Leak Detection Webinar, Pipeline and Gas Technology
July 2009

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Mass Balance Systems, 101

We know leaks are going to happen, the question is how do you minimize the effects without major expenses. Many of the pipelines in the ground today are old and may date back to the 50's or earlier. As areas grew in size pipeline right of ways became part of our urban area and more susceptible to construction accidents or malicious intent. Fortunately leaks are a rare occurrence with most operators never experiencing that situation. The problem is when a leak happens, will the operator make the right decision? That is where Computational Pipeline Monitoring or CPM comes in to provide operators with additional information to take the right actions.

In the interest of time I'm going to skip over Other CPM Options and go right into mass balance.

Mass Balance

A mass balance leak detection system is probably one of the most common methods in use. The method is easy to understand and utilizes some of the most common instrumentation. Many pipeline SCADA vendors supply some form of mass balance as part of their product or as a low cost add-on. API-1130 identifies four basic mass balance types, each building on the features of the previous one.

Theory

In theory, a mass balance system works by keeping track of what is going in minus what is coming out. For short and small pipelines a simple line balance is usually enough to detect a leak. As a pipeline gets larger and longer certain physical properties start to become problematic in this simplistic concept requiring the better analysis.

Line Balance is the simplest form of leak detection and many pipeline operators have manually utilized this form of leak detection for years. Automation of this method eliminated operator errors and allowed for better tracking of meter differences. The only required instrumentation is meters.

Volume Balance and Modified Volume Balance became necessary as the operators needed faster response to smaller leaks. Volume balance takes into account line pack based on pressure changes in a pipeline. Calculating line pack requires additional pipeline information, namely pressures, temperatures and product gravity. Modified Volume Balance allows for batches with different gravities. You will need some physical characteristics of the pipeline.

Compensated Mass Balance expands upon the previous methods by breaking the pipeline into multiple segments such as at pump stations. Volume imbalances are monitored over a range of time intervals to detect the smaller leaks. This method requires the most instrumentation since every segment is now monitored individually.

Mass Balance, the real world

Mass balance leak detection systems do not model pipelines. This makes them easy to install, configure and maintain. They are not CPU intensive nor have high speed data requirements. They work by detecting unexplained changes in the pipelines, greatly simplifying their operation.

Installation

Installation will consist of loading the software, connecting to the SCADA data, installing any required field equipment, testing and tuning. Starting with a pipeline layout a list of minimum data points can be determined. Additional field instrumentation may be required or suggested to improve sensitivity or for additional features.

Instrumentation

Mass balance systems require two primary forms of instrumentation, mass compensated meters and pressures. The accuracy of the meters is the limiting factor in how small a leak can be detected.

Pressure data is highly recommended for each segment for line pack calculations. While having pressure for each segment is not required it does give faster detection and localizes the leak.

Temperature is required but sensors are not as important as you might think. Many pipelines are buried and the temperature of the product tends to change very slowly and can remain relatively constant.

Finally flow and density meters can help make the operator's job a little easier and in some case help verify leak conditions.

Calibration and Maintenance

Calibration, maintenance and verification of all the field instrumentation is important for the mass balance system to function properly. A routine maintenance schedule should be implemented to periodically verify all sensors are working properly and verify the proper data is being used.

One big advantage of using line pack is that it relies on pressure changes and not absolute pressures. This means if a transducer is slightly out of calibration it will still give valid results.

Telemetry

Data needs to be scanned at a reasonable rate or processed by exception. Many pipelines rely on satellite, radio or leased lines to gather field data. These work just fine but as the speed gets slower data

skew will add additional uncertainty to the process.

SCADA data

SCADA data is going to be needed by the mass balance system. This will include meters, pressures, flows, temperatures, and product densities for each pipeline. Additional inputs may be utilized to minimize false alarms during pipeline upset conditions.

Scan Rates

Ideally pressure data scanned every few seconds would be nice but is not always practical. If available a scan by exception works well because most of the data is relatively static.

Each pipeline's inlet and outlet meters should be scanned at the same time. If the inlet/outlet meters are out of sync with each other the “noise error” is higher adding additional uncertainty to the process.

The remaining data points are less critical and can be scanned at slower rates.

Data Quality

Data quality is another factor. There are times when a data point can be down for various reasons. Allowing that point to be processed might produce invalid results.

Real World Issues

So far we have mostly talked about leak detection in perfect world terms. So now lets talk about real world issues.

Tuning.

Tuning a mass balance systems is based on past operating conditions and experience, you set a few parameters and you are done. Because mass balance is not based on parameters such as viscosity or friction losses, activities such as pigging or drag reducers do not affect operation, which greatly simplifies the tuning process.

System Upsets

System upsets make the pipeline difficult to monitor. So how does a mass balance system handle them? The answer is many systems don't. During an upset condition many stop processing so they don’t generate false alarms. The better systems go into an upset mode allowing for the larger data swings and then adjust back to normal operation as the pipeline settles. Some pipelines can take an hour or more to return to steady state conditions following an upset.

Leak Location

Leak location and size is determined by the calculated line pack loss in a particular segment. Because line pack can only localize the leak to a segment or two that still leaves a lot of pipeline to check.

Some systems do a pressure analysis to get a better estimate of the leak location. By analyzing the time of each pressure drop a milepost can be estimated. The accuracy of the milepost is dependent upon the accuracy of the pressure drop times.

Batch Tracking

Batch tracking is required if you are flowing more than one product in your pipeline. The average API is a significant factor in calculating line pack. Knowing where your products are and knowing interface arrival times can also help you in operating your pipeline.

Alarms

The basis for an alarm with a mass balance system is detecting a mass imbalance. This is easy in short inlet/outlet pipelines but transmission lines tend to be noisy. The three trends were taken at about the same time from a 400 mile pipeline. The pressures and flow rates cover 2 hours while the line pack is 24 hours. These trends indicate that at about 6:40 the rate was being increased and about 7:02 something happened causing a flow rate drop at one station. As you can see 1 ½ hours after all this started the system is still in an upset mode with pressures still not settled.

Real

Real alarms are important and hopefully you will never see one.

The graph on the right is trending line pack in red, and meter differences + line pack in blue. All things being perfect the blue line should be flat but as you can see it is far from that. From a pure mass balance perspective it is hard to tell if there is a leak or not based on this data. Certainly there is not a large leak. For smaller leaks you would look for an increasing meter difference over time. The mid size to larger leaks will show up as a line pack loss and a significant meter difference.

False, a serious problem

False alarms are more important. I can almost guarantee you will see more false alarms than real alarms. Many major pipeline leaks in the past had some form of leak detection installed when a leak happened. At the time of the leak the operators dismissed the alarm as false. This happens with more frequency than we would like to admit. Check out the article Spill Alerts Rang, Dismissed as False, a link can be found under articles on my website LeakTrack2000.com.

One way to minimize false alarms is to make software smarter. The question is how do you determine the state of the pipeline without doing a full modeling method? The software has to understand what a leak looks like. If pressures are available and one point is decreasing while an adjacent point is increasing it is probably not a leak. Same can be said using flow rates. If the flows are constant or don't support a possible leak then it is probably not a leak. The better mass balance systems analyze all system

data to help minimize false alarms.

Mass balance, Evaluating

Selecting a system

Selecting the right leak detection system is complicated work and filled with trade-offs. If you have an unlimited budget you can go for the Rolls Royce of systems and select a real time transient model. If the budget is tight you might use a low cost Yugo model. There are many vendors and various CPM solutions for leak detection, each having their own strengths and weaknesses. The bottom line is you want something that works reliably and fits with your operational structure. With a few exceptions a mass balance system can handle most pipelines.

Pros:

A few good reasons to pick a mass balance system are:

- maintenance – less field maintenance is required because there is less data points required for proper operation. Because of the low maintenance and flexible data requirements mass balance systems tend to be very robust and reliable.

- lower data rates – mass balance does not need to know what is going on every second. This is good news for pipelines using slower communication hardware.

- can detect small leaks – over time the differences between the inlet / outlet meters can detect very small leaks.

Cons:

A few reasons to pick something else:

- gas pipeline – mass balance does not handle gas very well. It is possible to have a mass balance system but the compressibility of gas changes the processing.

- slack or 2 phase flow – the mass balance assumes the line is always packed. If your pipeline topology can allow for occasional slack line flows or routinely operates as 2 phase flow you will need a different method. Pipelines that operate with large elevation changes might require some form of hydraulic gradient processing to insure they are not operating sections of the pipeline in a slack mode.

- limited simulation – mass balance does not model a pipeline. This also means it can not simulate one. If a simulation or training mode is available it might use prerecorded data or a simple way to emulate pipeline data.

Conclusions

Most pipelines might already have the necessary installed instrumentation needed for a mass balance system to operate. This means spares are already in stock along with skilled technicians to service and maintain them. Because of the limited data requirements interfacing with an existing SCADA systems generally is an easy exercise. The simplicity of mass balance usually means the user can be trained on the maintenance and operation of the system without having to resort to outside help to keep everything running. A mass balance system is a simple and reliable method of leak detection.

--How can operators very hope to get to resolve the tradeoff between sensitivity and false alarms/Is there necessarily a tradeoff?

--With regard to Mass Balance systems, are there different considerations as they are deployed on older pipelines versus new pipelines?