

## **PRACTICAL EXPERIENCE ON INSPECTIONS OF ORIFICE PLATES MEASUREMENT SYSTEMS FOR NATURAL GAS**

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### **Flow Metering Systems**

Everyday, in many countries producers and importers supply large volumes of natural gas produced from domestic fields or purchased abroad. To attend to this need, a whole host of interlinked and co-ordinated activities and technical installations are required both on the purchase and the sales side. Besides the production and processing facilities, compression stations, transmission and distribution pipelines, operation and control stations, many measuring systems are necessary to quantify the huge volumes of gas commercialized among parts.

Natural gas measurement systems can be found in gas production plants, custody transfer stations, citygates, gas processing units and industrial gas consumers. Due to the commercial aspects involved, in most of these cases, gas deliverers and gas receivers operate its own independent measurement systems, always checking if the differences between both measurements are under the tolerances agreed through detailed contracts.

The main objective of gas measuring stations is to perform accurate and reliable measurements of gas volumes, by use of controlled equipment and recognized metering techniques, which can assure an acceptable level of uncertainty for the measurement and that comply with the national regulations for the gas industry. More complete metering systems are able to measure gas flow in terms of energy flow, the effective product under trade.

Though the thousands of turbine meters in operation and the increasing acceptance of multipath ultrasonic flowmeters in the gas industry, one of the most common measurement principle for natural gas still used throughout the world is the orifice plate. It is a traditional and well-known technology which origin goes back to 1779 when Giovanni B. Venturi, an Italian physicist, first conceived a differential pressure type flowmeter.

Some of the main advantages of an orifice plate is that it has no moving parts exposed to wear, and it doesn't require a calibration of the primary element in a laboratory since the discharge coefficient of an orifice plate can be calculated by empiric relations like the Reader-Harris-Gallagher (RG) equation.

Two of the main disadvantages of the orifice plate is the significant pressure drop and the relatively low rangeability, making it suitable especially for metering stations operating under a relatively low flowrate variation regime and installed in pipelines where a permanent pressure loss is not a critical factor.

### **Standards**

Gas flow measurement is regulated by a number of recognized international standards, reports, and recommendations and particularly to each country by national standards and technical and metrological regulations.

Natural gas flow measurement using metering systems based on orifice plates should comply with the requirements defined in the following documents and in their most recent editions. Certainly, the list is not complete and many other reference documents could be added. In fact, the objective is to present to the new comers some of the most important standards related to natural gas flow measurement

and which has been adopted in many countries due to the technical reputation of the issuers, completeness of the document, easiness of understanding and application.

ISO standards:

- ISO 5167 Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices, Part 1: General and Part 2: Orifice plates, 2002.
- ISO/TR 5168 Measurement of Fluid Flow - Evaluation of Uncertainties, 1998.

API standards / AGA reports:

- API, Manual of Petroleum Measurement Standards, Chapter 14 - Natural Gas Fluids Measurement, Section 3 - Concentric Square-Edged Orifice Meters, Parts 1 to 4 (equivalent to AGA Reports #3):
  - Part 1 General Equations and Uncertainty Guidelines, 3rd Edition, Sep. 1990.
  - Part 2 Specification and Installation Requirements,
    - 3rd Edition, Feb. 1991. Based on researches and tests carried out between 1922 and 1989.
    - 4th Edition, Apr. 2000. Based on researches and tests carried out between 1922 e 1999, with great emphasis on installation effects.
  - Part 3 Natural Gas Applications, 3rd Ed., Aug. 1992.
  - Part 4 Background, Development, Implementation Procedures and Subroutine Documentation, 3rd Edition, Nov. 1992.

### **The Brazilian ANP/INMETRO Petroleum and Natural Gas Measurement Technical Regulation**

The history of the natural gas industry in Latin America is still relatively short when compared for instance to the European long tradition in this area. In Brazil, the production of natural gas in onshore and offshore wells is increasing at high rate and the gas industry is at this moment in a great boom enlarging the infrastructure of production, transportation and distribution. Figures from governmental agency show that during the year 2001 the volume of natural gas produced was around 14 billion of cubic meters and the country also imported additional 4,6 billion of cubic meters. In last year 2002, projections showed that the total amount would certainly surpass 20 billion m<sup>3</sup> of gas.

As mentioned, natural gas industry in Brazil is still a recent business. Until some years ago, natural gas was an unvalued subproduct of petroleum exploitation, used mainly for re-injection purposes in oil wells or simply burned in the platform flares.

With a long tradition of domination by the oil and hydroelectric energies, since the last decade natural gas has become increasingly important in the Brazilian energy market. In the year 2000, natural gas represented 6% of the total primary energy production in the country. Even the most conservative perspectives are that in year 2010 this participation will be around 10%.

Under such a scenery, in 1997, the Brazilian Federal Government created the ANP-*Agência Nacional do Petróleo*, a national autarchy bound to the Ministry of Mines and Energy, and in which main duties are to promote the regulation, the contract and the inspection of the economic activities related to oil and gas industry in the country.

In June.2000, ANP together with INMETRO-*Instituto Nacional de Metrologia, Normalização e Qualidade Industrial*, issued the ANP/INMETRO Joint Directive N°1, which approved the *Petroleum and Natural Gas Measurement Technical Regulation*.

The objective of the regulation is to establish the terms and minimum requirements that must be complied by the measurement systems applied to the production, transportation, storage, importation and exportation of petroleum and natural gas, in order to guarantee accurate and complete results.

The regulation establishes that the measurement of natural gas in the metering locations at the production should use orifice plates, turbines or ultrasonic meters. Other types of meters can be used provided previously authorized by ANP.

The regulation determines that gas measurement systems applied to fiscal metering should be designed, calibrated and operated so that the measurement uncertainty results lower than 1,5%. Other categories of measurement systems should provide a measurement uncertainty lower than 3,0%.

The regulation also determines that gas meters should be calibrated according to the criteria of the ISO 10012-1 standard, with an initial interval between successive calibrations not higher than 60 days for fiscal meters and not higher than 90 days for meters of other classes.

The reference standards, the working standards and the equipment used for the calibration of the measurement instruments and systems should prove traceability to national standards, and all calibrations and inspections required in the regulation should be accomplished by qualified people or entities.

In measurement systems based on orifice plates, it is necessary to calibrate the differential pressure, the static pressure and the temperature transmitters, so that the accuracy in the measurement of these flow parameters be inside the limits to obtain an uncertainty in the result of the measurement, lower than the specified in the regulation. If the measurement uncertainty results higher than the limit, the instruments should be adjusted and recalibrated.

According to the regulation, orifice plates used in fiscal measurement of natural gas should be inspected annually to verify whether they comply with the dimensional tolerances established by the standards.

In its turn, the meter tubes used for fiscal metering should be inspected, internally and externally at maximum every three years, checking for its dimensions and internal surface roughness, which should comply with the limits established in the standards.

The referred directive granted a maximum period of 24 months from the date of its publication, so that the measurement systems already in operation should be integrally adjusted to fulfill the established in the technical regulation. In addition, all new natural gas flow measuring systems should be designed, constructed and operated to meet with the terms and conditions defined by the regulation.

### **The Effect on the Gas Industry**

Due to the ANP/INMETRO regulation, oil and gas producers, transporters, distributors, and manufactures of flow measurement facilities are carrying out a hard campaign of adjustments and improvements of the measurement systems to comply with the requirements of the regulation.

One interesting thing is that it has been evident that the great majority of the new natural gas flow measuring stations are being designed and constructed to operate with orifice plates.

The metrological adjustment of a natural gas flow measurement system based on orifice plate is not trivial neither simple. Differently from a volumetric gas meter such as a turbine meter which can be taken from the operation site, usually at high pressure, and sent to be calibrated in a laboratory for the determination of its effective K factor or error curve, a measurement system based on an orifice

plate must fulfill the requirements and limits of a series of parameters established by the reference standards, as the ISO 5167 and API 14.3/AGA #3 Standards.

To guarantee a measurement uncertainty under certain level, regardless of a laboratory calibration, these standards establish design, manufacturing, installation and operation criteria for the primary elements, fully integrated to the secondary and tertiary instrumentation.

AGA Report#3 Part 2 defines the primary element as the orifice plate, the orifice plate holder with its associated pressure sensing taps, the meter tube, and the flow conditioner, if used.

The secondary instrumentation is normally composed of differential and static pressure transmitters, temperature transmitter and a densitometer, sampler or gas composition/energy analyzers, if used.

Nowadays, flow computers are extensively used in natural gas measurement systems since they can monitor parameters, convert signals and process flows at real time, displaying gas volumes referred to base conditions of pressure and temperature. More complete metering systems are able to measure gas flow in terms of energy flow, the effective product under trade between deliverers and receivers.

### **Procedure for the Inspection of Natural Gas Measurement Systems**

From the technical point of view, any flow measurement system must be metrologically inspected in order to validate the final value of the parameter measured by the system, which can be flow, volume, mass or energy. The on site inspection of natural gas measurement systems requires skilled personnel, with experience in gas flow measurement and with updated knowledge of the applicable standards. Inspection activities also demand for the use of suitable instrumentation for verification of dimensional, mechanical and electric parameters in the field.

IPT Flow Laboratory has adopted a methodology for the inspection of natural gas flow measurement systems which is based on the full understanding of the operation of a gas measurement system, and consists on the execution of a series of steps, in order to verify the degree of conformity of the flow measurement system to the limits defined by the reference standards, so as to comply with the requirements established in the national regulations for petroleum and natural gas measurement.

- (1) *Analysis of the measuring system documentation*: In the case of a natural gas flow measurement system based on orifice plate, the inspection is conducted, first focused on the analysis of the specifications, verification of design parameters, process data, gas properties, drawings and project documents, checking for operation conditions, flow rangeability and standardized parameters.
- (2) *Inspection of the primary element (orifice plate, orifice plate holder, pressure taps, meter tube and flow conditioner, if used)*: The primary element quality which results from the manufacturing process is verified, since it is the device responsible for the generation of the flow conditions to be measured. Inspection is accomplished for checking the dimensional, form and surface quality parameters of the primary element according to the parameters and limits of the reference standard.
- (3) *Inspection of the secondary instrumentation (static and differential pressure transmitters, and temperature transmitter)*: After the correct installation of the primary element, the secondary instrumentation is checked for calibration, as long as the sensors and transmitters convert analogic parameters into electrical signals.
- (4) *Inspection of the communication between the secondary instrumentation and the flow computer*: Depending on the metering system, the flow computer may be located far from the process and it may be important to check for the correct transmission of the electrical signals from the

transmitters to the flow computer. For instance an electrical resistance due to a defective connection or wire can generate a higher indication of temperature in the flow computer than in the transmitter.

- (5) *Inspection of the flow computer configuration and validation of the calculation algorithm:* In most cases, electrical signals from process are converted into digital signals in the flow computer, which also uses other data, factors and protocols to calculate the flow parameters. All this algorithm must be validated for accuracy according to the relations defined in the standards.
- (6) *Estimation of the measurement uncertainty of the system:* The last step in the metrological inspection is the evaluation of the flow measurement uncertainty of the system. The uncertainty assessment must be accomplished considering the different influence factors and the respective contributions for the global uncertainty.

It is important to mention that this methodology is simply an indication of an inspection procedure and should not be considered as a general or closed matter since each measurement station has its particularities that makes it different from the others.

### Study Cases

"Theory and practice". That is exactly what a metrological inspection of a measuring system is concerned with. Fluid flow measurement is theoretically regulated by dozens of standards and directives that define technical requirements and parameters that a measuring system should comply with in order to give accurate results. However, practice shows that many measuring systems present some type of non-compliance, design or manufacturing mistakes, or even simply erroneous or biased operation of the facility.

Among several inspections carried out by IPT in gas measuring systems, the following are typical cases that shows some of the different kinds of problems identified, and what indeed makes the technical inspection a real need.

### CASE 1: NATURAL GAS MEASURING SYSTEM FOR AN INDUSTRIAL CONSUMER

- Measuring principle: orifice plate
- Measuring system: one stainless steel pipe of 3"
- Beta ratio: 0,50
- Pressure taps: corner taps
- Material: stainless steel for pipe and plate
- Flow conditioner: no
- Sensors: MVS-multivariable sensor of pressure, temperature and differential pressure
- Flow computer: Fisher-Rosemount *Floboss 407*
- Normal operating conditions: 1,4 MPa and 25°C
- Nominal gas flowrate range: 1000 Nm<sup>3</sup>/h up to 1800 Nm<sup>3</sup>/h (maximum)
- Reference standard: ISO 5167: 1991



**Photo 1.** Measuring system.

Inspection by a third part was requested by the gas company due to claims from the gas consumer concerning differences in the flow measurement.

IPT inspection was carried out by diverting the gas supply to a by-pass line, and dismantling the meter tube. The main problems identified are described below:

❑ **Meter tube straight pipe lengths**

The straight pipe lengths of a meter tube has the basic function of conditioning and straightening the flow profile, usually disturbed by the fittings present upstream of the orifice plate.

For the case of a  $\beta = 0,50$ , a meter tube with no flow conditioner, with an upstream fitting adopted as equivalent to a globe valve fully opened, the reference standard requires a minimum straight pipe length of 22 D upstream and 6 D downstream of the orifice plate, for a zero additional uncertainty.

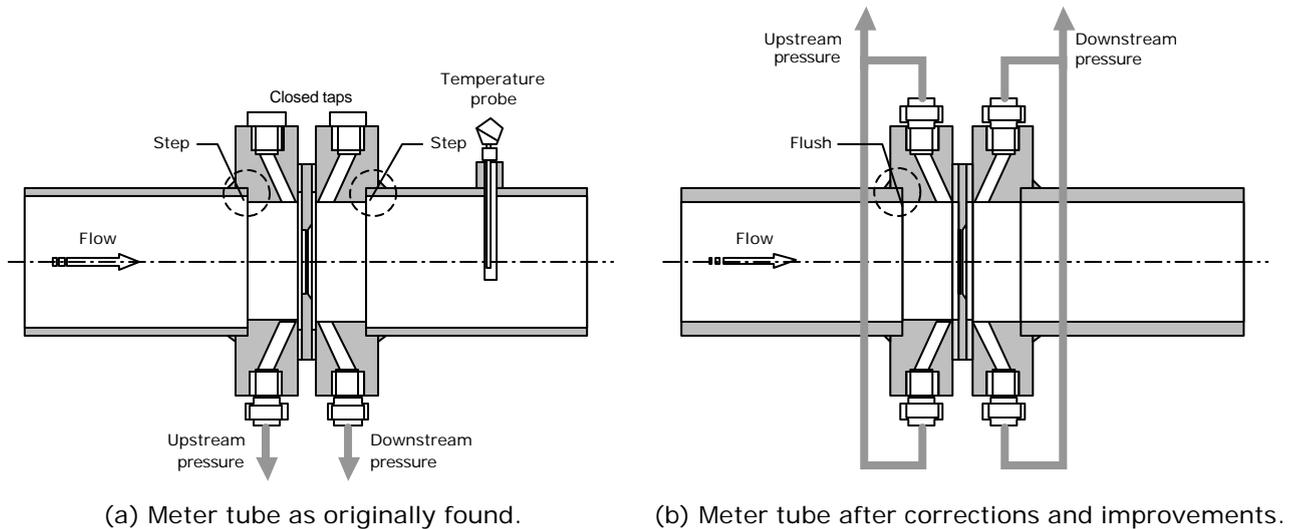
Inspection showed that, due to an incredibly error in the project of the meter tube, the upstream straight pipe length was too short and the downstream pipe longer than the necessary. Corrective actions were taken to adapt the meter tube to comply with the requirements of the standard. Results in both situations are shown in table 1.

**Table 1.** Meter tube straight pipe lengths.

Situation	Upstream pipe	Downstream pipe
As found	900 mm (11 D)	1800 mm (22 D)
As left	3000 mm (38 D)	1000 mm (13 D)
ISO 5167 requirements	minimum 22 D	minimum 6 D

❑ **Internal diameter of the piping**

One of the first things noticed when the meter tube was opened, is that orifice plate holder showed significant steps around the whole internal perimeter of the tube-flange connection, at the union of the upstream and downstream piping and the flanges, as illustrated in the drawing of figure 1 (a).



**Figure 1.** Scheme of the meter run before and after correction.

The steps, of 2,45 mm height, were caused by the difference between the diameter of the flanges orifice, of *Schedule 40* ( $d_{flange} = 77,9$  mm), and the internal diameter of the *Schedule 10* ( $d_{tube} = 82,8$  mm) pipe, erroneously used in the manufacturing process of the meter tube. A quick checking to this item showed that the design documents and drawings were correct.

The reference standard does not allow this type of discontinuity in the cross-section area of the piping since it can cause disturbances in the flow, inducing an erroneous reading of the differential pressure and, consequently, in the flowrate measured by the system.

This problem was pointed out by IPT and corrected by the gas company by changing the whole meter tube. Figure 1(b) shows the meter tube after corrections and improvements.

#### ❑ Pressures taps

During the inspection, it was possible to verify that the orifice plate holder with its associated pressure sensing taps were in good conditions, free from burrs with no evidence of dirty accumulation or visual imperfections.

However, originally the pressure was measured using only one tap at each side of the orifice plate, as can be seen in figure 1(a). Considering that the flanges already had two pressure taps machined in radially opposite sides of each flange, it was recommended the use of the average value of the pressure signal obtained by interconnecting both taps at each side of the orifice plate, as illustrated in the drawing of figure 1(b).

#### ❑ Eccentricity of installation of the orifice plate

Considering the orifice plate was held by RF type flanges with no centering devices, after its withdrawal, it was possible to see the marks of a fine powder accumulated on the plate surfaces, which were exposed to the gas flow. Figure 3 shows the problem.

This mark gave evidences of the eccentricity of installation of the orifice plate in the meter tube. The larger eccentricity was estimated in 2,5 mm in relation to the upstream face of the orifice plate. This value was above the maximum limit allowed by the standard, and that should not be more than 0,80 mm.

The problem was corrected by installing centering pins in the flanges to help reinstalling the plate.

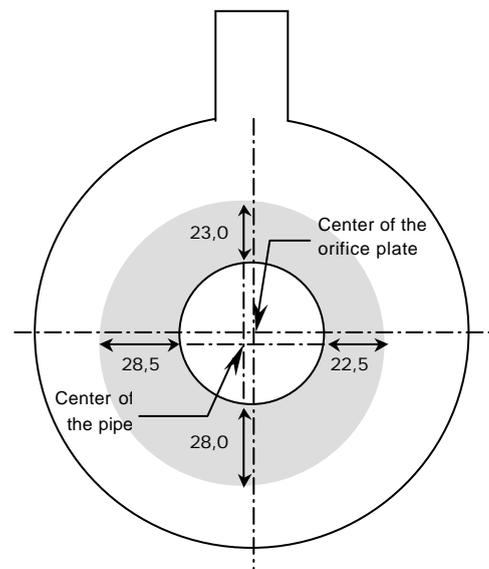


Figure 2. Eccentricity of the orifice plate.

#### ❑ Thermometer well

Inspection showed that the PT100 $\Omega$  thermometer well of the measuring system was originally installed at only 140 mm (1,8D) downstream of the orifice plate. Measurement of the gas temperature at this position is not recommended since it is too close to the orifice plate. In fact, it is located close to the *vena contracta* zone where strong thermodynamic phenomena associated with pressure and temperature variations of the flow occur. In other words, the temperature measured in this position could not represent exactly the average temperature of the main flow that should be used in the calculation of the gas flow.

Location of the thermometer well was transferred to a distance equal to 1560 mm downstream of the orifice plate, since the ISO 5167 determined a distance of 20D for this parameter.

#### ❑ Flow computer configuration

Flow computer configuration was checked to dimensional parameters, gas composition, gas properties, process parameters, calibration set points, base pressure and temperature conditions, atmospheric pressure and others. Calculation algorithm was also verified by comparison with an independent calculation program based on the ISO 5167 equations.

Surprisingly, one of the main problems detected was that the flow computer configuration was set up for a metering system based on flange taps instead of corner taps. So, the flow computer was carrying out flow calculations incorrectly since its last configuration.



Photo 2. Flow computer inspection.

#### CASE 2: NATURAL GAS METERING SYSTEM FOR CUSTODY TRANSFER

- Measuring principle: orifice plate with beta ratio of 0,60 and flange taps
- Measuring system: 2 stainless steel pipes of 8"
- Sensors: pressure, temperature and differential pressure transmitters
- Flow computer: OMNI flow computer model 3000
- Normal operating conditions: 1,7 MPa and 10°C
- Nominal gas flowrate range: 30.600 m<sup>3</sup>/h up to 43.750 m<sup>3</sup>/h (maximum)
- Reference standard: AGA Report #3 Part 1: 1990 and Part 2: 2000

Figure 3 shows schematically the measuring system inspected.

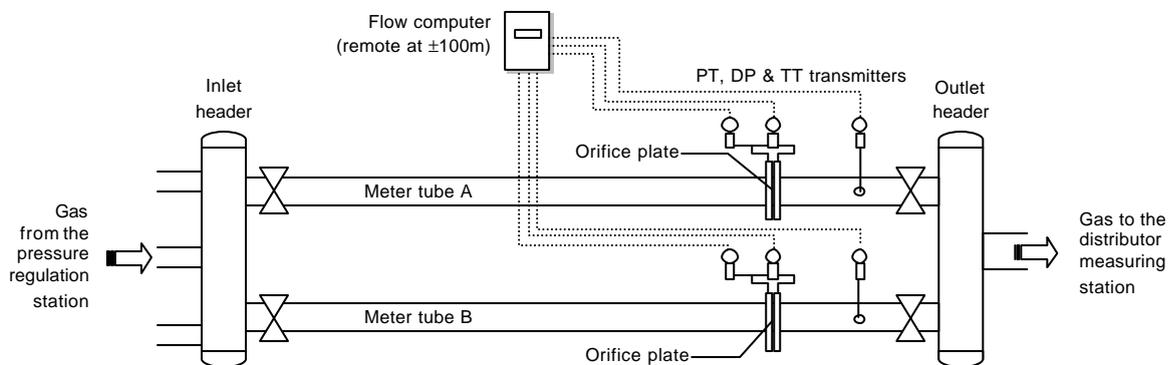


Figure 3. Scheme of the natural gas measuring system.



**Photo 3.** Natural gas flow measurement station for custody transfer.

In this case, inspection was carried out to certify a new measuring system to operate according to the requirements of the technical regulation. The main problems identified are described below:

#### ❑ Meter tube inner surface roughness

The dimensional inspection showed that the meter tube had been built according to project parameters. However, it was verified that the internal walls of the meter tubes had suffered a fine polishing process, what resulted in a surface roughness of the order of  $0,25 \mu\text{m}$  ( $10 \mu\text{inches}$ ) Ra, below the lower limit established for this parameter by the reference standard. See photo 4.

AGA Report #3, Part 2: 2000 establishes that the surface roughness of the inner wall of a meter tube for operation with an orifice plate, for nominal diameters of 12 inches or smaller, has as a lower limit of  $0,86 \mu\text{m}$  ( $34 \mu\text{inches}$ ) Ra, and an upper limit of  $6,35 \mu\text{m}$  ( $250 \mu\text{inches}$ ) or  $7,62 \mu\text{m}$  ( $300 \mu\text{inches}$ ) Ra, depending in this case on the beta ratio of the measuring system.

The meter tube had to be sent to the machine shop to make its internal surface roughness higher.



**Photo 4.** Meter tube low surface roughness.

Reinspection of the meter tubes was carried out at the manufacturer, prior to installation in the field, as shown in photos 5, 6 and 7.



**Photos 5, 6 and 7.** Dimensional and roughness inspection of the primary element.

### ❑ Static pressure transmitter calibration

Inspection of the secondary instrumentation was performed in the field, and analysis of the two static pressure transmitters calibration certificates showed that both contained a serious discrepancy.

Although the certificate declared a calibration range of 0 to 25 kgf/cm<sup>2</sup>, the values presented in the calibration results for a 4 to 20 mA range were referred to respective pressures in the range of 0 to 24 kgf/cm<sup>2</sup>.



**Photo 5.** Secondary instrumentation inspection.

The calibration laboratory was consulted about this difference of approximately 1 kgf/cm<sup>2</sup> and, verifying the calibrations records, recognized that it had occurred a mistake in the calibration process of both transmitters. Immediately, the calibration laboratory proposed itself to recalibrate both transmitters.

That had been an example of a careless procedure of accepting a calibration certificate without a technical analysis, what can give raise to an erroneous measurement with serious consequences.

### ❑ Leakage in the piezometric tubes

At first sight, apparently the connection of the pressure taps to the transmitters were correctly installed, with stainless steel tubes, connections and valves of appropriate sizes, without constrictions that could interfere in the transmission of the pressure signal, and also with no regions where liquid accumulation in the line could occur.

However, using the old soap foam technique, pressure lines were inspected and small leaks of gas were detected close to some fittings. These leaks could induce erroneous pressure measurements, so they were eliminated simply tightening the fittings.



**Photo 5.** Leakage in the piezometric tubing.

### ❑ Pressure units and conversion factors

Inspection showed also a quite common problem concerned to the measurement of pressure: the use of pressure units in terms of a liquid column. That is definitely a not recommendable practice since a liquid column is not a true unit of pressure since it depends on a clear definition of the value used for the gravity acceleration (the standard  $g = 9,80665 \text{ m/s}^2$  or the local  $g$  value). This matter usually generates confusion and, consequently, mistakes and misunderstandings when it is necessary to convert the measured pressure to coherent units of pressure as Pa, kPa, mbar, psi, etc. Therefore, it was recommended the use of units of pressure in the metrological processes.

Another point to be observed is the relatively great confusion that exists in Brazil where the Imperial units are still common in the oil and gas industry, and only in the last few years the SI units have been gradually adopted.

### CASE 3: NATURAL GAS METERING SYSTEM IN A CITYGATE

- Measuring principle: orifice plate with beta ratio of 0,59 and flange taps
- Measuring system: 3 stainless steel pipes (1 x 8" and 2 x 6")
- Sensors: MVS-multivariable sensor of pressure, temperature and differential pressure
- Flow computers: Fisher-Rosemount *Floboss 407*
- Normal operating conditions: 17 bar and 20°C
- Maximum flowrate: 1.500.000 m<sup>3</sup>/h
- Reference standard: *AGA Report #3 Part 1: 1990 and Part 2: 2000*

Photos 7 and 8 show the measuring system inspected.



**Photo 7.** Meter tubes being removed for inspection.



**Photo 8.** Sensors & flow computers inspection.

In this inspection, two aspects should be pointed out: the Joule-Thompson effects on the flow measurement and the quality of the natural gas.

#### □ Joule-Thompson effect

At first sight, it was possible to see that the metering system under inspection had a conception problem. The meter tubes were located immediately after the pressure regulator valves, a configuration that makes the gas suffer the effects of a strong cooling as it passes through the set of valves.

The Joule-Thompson effect associated to the abrupt expansion of the gas from a pressure of 42 bar to about 17 bar reduced its temperature to very low values.



**Photo 6.** Pressure regulator immediately upstream the meter tube.

In such a situation where the gas is not pre-heated, after this cooling, the temperature of the gas increases gradually along the piping due to the heat changes with the walls of the tubes that are in contact with the ambient air, until reaches about 10°C at the thermometer well section.

This cooling effect of the natural gas is evidenced by the occurrence of water vapor condensation in the external walls of the meter tube, since its surface temperature is usually below the dew point temperature of the ambient air.

Fact is that the temperature measurement in the thermometer well may not represent exactly the average temperature of the natural gas at the orifice plate, which should be used in the calculation of the gas flow.

Obviously, this matter demands a deeper experimental and theoretical analysis, much more than the scope of inspection carried out at that moment. Thus, for effect of the estimate of the flow measurement uncertainty of the inspected measurement system, it was considered a larger uncertainty for the value of the temperature of the gas in the orifice plate.

#### ❑ Quality of the natural gas

An important factor in any flow measurement process is the quality of the fluid under measurement. In the inspected system, natural gas flowing through the metering system was exceptionally dirt, carrying a black powder mixed with other contaminants that in a short time modified the dimensional characteristics of the meter tubes and the orifice plates.

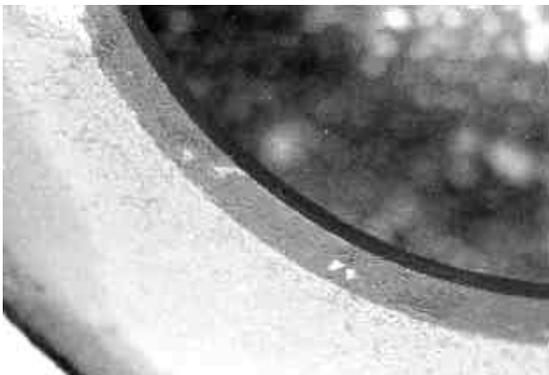
Photos 4 to 7 show what occurred with the measuring system exposed to the natural gas with impurities after some time.



**Photo 6.** Meter tube and pressure tap.



**Photo 7.** Orifice plate.



**Photo 8.** Orifice plate with a thick dust layer.



**Photo 9.** Deposits on the face of an orifice plate.

As can be seen, in such a situation no matter the measuring principle used, or how sophisticated could be the metering system. Any measurement result will certainly be unbelievable due to the gas quality conditions and the potential effects on the meter tube and orifice plate behavior.

Operator was requested to improve the filtering process of the natural gas and to establish an inspection and maintenance program for the primary elements.

### **Conclusion**

As related in this paper, inspection of flow measuring systems is of paramount importance. No matter how well can a meter be calibrated in a laboratory test bench, under low uncertainties, if when the meter is installed in the process, it will depend on the secondary instrumentation, flow computers and meter tubes associated to it, and many other influence factors that play important rule in the final value of volume of gas measured.

The intention of this document is to inform and alert the metrological community, the gas industry and the standardization entities to what may be happening in the natural gas flow measurement activities.

For the metrologists, it is important to enlarge the concepts of calibration, looking for the whole metering system including the meter, its associated elements, the operational procedures, and the gas flow itself.

### **References**

1. The natural gas industry in outline, Ruhrgas, 1999.
2. ANP-Agência Nacional do Petróleo, Boletim Mensal de Produção submetido à ANP.
3. ISO 5167 Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices, Part 1: General and Part 2: Orifice plates, 2000.
4. API, Manual of Petroleum Measurement Standards, Chapter 14 - Natural Gas Fluids Measurement, Section 3 - Concentric Square-Edged Orifice Meters, Parts 1 to 4 (similar to AGA Reports #3):
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  - Part 3 Natural Gas Applications, 3rd Ed., Aug. 1992.
  - Part 4 Background, Development, Implementation Procedures and Subroutine Documentation, 3rd Edition, Nov. 1992.
5. AGA Report #8 *Compressibility of Natural Gas and other Related Hydrocarbon Gases*.