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Flare Pilot System Safety

John Bellovich, Jim Franklin, and Bob Schwartz
John Zink Company, LLC, 11920 East Apache, Tulsa, OK 74116; john.bellovich@johnzink.com (for correspondence)

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One of the worst nightmares a plant manager can experience is a complete flare system outage. The flare system is the last line of defense for many refining and petrochemical facilities and, when out of commission, can cause the shutdown of the entire facility. Flare ignition failure may lead to unburned venting of dangerous gases, and may develop into an explosive hazard leading to the loss of property and equipment, or worse, injury to personnel or loss of life. The safety and effectiveness of flaring are dependent upon one or more continuously burning pilots for immediate and sustained ignition of gases exiting a flare burner. Because pilot failure can compromise safety and effectiveness, it should be detected quickly and accurately to allow prompt automatic and/or operator response. Proper disposal of process and waste gases during routine and/or emergency conditions is crucial to help operating facilities protect plant employees and the surrounding community, and to avoid hundreds of thousands of dollars in fines. These reasons alone make the pilot monitoring and ignition system the most important component of any flare system. The advanced flare pilot systems explained in this article offer increased protection from harsh environmental conditions and rapid notice of pilot flame failure. Recently published industry standards for flare pilot design and performance are also discussed. © 2006 American Institute of Chemical Engineers Process Saf Prog 26: 10–14, 2007

Keywords: flare pilots, flare ignition, flare monitoring, SoundProof®, flame ionization

INTRODUCTION

A flare can only achieve its objective of safe, effective disposal if the exiting gases are ignited and the ignition is sustained. Ignition is sustained through the use of a design concept that includes several elements: the pilot, the pilot ignitor, and a pilot flame monitor. While each is important, the critical element in this system is the pilot; flare pilots are typically premix type burners designed for operation at a fixed heat release. In application, the pilot is positioned adjacent to the exit of the flare tip. When the flare is in service, the flare tip and its pilot(s) are remote, inaccessible, and exposed to external influences. Therefore, the pilot must be capable of operating for long periods of time without adjustment or maintenance.

API STANDARD 537

The recently released API Standard 537 is a good reference to have concerning flare systems. API STD 537 states that the pilot should continue to burn and ignite the flare at wind speeds of 100 mph under dry conditions and 85 mph when combined with a rainfall of 2 in/hr. These guidelines should be viewed as the minimum level for performance. When the height of most flares is taken into consideration, an effective wind stability of 125 mph or more is desirable. In this same section, API STD 537 recommends a minimum pilot heat release of 13.2 MW (45,000BTU/hr) (LHV) when flaring hydrocarbon gases, with a lower heating value of 11,175 kj/Nm^3 (300 BTU/scf) or greater. Pilots must be able to provide sufficient energy to initiate burning of the waste products as they exit the flare tip. The energy level required is dependent on a number of factors, including: the composition of the waste gas being burned, the gas exit velocity of the flare burner, the design of the flare burner, and the atmospheric conditions under which the pilot is operating. Good practice recommends a minimum pilot heat release of 45,000 Btu/hr for favorable conditions. The use of lower-heat-release pilots can compromise the initiation of burning.

Most flare manufacturers use a premixed pilot of some design. Premix pilots offer greater stability over raw gas burners.

PILOT ANATOMY

A pilot will usually consist of a pilot tip, a windshield, a venturi mixer, and a metering orifice, as shown in Figure 1.

PILOT ENVIRONMENT

During the course of a pilot's service life on a flare, the pilot can be exposed to a number of external influences, including: wind, rain, envelopment in flare flame or inert gas, smoke suppression media, and caustic or acidic gases. Recent Computational Fluid Dynamics (CFD) modeling and testing has shown that wind can cause variations in the local static pressure, which will affect the ability of the pilot mixer to supply a

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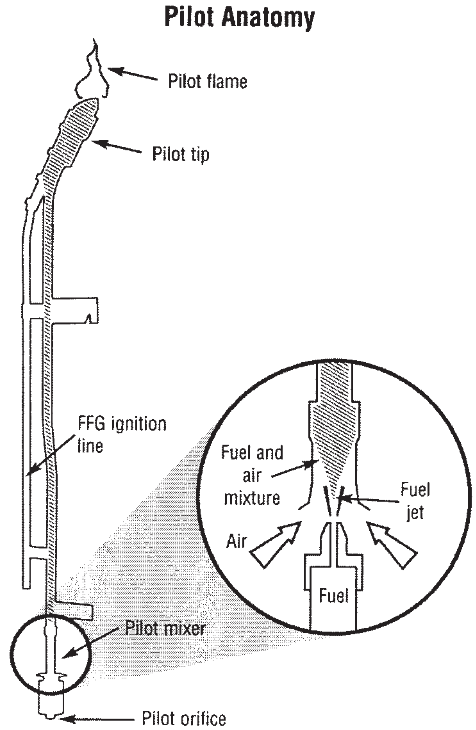

Figure 1. A typical pilot assembly.

combustible mixture to the tip. Surprisingly, the upwind pilot is the least affected by winds and is the most stable. The pilots in the cross wind and down wind positions are more unstable because of the low pressure zones created by the wind. It is important that the cross wind and down wind pilots remain lit, as they are in the best position to light the flare gas.

PILOT LIFE

Extending the service life of a pilot has become more important in recent years as facilities have increased the amount of time between major turnarounds. The average service life of a pilot is about 7 years, but it is not uncommon for a pilot to last 30 years depending upon the situation. The number one cause of pilot failure is flame envelopment from the main flare flame. Temperatures caused by direct flame impingement are far greater than the maximum continuous temperature that alloys can take in a reducing atmosphere.

PILOT MATERIAL

As stated in API STD 537 section 5.2.3[1], "The pilot tip should be constructed of a heat resistant material, such as 309SS, 310SS, CK 20, or a nickel-based alloy such as 800H." For applications with any amount of H2S in the fuel or flare gas, 800 alloys are not recommended.

It is possible that the piping between the pilot tip and mixer may be exposed to the flare flame. "For this portion of the pilot, an austenitic stainless steel, such as 304SS or 316SS, is adequate."[1]

PILOT FUELS

According to API STD 537 section 5.2.4[1], "In order to maximize pilot reliability, the most consistent and reliable fuel source should be used. Where possible, natural gas should be used." The pilot should be designed to handle a reasonable range of fuels. These fuels typically consist of natural gas, methane, ethane, propane, and refinery fuel gases. Fuels with moderate to high amounts of hydrogen, ethylene, and acetylene should be avoided, as these fuels have such a high flame speed that burning can occur in the mixer and not at the tip as intended.

PILOT IGNITION

There are two primary methods of pilot ignition in the refining and petrochemical industry. The oldest and most common method uses the Flame Front Generator (FFG), shown schematically in Figure 2. The FFG combines ignition fuel and compressed air at a mixing tee with the ignition air and gas mixture flowing through an ignition line to the pilot tip. After filling the ignition line with the air-fuel mixture, an electrical spark is initiated at the mixing tee. The resulting fire ball, or flame front, travels through the ignition line up to the pilot and ignites the pilot. Each pilot is ignited in sequence. FFG ignition can be quite reliable if maintained properly. Proper maintenance includes frequent draining of the ignition lines and routine practice attempts to create a fire ball by each operator responsible for the FFG system.

The second method of pilot ignition uses a high energy or high voltage spark at or near the pilot tip, as shown in Figure 3. This may be done with a spark probe or electrode in direct contact with the pilot gas or in a slip stream tube. The design must protect the probe from the high temperatures at the pilot tip. Electronic Spark Ignition (ESI) pilots are easy to use compared to the FFG system and require little training or maintenance. The downside to ESI is that shutdown of the flare system is required for maintenance.

Often confused with the ESI system, Direct Spark Ignition (DSI) uses a spark probe in place of a pilot. In order to reduce maintenance costs, DSI has been used in lieu of a continuous pilot to ignite the flare. This is not recommended as it is not in compliance with EPA regulations and cannot ensure that a destruction efficiency is occurring in the flame zone. As stated in section 5.2.2 of API STD 537[1], "Such designs are not considered to be a suitable alternative to a continuous pilot because, without an independent fuel supply, it is impossible to ensure that a flammable mixture will always exist at the location of the spark."

Other methods, such as flare guns, flaming arrows, oily rags, and magnesium or phosphate pellets, are generally unacceptable in the petrochemical and refining industry as they are potential safety hazards.

PILOT DETECTION

Flare performance is closely linked to reliability of the flare pilots and the verification that they are burning. Good operating practice and, in many locations, governmental regulation require that the presence of a flame at each pilot be verified on an ongoing basis.

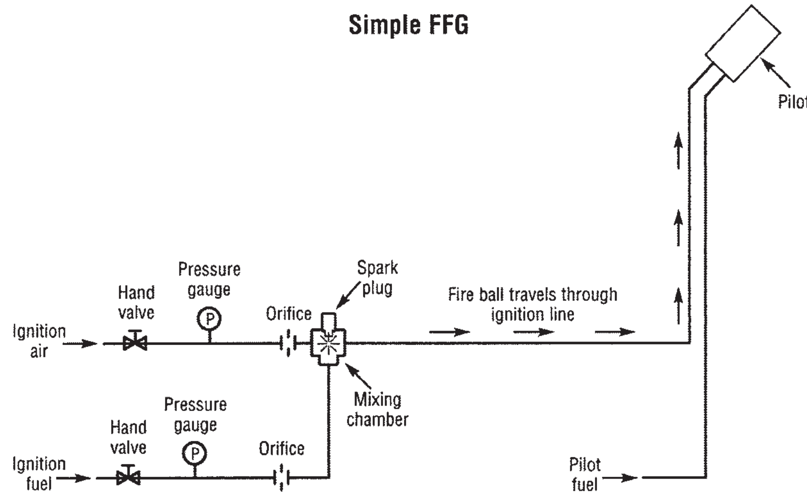

Figure 2. A simple flame front generator (FFG).

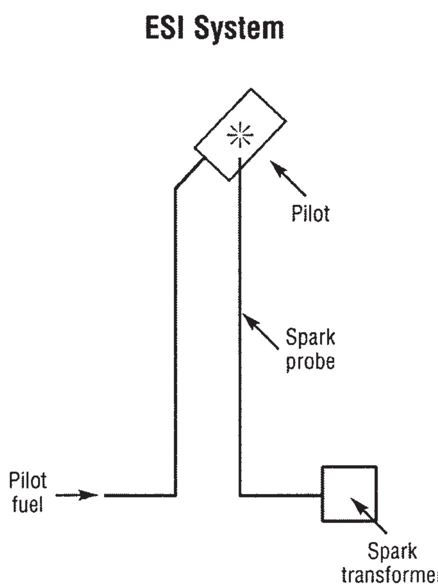

Figure 3. An Electronic Spark Ignition (ESI) pilot.

More than 50 years ago, visual sighting of the flame, although difficult in the daytime, was an accepted means of flame verification. Today, visual verification is no longer accepted for most flares. Federal Regulation 40 CFR 60.18[2] states, "The presence of a flame shall be monitored using a. . . device to monitor the presence of a flame." Fortunately, there are four different detection methods that can be used. Because of the nature of combustion, energy is emitted in three different forms: heat, light, and noise. The fourth method uses a unique phenomenon that occurs within the flame during combustion.

Thermocouples

The most common means of compliance with 40 CFR 60.18 is to detect the heat produced by the pilot flame by means of a thermocouple. In practice, the thermocouple junction is placed in a position in or near the pilot flame so that the thermocouple is heated when a flame is present. The thermocouple is connected to a temperature switch with an adjustable set point. The pilot is assumed to be "on" when the temperature is above the set point and "off" when it is below the set point. The primary drawback of the thermocouple is that the response time may take anywhere from 30 seconds to 10 minutes to alert the operators that there is a problem. It is possible to operate the flare for some time without knowing the pilots are out.

Because the pilot ignition system is a safety control system, it is important to adhere to a routine maintenance procedure. Maintenance performed on a thermocouple is minimal; there is little more to do than monitor its performance to ensure it has not failed.

Optical Systems

Optical systems use the light emitted by the fire to detect the presence of a flare flame. Much like a camera, these devices use a set of lenses aimed at the flare tip to direct infrared or ultraviolet light into a sensor. In principle, the presence of any flame in the viewing area is detected. Upon flame failure, the device sends a signal to the control room to alert the operators. The advantages of an optical device are that it may be maintained at grade, is easy to use, and has a fast response time. However, there are several disadvantages. Because the optical monitors are looking for the presence of any ultraviolet or infrared light, there is no way to detect if a pilot is out or not. The presence of any flame in the viewing area will satisfy the "pilot proved" requirements. It is quite possible that the main flare flame be lit and all pilots are out, creating a potentially dangerous situation. Another disadvantage of the optical system is that environmental conditions can hide the flare from the field of view. Snow, rain, and fog can, if dense enough, blind these sensors.

Acoustic Systems

The third way energy is released from a pilot flame is in the form of noise. An acoustic system operates by

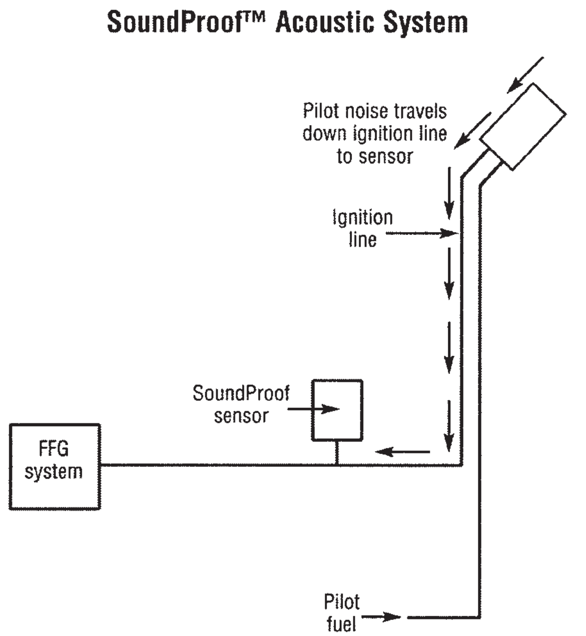

Figure 4. SoundProof® Acoustic System.

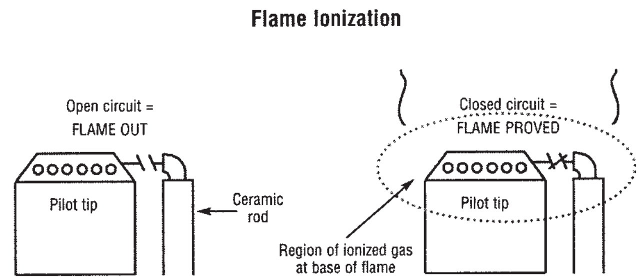

Figure 5. Flame ionization system.

using the sound generated by the energy release of the flame. The acoustic monitoring system is responsive to the difference between the sound signature of a pilot burning and that of a pilot with no flame. The acoustical selectivity of this system allows it to monitor a specific pilot and ignore extraneous sounds, such as those generated by other pilots, the flare flame, or steam used for smoke suppression.

John Zink's system, SoundProof®, takes advantage of the fact that most flare pilots are ignited by using an FFG. The FFG pilot ignition system includes a conduit connecting the FFG panel to the pilot, as shown in Figure 4. This conduit is used only during pilot ignition, and provides a convenient means of conducting the pilot flame sound to a location remote from the pilot, usually a point at or near the base of the flare stack. Based on the characteristics of the signal received, a signal processing unit indicates that the pilot is "on" or "off" using signal lights on the face of the unit. The "on" or "off" indication is also available through a set of dry contacts.

Maintenance of acoustic systems is capable of being done as required online; regular maintenance is minimal and includes checking the drains in the sound conveying piping. The primary advantage of the acoustic systems is that each monitor is dedicated to a specific pilot and has a fast response time. Current acoustic technology limits the pilot distance to approximately 350 feet from the pilot, which may be an issue for taller stacks.

Flame Ionization

The final method of flame detection takes advantage of a unique phenomenon that occurs during combustion. As the chemical reaction occurs in the pilot tip between the hydrocarbon gases and the air, a pool of ionized gas forms at the base of the combustion zone. This pool of ionized gas is conductive and can actually carry a small current. To accomplish this, a ceramic rod with a conductive core may be placed in the flame zone, as shown in Figure 5. A continuous current may be run through the flame rod into the ionized gas and into common ground. The monitoring system looks for a flow of current between the electrode and ground. If current flow is detected, a flame is present. If there is no current (open circuit), no flame is present. Flame ionization is a fast method of pilot detection and is also highly reliable. Unless the flare is taken out of service, no maintenance can be performed on a flame ionization system.

Retractable Systems

Critical components on the flare stack, such as pilots and thermocouples, may be installed with a retractable system. The advantage of a retractable system is that it allows the operators to maintain or change a component while the flare system is still in operation. Retractable thermocouples usually consist of a thermocouple being pushed through a tube that runs from grade to the pilot tip. Replacing the thermocouple is fairly simple. Retractable pilots are slightly more complicated and generally consist of a set of cables and possibly

Table 1. Comparison of flare pilot ignition systems.

Ignition System	Conventional Flame Front Generator (FFG)	Spark Probe Igniter
Compressed air	Required	Not required
Ignition line	1 in. diameter	Not required
Max distance	1 mile for FFG line	750 ft. for ignition transformer
Components at grade	Main	Some
Control	Automatic or manual	Automatic or manual
Response time	One to several minutes	1–10 sec.

Table 2. Comparison of flare pilot detection systems.

Method	Thermocouple	Flame Ionization	IR Sensor	Acoustic
Sensed phenomenon	Heat	Electrical current	Light	Sound
Able to distinguish between individual pilot flames?	Yes	Yes	No	Yes
Able to distinguish pilot flame from main flare flame?	Partially	Yes	No	Yes
Average response time (sec)	100–300	<5	<5	5–10
Location of key system components	Pilot tip	Pilot tip and grade	Grade	Grade
Installation while flare is operational?	No	No	Yes	Yes
Serviceable while flare is operational?	No	Partial	Yes	Yes
Resistant to:				
Rain	No	Yes	No	Yes
Fog	Yes	Yes	No	Yes
Snow	Yes	Yes	No	Yes
Steam	No	Yes	Yes	Yes
Sunlight (direct or reflected)	Yes	Yes	No	Yes

slides. The idea is that the pilot is simply lowered to the ground by a winch or crank when maintenance is required. Although retractable systems can be somewhat costly, they can be worth the extra expenditure if a shutdown or fines can be avoided.

CONCLUSION

In order to protect plant employees, preserve the environment, and avoid costly fines, it is critical to operate and maintain flare systems properly. The pilot and pilot verification system are directly related to flare performance, making them essential elements of safe, effective flaring. In this article we have examined several methods of pilot ignition and monitoring that are available, as well as their advantages and disadvantages. Using redundant ignition and monitoring systems can help prevent costly shutdowns and flare outages.

LITERATURE CITED

1. API Standard 537, Flare Details for General Refinery and Petrochemical Service, September 2003.
2. U.S. Code of Federal Regulations, 40 CFR § 60.18. (f) (2).