Desensitisation of optical based flame detection in harsh offshore environments

Safety Consultant James McNay BSc(Hons) MIFireE CFSP MIET reports on the difficulties designers face in the practical applications of optical flame detection

After Piper Alpha in 1988, the industry was given an abrupt awakening to the potential for disaster offshore. This in turn led to an increase in awareness of safety. Subsequently, a great deal of time, money and effort was invested in the development of appropriate technologies and safety systems to help mitigate potential hazards naturally present on site. One of those technologies developed was optical based flame detection.

Only, however, through years of application and trial and error have we learned what optical based flame detection does well, what the drawbacks of each technology are, and the effects that the harsh offshore environment has on each. Moreover, as it becomes clear that a certain technology has a substantial drawback, we see the industry drive towards the 'next big thing' in flame detection, so to speak.

It cannot be emphasised enough how important it is that each of these technologies is applied correctly, and that the limitations of each are documented in the design. It is all too clear the potential for disaster present within the industry if inappropriate fire detection and protection is applied.

In fact, as the industry in the 21st century moves towards the reduction of the potential for 'fail to danger' in safety systems (with an increase in the prevalence of IEC 61508 [1] and IEC 61511 [2]), it is of great concern that flame detection technologies applied today still allow for this potential and, even worse, that it may never be accounted for in design.

Practical Applications of Optical Flame Detection

So why use optical based flame detection in these environments? As one can imagine, the open based designs of most oil and gas structures can expose personnel to extremely harsh conditions even in the summer months. For this very reason, it is entirely unacceptable to rely upon standard smoke/heat detection within one of these highly hazardous areas to detect a fire, even if the detection target is a fire of significant radiant heat output (RHO). As the role of fire detection is to mitigate an incident before it becomes a Major Accident Hazard (MAH), designing to wait until enough heat is generated from a potential fire to set off a heat detector located on the ceiling of a ten metre high process module would be akin to waiting until a car has been completely destroyed in a road traffic accident before deploying an airbag. From this we can conclude that there needs to be a detection technology which can detect a flame before it gets to this level.

In theory this can be straightforward to design, however there are a number of underlying issues which can catch out the designer if he/she is not experienced in the field of fire and gas detection. One of these issues is that of the effectiveness of the detector; can we believe the detector manufacturer when they specify the capabilities of the detector?

It is important not to misinterpret this. The manufacturer of the detector is not misleading the client into the capabilities of the detector – the detectors have to be capable of detecting the fuels specified within their manuals at the specified distances if they are to achieve certification from an approved body (eg Factory Mutual). What the designer must be aware of is the effect the environment will have on these detection characteristics.

As previously discussed, the environment in which these optical flame detectors are to be applied is harsh, and variable, to say the least. There is no difference in the devices which are installed in the frozen wilderness of the Alaskan Prudhoe Bay, to the bleak Saharan desert of Algeria. Occasionally we have sites which experience both extremes, for example the Baku Tbilisi Ceyhan (BTC) pipeline pumping stations, which in some months of the year can resemble a desert environment and, in the winter, can resemble the landscape of the Arctic.

We also have constantly changing environments day to day in areas like the North Sea where it is not uncommon to have heavy fog in the morning followed only a couple of hours later by clear skies, calm seas and bright sunlight.

This is where the wavelength at which the detector operates and the method of detection play a significant role.

Differences in Optical Flame Detection Technology

Ultraviolet (UV) Detectors:

UV detection was one of the first technologies applied to detect the phenomenon of fire through optical means and typically operate at wavelengths shorter than 0.3μm.

UV detectors are prone to severe degradation by oil and smoke and are generally not used in external petrochemical applications. As well as this, UV flame detectors should not be used on sites where direct or reflected flare radiation is present as it is difficult for the detector to distinguish between a real fire, and the UV emitted by a 'friendly fire'. There is also the potential for false alarm with this technology in the presence of lightning, arc welding and radiation. All of these factors can therefore have an effect on the overall performance of the detector in the field.

Single Channel Infrared (IR) and Triple IR:

Single IR devices were designed to reject transient or periodic sources of infrared radiation while remaining responsive to genuine fires. This approach cannot, however, reject infrared radiation associated with flare reflections or turbine combustion exhausts, and can result in false alarms as these generate the products of combustion the IR detector is designed to detect.

Single IR also only allows for relatively short viewing distances even before desensitisation. Within its well-understood limitations, this is a reliable and robust technology; however, it does suffer from certain aspects of the external environment which cannot be avoided as a radiative based optical flame detector.

The next step in optical flame detection was to expand on the fairly robust IR technology. This led to using two or more reference bands in addition to the detection wavelength, resulting in the commonly used name 'Triple IR'. This technology attempted to cancel out spurious alarms (from Single IR devices) by detecting the flame at three wavelengths and, using the on board algorithms, distinguish between a blackbody/radiative source and an actual fire. This ultimately did reduce the number of false alarms, but the technology is still susceptible to spurious trips.

As a result of these algorithms, the sensitivity of this type of detector is also reduced, sometimes by a large amount, in the presence of blackbody radiation/any of the stimuli that would provide a false alarm to a single IR detector. This reduces the effective viewing distance of the detector, and even then does not show the severity of desensitisation in certain cases (where the viewing distance can be reduced to only a couple of metres).

One main environmental factor which desensitises both the single and Triple IR flame detection is water. Fog, mist or even water droplets on the lens can greatly affect the viewing distance of these detectors to a flame stimuli. At the operating wavelength of approx. 4.3 μm, water absorbs a great deal of IR meaning that the IR stimuli from the flame is not able to pass through the water, mist or fog to reach the detector, resulting in desensitisation and a possible 'fail to danger'.

Visual Flame Detection:

At the time of writing, the most recent flame detection technology to emerge on the market is visual based flame detection.

This technology was initially designed for application on Floating Production Storage and Offloading (FPSO) assets where flare radiation was a real problem for radiative based flame detectors, be it false alarm or desensitisation. This technology looks for the visual footprint of a flame to produce an alarm.

Certain models of visual technology can also provide a control room operator with real time images of each detector's field of view, therefore allowing a potential incident to be assessed and controlled from a safe distance, which in turn reduces the risk to personnel and reduces the risk of unwanted shutdown.

The main drawback with the visual technology is the fact it cannot detect clean burning fires. This type of fire is present when Methanol, Hydrogen, Sulphur etc are burnt.

Calculation of Flame Detection Desensitisation

In general there are three factors which must be accounted for in order to obtain the 'in-field' viewing distance of a detector.

The first of these factors to be considered is the reduction in sensitivity to genuine flame in the presence of unwanted/false alarm stimuli. Values for this can be taken from the manufacturer or detector manual if supplied. Unwanted stimuli can include sunlight (direct, modulated, unmodulated, reflected), welding activities, blackbody radiation (modulated/unmodulated), florescent/incandescent lamps, shielded and unshielded quartz halogen lamps etc.

The second factor to be accounted for is that of dirty optics. As the optical fault will not occur until potentially 50 per cent degradation in field of view, the detector could potentially only have 51 per cent of the stated capability in viewing distance without an optical fault. It is therefore critical that the design takes account of this potential reduction.

The final factor to be accounted for is that of the filter edge effect. This represents the reduction in sensitivity across the claimed field of view from the maximum at the centerline (as the fire is present further from the centerline of a detector, the sensitivity reduces). This value should be justified from an analysis of the flame detector's specific detection cone of vision as this will differ from detector to detector.

The following figures represent the fields of view of various detectors available on the market to the 1 ft sq n-Heptane fire. Please note that many different manufacturers and models of each of these technologies are available at the time of writing.

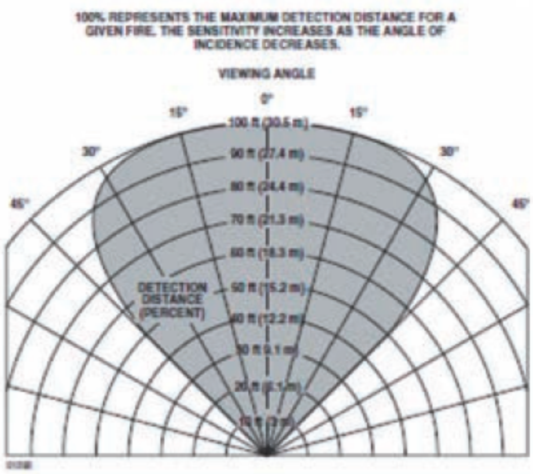

Figure 1: Detronics X9800
(Reference 3)

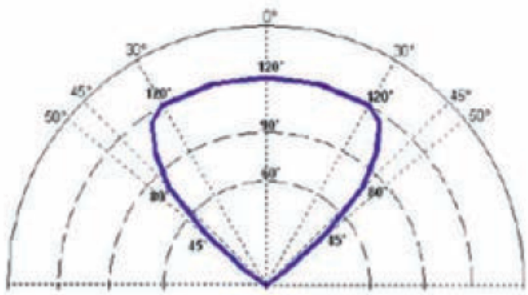

Figure 2: General Monitors FL4000H
(Reference 4)

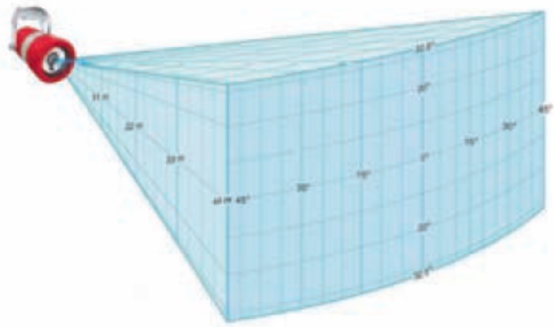

Figure 3: Micropack FDS301 (Reference 5)

It must also be noted that when we have this 'in-field' viewing distance, this is not the maximum viewing distance at which the detector will detect a fire. This is simply the effective viewing distance of the detector to the standard n-heptane fire. This data must then be accurately extrapolated to suit the target fire size for that particular piece of process equipment.

Conclusions

In a time where 'fail to danger' of any safety related system is simply unacceptable, the effects of the environment which will prevent a detector from operating as specified by the manufacturer is a clear fail to danger and must be accounted for.

The main conclusion to be drawn is that during any mapping study or review of a flame detection system, desensitisation should always be taken into account by professionals who are familiar with the drawbacks of optical flame detection, in order to reduce the potential for fail to danger of a safety critical event.

References

1. IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems, BSI British Standards, 2002
2. IEC 61511 Functional safety - Safety instrumented systems for the process industry sector, BSI British Standards, 2004
3. Detronics X9800 User Manual, Detector Electronics Corporation, 2013
4. General Monitors FL4000H User Manual
5. Micropack FDS301 User Manual

About the Author

James McNay is Lead Technical Safety Consultant at Micropack (Engineering) Ltd and specialises in the design of fire and gas detection systems in the process industry. A graduate of Glasgow Caledonian University, James' career began in commercial fire engineered design, however a move into the energy industry shortly followed. While overseeing a team of technical safety consultants at the Micropack Headquarters in Aberdeen, Scotland, he has had heavy involvement in the design of F&G detection systems in the Gulf of Mexico, Alaska, North Sea, Caspian Sea, Australia, Qatar, Malaysia, Thailand and Vietnam.
Email: jmcnay@micropack.co.uk