



BSI Standards Publication

Nuclear energy — Guidance to the evaluation of measurement uncertainties of impurity in uranium solution by linear regression analysis

National foreword

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Nuclear energy — Guidance to the evaluation of measurement uncertainties of impurity in uranium solution by linear regression analysis

*Énergie nucléaire — Lignes directrices pour l'évaluation des
incertitudes de mesure des impuretés en solution d'uranium par
analyse de régression linéaire*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 5, *Nuclear installations, processes and technologies*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Nuclear energy — Guidance to the evaluation of measurement uncertainties of impurity in uranium solution by linear regression analysis

1 Scope

This document provides a method for evaluation of the measurement uncertainty arising when an impurity content of uranium solution is determined by a regression line that has been fitted by the “method of least squares”. It is intended to be used by chemical analyzers.

Simple linear regression, hereinafter called “basic regression”, is defined as a model with a single independent variable that is applied to fit a regression line through n different data points (x_i, y_i) ($i = 1, \dots, n$) in such a way that makes the sum of squared errors, i.e. the squared vertical distances between the data points and the fitted line, as small as possible. For the linear calibration, “classical regression” or “inverse regression” is usually used; however, they are not convenient. Instead, “reversed inverse regression” is used in this document^[2].

Reversed inverse regression treats y (the reference solutions) as the response and x (the observed measurements) as the inputs; these values are used to fit a regression line of y on x by the method of least squares. This regression is distinguished from basic regression in that the x_i 's ($i = 1, \dots, n$) vary according to normal distributions but the y_i 's ($i = 1, \dots, n$) are fixed; in basic regression, the y_i 's vary but the x_i 's are fixed.

The regression line fitting, calculation of combined uncertainty, calculation of effective degrees of freedom, calculation of expanded uncertainty, reflection of reference solutions' uncertainties in the evaluation result, and bias correction are explained in order of mention. [Annex A](#) presents a practical example of uncertainty evaluation. [Annex B](#) provides a flowchart showing the steps for uncertainty evaluation. In addition, [Annex C](#) explains the use of weighting factors for handling non-uniform variances in reversed inverse regression.

NOTE 1 In the case of classical regression, the fitted regression line is inverted prior to actual sample measurement^[3]. In the case of inverse regression, the roles of x and y are not consistent with the convention that the variable x represents the inputs, whereas the variable y represents the response. For these reasons, the two regressions are excluded from this document.

NOTE 2 The term “reversed inverse regression” was suggested taking into account the history of regression analysis theory. Instead, it can be desirable to use some other term, e.g. “pseudo-basic regression”.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 calibration

fitting of a regression line of y on x through n data points using the method of least squares

Note 1 to entry: The n data points are typically obtained by measuring n different reference solutions. After the fitting, the fitted regression line is used as a measurement formula for determining the physical or chemical quantity of a sample.

3.2 calibration quality control factor

factor that is used to check the adequacy of the fitted regression line from the aspect of calibration quality

3.3 calibration uncertainty

uncertainty due to such possible variations of the slope and intercept supposing that the regression line fitting is repeated according to the same procedure using a “new set of n different reference solutions” each time

Note 1 to entry: In this case, the fitted regression line will be different each time, i.e. the slope and intercept of the fitted regression line will vary.

3.4 combined uncertainty

uncertainty obtained by combining the *calibration uncertainty* (3.3) and the *random uncertainty of sample measurement* (3.9) according to the error propagation rule

3.5 effective degrees of freedom

degrees of freedom calculated by Welch-Satterthwaite approximate formula

3.6 expanded uncertainty

multiplication of the combined uncertainty u_y by a coverage factor k given depending on the effective degrees of freedom of the *combined uncertainty* (3.4)

Note 1 to entry: The probability that the true value of the physical or chemical quantity will be within $\pm$ the “final expanded uncertainty” from the determined and bias-corrected value is “exactly” or “approximately” 95 %; in most cases, “approximately” is more suitable expression.

3.7 predicted y value

y value of a point on the fitted regression line

Note 1 to entry: The predicted y value given by the regression line formula $y = a + bx$ indicates the physical or chemical quantity that will be determined in response to the light or current signal intensity “ x ” measured by instrument. The square root of the estimate for the variance of the predicted y value is treated as the calibration uncertainty in this document.

3.8 prediction interval

possible vertical distance between the additional data point and the previously fitted regression line after a regression line has been fitted using a set of n data points

Note 1 to entry: Another data point is additionally produced by measuring “a new reference solution”.