NIST Special Publication 260-151

The NIST-Traceable Reference-Material Program for Wavelength-Reference Absorption Cells

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NIST National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce

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[1] At Boulder, CO 80303.
[2] Some elements at Boulder, CO.

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FOREWORD

The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards, was established by Congress in 1901 and charged with the responsibility for establishing a measurement foundation to facilitate both national and international commerce. This charge was purposely stated in broad terms to allow NIST the ability to develop its programs to respond to changing national needs and priorities.

Increased requirements for quality systems documentation for trade and effective decision-making regarding the health and safety of the U.S. population have increased the need for demonstrating "traceability to NIST" and establishing a more formal means for documenting measurement comparability with standards laboratories of other nations and/or regions. Standard Reference Materials (SRMs) are certified reference materials (CRMs) issued under the NIST trademark that are well-characterized by use of state-of-the-art measurement methods and/or technologies for chemical composition and/or physical properties. Traditionally, SRMs have been one of the primary tools that NIST provides to the user community for achieving measurement quality assurance and traceability to national standards. Currently, NIST catalogs nearly 1300 different types of SRMs covering 28 technical categories. Since it has the world's leading, most mature, and most comprehensive reference-materials program, most of the world looks to NIST as the de facto source for high-quality CRMs for chemical and physical measurements.

NIST has met the reference-materials needs of U.S. industry and commerce for over 100 years. While our reference-materials program has focused primarily on U.S. requirements, it is clear that these materials address international measurement needs as well. As the demonstration of quality and traceability for measurements have become increasingly global issues, the need for internationally recognized and accepted CRMs has increased correspondingly. Their use is now often mandated in measurement/quality protocols for testing laboratories. The fast pace of technological change, coupled with increased demands on quality, traceability, and different SRM types, have required NIST to devise new strategies for customers to obtain measurement linkage to NIST. With a shift in paradigm, NIST is able to more effectively address future needs for reference materials, both nationally and internationally.

The NIST-Traceable Reference Materials (NTRM) program was created to address the problem of increasing needs for reference materials with a well-defined linkage to national standards. An NTRM is a commercially produced reference material with a well-defined traceability linkage to existing NIST standards. This traceability linkage is established via criteria and protocols defined by NIST and tailored to meet the needs of the metrological community to be served. Reference-materials producers adhering to these requirements are allowed to produce and market artifacts with traceability certified by NIST under the NTRM trademark. The NTRM concept was implemented initially in 1992 in the area of gas-composition standards, to allow NIST to respond to sharply increasing demands for high-quality gas reference materials. The program has been highly successful in providing over 400,000 NIST-traceable gas standards to end-users. More recently, visible-absorbance spectrophotometric NTRMs have become available. Additional potential NTRMs are under investigation, in the areas of spectrophotometrics and optoelectronics, as well as in other research areas. The NTRM concept is relatively new and is still evolving. In all cases, NTRM programs are considered to be supplemental to, rather than replacements for, the well-established and successful NIST SRM Program. It can be anticipated that the NTRM concept will have increasing appeal in many areas where sharply increasing demand for CRMs outstrips NIST's SRM production capabilities.

This document provides the technical and administrative requirements for operating laboratories that produce wavelength-reference absorption-cell NTRMs. Inquiries concerning such NTRMs should be

directed to the authors. Other questions concerned with the availability, delivery, and price of NIST SRMs should be directed to:

National Institute of Standards and Technology
Standard Reference Materials Group
100 Bureau Drive, Stop 2322
Gaithersburg, MD 20899-2322
USA
Telephone: (301) 975-6776
Fax: (301) 948-3730
Web: http://ts.nist.gov/ts/htdocs/230/232/232.htm

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ABSTRACT

A program is described by which commercially produced wavelength-calibration gas-absorption cells may be related to primary standards maintained by the National Institute of Standards and Technology (NIST) and Standard Reference Materials (SRMs) produced by NIST. Currently NIST produces four absorption-cell SRMs for calibration of wavelengths in the 1510 nm to 1630 nm optical-fiber communications region: acetylene $^{12}C_2H_2$ (SRM 2517a; 1510 nm to 1540 nm), hydrogen cyanide $H^{13}C^{14}N$ (SRM 2519; 1530 nm to 1560 nm), carbon monoxide $^{12}C^{16}O$ (SRM 2514; 1560 nm to 1595 nm), and carbon monoxide $^{13}C^{16}O$ (SRM 2515; 1595 nm to 1630 nm). The commercially produced gas-absorption cells, referred to as NIST-Traceable Reference Materials (NTRMs), must be similar to NIST standards, and the pressure of the certified absorption cells must be within a range that NIST has characterized. Although the NTRM gas-absorption cells are produced and distributed by commercial vendors, the pressure and wavelength value assignments and respective uncertainties are determined by NIST. The responsibilities of the producer and NIST are detailed in this document, along with NTRM specifications and evaluation procedures. Appendices are included for the preparation of NTRMs related to various SRMs.

Keywords: absorption; molecular spectroscopy; NIST-Traceable Reference Material; NTRM; optical-fiber communication; SRM; Standard Reference Material; wavelength calibration; wavelength reference.

1. INTRODUCTION

This document provides the technical and administrative requirements for operating laboratories that produce wavelength-reference absorption-cell ***NIST-Traceable Reference Materials (NTRMs)*** (the definitions of emphasized words can be found in Appendix 1, "Definitions of Terms"). NIST ***traceability*** for these materials is assured through strict adherence by producers to specifications and requirements set forth by NIST (Sec. 2) and measurements made by NIST that are part of well-defined and rigorous procedures used in certifying NIST wavelength-reference absorption-cell ***Standard Reference Materials (SRMs)*** (Sec. 1.2).

1.1 NIST-Traceable Reference Materials (NTRMs)

The program described in this document extends the concept of the NTRM to a new type of material. Defined generically, an NTRM is a commercially produced reference material with a well-defined traceability linkage to existing NIST standards. This traceability linkage is established via criteria and protocols defined by NIST and tailored to meet the needs of the metrological community to be served.

1.2 NIST Wavelength-Reference Absorption-Cell Standard Reference Materials (SRMs)

Currently NIST produces four absorption-cell SRMs for wavelength calibration in the 1510 nm to 1630 nm optical-fiber communications region:

SRM 2517a: Acetylene $^{12}C_2H_2$ at a pressure of 6.7 kPa (50 Torr); 56 line centers certified for 1510 nm to 1540 nm wavelength calibration [1]

SRM 2519: Hydrogen cyanide $H^{13}C^{14}N$ at a pressure of 13.3 kPa (100 Torr); 51 line centers certified for 1530 nm to 1560 nm wavelength calibration [2]

SRM 2514: Carbon monoxide $^{12}C^{16}O$ at a pressure of 133 kPa (1000 Torr); 41 line centers certified for 1560 nm to 1595 nm wavelength calibration [3]

SRM 2515: Carbon monoxide $^{13}C^{16}O$ at a pressure of 133 kPa (1000 Torr); 41 line centers certified for 1595 nm to 1630 nm wavelength calibration [3]

The SRMs are single-mode optical-fiber-coupled absorption cells containing a pure isotopic species of gas. Each cell is packaged in a small instrument box with two FC/PC fiber connectors for the input and output of a user-supplied light source. These SRMs can be used for calibrating tunable lasers and a variety of wavelength-measuring instruments, such as optical spectrum analyzers and wavelength meters.

1.3 Wavelength-Reference Absorption-Cell NTRMs

The purpose of this program is to produce wavelength-reference absorption-cell NTRMs to supplement the supply of existing NIST SRMs. NTRMs can be used where SRMs have been used in the past, but, through potential variations in packaging and higher-volume production, NTRMs are anticipated also to be used in applications where SRMs heretofore have not had direct use. The procedures described in this document are based on NIST experience relative to the production and certification of wavelength-reference absorption-cell SRMs and are intended to ensure the development of reliable NTRMs.

The flowchart in Appendix 2 is an overview of the typical NTRM production and certification process. A wavelength-reference absorption-cell NTRM is one of a multiple-absorption-cell ***batch*** (consisting of 20 to 100 absorption cells), prepared in such a manner that all cells in the batch are ***homogeneous*** (i.e., all absorption cells are nominally identical in construction, as well as gas composition, pressure, etc., to

within specified production tolerances; see Sec. 2). The cells, cell treatment, and filling apparatus and procedures must assure batch homogeneity and long-term ***stability***. NIST evaluation verifies homogeneity and stability, and, through ***sample***-testing, a single set of certified wavelengths and uncertainties is assigned by NIST to the batch. Each certified ***uncertainty*** depends on the combined uncertainties due to homogeneity tolerance, statistics of the batch-sampling scheme, and NIST wavelength measurements. Determination, promulgation, and expression of uncertainties follow conventional NIST guidelines [4], which are compatible with ISO definitions and requirements. NIST's Statistical Engineering Division will assist in developing sampling plans, in which only a fraction of the cells are rigorously tested. Standard procedures will be followed (Sec. 3). 100 % testing will be used initially and later, occasionally, to evaluate and confirm the quality level of production.

The integrity of the NTRMs produced through this program is ensured by NIST through active quality-assurance measures. These measures include: NIST review of production procedures and any evaluation of NTRMs by the producer; NIST evaluation of homogeneity, pressure, and stability; NIST assignment of NTRM certified values and associated uncertainties; documentation supplied by NIST, including details of the NTRM certification, Certificates of Traceability, and NTRM labels; and NIST review of the long-term stability of NTRM-production processes.

2. NTRM PRODUCTION

A laboratory that wishes to become a wavelength-reference absorption-cell NTRM producer should contact the NIST Optoelectronics Division. NIST personnel will explain required specifications and tolerances and provide an estimation of certified uncertainties that could be achieved if specifications are met. If both parties are satisfied, NIST will proceed with the qualification procedures described in Sec. 2.1. When NIST is satisfied that the producer is qualified, the candidate will be approved as an NTRM producer. The flowchart in Appendix 2 is an overview of the typical NTRM production and certification process; Appendix 3 lists information required by NIST about cell-production procedures; Appendix 4 gives NTRM specifications; and Appendix 5 shows the information required from the producer for each NTRM batch.

2.1 Qualification of Producer

In order to qualify for participation in the NTRM program, the producer must meet certain minimum requirements. These requirements are intended to ensure the high quality of NTRMs and their availability to U.S. laboratories. There are three requirements:

(1) The producer must have the necessary facilities, equipment, and personnel to produce gas-absorption cells to the specifications described in this document (see Appendix 4). NIST will review pertinent aspects of the producer's absorption-cell-production procedures (Appendix 3) and may require a meeting with key personnel and/or a site visit to the producer's facility.

(2) The producer must submit prototype absorption cells to NIST that are similar to the cells that they plan to produce as NTRMs. NIST will conduct a preliminary evaluation of the cells. If any problems are found, NIST will discuss and attempt to resolve these issues with the producer.

(3) The producer must agree to make the NTRMs available for sale, with a uniform pricing structure, to any U.S. customer.

2.2 Batch Planning and Scheduling

Before an NTRM batch is prepared, the producer must contact NIST for discussions, including the establishment of a schedule, agreeable to both parties, for production and certification. At this time any questions can be addressed, so that there is a mutual understanding of procedures. The producer must verify that qualifications (Sec. 2.1) are still met and must review production procedures and facilities, notifying NIST of any changes. NIST reviews, with the producer, the technical specifications that the NTRM batch is expected to meet or exceed in order to be certified. After concurrence on pertinent points, the batch preparation can proceed.

2.3 Batch Production

Each NTRM cell must be prepared as one of a multicell homogeneous batch (minimum 20 cells; maximum 100 cells). Any one of several fill methods can be used, as long as they are shown to be effective by the producer. All NTRM cells within the batch must be nominally identical with respect to size, construction, and treatment. The gases used must be of high purity, to ensure that impurity levels meet NIST technical specifications. The producer should mark each cell for individual identification.

Homogeneity and long-term stability are of utmost importance. In order for the batch to meet NIST homogeneity specifications, care must be exercised when filling the cells. All NTRMs must be stable, and each batch should be homogeneous. Unstable cells (such as cells that show evidence of leakage)

must be rejected. A batch exhibiting small inhomogeneities may be acceptable, providing that the resulting overall expanded uncertainties do not exceed desired levels. The NTRM program is based on a batch certification; all cells composing the batch are assigned the same values of certified wavelengths and uncertainties. Thus, any batch inhomogeneity will increase the uncertainties of the batch.

The bases for achieving the required homogeneity are the specifications listed in Appendix 4. All specifiable parameters are identified, and nominal required tolerances are shown. This sheet, as shown, (or possible future revisions reflecting changes in standard practices) should provide the specification framework for the majority of NTRM production. In some cases a version of this sheet, specific to a given producer/batch, may be prepared, in which some of the parameters or tolerances may be modified after joint approval by both NIST and the producer; it must be remembered, though, that changes to any specified values will likely change achievable certified uncertainties. NIST has final authority in deciding whether to proceed with NTRM certification of batches with other-than-typical specifications.

2.4 Batch Evaluation by Producer

Ultimate responsibility for formal evaluation of these NTRMs lies with NIST. However, the producer is expected to conduct some evaluation during production. As described in Appendix 3, used when a laboratory first seeks to become an NTRM producer, the producer is expected to use a tested procedure to produce the required homogeneity, purity, pressure, and stability for all absorption cells in a batch. Inherent in this procedure are tests that have been identified by the producer. Such producer testing allows for early identification (and correction) of any instabilities or large inhomogeneities and ensures that the producer has made their best attempt at submitting a homogeneous batch of stable cells to NIST. All of the data at this stage of NTRM production must support the assumption that the batch is stable and homogeneous and meets all other specifications for an NTRM. If there is any indication that the batch may be unstable or inhomogeneous, then further diagnostic work should be conducted by the producer, before a final decision is made to proceed.

The producer must submit the entire batch of cells to NIST. (Even though certified values will be determined from measurements on a statistical sample of the batch, NIST will perform a subset of measurements on all cells.) If requested by NIST, the producer must also submit all results of in-house testing and evaluation.

3. NTRM CERTIFICATION

After the producer submits the required data to NIST (see Appendix 5), the data will be reviewed, and the entire batch of cells will be sent to NIST for evaluation. Procedures that are similar to those used for the corresponding SRM certification will be used to evaluate selected NTRM cells. The purpose of the procedure is to verify that the cells (a) contain the correct pressure of the appropriate isotopic species of gas, (b) have no significant contaminants that may compromise the use of the NTRM, and (c) show no evidence of leakage. This process will normally be completed within two months of sample submission. A Report of Analysis and Certificates of Traceability will be prepared by NIST and issued to the producer for all approved NTRMs, and NTRM cell labels will be affixed to each cell. A Report of Analysis will also be issued to the producer for any rejected batch, detailing the reasons that the batch failed certification.

3.1 NIST Evaluation Protocol

Due to pressure broadening and pressure shift, the absorption lines' centers and widths are sensitive to the pressure within the cell. NIST has evaluated the pressure shift and broadening for the gases used in SRMs 2514, 2515, 2517a, and 2519, and the certified wavelengths of the SRM lines' centers include the pressure-shift contribution [1–3]. The pressure shift varies with line number and gas and is greater than 2 pm for some lines at the SRM pressures. Thus, if sub-picometer wavelength accuracy is desired, it is important that the pressure within an NTRM cell is stable and close to the target value.

NIST conducts rigorous testing on 100 % of the cells in a first batch from a producer, to estimate the quality level of production. Based on these data, a statistical sampling plan, determined in consultation with NIST's Statistical Engineering Division, determines the number of cells to be tested for subsequent batches. The sampling plan is based on a number of factors, including target NTRM uncertainties as well as systematic and random variations of cell measurements, and follows appropriate statistical procedures [5–7, for instance]. NIST randomly chooses the sample of cells to be rigorously tested from subsequent batches. While rigorous testing is done only on the selected sample of cells, less rigorous, moderate-resolution scans of relative widths of selected absorption lines will be made on all cells in the batch, to ensure nominal homogeneity and stability. Such scans, while giving no absolute information about the wavelength of the absorption lines, will identify any batches that have unacceptable inhomogeneity or instability.

NIST evaluation of the selected cells from the NTRM batch is modeled on the procedures used by NIST to certify SRMs 2514, 2515, 2517a, and 2519. Measurements of the spectral band, similar to those shown in Fig. 1 of the corresponding SRM certificates [1–3], are made using a broadband source and an optical spectrum analyzer. High-resolution measurements are made using a tunable diode laser (~1 MHz linewidth) and a calibrated wavelength meter or a NIST SRM unit; one or more absorption lines are accurately fitted, to verify center and width of the line(s). Details of NIST measurement methods, line-fitting techniques, and calibration of the wavelength meter can be found in Refs. [1–3]. The cell pressure is derived from the linewidth measurement. Small deviations of cell pressure from the target value, arising from a filling error, contamination, or leakage, can be determined from these high-resolution measurements.

To test for cell leakage, the moderate-resolution measurements described above are repeated after a minimum waiting period of one month, and the results are compared to the earlier data. Any significant differences between the two data sets may indicate cell leakage. Selected cells are also visually inspected under a microscope to assess the seals (at the windows, fill port, etc.). If there is any indication of cell leakage, the batch will be rejected and the producer must repeat the qualification procedure (Sec. 2.1), with sufficient assurances that problems in their procedures have been corrected.

The procedure of initial 100 % testing and statistical analysis will be required for each of the gases and pressures listed in Appendix 4 that the producer intends to certify as an NTRM. 100 % testing may also occasionally be used in later batches, to evaluate and confirm the quality level of production.

3.2 Batch Certification

If NIST determines that the batch meets specifications, an average pressure and pressure uncertainty will be assigned to the batch. A table of certified wavelengths will then be generated, based on the average pressure and the pressure-shift coefficients previously determined by NIST [1–3]. Each reported wavelength value is accompanied by an uncertainty value. These uncertainties are calculated following standard NIST guidelines [4]. Each combined uncertainty value is determined by combining the variances corresponding to uncertainty of the NIST measurement, uncertainties due to specification tolerances, and uncertainty due to the sample-testing scheme. These values are then expanded by a coverage factor of two, yielding the reported uncertainties, which correspond to an approximate confidence interval of 95 %.

After the certification process is completed, the NTRM cells are returned to the producer, and NIST generates a Report of Analysis (ROA), which is issued to the producer. The ROA: (1) identifies all cells in the batch; (2) describes and reports results of NIST analyses, including homogeneity/stability data, typically determined from moderate-resolution measurements, and high-resolution data for the selected sample of cells; and (3) discloses the acceptance or rejection of the batch for NTRM certification. For an accepted batch of NTRMs, Certificates of Traceability and cell labels are also prepared. Each Certificate of Traceability displays the NTRM logo, the cell identification number, and the absorption wavelengths and uncertainties. Each cell label displays the NTRM logo and the cell identification number.

3.3 NTRM Rejection Criteria

NIST may reject an NTRM for any one of the following reasons: (1) gas-impurity levels that may compromise the use of the NTRM; (2) instability of gas pressure (due to cell leakage or other factors); (3) NIST's homogeneity data show a spread larger than that listed in the specifications (Appendix 4); or (4) NIST's pressure determination does not agree with the producer's pressure determination. In all these cases NIST will work with the producer to resolve the problem for future NTRM work. NIST may reconsider the certification of a rejected (but stable) batch if additional diagnostic work is performed by the producer and the batch is resubmitted for certification.

3.4 NTRM Certification Cost

NIST is compensated directly by the producer for certification of each candidate NTRM batch. Fees are "at cost" and based on the number of cells in the batch, costs for preparation of documentation (ROA, Certificates of Traceability, and NTRM labels), and projected or typical sample fraction. A purchase order must be submitted to NIST before any work can proceed.

3.5 Certification Period and Maintenance of NTRMs

Wavelength-reference absorption-cell NTRMs should be essentially maintenance free, as long as appropriate care is taken in storage, handling, and usage. Furthermore, there is no anticipated need for periodic re-certification of these NTRMs. Once an NTRM is verified to be stable, its certification should remain valid indefinitely. A cell could become unstable if damaged (and, hence, a leak were to develop). Such an event, though, would be considered a "catastrophic failure," and an unstable cell could not be re-certified.

4. TRACEABILITY TO NIST

The traceability of a wavelength-reference absorption-cell NTRM batch relies on the unbroken chain of comparisons to NIST's primary wavelength and/or frequency standards. The NIST-certified standards, such as absorption-cell SRMs, are measured using a wavelength meter that is calibrated with a laser that is locked to a narrow rubidium absorption line [1–3]. The line centers of the hyperfine components of the rubidium transition have been measured with an uncertainty of ±0.4 MHz [8], and a subset of these lines have been measured to higher accuracy [9]. The vacuum wavelengths of these rubidium absorption lines are ultimately traceable to the cesium frequency standard, through a series of accurate measurements [8, 9]. The NTRM measurements are made either by accurate comparison to the corresponding SRM or direct measurement using the calibrated wavelength meter.

Thus, there is an unbroken series of measurements comparing NTRM absorption cells to NIST primary standards and a direct NIST involvement in the NTRM certification. NIST maintains records of all certified NTRMs. The direct involvement of NIST in the quality assurance of each NTRM batch should provide continued reliability with time.

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Appendix 1: Definitions of Terms

This section defines terms used in this document. The initial use of each of these terms within this document is signified by ***emphasized*** print. These terms may be defined differently in other documents released by NIST.

Batch: A group of wavelength-reference absorption cells, prepared by a producer to be homogeneous and stable. For the purposes of this program, each batch will contain a minimum of 20 cells and a maximum of 100 cells.

Homogeneous: The property by which all cells in a batch are nominally identical in construction, as well as gas composition, pressure, etc., to within specified production tolerances.

NIST-Traceable Reference Material (NTRM): A certified reference material, produced by a commercial supplier, with a well-defined traceability linkage to the National Institute of Standards and Technology (NIST). This linkage is established via criteria and protocols defined by NIST that are tailored to meet the needs of the metrological community to be served.

Sample: A statistically determined number of cells (a subset of the batch), randomly chosen for testing.

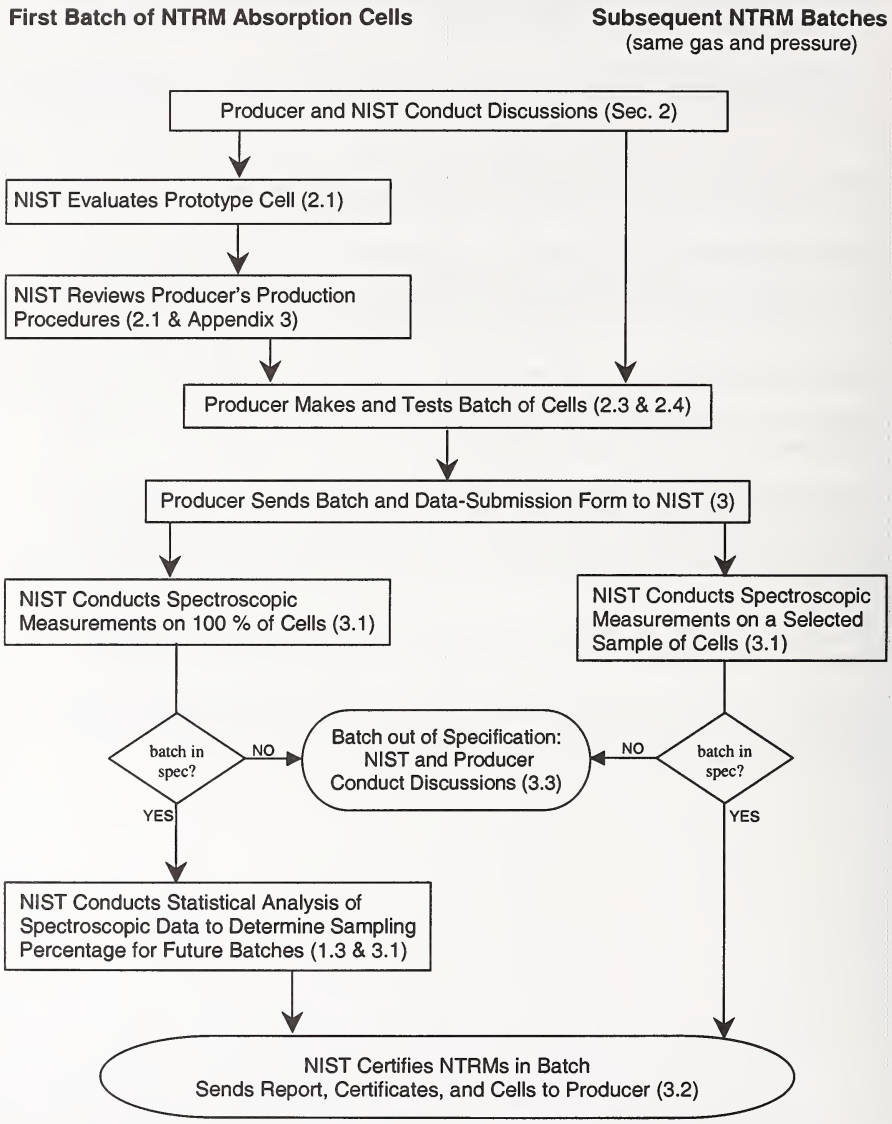
Stability: In this document, the long-term stability of the gas in an NTRM cell. For such an NTRM, a major potential source of instability is cell leakage.

Standard Reference Material (SRM): Certified reference material issued by the National Institute of Standards and Technology (NIST). These are well-characterized materials, produced in quantity, to improve measurement science. SRMs are certified for specific chemical or physical properties and are issued with certificates that report the results of the characterization and indicate the intended use of the material.

Traceability: The property of a result of a measurement whereby it can be related to appropriate standards, generally national or international standards, through an unbroken chain of comparisons.

Uncertainty: The estimated amount by which a measured or calculated value may differ from the true value. In this document, usage, including the terms *standard uncertainty*, *combined uncertainty*, and *expanded uncertainty*, follows conventional NIST guidelines [4].

Appendix 2: NTRM Production and Certification Flow Chart
(With Sections Referenced)



Appendix 3: Cell-Production Procedures

To assess the procedures for producing absorption cells of consistent quality, NIST requires the following information for each NTRM gas that the producer plans to make.

1. Gas Purity
   a. Describe your procedure for ensuring gas purity within the absorption cell.
   b. Describe any tests you use to assess the gas purity in the absorption cells.

2. Gas Pressure
   a. Describe your procedure for achieving the target gas pressure within the cell.
   b. Describe any tests you use to assess the gas pressure in the absorption cells.

3. Gas Pressure Stability
   a. Describe your procedure for ensuring that the absorption cells do not leak.
   b. Describe any tests you use to detect leaks (examples include vacuum leak-testing, visual inspection of seals, spectroscopic evaluation, etc.).

4. Cell Design and Construction
   a. Describe aspects of your cell design that minimize interference effects on light transmitted through the cell (examples include: angled and/or wedged windows, anti-reflection coated windows, etc.).
   b. Describe methods used to ensure and test that there is minimal residual strain in the completed cell.

Appendix 4: NTRM Specifications

Table A4. A nominal listing of gas-absorption references, cell pressures, and wavelength ranges, certified as NTRMs.

Gas	Isotope	Cell pressure(s)	Wavelength range
Acetylene	$^{12}C_2H_2$	6.7 kPa (50 Torr) 27 kPa (200 Torr)	1510–1540 nm
Carbon monoxide	$^{12}C^{16}O$	133 kPa (1000 Torr)	1560–1595 nm
Carbon monoxide	$^{13}C^{16}O$	133 kPa (1000 Torr)	1595–1630 nm
Hydrogen cyanide	$H^{13}C^{14}N$	13 kPa (100 Torr)	1530–1560 nm

This list may be expanded; any questions concerning other pressures or gases can be answered by contacting NIST.

Minimum gas purity: 99 % of one of the isotopic species listed above; no buffer gas.

Gas-pressure stability: The absorption-cell pressure must be stable. Any cell showing evidence of pressure change should be rejected. All cell seals must be permanent (no valves, etc.), and the producer must demonstrate to NIST that their cell-sealing method(s) yield leak-free seals.

Gas-pressure batch variation: Standard deviation less than or equal to 10 % of the target cell pressure.

Appendix 5: Data-Submission Form

FORM A - Producer's Report of Candidate NTRM

Report Prepared by:
Date:
Company Name:
Address:

Individual preparing report:
Phone and FAX #:
Email address:

Description:
NTRM Gas:

Date Cells Filled:

Number of Cells in Batch:

Data:
Gas Purity:

Cell Pressure (in kPa or Torr):

Cell-Pressure Estimated Standard Uncertainty (1 sigma):

Cell Length (in cm):

Cell-Length Estimated Standard Uncertainty (1 sigma):

Cell-Production Method:

Have there been any changes to your cell production method? If so, describe:

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