Condition Based Monitoring – A Fully Automated Station Solution

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Abstract

During the past several years the use of ultrasonic meters (USMs) has gained worldwide acceptance for fiscal applications. The many benefits of USMs have been documented in papers at virtually every major conference. The significance of knowing the ultrasonic meter is operating accurately has never been more important. The use of diagnostics to help identify metering issues has been discussed in several papers at many conferences [Ref 1, 2 & 3].

USM technology has played a key role in reducing Lost and Un-Accounted For (LUAF) numbers. However, like any technology, the client must understand the meter's diagnostics in order to validate it is working correctly. Due to mergers, acquisitions, changes in technology and purchasing preferences within an organization, this can be extremely difficult as technicians often encounter multiple manufacturers' equipment. Thus, what is needed is a system that can monitor the USM's health, regardless of manufacturer, and provide a single report to the client when problems occur.

This paper is about a system that not only monitors all the USM diagnostics from most common brands, but also monitors data from the flow computer, and by utilizing separate P&T transmitters, computes flow for comparison to the customer's fiscal flow computer. In addition, the system monitors the gas chromatograph (GC) diagnostics to insure proper operation and validation of the gas quality data used in the flow calculations.

Field information is transmitted via a secure cellular data modem to a cloud server. The client then automatically receives periodic reports via email providing detailed information about the meter stations operation. In the event a problem occurs with the USM, pressure or temperature transmitter, GC, or even if flow computer volumes are in question, the system will send an email or text message (SMS) immediately to the appropriate personnel.

Introduction

The traditional method of verifying whether the USM is operating accurately essentially requires using the USM manufacturer's diagnostic information to help understand the meters health. This is usually accomplished by having a technician visit the site periodically (typically monthly) to collect a maintenance report. This report is analyzed by the technician while onsite, and often analyzed a second time by office measurement specialists at a later date. However, if a problem has occurred during the month, and isn't present at the time of the site visit, added measurement uncertainty may be the result.

More recently some customers have implemented a semi-continuous monitoring system that collects diagnostics from the meter on a more real-time basis. This has often been referred to as Conditioned Based Maintenance, or CBM for short. Essentially when any of the meter's diagnostics are outside prescribed limits, the SCADA system will alert the client of a potential problem. Implementing a system to not only collect the USM data, but also transmit and provide further analysis, is not easy and is often very costly.

Another problem clients face within this model of CBM is that different USM meter designs require different analysis techniques, especially for the velocity profile analysis. For the field technician, it is often difficult to understand all the diagnostic features of each USM meter design. Diagnostic limits vary from one brand of USM to another. They also may not have sufficient data communication bandwidth to bring the diagnostics back thru their SCADA system. Additionally companies may lack the internal technical expertise to fully understand what the meter is telling them. Thus developing a company-based system can be challenging.

Through the years manufacturer's software has continuously evolved to significantly simplify determining if the meter is operating correctly. While this is an improvement for CBM, in most cases the client still has to travel to the site to collect the data. In addition, since companies are generally required to validate the accuracy of the P&T transmitters, remote data collection of the USM diagnostics is not widely used. A system that continuously monitors the health of the USM, rather than relying on a periodic analysis of a USM maintenance report, greatly improves the potential of timely data review.

The CBM concept is not new. For many years some clients and manufacturers have programmed their onsite flow computer to do some basic monitoring of the gas USM diagnostics. From an industry perspective, these programs were generally proprietary to a given brand of flow computer and USM, thus implementation for other customers was generally not possible.

Another issue with traditional CBM implementations is additional data has to be transmitted via the customers telecommunications network (usually via the SCADA network). This creates a significant amount of work to get the programming in place, and uses up valuable bandwidth. The programming is generally specific for a brand or two of USM, and thus it becomes costly to add additional suppliers to the system.

Traditional CBM implementations generally focus on only monitoring the USMs health, and does little, if anything, to validate the integrity of the entire measurement facility. It is certainly important to insure proper USM operation, but it is equally important to verify the flow computer is also working correctly, that the P&T transmitters are still accurate, and the gas chromatograph (GC) is performing properly.

What is needed is a separate, independent system that can be easily retrofitted to the existing sites without requiring modification to the existing SCADA network, and that can work with equipment currently in use by the customer. It needs to validate all aspects of USM facility operation in order to minimize site visits and immediately report when problems occur. This system needs to work with a variety of USM brands as well as GCs. It should also validate that the existing fiscal flow computer is collecting all the USM pulses (no more, no less), that it is correctly computing AGA 7, 8, 9 & 10, as well as correct energy rates. With today's technology, this is now possible.

System Overview

This paper discusses an entirely new concept that provides many unique benefits over traditional CBM systems. Continuous station health monitoring includes not only verifying the USM diagnostics are OK, but also validating P&T values are still accurate, the flow computer is performing properly, and the GC is also providing accurate information. This is accomplished by utilizing a variety of advanced diagnostic techniques that quickly and accurately identify measurement problems. Benefits include extending periodic site inspection and calibration intervals, providing immediate alarming via email and/or text messaging when problems occur, reducing travel time by technicians and lowering overall measurement station O&M costs. Continuous “health” monitoring translates into overall reduced facility uncertainty and ultimately lower company-wide LUAF. Perhaps a better acronym for this would be “Continuous Based Monitoring System,” or CBMS.

The CBMS system is comprised of both site-installed hardware and cloud-based software server components. Field installed hardware collects, computes and transmits a variety of measurement data to an off-site server. A secure cloud-based software system receives and analyzes the data, then provides periodic reports to the client via the Internet at prescribed intervals. Both hardware and software work together to remotely monitor and verify all aspects of the USM measurement station performance continuously (24/7/365).

The Hardware Component

The field hardware consists of a flow computer based device that monitors the measurement station equipment’s performance in “real-time.” USM diagnostic “health” information, along with volumetric flow data, is obtained serially to ensure all values are within the normal operating range. Fiscal pressure and temperature readings, as well as actual and corrected volumes, are acquired directly from the client’s flow computer. The hardware component then computes AGA 7, 8, 9 & 10 to confirm the fiscal flow computer is obtaining the correct number of pulses from the USM, thus ensuring accurate volume and energy values. In addition, the meter’s reported SOS is directly compared to the AGA 10 computed SOS within the CBMS unit. No other system offers this complete level of computational redundancy and verification.

This field hardware device continuously performs short-term analysis of USM diagnostics. This consists of transducer Performance, SNRs, path-to-path SOS deviations, Gains, Turbulences, Profile Factor, Symmetry and Crossflow. It also monitors for deviations in the fiscal P&T transmitters, GC performance problems (response factors and alarms), and flow computer calculation discrepancies (actual volume, compressibility, corrected volume and energy). This is accomplished by incorporating a redundant P&T transmitter for each meter run. By comparing the CBMS pressure and temperature readings with the fiscal flow computer’s values, deviations can be quickly and easily identified.

When an issue occurs with any of the facility's equipment, the field unit immediately transmits the problem to the AT&T cloud-based system. The client can choose to receive these alerts in real-time and/or daily via email and/or text messages. Hourly average flow data and diagnostics information is automatically transmitted once per hour for further detailed analysis, trending, archiving and reporting by custom-developed software. All communication is via a secure digital cellular network that is 100% independent of the client’s SCADA system. In the event cellular data is not available, satellite communication can be used.

Today many clients use multiple USMs at their facility in order to provide added rangeability or, in some cases, redundancy. In many Transmission applications, the USM is used for bi-directional applications. In order to be cost effective, is important that any device attempting to provide this information be able to handle more than one meter. A meter run is defined as one USM electronics head with a single flow direction. Thus, a bi-directional single meter run station would be considered as two meter runs. A single CBMS field unit is designed to handle up to four (4) meter runs; thus it is capable of handling a two-run bi-directional meter station. Additional field units can be added for larger stations.

Figure 1 is an example of a two parallel meter runs with two meters in series. This configuration is often used in high volume application to help validate the fiscal USM. Two USMs in series provide redundancy and reduced uncertainty because generally two different path configurations are used.

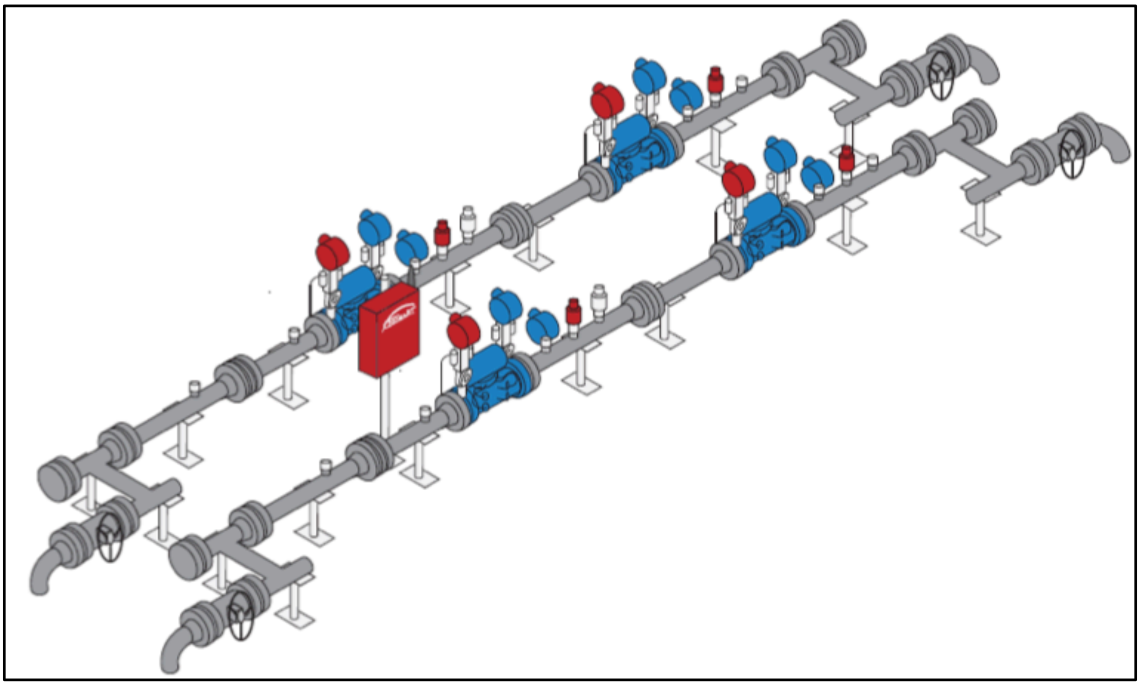

Figure 1 - Dual Meter Runs in a Series/Parallel Configuration

Figure 1 shows the client's transmitters in blue and the CBMS system components that are added (hardware and transmitters) in Red. Some key system features are as follows:

- It incorporates a separate, fully independent internal flow computer for obtaining P&T readings, computing uncorrected and corrected flow (from serial USM data), AGA 10 SOS, and communicates with the gas USM and GC.
- P&T readings for each meter run are continuously validated by comparing the fiscal transmitter readings to the unit's independent multi-variable transmitter (MVT).
- Daniel, Instromet and SICK ultrasonic meters, Daniel and ABB gas chromatographs, and most common flow computers are polled via Modbus using a local RS-232 or RS-485 port.
- When physical wiring isn't practical between the CBMS base unit and the new MVT transmitters, existing fiscal flow computer, USM and/or the GC, the system can be equipped with an optional 900 MHz radio system data communication.
- All data is transmitted via secure digital cellular radios by either an AT&T Asavie VPN client, or by AT&T ANIRA software. Other cellular data providers can be used where AT&T is not available. This fully isolates the client's site from the public Internet. In other words, the IP address of the field unit is invisible to the public Internet.
- All radio data transmission is secured by SSL, 256-bit AES, and other encryption technologies.
- One field-installed system can support up to four parallel ultrasonic meter runs (four uni-directional or 2 bi-directional), or two parallel meter runs utilizing two series USMs in each run. Additional systems can be added to accommodate larger stations.

The "Cloud-based" CBMS Software and Hardware Components

The off-site "cloud-based" system host is a proprietary software application developed in conjunction with AT&T. It is specifically designed to collect, analyze and monitor measurement station performance data. The unique algorithms incorporated provide storage, trending and further data analysis, and automatically generates warnings, alarms, and a variety of reports. This provides clients with fast, easy and secure proactive access to their site information without the limitations of corporate SCADA networks.

Some key features of the "cloud-based" CBMS system are:

- Performs AGA meter run flow calculations to provide back up (redundant) flow data.
- The AT&T Data Center system provides multiple levels of security and encryption, including SSL and 256-bit AES encryption, VPN connections, and managed firewalls.
- All reports are accessible via the Internet from any computer using Microsoft Silverlight & Internet Explorer (or other web browser). No special software is required to obtain reports.
- Customized reports can be user-developed with Excel 2010.
- All meter station reports, regardless of gas USM brand, look the same. Consistent report structure greatly reduces training and simplifies understanding of meter station performance.
- Standardized reports are delivered in a PDF format for ease of viewing and sharing.
- Series and parallel meter run flow rate ratios are analyzed and alerts are generated when deviations exceed customer specified limits.
- Provides long-term trending of all vital USM diagnostic data to help identify "slow-to-develop" issues like contamination, gasket extrusion, and minor flow conditioner blockage.
- This AT&T solution provides all the necessary infrastructure to support the statistical processing, control chart development, and data filtering for analysis and generation of custom reports.

Figure 2 is a drawing that shows an example of the communication topology.

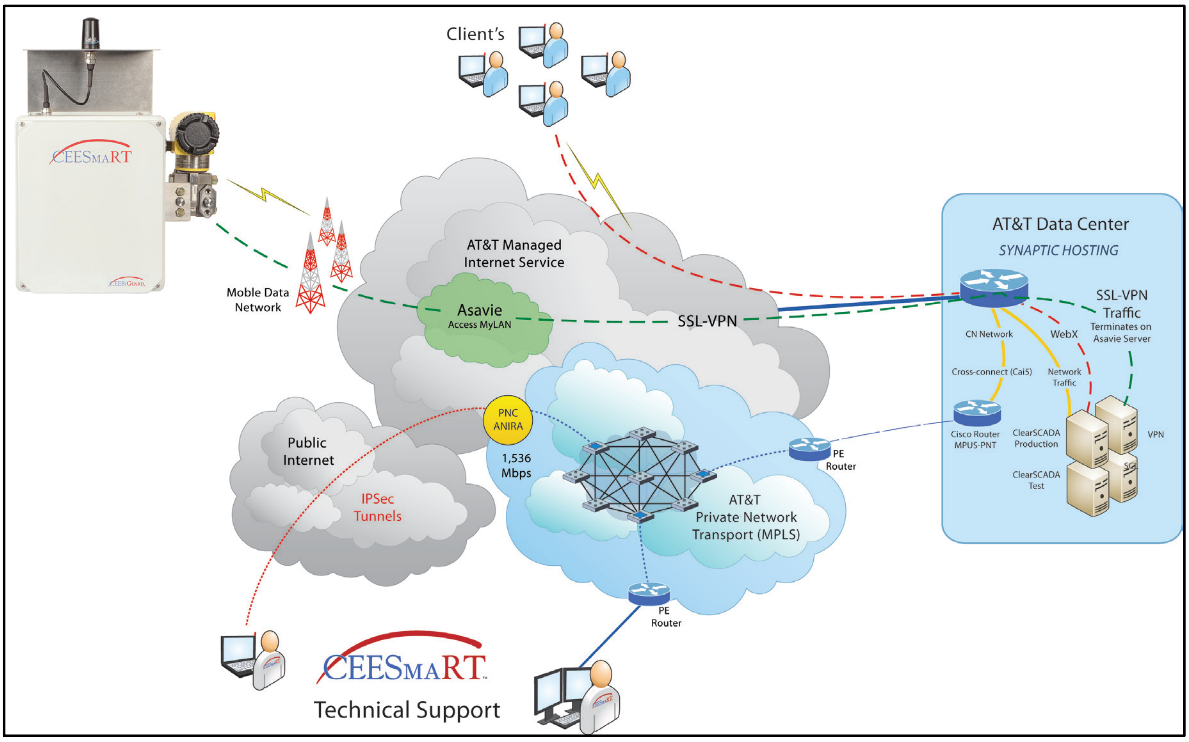

Figure 2 - Overall System Communication Topology

This Figure 2 graphic includes the field-installed hardware in the upper left of the drawing, the client's communication with the AT&T Data Center, and how the technical support team gains access to set up each client and meter run.

Periodically the client receives reports via email that summarizes the performance of the USM metering station. This not only includes the USM diagnostics, but also P&T verification, actual and corrected volume validation, GC performance and flow rate ratios for series or parallel meter station designs. These reports are sent either daily, weekly or monthly, depending upon the client's need. They are in a PDF format for ease of viewing and distribution. In the event an alarm or event occurs in the field, the client can choose to receive these immediately, or daily via email or text message.

The client can also gain access to data by logging into the system. Clients can easily assign different levels of access to each user. Using Internet Explorer with Microsoft Silverlight, the user simply needs to connect to the system's URL, enter their user name and password, and all sites to which they have authorized access become available.

Once connected to a specific meter station, additional reports and quasi-live data (last two minute average flow data) is available. There are many reports (more than 50) that the client can choose from. Historical trend reports for all USM diagnostics, meter run pressures and temperatures, actual and corrected flow rates, as well as gas chromatograph information are readily available. Customized reports can be generated using Excel 2010.

Report Examples

The client will automatically receive reports summarizing the health of the facility. Depending upon client preference, these can be daily, weekly or monthly. The client can choose from a vast menu of available reports to customize data presentation for their particular needs. The "Alarm

Report" is one report option that summarizes the facilities performance, and includes an overview of not only the USM, but all other aspects of station operation. This report provides alarm condition summaries for the following categories:

- USM Detailed Analysis
- USM Path Status
- USM Summary Analysis
- USM Meter Head Analysis
- Pressure and Temperature
- Flow Calculations
- Series and Parallel Meter Analysis
- Events like Testing and Calibration

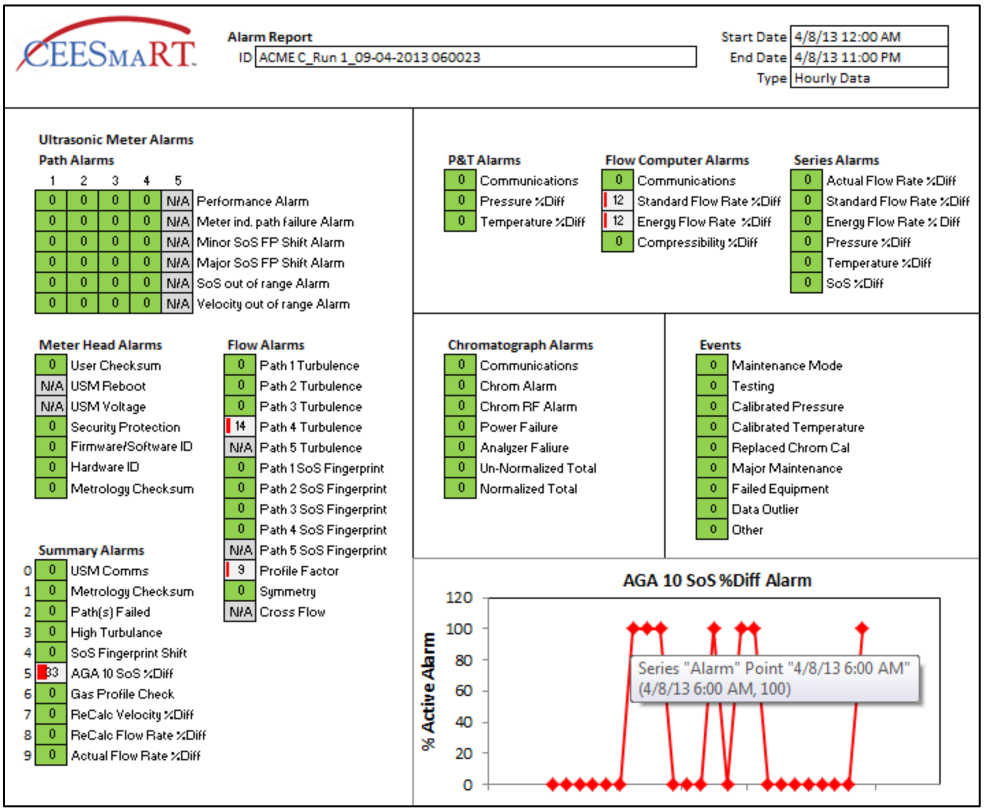

Figure 3 - Alarm Report Example

Figure 3 above illustrates an Alarm Report. The report quickly illustrates the percentage of time any alarm condition monitored by the CBMS field unit that was in alarm during the report test period. Green boxes with zeros indicate that no alarm condition was detected during the test period, while a red bar with a number other than zero indicates the amount of time a particular alarm condition was active. For example, the AGA 10 SoS %Diff alarm was active for 33% of the test period (see bottom left of Figure 3). The graph in the bottom right of Figure 3 illustrates when the AGA 10 SoS %Diff alarm was active. The user can use the graph to select and interrogate any of the active alarms.

A second report, called the Run Verification Report, provides detailed values for each of the diagnostic tests. The Run Verification Report is illustrated in Figure 4.

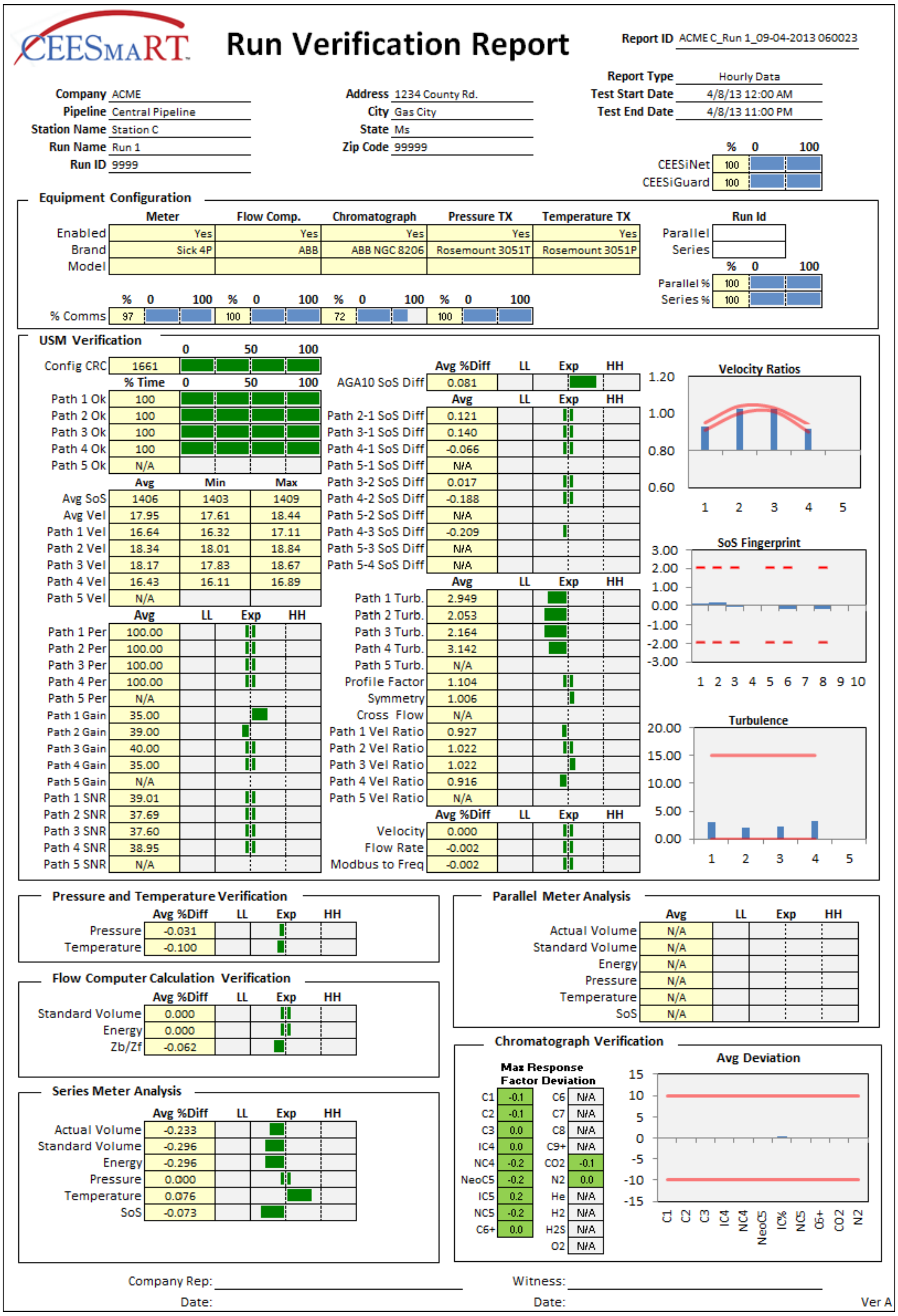

Figure 4 - Run Verification Report Example

The Run Verification Report provides a concise summary of how close the various diagnostic tests are to their expected values. This report summarizes each of the test conditions in more detail. For example, transducer performance is shown as 100% for all 4 paths. The individual per-path SOS differences are graphed with some reading slightly low and some reading slightly high. The “Exp” in the middle is the “expected” value. The bar graph for each variable may be to the right or left depending upon if the variable is above or below the expected value. For transducer performance, it can only show a bar to the left of “Exp” since performance can never be greater then 100%, which is the expected value. Once a variable exceeds the LL (Low Limit) or HL (High Limit) limit, it will turn red indicating a potential problem.

This summary includes all diagnostic tests on the USM, and includes others like the P&T Verification, Flow Computer Calculation Verification, Series and Parallel Meter Analysis and Gas Chromatograph Verification. The combination of the Status Report and the Run Verification Report provides a comprehensive overview of all aspects of the facilities' operation.

Another example this report provides is to show the USM diagnostics are all near the expected values, and the percent difference between the meter's measured speed of sound and the AGA 10 calculated speed of sound was 0.081% for the test period. The percent difference between the pressure and temperature measurements during the test period were -0.031% and -0.100% respectively. For this test period there was no difference in the volume calculations (0.000%) when comparing the customer's flow computer and the CBMS field unit values. The percent change in the response factors are also illustrated in the bottom right of the report and are all minimal (typical values).

Figure 4 illustrates a report from a series meter installation. This can be seen by examining the Series Meter Analysis Section (lower left of the graphic). It incorporates data from both meters. In this example the user can easily see the average flow difference between the two meters (-0.233%), plus the speed of sound difference between the two meters (-0.073%). This allows users of Daniel Senior Sonic and Junior Sonic series installations, or users or SICK 4+1 or 4+4 installations, or for that matter in combination of ultrasonic series metering, to easily take advantage of the series diagnostics.

Should the client want to review any particular variable over time, a simple "mouse click" will then permit reviewing a report that trends the variable over time. For instance, if the client would like to see how the Profile Factor has been behaving over the past week, clicking on the cell will bring up a report as shown in Figure 5. The same function applies to all other diagnostic parameters.

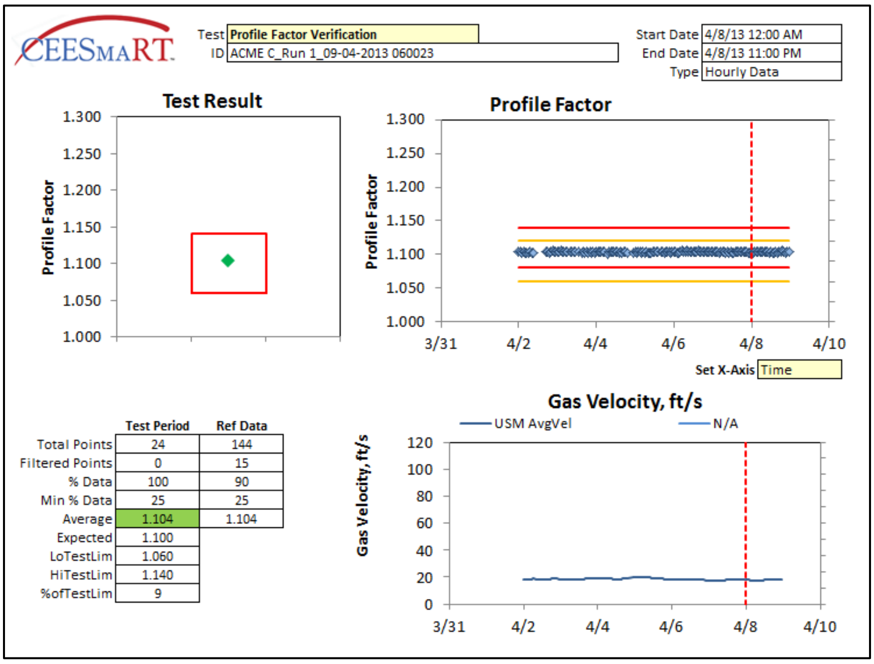

Figure 5 – USM Profile Factor Example

Figure 5 shows a trend for the Profile Factor over 1 week. The data to the right of the red dashed, vertical line represents the test period, while the data to the left of the line provides a quick, visual reference. The Profile Factor illustrated in Figure 5 is very stable during the entire period, which is expected because the velocity, graphed in the lower right, was also very stable.

Figure 6 illustrates a Profile Factor Test for a meter flowing from 1 fps to 15 fps. The data is from a Q5 Instromet meter. The Profile Factor is expressed as the ratio of the swirl to axial velocities, and therefore is less than one under normal conditions. This figure shows that the alarm limits are a function of velocity, and thus the tolerance changes as the velocity changes. This method allows the user to establish tight alarm limits through the entire operating range. It also allows the user to characterize the USM diagnostics down to very low velocities.

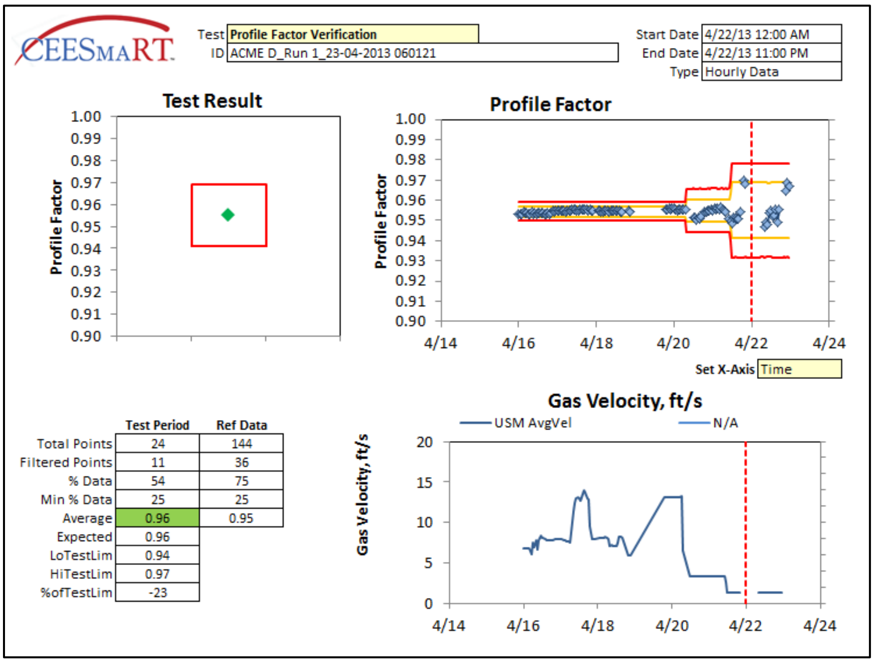

Figure 6 – USM Profile Factor Example

Figures 7 and 8 that follow illustrate how the same test report format is used to other diagnostics. Figure 7 is an example of a report for the AGA 10 Speed of Sound Percent Difference test. This figure shows that during the weeklong period the percent difference between the meter's measured speed of sound and the calculated speed of sound was within a tenth of a percent. For the test period the average was -0.06%.

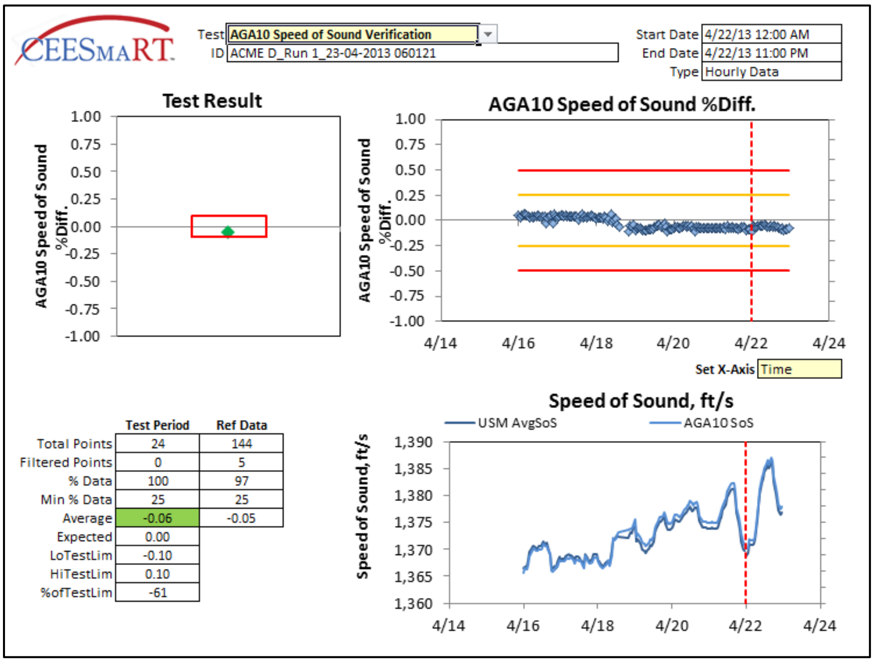

Figure 7 – AGA 10 SoS % Difference

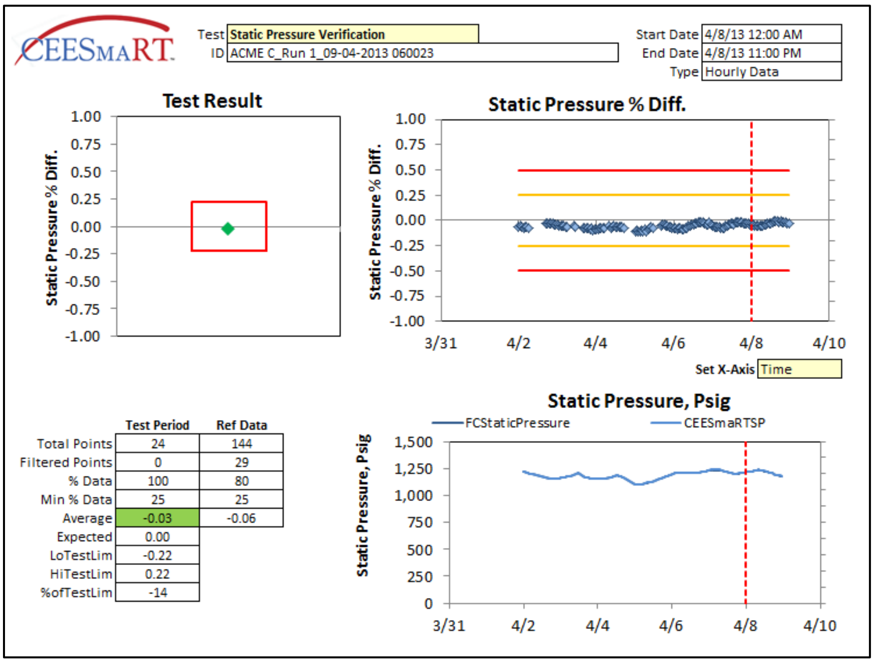

Figure 8 – Static Pressure % Difference

Figure 8 illustrates the percent difference in static pressure between the fiscal measurement transmitter and the monitoring systems transmitter. This graphic shows that for the test period the difference was approximately -0.06%.

Conclusions

As technology continues to advance, more automation is the result. Residential Automatic Meter Reading (AMR) is commonplace today. The cost and reliability of these systems has significantly improved during the past decade.

Providing a system that does more than just monitor a USM metering station performance is now more practical then ever. Through the use of web-based systems like the AT&T cloud, more automation is being achieved today in order to lower meter station uncertainty. As the entire facility can now be monitored on a real-time basis, problems like liquid contamination from hydrates, blocked flow conditioners, contamination buildup within the metering facility, and much more can be quickly identified and immediately communicated to the client via an email or text message. All of this is now possible without the need to visit the facility periodically.

By incorporating a CBMS system, not only is the USM facility station uncertainty lowered, the need for monthly site visits to verify the accuracy of pressure and temperature transmitters is also reduced by incorporating separate redundant measurements for each meter run. With the addition of AGA 10 SOS being computed by the CBMS unit, any problem with the gas chromatograph can also be quickly identified. This even includes components in the flowing stream that are not being detected like H_2 and He.

With the emphasis by many clients to “do more with less,” every aspect of field maintenance is being reviewed in order to reduce costs. Fewer site visits can increase vehicle longevity, reduce exposure time for potential vehicular accidents, and reduce vehicle emissions that translate into a better environment for everyone.

Finally, calling this system a Condition Based Monitoring System isn’t fully descriptive. Perhaps it should be called a Complete Measurement Verification System (CMVS) since it not only reports in when a “condition” exists, it verifies the operation of all ancillary equipment including the flow computer, P&T transmitters and GC. Maybe a better term than this CMVS “reduces your measurement uncertainty” would be “**Increases Your Measurement Certainty**” by insuring all equipment is operating correctly 24/7/365.

References

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