Furnace Flame Instability Detection With Advanced Pressure Diagnostics

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BACKGROUND

Furnaces are found throughout many industries including chemical, power, and refining. A large refinery may have dozens of furnaces. One common problem that occurs in furnaces is instability in the burner flames. When a flame goes unstable, it gives a “flickering” appearance. The furnace operator will attempt to bring the burner flames back to stability, normally by adjusting either the air or the fuel into the furnace. If the instability is not immediately corrected, it could lead to a flame-out, a dangerous condition of unburned fuel left in the firebox. This unburned fuel presents a hazard because if it does light up, the uncontrolled combustion could damage equipment, and pose a safety hazard to anyone in the vicinity. If a flame-out does occur, the furnace operator may have to shut the furnace down, taking part of the process offline, and resulting in a costly loss of production to the plant.

Because of the importance of keeping furnace flames healthy, many different technologies have been tried for monitoring burner flames, such as thermal measurement, flame sensors, combustion analyzers, and photographic or optical techniques. Another method is simply mounting a camera in the furnace and viewing the burner flames on a monitor in the control room. These technologies all have shortcomings, such as being reactive (detecting only after the flame is out), subject to false alarms, or expensive to install and maintain.

However, most furnaces utilize one or more pressure transmitters at the firebox to measure the inlet draft pressure. Recently, it has been shown that by using a pressure transmitter with advanced diagnostics for this measurement, it is possible to gain insight into the health of the burner flames, and to gain an early detection into flame instability(1).

ADVANCED PRESSURE DIAGNOSTICS

Emerson Process Management has developed a unique patented technology that provides a means for early detection of abnormal situations in a process environment. The technology, called Statistical Process Monitoring (SPM), is based on the premise that virtually all dynamic processes have a unique noise or variation signature under normal operation. Changes in these signatures may signal that a significant change in the process, process equipment, or transmitter installation will occur or has occurred. For example, the noise source may be equipment in the process such as pumps, agitators or the natural variation in the DP value caused by turbulent flow or any combination thereof.

The sensing of the unique signature begins with a high speed sensing device such as the Rosemount 3051S Pressure Transmitter equipped with patented software resident in a HART® Diagnostics or FOUNDATION™ fieldbus Feature Board. This powerful combination has the ability to compute statistical parameters that characterize and quantify the noise or variation and represent the mean and standard deviation of the input pressure. Filtering capability is provided to separate slow changes in the process due to intentional setpoint changes from inherent process noise which contains the variation of interest. The transmitter provides the statistical parameters to the host system via HART or FOUNDATION fieldbus communications as non-primary variables. The transmitter also has internal software that can be used to baseline the process noise or signature via a defined learning process. Once the learning process is completed, the device itself can detect changes in process noise and will communicate an alarm via the 4 – 20 mA output or alert via HART or FOUNDATION fieldbus.

(1) *E. Eryurek, P. Sharpe, D. White. Abnormal Situation Prevention through Smart Field Devices. NPRA Hydrocarbon Processing, March 2006, pp. 41-48.*

The Advanced Diagnostics capability of the pressure transmitter is done on a software path parallel to the standard pressure measurement signal. The standard 4-20 mA control signal is not affected by this additional advanced diagnostics functionality. Figure 1 illustrates a field device providing both the control signal, and the advanced diagnostics data, to the control system.

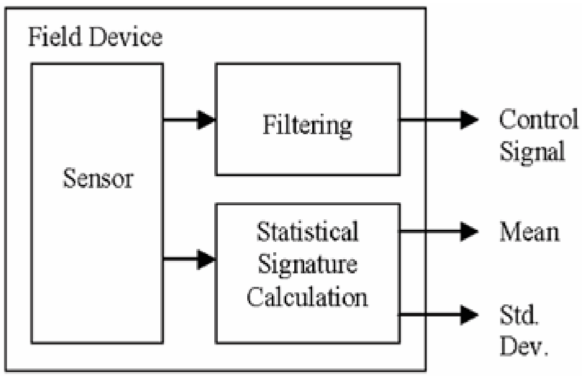


FIGURE 1. Field Device Providing both Control Signal and Advanced Diagnostics Data

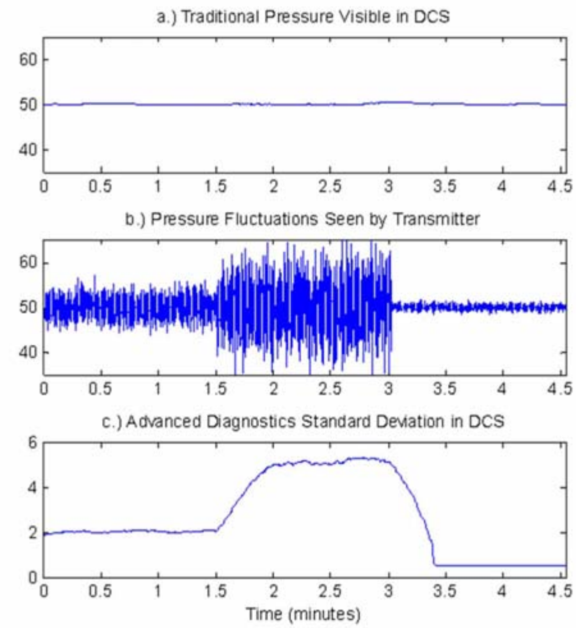


FIGURE 2. Trend of Advanced Pressure Diagnostics Data

Figure 2 further illustrates advanced pressure diagnostics technology. The top trend (a) represents a typical control pressure signal received by a Distributed Control System (DCS); in this example, relatively flat over time. The middle trend (b) shows the pressure fluctuations measured by the transmitter. In contrast to the control signal, changes in the process variability are clearly visible. Often this change in variation, when there is no change in the control pressure signal, can be indicative of an abnormal process condition. The bottom trend (c) shows the standard deviation, a statistical measure of the process variability, calculated by the diagnostics pressure transmitter, and visible in the DCS.

When the advanced diagnostics standard deviation is viewed in the host system, it is possible to detect abnormal conditions that would otherwise be unobservable using the traditional pressure signal alone. Many different abnormal conditions have been shown to be detectable using advanced pressure diagnostics, ranging from plugged impulse lines(1), to entrained gas(2) or liquid(3), to FCC catalyst circulation problems(4).

(1) *D. Wehrs. Detection of Plugged Impulse Lines using Statistical Process Monitoring Technology. Whitepaper, Rosemount.com, December 2006.*
(2) *D. Wehrs, A. Klosinski. Entrained Gas Diagnostic with Intelligent Differential Pressure Transmitter. Whitepaper, Rosemount.com, January 2008*
(3) *D. Wehrs, A. Klosinski. Wet Gas Diagnostic with Intelligent Differential Pressure Transmitter. Whitepaper, Rosemount.com, January 2008.*
(4) *R. Szanyi, M. Raterman, E. Eryurek. Diagnostics capabilities of FOUNDATION fieldbus pressure transmitters. Hydrocarbon Processing, April 2003, pp. 53-59.*

Instability in furnace flames can also be detected using advanced pressure diagnostics. During normal operation a burner has a relatively solid and steady flame. But when a burner flame goes unstable, it is evidenced by a flickering in the flame, producing pressure fluctuations that can be seen by a pressure transmitter measuring the inlet draft of the furnace. A pressure transmitter with advanced diagnostics can detect this flickering as an increase in the standard deviation [(1)]. This technical note describes recent furnace testing that further substantiates the use of advanced pressure diagnostics in furnace applications.

FURNACE FLAME INSTABILITY FIELD TEST

During the week of December 15-19, 2008, a field test, partnering Emerson Process Management with a major international petroleum and refining company, was conducted on an R&D test furnace to study technologies for detecting flame instability. The test furnace has three burners, of type Raw Gas Low NOx. During the week of furnace testing, the team looked at how the advanced pressure diagnostics data reacted to the presence of flame instability under various scenarios. These scenarios consisted of inducing flame instability when: 1.) transmitters were installed in proximity to each of the burners, 2.) transmitters were installed at different heights on the furnace, 3.) the furnace was running at different heat rates, and 4.) the furnace was running with different fuel types.

In the first test (A), flame instability was tested with three transmitters installed around the perimeter of the catwalk level of the furnace. Each of the three transmitters was installed in proximity to one of the three burners. During this test, one of the three burners would be made unstable. The advanced diagnostics data from all pressure transmitters would be trended and analyzed, to determine 1.) if the flame instability can be detected, and 2.) if it is possible to identify which burner is unstable.

Figure 3 shows a picture of the test furnace, with the arrow indicating the catwalk level at which the transmitters were installed. The figure also illustrates a cross-section of the furnace, with the three burners in the center of the furnace and the three transmitters outside of the furnace. Each of the three transmitters was connected to the furnace via impulse lines as close as possible to one of the burners. Thus, as illustrated, transmitter 1 (PT 1) was installed nearest to burner 3, transmitter 2 (PT 2) was installed nearest to burner 2, and transmitter 3 (PT 3) was installed nearest to burner 1. Figure 4a shows a picture of the three burners through the furnace viewport, while Figure 4b shows a picture of one of the pressure transmitters connected to the furnace firebox.

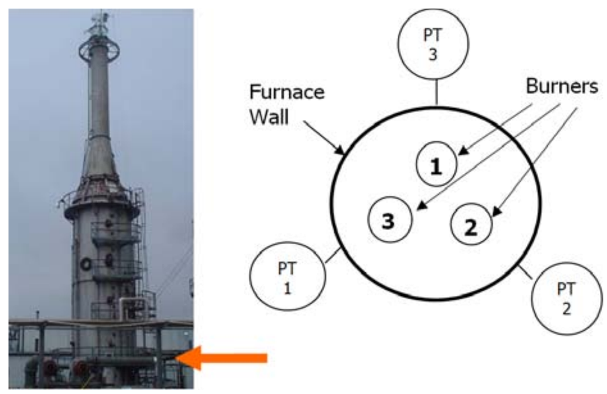
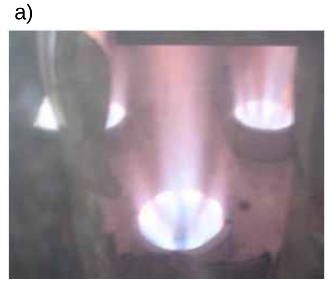


FIGURE 3. Test Furnace, location of transmitters for Test A

a)



b)

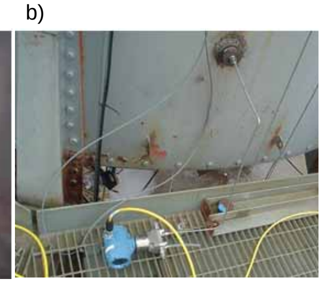


FIGURE 4. a.) Furnace Burners Seen through the Viewport b.) Pressure Transmitter Connected to the Furnace Measuring Draft Pressure

(1) *E. Eryurek, P. Sharpe, D. White. Abnormal Situation Prevention through Smart Field Devices. NPRA Hydrocarbon Processing, March 2006, pp. 41-48*

In the second test (B), the three transmitters were installed at three different heights on the furnace firebox. The purpose of this test is to determine if the height or vertical location of the transmitter has any effect on how reliably the advanced diagnostics data can detect flame instability. One of the transmitters was kept at the catwalk level, the same location as in test A. The second transmitter was moved to a lower position, while the third transmitter was moved to a higher position.

The final two tests consisted of testing flame instability with the furnace running at different heat rates, and with different fuel types. In the heat rate test, the furnace was at three different heat rates, representing the typical operating range of this furnace. In the fuel type test, the furnace was run with a refinery fuel gas, and compared against the results when natural gas was the fuel. Both of these tests involved inducing flame instability and trending the advanced pressure diagnostics data.

TEST RESULTS

Test A was conducted with the three transmitters installed at the catwalk level. In test A1 (shown in Figure 5) burner 1 was made unstable, while the other 2 burners were kept stable. In the figure, the flames were stable during the beginning of the test, and they were made unstable starting at approximately 10:06, as indicated by the arrows.

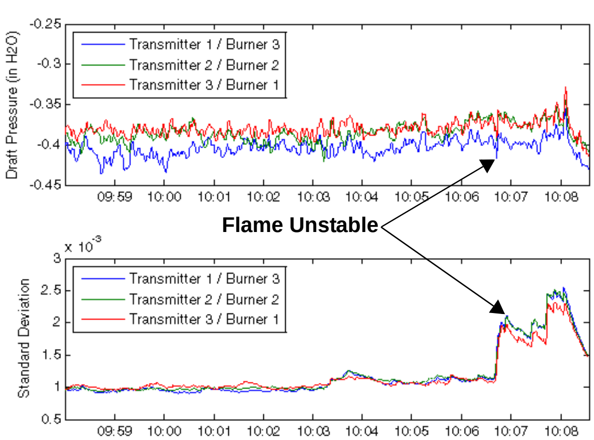


FIGURE 5. Test A1 - Burner 1 is Unstable - Draft Pressure and Standard Deviation

Note that the draft pressure does not change on any of the three transmitters throughout the test. The pressure is always around -0.4 inches of water. However, at the point of instability, we see the standard deviation go up on all three transmitters by roughly the same magnitude. Thus, all of the transmitters detected instability equally well.

Another burner test, A2, was performed, identical to test A1, except that this time, burner 2 was made unstable. The result of this test was similar to the first: the standard deviation of all three transmitters increased by around the same amount. These tests show that even if only one burner is unstable, the condition can be picked up by any of the transmitters measuring the draft pressure. Only one pressure transmitter is needed to detect the flame instability. An operator’s response would involve regulating the air or the fuel to the furnace, and they would do this regardless of whether one or multiple burners are unstable.

DIFFERENT TRANSMITTER LOCATIONS

The second test (B) looked at if the height, or vertical position, of the transmitter on the furnace firebox has any effect on if the flame instability could be detected. Figure 6 shows the draft pressure and the standard deviation during this furnace test, in which the flame instability was induced at approximately 14:32.

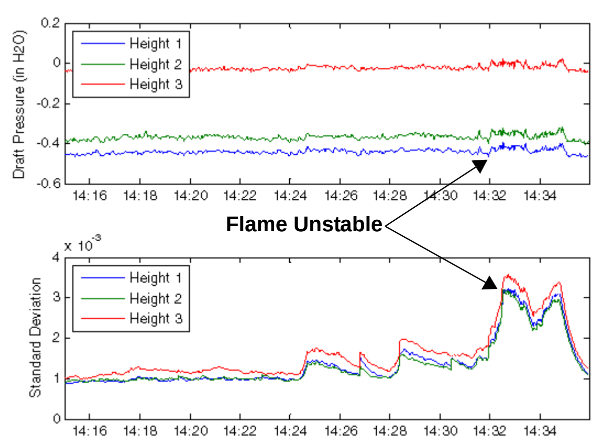


FIGURE 6. Test B - Transmitters at Different Heights on the Furnace Firebox

Notice that again, during the period of instability, the standard deviation of all three transmitters increased by approximately the same amount. Regardless of whether the transmitter was near the bottom of the furnace (heights 1 and 2) or higher up towards the stack (height 3), the advanced diagnostics data indicates the unstable condition. This test demonstrates that the installation location of the transmitter on the fire box has little or no effect on the ability of an operator to use advanced diagnostics to detect flame instability.

OTHER COMPARISONS

During the furnace testing, the team also investigated whether advanced pressure diagnostics could detect flame instability when the furnace was running at different heat rates, or with different fuel types.

Table 1 shows a summary of the test results when the furnace was run at three different heat rates, representing the typical operating range for the test furnace. At every heat rate, the flame instability was detectable by a significant increase in standard deviation.

TABLE 1. Flame Instability Testing using Different Heat Rates

Heat Rate	Std. Dev. Change	Flame Instability Detected
A	increase 3.2x	Yes
B	increase 2.7x	Yes
C	increase 3.5x	Yes

Table 2 summarizes the results of similar tests run with two different fuel types: Natural Gas and Refinery Fuel Gas, while all other test factors were the same. With both types of fuel, the standard deviation increased significantly, and the flame instability could be detected.

TABLE 2. Flame Instability Testing using Different Fuel Types

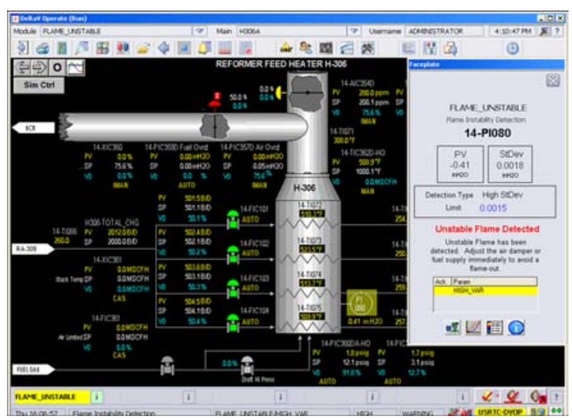
Fuel	Std. Dev. Change	Flame Instability Detected
Natural Gas	increase 2.8x	Yes
Refinery Fuel Gas	increase 1.9x	Yes

IMPLEMENTATION IN HOST SYSTEM

Using HART or FOUNDATION fieldbus, Rosemount Advanced Pressure Diagnostics data can be trended, logged to a historian and monitored in any host system. Plant operators and engineers can reference this advanced diagnostics information, and use it to identify and prevent flame instability. A limit or trip-point can be set, and an alert can be generated if the standard deviation exceeds this limit. A furnace operator can make appropriate adjustments to correct the problem.

Figure 7a shows an example of a flame instability alert detected in a DeltaV Operator Interface, while Figure 7b shows a DeltaV Process History View trend of the draft pressure (top) and the standard deviation (bottom) during flame instability. Notice that during the period of flame instability, even through the draft pressure remains constant, the standard deviation increases.

a.



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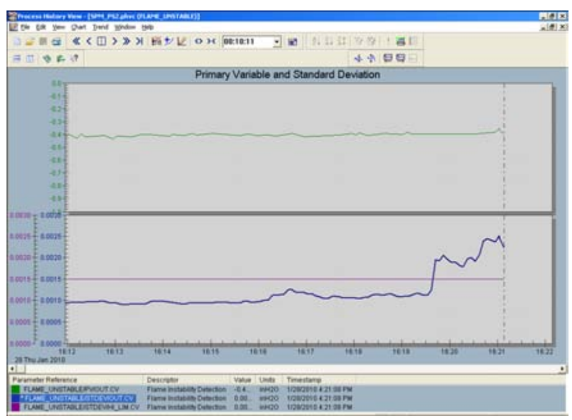

FIGURE 7. Furnace Flame Instability Detection in a Control System: a.) Operator Interface showing Flame Instability Alert; b.) Trending Advanced Diagnostics Data in Process Historian

CONCLUSION

Flame instability is a significant problem in industrial furnaces that can lead to a dangerous flame-out condition and a costly process shut-down. Emerson Process Management has developed a patented and unique technology, Statistical Process Monitoring, that can be used to detect the presence of unstable furnace flames under a wide variety of operating and installation conditions. This technology is resident in HART and FOUNDATION fieldbus versions of the Rosemount 3051S Pressure Transmitter, and can provide early warnings of process, equipment and installation problems.

ACKNOWLEDGEMENT

This technical note is based upon a paper first published at the 2010 AIChE Spring Meeting.(1)

(1) *J. Miller - Furnace Flame Instability Detection Using Pressure Measurement with Advanced Diagnostics – Session 57 – Advances in Fired Heater Safety and Operations – 2010 AIChE Spring Meeting and 6th Global Congress on Process Safety – March 21-25, 2010 – San Antonio, TX, USA*

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