Standard Operating Procedure for
Office of Weights and Measures Proficiency Tests (OWM PT)

1. Purpose

This procedure is used by the National Institute of Standards and Technology (NIST), Office of Weights and Measures (OWM), Proficiency Testing (PT) Program, which is operated to support the State legal metrology laboratories. This procedure is part of the OWM PT Quality System which includes NISTIR 7214 "Weights and Measures Division Quality Manual for Proficiency Testing and Interlaboratory Comparisons", NISTIR 7082 "Proficiency Test Policy Plan", and associated PT Tools. This procedure describes how to implement a PT in the OWM program.

2. Scope

This procedure is not limited to proficiency tests; it may be used for any interlaboratory or intralaboratory comparisons (ILC). It may also be used for training, completion of Laboratory Auditing Program (LAP) problems, method validation activities, or other unique efforts. This procedure may be used for any measurement parameter, range, or level of uncertainty.

A separate procedure is available for a "Mini Measurement Assurance Program" (Mini-MAP) that can be used among two or three laboratories for small, or unique applications and laboratory requirements.

2.1. General Requirements

All NIST OWM PT quality system policies, procedures, and tools must be followed for OWM PTs. All participating laboratories are expected to comply with ISO/IEC 17025.

2.2. PT Stages and Tools

Table 1. PT Stages and PT Tools.

Stage	Tool
Planning	OWM PT Workbook (sections P1, P2, P3, and P4)
Operation	OWM PT Workbook (sections O1 and O2)
Analysis	OWM PT Analysis Excel Template
Reporting	OWM PT Reporting Word Template
Follow-Up Actions	OWM PT Follow-Up Form

3. Procedure

3.1. Planning the PT

This section covers general expectations and instructions for the coordinator, analyst, and participants for planning a PT. To implement an effective PT, it is imperative that a good plan is in place.

The PT Workbook sections P1, P2, P3, and P4 are used for all OWM PTs to plan the PT. These sections are completed by the coordinator, reviewed by the participants, and submitted to OWM for approval. PTs are coordinated through the OWM Regional Measurement Assurance Program (RMAP) groups or nationally. See NISTIR 7082 for more information on coordination and policies for PTs.

3.1.1. Identify the PT and Title

The PT and Title are documented in the PT Workbook, Section P1: Organize the PT.

The PT title is based on five components 1) the NIST RMAP region, 2) the year the PT is expected to be reported, 3) the measurement parameter, 4) the unit system, 5) a sequential number to differentiate between names when the first four components are identical. For example, the name of NEMAP-18-MIII-US-01 would mean that this PT was performed in the NEMAP group, is to be reported in 2018, was in Mass Echelon III, reported in US Customary units, and this is the first PT of this exact type reported in 2018.

The range or nominal value of the artifact is identified at this time.

3.1.2. Recruit Technical Advisory Group (TAG)

All members of the Technical Advisory Group (TAG) in this section are documented (as applicable) in the PT Workbook, Section P1: Organize the PT.

3.1.2.1. Coordinator

The coordinator is one or more individuals with responsibility for organizing and managing all of the activities involved in the operation of a proficiency testing scheme. Coordinators document observations, feedback, and complaints related to the PT, and provide input to the analyst for drafting the final report.

3.1.2.2. Analyst

The analyst provides initial analysis and feedback to participants. They draft the final analysis and report with input from the coordinator.

3.1.2.3. Mentor

The mentor provides one-on-one guidance to the coordinator or analyst with less experience. Having a separate mentor is optional for OWM PTs, otherwise the regional coordinator acts as the default mentor.

3.1.2.4. Observer

The observer role allows a participant to observe how the coordinator and analyst plan, operate, analyze, and report a PT. This allows them to gain valuable experience before volunteering as a coordinator or analyst in the future. The observer must be an intimate part of all communications for the PT. Having an observer is optional for OWM PTs.

3.1.2.5. Regional Coordinator

Each RMAP group is assigned one regional coordinator. This position requires an experienced and effective PT coordinator and analyst. They manage and document the PT participation planning schedule process for their RMAP. They mentor and assist, as needed, all the coordinators and analysts for the PTs in their group. They serve as backup to take over a PT if the coordinator or analyst is no longer able to perform their duties. They regularly report to OWM and participant laboratories on the status of PTs in their region.

3.1.2.6. NIST Coordinator and Analyst

The NIST coordinator and analyst provides guidance and support to the volunteers and participants. They approve the PT Workbook information before starting a PT, and finalize the analysis and language used in the final report. Some coordinators and analysts are reluctant to be critical of fellow metrologists when it is necessary to identify and address deficiencies in processing a PT in the report. The NIST coordinator and analyst provides any additional feedback necessary regarding the performance of participants and serves as the final arbitrator for all PTs performed under the program guidelines.

3.1.2.7. NIST Technical Contact

The NIST technical contact provides subject matter expert guidance and support to a PT. Having a NIST technical contact is based on the parameter and needs of the PT.

3.1.3. Identify Participants (See NISTIR 7082 and NIST Handbook 143 for participant requirements.)

Participants are documented in the PT Workbook, Section P1: Organize the PT. Do not abbreviate the laboratory or participant name.

All state laboratory authorized signatories and trained metrologists for the PT parameter that is on their scope are expected to participate.

All participants must be approved by OWM prior to participating in the PT. If a laboratory wishes to participate with the intent of adding measurement capabilities to their laboratory scope, they must contact OWM for approval, which may include additional recommendations or requirements prior to participation. If a laboratory or participant would like to join a PT that is already in progress, they must contact OWM for approval.

3.1.4. Define Objectives

The Objectives are documented in the PT Workbook, Section P2: Objectives and Details.

Objectives are selected based on the requirements and needs of the participating laboratories and guidance from OWM. Likely objectives selected for OWM PTs are:

- Demonstration of Competency for accreditation or recognition;
- Validation of Expanded Uncertainties;
- Evaluation of Calibration Certificates;
- Method Validation;
- Laboratory Auditing Program (LAP) problems;
- Demonstration of Effective Corrective Action from previously failed PTs;
- Conformance or Suitability Evaluation of Artifact;
- Identifying Artifact Characteristics (stability, material, density, etc.); and
- Customer Service and Contract Review (e.g., timeliness, follow instructions).

3.1.5. Define Evaluation Methods

The Evaluation Methods are documented in the PT Workbook, Section P2: Objectives and Details.

All PTs are required to identify how the participants are going to evaluated to meet the objectives of the PT. Evaluation methods are aligned to the objectives.

See paragraph 3.3.1 Evaluation Statistics for details and explanations on the statistical evaluation methods.

3.1.6. Select a Design and Pivot Laboratory (as applicable)

The Pivot Laboratory is documented in the PT Workbook, Section P1: Organize the PT.
The Design is documented in the PT Workbook, Section P2: PT Objectives and Details.

3.1.6.1. Pivot Laboratory

A pivot laboratory may take multiple measurements of the PT artifact at various times throughout the course of the PT to actively monitor stability of the artifact. Not all OWM PTs utilize the function of a pivot laboratory based on the stability of an artifact as determined by historical analysis.

3.1.6.2. Circular Design

The PT starts and ends with the pivot lab. Each lab ships the PT to the next lab without returning it to a pivot lab for intermediate measurements.

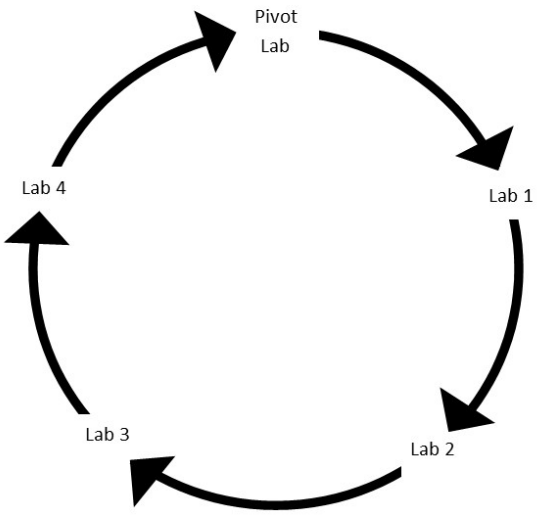

Figure 1. Circular PT Design.

3.1.6.3. Petal Design

The pivot lab makes initial measurements, then one of the participating labs makes measurements, then the pivot lab gets the PT back and makes intermediate measurements before sending the PT to the next lab. This is repeated for every laboratory.

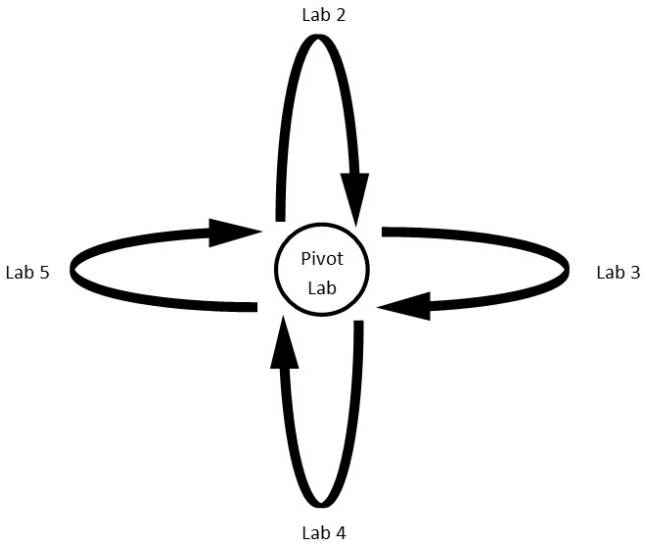

Figure 2. Petal PT Design.

3.1.6.4. Modified Petal Design

This design is similar in concept to the Petal Design, with the difference being that the PT does not return to the pivot lab after each lab. The number of labs a PT is passed through before returning to the pivot lab is optional based on the objectives and stability of the artifact.

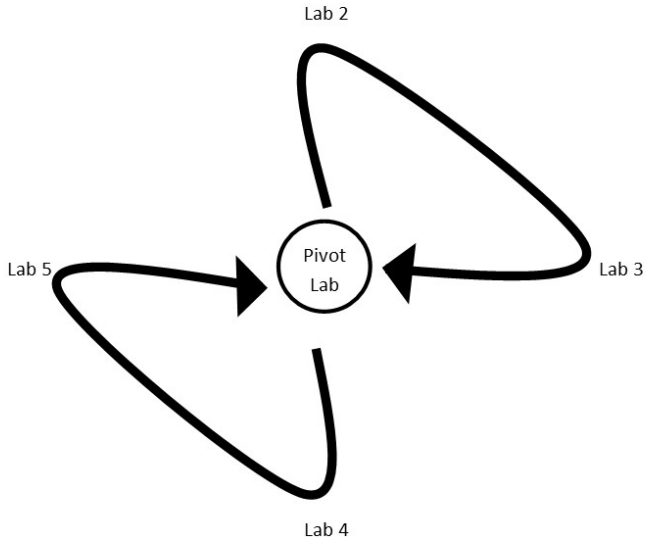

Figure 3. Modified Petal PT Design.

3.1.7. Define Details

3.1.7.1. Calibration Procedure

The Calibration Procedure is documented in the PT Workbook Section P2: Objectives and Details.

It is expected that NIST Standard Operating Procedures (SOPs) are used. When there is no NIST SOP available, use of internationally or nationally published SOPs are expected. If designated procedures are not available, or participants are from laboratories that do not use OWM procedures, those procedures shall be submitted with the calibration certificates from those laboratories.

Participants should agree to use the same procedure(s) to avoid having procedure dependent discrepancies introduced that make troubleshooting problems and analysis troublesome.

Environmental conditions, equilibration, and uncertainty budget components identified in the NIST SOPs must be followed by all participating laboratories, even if they are using other procedures or laboratory-developed methods.

3.1.7.2. Environmental Conditions

The Environmental Condition requirements are documented in the PT Workbook Section P2: Objectives and Details.

The environmental requirements of the designated SOP are used by all participants and restated if/as needed.

3.1.7.3. Equilibration

The Equilibration requirements are documented in the PT Workbook Section P2: Objectives and Details.

The equilibration requirements of the designated SOP are used by all participants and restated if/as needed.

3.1.7.4. Equipment

The Equipment requirements are documented in the PT Workbook Section P2: Objectives and Details.

All participants must have suitable equipment and reference standards that can provide suitably small uncertainties to meet the objectives of the PT. In general, the laboratory will already have the measurement parameter, range, and uncertainty (Calibration and Measurement Capability, CMC) on their scope of accreditation or recognition.

Participants use their typical, suitable equipment unless specified otherwise in this section.

3.1.7.5. Measurand and Characteristics of Interest

The Measurand and Characteristics of Interest are documented in the PT Workbook Section P2: Objectives and Details.

The measurand is the quantity intended to be measured. An example measurand for mass could be the “Conventional Mass Correction”, while for volume it could be the “Volume To Deliver”.

The characteristics of interest could be something for the participant to identify, such as the material, coefficient of cubical expansion, or the density.

3.1.7.6. Units to be Reported

The Units to be Reported are documented in the PT Workbook Section P2: Objectives and Details.

Indicate the units the measurand and uncertainties are reported in.

3.1.7.7. Number of Significant Figures

The Number of Significant Figures is documented in the PT Workbook Section P2: Objectives and Details.

The significant figures are two, unless specified otherwise.

3.1.7.8. Supplemental Data Sheet

The Supplemental Data Sheet option is documented in the PT Workbook Section P2: Objectives and Details.

A supplemental data sheet is an option of the analyst, but does not replace the requirement for calibration certificates to be submitted. When one is used, the format must match the first data entry row and headings in the Data Entry tab of the PT Analysis Excel Template. The analyst verifies that the values in the calibration certificates match the values in the supplemental data sheets.

3.1.7.9. Expected Uncertainties

The Expected Uncertainties are documented in the PT Workbook Section P2: Objectives and Details.

Uncertainties must represent the actual uncertainties used by the laboratory. The expected value is small enough to pass the P_n statistical test and includes the components identified in the NIST SOPs.

3.1.7.10. Expected Range

The Expected Range is documented in the PT Workbook Section P2: Objectives and Details.

The expected range of values from participants is less than the tolerance, unless specified otherwise.

3.1.7.11. Stability Limits

The Stability Limits are documented in the PT Workbook Section P2: Objectives and Details.

The first and last measurements comparison made by the pivot laboratory must result in E_n values of less than 1, with no significant observed shift in values.

3.1.8. PT Artifact Ownership and Characteristics

The PT Artifact Ownership and Characteristics are documented in the PT Workbook Section P3: Artifact and Shipping.

Ownership information is supplied by OWM. Artifact characteristics (e.g., 4 in neck vs 3 in neck, or stainless steel vs cast iron) that are being requested for the PT are documented by the coordinator during the planning stage. Once an artifact is selected, the other relevant characteristics are identified on the artifact (or case), or supplied by OWM.

3.1.9. Care and Handling

The Care and Handling instructions are documented in the PT Workbook Section P3: Artifact and Shipping.

The coordinator provides sufficient details on handling requirement of the artifact. Some items to consider are cleaning, gloves/weight handlers, and drying before packing it for the next laboratory. Participants must be trained, or supervised by a trained metrologist for proper handling when participating in PTs.

3.1.10. Packaging

The Packaging instructions are documented in the PT Workbook Section P3: Artifact and Shipping.

Artifacts were packaged to avoid damage. The coordinator includes a description with sufficient detail of the case (and acceptable methods of securing), packaging material, and how the artifact(s) are packaged. Any PT specific instructions or pictures are documented here. This section includes the following or similar statement: "Any participant that receives the artifact packaged in a manner that is not appropriate or mishandling by the shipper is evident, must contact the coordinator and OWM."

3.1.11. Shipping Instructions

The Shipping Instructions are documented in the PT Workbook Section P3: Artifact and Shipping.

OWM informs the coordinator if alternative shipping methods are designated for a PT, but they are mostly shipped via the default method to reduce transport time, lost, or damaged PTs. The required default shipping method is FEDEX Express, 2nd Day Air (2nd Business Day). This section includes the following or similar statement: "If your laboratory is unable to use this shipping method, contact OWM for alternative method approval."

OWM pays the shipping costs for state laboratories. In these instances, the billing is "3rd Party" with the account number of "242 949 366". In the billing reference or internal comment section, indicate "NIST Div 680.02 (*your RMAP group, e.g., NEMAP*)".

OWM does not pay for shipping costs for non-state laboratories.

The coordinator completes the insurance field and ship weight by locating the corresponding values provided.

3.1.12. Identify Addresses and Laboratory Contacts

The Addresses and Laboratory Contacts are documented in the PT Workbook, Section P4: Addresses and Contacts.

OWM supplies a list of addresses and contacts for each region during the RMAP. The list is from the OWM contact database. Participating laboratories communicate with the coordinator if the information is not correct, and update their information in the OWM Contacts System.

3.1.13. Create the Schedule and Timing Expectations

The Schedule and Timing Expectations are documented in the PT Workbook, Section P1: Organize the PT.

The coordinator creates the schedule. A preliminary schedule is sent out for laboratories to identify any conflicts before the schedule is set. Laboratories that have been historically slow at finishing PTs are scheduled at the end of the list. This way, the PT can be finalized even if that lab keeps the artifact too long, doesn't complete measurements, or submit a calibration certificate.

Laboratories that "hard schedule" their work or have planned any extended periods of time that temporarily prohibit them from making measurements (e.g., vacations, standards calibrations, new equipment installations, etc.), communicate this with the coordinator before the schedule is created or as soon as they are aware.

OWM supplies the coordinator information on when and how long the PT artifact is available, the due date for submitting a draft analysis and report to OWM, and any logistical considerations that must be considered.

3.1.14. Submit PT Workbook to OWM for Approval

The coordinator submits to OWM, the completed PT Workbook (Sections P1, P2, P3, and P4) for approval prior to starting the PT.

3.2. Operation

This section covers general expectations and instructions for the coordinator, analyst, and participants beginning with the starting measurements, through ending the measurements. To

provide timely analysis and reporting of final results, it is imperative that everyone involved adheres to the PT Workbook.

The PT Workbook Sections O1 and O2 are used for all OWM PTs to track the operation and feedback of the PT. This section is completed by the coordinator, then shared with the analyst and OWM.

3.2.1. Coordinator

3.2.1.1. Starting the PT

Email the OWM approved PT Workbook to all participants, lab contacts, and your regional coordinator. Coordinate with OWM to provide the artifact is shipped to the opening laboratory. Ensure a hard copy of the PT Workbook is included with the artifact, and labeled to indicate that it remains with the artifact. Request OWM to send available initial reference values to the analyst.

3.2.1.2. Monitoring the Progress and Reporting Status

The Monitoring of the Progress and Reporting Status is documented in the PT Workbook, Section O1: Coordinator Tracking.

The coordinator is responsible to always know where the PT is and reports the status of the PT to OWM when requested. The status is tracked as the PT moves from laboratory to laboratory.

The coordinator actively communicates with the laboratories and analyst to keep the PT on schedule, and reports any delays or problematic laboratories to OWM before delays become lengthy. It may be required to jump over a laboratory to get the PT to a “hard scheduled” laboratory.

PT shipments are not approved without confirming from the receiving laboratory that they are available and prepared to participate in a timely manner.

3.2.1.3. Feedback and Complaints

Feedback and Complaints are documented in the PT Workbook, Section O2: Coordinator Feedback.

The coordinator records feedback, recommendations, observations, and complaints throughout the course of the PT.

3.2.1.4. Ending the Measurements and Preparing for the Draft Report

If there are any question on the stability of the artifact, then ending measurements are obtained. After all measurements are completed, the coordinator notifies OWM and

the analyst. The coordinator asks where the PT artifact will be shipped, and informs the analyst that all measurements are completed.

The coordinator sends to OWM, electronic copies of all the calibration certificates submitted by the participants and the completed coordinator tracking and feedback sections O1 and O2 of the PT Workbook. The coordinator prepares a draft summary based on their observations, feedback, and complaints (formal or informal) from participants and OWM, and forwards it to the analyst,

3.2.2. Analyst

3.2.2.1. Initial Data Analysis and Providing Feedback

The analyst conducts analysis using the OWM PT Analysis Excel Template. The Participant ID on the Data Entry tab, consists of the Lab Code and the initials of the participant (e.g., NH-JD, represents New Hampshire – John Doe). For non-state laboratories, there are designated codes in the Template. Data is entered in a chronological order by calibration date.

The analyst conducts initial analysis and provide "go/no go" feedback. Analyst feedback does not include specific or general details on performance (e.g., En, Pn, reference values). Pass/Fail information is not known until final analysis with all participant data. For values that appear to be marginal or outliers, laboratories are advised to check their results. After the laboratory has checked their results and their values still appear significantly out of line, OWM is contacted for guidance.

The analyst maintains the integrity of the PT by not informing participants of reference values, or how close a participant is to the reference value.

Feedback is not provided on values submitted via phone, fax, email, or in person. The only acceptable forms of submission are an official calibration certificate or an official amended calibration certificate.

For certain unique PTs that are slow moving and are continuous in nature (e.g., national trailer based PTs), interim reports are provided by OWM.

3.2.2.2. Preparing for the Draft Analysis and Report

Any remaining data is inputted into the OWM PT Analysis Excel Template, there should be very little remaining as data is inputted on a continual basis to provide initial feedback. Laboratories are sent the Data Entry page so they can confirm there are no data entry errors. No other sections of the analysis tool are sent. To prevent lengthy delays, it is helpful to provide a deadline (e.g., 2 weeks) for the review period.

Data entry errors made by the analyst are corrected. Data entry errors made by participant calibration certificates or submitted data sheets must be retained, though not included in the statistical analysis. Data entry errors by the participant are considered failures and must be corrected with an amended certificate. All data is retained for the final report.

The data entry file is submitted to OWM for review to provide any necessary input/suggestions on data points to be questioned further.

3.2.3. Participant

3.2.3.1. PT Workbook

Participants read and follow the directives of the PT Workbook and ask the coordinator questions.

3.2.3.2. Following the Schedule

The PT schedule is developed by the coordinator based on input from participants, the OWM, the logistics of shipping the PT, and the time allotment for each laboratory. NIST OWM PTs typically have multiple metrologists from several laboratories participating, to minimize disruptions and costs, follow the schedule as designed.

3.2.3.3. Reporting Delays or Conflicts

When a laboratory is in possession of the PT and experiences an unexpected event that may cause a delay of the PT, they immediately communicate this with the coordinator. This allows the coordinator to make timely informed decisions on the progression of the PT.

When a laboratory is not in possession of the PT and identifies a potential conflict with the schedule of the PT, they immediately communicate this with the coordinator. This allows the coordinator to make timely informed decisions on the progression of the PT.

3.2.3.4. Receiving PT Shipments

When a laboratory receives the PT, they inform the coordinator of the date of receipt, any damage to the artifact or case, and if artifacts were packaged in a manner that is not appropriate.

3.2.3.5. Performing Measurements

PTs are priorities, measurements are performed in a timely manner to keep the PT on schedule.

Unless otherwise directed by the PT Workbook, measurements are made as a normal customer artifact. PTs are not treated as special calibrations by changing the process you would normally perform.

PT artifacts and associated equipment (e.g., cases, trailers) are not permitted to be used for purposes not defined in the PT Workbook.

3.2.3.6. Submitting Calibration Certificates

Participants are required to report their values to the coordinator using an official calibration certificate. New values resulting from corrective action or new measurements are submitted in an official amended calibration certificate.

Calibration certificates are submitted in a timely manner so the coordinator can supply initial feedback and keep the PT on schedule.

Before receiving initial feedback, each laboratory selects one participant to represent their laboratory's "official values". These values are used in the analysis of the PT.

If a participant uses a non-NIST procedure, they must submit a copy of the procedure to the analyst along with their calibration certificate.

3.2.3.7. Uncertainties

Laboratories are required to report their actual uncertainties based on officially reported uncertainties per their Scope. Uncertainties that are reported based on guard-banding, test-uncertainty ratios, or fractions of tolerances or maximum permissible errors are not permitted.

3.2.3.8. Shipping PTs

When the laboratory receives approval to ship the PT to the next laboratory, they email the coordinator the date of shipment, the tracking number, and which laboratory they shipped it to. Additional shipping information (e.g., carrier used, method used) that deviates from the Section P3: Artifact and Shipping, is emailed to the coordinator.

A PT should never be shipped to a laboratory without confirming with the coordinator or the receiving laboratory, that they are available and prepared to participate in a timely manner.

PT artifacts are repackaged in the same manner as received (if appropriate). Inform the coordinator if packaging instructions were not followed, if deviations have occurred, if artifacts were damaged, or if the instructions and packing needs improvement.

3.3. Analysis

This section covers an overview of the analysis of a PT. This is completed by the analyst, with final approvals from OWM. The OWM PT Analysis Excel Template is used to analyze and graph data for all OWM PTs.

3.3.1. Evaluation Statistics

3.3.1.1. Bias (Difference)

The difference between the laboratory reported value and the reference value is the bias as shown in this equation: ($Bias = X_{lab} - X_{reference}$.)

3.3.1.2. Normalized Error, E_n

The formula used for calculating the normalized error (E-normal, E_n) is shown in Eqn. 1. The result must be less than 1 to pass this statistic.

Eqn. 1. Normalized Error, E_n.

$$E_n = \left| \frac{x_{lab} - X_{reference}}{\sqrt{U_{lab}^2 - U_{reference}^2}} \right|$$

This equation evaluates the bias of the laboratory value from the reference value relative to the combined uncertainties of the values. Values failing the E_n test are omitted from the calculation of the adjusted statistics but values are assessed in the draft and final report.

3.3.1.3. Precision Assessment, P_n

The formula used for calculating the precision test (P_n) is shown in Eqn. 2. The result must be less than 1 to pass this statistic.

Eqn. 2. Normalized Precision, P_n.

$$P_n = \frac{U_{lab}}{\%\ or\ fraction\ of\ tolerance}$$

The precision test evaluates whether the uncertainty of the laboratory value is less than the tolerance or less than a specified ratio of the tolerance. It is used to assess whether the laboratory may properly determine conformity to specific documentary standards. In some of the documentary standards for legal metrology, conformity assessment requires the uncertainty to be less than one-third of the tolerance or maximum permissible error. In others, the uncertainty must be less than the tolerance and the normal calibration practice is to adjust standards to their nominal value. Uncertainties must be sufficiently small to perform proper conformity assessments. The P_n assessment identifies whether the uncertainty is sufficiently small so that the potential error in the value does not significantly impact the value.

Values that are excessively small may also be cause for concern and may signify that uncertainty budgets are incomplete or inappropriate procedures were used. Values with uncertainties failing the P_n test are omitted from the calculation of the adjusted statistics.

3.3.1.4. Z Score

Eqn. 3. Z Score Equation.

$$Z = \frac{x_{lab} - X_{reference}}{s_{PT}}$$

The s_{PT} is the standard deviation for proficiency assessment. The PT standard deviation may be calculated from the following:

- A fitness for purpose goal for performance, as determined by expert judgement or regulatory mandate (prescribed value);
- An estimate from previous rounds of proficiency testing or expectations based on experience (by perception);
- An estimate from a statistical model (general model);
- Results of a precision experiment; or
- Participant results, i.e., a traditional or robust standard deviation based on participant results.

3.3.2. Assessment of the Mean, Standard Deviation, and Adjustments

Visually evaluate the data, look for trends/drift and major changes to the measurement results during the PT as well as after all measurements are completed. Closing values from the pivot lab are necessary if there is question about the stability of the artifact.

To avoid a bias in the results, each laboratory is represented by the data of only one participant. The data from these designees are referred to as the official values. The "Initial Statistics" are calculated using all the official values. To calculate the "Adjusted Statistics" official values that fail certain criteria are omitted. The first step is to omit all values that are outside of two standard deviations (this must be done in one iteration). Then the values that fail the E_n and P_n tests are omitted. All "omitted" values from the calculations are still retained in the report.

3.3.3. Assessment and Determination of the Reference Values and Uncertainties

There are various approaches for determining suitable references, and there is need for technical expertise to make an appropriate determination. The hierarchy of approaches for the most accurate or "best" reference value, may not match the hierarchy for the most

accurate or "best" reference uncertainty. The most common methods used by OWM are listed below, and the hierarchy rankings are generally what is expected, but not always.

Table 2. Selection Hierarchy for Reference Values and Uncertainties.

Item	Source	Typical Reference Value Hierarchy[a]	Typical Reference Uncertainty Hierarchy[b]	Comments
3.3.3.1.	NIST or other National Metrology Institute (NMI) Value	1	1	If stable and sufficiently small uncertainty
3.3.3.2.	Historically Stable Reference Values	2	3	E.g., other RMAP regions
3.3.3.3.	Adjusted Mean/Median Value – Consensus	3	4	E.g., one value per lab
3.3.3.4.	Adjusted Mean/Median Value - Selected Participants	4	2	E.g., accredited labs; pivot lab; labs with lowest uncertainty
3.3.3.5.	Monte Carlo Simulation Values			

[a] The lower number is the better choice. [b]The lower number is the smaller uncertainty.

3.3.3.1. NIST (or other NMI) Reference Value

This is typically the ideal reference value to use when there is evidence of stability and the uncertainties are sufficiently small relative to the participant values. This source is not always an option due to the high cost and the time associated with obtaining this value. Stability of the standard may also make this value less desirable. The uncertainty is reported from the calibration certificate.

3.3.3.2. Historically Stable Reference Values

This can be an individual value or a collection of values from a variety of sources including past NMI calibrations, past RMAP data, or past accredited lab calibrations. The uncertainty is a mean of the uncertainty of the selected values.

3.3.3.3. Adjusted Mean/Median Value – Consensus

This value is most often used when there is no other good alternative, or when the tolerances are sufficiently large that the use of this value no significant negative impact on the analysis. Other options in this category is to us a trimmed mean or Windsorized mean. The uncertainty is from the standard deviation of values used, multiplied by *k* as a coverage factor.

3.3.3.4. Adjusted Mean/Median Value – Selected Participants

This value comes from a smaller select group of participants (i.e., one value from each laboratory is not included). The selected group is often laboratories that are working at a high level with low uncertainties, accredited laboratories, or laboratories with recent calibrations of their standards when they agree relatively well. When appropriate, the values from a pivot may be used. The uncertainty is a mean uncertainty of the selected values.

3.3.3.5. Monte Carlo Simulations Value

This is a tool to simulate a value based on statistical simulations using data from participants. The values are neither conservative or liberal in nature, rather they should coincide relatively close to participants data. The uncertainty is from the statistical simulations.

3.3.3.6. Other Considerations

When trying to determine the best reference value to use, it often helps to look to see what the data tells you instinctively, what makes sense to you. Sometimes the agreement between multiple approaches agrees enough, that it may not matter which value is selected.

If there are changes due to damage, cleaning, or some other incident, multiple reference values may be needed for a PT artifact. If there is major drift, a linear best fit value may be needed that is time dependent (not common for OWM PTs).

3.3.4. Specialized Assessments

3.3.4.1. Youden Analyses

Although not widely used for OWM PT analysis, this tool is comparing the variability within a lab or between labs. Two data points are needed, either from two similar artifacts or the same artifact calibrated twice.

3.3.4.2. Simulations and Monte Carlo Assessments

Although not widely used for OWM PT analysis, this tool generates simulated values based on an inputted distribution and variables for your data set. Simulation iterations can run in the tens of thousands, hundreds of thousands, or more depending on the computing capabilities.

3.4. Reporting

This section covers an overview of the reporting of a PT. This is completed by the analyst with support from the coordinator, with final approvals from OWM. The OWM PT Reporting Word Template is used to report all OWM PTs.

3.4.1. Complete Submission

The coordinator and analyst send (electronically) all the components listed below to OWM:

- The PT Workbook with the completed Section O1: Coordinator Tracking, and Section O2: Coordinator Feedback;
- Copies of all participant calibration certificates and amended calibration certificates (as applicable);
- A completed draft OWM PT Analysis Excel Template; and
- A completed draft OWM PT Reporting Word Template.

3.4.2. Recommendations, Feedback, and Final Approval

The coordinator, analyst, and OWM provide observations and feedback regarding the PT results, that are included in the report. If the coordinator or analyst identify corrective actions for other participants, it is represented as OWM feedback in the report. The NIST OWM reviews and approves all OWM PTs before they are considered final.

3.4.3. Presenting the Final Report

The coordinator or analyst prepares to present the final report at the RMAP training session. OWM is available to supplement information on the failures and required follow up actions for state laboratories. Participants receive a copy of the final report.

3.5. Follow-Up Actions

Successful PT participation does not end after providing measurement results and submitting calibration certificates. Completing follow-up forms and action items is required.

3.5.1. Follow-Up Forms

All state laboratories that participated in the PT complete a follow-up form to document the formal review and assessment of the report and their participation, whether they pass or fail. OWM provides a template for this function or the laboratory may develop their own equivalent form. This form is not a "Yes/No" checklist, it requires descriptions, summaries, and conclusions of PT results and actions needed, which feed into the laboratory measurement assurance and management review processes.

3.5.2. Action Items

Depending on the design from the laboratory, items that require action can be categorized as one of the following:

- Complaints (C);
- Corrective Actions (CA); and
- Improvement Actions (IA).

All outside feedback and internal analyses that fall into one of these categories must be documented and acted upon by the laboratory. Submitting this documentation to OWM is required during the recognition cycle (See NIST Handbook 143, Program Handbook).