DET-TRONICS
United Technologies

TECHNICAL PAPER

HIGH-SPEED DETECTION AND RELEASING SYSTEM

Ultra-high-speed optical flame detection and releasing system solutions

By Michael J. Hosch, Senior Applications Engineer, Det-Tronics

This paper will discuss solutions for the application of ultra-high-speed optical flame detection and releasing systems within munitions manufacturing plants and other facilities requiring high-speed deluge fire suppression. It will also review optical flame detection technology and recent developments in a system that assists users in obtaining compliance with industry codes and standards.

1.0 Introduction

To meet overall system response time requirements of **ultra-high-speed** industry codes and standards, the flame detection and releasing system must be capable of detecting an event and providing a signal to the deluge system, which must respond in 100 milliseconds (ms) or less from the presentation of the energy source at the detector to flow of water from the water spray nozzle. To be considered **high-speed**, the system must operate in 500ms or less (reference National Fire Protection Association, NFPA 15). In applications that require these systems, a fire develops much too rapidly for the use of heat and smoke detectors, which may take many seconds to detect the fire.

To understand the techniques used in applying ultra-high-speed optical flame detection in munition processing plants, a brief review of the basic operating principles of flame detection technology is warranted.

2.0 A review of optical flame detection

Radiant energy-sensing flame detectors detect fire by sensing and analyzing the electromagnetic radiation that is emitted from fire. Different types of fires emit differing spectra of light energy that allow for their detection. The region of spectral emission to which a detector is sensitive is ideally tightly controlled to minimize the effects of the spectral emission from sunlight, ambient light, machinery and processing equipment. Figure 1 below gives a broad view of the electromagnetic spectrum and depicts the infrared (IR) and ultraviolet (UV) regions that are favorable for the detection of flame.

A brief description of each technology that is suitable for ultra-high-speed flame detection (UV, IR and UVIR) follows.

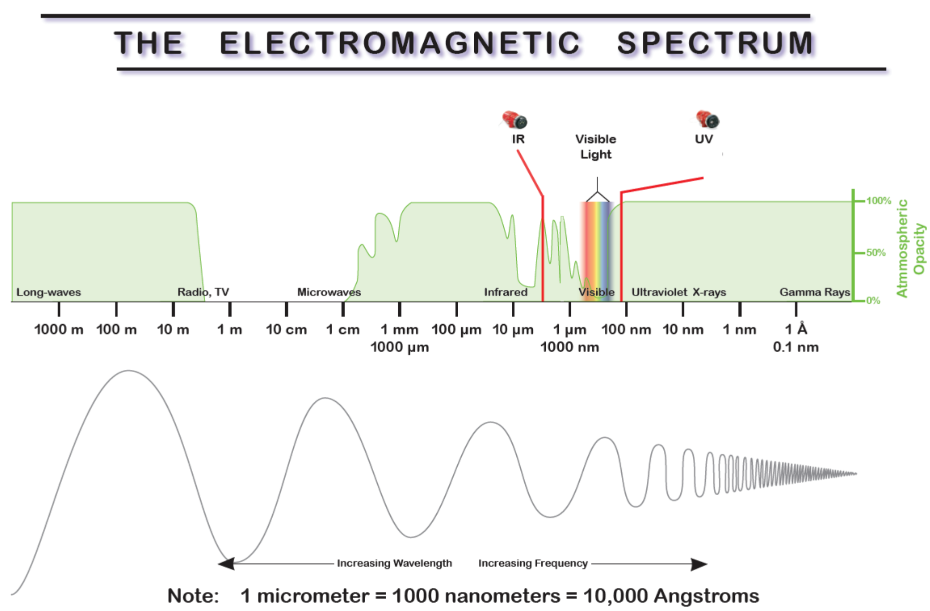


Figure 1: **Depiction of the electromagnetic spectrum and wavelengths of interest to ultra-high-speed optical flame detectors**

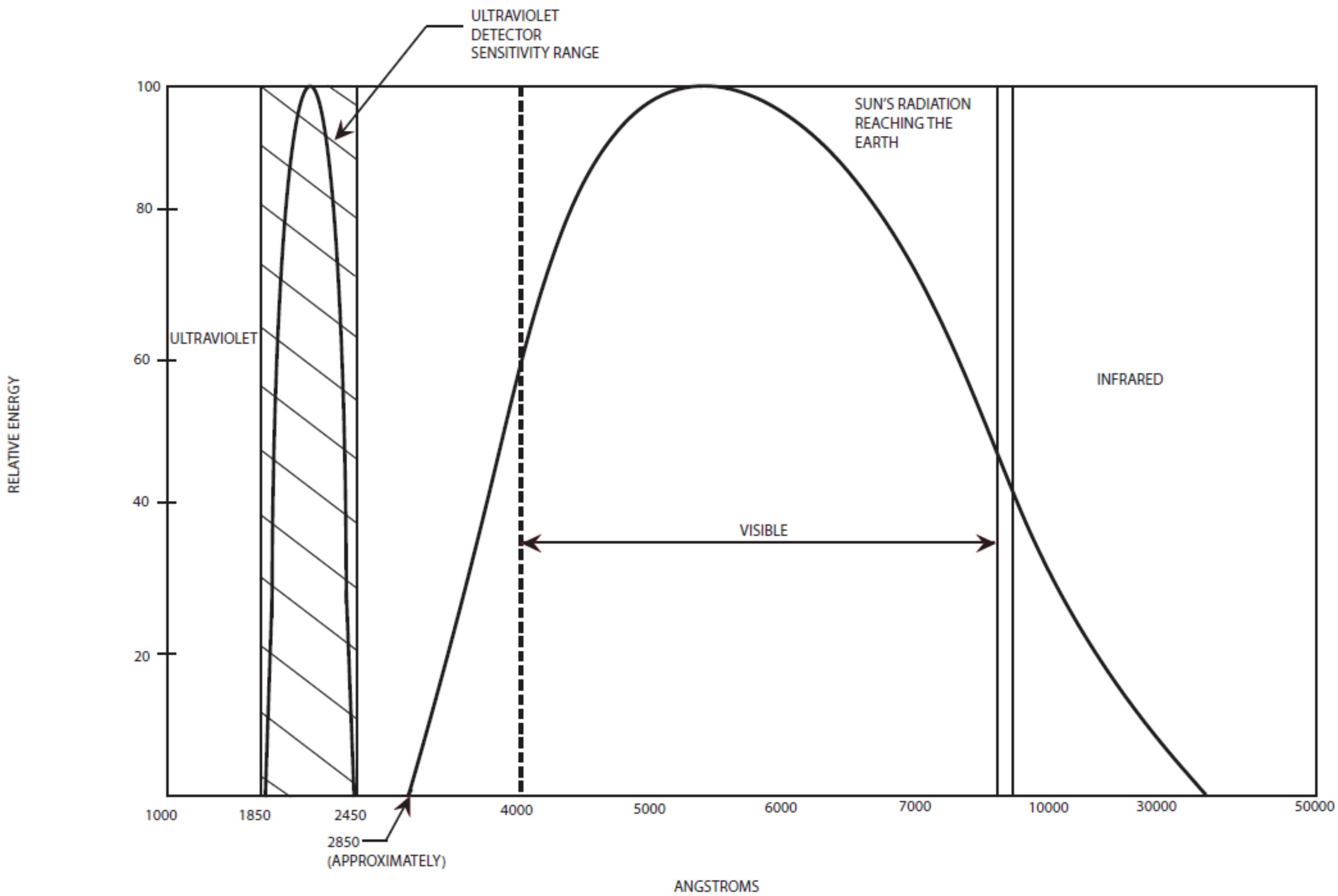


Figure 2: Relationship between ultraviolet sensors and solar radiation

2.1 Optical flame detection technologies

2.1.1 Ultraviolet (UV)

UV flame detectors utilize a sensor that is comprised of Geiger-Mueller type vacuum tube. This sensor is typically designed to be responsive to an extremely narrow band of light energy of 1850-2450 Angstroms (Å), with special models available that extend to 2650Å. As shown in Figure 2, the UV sensitivity range is outside of the range of human visibility and is not influenced by sunlight. As UV radiation emitted from the fire comes in contact with the sensor, voltage pulses are generated with their frequency proportional to the intensity of the UV radiation. These pulses are signal-processed by a microprocessor where they are compared against programmed parameters. If the amount of processed voltage pulses exceeds a predetermined threshold, an alarm is activated.

UV flame detectors (Figure 3) can detect nearly every type of fire and are capable of response times under 15ms in ideal conditions. Because UV sensors can be made solar-blind and are not affected by heat radiation, they can be successfully applied in many applications.

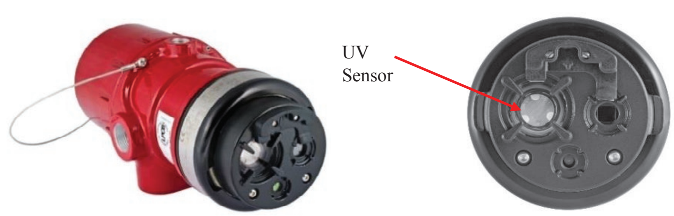
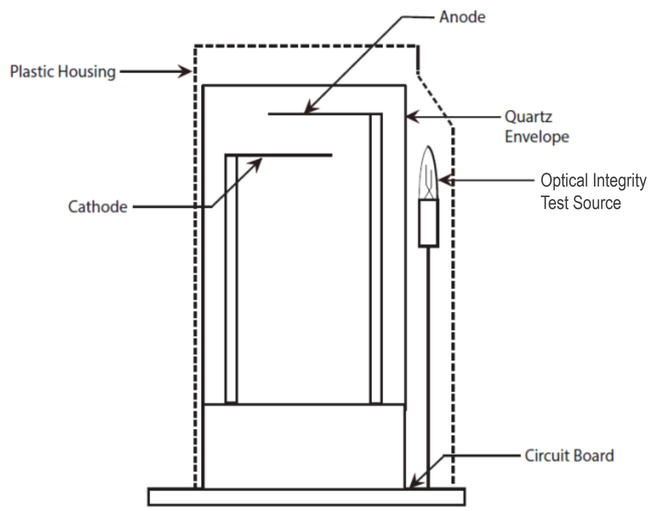


Figure 3: Det-Tronics X2200 UV technology optical flame detector

ULTRAVIOLET SENSOR OPERATING PRINCIPLES

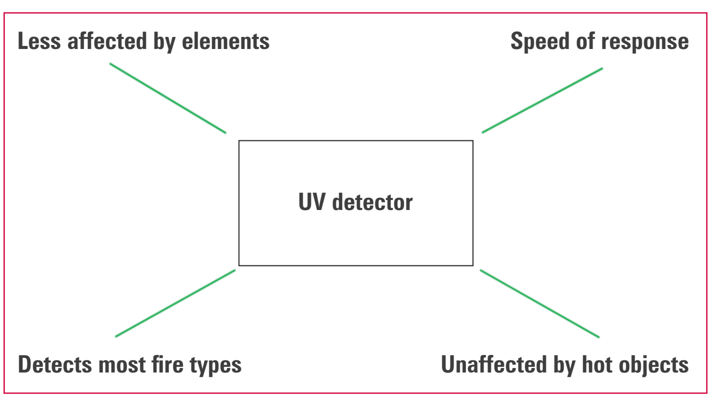
- Utilizes solar-blind wavelengths of 1850Å to 2650Å
- UV photons strike tube cathode
- Cathode releases electron
- Electron strikes gas molecule
- Cascade effect occurs to anode
- Discharge is quenched and a pulse is created
- Pulse output is measured in counts per second (CPS)
- Designed and manufactured by Det-Tronics since 1973



Det-Tronics UV Sensor

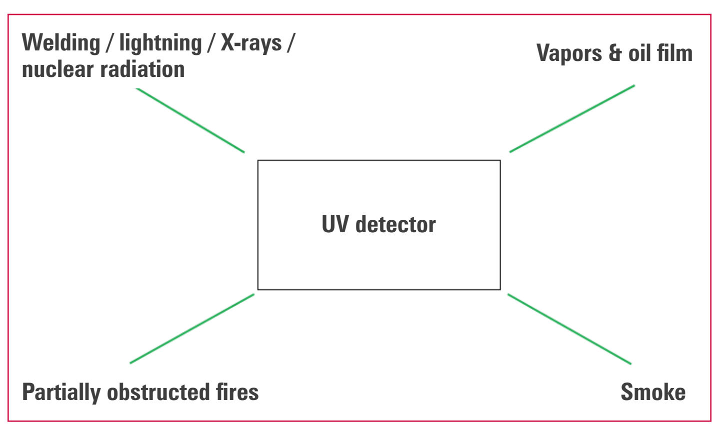
As with any detector technology, there are advantages and disadvantages. UV flame detectors are sensitive to lightning, welding and x-rays. Partial physical obstruction of the fire or the presence of smoke and/or UV-absorbing vapors may delay or possibly even prevent detection. See Figure 4 below.

Figure 4: Potential benefits and limitations of UV flame detection technology



Potential benefits of a UV detector

Potential limitations of a UV detector



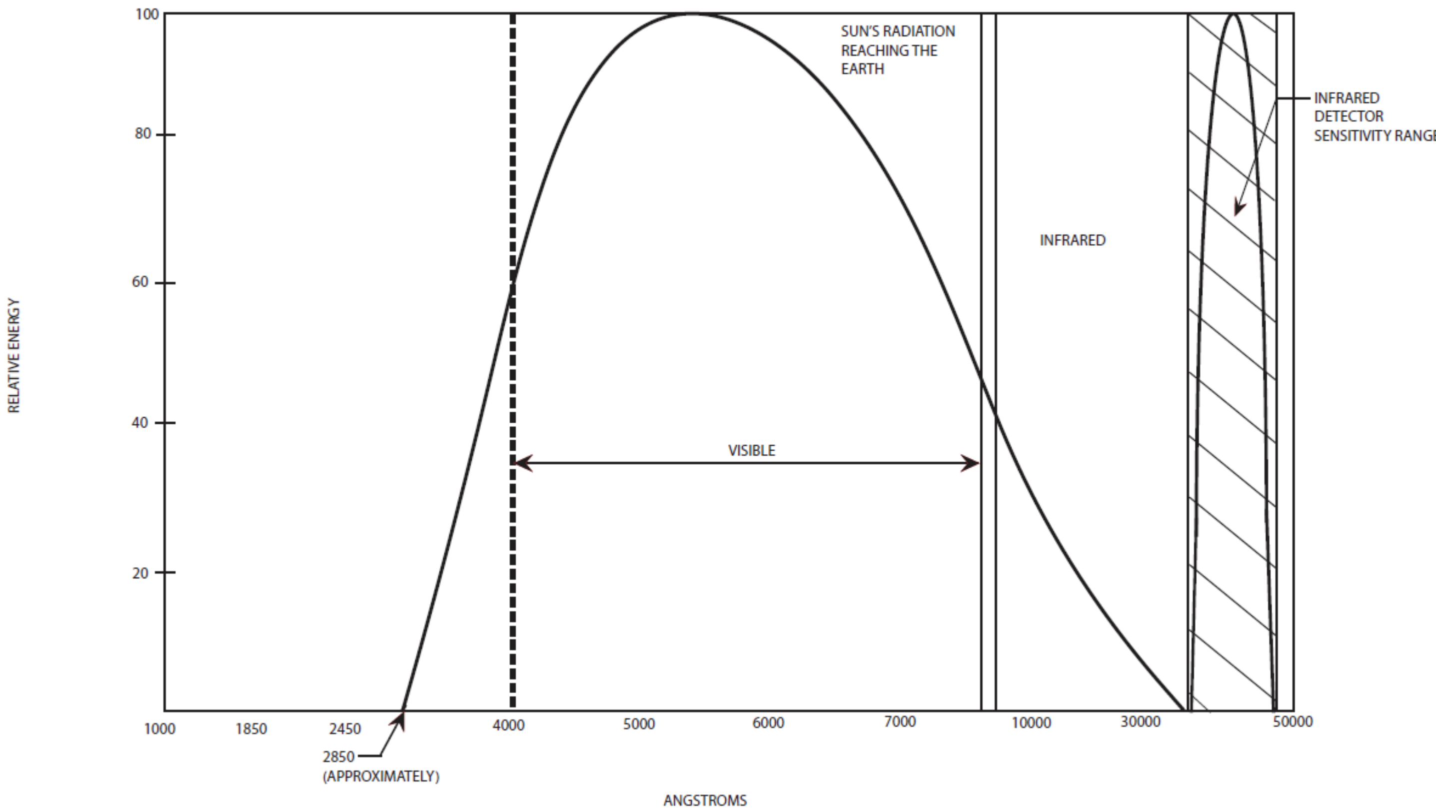


Figure 5: Relationship between infrared sensors and solar radiation

2.1.2 Infrared (IR)

IR flame detectors utilize a sensor that is typically comprised of a pyroelectric detector. An optical interference filter is utilized within the pyroelectric detector to establish a bandpass region that is favorable for the exclusive detection of fire. These filters are selected depending upon the desired wavelength of interest, typically 4.2 – 4.8 micrometers (μm) within the CO_2 emission band. As shown in Figure 5, the IR sensitivity range is outside of the range of human visibility and not influenced by sunlight.

IR flame detectors (Figure 6) can detect fires that are preceded by smoke or contain vapors more readily than detectors that utilize UV technology. Response times can be less than 15ms in ideal conditions. Because IR sensors can be made solar-resistant and are not affected by UV radiation, they can be successfully applied in many applications that challenge UV detectors.

If the emitted electromagnetic energy includes wavelengths that will pass through the bandpass interference filter, the light will encounter a single-crystalline element. The element generates a small signal that is proportional in magnitude and frequency to the electromagnetic radiation that is being emitted from the fire. This signal is further signal-processed by a microprocessor where the resulting signal is compared against predetermined thresholds, and if the signal qualifies, a fire alarm is activated.

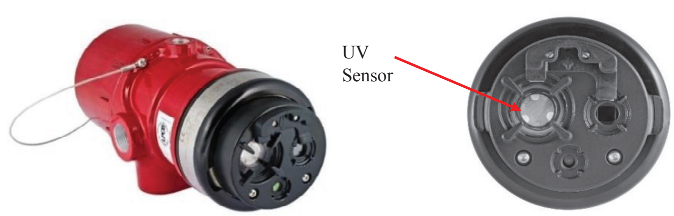
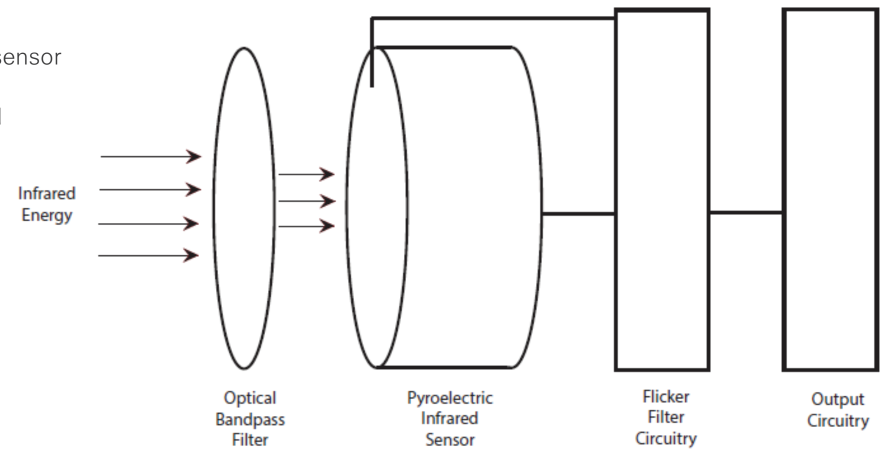


Figure 6: Det-Tronics X9800 IR technology optical flame detector

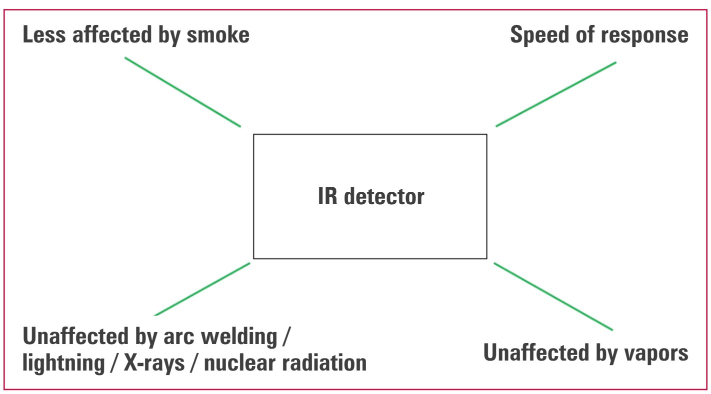
INFRARED SENSOR OPERATING PRINCIPLES

- Optical bandpass filter is mounted to sensor
- Optical bandpass filter determines and controls wavelength sensitivity
- Det-Tronics IR sensors used for ultra-high-speed have 4.45μm center wavelength
- IR sources in a steady state ignored



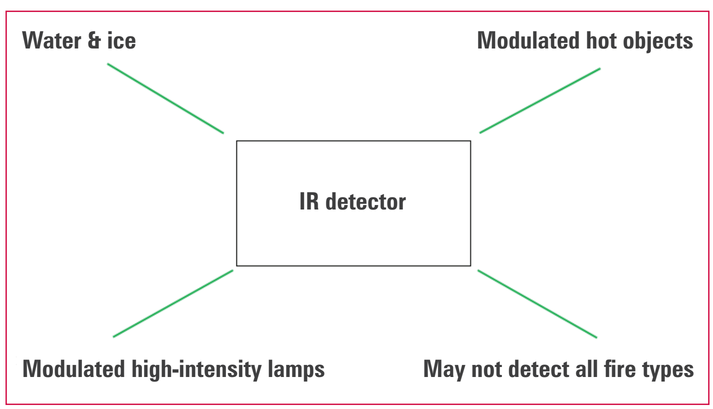
As with any detector technology there are advantages and disadvantages. IR flame detectors may be sensitive to modulated hot objects and light sources. The presence of water, snow or ice on the detectors optics may also delay or prevent it from detecting a fire. See Figure 7.

Figure 7: **Potential benefits and limitations of IR flame detection technology**



Potential benefits of an IR detector

Potential limitations of an IR detector



2.1.3 Ultraviolet infrared (UVIR)

UVIR flame detectors combine UV and IR technologies in a single flame detector (Figure 8). For a fire alarm to be activated, both the UV and IR detectors must sense the electromagnetic radiation being emitted, and both signals must be signal-processed and compared against predetermined thresholds. Figure 9 identifies the regions of electromagnetic sensitivity for a UVIR detector. UVIR technology can provide adequate fire detection performance while being more resistant to false activation than UV or IR technology alone. All of the potential benefits and limitations of UV and IR technology applies to a UVIR flame detector. UVIR technology has gained a wide acceptance because of these attributes.

In addition to a fire alarm relay that operates when both the UV and IR sensors detect fire, Det-Tronics UVIR flame detectors have an onboard programmable auxiliary relay. The auxiliary relay can be configured to change states upon a UV-only alarm, an IR-only alarm or a UVIR pre-alarm condition, adding further flexibility to the flame detector for areas where the spectral emission characteristics of the material of interest may be in flux.

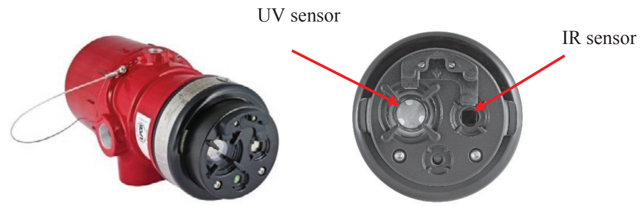
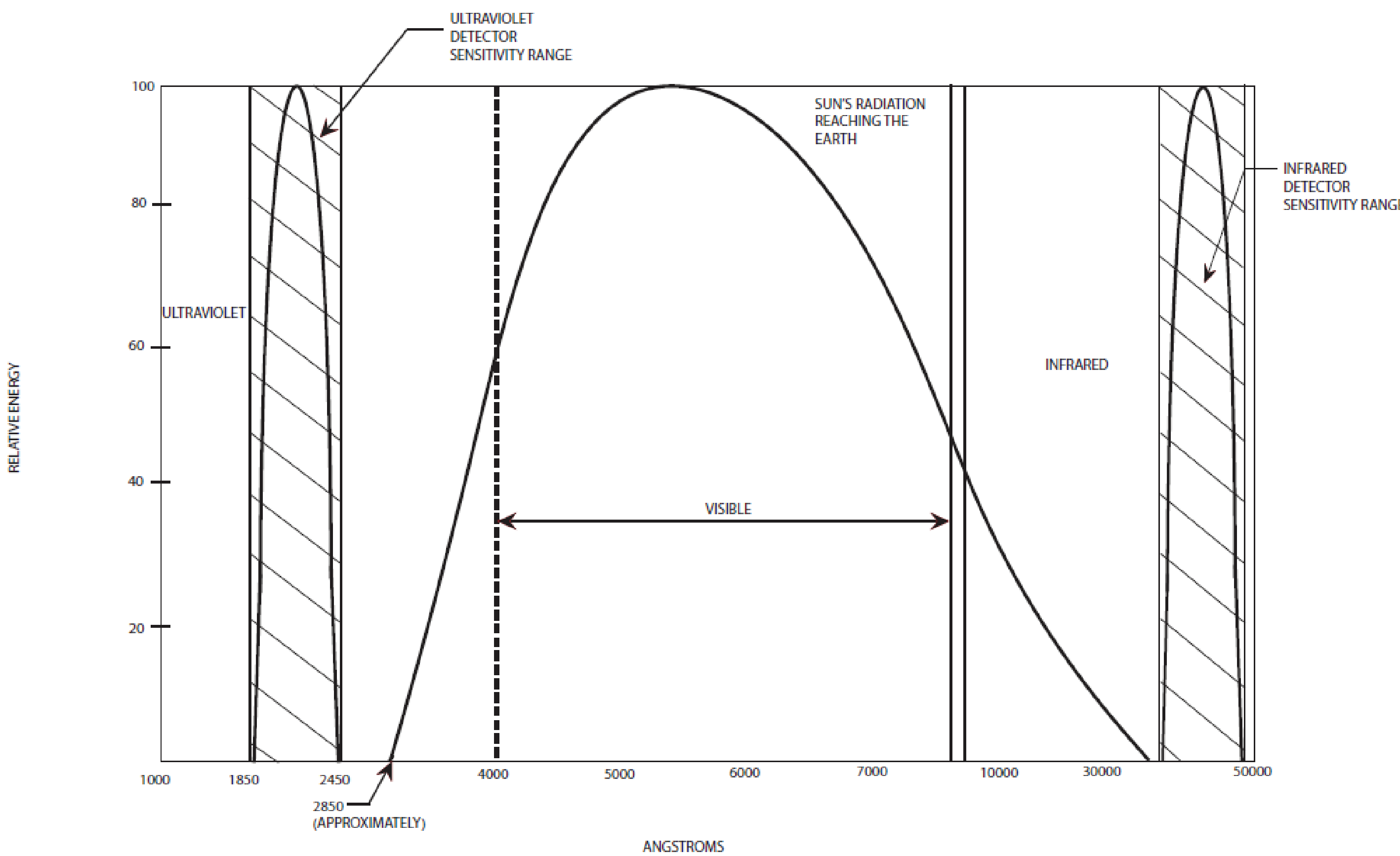


Figure 8: **Det-Tronics X5200 ultraviolet infrared (UVIR) technology optical flame detector**

Figure 9: **Relationship between ultraviolet and infrared sensors and solar radiation**



2.2 Maintaining detection performance

The potential exists within most applications for the detector's optics to become blocked by foreign materials. Contamination of the detector's optics may delay or even prevent the spectral emission of the fire from reaching the sensor(s) contained within the flame detector. Therefore, it is extremely important that the detector be capable of self-checking all of its optical surfaces, sensors and internal circuitry. The detector should be capable of automatically notifying the operator if its performance has been affected. If this fault condition occurs, a given process can be shut down or other action taken as required.

All Det-Tronics optical flame detectors include an *Automatic Optical Integrity* (oi®) feature that provides a calibrated performance test once per minute to verify complete detector operational capabilities (Figure 10). Microprocessor-controlled calibrated internal IR and UV sources for every sensor within the detector are used to provide the test signals for the optical integrity test. If the detector encounters optical contamination or has developed any type of internal performance issue, the detector will signal an optical integrity fault condition when less than half of the original detection range remains. Typically, an optical integrity fault is caused by a dirty lens and the detector only requires cleaning to restore it to its full performance.

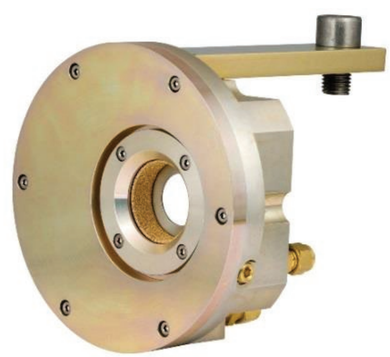
Figure 10: Dramatization of the X5200 UVIR optical integrity signal

Some plant areas are prone to airborne dust and contaminants that may cause deposits to accumulate on the detector's optics. For these areas, Det-Tronics offers air shields that provide a constant flow of clean air across the outside surface of the detector's optics, thereby reducing the buildup of contaminants and helping to extend necessary maintenance intervals. These air shields do not interfere with the detector mounting, cone of vision or the optical integrity testing of the detector.

AIR SHIELDS FOR OPTICAL FLAME DETECTORS

Q1118 air shield flange mount for X-series

Q1116 air shield for X-series



Q1198 air shield for X9800 IR

2.3 Event logging

When an event or fault condition occurs, it is imperative that detailed information be quickly assembled. The releasing service fire alarm control unit will ideally have the capability to provide high-level information that indicates which inputs were activated or what type of fault is occurring. In addition, it is useful to obtain more detailed information when investigating events. Each Det-Tronics flame detector contains a built-in event log feature that automatically records a time and date stamp for each event or fault that occurs. Events such as power up, power down, fault conditions, pre-alarm and fire alarm conditions are recorded along with the temperature and input voltage that were present when the event occurred.

2.4 Selection of technology

When selecting technology for the purpose of protecting people, processes, plant assets and buildings, the utmost care should be taken to design the system so it will function correctly under anticipated situations. The type of flame detection technology selected to monitor a given area should be based upon a performance-based design evaluation. A thorough understanding of the intended performance objectives for each detector within the system must be gained.

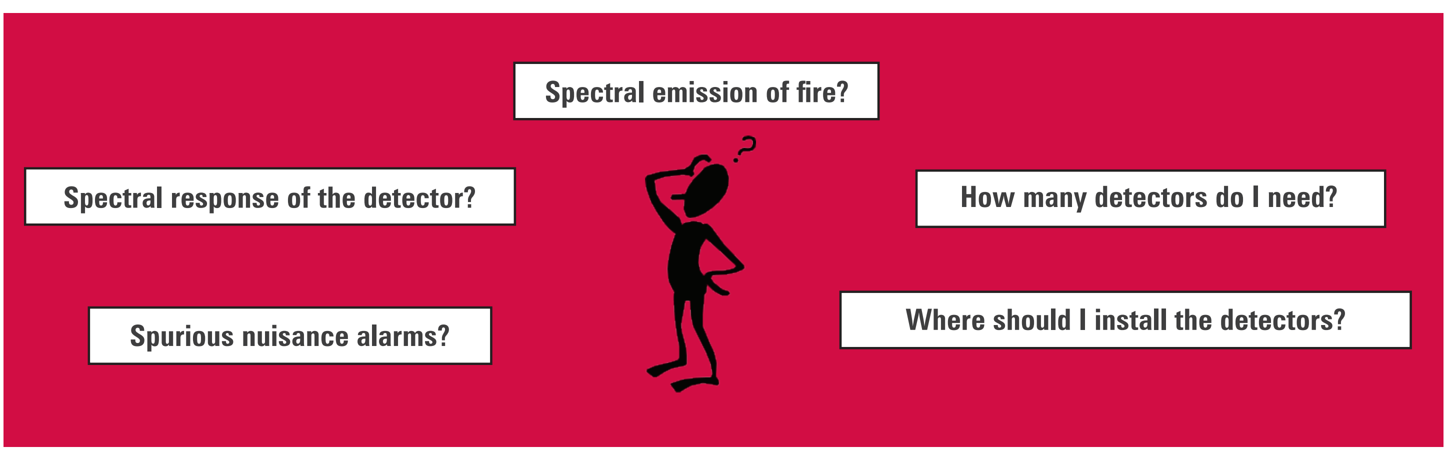
Some items that can be considered when conducting a performance-based design evaluation include:

- Fire composition
- Fire characteristics (growth rate, burning characteristics, spectral emission)
- Minimum fire size that requires detection
- UV attenuating vapors or IR attenuating dusts
- Non-fire sources

Optical flame detectors may provide different performance results depending upon make and model. The only verifiable method for measuring a flame detector's sensitivity to a given material of interest is to expose it to an actual controlled event. However, it is difficult to consistently produce repeatable test fires that result in an absolutely identical fire. Therefore, repeated exposures to a given material of interest are typically required to obtain valid test data.

In addition, a balance must be achieved between desired detector sensitivity to the material of interest and its sensitivity to non-fire radiant energy sources. A detector that is too sensitive to its surroundings and causes nuisance alarms is certainly undesirable. The detector must therefore be subjected to common sources within the area that is to be monitored so an effective evaluation of the overall flame detector performance can be determined.

These aspects may present numerous challenges to the engineer responsible for conducting the performance-based evaluation. Effective planning and control by the test engineer will maximize the accuracy of each performance-based measurement.



2.5 Considerations for a performance-based design evaluation of optical flame detection

2.5.1 Test site

- Identify a test site that offers safe access, observation and exit capability for all involved. The ability to control access to the test site is desirable.
- Indoor fire tests may be susceptible to the accumulation of attenuating airborne materials such as smoke, dust and solvent vapors, all of which may negatively affect fire detection performance. In order to obtain consistent test results and flame detection performance, an exchange of clean air should be provided before and between all indoor tests.
- Ensure that a suitable method of extinguishing the test fire is readily accessible at the test site or if the material is not easily extinguished, that precautions have been taken to control the burn.
- Ensure all burned materials have been fully extinguished and dispose of all burned residual materials properly.
- It is best to attempt to mimic the conditions that will be encountered within the actual application where the detectors will be installed. Take potential obstructions to the flame detectors view of the area into account.
- Control, if possible, ambient temperature, humidity, wind direction and velocity.

2.5.2 Test process

- Prior to the start of testing, record ambient temperature, humidity, wind direction and velocity.
- Depending upon environmental conditions, fire tests that are performed outdoors may be susceptible to variations in fire emission characteristics. Videotaping outdoor fire tests may be valuable in determining the potential effects of changes in wind direction and velocity.
- Identify the fuel type(s) and desired fire sizes, distances and time requirements to which the flame detector(s) should respond within the actual application. Use this data to establish the performance benchmarks that are desired for the application and the evaluation procedure.
- Conduct a minimum of at least three (3) repetitive tests of each fuel type at each distance to obtain valid data.
- The method that is used to ignite the material should not cause the flame detectors to respond. If the detectors respond to the ignition source, this may affect the accuracy of the time measurement.
- Fire ignition sources such as electric matches are not recommended due to the possible introduction of flammable material into the material of interest that would not normally be present. This material may produce a different spectral emission than the emission from the material of interest.
- Determine an accepted means of determining the detector's speed of response. Typical examples include the use of a digital timer or a high-speed video recording system.
- Record all detector technologies/types, serial numbers and locations (distance and angle) relative to the fire as well as all detector fire threshold settings and/or time delay settings.
- Ensure all detectors are aligned properly and the lenses are clean.

2.5.3 Test fuels

- Fire tests of flammable solids, munitions and propellants require special considerations due to wide variations in flammability and fire propagation rates. The fire size generated by these materials is established by defining weight of the unburned material, volume and arrangement prior to ignition. Flammable powders and propellants will burn at different propagation rates depending upon the arrangement of the material (example: 30 grams of black powder in a concentrated pile will burn differently than 30 grams spread out over a 5 cm square surface). Standardize the method of arranging the flammable powders or propellants and repeat for each test burn. If the area being monitored will process multiple pyrotechnic materials, the system should be designed to enable detection of the worst-case, slowest burning material.
- Each test should be performed using new material, never burning fuels more than once, as it is likely the material will exhibit different characteristics if it is reignited.

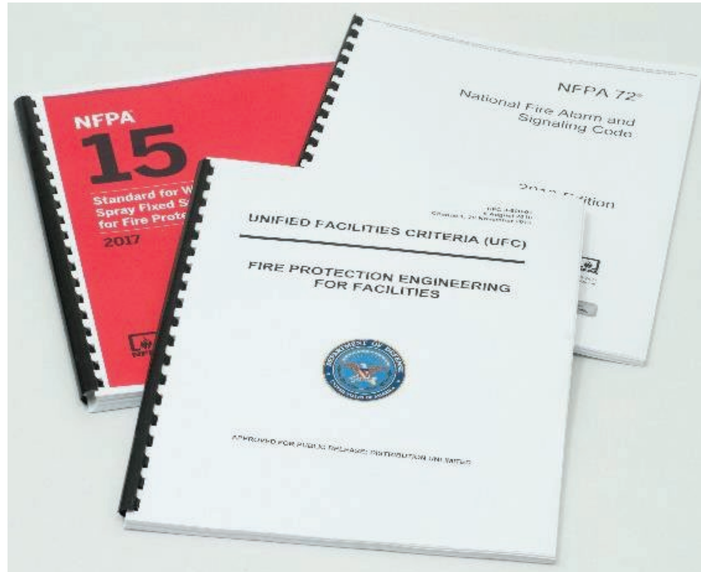
2.6 Nuisance alarm source testing recommendations

Typical flame detector nuisance alarm sources are listed below. There should be no flame detector fire alarm response caused by exposure to these sources:

- Direct sunlight
- Incandescent 300 watt light bulb at five foot distance
- Fluorescent 34 watt light bulbs at one foot distance
- Halogen 500 watt lamp (with plastic or glass lens in place) at five foot distance
- Electric quartz infrared heater (1500 watt) at ten foot distance
- A hand-held two-way radio (5 watt) keyed during transmit mode at three foot distance
- Modulating the nuisance source energy at a rate of approximately 2 to 10 Hz (via an unheated chopper, not your hand) should also result in no flame detector fire alarm response.
- Any other known nuisance alarm sources should be presented to the detectors as they will exist at the actual application so that an understanding may be gained as to their possible affect.
- The ability to detect flames while in the presence of the common radiant energy sources listed above. These sources are typical to those found in many plants and manufacturing areas.

There may be needs that are unmet or undiscovered. A thorough investigation that involves open discussion may reveal unconventional approaches and lead to detection solutions.

Det-Tronics may be able to assist in your performance-based flame detector evaluation.



3.0 Meeting codes and standards

Codes and standards, such as those written by the National Fire Protection Association (NFPA) and the U.S. government, provide knowledge and information to minimize the risk and effects of fire. Codes such as NFPA 101® Life Safety Code®, NFPA 72® National Fire Alarm and Signaling Code®, NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection, and Unified Facilities Criteria (UFC) UFC 3-600-01 are such examples.

Typically, there is an interlinking of these codes that ensures compatibility and consistency with one another. For example, UFC3-600-01 references both NFPA 72 and NFPA 15. It is important to gain a thorough understanding of each code and how it applies to the application.

It is also important that any system whose intended purpose is to detect and suppress fire, fully comply with all applicable codes and standards. It is therefore important to select flame detectors and control systems that are third-party agency listed. The selection of the proper products will ultimately assist the user in obtaining compliance.

3.1 Listed solutions for the control unit and releasing system

In order to meet current codes and standards, the outputs from ultra-high-speed flame detectors must be connected to a releasing service fire alarm control unit specifically listed for releasing service, and the detectors must also be listed for use with the same control unit. This control unit performs important functions such as supervising the input and outputs to help ensure the system will operate as intended when required to do so.

To this end, Det-Tronics has designed a new high-speed deluge module. The twelve (12) channel high-speed deluge module (HSDM) is specifically designed to expand the capability of the Det-Tronics Eagle Quantum Premier® (EQP) safety system. It provides the capability to activate ultra-high-speed suppression systems for hazardous applications such as munitions manufacturing.

The HSDM is designed to have an independent response time of 2ms and when used in combination with a Det-Tronics UV, UV/IR or IR flame detector, the combined system can provide a response to an event in less than 15ms under ideal conditions.

The HSDM ensures system operation through continuous supervision of all inputs and outputs and utilizes a local operating network/signaling line circuit (LON/SLC) providing Class X monitoring for the connection between the HSDM and the EQP safety system controller.

The HSDM module provides six configurable input channels and six configurable output channels that can be programmed for supervised or unsupervised operation. Each input channel accepts contact closures from fire detection devices such as optical flame detectors, heat detectors, smoke detectors and manual pull stations. Output channels are designed to activate third-party approved solenoids used to initiate pilot-actuated deluge valves.

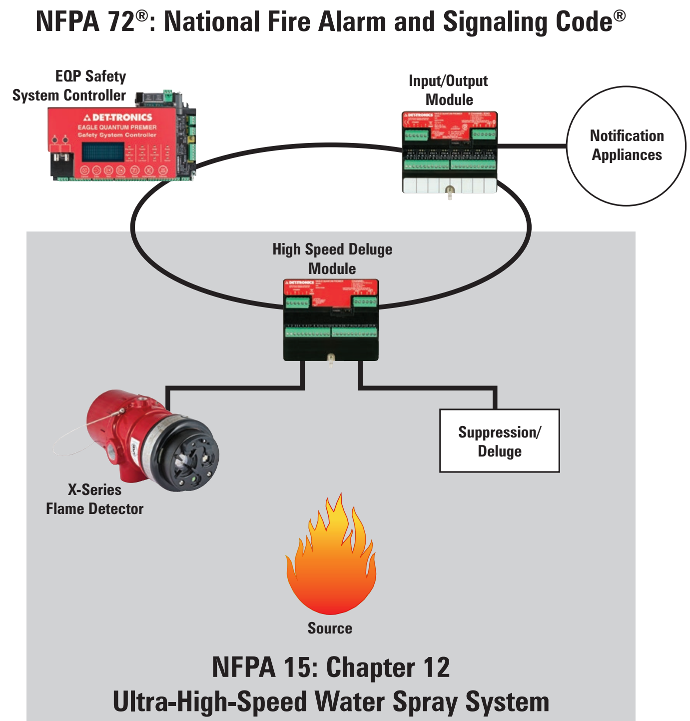
Det-Tronics has designed the entire system, including optical flame detectors, high-speed deluge module and safety system controller, to enable customers to design a system that complies with UFC and NFPA requirements (Figure 11).

The fire alarm relay output from the UV, IR or UVIR optical flame detector is connected to the HSDM. The flame detector combined with the HSDM is capable of providing an ultra-high-speed of response, which may be less than 20ms in ideal conditions.

The HSDM sends a priority signal onto the LON cabling, which is received by the EQP safety system controller. This communication is not high speed. The EQP uses pre-programmed logic to determine the next actions, which typically include sending a signal to an enhanced discrete input output module, which, in turn, is utilized to activate notification appliances. Additional communication to guards, the police and fire departments or other needed areas is also possible.

A properly designed and listed flame detection and releasing system can help users meet UFC and NFPA code requirements for an ultra-high-speed water spray system.

Figure 11: Visual depiction of an ultra-high-speed capable Det-Tronics system



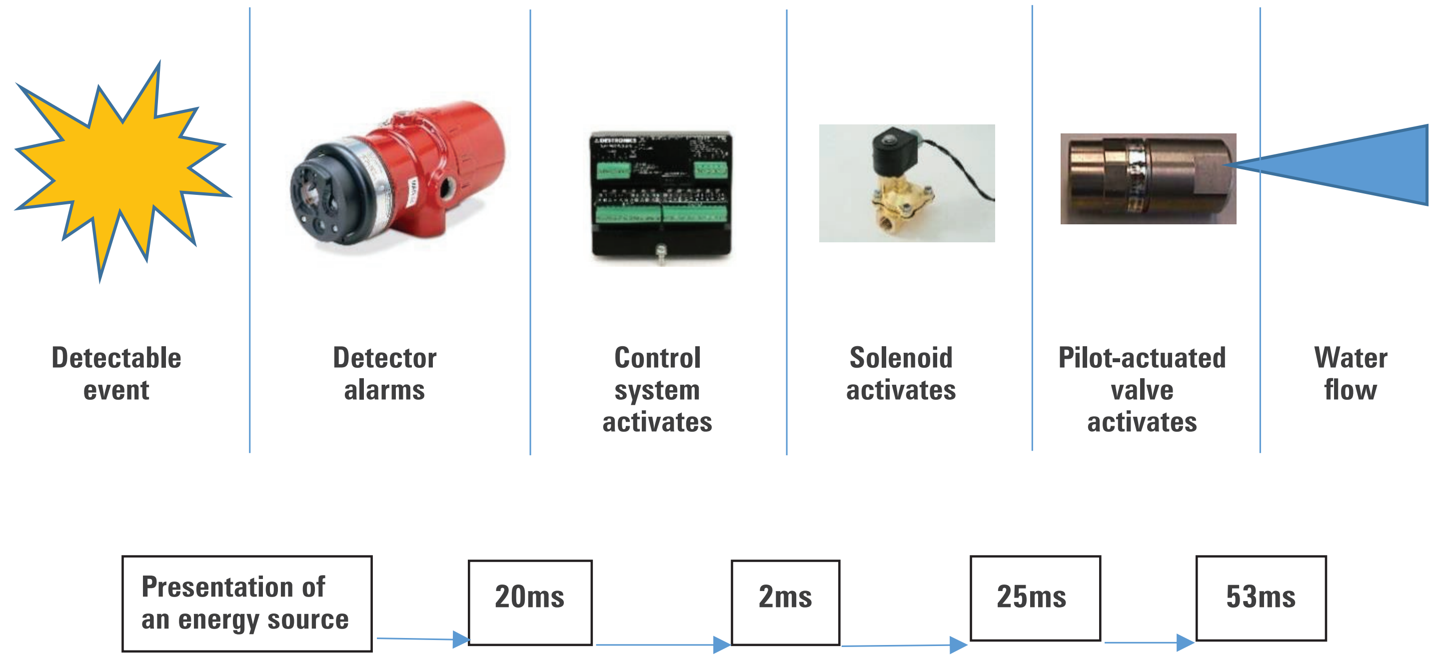


Figure 12: **Response time for an entire ultra-high-speed detection and suppression system from presentation of an energy source at the detector to flow of water from the water spray nozzle cannot exceed 100 milliseconds (ms).**

3.2 Meeting response time requirement of <100 milliseconds (ms)

While discussion of the speed of response for flame detectors is important, it must be recognized that an even more important measurement is the speed of response of the entire system, which includes the flame detector, releasing service fire alarm control unit, solenoid valves and a deluge component. An ultra-high-speed flame detector is capable of detecting a rapidly developing fire in approximately 20ms under ideal circumstances. The releasing service fire alarm control unit may also respond in a matter of milliseconds. The solenoid takes time to relieve the pilot pressure from the deluge valve and, finally, the water requires time to travel through the piping to the nozzle and from the nozzle through the air to the fire. Therefore, it is important to realize that the speed of response of the detector and control unit is a small subset of the total response time of the system.

Careful attention must be paid to ensuring that the detectors are installed as closely as possible to the potential hazard and that nothing comes between the detector and area being monitored that could block the detector's line of sight. All air bubbles must be purged from within the piping of the hydraulic system. In addition, the fastest possible solenoids should be utilized, and the deluge nozzles should be installed as closely as possible to the potential hazard. Close adherence to these aspects will greatly improve the speed of the *entire* system. See Figure 12.

4.0 Det-Tronics solutions for ultra-high-speed optical flame detection

Modern optical flame detectors are designed to help users obtain compliance with UFC and NFPA codes and standards. Det-Tronics offers the X2200 UV, X9800 IR and X5200 UVIR flame detectors, which, when configured and installed properly, are capable of high-speed and ultra-high-speed response times.

Beyond the stringent thermal testing, bench tests and simulations performed within our factory, all Det-Tronics flame detectors are tested using real fire at our Engineering Test Center before shipment to our customers.

Det-Tronics Engineering Test Center

5.0 About Det-Tronics

Det-Tronics is a global leader in flame/gas detection and hazard mitigation systems for high-risk processes and critical industrial operations. Det-Tronics designs, manufactures and commissions certified SIL 2-capable flame and gas detection solutions and is a part of Carrier, a leading global provider of innovative heating, ventilating and air conditioning (HVAC), refrigeration, fire, security and building automation technologies.

Det-Tronics ultra-high-speed optical flame detection systems have been the standard within plant safety systems for over 40 years.

6.0 References

1. National Fire Protection Association, NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection
2. National Fire Protection Association, NFPA 101®: Life Safety Code
3. National Fire Protection Association, NFPA 72® National Fire Alarm and Signaling Code®
4. United States of America, Department of Defense, *Unified Facilities Criteria* (UFC) 3-600-01 Fire Protection Engineering for Facilities
5. FM Approvals Standard 3260 — *Approval Standard for Radiant Energy-Sensing Fire Detectors for Automatic Fire Alarm Signaling*

Note: This paper was delivered at the National Defense Industrial Association (NDIA) International Explosives Safety Symposium and Exhibition — San Diego, California, USA, August 8th, 2018

31-1015

DET-TRONICS
United Technologies

Corporate Office
6901 West 110th Street
Minneapolis, MN 55438 USA
det-tronics.com

Phone: 952.946.6491
Toll-free: 800.765.3473
Fax: 952.829.8750
det-tronics@det-tronics.com