AUDITING LIQUID MEASUREMENT FACILITIES

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Introduction

The word "Auditing" is often used to imply that activities related to a review of general business practices, and procedures for an asset or business unit, are under way.

The objective of those activities is to assure compliance with corporate policies and procedures, industry and government standards, and sound management principles. Additional objectives may include review of accounting and financial transactions for accuracy, completeness and timeliness. The Institute of Internal Auditing defines the process as: "Internal auditing is an independent, objective assurance and consulting activity designed to add value and improve an organization's operations. It helps an organization accomplish its objectives by bringing a systematic, disciplined approach to evaluate and improve the effectiveness of risk management, control, and governance processes."

Relating those processes is not the goal of this paper. The general definition of an audit is "an evaluation of a person, organization, system, process, enterprise, project or product". While multiple evaluations will be involved, the goal here is to provide a systematic approach to imbalance resolution through an understanding of its source(s).

What is a material imbalance?

Liquid assets such as pipelines, storage facilities, processing facilities (fractionation, cryogenic gas processing, refining, terminals, etc.) are multidimensional processes. The basic tool for judging a systems measurement performance is an evaluation of gains and losses. In simplest terms and like a checkbook, without a balance remaining; do deposits equal withdrawals? Pipeline capacity, duration of transmission, and internal storage all serve to blur this oversimplified comparison. Nonetheless, the view from 30,000 feet can be illuminating before the sifting of relative minutia is called for.

Frames of Reference

For any given magnitude of gain/loss, the significance of the imbalance must be judged from the perspective of interval (i.e., a day, a week, a month, etc.) and whether the gain/loss represents a continuing trend. Consideration must also be given the migration duration constant for the asset. In other words, how long does it take material entering the system to exit the system? A pipeline having a migration constant of 9 days, and a gain/loss imbalance reflective of a one week period, is not particularly significant to a material balance gain/loss.

At the other end of the time spectrum, gain/loss information represented by monthly balances for a pipeline are, in the context of judging whether a shorter term imbalance is meaningful, useful for determining performance relative the mean performance of the asset. In addition, they can provide insight as to non-seasonal trends and line fill issues related to transported material variations in density, temperature and pressure.

From 30,000 Feet

Entering in upon the resolution of imbalances in an NGL system the investigator should be familiar with and mindful of the innate features of such systems.

- Is the measurement system made up of inferred mass measurement equipment deployments?
- Is the measurement system a combination of inferred mass measurement and direct mass installations?
- What essential qualities define a mass system?
- What constitutes "measurement" in a mass system?

To illustrate the point, if you re confronted with a loss complaint described as, "such and such asset lost 90,000 Bbls of propane last month." how would you respond? Would you begin by examining the applicable sample, audit the lab, begin a field equipment survey to determine the cause, or pursue any of several other possible avenues of inquiry? If so, you will have failed to take that 30,000 foot view.

Advice of a 90,000 Bbl loss of propane in a mass measurement system simply isn't meaningful. After all, it's a volume, isn't it? Moreover, it's a component in what is undoubtedly a mixed component stream. If this were a purity stream, the measurement would likely be by volume simply because the equipment deployment would be less burdensome. Measurement in these systems is mass measurement, and before any judgment regarding component losses can be made, the mass balance of the system must be ascertained. As a consequence, a component imbalance, though it may have a financial impact, is not strictly speaking an initial measurement concern unless the system in which it occurs exhibits a concurrent mass loss.

In NGL mass measurement systems, the mass balance underlies and overshadows all other considerations and is the beginning focus of any inquiry. Persons without the requisite training and understanding of mass measurement systems whether populated with direct mass devices (Coriolis meters) or inferred mass meter systems, should make every effort to become educated to the prevailing relationships that govern performance and outcome.

The Balancing Concept and Accompanying Confusions

The Checkbook

Many believe that balancing an asset is closely akin to balancing a checkbook even in reverse notation accounting where receipts are accrued as negative values and deliveries are positive values. The balance remaining consistent in concept to that of money in the bank, though in this case held as remaining inventory. To continue the metaphor, if components were synonymous with the various coins of the realm, this strange sort of bank doesn't necessarily deliver the same number of nickels, dimes, quarters, and dollars as those received. Better to deal in bullion here by weight. In these systems, the perceived components volumes received, represented by their composite mass, are not necessarily relatable to the delivered component volumes.

A Two Reality World

In any NGL gain/loss discussion one immediately encounters two very different views. On the one hand, the commercial view is always focused on component gain/loss, while measurement personnel must focus on the initial and underlying question of mass gain/losses. The commercial reality is based on the perception of commodity component financial impact. Measurement personnel must focus on the inventory imbalance before any attempt at reconciling a component imbalance can even be attempted.

Financial performance is a result of both accurate inventory accounting (primary measurement) and the proper apportionment of that inventory to quantities of saleable components. On the one hand; measured mass values, and on the other; calculated component volumes.

It is entirely possible to have a system balance on mass but fail to balance on components with the subsequent commercial view that a loss of some component has occurred. In point of fact, the component isn't lost, but merely improperly apportioned. Hence a two reality world – commercial gains and losses associated with a system whose fundamental measurement balances. For the investigator this requires a clear understanding of the contributors to both competent mass measurement and those factors affecting calculated component volumes.

In addition to the measurement principles, analytically derived apportionment of components and calculation methodologies employed, it is essential that the investigator possess a method upon which to proceed. A systematic approach coupled with a clear understanding of the imbalanced to be reconciled is a prerequisite and is often neglected.

A Methodology

Quantify the Boundary Limits

This is a matter of identifying not only the physical limits of the loss (a gathering system, line segment, pipeline, fractionator, etc.), but also having a complete understanding of the type and magnitude of the imbalance. For instance, when confronted by the typical complaint expressed as, *"The______________________(insert name of facility or asset) is_______________(insert condition; gaining/losing). Please tell us what is wrong with the asset and how the gain/loss can be mitigated (to our advantage)."*

Where would you begin?

1. What is being gained or lost?
   a. Is it a component gain/loss?
   b. Is it a mass gain/loss?
   c. What is its magnitude relative to throughput?
   d. Is the imbalance within operational or contract limits?
   e. If within contract or operational limits, is it also within the uncertainty limits applicable to receipts and deliveries?
   f. Most importantly, is the gain/loss systemic and of such duration that it is readily identifiable as a bias?

For the sake of efficiency and embracing a realistic view of what can be attained, these considerations are mandatory.

Where the gain/loss is of such small magnitude as to be within delivery or receipt uncertainty bounds, even when the gain or loss is systemic, pursuit of a resolution may be impractical. Much time, energy and resources are expended to reduce continuing losses that are within uncertainty limits (typically less than 0.07% of throughput) to little avail. Consultation with management and careful evaluation should be utilized in the initial evaluation and determination of the attention to be given in such cases.

Resolving a loss on a batched pipeline transporting multiple products (y-grade, EP mix, ethane) or multiple variations of the same product (y-grade of varying density) and exhibiting a 9 day transit constant cannot be satisfactorily pursued based on a weekly imbalance. Nor is it efficient or reasonable to pursue a solitary monthly imbalance in such a system for the same reason. Losses in such a system for two months back to back should arouse suspicion. A third month should precipitate action.

Commercial demands often impose a necessity to pursue an imbalance resolution absent any realistic potential of accomplishing it. The emphasis is on dollars not measurement performance and the professional must know and be able to demonstrate futile efforts, as well as, viable ones.

As an example, in considering a pipeline segment exhibiting a mass gain, and viewed from 30,000 feet, three things are immediately apparent.

1. A gain is the result of instrument error. Pipelines don't make product, and logically, should exhibit a slight loss.
2. A gain (more material comes out than went in) can only result from one of two conditions;
   a. Understating the receipts
   b. Overstating the deliveries

Imposing Segmentation

Proceeding from this view, deduct each receipt point value, beginning with the largest contributor, from total receipts and from the total of deliveries. Compare the gain/loss. Do this for each receipt point, one at a time.
If the gain decreases at any point in this exercise, the problem is on the receipt side of the system, if it remains the same or rises, it is on the delivery side. Due caution should be exercised and the results judged with restraint for rarely is there a single smoking gun.

Measurement segmentation of the asset must typically be imposed in order to isolate offending processes or equipment. The more extensive and logical the segmentation is, the easier the problem will be to resolve. The usual material balance view of the asset may not be useful in these instances simply because they are related to inappropriate boundary limits for purposes of error resolution.

Quantifying Observable Error in Each Segment of the Asset

For instance, when confronted with a loss complaint such as, "*The XYZ fractionation plant is losing propane. Please tell us what is wrong with the asset.*" and where the facility balance is kept from gathering to plant deliveries, segmentation of the asset other than that typically used to determine gain/loss must be used.

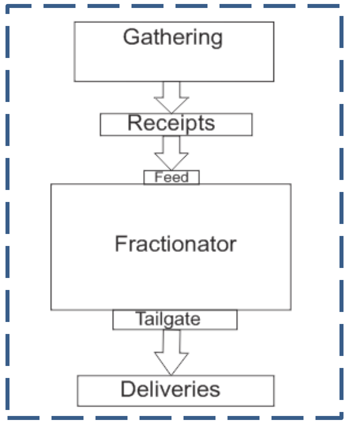

FIGURE 1. Normal Boundary Limits

In such cases, further segmentation to compare gathering with receipts, receipts to plant feed, plant feed to plant tailgate, etc. are necessary to determine the probable origin of the imbalance. Again, even though the complaint is in regards to a component imbalance, a determination of the mass bass balance must be accomplished before moving on to the component problem. In many cases, reconciling a mass imbalance goes a long way toward mitigating the volume loss.

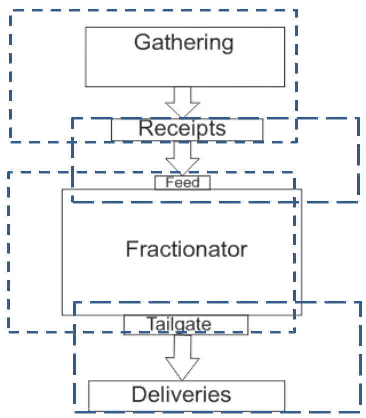

FIGURE 2. Measurement Segmentation

Positing Causal Theories

The mass comparison of receipts to deliveries is just that, a comparison of received pounds to delivered pounds transiting the system. The way in which those pounds are measured can vary widely. Some may be from receipts over scales (trucks). Some may be from inferred mass measurement installations (volume meter and live densitometry). Some may be from direct mass measurement (Coriolis meters) and each brings inherent potential error in its use.

Inferred mass measurement is, by far, the most common mode of mass measuring NGLs. The arrangement of devices is straight forward but accompanied by a host of not so simple operational relationships. Direct mass measurement is becoming more common but is accompanied by its own deficiencies.

In inferred mass measurement systems, mass is calculated as;

Mass = Iv X MF X Density (g/cc) X DCF X 350.507 (Equation 1)

Where:
Iv = indicated volume
MF = meter factor
DCF = density correction factor
* 350.507 is a constant used to convert g/Bbl to pounds mass.

Each component is a potential error contributor.

Correcting the indicated volume reading includes applying the meter factor which is derived using a prover to develop information regarding the difference between reported volume and actual volume. The prover has limited error based on its calibration but may have malfunctioned in any number of ways from leaking to having faulty pressure or temperature indication during the meter proof.

The density has an equal degree of error contribution (1% density error is 1% mass error) and is corrected for accurate reading based on a calibration exercise involving accurate temperature measurement, accurate pressure measurement, the use of a volume collection device (pycnometer) , weights, scales and human interaction.

Each potential error contributor must be verified and each will be inaccurate to some degree (uncertainty). Each will be expressive of an approximate value bounded by the window of certainty.

Verify or Discard your Theories by Data Comparison

Verification of each contributing factor must be verified and its applicability judged with reference to baseline performance values as historically charted. Over the period of interest receipts average density should closely match delivery average density, absent intermediate storage (wells, caverns, tankage, etc.).

An exercise similar to that previously discussed regarding receipt and delivery mass comparisons may be necessary to help discover whether the live density in either area are the causal. If multiplying the indicated delivery volume by the average receipt density eliminates the mass imbalance, delivery densitometry should be suspected. Obviously, the converse will be true of receipts.

Should these comparisons indicate that flowing densities for both receipts and deliveries are unlikely to have caused a mass gain/loss, suspect the volume contribution. Pay special attention to proof data and each corresponding meter baseline for stability. Drift in the meter factor either high or low of the baseline should be cause for concern and further investigation.

Component Imbalances

Having resolved the mass imbalance, if any, to reasonable levels, it is proper to proceed to a review of any component imbalance. The investigator should keep in mind that where no mass imbalance is evident or is small, the component imbalance is thus far constrained. Essentially and logically, there can be no component loss where there no mass loss.

Component volumes are calculated, not measured volumes, derived from measured mass multiplied by the percentage of the component extant in the stream as determined by gas chromatographic analysis of a flow proportionately obtained sample. In other words, the flow signal for indicated volume is used to drive a sampling system to capture a minute volume of the flowing material at predetermined and regular intervals and deposit them in a receiver during the course of the product movement. Hence it is "flow proportional".

The chromatographic analysis is used to differentiate each of the components by molecule and mol%. The mol% is subsequently converted a weight percent and applied to the total mass for the associated measurement point to yield the mass value of the subject component. Using GPA 2145 volume/weight ratio values for each component produces the constituent volumes for the components.

If an analysis error is suspected and the error exceed 0.04% (the analysis uncertainty at 2 sigma), a comparison of average flowing density as reported by densitometry to that reported by analysis should be made to determine whether the sampler or the lab is at fault.

Pull a spot sample at the densitometer connection while simultaneously obtaining a reported flowing density value from local instrumentation (flow computer). Have the sample analyzed and compare the density from analysis with the flowing density on the spot report from the sample pull. If the value agrees with densitometer, the sampler or the sample pull process is at fault. If not, the fault is in analysis. This assumes that the densitometer has been calibrated before beginning the exercise.

Process Error

When all efforts to resolve the imbalance through data comparison, equipment survey, and calculation review, review of flow computer setup and associated field reviews have proved unsuccessful as is almost always true to some degree. Look for operational causes associated with training deficiencies.

Much of our training is on the job training, or as I sometimes refer to it, the transfer of “tribal knowledge”. Improper process is often a major contributor to imbalances. Review of all calibration procedures are a mandatory review, as are sample pull technique and sample handling.

Conclusion

No dissertation on the subject of imbalance resolution of less than novel proportions an adequately deal with all of the nuances that may be encountered. Every methodology will prove incomplete at some juncture and new approaches continually developed to suit specific cases. This work should be considered and overview of one potential process.

Regardless of the process employed, each individual involved in effort to reduce, for it is unrealistic to talk of eliminating, gain/losses should keep firmly in mind the limitations on success imposed by the equipment deployed. Experience is replete with instances in which much time effort and money were expended in pursuit of imbalance resolutions that were never reasonably forthcoming.

As an example, It is of little purpose to pursue the reduction of volumetric loss (volume system) wherein the loss is less than 0.07%, even if systemic and recurring, month-to-month. After all the uncertainty of a single turbine meter is +/- 0.0275%, without considering those associated with co-installed temperature and pressure transmitters. Each gain/loss must be judged from the perspective of possible resolution on its on merits.

Where human interaction prevails, there will always be room for error. This, of course applies to every nuance of the balancing process from setup and calibration of equipment to calculation processes. The good news is: All of the resources are available in any gain/loss scenario to allow for reasonable resolution.