Proficiency Testing of API-2000 Flow Rate Test Labs.

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April 16, 2020

1 Abstract

The API 2000[1] Flow Rate Taskgroup decided that the complaints by some venting device manufacturers that published and certified flow curves by some vendors were not accurate motivated the committee to charter a Flow Certification Taskgroup[2] to investigate this issue. The Taskgroup's statistical analysis report[3] concluded that

> *Four vendors submitted complete data. After analyzing these data, we found that flow rates measured by the four vendors under identical conditions of inlet pressure and orifice diameter differ by -8.7% to 6.2% . **Disparities of this magnitude cast doubt on the reliability of vendors' sizing tables.***

Having demonstrated that there is a problem, the aim of this paper is to show how monitoring protocols that are in wide use in a variety of industries could be incorporated in API-2000.

[1] API Standard 2000, 7th edition, March 2014 "Venting Atmospheric and Low-Pressure Storage Tanks"
[2] PEMyers (phil@pemyconsulting.com) chairs this taskgroup. The TG is made up of PV venting valve manufacturers, owners, and users as well as consultants. The taskgroup reports to the API 2000 committee.
[3] https://github.com/rbitip/Public-API-2000-Flow-Certification-Testing/blob/master/FlowCertTestingProgramFinalRpt_050820.pdf

2 Monitoring precision and accuracy.

- Lab measurements are ***precise*** if:
  - Replicate measurements of the same thing by the same lab are in good agreement
  - Measurements of the same thing by different labs are in good agreement.

- Lab measurements are ***accurate*** if they are both precise and are close to ***reference standards***.
  - One way to develop reference standards might be sending test specimens such as the nozzles used in this Flowrate Taskgroup study to a ***reference laboratory***.

Although we don't agree with every detail of ISO 13528:2015 ,"Statistical methods for use in proficiency testing by interlaboratory comparison," it is a starting point for revising API:2000.

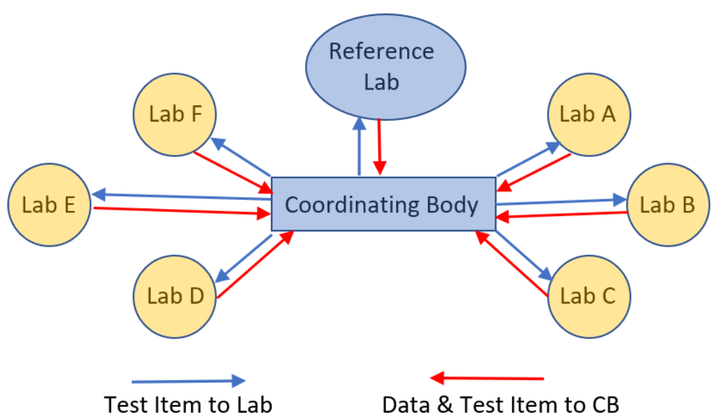
3 Proficiency Testing

Ideally, proficiency testing compares participating labs to a reference standard. If a reference standard is not available, ISO 13528 Algorithm "A" shows how to compute a proxy standard[4]; however, we can't recommend this practice, since the proxy may not be an accurate estimate of a true reference standard.

A coordinating body (CB) sends a test item to a reference lab for testing.

The CB sends the item (or a replica) to each participating lab (PL) for subsequent testing. PL must run each test at least twice to allow CB to compute PL's precision.

CB evaluates the returned test/retest data and issues a performance report to each PL.



[4] Technically, an *outlier-resistant* estimate of the mean of the PT's measurements.

4 Performance Reports for Participating Laboratories

As we understand it[5], ISO 13528:2015 suggests two classes of statistical performance measures: statistical deviations, or Z-values[6], and percent deviations[7], $D^{\%}$.

$$Z_{pt} = \frac{\left(X_{pt} - X_{ref}\right)}{\sqrt{\sigma_{pt}^2 + \sigma_{ref}^2}} \quad \text{and} \quad D_{pt}^{\%} = 100 \cdot \frac{\left(X_{pt} - X_{ref}\right)}{X_{ref}}$$

where

X_{pt} = measurement report of participating lab

X_{ref} = measurement report of reference lab

σ_{pt} = test-retest standard devition of participating lab

σ_{ref} = test-retest standard devition of reference lab

To illustrate, we generated performance reports for Task Group participants A,B,C,D, and F, using the most precise lab (participant E[8]) as a stand-in for the reference lab. Reports for participant A are in Figure 1 and Figure 2.

Each participant measured flow rate for three nominal orifice diameters: (2, 6, and 10 inches) and five pressure drops (1, 2, 3, 4, and 5 inches of water column).

[5] Our understanding of ISO 13528:2015 is comes from:
Analytical Methods Committee, AMCTB No. 74, "z-Scores and other scores in chemical proficiency testing--their meanings, and some common misconceptions." *(requires creating an account for free access)*.

[6] Z can also be expressed as E_n which is Z divided by a 95% or 99% normal critical value. The advantage of using E_n values is that the action limits are always ±1, whereas Z action limits are either ±1.96 or ±2.58, corresponding to 5% and 1% false positive rates, respectively.

[7] Action limits for $D^{\%}$ values are set by the coordinating body.

[8] As it happens, participant E was very close to the proxy standard generated by ISO 13528 Algorithm “A”.

The Statistical Significance Report (Z-values) that would be delivered to Participant A shows Z-values for all other participants in black and participant A in red[9].

The conclusion is that participant A has a consistently positive bias but does not reach the "2-sigma" action limit.

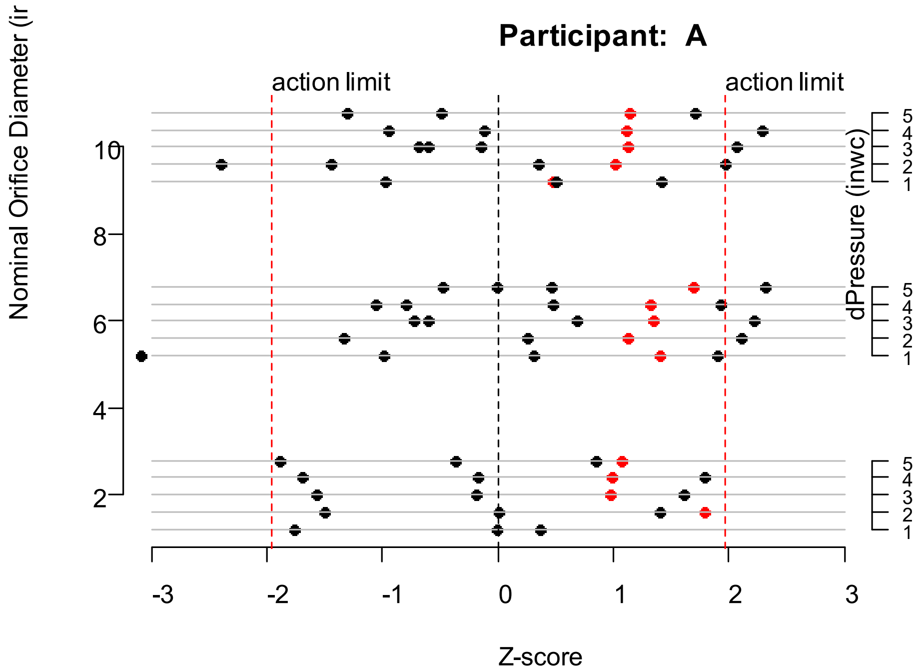


Figure 1 Z-value Report

[9] Note the absence of a red dot on the lowest gray ledger line, indicating that Participant A was not able to measure flow rate for the nominal 2" diameter orifice at differential pressure 1 inwc.

The Percent Deviation Report (Z-values) that would be delivered to Participant A shows % deviation values ($D^{\%}$) of all other participants in black and participant A in red. The action limit is arbitrarily shown at 10% deviation.

The conclusion is that participant A has a consistently positive bias and that it exceeds the upper action limit for the nominal 6" diameter orifice (except at 2 inwc) and for the nominal 2" diameter orifice at 2 inwc.

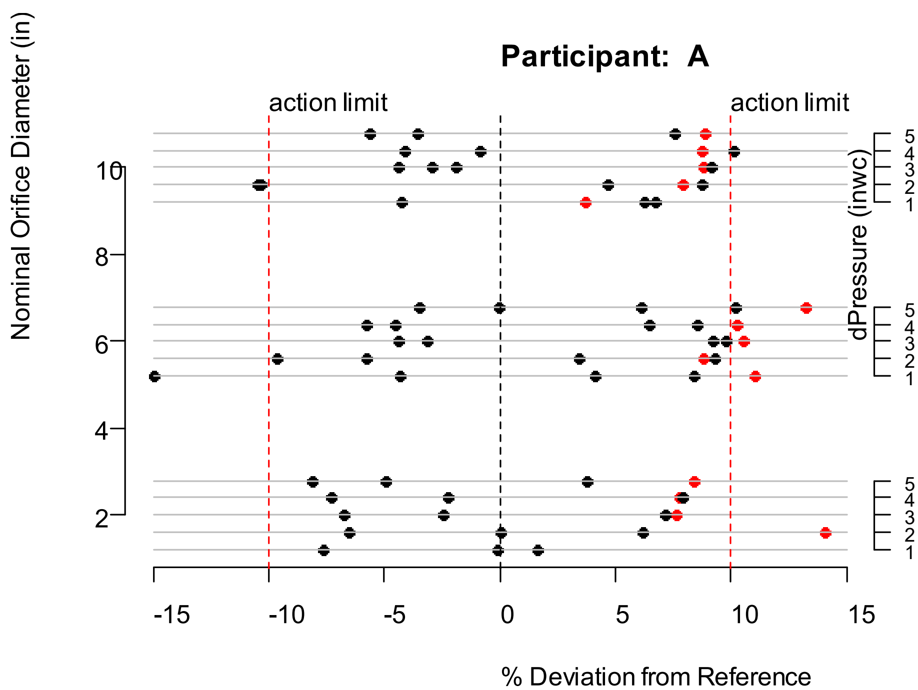


Figure 2 % Deviation Report.