Designation: C1068 – 15

Standard Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry[1]

This standard is issued under the fixed designation C1068; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides guidance for selecting, validating, and qualifying measurement methods when qualification is required for a specific program. The recommended practices presented in this guide provide a major part of a quality assurance program for the laboratory data (see Fig. 1). Qualification helps to assure that the data produced will meet established requirements.

1.2 The activities intended to assure the quality of analytical laboratory measurement data are diagrammed in Fig. 1. Discussion and guidance related to some of these activities appear in the following sections:

	Section
Selection of Measurement Methods	5
Validation of Measurement Methods	6
Qualification of Measurement Methods	7
Control	8
Personnel Qualification	9

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials

C1009 Guide for Establishing and Maintaining a Quality Assurance Program for Analytical Laboratories Within the Nuclear Industry

C1128 Guide for Preparation of Working Reference Materials for Use in Analysis of Nuclear Fuel Cycle Materials

C1156 Guide for Establishing Calibration for a Measurement Method Used to Analyze Nuclear Fuel Cycle Materials

C1210 Guide for Establishing a Measurement System Quality Control Program for Analytical Chemistry Laboratories Within the Nuclear Industry

C1297 Guide for Qualification of Laboratory Analysts for the Analysis of Nuclear Fuel Cycle Materials

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E2554 Practice for Estimating and Monitoring the Uncertainty of Test Results of a Test Method Using Control Chart Techniques

E2655 Guide for Reporting Uncertainty of Test Results and Use of the Term Measurement Uncertainty in ASTM Test Methods

2.2 *ISO Standards:*[3]

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *Other Standards:*

ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications[4]

IEEE/ASTM SI 10 American National Standard for Metric Practice[5]

JCGM-100 Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement (GUM)[6]

JCGM-200 International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)[6]

3. Terminology

3.1 Except as otherwise defined herein, definitions of terms are as given in Terminology C859.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.08 on Quality Assurance, Statistical Applications, and Reference Materials.

Current edition approved June 1, 2015. Published June 2015. Originally approved in 1986. Last previous edition approved in 2011 as C1068 – 03 (2011). DOI: 10.1520/C1068-15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854-4141, http://www.ieee.org.

[6] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

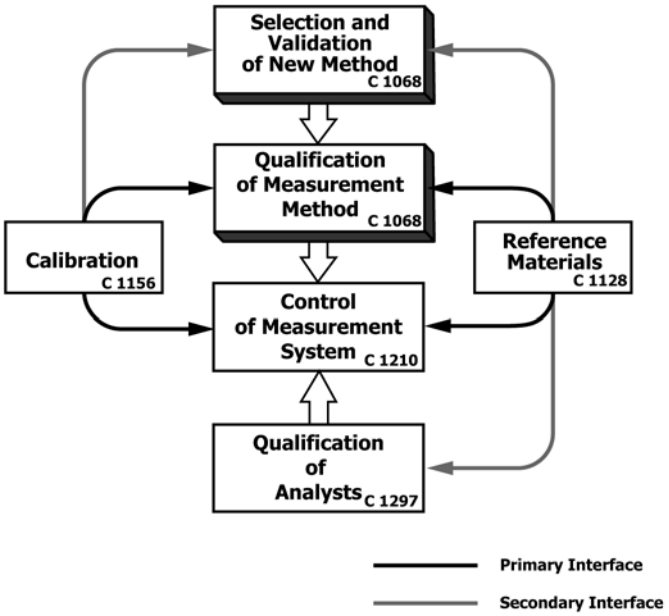

FIG. 1 Quality Assurance of Analytical Laboratory Data

3.2.1 *fitness for purpose, n*—degree to which data produced by a measurement process enables a user to make technically and administratively correct decisions for a stated purpose (**1**).[7]

3.2.2 *qualification*—a formal process to provide a desired level of confidence that measurement methods used will produce data suitable for their intended use. The methods must meet established criteria prior to use and must be used under conditions established for qualifications.

3.2.3 *representative sample, n*—a sample resulting from a sampling plan that can be expected to adequately reflect the properties of interest of the parent population (**1**).

3.2.4 *validation, n*—investigation to determine the applicability of a measurement method to a particular use.

4. Significance and Use

4.1 Because of concerns for safety and the protection of nuclear materials from theft, stringent specifications are placed on chemical processes and the chemical and physical properties of nuclear materials. Strict requirements for the control and accountability of nuclear materials are imposed on the users of those materials. Therefore, when analyses are made by a laboratory to support a project such as the fabrication of nuclear fuel materials, various performance requirements may be imposed on the laboratory. One such requirement is often the use of qualified methods. Their use gives greater assurance that the data produced will be satisfactory for the intended use of those data. A qualified method will help assure that the data produced will be comparable to data produced by the same qualified method in other laboratories.

4.2 This guide provides guidance for qualifying measurement methods and for maintaining qualification. Even though all practices would be used for most qualification programs, there may be situations in which only a selected portion would be required. Care should be taken, however, that the effectiveness of qualification is not reduced when applying these practices selectively. The recommended practices in this guide are generic; based on these practices, specific actions should be developed to establish a qualification program.

5. Selection of Measurement Methods

5.1 *General:*

5.1.1 Before qualifying a method for a specific application, there should be assurance that the method has been properly selected for that application. The guidance given in this section can be used to assess the adequacy of the method's application. The guidance can also be used to select a new method when a new measurement capability is required within a laboratory.

5.1.2 Measurement methods generally can be classified as one of three types as follows:

5.1.2.1 Those published as national or international consensus standards,

5.1.2.2 Those established as acceptable for a specific application based on long-term and wide usage, and

5.1.2.3 Those having limited use, for example, those used only by a few laboratories or those that are relatively new.

5.1.3 For some applications, there is a choice available of two or more acceptable methods. In those cases, one method is usually recognized as the reference method, particularly if it is a published standard or if it is capable of producing the least bias and best precision.

5.1.4 The selection of a method should be based on the criteria in 5.2. In situations where a reference method and one or more acceptable methods are available, there should be no technical restrictions placed on which method is used.

5.2 *Recommended Practices for Method Selection:*

5.2.1 *Technical Basis*—The method should be based on sound technology. This means that proven laboratory and instrumental techniques are used in ways recognized and accepted by the community of users.

5.2.2 *Interferences*—The method should not be adversely affected by components in the matrix of the material to be analyzed. Knowledge about the method's limitations and about the composition of the material should be used to determine if the analysis will be affected by interferences. Other potential interferences such as environmental or electrical/electronic conditions should be considered in the selection process.

5.2.3 *Range*—The method should be capable of responding adequately across the range of concentration levels that will be encountered for the constituent to be measured. This requirement is most often of concern for methods used to measure impurities in materials since impurity concentrations may fluctuate to a greater extent than other constituents. It is important that the measurement technique used discriminates adequately between concentration levels encountered. The lowest concentration level that can be measured reliably should be clearly established (detection limit).

5.2.4 *Reliability of Method*—The method must be capable of producing data that will meet the bias and precision requirements established for the required analysis under the expected conditions of use. The requirements are usually

[7] The boldface numbers in parentheses refer to a list of references at the end of this standard.

established by the user of the data and they should be based on the concentration levels of the constituents to be measured and on specification limits set for the constituents.

5.2.5 *Fitness for Purpose of Safeguards and Nuclear Safety Applications*—Methods intended for use in safeguards and nuclear safety applications shall meet the additional requirements specified in Annex A1.

6. Validation of Measurement Methods

6.1 There are occasions when it is desirable to investigate the applicability of a method to a particular use. This may be the case when the method has had limited use or it is being considered for a new or unique application. To provide some confidence that a qualification effort would be successful, it may be desirable to validate the application of the method. Validation is not a mandatory step in the selection and qualification process, but it can prevent wasted effort from attempts to qualify inadequate methods.

6.2 Validation of a method is usually done by an analyst under controlled conditions. Basically, validation involves investigating any or all of the selection criteria in 5.2. The intent is to define method capability and to determine if the method can be properly applied as intended. If modification of the method is required for it to be applicable, validation will provide the technical information needed for modification. Validation also provides the experience and information to write a detailed procedure if necessary. The result of the validation process will be either the rejection of a proposed method or confidence that it is acceptable for use as intended.

7. Qualification of Measurement Methods

7.1 *General:*

7.1.1 Although a method is selected based on the criteria in 5.2 of this guide, there is no assurance that a laboratory can actually obtain the performance expected from the method. In addition, there may not be sufficient assurance that the method is in fact adequate for its intended use. To provide those assurances, demonstration is included in the qualification process.

7.1.2 Qualification requires having a laboratory demonstrate that a method can produce acceptable data under specified conditions of qualification. Demonstration must be done under actual operating conditions and not under ideal test conditions. A specified material is analyzed to produce a specified amount of data. These data are evaluated by the person or organization that is responsible for approving qualification. The procedure established for demonstration should include provisions for handling failures in the demonstration and for repeating the demonstration should the method not be used for a specified period of time. Demonstration could also include producing other evidence such as appropriate literature references that the method is in fact applicable to the material to be analyzed.

7.2 *Recommended Practices:*

7.2.1 *Procedures*—The use of a method to make a laboratory measurement involves taking discrete actions in a specific order. Any change in an action or in the order may produce unsatisfactory data. To minimize potential problems, written, stepwise procedures should be provided within the methods. It is important that procedures are well-written, complete, and correct. They should receive technical and editorial reviews, and should be approved by appropriate management. Approval by the user of the data to be produced also may be required. Procedures prepared in accordance with Guide C1009 will meet these criteria.

7.2.2 *Method Performance Requirements*—To provide acceptable data, the method must be capable of meeting performance requirements for bias, precision, and range. Before a laboratory demonstrates its capability, these requirements should be clearly established (this should be done even before a method is selected for use; see 5.2). Specifications established for a process or material are the primary source of information on which the performance requirements are based. The performance requirements should be used to establish conditions required for qualification. Such conditions may require a statistically designed experiment to allow for other sources of variability such as the number of analysts or instruments, or both, as well as the concentration range of interest.

7.2.3 *Test Materials*—The material or materials that will be used for demonstration should be specified. The test materials should be as similar as possible to the material that will be analyzed. When possible, the composition or properties of test materials should be defined by measurements traceable to certified reference materials. See Guide C1128.

7.2.3.1 *Major Constituents*—When the method is to be used to determine a major constituent (for example, uranium in uranium oxide), a single test material may be specified. The concentration of the constituent in this test material should approximate the specification value established for the constituent in the material to be analyzed. The concentration value of the test material should not be given to the laboratory; only those responsible for evaluating the data and approving qualification should know the value (see 7.2.4.4). The calibration standard should be specified. See Guide C1156.

7.2.3.2 *Impurities*—When the method is to be used to determine an impurity, at least two test materials should be specified. One should serve as a test standard, meeting the same criteria given in 7.2.3.1 of this guide. Another should be used to demonstrate the detection limit of the method. When possible, the detection limit should be sufficiently below the specification limit to determine whether or not the concentration level of the impurity is within specification. Both test materials would serve to demonstrate the range of the method. When a method requires one or more standards for calibration, the calibration standard(s) that will be used should be specified. See Guide C1156.

7.2.4 *Qualification Requirements*—A procedure to be followed during demonstration should be established. The procedure that will govern qualification should include the following criteria:

7.2.4.1 *Bias*—A statistical sampling and hypothesis testing plan should be developed such that the risk of qualifying a method is acceptably small when the true bias exceeds the stated requirement and the risk of not qualifying the method is acceptably small when the true bias is zero. The plan would include the number of analyses of a test standard required to

control these risks at acceptably small levels and would express the requirement for qualifying based on bias as a statistical hypothesis testing procedure.

7.2.4.2 *Precision*—The precision requirement should state a value of the true standard deviation (larger than zero) that is both desirable and practical to maintain together with an upper limit, above which the true standard deviation would be unacceptable. A statistical sampling and hypothesis testing plan should then be developed such that: the risk of qualifying a method is acceptably small when the true standard deviation exceeds the specified upper limit, and the risk of not qualifying the method is acceptably small when the true standard deviation is less than or equal to the desired value. The plan would include the number of analyses of a test material required to control these risks at acceptably small levels and would express the requirement for qualifying based on precision as a statistical hypothesis testing procedure.

7.2.4.3 *Range*—A requirement, such as the following, should be stated when range is of concern: "Data obtained from the analysis of test materials, including calibration standards, shall be submitted to demonstrate the range of the method under the specific conditions of qualification. The calibration of the method should cover the expected range of concentration."

7.2.4.4 *Reporting Data*—The agency to whom demonstration data will be submitted should be specified. The agency could be a person or group within or outside of the laboratory, depending upon the program or project requiring qualified methods. The person or persons evaluating the data should be technically competent to do so.

7.2.4.5 *Failure*—Criteria should be established to govern the situation when a laboratory fails one or more of the demonstrations. Based on statistical evaluation, consideration should be given to specifying the following: the number of additional tries that will be allowed and whether or not increased number of analyses will be required for each new try.

7.2.4.6 *Requalification*—Criteria for requalification should be established. For example, requalification may be required if a change is made in a method or if a specific period of time elapsed during which a method was not used and no control standards were analyzed.

7.2.5 *Documentation*—The capability to substantiate the qualification of a method through appropriate records should be available. Actions taken and data generated with each step of qualification should be documented and those records should be easily retrievable.

7.2.5.1 *Laboratory Records*—The records used by the laboratory to record analysis and control data should be based on the appropriate parts of 9.2 in Guide C1009.

7.2.5.2 *Control of Records*—Records used to document qualification activities should be controlled in accordance with 10.2 of Guide C1009.

7.2.5.3 *Approval Records*—The agency responsible for approving qualification should document actions that it takes in evaluating and approving qualification (see 7.2.4.4). The records generated should be controlled in accordance with 10.2 of Guide C1009.

8. Control

8.1 *Measurement Control:*

8.1.1 Control of the measurement system is a major activity in assuring the quality of analytical data and control should be established as described in Guide C1009. A control system will help to ensure that analytical results are generated by methods that are in control, and under such conditions, those methods remain qualified. This section provides a general description which shows the key points that relate to this guide.

8.1.2 Once a method has been selected and the laboratory has successfully qualified the method, the laboratory is ready to use the method for analysis. However, there should be a continuing effort to assure the acceptability of the data produced as the method is used over time. Acceptability can be assured with the use of a control system that is applied each time the method is used to control the measurements made (Fig. 1). Control can vary from a simple manual calibration and control-charting system to a sophisticated computer program (see Guide C1210).

8.1.3 Requirements should be specified to prevent one analyst from calibrating a method and producing control data while a second analyst analyzes the samples. When necessary, there should be a specified process for a partially completed analysis to be continued by an incoming analyst. This process should assure that measurement control is maintained.

8.2 *Change Control*—Once a method has been published as a standard or has been written, reviewed, and approved within a laboratory, changes in that method, particularly in the stepwise procedure, should be controlled to avoid introducing errors. Uncontrolled changes made in a qualified method could become a reason to disqualify that method. A planned, systematic, and controlled system to make changes in a method should be established so that valid and necessary changes can be made while the method is in use. If changes are required in qualified methods, changes should be made in accordance with 8.2.2 of Guide C1009. Significant changes should be evaluated to determine if requalification of the method is required.

9. Personnel Qualification

9.1 Analysts producing data should be qualified in accordance with Guide C1009. Guide C1297 outlines steps in the qualification of laboratory analysts.

9.2 The adequacy of the laboratory's existing practices for selecting, training, and qualifying analysts should be evaluated. The results of the evaluation should be included in the criteria used to qualify methods.

10. Keywords

10.1 control; laboratory; measurement(s); personnel; qualification; validation

ANNEX

(Mandatory Information)

A1. CHECKLIST FOR SAFEGUARDS OR NUCLEAR SAFETY APPLICATIONS – DEMONSTRATING FITNESS FOR PURPOSE OF A MEASUREMENT METHOD (2, 3)

A1.1 All measurement methods utilized in laboratories within the nuclear industry should be selected based on fitness for purpose. This is a particularly important for methods used for safeguards or accountancy, or for nuclear safety applications. This Annex provides requirements for demonstrating fitness for purpose for such methods. Although this checklist has been developed primarily for methods used for safeguards and nuclear safety applications, it may also be applied to other methods.

A1.2 Standard test methods published by standards development organizations such as ASTM International or ISO have typically been validated and qualified with published data for repeatability, reproducibility, uncertainty, or a combination of these, and may not need the full level of effort to demonstrate fitness for purpose that is described below. The same may also be true for standard methods from governmental bodies, depending on the level of validation and qualification that has been performed.

A1.3 To be considered fit for purpose, a measurement method or system shall satisfy requirements A1.3.1 through A1.3.6, with documentation as described in A1.5.

A1.3.1 *The analytical capability shall be appropriate for the need or needs being met:*

A1.3.1.1 There is a justified and documented need for the measurement service, and compliance with regulatory requirements is defined.

A1.3.1.2 Data quality objectives (DQOs) are clearly defined by end users (such as customers, sponsors, and regulators) and accepted by the laboratory. These include the following:

(1) Uncertainty estimates for the applicable range of each analyte;

(2) Detection requirements;

(3) Turnaround time;

(4) Capacity requirements;

(5) Reporting requirements;

(6) Where applicable and required, ability to achieve international target values, as defined in Ref. (**4**).

A1.3.2 *The analytical capability shall be qualified as follows:*

A1.3.2.1 An effective selection, validation, and qualification process is used, following appropriate requirements of this Guide and ISO/IEC 17025.

A1.3.2.2 The method selected should be a standardized method whenever a standardized method suitable for the need is available.

A1.3.2.3 If no standardized method is available or suitable, a method developed in-house may be used provided qualification testing per guidance in this guide demonstrates sufficient confidence in the method. Testing should focus on characterizing, to the extent required to meet the customers' needs, the method uncertainty, detection limit, selectivity, linearity, repeatability, reproducibility, robustness against external influences, and cross-sensitivity against interference from the matrix (ISO/IEC 17025). In addition, the following supplementary processes can also be used to increase confidence in the method when required.

(1) Comparison of results achieved by the in-house method with results from the same samples using a standardized method;

(2) Assessment of the uncertainty of the results based on available literature and scientific understanding of the theoretical principles of the method and practical experience.

A1.3.2.4 The service provider demonstrates readiness to perform requested analytical services in advance of initiating requested measurements.

A1.3.3 *Traceability to the International System of Units (SI) shall be clearly defined and documented.*

A1.3.3.1 Analytical instruments and associated test equipment such as balance, pipets, and temperature probes, shall be properly calibrated and be traceable to SI, in accordance with guidance found in Guide C1156 and ISO/IEC 17025.

A1.3.3.2 Working reference materials used for calibration, quality control, and when necessary qualification shall be prepared in accordance with established practices, traceable, and stable for their declared shelf-life (Guide C1128).

A1.3.3.3 Guidance on metrological traceability is available from many sources, including IEEE/ASTM SI 10, JCGM-200, Ref. (**5**), the U.S. National Institute of Standards and Technology (NIST), and the International Union of Pure and Applied Chemistry (IUPAC) (**6**).

A1.3.4 *Measurement uncertainty calculations shall be adequate for the application:*

A1.3.4.1 Accepted statistical practices for computing measurement precision, bias, and uncertainty, shall be used. These include Practices E177 and E2554, Guide E2655, and JCGM-100 with associated standards. The uncertainty methodology should include an analysis of variance.

A1.3.4.2 In cases where a method is used to measure an analyte at or near the DQO for detection, the method detection and quantification limits shall be calculated by an appropriate protocol.

A1.3.5 *Measurements shall be controlled by a quality assurance (QA) program and a quality control (QC) program* that include measurement control practices, training, and technical oversight by competent scientists and QA professionals, in accordance with Guides C1009, C1210, and C1297.

A1.3.5.1 Clear thresholds should be set for determining and monitoring measurement performance, including control limits

that are derived statistically, requirements for replicate sample variation, and monitoring of variation in QC results, blank or background levels, and so forth.

A1.3.5.2 Participation in a representative proficiency testing or external exchange program is an effective process for independent validation of measurement quality and overall performance. Participation in proficiency testing programs, when available and applicable, is a requirement of ISO/IEC 17025. Laboratories should participate in proficiency testing or external exchange programs when available and feasible.

A1.3.6 *Measurement methods shall conform to the latest international measurement standards.*

A1.4 The following additional considerations apply to measurement methods and sampling:

A1.4.1 Compliance with the requirements in A1.3 is intended to serve the following purposes:

A1.4.1.1 Describe how well the measurement method performs;

A1.4.1.2 Identify which parameters are important to effective performance and uncertainty;

A1.4.1.3 Identify improvement opportunities and facilitate continuous improvement;

A1.4.1.4 Establish and maintain proficiency and excellence;

A1.4.1.5 Achieve world-class analytical measurement capabilities.

A1.4.2 In addition to analytical fitness for purpose, measurement methods shall be safe to operate and shall comply with regulations and rules as applicable to the location and facility where the method is implemented.

A1.4.3 Representative samples shall be obtained.

A1.4.3.1 Sampling equipment and processes are qualified, or have a historical performance basis.

(1) The sampling process is reliable, reproducible, and is not adversely impacted by normal environmental variation.

(2) Sample integrity is maintained through delivery and until analytical sampling or subsampling is completed.

A1.4.3.2 Sampling is uncertainty calculation shall be adequate.

A1.4.3.3 Samples are validated as appropriate, in one or more of the following ways:

(1) By correlation with process parameters such as solution density;

(2) By taking duplicate samples;

(3) By replicate subsamples and measurements;

(4) By a defined chain-of-custody.

A1.5 Documentation Requirements—Demonstrating compliance with the requirements in A1.3 should be accomplished through implementation of a comprehensive, documented QA program as described in Guides C1009 and C1210.

A1.5.1 Effective QA programs include a rigorous internal self-assessment process that evaluates initial readiness and ongoing measurement method fitness for purpose, including personnel training and performance. This process shall also evaluate changes to measurement methods, sample variation, DQOs, and program requirements in advance of their application or implementation.

A1.5.2 Laboratory accreditation of test methods used for safeguards or nuclear safety measurements in accordance with ISO/IEC 17025 is a recognized and effective process for demonstrating competency. Alternative means for documenting demonstration of competency (based, for example, on ASME NQA-1) may also be effective.

REFERENCES

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(3) European Safeguards Research and Development Association, *Report on the Workshop on Reference Material Needs and Evaluation of Measurement Uncertainties in Destructive (DA) and Non-Destructive Analysis (NDA)*, Report Bulletin WS DA-NDA-NANT CRMs, March 2013, available at esarda.jrc.ec.europa.eu.

(4) International Atomic Energy Agency, *International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials*, STR-368, IAEA, Vienna, Austria, 2010.

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(6) De Bievre, P., Dybkaer, R., Fajgelj, A., and Hibbert, D. B., "Metrological Traceability of Measurement Results in Chemistry: Concepts and Implementation (IUPAC Technical Report)," *Pure Appl. Chem.*, Vol 83, No. 10, pp. 1873-1935, 2011.