



Superior

FSXTM WideBand IRTM

Fire / Flame Detection

Technology

I. Introduction

Fire Sentry Corporation continues its long tradition in utilizing superior and innovative technology with the creation, design, development, testing, and manufacturing of all its fire detection products. Our products are designed to provide the fastest response to all types of fires without false alarms over the widest fields of view in all environmental conditions. Fire Sentry Corporation has been the technological leader in electro-optical fire and flame detection for over a quarter of century and continues to capitalize on the military/aerospace electro-optical detection background of its engineers. Our tens of thousands of installed fire detection products continue to perform as advertised in a myriad of applications worldwide.

Fire Sentry Corporation's entire product line of WideBand IR™ fire / flame detectors including the newer FSX detectors (FS24X Multi-Spectrum QuadBand™ Triple IR and FS18X Multi-Spectrum TriBand™ IR) Models FS24X and FS18X), Ultraviolet/Infrared (UV/IR) detectors (Models SS2, SS3, and SS4) and Infrared (IR/IR) fire/flame detectors (Models FS10 and FS7) do not rely on the narrowband 4.3-micron CO₂ molecular emission line with its intrinsic shortcomings, restrictions, and as do other flame detectors, whether it is Triple IR, Dual IR, single band IR or other UV/IR flame detectors. All Fire Sentry Corporation FSX fire and flame detectors use its patented WideBand IR™ technology with high-speed, wide temperature range photoconductor quantum-based sensors.

Furthermore, Fire Sentry detectors are designed to alarm to all fire types, hydrocarbon and non-hydrocarbon, which is made possible by its patented and unique WideBand Infrared technology. This means one can use a single FS18X or FS24X Triple IR flame detector (or a single SS2, SS3, or SS4 fire detector) to protect against both hydrocarbon fires and non-hydrocarbon (i.e., hydrogen, silane, metals, etc.) fires in virtually all weather conditions, altitudes, and environments. Others require two separate flame detectors (great for selling more flame detectors, but more costly for users) for complete fire coverage against both hydrocarbon and non-hydrocarbon fires. Unfortunately, the narrowband CO₂ technical problems remain and shall remain as one would have to change physics (and how our entire universe operates) to overcome these intrinsic and inherent shortcomings, restrictions, and limitations when using narrowband 4.3 micron sensors.

Fire Sentry's Multi-Spectrum QuadBand FS24X Triple IR Detectors' sensor array uses high speed and wide temperature range photoconductive quantum sensors with four (quad) distinct wide spectral bands that include the 4.3 micron band with:

- 1) WideBand IR: 3 to 5 microns
- 2) WideBand IR: 1.1 to 7 microns
- 3) Near Band IR: 0.7 to 1.2 microns
- 4) Visible Band: 0.4 to 0.7 microns

Fire Sentry's FS24X flame/fire detectors with its patented WideBand sensor array technology achieves the long detection ranges of 4.3 micron based sensing without the numerous inherent and intrinsic disadvantages by all other narrowband Triple IR flame detectors.

II. WideBand IR vs. Narrowband 4.3 Micron IR Flame Detection

When comparing Fire Sentry's proprietary, patented WideBand IR based Multi-Spectrum QuadBand Triple IR FS24X Detector's quantum four sensor array with the conventional Narrowband 4.3 micron based three sensor array used by every other "Triple IR" flame detector manufacturer, one should consider the following:

1. Narrowband "Triple IR" (or as falsely claimed by some manufacturers as MultiSpectrum IR) flame detectors depend solely on a hot fire generating a strong, clean 4.3-micron signal from the excitation of hot carbon dioxide (CO₂) molecules. All Triple IR flame detectors are essentially single band 4.3-micron detectors with the addition of two false alarm rejection, non-flame sensing "guard" bands. If there is insufficient 4.3-micron flame signal or if the adjacent non-flame signals generate a larger signal (due to blackbody radiant energy from hot sources or a "dirty" fire), there is no flame detection. Basically, Triple IR flame detectors measure the amplitude of the 4.3-micron signal generated by the fire and then subtract (cross-correlate) the two guard band signal strengths to obtain a fire signal. On the other hand, Fire Sentry FSX WideBand fire and flame detectors see and alarm to all fires, whether the signal is predominately a molecular-based (i.e., CO₂, CO, H₂, etc.) flame or a predominately a "dirty" blackbody radiant heat fire, and all combinations thereof.
2. Although CO₂ is generated throughout a fire's total volumetric area, essentially it is the outer surface flame front that actually produces the bulk of the radiated 4.3-micron CO₂ signal. The reason is the CO₂ gasses produced inside the fire volumetric area actually absorbs the hot radiated 4.3 micron CO₂ emission line because of Kirchoff's Law that states essentially that a good emitter (CO₂) is also a good absorber. Conversely, Fire Sentry's WideBand IR™ senses not only the surface front CO₂ signal but also, importantly, the blackbody radiated energy from the entire volumetric area of a fire. The small, hot Planckian blackbody particulates and other hot gasses inside the fire do not absorb in the radiated energy inside the fire's volume as the narrowband 4.3-micron band CO₂ does.
3. Not ALL fires produce pure, clean burning flames that generate a reliable, strong 4.3 micron signal – many, if not most, real-world fires are dirty, sooty, smoky fires (i.e., heavy crude oil, JP jet fuels, diesels, etc.) with copious amounts of primarily hot carbon-based particulates each radiating Planckian blackbody energy which can obscure, absorb, or seriously degrade a 4.3 micron flame surface front CO₂ signal while increasing the signal strengths of the guard bands radiated inside the fire's volumetric area thereby reducing the subtracted resultant fire signal. The final result is a much-reduced real world fire detection range and fire response time to real world fires compared to ideal test conditions against clean burning test fires. Alternatively, Fire Sentry FSX WideBand fire and flame detectors see and alarm to fires based on the wide band total, integrated radiant energy of a fire including all molecular emission lines and blackbody sources.
4. The fires must burn sufficiently hot to generate a strong 4.3-micron signal (colder fires may not produce sufficient 4.3 micron signal needed to produce a positive signal when subtracted from its two guard bands). For example, IPA, ethanol, methanol and other alcohol derivatives fall in this category

of cold burning fuels. The result is reduced detection and longer detection times. In contrast, the Fire Sentry FSX WideBand fire and flame detectors see and alarm to fires based on the wide band radiant energy emitted. In other words, if the fire generates heat (radiant energy), Fire Sentry detectors will see it.

5. Non-hydrocarbon fires, such as hydrogen, silane, metals, etc. do not generate a 4.3 micron signal because there is no carbon dioxide (CO₂) in the combustion process and conventional Triple IR flame detectors are totally blind to these fires. Conversely, the Fire Sentry FSX WideBand fire and flame detectors see and alarm to all fires based on the fire's total, integrated fire radiant energy and do not rely solely (as narrowband Triple IR detectors do) on a 4.3 micron signal.
6. Atmospheric conditions can attenuate or seriously degrade the 4.3-micron signal before it reaches the conventional Narrowband Triple IR flame detector. Again, this is partially due to Kirchoff's Law where the CO₂ in the atmospheric path from the fire to the detector absorbs the 4.3-micron signal. The result is reduced detection range and slower response times. Again, Fire Sentry FSX WideBand fire and flame detectors are designed to see and alarm to all fires as they sense the total, integrated radiant energy generated by fire.
7. Carbon dioxide (CO₂), water, and other commonly used fire suppression agents absorb the 4.3-micron fire signal, so suppression discharges can absorb the 4.3-micron signal before it reaches the conventional Triple IR flame detector. Again, this is because of Kirchoff's Law. The result is reduced detection range or complete blindness to the fire under certain conditions. This also prevents detection of fire re-flash after a suppression release. On the other hand, the Fire Sentry FSX WideBand fire and flame detectors are not blinded by these conditions.
8. Altitude effects can degrade the 4.3-micron signal generated by a fire since there is less oxygen to produce a strong CO₂ signal. The result can be reduced detection range for Narrowband Triple IR at higher altitudes. In contrast, the Fire Sentry FSX WideBand fire and flame detectors do not rely solely on the 4.3 micron narrowband signal, rather the total, integrated radiant energy of a fire.
9. Type of hydrocarbon fuel (different types and grades of gasoline, for instance) can significantly alter the 4.3-micron signal strength resulting in different detection capabilities and alarm times of Narrowband Triple IR detectors. On the other hand, the Fire Sentry FSX WideBand fire and flame detectors are not appreciably affected by this.
10. Water, ice, snow, fog, rain, condensation, mist, etc. on the detector viewing window lens can completely attenuate (blind) the 4.3 micron fire signal on conventional Narrowband Triple IR flame detectors. The slightest, thinnest film of water on one or more of the three sensor windows will completely attenuate the 4.4 micron emission line signal on conventional Triple IR / multi-spectrum detectors. This is the primary reason why conventional Triple IR detectors must be heated to keep condensation off the viewing lens and the result is detectors that consume more unnecessary electrical power thus leading to more costly larger gauge wiring, increased size of power supplies, and larger battery backup systems. If the heaters fail or cannot keep the water or ice off all three sensors,

the result can be a fire that is not detected or, a false alarm can occur. This is why rain can cause these narrowband 4.3 Triple IR detectors to false alarm. Again, Fire Sentry FSX WideBand IR fire and flame detectors are designed to see and alarm to fires and not false alarm to non-fire stimuli in all environmental scenarios.

11. The 4.3 micron signal is completely attenuated (absorbed) by ordinary window glass which is why conventional Triple IR flame detectors cannot detect (blind to) fire and flames looking through ordinary window glass. This is why CO₂ based flame detectors will not alarm to a fire if it is on the other side of window glass. If one of these detectors must protect against a fire threat behind a window, the window must be made of extremely expensive sapphire. On the other hand, the Fire Sentry FSX WideBand fire and flame detectors see and alarm to fires on the other side of ordinary window glass, but since the CO₂ emission line (but not the integrated WideBand IR radiant energy) is completely attenuated (blocked) by the glass, the detection distance is reduced.
12. The 4.3-micron signal requires that the fire have adequate oxygen for complete combustion or the 4.3-micron signal is reduced since it partially shifts to wavelengths outside the narrow 4.3-micron pass band producing more carbon monoxide (CO) instead of carbon dioxide (CO₂). This can result in reduced detection range and longer response times for conventional Triple IR detectors for fires that are oxygen starved. Fire Sentry Corporation's WideBand IR quantum sensors easily accommodate wavelength shifting because of their wide bands provides coverage for the CO fire emission line. Importantly, our FSX WideBand IR detectors do not rely solely on the 4.3 micron narrowband signal, rather the total, integrated radiant energy of a fire which includes all the molecular emission bands including CO₂ and CO.
13. Hand-held portable Test Lamps can be used at a longer alarming distance with the Fire Sentry WideBand IR detectors when compared to conventional Triple IR detectors. The result is easier manual testing of Fire Sentry detectors that provides end users and Authorities Having Jurisdiction with the assurance that the entire fire protection system including the flame and fire detectors, cabling, control systems, and suppression systems operate "end-to-end" as a complete system.
14. Since all conventional single, dual, and Triple IR hydrocarbon detectors depend solely on the narrow band 4.3 micron CO₂ signal, Fabry-Perot type interference filters are necessary to select this narrow band 4.3 micron signal and as well as narrow band guard bands. This is why these narrowband detectors have difficulty with external environmental temperatures changes since interference filters shift their peak pass band wavelength as a function of the ambient temperature. One solution to help alleviate this problem of the wavelengths from drifting and shifting out of the pass band and guard bands is to maintain the sensors' interference filter elements at a constant temperature using electrical heaters. However, this consumes significantly more electrical energy thereby causing the detector to have significantly higher electrical power requirements, especially in low temperature environments. This also results in the need for larger backup batteries and power supplies.

III. Thermal-Based Sensors vs. Photoconductive Quantum Sensors

Fire Sentry's FSX detectors, including its FS24X QuadBand Triple IR Detectors, utilize an array of high-speed solid-state photoconductive quantum sensors with a combination of wide band spectral absorption type optical filters and wide band spectral interference optical filters that are not adversely affected by temperature and incident angle. Therefore, Fire Sentry Detectors exhibit a wide 110-degree full field of view and a significantly higher operating temperature of +85C with a wide temperature option available for -60 to 110C operation at reduced detection ranges. Other competitive flame detectors use thermal (bulk heat sensing) pyroelectric sensors or thermopile heat sensing sensors with narrow band temperature dependent and angle of incidence limiting optical narrowband interference filters.

Pyroelectric sensors (thermal-based) intrinsically are limited to maximum operational temperatures significantly less than photoconductors and thermopiles because of the physics of their operation. They indirectly respond only to changes in incident radiant energy and are intrinsically insensitive to non-changing constant radiant energy. This means these sensors do not provide an output signal corresponding to the magnitude level of background infrared energy as photoconductive and thermopile sensors. The incident radiant energy is converted to thermal heat when striking the pyroelectric crystal which causes expansion and contraction in the bulk crystal material that generates a small electrical signal due to the "piezoelectric effect." Mechanical shock and vibration to a pyroelectric crystal sensor can also generate these electrical signal currents that can result in a false alarm.

Thermopile sensors (thermal-based) sense radiant heat using the "thermocouple effect" of dissimilar materials. Their primary advantage is they, like quantum sensors, provide the blackbody infrared magnitude of the fire radiant energy. Since thermopile sensors respond indirectly to the thermal heat provided by the incident radiant photon energy, they exhibit an intrinsically slow response to radiant energy when compared to the response times of pyroelectric or photoconductors and are not used by our major competitors.

Photoconductive solid-state sensors operate on a quantum basis since each incident radiant energy photon quanta (which have quantum energy of $h\nu$) directly releases electrons from the electron-hole pairs in the sensor's crystal lattice. Therefore, they are intrinsically capable of very high speed response and, since the electron emission is not the result of the sensor's crystal temperature, wider temperature operation. For wide temperature operation, Fire Sentry flame/fire detectors use special sensor crystals developed from aerospace/military applications that can tolerate high and low temperature variations without crystal degradation.

Quantum-based photoconductive sensors directly provide both the magnitude and dynamic signal amplitudes of the incident radiant energy photon energy generated by fire. Pyroelectric sensors, on the other hand, only indirectly provide the amplitude of the change of the radiant heat energy. Pyroelectric sensors do not sense or detect the fire or flame's blackbody energy level increase (or for a dying fire's decreased signal strength); they only sense change of incident radiant energy. A fire's Planckian

blackbody radiant energy is essentially the radiant heat generated by the fire and is measured in watts and is the best indicator of fire's growth and decay.

In conclusion, all Fire Sentry FSX detectors utilize photoconductive quantum solid-state sensors. All other Triple IR flame detectors use either pyroelectric or thermopile thermal effect sensors. Pyroelectric and thermopile sensors all use temperature-dependent interference filters to obtain the narrow pass band spectral filtering. All of these detectors only rely on the narrow band 4.3-micron molecular emission of hot CO₂ (carbon dioxide) as the fire radiant energy sensing channel and use one or two adjacent narrow bands to compare against for background and false signal reduction. Hence, these types of flame detectors respond only to hot, carbon-based fires or false alarm scenarios that simulate these conditions.

All Fire Sentry WideBand IR flame and fire detectors utilize optical absorption and wide band interference filters that provide WideBand IR spectral coverage which includes all molecular emission lines (i.e., 4.3 micron CO₂, CO, etc.) for sensing both complete combustion flames, incomplete combustion (oxygen-starved) and sooty, dirty hydrocarbon and non-hydrocarbon (i.e., hydrogen, silane, ammonia, and metal fires, etc.) real world dynamic fires as well as hot and colder burning hydrocarbon fires such as isopropyl alcohol. Both growing and steady state fires are detected as well as shuttered and non-shuttered fires.