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DYNAMIC TRACEABILTY FOR GASMETER CALIBRATION STATIONS USING ULTRASONIC AND DIAPHRAGMATIC REFERENCE METERS AS A TWIN PACKAGE

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Abstract: A Sonic Nozzle Prover System (SNPS) stepped into service at Gas Work of Budapest. After a two-(2) years of operation a Round-robin test was made to control the basic accuracy and repeatability. The test involved the National Standard gas meter calibration system[1] and the SNPS. Also a new one –which operation just going on - based on PD master meter was tested. The calibration systems working at low pressure using vacuumed and pressure controlled flow circle. The twin meters has temperature compensators. Repeatedly obtained tests based on twin meter package pointed out reasonable results.

Keywords: Youden-plot, interlaboratory comparison test, dynamic traceability, sonic nozzles, gas-meter, bell prover, rotary chamber meter, master meter, national standard

1 PREFACE

An interlaboratory traceability test process was made among three (3) various type of gas-meter calibration stations in Hungary using Youden plots [1]as a basic evaluation technique.
The laboratories involved have various types of calibration systems, i.e.

- positive displacement method based on Bell Prover[2]
- Sonic Nozzles Prover System (SNPS) -calibrated to HMO's Bell Prover -as secondary standards
- Rotary Piston (PD) type of master meter –previously calibrated to HMO's Bell Prover - as secondary standards

Preceding-test was made with various types of meters [3] in order to get the possible narrowest plots. During this preceding-process, four diaphragm meters and one ultrasonic household meter were tested at various flow rates and temperatures. There were also measured the meter's acclimatisation capabilities to the rapidly changing temperature.

The results has shown the acceptable reliability of ultrasonic gas flow meters and sonic-nozzle measuring system. This kind of tests with the above-mentioned technique never made before between such a type of different calibration systems in Hungary.
The intercomparison tests –based on the preceding test results - were made by a twin meter package[2], where the master meters are of various types, i.e.

- diaphragm type
- ultrasonic type

The elements of the twin meters package were temperature compensated gas flow meters.

2 THEORY

Using Youden plots, as an evaluation system of a real traceability test is well known and reliable since late 70's [1].
Generally a twin meter package is use for this purpose, which is two-meter in serial connection (Fig. 1).

1 Working at Hungarian Measurement Office and traceable to international gas labs, like PTB, NMI etc.
2 At Hungarian Measurement Office, traceable to international laboratories (PTB, NMI etc.)

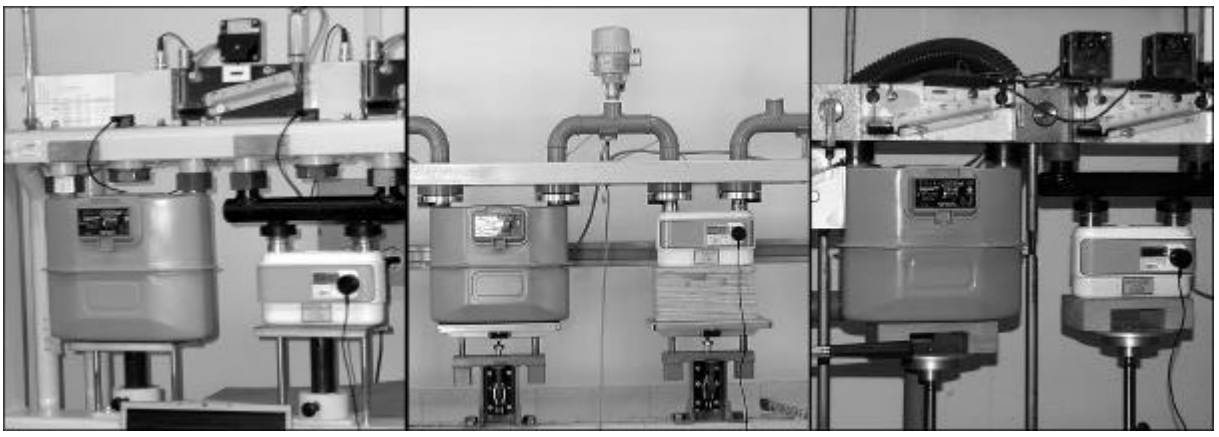

Figure 1. Twin meter package, a diaphragmatic and an ultrasonic meter in serial connection in different labs

The applied elements [4] of a twin meter package depend on the application (liquid or gas), but the main request are:

- the good repeatability ,
- the good sensitivity and the
- the secure data collection.

These various elements also gave a good chance to test whether the new and smart gas meter-based on ultrasonic technique - without moving parts, how can fulfill the above mentioned descriptions.
After the various type of used meters the tested “gas meters calibration laboratories’“ (Fig. 2) etalon or basic elements were also various, and it was more than interesting how their technical features will show on well based test, like a dynamic traceability.
As it was expectable the HMO’s Bell Prover – as a basic etalon - has the best numbers, but SNPS is very close to them.

Figure 2. Different prover systems

Since the early 90s - when intercomparison tests and a couple of papers pointed out good and reliable metrological features of sonic nozzles - many flow-metering people –users and manufacturers as well - turned into this direction and installed Sonic Nozzle Prover Systems[5].
It became popular mainly at low pressure[3] ambient and clear and well-known gas composition.

3 PRACTICAL CONSIDERATIONS

During the test it became obvious that, both member of the applied twin meter package has reasonable technical features including repeatability, accuracy, standard deviation. If we use the standard deviation as a calculated parameters, it also convinced the first position of HMO.

3 No meaningful effect of C and C* because of the low pressure.

Table 1 Standard deviation of the elements at various labs.
Note: values in +/- % accuracy of measured values. The best results in Bold.

	Nat.et.[4](first)	Tested lab.# 1[5]	Tested lab.# 2.[6]	Nat.etalon (second)
G4 std (t)	0,082	0,088	0,09	0,058
E6 std (t)	**0,052**	0,061	0,192	0,056
G4 std (r)	0,082	0,087		0,082
E6 std (r)	**0,052**	0,075		**0,052**

The aimed results has shown -over the basic accuracy and traceability - the effect of various types of calibration methods and systems, as well as the difference between two absolutely unlike gas-measuring devices, like a diaphragm and an ultrasonic one.
At SNPS there is a smaller[7] Bell Prover, installed as a normal part of the SNPS, which easily can make the verification of the given nozzles data a more reliable[8] measurement points of view.
Data from twin meter package was obtained by electronic data collection system. It means that the complete calibration systems involved have shown reasonable results during the test
The test proved that the SNPS based on its sonic nozzle type of calibration elements – with careful operation – has achieved the main feature of Bell Prover systems.
From the Youden Plots point of view it is obvious, that the area[9] of the resulted – usually ellipsoids-graphs has a correlation to the used meters used as well as the tested lab's technical features. Otherwise all of the calculated parameters has to be running about 0.1%, even at the Round–robin tests of gas meter calibration systems.

Table 2. Features of different kind of laboratories.
Note : values in +/- % accuracy of measured values. The best results in Italic.

	Nat.et.[10] (first)	Tested lab.# 1[11]	Tested lab.# 2.[12]	Nat.etalon (second)
e.area(t)	0.0235	0.0213	0.0537	0.0261
σ sys.(t)	0.1029	0.121	0.124	0.108
σ rand(t)	0.0726	0.056	0.138[13]	0.077
e.area(r)	*0.0197*	0.0235		0.0379
σ sys.(r)	*0.098*	0.1149		0.142
σ rand(r)	*0.064*	0.065		0.085

To show it we used the area of ellipsoid that can be resulted at various gas labs with turn/return position where every tests were repeated eleven (11) times.
Even with the reasonable results some technical considerations have to be mentioned:
According to some experimental data the ″critical pressure ratio" (p_2/p_1) has to be ≤0.8 if there are sonic nozzles according to ISO 9300.
A stable and real sonic flow depends on the pressure ratio (p_2/p_1). But this ratio has a changing mainly at lower nozzle's ID.
This should be true when the inside throat diameter (ITD) is big enough and the effect of the requested radius and other geometrical parameters become true. But if the ITD is less than approx. 1 [mm] the effect of the geometrical parameters becomes less and less, and the nozzle starts to be similar to a simple hole when the ″critical pressure ratio" runs about 0.53. Because of the above a big attention requested during the calibration process.

4 Working at National Measurement Office
5 An SNPS operating at Gas Work of Budapest
6 A rotary piston master meter , being operated at a manufacturer
7 up to 8 [m^3/h]
8 There are possibility to set up a serial connected Bell Prover and selected nozzles to have a cross correlation between the devices (Youden analysis)
9 Youden ellipsoid's area = $\sigma_{random} \times \sigma_{syst} \times \pi$
10 Working at National Measurement Office
11 An SNPS operating at Gas Work of Budapest
12 A rotary piston master meter, being operated at a manufacturer
13 At this lab the kind of the test has to be finited

4 TEST RESULTS

As it has described above the Round-robin tests were made by a twin meter package, when the meters of the twin were of various types. (e.g. diaphragmatic and ultrasonic).
At all of the tests the flow-rate was $0.2 \times Q_{max}$ of G4 meter which is 1.2 [m^3/h]
There were various types of diagrams according to the round-robin tests, e.g.

- Youden Plot for all of the accepted participants (Fig 3.), where every laboratory represented with them measured features, like sigma random [SR], sigma systematic [SS]. Those features are quite close together, and the distance between the parameters of them less then 0.5%.

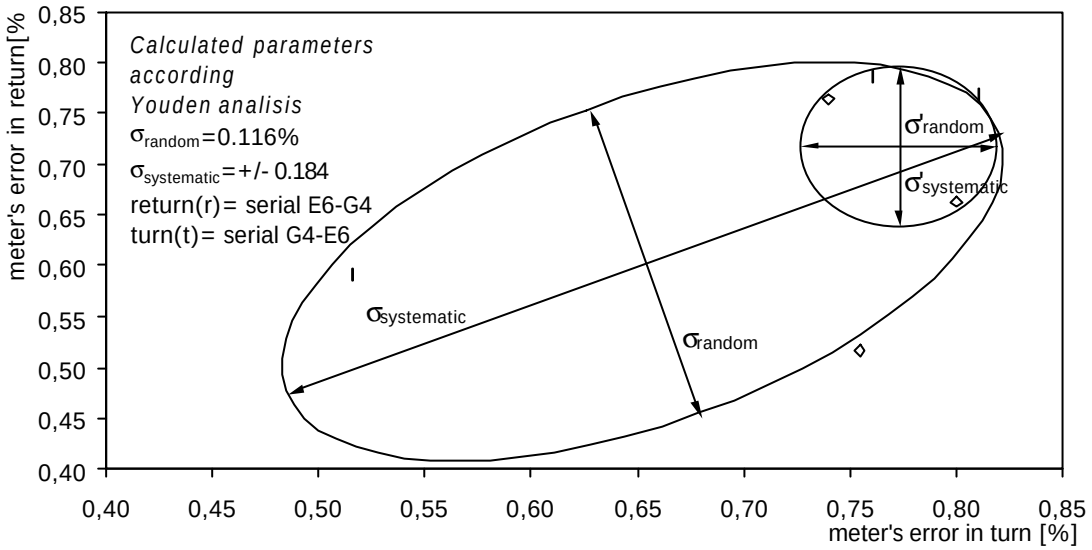

Figure 3. Round-robin summary graph w/o lab #2.

- Youden Plot of twin meter package at SNPS (Fig 4.).

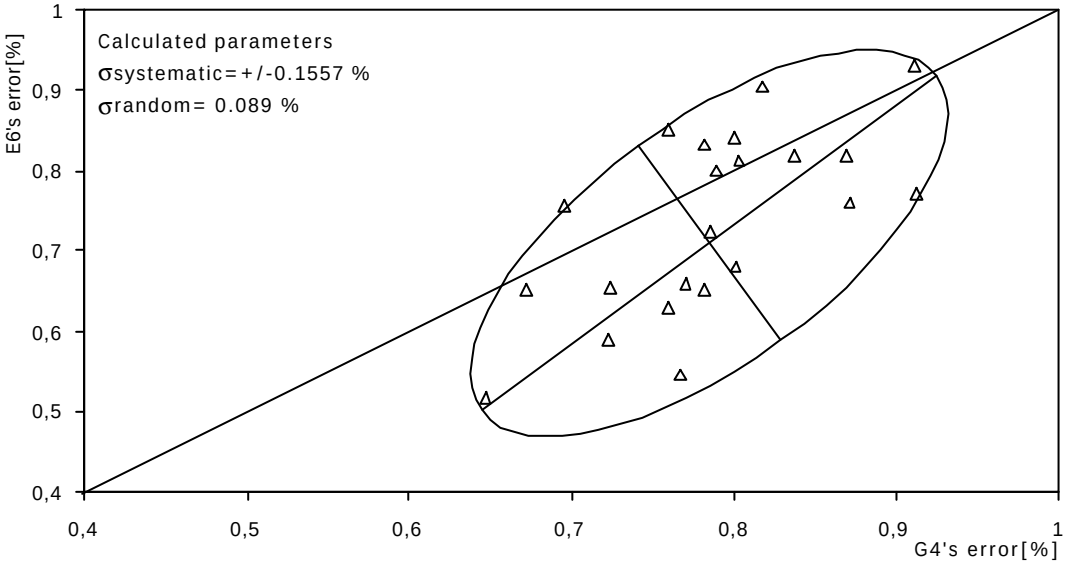

Figure 4. Test results at lab #1

- Effect of the various calibration techniques on the diaphragm and ultrasonic types of gas meters.

Based on this technique, technical officials can focus more powerfully on reducing the uncertainty of the traceability and can check the systems against itself and the other systems from time to time.

That means the systems could be more maintained and "be closer" to the national etalons in the traceability chain.
The test results have shown a quite “acceptable“ relationship between the tested laboratories, even have shown immediately the quite meaningful delta at a previously calibrated rotary piston type of master meter.

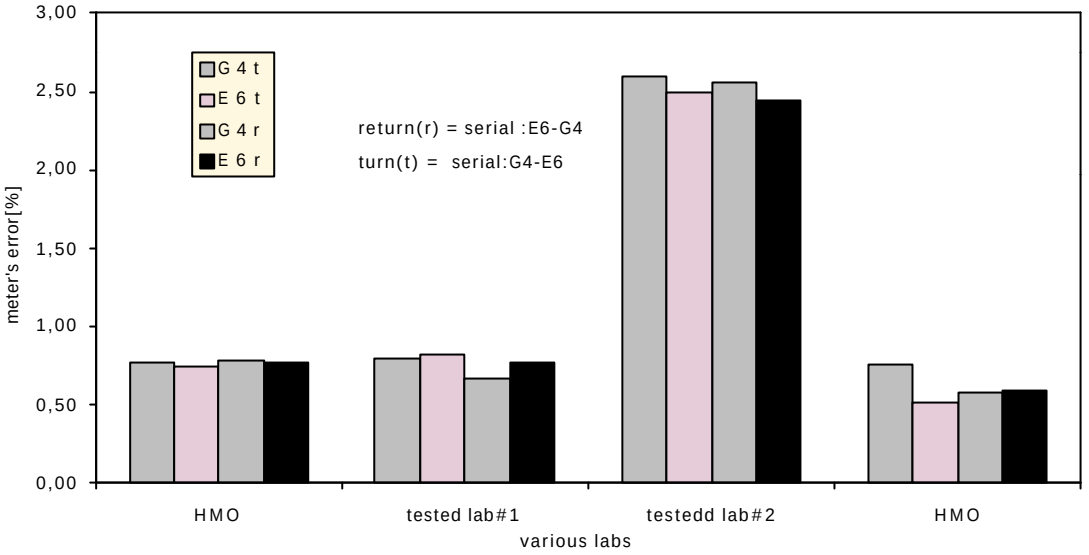

Figure 5. Round Robin test results

5 CONCLUSION

The round robin test with various types of meters at various types of gas calibration systems has shown acceptable results at the first round.
It has also pointed out , that the operational of the first and secondary units -except the 2% delta resulted by rotary piston master [6] was because of falls operation - proved to be acceptable.

After the first round it became obvious that the continuously and careful Round –robin test requested with given recurrence among a nation to keep alive the traceability chain.
The evaluated tests have also well shown the SNPS’s capability of testing normal and temperature compensated ultrasonic (E 6) type of gas meters.

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