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METROLOGY FOR PIPELINES TRANSPORTING GASEOUS AND LIQUID FUELS

Flow metrology is the most important issue in the field of liquid and gaseous fuel transport and storage but, by no means, the only one. Many issues concern pressure, temperature and geometry measurement, as well as data analysis, isokinetic sampling etc. The aim of this paper is to encourage metrologists to take up the challenge and apply for research projects in this domain, as this industry eagerly invests in R&D.

Keywords: pipeline transport, pipeline diagnostics, flow measurement

1. CUSTODY TRANSFER OF NATURAL GAS

Construction of gas metering stations in Poland is restricted by industrial standards of Polish Oil and Gas Company [1]. Maximum flow rate determines appropriate metering installation scheme. Basic U1 type – one meter with by-pass enabling exchange the meters in case of calibration can be used when flow rate does not exceed 5000 m^3/h at standard conditions. Between 5000 and 50 000 m^3/h there should be a possibility to periodically check one gas meter by another, this is U2 scheme, or so called Z-type installation shown in in fig. 1. Above 50 000 m^3/h each gas meter should be monitored by a meter of a different type, installed in series. Any installation type may consist of one or more metering lines.
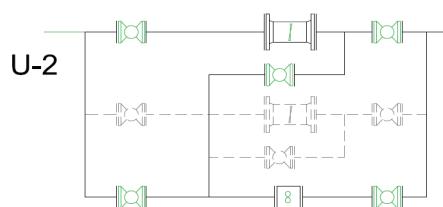

Fig. 1. U-2 type gas metering stations according to PGNiG factory standard

A good example may be a gas metering station designed by M. Turkowski for measurement of regasified Liquified Natural Gas (LNG) in terminal in Świnoujście, presented in fig. 2.

Three metering lines are installed in parallel, each with turbine gas meter monitored by an ultrasonic gas meter. Two lines, each 2,5 mln m^3/y ensure the present capacity of the LNG terminal (5 mln m^3/y). The third line forms a reserve in case of failure. Because of the planned expansion of terminal's capacity to 7,5 mln m^3/y, an additional line (now sealed by blind flanges) has already been designed and built.

Apart from gas meters a variety of other metering transducers is necessary to build the complete metering station. To recalculate the actual volume to base conditions (usually standard conditions, but not always) the information about pressure and temperature must be taken into account. Specialized flow computers calculate volume in base conditions. The necessary algorithms for calculations of compressibility factor (AGA in USA, ISO in Europe [2]) are also implemented in the flow computer.
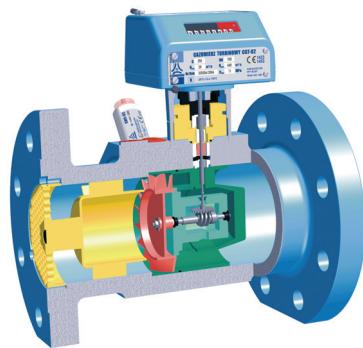
Fig. 2. Left: gas metering station at the LNG terminal in Świnoujście, Right: typical turbine gas meter (COMMON S.A.)

Nowadays special emphasis is given in the measurement of energy contained in the gas instead of volume.

Both the algorithms of calorific value and compressibility factor calculations require gas composition as input data. The most important metering stations are therefore equipped with gas chromatographs. As chromatograph is an expensive instrument, in smaller branches of gas grid the gas composition and calorific value is calculated by numerical simulations.

2. CUSTODY TRANSFER OF CRUDE OIL

High value of transported products extorts application of systems enabling highest possible accuracy. Contemporary designs of such meters are presented in fig. 3. At gas metering stations wide rangeability is of great importance because of fluctuations of gas demand depending on season, and even the time of day. In contrast, flow rate in oil pipelines is rather constant. As opposed to liquid fuels which density and viscosity lie within narrow limits, special construction of turbine meter with two helical blades (Fig. 3, left) has been developed. It assures low influence of density and viscosity, which changes in wide range depending on localization of production field and temperature. Low influence of flow profile disturbances is also important. It can be achieved with the use of multi-path ultrasonic flowmeter (Fig. 3, right).
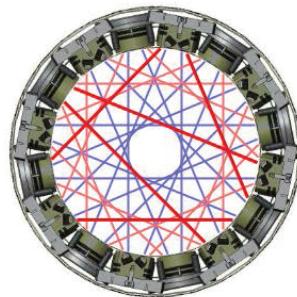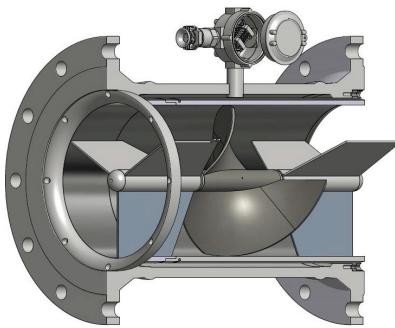

Fig. 3. Turbine flow meters dedicated for crude oil measurement: Left – two helicoidal blades turbine flowmeter, right – 32 path ultrasonic flowmeter (cross section) www.mnt-sas.com

Crude oil may also contain water and solids. The water content can be measured on-line by microwave sensors. The content of solids is measured in laboratory, so the isokinetic sampling device must be installed. Net volume is obtained by subtracting water and solid contents from rough volume

measurement. Finally, based on actual temperature and pressure measurements the volume in standard conditions (usually 1 bar and 15 °C) is calculated according to API standards [3].

3. CUSTODY TRANSFER OF LIQUID FUELS

As parameters of liquid fuels (gasoline and diesel fuel) are standardized in terms of density, viscosity and calorific value, they are also very clean, which makes liquid fuels measurement easier than crude oil measurement. Despite this fact, methods of liquid fuel volume measurement were being improved during the last decades because of constantly growing demand on liquid fuels and increasing prices. Commonly used methods of tank gauging (static systems) have several flaws. Even when measurement is performed according to state-of-the-art procedures, uncertainty of this method is not better than 0,25%. Among other problems, tank shells are prone to dimension changes due to temperature. Filling a large tank causes its bottom to sink. Temperature and density of product inside a tank is averaged based on a couple of probe points.

Dynamic measurement with flowmeters is more accurate, especially when small quantities of liquid fuel are to be measured. Best stands achieve uncertainties down to 0,05% and uncertainties of 0,1% are common. Low uncertainty of measurement not only leads to reduced financial risk in custody transfer, but also helps in tracing losses. Another advantage of dynamic systems is that Coriolis flowmeter can measure mass flow directly.

However, introduction of dynamic measurement system requires substantial funds. Both initial and operational costs are high. Flowmeters should be calibrated frequently. In case of Coriolis flowmeters, it is easy to introduce mechanical stresses upon installation. This results in a zero-offset which significantly contributes to uncertainty. On-site calibration or verification methods are therefore favorable, e.g. mobile provers, volume tanks or reference meters.

Before a dynamic system is introduced, thorough analysis of custody transfer regulations is necessary. Pistons or markers separating batches of product may be needed if consequent batches belong to different owners. If one pipeline is used to transport various products (e.g. petroleum and diesel), a flowmeter system will have to determine quantity of liquid fuel that has been received by each tank. Additional issues may arise if transport routes can be switched while pumps are continuously running.

To verify that dynamic measurement system operates properly, it is possible to perform series of comparisons: tank-flowmeter (expediting terminal), flowmeter-flowmeter, and flowmeter-tank (receiving terminal), as shown in fig. 4.

$$D_{ET} = \Delta V_{FE} - \sum \Delta V_{T\_i} \qquad D_{RT} = \sum \Delta V_{T\_i} - \Delta V_{FE}$$

$$D_{FF} = \Delta V_{ET.FE} - \Delta V_{RT.FE}$$
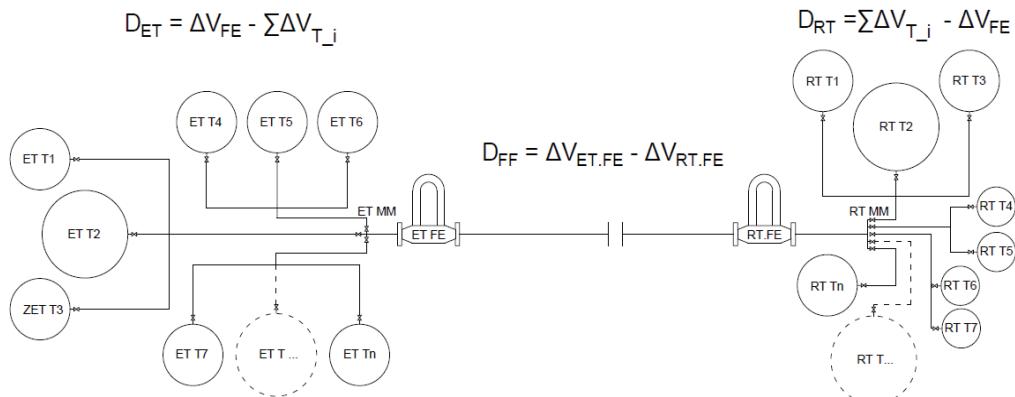
Fig. 4. Simplified scheme for comparisons between static and dynamic systems. ET – expediting terminal, RT – receiving terminal, FE – flowmeter, T – tank, MM – main manifold

The difference D between static and dynamic systems has expected value equal to zero. It is supposed to be smaller than its expanded uncertainty for 95% of comparisons. The most difficult part of the analysis is to estimate all the uncertainty components.

4. CALIBRATION OF FLOWMETERS

Most of the flowmeters are calibrated at stands using water or air as working media. As performance of almost all flowmeters depends on fluid properties, there is now a strong tendency to calibrate flowmeters with the use of a fluid that is measured by it on-site. Especially in case of expensive raw materials and fuels.

4.1 Calibration of gas meters

A unique gas meter calibration facility has been recently built by the polish Gas Transmission Operator GAZ-SYSTEM SA at the premises of gas compressor station. It can work in a closed loop (blue lines) with the use of dedicated blower. When higher flow rates or larger permissible pressure drops are necessary, facility can work in an open loop, with the use of machines at compressor station (green lines). More detailed description can be found in [4].
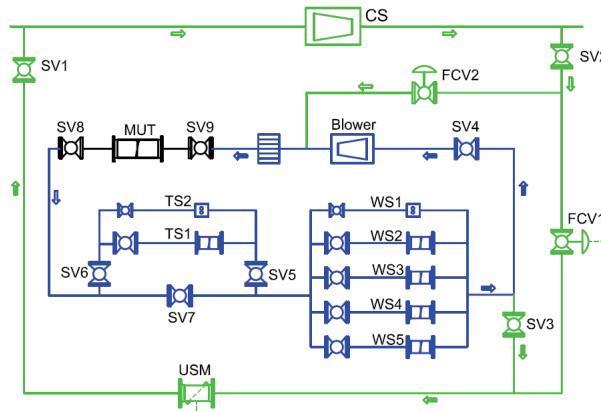

Fig. 5. High pressure gas meter calibration facility built by GAZ-SYSTEM SA. CS – compressor station, SV – shut-off valves, FCV – regulating valves, MUT – meter under test, WS – working standards, TS – transfer standards

4.2 Calibration of liquid fuel and crude oil flowmeters

To calibrate fuel and oil flowmeters sphere provers (fig. 6) are frequently installed.
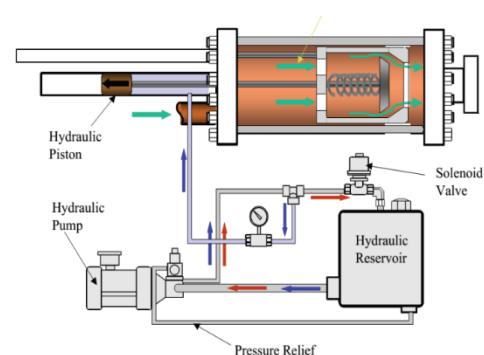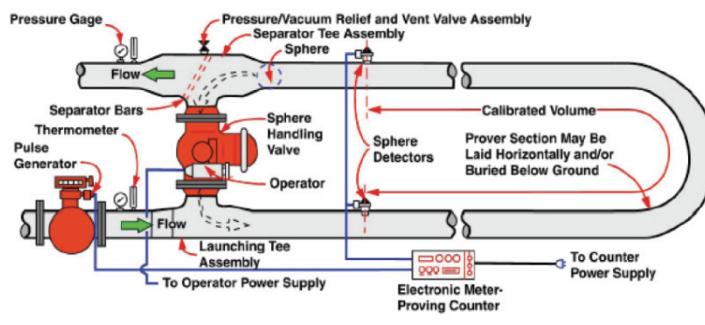
Fig. 6. Left – sphere prover, right – compact piston prover. www.emerson.com

These are located permanently at the metering station, especially in places where high quantities of these media are transferred, e.g. at oil ports with high handling capacities. Another solution is to install prover on a truck, which can be used to calibrate flowmeters situated at various locations. To perform calibrations or verifications, mobile provers require special by-passes in places where flowmeters are installed.

5. CONCLUSIONS

Growing prices and increased demand for liquid raw materials and fuels implies the necessity of increased measurement accuracy. It concerns not only flow measurement but also temperature, pressure, fluid composition, level, density, viscosity, contamination, geometric measurement etc., influencing the flow rate and quantity of transported media measurement. There are therefore numerous issues to be resolved by metrologists from various branches. Pipeline operators willingly support R&D activities in this domain. A good example is INGA, recent joint project of Polish Oil and Gas Company PGNiG, Gas Transmission Operator GAZ-SYSTEM and The National Centre for Research&Development NCBR.

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