

AUDITING ELECTRONIC GAS MEASUREMENT PER API CHAPTER 21.1

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Introduction

Auditing evolved as a business practice as owners began to realize a standardized form of accounting must exist to prevent fraud. Financial audits made their way into businesses during the late 1700s. The industrial revolution brought about the separation of job duties beyond what a sole proprietor or family could oversee. Managers were hired to supervise the employees and the business processes. Businesses began to expand geographically where previously they were all local. Owners, who could not be in more than one place at a time or chose to be absent, found an increasing need to monitor the accuracy of the financial activities of their growing businesses. Owners responded by hiring people to check their financial results for accuracy, resulting in the process of financial auditing. In the early 1900s and at the request of the Securities and Exchange Commission, the auditors' reports of duties and findings were standardized. Financial auditors developed methods of reporting on selected key business cases as an affordable alternative to examining every detailed transaction. It was found with auditing that the evaluation of both financial risk and financial opportunity was improved.

The fingers of the financial audit began to reach into other areas of business operations. Owners became interested in the integrity of the financial transactions and began to look at the values used to generate them. Business owners began to understand that not only are the numbers important, the neutrality and consistency of their derivation is important as well. This most recent wave of fraud protection in auditing practices culminated in the Sarbanes-Oxley Act of 2002 (SOX).

Decades prior to SOX, the auditing process reached into gas measurement. Auditing of gas measurement is particularly relevant because gas measurement can be directly tied to the monetary value of natural gas through both the quality and the quantity of the gas. However, the gas measurement process is made complex because the commodity is hazardous, invisible, compressible, and measurement is often made inferentially.

Advances in technology throughout the last half of the 20th century led us from the pneumatic / analog age to the electronic / digital age. While these advances allowed the industry to improve the accuracy of gas measurement, they also brought additional complexity. Managers and owners still needed assurances of the integrity of their measurement processes. The industry's response was to standardize the electronic gas measurement process, resulting in the American Petroleum Institute's Manual of Petroleum Measurement Standards Chapter 21.1 – Flow Measurement Using Electronic Metering Systems (API 21.1). This standard provides the framework for auditing electronic gas measurement systems.

American Petroleum Institute's Manual of Petroleum Measurement Standards Chapter 21.1 – Flow Measurement Using Electronic Metering Systems (API 21.1)

API 21.1 is an international standard which describes the minimum specifications for gas measurement systems of hydrocarbon and other related gases. It attempts to practically minimize the uncertainties associated with electronic gas measurement. It applies to both production and custody transfer applications using industry-recognized primary measurement devices.

There is a great deal of information contained in the API 21.1 standard and it has proved vital to ensure the integrity of electronic gas measurement. One of the topics covered within API 21.1 is a description of an electronic gas measurement system, including its various components, the algorithms necessary for adequate calculation, specifications for equipment installation and commissioning, and data security requirements. The standard also describes the minimum necessary data to be made available in order to allow for a thorough audit of the system. Of particular interest to the auditor is Section 1.6 - Audit and Reporting Requirements. The gas measurement audit process should consider all aspects of this standard as it details at great length the necessary steps for a thorough, complete audit; much of which is touched upon in this paper.

Audit Programs

The process of auditing can be looked at from many different perspectives and approached in various ways and with differing objectives. The same questions that apply to any business process need to be asked as part of developing a formal audit program within the company.

Why do we need to audit electronic gas measurement? In a word: Economics. The benefits of electronic gas measurement audits have been proven to justify the costs. However, prudence should be used in focusing audit resources. Valuable lessons can be learned from the financial accounting profession. Just as they migrated from verifying every transaction to developing a reporting system on selected key business cases, the gas measurement auditing process should develop selected key measurements to audit.

Redundancy, used wisely, can be an extremely effective way to focus audit resources. Some redundancy should be built into the business processes of all natural gas companies. The two most common uses of redundancy in gas measurement are balances and check meters.

Balances compare volumes, energy and / or mass going into a system against what goes out. The measurements going into the system should match the measurements going out within an uncertainty tolerance. Differences outside the tolerance can



Check Meter with Separate Taps

help to isolate measurement problems and point to where audit resources can be applied. A system

strategically segmented will aid in this process. A good enterprise measurement system will calculate the balance indifferences automatically.

Check meters measure the same gas as another meter, usually a custody transfer meter. Ideally, a check meter has separate, matching primary devices. However, it is not uncommon to see shared primary devices, with separate (check) orifice taps and / or secondary and tertiary devices. Check meters are not only the best form of gas measurement redundancy - they are the definition. They are invaluable when failures occur at critical stations. Besides failures, some types of measurement errors cannot be compensated for mathematically, such as damaged or reversed orifice plates. Check meters allow for accurate replacement of missing or erroneous measurements and can carry tremendous weight in audit adjustment negotiations.

Key process indicators (KPIs) are another means of focusing audit resources. Certain metrics apply to the healthy operation of a business. Gas measurements that can be directly associated to those key process indicators are good candidates for audits. Beyond KPIs, just as in the financial profession, Key Risk Indicators (KRIs) can be developed which help the business know when and where to expand audits. KRIs are metrics which apply to changes in the industry or the company's environment which have shown to be related to measurement errors.

An effective audit program will also include random audits. The cost effectiveness of these random audits is enhanced with a risk-based approach by varying frequency, scope and depth of evidence required. Risk assessment should include total energy measurement, past compliance, and the cost of the audit. Revenue recovered is not the only justification for the cost of an audit. The potential revenue not lost must also be considered, which is hard to quantify. There is a lot of good to be said about accountability. Most people perform better when they know someone may be watching.

Once the decisions have been made regarding the value of the audit, then other decisions become easier to make. The focus of the audit can be narrowed with a discussion of objective, scope and expertise.

Audit Objective and Scope

Before determining who should do the audit, it is best to define the objective and the scope. The

objective makes clear to all involved what the purpose of the audit is. The scope of the audit is the range of activities and the periods of records that are to be subjected to examination.

The objective should always include an unbiased examination and evaluation of the electronic gas measurement. However, the objective will also help to determine the scope of the audit and the best approach to take in conducting the audit. For example, if the purpose of the audit is to confirm pressure bases used in volume calculations match contractual obligations, an internal audit may achieve this objective. On the other hand, if the purpose of the audit is to support legal action, an external audit by a reputable third party may be necessary. If the purpose of the audit is to help minimize the risk of errors in reporting critical data, then certain policies and procedures will need to be confirmed. Defining the objective of the audit provides the landscape for defining the scope.

Scope determines the breadth and depth of the audit and defines what material, equipment, information, processes, time periods and business departments / entities will be examined. Scoping will define what documents need to be reviewed. These documents will likely include contracts, volume logs, meter configuration logs, event logs, meter inspection and testing reports, meter installation and change reports, and gas quality reports. However, depending on the scope of the audit, other documents may be required. If the scope of the audit includes examination of compliance with procedures, then policies and procedures will have to be studied and understood as well as any supporting documents that are referenced by the policies and procedures. If the scope includes the calibration of instruments, certification documents that reference the calibration device back to a standard, such as NIST may be required. A well-defined scope sets the stage for how the audit is conducted.

Audits vs. Reviews

Just like in financial audits, there is a difference between a review and an audit. Audits provide a reasonable basis for expressing an opinion regarding the gas measurement process as a whole. Reviews do not provide the same basis, because they are not concerned with internal control structure; risk control assessment; tests of measurement data; or corroborating evidence via validation, observation or physical inspection. A review may include some of these elements, though.

In the gas measurement world a review is almost always referred to as an audit. It is just an audit with a smaller scope. It confirms the documentation for a certain meter matches with its final quantity transaction records. These reviews are sometimes called office audits or administrative audits. These reviews can be very valuable, and they are much less costly than a fully-scoped audit. Sometimes they discover significant errors, while other times the review provides direction for an examination to be expanded. As questionable areas arise during the review, the scope can be expanded to investigate certain parts of the review in more detail.

Reviews can be done in the field, too. Depending on the scope, this is often called witnessing or field auditing. The practice involves confirming that the data from the electronic gas measurement (EGM) device matches the conditions, settings and sizes actually in use. This expands the scope significantly to include observation, physical inspection, and validity tests of the operation of the equipment. Reviewing only documentation in the office does not mean the equipment and quality tests were performed properly or in the right sequence. For example, some multi-variable instruments require the differential pressure to be verified before the static pressure is calibrated. Is the sample pulled before or after the meter tube is isolated to check the orifice in a single chamber or flange union fitting? Are verification tests performed at each of the set points after a field calibration? The sequence of some tests does affect the accuracy of the measurement.

As EGM devices replaced pneumatic devices and chart recorders, field reviews became much more valuable. Although the term "garbage in, garbage out" was coined in the data processing office, it now applies equally as well in the field. Much of the source of flow measurement data and procedures must now be examined in the field.

An EGM system audit would include the same things as an office and field review. However, it would also include any data or measurement from the primary devices to the corrected quantity transaction records, including how that data was derived, is normally derived, and any supporting documentation. Audits pull in data from regulations, tariffs, contracts, as well as standards and the documents they may reference. Policies and procedures would be examined for exposure to risk. Included in the examination would be the flow device, transducers / transmitters, and the flow calculations. Primary, secondary, tertiary and auxiliary devices are examined and tested, with supporting documentation. All equipment testing should be comprehensive and fully documented.

Transmission, recalculation and storage of the data are also verified and tested.

The Auditor

Knowing the objective and scope of the audit will help in determining who should perform the audit. If the audit is an office review of data, someone with a general knowledge of gas measurement and some guidance may be able to verify data was correctly applied to final quantity transaction records. Field audits require more expertise. Field auditors have to also understand how instruments function and interact with each other and the process. They require knowledge of the limitations of various devices and the ability to recognize when those limitations are being exceeded.

As the scope expands, so must the auditor's knowledge. Skills required may include auditing, engineering / technical, and business management consulting skills. For large, fully-scoped audits, a team of auditors may be required with different members being well-versed in different aspects of the audit.

The auditor should be aware of the prevailing regulations and tariffs which apply to each of the particular measurement(s) being audited. He or she should be very knowledgeable of the industry standards and common industry practices. It helps if the auditor has an understanding of the equipment manufacturers' hardware, software, and operational specifications as well. Auditors tend to lean upon their background as they diagnose problems. So, it is preferable if the background of the auditor matches the scope. However, auditors with a solid foundation of technical skills can quickly gain proficiency in equipment knowledge. Most likely they will have to gain an understanding of the meter owner's measurement policies and procedures. Experience with various companies' policies and procedures can help in finding holes in other policies and procedures. In essence, it is good for the auditor to know the gas measurement business forward and backwards. A thorough knowledge of how gas is measured electronically provides a framework for the auditor to quickly recognize undesirable practices.

Furthermore, the auditor should be able to act independently and be unbiased. He or she should not be in, or reasonably seen to be in, a position to be influenced by or in conflict with any commercial interest, duty or obligation. The auditor should not be currently or recently employed or contracted by either of the parties in a role which could be viewed as a conflict of interest.

The auditor should also maintain an attitude of professional skepticism. He should be very critical of everything, but be willing to suggest a compromise if a win-win solution is unavailable or an equitable solution would severely affect the viability of one of the parties. Ideally, the relationship between the transacting parties will remain beneficial and not adversarial. Usually errors are the result of simple oversights or misunderstandings. Disagreements between transacting parties with important business relationships can be taken out of the auditor's hands. The auditor can always be called back when expertise is required to gain understanding.

Gathering Data

Once the auditor is chosen, one of his or her first steps will be to gather information. The auditor will want to be aware of any regulatory requirements, such as those from FERC, BLM or BOERME. It is important to understand that regulatory requirements may supersede contractual requirements in custody transfer situations.

Copies of contracts are to be acquired and scrutinized. Contractual requirements can and should include very important agreements, such as pressure and temperature base conditions, measurement units, contract hour, and the location of the transfer of the custody of the gas. Contracts should be reviewed for references to industry and internal standards and noted exceptions to those standards. Sometimes references are made to the latest edition of a standard, as standards are amended from time to time. Other times, a specific dated standard is referenced. Gas quality thresholds may be spelled out, as well as how and when gas quality updates are handled. Instrument calibration methods and frequency may be defined. Any limitations on access to data for auditing purposes may also be stipulated. Data retention and prior period adjustment thresholds for amount and time should be mentioned and are of particular interest to the auditor.

As noted above, standards may be referenced in the contract. If not, their contents may still prevail. Industry standards are generally accepted at the negotiating table and in the courtroom. Different standards apply to different areas of gas measurement and some standards reference other standards. For example, API 21.1 references AGA Report No.'s 5, 7, and 8; API MPMS Chapter 14.3, Parts 1 through 4; GPA 2261 and 2286; and NFPA 70. When the next revision is released, it will likely reflect the growth of the use of ultrasonic and coriolis

meters in gas measurement by referencing AGA Report No.'s 9 and 11.

Of particular note in standards are the phrases "shall", "should", "shall not", and "should not". "Shall" and "shall not" indicate items which are required by the standard. "Should" and "should not" reference preferred items which are not necessarily required. Recently, sections of standards are being identified as "normative" or "informative." Normative sections are required. Informative sections are informational only and are not required.

When requesting data, the auditor should make the request in writing and be as specific as possible. The amount of data requested depends on the scope of the audit. When scoping is performed correctly, the information to be requested becomes easier to define. Information required for most audits include:

- Station Name
- Station Identification
- Station Location

The auditor may also request the following supporting documentation:

- Contracts
- Meter Installation and Facility Design Drawings and Documentation
- Flow Diagrams
- Standard Measurement Operating Policies and Procedures
- Meter Change Reports
- Audit Trail Information
- Witness Reports
- Check Station Reports

Tests should be specifically requested as well. Schedules may need to be developed for interested parties' representatives to all be present. Tests should be performed on each part of the measurement system within scope to ensure repeatable and reproducible performance. Personnel are observed as they perform their normal activities. Processes and sequences are documented. When measurement information is transferred from one location or machine to another, methods to insure data integrity and security are verified.

Examining Information

When all of the information required for the audit has been acquired, the information is examined. Information comes from many different sources and merges together in the form of the final quantity transaction record. Actually, the examination process is usually begun as each process or document is inspected. The auditor may note items which are suspect and validate these later.

An auditor looks for conflicts in the terms of the regulations, tariffs, contracts, standards, and

- Meter Identification (if different from the station)
- Production Dates (Beginning and Ending)
- Original (Raw) Data Files
 - Periodic Volume Data Logs
 - Meter Configuration Logs
 - Event Logs
 - Alarm Logs
- Meter Inspection and Test Reports (including the report just prior and just subsequent to the audit period)
- Gas Analysis Reports (including the report just prior and just subsequent to the audit period)
- Final Volume and Energy Data

API 21.1 sets the minimum retention period of the audit trail at two years. If there is reason to believe an error has existed longer than two years, more data should be requested. But, it may not be available.

Object Type	Effective From	Effective To
Meter Configuration	01/01/07 00:00	12/01/07 00:00
Meter Configuration	01/01/07 00:00	12/01/07 00:00
Meter Configuration	01/01/07 00:00	12/01/07 00:00
Meter Configuration	01/01/07 00:00	12/01/07 00:00
Meter Configuration	01/01/07 00:00	12/01/07 00:00
Periodic Flow	10/01/09 08:00	11/01/09 08:00
Periodic Flow	10/01/09 08:00	11/01/09 08:00
Periodic Flow	10/01/09 08:00	11/01/09 08:00
Periodic Flow	10/01/09 08:00	11/01/09 08:00
Periodic Flow	10/01/09 08:00	10/01/09 10:00
Periodic Flow	10/01/09 08:00	11/01/09 08:00
Periodic Flow	10/01/09 08:00	10/01/09 10:00
Periodic Flow	10/01/09 10:00	10/01/09 12:00

procedures (governing documents) against what is actually being done. If a procedure conflicts with a contract, the terms of the contract override the procedures. If a contract conflicts with a regulation, the regulation will override the contract or the measurement system may be required to comply with both. Standards and common industry practices play a role here, too. If the governing documents are silent regarding standards, the standards should be followed. If regulations and contracts are silent, but procedures conflict with

standards, documentation as to why standards are not followed should exist.



The auditor determines if the measurement system is capable of complying with the terms of the governing documents. If the measurement facility is not properly designed, errors may result. If the instruments are not capable of performing at the levels specified in the contract, this is

noted. Sometimes the instruments are properly installed and maintained, but the process requires different or additional equipment to perform satisfactorily.

Common problems are associated with device sizing. For example, if a separator is too small, liquids may spill over into the gas line causing measurement errors. If a pressure transducer is not sized properly, it can become saturated and unable to measure beyond its upper limit. If an orifice plate is too small, it may saturate the differential transducer. If it is so small it is out of beta ratio, it may add to uncertainty. If the upstream meter tube is too short, elbows, pipe fittings, pinched valves, strainers, reducers, or expanders can affect the velocity profile and proper measurement.

Other times, equipment is not properly installed. Excessive pressure drops upstream of the meter can cause phase changes. Liquids can accumulate and flow into the meter run. Hydrates can form. Reciprocating compressors can cause pulsating flow and if too close to the meter, distort measurement.

Equipment should operate within the specifications of the manufacturer and any applicable standards, such as API 21.1 and NEC. Tests can be made for most of the processes involved. Although some tests may be possible, they may not always be feasible. An orifice meter may not be flow tested, but if measurements can be made to show it complies with API 14.3, it can reasonably be assumed the calculated flow rate will be correct.

Tests can also be performed on the differential pressure, static pressure and temperature transducers. Ideally, tests will be made to confirm all values from their source to the final quantity transaction record.

Tests can also be made on gas quality. The equipment and procedures are reviewed for compliance with regulations; contracts; and GPA-2166, 2145, 2261, and 2172. Gas samples should be obtained, prepared, and analyzed according to these governing documents. Samples should be obtained during normal flowing conditions. Poorly cleaned sample cylinders, sampling systems, and gas chromatograph inlet systems, as well as improper purging, will cause analyses to be misrepresented. Gravimetrically prepared gas standards which are traceable to NIST standards can be analyzed as an unknown gas, with the results compared to the certificate of analysis. This is one of the best ways to insure a lab or online gas chromatograph is performing properly.

The auditor is concerned not only with the results of the test, but also how the tests are performed. Tests should be done accurately, completely and, where applicable, in the proper order. Because good technicians work quickly and auditors are taking notes, an auditor may ask to see a test performed a second or even a third time.

Many of the errors found during audits are the result of inadequate maintenance. Accumulation of water, debris, salt, scale, sand, paraffin, treating chemicals, or compressor oil in the primary and secondary devices causes measurement errors. Under extreme conditions, these can plug or even damage the primary device. This buildup of solids and liquids should be removed during routine maintenance and minimized where possible. Leaks are also a problem and should be tested. Checks are made for leaks in gauge lines and manifolds. Leaking seal rings cause under-registered flow, while leaking check valves can cause backflow which may not be registered because of the no-flow cut-off.

Rare is the circumstance where an orifice plate is not checked during an audit. Besides confirming its bore diameter, the plate is checked for concentricity, orientation, thickness, and flatness. The bore should have no nicks or burrs and the bore edge should be sharp.

All of the information from the various sources should come together to produce the final transaction record. This begins with the original quantity transaction records. The flow computer manufacturer's software may be required to view the original quantity transaction records or generate an

ASCII file to be imported into another system for analysis. If ASCII files are supplied for the audit, the auditor understands these may not be the original quantity transaction records. The same applies for daily records.

All edits to the original data should be traceable from the original data to the final quantity transaction record(s). Contract information can be matched to the meter configuration log. Other components of the meter configuration log should agree with the specifications of the meter, the gas quality, and the calculation methods. Events should be reviewed for parameter changes, transducer verification, and calibration adjustments. Alarms can sometimes shed light on failure and override conditions (including no flow conditions), frequent out-of-range readings, power and communications problems. Meter configuration logs are reconciled to the final transaction records, adjusted by events, valid edits, and gas analyses.

Gas analyses play a big role in volumes. Gas chromatography has replaced almost all physical testing for density and heating value. For this reason, representative component percentages are very important. Not only must the analysis be representative, it must be applied and applied correctly. Conversely, misrepresentative samples should be discarded. Statistical analysis of the component data can help to determine which samples are not representative.

Statistical analysis can also be applied to other volume data. As volume and analytical data resolution have increased, statistical analysis of the data has become more important. It can help the auditor focus on anomalies instead of plowing through thousands to hundreds of thousands of data records. It allows the auditor to analyze the individual data records without losing precision from summation and averaging. Statistical analysis can help identify missing, corrupted, static, inconsistent, or incorrect data. Along with graphical representations of the data, it can help to identify when a problem existed or began.

Data can become lost. Sometimes production month closing constraints do not allow enough time for data to get into the final volume records and they are closed with the best available data. When the data later becomes available, it does not get updated. Other times, records can be lost during transmission or accidentally deleted. Charging system, battery, device, and circuit board failures can cause measurements to be lost. If a missing record cannot be produced, check meters are the best means of reconstructing missing transactions. If a check meter is not available and the contract does

not speak to the issue, an equitable method of estimation can be used to determine the adjustment.

If adjustments to previously calculated volumes were made for errors found prior to the audit, the period and amount of the adjustment should be confirmed. Adjustment periods which extend beyond the scope of the audit should prompt an automatic extension of the audit through the adjustment period.

If the auditor sees that all the data is present, the flow computer is properly configured, the events correspond with physical changes, and the gas analyses were properly applied, there may still be differences to be resolved. Errors can occur in the calculation of the final transaction record if the proper volume calculation, equation of state, or energy calculation is not used. While allowing for calculation errors introduced by averaging non-linear parameters, reconstructing the volume on a separate system may help to flesh out these calculation problems.

The Auditor's Report

The word "audit" comes from the Latin root word meaning "a hearing." It is the same root word we use to get our words audible and auditorium. The idea is all of the information is presented so everyone involved can hear and understand what has taken place. The auditor provides a bird's-eye perspective to the story to help all parties with this understanding.

The audit culminates in an auditor's report. This is the main medium used for communicating the auditor's story. It represents his or her comments and assertions pertaining to the company's, system's, or station's gas measurement. The auditor's report consists of three main sections: objective, scope and opinion.

The first two sections reiterate the objective and scope assignments of the auditor. Although the auditor may have clearly understood the objective and scope of the audit, the documentation of these is still important for other uses. For example, other interested parties may desire to review the results of the audit. Before they can fully understand the auditor's opinion, it is necessary for them to be able to gain an understanding of the objective and scope. Also, the audit may be reviewed again months or even years later. Proper documentation of the objective and scope help to recollect the intent of the parties.

The section which contains the auditor's opinion is what most people think of when the term "auditor's report" is used. It may begin with a statement such

as, "It is my opinion..." and is just that; an opinion. However, it is an expert's opinion. The auditor's opinion should indicate whether the measurement processes comply with contractual obligations and industry standards. The auditor's opinion should also draw attention to any unusual practices which could result in poor measurement. The auditor's report expresses any restrictions or constraints in gathering or examining data. Here, the auditor may note limitations placed on his opinion by the scope. The report should also identify areas for improvement and recommended corrective action where necessary. If the auditor's opinion is adverse, he or she should provide remedies and the likely results if problems are not addressed. The specific errors found should be documented. If a payment adjustment is recommended, it will include specific volume, energy or monetary values. The reasoning behind the adjustment should be sound and explained in detail, especially when subject to interpretation. Any data to support the adjustment should be included.

Alternatively, if the audit produced no substantial results, there is still great value in knowing measurement processes are producing good results. Either way, if the opinion is not honored, the audit was of little value.

Conclusion

Audit resources, including the expertise of the auditor, can be applied with various objectives and scopes to capture the bulk of measurement errors and potential errors. Tests are administered, data is validated, and information is examined from the regulations and contracts to the final transaction records. Problems and errors encountered are documented in an auditor's report, with remedies and recommendations.

All sides to the stories of the transactions are heard and, if necessary, equitable adjustments can be made. The final result of this entire auditing process is an assurance of the integrity of an organization's electronic gas measurement business process.

API 21.1 is the backbone of the auditing process for electronic gas measurement. It provides the guidance necessary to ensure the integrity of electronic gas measurement values. Its guidelines can be used to develop an effective electronic gas measurement program. API 21.1 helps the auditor to transform the complexity of electronic gas measurement into an effective means of evaluating financial risk and financial opportunity.