The Advantages of Monitoring Flare Pilots With Instantaneous Response

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Abstract

This paper will discuss applications for and details of a fiber optic pilot monitoring system that addresses known, specific challenges in the market. For decades, thermocouples have been the most widely accepted device for determining flare pilot status. However, there is a growing desire in the industry to have a pilot detection system that can surpass five-year run cycles, differentiate between pilot and flare flames, and make an instantaneous determination of pilot flame signal. Zeeco developed the VerifEye fiber optic pilot monitoring system to meet these three critical criteria.

Employing optical technology in pilot flame detection is a common practice; however, those systems typically monitor the entire combustion envelope from a distance and have trouble discriminating between the pilot flame and the flare flame. Zeeco addressed this challenge through fiber optic technology integrally mounted in the flare pilot to relay the pilot ignition status of each unique pilot flame to an at-grade monitor in real time. An optical sensor in the monitor discerns pilot status and controls pilot ignition and function.

This paper details how Zeeco's technology surpasses others while detecting flame by withstanding the extreme temperatures present over a significant lifespan. We will also share lessons learned and test results of this new fiber optic technology and monitoring system to show how it can solve the flame discrimination challenge.

The aggregate effect of these design aspects creates a pilot monitoring system requiring no regular or anticipated maintenance between plant shutdowns. The maintainable electronics are at grade, out of the heat affected zone, and easily accessed while the flare is in service. With accurate-to-the-second pilot status signals, discriminant of other flames, operators can have greater control and confidence in their flare system.

Multiple flare pilot detection technologies are available to operators, but each available technology falls short in some aspect when evaluating these systems on the criteria of operational longevity, differential pilot detection, and instantaneous response.

	INDIVIDUAL	**MAINTAINABLE/ROBUST**	**INSTANTANEOUS**
THERMOCOUPLE	✓	✓	✗
OPTICAL AT GRADE	✗	✓	✓
FLAME ROD	✓	✗	✓

Figure 1: Survey of common flare pilot detection methods

Drive for Instantaneous Feedback

The initial impetus for developing the technology largely derived from calls in the industry for instantaneous feedback from the pilot detection system. Operators wanted to know the moment a pilot was initially lit or reignited. It is not uncommon for a pilot to be lit successfully, but due to delayed feedback in the status signal, antsy operators continue with unnecessary adjustments potentially putting the stability of the pilot at risk. More importantly, a delay in the status signal allows for an extinguished pilot to go undetected.

Subsequent to these requests, operational rules, such as the Refinery Sector Rule (RSR) and Ethylene Production Maximum Achievable Control Technology (EMACT) standards, have emphasized the need for quick identification of a change in pilot status. RSR and EMACT divide flare operations and monitoring in 15-minute blocks and define proper operations that must be measured and controlled to ensure the proper destruction of the flare gasses. Each 15-minute block comprises a deviation if the parameters are not met and an onerous criterion for flare pilot status is included. Any 1-minute interval with no positive pilot flame confirmation inside each 15-minute block is a deviation [1]. This new standard for detection necessitates a method with instantaneous response, otherwise the reaction rate of the detection technology will be a source of compliance issues in and of itself. These rules will conceivably be rolled out to apply to flares across all industries in the USA, and they are already being adopted in other countries.

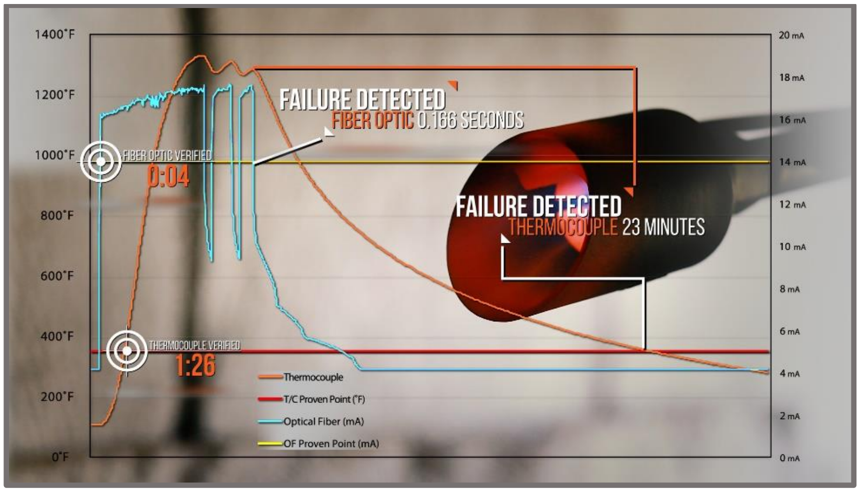

Figure 2: Demonstration of the quick response of fiber optic pilot detection compared to thermocouples

Safety Through Distinction

Grade mounted optical monitors have long been a stopgap for failed thermocouples and flame rods for flare pilot detection. These monitors can be implemented in the field without necessitating a shutdown and provide confirmation of a flame at the flare tip. However, there can be dangerous consequences from reading a false positive from such a system. If the monitor cannot distinguish between multiple pilots or between pilots and the flare flame, a failed pilot may persist undetected. Sophisticated flare vendors position the thermocouple so that it is most responsive to the flare pilot flame as separate from the general flare flame. In this way, an exclusive pilot status is relayed to the control system in most operations. However, because thermocouples detect heat, even the most competent systems are subject to false positive pilot indications on the downwind side of the flare when the pilot can become heat-saturated by flame impingement. It is imperative to address a failed pilot immediately as the root cause of failure could be failed fuel supply, blocked strainers or piping, or mis-operation of valves and regulators - all of which could have a larger impact on the flare stability or the ignition operation as a whole. Consequently, instability or venting could occur unnecessarily when an otherwise resolvable issue persists. In general, having multiple pilots burning helps ensure safety through combustion, so a detection system incapable of identifying the pilot status separate from the flare flame allows issues to persist.

New Durability

Facilities are maximizing online performance all the time, so the timing between shutdowns is extended considerably. It wasn't that long ago that turnarounds occurred on a three-year interval, and pilot detection systems could be serviced or replaced prior to failure. Now, with turnarounds occurring on four- or five-year intervals, the maintenance opportunity exceeds the service life of typical detection systems. The two most common flare pilot detection systems, thermocouples and flame rods, are in direct contact with the pilot flame to determine the status. Very high temperatures, vast temperature fluctuations, and rigorous chemical reactions of combustion limit the lifespan of these systems. Ultimately, for systems to be capable of operating in excess of five years, functioning components must operate away from direct flame impingement to remove the root cause of failure.

Mechanical Configuration

The introduction of an optical fiber in a flare pilot enhances the function of an optical measurement approach to pilot detection while simultaneously satisfying the requirements of instantaneous detection, differentiation between flames, and enhanced durability.

The fiber is located concentric to the air/gas piping of the flare pilot, and it terminates a short distance away from the pilot nozzle. The fiber at the end of the pilot line collects the infrared (IR) energy from an individual pilot through the gas nozzle and transmits it to grade through a series of optical fibers between the pilot and the base of the flare stack. The fiber and its packaging are kept concentric to the pilot air/gas line with spacers that prevent contact with the outside wall. As the gas and air continuously flow through the pilot while the flare is in service, a cooling flow protects the fiber assembly in the most intense heat-affected zones. In this way the fiber optic system is protected against failure from heat and combustion associated with other technologies. Even though the assembly is mechanically protected from the intense heat input of a flare's combustion zone, the materials of construction are still made extremely durable against high temperatures. All materials – the selected fiber, the potting, and even the vibration dampening casing – are of higher temperature suitability than the pilot itself.

Figure 3: Highlight of fiber optic layout in flare pilot

At the base of the pilot, the fiber feeds through a custom piping lateral in a sweeping, progressive manner. It is imperative that whatever equipment is introduced to the pilot does not disrupt the air flow or resulting stability of the pilot. The lateral is designed to minimize drag across the fiber assembly. As the fiber feeds through, it is kept concentric to the pilot air/gas piping, again avoiding heat input from the heat-affected zone. The fiber is captured in the lateral so that its movement downstream is completely unrestricted, thus preventing any thermal stresses from damaging the assembly. Additionally, the connection of the fiber assembly to the lateral is gas tight, preventing the transmission of gases to grade, and allowing utility conduit material to be employed upstream of the lateral connection.

Infrared Signal

The viewing end of the fiber is machined and finished in a way that narrows the viewing angle. The fiber focuses on the back of the pilot nozzle where pilot flame is stabilized. The entire view of the fiber is saturated with IR energy, which is collected and transmitted to grade. The total amount of IR signal available to the sensor at grade is three orders of magnitude greater than the minimum switch point volume, meaning normal degradation of the equipment over time will not inhibit the system's ability to determine pilot status. In addition to the fiber optic sensor focusing on individual pilots, the monitor at grade incorporates flame flicker technology to discern between the pilot and flare flame. Since the pilot flame is pre-mixed with air and exits through small orifices, it has a rapid frequency fluctuation (or "flicker") discernible by the optical detector, which differs widely from the slower pulsation of the flare flame. Software within the optical monitor can then eliminate the lower frequency flicker, thereby discriminating between the pilot and flare flames. No false-positive pilot signal is given, and operators are alerted to potential problems before signals manifest as an extinguished flare flame.

Modular Installation

Compared to the piping, cables, and tubing normally associated with flare utilities and operation, fiber optic cables are relatively delicate. In order to be successful in a rugged flare application, considerations had to be made for the vertically installed length of fiber between the flare pilot and the base of the flare stack. Making single-length fibers for the vertical height of the flare stack was impractical, and customizing lengths was costly and time-consuming. Fiber optic cables are typically installed horizontally, and managing extremely long cables during installation put the equipment at risk of damage. These issues were addressed by making the vertical extension of the fiber optic system modular in its construction. In smaller, typically 50-foot lengths, a standard assembly is mass-produced and stocked, giving clients an economical solution with timely delivery. The shorter lengths are packaged in poly coating and corrugated sheathing which mechanically protects the fiber from overstressing (bending too tight) and vibrating during operation. The manageable length and mechanical protection facilitate successful installation as well as durable and lengthy operation.

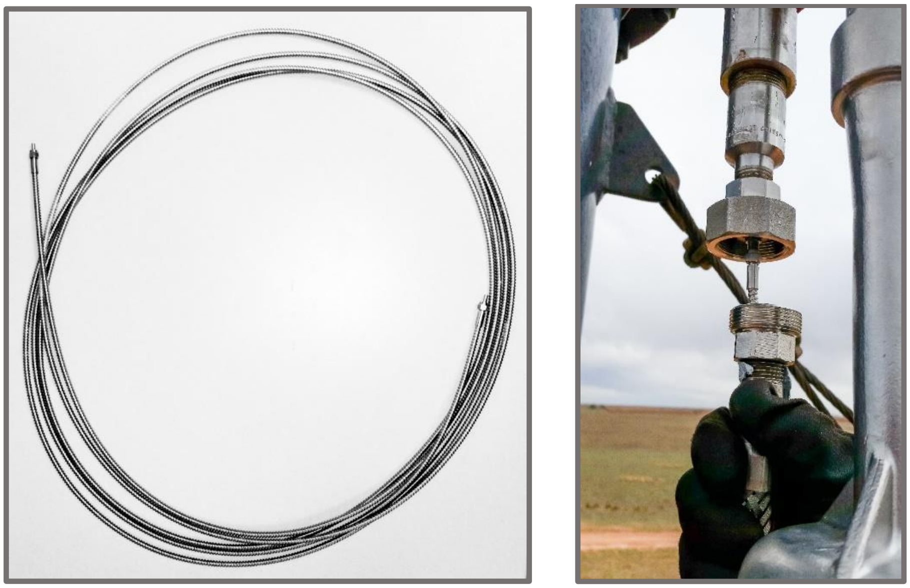

Figure 4 and Figure 5: Packaged fiber optic extension cable for vertical installation (left) and quick-connect expansion joint for modular installation in field assembly (right)

The modular lengths are installed in customized conduit runs – one for each pilot orientation. Typical expansion loops in the conduit cannot be employed in this instance, as the fiber cannot route through a 90-degree elbow. Vertically oriented conduit expansions are used in conjunction with a union connection. The expansion joints allow for thermal growth between the flare stack and conduit while the unions provide an installation and connection point for the fiber units. A bulkhead in the union contains a standard, threaded connector to join lengths of optic cable and to suspend the subsequent fiber optic cable. Some signal loss does occur across each threaded junction; however, due to the large magnitude of IR signal available from the pilot, dozens of connections still do not diminish the signal below useful thresholds. At the base of the flare stack, the conduit is terminated at a junction box or the local control panel for connectivity to the IR pilot monitor. One monitor is used per pilot, where the IR signal is collected from the pilot flame and transmitted through the extended cables. Overall, the operational advantages of an IR pilot monitor, the instantaneous status determination, and grade-mounted critical components are maintained while the fiber optic assembly ensures the selective investigation of a single pilot flame.

Figure 6: Fiber optic capable pilot on flare tip installation

Field Experience

Between testing and development, beta installations, and customer facilities, the aggregate operations have shown excellent durability and promising service life. Comparing the magnitude of IR signal from initial commissioning to inspection points during the life of the equipment, minimal reduction in the signal is observed. If the rate of signal loss is extrapolated, the fiber optic collection system is viable for many years of service – likely equivalent to that of the flare pilot itself.

Experience is showing the requirements from regulators and operators alike can be achieved. With the integration of a fiber optic collection system to the flare pilot, precise and instantaneous detection is achieved with reliable, long-lasting results.

References

[1] National Emission Standards for Hazardous Air Pollutants From Petroleum Refineries, EPA 40 CFR 63.670 (b) (2015)