CLEARSIGN EYE™: PILOT SENSOR

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I. Abstract

For decades the industrial combustion industry has predominantly relied on flame rectification technology to monitor the presence of the pilot flame. As an integral part of the safety system, the current flame rectification device, or flame rod, is placed directly in contact with the pilot flame and as a result has disadvantages regarding its reliability and longevity. This leads to unwanted maintenance issues and often expensive preventative maintenance programs. At the 2020 AFRC conference, ClearSign Technologies announced the development of a new sensor technology, the ClearSign Eye™ Pilot Sensor. The new sensor is designed to eliminate the reliability issues associated with industry standard flame rods. The innovative flame monitoring sensor accurately detects the presence of a pilot flame without direct flame contact. Extensive reliability and run life testing demonstrates this technology provides reliable pilot flame monitoring without experiencing failures associated with the current industry standard flame rods.

This paper will discuss the product enhancements since the initial product demonstration and focus on electrical/software modifications, mechanical connection improvements, and simplified installation changes. These improvements resulted from customer observations, continued laboratory testing, endurance testing, and the fabrication of our mobile testing unit. The testing unit will be brought to the Symposium and will be available for live demonstration and inspection. Test data from lab, factory testing will be shared, as will real operating results and lessons learned from field installations and case studies.

II. Introduction

At the 2020 AFRC ClearSign Technologies introduced the development of a new method of flame detection for industrial burner applications. The new technology uses an electrical technique to detect the presence of a flame. Electrical flame sensing makes use of the well-known electrical characteristics of flames. Up to now, the flame rod is the only electrical flame detection technology to be developed. However, our new approach is distinctly different than a flame rod. Whereas the flame rod must be submerged in the flame to operate properly, this new method keeps the sensor away from the flame. This difference provides a more robust, low-maintenance, reliable flame detecting solution for the industry.

The technology requires two sensing electrodes situated at the periphery of a flame. A signal is sent from the sending electrode to the receiving electrode through the ionization field of the flame. This signal is then transmitted to the electronics at the base of the unit and back to a control module. The control module analyzes the signal and measures the capacitance between the emitting and receiving electrodes, thereby determining the presence and intensity of a flame.

Figure 1 (Left) Top view of sensing probes (Right) Clearsign Eye pilot sensor shown mounted on operating pilot zoomed in at the pilot tip.

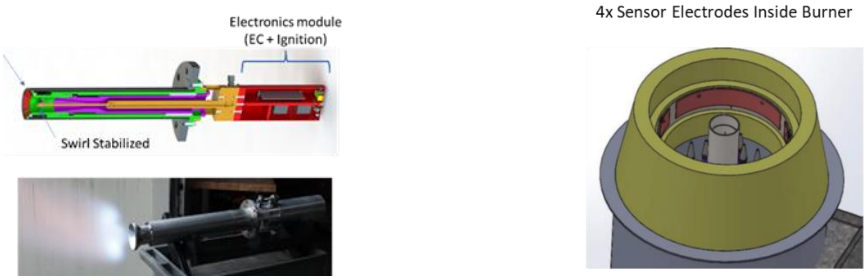

Figure 2 (Left) Custom swirl-stabilized burner with sensing electronics completely integrated (Right) Sensing electrode integrated into a burner tile.

The ClearSign Eye product is the results of years of development with this new electrical technique. Throughout the development of the sensor several concepts have been explored. As presented at the previous AFRC conferences, the sensing technology was integrated directly into a customized, swirl-stabilized burner, Figure 2 (Left). This burner contained sensing electrodes at the exit throat. The swirl-stabilized configuration resulted in a lifted flame directly above the electrodes. This configuration of the sensor successfully demonstrated the capability of this new electrical technique. Another burner configuration was also tested whereby electrodes were integrated directly into a burner tile, Figure 2 (Right). This configuration of the sensor successfully demonstrated how it is possible to scale the sensor to larger diameters (> 1 ft diameter). Scaling the sensor in this way may be useful for locally detecting main flames in burners. Finally, the ClearSign Eye was developed as a solution for detecting flames on pilots, Figure 1 (Right). The pilot flame sensor attaches to standard pilots and can be a direct replacement for a flame rod. The end of the probe sits just below the weeps hole of the pilot tip and provides a reliable flame on/off signal from a distance.

The ClearSign Eye pilot sensor works with most standard pilots. A sensing probe fits through a 1/2” fitting on the pilot mounting plate. A bracket is used to secure the probe to the 1” pipe of the pilot. Below the pilot mounting plate is the probe end enclosure which contains some electronics. A 6-wire cable bundle connects the probe end electronics to a control module. The control module can be situated within the Burner Management System enclosure for easy integration. The control module is powered by two 15V DIN rail mountable power supplies. The control module offers both a 4-20mA output as well as a dry-contact relay output.

Figure 3 ClearSign Eye mounted on an operating pilot with the control unit shown on the far right mounted on a DIN rail next to the power supplies.

ClearSign chose to productize the pilot flame sensing solution based on an observed customer need for a more reliable pilot flame sensing solution. Flame rods tend to have short lifetimes (~ months), depending on the specific application, due to the extreme environment in which they operate. Electrical shorting is a common problem caused by ceramics isolators breaking or water and/or soot coating the rod. Often, flame rods are avoided completely and optical techniques such as UV scanners are used. Flame scanners can be challenging as they must maintain line of sight with the flame of interest. This can make it difficult to specifically monitor a pilot flame. False positive signals can occur when there are multiple nearby flames. The ClearSign Eye address several of these issues. It only measures the local flame, within inches from the tip of the probe, therefore providing a local flame signal. The probe design is robust; there are no exposed ceramic parts that can break, and the flame never makes contact with the probe providing several years of lifetime. Furthermore, the sensor electrodes are designed to reduce the possibility of shorting due to water or soot.

The pilot flame sensor is currently undergoing long duration operational testing at the ClearSign test facilities in Seattle, WA. The goal of these tests is to ensure robust performance over extended operational periods. Furthermore, it is important to install the unit in customer sites to acquire field test data which can help improve the product and match customer needs. For that reason, we have designed a mobile demonstration unit to show customers the technology.

III. ClearSign Eye™ Field Demonstration Unit

ClearSign has built a Field Demonstration Unit of the ClearSign Eye Pilot Sensor, Figures 4 and 5, to demonstrate the capabilities of the technology to our customers. It was built understanding that many customer sites are in extremely remote locations and therefore the unit would need to be easily transportable. It consists of an industry standard process burner pilot, a propane tank, the Retrofitted ClearSign Eye™, and the sensor control module. During a field demonstration the product is presented, and the pilot is ignited. Ignition of the pilot is detected by the sensor and can be observed by the LED displays on the front of the control module. Multiple test points can be demonstrated by increasing and decreasing pressure which in turn causes the signal response (LED display) to change proportionally. Finally, the pilot can be shut down causing the control module to register a flame off signal.

Figure 4 ClearSign Eye demonstration unit case contents. What's Included: Demo unit case, DIN Rail Bracket, ClearSign Eye Control Module, Power Modules, Demonstration Unit tripod stand, Pilot Assembly with Retrofit ClearSign Eye configuration mounted, pilot tip, propane tank connecting hose.

Figure 5 ClearSign Eye demonstration unit.

IV. ClearSign Eye Pilot Sensor Configurations

ClearSign Eye Retrofit Pilot Sensor

The ClearSign Eye RetroFit Pilot Sensor is designed to directly replace flame rods on installed burners without requiring any modification to the existing mounting plate. This sensor configuration is installed using the existing flame rod mounting plate hole. This retrofit configuration was designed with the customers' installation ease in mind.

The solution ClearSign provides with the below (Figure 6) configuration is designed for customers with existing Process Burner applications in which there is an existing pilot flame detection system (Flame Ionization Rod) in place and are looking for a more reliable and robust solution.

Figure 6 ClearSign Eye Retrofit Pilot Sensor Configuration.

This configuration consists of the two sensing probes (Sending and Receiving probes) being situated at the periphery of the Pilot Flame via the pilot tip weephole as can be seen on the right side of Figure 6. From there the two sensing probes run alongside the body of the pilot to a Y or 2-to-1 enclosure just above the burner mounting plate where the two cables withing the rods are merged into a single line. This single cable then runs through the existing flame ionization rod cutout in the burner mounting plate down to the electronics enclosure at the far left of Figure 6. From this point the cables run to the Control Panel where the Control Module with the LED Intensity Meter and Status display would be mounted on to a customer's DIN rail within the panel box.

Upon initial installation, the pilot would need to be either pulled from the burner or the burner would need to be accessed from inside the process heater during an outage or planned turnaround for this configuration to be installed.

ClearSign Eye INPlace Pilot Sensor
The ClearSign Eye INPlace Pilot Sensor is designed to be installed with a custom or modified mounting plate allowing for the sensor to be removed while leaving the pilot in place during operation. This key benefit allows for a simple and efficient method of removing the probes by maintenance and operations personnel as needed according to a customer's specific site requirements. Figure 7 shown below details this configuration.

Figure 7 ClearSign Eye INPlace Pilot Sensor Configuration.

In this design the two sensing probes (Sending and Receiving) each have their own mounting plate feedthrough. For a new application this configuration can be incorporated into the design of the pilot mounting plate. However, for an existing application, in which this design is specified by the customer, there would be minimal modifications required to the pilot mounting plate to accommodate both probe access points. The component layout of this configuration is similar to the Retrofit configuration in that the two sensing probes are situated at the periphery of the Pilot Flame via the pilot tip weephole as can be seen on the right side of Figure 5. The key difference is the two probes run alongside the entire body of the pilot and exit via individual customized access points on the pilot mounting plate and run directly to the electronics enclosure shown the far left of Figure 5.

V. Discussion

Pilot flame monitoring technology has not advanced significantly to meet users growing reliability expectations. The current technology suffers from operational inefficiencies due to frequent failures or environmental conditions. Operators have created preventative maintenance programs around the known failure mechanisms of traditional solutions such as Flame Rods and Flame Scanners. The ClearSign Eye was designed to eliminate the reliability issues surrounding legacy pilot monitoring solutions. The following details a list of the critical benefits of this ClearSign Eye Pilot Sensing Technology:

1. Long Expected Life: Resides outside of Flame Envelope and has all Stainless-Steel Components.
2. Reliable: Permanently Mounted in Place.
3. Accurate: Able to differentiate the pilot flame from main burner flame.
4. Maintenance Free: Maintenance interval designed to exceed standard turnaround cycles.
5. Ease of Installation: All components are designed for integration into standard systems.
6. Adaptable: All components can be customized to specific customer configurations.

ClearSign is currently seeking opportunities for customer field trials, which is seen as the final stage of commercializing the product. Through these trials Clearsign will work closely with the end user to ensure the product meets the requirements for their application.

Additionally, the technology lends itself to additional potential uses, as the signal received has variable intensity that can be calibrated for future uses such as burner health monitoring, or fuel to air ratio measurement at the point of combustion.