HOW TO PERFORM A LOST AND UNACCOUNTED-FOR GAS PROGRAM

Rick Feldmann

Rick Feldmann & Associates
6518 Briarstone Lane
Spring, Texas 77379

INTRODUCTION

This paper is written for the natural gas pipeline industry, from the vantage point of wellhead to burner tip. It's for:

- ***Production Companies*** wanting to ensure proper measurement of the Btus delivered to, and normally measured at their wellheads by, gathering companies,
- ***Gathering and Processing Companies*** wanting to control losses across their gathering lines and across treatment and processing plants,
- ***Transportation Companies*** wanting to control gas losses across high pressure pipe that extends for thousands of miles, and
- ***Distribution Companies*** that are concerned with gas losses across both high and low pressure distribution systems within city plants.

The value proposition to most companies is that a physical loss of gas directly affects their bottom lines as either a loss of revenue or as an expense.

Production Companies

Production Companies sell their gas directly from the wellheads or through common delivery points and their primary concerns are that the gathering and processing companies are accurately measuring the volumes and energy delivered. Problems with metering volumes or problems with sample analyses directly affect the amount of energy they are selling.

Gathering and Processing Companies

Gathering and Processing Companies gather and process the gas under various arrangements from returning gas "in kind" for liquids extracted, to processing and selling liquids for a fee charged to the producers.

Profits are made through processing arrangements, reducing fuel usage below the amount retained, and reducing L&U below the amount retained.

We show in Figure 1 that a typical gathering company can increase its bottom line by over 10 million dollars annually by reducing it L&U by 1 percent with gas prices being at $6 per MMBtu. Gathering companies typically have leaks in their gathering lines. But with a good leak detection program and "best practices", gathering companies are achieving L&U goals as low as 1 percent.

182,500,000	MMBtu Annual Throughput
2.00%	Average Percentage of L&U
3,650,000	MMBtu Lost Annually
182,500,000	MMBtu Annual Throughput
1.00%	Average Percentage of L&U
1,825,000	MMBtu Lost Annually
3,650,000	MMBtu Lost Annually at 2%
(1,825,000)	MMBtu Lost Annually at 1%
1,825,000	MMBtu Potential from Loss Reduction
$6.00	Price per MMBtu
$10,950,000	Value Potential from Loss Reduction

FIGURE 1. GATHERING COMPANY OPPORTUNITY

Transportation Companies

Intrastate and interstate transport companies make money by moving gas, limited only by the capacity of their pipelines. They charge fees in the form of a firm or interruptible transport fee, plus retainages for compressor fuel and L&U...

Similar to gathering and processing companies, when there is no competition they theoretically can raise fees and retain gas up to the limits set by tariffs.

365,000,000	MMBtu Annual Throughput
0.80%	Average Percentage of L&U
2,920,000	MMBtu Lost Annually
365,000,000	MMBtu Annual Throughput
0.25%	Average Percentage of L&U
912,500	MMBtu Lost Annually
2,920,000	MMBtu Lost Annually at .8%
(912,500)	MMBtu Lost Annually at .25%
2,007,500	MMBtu Potential from Loss Reduction
$6.00	Price per MMBtu
$12,045,000	Value Potential from Loss Reduction

FIGURE 2. TRANSPORT COMPANY OPPORTUNITY

We show in Figure 2 that a typical transport company can increase its bottom line by over 12 million dollars annually by reducing it L&U by approximately ½ percent with gas prices being at $6 per MMBtu. Best Practice transport companies are now achieving controlling their L&U at ¼ percent or lower.

Distribution Companies

Distribution companies normally have higher tariff limits for gas losses and their primary concern is being forced to undergo leak survey tests when losses get too high. Low losses carry favor with constituent and public utility commissions and can benefit their rate structures.

There are also some states that offer incentives for lower reported gas losses.

Many of the larger distribution companies will also transport gas to their large industrial and commercial customers, retaining fuel and gas for L&U as necessary. These retainages are not considered in the gas cost adjustments for their sales customers and therefore do have a direct bottom line affect on the companies' profits.

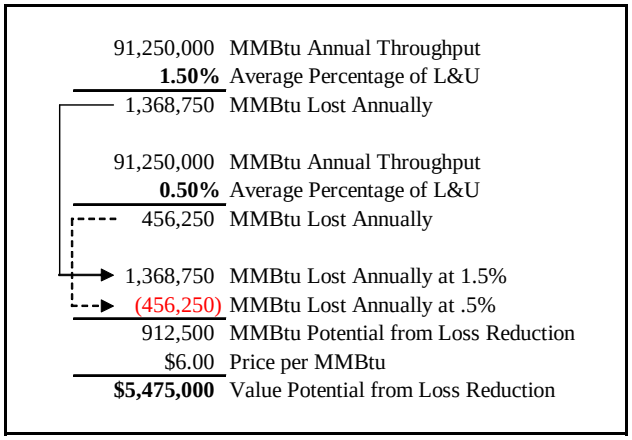

FIGURE 3. DISTRIBUTION COMPANY OPPORTUNITY

We show in the inset above that a typical distribution company can increase its bottom line by over 5 million dollars annually by reducing it L&U by one percent with gas prices being at $6 per MMBtu. Best Practice distribution companies are now achieving controlling their L&U at ½ percent or lower.

Unbundling

Unbundling during the mid 1990s undoubtedly has had the most dramatic affect on measurement accuracy. FERC Order 636 broke companies apart and created a competition. Companies therefore reduced their operating costs with personnel reductions and by cutting back on measurement procedures. They also cut capital expenditures at metering stations by eliminating secondary runs, bypasses, and secondary equipment.

In changing operations, they created many opportunities for measurement error, some of which are:

- Stations being designed with cost control in mind that ultimately causes poor measurement conditions.
- Operating teams assigning measurement responsibilities to technicians not fully qualified to evaluate and properly correct measurement problems.
- Test equipment becoming outdated or not being certified as required.
- Time constraints on field operations causing technicians to cut corners on meter tests, and skip the witnessing of third-party meter tests.
- Time or budget constraints in gas measurement services causing third-party measurement not to be audited.
- Measurement errors and alibis going unreported.

More importantly, we have been seeing a trend in the industry where:

- Gas quality is deteriorating,
- Measurement technicians are becoming overworked and not receiving adequate basic training,
- Measuring stations are designed poorly and meters are operating below their minimum recommended flow rates,

We wrote an article "Lost & Unaccounted-For Gas: Chasing the Silver Bullet" for the Pipeline and Gas Journal in July, 1998. In it we stated that companies rarely find a single metering station error causing the L&U anymore. They typically find problems across all of the systems, processes and people related to gas measurement. Gas prices then were only $2.00 per MMBtu and few companies were addressing their losses. Today with gas prices at $6.00 per MMBtu, many companies are now trying to turn their gas losses around. This paper is written for those companies on how to manage that gas loss turnaround project.

MANAGING A GAS LOSS TURNAROUND PROJECT

Key Considerations

Now that you see the carrot, you need to consider the key issues to achieving the goal, and making it sustainable.

- First, you will need management's "buy in" and the company must be willing to make changes. Those changes involve implementing industry "best practices" for measurement and gas loss control, i.e.

  - A really good, state-of-the-art, measurement collection, balancing, and reporting system,
  - Pipeline segmentation for loss control,
  - Well trained people in both the field and measurement support,
  - Regional Specialists,
  - The proper equipment for testing and calibration,
  - Good standards and procedures, etc.

- You will need a full-time project management team that fully understands the measurement process and "best practices".
- You will need programs and checklists to ensure full and adequate coverage of work.
- You will need someone with strong data mining expertise, along with a thorough knowledge of gas measurement systems.
- Determine early on if you have the experts you will need, or contract that experience.

Two Very Important Rules to Follow

The first important rule to follow for a successful lost gas turnaround project is that you must have dedicated experts who make no assumptions.

You cannot have field technicians audit meter stations unless you are sure of their expertise on all of the devices they will encounter, and that they will do a complete audit of the stations. Complete means to review everything, from technician skills, equipment used, certifications, and all equipment present at the site.

And you cannot have measurement systems support people review their own procedures, processes, and systems use. To not use outside expertise in these areas will doom the project from the start.

One of the main benefits from performing an L&U Turnaround project with outside contract assistance is that the outside contractors bring with them extensive industry experience and "best practices" that guide the program, train the field and office technicians, and outline a reinvestment program that provides value in return for the dollars spent.

The other very important rule to follow is that the program must be organized and a thorough "A to Z" program.

One Assumption You Should Make

The one assumption you should make at the beginning is that you will find problems across all processes, systems, designs, operational procedures, people skills, test equipment, etc. This is typical and that is why you need to perform a complete, thorough review with people you are sure are experts.

Field Audit Preparation

We focus on determining which meter stations to audit as soon as possible because it takes significant lead time to schedule the field audits with third party witnesses, and to match the normal operating schedule.

There are two major considerations in selecting meter stations for field audits and you should accomplish both:

1. Getting the biggest bang for the buck.
2. Getting an oversight on all types of meters, EFMs, people, divisions, etc. across the entire system.

Factors that should be considered in selecting meter stations for field audits that give the quickest reductions in L&U are:

- High volumes stations should be audited first because of the 80/20 rule where 80% of the volumes may be flowing through 20% of the stations.
- Audit delivery meters before receipt meters because, 99 times out of 100, measurement error caused by physical devices will record less gas than actually flowing through the meters. Exceptions should however be made if large volume receipt stations are suspected of pulsation problems.
- Consider performing full gas plant audits to include all gas and liquid meters if gas plants are not isolated from the pipeline system balancing with inlet and tailgate meters.
- Include large volume receipt meters near recip compressors because of potential square root error.
- Include stations using V-Balls for flow control.
- Include stations reflecting problems found in meter test/inspection reports, especially very dirty plates and liquids in the runs.

Other factors for selecting meter stations for field audits will depend on what is found through analysis of the physical balancing and reporting system, review of system balancing reports, and other data analyses.

Once you make the initial selection, make sure you have covered:

- All types of meters (orifice, turbine, rotary, ultrasonic, etc.)
- All types of station designs (chromatographs, accumulated samplers, flow control, run control, filter separators, bidirectional meters, etc.)
- All districts or regions because of different procedures, assignments, skill sets, etc., and
- Some non-custody meters used for pipeline segmentation.

You should ensure a full coverage as shown above because of differences across the system. You don't need to visit every site that is identified with the same problem. After seeing a small number of sites with the same problem, you can most likely determine what may be causing the problem(s) and therefore give direction to field technicians on how the problem should be fixed.

Preparing Field Audit Packages

The following documents should be printed, evaluated, and sent out to the field with the field audit teams. An initial evaluation of these also serves to fine-tune the stations selected for field audits.

- Current configuration log (EFMs)
- 3 most recent months of event logs & error logs (EFMs)
- 3 most recent months of hourly flow data (EFMs)
- 12 most recent months of charts (Dry Flows).
- 12 most recent months of *Meter Volume Statements*.
- 3 most recent *Meter Test/Inspection/Proving Reports*
- *Meter Change Reports* associated with the period beginning with the first *Test/Inspection/Proving Report.*
- Copies of the station design schematics, if located.
- A copy of the original meter mic form.

A review of these documents may provide clues to significant problems that would benefit prioritizing the field audit performance.

Scheduling Logistics

It is extremely important to notify gas control of planned field audits because a station can only be fully audited when gas is flowing. It is also a good practice to have gas control operate station actuators and flow gas under both normal and unusual conditions that may be found in the station historic data.

Important factors in scheduling the audits are:

- You want to witness the technicians normally assigned the stations so you can evaluate their knowledge and skills, and their equipment used for testing and provings.
- You want to audit the station at the normal times for testing and provings to both reduce the amount of field time required, and to see the stations in there normal condition (You do not want to see plates just cleaned a couple of days before the audit).
- You want to follow an organized travel schedule to reduce the amount of travel between stations being audited.

Analyzing System Data

Another data source for selecting stations for field audits will be analysis of the measurement system data. This should begin on the first day of the engagement. Use SQL, or another database query tool, to analyze the system data for anomalies. Consider including the following in the data mining analysis:

- Default factors such as 1000 Btu, 60 degrees temperature, etc.
- Meters showing a change in plate size without an appropriate change in differential.
- Meters showing differential or pressure exceeded the respective spans.
- Meters showing differential or pressure < 20% or > 80% of their spans.
- Meters showing flow > 1440 minutes for any day except for the change back from daylight savings.
- Meters showing flow time evenly divisible by 60 minute increments.
- Meters where the calculated flow extension ((DP*AP) ^.5) <> 2% of reported flow.
- Meters where the flow extension * C Prime varies from the final volume by > 2%.
- Meters where the adjusted energy factors varies by > 2%.
- Meters showing DP, SP, flow time, and flow extension but reporting zero flow.
- Meters showing zero DP, SP, flow time, and flow extension but reporting flow.
- Btu values remaining unchanged from one test to another, or where chromatograph readings appear unchanged.
- Meters where original and adjusted Btus vary > 2%
- Gas qualities where Btu changed > 2% or gravity changed > .005 compared to the previous sample.
- Meters reporting flow when DP is below the low point cutoff.
- Fuel meters with expected flow showing zero flow.
- Meters with beta > .6 without flow conditioners.
- Meters with hard edits.
- Meters where original and final volumes changed > 1%.
- Meters flagged to recalculate and overlay EGM data.
- Meter ids and orifice plate sizes that are exact standard or default sizes.

Analysis of the Measurement System Balance Reporting

Another source of information for both selecting stations for audits and for determining overall accuracy of reporting is the system balance report.

The report should follow the format shown in Figure 4 below:

	Mcf	MMBtu
Custody Receipts		
Less		
Custody Deliveries		
Fuel Used		
Known Gas to Atmosphere		
Hydrocarbons & Water Removed		
Change in Linepack (+/-)		
Lost & Unaccounted For Gas		
Percentage (L&U / Receipts)		

FIGURE 4. BALANCE REPORTING FORMAT

Key items for consideration:

- Consider the reasonableness of the fuel being reported. Is all fuel metered and the meters reflected in the balance report, in the right segments? If some compressors operate without fuel meters, is the fuel calculated and reported under dummy meters in the balance report?
- Does the report include known "gas to atmosphere" for blowdowns, blowouts, flared gas, etc.? If not, it should be. Estimates can be included for all junior runs tested each month to cover the gas released to atmosphere. This should be done by segment.
- If liquids (hydrocarbons and water) are being collected and hauled away, they should be reflected. Use best estimates to equate Mcf and MMBtu to the amounts of liquids believed removed each calendar month, and periodically verify with run reports.
- Does the report show changes in linepack from one month end to another? Is it reasonable and is it reflected within each appropriate segment? If not, you will want to begin doing this. You will want to review the formulas used along with the points, pressures and temperatures are taken along pipe with major swing potential.
- Compare the Mcf and MMBtu gas loss percentages. Note that if they track (fairly close from month-to-month) both in the segments and for the entire pipeline, then you should suspect no serious problems with gas quality determination. If they vary significantly however, you will need to consider a very thorough review of how gas quality is determined and applied.

Another key piece of information from the monthly system balance report is the gas loss percentages. When comparing these percentages, you should suspect independent problems with "quality errors" if the two percentages do not track.

These problems will be identified through office data analysis and field audits, with one exception. That exception is the assignment of chromatographs to metering stations.

The proper time to analyze chromatograph assignments will be on the conclusion of the Meter Confirmation Process, when you know the location of all stations and what is immediately upstream and downstream of each station.

The Meter Confirmation Process

When beginning a Lost Gas Turnaround Program you should ask yourself the following questions:

- Are all meters that should be included in the balance report in the report?
- Are they in the correct segments?
- Are they reflected correctly as receipts and deliveries?

To determine the answers, you will need to confirm the accuracy of the system data with the field technicians.

All key meter data should be extracted from the system database, analyzed and sent to the field for confirmation. Include data on meter type, characteristics (EFM?, chart?, size run?, size plate?, etc.), purpose (custody?, check?, zone balancing?, receipt?, delivery?, etc.), location, etc. Strongly consider using a "positive confirmation" process that requires each technician to review, confirm, or correct information, and return the form(s).

Also ask the field technicians to:

- Identify the meters immediately upstream and downstream of each meter.
- Identify meters they know of that are not included in the system list.
- Identify any known problems at each meter station (i.e. equipment not working, pulsation, liquids, not designed correctly, etc.)

During the normal course of a Gas Loss Turnaround Project there is an ongoing office review team and a field audit team. This confirmation process should begin as soon as possible and will continue until completed. The office team will perform the confirmation process but will coordinate with the field audit team for assistance, to identify reported problems, and to seek additional information as necessary.

System Editor Review

In addition to supporting the field audit team throughout the project, the office review team will need to review and evaluate the use of the system editors.

Measurement systems sold by third party vendors contain edit capabilities to both identify and report problem data, missing data, etc. These third party systems also have the capabilities of setting ranges on meters to identify potential problems with Btu factors, differentials, static pressures, temperatures, etc. Verify that the editors are being used appropriately, and acted on timely.

If the measurement system was developed in-house, verify that it contains full edit capabilities and the ability to monitor anomalies as discussed above.

Data editors should address whether data received is accurate, complete, etc. Some are included in the list presented in the section titled "*Analyzing System Data*" on the previous page.

Process Review – Measurement Support Group

The office team should also perform a detailed review of all processes performed by the Measurement Support Group from a monthly close through a subsequent monthly close.

Key questions you will be seeking answers to are:

- Is the group adequately staffed?
- Do they have the appropriate skills?
- Are they receiving adequate training in new systems and equipment?
- Do they know the pipeline system, segments, stations, meters, etc.?
- Are they fully capable of using the system balancing system and its full functions?
- Are they working correctly, efficiently, and timely to identify potential errors, control gas losses, and close data to the allocation or sales systems/
- Do they work appropriately with field technicians and measurement specialists?
- Are they auditing third party measurement data?

Review – Outside Contract Support

If support services, such as chart integration, has been outsourced, consider having a selection of charts re-integrated by other service providers to test the accuracy of the current service.

FIELD AUDIT PERFORMANCE

Guidelines for Thorough Field Audits

The number one guideline to ensure that a station audit is complete and accurate is "never assume" anything. Don't assume the technician's equipment is accurate. Don't assume the technician knows how to perform his or her duties correctly. Don't assume the EFM configuration data is correct, etc.

Some key guidelines for performing Lost Gas Turnaround Projects include:

- Determine early if you will be developing an ongoing Measurement Specialist Group (see the later section on Measurement Best Practices). If so, involve them early in the process of station selection, logistics, etc.
- If you are unsure of the knowledge and capabilities of your field auditors (potentially Measurement Specialists in training), contract expert assistance for a minimum of one week to assist and train each field auditor. A mistake here can doom the entire program.
- The audit team should carry certified meter test equipment as a backup should they find that technicians don't have proper equipment, or that it isn't certified. The equipments should be as accurate as the transducers being used.
- Carry a Square Root Error (SRE) indicator, bore scopes, and different size micrometers.
- Carry extra orifice plates and seal rings of standard run sizes should you need to make quick fixes and find the technicians don't have the items.
- Carry plates with very small holes, below minimum beta, to determine if gas is flowing below cutoff points.
- Carry a couple of gas sample bottles should the need arise to take a spot sample and to use when a technician doesn't have a sample bottle on hand for demonstrating his or her skills in taking samples.
- Carry sample bottles to capture liquids for later analysis, should it be necessary.
- Carry a previously determined certified gas sample to be run against chromatographs as an "unknown" should you discover that certified gas being used at a site is not appropriate or old and doesn't calibrate correctly.
- Carry a digital camera and laptop to capture pictures of each station and problems identified. The pictures will aid later discussions, reporting, and station fixes.
- Assign a minimum of two "trained" auditors to each audit team. If using "Regional" Measurement Specialists, one should be from the region under audit and the other should be from an outside region. This helps eliminate mistakes that may be created by technician or station familiarity.
- Witness the technician first in all tests, then correct and teach later. It is very important to observe each technician to evaluate his or her knowledge and skills. You may want to consider having a member of the training staff assigned to assist on the audit so they can make first hand judgments also on the training the technicians need and are getting.

- If a member of the training department accompanies the field audit team, he or she should be assigned the additional duties of 1) logistics for the week, 2) getting lunch for the team so they can eat at the station and not lose valuable time, 3) taking digital pictures of the station and its problems, 4) overseeing the end-of-day write-up of each station, 5) making audit checklists available, and 6) assisting in taking measurements of each meter run.
- Consider performing field audits on a four-day week, Monday through Thursday. This allows the field auditors time on Fridays to conduct other necessary business, to finish all write-ups from the week finished, and time to review plans for the next week.
- Consider having "Sunday Night Supper Meetings" where the field audit team meets the area managers and technicians being audited during the following week. Be open about the process, the extensive amount of time required at each station, and that the audit is not a "witch hunt" to identify any individual poor performers.
- Begin each morning by meeting the assigned measurement technician early to 1) review station schematics, 2) review original micing sheets if kept in the field, 3) to review his or her equipment certifications, and 4) to resolve questions the office team may have on the meter confirmation process.
- On completing the write-up at the end of each day, review the audit package for the next day.

Considering an audit team consists of two Measurement Specialists (one possibly an outside contractor to train the Specialist) and a member of the training department, predetermine responsibilities.

The first decision is to determine who is "in charge". Normally that person would be the one with the most experience. If both Specialists are equally experienced, assign that responsibility to the Specialist from outside the region and most unfamiliar with the technicians or stations.

The Specialist with the least amount of familiarity to the station technician should be responsible for reviewing the technician's testing (meters, chromatograph, spot samples, etc.). The unfamiliarity makes it easier to be thorough and not overlook steps.

The Use of Checklists

Based on experience, it is extremely valuable to use checklists throughout the conduct of the field audits. They will serve to make documentation easier, to list AGA standards, and to ensure nothing is overlooked.

The standard checklists used by Rick Feldmann & Associates include:

Technician's Test Equipment
Station Design
Meter Tube – Orifice
Meter Tube – Ultrasonic
Meter Tube – Turbine
Meter Tube – Rotary
Orifice Plates
Gauge Lines
Gas Samplers
Chromatographs
Ultrasonic Meter Test
Orifice Meter Test
Turbine Meter Test/Proving
Rotary Meter Test/Proving
SRE and GLE

The checklists should contain the industry standards and guidelines, along with the procedural steps for testing. They should also contain sufficient space for documenting information and problems.

Initial Assignments

Basic assignments for a field audit would include:

Lead Auditor (Specialist)

The Lead Auditor should make all decisions and be responsible for witnessing the meter tests and provings, chromatograph tests, and technician's qualifications. If the Lead Auditor determines that the technician's equipment may not be accurate, he should have the technician perform the first test with the normal test equipment. It should then be re-performed with the audit team's backup equipment, and that backup equipment should be used for the balance of the tests.

The Lead Auditor should have the technician perform the first test on his or her own without interruption. If not done correctly, correct the technician and work together on the remaining runs. This similarly applies to testing the chromatograph.

Assistant Auditor

The Assistant Auditor should walk the station and review it against the schematics. He is responsible for looking for leaks, checking valves, and reviewing all peripheral equipment such as filter separators, flow control devices, run control devices, dampening bottles, etc.

With the assistance of the Trainer (or someone else), the Assistant Auditor performs measurements and completes the appropriate checklists for the station design, meter runs, orifice plates, gauge lines, gas samplers, etc.

Trainer (or other assistant)

The Trainer, in addition to the duties discussed earlier in the "*Guidelines for Thorough Field Audits*" will

take digital pictures of the station, runs, and problems noted by the specialists.

He or she will also assist in taking measurement and will call Gas Control to change flows as necessary to properly test all equipment under normal and extreme operating conditions.

Special Note on This Paper

It is not the author's intent in this paper to provide a detailed step-by-step list of procedures for performing meter tests and provings, nor to list all of the AGA and industry standards. These are understood in the industry and should be documented in the checklists.

From this point forward the discussion on field audits will address key points and special review work.

Key Notes – Station Designs

It is important to take pictures of the station design, and especially the upstream and downstream header configurations.

A review of the station schematics will identify underground header configurations which should be drawn on the Station Design Checklist if you can't make a photocopy.

Key Notes - Meter Run Designs

The meter runs need to be measured to ensure compliance with AGA specifications. The measurements can be handwritten on the checklist designs, or written on "stickman" drawings (should your checklists not contain run pictures with specifications).

In addition to taking measurements, ensure:

- Straightening vanes, or other flow conditioners, are in place, and in the right location (verification of condition will be accomplished by bore scoping or removing "end caps").
- The temperature probe and test well are in the right locations, set to the right depths of the pipe, and carry a proper medium.
- The static pressure tap is in the proper location and uses the right size tubing.
- The differential taps are in the proper location on orifice runs and are not configured with takeoff tees.
- Gauge lines on orifice meters, if used, slope correctly and are the right size tubing.
- The gas analysis tap for chromatograph or accumulated sampler, and spot sample tap, are in the right locations and are also of the right depth.
- The sample line for the chromatograph or sampler should be proper size tubing and the shortest distance possible from the run to the chromatograph or sampler. There should be no liquid traps, and the line should be "heat traced" to a chromatograph.
- All valves should be "full opening".

There may be other devices installed on meter run piping, such as flow regulators, valves, controllers, etc. These should be properly located on piping, off the run, so not to interfere with a conditioned gas flow.

Other notes:

Grandfathered Runs

Just because the AGA has grandfathered some run designs doesn't mean that they are accurate. Determine the purpose and accuracy required. If justified, replace old grandfathered runs being used for custody measurement. Those runs can be used for zone balancing meters.

Oversized Orifice Runs

There are a lot of twenty inch runs being used and these are not accurate for custody measurement and should be considered only for zone balancing.

Pipe Welds

A number of companies have made their own meter runs or made changes through welding. Cutting and welding on a meter run will create measurement problems and can cause significant measurement error.

Fittings

While taking measurements and checking runs for compliance, leak test all fittings.

Key Notes - Orifice Plates

Be prepared to take a close up digital picture of both the upstream and downstream side of the orifice plate as it is removed.

Pictures of dirty plates provide evidence of problems in the gas stream, support estimating potential measurement error, and show evidence on how the gas flows through the meter through striations.

Consider using the special plates with small holes to test for flowing gas below cutoff points.

Consider changing plates as necessary to maintain differentials between 20 and 80 percent of the transducer range. Alternative procedures would include realigning run control, if used, and changing transducer ranges.

In addition to testing the plate don't forget to mic the seal rings.

On Concluding Tests and Provings

On concluding all meter tests and provings, the Lead Auditor should have the technician verify the accuracy of the characteristics loaded in the EFMs.

The Run ID should be verified to both the mic sheet and the flange stamp. They should all agree.

Another step to perform with orifice runs, not part of a routine test, is to do a "field pulsation test" by locking in a true zero, closing both the high and low dp sides and observing to see if there is any differential shift in the EFM.

Bore Scoping Runs

Be prepared to blow down and bore scope runs:

- If you need to determine if straightening vanes are in place.
- If you are unsure when the tubes were last cleaned and you need to determine the condition of the tubes.
- If you note dirty plates.

Note that it is not necessary to bore scope all runs off the same common header. The decision on which runs to look at, if looking only for dirt and/or liquids, should be based on 1) the amount of flow, and 2) the run at the farthest end of a header.

When gas flows equally through a series of runs off a common header, dirt and liquids tend to accumulate more at the last run off a common header.

Testing for Square Root and Gauge Line Error

Earlier we discussed performing the field test for potential square root error. If you detect any pulsation with a visible shifting of differential during the field test, if the station is located near any reciprocal compressors, or if you suspect any noise in the lines due to misaligned flow regulators, perform a square root error test.

Take three separate readings and average them for the square root error at the flange taps. When transmitters are not close mounts, the steps should be repeated at the ends of the gauge lines. Gauge line error is then determined by subtracting the second average calculation from the first calculation of square root error. Note that the acceptable level for square root error is set at 1/10 percent.

Miscellaneous Devices

Don't overlook miscellaneous devices around the metering station. These may include the following:

Scrubbers and Filter Separators

These would normally have been installed to remove dirt and liquids. If you note dirty gas or liquids on plates, check these devices to see that they are working correctly. They may be clogged and not dumping automatically or filters may be sized incorrectly to be working effectively.

Run Actuators

Test these to see that they are set correctly to perform run control based on correct differential ranges. Also verify that they open valves slowly enough to even out pressures and not dish plates.

Flow Control Devices

Ensure these are properly located to not affect the gas flow upstream of measurement. Also, if you find more than one used side-by-side check to see that they operate in tandem so not to cause noise in the gas stream.

Pressure Regulators

Ensure these are properly located to not affect the gas flow upstream of measurement. Also check the pressure drops to ensure they aren't significant to cause water or hydrocarbon liquids to drop out of the gas stream.

Follow-up Steps for Dirty Gas and Liquids

When observing dirty plates and liquids in the gas stream, it becomes necessary to isolate the source of the problem and correct it.

This may require determining the makeup of liquids: Is it water, hydrocarbons, compressor oil, or something else? You may have to send a sample to a lab to get a fingerprint of the manufacturer as a way of determining where it comes from.

Quantifying the Results and Making Recommendations

Quantifying the results is as simple as multiplying the meter's throughput by the potential error factor that can be extrapolated from various studies that have been published over the years.

Most primary element problems will cause the meters to record lower volume deliveries than actual. An exception is square root error that will have an opposite effect in the lower ranges.

Errors in secondary recording devices can be more easily calculated by running laptop flow calculations with both the wrong and correct data.

The errors can be looked at in two ways: Either as an amount lost that has a direct relationship to the amount of gas being retained for L&U on a percentage basis, or by multiplying the losses by a conservative price per MMBtu.

Once these calculations are determined, you should build value propositions by developing the offset costs for implementing the recommendations. Those with the best "value propositions should be implemented first.

Key Best Practices

Below are two of the more significant industry best practices to reduce and control L&U.

Accountability

Leading pipeline companies have made operating teams accountable for controlling the L&U in their responsible areas. Some of the key components to this concept are:

- Teams are given incentives to achieve preset results,
- They are given equipment and training necessary to achieve and control accurate measurement,
- The pipelines have been segmented and they are aligned with specific pipeline segments and meters,
- They are given access to the physical measurement system data,
- They have Measurement Specialists to assist them in both the field and office.

Measurement Specialists

A large number of companies have created positions of regional or division measurement specialists whose responsibilities include:

- Meeting routinely with facility planners and engineering to review new station designs and existing design changes,
- Meeting routinely with and gas control to identify potential measurement problems on the systems,
- Assisting the training function through field hands-on training and the certification of skill sets,
- Leading routine field audits on large volume stations, new stations, and stations that have undergone change,
- Working with field technicians and gas measurement services to design system balancing controls, and to monitor gas losses across the systems.
- Meeting regularly with gas measurement services to monitor system changes and reporting, and
- Participating in (and guiding) emergency response audits if significant errors occur.

People assigned these responsibilities need to be knowledgeable of:

- AGA specifications and industry measurement standards,
- measurement equipment and techniques,
- how to access and use the physical measurement balancing and SCADA systems, and
- how to perform analytical analyses.