

Chart Auditing

Auditing and Verification of Measurement at Chart Measurement Stations

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Auditing of measurement stations is critical to insure proper credit for gas produced and sold. Our experience has shown that over 3% of months audited on chart measurement stations have problems which result in a measurement adjustment. Return on investment in auditing should be greater than two to one. If properly installed check measurement exists and is used to select those stations for which a full audit is performed, the return may be as high as ten to one, not including the ongoing cost of the check measurement, or four to one including such costs. Therefore failing to properly audit can result in substantial profit loss for your company.

There are benefits to auditing above the direct increase in revenues associated with retroactive measurement adjustments. Verification of your own measurement procedures, identification of certain operational problems and correction of conditions which result in poor measurement are among these benefits. Also, there is the difficult to quantify effect, that once a problem is identified in the audit process and corrected, the same problem does not continue in following months, though it may re-occur. There may be a reduction in the number of mistakes occurring after an audit program begins, since no one likes someone else finding their mistakes.

Information Collection: A full measurement audit consists of several parts. The first is collection of information. Each of these categories will be discussed more fully later. The necessary information to conduct a full measurement station audit includes:

- 1) Contract information concerning measurement and quality of the gas;
- 2) Witness meter station test reports (or in their absence meter station test reports by the other party).
- 3) The charts for the audited station.
- 4) The measurement statement for the audited station including integration, calculation and estimation information.
- 5) Gas analyses on the audited station.
- 6) Check measurement records or line balance information if no check measurement exists. This includes charts, test reports and analytical info for the check meter.
- 7) Station information concerning the conditions of measurement.
- 8) Any other information which exists concerning the gas measured and the equipment used.

Once all of the information available is collected, the rest of the audit can begin. I say the rest of it, because if some of this information is not available, this should be documented and procedures corrected so that in

the future, this information is available. In the audit we are looking for several things.

Contract Verification: The first is, did the original measurement follow the specified procedures for measuring the gas as per the contract including the type or equipment used and its operation. These contract checks include:

- 1) Was the measurement at the proper base conditions, both Mcf and Btu?
- 2) Were samples taken and applied properly?
- 3) Were any adjustments for meter calibration properly applied.
- 4) Were any estimates made for missing or incorrect data made using the proper method?
- 5) Were the proper calculations used?
- 6) Does the equipment used to measure the gas such as samplers, recorders, temperature elements etc. meet contract specifications?

If the answer to any of these things is no, then the other party should be notified of this discrepancy. If the actual procedures followed are in fact agreeable to both parties then the contract should be amended to reflect this. Otherwise needless lawsuits can result well after that fact for very little gain. Most of these problems can be fixed before they become a matter of litigation.

Measurement Verification: The second thing to look for, is if the measurement is the best that can be determined from the measurement data. Were proper corrections made for any problems that occurred in the original measurement such as recorder calibration, missing data or equipment malfunction and were there any mistakes made in the original measurement. Many audits only include this portion of the complete procedure and thereby miss many of the benefits of auditing. There are two types of errors which can occur in the original measurement at this point. Errors of omission, which is where a problem exists which should have been corrected and was missed in the original measurement and errors of commission which is where corrections were made for conditions that in fact were not present, or incorrect corrections were made. Errors of commission also include inadvertent mistakes.

These errors may include many different things. Such errors can be broken down by which part of the measurement process is their source. There are errors associated with the primary device (meter tube, plate and seal ring), the secondary device (recorder, tubing, tap valves, and manifold), the gas analyses, the charts themselves, chart processing and integration and data entry and processing.

Primary Element Problems: Problems to look for at the primary element are usually documented on meter station inspection reports. They include the incorrect plate size documented, plates in backwards, obstructions in the meter run such as straightening vanes that have pulled loose and lodged against the plate, plates missing or damaged (dished) and leaking fittings or seal rings. Some of these problems will only be found on special tests, not routine tests. These test are often only conducted once a measurement discrepancy (of unknown cause) is identified. Others, such as plates installed backwards or incorrect plate size documentation should be caught on a routine meter test, but only if the plate is inspected. To identify many of these problems requires check measurement. Such check measurement needs to be a complete check measurement station, not just a check recorder, since a check recorder uses the same primary element and therefore records the same (incorrect) information. Check recorders are useful, just not as useful as check measurement stations. Other than damaged, backwards or incorrect plates these problems require a check measurement station to properly quantify.

Plate Problems: For the plate problems and check measurement station can help in quantifying the adjustment due, and can identify the period for which the adjustment is due. Problems of unknown duration are generally adjusted half way back to the preceding test unless the period can be determined. Check measurement allows the period to be determined, and often the contract will specify that properly recording check measurement will be used if available as the first source of adjustment where the sales measurement is in error. For incorrect plates, the adjustment should be based upon recalculating the sales meter using the correct plate size. For backwards plates or damaged plates a comparison between the recorded flow with a proper plate installed and one with the bad plate installation can be made. If the plate is severely dished, or if the flow fluctuates hour to hour, such comparisons may be problematic. The plate in question may be taken to a test location and the ratio of the basic orifice coefficient for that plate and the nominal one can be used. Therefore, severely damaged plates should be preserved in case such testing is necessary.

If a plate change needs to be made, the audit department should inform the field. Best measurement at a station is achieved at the highest operating differential within range at the station, all other things being equal.

Sometimes operational concerns require measurement to be made routinely, lower on the chart, but the average differential should be maximized, and kept above 30% of the chart range if at all possible. This applies to pressure readings as well, and a pressure range change should be requested if a station switched from high to low pressure operations.

Seal Rings and Fittings: Leaking seal rings and fittings are confirmed by blind plate tests. However, these tests cannot be used to definitely quantify the amount of the error. One indicator of the possibility of such leaks is the use of Teflon seal rings. Unless the fitting is new with a perfect seating surface, Teflon seal rings may not seat properly and will usually leak. Measurement errors in excess of 20% may result. Sometimes seating surfaces may be damaged so that even the softer rubber seals won't seat properly. Since each time the plate is placed in service it may seat differently, quantifying the magnitude of these errors without check measurement is not generally possible; however, fixing the problem is!

Finally, there may be conditions present, which adversely affect measurement at the station, for which no adjustment can be readily determined. These conditions may be the result of measurement practices or operation and equipment problems. These problems include, pulsation, improper plate sizing, ongoing problems with calibration, the presence of fluid, and differences between check and sales measurement of unknown cause. Where these problems are identified, they should be pointed out to the operations department, the meter technicians, etc. so that they can be fixed and will not continue to adversely affect measurement.

Liquids: The presence of liquid in the measurement fittings and taps can cause severe measurement errors. If only a small amount of liquid is present in the orifice fitting, it may not cause a noticeable effect on measurement. If this same amount of liquid is present in the tap valves, tubing or manifold, it can cause a severe mis-measurement. Large amounts of liquid at the station cause problems even if there is none in the meter tubing. Where any liquid is routinely present in the fitting, the meter station configuration should be checked to make sure there are no possible liquid traps in the meter tubing. This includes horizontal orientation of the meter taps! If the taps are oriented horizontally and the gas is not completely dry (without

liquids of any description), then the meter tube should be rolled until these taps or in a vertical orientation. Otherwise 2-3% measurement errors are likely and 10% measurement errors are not unheard of. In order to quantify this particular measurement error, a properly installed and recording check measurement station must be present, and even then it may not be possible to get an adjustment, but at least the ongoing problem may be rectified.

Pulsation: Pulsation, which is the presence of high amplitude sound (pressure) waves in the flowing gas can result in substantial mis-measurement. Usually pulsation results in the measurement being high, but not always. It has been our experience that greater than ninety percent of the stations where the source of the pulsation is upstream of the measurement station, the pulsation causes high measurement. This percentage is substantially lower where the pulsation source is downstream of the measurement. Pulsation can be caused by control valves or simple turbulence and well as compressors, though anywhere slow speed reciprocating compressors exist, a check for the presence of pulsation should be made. Sometimes, indication of possible pulsation is present on the chart, but not always. The presence of vibration on the pressure and temperature pens is often indicative of pulsation especially if there is a day to night variation in the magnitude of this vibration. However, such vibration may at times be caused by wind or rain, or may be “ground shake” from by a nearby compressor. Therefore the actual presence of pulsation must be confirmed in the field.

One method of confirming the presence of pulsation in the field is a “Tap Test”. This test may confirm the presence of pulsation but unfortunately cannot confirm its absence. However it is a simple test and should be run anytime pulsation is suspected. This test consists of observing the differential zero on the meter with the meter equalized and the upstream tap valve open and downstream tap valve closed versus the zero with both tap valves closed, and with the downstream tap valve open and the upstream tap valve closed. If there is a zero shift, it is confirmation that pulsation exists at the station and is affecting measurement. Where pulsation exists, steps should be taken to eliminate it, as any measurement is uncertain in the presence of pulsation.

Chart Recorder: Errors can occur at the chart recorder including Clock problems, Calibration, Range spring and Bellows problems, and Meters left wholly or partially out of service.

Calibration: Generally the contract specifies how big a recorder calibration error needs to be in order to have a retroactive correction made. These corrections are usually made routinely and correctly and seldom require an audit adjustment. Such corrections may be made at the time of chart integration by setting the integrator calibration to correct for the error. Mathematical corrections can also be made, but need to be checked since the percent error will depend upon the flowing conditions. Determining how far back to carry an adjustment may be difficult without a check recorder. If the time that an adjustment should be made cannot be determined, generally the contract will specify that the adjustment will be made half way back to the proceeding meter test. The period for which a differential zero needs to be adjusted can often be determined more closely than this, by observing if the meter properly zeros during periods of no flow. In order for this to be possible, the low differential stop should be set below the zero line. If the meter is routinely checked for proper zero when the charts are changed, this will eliminate many adjustments to prior month periods, and may help identify problems in the field, such as liquids, pulsation, bad bellows, etc. Such checks, if they are performed should be recorded and noted on the charts.

Meter Left Out of Service: If the meter is left completely out of service, it will usually record zero. The meter can also be left partially out of service, with the equalization valve open. Then a meter will generally record flow that looks to be valid but is in fact much lower than the real volume. This problem generally occurs after a meter zero test is performed, the meter is blown down for meter freeze, at a plate change or at a meter calibration test. The field technician should make a note on the chart any time this problem is found and corrected. A check meter is the best estimate method. A check recorder, especially one that shares common taps may also record low during this period.

Estimates for Missing Data: Estimates for missing data due to charts damaged or lost, pens not inking, or stopped clocks can best be made using check measurement. Clock factors or estimates from preceding and following periods should generally be used in the absence of check measurement. The question should be, is an estimate necessary, and if so is the one made reasonable.

Meter Freeze: Meter freezing can result in estimates needing to be made. Meter freeze is the formation of natural gas hydrates in the meter taps and tubing. It can occur any time the ambient temperature is less than 70° F if there is water vapor present in the gas and it is at high pressure. At lower temperatures even dehydrated low pressure gas may exhibit meter freeze. High temperature of the gas does not prevent meter freeze and may even contribute to it since high temperature gas can hold more water vapor. Since there is no flow through the meter leads, they will generally be close to ambient temperature, regardless the temperature of the flowing gas. Meter houses may mitigate this effect, especially heated ones, if the heater is working.

Meter freeze can usually be recognized by comparing the check meter to the sales. Both may freeze, but unless the check measurement is a recorder hooked to the same taps, usually not at exactly the same time or with the same error. Usually when a meter freezes, some or all of the fluctuation in the differential present when the meter is recording properly, disappears and the differential increases steadily to over-range or decreases steadily until it hits the low zero stop. This process usually begins in the early evening or early morning hours. Meter freeze usually ends suddenly, either when a meter man blows down the meter to unfreeze it, which should be noted on the chart, or by itself when the temperature rises in the morning. Sometimes meter freeze will also result in the pressure record dropping off slowly due to pin-hole leaks in the meter leads. If the pressure drops all the way to zero, and the temperature record starts tracing ambient, then there is a chance that the entire flow line froze and that there is no-flow during this period. Many times a sudden temperature change is the only indication of this during a period of meter freeze. With check measurement, meter freeze that was not originally corrected, may be noticed and corrected in the audit.

Range Springs, Bellows and Clocks: Recorder malfunction due to broken range springs, bad bellows, and bad clocks can also best be corrected for using check measurement. If there is no check measurement, then the period of the error will have to be estimated. Malfunctioning clocks are usually easy to spot using chart on and off times. They can usually be estimated using clock factors, (multiplying the recorded volume by the ratio of the correct time over the recorded time). If the time for which the clock was malfunctioning includes downtime, then the entire time on the chart should be used, unless there are field records indicating how much actual down time occurred. If the malfunction includes only flowing time, then only flowing time

should be used. If the clock stops, and the differential was steady for the missing time, then the differential can be drawn in.

Broken range springs cause the meter to record high, throughout its range. Often the meter will over-range while the range spring is broken. There is usually a sudden rate change indicated when the range spring breaks. This, plus an indication on the test report of how high the meter was recording when the broken spring was found, allows an estimate to be made for some stations as to how long the problem occurred, and how much to adjust by. Otherwise, half way back to the preceding test and using flow during similar periods may have to be used.

A bad bellows causes the differential record to cease responding to changes in flow either partially or completely. The period during which a bellows was bad is may be impossible to determine without a check meter. Sometimes the differential stops showing the peaks of its swings, or stops traveling at all, but sometimes there is only a subtle effect, until the meter is ranged during calibration. Therefore the percent error at the time of the meter test is often not an indication of the amount of the error, since the meter test itself can aggravate the problem.

Other Problems in the Field: Occasionally, because the auditor is looking at the history of a station they may notice an ongoing problem with the calibration of a meter that the meter technicians fail to observe. If for instance the differential zero is always substantially off when the meter is tested and no operation (over-ranging and under-ranging) causes are present then this may be indicative of a loose linkage somewhere in the differential assembly. This should be brought to the attention of the meter tech, the sooner the better.

Finally there are discrepancies between the check and sales measurement for unknown causes. Both recorders are calibrated, and all standard causes have been ruled out, yet the two stations record differently in the field. In this case the field should be contacted to run additional tests on the two meters to identify the source of the problem. Pulsation tests, leak tests, blind plate tests, verification of meter specifications, borescope tests, and if necessary tearing down the meter tubes and re-mic'ing them and testing them for plate centering may need to be conducted. A check meter does much less good if it is not properly recording, and the error could just as likely be at the sales meter, or both.

Integration and Calculation: Mistakes in integration, and calculation are a major source of errors found in auditing. Integration errors include not integrating the entire chart, calibration of the integrator, computer problems, and failure to follow the chart pattern. Interpretation of banded differential is addressed as a separate problem. Data entry and calculation problems are also possible such as incorrect meter ranges, plate sizes, temperatures, and analytical data. Occasionally the wrong chart is used. The auditor is more likely to recognize this problem since they generally see an entire months charts, instead of processing them as they come in throughout the month. Re-integration and calculation of the station using the meter test, equipment change reports and analysis will generally catch most integration and calculation errors, though tracking down what exactly is wrong is more difficult. Errors in integration are usually confined to a single chart period whereas data entry errors, in the meter set-up info can go on for months at a time.

Gas Composition: Gas analyses affect volume and energy measurement. If an incorrect analysis is used,

depending upon what is wrong with it, the error may be either high or low. Most errors in analysis result from bad samples taken in the field. Rarely, samples are lost or switched in the lab. Duplicate samples can be taken, which will identify most of these errors. Along with a historical comparison of samples, these duplicates can provide a source for an adjustment. Historical comparisons alone, do not always apply. The gas composition can and does change, sometimes drastically with operational changes. If the sales measurement party is using such methods to identify bad samples, they made not use a sample that is valid because it lies outside the bounds of historical gas compositions. On production sales or plant residue charts the auditor may also have access to operational information indicating that the gas composition should have changed. One possibility is that the original party did not use a sample, assuming that it was bad, when in fact the gas composition had changed.

Error in gas sampling usually consist of high nitrogen due to improper purging of the sample loop and bottle, high “heavies” due to liquid trapped in the sample bottle, low “heavies” due to fractionation of the gas during sampling, loss of the sample, and failure to properly obtain a composite sample resulting in the sample being more of a spot sample. In this last case, if two bottles are hooked to the same sampler, both will be incorrect. “Heavies” refers to the higher carbon number hydrocarbons: butanes, pentanes and hexanes plus in the sample which have a higher specific gravity (heavier) and higher heating value.

If the sample contains high nitrogen due to air included in the bottle, the specific gravity will also generally be too high. This results in a low Mcf being calculated and a low Btu factor, thereby a much lower MMBtu. If the sample has high “heavies”, it will generally result in a lower Mcf due to the higher gravity of the gas and a higher MMBtu due to the higher Btu factor. This is not always the case. For certain conditions, (high pressure and low temperature) the calculated volume may actually increase with increase in gravity and therefore the MMBtu will doubly increase. Low “heavies” generally result in a higher volume and lower MMBTU. Improper composite sampling may result in either high or low measurement depending upon how the gas composition changed during the sample period.

Interpretation of Integration: The final and biggest source of adjustments in chart auditing is interpretation of integration. This is where the incorrect average differential is used on charts where the differential fluctuation creates a band. The AGA part No. 5 put out by the transmission and distribution committee suggests the use of fast clock test and other information to properly interpret wide band differentials, and only in their absence using the average of the flow at the top and the bottom of the band. This assumption which assumes that the differential is either at the top or the bottom spending 50% of the time at each may be reasonable for those patterns caused by a unit cycling on and off, but is the lowest volume for all patterns where the average differential is at 50% of the band. If the average differential is at 50% of the band, and spends any time between the high and low differential extremes, then the volume is higher than that calculated using this assumption.

The average differential in a band may be significantly higher or lower than 50% of the band. Without testing, the correct percentage to integrate a banded differential cannot be determined. Fast clocks tests give at least a spot reading of what is reasonable for a given station, but if the problem is severe, the installation of a EGM recorder at either check or sales may be the best method to resolve the discrepancy. Such a meter may be used on a temporary basis to establish what the long term average should be, if the delivery does not justify the expense of a permanent EGM recorder. Though some would argue that a fast

clock is only accurate for the period during which the test is performed, at least it is real data. Using any (often self serving) standard percentage is a rank guess. Any fixed percentage of the band is not correct in some instances, since even the AGA part 5 method varies between 25% of the band and 50% of the band.

Sometimes simple equipment or operational changes may greatly decrease the problem of banding differentials. Using a throttling dump valve rather than a snap acting valve is one possible change. This may not be possible however, if measurement of the liquids from different separators using turbines is being done. The throttled flow of the liquids may be too low to measure through such meters, and the pressure drop across the valve may cause flashing. Gas measurement may thereby have to suffer at the expense of good liquid measurement.

Some stations may have no solution, though steps may be taken to get better measurement, good measurement may be impossible. The primary example of this is well sales where the wells are on an intermitter. Chart measurement on these stations is problematic. The production goes from zero to 100 percent of the chart and back to zero or almost zero in a time that usually is not resolved on the chart. One possible solution is the use of fast-slow clocks, which turn at a much higher rate for the first quarter of their rotation. However, these clocks may not offer enough resolution. If the period of the fast clock is less than the time between kicks, this may result in worse, not better measurement. If the flow is worth 24 hour clocks and their associated expense (chart changing or automatic chart changers and their problems) then this may sometimes be a solution. Even so, some of these stations have peak flow for less than ten minutes at a time and much of the flow may be during the tail off period where the differential is too low for good measurement using a plate designed for maximum flow. Electronics may or may not give better measurement, depending upon the ratio of the flow during the peak to that during the tail. The EGM's low zero cut off may create more error than its more exact measurement of the kick eliminates. Such judgements need to be made on a case by case basis. Sometimes many such stations may be combined into one gathering point and that common points measurement used, but the cost of this may be prohibitive. The only saving grace on intermitter stations is that relatively speaking they do not have much gas. If the well produced a lot of gas, it would be capable of lifting itself without using the intermitter. Intermittent flow on the distribution side is another matter, and may require dual meter runs with orifice and turbine or positive displacement measurement. Even then, problems may occur with run switching.

Requests for adjustments due to discrepancies should identify the source of the error and a recommended resolution. We have found that properly identifying the source of the error goes a long way in getting the other party to agree to an adjustment. One benefit of routine auditing and proper communication is that on-going problems are identified and eliminated so that retroactive adjustments are minimized. Of course without any auditing, retroactive adjustments are often absent but this is a different problem. Elimination of on-going problems plus operational changes to obtain better measurement are a vital and often overlooked benefit that proper and complete auditing can help achieve. Requests for equipment and operational changes should be made to the appropriate field personnel. Without checking the measurement, you can never be sure you are getting the proper credit for your gas deliveries or paying the right amount for your gas receipts.