SOP 20

Standard Operating Procedure for Control Charts for Calibration of Neck-Type Provers (Volume Transfer Method)

1 Introduction

1.1 Purpose

This procedure describes a process to be followed to monitor the statistical control of the volume transfer method for the calibration of neck-type provers, especially when using the Standard Operating Procedure (SOP) 19 for this purpose. The same principles may be adapted to the development of control charts for other calibration procedures.

1.2 Prerequisites

The verification procedure is the same as that required by SOP 19.

2 Summary

Because of the size and cost of neck-type provers, it is not always practical to have check standards remain in the laboratory for the purposes of measurement control. However, it is practical to maintain a range (*R*) chart for each size prover to establish the standard deviation of the measurement process. Directions for preparing and using an *R* control chart that monitors the precision of the test procedure are given. It is assumed that provers of the same nominal capacity and design will have similar characteristics with respect to the repeatability of tests. Since it is not practical to run a sufficient number of tests on each unknown prover to determine the repeatability, the absolute difference between two test results on individual provers of the same nominal size are graphed on the same *R* chart to reflect the repeatability of measurement of the provers tested in the laboratory. Provers of similar readability may be grouped together on the same chart (e.g., provers greater than and equal to 500 gal generally have 20 in^3 graduations and similar repeatability.)

3 Equipment

All equipment is designated in SOP 19.

4 Procedure

4.1 Data Collection

4.1.1 Conduct a minimum of two runs on each prover. A minimum of 12 provers must be tested before a reasonably adequate data base is established. Note: 25 to 30 points are recommended to determine uncertainties.

4.1.2 Tabulate the measured errors as determined by each of the two trials using a form such as the one contained in the Appendix. The data may be maintained in a spreadsheet or other electronic program in lieu of a paper form. (If the prover is adjusted after the first trial to indicate zero error at a reference temperature, the first trial reading is evaluated after the adjustment.)

4.1.3 Calculate the absolute difference $|d|$ of the two trials and the summation $\Sigma|d|$. Note that $|d| = R$, the range of the two trials.

4.1.4 Calculate the average range of the trials, $\overline{R}$, for the n tests as follows:

$$\overline{R} = \frac{\sum |d|}{n} \qquad \text{Eqn. 1}$$

4.2 Construct a Range Control Chart

4.2.1 Construct an R control chart having the following limits:

Central Line $= \overline{R}$
Lower control and warning limits LCL $=$ LWL $= 0$
(There should be no negative numbers recorded when using absolute values!)
Upper warning limit UWL $= 2.512\,\overline{R}$
Upper Control limit UCL $= 3.267\,\overline{R}$

4.2.2 The recommended format for construction of R control charts is given in NISTIR 6969, Section 7.4.

4.3 Use of Control Charts

4.3.1 Two trials are run on each prover submitted to the laboratory for calibration. The values for R are plotted on the appropriate control chart, preferably in sequential order. The limits of the charts are such that 95 % of the values should fall within the warning limits and rarely should a value fall outside the control limits, provided that the system is in a state of statistical control.

4.3.2 If the values plotted on the R chart fall outside of the control limit, a decrease in precision is indicated. Cleanliness, valve leaks, or procedural problems (e.g.,

meniscus reading, drain times) should be investigated.

4.3.3 No calibration data should be accepted when the system is out of control.

4.3.4 If a plotted value for *R* is outside of the warning limit but inside the control limit, a second set of duplicate calibrations should be made. If the new value for *R* is within the warning limit, the process may be considered in control. If it lies outside of the warning limit, lack of control is indicated. Corrective action should be taken and attainment of control demonstrated before calibration measurements are considered to be acceptable.

4.3.5 Even while the system is in an apparent state of control, incipient troubles may be indicated when the control data show short- or long-term trends, shifts, or runs.

5 Interpretation of Control Chart Data

5.1 Demonstration of "in control" indicates that the calibration process is consistent with the past experience of the laboratory. That is to say, there is no reason to believe that excessive changes in precision have occurred.

5.2 The accuracy is inferred from a consideration of control of the sources of bias. These include drain characteristics of the prover, time required to drain the prover, and prover design (geometry and piping).

5.3 To the extent appropriate, the precision of measurement of provers may be extended to the calibration of other provers of the same capacity and design. Care must be exercised in this approach because each prover is custom made and has unique metrological characteristics. The lack of precision in the test of a prover may indicate a defect in that particular standard and may not reflect inconsistency in the measurement process. Uncertainty values may need to be adjusted when prover design problems are indicated.

5.4 It is expected that the maximum imprecision (the upper control limit) of the volumetric method of prover calibration will be less than one-third of the applicable prover tolerance in field applications. If this is not the case, contact the NIST Weights and Measures Division to discuss the problem.

Appendix

Control Chart Data
Prover Capacity & Graduation Size: _____
Laboratory: _____

Test Number	Date	V_{TD}, X_1 Trial No. 1	V_{TD}, X_2 Trial No. 2	V_{TDM} $\bar{x}$	$\|d\|$ = |Trial 1 - Trial 2|*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
SUM					
				$\sum \bar{x}$	$\sum \|d\|$

*n*** = _____ $\bar{R} = \frac{\Sigma|d|}{n} =$ _____

UWL = 2.512 $\bar{R}$ = _____ UCL = 3.267 $\bar{R}$ = _____

* This is the range, *R*, of the two trials and is actually the larger value minus the smaller value.
***n* is the number of tests used to calculate the control limits.