TRAINING FIELD MEASUREMENT PERSONNEL

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INTRODUCTION

Technology in the field of gas measurement and control is constantly evolving. Although many are well trained in the specific equipment used in their own company's operation, it is also important to have a solid understanding of the fundamentals and theory of operation of the mechanical and physical processes involved. Therefore, the training of field measurement technicians is of the utmost importance. These technicians must be continually educated to have the most current knowledge of the latest equipment, electronics, communications, and metering devices on the market. Also, it is essential that this type of instruction be taught in a controlled environment where the technicians can learn and develop the necessary skills with the least number of interruptions from external sources.

BEFORE FERC 636

In the 1980s, many of the larger companies owned individual training centers where engineers attended regularly scheduled training and where this training was specific to the company, its equipment, and operation. Many of these companies formalized their training programs to certify their personnel. A certified technician would be trained to operate and maintain every type of field equipment.

Federal Energy Regulatory Commission Order 636 (April 1992) fostered competition in the natural gas industry by ensuring that all natural gas suppliers compete for gas purchasers on equal footing. Its policy goals are to enhance competition in the natural gas industry and to ensure that adequate and reliable service is maintained. Prior to Order 636, pipelines bought natural gas from producers and sold it to customers, in competition with other sellers. Bundled rates included charges for services such as transportation, storage, and peak shaving. Order 636 required pipelines to separate the offering and pricing of gas sales from the transportation of natural gas, with this unbundling taking place at a point near the gas production area. Pipelines are required to transport gas in a non-discriminatory fashion, regardless of who owns the gas. Pipelines can offer firm and interruptible sales services and must offer a variety of transportation services, including an unbundled no-notice, firm transportation service and storage on an open access basis. This meant that ancillary operations, such as training facilities, lab analysis facilities and other non-transportation costs, could not be tied into the transportation costs.

AFTER FERC 636

With deregulation in the 1990s, the industry went through major changes. The major U.S. gas pipelines went from being regulated rate-based operators to being deregulated market price-based transporters. This change in business drove consolidation, debt restructuring, and budget cuts. Most companies eliminated or significantly downsized their training programs, and gas measurement was not a priority. Further, the price of gas was averaging in the $1.25 to $1.75 range, so measurement became even less of a priority. During this time, companies reduced staff, and training that occurred was largely on the job.

In general, the gas industry attempted to hire new personnel, and as a result, companies supported their operations by using mature, well-trained gas measurement professionals, many of whom were downsized by one company and then hired by another.

In 2005, the industry recognized that the aging of the existing workforce would soon create an immense need for new measurement and automation professionals. Most companies had an average field technician age of 45, and many have an average age of over 50. In the next 5 to 15 years, virtually all of the business expertise in the industry will be eligible for retirement.

TRAINING NEEDS THEN VERSUS NOW

Most of our current workforce learned measurement when the devices were largely mechanical or pneumatic. They often came from a background where they had formal training or experience in the mechanical aspects of the equipment. Also, they came to work in an environment where time was set aside in large blocks to learn the theory and electronic aspects of their jobs. In the 90s, this highly skilled workforce was focused on learning the electronic and computer skills necessary to work with modern measurement equipment.

In today's environment, entry-level measurement technicians often have a 2-year college degree in electronics or instrumentation and have grown up with computers. Typically, they are very comfortable with technology but have had little exposure to the theory, math, and hands-on tasks required.

This means that to bring new measurement engineers and technicians on board, they need not only on-the-job training but dedicated theory and hands-on application training.

CHALLENGES

In today's environment, it is rare that a mature engineer or technician can be released from normal job duties to attend training for more than four days. Consolidation and downsizing in the gas business has created situations where an employee has more responsibility and accountability for more gas measurement points, making it difficult to attend long-term training. Therefore, for training to be worked into the senior employee's schedule, it needs to be in short segments of 1.5 to three days.

In many cases, the individual became a measurement technician upon a previous measurement employee leaving their job, and no intellectual knowledge was written or transferred. In some cases, a pumper is told one day he will now be a measurement technician and is sent to a short 3- to 4-day measurement school, such as ISHM or ASGMT, in hopes of getting him up to speed in short period of time.

Typical training in many cases has become the "Big Bubba Method" where an experienced measurement technician shares his knowledge with "Little Bubba" whether that knowledge is valid or not. Complicating the problem is lack of a current set of Sarbanes-Oxley standard operating procedures (SOPs) for gas and liquid measurement. With little knowledge transferred, both physically and in writing, a new measurement technician is left to "swing in the wind" to determine how best to be trained.

Ideally, a company would take their most senior measurement executive out of the field to conduct training for their measurement technicians. The challenge is that the senior measurement lead needs five weeks of preparation for one week of training, which the company might not find feasible. Due to the nature of the gas measurement business, there may not be enough personnel to support in-house training without operations suffering.

Another challenge is the nature of "triage" of our measurement technicians, where companies require their personnel to wear multiple hats. Not only is a technician performing measurement but also may be troubleshooting communications, pigging, or other duties with no relationship to measurement. Training the triage technician in his primary measurement job may be difficult under the best of circumstances.

Expediting training is important for those companies already in the midst of staffing up and replacing their retiring workforce. Unfortunately, formal gas and liquid measurement training has been focused on vendor or manufacturer training, which is comprehensive from an equipment viewpoint, but is rarely based in API, AGA, or GPA standards. Standards-based training can be the most difficult training because it requires an instructor who has familiarity with the standard and can relate the importance of the measurement practice.

REASONS & BENEFITS

Even with all its challenges, effectively delivering training remains an increasingly important issue. Following are some of the most significant reasons for training field measurement personnel.

1. By developing a thorough understanding of gas measurement, each technician can contribute to maximizing measurement accuracy, thereby directly affecting the revenue generated through the sales, purchase, or transportation of natural gas.

2. Gas measurement equipment is consistently being upgraded to accommodate the changes in technology and the rulemaking policies required by FERC. Therefore, the technician has more responsibility to operate and maintain the measurement equipment according to the manufacturer's specifications and the standards mandated by FERC.

3. Formal classroom training provides better control for consistent implementation of company policy and procedure than on-the-job training where senior technicians pass down the "tricks of the trade" to an apprentice and is no longer an accepted methodology for training gas measurement personnel.

4. Hands-on training in a live gas environment is superior to classroom training only, as training is delivered in virtually the same environment as the technician faces in the field.

5. Training on the most current measurement devices, electronics, and software provides even the senior technician with the skill to properly and efficiently implement state-of-the-art techniques into their daily roles and responsibilities.

6. Formal training programs that are integrated into the career development and performance review process enable companies to meet the intent of operator qualification requirements.

7. As senior personnel retire and leave the workplace, new employees will need training in all aspects of natural gas operations and measurement. A formal training program designed to meets these needs can improve operations and safety.

AGA WHITE PAPER ON TRAINING GAS MEASUREMENT TECHNICIAN

In 2010, the American Gas Association (AGA) identified the need to provide a comprehensive list of tasks, including the minimum knowledge, skill, and time requirements to develop necessary competence for measurement field personnel. The AGA Transmission Measurement Committee determined that management at many gas measurement companies had little guidance in the challenges of maintaining adequate training regimes that produce measurement technicians with the skills and competencies required to perform measurement tasks safely and effectively. In issuing the *Natural Gas Measurement Technician Training and Development Guidelines* white paper, AGA provided recommendations for skill development.

The white paper proposed a training guide to be a precursor to demonstration of competence. Competency is defined in the white paper as *the ability to safely and proficiently execute tasks without supervision*. A table in the white paper lists a series of tasks that are considered to be relevant to the operation of measurement facilities. The tasks are categorized as either base knowledge (B) or advanced knowledge (A). A recommended minimum and an expected maximum number of training and skill development hours required to reach competency are listed for each task. For example:

Task	**Level**	**Recommended Minimum Training Hours**	**Estimated Maximum Training Hours**	**Recommended Minimum Skill Development Hours**	**Estimated Maximum Skill Development Hours**
Clean & Inspect Meter Tubes	Base	8	12	8	16

According to the white paper, skill development hours represent time spent on the job to develop proficiency. Further, it stipulates that companies should evaluate the listed tasks to determine appropriate hours required to reach competency (training and/or skill development) for their specific measurement job description. The ranges in the white paper are estimates, and it is left to a company's discretion in establishing an effective training and competency program.

Ideally, measurement technicians are trained according to the AGA white paper and Sarbanes-Oxley SOPs.

SARBANES-OXLEY GAS MEASUREMENT STANDARD OPERATING PROCEDURES

No training program will be effective in any organization for gas measurement without a comprehensive set of Sarbanes-Oxley (SOX) compliant gas measurement SOPs. Why SOX for training? Why SOPs for training?

Sarbanes-Oxley is the most comprehensive law governing corporate financial balance sheets since 1934 when the Securities and Exchange Commission (SEC) was created in 2002. SOX is a regulatory requirement that requires complete transparency of all financial transactions up to the highest levels of the company. Because gas measurement is a financial transaction (or cash register), it follows that all gas measurement transactions be compliant with SOX regulations.

Companies have been in the process of implementing SOX Section 404, Management Assessment of Internal Controls, to establish and maintain an adequate internal control structure and procedures for financial reporting. A control is defined as *a process designed to provide reasonable assurance regarding the achievement of objectives for effectiveness and efficiency of operations, reliability of financial reporting and compliance with applicable laws and regulations* (www.sec.gov). Simply stated, controls are documented, traceable evidence of the path of information from field to financial allocations. Companies who choose to be in compliance with SOX ensure their measurement controls are represented by their SOPs, which protect not only the company image and reported value but also employee (and third-party) jobs and personal integrity.

Many companies have implemented their own SOX-compliant SOPs for gas and/or liquid measurement. These SOPs are based on AGA, API, and GPA standards and reflect the contractual relationships with their partners. An up-to-date set of gas measurement SOPs is essential to any training program for new measurement technicians. Without a set of SOPs, measurement training turns into a "Big Bubba" training, which lends itself to measurement errors and problems.

Training without SOPs is definitely a disadvantage. Here are a number of reasons why companies should consider having a set of SOPs:

- Reflects company's contracts.
- Reflects company's commitment to Sarbanes-Oxley management controls.
- Provides guidelines to both experienced and new measurement personnel on measurement processes.
- Provides guidelines to third-party measurement vendors.
- Provides training documentation.
- Provides proof during audits of company's best practices.
- Provides clear procedures for new BLM Onshore Orders 3174 and 3175.
- Reduces risk by allowing company to operate in good faith with partners.

HANDS-ON & LIVE GAS

The most effective method of teaching and training should be done under actual operating conditions. This type of learning technique has a greater impact on the technicians because all the training utilizes equipment that is under line pressure and contains natural gas. When a technician is wearing safety equipment and working on flow or pressure controllers in a live gas environment, the schooling procedures of hands-on training create a realistic atmosphere where the technician learns to perform tasks under actual conditions.

It is clearly apparent that learning under authentic working conditions in a controlled training environment has a definite advantage. Through this method, technicians learn through experience to develop the problem-solving expertise that is necessary to enhance their troubleshooting techniques. At the same time, technicians learn proper safety procedures.

In this way, newly developed skills are immediately transferred to daily operations for resolution of operating and maintenance problems as they arise in the field. Technicians should be trained to handle and resolve a wide range of complex problems when working with gas measurement and control equipment.

To be a productive employee in today's market, it is imperative that technicians receive training on different types of measurement equipment available in the gas industry. These diversified skills and knowledge will enable technicians to be valuable employees who have the ability to increase their company's net profit.

EXAMPLE CURRICULUM

Typically, field measurement technicians have a variety of necessary gas measurement skills. Following is a list (but by no means comprehensive) of skill sets that every company should ensure that their field people possess and fully understand. Ultimately, each employee should understand the relationship between these activities and the company's profitability.

Any training curriculum should include testing and skills demonstration to assure effective learning by the students. In addition, it is important to note that a curriculum should be tailored to the needs of the student population to optimize investment in the program.

<u>Basic Principles of Gas Measurement</u>

Fundamentals encompass an understanding of principles that guide all measurement practices. The foundation of all measurement is based on AGA, API, and GPA principles. It is recommended that fundamentals training be grounded first in developing skills in basic mathematics. This ability enables the student to understand and use the simple equations encountered through the course of further training.

Part 1: Basic Math

A great deal of work done in the measurement of natural gas cannot be accomplished without a general knowledge of mathematics. The mathematical functions necessary to calculate areas, volumes, and flow through a pipeline are a requirement of this course.

Part 2: Fundamental Gas Law

The absolute pressure, absolute temperature, and volume of gas are very closely linked. Changes in any of these variables cause changes in one or both of the others. Therefore, the behavior of gas is reviewed to enable visualization of physical processes involved when these changes occur.

Part 3: Specific Gravity
By definition, specific gravity of gas is the ratio of its density—or weight per volume—to the density of air. In measurement work, especially when using formulas for calculating amounts of flowing gas, the specific gravity of the gas is an important factor. This course discusses how specific gravity is measured and used and discusses the equipment used to determine specific gravity.

The study should include purpose and principles of measurement equipment such as manometers, pressure gauges, deadweight testers, and recording thermometers.

Boyle's Law, Charles Law, deviation from Boyle's Law, and standard units of measurement are the particulars studied to obtain a working knowledge of the relationship between pressure, temperature, and volume.

Differential Measurement Training

Orifice Tubes, Orifice Plates
Development of an understanding of flow measurement by means of an orifice is required based on AGA Report No. 3, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids*, (also API 14.3). Also, the theories of orifice measurement and the physical application should be presented. AGA 3 guidelines pertaining to actual dimensions of orifice meter runs and their appurtenances are reviewed. The bellows type orifice meter is also studied in detail.

This hands-on training portion should provide the participant the opportunity to perform inspections to determine if an orifice meter meets AGA 3 specifications. The practice of inspecting, adjusting, and calibrating orifice meters under actual (gas flowing) conditions to teach normal operating and safety procedures should be learned and demonstrated.

Electronic Flow Computer
This course should teach operations and maintenance of electronic digital field computers with special emphasis on gas flow computers and API MPMS Chapter 21.1, *Flow Measurement Using Electronic Metering Systems – Section 1: Electronic Gas Measurement*. The content of this course assumes understanding of basic DC electricity, the use of volt ohm and current meters, and familiarity with basic circuit components. However, no knowledge of computers on the part of the participant is required, as this course develops a fundamental understanding of an electronic computer. Specifications, flow calculations, installation, operation and maintenance are discussed along with hands-on training.

Volume Calculation
In this course, the various correction factors used to calculate gas flow through an orifice should be conveyed in detail. Also, calculations pertaining to gas flow through positive and turbine meters should be included.

Gas Quality Training

Gas Sampling
Natural gas is sampled for many reasons to determine quality and quantity based on GPA Midstream Association Standard 2166, *Obtaining Natural Gas Samples for Analysis by Gas Chromatography*, and API MPMS Chapter 14.1, *Natural Gas Fluids Measurement, Section 1: Collecting and Handling of Natural Gas Samples for Custody Transfer*. Techniques for sampling must vary according to the type of test for which the sampling is done. Locations of sampling points, sample size, sample pressure, when and how the sample is taken are all dependent on the desired result. Participants should acquire knowledge of the general purpose for which a sample is being taken prior to actually taking the sample. Participants should learn and demonstrate industry-accepted methods to transfer a representative sample from a source (usually a pipeline) into a transporting device (usually a sample cylinder), to transport the gas from the source to the lab without affecting the representative sample, and to remove the sample from the transporting device and divert it to the measuring device without distorting the sample.

Determination of Moisture Content
Excessive amounts of water vapor in gas can condense and form liquid or ice-like hydrates that inhibit the flow of gas. Even as a vapor, it takes up space that could be occupied by gas. Water can also combine with other contaminates, such as CO_2 and H_2S, and form acids that can corrode the pipe. For these reasons, water vapor must be removed from the gas stream. This course presents in detail the methods used for determining water vapor content and the industry standard of 7 pounds of water per MMCF.

Odorization
This course is should provide a complete understanding of natural gas odorization. Information is presented on the many aspects of odorization, including odorant compounds, odorization equipment, test methods, and appropriate recordkeeping.

To comply with 49 CFR 192.625, odor level instruments must be used to assure proper concentration of odorant. Therefore, several odorant level test instruments are discussed and actual tests performed to provide training, using the best industry-accepted methods.

Chromatograph
A chromatographic gas analysis provides a quantitative breakdown of gas composition based on GPA 2166 and API 14.1. It is, therefore, the purpose of this course to provide an understanding of the principals involved and training in the operation of special equipment used to obtain a gas analysis.

Linear Meter Training

Coriolis Meters
Both API 21.1 and AGA Report No. 11, *Measurement of Natural Gas by Coriolis Meter*, address Coriolis measurement. Coriolis meters measure mass flow rate effect by measuring tube displacement resulting from the Coriolis Effect. Utmost importance is understanding the meter operates accurately with any of the “normal range” natural gas composition mixtures specified in AGA Report No. 8, *Thermodynamic Properties of Natural Gas and Related Gases.*

Turbine Meters
Flow measurement by means of turbine metering should be presented in detail in this course. Also, the advantages and disadvantages of using a turbine meter, along with its operating principles are presented. AGA Report No. 7, *Measurement of Natural Gas by Turbine Meter,* guidelines for turbine meter runs and their appurtenances are reviewed.

Ultrasonic Meters
This course should provide an understanding of the principles of an ultrasonic meter based on AGA Report No. 9, *Measurement of Gas by Multipath Ultrasonic Meters*. Transit-time multipath ultrasonic meters are inferential meters that derive the gas flow rate by measuring the transit times of high-frequency sound pulses. Understanding the accuracy of the ultrasonic meter and various factors that can affect the meter’s performance is important to the uncertainty factors.

Basic Electronic Training

Principles of Automatic Control (Controllers)
Automatic controllers to control pressure and flow rate are useful tools, but to use them, one must understand the basic principles of automatic control. In this course, the basic principles should be presented in everyday words. Basic responses of controllers should be illustrated with common, familiar devices. Simple graphs show how the measured variable acts under regulation by an automatic controller. Proportional band, reset action, derivative response, offset and other terms in the language of instrumentation should be simply explained to help people who are not instrument specialists.

Control Equipment (Valves and Regulators)
This course encompasses the study of fundamental gas pressure regulation with special emphasis on the regulator's operation. The essential elements of a regulator and function of each element are thoroughly discussed. The first part of the course is devoted to self-operated and pilot-loaded regulators. The course then goes into a thorough investigation of the operation and different applications of expansible-tube type regulators.

The third part of the course deals with the selection of control valves. Special attention is given to diaphragm-operated globe valves and also ball valve regulators. Split range control and valve positioners are discussed.

This is primarily a hands-on course where the students disassemble and reassemble regulation equipment to gain complete understanding of their operation. Students will also field adjust regulators, relief valves, and control equipment on a live natural gas station.

Basic DC Electricity
Depending on the pre-qualifications for a measurement technical, a course primarily designed for the entry-level student, where no sophisticated math background or previous knowledge of electricity is assumed may be required. Therefore, with this course, an entry-level student can learn the basic concepts of DC electricity.

Basic Electronics
Electronics is a field of study that comprises many different components, circuits and systems. In the interest of time, only those areas that affect electronic measurement equipment will be studied; however, other items may be briefly discussed. Digital electronics will be the main emphasis of this course.

After some preliminary material is covered, a variety of electronic components will be studied, such as diodes, transistors, and integrated circuits. Then, some electronic circuits will be presented, such as amplifiers, oscillators, and power supplies. The bulk of the course will be devoted to digital electronics, including number system, logic circuits, counters, registers, and memories. Also, analog to digital (A/D) and digital to analog (D/A) conversion will be discussed.

Electronic test equipment, such as multimeter and oscilloscope, usage will be included in the laboratory experiments. Overall, this course will provide a very good understanding of the workings of electronic systems.

Again, depending on the pre-requisites for a new hire, this course may or may not be required.

Electronic Instrumentation
Measurement technology is rapidly changing, particularly in terms of the electronic aspects. Process variables are measured and calculations are made instantaneously. The variable measurements (differential, temperature, etc.) are made by a variety of transmitters or transducers. These devices along with their practical applications and operations are thoroughly reviewed.

CONCLUSION
Today's field of gas measurement has created an environment where the learning curve is no longer a variable in the gas industry but a constant. Training has evolved into a continuous learning process that proceeds throughout one's career. Many factors go into training measurement professionals.

Here are some questions that companies should be asking:

1. Do you have a formalized training program?
2. Have you identified which tasks your measurement technicians need to be trained on?
3. Do you train to your up-to-date SOPs?
4. Have you identified how much time is allocated for training during first of year of a new measurement technician?
5. Do you test and record the scores?
6. Are your measurement technicians “triaged”? What percentage of their time is spent on gas measurement tasks?