Transmitter Data and Redundancy Manage Measurement Impacts

Rick Rans P. Eng., RANSolutions

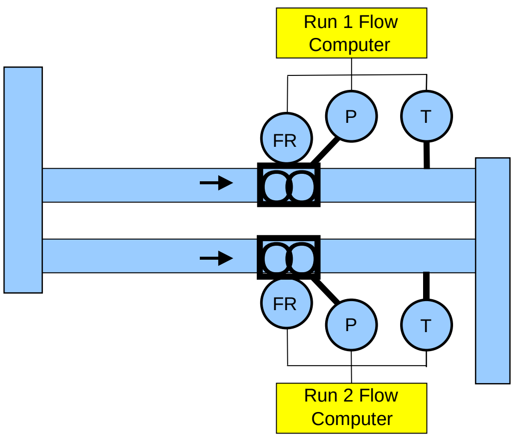
Abstract

Daily supply/demand management of over 12,000,000 GJ's/day (12 BCF/d) of natural gas commodity allocated to 350+ shippers/connecting pipeline operator accounts presents a significant challenge to management of TransCanada's 1300+ meter stations. New technology, hourly measurement, automated validation, exception based problem reporting and energy impact based prioritization is used to meet customer demands of identifying and managing measurement impacts to meet "Near Time" deadlines.

The Measurement Process

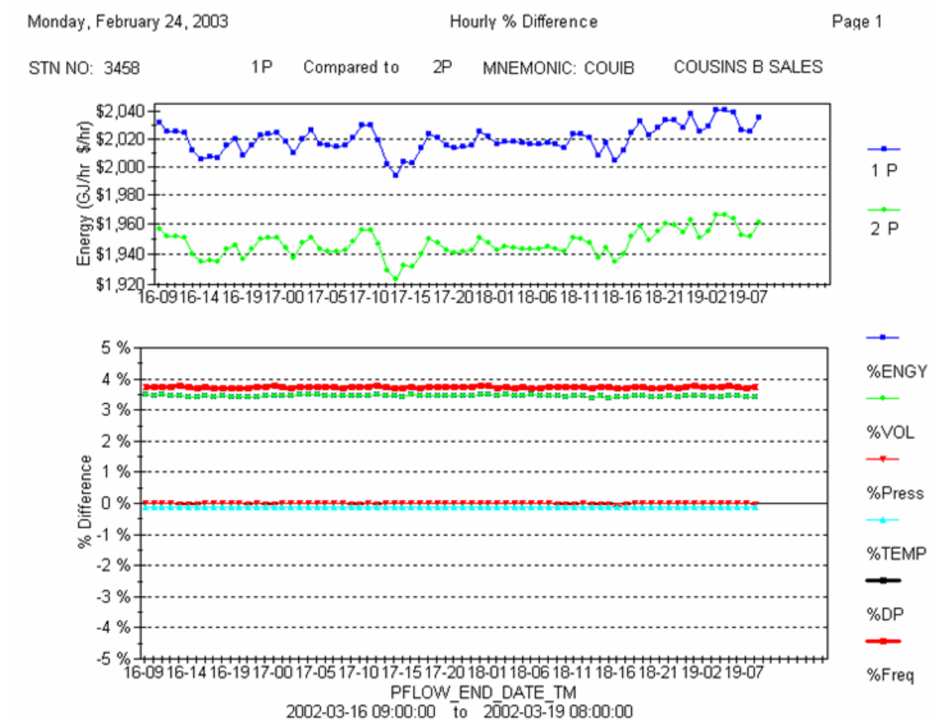
TransCanada uses their Gas Measurement System (GMS) to perform hourly validation and material balance in "near time" (with-in an hour after the hour) to identify measurement and imbalance problems. Through a combination of transmitter redundancy schemes, it is possible to apply comparative analysis techniques to a variety of installations while minimizing equipment costs.

Transmitters on the Base Run Validated Against Other Runs on Multi-Run Stations

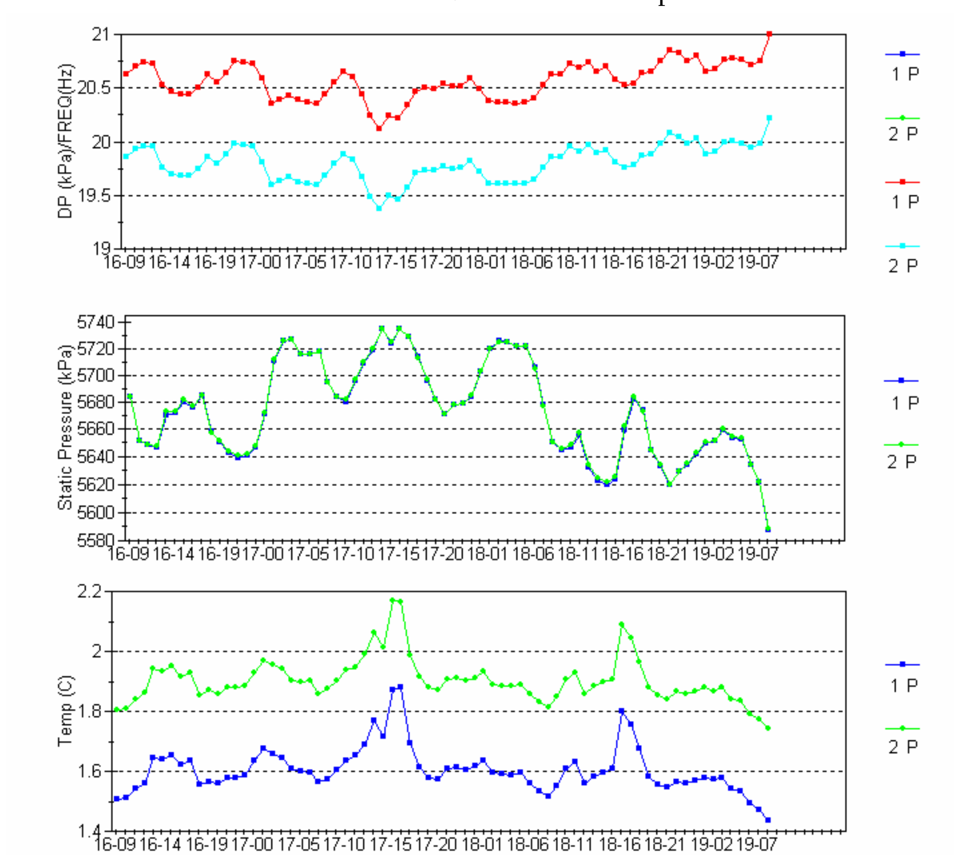


At multi-run Turbine and Ultrasonic meter stations, check measurement is based on automated Run to Base Run comparisons. One set of pressure and temperature transmitters is installed on each meter run. The transmitters and the pulse output from the meter are connected to a minimum of two independent flow computers. By maintaining a minimum of two runs in service, the flowing runs can be validated against the base run. The Gas Measurement System collects data from these facilities on an hourly basis and directly compares pressure and temperature readings. The volume, energy and frequency are compared between the flowing runs and the base run using the historical flow split for the meter station.

If one of the flow computers fails, the historical flow split is also used to estimate its flow. This practice increases the reliability of measurement for use in the "near time" business processes and provides for flexibility in scheduling equipment repair.



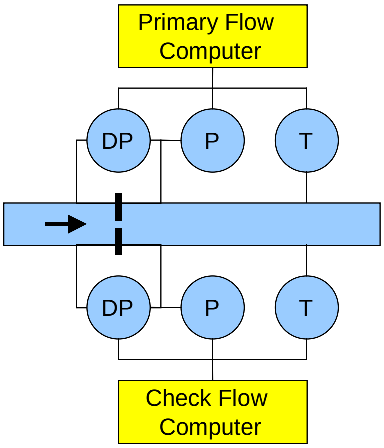
Run 1 to Run 2 % Difference Comparisons

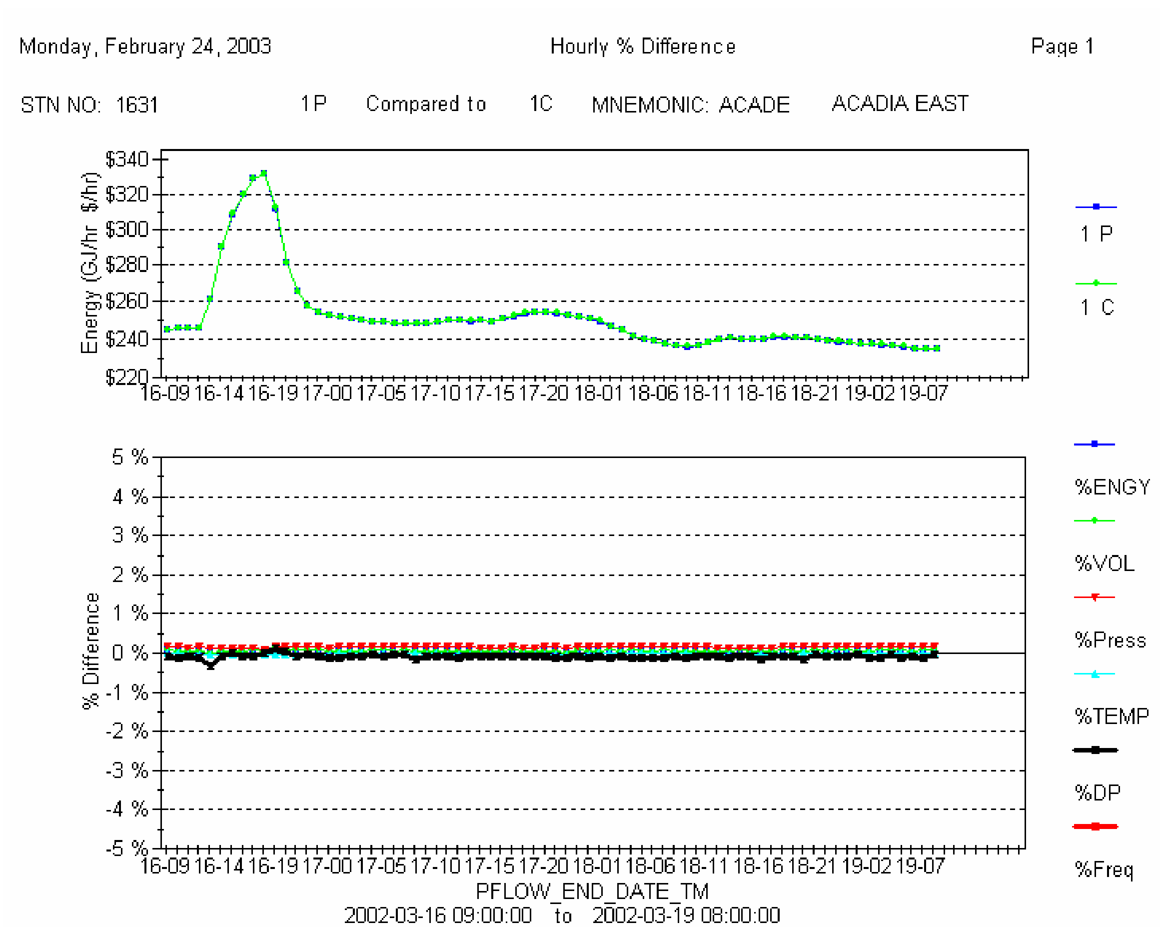


Base Run to Run Frequency/Pressure/Temperature Comparisons

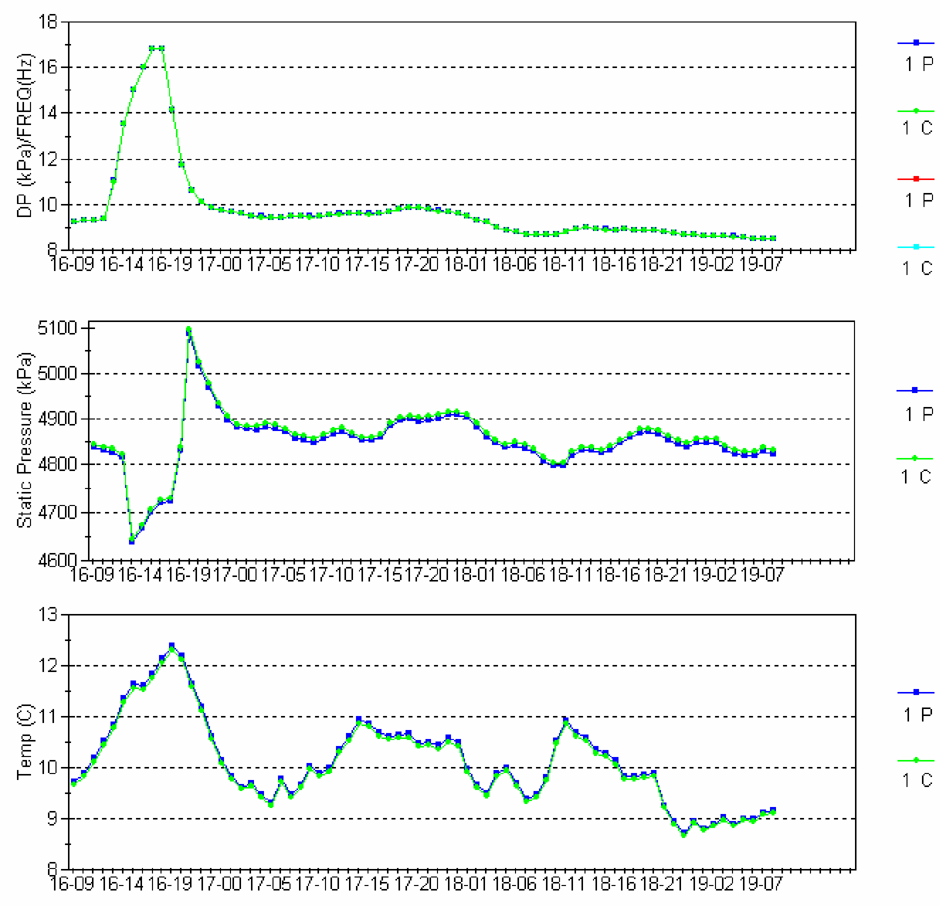
Primary to Check Validation of Orifice Check Measurement Systems

TransCanada employs automated check measurement systems at its orifice meter stations. At these stations, one set of pressure transmitters is connected to each of the two pressure taps located on each side of the orifice meter. The transmitters in turn are connected to their own flow computer to perform independent flow calculations. This information is communicated hourly to TransCanada's central Gas Measurement System where comparisons are performed to validate energy, volume, pressure, temperature and differential pressure on an hourly/daily basis. (See figure below for hourly % and process comparisons.)





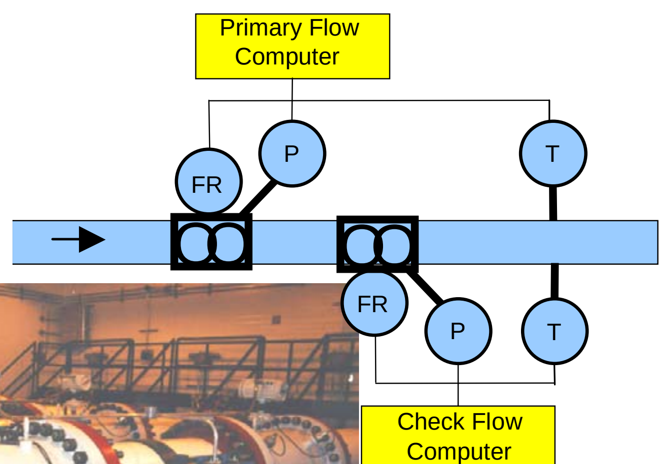
Primary to Check - % Difference Comparison

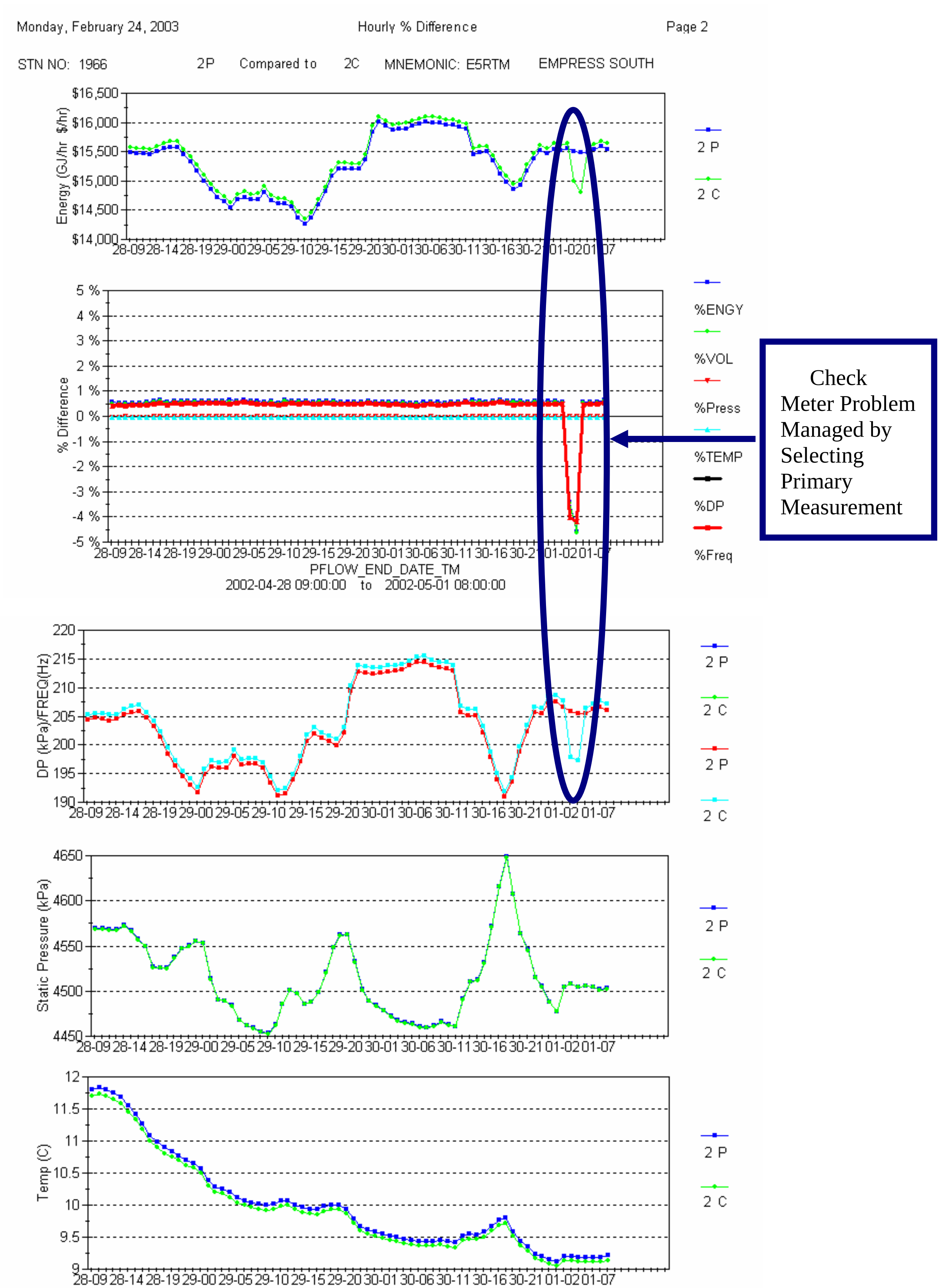


Primary to Check – DP, Pressure and Temperature Process Comparison

Primary to Check Validation of Series Meter Check Measurement

At large Ultrasonic meter stations, check measurement is based on series meter and instrumentation comparisons. One set of pressure and temperature transmitters is installed on each meter and connected, along with the pulse output from the meter, to two independent flow computers. The Gas Measurement System collects data from these facilities on an hourly basis and directly compares pressure, temperature, volume, energy and frequency.

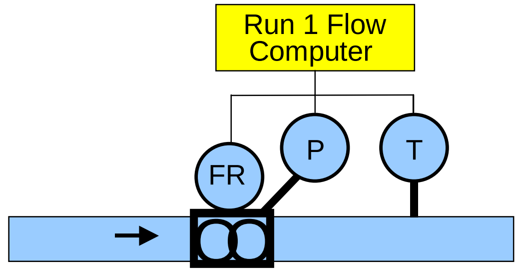


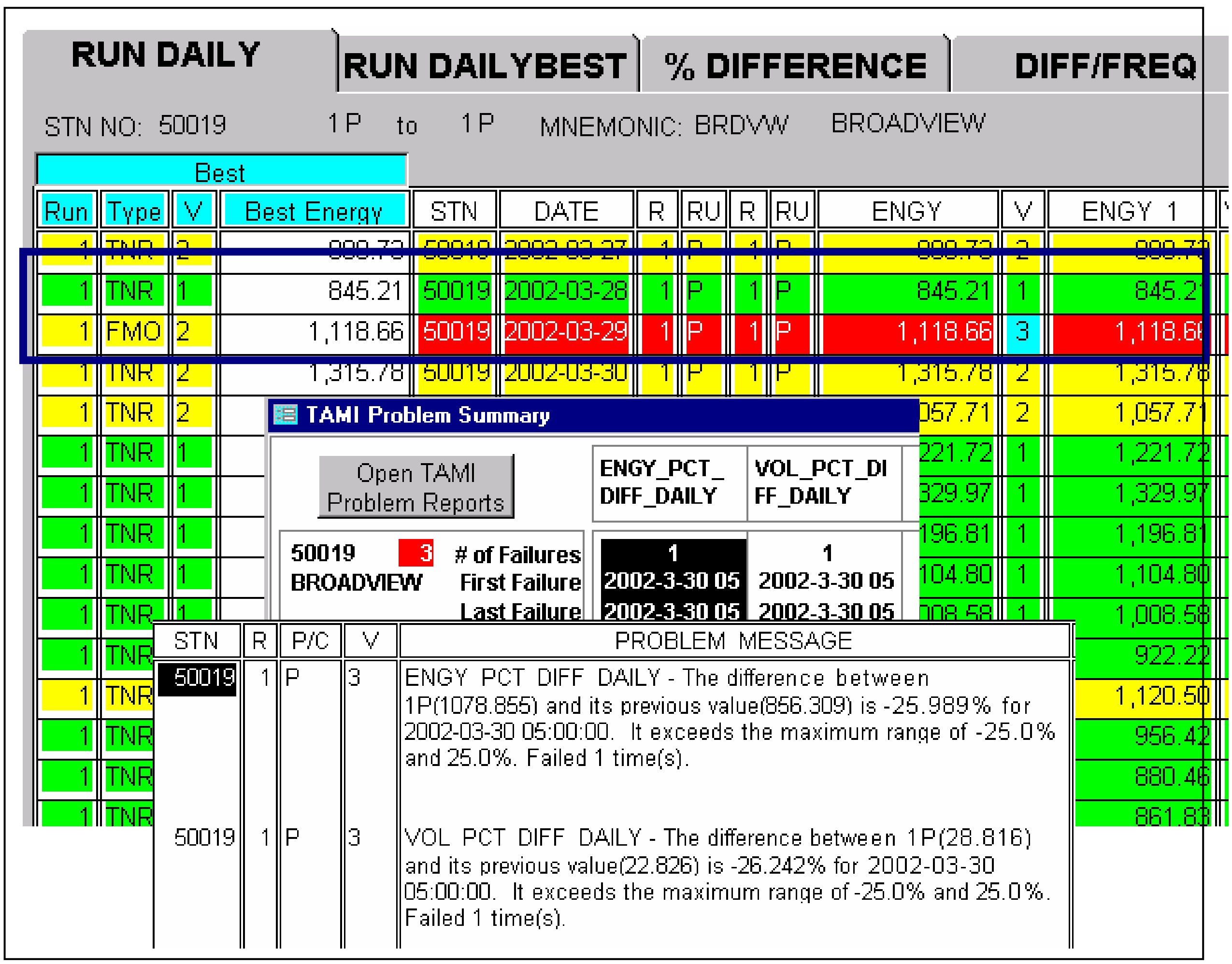


Primary to Check Ultrasonic Meter Comparison Data

Validation Single-Run Previous Day Check Measurement Systems

At small volume meter stations, the expense of additional transmitters and flow computers is not economical. Validation checks are still done based on comparison of the current hour and day pressure, temperature, volume, energy and frequency values to the previous hour and day values.





Validation Reports for a Single Run – Previous Day Measurement Check

TransCanada Experience With Redundant Transmitter Data

Analysis of monthly routine electronic re-calibration and detection of calibration problems based on Primary to Check comparison identified four significant findings:

- electronic calibrations enabled tracking calibration drift over time (The original calibration table of engineering values to A/D values can be compared to future calibrations done over the entire life of the facility unless the transmitter or transmitter range is changed)
- analysis of calibrations over a three year time-frame indicated no significant calibration drift (Problems during the evaluation period were related to mechanical adjustment of the transmitter, calibration problems caused by liquid or hydrocarbon contamination of the transmitter cell and transmitter failure.)
- routine monthly re-calibration caused more calibration problems than they fixed (The majority of re-calibrations didn't cause a problem, but ones that created a calibration problem exceed those correcting a calibration problem by a factor of between 2:1 and 10:1)
- primary to check comparisons identified all significant calibration problems

These findings enabled TransCanada to transition in 1997/98 from routine re-calibration and manual validation to exception based maintenance comprised of primary to check comparisons and automated validation.

Experience gained from analyzing hourly transaction record averages of transmitter data since 1997 has identified two significant uncertainties that complicate the accurate determination of transmitter operating errors:

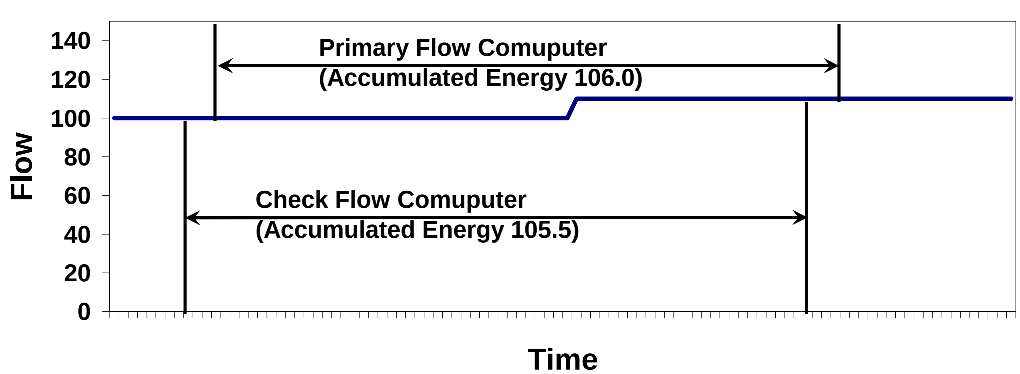
- the time differences, if any, between the devices providing the hourly averages
- the sampling frequency of the flow computer calculating the hourly averages

The bad news is these uncertainties can add together to limit the detectable size of operating problems. The good news is these uncertainties reduce as you increase the duration of the comparison. Problems that are undetectable in an hour due to process fluctuations are detectable if you extend the period of analysis to days or weeks.

To illustrate this point you can easily see the effect of time differences by considering a 10% step change in flow (see figure below). In this situation the flow computer that is starting its accumulation last will accumulate more flow.

$$\frac{\text{10\% of the flow rate times the time difference}}{\text{accumulation interval}}$$

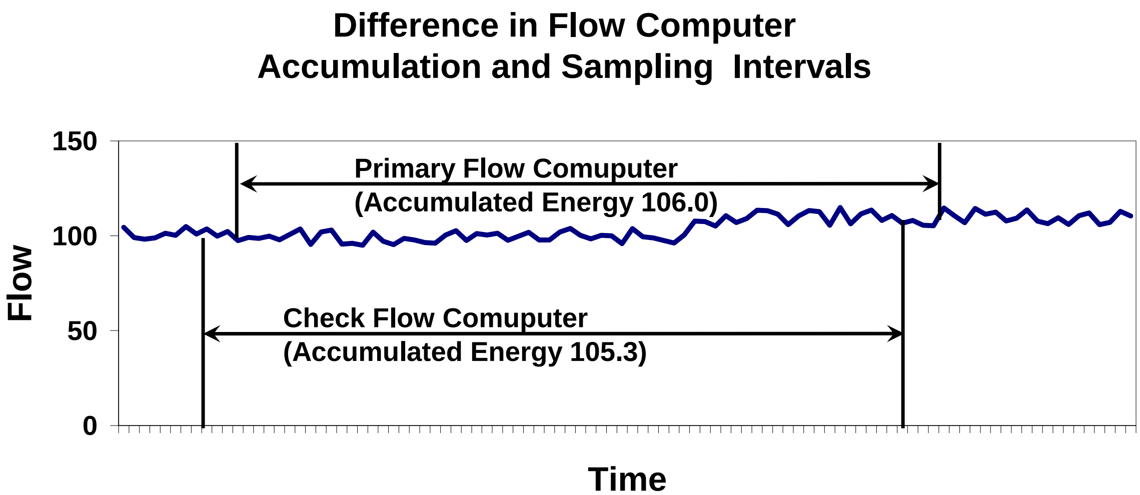
Difference in Flow Computer Accumulation Intervals



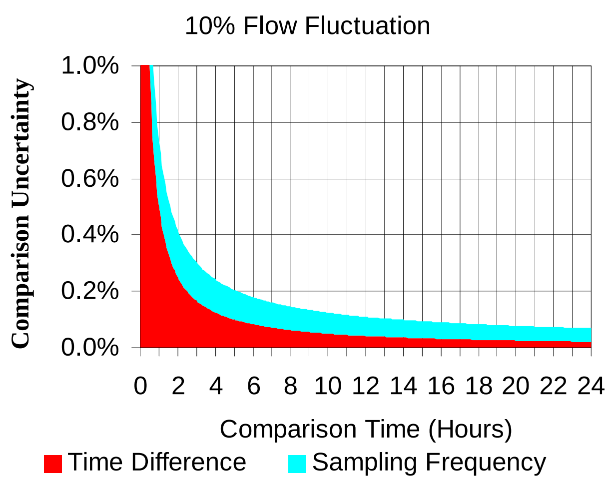
The sampling frequency is harder to visualize, but if you had a stable flow with a 10% flow fluctuation and you would be unable to take one sample and know the stable flow rate. Using statistics for a normally distributed random flow fluctuation the error would be:

$$\frac{10\%\ \text{flow fluctuation}}{\text{Square Root (Number of Samples)}}$$

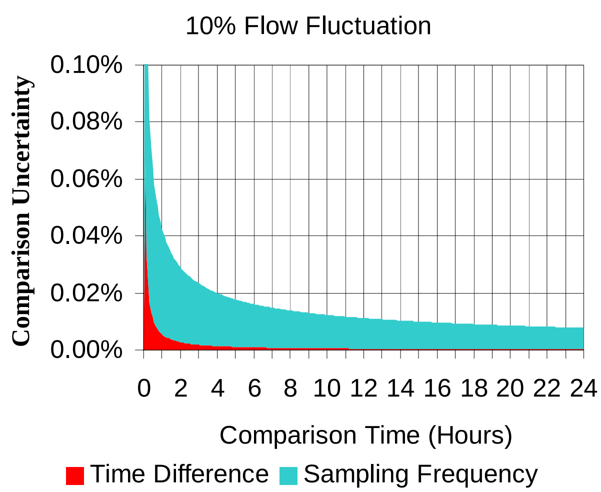
To reduce the sampling error to 1% would require 100 (10^2) samples, to reduce the sampling error to 0.1% would require 10,000 (100^2) samples.



Here are examples of these errors as a function of comparison interval. The Barton flow computer time and sampling uncertainty is estimated in the lower left figure. It requires a comparison interval of 24 hours to reduce the 10% flow fluctuation comparison uncertainty to <0.1%. The Datek flow computer system uncertainty is estimated in the lower right figure. It is able to achieve 0.1% comparison performance in <5 minutes for the same flow fluctuation.

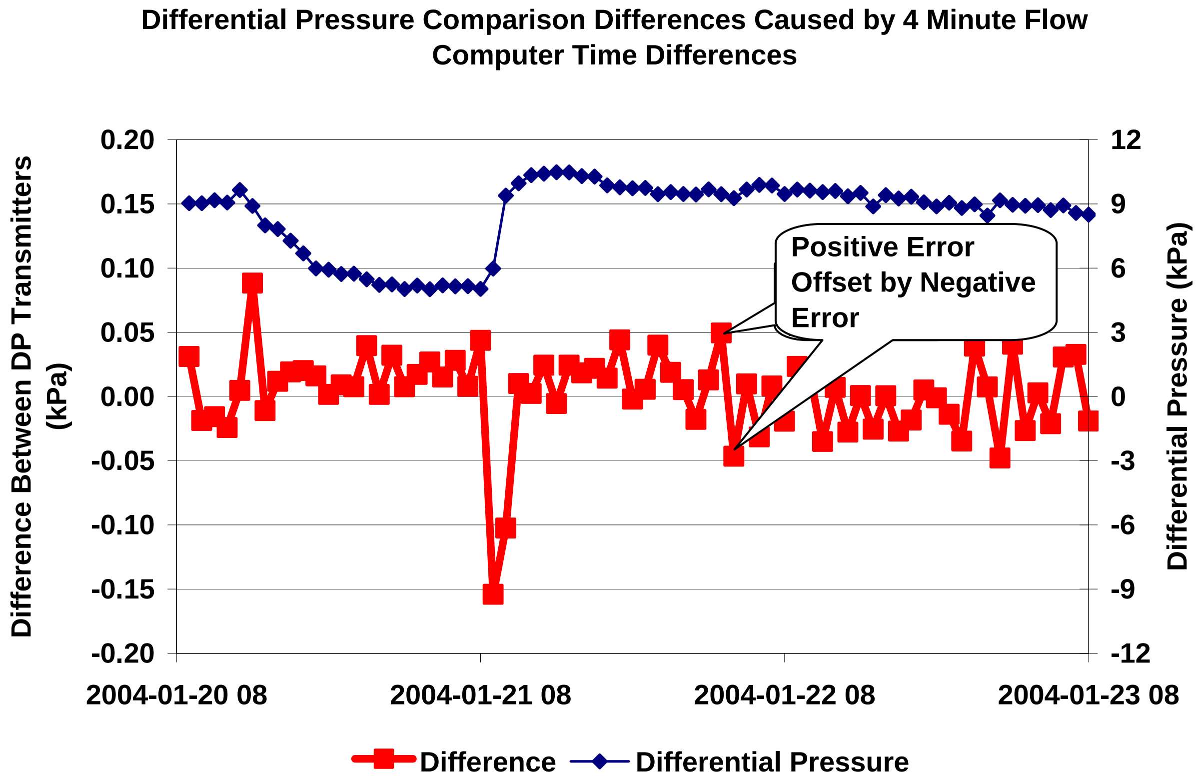


2 Second Sampling < 3 Minutes Time Dif.



20 Samples/Second <2 Second Time Dif.

To illustrate the impact of time differences between averaging devices, refer to the two examples below. The first shows comparison differences calculated from the hourly averages of two differential pressure transmitters, each connected their own flow computer. There was a 4 minute time difference between two flow computers.

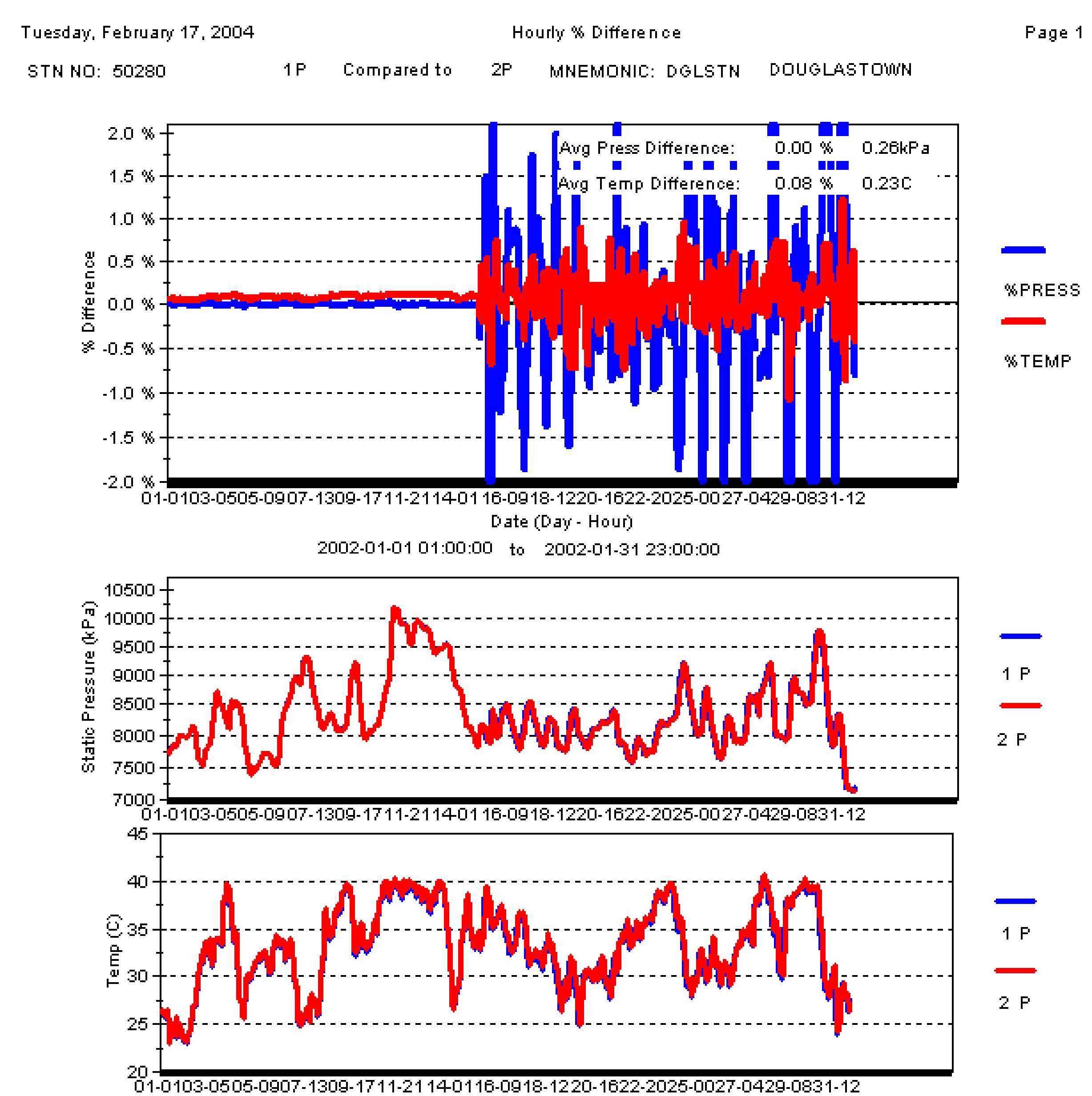


Note the plus/minus alternating errors caused by small changes in differential pressure while the average difference over the 3 days is <0.02 kPa.

The second example shows the hourly comparison differences when one of the flow computer times is set to daylight savings incorrectly. Even though the hourly comparisons are as much as 2% different, the monthly differences are with-in <0.1% of each other. This shows that the calibration doesn't change from the first half of the month and the differences are due to time differences between the two flow computers.

This technique of reducing measurement comparison errors by increasing the comparison interval is also applicable to comparisons between two meter stations, when trying to resolve measurement disputes. One of the biggest causes for hourly/daily differences is use of different gas day start/end times due to time zone/daylight savings settings. If the facilities have any significant distance between them, there will also be comparison "noise" caused by linepack that will reduce when the comparison interval is increased.

Hourly Comparison Differences Caused by a One Hour Time Difference Between Flow Computers



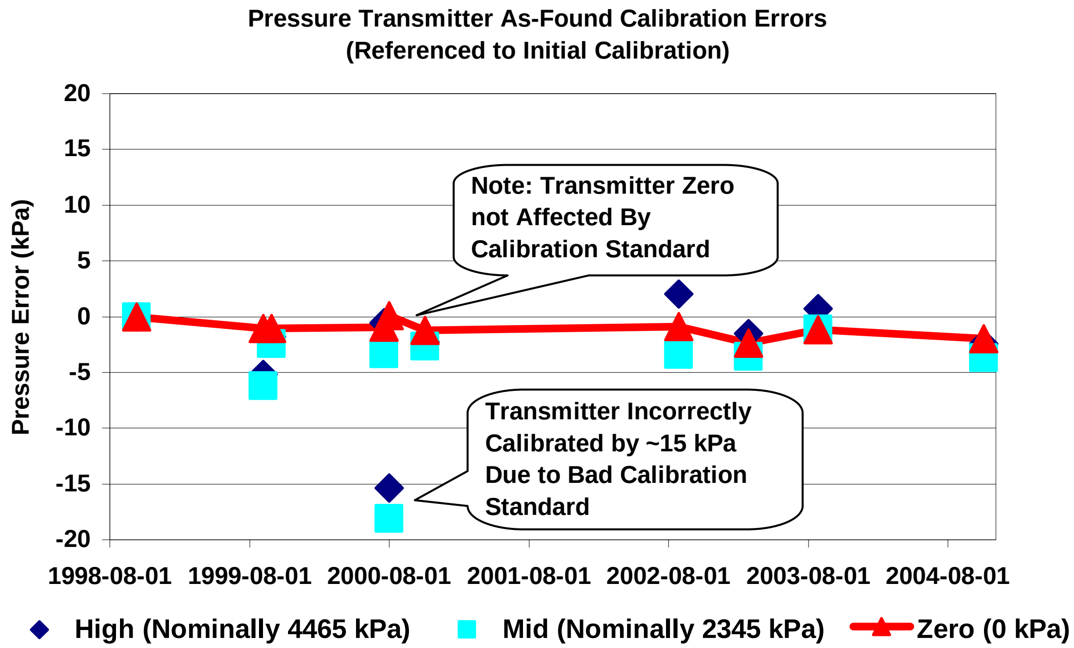
Note: Even though the hourly comparisons are as much as 2% different, the monthly differences are with-in <0.1% of each other. Calibrating the transmitters won't get rid of the hourly comparison differences, the times of the flow computers need to be synchronized.

Examples of Operating Problems and Analysis Techniques

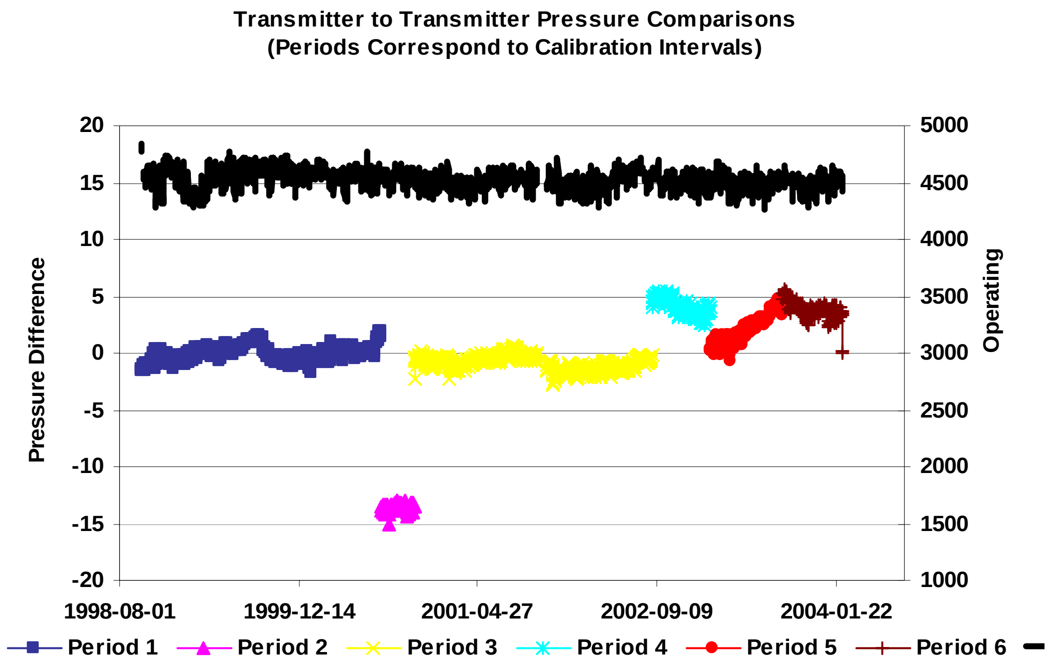
The following five examples demonstrate the value of using transmitter comparisons to identify and address operating problems.

Example 1: Calibration Induced Problems

The following is an example of pressure calibrations done over a 5½ year period at our Empress South meter station. All of the calibrations relative to the initial calibration are with-in 5 kPa of the original calibration except for the one done in August 2000.

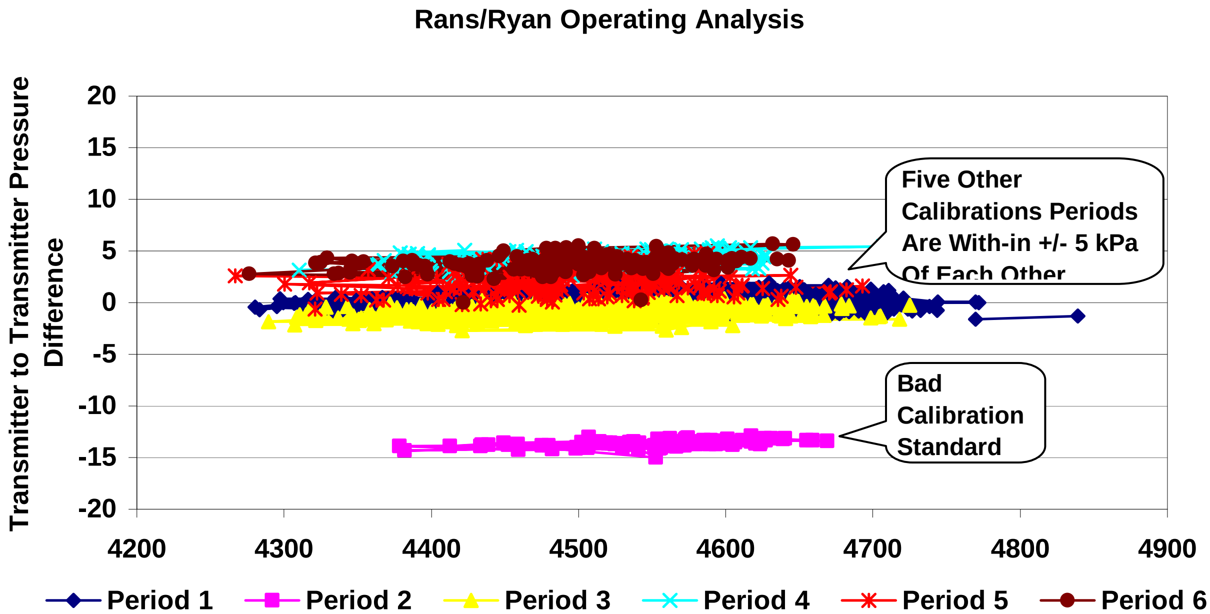


To confirm no significant calibration drift over time, the periods between the above calibrations have been plotted relative to a second un-recalibrated pressure transmitter.



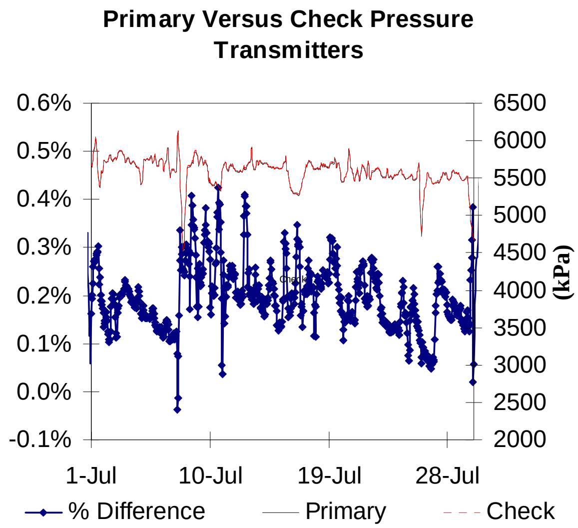
A Technique to Analyze Transmitter Comparison Problems – Rans/Ryan Analysis

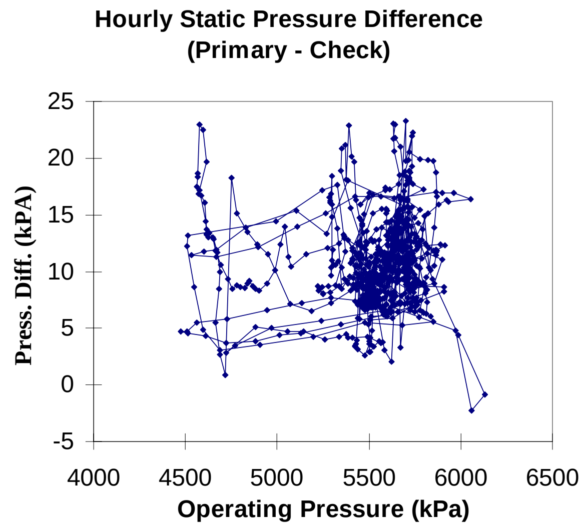
A technique to show transmitter performance plots the transmitter to transmitter difference as a function of one of the transmitter's operating values. The following graph shows this data for the six calibration periods for Empress South.



If there is a calibration problem, then the graph will show an operating bias as shown by the Period 2 comparisons. All of the operating periods fall in a +/- 1-3 kPa operating band around the calibration offset. This indicates that the transmitters are repeatable over time.

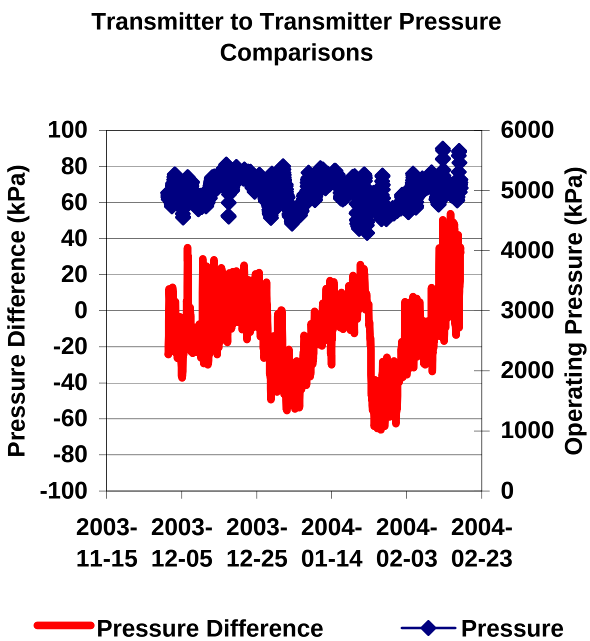
Example 2: Transmitters with a Repeatability Problem

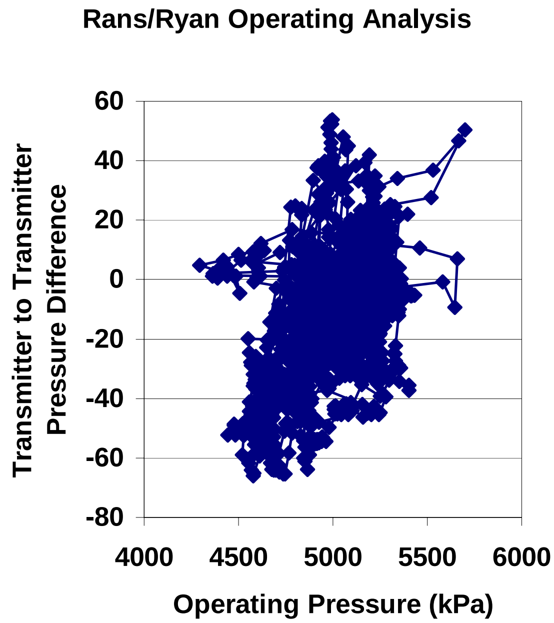




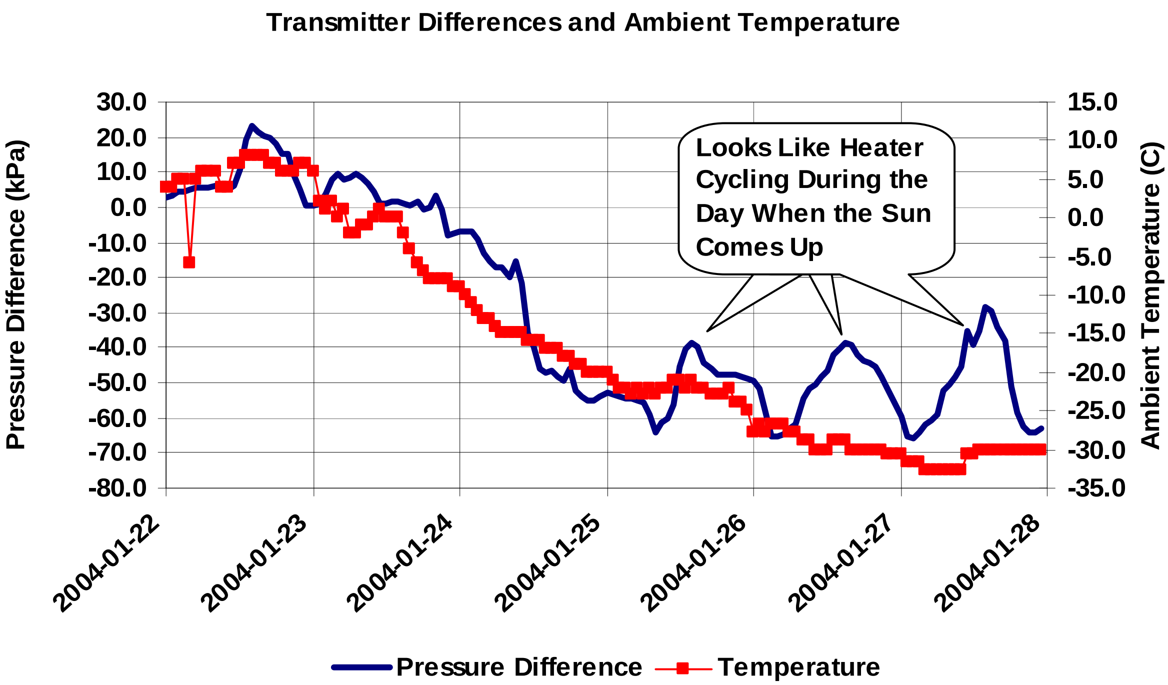
In this case the transmitter comparisons randomly changed +/- 15 kPa. The lack of repeatability was tracked down to a manufacturing problem that resulted in what appeared to be "mechanical hysteresis".

Example 3: Pressure Transmitter With Temperature Related Operating Problems



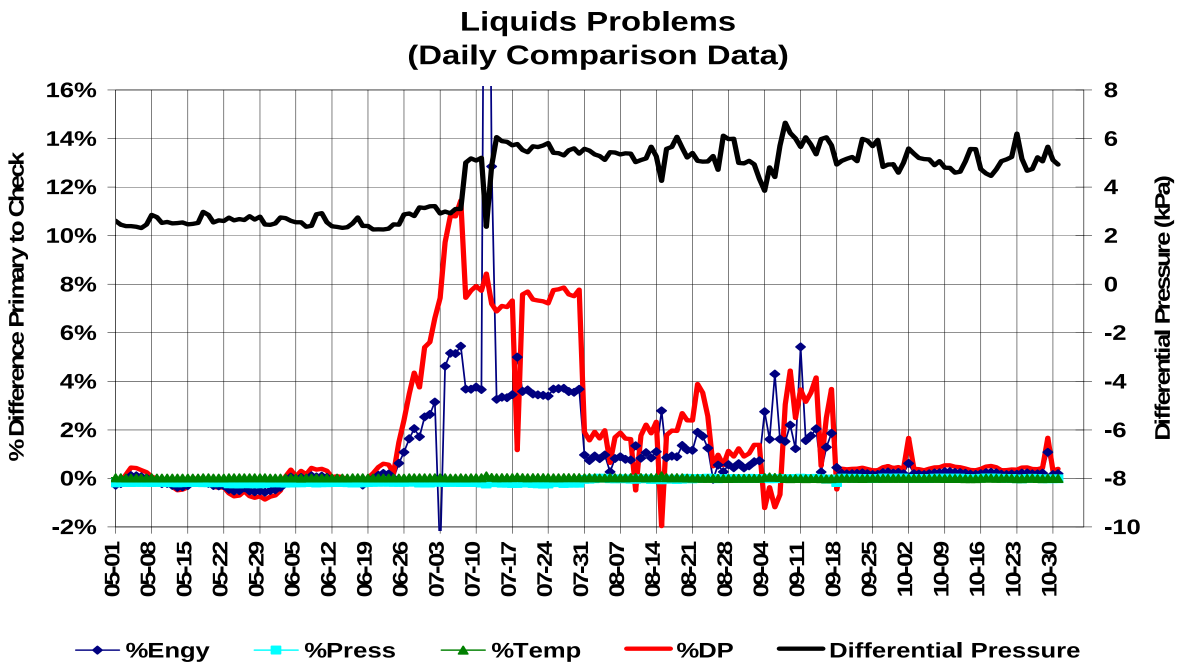


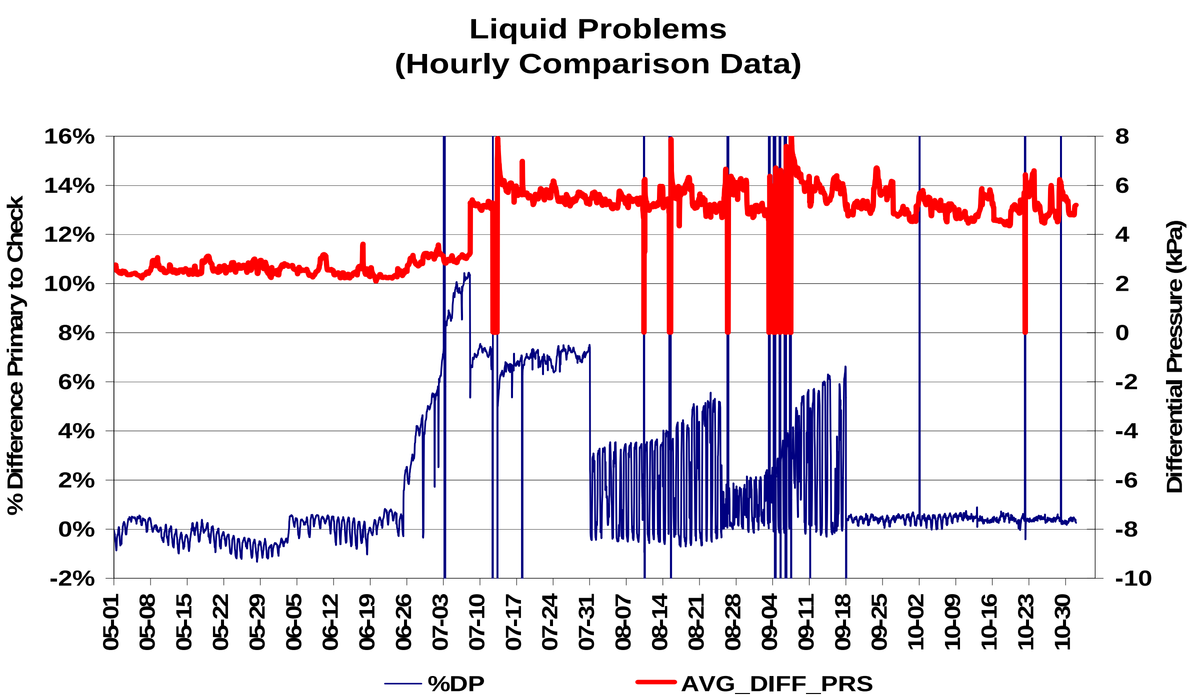
No additional information is available from this analysis technique. The problem related to ambient temperature and the building heat having trouble keeping up to the cold.



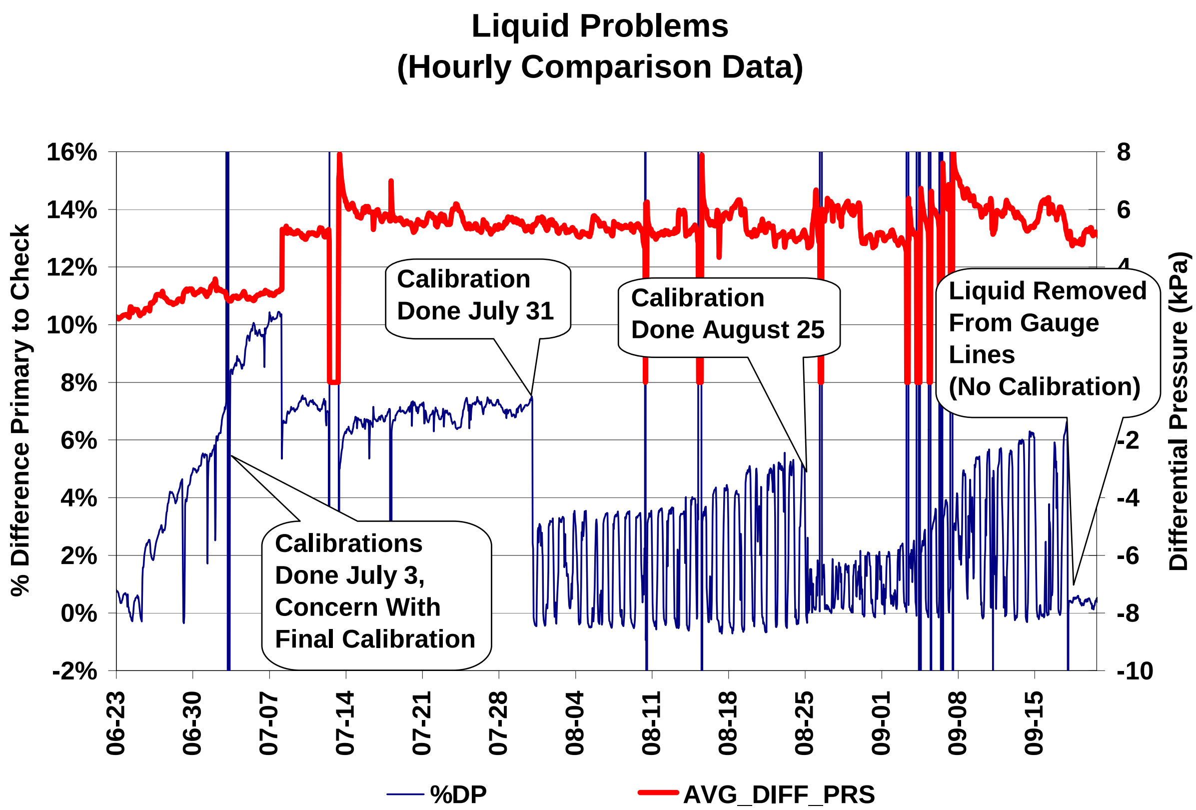
Example 4: Gas Quality Problems Directly Affect Measurement

The following example shows a situation where the primary to check comparison of the differential pressure transmitter identified a problem in late June. The first graph shows the daily comparison for the problem period, the second graph shows this same period based on hourly information.





Analysis of the maintenance activities for this period shows a number of attempts to fix the problem based on calibrating the differential pressure transmitter. Removal of gauge line liquids in late September fixed the comparison error with out the need for further calibrations. Review of the calibrations done over this period identified no significant calibration adjustments, but de-pressurizing the transmitter changed the operation due to the liquids in the gauge line.



Example 5: Statistical Analysis Identifies Meter or Transmitter Failure

With a number of meter stations only having a single transmitter, a number of techniques to identify measurement accuracy impacts were evaluated. The industry mainstay of previous day to current day percentage difference checks of pressure, temperature and flow identify problems when the process is very stable. To identify problems when the process is changing, three operating ratios are calculated from hourly data.

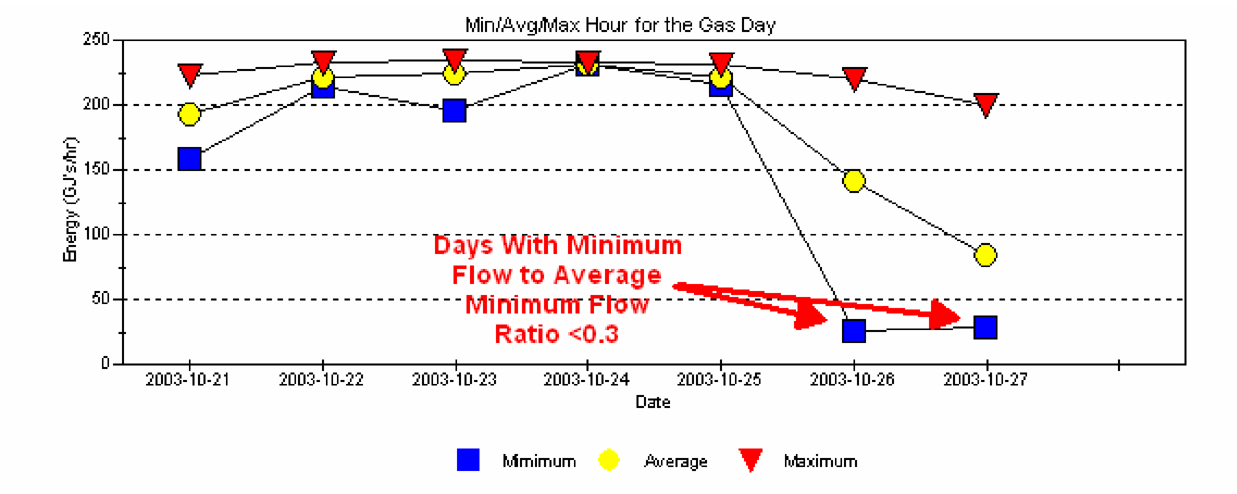
- daily minimum flow/average daily minimum flow
- daily maximum flow/average daily maximum flow
- daily standard deviation of flow/ daily maximum flow

These single transmitter techniques were applied to problems identified by comparisons to a second transmitter. It quickly became apparent that normal changes in the process (pressure, temperature and/or flow) are an order of magnitude larger that the transmitter problem. This limitation disables detection of small transmitter problems but does support detection of equipment failure.

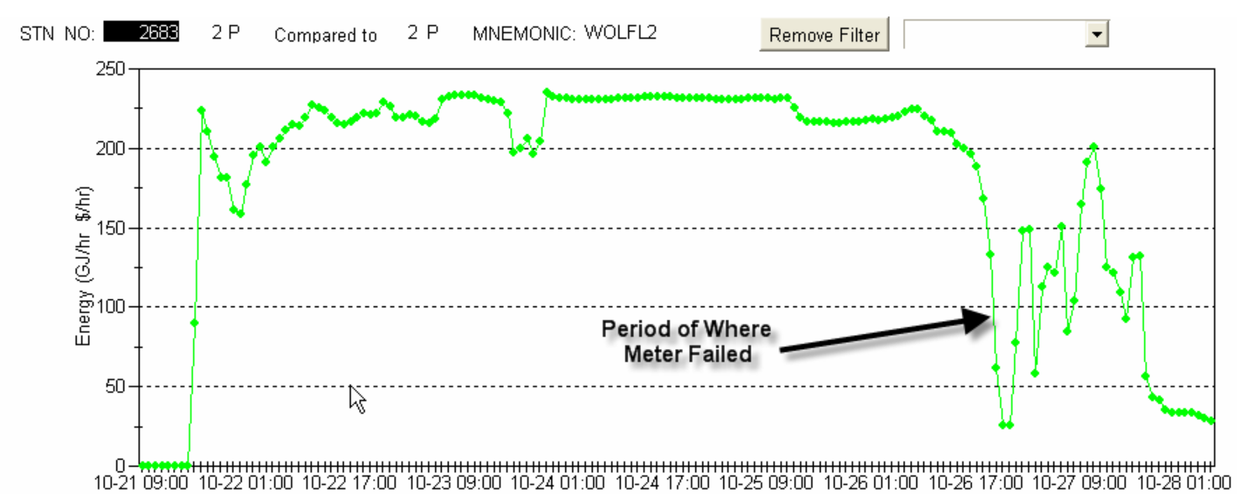
The following example uses these analytical techniques to identify the failure of a PD meter used to measure fuel gas.

Stn No	R	Date	Hr Check	Minimum	Maximum	Average	StdDev	Min/Avg Min	Min Ratio	Max/Avg Max	Max Ratio	StdDev/Max	Std Ratio
2683	2	2003-10-21	14	158.77	223.30	193.44	19.49	1.04	0.17	0.99	1.04	0.09	0.29
2683	2	2003-10-22	23	214.22	232.81	221.41	5.01	1.40	0.17	1.03	1.04	0.02	0.29
2683	2	2003-10-23	24	196.01	234.77	224.76	13.02	1.28	0.17	1.04	1.04	0.06	0.29
2683	2	2003-10-24	24	230.86	232.66	231.52	0.53	1.51	0.17	1.03	1.04	0.00	0.29
2683	2	2003-10-25	24	215.68	231.45	220.84	5.47	1.41	0.17	1.03	1.04	0.02	0.29
2683	2	2003-10-26	24	25.23	220.35	141.64	62.50	0.17	0.17	0.98	1.04	0.28	0.29
2683	2	2003-10-27	24	28.01	200.58	84.96	57.72	0.18	0.17	0.89	1.04	0.29	0.29

Display of Statistical Analysis Table Identifying Min/Average of Min Flow Ratio <0.3



Display of Minimum/Average/Maximum Flow



Graph of Hourly Flow Rate for the Period When the PD Meter Failed

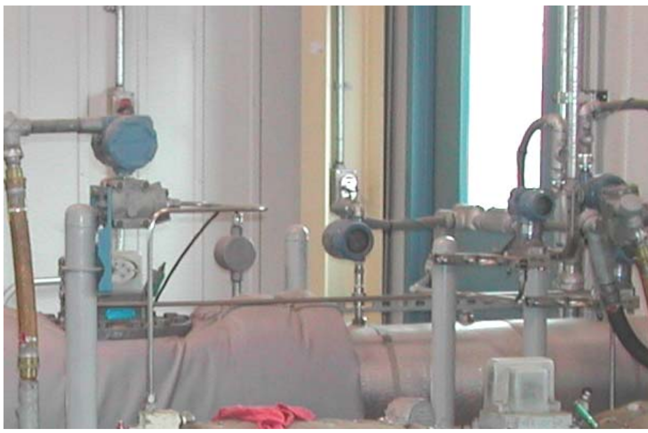
By running this analysis daily for a one week period and analyzing the results, it is possible to identify the onset of the PD meter failure.

This technique has also successfully identified significant false flow from a failed barrier, wiring failure/short circuit of an RTD sensor and failure of pressure transmitters. To identify small calibration problems, routine calibration checks are required.

Opportunities to Expand These Techniques

Experience with transmitter comparisons has clearly demonstrated its ability to confirm operating accuracy and identify the need for transmitter calibration. To date this technique has been applied to measurement equipment only as this equipment provides digital process data to SCADA and control equipment in ~80% to 90% of TransCanada's meter stations. Recent acquisitions have resulted in facilities which have separate measurement and SCADA/control equipment and instrumentation.

To reduce maintenance costs, a mechanism to take data from two different systems and generate long term comparative data is required. At first glance this task seems trivial. Lets look at an example where pressure and temperature data is collected by the flow computer and "redundant" pressure and temperature is collected downstream of the meter by-pass by the control PLC to ensure the control is operational during periods that the meter is in by-pass.



Turbine Meter and Instrumentation

Temperature/Pressure Down-stream of By-Pass

"Redundant" Temperature and Pressure Transmitters

Isn't all that's required is a report to compare transmitter averages on a daily/weekly/monthly basis and use this information to identify equipment problems? The task is complicated by a number of factors:

- flow computers that use flow time averages and report time averages or 0 for hours with no flow
- flow computers that don't report flow time or inability to collect this information
- getting SCADA systems to create hourly averages
  - the frequency of SCADA polling determines the minimum comparisons period
  - how do you handle communication outages (maybe % communication reliability or # of values used in the hourly average)
  - SCADA system filtering/dead banding of analog values will skew the averages
- how to get the information out of different systems and create the required daily/weekly/monthly reporting for a number of facilities (This reporting needs to filter out periods of no flow, communication problems and/or operating conditions that invalidate the comparisons.)
- how to get the maintenance identified by these comparisons into the maintenance process to record the identified problems and ensure that each problem has been addressed

The right design will requiring a balance between central system complexity, modification of field equipment architecture and the ability of technicians to understand the process and perform the correct maintenance at the lowest life cycle cost. Opportunities also exist to apply these techniques to compressor stations and other pipeline monitoring/control equipment where accuracy of the information is important and/or travel and routine maintenance costs are high.

Conclusion

Measurement plays a key role in TransCanada's daily operation and the custody transfer of over 12,000 TJ's of gas on a daily basis. Producers, transporters, consumers and government agencies use this information to account for billions of dollars of natural gas transfer annually. Analysis of transmitter data to identify operating problems and confirm measurement accuracy is a key component to TransCanada's measurement operational excellence.

References

1. Rans, Rick, *Use of Transmitter Data to Identify Measurement Accuracy Impacts,* 2004 Canadian School of Hydrocarbon Measurement
2. Rans, Rick, *TransCanada's Use of "Near Time" Measurement For Supply/Demand*, 2002 Canadian Gas Association Gas Measurement School
3. Mah, Dean, *Implementing New Technology at TransCanada Meter Stations -- Better, Faster, Cheaper,* CGA Measurement School, 2000
4. Rans, Rick, *Timely Accurate Measurement Information; Management of Data Collection, Validation, Maintenance and Publication of Measurement Information*, 4th International Flow Symposium on Fluid Flow Measurement, 1999
5. Rans, Rick, *Real Time Measurement, Coordination of Information Processing from the Field Meter to the Bill*, 2nd International Flow Symposium on Fluid Flow Measurement, 1989