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# STATUS REPORT ON THE NCSL INTRINSIC/DERIVED STANDARDS COMMITTEE

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Abstract

The history and present status of the NCSL Intrinsic/Derived Standards Committee is presented, including a review of the current published Recommended Intrinsic/Derived Standard Practices (RISPs) and the four Working Groups that are in the process of developing new RISPs. One of the documents under development is a Reference Catalogue that documents important information associated with over forty intrinsic/derived standards. The generic information on each standard in the Catalogue, as well as its Table of Contents, are presented.

## Introduction

The Intrinsic/Derived Standards Committee (IDSC) was formed in early 1988 as an ad hoc committee for the National Conference of Standards Laboratories (NCSL). The committee was formed to investigate ways to provide solutions to the lack of availability of certain standards as identified in the latest National Measurements Requirements Committee (NMRC) report. [The NMRC is a full standing committee of the NCSL.] The initial meeting of the committee was on January 19, 1988.

Recruitment of members for the IDSC continued during the first half of 1988 with the objective of keeping the size of the committee small and yet achieving representation from a cross-section of U.S. metrology organizations. The NCSL Board of Directors voted in April 1988 to make this a full standing committee. The committee currently reports to the Vice-President of Measurement Science and Technology, Dr. Tom Huttemann. Committee members include representation from the National Institute of Standards and Technology (NIST), the Department of Energy, the Department of Defense, the National Aeronautics and Space Administration, and several from industry.

## Committee Status

The objective of the committee is to identify primary standards that are either intrinsic or are derived via other well known sources and to develop documented procedures for realizing the standards. For the purposes of this committee, an intrinsic standard is defined as "a standard based on the absolute value of natural physical constant(s) whose value(s) can be accurately reproduced under

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carefully controlled conditions." In addition, a derived standard is defined as "a standard for which no direct artifact is available or is needed and whose value is determined through one or more of the following: a measurement of one or more well-known traceable quantities; or a standard that can be established through the ratio technique; or a standard that can be established through the reciprocity technique."

If well documented procedures already exist for an identified primary intrinsic or derived standard, then a description of the standard and reference to the associated procedure(s) are included in a Reference Catalogue of intrinsic/derived standards, which is periodically updated by the IDSC (see below). However, if procedures do not currently exit and the committee feels that NCSL members are interested in the standard, then the committee attempts to form a Working Group which will develop a Recommended Intrinsic/Derived Standard Practice (RISP) documenting the standard.

Each RISP developed by a Working Group is organized following a common set of guidelines shown in Table 1. Note that each recommended practice contains sections describing the available literature, major hardware needed to realize the standard, the data acquisition and data analysis procedures, description of uncertainty sources, how to maintain traceability, and quality control procedures. It should be emphasized that each RISP is only an NCSL recommended procedure and thus does not represent a requirement that must be followed by a metrology laboratory. However, if the need exists, the committee will also work to obtain acceptance of the NCSL RISP by the appropriate agencies and organizations as a valid source of traceability. For example, the RISP may be developed into an American National Standard through the appropriate standard sponsoring body, such as IEEE, ANSI, ASQC, etc.

Current RISPs

At present there are two RISPs that have been published by the IDSC:

RISP-1: Josephson Voltage Standard. This document, which was first published in August 1991 and was revised in November 1993, discusses the realization of DC voltage using the ac Josephson effect in order to provide a stable reference voltage. Voltages require using a frequency standard and the internationally accepted value for the Josephson constant to reproduce DC voltages to within ± 0.01 ppm. One unique feature of this RISP is the inclusion of a training exercise which consists of 40 questions (with separate answers) that can be used to evaluate the understanding of the standard by newly trained operators. In addition, another section describes potential problem areas to consider when assembling and using a Josephson standard.

RISP-2: Triple Point of Water. This document, which was first published in August 1992 and is currently under revision, describes procedures for realizing a triple point of water cell. This cell is defined on the International Temperature Scale of 1990 (ITS-90) as occurring at exactly 0.01°C. A triple point of water cell is a critical element in the calibration of a Standard Platinum Resistance Thermometer (SPRT). Of crucial importance for the triple point of water standard is assessing the integrity of the cell, verifying its proper operation, and implementing adequate quality control procedures.

Current Working Groups

There are four new Recommended Intrinsic/Derived Standard Practices currently under development:

(1) Deadweight Pressure Gages headed by Charles Ehrlich (NIST);
(2) Quantum Hall Resistance headed by Randolph Elmquist (NIST);
(3) Two-Pressure Humidity Systems headed by Dave Duff (A-Metrology-Z); and
(4) Intrinsic/Derived Standards Reference Catalogue headed by R. B. Pettit (Sandia).

The status of the Deadweight Pressure Gages and Quantum Hall Resistance Working Groups are discussed in companion presentations in this session. The Two-Pressure Humidity System RISP is currently in the process of forming a Working Group and thus has not started the process of developing a recommended practice.

The Intrinsic/Derived Standards Reference Catalogue, which is under development by the IDSC, has over 45 entries, as shown in Table 2, covering intrinsic and derived standards in metrology areas such as electrical, pressure, microwave, temperature, optical, and mechanical. Each entry summarizes important information about the standard and contains, as a minimum, the following information: a brief description of the standard, how traceability is realized for the standard, typical uncertainties for the standard, and a list of references to both the current published literature or existing recommended practices. Example summaries for the Josephson Array Voltage Standard and Liquid Manometers are shown in Tables 3 and 4. At this time the IDSC is expanding the list of standards included in the Catalogue and updating the associated references included for each standard before publishing the information as a RISP later this year. NCSL members who have important information on any of the standards listed in Table 2 (especially practical references or existing recommended practices) or who would like additional intrinsic or derived standards included in the Catalogue are encouraged to contact the chairman of the IDSC, R. B. Pettit at Sandia National Laboratories, or other IDSC members.

Conclusions:

The Intrinsic/Derived Standards Committee has developed and published two Recommended Intrinsic/Derived Standard Practices, one describing the Josephson Voltage Standard and the other describing the Triple Point of Water. Currently there are four additional RISPs under development: Deadweight Pressure Gages, Quantum Hall Resistance, Two-Pressure Humidity Systems, and Intrinsic/Derived Standards Reference Catalogue. The Catalogue contains limited information on primary intrinsic or derived standards, including existing literature references or recommended practices. Comments on the Catalogue are solicited from the NCSL membership and should be directed to R. B. Pettit at Sandia National Laboratories.

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Table 1. Recommended RISP outline as discussed in the IDSC's Guidance Document.

- A) Identification
  - a) Name of Parameter: (Example: DC Voltage)
  - b) Name of Standard: (Example: 10.0 V Array Josephson-Junction)
  - c) Range of Standard: (Example: 200 $\mu$V - 12.0 V)
  - d) Special Comments: (Example: Requires cryogenic equipment and high frequency (> 70 GHz) microwave source and counter.)
  - e) Disclaimer
- B) Available Literature
  - a) Relevant/Critical Articles
  - b) Existing Procedures or Recommended Practices
  - c) Bare-Bones Literature
- C) Principles of Intrinsic/Derived Standard
  - a) Brief Description of Principle
  - b) Formalism
  - c) Example
- D) Overall Set-up
  - a) Hardware Arrangement Diagram(s)
  - b) Special Schematics and Circuit Diagrams
  - c) List of all Major Components
  - d) Functional Diagram(s)
- E) Major Hardware Components
  - a) Measuring Apparatus
  - b) Special Performance Specifications
  - c) Standards
  - d) Computer/Instrument Controller
- F) Data Acquisition and Data Analysis
  - a) Manual or Automatic System Description
  - b) Measurement Techniques and Procedure
  - c) Calculations
  - d) Data Display and Maintenance
  - e) Statistical Analysis
- G) Personnel
  - a) Educational Requirements
  - b) Training and Experience
- H) Uncertainty
  - a) All uncertainties that can be quantified by statistical means.
  - b) All uncertainties that do not fall under (a) above.
  - c) Overall Uncertainty
- I) Traceability
  - a) Value of Physical Constants (if any)
  - b) Other Standards Required For Traceability
  - c) Measurement Interval
- J) Quality Control
  - a) Control and Trend Charts
  - b) Intercomparisons and Results (Include, as relevant: Technique; Participants; Interval; Organization; Control; Transfer Standard Used; Uncertainty of Process; Overall Results)
- K) Safety
  - a) Briefly describe safety issues that need to be considered for system operation, including personnel and environmental safety.

Table 2. Table of Contents for the Intrinsic/Derived Standards Reference Catalogue showing the 45 Entries.

ELECTRICAL
- Thompson-Lampard Capacitor
- DC Current
- Quality Factor of Capacitors or Inductors
- Josephson Array Voltage Standard
- Quantum-Hall Resistance Standard
- Ratio Devices
- Digitally Synthesized Source

LEAKS
- Accumulate Dump Gas Leak Calibration
- P-delta-V Gas Leak Calibration

PRESSURE
- Liquid Manometers
- Piston Gages
- Pressure Fixed Point: $CO_2$
- Pressure Fixed Point: $H_2O$ Triple Point
- Vacuum
- Molecular Drag Gauge or Spinning Rotor Gauge (SRG)

MICROWAVE
- Periodic Microwave Phase Shifter
- Air-Dielectric Transmission Line Impedance Standards
- Dual 6-port Network Analyser
- Wavelength-Beyond-Cutoff or Piston Attenuator
- Voltage Doubler
- Cryogenic Loads for Noise Measurements
- Microcalorimeters

TEMPERATURE
- Standard Platinum Resistance Thermometer (SPRT)
- Temperature Fixed Points
- Blackbody/Radiation Thermometry
- Optical Fiber Thermometry
- Correlated Color Temperature

TIME/FREQUENCY
- Atomic Frequency Standards
- Satellite Controlled Clocks

OPTICAL
- Optical Power and Energy
- Optical Irradiance
- Optical Fiber (Group Index & Time Delay)
- Wavelength
- Optical Illuminance

MECHANICAL
- Angle
- Planeness and Bending of Optical Flats
- Force
- Length (Gage Blocks)
- Length (He-Ne Laser)

MISC.
- Associated Particle Counting
- Shock
- Accelerometer/Vibration Transducer
- Gas Flow
- Humidity
- Sound Pressure Microphones

Table 3: Current information in the Reference Catalogue for the Josephson Array Voltage Standard

| | |
|---|---|
| <u>Name</u>: | Josephson Array Voltage Standard |
| <u>Parameter</u>: | Direct voltage, 100 microvolts to 11 volts. |
| <u>Type</u>: | Intrinsic Standard |
| <u>Description</u>: | An array of many thousands of series-connected Josephson junctions maintained at a temperature of about 4 K is irradiated with millimeter wave energy. Under these conditions, the voltage-current dependency is quantized such that the voltage increases in discrete steps as current is increased. The size of the voltage steps depends only on the frequency of the millimeter wave signal and the Josephson Constant. |
| <u>Traceability</u>: | Frequency and fundamental constant ($K_J = 2e/h$) |
| <u>Uncertainties</u>: | Typically less than ± 0.01 ppm, determined almost entirely by noise in the system measuring the voltage and the device being tested. (Because of uncertainties in $K_J$, the SI volt uncertainty is ± 0.4 ppm.) |
| <u>References</u>: | <u>Array Josephson Junction</u>, RISP-1, December, 1993 (Available NCSL, 1800 30th St., Suite 305B, Boulder, CO 80301). |
| <u>Comments</u>: | None. |

Table 4: Current information in the Reference Catalogue for Liquid Manometers.

| | |
|---|---|
| <u>Name</u>: | Liquid Manometers |
| <u>Parameter</u>: | Pressure from 0.1 torr to 1000 torr |
| <u>Type</u>: | Intrinsic Standard |
| <u>Description</u>: | Liquid manometers utilize a column of liquid to generate known pressures; the most common for atmospheric pressures is a column of mercury. The height of the column can be measured in a variety of ways, including the use of a cathatometer, a laser interferometer, an ultrasonic pulse, or a mechanical micrometer. |
| <u>Traceability</u>: | Need to measure the height of a liquid column and its temperature. Also need the local acceleration of gravity and the density of liquid. For the ultrasonic technique, need to know the ultrasonic velocity of the liquid; for the laser technique, need the laser wavelength. |
| <u>Uncertainties</u>: | From 20 ppm on up. |
| <u>References</u>: 1. | <u>Using Liquid Column Manometers - Considerations and Applications</u>, R. W. Hyland, Measurement Science Conference, Jan. 1992. |
| 2. | <u>The Speed of Sound in a Mercury Ultrasonic Interferometer Manometer</u>, C. R. Tilford, Metrologia <u>24</u>, 121-131, 1987. |
| <u>Comments</u>: | NIST has recently developed an ultrasonic interferometric manometer using liquid mercury. |

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