



First Brazilian Program for Gas Flow Interlaboratory Comparison on Medium and High Flow Rates

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Abstract: This article presents an evaluation of the first Interlaboratory comparison program for medium and high gas flow measurement. Four important Brazilian laboratories, from São Paulo, Rio Grande do Norte, Rio de Janeiro and Minas Gerais had participated on the program.

Key words: flow measurement, turbine meters, rotatory positive displacement meter, inter-laboratory comparison, gas.

1. INTRODUCTION

For years Brazil metrological gas flow chain lacks of comparison programs for their laboratories. Accredited laboratories have individually managed to attenuate this problem comparing its measurements with the results from meters calibrated at national laboratories at Germany, Holland and other countries; or making bi-lateral comparison with these laboratories and others. On 2008, a commission was created, under the Accreditation division of the National Institute of Metrology Normalization and Industrial Quality (CGCRE-INMETRO), in order to, among other issues; develop programs for laboratories intercomparison in the flow metrology area (CT-13). At the same time, Gas Technological Center (CTGAS-ER) had developed a project for a laboratorial intercomparison program for medium and high gas flow measurement that was presented and accepted by Petrobras and ANP (National Petroleum Agency) assuring financial resources for the program.

Under this scenario, four important Brazilian laboratories elaborated a comparison program for gas flow at medium and high flow rates. The program followed the directives of the reference documents “*The Guidelines*”[2], DICLA-DOQ-CGCRE-005 [6].

The program objective is to determine the degree of equivalence between the laboratories for gas flow calibration and measurement. Laboratorial comparison is one of the most important tools to assure the measurement quality of the laboratories and is a mandatory requirement for laboratory accreditation under ABNT NBR ISO/IEC 17025-2005. Besides that, this will be an important effort towards an improvement on the energetic integration that is taken place in Brazil involving natural gas, especially with the

future connections that are being constructed between northeast and southeast gas pipe lines.

In this article we will present the standards used, the laboratories, the comparison methodology, the results obtained and a brief discussion of the results.

2. LABORATORIES INVOLVED

The Brazilian laboratories involved in this program are: Fluid Metrology Center from Technological Research Institute (CMF-IPT) located at Sao Paulo - SP; Gas Technological Center (CTGAS-ER) located at Natal-RN, Gas Distribution Company from Rio de Janeiro (CEG) located at Rio de Janeiro- RJ and Technological Center Foundation of Minas Gerais (CETEC) located at Belo Horizonte - MG.

The CTGAS-ER laboratory of gas flow measurement is designed to meet the Brazilian demand for calibration of all natural gas flow meters, especially in the north and northeast of Brazil. CTGAS-ER aims to provide high technology laboratories for the provision of services in the area of natural gas. The laboratory counts with a high flow bench that has been designed for the calibration of meters that are in the range of 2 m³/h to 4000 m³/h and can work with meters of 1 ½ "to 12". This bench considers air, as the working fluid, flowing close to atmospheric pressure. As patterns of work, the laboratory has three turbine meters and a rotatory meter. The traceability is achieved for PTB calibrations.

The gas flow laboratory of CETEC has three benches for calibration of natural gas meters. The calibration fluid is the atmospheric air and the absolute operational pressure is close to that of the ambient. The working intervals are: from 1 m³/h to 260 m³/h; from 7 m³/h to 600 m³/h and from 40 m³/h to 2500 m³/h. The working standards are respectively: a sonic nozzles bank, a rotatory duo meter (G400) and a manifold of three turbine meters (G250, G650 e G1600). The discharge coefficient of each sonic nozzle was evaluated experimentally through the laboratory primary standard meter bell prover, calibrated by the strapping method, which determines its volume by measurement of the pertinent physical dimensions traceable to the national institute of USA (NIST). The flow measurements of the other standards are traceable to the national institute of Holland (NMI).

The IPT gas laboratories has four benches for flows from 0,001 dm³/min to 250 m³/h, one bench exclusive for diaphragm gas meters and the high flow gas laboratory This laboratory has two test benches working with air, close to atmospheric pressure: one is designed to reach flows from 0,5 m³/h to 5100 m³/h and works with two rotary duo lobules meters for flows up to 400 m³/h and with four turbine meters from 80 m³/h to 5100 m³/h. The other bench is a compact one for flows from 0,3 m³/h to 2500 m³/h using three rotary meters (two G650 duo , and one G16 duo). Some flows where tested in both benches for internal investigation purposes but in this program we will only present the results from the bench that goes up to 5100 m³/h. The metrological traceability is assured by a primary standard bell prover, calibrated by the strapping method (dimensional) and verified thought a set of sonic nozzles, a turbine meter calibrated at PTB and a set of sonic nozzles also calibrated at PTB.

CEG is one of the largest gas distributors in Brazil. The company is present in Rio de Janeiro over more than 150 years and today distributes natural gas in the city and in the state of Rio having almost 800.000 customers among commerce, industries and residential customers . In order to supply these customers with a just and fair gas measurement the company invested in its own laboratories. Currently the company has two laboratories: a laboratory for diaphragm gas meters (from 16 dm³/h to 16000 dm³/h) with two benches, one is based on a bell prover and the other works with sonic nozzles operating pressurized, and a high flow bench. The high flow test bench that was used in this program operates with air close to atmospheric pressure and for flows from 4 m³/h to 2500 m³/h. The bench uses two rotary duo lobules meters for flows up to 400 m³/h and a turbine meter for 250 m³/h up to 2500 m³/h. The metrological traceability is assured in both laboratories calibrating the standards at the IPT laboratory.

The laboratories involved are accredited, or about to get its accreditation, by INMETRO. That assures a certain level of quality control and also assures that the uncertainties for each laboratory were calculated according to the ISOGUM[2] and ISO 5168[5] .

3. COMPARISON STANDARD METERS

The standard meters chosen for the metrology comparison are:

- a Fluxi/Tz, G-1600, Itron, turbine meter, with two high frequency (namur) outputs on the body of the meter with a resolution of 1514 impulses/m³
- A Delta S3-Flow, G 250, as seen in Figure 1, Itron, S-flow rotary positive displacement meter with a resolution of 1673 impulses/m³
- A Delta S1-Flow, G 25, Itron, S-flow rotary positive displacement meter with a resolution of 20590 impulses/m³

The main characteristics of the meters are presented in Table 1.



Figure 1 Delta S-Flow, G 250 rotary meter

Table 1 - Characteristics of the meters

| Meter | G1600 | G250 | G25 |
|--------------------------------------|---------|---------|---------|
| Nominal Diameter | 200 mm | 150 mm | 50 mm |
| Q _{min} (m ³ /h) | 250 | 40 | 4 |
| Q _{max} (m ³ /h) | 2500 | 400 | 40 |
| Linearity | 0,5 % | 0,5 % | 0,5 % |
| Repeatability | ≤ 0,1 % | ≤ 0,1 % | ≤ 0,1 % |

The standards were chosen for its good metrological behavior, specially reproducibility and repeatability, at the desired flow rates. Despite of its good characteristics, special care had to be taken with flow conditioning in the assembling of the turbine meter in each bench.

The rotary S-flow meters was also chosen due to its design that leads to a relative insensibility from the resonance effects that are typical in the calibration of rotary meters.

4. COMPARISON METHODOLOGY

For the comparison, it was agreed on a calibration interval of 4 m³/h to 2500 m³/h, taking account ten points equally disposed in the flow range of each standard. All laboratories calibrates with air at low pressure (close to atmosphere pressure).

Each laboratory took at least 3 runs in each flow set-point, using their own procedure.

The set-points chosen match with the set-points of a PTB previous calibration of the standards.

All the meters were calibrated using the high frequency output (HF) and the meter index indication with low frequency, named (LF) .

4.1. Mensurand

The mensurand is the percent volumetric error, obtained in the calibration of the comparison standard, as defined by equation (1):

$$E(\%) = \frac{V_S - V_{Lab}}{V_{Lab}} * 100 \quad (1)$$

Where:

E = Comparison standard meter error
 V_S = Comparison standard indicated volume
 V_{Lab} = Laboratory volume true value

4.2. Comparison order

The comparison order follows the following sequence: CTGAS-ER– CETEC – IPT – CEG – CTGAS-ER.

In order to assure that the meters did not suffer a significant deviation during the transportation in Brazil, the meters were calibrated at CTgas at the beginning and the end of the program.

4.3. Uncertainty

Each laboratory was responsible for evaluate and declare the uncertainty of the measurements results of the calibration, considering the directives of GUM[2] and ISO 5168 [5].

4.4. Reference values

Despite of the fact that it was not being a direct participant of the comparison, the results from the previous calibration made by the Germany Physikalisch-Technische-Bundesanstalt gas laboratory (PTB) will be used as a reference value for the intercomparison as the meters were calibrated there before they were brought to Brazil for this program.

4.5. Treatment of the results

Each laboratory has sent its results for INMETRO technicians that will proceed the initial treatment of the data and report the treated results representing each laboratory by a letter preserving the confidentiality of each laboratory in the program as A, B, C and D laboratories (the alphabetic order of the laboratories were random attributed by INMETRO), that in this document we will treat as LAB A; LAB B; LAB C and LAB D respectively.

The mayor parameter that will be presented and analyzed is the normalized error [9]. This is calculated by equation (2) for each participant laboratory:

$$En = \frac{V_{lab} - V_{ref}}{\sqrt{U^2_{lab} + U^2_{ref}}} \quad (2)$$

Where

V_{lab} – is the value obtained by the participant laboratory;

V_{ref} – is the value obtained by the reference laboratory;

U_{lab} – is the standard expanded uncertainty declared for the values of the participant laboratory;

U_{ref} is the standard expanded uncertainty declared for the values of the reference laboratory.

It is also presented in the results the medium value for the normalized error calculated by equation (3):

$$E_{nm} = \frac{E_{nA} + E_{nB} + E_{nC} + E_{nD}}{4} \quad (3)$$

Where

E_{ni} – Is the normalized error calculated for the i laboratory where i goes from A to D.

This medium value parameter was created and presented for better visualization of a possible systematic difference from the participant laboratories regarding the reference laboratory (PTB).

The uncertainty declared from the reference laboratory is 0,12 % of the measured values.

4.6. Program current situation

At the present time, the program is finished. All the participant laboratories already received their results and a first meeting to discuss the results took place at IPT in may 3, 2011.

A second meeting took place at June 21, 2011 were the results were presented to the CT-13 commission.

5. RESULTS

Table 2 to Table 4 presents the results for the normalized error for the LF output for all four participant laboratories for the G25, G250 and G1600 standard respectively.

It was chosen to show the results for the LF output because, especially for the rotary meters, the LF is the most common used output when the meter is installed in the final customer (in fact, most rotary meter do not have a HF output). Also, in most laboratories and flows, this result is very similar to the HF output as will be exemplified further in this article.

Table 2 –Normalized error for the G25 standard

| Flow (m ³ /h) | En | | | | |
|-----------------------------|-------------------|-------------------|-------------------|-------------------|--------------------|
| | Lab A E_{nA} | Lab B E_{nB} | Lab C E_{nC} | Lab D E_{nD} | medium E_{nM} |
| 4,0 | -0,62 | -0,03 | 0,74 | -0,43 | -0,09 |
| 8,0 | -0,82 | 0,27 | 0,14 | -0,40 | -0,20 |
| 12,0 | -0,75 | -0,10 | 0,34 | -0,14 | -0,16 |
| 16,0 | -0,52 | -0,04 | 1,08 | -0,17 | 0,09 |
| 20,0 | -0,61 | -0,04 | 0,60 | -0,17 | -0,05 |
| 24,0 | 0,11 | 0,04 | 0,94 | -0,20 | 0,22 |
| 28,0 | 0,29 | 0,13 | -0,83 | -0,37 | -0,19 |
| 32,0 | 0,29 | 0,22 | -0,67 | -0,50 | -0,16 |
| 36,0 | 0,25 | 0,30 | -0,51 | -0,40 | -0,09 |
| 40,0 | 0,23 | 0,49 | -0,38 | -0,23 | 0,03 |

Table 3–Normalized error for the G250 standard

| Flow (m ³ /h) | En | | | | |
|-----------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|
| | Lab A E _{nA} | Lab B E _{nB} | Lab C E _{nC} | Lab D E _{nD} | medium E _{nM} |
| 40 | 0,17 | -1,50 | -0,26 | -0,37 | 0,10 |
| 80 | 0,21 | -0,13 | -0,18 | -0,01 | 0,03 |
| 120 | 0,34 | -0,61 | -0,29 | -0,16 | -0,10 |
| 160 | 0,49 | -0,77 | -0,09 | -0,11 | -0,07 |
| 200 | 0,31 | -0,57 | -0,15 | -0,06 | 0,16 |
| 240 | 0,29 | -0,54 | -0,03 | -0,05 | 0,10 |
| 280 | 0,29 | 0,86 | -0,03 | 0,32 | 0,18 |
| 320 | 0,34 | 0,69 | 0,00 | 0,28 | 0,08 |
| 360 | 0,46 | 0,58 | 0,15 | 0,39 | 0,38 |
| 400 | 0,32 | 0,42 | 0,03 | 0,18 | -0,05 |

Table 4–Normalized error for the G1600 standard

| Flow (m ³ /h) | En | | | | |
|-----------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|
| | Lab A E _{nA} | Lab B E _{nB} | Lab C E _{nC} | Lab D E _{nD} | medium E _{nM} |
| 250 | -0,20 | -0,43 | 1,03 | -0,29 | 0,03 |
| 500 | -0,25 | -0,18 | -0,44 | -0,13 | -0,25 |
| 750 | -0,10 | 0,27 | -0,25 | -0,08 | -0,04 |
| 1000 | -0,07 | 0,99 | 0,06 | -0,35 | 0,16 |
| 1250 | -0,20 | 0,97 | -0,78 | -0,43 | -0,11 |
| 1500 | -0,05 | 0,87 | -0,63 | -0,43 | -0,06 |
| 1750 | -0,03 | 0,79 | -0,69 | -0,43 | -0,09 |
| 2000 | 0,07 | 0,73 | -0,57 | -0,14 | 0,02 |
| 2250 | 0,26 | 0,66 | -0,45 | -0,27 | 0,05 |
| 2500 | -0,03 | 0,70 | -0,39 | -0,16 | 0,03 |

Figures 2 to 4 presents in a graph format the results of tables 2 to 4 respectively

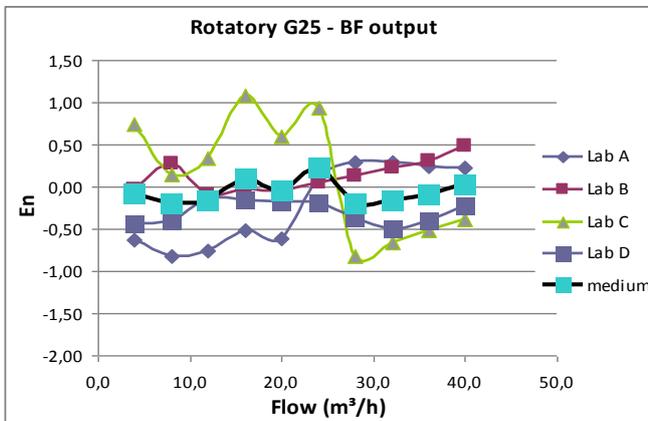


Figure 2 En results for LF output for the G25 rotary meter

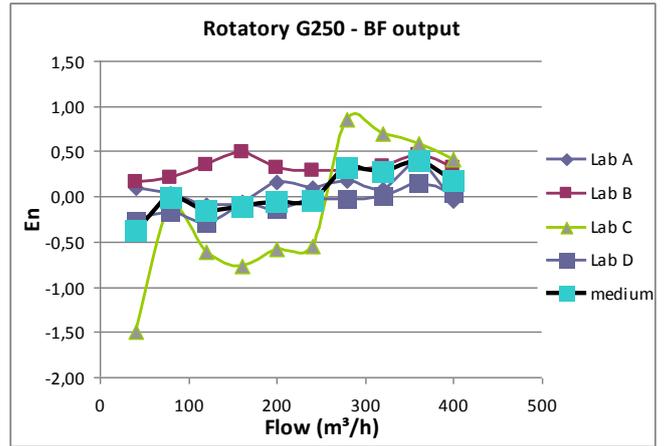


Figure 3 En results for LF output for the G250 rotary meter

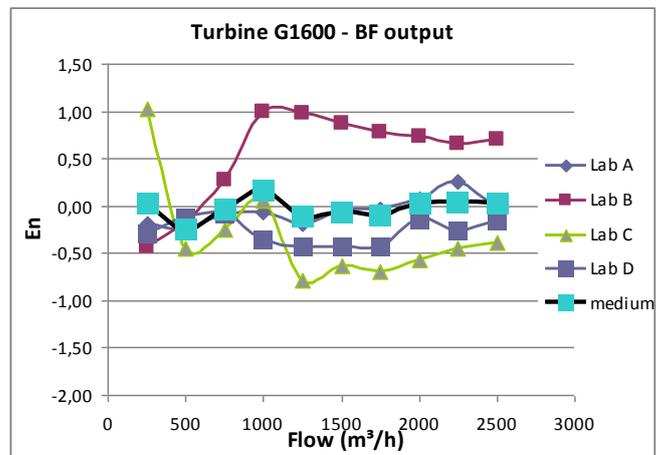


Figure 4 En results for BF output for the G1600 turbine meter

Figure 5 presents the results of the En for laboratories C and D for the high frequency output and the low frequency output for comparison. These results were presented here just as an example of the behavior for the two outputs .

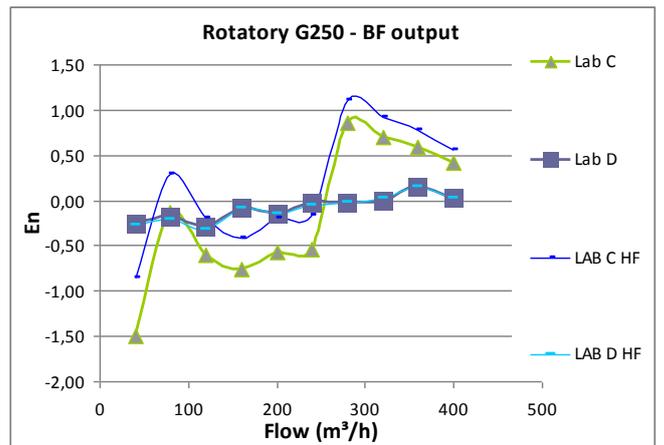


Figure 5 En results for D and C laboratories for high and low frequency outputs

It is important to notice on Figure 5, that in this case, Lab D presents almost no variation from both outputs and Lab C presents a certain degree of variation. It is worth to point out that that, the data presented in this figure for lab D

correspond to one example of results where both outputs have the same result and that the differences presented in these case for Lab C results correspond to one of the cases where the results presented the higher differences.

Its also worth to point out about the presented results that INMETRO analyzed the calibration results from CTGAS from the initial calibration (made before the meters were send to the others laboratories) and the final calibration (after the meters passed for all laboratories) and did not notice any significant difference between the calibrations. That indicates that apparently no significant derivation occurred with the standard meters during the transportation on the Brazilian territory.

6. CONCLUSION

The most important conclusion is that the program have shown a very good compatibility of the laboratories error results and estimated uncertainties. That indicates that there is no major problem in the metrological high and medium gas flow chain in Brazil. A good indication of that is that for the 240 points analyzed in this program in a very extended range of flow rates (from 4 to 2500 m³/h) only 7 points presented $|E_n|$ greater than 1 and 6 of these values are very close to this limit. Some references indicates that values for 1 to 1,2 set only a warning sign in the laboratory and did not necessarily indicates a failure in the comparison for that point [5]. It also worth to point out that, If we consider a $|E_n|$ range close to 0,6 a very secure area for a laboratory to be working, only 20% of the results presented here are greater than this value.

The results of all comparison standards also shown that there are a good distribution of negative and positive values of E_n . That indicates that for gas flow, there is no significant systematic error between the Brazilian metrological chain and the PTB.

It significant to notice that despite the fact that almost all laboratories has traceability to PTB, there is also involved some traceability to dimensional standards from INMETRO and NIST (National Institute of standards and Technology - EUA) and traceability to flow Standards from the national institute of Holland (NMI).

About the logistic of the process, the program had experience some delay in schedule at the beginning because of supplying times for the standard and initial calibration on PTB but despite of some minor problems, after the arrival of the standards in Brazil the process itself (transportation, packaging, documentation, invoices, etc) occurred very well and the all process could be finished in a 5 months period.

It already is being discussed the continuation of the program for the next years. One of the possibilities being discussed is to use some of the same standards. In this case, for assuring that the laboratories did not have the results previously, the high frequency outputs would be removed and, INMETRO would be asked to modify some gears of the standards to change the error results.

7. NOTES

Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the participant laboratories or INMETRO, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

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