METROLOGICAL INFRASTRUCTURE FOR OIL FLOW METERS CALIBRATION AND TESTING

Kazuto Kawakita [1], *Guilherme Silveira dos Santos* [2], *André Ferreira* [3]

[1] IPT-Instituto de Pesquisas Tecnológicas, São Paulo/SP, Brasil, kawakita@ipt.br
[2] IPT-Instituto de Pesquisas Tecnológicas, São Paulo/SP, Brasil, gsantos@ipt.br
[3] Petróleo Brasileiro SA – Petrobras / CENPES/PDAB/DLT, Brasil, andref@petrobras.com.br

Abstract: This paper presents a laboratory infrastructure for calibration and testing of flow meters and measurement systems components for oil and liquid petroleum derivatives newly built in Brazil. The laboratory is installed in a fully air-conditioned four floors building with a total area of 700 m². The set of flow meter working standards is composed of two five path ultrasonic meters and two Coriolis master meters, calibrated by the laboratory reference standard, an especially designed 6 tons diverting type gravimetric system. The measurement uncertainties attainable with the test facility lie between 0.04 % and 0.05 % depending on the flow rate and the product used for the tests.

The laboratory was conceived with the main purpose of building not only a traditional flowmeter calibration laboratory, but also an installation capable of carrying out tests and researches in order to assure the accuracy and reliability of the metrological activities performed under the fiscal, legal and commercial scopes, fulfilling the needs of the Brazilian oil industry and the national regulatory bodies [1].

Keywords: oil flow laboratory, oil flowmeter calibration, oil meter testing, installation effects on flowmeters, viscosity effects on flowmeters

1. INTRODUCTION

Though the great efforts of many countries in developing renewable sources of energy, oil is still a vital source of energy in virtually every country in the world. Daily, these countries need to process and supply large quantities of liquid hydrocarbons produced in domestic fields or purchased abroad. In Brazil, oil is an important source of energy with a stake of approximately 40 % in the national energy matrix in terms of the domestic energy supply [2].

Besides the production and processing facilities, pumping units, transmission and distribution pipelines, operation and control stations, several measurement systems are necessary to quantify the enormous volumes of products transferred every day among commercial partners.

Liquid hydrocarbons measurement systems can be used in fiscal measurement applications in production units, in custody transfer sites, refineries, in liquid fuels distribution stations, in airports for refuelling aircrafts, at service stations to consumers and in several other uses. In all these cases, the primary function of the metering systems is to provide accurate and reliable measurements of volumes of oil and its derivatives, by using properly calibrated and controlled equipment, and recognised and validated measurement techniques that can ensure reliability and acceptable levels of uncertainty for the amount of products traded.

In an oil metering system, the meter is a major component, and like any measurement instrument, it must be accurate and reliable. However, as an intrinsic characteristic, all flowmeters present some indication error and this error is dependent, among other factors, of the operating principle and its operating conditions. That is, all fluid flow or volume measurement incorporates into a greater or lesser degree, an error that can be positive or negative, critical or negligible.

Although many technologies have been developed over the years, and meter manufacturers often exalt the qualities of their products, it is well known that the measurement accuracy of a meter is necessarily dependent on its technical characteristics and on a proper calibration and use of the equipment. Only a suitable calibration of the meter, carried out under controlled conditions, performed against recognised standards and duly traced to national measurement standards, allows the determination of the indication errors and an assessment of the uncertainties associated to the measurements performed by this meter.

2. MOTIVATION

Till recent years Brazil did not have an appropriate infrastructure and not even a metrological tradition in the field of oil flow metrology comparable, for example, to that which exists in other countries where several laboratories have been operating for decades testing and calibrating flow meters for the oil industry.

However, in recent years this scenario has been changing gradually, possibly due to the growing national oil production rate, promoting the emergence of some private oil flow laboratories, mainly operated by flowmeter manufacturers.

Since 1994, IPT Fluid Metrology Centre operates two small calibration laboratories, one for water meters (Q_{max} up to 250 m³/h) and the other for oil meters (Q_{max} up to 90 m³/h), both approved by the national accreditation body INMETRO, an ILAC member, according to the ISO/IEC 17025 [3] requirements. During the last years, these laboratories conducted tests and calibrations on hundreds of liquid meters from different users and applications.

Just in order to illustrate the current status of the measurement of liquid flowrate in the country, figure 1 depicts the results of original indication errors of a sample of 25 liquid meters, taken randomly from the set of meters that were received for calibration in these laboratories. These errors represent the percentage differences between the measured volumes indicated by the meters before any adjustment, and the reference volumes measured by the laboratory standards.

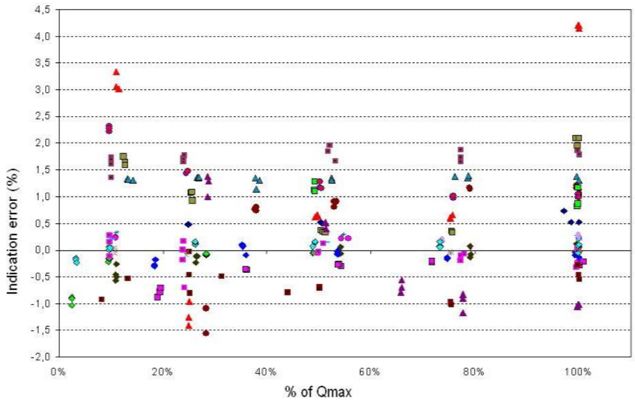

Fig. 1. As found indication errors of a sample of 25 oil meters received for calibration in IPT laboratories

Based on this sample, it is possible to see that most of the meters presented indication errors between the range from -1.5 % to 2.0 %, much larger than the maximum permissible errors for class 0.3 and 0.5 of OIML R117 [4].

These figures technically justified the need for the installation of a laboratory capable of performing calibration and tests on the different flow metering technologies, in an operating range greater than the currently available, and which could enable measurement uncertainties to be reduced, and that could operate with calibration fluids similar to the real operating products in the field.

Furthermore, many questions arise. For instance: are laboratory calibrations of flowmeters being performed under conditions that represent the real metering process? How reliable and accurate can a flowmeter calibration be when carried out under non ideal conditions? How should reproducibility of a flowmeter be evaluated? Are laboratory calibrations inducing flowmeter users to errors?

The answers to such questions are not easy to come by because they depend on studies conducted in laboratories capable of performing tests and investigations at different operating conditions and enabled to reproduce the dimensional and dynamic similarity parameters.

3. THE LABORATORY FACILITY

The laboratory presented in this paper is installed in a fully air-conditioned four floors building with a total area of 700 m². The set of flow meter working standards is composed of two five path ultrasonic meters and two Coriolis master meters, calibrated by the laboratory reference standard, an especially designed 6 tons diverting type gravimetric system.

The measurement uncertainties attainable with the test facility lie between 0.04 % and 0.05 % depending on the flowrate and the product used for the tests.

The calibration and testing lines were designed to allow the assembling of pipes up to 16 inches diameter and straight pipes runs up to 35 meters long, capable of delivering well conditioned flow profiles to the meters, as well as enabling the assemblage and reproduction of practically any type of non-ideal pipe configuration used in custody transfer stations or metering skids installed on-shore and in off-shore platforms.

Three types of oils with low, medium and high viscosity are used to simulate the operation of flow meters and components with different products.

Additionally, an electronic temperature control system stabilises the test oil temperature to precisely define its viscosity during a test or calibration, making possible the simulation of the original operating conditions of the metering system in the field.

Furthermore, based on its unique characteristics and capabilities, installation and operating conditions can be stressed to a maximum to evaluate the performance of metering systems under such non-ideal circumstances.

The laboratory infrastructure is complemented by a trucked mobile calibration unit composed of an 18" compact prover associated to an 8" helical turbine master meter that enables meter provings to be performed at their own operating location.

The laboratory was conceived with the main purpose of building not only a traditional flowmeter calibration laboratory, but also an installation capable of carrying out tests and researches in order to assure the accuracy and reliability of the metrological activities performed under the fiscal, legal and commercial scopes, fulfilling the needs of the Brazilian oil industry and the national regulatory bodies.

The laboratory four floors building totalizes an internal height of 14 m and was designed to house a gravimetric reference standard associated to a diverting valve which delivers test oil to the weighing tank or to the main oil reservoirs.

The laboratory reference standard is a especially designed 6 tons diverting type gravimetric reference system, tracing the measurement results to the national standards of mass and time so that measurement uncertainties result bellow 0.04 % of the measured value for mass flowrate and 0.05 % for volumetric flowrate, considering a coverage factor $k = 2$ and a 95 % confidence level [5].

A hydronic refrigerating system of indirect expansion based on two water coolers units with nominal capacities of 281 kW and 422 kW, with screw type compressors and air cooled condensers, is responsible for supplying a fully air-conditioned ambient for the test facility and for maintaining the oil temperature at a predefined condition, including the generation of controlled temperature slopes if necessary during the tests. This feature intends to reduce to a minimum the random temperature dependent sources of uncertainties in the measurements.

Figure 2 shows an external view of the laboratory building and Figure 3 presents a tridimensional simplified schematic diagram of the laboratory.

Fig. 2. External view of the laboratory

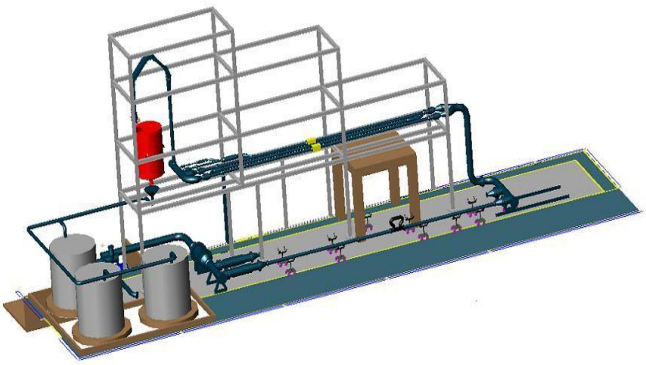

Fig. 3. Schematic diagram of the laboratory

Figure 4 shows, in a simplified way, the hydraulic circuit of the laboratory.

The pipes in the laboratory were designed and built with a slight slope in order to promote the return of the oil used in the tests to the reservoirs by gravity, so that blending effect along the time will be minimized.

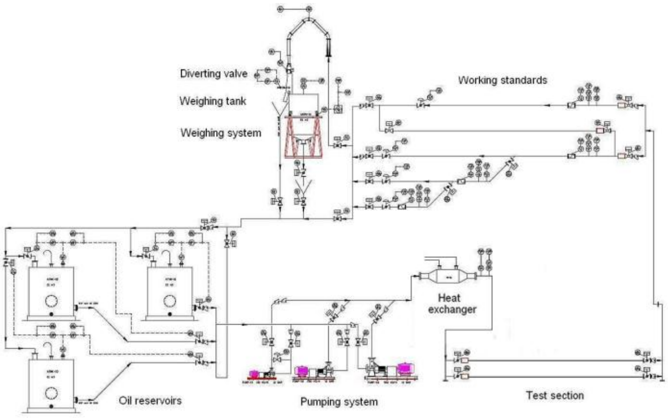

Fig. 4. Hydraulic circuit of the laboratory

The set of working standard flow meters is composed of two five path ultrasonic meters, for higher flowrates, and two Coriolis master meters for lower flowrates. These working standards are installed in series upstream to the reference standard, in a mezzanine according to a special piping configuration that allows them to work in a single or parallel mode, and also permit their alignment in series, one against the other, for routine comparison purposes.

Figures 5 shows the working standards lines and Figure 6 presents two of the standard flowmeters.

Fig. 5. Working standards lines

The two calibration and testing lines were designed to allow the assembling of pipes up to 16 inches diameter and straight pipes runs up to 35 meters long, capable of delivering well conditioned and axisymmetric flow profiles to the meters.

Additionally, the wide and versatile testing area enables the assemblage and reproduction of practically any type of non-ideal pipe configuration used in custody transfer stations or metering skids located in onshore installations and in offshore platforms. Figures 7, 8 and 9 show partial views of the test section.

Fig. 6. Two Coriolis master meters used as working standards of the laboratory

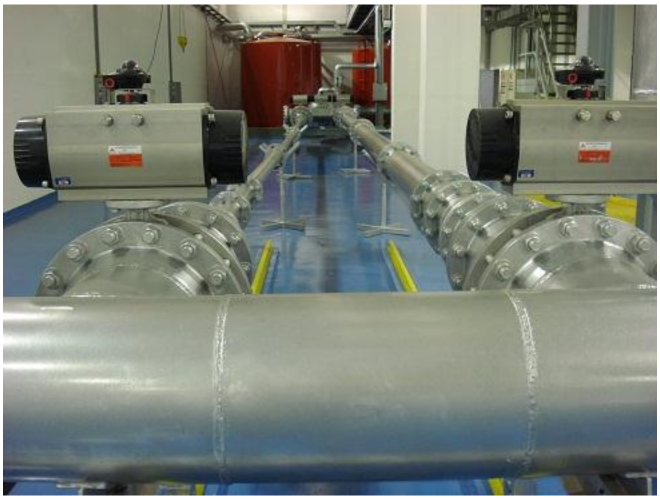

Fig. 7. General view of the test section including the two parallel test lines

Fig. 8. Partial view of the test section including the telescopic connections to adapt the piping runs

Fig. 9. Partial view of the test section highlighting the header for receiving oil from the test lines

Three types of oil with low, medium and high viscosity are used to simulate the operation of flow meters and components with different products. Additionally, an electronic temperature control system stabilises the test oil temperature to precisely define the operating viscosity during a test or calibration, so as to be capable of simulating the original operating conditions of the metering system in the field.

Furthermore, based on its unique characteristics and capabilities, installation and operating conditions can be stressed to a maximum to investigate the performance of metering systems under such circumstances.

4. MOBILE UNIT

A trucked mobile unit with an 18" compact prover associated to an 8" helical turbine master meter complements the laboratory infrastructure, serving as a versatile tool that allows the testing of meters in their own operating sites. Figure 10 shows the mobile unit used for transportation of the compact prover.

Fig. 10. Mobile unit with compact prover and turbine meter

The mobile unit is important due to its inherent accuracy, versatility, mobility, robustness and immunity to flow, allowing investigations on the effects of installation, the process conditions and flow characteristics of the operation on the performance of different types of meters for oil and derivatives, since they can be tested under the ideal conditions of a laboratory and also *in-situ*. Results can be compared in order to validate the laboratory calibrations or to identify and quantify eventual differences between the two procedures.

Figure 11 shows the compact prover and the helical turbine master meter.

Fig. 11. Compact prover and turbine meter

The helical turbine master meter is a useful tool for provings where large sample volumes are required, for instance, in the case of ultrasonic flowmeters calibration according to the MPMS 5.8 – Measurement of Liquid Hydrocarbons by Ultrasonic Flow Meters Using Transit Time Technology [6].

Figure 12 shows the the calibration of the compact prover in the laboratory using the water draw method.

Fig. 12. Compact prover calibration by water draw method

Figure 13 shows the high repeatability obtained in the calibration results.

	RESULTADOS			
Fator de correção CPS	Vazão de ensaio	Volume do Prover corrigido	Desvio em relação média	Desvio em relação Vazão
(-)	(m^3/h)	@ 20°C	(%)	(%)
0,999999	3,22	120,202	-0,001	-0,003
0,999999	3,02	120,204	0,000	-0,001
0,999999	3,13	120,203	-0,001	-0,002
0,999999	1,18	120,205	0,001	0,000
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1,000000	#DIV/0!	0,000	##########	##########
1,000000	#DIV/0!	0,000	##########	##########

Fig. 13. High repeatability of the compact prover calibration results

5. APPLICATIONS

The main applications of the laboratory are in developing:

- Research on the metrological performance of meters for oil and derivatives when subjected to different operating conditions. For example, assessment of the effects on meter factor due to changes in the viscosity of the fluid or due to changes in the flow regime conditions.
- Studies on the effects of installation on the performance of meters and the presence or absence of straight pipe sections, bends and swirl generators, vibration and pulsating flow, among other situations commonly present in measurement systems installations.
- Analysis of levels of repeatability possible to obtain with the different types and models of meters of oil available in the market by means of laboratory tests and *in-situ* measurements.
- Comparative performance tests on types and models of meters from different manufacturers, sponsored by a consortium of users of these technologies.
- Analysis of the efficiency of flow straighteners and flow conditioners.
- Research on signature analysis of flowmeters to control its performance and for preventive maintenance.
- Performance analysis and follow-up for maintenance of meters.
- Study on pressure loss imposed by meters, valves and pipeline components.
- Testing of electronic components of measuring systems.
- Pattern approval on models of meters for legal metrology.
- Validation tests on new measurement technologies.
- Interlaboratory comparisons programs with other reference laboratories.
- Projects related to the development of the scientific metrology in the field of liquid hydrocarbons flow measurement.

6. CONCLUSION

The laboratory was conceived with the main purpose of accomplishing not only a traditional flowmeter calibration laboratory, but also an installation capable of fulfilling the needs of the Brazilian oil industry and the national regulatory bodies for tests and researches that can assure the accuracy and reliability of the metrological activities performed under the fiscal, legal and commercial scopes.

Due to its intrinsic accuracy, versatility and the possibility of combining and assessing laboratory tests with field measurements, tracing them to the same references, the new installation described in this paper indeed represents a milestone in Brazilian oil flow metrology.

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