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Technical Instructions and Engineering Guidelines

GS-ENG-07-06: Determination of Short-term Repeatability and Long-term Reproducibility of Bell Provers Using Diaphragm Transfer Meters

Version 1.2

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Record of Change

Revision	Date	Description
0.1	2007-01-10	Original
0.2	2007-01-17	Draft for Consultation
0.3	2007-07-19	Editorials and PDD Consultation
0.4	2007-09-06	Technical additions in section 7.0 provided by Henry Telfser
1.0	2007-09-30	Date of issue
1.1	2007-10-11	Editorial changes
1.2	2007-10-19	Editorial changes

1.0 Scope

The purpose of this document is to provide instructions relating to the use of Diaphragm Transfer meters (DTMs) in the correlation process between a level 2 Master Bell Prover and level 3 Working level (production type) Bell Provers. This document must be read in conjunction with the references listed below.

2.0 Authorization

This document has been produced under the authority of the Senior Engineer – Gas Measurement, for the purpose of setting out Technical Instructions and Engineering Guidelines relating to the selection and use of diaphragm meters for the purpose of establishing traceability the short-term repeatability and long-term reproducibility of a bell prover.

3.0 References

(a) LMB- EG-13, Provisional Specifications For the Calibration and Use of Gas Measuring Apparatus – Bell Provers, 1989,

(b) S-G-01, *Specifications for the Calibration, Certification and Use of Gas Measuring Apparatus - Working Level Sonic Nozzle Provers,*

(c) S-S-02, *Measurement Uncertainty and Meter Conformity Evaluation Specification,* Measurement Canada, 2007,

(d) GS-ENG-04-06, *Recommendations for The Determination of Measurement Uncertainty In Automated Master Bell Provers, 2007,*

(e) GS-ENG-07-02, *Temperature and Humidity Measurements in Prover Rooms,*

(f) *Guide to the Expression of Uncertainty in Measurement (GUM)* ISO, 1993,

(g) ISO 7870, Control charts – General guide and instruction, 1993,

(h) ISO 7871, Cumulative sume charts – guidance on quality control and data analysis using cusum techniques, 2004,

(i) ISO 7873, Control charts for arithmetic average with warning limits, 2004,

(j) ISO 8258, *Shewhart Control Charts,* 1991,

4.0 Introduction and Background

This text is based on a set of methods and philosophies presented in the current bell prover and sonic nozzle prover specifications. This document recognizes the traditional method of on-going measuring apparatus correlation with a master bell prover and allows for the introduction of Statistical Process Control (SPC) methods and their use in the determination of measurement uncertainty for the volume transfer process.

Generally, DTMs are used as check standards for the purpose of determining and monitoring the effect of sources of variability that manifest them selves over time. This is also referred to as the System Total Reproducibility ($u_{R\ lt}$). Refer to section 2.4.9 of GS-ENG-04-06 for specific details for combining $u_{R\ lt}$ into the total measuring apparatus uncertainty. This is accomplished by determining the deviation from true of the DTM relative to local volumetric standard (Level 2 Master Bell) and that of the of the gas measuring apparatus through an inter-comparison. In doing so, the uncertainty of the correlation process directly influences the uncertainty of the working bell. This process and its sources of uncertainty are shown diagrammatically in figure 1.

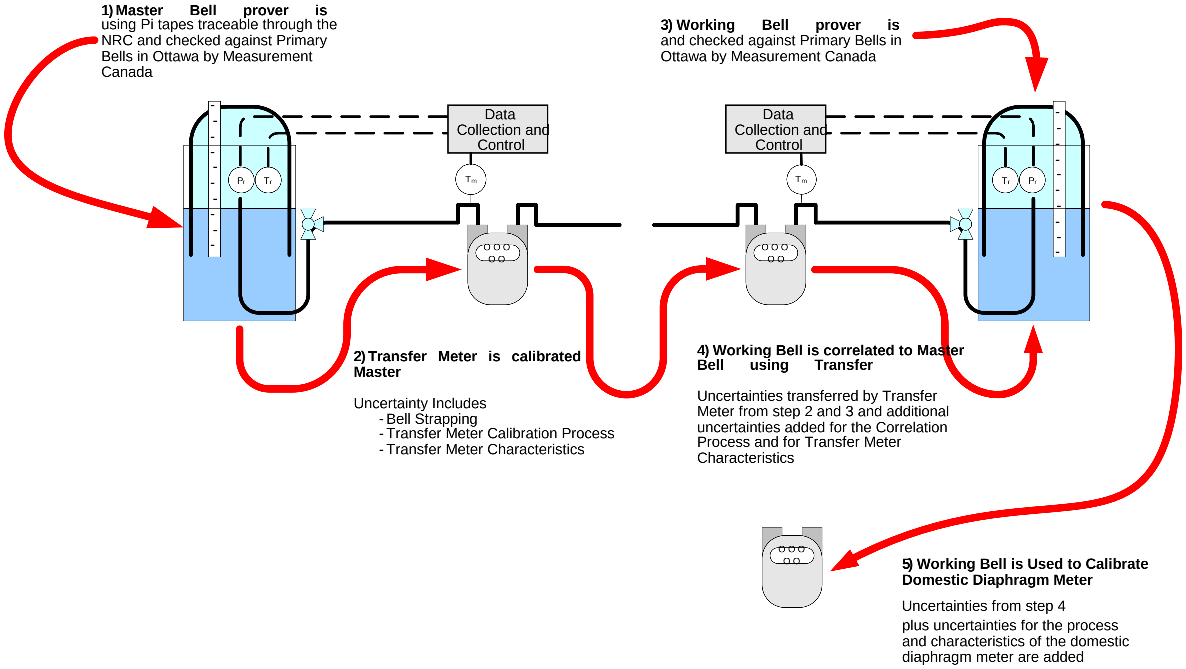

Figure 1: Traceability chain for working level Bell Provers using DTMs

5.0 Selection of Transfer/Check Meters

The repeatability and moreover the long-term reproducibility of the DTM is of paramount importance in controlling and minimizing the measuring apparatus uncertainty. As such, when a DTM / check meter is selected by the applicant it should:

- be representative of meters in the various meter classes or meter classifications,
- be Measurement Canada verified and accepted,
- have a rated flow rate capacity sufficient to provide for test flow rates within the intended range of use of the associated measuring apparatus and domestic diaphragm meter,
- provide for monitoring of calibration stability and system performance of the measuring apparatus in all intended modes of operation, e.g. optical sensor, ID mounted pulser, etc.,
- be repeatable and reproducible within applicable limits,
- meet the requirement of the referenced documents.

6.0 Standard Recommendations for Short Term Repeatability of the Process

For the purpose of the determination of measurement uncertainty of the bell prover, the short term repeatability for the process of domestic meter calibration can be determined using the data captured during daily correlations. Here, the sample standard deviation of the low flow errors as determined on the level 3 working level Bell prover can be used to determine this value. It is also highly recommended that a repeatability study be conducted for each DTM. Refer to GS-ENG-04-06 for details.

7.0 Transfer Meters using Statistical Process Control (SPC) Methods

Diaphragm type check meters should be selected in accordance with section 6.0 and the appropriate sections of the referenced documents. As previously stated, the repeatability and moreover the long-term reproducibility of the DTM is of paramount importance in controlling and minimizing the measuring apparatus uncertainty. Therefore it is recommended that efforts be made to insure the correct handling and storage of the DTMs. Accordingly:

- DTMs should be acclimatized in the proving room for a minimum of four (4) hours prior to use at the flow rate between 10 and 15% of the meter's badged flow rate.
- DTMs should be subject to a minimum of temperature differential during the acclimatization process i.e. meters should not be placed on cold floors.
- When not in use, DTMs should be continuously exercised at a flow rate between 10 and 15% of the meter's badged flow rate, at uniform temperatures approximating the proving room's air temperature.

A significant difference between the short-term monitoring process described in section 6.0 and the System Total Reproducibility or long-term reproducibility of the system ($u_{R\ lt}$) is that during the determination of $u_{R\ lt}$, the average DTM error (as determined on the working level bell) is plotted as a function of time. In this case, the standard deviation of the averages (usually 30 tests) is used to determine process control limits and $u_{R\ lt}$. By applying SPC methods the long-term variability, process drift and reproducibility can also be monitored. Please refer to reference (g), ISO 8258, *Shewhart control charts*, for details.

Because the correlation process deals with small process shifts the EWMA (Exponentially Weighted Moving Average) Charts are also useful. These charts are also less sensitive to the assumption of normality (Montgomery, 1997). They are capable of detecting shifts of 0.5 sigma to 2 sigma much faster than Shewhart charts with the same sample size. They are, however, slower in detecting large shifts in the process mean; consequently it is recommended that a combination EWMA and Shewhart chart be utilized. An alternative to the EWMA is the CUSUM (cumulative sum) chart for which there is an ISO standard, ISO 7871.

The certificate of calibration issued by Measurement Canada for the measuring apparatus will include these conditions of use. These conditions will include a requirement that the applicant implement some means of post-certification monitoring of the long-term stability and performance of the measuring apparatus. These procedures should form part of the information presented to Measurement Canada's Regional Gas Specialist along with the *Statement of Measurement Uncertainty* and the *Statement of Intended Use*. The written SPC procedures should detail the SPC method, data handling, control limits and how it is to be updated. A sample spreadsheet for this purpose is available from Measurement Canada. Final review and acceptance of the applicant's SPC procedures shall be the responsibility of the Senior Engineer – Gas Measurement.