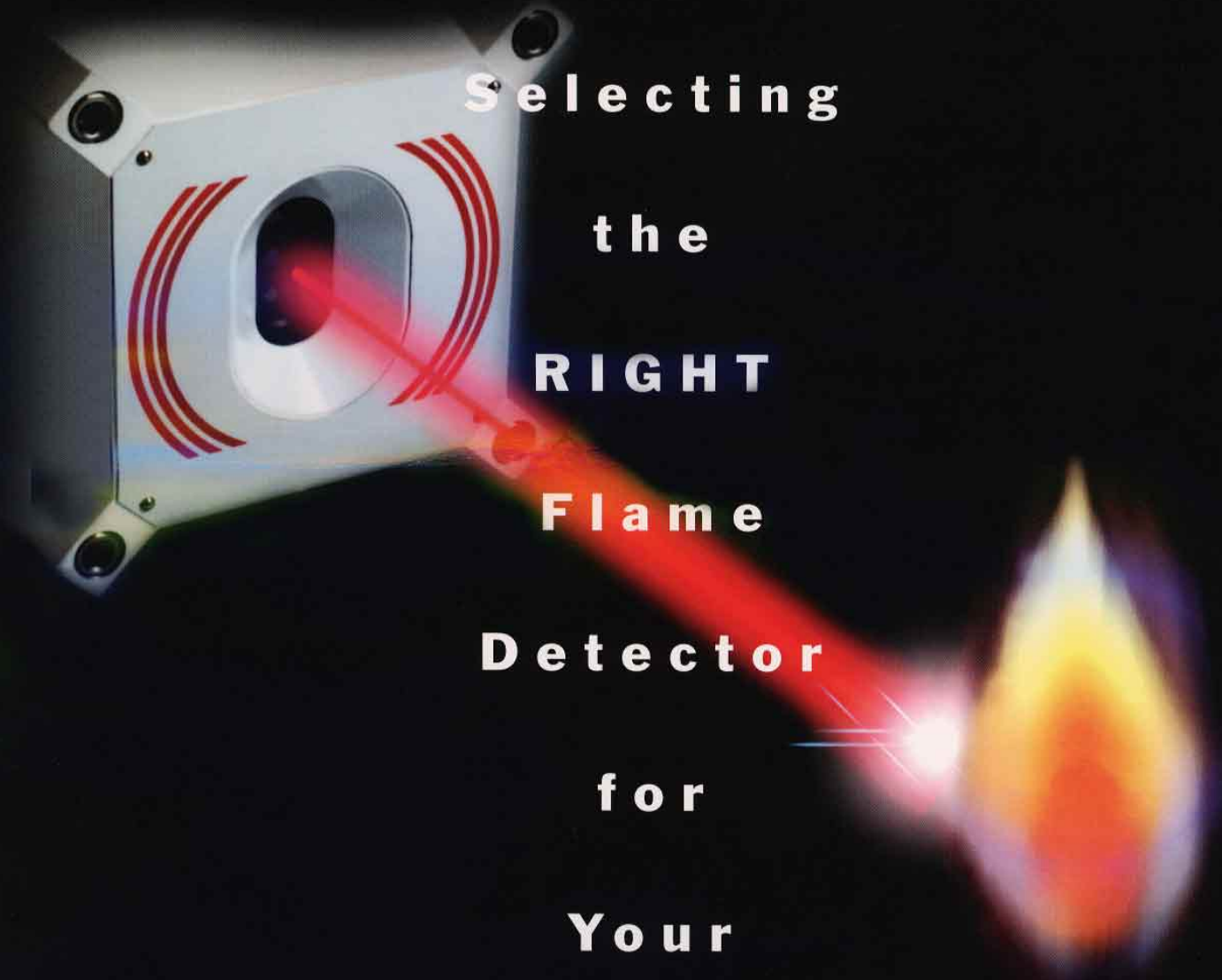


TECHNICAL INFORMATION
SERIES

MSA's
Guide to
Selecting
the
RIGHT
Flame
Detector
for
Your
Application



MSA

MSA's 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 to remotely detect a small 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 applications for optical flame detectors are "High Risk - High Value", that require detectors to be designed, qualified and manufactured according to sophisticated and advanced methods to ensure the installed product is reliable.

These requirements have accelerated the technology race to research and develop new 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 unique multipurpose Infrared-type (IR) flame detector.

BACKGROUND FOR FIRE DETECTION

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. Figure 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, H₂O, HC - (unburned hydrocarbon molecules), C (Soot), CO. Fire detection technologies throughout the years have relied on these factors for the developing 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. Figure 2 schematically shows 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 predetermined technique that includes one or more of the following:

1. **Flickering frequency analysis**
2. **Threshold energy signal comparison**
3. **Mathematical correlation between several signals**
4. **Comparison techniques (Ration, AND gate, OR gate techniques)**
5. **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**
2. **IR Detectors**
3. **UV/IR Detectors**
4. **IR/IR Detectors**

Each of these detector families uses one or several of the parameter analyses listed previously, and employ the most advanced optical sensors at the specific spectral wavelengths. However, each family of detectors is recommended for use only 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

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 radiation dispersed in the atmosphere, 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. 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.

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 reorganized by employing IR sensor technology.

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

DUAL WAVELENGTH DETECTION

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 plus others).

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

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

UV/IR FLAME DETECTION

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 but is easily activated by alarm stimuli such as welding, lightning, Xrays and solar

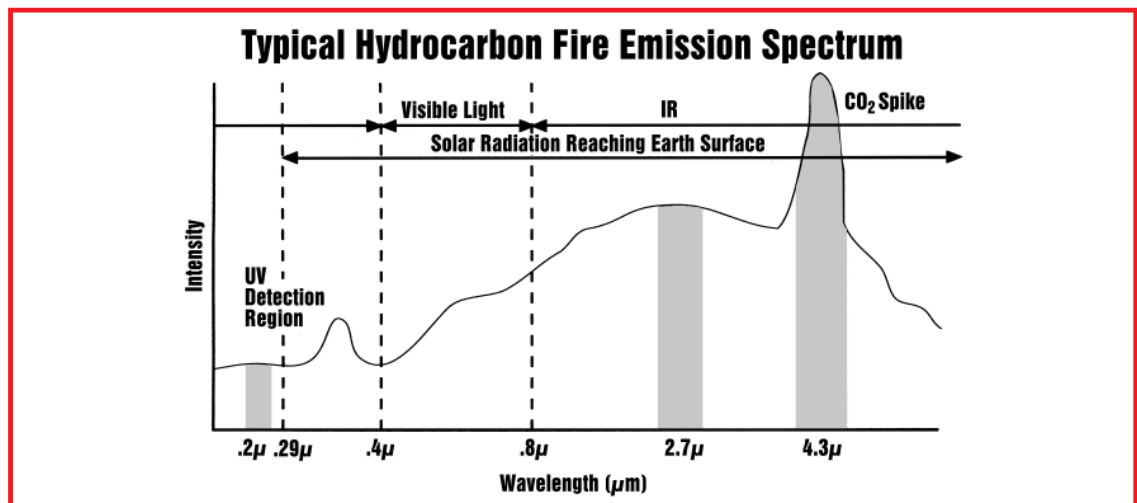


Figure 2.

spikes. 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 and together serve as a reliable detector for most mid-range applications. Even this advanced technology has 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 generates 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 fire that 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.

The fire alarm is confirmed only when all parameters satisfy the detection mathematical algorithm. 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, and IR radiating sources (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, i.e.: when an IR source (sunlight) and a UV source (welding) are present at once.

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 "windows" where the UV signals are counted continuously, enable elimination of strong signals 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 (0.9um - 3.0um) and a unique peak at the 4.3um -4.5um (caused by the hot CO₂ fire product) these features are the "heart" of most dual IR detectors. Common dual IR flame detectors employ two narrow bands 0.9um and 4.3um, for fire signal analysis.

Another approach to dual IR detection technology has emerged in recent years, where a fire's main spectral characteristic feature at 4.3um -4.5um 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. The ratio between these two signals provides 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 2 sensors

Since most of these dual IR detectors use the 4.3um sensor as their main channel for fire recognition (where the CO₂ emission peak exists), they suffer from atmospheric attenuation, especially on long range detection applications.

ADVANCED TECHNIQUES FOR FLAME SPECTRAL ANALYSIS

Each of the previously described detection methods has drawbacks. It is evident that classic fire analysis methods are insufficient for some applications. The development of electro-optic technology enables advanced techniques for performing 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 CO₂ 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 3.3um 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 4.3um spectral band and the second IR channel (the background 4.9um 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, even 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, but will not solve the problem discussed in the second limiting factor (2). The ratio between the two IR channels becomes equal for a long distance fire in the case of high concentration of CO₂ in the atmosphere. This criteria, when employed in IR/IR fire detectors, makes the distinction between flames and false alarm sources (electrical heaters) virtually impossible.

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 measured intensity are not reliable as fire indicators. IR sensors currently available on the market have low ratios 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, requiring sophisticated mathematical techniques for proper signal recognition.

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

To resolve some of these limiting factors, a unique approach has been introduced into the fire detector market. Its scientific background can be described as follows:

Most fire radiation is due to hot CO₂ and H₂O molecules that are the main combustion products. In this novel approach, the fire is considered an alternating infrared source that emits strongly at the CO₂ emission band and weakly at the background emission band. Most of the IR sources (considered IR false-alarm stimuli) including 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:

The mathematical relation between the three (or more) sensors, detecting the specific wavelengths of IR radiation, is typical to each IR source for 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 (smoldering fire) where the radiating flames are hidden, but the hot mass of CO₂ gases are emitted and therefore detected.

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

CONCLUSIONS

Optical flame detectors have existed 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.

MSA's FlameGard® IR³ Flame Detector is the new generation in flame detection, offering high sensitivity as well as immunity to false alarms.

With the introduction of the FlameGard IR³ Flame Detector with its extended range, fewer detectors are required to cover an area.

For example, when laying out detection for an oil or gas loading facility in the past, 4 or 5 detectors per bay were required. With the FlameGard IR³ detector, only 2 to 3 detectors per bay would be required. This results in substantial savings on the cost of equipment, while at the same time providing the same protection.

In the case of train loading, the number of detectors required could also be cut substantially with the new FlameGard IR³.

Charts and Graphs

Maximum Distances from Detector to Potential Fires

Type of Fire	30FT.	40FT.	50FT.	100FT.	200FT.
1 SQ.FT. Gasoline	All models	All models	All models	U; I	I
1 SQ.FT. Diesel	All models	U; I	U; I	I	I
11 SQ.FT. n-Heptane	All models	All models	All models	U; I	I
1 SQ.FT. Alcohol	All models	U; I	U; I	I	I
4 SQ.FT. JP4/JP8	All models	All models	All models	All models	I

Comparison Between Various Types of Flame Detectors

Technology	Advantages	Disadvantages	Applications
Infrared (IR)	High speed. Moderate sensitivity. Manual self-test. Low cost.	Affected by temperature. Subject to false alarms. IR sources.	Indoors
Ultraviolet (UV)	Highest speed. High sensitivity. Automatic self-test. Low cost.	Affected by UV sources. Subject to false alarms. Blinded by thick smoke. Moderate cost.	Indoors
Dual Detector (UV/IR)	High speed. High sensitivity. Low false alarm rate. Automatic self-test.	Affected by specific UV/IR. Ratio created by false stimuli. Affected by thick smoke. Moderate Cost.	Outdoors/ Indoors
Dual Detector (IR/IR)	Moderate speed. Moderate sensitivity. Low false alarm rate.	Limited operation by temperature range. Affected by IR sources. Moderate cost.	Outdoors/ Indoors
Triple IR	High speed. Highest sensitivity. Lowest false alarm rate. Automatic self-test.	Moderate cost.	Outdoors/ Indoors

Recommended Flame Detectors for Various Fire Scenarios

For These Types of Potential Fire Hazards...

	Gasoline JP4/JP8 Oils Diesel	Paints Solvents	Alcohol Propane Methane CFC's	Hydrogen	Plastic Wood Paper
Possible False Alarm Sources Present	Use These Detectors:				
Arc welding	UV/IR*, IR3	UV/IR*, IR3	UV/IR*, IR3	UV/IR*, IR3	UV/IR*, IR3
X-rays (for maintenance properties)	UV/IR* IR3	UV/IR* IR3	UV/IR* IR3	UV/IR* IR3	UV/IR* IR3
Hot surfaces High temperatures	UV, UV/IR IR3	UV, UV/IR IR3	UV, UV/IR IR3	UV, UV/IR IR3	UV, UV/IR IR3
Background					
Incandescent light Fluorescent light	UV**, UV/IR IR3	UV**, UV/IR IR3	UV, UV/IR IR3	UV, UV/IR	UV, UV/IR IR3
Halon lighting- w/glass Halon lighting- w/o glass	UV**, UV/IR IR3	UV**, UV/IR IR3	UV**, UV/IR IR3	UV, UV/IR	UV, UV/IR IR3
Mercury lamps Flash lamps	UV/IR IR3	UV/IR IR3	UV/IR IR3	UV/IR IR3	UV/IR IR3

*Model UV/IR only.

**For indoor applications only.

FlameGard® Models* and Characteristics

Model	Type	Detection Range 1Ft. x 1Ft.		Description
		Pan Fire	Response Time	
U	UV	50FT.	0.5 second nominal	Fast response UV detector
U	UV	50FT.	0.5 second nominal	As above with automatic or manual built-in test for verifying lens cleanliness and electric operation. Indoor operations.
I	UV/IR	50FT.	1 second nominal	Dual UV/IR indoor and outdoor applications.
I	UV/IR	50FT.	2 seconds nominal	As above with automatic or manual test for verifying lens cleanliness and electric operation. Indoor and outdoor applications.
IR3	IR3	200FT.	5 seconds	Extended detection range alarms. Automatic or manual bit 4-20mA interface. Optional RS85 interface. Adjustable time delay up to 30 seconds.
		4 SQ.FT. JP4 Fuel at 100FT.	1 second	

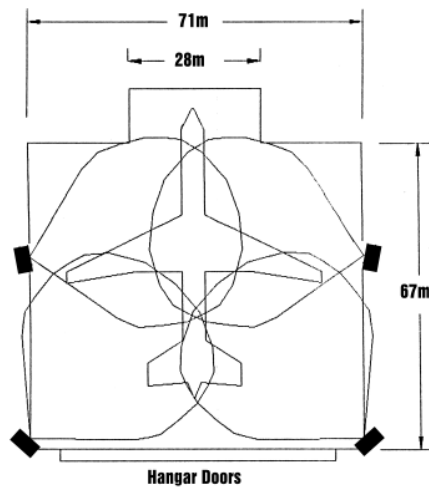
*All models are explosion-proof and approved by FM/CENELEC/CSA.

Typical Layouts

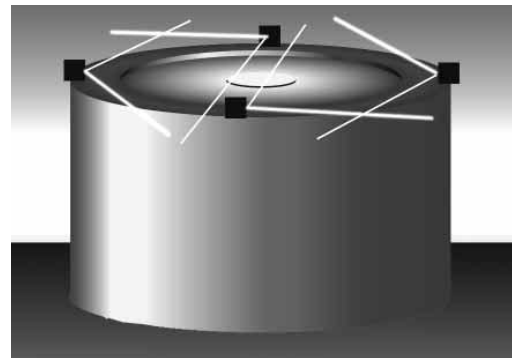
Single Plane Hangar

Underwing coverage using 4 FlameGard IR³ flame detectors.

Sensitivity: 10' x 10'.



Industrial Application

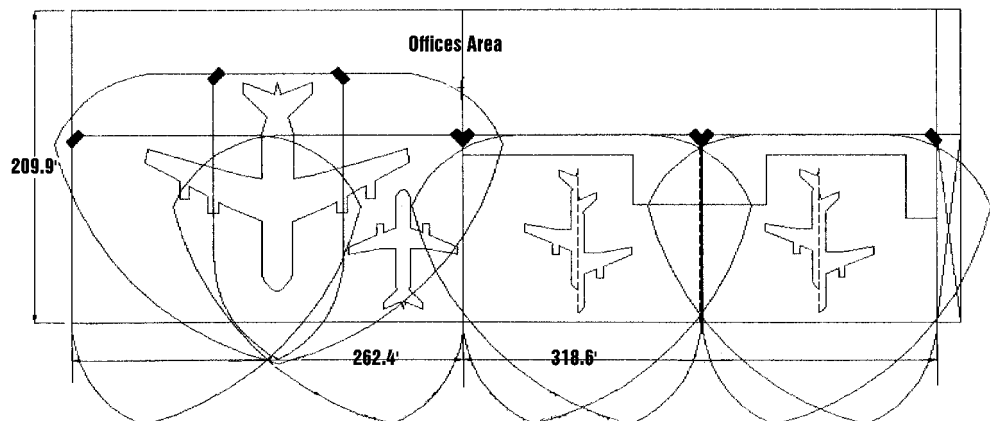


Oil tank installation with floating roof.

Overwing Protection

Hangar detector coverage using 8 FlameGard IR³ flame detectors. Double coverage.

Sensitivity: 1' x 1' pan fire at 200 feet.

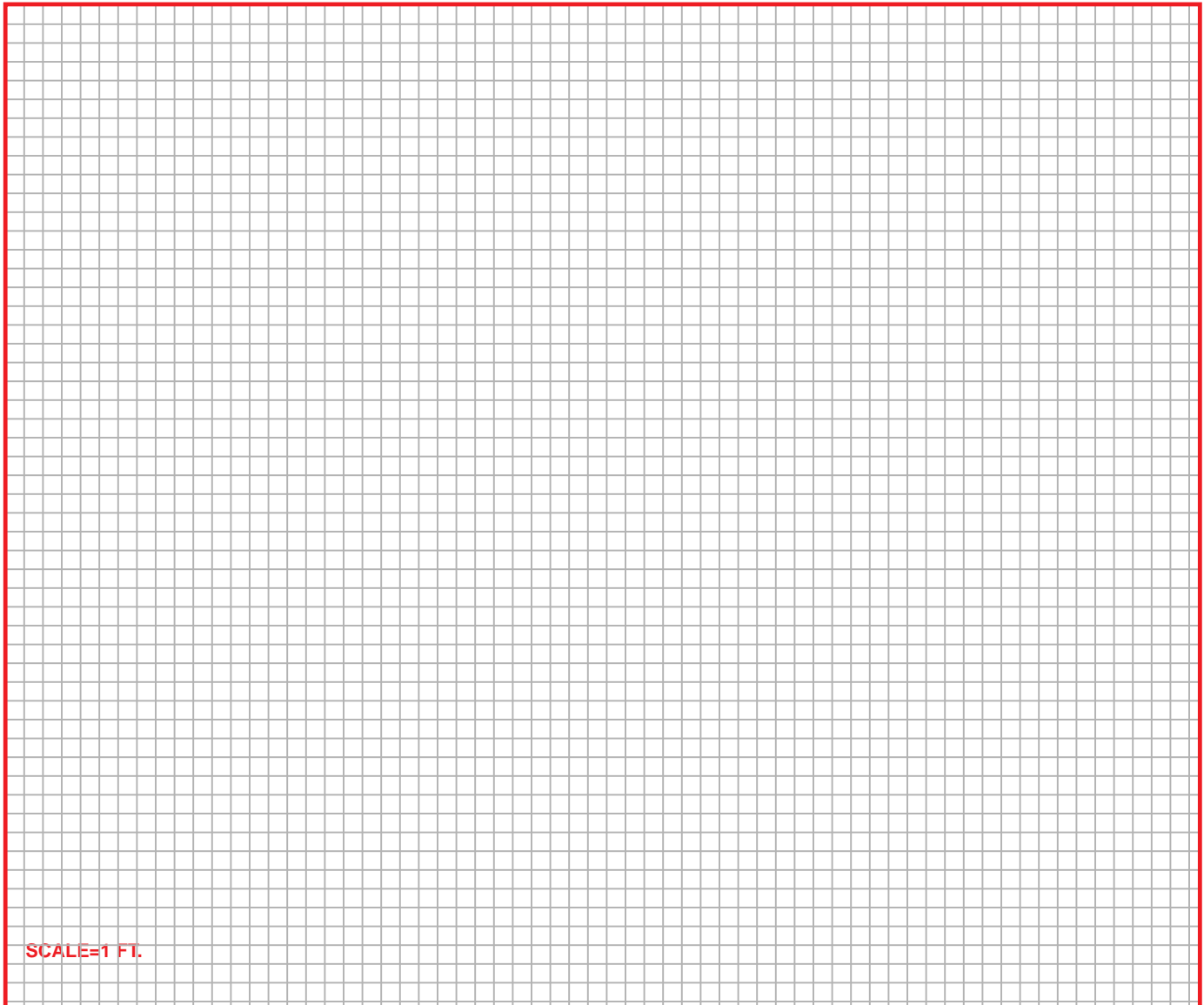




If you would like MSA to generate a suggested layout, please FAX us at (412) 776-3280 with the outline dimensions showing clearly any

Laying Out the Area to be Protected

1. Draw a floor plan of the area for which detection is to be provided. Use graph paper if possible and fill in the outline measurements.
2. Locate detectors within and around the potential hazard area so at least one detector has an unobstructed view of every location within the hazard area. Use the distance charts in this guide, taking into account the type of fire that is likely to occur.
3. For example, in an aircraft hangar, the most likely fire would occur in a spill underneath the aircraft. Therefore, detectors should be looking underneath the aircraft wings. In a warehouse application where chemicals are being stored in racks, the entire volume should be covered, taking care not to have non-burning obstructions within the detector's field of view.
4. If performance criteria have been established, define the minimum size fire to be detected (i.e. 1FT. pan fire at 50FT.). Then use the chart provided in this guide to determine the distance from the potential source of fire to where the detector(s) can be located. (Remember, the larger the area the detector can cover, the fewer the detectors required for your application.)



Note: This bulletin contains only a general description of the MSA FlameGard Flame Detectors. While uses and performance capabilities are described, under no circumstances should the product be used except by qualified, trained personnel, and not until the instructions, labels or other literature accompanying the product have been carefully read and understood and the precautions therein set forth followed. Only they contain the complete and detailed information concerning this product.

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