

# Testing Electronic Gas Measurement Flow Computers

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## INTRODUCTION

First developed in the middle 1960s, modern-era electronic natural gas flow computers came into wider use for custody transfer measurement beginning in the late 1970s. In the 1980s and 1990s, improvements in charging systems, microprocessors, and transducers made flow computers much more practical for everyday use even in remote locations. In the earlier days, gas flow computers simply calculated flow – and not much more.

Today, flow computer systems do much more than *just* calculate flow by providing extensive amounts of measurement-relevant data while also performing many tasks that are necessary in today’s complex and fast-moving energy industry.

In this brief article we will focus only on the custody transfer gas measurement issues that are relevant to testing natural gas flow computers.

## FLOW MEASUREMENT SYSTEMS COMPONENTS

An electronic flow computer (often called by abbreviations including EFM, EGM, EFC, etc.) is only one part of a flow measurement system. Many measurement systems are described as having three fundamental parts.

1. Primary device – the basic meter<sup>1</sup> type (e.g., orifice meter, ultrasonic meter, turbine meter, rotary-displacement meter, diaphragm meter, Coriolis meter, 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, may be contained in one or more incongruent enclosures or can be packaged, and even located, in the same general vicinity.

This article addresses only secondary and tertiary devices. Also, see API MPMS Ch. 21.1<sup>2</sup> and the many different meter-specific standards and reports which will provide additional valuable information.

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<sup>1</sup> The term “meter” as used in this article can also be read “flow meter” or “flowmeter” – a device used to measure flow.

<sup>2</sup> API MPMS Ch. 21.1 is currently undergoing revision. Those with an interest in gas measurement are strongly encouraged to become involved in reviewing and commenting on this important standard.

## FLOW COMPUTER TESTING

When we read the word “testing,” many things come to mind. Flow computers used for custody transfer and other critical measurement applications should be “*tested*” in at least two ways.<sup>3</sup>

1. Statically (static testing)
2. Dynamically (dynamic testing)

Both types of testing are necessary to understand how flow computer systems:

- Operate reliably under various flowing conditions and ambient temperature changes.
- Correctly calculate flow using reliable averaging methods while providing a viable audit trail.

Performing only one type of testing, such as static testing (sometimes called “bench-testing”) has often resulted in misunderstandings about the performance of a flow computer and its related systems.

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

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.

Following are some general thoughts relating to both types of testing.

### Flow Computer Static Testing

Since 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)<sup>4</sup> for flow rate and 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. There is no known way to strictly standardize such testing protocols and attempts to do so over the past thirty years, or so, have failed. Instead, the researcher must have a clear understanding of the equipment under test as well as its 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.

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<sup>3</sup> Some of the ideas presented here have been offered to other members of the API MPMS Ch. 21.1 standard-writing committee, but have yet to be included in draft revisions of that document.

<sup>4</sup> Fifty parts per million is 0.005%.

Values verified for orifice meters (and other differential pressure meters) include the following.<sup>5</sup>

- Conversion from psig to psia (as applicable, depending on flow computer, transducer type, and transducer design).
- Differential pressure (inches H<sub>2</sub>O @ specified temperature).
- Static pressure (psia).
- Temperature (°F, and correct conversion to °R).
- Discharge coefficient (Cd(FT) for orifice meters conforming to API MPMS Ch. 14.3).
- Pipe Reynolds number.
- Pressure tap location (P<sub>1</sub>, P<sub>2</sub>).
- Expansion factor (Y<sub>1</sub> or Y<sub>2</sub>).
- Velocity of approach factor (E<sub>v</sub>).
- Flow extension ( (Hw Pf)<sup>0.5</sup> ).
- Gas compressibility (Z<sub>b</sub>, Z<sub>f1</sub>, Z<sub>f2</sub>).
- Gas relative density (Gi or G<sub>r</sub>, as applicable).
- Gas density (where applicable, and based on the selected EOS)
- Gas heating value (Btu/ft<sup>3</sup>).
- Acceleration of gravity (F<sub>pwl</sub>).
- Accumulated flow time (minutes/hour).
- Instantaneous flow rate (Scf, Mcf, MMScf).
- Accumulated gas flow (Scf, Mcf, MMScf, MMBtu).
- Alarms.
- Logs.
- Audit trail (API MPMS Ch. 21.1).

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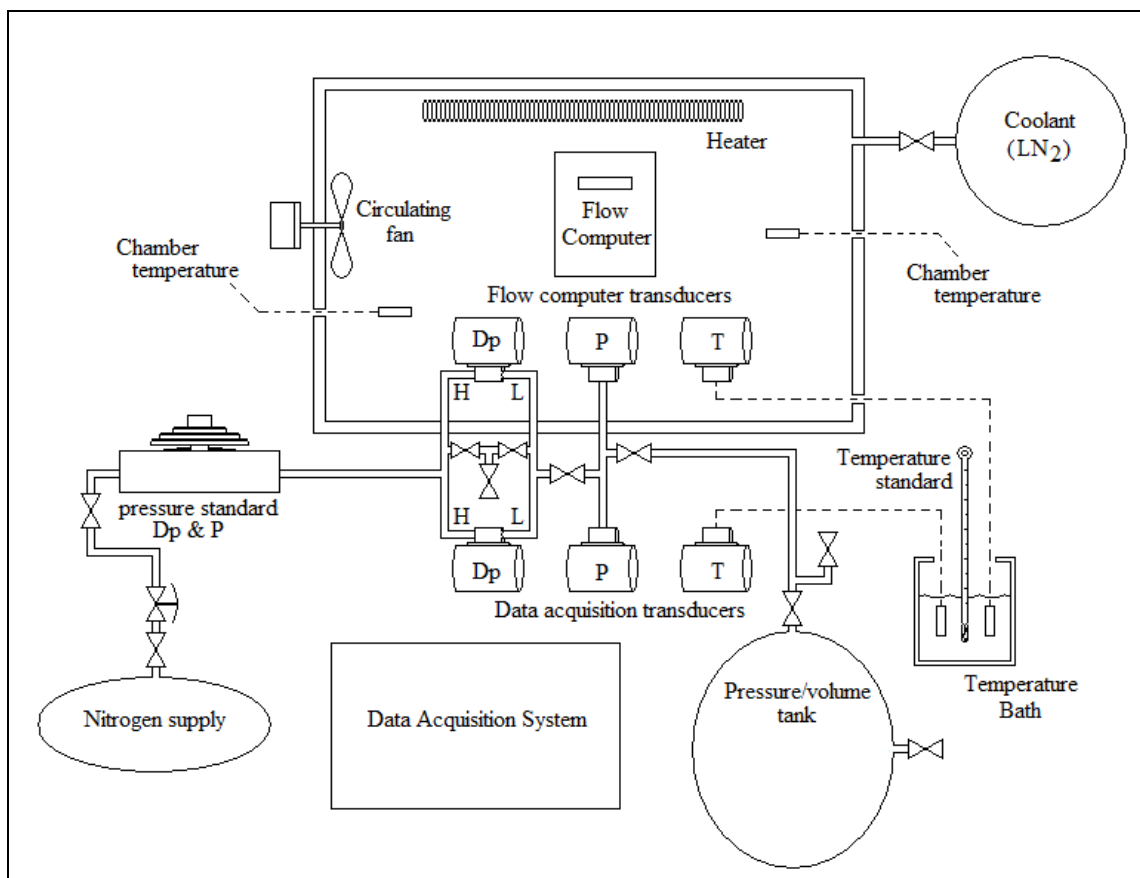
<sup>5</sup> The values which are verified depend on the specific meter type, design, and use.

- Isentropic exponent
- Gas viscosity
- Other parameters required by standards and specific meter type, design, and intended usage.

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 are reviewed.

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

Additional tests under controlled static conditions are conducted to define performance limitations under hot and cold ambient temperatures ranging from approximately  $-30^{\circ}$  F to approximately  $+130^{\circ}$  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 transducers and transmitters. Figure 1 shows the fundamental parts of a typical temperature test chamber that has been used in the evaluation of flow computer systems for more than three decades.



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

## Flow Computer Dynamic Testing

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.

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

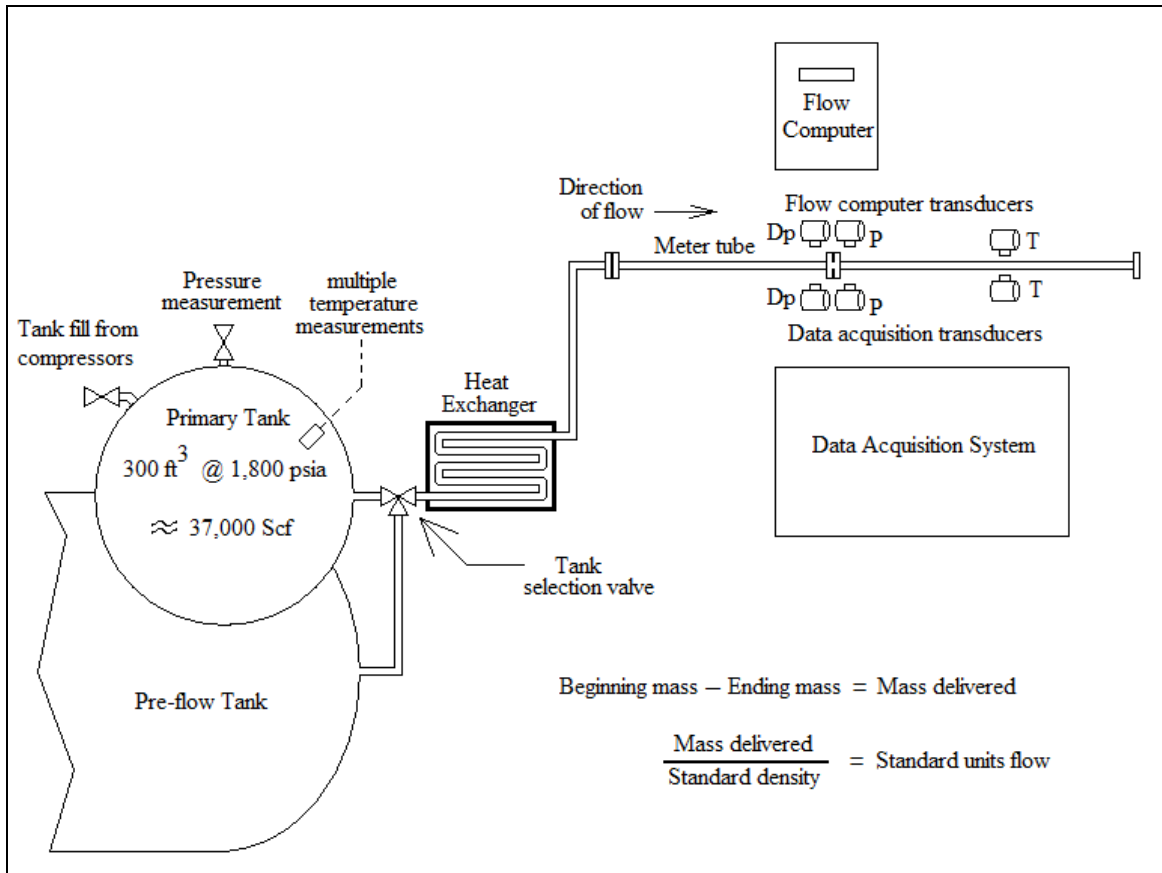


Fig. 2 – Primary mass flow testing system

Orifice 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 gaseous fluid may be used as long as its physical properties are completely identified and well documented. As a matter of practicality, ultrasonic meters and turbine meters should be tested using natural gas only.

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 should problems arise during testing.

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<sup>6</sup> are confirmed as well.

There is currently no standard addressing either static or dynamic testing, however such a standard would be of value to the natural gas industry and others having an interest in reliable flow computer performance.

## CONCLUSION

Gas measurement technology has improved significantly from the mid-1960s until today. The advent of flow computers, electronic flow measurement systems, and new metering technologies has drastically changed the way natural gas is measured. Even so, great care must be taken to ensure high quality in the testing, maintenance, and operation 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](http://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, 2009).
6. Stark, Stephen T. — Standards, Considerations Ensure Effective Auditing of Measurement Systems. *The American Oil & Gas Reporter* (October 2007).

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<sup>6</sup> 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.