SOP 20

Standard Operating Procedure for Standard Deviation and Range Charts

1 Introduction

1.1 Purpose

This procedure describes a process to be followed to monitor the statistical control of a measurement process using standard deviation charts or range charts for any calibration method where it is not practical or feasible to maintain laboratory check standards.

1.2 Prerequisites

The procedure must match the calibration procedure that is being monitored.

2 Summary

Because of the size and cost of some laboratory standards, 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 standard deviation (s_p) charts or range (R) charts for each nominal size standard to evaluate the standard deviation of replicate runs. Directions for preparing and using an R control chart that monitors the precision of the test procedure are given. It is assumed that standards 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 standard to determine the repeatability, the absolute difference between replicate test results on are graphed on the same s_p or R chart to reflect the repeatability of measurement of the unknown standards tested in the laboratory. Note: 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 the respective calibration SOP.

4 Procedure

4.1 Data Collection

4.1.1 Conduct a minimum of two runs on the unknown test item per the designated SOP. A minimum of 12 sets of data must be available before a reasonably adequate data base is established. Note: 25 to 30 replicate sets of data are recommended to determine valid 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 unknown item is adjusted after the first trial to indicate zero error the first trial reading is evaluated after the adjustment.)

4.1.3 A standard deviation may be calculated for each set of runs according to the appropriate SOP with a pooled standard deviation determined for the measurement process. This is preferred.

4.1.4 Calculate the absolute difference $|d|$ of the two trials and the summation $\Sigma|d|$. Note that $|d| = R$, the range of the two trials. Be sure that only absolute values are used in the determination of the range and average range!

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

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

4.1.6 The estimated standard deviation may be calculated using the average range as follows (obtain values for d_2^* from NISTIR 6969 Table 9.10 and see NISTIR 6969 Section 8.3 for additional notes):

$$s_p = \frac{\overline{R}}{d_2^*} \qquad \text{Eqn. 2}$$

4.2 Construct Appropriate Charts

4.2.1. Construct Standard Deviation Charts and Range Charts using the same approach. However, you may use 2 and 3 as the respective multipliers for the Upper Warning Limit and Upper Control Limits. Note that there will be no negative numbers when calculating standard deviations.

4.2.2. 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 = $3.267\,\overline{R}$

These limits are *t* values for 95 % and 99.7 % confidence intervals for a sample size of 30.

4.2.3 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 standard deviation or range 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 standard deviation or range chart fall outside of the control limit, a decrease in precision is indicated. Problems with the standards or process will need to 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 standard deviation or range 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.

5.3 To the extent appropriate, the precision of measurement of standards may be extended to the calibration of other standards of similar type, capacity and design.

Appendix

Standard Deviation and Range Data

Standard Capacity: : _____ Laboratory: _____

Test Number	Date	*Run 1*	*Run 2*	*Average of Runs*	Range* $\lvert d\rvert$ = |Run 1 - Run 2| (Max – Min)	Standard deviation**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
SUM						
				$\sum \bar{x}$	$\sum \lvert d\rvert$	

*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.

** Use of the standard deviation and pooled standard deviations are preferred to the use of Range as an estimate of the standard deviation.

****n* is the number of tests used to calculate the control limits.