Tank-nically Speaking

by Marcel Moreau

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Baffled by a Leak? Check the Inventory Records

Inventory control of fuel stored underground, though long recognized as an invaluable business practice and a valuable leak detection staple, has often been as palatable to UST system operators as Brussels sprouts to a five-year-old. The petroleum marketing trade press from the 1960s and '70s, a time when inventory control was touted as the first line of defense against leaks, documents that even in the face of a burgeoning storage system leak problem, inventory control was not a popular activity among service station operators. Given that inventory in those days required manual sticking, visual reading of totalizer meters, and pencil-and-paper arithmetic, it is no wonder that it seemed more a burdensome chore than a safeguard for economic well being against the possibility of a financial, environmental, or public relations disaster.

And, truth be told, while the mechanics of conducting inventory control are fairly straightforward, the interpretation of the resulting data can be complex. Most petroleum marketers had (and still have today) only a primitive understanding of the sources of error in inventory control and why it is that there are always differences between the book and the stick values in their inventory records. (For a discussion of sources of error in inventory control, see "Inventory Control—the Untold Story," *LUSTLine* #14.)

Today, reliance on inventory control for storage system leak detection, especially the kind performed completely manually, has largely been supplanted by more mechanically or electronically sophisticated methods. While most of these methods offer clear advantages in terms of leak detection accuracy and reliability, they can also foster an overly complacent attitude that nothing can go wrong. Putting all our leak detection eggs in one basket, even a basket as seemingly secure as secondary containment, has its pitfalls. Consider the following examples.

The Case of the Frosty Fill Pipe

A C-store was doing great—selling over a million gallons a year of gasoline—when the owners went bankrupt. They were puzzled as to why they couldn't seem to make any money. Their storage system was completely secondarily contained, their ATG continuously monitored sensors in the tank interstitial spaces and the piping sumps, and they had electronic line leak detectors, to boot. It was not until an assessment conducted as part of a pending sale of the property revealed tens of thousands of gallons of gasoline in the subsurface that it dawned on all concerned that something had gone very wrong.

The operator had been a pack rat with regards to records, keeping daily sales reports from the point of sale system (POS), daily ATG printouts, and delivery receipts carefully stashed in boxes. But he had never bothered to do the math to track his gasoline inventory. When the inventory data were put together, it became glaringly obvious that some 3 to 4 percent of each delivery into the regular unleaded tank over a three-year period was unaccounted for. The total volume lost was estimated to be in excess of 50,000 gallons.

Because the tank was located in a northern climate and the fill pipe lacked a drop tube, a break in the fill pipe seemed like the most likely

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cause of the problem. Subsequent visual observation confirmed that the spill containment manhole had completely separated from the fill-pipe riser.

The Case of the Faulty Filter

A C-store/diner facility was less than a year old and business was good… until the water acquired an unpleasant odor and taste. Water quality testing revealed hydrocarbons and MTBE. How could this happen? The facility was completely secondarily contained and equipped with an ATG that continuously monitored sensors in the tank interstitial spaces and the tank-top piping sumps. There had been no alarms.

Inventory records had been kept, but when things were busy they often slipped to the bottom of the "in" box and no one really looked at them. After all, the facility was virtually brand-new and state-of-the-art, so why bother with inventory records except to see how gasoline sales were doing?

When the "in" box was finally cleaned out, a review of the records revealed disturbingly large daily losses in the super unleaded product for the previous month, amounting to some 5,000 gallons. Visual inspection revealed a dispenser sump with product in it and a leaking fuel filter. Further investigation found a leaky penetration fitting in the dispenser sump. Because there was no sensor in the dispenser sump, the leaky penetration fitting allowed the leaked product to escape silently from the secondary containment system without ever triggering alarms.

Murphy Rules

The moral of these stories is that storage systems are not yet exempt from Murphy's law. With that in mind, let us not forget the virtues of redundant leak detection systems in preventing mishaps from turning into disasters. Though inventory control is far from perfect, these stories illustrate how inventory can be very useful in spotting significant problems that much more sophisticated systems may fail to detect. And with today's technology for determining physical inventory, recording sales volume, and doing the actual math, keeping inventory records and figuring out what they are telling you is a much simpler process than it was 20 years ago.

Where to Begin?

So, you've got a pile of inventory records in front of you, now what? Maybe you want to know the magnitude or the duration of a leak, or maybe you are trying to determine if there is evidence of a leak in the records. Where do you begin? Because reading inventory records is not taught in high schools or colleges, I've prepared an 11-step primer on how to read inventory control records. These are tips that I have learned from reviewing multitudes of inventory records over the years. They are presented in order from simple to more sophisticated:

If you need a refresher on inventory terminology and how to do the calculations, refer to U.S. EPA's publication *Doing Inventory Control Right for Underground Storage Tanks.* (#EPA510-B-93-004, available on the Web at: *www.epa.gov/oust/pubs index.htm.*

How Much Data?

Before we go to our primer, we need to think about how much inventory data is enough. Though one month is the industry and regulatory standard period for checking inventory variances, a month is rarely sufficient to get a firm handle on what is happening using the simple means described here. I like to see at least a year of records—and more is always better. It is also often useful to compare what is happening with the different petroleum products at the site, so don't forget to check the records for all products, even if you know which product leaked.

An 11-Step Primer on Reading Inventory Records

Step #1: If the math is done by hand, check the arithmetic.
Though inventory recordkeeping is increasingly automated, some folks are still in the pencil-and-paper era. There are many opportunities for computational errors and slips of the pencil in a 30-day inventory record. A simple procedure to check for these types of errors is to calculate the monthly variance using a process other than summing up the daily variances to see if you get the same result. To do this, follow these steps:

1. Start with the physical inventory (i.e., the gallons in the tank based on a gauge stick or ATG reading) for the beginning of the month.
2. Add up all the delivery volumes for the month and add this sum to the beginning physical inventory.
3. Add up all the sales numbers for each day of the month and subtract this sum from the beginning physical inventory plus deliveries sum that you just calculated. This gives you the "book" inventory for the month.
4. Subtract this book inventory from the physical inventory for the last day of the month to calculate the monthly variance. The monthly variance calculated this way should be exactly the same as the monthly variance calculated by summing the daily variances for the month.

If the numbers are different, then there is a math error either in the calculation that you just did or in the original inventory record. This little check says nothing about whether the variance is acceptable or not, it just determines whether the variance has been calculated correctly. If you're doing this for more than two months' worth of data, it is probably worthwhile to construct a spreadsheet, using standard software, to do the calculations for you. If you don't feel like reinventing the wheel, an inventory calculation spreadsheet can be downloaded for free at *www.kwaleak.com/technical/index.htm.*

Step #2: If physical inventory is measured with a gauge stick, check the stick and the records to determine if measurements were made properly.
Check the gauge stick to be sure that it doesn't have a piece missing from the bottom and that the numbers are clearly legible. Also check the tank chart and try to determine if it is the correct chart for the tank. If you have no way of telling whether the tank chart is correct, don't worry, the

inventory records will tell you. (See Step #10, below.)

If you are interested in checking the inventory records for regulatory compliance purposes, you need to know whether measurements were made to the nearest 1/8 inch. If inch measurements are recorded (as opposed to just gallons), you can verify that the required accuracy is being used by checking the frequency with which 1/8-inch measurements occur in the inventory record. In any given inch on a gauge stick, there is one whole-inch mark, one 1/2-inch mark, two 1/4-inch marks, and four 1/8-inch marks.

Because four out of the eight possible readings are eighths of an inch, then pretty close to half of all the measurements in an inventory control record should be 1/8-inch measurements (assuming that the liquid-level variation in the tank is random). If only a few measurements in a 30-day record are eighths of an inch, then measurements are not consistently meeting regulatory requirements.

Step #3: Count the positive and negative variances.

One of the most powerful methods for quickly evaluating an inventory record is to count the number of positive and negative daily variances over a month-long (or longer) period. If there are no leaks and there are no other measurement issues (e.g., meters are accurately calibrated, correct tank chart is used, ATG is programmed correctly), then there should be a very nearly equal number of positive and negative daily variances over the period of record. If the number of positives and negatives is not closely balanced, then there is something going on that you need to investigate. Keep in mind that it is not necessarily a leak. There could be a meter-calibration problem or a tank-chart problem or some other problem with the measurements. But the inventory records may not be very useful for release detection unless the cause of the imbalance is identified.

Step #4: Look for "bounce" in the record.

It is not uncommon in inventory records to see a substantially larger than normal variance one day and a similarly large variance, but with the opposite sign, the following day. This type of event is often referred to as "bounce," which is usually attributable to some slip in the recordkeeping, perhaps a misreading of the gauge stick or an erroneous conversion from stick reading to gallons. Bounce could also be due to sales volume and physical inventory measurements not being taken at the same time, or failure to record a product delivery on the correct day. Because the errors are typically of similar magnitude and opposite sign, they do not have a significant effect on the overall inventory variance calculation, as long as they occur infrequently.

Let us not forget the virtues of redundant leak detection systems in preventing mishaps from turning into disasters. Inventory can be very useful in spotting significant problems that much more sophisticated systems may fail to detect.

Step #5: Look for large discrepancies on delivery days.

Delivery-day variances are often larger than non-delivery-day variances. This is because tank-tilt and tank-chart errors will be accentuated by the typically large quantity of fuel that is added to the tank. But unusually large delivery-day variances that do not "bounce" back the next day may be an indication that a tank was overfilled. Alternatively, it might be a sign that the overfill prevention device was triggered before the entire quantity of fuel brought to the site was delivered into the intended tank.

What may have happened is that the driver dropped the excess fuel into an adjacent tank, even if the fuel had a different octane rating. This is often called a "cross drop." Check for this by comparing inventory variances for all the tanks present at the site. You might find that on a given day, there was a 400-gallon shortage in the regular unleaded product, and a 410-gallon overage on the super product. If the normal daily variances are much smaller than this (say a few tens of gallons), then this is fairly conclusive evidence that a cross drop has occurred.

Depending on whether the cross drop was the result of an overfill or the activation of an overfill device and the driver's response to the situation, a delivery spill may also have occurred. Check the delivery receipt for before and after stick readings that the driver may have recorded for additional clues as to what happened. A post-delivery stick reading of 110 inches in a 92-inch diameter tank is a dead giveaway to an overfill event. If available, ATG delivery reports can also provide information about the after-delivery tank level and the amount of fuel that was actually delivered into each tank.

Step #6: Check meter calibration.

Look for meter-calibration stickers typically affixed to the dispensers by weights and measures people to determine if meter miscalibration may be an issue. Even if meters have been calibrated in the not-too-distant past, meter calibration is always something to consider when inventory variances are out of line.

Step #7: Evaluate the variances with a critical eye.

Are the daily variances in the hundreds of gallons most every day? If so, it may be difficult to see anything but a leak of epic proportions. Still, this type of record can be evidence of carelessness, unless the facility is a truck stop with extraordinarily high sales volume.

Do the daily inventory variances seem too good to be true? If a facility is receiving a delivery a day and the delivery variances are consistently in the single digits, you should begin to wonder. While there are completely automated inventory systems that can deliver this kind of accuracy, they are not in common use. The extreme case of "impossible" variance is if the daily variance is zero. If variances are zero more than about once a year, then it is fairly safe to conclude that the data are being fudged.

The most common "fudging" technique is to calculate the book inventory and then either make the physical inventory equal the book

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value or find a value on the tank chart that is close to the book inventory and write it in. If you suspect fudging, look for errors in copying numbers such as transposing digits (the stick inventory is 3,572, but it is carried forward the next day as 5,372) that still somehow result in very small daily variances.

Another check on fudging is to see if the end-of-month stick inventory is carried forward to the beginning of the next month. Often, an actual beginning inventory number is used to start the month, but this number may be substantially different than the "fudged" stick inventory from the end of the previous month. In an accurate inventory record, the end stick inventory of the previous month is equal to the start stick inventory of the following month.

Step #8: If it's a blended system, look for significant gains in one product that may be approximately equal to significant losses in the other product.

This is often an indication that the blend ratio programmed into the cash register or point-of-sale (POS) system is not exactly equal to the blend ratio that is happening at the dispenser. This happens because the POS system tracks sales of mid-grade product separately from the other products. At the end of the day, the mid-grade sales are divided up and added to the regular and super product according to a fixed ratio (typically 60/40 or 70/30). If the dispenser is in fact blending in a ratio of 65/35, then the fraction of the mid-grade sales volume allocated to the regular and super products will be in error, and corresponding overages and shortages will appear in the regular and super inventory records.

One way to check for this type of error is to compare the sales numbers for the regular and super products obtained from the POS data (add the mid-grade sales in the proper ratio to the regular and super sales volume recorded by the POS system) with the sales numbers recorded by the mechanical totalizers at the dispensers for the regular and super product. If these numbers don't match almost exactly, then some adjustment in the blend ratio used to allocate the mid-grade sales to the regular and super product must likely be made.

Still scratching your head?

Now that spreadsheet programs with graphing capabilities are commonly available, the graphical analysis of inventory records is simple to do and can be very informative. I usually look at two plots. The first is a plot of the daily variances over time, the other is the cumulative variances (sum of the daily variances) over time. These plots can be done over a period of a month, but the cumulative variance, in particular, is most instructive when plotted over much longer periods, such as a year. The following three steps cover some things to look for in this regard.

Step #9: Evaluate long-term trends.

Cumulative variance plotted over periods of six months or a year can reveal longer-term trends that are often masked when shorter time periods are plotted, especially if the daily variances show a lot of scatter. The longer-term picture allows you to see the "forest" as well as the "trees" more easily.

It may be necessary to eliminate some daily variance data points because they are so large they obscure the trends. For example, if there is a 5,000-gallon-plus daily variance that did not bounce, odds are that there is a delivery that was never recorded into the inventory records. This enormous variance will overwhelm smaller trends because the plotting software will automatically plot the data on a scale that accommodates this 5,000-gallon variance. Removal of such large "outliers" is often required to see more clearly what an inventory record is telling you.

Step #10: Look for a saw-tooth pattern.

A not uncommon pattern that appears when cumulative variance is plotted on a shorter time frame (e.g., a month or so) is a saw-tooth pattern. This pattern may show decreasing cumulative variance for several days, followed by a single positive variance approximately equal to the sum of the negative variances of the previous few days. A check of the data will reveal that the negative variances occur on non-delivery days, while the positive variances occur on delivery days.

This pattern is indicative of a chart error or ATG calibration error. For example, if an ATG has been programmed for a 10,500-gallon tank when it is really monitoring a 10,000-gallon tank, then sales volume (metered at the dispenser) will be overestimated by the tank gauge, and the daily variance on non-delivery days will be negative. On delivery days, the volume of the delivery will also be overestimated, and the daily variance on delivery days will tend to be positive. Of course, this pattern will be inverted (positive variances on non-delivery days and negative variances on delivery days) if the ATG has been programmed for a 9,500 gallon tank when it is really monitoring a 10,000 gallon tank.

Depending on the magnitude of the chart error and the accuracy of the inventory records, this error may be very obvious, or it may be obscured. Although this error sounds like it might totally invalidate an inventory record, this is not the case. If the period of the inventory records is long relative to the period between deliveries, the net effect of the error is negligible, and the long-term trend of the cumulative variance will still be valid.

Step #11: Look for diverging variances in a blended system.

Plotting cumulative variances of both the low- and the high-grade products in a blended system on the same chart will clearly illustrate if there is a blending error. This will show up as diverging variances of approximately equal value, even over long periods of record. To remove the effects of blending error from the record, simply plot the sum of the variances of the low-grade and high-grade products.

Tip: Know What You Won't Know

Though inventory control may reveal leaks that escape other leak-detection methods, it is also true that there are some leaks that are invisible to inventory control. Most obviously, inventory will not tell you anything about what is happening beyond the meter in the dispenser.

For example, truck stops often have "satellite dispensers," where a second hose connected to the primary dispenser goes underground to the opposite side of the vehicle so both tanks of the truck can be fueled at the same time in a single sales transaction. Any product leaked from the piping that goes over to the satellite dispenser has already been accounted for by the meter in the primary dispenser and will not appear as a loss in the inventory record. Thus inventory control (and, for the same reason, SIR too) cannot be used for leak detection on satellite dispenser piping.

Also, if it is the meter itself that is leaking, the leak may remain undetected if the product is leaking out at a point on the meter after it has passed through the metering mechanism.

Inventory may not always be able to tell you what has happened. As always, the "garbage in/garbage out" rule applies. The value of inventory records in deciphering the history of a storage system is directly related to the accuracy and consistency with which the records were kept.

A Final Word

Although it's been a long time since I've heard anyone proclaim that inventory is the first line of defense against leaks, there is no question that inventory is still an indispensable business practice and a potentially valuable tool for a tank operator in detecting large releases or for a tank regulator in getting to the bottom of a release "after the fact." While inventory records can be laborious to decipher, the "Aha!" moments that sometimes occur when a plot of the data reveals a clear picture of a problem can also be a great feeling. For those of you who love a good detective story, inventory presents a real world opportunity to test your Holmesian skills. ■

P.S. If you have any favorite inventory analysis tips that you use, drop me a line at marcel.moreau@juno.com *and we'll share it in a future* LUSTline. *Or if you have a particularly puzzling inventory record, send it along and I'll take a peek at it.*