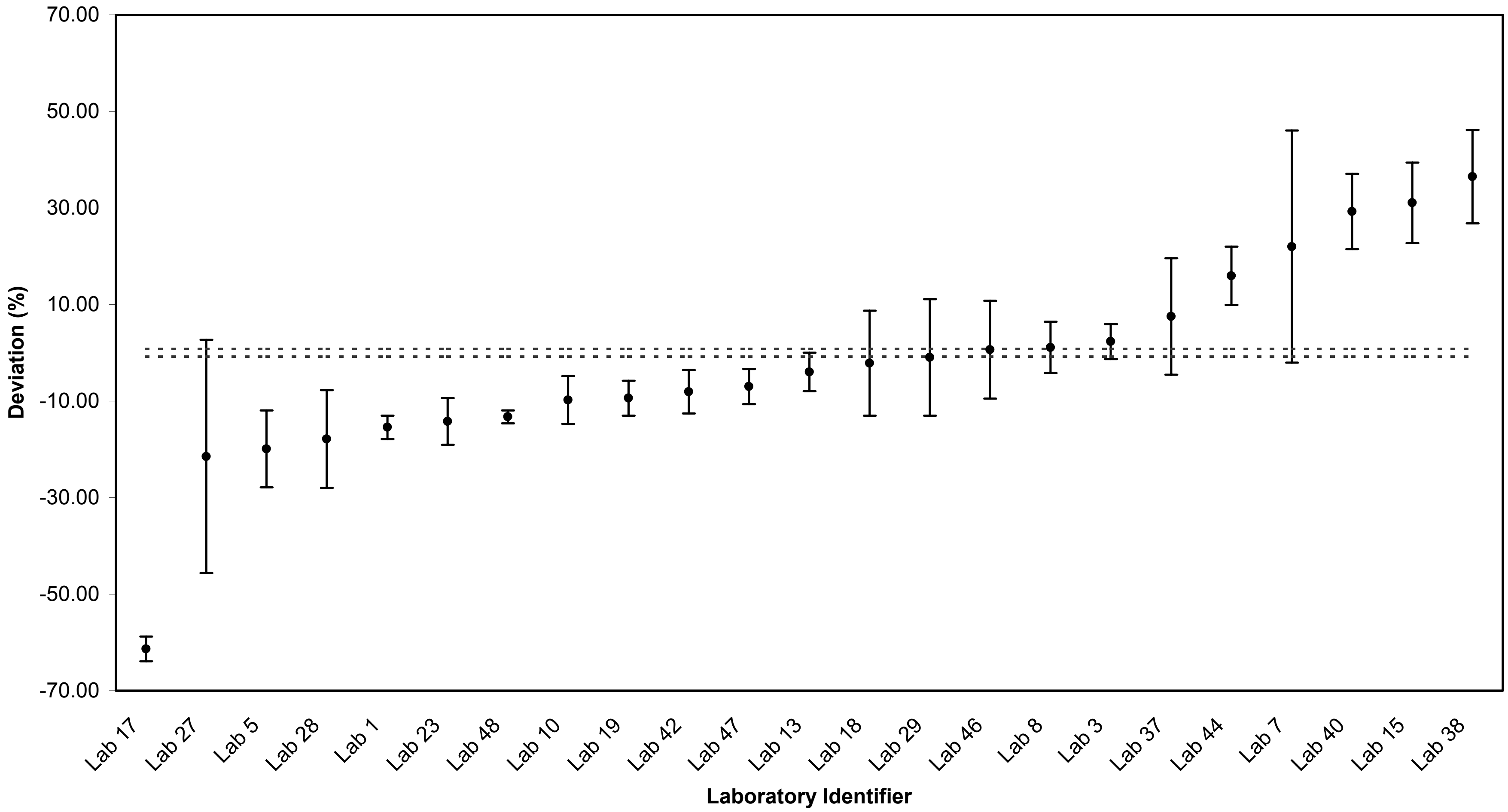


Figure 54 - Eu-154 low level results
(Two outside limits of plot)

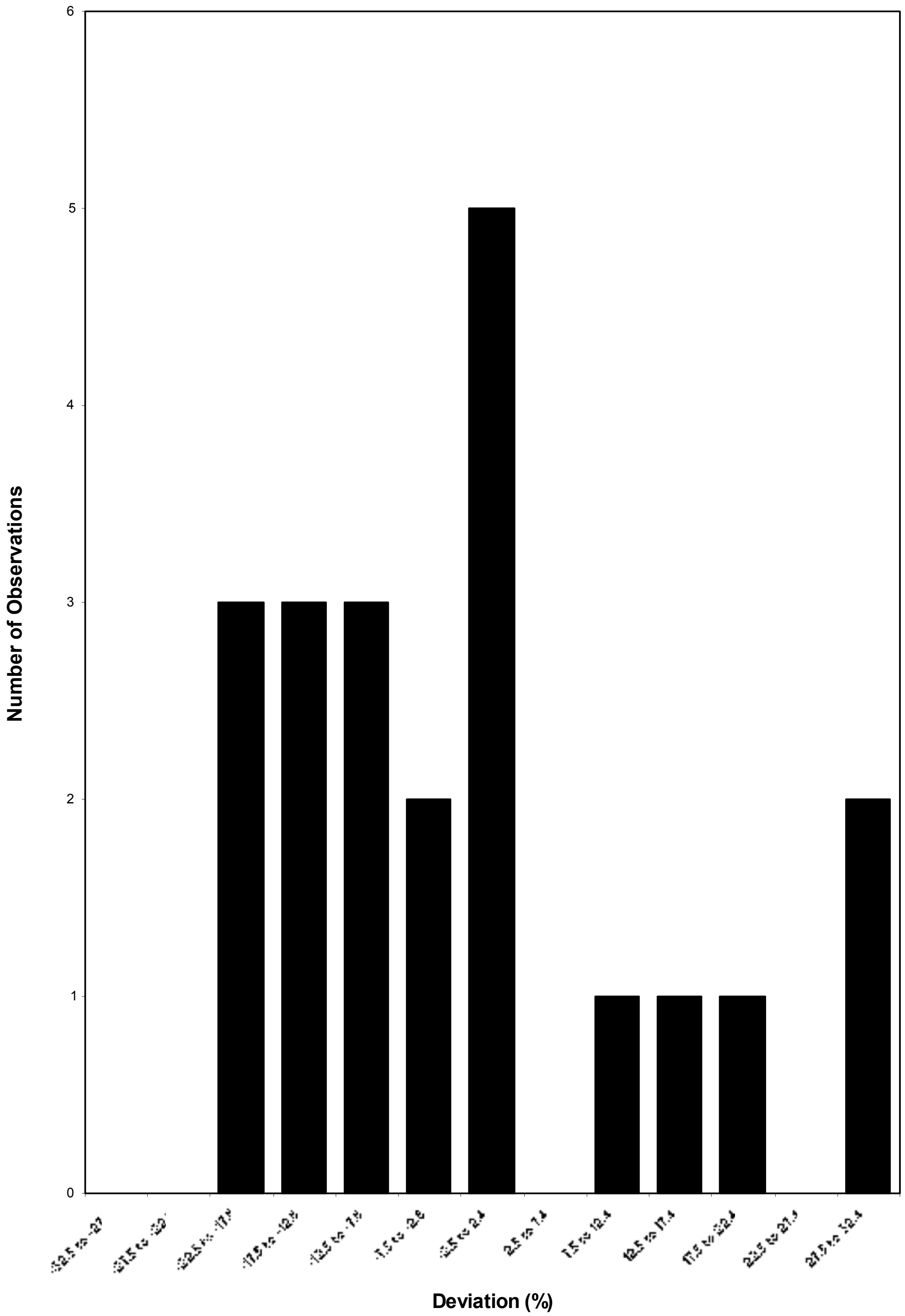


Figure 55 - Reported Eu-155 low level results

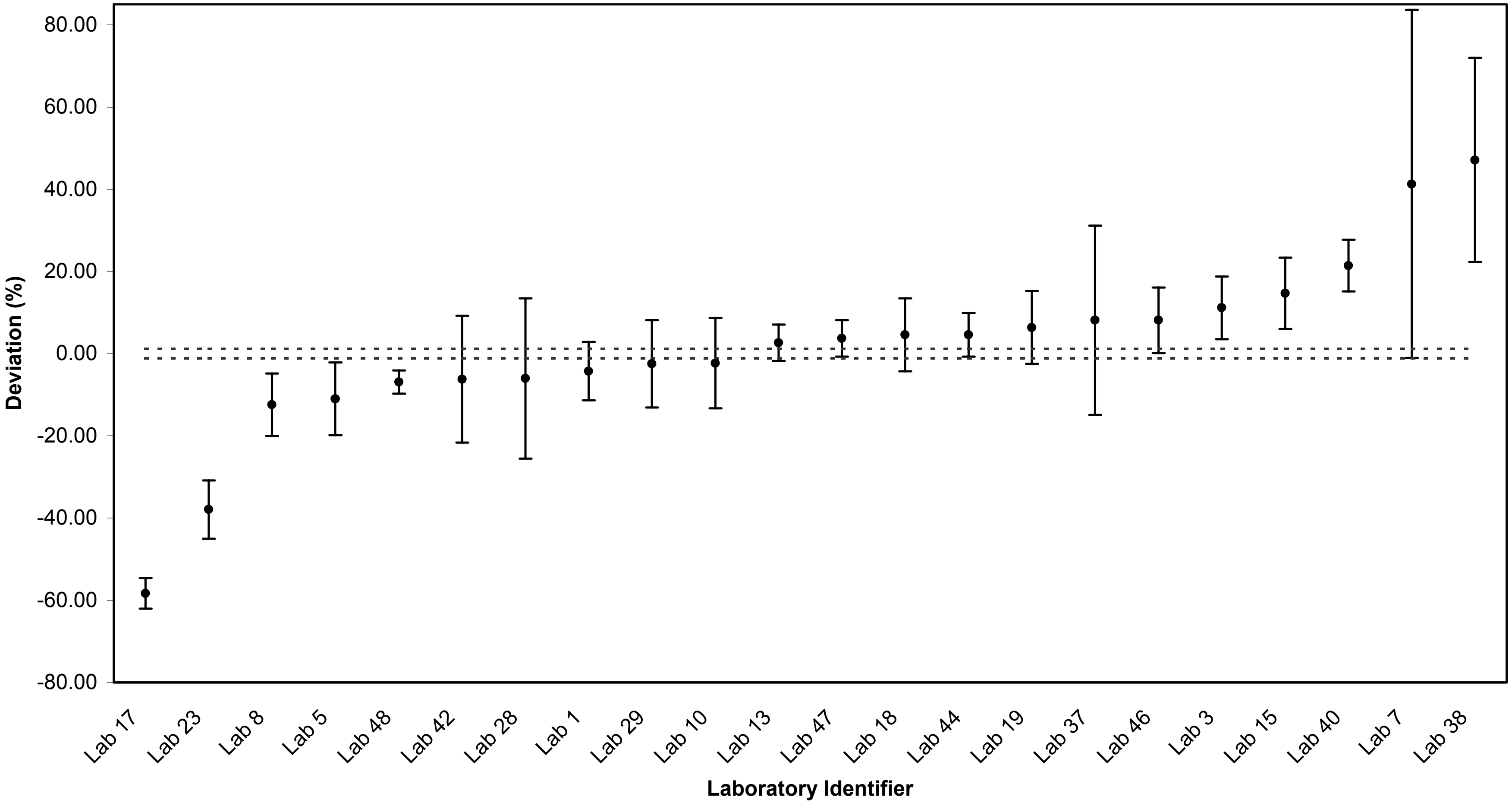
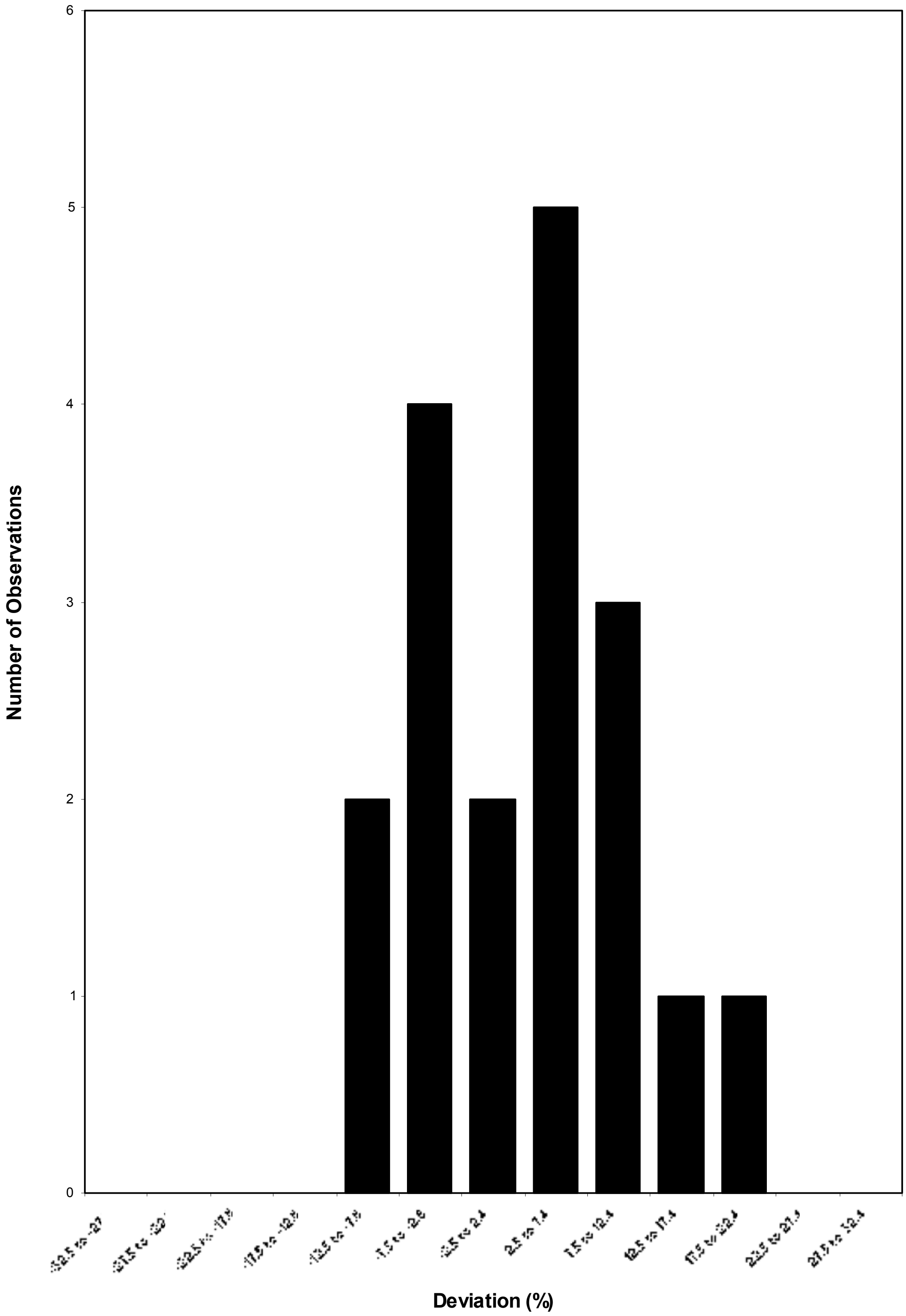


Figure 56 - Eu-155 low level results (Four outside limits of plot)



APPENDIX 1

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