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IN-SITU CALIBRATION OF NATURAL GAS ORIFICE METERS -- A RECENTLY ACCEPTED CONCEPT IN CHINA

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Abstract: This paper presents the details about in-situ calibration of natural gas orifice meters in China, and discusses some actual calibration results made in the custody transfer metering station of natural gas transportation pipeline from Shanxi to Beijing
Keywords: In-situ Calibration, Orifice Meter, Natural Gas

1 INTRODUCTION

In China orifice meters are the most commonly used devices to measure natural gas, and about 95% of custody transfer metering stations are equipped with this kind of flow meters. One of the main reasons why orifice meters are widely used is that their primary elements do not require calibration with actual flow. So as the routine procedures, only the specifications of orifice plate and meter tube are inspected before installation and checked during operation, the related secondary instruments such as differential pressure, temperature, pressure transducers and flow computer are checked or calibrated periodically. Then the overall uncertainty of the natural gas measurement system can be estimated with the dry calibration results according to the specified methods in the related standards. The most of orifice meters are operated in accordance with China National Standard which is equivalent to ISO 5167, and some of them in accordance with ANSI/API 2530, more commonly known as AGA No.3 Report.

As the increase of China's natural gas outputs and the construction of long distance natural gas transportation pipelines, the in-situ calibration becomes great important because of the monetary value of the large volume of natural gas transferred in the metering stations. When a contentious measurement result arises and both parties related apply for an arbitration verification from the authorized metrological organization, in-situ calibration of the orifice meter will be made. If nonstandard operation conditions of an orifice meter cannot be avoided, or much better measurement result is expected, it is also necessary to do this kind of calibration. For the purposes we purchased one mobile proving system manufactured by Colorado Engineering Experiment Station Inc.(CEESI) and modified by Flow Systems, Inc. (FSI), it is the only secondary standard equipment which can be used to do the calibrations of natural gas flow meters on site at the moment in China.

Through some actual calibrations made in the custody transfer metering station of natural gas transportation pipeline from Shanxi to Beijing the new and deep understandings of in-situ calibration of natural gas orifice meters have been acquired, and it is becoming an accepted concept now in China. In comparison to other calibration methods the in-situ calibration of natural gas flow meters accords most accurately with the metrological demands of consistence and traceability.

2 MOBILE PROVING SYSTEM

Sonic nozzles are commonly used as master meters in the most of natural gas secondary standard flow facilities in China, and positive displacement meters and turbine meters are used also sometimes. Someone is considering the possibility of using multipath ultrasonic meters as in-situ transfer standard of natural gas flow measurement. The master meters are calibrated against the primary standard facilities, but inter-comparisons between the secondary facilities are accepted also.

The mobile proving system used for in-situ calibrations was manufactured and calibrated by CEESI in 1987, and was refurbished by FSI in 1999. It is a sonic venturi based gas flow standard capable of providing primary standard facility traceable calibrations for flow meters in natural gas, air, or nitrogen service. The main components of the system include a digital valve, instrumentation and data acquisition computer, on-line gas chromatograph. The reference standard is the digital valve which consists of 16 different size critical flow (sonic) venturi nozzles, designed to ISO 9300- 1990 specifications (Smith-Matz design). The venturis are installed in the digital valve in parallel, with common inlet and outlet piping. The venturis can be inserted to the flow stream individually or in any combination of the 4096 combinations possible. The inserted venturis establish the gas mass flow rate passing through the meters under calibration. The venturis are calibrated against the m-t method and p-V-T-t method facilities with air or natural gas at different operating pressures every five years, the power or polynomial curve for each venturi's discharge coefficient will be calculated according to the calibration results. The estimated uncertainty of the discharge coefficients is within 0.25 at 95% confidence level. The venturis used in the proving systems are listed in Table 1.

Table 1. Venturis Used in the Proving System

Element Number	Bit Number	Percent of Flow	Throat Diameter (in)
1	0	0.024	0.0592
2	1	0.049	0.0815
3	2	0.098	0.1155
4	3	0.195	0.1639
5	4	0.391	0.2311
6	5	0.781	0.3270
7	6	1.563	0.4634
8	7	3.125	0.6550
9	8	6.25	0.9265
10	9	12.5	1.3086
11	10	12.5	1.3091
12	11	12.5	1.3085
13	12	12.5	1.3089
14	13	12.5	1.3087
15	14	12.5	1.3081
16	15	12.5	1.3084

The integral to the mobile proving system is the data acquisition and control system which consists of an IBM ThinkPad computer, National Instruments Field Point DAC system with digital output, digital input, and analog input modules, a Hewlett-Packard universal counter, a Daniel natural gas chromatograph and a power conditioning and distribution case. The IBM ThinkPad stores and executes the system software as well as stores calibration log files in ACSII text – tab delimited file format. The system software is fundamentally a computerized flow controller with a graphical user interface and a data logging system designed to collect and report calibration data for orifice meters, turbine meters, critical flow venturis, subsonic venturis, positive displacement meters, ultrasonic meters and flow transmitters.
The mobile proving system is designed to be connected in series, down stream of the meters being tested. The system includes piping to connect test meters to the prover. Test meter pressure, temperature, and differential pressure are measured using the transducers supplied with the system. Frequency cables are included for connecting to meters that output a frequency or pulse signal. An auxiliary cable is provided to power and meters that output an analog voltage or milliamp current signal. Cables have been provided to locate the electronic data acquisition and control system and power supply up to 50 meters from the prover skid and it is potentially explosive environment.
The Daniel Danalyser 2350 gas chromatograph will analyze the molecular concentration percent within the sampled natural gas of following components: C6+, Propane, i-Butane, n-Butane, Neopentane, i-Pentane, n-Pentane, Nitrogen, Methane, Carbon Dioxide, Ethane. The 2350 gas chromatograph has one sampling column and two streams. Stream 1 is setup for natural gas flow from the prover's exit pipe and called the sample stream. Stream 2 is setup for calibration gas from the calibration gas storage tank inside the GC enclosure and is called the cal stream.
The overall uncertainty of the gas mass flow measurement of the proving system is estimated within 0.5% at 95% confidence level. The maximum flow rate is 12,000 SCMH at 0.20 MPa or 90,000 SCMH at 1.57 MPa, and the operating pressure is 0.2 – 1.6 MPa.

3 IN-SITU CALIBRATION OF ORIFICE METERS

China longest natural gas transportation pipeline from Shanxi to Beijing has a distance about 1000 km, and will transport yearly up to 2.5 billion SCM of natural gas. At the end of the pipeline Beijing gate station leads natural gas into the civic pipelines system. In the station natural gas first comes into the separating loop, and then flows through the metering section, and goes to the pressure regulating and controlling loop finally. The metering section consists of four Daniel orifice meters with necessary secondary instruments and flow computers. The orifice meters specifications are listed in Table 2, and the schematic flow diagram of the gate station is shown in Fig.1.

Table 2. Orifice Meters Specifications

Meter No.	Type	Serial No.	Throat Diameter (mm)	Inlet Diameter (mm)
1	A216/OB	96410049	373.075	186.5370
2	A216/OB	96410048	373.076	130.6271
3	A216/OB	96410051	373.075	149.2250
4	A216/OB	96410050	373.075	205.1507

The actual in-situ calibration was carried out in December 1997, and it was the first time to do this kind of calibration in China. The first step in the calibration process was setting up the mobile prover in close proximity to the orifice meters to be calibrated. Two suitable connection ends for the mobile prover had been provided, and the distance was dictated by the length of piping that had been supplied and any other piping that might be added using the hammer-union connections. After the prover had been situated close to the meter test section, the skid should be stabilized and leveled. Thus a controllable flow path from the gas supply through the test meter and prover could be created. Then the gas chromatograph should be heated, and the meter instrumentation installed.

When the calibration system reached the stable conditions, the calibration data could be logged. Each orifice meter was calibrated at four different flow rates, and the calibration results are shown in Table 3. The calibration results indicated that all of four orifice meters operated very well, their uncertainties of natural gas measurements were within 1.0%, which were much better than the expected. To increase the accuracy of natural gas measurement in the gate station, the meter factors of the four orifice meters were used to calculate the flow rates since then.

Table 4. Calibration Results of Orifice Meters

Meter No.	Operation Pressure (MPa)	Operation Temp. (° C)	$1.0Q_{max}$ (%)	$0.8Q_{max}$ (%)	$0.5Q_{max}$ (%)	$0.3Q_{max}$ (%)
1	1.435 – 1.444	5.3 – 7.6	0.16	0.23	0.34	0.31
2	1.426 – 1.432	2.7 – 4.5	0.04	0.70	0.83	0.98
3	1.408 – 1.434	7.7 – 8.2	0.06	- 0.27	0.30	0.93
4	1.428 – 1.437	5.3 – 7.6	0.02	0.49	0.23	0.47

4 CONCLUSIONS

1. In comparison to some other calibration methods, the in-situ calibration of natural gas flow meters accords most accurately with the metrological demands of consistence and traceability. The in-situ calibration becomes great important because of the monetary value of the large volume of natural gas transferred in the custody transfer metering station.
2. The mobile proving system can be used for the in-situ calibration, which is a sonic venturi based gas flow standard, and equipped with an on-line gas chromatograph. The modified proving system is estimated with an uncertainty of 0.5% at a confidence level of 95%, and can meet the calibration demands of the most natural gas flow meters on site.
3. The orifice meters at Beijing gate station were calibrated against the mobile proving system, the calibration results indicated that their uncertainties of natural gas flow measurement were within 1.0%, and the in-situ calibrations were accepted.

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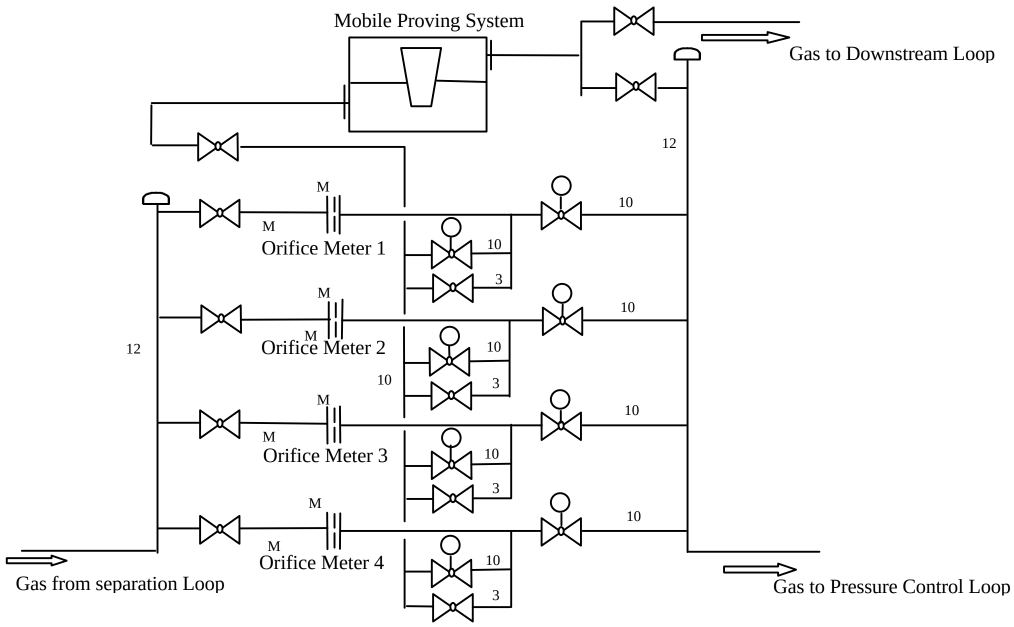

Figure 1. Schematic Flow Diagram of Beijing Gate Station