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TESTING, MAINTENANCE, AND OPERATION OF ELECTRONIC FLOW COMPUTERS FOR THE GAS INDUSTRY

Class # 3170.1

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INTRODUCTION

Natural gas flow computers came into much wider use for custody transfer (fiscal) measurement beginning in the late 1980s following their less common application in the 1970s and before.

Used almost exclusively to calculate flow, early flow computers simply replaced chart recorders and offered an alternative means of storing data.

With improvements in microprocessors, field-hardened electronics, power systems, communications, batteries, and pressure transducers came countless other uses. No longer as they used to simply calculate flow.

Today in 2011, flow computers provide large amounts of data and perform tasks that are essential to the success of a complex and fast-paced gas energy industry.

We will focus here only on gas quantification matters relevant to testing, maintenance, and operation of natural gas flow computers, and steps taken to help ensure the reliable calculation of natural gas quantities.

FLOW MEASUREMENT SYSTEMS COMPONENTS

An electronic flow computer is only one part of a flow measurement system. Many measurement systems can be described as having three fundamental parts.

1. Primary device – the basic meter type (e.g., orifice, turbine, Venturi, rotary-displacement, diaphragm, ultrasonic, Coriolis, etc.).

2. Secondary device – the transducers, transmitters, and other components that communicate pressures, temperatures, and other measured variables from the primary device to the tertiary device.

3. Tertiary device – the flow calculation device (the flow computer).

The secondary and tertiary devices, as well as the primary device, can be contained in one or more enclosures, or can be packaged and housed at the same general location. In other cases, a tertiary device can be located at great distances from the point of measurement.

This paper addresses only secondary and tertiary devices. API MPMS Ch. 21.1[1] and the meter-specific standards and reports can provide additional valuable information.

FLOW COMPUTER TESTING

The word "testing," brings many things to mind. Flow computers used for custody transfer and other crucial measurement applications should be "*tested"* in two different and separate ways.

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[1] As of the writing of this article in January 2011, API MPMS Ch. 21.1 is being revised and reportedly slated for publication in the near future. Anyone with an interest in custody transfer gas measurement is strongly encouraged to become involved in the standard development process because standards form the genesis of the fiscal measurement process.

1. During the flow computer selection process where testing helps ensure correct calculations and component performance.

2. On a regular and recurring basis in the field to confirm that flow computer transducers and other parts are working correctly and communicating reliably with the flow computer.

Natural gas flow computers used for custody transfer and other critical measurement applications should be tested and evaluated in two completely separate and detailed ways during the equipment selection process. They are:

1. Static testing

2. Dynamic testing

Both types of testing are necessary to ensure that flow computers operate:

- reliably under various flowing conditions and during ambient temperature changes;

- dependably relative to alarms and systems control functions; and

- correctly concerning flow calculations and parameter averaging methods, including the providing reliable audit trail documentation after flow occurs.

Conducting only one type of testing, such as static testing (sometimes called "bench-testing"), has often resulted in misunderstandings about the performance of flow computers and their related systems. Simply producing electrical signals to flow computer components can provide unreliable results.

Just because a flow computer correctly calculates flow from fixed inputs is no indication that it will correctly calculate flow under actual flowing conditions.

There are many instances where attempts to perform dynamic testing using a bench-test method have failed due to the inability to reliably track and hold measured variables, often due to the effect of thermal instability in a test system. The concept of bench testing seems simple, but in fact is quite complex. Nothing can duplicate "real flow" when testing and evaluating flow computers.

There is no known way a "canned" test can be performed, as has been clearly demonstrated over the past thirty, or so, years. Attempting to fit all flow computers into a standard testing protocol will often lead to confusion and misunderstandings.

The prudent investigator must have a clear understanding of the equipment under test, its intended use, the test facility, and the practical application of the flow computer in the "real world." No two testing protocols are identical.

Also, no industry measurement standard currently addresses either static testing or dynamic testing. However, an API Standard is currently under development by the COGFM, titled "Testing Protocol for Electronic Flow Computers for Gas Flows," and designated as API MPMS Ch. 22.5.

Following are some general thoughts relating to static testing and dynamic testing.

Flow Computer Static Testing
Because not all operating conditions can be reliably replicated, a test matrix is developed to address the desired operational parameters. Initially, nine sets of operational parameters are selected based on typical flowing conditions. Engineering units are compared in all cases to a tolerance of fifty parts per million (50 ppm) for flow rate or accumulated flow.

Following the completion of the initial nine tests, additional test cases are developed to emulate a representative range of meter sizes, gas compositions, operating parameters, and other anticipated conditions of use. Data retrieval through the entire communication system can also be tested during the static testing phase. Additional inputs and outputs are likewise tested, and are dependent on the particular equipment design and intended use.

Static testing is accomplished by manually imputing fixed values into the flow computer registers and comparing intermediate calculated results with individually calculated values that are traceable to the applicable standards. Values verified for orifice meters (and other differential pressure meters) include the following.[2]

- Conversion from psig to psia – applicability depends on flow computer design, transducer type, and transducer design;
- Differential pressure – inches H_2O;
- Static pressure – psia;
- Temperature – °F and correct conversion to °R;
- Discharge coefficient – ($Cd_{(FT)}$) for orifice meters conforming to API MPMS Ch. 14.3 and per special tests for other differential meter types;
- Pipe Reynolds number – necessary for calculating discharge coefficient where empirical data are used;
- Pressure tap location – P_1 or P_2 ;
- Expansion factor [3] – Y_1 or Y_2 ;
- Velocity of approach factor – E_v ;
- Flow extension – $(Hw\ Pf)^{0.5}$;
- Gas compressibility – Z_b, Z_{f1}, Z_{f2} ;
- Gas relative density – Gi, G_r ;
- Gas density – where applicable as based on suitable EOS or densitometer input;
- Gas heating value – Btu/ft^3 ;
- Acceleration of gravity – F_{pwl} ;
- Flow time – seconds, minutes, hours;
- Instantaneous flow rate – Scf, Mcf, MMScf, MMBtu ;
- Accumulated gas flow – Scf, Mcf, MMScf, MMBtu ;
- Alarms;
- Flags
- SCADA – including CFR 193 and 195 (September 2010) and API RP 1165;
- Audit logs;
- Audit trail – API MPMS Ch. 21.1;
- Other parameters required by standards and legal agreements, state agencies, federal agencies and depending on the specific meter type and design.

Values verified for linear meter types (e.g., ultrasonic meters, turbine meters, rotary meters, diaphragm meters, Coriolis meters, etc.) include (as applicable) many of the same values as listed above. Additionally, K factors, meter factors, and the original flow calibration audit trail data are reviewed.

Additional tests under controlled static conditions are conducted to define performance limitations under hot and cold ambient temperatures ranging from approximately –30º F to approximately +130º F. During these tests, all flow computer enclosures, electronics, transducer, wiring, and other components are subjected to the same temperature extremes while fixed values are input using identical transducers and transmitters to be used in practice. Figure 1 shows the fundamental parts of a typical temperature test chamber used in the evaluation of flow computer systems.

The equipment manufacturer should provide a complete listing of all standards, reports, and recommended practices used in developing their equipment, including the auxiliary components (e.g., gas chromatographs, editor systems) they have tested for compatibility, and provide documentation of such tests.

[2] The selection of tested and verified values depends on the specific meter type, meter design, and intended use.

[3] Latest and pending revisions to industry measurement standards are reviewed to help ensure that all applicable measurement calculations and parameters are checked. For example, the next revision to API MPMS Ch.14.3 (orifice metering) is anticipated to include more than one expansion factor (Y_1 or Y_2) calculation.

It is important that all testing address the same equipment, including the actual software and firmware to be used in operation, and that all static test parameters are documented completely.

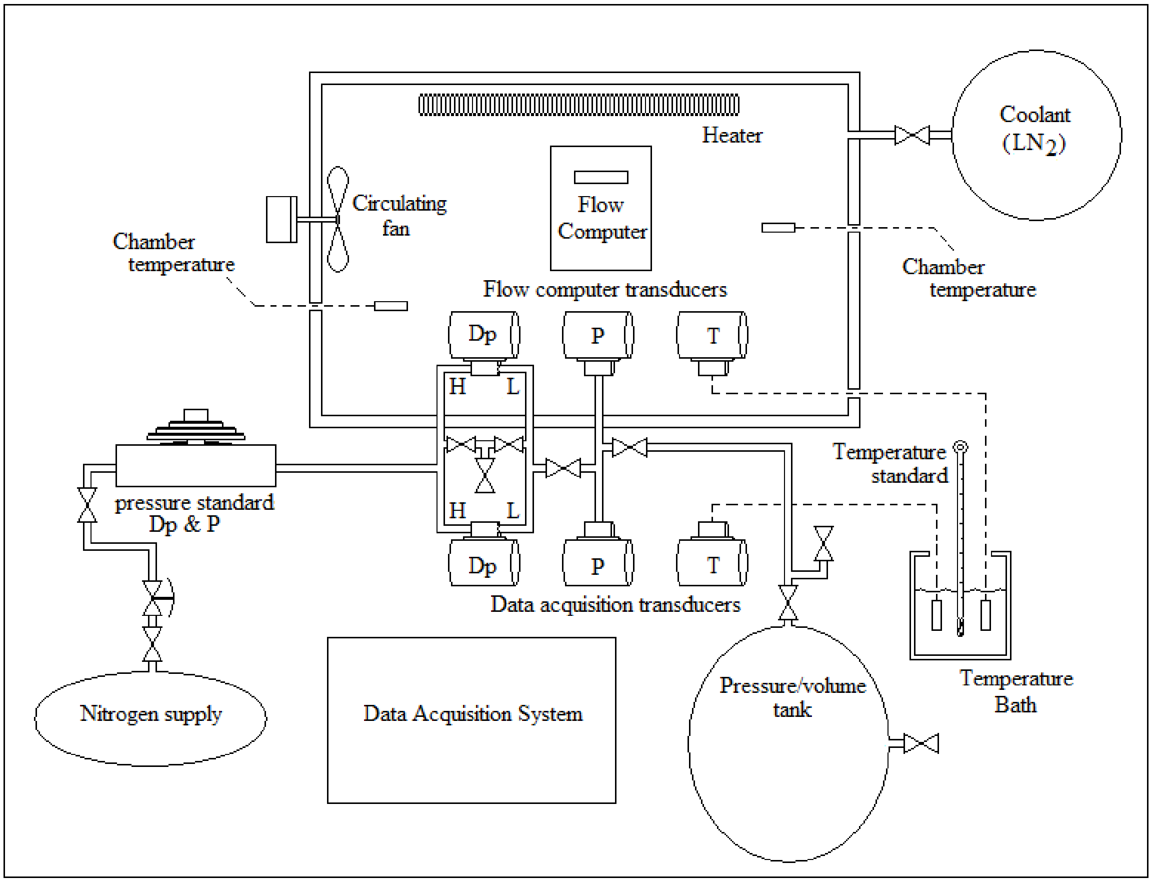

Fig 1 – Basic components of a flow computer temperature test chamber

<u>Flow Computer Dynamic Testing</u>

A primary mass measurement system is employed for the performance of dynamic testing to traceable and verifiable accuracy tolerances of +/-0.1% of delivered mass flow, and having uncertainty tolerances directly traceable to the National Institute of Standards and Technology (NIST), preferably conforming to the National Voluntary Laboratory Accreditation Program (NVLAP) process.

Orifice meters and other square root meters undergo a minimum of five separate flow tests. Turbine meters, rotary meters, diaphragm meters, ultrasonic meters, Coriolis meters, and other linear meter types are subjected to a minimum of three separate flow tests.

Dry air is the preferred test fluid due to excellent uncertainty regarding its physical properties, although any gas may be used as long as its physical properties are well documented.

Test parameters include steady state and varying flow rates designed to meet the most stringent operating conditions under which the flow computer will be installed. Standard flow patterns for such testing have been developed over the years that may be used to replicate gas lifts (gas intermitters) and other severe flowing conditions. At least one of the varying flow tests should include a period of zero-flow time which overlaps two of the audit log periods.

It is crucial that the flow computer clock is settable to a resolution of +/- 0.5 seconds of the flow laboratory clock. A separate data acquisition system installed by the flow laboratory is used to facilitate troubleshooting to help identify problems during the data analysis process.

Figure 2 is a general diagram of a primary mass flow testing system.

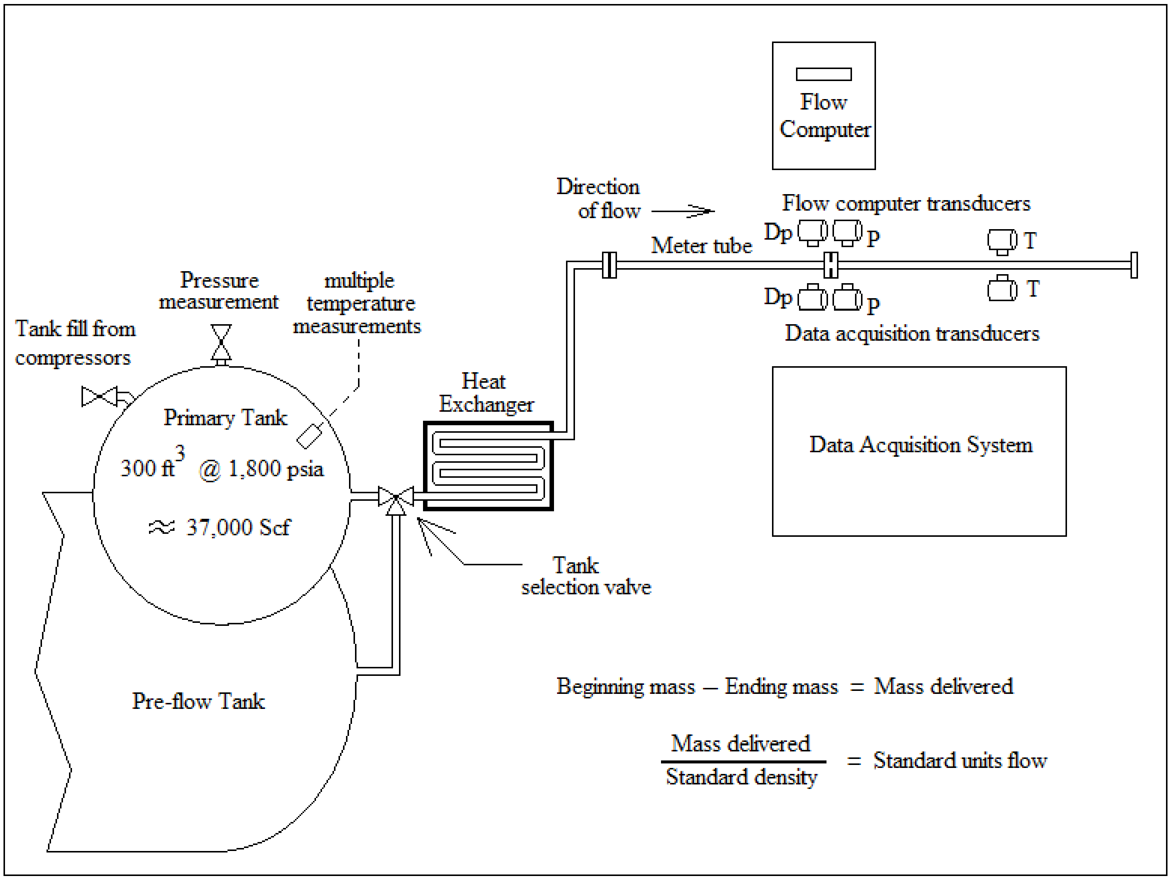

Fig. 2 – Primary mass flow testing system

Historically, flow test results of high-quality flow computers have compared to laboratory results to a tolerance of better than +/- 0.4% for all dynamic test cases.

In all static and dynamic testing, it is essential that the test parameters selected are similar to those typical of actual operational conditions and that intermediate as well as final calculated values are verified in all cases. This means that not only the final calculated gas volumes (e.g., Mcf) are confirmed, but also that transitional values[4] are confirmed as well.

FIELD TESTING, OPERATION, AND MAINTENANCE

The process of field testing a flow computer requires careful attention to detail and prudent correction and documentation of all problems and errors detected.

Field testing of flow computers consists of a visit to the field site whereupon the following items are checked and corrected if necessary.

All input values including the following.

- Pressure base
- Temperature base

[4] What are referred to in this article as “intermediate” and “transitional” values include discharge coefficient, compressibility, expansion factor, water vapor correction factors, acceleration of gravity correction, calculated Btu, calculated MMBtu (Dth), and other flow-dependent variables which are selected depending on the particular primary device for which the flow computer is designed.

- Static pressure source (e.g., upstream / downstream pressure tap for orifice meters)
- Gas composition source information (e.g., manually input, from GC, etc.)
- Compressibility calculation method (and, depending on method used, the source of gas composition, Sg, CO_2, N_2, etc.)
- Specific heats ratio (Cp/Cv) for differential pressure producers
- Gas viscosity (with special attention paid to the correct viscosity units)
- Meter tube diameter
- Orifice plate bore (or flow restrictor diameter/size)
- Required "K" factor or meter factor (where applicable)
- Transducer ranges and/or URL (original and as calibrated)
- Flags and alarms (settings and limits functionality)
- Peripheral component settings (gas sampling systems, odorant injector settings, etc.)
- Other input values as are applicable to the particular meter type or flow computer
- Transducer and transmitter performance

In addition, the following steps should be taken.

1. Thoroughly leak check entire measurement system from pressure source throughout tubing including all valves and connections and at the temperature well and sample point locations.
2. Determine the as-found condition of transducers including readings taken at or near typical operating conditions (e.g., temperature, pressure, and differential pressure checks).
3. Perform a re-calibration of transducers as necessary.
4. Determine the approximate error caused by any transducers which are found operating outside anticipated limits.
5. Record and document the as-left condition of all transducers.
6. Perform other checks as are applicable to the particular meter type and flow computer.

Experienced flow test laboratories and prudent investigators also check other items as applicable.

CONCLUSION

Gas measurement technology has improved significantly from the mid-1960s until today in 2011. The advent of flow computers, electronic flow measurement systems, and new metering technologies has drastically changed the way natural gas is measured. Even so, greater care today must be taken today in the selection of electronic flow computers.

REFERENCES

The following references are among those used in the preparation of this paper. Please contact the author through his Web site at ***www.StarkAssoc.com*** for questions, additional technical clarification, or comments.

1. American Petroleum Institute (API) — Manual of Petroleum Measurement Standards (MPMS), Chapter 21 – *Flow Measurement Using Electronic Metering Systems, Section 1 – Electronic Gas Measurement*.
2. AGA Report No. 7, *Measurement of Natural Gas by Turbine Meters*.
3. American Gas Association, Transmission Measurement Committee (AGA TMC) Report No. 9 (AGA-9), *Measurement of Gas by Multipath Ultrasonic Meters*.
4. AGA Report No. 3, *Concentric, Square-Edged Orifice Meters*.
5. Stark, Stephen T. — *Auditing Gas Measurement and Accounting Systems*. Proceedings of the International School of Hydrocarbon Measurement, Oklahoma City, Oklahoma (2002 and other years).
6. Stark, Stephen T. — Standards, Considerations Ensure Effective Auditing of Measurement Systems. *The American Oil & Gas Reporter* (October 2007).
7. Stark, Stephen T. — *Testing, Maintenance, and Operation of Electronic Flow Computers for the Gas Industry*. Proceedings of the International School of Hydrocarbon Measurement, Oklahoma City, Oklahoma (2010 and other years).