INTRODUCTION

In light of volatile prices, the industry has assumed an “every drop counts” approach to running the business. In this environment, issues such unaccounted-for (UAF) gas, with which every operation has dealt before, find themselves under new scrutiny.

Production, gathering, midstream, pipeline and distribution companies are all responsible for managing UAF. Long gone are the days when the cost and impact of UAF was passed directly to the customer with virtually no requirements for managing and reducing costs associated with the loss.

While UAF has, historically, been the result of a combination of issues, current trends in the industry have managed to further complicate it. Interest in shale plays has given rise to mergers and acquisitions, which have resulted in diversified, oil & gas operations. An increasing number of producers and midstream companies must track and balance multiple fluids, including natural gas, natural gas liquids (NGLs) and heavier hydrocarbons in their systems. At the same time, measurement departments are faced with more ambitious UAF loss targets.

In light of the industry dynamics, it is a good time to review the latest in terms of UAF issues and the processes used to identify and mitigate them.

LOST AND UNACCOUNTED-FOR REVIEW

The first illustration provides a simplified view of a system such as a gathering network, pipeline or local distribution utility. The gain or loss is simply the difference between the physical inputs and the physical outputs of the system.

- A LOSS occurs whenever the physical inputs are greater than outputs of the system.
- A GAIN occurs whenever the physical outputs are greater than inputs of the system.

The illustration shows 100 MMBTU entering the system and 95 MMBTU exiting, resulting in a loss of 5 MMBTU. The company is able to account for 4 MMBTU of that loss, for instance, gas used to fuel compressors, leaving 1 MMBTU that could not be accounted for.
Mitigating Lost & Unaccounted-For Gas

CAUSES OF UNACCOUNTED FOR LOSS

UAF causes fall within the following, broad-based categories:

- Actual losses such as from leaks or theft
- Unreported use such as unmeasured fuel
- Losses caused by system operation events such as a relief valve opening, line pack changes or timing issues
- Measurement Errors
- Third party measurement

ACTUAL LOSSES

Leakage losses could constantly be occurring through practically any connections or process equipment such as the following:

- Regulators/controllers
- Dehydrators
- Heaters
- Couplings

In addition, venting could be occurring without the knowledge of operations or field staff. Oil or gas theft could be taking place through unknown connections or connections that are thought to be out of service.

UNREPORTED USE

Legitimate but unreported use of oil or gas in the system is typically the result of the following:

- Fuel
- Construction activity
- Other uses within the company

LOSSES CAUSED BY SYSTEM OPERATIONS

Losses could occur through circumstances that may be considered normal, day-to-day operations. The main problem with these sorts of losses is that they are sporadic and, if not well-documented, could be very difficult to track down and account for.

While natural gas escaping through a relief valve is the most notable loss in this category, such common operations as taking a meter, compressor or other process unit out-of-service could also result in losses that are big enough to require accounting.

In pipeline operations, line pack changes that are not properly reported could appear on the unaccounted-for radar.

Finally, simply the timing of such operations events could be enough to appear as unaccounted-for losses. The classic case is a loss event that occurs toward the end of an accounting period but the report is delayed.

MEASUREMENT ERRORS

While most of the afore-mentioned losses are real, losses due to measurement errors are “on paper.” In fact, measurement errors could even result in gains! Among the favorite expressions in the industry is that anyone in need of a credibility problem should, without further investigation, go ahead and report such a gain.
In a measurement system, there could be seemingly countless sources of uncertainty. The more meter classes and types that are involved in a company's UAF loss, the more complicated the actual determination of the loss becomes. Tracking multiple fluids such as natural gas, NGLs and heavier oils further complicates measurement and system balancing. The frequent mergers and acquisitions in the industry also complicate the process as management is faced with integrating numerous entities, which previously operated with little or no coordination.

Measurement problems that contribute to UAF are as follows:

- Measurement accounting, calculation or procedure errors
  - Incorrect entry of parameters that are used in flow calculations
  - Incorrect compensation for ambient temperature, atmospheric pressure and line pressure effects
  - Incorrect "no flow" detection
  - Poor or incorrect documentation and processing of meter test, calibration and verification
  - Lack of coordination resulting in difficulty integrating information even at the meter level—such as calibration/verification, flow information and gas quality information

- Meter inaccuracies due to faulty equipment
  - Improperly sized meter—flow falls outside of accurately measured range
  - Improper transmitter ranges—flow falls outside of accurately measured range
  - Incorrect orifice plate size, dirty plate or plate installed incorrectly in an orifice meter
  - Long gauge lines
  - Pulsation
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- Dirty or damaged meter tubes
- Undetected equipment failures
- Incorrect input / output coding, data entry errors (“keypunch” errors)

The ability of the measurement staff to understand the fundamental areas that impact measurement accuracy and uncertainty are integral to the overall measurement integrity in an organization. The knowledgebase that is required to recognize keypunch errors and the timing of meter characteristic events could easily correct a loss impact up to +/- 2% on a meter.

Gas quality analysis and its relationship to a meter have recently received added attention by UAF investigators. Assessments in shale gas production and gathering systems have revealed issues that could severely impact measurement accounting:

- Measuring and sampling gas that is at the hydrocarbon dew point pressure and temperature
- Measuring and sampling non-stabilized liquids that are at the flash point
- Measuring at conditions that are outside the AGA8 limits
- Presence of oxygen in the gas stream from producers’ vapor recovery systems

Among the more traditional issues are comparisons between monthly or quarterly samples and live qualities derived from on-line gas chromatographs. Those could substantially influence the UAF loss swing on a monthly basis.

THIRD PARTY MEASUREMENT

After assessing all the potential measurement problems in the company’s system, the team will be more than ready to consider the errors that are possible in a third-party’s measurement.

THE UAF REDUCTION PROCESS

The UAF reduction process continues to require multi-disciplined teams to “roll up the sleeves” and assess system details on a one-by-one basis. The audit and investigation processes are considerable. It is of utmost importance to incorporate corrective actions not only as remedial activities but also into the company’s day-to-day operating procedures going forward.

UAF reduction process activities fall within the following categories:

- Leak/theft audit and survey
- Operations audit
- Segmentation
- Metering improvements
- Third party measurement improvements
- Analysis/quality improvements
- Measurement process improvements

LEAK/THEFT AUDIT AND SURVEY

The investigation process is primarily a detailed audit of the system to identify all sources:

- Leak Report Survey
- Gas Control Log Notes
- Soap Test Equipment
- Identify all unmeasured venting of gas
For operations going forward, the following have proven to be beneficial:

- Leak detection software
- GIS software
- Performance of annual meter usage comparisons

**OPERATIONS AUDIT**

Questions to be addressed include how the organization handles line pack, unmeasured fuel, unmeasured company use gas, retrograde condensate, timing of reported loss events, and missing loss events.

- Unreported loss
- Identify all unmeasured fuel
- Identify all company use gas loss
- Quantify and report construction activity in a timely manner
- Line pack
- Quantify line pack in segments (please see “Segmentation,” below)
- Maintain calibration of pressure transmitters
- Timing of UAF events
- Coordinate loss events to the correct day and time
- Coordinate with Operations to ensure all loss events are recorded

**SEGMENTATION**

As a day-to-day practice, segmentation greatly simplifies the system by dividing it into smaller portions in which UAF losses could much more easily be isolated. Segmentation reduces the number of meters that must be inspected when a loss is detected and helps with the detection of smaller-volume issues that could affect the balance.

It is up to the company to decide exactly where to segment. A segment could be a length of pipeline, a station or any, other logical entity. Each segment must include meters, which are installed in locations that allow balancing within. Segment boundaries could be political entities such as countries, provinces, or states or they could be based on operating regions in the system.

A detailed segment balance relationship should be established for every gathering segment, processing plant balance, pipeline segment, and distribution segment. Where possible, companies should create balances that take advantage of field-to-sales, check-to-sales or similar comparisons. Graphical representations of the physical relationships of meters in a system enable companies to identify the issue when a problem is noted. The relationships that are identified should include:

**Inlets**

- Physical Receipt Meters
- Storage Withdrawal

**Outlets**

- Physical Delivery Meters
- Storage Injection
- Measured Fuel
- Unmeasured Fuel
• Accounted For Gas to Atmosphere
• Retrograde Condensate
• Water
• Delta Line pack (+/-)

Accounting and reporting requirements, per segment, are as follows:

• Calculated UAF Gas Loss (Volume and Energy)
• Percentage UAF Gas Loss (Volume and Energy)
• Hourly, Daily, Monthly Level Station, Segment, and Balance Level Validation
• Validate totals for an hour relating to split records or quarter hour data
• Station, Segment, and Balance summary level validation
• Daily and monthly level validation
• Contract quantities
• Reasonable daily and monthly quantities
• Plunger lift wells
• Batched totals

The bottom line on segmentation is that it only helps if done properly. Segmentation metering should be installed and maintained as custody transfer-quality metering. In too many cases, companies terminate segments with non-custody transfer check meters. Due to the uncertainty of such meters, that could defeat the purpose. In addition, testing and sampling should follow the same procedures as custody transfer metering.

METERING IMPROVEMENTS

While meter inspection might impress many as simply a “back to basics” practice, it could considerably cut the company’s UAF loss—and explain a “gain.” Relative to meter inaccuracies affecting UAF, the following practices have proven to be effective:

The importance of a clean meter cannot be overemphasized. Before cleaning, the reading difference between this meter and the downstream check meter was 0.5%. After cleaning, the difference was 0.03%.

• Incorrect Input / Output Coding
  • Develop Communication Framework to Verify Meter Coding
  • Inlet / Outlet / Meter Behind Meter / Proper Segment
• Keypunch Errors
  • Utilize Validation and Exception Reporting to Identify Errors
  • Utilize Master Characteristics to Identify Field Key Punch Errors
• Verify orifice plates sizes and condition
• Remove gauge lines
• Maintain beta ratios
• Inspect meter tube
• Validate certification of calibration equipment
• Ensure field understanding of test and calibration standard operating procedures
• Review all test and calibration reports for accuracy and process required, prior period adjustments (PPAs)

It is also important to review field inspection, calibration and verification reports in a search for any meters or other equipment for which there have been lapses in these practices.

THIRD PARTY MEASUREMENT IMPROVEMENTS
Armed with up-to-date knowledge regarding how their own measurement process affects UAF, the team members can request audit information on third-party measurements and, on an on-going basis, perform periodic witness tests.

ANALYSIS/QUALITY IMPROVEMENTS
The more traditional, “back to basics” issues are, like those for metering, oriented to inspection, calibration and validation:

• Ensure Timely Gas Quality Data - Online Chromatograph / Daily Chromatograph / Monthly Sample / Annual Sample
• Verify that continuous samplers are functioning properly
• Addressing issues related to pressure base, heating value pressure base and the proper coding of meters and their relationship to a regional chromatograph must all be worked through to minimize the UAF impact.

Operators of shale gas systems and those which balance a combination of natural gas, NGLs and oils have more recently encountered a variety of issues with analysis and sampling. Among them are measuring and sampling gas that is at the hydrocarbon dew point pressure and temperature and sampling non-stabilized liquids that are at the flash point.

Temperature Difference

Validation of a chromatograph sample using hydrocarbon dew point can highlight major differences between temperatures in the meter and sample cylinder.
• The sample procedures described within GPA 2166 for purging a sample cylinder must be followed when purging a cylinder for composite sampling
• Preheat sample cylinder before using the fill and empty method purge method but do not heat a sample system upstream of liquid separators
• Use data validations on all analysis information, whether it originates from a live chromatograph or laboratory sample analysis (for more on validations, please refer to “Measurement Process Improvements” below)

MEASUREMENT PROCESS IMPROVEMENTS

In response to evolving audit requirements resulting from Sarbanes-Oxley (SOX), API 21.1 second edition for electronic gas measurement (released in 2013), API 21.2 for electronic liquids measurement and Alberta Energy Regulator Directive 17, oil & gas companies have made significant improvements to their measurement processes. Along the way, they have identified and mitigated significant UAF losses.

Measurement applications software has advanced to the point that it is able to pull together metering and analysis information from widely-varying sources, synchronize their timing, validate the information, recognize errors and perform accurate recalculations. It is able to unify measurement processes that were never before conducted in a coordinated manner.

Such applications allow measurement departments to accomplish the following:

• Improve measurement operating procedures (inspection, calibration, verification and scheduling of field tasks)
• Easily identify critical issues at the meter, station, segment, and system balance levels
• Resolve measurement issues prior to closing; eliminate PPAs (Prior Period Adjustments)
• Identify trends in transmitter, flow computer, primary device, and related equipment failures
• Apply a consistent validation approach throughout an organization
• Improve communication and resolution management between the field and office staff
• Enhance identification understanding for field and office staff
• Provide timely and accurate information to customers in near real time
• Improve customer service

The applications allow for improvements across the company’s measurement system and incorporating the following reporting into day-to-day procedures:

• Measurement system data
• Third Party reported volumes
• Processing plants
• System loss events
• Meter station operations
• Unaccounted for reports
• Field verification of meter station data

New measurement software applications enable additional improvements in UAF mitigation and allow users to vastly improve their overall measurement integrity.

Data validations can be applied to all metering and analysis information in order to pinpoint anomalies. A broad variety of issues such as deviations in gas composition, operating meters or transmitters out of range, operating near the hydrocarbon dew point and sampling errors can rapidly be detected.
Measurement software with sophisticated validations capabilities can actually turn a large, complex system to an advantage because it allows benchmarking. For example, in an upstream system with thousands of wells, the measurement staff can validate a given well against similar wells to detect deviations and adverse trends.

Mass balancing is another capability that applies particularly to systems that track multiple fluids. Operators of such systems have found that volumetric balancing is prone to under-reporting or entirely missing quantities of lighter hydrocarbons in the presence of heavier hydrocarbons. The “rocks and pebbles” analogy applies, here. The large, massive molecules that characterize the heavier hydrocarbons are analogous to the rocks while the smaller, simpler, light hydrocarbon molecules are analogous to pebbles. Mass balancing will accurately account for light hydrocarbons, even in the presence of liquids.

CONCLUSION

With the industry taking on an “every drop counts” approach to running the business, issues such as unaccounted-for (UAF) gas find themselves under renewed scrutiny. Meanwhile, mergers, acquisitions, shale plays and systems that track multiple fluids have expanded the complexity of today’s operations.

UAF causes fall under a broad range that includes actual losses from leaks or theft, unreported internal use, system operation events or timing and measurement errors.

At its disposal, the industry has proven UAF mitigation techniques plus new technology that is up to the challenge. Operators can more quickly pinpoint anomalies, improve the measurement process and improve system balancing. Contemporary measurement software applications enable UAF reduction at the project level and allow users to vastly improve their overall measurement integrity in on-going processes.