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Standard Practice for Competency Requirements of Reference Material Producers for Water Analysis[1]

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1. Scope

1.1 This practice establishes the general requirements with which a reference materials (RM) producer has to demonstrate that it operates, if it is to be recognized as competent to produce RMs used for water analysis.

1.2 This practice establishes the quality system requirements in accordance with which waters RMs shall be produced. It is intended to be used as part of a RM producer's general QA procedures. RM producers shall define their scope in terms of the application, the measurement methods used in the homogeneity, stability and characterization studies.

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:*

D 1129 Terminology Relating to Water[2]

D 6362 Practice for Certificates of RMs for Waters Analysis[2]

2.2 *ISO Documents:*[3]

ISO/IEC 17025:1999 General Requirements for the Competence of Calibration and Testing Laboratories

ISO 8402:1994 Quality Management and Quality Assurance—Vocabulary

ISO 10012-1:1992 Quality Assurance Requirements for Measuring Equipment—Part 1: Metrological Confirmation Systems for Measuring Equipment

ISO/IEC Guide 2:1996 Standardization and Related Activities—General Vocabulary

ISO Guide 30:1992 Terms and Definitions used in Connection with Reference Materials

ISO Guide 31:2000 Contents of Certificates and Labels of Reference Materials

ISO/IEC Guide 32:1997 Calibration in Analytical Chemistry and Use of Certified Reference Materials

ISO Guide 34:2000 General Requirements for the Competency of Reference Material Producers

ISO Guide 35:1989 Certification of Reference Materials—General and Statistical Principles

ISO 3534 Series: 1993 Statistics—Vocabulary and Symbols

VIM: 1993 International Vocabulary of Basic and General Terms in Metrology (issued by ISO, IEC, BIPM, IFCC, IUPAC, IUPAP and OIML)

ISO Guide to the Expression of Uncertainty in Measurement: 1995 (issued by ISO, IEC, BIPM, IFCC, IUPAC, IUPAP and OIML)

3. Terminology

3.1 For the purposes of this practice, the definitions given in Terminology D 1129, ISO/IEC Guide 2, ISO/IEC 17025, ISO Guide 30, ISO 8402, ISO 3534, VIM and the following definitions apply.

3.1.1 *collaborator*—technically competent body (organization or firm, public or private) that undertakes aspects of the manufacture, or characterization, of the (certified) RM on behalf of the RM producer, either on a contractual (as a sub-contractor) or voluntary basis.

3.1.2 *reference material producer*—technically competent body (organization or firm, public or private) that is fully responsible for assigning the certified or other property values of the RMs it produces and supplies, which have been produced in accordance with ISO Guide 35, Practice D 6362, and ISO Guide 31.

4. Significance and Use

4.1 This practice is for the use by RM producers in the development and implementation of their quality system and by those concerned with assessing the competence of RM producers. It should be recognized that a RM needs to be characterized mainly to the level of accuracy required for its

[1] This practice is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.02 on General Specifications, Technical Resources, and Statistical Methods.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

intended purpose (that is, appropriate measurement uncertainty). The RM producer shall describe the procedure for establishing the quality of materials as a component of the quality system.

4.2 This practice is for the use of RM users in the establishment if a RM producer has a quality system adequate to produce high quality RMs. It can be used by users to determine if the scientific and technical competence of a RMs producer is adequate to ensure the quality of RMs. This practice is consistent with the requirements for RM producers established in ISO Guide 34.

4.3 This practice does not specify specific protocols for the contents of RMs certificates of analysis, for calibration in analytical chemistry and use of certified RMs and for certification of RMs. For this information, users are referred to Practice D 6362, ISO Guide 32, and ISO Guide 35.

5. Organization and Management Requirements

5.1 *Quality System Requirements*:

5.1.1 The RM producer shall establish, implement and maintain a quality system appropriate to the scope of its activities including the type, range and magnitude of the RM production it undertakes.

5.1.2 *Quality Policy*:

5.1.2.1 The RM producer shall define and document its policy, objectives and commitment to ensuring and maintaining the quality of all aspects of RM production, including material quality (that is, homogeneity and stability), characterization (that is, equipment calibration and measurement method validation), assignment of property values (that is, use of appropriate statistical procedures) and material handling, storage and transport procedures.

5.1.2.2 The quality policy shall, when appropriate, include use of interlaboratory characterization studies employing laboratories that are active and competent in the respective field of measurement in this context. The policy shall include a commitment to interact with the appropriate sectors of the measurement community in order to prevent working in isolation. The policy shall also include a commitment to produce RMs which conform to the definitions given in ISO Guide 30, characterized according to the requirements of ISO Guide 35 and whose property values are assessed using accepted statistical techniques. The policy shall, where appropriate, include a commitment to comply with Practice D 6362 for the contents of RM certificates and supply of associated information for users. It is important that the policy also specifies the intended use of the RMs in order to ensure that the RM producer fully advises the user which types of application the materials may be used.

5.1.3 *Quality System*:

5.1.3.1 The RM producer shall establish, implement and maintain a documented quality system appropriate to the type, range and volume of RM production it undertakes. The RM producer shall document all of its policies, systems, programs, procedures, instructions, findings, etc., to the extent necessary to enable the producer to assure the quality of the RMs produced. Documentation used in this quality system shall be communicated to, understood by, available to and implemented by all personnel concerned. In particular, the producer shall have a quality system that covers the following:

(a) Arrangements for ensuring the suitable choice (for example, particle size range, concentration range, etc.) of the candidate RMs;

(b) Preparation procedures;

(c) Achievement of the required degree of homogeneity of the RM;

(d) Assessment of the stability of the RM; including on-going assessment of stability where necessary;

(e) Procedures for undertaking characterization;

(f) Practical realization of traceability to national or international standards of measurement;

(g) Assignment of property values, including preparation of certificates or statements in accordance with Practice D 6362 when appropriate;

(h) Arrangements for ensuring adequate storage facilities;

(i) Arrangements for suitable identification, labeling and packaging facilities, packing and delivery procedures and customer service; and

(j) Compliance with ISO Guides 30, 34 and 35 and Practice D 6362.

It is encouraged that the documented quality system specify which activities are undertaken by the RM producer and, where relevant, which activities are undertaken by collaborators and shall include policies and procedures used by the producer to ensure that all activities conducted by collaborators comply with the relevant clauses of this practice.

5.1.3.2 The documented quality system shall define the roles and responsibilities of the technical manager (however named) and quality manager including their responsibilities for ensuring compliance with this practice.

5.2 *Organization and Management*:

5.2.1 The RM producer, or the organization of which it is part, shall be legally identifiable.

5.2.2 The RM producer shall be organized and shall operate in such a way that it meets all the applicable requirements of this practice whether carrying out work in its permanent facilities or at sites (including associated temporary or mobile facilities) away from its permanent facilities (including work undertaken by collaborators).

5.2.3 The RM producer shall:

(a) Have managerial personnel supported by technical personnel with the authority and resources needed to discharge their duties and to identify the occurrence of departures from the quality system or the procedures for the production of RMs and to initiate actions to prevent or minimize such departures.

(b) Have arrangements to ensure that its management and personnel are free from any commercial, financial and other internal and external pressures that may adversely affect the quality of their work;

(c) Have policies and procedures to ensure the protection of its client's confidential information and proprietary rights;

(d) Have policies and procedures to avoid involvement in activities that might diminish confidence in its competence, impartiality, judgement or operational integrity;

(e) Define, with the aid of organizational charts, the organization and management structure of the RM producer, its place in any parent organization, and the relations between management, technical operations, support services, collaborators and the quality management system;

(f) Specify the responsibility, authority and interrelationships of all personnel who manage, perform or verify work affecting the quality of production of RMs;

(g) Have technical management, which has overall responsibility for the technical operations and the provision of the resources needed to ensure the required quality of each operation which forms part of the RM production;

(h) Appoint a member of staff as quality manager (however named) who, irrespective of other duties and responsibilities, shall have defined responsibility and authority for ensuring that the requirements of this practice are implemented and followed at all times. The quality manager shall have direct access to the highest level of management at which decisions are taken on production policy or resources; and

(i) Where appropriate, appoint deputies for key managerial personnel such as the technical and quality managers.

5.3 *Document and Information Control*

5.3.1 *General*:

5.3.1.1 The RM producer shall establish and maintain procedures to control all documents (both internally generated and from external sources) and other information that forms part of its quality documentation. These may include documents of external origin such as standards, guides, test and/or calibration methods as well as specifications, instructions and manuals related to the RM under production (see Note 1).

NOTE 1—In this context "document" means any information or instruction including policy statements, text books, procedures, specifications, calibration tables, charts, software, etc. These may be on various media whether hard or electronic and they may be digital, analogue, photographic or written.

5.3.2 *Document Approval and Issue*:

5.3.2.1 All documents (including documented procedures) issued to personnel as part of the quality system shall be suitably controlled. This shall include review and approval for use by authorized personnel prior to issue. A master list or equivalent identifying the current revision status of documents in the quality system shall be established and be readily available to preclude the use of invalid and/or obsolete documents.

5.3.2.2 The procedures adopted shall also ensure that:

(a) Authorized editions of appropriate documents are available at all locations where operations essential to the effective production of RMs are performed;

(b) Documents are periodically reviewed and, where necessary, revised to ensure continuing suitability and compliance with applicable requirements;

(c) Invalid or obsolete documents are promptly removed from all points of issue or use, or otherwise assured against unintended use; and

(d) Obsolete documents retained for legal or informational purposes are suitably marked.

5.3.3 *Document Changes*:

5.3.3.1 Changes to documents (including documented procedures) shall be reviewed and approved by designated personnel performing the same function as that conducted for the original review and approval unless specifically decided otherwise. The designated personnel shall have access to pertinent background information to base their review and approval.

5.3.3.2 Where practicable, the nature of the change shall be identified in the document with appropriate attachments.

5.3.3.3 If the RM producer's documentation control system allows for the amendment of documents by hand, pending the re-issue of the documents, the procedures and authorities for such amendments shall be defined and shall ensure that amendments are initialed and dated. Documents amended by hand shall be marked, signed and dated and shall be formally re-issued as soon as practicable.

5.3.3.4 Procedures shall be established to describe how changes in documents maintained in computerized systems are made.

5.4 *Request, Tender and Contract Reviews*:

5.4.1 When relevant, each request, tender or contract (see Note 2) concerning the production of a RM shall be reviewed by the RM producer to ensure that:

(a) The requirements are adequately defined, documented and understood;

(b) The RM producer has the capability (see Note 3) and resources to meet the requirements;

(c) In the case of external contracts (see Note 4) any differences between the contract or order requirements and those in a tender are resolved to the satisfaction of the RM producer and the customer or client.

NOTE 2—The request, tender or contract review should be conducted in a practical and efficient manner and the financial, legal and time schedule aspects be taken into account.

NOTE 3—Capability means that the RM producer possesses the necessary equipment, intellectual and information resources and that its personnel have the skills and expertise necessary for the production of those RMs in question. The review of the capability may include an assessment of previous RM production and/or the organization of interlaboratory characterization programs using samples of similar composition to the RMs to be produced.

NOTE 4—A contract may be any written or verbal agreement to provide a customer or client with RMs from stock or custom-produced respectively.

5.4.2 Records of such reviews including any changes shall be maintained. Records shall also be maintained of pertinent discussions with a customer relating to the customer's requirements or the results of the work during the period of execution of the contract or request.

5.4.3 The review shall include any work that has to be sub-contracted by the RM producer.

5.5 *Use of Collaborators*:

5.5.1 The RM producer shall establish and maintain procedures to ensure that all tasks performed by collaborators comply with specifications set by the RM producer for such tasks. The RM producer shall ensure also that collaborators comply with any clauses of this practice relevant to the tasks performed by them for the RM producer.

5.5.2 The RM producer shall select collaborators based on their ability to meet sub-contracted requirements in terms of

both their technical competence and any specific quality assurance requirements relevant to their tasks. The technical requirements to be satisfied by collaborators shall be equivalent to the technical requirements specified in Section 5 of this practice.

5.5.3 The RM producer shall maintain a register of all collaborators used in the production process, and include a record of any assessments made of their abilities to carry out sub-contracted tasks according to the requirements of this practice (see Note 5).

NOTE 5—The RM producer is always responsible for ensuring that a collaborator is competent. The collaborator should be able to demonstrate compliance with the requirements of this practice for all sub-contracted work.

5.6 *Procurement of Services and Supplies*:

5.6.1 The RM producer shall have policies and procedures for the selection of services and supplies that affect the quality of its RMs.

5.6.2 The RM producer shall use only those services and supplies that are of adequate specification to ensure the quality of its RMs.

5.6.3 When no formal approval of the quality of services and supplies is available, the RM producer shall have procedures to ensure that purchased materials and services comply with specified requirements and records of actions taken shall be maintained.

5.6.4 The RM producer shall ensure that purchased equipment and consumable materials are not used until they have been inspected, calibrated or otherwise verified as complying with standard specifications or requirements defined in specifications for production, characterization and certification of its RMs.

5.6.5 The RM producer shall maintain records of the main suppliers and collaborators from whom it obtains supplies required for the production of RMs. These records should include any quality assurance approval the suppliers and/or collaborators hold.

5.7 *Client Feedback*:

5.7.1 The RM producer shall have a policy and procedures for the resolution of complaints or other feedback received from its customers or other parties. Records shall be maintained of all complaints and of the investigations and corrective actions taken by the RM producer.

5.8 *Control of Nonconforming (Poor Quality) RMs*:

5.8.1 The RM producer shall have a policy and procedures that shall be implemented when it establishes that any aspect of its production activities do not conform with its own specified production procedures (see Note 6). The policy and procedures shall ensure that:

(a) Responsibilities and authorities for the management of non-conforming work are designated;

(b) The actions which must be taken when any non-conforming RMs are identified are defined, together with a system which ensures they are implemented;

(c) An evaluation of the significance of the non-conforming work is made;

(d) Work is halted and, if appropriate, certificates withheld as necessary;

(e) Remedial actions are taken within a defined timeframe;

(f) Where necessary, the results of non-conforming RMs already distributed to customers are recalled; and

(g) The responsibility for authorization of the resumption of work is defined.

NOTE 6—The identification of non-conforming RMs or problems with the quality system or with certification activities can occur at various places within the Quality System such as: customer complaints, quality control, checking of consumable materials, staff observations or supervision, certificate checking, management reviews, and internal or external audits.

5.8.2 Where the evaluation indicates that the supply of non-conforming RMs could recur or that there is doubt about the RM producer's compliance with its own policies and procedures, the corrective action procedures in 5.9 shall be promptly followed to identify the causes of the problem and to eliminate them.

5.9 *Corrective Action*

5.9.1 *General*:

5.9.1.1 The RM producer shall establish a policy and procedures and shall designate appropriate authorities for implementing corrective action when non-conforming RMs or departures from the policies and procedures in the quality system have been identified (see Note 7).

NOTE 7—A problem with the quality system or with technical operations may be identified through a variety of activities within the quality system such as control of non-conforming RMs, internal or external audits, management reviews, feedback from clients, or staff observations.

5.9.1.2 Any corrective action taken to eliminate the causes of non-conformances or other departures shall be to a degree appropriate to the magnitude of the problems and commensurate with the risks encountered.

5.9.1.3 The RM producer shall document and implement any required changes to the operational procedures resulting from corrective action investigations as described in this section.

5.9.2 *Cause Analysis*:

5.9.2.1 Corrective action procedures shall include an investigation process to determine the causes of the problem (see Note 8).

NOTE 8—This is sometimes the most difficult, but the key part in the corrective action procedure. Often the root cause is not obvious and thus a careful analysis of all potential causes of the problem is required. Potential causes could include, inter alia, the nature of the RM and its specification, methods and procedures used for characterization, staff skills and training, and the materials and equipment (and/or its calibration) used in the production processes.

5.9.3 *Corrective Actions*:

5.9.3.1 The RM producer shall identify possible causes and potential corrective actions. It shall select the actions most likely to eliminate the problem and to prevent it recurring.

5.9.4 *Monitoring of Corrective Actions*:

5.9.4.1 After having implemented the action plans, the RM producer shall monitor the results to ensure that the actions taken have been effective in overcoming the problems originally identified.

5.9.5 *Management Review*:

5.9.5.1 The results of corrective action shall be submitted for management review.

5.10 *Preventative Action*:

5.10.1 All operational procedures shall be systematically reviewed at regular intervals to identify any potential sources of non-conformances and any opportunities for improvement, either technical or with the quality system. Action plans shall be developed, implemented and monitored, to reduce the likelihood of occurrence of such non-conformances and to take advantage of the improvement opportunities (see Note 9).

NOTE 9—Preventative action is a pro-active process to identify improvement opportunities, rather than a reaction to the identification of problems or complaints. TQM tools such as brainstorming, flowcharting, mind-mapping and parieto charts will assist this process.

5.10.2 After the implementation of the preventative actions, the RM producer shall monitor the results to establish any reduction in deficiencies or other improvements in this operational area, thereby establishing the effectiveness of the preventative action.

5.10.3 The results of preventative actions shall be submitted for management review.

5.11 *Records*

5.11.1 *General*:

5.11.1.1 The RM producer shall establish and maintain procedures for identification, collection, indexing, access, storage, maintenance and disposal of quality (see Note 10) and technical records (see Note 11).

NOTE 10—Quality records are records providing objective evidence of the extent of the fulfillment of the requirements for quality or the effectiveness of the operation of the quality system. For example, they include reports from internal audits and management reviews and corrective and preventative action records.

NOTE 11—Technical records are accumulations of data and information which result from carrying out testing and calibration procedures and which indicate whether specified quality or process parameters are achieved. They include forms, contracts, work sheets, work books, check sheets, control charts/graphs, calibration reports/certificates and papers, reports and certificates to customers and clients.

5.11.1.2 All records shall be legible and shall be stored and retained in such a way that they are readily retrievable, and in facilities that provide a suitable environment to prevent damage, deterioration or loss (see Note 12). Retention times of records shall be established and recorded.

NOTE 12—Records may be in the form of any type of media, such as hard copy or electronic media.

5.11.1.3 All records shall be held secure and, where appropriate, in confidence to the client.

5.11.1.4 The RM producer shall have procedures to protect electronically-held data at all times and to prevent unauthorized access to, or amendment of, such data.

5.11.2 *Records and Reports*:

5.11.2.1 The RM producer shall establish and maintain a record system to suit its particular circumstances and to comply with any applicable regulations. The RM producer shall arrange for all individual measurement observations, appropriate calculations and derived data (for example, statistical treatments and uncertainty budgets), calibration records and preparation reports to be retained for a defined period beyond which it is no longer probable that they will be referred to, taking into account the period for which the RM remains valid.

5.11.2.2 The results of each calibration or measurement (or series of either) carried out by the RM producer and, where appropriate, its collaborators, shall be reported unambiguously and objectively, in accordance with any instructions in the calibration or measurement methods. The results shall normally be reported in a calibration or measurement report and shall include all information necessary for interpretation of the calibration or measurement results and a summary of the method employed (see Note 13).

NOTE 13—This is for internal reports of the RM producer and should not be confused with a certificate of analysis or certification report which is supplied with a RM to the customer or client.

5.12 *Internal Audits*:

5.12.1 The RM producer shall, periodically and in accordance with a predetermined schedule and procedure (see Note 14), conduct internal audits of its activities to verify that its operations continue to comply with the requirements of the quality system and the requirements of this practice. The internal audit program shall address all elements of the quality system, including the technical and production activities leading to the finished product (RM). It is the responsibility of the quality manager to plan and organize audits as required by the schedule and requested by management. Such audits shall be carried out by trained and qualified personnel who are, wherever resources permit, independent of the activity to be audited. Personnel shall not audit their own activities except where it is necessary and it can be demonstrated that an effective audit has been carried out.

NOTE 14—The schedule for internal auditing should normally be completed in one year.

5.12.2 When audit findings cast doubt on the effectiveness of the operations or on the correctness or validity of its RMs, the RM producer shall take timely corrective action and shall notify, in writing, its customers whose activities may have been adversely affected.

5.12.3 All audit findings and corrective actions that arise from them shall be recorded. The RM producer's management shall ensure that these actions are discharged within an appropriate and agreed timescale.

5.13 *Management Reviews*:

5.13.1 The RM producer's senior management shall periodically (see Note 15) conduct a review of it's quality system and production processes to ensure their continuing suitability and effectiveness and to introduce any necessary changes or improvements. The review shall take account of reports from managerial and supervisory personnel, the outcome of recent internal audits, assessments by external bodies, feedback from customers, including complaints and other relevant factors.

NOTE 15—A typical period for conducting a management review is once every year. Results should feed into the corporate planning program and should include the goals, objectives and action plans for the coming year.

5.13.2 Findings from management reviews and the actions that arise from them shall be recorded. The management shall ensure that these actions are discharged within an appropriate and agreed timescale.

6. Technical and Production Requirements

6.1 *Management, Staffing and Training*:

6.1.1 The production of RMs should, where possible, only be undertaken by organizations having experience in the production of the particular type of RM (or related material), as well as having experience in the measurement of the properties being determined. The RM producer and any associated collaborators shall have managerial staff with the necessary authority, resources and technical competence required to discharge their duties. Measurement of the property of interest shall be completed by, or under the supervision of a technically competent manager qualified either in terms of suitable academic qualifications or relevant work experience. The RM producer's management shall define the minimum levels of qualification and experience necessary for the key posts within its body.

6.1.2 The RM producer shall have sufficient personnel having the necessary education, training, technical knowledge and experience for their assigned functions (see Note 16).

NOTE 16—For example, a staff member undertaking thermal expansion measurements should have a degree or appropriate level qualification, together with adequate experience in the field working with a more senior scientist making measurements at an equivalent level of accuracy.

6.1.3 The RM producer shall also ensure that staff receive additional training, when necessary, to ensure competent performance of measurements, operation of equipment and any other activities which affect quality (see Note 17). Where possible, objective measures should be used to assess the attainment of competence during training.

NOTE 17—The need to retrain staff periodically should be considered (for example, the RM producer should have in place a policy for retraining staff when a method or measurement technique is not in regular use). Staff training and retraining policies should take account of technological change and aim at continuous skill upgrading.

6.1.4 The RM producer shall maintain an up-to-date record of the training that each staff member has received. These records shall provide evidence that individual staff members have been adequately trained and that their competence to complete particular types of material preparation and measurement has been assessed.

6.2 *Collaborators*:

6.2.1 Where a RM producer undertakes any part of the procedure for the production or characterization of a RM on an interlaboratory basis, the producer shall be able to demonstrate that the experience of any collaborators is sufficient, and that the results produced are of the required quality. In assessing the competence of a collaborator, the RM producer shall require information on the collaborator's knowledge of the subject and details of past experience in the field (for example, valid results for comparable measurements). In the latter context, the producer may consider distributing materials of a comparable matrix whose property values are well established and at appropriate concentration levels, ranges, etc., prior to distributing any candidate RM samples. Evidence of collaborators being accredited to ISO/IEC 17025 when testing is carried out, or registered to the ISO 9000 series for other activities, will generally be appropriate. Evidence of collaborators participating in a relevant proficiency testing scheme and producing acceptable results on well-characterized materials of similar or equivalent nature to that of the RM would also be considered appropriate. In the limit, the RM producer may have no laboratories facilities, but shall ensure that all scientific work carried out by collaborators which may contribute to the assignment of the property values of interest is fit for that purpose and in compliance with the above requirements.

6.2.2 The RM producer shall ensure that all details of the methodology, results and all the performance procedures of any collaborators are available, if required, and that a register/database of all collaborators and their accreditation/quality system/other forms of competence status is maintained.

6.3 *Production Planning*:

6.3.1 The RM producer shall identify and plan those processes which directly affect the quality of RM production and shall ensure that they are carried out in accordance with prescribed procedures.

6.3.2 Organizational and technical input of the different collaborators involved shall be identified and the necessary information documented and regularly reviewed (see Note 18). A mechanism (for example, a management/technical advisory group) shall be established to make recommendations on how to plan the production processes.

NOTE 18—These could include recommendations for production, setting up a monitoring system (to ensure timeliness and quality for each production phase) and having an evaluation procedure to assess the production processes retrospectively.

6.3.3 In planning the production processes, the RM producer will need to have procedures and service facilities, where appropriate, for:

(a) Material selection (including, where appropriate, sampling);

(b) Maintaining suitable environments for all aspects of production;

(c) Material preparation;

(d) Measuring/testing;

(e) Calibration/validation of equipment/measurement methods;

(f) Assessing material homogeneity;

(g) Assessing material stability;

(h) Organizing interlaboratory studies with its collaborators;

(i) Assigning property values based on the results of measurements;

(j) Producing uncertainty budgets and uncertainty intervals to the assigned property values;

(k) Ensuring adequate storage facilities and conditions;

(l) Ensuring adequate packaging facilities;

(m) Ensuring appropriate transport arrangements; and

(n) Ensuring an adequate post-distribution service;

6.4 *Production Control*:

6.4.1 The RM producer shall identify the verification procedures necessary to ensure the quality of each stage of RM production, and shall assign adequate resources and personnel for such activities. These activities should include inspection, testing and monitoring of all stages of production.

6.5 *Environment*:

6.5.1 The RM producer shall ensure that all laboratory accommodation, calibration and measurement arm, material preparation and packaging areas, energy sources, lighting, temperature, pressure and ventilation are such as to facilitate proper material preparation and packaging as well as proper performance of calibration and measurements (see Note 19).

NOTE 19—It is imperative that all possible precautions are taken against possible contamination of the RM during its production and certification. All RM production and testing areas, in addition to satisfying requirements for humidity and temperature, should be protected from vibration, airborne dust and microbiological contamination, magnetic fields and electromagnetic radiation (as appropriate). For example, the packaging of a cement material will require conditions of low humidity, and the preparation and characterization of a material in which the content of traces of lead is to be measured will require clean-room conditions to prevent contamination from airborne lead particulates due to car emissions. Clean-room conditions may also be required for other types of trace analysis.

6.5.2 The RM producer shall also ensure that all environmental requirements are also met by any collaborator involved in any production process.

6.5.3 Where appropriate to do so, the environment in which these activities are undertaken shall be monitored with appropriately calibrated equipment, controlled and recorded, such that results and processes are not adversely affected.

6.5.4 Appropriate health, safety and environmental protection precautions shall also be implemented where necessary (for example, when handling pesticides or serum).

6.6 *Material Handling and Storage*:

6.6.1 In order to avoid any contamination, the RM producer shall identify, preserve and segregate (that is, from other chemicals and samples) all candidate materials and RMs from the time of preparation through to their distribution to users.

6.6.2 The RM producer shall ensure adequate packaging of all RMs (for example, where appropriate, use air-free, moisture-free or inert gas packaging) and provide secure storage areas/stock rooms which prevent damage or deterioration of any item or material between characterization and distribution. Appropriate methods for authorizing dispatch to, and receipt from, such areas should be stipulated.

6.6.3 The condition of all stored/stocked items and materials shall be assessed at appropriate intervals throughout their storage life in order to detect possible deterioration.

6.6.4 The RM producer shall control packing and marking processes to the extent necessary to ensure conformity with the safety and transport requirements (see Notes 20 and 21).

NOTE 20—The proper distribution of samples, for example, can present a severe problem for some types of material which require uninterrupted storage in a freezer, or which should not be exposed to X-rays, shocks or vibrations. Most types of chemical materials would benefit from air-tight packaging to avoid contamination by atmospheric contaminants (for example, fuel vapors or engine exhaust gases) which may be encountered during transport.

NOTE 21—The RM producer has a responsibility to ensure that the integrity of the RM is maintained until the seal has been broken, or up to the point when presented for analysis. The producer cannot be held responsible for the material once its seal has been broken. This may require, in some cases, that the RM be packaged in unit quantities sufficient for a single use.

6.6.5 The RM label shall be securely attached to the product packaging of an individual RM unit, and shall be designed to remain legible and intact within the period of validity of the material (that is, the expiration date). The label shall identify the material, the producer, its batch and catalogue numbers, and any other information necessary to enable the material to be uniquely distinguished and referenced, where appropriate, to its statement or certificate.

6.6.6 The RM producer shall make arrangements to ensure the integrity of each RM throughout the entire production process. Where contractually specified, this protection shall be extended to include delivery to destination.

6.7 *Post-Distribution Service*:

6.7.1 The RM producer shall establish, document and maintain procedures for ensuring that corrective action is undertaken whenever a product is found not to conform to the specified requirements. Any resultant changes (for example, in procedures or data) should be recorded, and all purchasers of the RM notified if there is a change to its assigned property values (for example, as a result of additional measurement studies) within the period of the validity of the material.

6.7.2 The RM producer should also provide an advisory service to offer guidance (including a complaints procedure) and technical services to users. Where the goods are subject to resale through a distributor, the RM producer should make arrangements with the distributor to keep records of purchasers of the RMs.

6.8 *Material Preparation*:

6.8.1 The RM producer shall establish whether the item or material has received adequate preparation for its intended use. Procedures for material preparation should include, where appropriate:

(a) Qualitative analysis for verification of material type;

(b) Machining, grinding, blending, sieving and riffling (that is, dividing into representative samples);

(c) Determination of particle size distribution;

(d) Cleaning of sample containers;

(e) Drying (including lyophilisation) and sterilization;

(f) Packaging (for example, bottling, etc.) representative samples from the batch;

(g) Homogeneity testing; and

(h) Stability testing over a range of conditions which may affect the property values and/or matrix composition of the RMs being produced (for example, different levels of humidity, temperature, light. magnetic fields, etc.).

6.8.2 The RM producer shall be able to demonstrate that the candidate RM is sufficiently homogeneous, that is, the difference, if any, between units must be smaller than the uncertainty limits stated in the certificate (see Note 22).

NOTE 22—A relatively inhomogeneous material may be the best available, and may therefore still be useful as a RM provided the uncertainties of the assigned property values take due account of this.

6.9 *Assessment of Homogeneity and Stability*:

6.9.1 Where appropriate, the RM producer shall carry out an assessment of the homogeneity of any candidate RM by analyzing a representative number of randomly, systematically or stratified randomly chosen units appropriate to the size of the lot being produced (see Note 23). This should be done by

means of a measurement method, the repeatability of which is fit for the purpose required (that is, good enough to not contribute significantly to the combined uncertainty). The assessment procedure shall be documented and conducted in accordance with acceptable statistical procedures.

NOTE 23—For RMs that are expected to be homogeneous on physical grounds, the main purpose of homogeneity testing is to detect unforeseen problems, for example differential contamination during packaging into individual units, or incomplete dissolution or equilibration of an analyte in a solvent (which could lead to steadily changing concentrations). For these types of examples, systematic sampling (for example, 1 from every 50 samples produced in a continuous process, sampling at regular intervals for each sub-batch in those cases where the sub-batch can be defined) may often be a better way to detect inhomogeneity than random sampling (for example, segregation of fine/coarse particles in a powder). A statistical trend analysis may also be helpful in detecting inhomogeneity. If the material is produced in several batches, it will be necessary to test the equivalence of the batches (or to assign property values to each batch separately). The assessment should be performed after the material has been packaged in its final form unless stability studies indicate that storage should be maintained in bulk form. In some cases, an intermediate homogeneity check may be necessary (for example, prior to ampouling).

Where appropriate, the property values to be assessed should be measured periodically, ideally over a range of conditions under which the material is to be stored prior to distribution to the user. The effects of light moisture, heat and time shall be quantified in order to provide advice on storage location and lifespan (and hence a suitable shelf-life/expiry date) (see Notes 24 and 25).

NOTE 24—Stability testing can only be performed after sufficient homogeneity has been demonstrated. Then any sample (assuming that it is not smaller than the samples used to test homogeneity can be considered representative; there is no constraint on the number of samples required, nor any requirement to choose them randomly. However, there will be variation in results depending on the repeatability and intermediate precision measure of the technique and so replicate tests should be performed.

NOTE 25—When the intended use of a RM is for the calibration of a method requiring a small quantity of test sample, (for example, graphite furnace AAS or ICP-OES), it will be necessary to assess the homogeneity on sample sizes of only several 100 µg to a few mg.

6.9.2 The sample size at which the homogeneity of the RM has been established shall be specified on the documentation supplied by the RM producer. It is encouraged that this documentation also state the minimum sample size for use.

6.9.3 Where appropriate, an assessment of the stability of the assigned property values of the RM performed at periodic intervals after characterization to confirm that all values are maintained from production until its expiry date (see Note 26). Wherever appropriate, the RM producer shall provide an expiry date for the usable life of the RMs produced, based on initial and on-going stability studies in compliance with ISO Guide 35. It is encouraged that it be made clear on the certificate of analysis on what criteria the expiry date is based (for example, the date of certification, the date of shipment or the date of opening the packaging).

NOTE 26—Some certificates may have more than one expiry date. For example, a date from certification, or a date from opening the container by the user.

6.9.4 The RM producer shall provide details of the homogeneity and stability studies carried out in accordance with the requirements of ISO Guide 35 and Practice D 6362.

6.10 *Measurement Methods*:

6.10.1 The RM producer and its collaborators shall use appropriate documented methods or procedures, which include protocols defining approaches to be adopted for different analyses, calibrations, measurements and related activities within their responsibility (including preparation of items, sampling, handling, preservation, storage, packaging, transport to collaborators, estimation of measurement uncertainty and analysis of measurement data). It is encouraged that these activities be consistent with the required accuracy, where appropriate, of the RM, and with any standard specifications relevant to the measurement concerned.

6.10.2 Measurement methods developed in-house by the RM producer, or by any collaborators, shall be validated and authorized (for example, by a management/technical advisory group or appropriately defined person) before use. Such methods shall be thoroughly investigated, and shall clearly and exactly describe the necessary conditions and procedures for which the measurement of the property values of interest are valid at the level of accuracy commensurate with the intended use of RM (see Note 27).

NOTE 27—In some cases, RMs will be characterized for method dependent properties (for example, leachable metals, pH or flash point).

6.10.3 Where sampling is carried out as part of the measurement method (for example, sub-sampling a representative quantity from a batch of material), the RM producer shall use documented procedures and appropriate statistical techniques to take test portions.

6.11 *Measuring Equipment*:

6.11.1 Measuring equipment used in RM production shall be properly calibrated or verified and maintained with all procedures being documented and the results recorded. Where appropriate, periodic performance checks should be carried out (for example, to check the response, stability, linearity, resolution, alignment, repeatability and separating efficiency) to ensure that the measuring equipment is performing adequately. The frequency of such performance checks shall be determined by experience and based on the type and previous performance of the equipment. Intervals between checks shall be shorter than the time within which the equipment has been found to drift outside acceptable limits in accordance with the requirements of ISO 10012-1.

6.11.2 Any item of equipment that has been subjected to overloading or mishandling, shown to provide suspect results, or shown by verification or otherwise to be defective, shall be clearly identified, withdrawn from service, and wherever possible, stored at a specified location until repaired and shown by calibration, verification or test to perform satisfactorily. The RM producer shall review the implications for results obtained using such equipment, with particular regard to the extent of the calibration deviation, the results involved and the allowable tolerance on the results. Where results have been significantly in error, the RM producer shall have the results checked and shall take appropriate remedial action. Records of the review and any checks/remedial action shall be maintained.

6.11.3 Each item of equipment, including any measurement standard, that is used in the calibration/validation of equipment/measurement methods used for RM production shall, when appropriate, be labeled, marked or otherwise identified to indicate its calibration status and expiry date. This shall include reagents used in chemical analysis, microbiological testing, etc.

6.11.4 All measuring and testing equipment having an effect on the accuracy or validity of calibrations or measurements shall be calibrated and/or verified before being commissioned into service. The RM producer and its collaborator shall have an established program for the calibration and verification of measuring and test equipment.

6.11.5 The overall program of calibration and/or verification of equipment shall be designed and operated so as to ensure that, wherever applicable, measurements made by the RM producer are traceable to nation and/or international standards of measurement through an unbroken chain of comparisons with stated uncertainties. Calibration certificates of measurement instruments shall, wherever appropriate, indicate the traceability to national standards of measurement and shall provide the measurement results and associated uncertainty of measurement.

6.12 *Traceability and Validation*:

6.12.1 Where traceability can be related to stated reference (usually national or international standards of measurement) through an unbroken chain of comparisons, all having stated uncertainties, the RM producer and its collaborators shall provide documentary evidence of the traceability of measurements (see Note 28).

NOTE 28—A more complete discussion on the concept and requirements of traceability is given in Appendix A.

6.12.2 Where this cannot be achieved, the RM producer shall provide satisfactory evidence of the correlation of results with other stated values, either by exhaustive evaluation of the measurement process or by correlation with known and accepted national and/or international certified RMs.

6.13 *Data Evaluation*:

6.13.1 The RM producer shall ensure that calculations and data transfers are subject to appropriate checks, including those from its own sources or, where appropriate those from its collaborators.

6.13.2 Where computers/computers-controlled systems are used for the capture, processing, evaluation, recording, reporting, storage or retrieval of calibration or test data, the RM producer shall ensure that, for itself and collaborators:

(a) Computer software is validated wherever possible, especially when developed in-house, and is adequate for use;

(b) Procedures are established and implemented for protecting the integrity of data; it is encouraged that such procedures include, but are not limited to, integrity of data entry and capture, data storage, data transmission and data processing;

(c) Equipment is maintained to ensure proper functioning and is provided with the environmental and operating conditions necessary to maintain data integrity;

(d) Appropriate procedures are established and implemented for the maintenance of data security, including prevention of unauthorized access to, and amendment of, computer records. Hard copies of all computer records and computer disk copies of programs should, where possible, be retained in order to overcome potential difficulties in comparing new data with data obtained using outdated/replaced software.

6.13.3 All technical data relating to the RM production shall be retained in accordance with the requirements of 6.11.2.

6.14 *Characterization*:

6.14.1 The RM producer shall use and document technically valid procedures to characterize its RMs. Where possible, the characterization should comply with the requirements of ISO Guide 35 (see Note 29).

NOTE 29—There are several technically valid approaches to characterizing a RM as described in ISO Guide 35. These include carrying out measurements using: (*1*) a single primary (definitive) method, preferably in duplicate, by a single organization (which may consist of a number of separate laboratories); (*2*) two or more independent reference methods by one organization; the methods should have small measurement uncertainties relative to the intended use by of the RM; the characterization should be corroborated by additional methods or laboratories; (*3*) a network of qualified organizations using methods of demonstrable accuracy and having an assessment of known and acceptable measurement uncertainty; and (*4*) a method-specific approach (interlaboratory study) giving only method-specific assessed property value(s). Depending on the type of RM, its intended use, the competence of the laboratories involved and the quality of methods employed, one approach may be chosen as appropriate. The single primary (definitive) approach should only be carried out when the equipment and expertise enable it to ensure traceability to the SI system. More usually, a property value can be reliably assessed when its value is confirmed by several collaborators working independently and using more than one method, for each of which the accuracy, repeatability and reproducibility have been well established. Generally, the RM producer will need to select collaborators in such a manner as to ensure meeting the objective of the production program, including ensuring an adequate level of quality for the RMs being produced, as defined by the producer and, where appropriate, the user.

6.15 *Assignment of Property Values and Their Uncertainties*:

6.15.1 The RM producer shall use documented procedures based on accepted statistical principles for the assignment of property values. These procedures should include, as appropriate:

(a) Details of the experimental designs and statistical techniques used;

(b) Policies on treatment and investigation of statistical outliers and/or the use of robust statistics (see Note 30);

(c) Whether separate, method-dependent property values are assigned when significant differences are established using different methods (see Note 31);

(d) Whether weighting techniques are used for contributions to assigned property values derived from different methods with different measurement uncertainties;

(e) The methods used to assign measurement uncertainties to the property values (see Note 32); and

(f) Other significant factors which may affect the assignment of property values (see Note 33).

NOTE 30—The RM producer should never rely entirely on a statistical analysis of the characterization data when assessing the property values of interest. Outliers should not be excluded on purely statistical evidence until they have been thoroughly investigated and, where possible, the

reasons for the discrepancies identified. Alternatively, the use of robust statistics may be appropriate in some cases.

NOTE 31—When several methods have been used to characterize a RM, difficulty may arise when the results show significant differences, in which case a property value based on the mean is inappropriate. It is essential in such cases that the RM producer and its collaborators have considerable experience of the different methods and be able to give more or less weight to the results from the use of a particular measurement method. For example, the means from two (or more) measurement methods may differ statistically, but the results from both methods may agree within the measurement uncertainty of each method. In some cases, the results may be weighted according to the inverse of the variance of each method. In some cases, measurement methods will produce irreconcilable results and it may be necessary to assign separate property values according to the methods used (that is, a method-specific approach).

NOTE 32—In assigning uncertainties to the property values of interest, any uncertainties resulting from between-unit variations and/or from possible instabilities (both during storage and during transportation) must be included.

NOTE 33—In assigning the property values of interest, the RM producer should consider establishing a group of independent experts whose responsibility is to check that all work, data and documents are fit for their purpose. It is also necessary for the RM producer to demonstrate the traceability of the property values in accordance with the requirements of ISO Guide 35.

6.15.2 The RM producer shall carry out an assessment of the uncertainties of the assigned property values (see Notes 34 and 35).

NOTE 34—This should always be based on a combination of the uncertainties arising from the corrections for recognized systematic errors, the uncertainties arising from possible systematic errors and the uncertainty due to random variations of repeated observations. Ideally, the latter should constitute the smaller proportion of the uncertainty of a particular property value. In some cases, it may be necessary to make uncertainty estimates based on experience with the measurement methods and their reliability. In such cases, the justification should be described.

NOTE 35—The most important aspect of establishing the property values of the RM being produced is an assessment of their measurement uncertainties. Every measurement has an uncertainty associated with it. Proper assessment and correction of all recognized and correctable systematic errors should be carried out and the uncertainties associated with these corrections assessed. An educated assessment of measurement uncertainty arising from possible systematic errors should also be made based on, for example, the results of intercomparisons.

6.16 *Certificates and Information for Users*:

6.16.1 The RM producer shall issue a statement or certificate, as appropriate, communicating information about the RM; this shall include information on the property values, their meaning, their uncertainties at a defined confidence level and, where appropriate, the expiry date of the material. The statement or certificate shall also contain information for the user on the proper application of the RM and on potential problems in its use. The contents of the certificates shall comply with the requirements of Practice D 6362.

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF TRACEABILITY OF THE PROPERTY VALUES OF RMs

X1.1 Concept of Traceability

X1.1.1 The term traceability is becoming increasingly used to describe the reliability of measurements, but it is not always clear what is meant. Essentially, traceability implies an unbroken path (with stated uncertainties) to some higher level accuracy or authority. In an absolute sense, this means to the base system of measurement units (International System of Units (SI) or their derivatives. However, it has been more generally defined in the International Vocabulary of Basic and General Terms in Metrology (VIM) as "the property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparison." In other words, when the result of a measurement is described as traceable, it is essential to specify to what (values of) "appropriate standards" traceability has been established. It may be to a base unit of the SI (such as the ampere), to a mass fraction number, to a defined scale (such as pH or hardness) or to a value resulting from the use of a method described in a national or international standard.

X1.1.2 In the case of RMs for physical properties, it is usually possible to establish traceability via a series of instrument calibrations to the appropriate base units of the SI. For example, the certification of a RM for specific heat capacity is based on measurements of electrical energy, temperature and mass, all of which are readily traceable to the SI by means of instruments calibrated by or traceable to values obtained at national metrology laboratories.

X1.1.3 In the case of RMs for chemical composition, establishing traceability will often involve more steps. For example, the analyte of interest is usually determined by the physical response of an analytical instrument only after carrying out a number of processes such as sampling, dissolution or extraction, as well as separation by chromatography or more traditional wet-chemical methods. Any or all of these processes may constitute links in the traceability chain, each with its own uncertainty. The analytical chemist must therefore assess how efficient each process has been in completely retaining the analyte, either unchanged or stoichiometrically converted to another chemical species up to the point that the traceability chain may be broken, and in separating it from substances which interfere with the final instrumental measurement.

X1.1.4 When the property is expressed in terms of the amount of substance, the analyst is faced with a particular problem. Because of the extensive use of a balance in a chemical laboratory, the property values of most RMs certified for chemical composition are expressed as mass fractions or mass/volume per mass (concentration), rather than amount of substance which must be expressed in moles/mass. However, working in mass is a very good approximation of working in

moles. The RM producer is therefore concerned with demonstrating that the methods used are the most reliable available for the determination of a particular analyte in a particular matrix and defining the units used, for example, grams of lead per gram of blood, or grams of DDT per gram of animal tissue.

X1.2 Certification of Reference Materials

X1.2.1 As noted in the main text, ISO Guide 35 recognizes four main procedures for the certification of reference materials:

(a) Measurement by a single, primary, definitive method in a single laboratory;

(b) Measurement by two or more independent reference methods in one laboratory;

(c) Measurement by a network of qualified laboratories using one or more methods of demonstrable accuracy; and

(d) A method-specific approach (inter-laboratory study) giving only method-specific assessed property values.

X1.2.2 A primary definitive method is considered to be one where the property "is either directly measured in terms of the base units of measurement or indirectly related to the base units through physical or chemical theory expressed in exact mathematical equations." The term can thus be used to include analytical chemical methods even where the result is not necessarily "in accordance with a definition of the unit" as required by VIM. Even where such a high quality chemical analytical method is available, it is desirable that two or more analysts make independent determination, preferably with different experimental facilities.

X1.2.3 Certification by interlaboratory testing presupposes the existence of a number of equally capable laboratories employing methods which have been independently validated, and implies that in differences between individual results are statistical in nature and can therefore be treated by purely statistical procedures. Although this approach to certification is often unavoidable, it frequently provides only comparability between laboratories and can lead to apparent authority being given to wrong values, especially if the statistical treatment is allowed to predominate over chemical wisdom and judgement. A subset of this procedure is when the analysis is method specific.

X1.2.4 The traceability of RMs can therefore range from a rigorous chain of instrumental calibrations back to the base units of the SI to the use of a well-defined reference method. In each case the RM producer will need to consider how to apply the relevant principle. What is essential, particularly for all certified RMs, is that the certificate contains a statement of traceability indicating the principles and procedures on which the property values (together with their measurement uncertainties) are based. A numerical value without this additional information is generally considered unacceptable in a RM certificate.

X1.3 Practical Examples

X1.3.1 *General*:

X1.3.1.1 The problem of establishing traceability of certified values is considered for some of the main categories of water RMs. It must be stressed, however, that if mass fractions of elements or compounds are certified, it is not sufficient to establish traceability for the determinant.

X1.3.2 *Gas Mixtures*:

X1.3.2.1 The certification of RMs of this type is the most easily traceable of all materials, for chemical composition in that comparisons (by gas chromatography) or other analytical methods) can be made with primary mixtures prepared gravimetrically. The traceability of the primary standard is established by the traceability of the masses to national standards of mass, the atomic/molecular masses of the components, and by the purity of the components. It is also necessary to establish the stability of the mixture in gas cylinders by the regular intervals and by comparing measurements on newly prepared mixtures with those which have been subjected to prolonged storage.

X1.3.3 *Pure Chemical Compounds*:

X1.3.3.1 It is usually not possible to determine the major constituent with sufficient accuracy to derive a meaningful value of purity, except for substance where accurate titrimetric methods can be employed. Methods based on the melting characteristic (for example, differential scanning calorimetry) measure total impurity but require the substance to be stable at its melting temperature, and are only reliable when the system is ideal and the impurities do not form solid solutions in the main component. When direct methods are not applicable, the analytical chemist has therefore to seek to separate and determine all the individual impurities, including the water content, by as many techniques as possible. Chromatography is most useful for organic compounds because of the variety of separation and detection systems available, but the problem of failing to resolve impurities which are chemically very similar to the main component has always to be acknowledged.

X1.3.3.2 The producer of a pure chemical should recognize that it is equally important to demonstrate the identity of the compound as well as its purity. The chemical literature is not free from compounds with wrongly reported structures, and evidence of identity should always be part of the traceability statement on a certificate of purity.

X1.3.4 *Trace Elements in Inorganic (Including Water) and Organic Matrices*:

X1.3.4.1 The use of isotope-dilution mass spectrometry (IDMS) has overcome many of the problems associated with the determination of trace elements. Its capacity to compare number ratios of isotopic atoms of different masses without quantitative separation of the sample yields results which , in theory, are directly traceable to the mole. "Spiking" the sample with an isotope of the analyte element, followed by the creation of conditions under which isotopic homogenization can occur, enables the amount of substance ratios of analyte and spike to be determined by mass spectrometry and be largely free from matrix effects, which equally influence the analyte and spike.

X1.3.5 *Organic Compounds in Organic Matrices and Water*:

X1.3.5.1 This category of RMs probably presents the greatest problems in establishing measurement traceability. The category includes trace pollutants in organic matrices (for example, PCBs and dioxins in animal fat), trace pollutants in water (for example, pesticides in public water supplies) and

clinical chemical analyses (for example, cholesterol in blood). Even IDMS may not be totally satisfactory since it requires the availability of a spike, of know purity, which behaves in an exactly similar way to the analyte in the separation and extraction processes which follow its addition.

X1.3.6 *Compounds Certified for Other Chemical Properties*:

X1.3.6.1 Some chemical properties cannot be expressed in the base units of the SI or their values are method dependent. Nevertheless, traceability is equally important for such materials but it is traceability to a reference method.

X1.3.6.2 For example, although conceptually pH has absolute definition in physical terms, it can only be usefully realized by assigning values on a practical scale to one or more solutions of selected chemical compounds. Certification of property values for these solutions is based on e.m.f. measurements of specified electrochemical cells under carefully defined conditions, and traceability of the property values of RMs for pH is to this measurement procedure.

X1.3.6.3 Many of the RMs used in clinical chemistry are certified by the results of reference methods. The catalytic activity of an enzyme in evaluated by its ability to increase the rate of a particular chemical reaction under specified conditions of pH, temperature and concentration. The importance of using RMs, rigorously traceable to a reference method, for the calibration of routine hospital instrumentation has only recently been recognized.