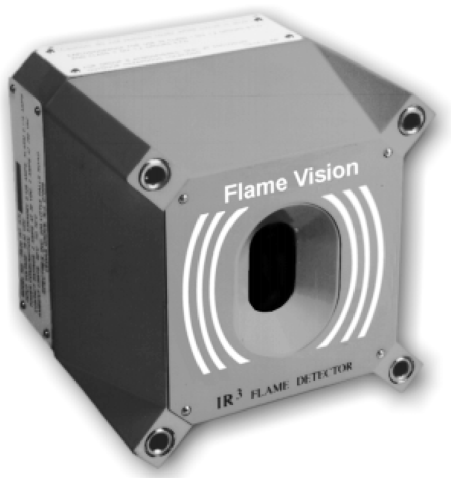
A Guide to Selecting the Right Flame Detector For Your Application



INNOVATION IN FLAME DETECTION

Industries involved in manufacturing, processing, storing or transportation of flammable material are constantly in need of reliable and fast response fire detection systems. It is evident that the smaller the fire, when detected, the easier it is to extinguish. In this respect, fire detection systems, especially optical flame detectors, are the most powerful apparatus in fire fighting due to their ability of remote detection of a small size fire from a long distance.

It may seem simple and straight forward to design a sensitive optical flame detector by utilizing Ultraviolet (UV), Infrared (IR) or a combination of UV/IR sensors. However, these detectors often operate in industrial environments, which contain many radiation sources that could impair detector performance and even cause false alarms. Moreover, many applications require flame detectors to withstand harsh environmental conditions and still maintain their entire envelope of performance.

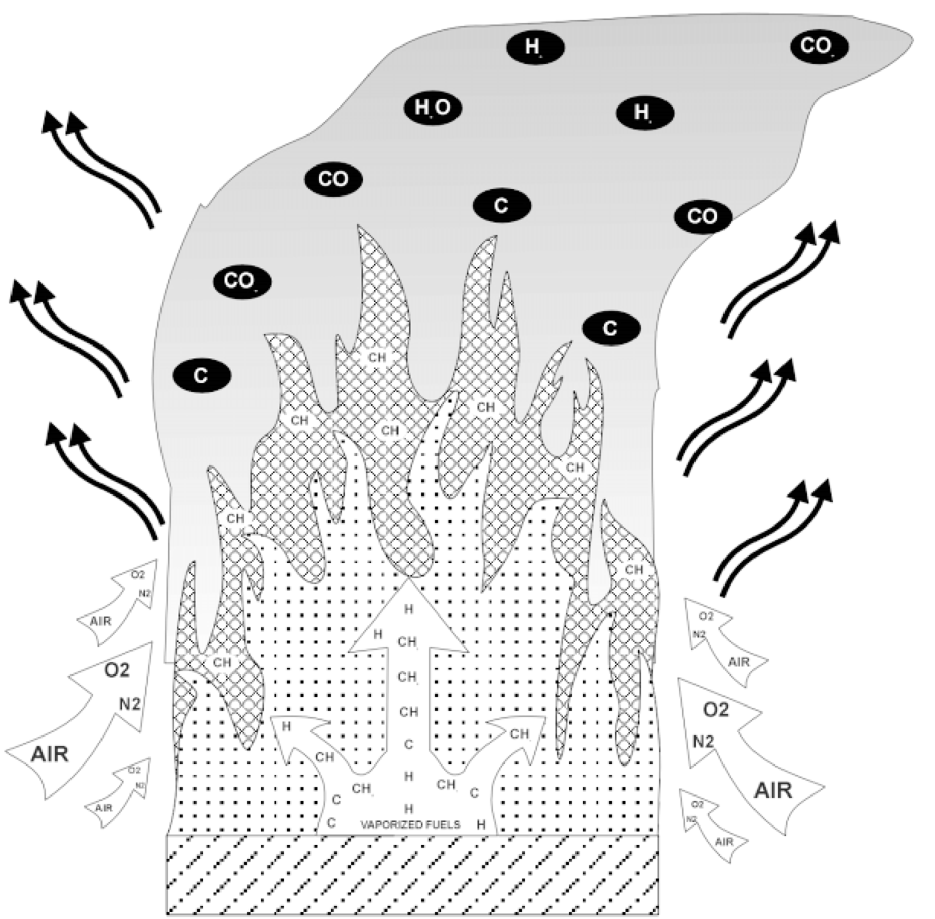
Most of the applications for optical flame detectors are "High Risk - High Value" ones, which require that detectors should be designed, qualified and manufactured according to sophisticated and advanced methods to ensure that the installed product is reliable.

These requirements have accelerated the technology race to research and develop novel approaches to fire detection employing scientific disciplines such as physical chemistry, physics, electro-optics, electromagnetic physics, electromagnetic spectral analysis and thermodynamics. This guide describes an innovative approach to flame spectral analysis that has led to the development of a novel multipurpose Infrared type (IR) flame detector.

BACKGROUND FOR FIRE DETECTION TECHNOLOGY

A fire scenario can be analyzed by several approaches, depending on the monitored parameters such as; fuel consumption, oxygen/air consumption, heat evolving or chemical reactions taking place in the vaporized fuel zone. Fig 1. describes the anatomy of a *hydrocarbon* fire where the vaporized fuel is dispersed in the surrounding atmosphere where it immediately reacts with oxygen and the flame chemical chain reaction takes place to give off gaseous products such as CO2, H20, HC - (unburned hydrocarbon molecules), C (Soot), and CO. Fire detection technologies throughout the years have

Figure 1



The Anatomy of Fire

relied on these factors for the development of detection devices.

OPTICAL FLAME DETECTION

The energy radiated from a fire serves as a major factor in its detection analysis. 30% - 40% of this energy is dissipated in the form of electromagnetic radiation at various spectral ranges, such as Ultraviolet (UV), visible, infrared (IR) bands. **Fig. 2** shows schematically a typical hydrocarbon fire emission spectrum where UV and IR spectral bands are "highlighted" to show the spectral ranges that are usually selected for existing flame detectors.

The flame radiation spectral pattern, being unique, allows several spectral ranges to be employed in the various detection devices. Flame detectors usually utilize optical sensors working at specific spectral ranges (usually narrow band) that record the incoming radiation at the selected wavelengths. The signals recorded by the sensor are then analyzed according to a pre-determined technique that includes one or more of the following:

- Flickering frequency analysis
- Threshold energy signal comparison
- Mathematical correlation between several signals
- Comparison techniques (Ratio, AND gate, OR gate techniques)
- Correlation to memorized spectral analysis

Detection devices using several of the above mentioned techniques, promise to be most reliable with respect to detection sensitivity versus immunity to false alarms.

Four major families of optical detectors have emerged in the last 20 years.

1. UV Detectors (Model FV-10)
2. IR Detectors
3. UV/IR Detectors (Model FV-20)
4. IR/IR Detectors

Each of these detector families has its advantages and drawbacks. They use one or several of the parameter analyses listed above and employ the most advanced optical sensors at the specific spectral wavelengths. However, each family of detectors are recommended for use in specific applications. These applications are usually determined by evaluating to what extent false alarms caused by environmental stimulus could create major problems.

UV FLAME DETECTION (Model FV-10)

The UV spectral band, because of shortwave characteristics, is absorbed in the surrounding atmosphere by air, smoke, dust, gases and various organic materials. Hence UV radiated by the sun, especially at wavelengths shorter than 300 nm (the solar blind spectral band), is being absorbed by the surrounding atmosphere and will not create false alarms on these flame detectors which are monitoring a bandwidth from .185 to .260 micrometers (185 to 260 nm). UV detectors based on this technology are detecting flames at high speed (3-4 milliseconds) due to the UV high energy radiation emitted by fires and explosions at the instant of their ignition.

However, the occurrence of random UV radiation from sources such as; lightning, arc welding, radiation and solar radiation (which are not absorbed by the atmosphere, due to holes in the ozone layer and solar bursts) cause false alarms in UV detectors.

IR FLAME DETECTION

Infrared radiation is present in most flames (as can be seen from **Fig 2**). The flame temperature, its mass of hot gases (fire products), emit a specific spectral pattern that can be easily recognized by employing IR sensor technology.

However, the flames are not the only source of IR radiation, and in fact any hot surface such as; ovens, lamps, incandescent halogen lamps, furnaces, solar radiation, emit IR radiation which coincides with the flame IR radiation wavelengths.

In order to discern the flames "spectral signature" from other IR source spectral signatures, various parameter analysis and mathematical techniques are employed. The most accepted are flickering analysis and narrow band IR threshold signals processed in the IR 4.1um-4.6um wavelengths. These IR detectors are still subject to false alarms caused by blackbody radiation (heaters, incandescent lamps, halogen lamps flickering sunlight, and others).

DUAL WAVELENGTH DETECTION TECHNOLOGY

In order to minimize or eliminate false alarms, dual wavelength technology has been adopted for optical flame detection.

This dual wavelength technology has two major branches:

1. *UV/IR Spectral Bands*
2. *IR/IR Spectral Bands*

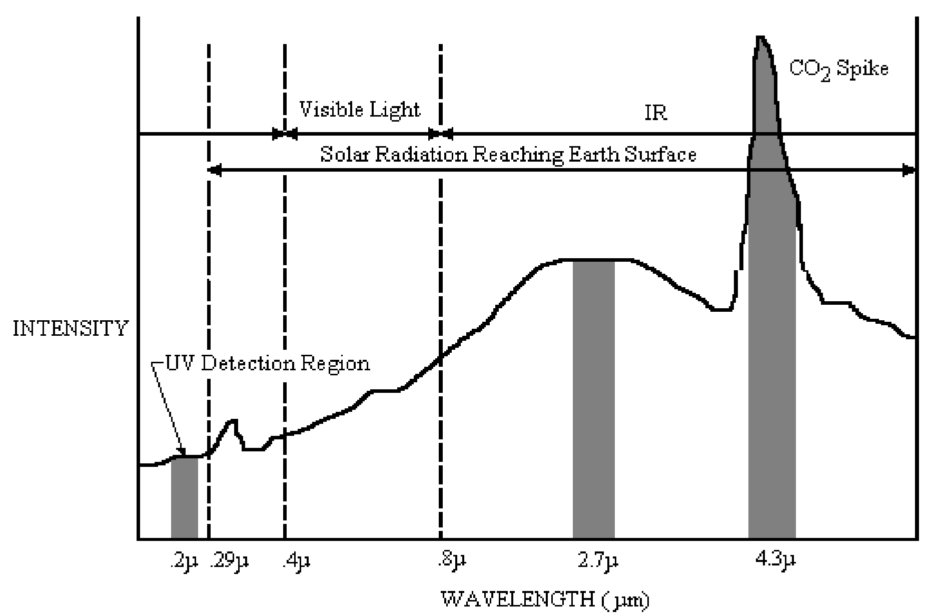


Figure 2- Typical Hydrocarbon Fire Emission Spectrum

In recent years dual spectral detection was considered the most advanced method to cope with false alarms.

UV/IR FLAME DETECTION (Model FV-20)

The dual spectrum UV/IR technology employs a solar blind UV sensor, with a high signal to noise ratio and a narrow band IR sensor. The UV sensor itself is a good fire detector, however, it is easily activated by alarm stimuli such as; welding, lightning, X-rays and solar spikes. In order to prevent false alarms caused by these sources, the IR sensing channel was added. The IR spectral channel, has a spectral signature characteristic to fire in addition to the fire's UV flame detector spectral signature, together they serve as a reliable detector for most mid-range applications. Even this advanced technology has its limitations, since each type of fire has its own specific ratio of UV to IR output. For example, a hydrogen flame generates a high amount of UV radiation with very little IR, while a coal fire will generate little UV radiation and a high amount of IR radiation. Since the dual UV/IR detector combines both signals to an "AND-gate" there could be a type of fire which will not be detected.

To ensure the reliability of the fire signal, a discriminating circuit compares the UV radiation threshold signal, the IR threshold signal, and their ratio, as well as their flickering mode. Only when all parameters satisfy the detection mathematical algorithm is the fire alarm confirmed. However, in industrial environments the sources for false alarms are variant, including UV radiating sources such as; welding, electrical arcs, lightning (high voltage coronas), torches (in the petrochemical industry), solar spikes; as well as IR radiating sources which include heaters, incandescent lamps, halogen lamps, etc.. Since these false alarms affect both UV and IR channels certain scenarios may occur where a false fire stimulus is present, for example when an IR source (such as sunlight) and a UV source (such as welding) are present at the same time. In certain detectors, a serious problem may occur when a strong UV source (welding) is present and a fire ignites. The strong UV signal blocks the detector's logic from comparison with the IR channel, thus impairing its ability to detect a fire.

Further discrimination relating to the percentage of time each signal is present, using so called "windows" where the UV signals are counted continuously, enable elimination of strong signals that are not emitted by actual fires. Comparable techniques using "AND-gate" methods, process the UV and IR signals received by both sensors in the detector, thus ensuring the accuracy of these detectors.

IR/IR FLAME DETECTION

Another dual wavelength technology combines two narrow spectral ranges in the near IR spectral band. Since the hydrocarbon flames emit energy of a continuous nature in the near IR (0.9mm - 3.0mm) and a unique peak at the 4.3mm -4.5mm (caused by the hot CO_2 fire product) these features are the "heart" of most dual IR detectors. Common dual IR flame detectors employ two narrow bands 0.9pm and 4.3mm, for fire signal analysis. However, another approach to dual IR detection technology has emerged in recent years, where a fire's main spectral characteristic feature at 4.3mm -4.5mm is analyzed thoroughly. The basis to this analysis is the "differential spectral" approach where two spectral ranges are analyzed: One spectral range is emitted strongly by the fire while the second spectral range is emitted weakly by the surrounding, thus the ratio between these two signals gives a substantial mathematical tool for fire signal processing. This type of IR detector senses the radiation at these two channels and processes the input signals based on the following parameters:

- **Flickering analysis**
- **Radiation intensity above a certain threshold**
- **The ratio between both signals received at the two sensors**

However, since most of these dual IR detectors use the 4.3mm sensor as their main channel for fire recognition (where the CO_2 emission peak exists) they suffer from atmospheric attenuation, especially on long range detection applications.

ADVANCED TECHNIQUES FOR FLAME SPECTRAL ANALYSIS

Each one of the above described detection methods has certain drawbacks. It became evident that the classic methods for fire analysis were insufficient. The development of electro-optic technology enabled advanced techniques to perform deeper and more comprehensive spectral analysis.

The spectrum of flame radiation measured by the detector is influenced by the distance between the detector and the fire and by the concentration of the CO_2 gas in the atmosphere.

Two factors limit the detection range of dual IR detectors:

1. The fires radiation intensity strongly decreases as the distance increases around the 3.3mm peak. The input signal received by the sensor is very weak (the more CO2 in the atmosphere, the higher absorption of this wavelength and the lower the signal received). This could be omitted and not recognized as fire by dual IR/IR type detectors.
2. The ratio between the 4.3mm spectral band and the second IR channel (the background 4.9mm spectral band), approaches equality (1:1) and ceases to be typical to the ratio existing in fires.

Once the ratio approaches 1:1 the algorithm processing the fire signals gives a no fire signal, though a fire may occur at that very moment.

The first limiting factor may be reduced by choosing a sensor with a wide band spectral range. This will enhance the input signal, however will not solve the problem discussed in the second limiting factor (2). The ratio between the two IR channels become equal for a long distance fire in the case of high concentration of CO_2 in the atmosphere. This criteria, when employed in IR/IR fire detectors, makes the distinction between flames and false alarm sources (electrical heaters) almost impossible.

In order to address both limitations, the use of a narrow band spectral filter is suggested. The use of this narrow spectral band sensor, in addition to the second IR channel, provides a typical fire ratio at longer distances. Once the proper spectral band is selected, the limiting Flame Detector factor for the detection range is no longer the atmospheric attenuation but the sensitivity of the specific sensor.

If the input signal is not significantly greater than the internal noise of the sensor, the ratio and the measured intensity are not reliable as fire indicators. The present available IR sensors on the market, such as PbSe, Pyroelectric and Thermopile, have low ratio between input signal and internal noise.

For these sensors the signal from a fire at a distance greater than a few meters is not significantly distinguishable from their internal noise, hence sophisticated mathematical techniques are required for proper signal recognition.

In summary, the dual IR fire detection technology: although suitable in some indoor and limited outdoor short range applications, there are serious limitations that prevent the application of this technology to long range fire detection.

The limiting factors are:

- Atmospheric attenuation of incoming signal
- Ratio between two IR channels subject to long distances
- Weak input signals due to narrow band filters
- Signal to noise problem of existing IR sensors.

MULTI INFRARED FLAME DETECTION (Model FV-30)

In order to resolve some of these limiting factors, a novel approach has been introduced into the fire detector market, its scientific background is now described.

Most of the fire radiation is due to hot CO_2 and H_20 molecules that are the main combustion products. In this novel approach, the fire is considered an alternating infrared source that emits strongly at the CO_2 emission band and weakly at the background emission band. Most of the IR sources (considered as IR false alarm stimuli) including the sun, incandescent and halogen lamps, arc discharge, electrical heaters, etc., do not possess this unique spectral feature.

Three spectral wavelength bands have been selected for this flame detection technique:

1. Within the CO_2 spectral emission band
2. Outside the CO_2 emission band
3. Over a background broad band

The mathematical relation between the three sensors detecting the specific wavelengths of IR radiation is typical to each IR source, thus distinguishing between a fire scenario and interfering IR stimuli. Each IR source has its own IR spectral signature and gives a different signal ratio at the three sources.

Taking into consideration the ratio between the three IR channels, *a fire can be singularly detected with almost no false alarms.* Further improvement of this IR analysis technique *enables the accurate detection of a hidden fire (smouldering fire)* where the radiating flames are hidden, but the hot mass of CO_2 gases are emitted and hence detected.

Using correlation techniques, where each IR channel is auto correlated to a predetermined value and by using the ratio between the specific IR channels, further discrimination between fire and false alarm stimuli is possible.

It has been found that the false alarm rate of fire detection has decreased without significantly decreasing the sensitivity, thus allowing fire detection up to longer ranges (100 m).

This unique flame analysis has been incorporated in the Flame Vision Model FV-30 fire detector which has a detection sensitivity of a gasoline pan fire of 1'X1' ft. (30cm X30cm) at a distance of 200 ft. (60 meters). This sensitivity is 2 to 4 times greater than all other existing detectors on the market. The surprising fact is that this technology has extremely high immunity to false alarms.

Optical Flame Detector Comparison			
Technology	***Advantages***	***Disadvantages***	***Applications***
Infrared (IR)	High speed, moderate sensitivity low cost	Affected by temperature, subject to false alarms from IR sources	Indoors/Outdoors
Ultraviolet (UV)	Highest speed, high sensitivity, low cost	Subject to false alarms, blinded by thick smoke and oil vapors on optics	Indoors
Dual Detector (UV/IR)	High speed, high sensitivity, low false alarm rate	Affected by specific UV/IR created by false alarms, blinded by thick smoke and vapors, moderate cost	Outdoors/Indoors
Dual Detector (IR/IR)	High speed, moderate sensitivity, low false alarm rate	limited operation by temperature range, affected by IR sources, moderate cost.	Outdoors/Indoors
Triple IR (IR3)	High speed, highest sensitivity, lowest false alarm rate	High-moderate cost	Outdoors/Indoors

FALSE ALARMS DUE TO BLACK BODY RADIATION

SINGLE BAND IR DETECTOR - Most single band IR detectors are based on pyroelectric sensors with a 4.4 micron (m.) optical filter, and a low frequency (1-10 Hz) electronic band pass filter (characteristic of a flickering fire). Any flickering radiation greater than the radiation emitted from a l sq. ft. gasoline pan fire at 4.4m. from a distance of 50 ft. will be recognized by this type of detector as fire.

Therefore, radiation sources other than fire will cause this type of detector to false alarm under the above mentioned conditions.

At the relevant wavelength the radiation from a black body at 1000° C at a distance of 50 ft. is approximately equivalent to the radiation from a 1 sq. ft. gasoline pan fire at the same distance. The same level of radiation is attained from a 1 sq. ft. 430° C black body at a distance of 15 ft. and for a temperature of 130° C at 3 ft. distance.

The single frequency IR detectors respond only to a certain flicker and radiation intensity of 4.4m. Thus they are sensitive to flickering or modulated blackbody radiation. Under certain conditions it is possible for flickering caused by such things as shimmering water, rotating lights or interrupted thermal radiation to be interpreted as fire by single frequency IR detectors.

IR³ DETECTOR - The Flame Vision Model FV-30 detector utilizes a combination of three IR sensors of extremely narrow band response. One covers the typical CO_2 emission spectral band, and the two other sensors cover different adjacent specially selected spectral bands.

The FV-30 detector will not false alarm to any continuous, modulated or pulsating radiation sources other than fire (including illumination, and other sources such as a black or gray body radiation).

CONCLUSIONS

Optical Flame detection has been known for over 20 years. Through the years there have been developments of these detectors by combining various sensors and employing new logic and mathematical techniques.

The Flame Vision Model FV-30 detector is the new generation in flame detection, presenting high sensitivity and immunity to false alarms.

With the introduction of this detector and its extended range, fewer detectors can be used to cover the same area. For example, when laying out detection for an oil or gas loading facility in the past, 4 or sometimes 5 detectors were recommended per bay. Now, with the Model FV-30, 2 to 3 detectors would be required per bay. This could cut the number of detectors in half, resulting in substantial savings on the cost of equipment, while at the same time giving the customer more than adequate protection. In the case of train loading, the number of detectors required could also be cut substantially with the new Model FV-30.

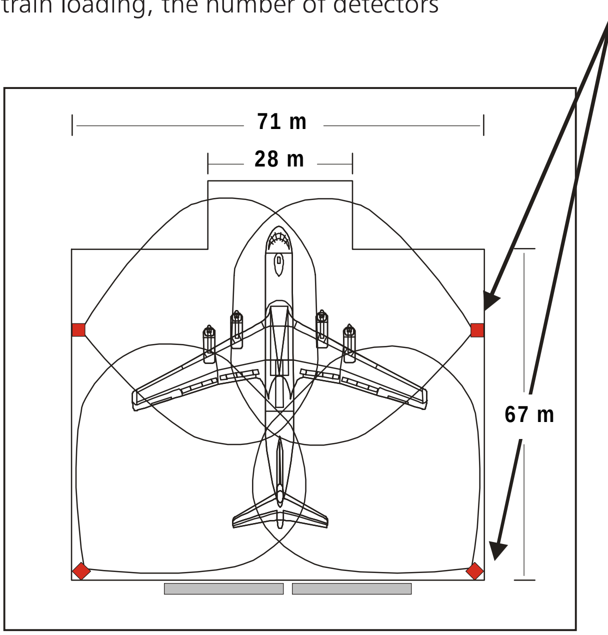
Of course, every facility is a little bit different, but with careful planning and proper layout, the customer can achieve the most cost effective and safe installation.

Flame Detector Model Features

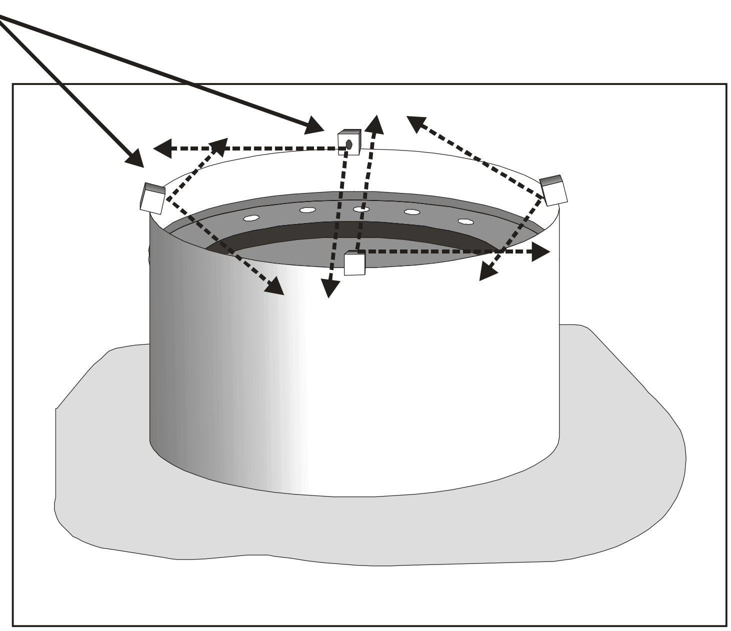
Model	Type Detector	Built-in Test	Detection Range [1ftx1ft pan fire]	Alarm Delay	Response Time **	Description	Outputs
10--1	UV	No	50 ft		0.5 sec	• fast response UV detector	• Alarm • 4-20 mA • Fault
10--2	UV	Built-in test feature	50 ft	Yes	0.5 sec	• fast response UV detector • Auto or manual built-in test for lense clarity	• Alarm • 4-20 mA • Fault
20--1	UV/IR	No	50 ft		1 sec	• Dual UV/IR indoor /outdoor applications	• Alarm • 4-20 mA • Fault
20--2	UV/IR	Built-in test feature	50 ft	Yes	2 sec	• Dual UV/IR indoor /outdoor applications • Auto or manual built-in test for lense clarity	• Alarm • 4-20 mA • Fault
30--1	Triple IR (IR3)	Built-in test feature	200 ft	Yes	3 sec	• Extendeddetection range alarms • Auto/manual BIT 4-20mA interface Optional RS-485 interface •Adjustible alarm time delay [max 30 sec]	• Alarm • Fault • 4-20 mA • RS-485

* gasoline pan fire
** actual response time depends on size and type of fire as well as distance from the detector.

Flame Detectors



Underwing Coverage using (4) Model FV-20 UV-IR detectors



Floating Cap Oil Tank Installation

NOTES:

Represented by:

Flame Selection 8-99

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