

IMPROVING FLOW MEASUREMENTS WITH IMPROVED CALIBRATION AND DATA HANDLING PROCEDURES

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Introduction

The knowledge base from a field measurement technician to the measurement analyst is extremely demanding.

Every field technician is tested in both knowledge and skills on a daily basis regarding:

- Electronic controls to pneumatic controls
- Communication system support
- Multiple technical disciplines
- Support of measurement equipment
- Procedures that must be followed (SOP) – Standard Operating Procedures
- Regulatory requirements governing the facilities
- Ongoing training of field personnel

These factors and many more create a tremendous and constant challenge for every organization.

The gas measurement analyst requires a completely different set of skills to interpret and understand the information documented by the field regarding testing and calibration procedures. The task for the measurement analyst is to absorb the wealth of information presented, and utilize their extensive knowledge base in determining when a current month adjustment or even a prior month adjustment is warranted. Each time an analyst reviews data from the field, a question should be asked, “Did the technician follow the correct procedures in performing the calibration?”

Past to Present

In the past, every major company staffed its own measurement training facility. A company would provide the training at regularly scheduled intervals throughout the year. The training would often take place at a live gas facility and might include videos, classroom training sessions, and hands-on field training. Every company had their own set of Standard Operating Procedures (SOP) and the appropriate AGA, API, and GPA documents. The procedures in each document were taught, demonstrated, and executed by all measurement technicians. Each SOP had a standard form which outlined the procedure on how to successfully document the gas measurement data. Every measurement technician was cycled through multi-level training classes. Upon completion of each measurement level obtained, they received certificates and sign-off.

By the mid to late 90s, FERC636, deregulation and major corporate organizational changes resulted in the majority of the company-staffed measurement training facilities being discontinued. Many companies experienced major SOP modifications and consolidations. During that time period, consolidation forced the “retirement” of a significant portion of the industries gas measurement knowledgebase. Fortunately, the prior training investment was able to sustain the industries needs for a number of years going forward.

Today, new measurement technicians being hired do not have the benefit of the training and knowledge their predecessors received. The bar has been raised as new measurement technicians require computer skills and operations knowledge for the never-ending list of new equipment. In addition, the Operator Qualification programs have made a significant impact on required documentation and sign-off for new and existing measurement personnel.

Equipping the Technician to Perform the Task

Measurement technicians must have access to the essential verification equipment. This is critical for validating the temperature, pressure, and differential transmitters while also adhering to the company standards (SOP) for the validation of linear meters.

Gathering the proper equipment and assuring that it is certified by the National Institute of Standards and Technology (NIST) is part of this process. The use of stain tubes and additional gas quality verification equipment should not be overlooked as this is also an important part of the process. In order to meet each company's SOP, Tariff, and/or contractual obligations, the proper documentation of the calibration and test is critical.

In order to ensure the measurement technician understands how to properly operate the equipment, a thorough training and review process should be conducted. Part of this review process should include equipment operations with all the various RTU brands and models, as well as, their related components.

The following topics should be covered to make certain the measurement technician understands the importance and potential impact of the verification process:

- Boyle's Law
- Charles Law
- Deviation from Boyle's Law
- Typical standard units of measurement
- Basic Electronics
- Basic Math
- Volume Calculation to Energy
- Orifice Metering and AGA 3
- Turbine Meters and AGA7
- Positive Displacement Meters and AGA 7
- Ultrasonic Meters and AGA 9 and AGA 10
- Coriolis Meters and AGA 11
- AGA 8 - Compressibility Factors of Natural Gas
- API 21.1 – Electronic Gas Measurement 1st Edition (1993)
- API 21.1 – Electronic Gas Measurement 2nd Edition (2013)
- Overall Measurement Accuracy
- API 14.1 Gas Sampling (Include Safely Transporting Gas Bottles/Samples)
- Chromatograph
- Specific Gravity Determination
- Determination of Moisture Content
- GPA 2172-09
- Automatic Control of Flow and Pressure
- Control Valve and Regulator Equipment
- Odorization
- Electronic Flow Computer
- Supervisory Control and Data Acquisition (SCADA)
- Corrosion Control and Cathodic Protection in Pipeline Operations
- Communication Techniques
- Safety Issues

Importance of Scheduling Inspections and Calibrations

The scheduling of meter test inspections and calibrations, gas sampling, and routine maintenance is crucial. Most company's tariff's, SOPs and/or contracts specify the frequency for the required tasks. Some facilities scheduling requirements are also driven by governmental agencies such as the Bureau of Ocean Energy Management (BOEM) formerly the Mineral Management Service (MMS) and Bureau of Safety and Environmental Enforcement (BSEE) formerly the Bureau of Land Management (BLM), Measurement Canada, plus State and Province regulations. There are a number of gas companies with significant exposure in the industry due to their inability to comply with their scheduled meter test inspections dictated by their contract, tariff, or SOP. When companies deal with a significant number of monthly inspections, the task to schedule these inspections and calibrations becomes labor intensive. It is usually during an audit that organizations determine whether they are in compliance with their scheduled commitments.

Many natural gas companies have taken advantage of computer based tools to document the required tasks along with the schedule for performing these tasks. These industry utilized tools can provide the required information in a format that makes it quick and easy to identify delinquent tests and therefore minimize a company's potential exposure. One of the strengths of these computer based tools is the ability to sort and prioritize the work by area, region, and throughput. This leads to better utilization of a technician's time. Figure 1 below illustrates how easily a delinquent test is identified and depicted. This calendar view (whereby delinquent tests are highlighted in red) is just one of many ways that the schedules can be viewed, reported, and exported.

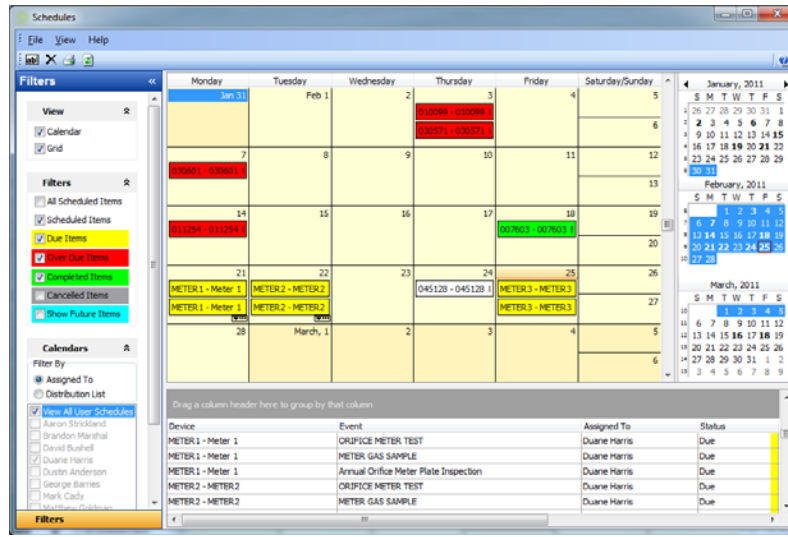


Figure 1. Calendar View

Understanding the Testing and Calibration Form

The importance of standardizing on an inspection/calibration form, whether it is paper or electronic, is essential in developing a consistent interpretation across all regions of a corporation. It is difficult for the measurement analyst or technician to interpret five different regional forms to determine if the information is complete, conflicting, or wrong. When a company incorporates standardization in both their form and procedures, it helps to eliminate some of the often confused aspects of a test (as listed below).

1. Is the working pressure zero adjusted prior to adjusting the atmospheric pressure zero?
2. Is the working pressure zero adjusted prior to determining the "as found" multi point calibration?
3. When making adjustments to the multi point calibration, are the adjustments made at each point or at the conclusion of the multi point calibration?
4. Is your calibration equipment PSIG or PSIA as compared to the transmitter?
5. Should any adjustments be made to the transmitter based on the multi point calibration or should the transmitter be replaced and recalibrated at the factory or certified facility?
6. The ability to attach pictures of key witnessed events is critical to the documentation process. As they say a picture is worth a thousand words as pointed out in Figure 2.



Figure 2. Picture to attach to documentation

Conducting the Test and Calibration

Typically, a fairly rigid guideline should be followed throughout the testing and calibration process to assure all steps are covered with the highest level of accuracy and reduced uncertainty. Following the best recommended practices of the AGA, API, or GPA is essential during this process. A technician should have a copy of the company's tariff, contract, or SOPs during the testing and calibration process. Procedural changes at a facility can often lead to a mistake or error on the verification/calibration report. Examples of such events that can cause deviations include weather, additional help, equipment malfunction and a witness.

The SOP governing each task should note what is required on the form before the task is considered complete. The AGA, API, and GPA have a recommended "best practices", and provide a listing of the essential information needed on the form, as well as its specific purpose. Good measurement training explains the consequences of incomplete test data and ensures that the technician understands the importance of properly documenting each test. Proper training, when coupled with a company's SOP, will yield more consistent measurement practices and provide an organization with better audit results.

The "As Found" meter values (when arriving at the meter) are often considered critical in helping determine the error. To determine the meter error as related to the test, most companies either utilize the "As Found" reading or they utilize the last month, quarter, or yearly average of the flowing parameters (depending on the testing and calibration frequency of the meter). Please review the Figure 3 diagram (as referenced from RANSolutions) below as a recommended Transmitter Verification and Calibration process. Its best to follow the companies recommended guidelines in determining where the threshold exists between a verification of "Yes" and "No". The threshold might be between 0 - ± 0.125 inches or pounds on the differential and/or static pressure transmitters and 0 - ± 0.5 degree for the temperature transmitter. The company may want to replace the transmitter or recalibrate the transmitter (based on their recommended practice) if the threshold reaches 0 - ± 0.250 inches or pounds on the differential and/or static pressure transmitters and 0 - ± 1 degree for the temperature transmitter

Transmitter Verification and Calibration Process

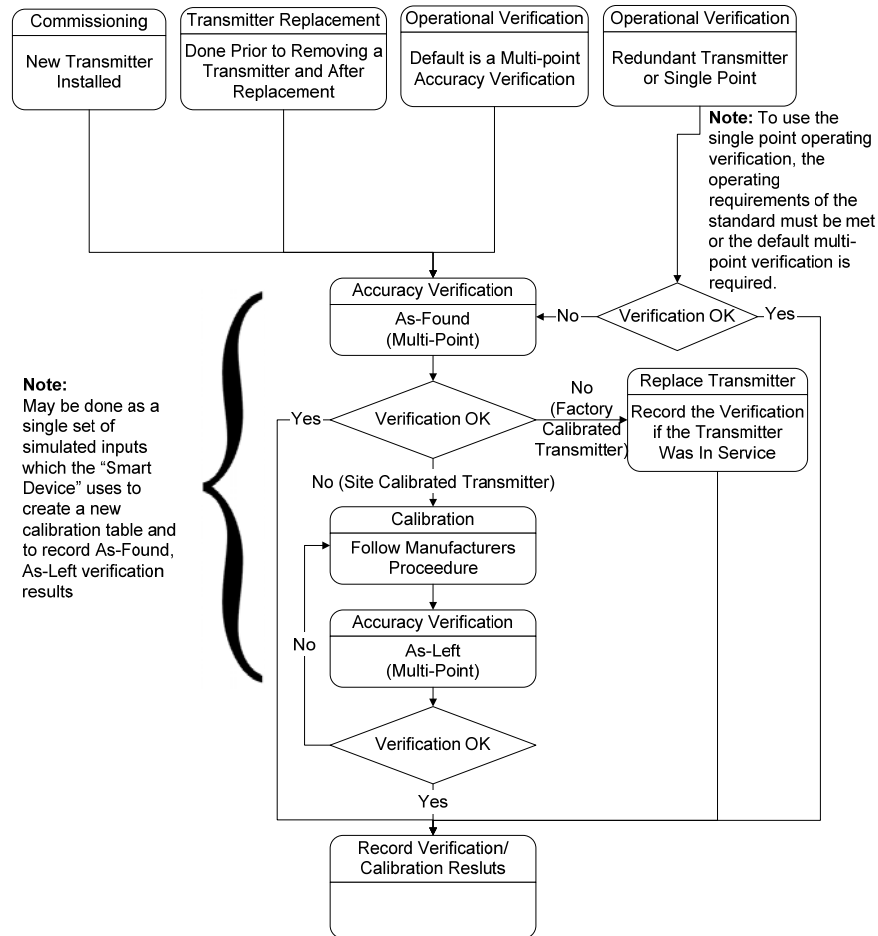


Figure 3. Transmitter Verification and Calibration Process Flowchart

Extreme caution should be taken while performing the verification on all transmitters due to the ability to impact that transmitters' hysteresis. *"Hysteresis - The lagging of a physical effect behind its cause (as behind changed forces and conditions) < all manometers must be tested for hysteresis as well as for sensitivity and natural frequency"* Quoted from Merriam-Webster's Dictionary.

The main caution regarding hysteresis pertains to when a technician adjusts the transmitter in order to bring the transmitter back into calibration. The process of adjusting the transmitter may have caused a hysteresis effect during the calibration process moving the transmitter out of calibration when the transmitter recovers from its hysteresis.

Once the technician has performed a multipoint calibration and successfully avoided any effect of hysteresis, the next step is to determine that an error exists. The error for differential pressure as seen below is a good formula for determining the "As Found" error at each point in the verification process.

Differential Pressure:

As Found = 99.82

Standard (Reference) = 100.0

$V(f)$ = Flow Rate at found conditions

$V(s)$ = Flow Rate at standard conditions

Error = $100 * (V(f) - V(s)) / V(s)$

Equation 1. Differential Pressure Error Calculation

$V(f) = V(99.82) = 33.956$

$$V(s) = V(100.0) = 33.987$$

$$\text{Error} = 100 * (33.956 - 33.987) / 33.987$$

$$\text{Error} = -.0898\%$$

These calculations should be based on using initial found conditions for static pressure and temperature along with the effective gas quality and current meter characteristics.

This exact formula can then be followed for determining the error at each standard or reference point for differential pressure, static pressure, and the temperature. Reference Figure 4 below.

Test Points	Standard	As Found	As Left	Flow Rate Error (%)
1	0.00	0.00	0.00	
2	125.00	125.10	125.00	0.12
3	250.00	250.10	250.00	0.06
4	200.00	200.10	200.00	0.07
5	50.00	50.00	50.00	0.20
6	10.00	0.00	0.00	

Figure 4. Differential Pressure Screen Shot

A similar formula can be followed to determine the Total Error of the meter as summarized below:

$$V(i) = \text{Flow Rate at initial found conditions}$$

$$V(a) = \text{Flow Rate at adjusted conditions}$$

$$\text{Error} = 100 * (V(i) - V(a)) / V(a)$$

Equation 2. Total Error Calculation

Reference Figure 5 below.

Flowing Conditions	Found	Left	Average
Differential	25.00	30.00	22.00
Pressure	650.00	649.00	650.00
Temperature	72.00	74.00	70.00
RTU Flow Rate	3471.00	3788.00	

Figure 5. Total Error Screen Shot

Processing the Test and Calibration Form – The Challenge: “Checking vs. Auditing”

The final step in the calibration and testing process often times receives the least amount of focus and therefore provides sketchy end results due to difficulty of the task. Time invested in this effort will have a direct bottom line impact on measurement. This process will provide the ability to determine a number of items including, but not limited to:

- when an adjustment should be made
- what equipment is out of tolerance
- where suspect plate sizes and tube-ids are in use on the system
- which measurement technicians may require additional training

For years the process of reviewing the calibration and testing forms has been a manual process or “checking”. A significant amount of time has been invested in validating plate sizes, Tube Ids, K-factor, Meter Multipliers, various transmitter/chart ranges, various transmitter/chart calibrated ranges, RTU gas quality, not to mention the endless list of user defined fields that every company requires and views as critical. The ability to identify any substantial variances in a manual environment depends upon the education and training of a measurement analyst. Most companies provide a plus/minus tolerance for static pressure, temperature, and differential pressure based on certain ranges. An analyst must perform additional analysis to determine if the adjustment made a 2% volume difference.

Today all of these processes of identifying variances can be automated and flagged to direct the analyst to problem areas automatically, eliminating the need to review every calibration and test report. The validation process can now be configured to create exceptions when warranted for all calibration and test reports received. An analyst can easily review automatically flagged data including:

- Plate Sizes and Tube Ids are different
- K-factors, meter multipliers various transmitter/chart ranges, various transmitter/chart calibrated ranges are different,
- Unique company required fields

All meter adjustments can be processed automatically or “audited” to determine if an adjustment is required based on the calibration and testing results for each reference point. Any auditor in the industry will strongly urge all companies to review each calibration and test report either through a manual or automated exception based process to make certain all reported discrepancies are identified and resolved.

Conclusion

Taking a few steps and reviewing existing measurement processes can provide some direction and help improve measurement accuracy.

1. Existing SOPs, contracts, or tariffs that dictate the scheduling of meter test inspection/calibration process should be reviewed. The following questions should be addressed:
 - Are all processes documented?
 - Are all measurement personnel trained in the complete process as described in your documentation?
 - Are all measurement personnel trained in completing the form properly?
2. Review the scheduling tools for meter inspection and calibration by asking the following questions:
 - Can compliance to testing and calibrating meters be determined on a daily basis?
 - Can a report be easily generated in the instance of an audit?
 - If needed, can a meter test inspection be provided for the last two inspections?
 - Over a year’s period of time, can the variance in the data easily be seen?
 - Where is the test meter data kept, and how easily can it be accessed?

3. Review the procedures for processing test meter data from the field. All processes should be documented for this “checking” procedure. Identify the companies “plus/minus” tolerance.

Reviewing the calibration and data handling procedures will improve the measurement accuracy and continue to reduce measurement uncertainty. This will not only improve customer relations, but can also help manage unaccounted-for gas loss.

The calibration and testing procedures continue to change and improve just about as frequently as the equipment and training requirements. It is imperative for every company to keep up with industry standards and gas measurement practices. By participating in measurement schools, companies will be able to stay current with the latest industry trends and policies. Time spent wisely on this endeavor will benefit every company.