SENSE-WARE
THE FLAME DETECTOR COMPANY

Flame School Handbook

www.sense-ware.com

SW_Flame_School_Handbook_v0

Contents

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1. Introduction

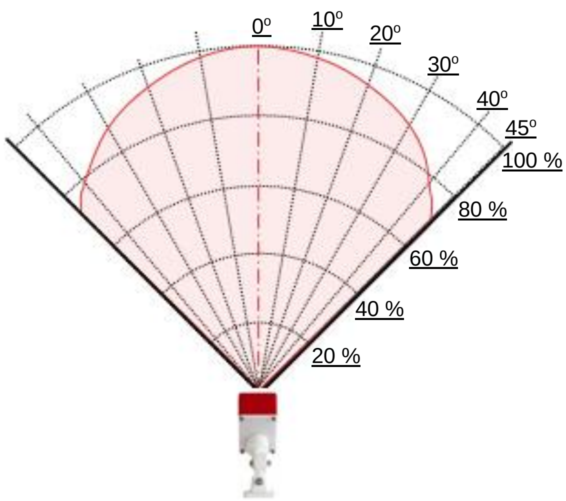
The Flame school handbook is meant as a guideline for end users, fire detector companies and installers who want background information before purchasing and commissioning of a fire safety installation. The Flame School Handbook provides information on flame detection properties, project design information and physical background information. In each section a self-containing subject is treated.

If you have specific questions, which are not answered in the Flame School Handbook, you can ask your question to SENSE-WARE info@sense-ware.com.

For the right choice of SENSE-WARE flame detectors for your application you can consult the flame detector selection guide on the website www.sense-ware.com.

2. Flame Detector Properties

2.1 Cone of Vision

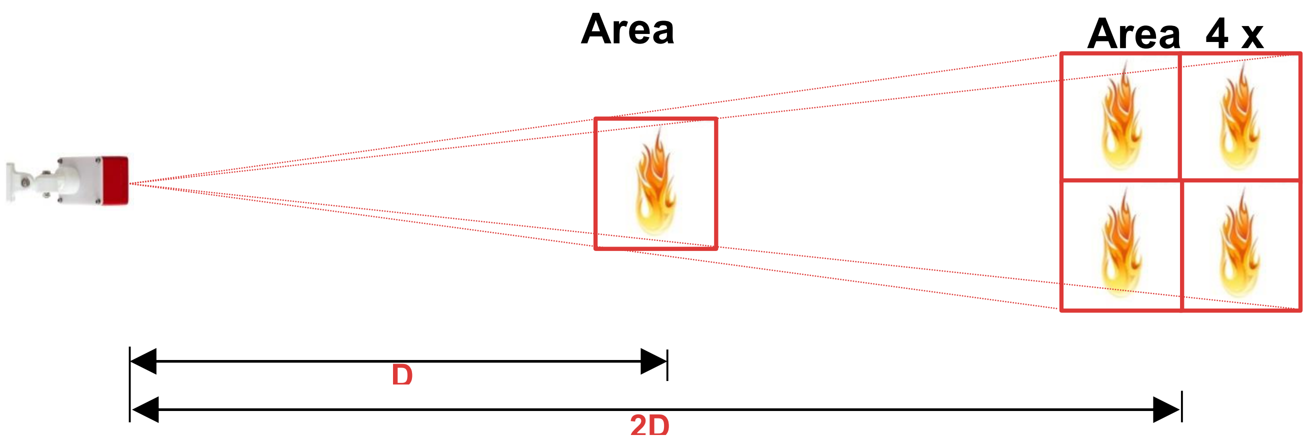


Cone of Vision.

The cone of vision of a flame detector depends on the shape and dimensions of the window/housing and the position of the sensor. With IR sensors lamination of the filter plays a role and can also limit the cone of vision. A wider cone doesn't automatically mean that the detector is better. Carefully aiming is needed to avoid having false alarm sources or friendly fires in the field of view.
The cone is three-dimensional and doesn't need to be perfectly cylindrical. The horizontal and vertical field of view are mostly different due to the shape of the housing or the location of mirrors. (applicable for flame detectors with an through the window optical self-test). Different fuels may result in different Cone of Visions in the same detector.

Very important is the sensitivity at the 45 degree edges. This must be minimum 50% of the maximum sensitivity on the central axis according to the American standard FM3260. Some detectors have a 70% or more performance here. In reality these detectors have a cone of vision that is wider than 90 degrees but the manufacturer normally will not provide this information. (See top picture). A high sensitivity at the edges of the Cone of Vision is an advantage when designing a flame detection system.

2.2 Square law



The Square law.

The square law is applicable to many optical devices including Flame Detectors. In this case the fire size and distance between the detector and the fire:

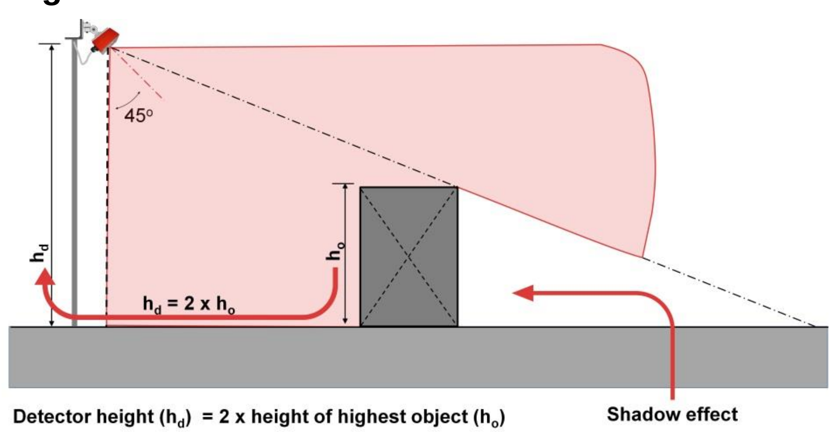
If a Flame detector is able to detect a fire at a certain maximum distance then the fire size must be four times bigger when the distance to the fire is doubled. In other words:

Double distance = four times bigger fire.

This goes for all fire detectors including the ones that are based on camera technology. The maximum sensitivity of a detector can be calculated by dividing the maximum surface A by the square distance: $c = A/d^2$.
With this factor "c" you can calculate the maximum distance d = root(A/c) and minimum fire surface $A = c \times d^2$.

NOTE! This calculation cannot be used infinitely. When the distance increases factors such as water vapor, cold CO_2 and flame flicker have more impact.

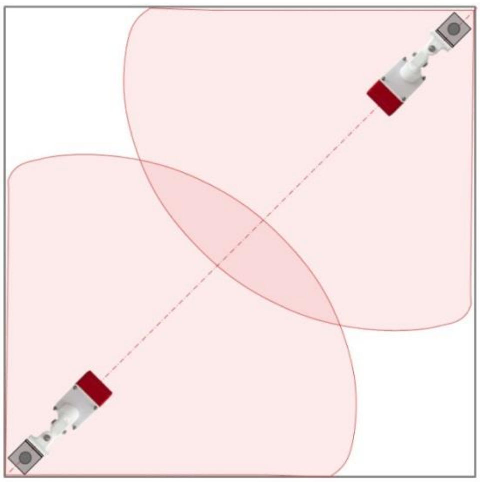
2.3 Detection range

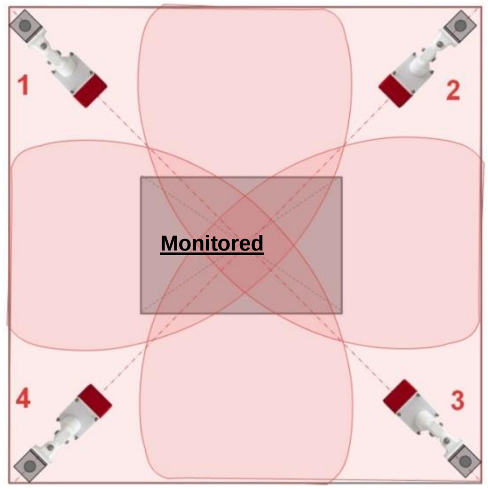


Detection Range.

The detection Range of a Flame Detector is very much influenced by the way the detector is installed. If fact you should put yourself in place of the detector and experience what the detector sees.

A rule of thumb is that the detector is put on a height that is twice the height of the highest object in the area. Beware of the fact that the detector needs maintenance and maybe even repairs. A retractable mast with little swing is recommended. A little roof (30 x 30 cm or 1 ft x 1 ft) protects the detector against quick contamination of the window.

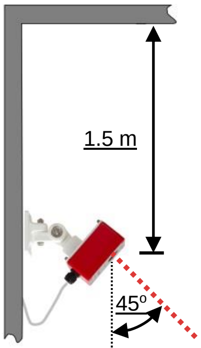




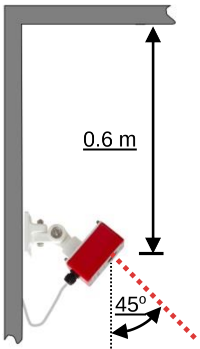
Be aware of the shadow effect. You can avoid the shadow effect by putting another detector in the opposite corner. This second detector also works as redundant device in case the other detector is blocked.

Due to the diminished sensitivity on the edges of the field of view there can be blind spots in the design. The detector will respond to a fire but that fire needs to be bigger. In practice this can be a fire that is four times larger than needed in the central axis.

NOTE: When using Flame Detector indoors please keep in mind that smoke absorbs fire radiation. A smoke layer at the ceiling will almost blind the UV detector but the IR detector is less effected. Please put UV detectors at least 150 cm (5 ft) from the ceiling and IR detectors at least 60 cm (2 ft).



UV Detector



IR Detector

2.4 Properties of SENSE-WARE Flame detectors

Legend

Sensor type	Impact	Detection range	Sensitivity
UV = Ultraviolet	' small	✗ very low	● very low
UV/IR = Ulitraviolet/Infrared	• medium	✓ (orange) moderate	●● low
IR3 = Triple Infrared or IR/IR/IR	● high	✓ (green) high	●●● medium
			●●●● high
			●●●●● very high

Property		UV-185/5	UV/IR-210/1	IR3-109/1
210 series Flame Detector				
Unwanted Alarms	Electric welding	●	•	•
	Static arcs	●	'	'
	Halogene lighting (without glass cover)	●	'	'
	Heat sources	'	'	'
	Chopped heat sources & electr. welding	'	'	'
	Chopped heat sources	●	●	•
	Direct or indirect sunlight	'	'	'
Inhibitors (make the detector less sensitive)	Oil and grease on the detector window	●	●	'
	Water or ice on the detector window	'	•	•
	Salt film on the detector window	●	●	•
	Dust and dirt on the detector window	●	●	'
	Hydrocarbon or Chlorine vapor	●	●	•
	Fog and rain	'	•	•
	Heat sources	'	'	'
	Chopped heat sources	'	'	•
	Smoke	●	●	•
Fires	Hydrogen	✓ (high)	✓ (high)	✗
	Ether, Methanol	✓ (high)	✓ (high)	✓ (high)
	Metals	✗	✗	✗
	Wood, paper	✓ (high)	✓ (high)	✓ (high)
	Gas (butane, propane or equivalent)	✓ (high)	✓ (high)	✓ (high)
	petrol, diesel or equivalent	✓ (moderate)	✓ (moderate)	✓ (high)
Response time/ sensitivity	normal	8 sec.	4-8 sec.	4-8 sec.
	Sensitivity	●●●	●●●	●●●●

During the design of a flame detection system the end-user will be asked to estimate the required fire size to be detected and its relation to the ignition probability and the consequential losses. The end-user has the best expertise to make an estimate of what the consequences are of a fire and how quick his organization is able to respond with follow up actions such as extinguishing and shut downs.

Flame detection system fires with Heptane as a reference fuel:

33 x 33 cm (10 kW) for "very high risk", approx. 650 ml Heptane

A. 50 x 50 cm (25 kW) for "high risk", 1500 ml Heptane
B. 100 x 100 cm (100 kW) for "moderate risk", 6000 ml Heptane

An estimate of the risk can be made with help of the zone classification of the ATEX 137 standard, the ignition probability and the expected consequential loss. The default response time is; a positive detection within 30 seconds. In an ATEX 137 zone 0 there is almost always an explosive (gas)mixture in the area and therefore always the design fire A (33 x 33 cm) will be applied. Below a table is shown which enables getting an indicative image of the performance fire size:

ATEX 137	Ignition probability	Consequential damage	Performance Fire
0	-	-	A
1	very high	very high	A
1	very high	high	A
1	high	very high	A
1	high	moderate	B
1	moderate	high	B
1	moderate	moderate	B
2	very high	very high	B
2	very high	high	B
2	high	very high	B
2	high	high	B
2	moderate	high	C
2	moderate	moderate	C

For industrial safe areas (areas where no explosion hazardous gases and vapor will occur) with flammable solids one may take the ATEX 137 zone "2".

When determining the ignition probability one should for example take the risk into consideration that a vehicle might collide with the object or that several hot machines or electrical equipment are in the vicinity. Also phenomena such as lightning or the fire risk in adjacent buildings should be taken into account.

Consequential losses are for example production losses, damage on production facilities, unscheduled shut downs, environmental damages etc.

Caution: The table shown and the descriptions are purely indicative with the purpose to enable the end-user to determine the size of a performance fire.

Example:
For a for gasoline and diesel loading area the performance fire size may be estimated as follows:
- Jetty:
The location of the interface between the vessel (ship) and the equipment on the dock is often ATEX zone 2, the ignition probability is high and the consequential losses are very high: design fire B. The rest of the Jetty and the Vessel itself: design fire C.
- Interconnecting piping between Jetty and Storage Tanks:
The pipe-racks have a moderate risk and high consequential losses: performance fire C.
- Loading location:
The location were the fuels are pumped into the tank of the truck has a very high ignition probability because of a hot exhaust or hot brakes of the truck and also because of the occurrence of much electrical (measuring)equipment and

the consequential losses are high: performance fire A.

Detection distance:
The system design distance of a flame detector relative to the object to be protected in a system design lies on 70% of the maximum distance as a safety factor to compensate for spurious factors:

Indoor application:
- The height of the room, due to the accumulation of smoke under the ceiling.
- The ventilation grade.
- The lighting.
- The ambient temperature.
- The relative humidity.
- The reflection-properties of the obstacles, walls, floor and ceiling of the room.
- The height above sea level.

Outdoor application:
- The wind velocity and direction.
- The outdoor temperature.
- The relative humidity.
- The reflection properties of obstacles and objects.
- The occurrence of sunlight.
- The position of the sun.
- The height above sea level.

Factory setting:
The manufacturer supplies the flame detectors with a standard setting which is typically 50% to 75% of the maximum sensitivity. The reason is normally the suppression of the probability of false alarms but under special conditions it is possible, after consulting the manufacturer, to deviate form the standard settings. You can also agree with the end-user that the standard settings are compensated in the design of the flame alarm system. It is also possible to agree that for example at the take over point the flame detectors are tested at the highest sensitivity and after the test are put back into the default factory settings.

Contamination: Often the decay of the sensitivity due to contamination on the flame detector window is neglected. Because of contamination regular maintenance is obligatory. Flame detectors with a Built in Test automatically check the window of the flame detector. A negative test means that the detector has only 50% of the original sensitivity of the detector but a blob in the middle of the window might not be detected while the flame detector is completely blind. Compensation is necessary for critical applications.

Cone of Vision limitation:
The sensitivity of flame detectors on the edge of the cone of vision is often not as high as the sensitivity in the optical axis of the flame detector. Often the minimum sensitivity is 70% at a total cone of vision of 90 degrees.

Example:
The end-user has determined that for an outdoor application a target fire of 33 x 33 cm Heptane must be detected and there must be a spacial coverage. The pollution is limited and therefore no compensation in the design is necessary for the pollution.

One applies a flame detector at a maximum detection distance of 60 meters for a 33 x 33 cm Heptane fire if the highest sensitivity settings are set. The factory setting is 75% of the maximum sensitivity and these settings will be applied in the project. The sensitivity on the edges of the field if view of the flame detector is 100% on 45 degrees off the optical axis.
Maximum distance from to the object on the optical axis of the flame detector :
60 meters x 0,7 (spurious influences compensation) x 0,75 (factory setting) = 31,5 meters.

3.2 System design questions

Before applying flame detectors you need to ask (yourself) a numbers of questions:

1 - Can the flame detector "see" the fire?

The detector choice depends on the kind of fuel at the application. A UV flame detector can detect virtually every fire, Hydrocarbon as well as non-Hydrocarbon based. An IR flame detector based on 4.4 micron radiation (CO_2 emission of a fire) can only detect Hydrocarbon fires such as burning Wood, Paper, Petrol or Natural Gas. Non-Hydrocarbons such as Hydrogen, Magnesium or Sulfur burn without CO_2 emissions and cannot be detected with a traditional IR or UV/IR (AND) detector. **See the properties table**!

2 - How big are the flames?

The distance between the flame detector and a fire and the surface of that fire are related by the square law. It means that when the distance from the detector to the fire is doubled the fires needs to be four times larger. E.g. a detector detects a 0.09 m^2 (1 sqft) gasoline fire at 15 meters (45 ft). In order to see the fire at 30 meters (90 ft) the size of the fire needs to be at least 0.36 m^2 (4 sqft). **See the chapter: square law. Double distance = 4 times larger fire**

3 - Are there any inhibitors?

It is important to know if there are inhibitors present or emerge from the fire. An inhibitors is a substance that blinds the flame detector. E.g., a UV detector will be blinded by oil or grease on the lens, Hydrocarbon vapors such as Xylene en Toluene, Chloride vapors etc. An IR flame detector will be blinded by fog, water and ice or a salt layer on the lens (salt takes up water). A multi IR flame detector can be blinded or masked by blackbody radiation from hot machinery or direct sunlight. **See the properties table**!

4 - What false alarm sources are present at the application?

A false alarm is the worst that can happen besides non-detection of course. The user looses faith and maybe a real fire alarm is discarded out of disbelieve. A UV flame detector false alarms to the radiation of Arc Welding, Halogen lamps or high pressure mercury lamps (without the protective glass), corona and static arcs. An IR flame detector may false alarm to chopped black body radiation and in some cases direct chopped sunlight. Multi IR sensor detectors are less susceptible to blackbody radiation or chopped sunlight but get insensitive. **See the properties table**!

5 - How fast is the detector?

In order to detect a munitions fire you need an extremely fast detector. A UV flame detector is able to detect (under ideal conditions) a fire within 10 msec. Usually such speed of response is not required and a time delay of 3 seconds is used. An IR flame detector responds in 3 to 10 seconds to a fire. **See the properties table**!

6 - How do you mount the flame detector?

Mount the detector in such a way that it covers the object that needs protection. **Try to see" from the detectors point of view see the chapter shadow effects.** Avoid shadows by e.g. putting another detector in the opposite corner. Most flame detectors have a cone of vision of 90 degrees, so 45 degrees from the central axe. Place the detector under an angel of 45 degrees downwards. This way the detector sees straight down and straight forward and so catches the least amount of dirt. Avoid having potential false alarm sources such as flares in the cone of vision.

3.3 Project description

For industrial projects it is necessary to follow the detection system design directives of the manufacturer and to involve the know-how of the supplier. The supplier can make an analysis of the flame detection aspects of the project by means of a "project description". It thoroughly describes the application and gives a clear motivation of the detection choice. National engineering standard or directives and the standard EN54 part 10 are not suitable for flame detection in industrial applications.

3.4 Project description flame detection, Explanation

Project name:	Name of the company and the site
Date:	The person who fills in this project description
Author:	
Object description:	For example: tank storage, silo, recycling

Fire properties

Class of risk:	Class of risk: For example: safe area, zone 2 (cat. 3), zone 1 (cat 2) etc.
Aggregation of the combustible:	For example: liquids, gases and solids.
Type of combustible:	For example: hydrocarbon or non-hydrocarbon
Type of fire:	For example leakage fire, spill fire, smoldering fire
Source of risk:	For example: disturbance of the process, accident with a vehicle.
Ignition source:	For example: spark, self ignition, activities like welding, hot exhausts or brake shoes.
Consequential losses:	For example: production losses, shut down approx. 8 weeks.

Situation

Location:	For example: outdoor, indoor, lean to.
Object shape:	For example: silo, vessel, pipeline, duct, atrium.
Limitation in the field of view:	For example: drain, lean to, vehicles
False alarm sources:	For example: chopped heat sources, corona, welding, flares.
Inhibitors:	For example: water, snow, ice, dust, fat, (chopped) heat sources, (direct) sunlight, vehicles, shadow effects.

Performance

Fire size to be detected:	For example: 10 kW, 25 kW or 100 kW n-heptane.
Response time:	For example: alarm within 30 seconds and follow up within 180 seconds.
Follow up:	For example: alarm, shut down, evacuation.
Projection:	For example: room-protection, single, complementary, voting.
Position:	For example: mounting height, angle of vision limitation.

Detector choice

Suitability:	For example: suitable for non-hydrocarbon fires.
Protection type/class;	For example: IP54, ATEX 95 category 2.
Strengths and weaknesses:	For example: 4.4 μm IR is desirable in this application, because of the possible occurrence of oil mist, despite the possible occurrence of water and ice.
Compensation conditions:	For example: 70% in clean free air conditions.
Compensation factory settings:	For example: 75% of the total sensitivity.
Compensation cone of vision:	For example: 50% for spatial detection.
Auxiliaries:	For example: adjustable mounting bracket, self test.

Test fire

Execution of test fires has many disadvantages. It is impossible to simulate laboratory conditions in a project on a site. A test fire is purely indicative and gives the observer an impression of a number of aspects of flame detection. How does a 25 kW n-heptane fire look? During execution of the test fire, possibly many fumes and dust will released, which will influence the subsequent tests. Also temperature, wind velocity and humidity have a significant influence on the test. Please take care of the personal safety.

3.5 Project description flame detection template

Project name:	
Date:	
Author:	
Object description:	

Fire properties

Class of risk:	
Aggregation of the combustible:	
Type of combustible:	
Type of fire:	
Source of risk:	
Ignition source:	
Consequential losses:	

Situation

Location:	
Object shape:	
Limitation in the field of view:	
False alarm sources:	
Inhibitors:	

Performance

Fire size to be detected:	
Response time:	
Follow up:	
Projection:	
Position:	

Detector choice

Suitability:	
Protection type/class;	
Strengths and weaknesses:	
Compensation conditions:	
Compensation factory settings:	
Compensation cone of vision:	
Auxiliaries:	

Test fire

3.6 Table: Comparison of Automatic Fire Detectors

T = Temperature detection
R = Smoke detection
F = Flame detection

more black bullets = better performance

Detector group	Detector type	Point detector	Linear detector	Beam detector	Sample system	Radiation detector	Purchase price	Cost of installation	Response time	Sensitivity	unwanted alarm resistance	Inhibitor resistance	Self-test	Maintenance friendly	Suitable for outdoor use
T	Heat detector High temp.	■	□	□	□	□	●○○○○	●●○○○	○○○○○	○○○○○	●●●●○	●●●○○	●○○○○	●●○○○	●○○○○
T	Heat detector rate of rise	■	□	□	□	□	●○○○○	●●○○○	●○○○○	●○○○○	●●●○○	●●●○○	●○○○○	●●○○○	●○○○○
T	Heat detector R.O.R.& High	■	□	□	□	□	●○○○○	●●○○○	●○○○○	●○○○○	●●●○○	●●●○○	●○○○○	●●○○○	●○○○○
T	Linear heat detector	□	■	□	□	□	●●●○○	●●●●○	●●○○○	●●○○○	●●●○○	●●●○○	●○○○○	●●●○○	●●○○○
R	Optical smoke detector	■	□	□	□	□	●○○○○	●●○○○	●●●○○	●●●○○	●●○○○	●●●○○	●○○○○	●○○○○	○○○○○
R	Ionisation smoke detector	■	□	□	□	□	●○○○○	●●○○○	●●●○○	●●●○○	●●○○○	●●●○○	●○○○○	●○○○○	○○○○○
R	Open path smoke detector	□	□	■	□	□	●●●○○	●●●○○	●●●○○	●●●○○	●●○○○	●●●○○	●○○○○	●●●○○	○○○○○
R	Smoke sample system	□	□	□	■	□	●●●○○	●●●●●	●●●○○	●●●●○	●●○○○	●●●○○	●○○○○	●○○○○	○○○○○
R	High sensitive smoke detection	□	□	□	■	□	●●●○○	●●●●●	●●●●○	●●●●●	●●○○○	●●●○○	●○○○○	●○○○○	○○○○○
R	Video smoke detection	□	□	□	□	□	●●●●●	●●●○○	●●●●●	●●●●●	●●●●○	●●●●○	●○○○○	●●●○○	○○○○○
F	UV flame detection	□	□	□	□	■	●●○○○	●●●○○	●●●●●	●●●○○	●●○○○	●●○○○	●●●○○	●●○○○	●●○○○
F	IR flame detection	□	□	□	□	■	●●○○○	●●●○○	●●●●●	●●●○○	●●○○○	●●●○○	●●●○○	●●●○○	●●●●○
F	UV/IR flame detection	□	□	□	□	■	●●●○○	●●●○○	●●●●●	●●●○○	●●●○○	●●○○○	●●●○○	●●○○○	●●●○○
F	IR2 flame detection	□	□	□	□	■	●●●○○	●●●○○	●●●●●	●●●●○	●●●●●	●●●●○	●●●○○	●●●●○	●●●●○
F	IR3 flame detection	□	□	□	□	■	●●●●○	●●●○○	●●●●●	●●●●●	●●●●●	●●●●○	●●●○○	●●●●○	●●●●○

3.7 Flame Detection Checklist

Please fill in this form as complete as possible and send it to SENSE-WARE info@sense-ware.com for a free advise,

Item	Check
1a Which combustible must be detected?	
Wood	
Paper	
Plastic (packaging)	
Petrol or gasoline and equivalent	
Solvents like xylene and toluene	
Natural gas	
Butane, propane and equivalent	
Ether, Methanol and equivalent	
Hydrogen	
Sulfur and metals like magnesium	
Ammunition	
1b Which color do you think the flame will have?	
Yellow/red	
Yellow/blue	
Blue	
Transparent/light blue	
2a What should be the size of the fire to be detected? Check	
0.1 m2 (33 x 33 cm) 1.2 sqft	
0,25 m2 (50 x 50 cm) 2.7 sqft	
1 m2 (100 x 100 cm) 11 sqft	
2b What us the distance to the fire to be expected? Check	
Less than 5 meter (15 ft)	
Less than 10 meter (30 ft)	
Less than15 meter (45 ft)	
More than 15 meter (45 ft)	
3a Do the following inhibitors apply?	
Water vapor, spray or fog	
Oil and grease; mist or spray	
Ice film	
Salt film	
3b What is the climate?	
Tropical	
Subtropical	
moderate	
Cold	
Extremely cold	
3c Is it an indoor or an outdoor application? Check	
Indoor	
Outdoor	
Roof only	
3d What is the application? Check	
Industrial	
Domestic	
Outback	
4 Are the unwanted-alarm sources? Check	
Electrical welding within 3 km distance	
Direct sunlight on the detector window	
Static arcs	
Heat and hot machinery	
Movements and chopped hot objects	
5 What are the requirements regarding the response time?	
Less than 10 ms (for example for ammunition)	
At least 10 seconds	
Less than 30 seconds	
6 Can you easily repair and maintain the detectors?	
Bad	
Fair	
Good	

3.8 High-end vs mid-range flame detectors

It is very hard to define the quality of detectors in relation to an application and the risk involved. The end user has a certain budget to protect a plant and has to makes choices where to invest the monies in. Sometimes Insurance Companies set a minimum requirement but mostly the end users have their own procedures on Vendor/Product selection.

Generally an application such as an Oil & Gas Offshore Platform is considered to be high risk where lives are at stake. An investment in a High-End product can be justified in such an application.

Typical Applications for a High-End product:

- Offshore Platforms and FPSO's
- Process Areas
- When High Sensitivity is required to detect very small fires
- When SIL2 or higher is required
- When Heated Optics are needed
- When the flame detector is connected to a e.g. DCS via a PLC

Typical Applications for a Mid-Range product such as the SENSE-WARE 210 series Flame detectors:

- Recycling Plants
- Solvent Storages
- Gas Service stations
- Workshops
- Garages
- EV charging stations, Hydrogen filling stations
- When no SIL or only SIL 1 is required
- When installed in and around buildings
- When the flame detector is connected to a Fire Panel (EN54)

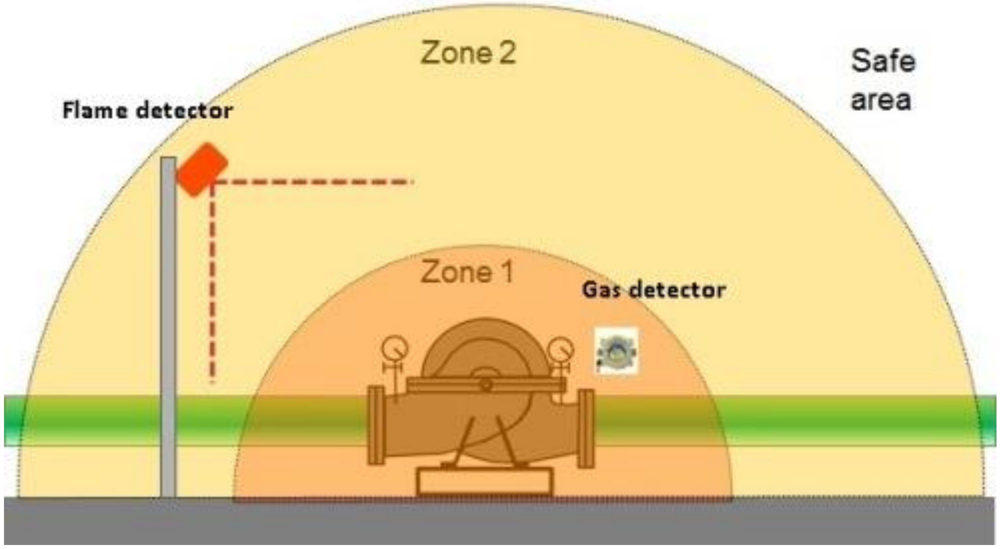
3.9 Flame Detectors Zone 1 versus Zone 2

In flame detection, an ATEX category 2 G certified product which is suitable for ATEX zone 1 is <u>not</u> a "better" product per definition than a category 3 G certified product which is suitable for ATEX zone 2. Just different.

There is a difference in approach of a flame detector as compared to a gas detector:

A <u>Gas Detector</u> is mounted close to a possible leak source such as a valve or pump as a typical ATEX zone 1 application. That is why a Gas Detector most logically has an EEx d or EEx ia construction.

A <u>Flame Detector</u> however is a line-of-sight device that is mounted at a certain distance from the hazard. At this distance the zone classification is normally zone 2 or Safe Area.



<u>This is one of the reasons why more than 85% of the Flame Detectors with EEx d housings, which are suitable for zone 1, are actually mounted in zone 2.</u>

Engineers design plants and installations with smaller ATEX zones 1 due to the high cost of operation of such hazardous areas. That is why zones 2 in the Industry are getting larger. More reasons to install ATEX category 3 G(D) equipment:

Pro's and Con's of EEx d housings for zone 1:

- + Rugged, Impact tested: 4 Joule (window) 7 Joule (housing)
- + Suitable for both zone 1 as well as zone 2
- - Heavy Aluminum or Stainless Steel
- - Has to be grounded
- - Corrosion sensitive

Pro's and Con's of non-Sparking (nonincendive) equipment for zone 2:

- + Rugged, Impact tested: 4 Joule (window) 7 Joule (housing)
- + Light weight GRP (Glass Reinforced Polyester)
- + No grounding required
- + Not sensitive to corrosion
- + Pressure Compensating Element ("breather") to avoid moisture build-up
- - Only suitable for zone 2

Zone explanation:

ATEX category 1 G equipment for zone 0:
-This equipment is suitable for an ATEX zone 1 application such as inside a storage tank. Flame detectors are not installed in these tanks generally due to e.g. contamination issues or limited line of sight. Gas detectors are not installed inside a tank since they will be alarming virtually all the time due to always present gas or vapor.

ATEX category 2 G equipment for zone 1:
-This equipment is suitable for an ATEX zone 1 application such as a Hydrocarbon pump (outside). Gas detectors are installed close to the possible leak. Flame detectors are not installed in close proximity to these objects generally.

ATEX category 3 G equipment for zone 2:
-This equipment is suitable for an ATEX zone 2 application such as around a Hydrocarbon pump (outside).

Flame detectors and the European standard EN54-10:2002

The European standard EN54 is a so called; "product standard". Part10 of this standard deals with the product requirements for flame detectors. In several European countries the national design standards refer to the standard EN54-10 for the quality requirements for flame detectors. The standard EN54-10 describes the quality requirements of the flame detector itself but not how the detector should be applied and if the detector is capable to detect a fire in a certain application. The standard EN54- 10 describes which laboratory tests the flame detector should pass; these are especially ambient and electrical aspects. The standard also describes a number of laboratory test fires, the flame detector must be exposed to and, after the tests, classifies the detector in one of three sensitivity classes. The EN54-10 will be revised by the PrEN54-10:2012. Sense-WARE thinks the changes are all positive although the standard is still strongly focused on avoiding false alarms. However, unfortunately, being able to detect flames under heavy EMC, ESD, shock or vibration conditions is not part of the tests. Also resistance to false stimuli is not a part of the revised standard. The scope is extended from "Buildings" to "In- and around buildings". In the PrEN a difference is made between flame detectors that are used mostly outdoors and mostly indoors. The PrEN practically excludes non-hydrocarbon fires such as Hydrogen, Munitions and Metals fires. And a fourth sensitivity class is added: "X" for flame detectors that can detector the standard fires at a distance of more than 25 m.

The national design standards and directives describe quality requirements of components and systems and also provides design guidelines for the fire safety in buildings.

'Buildings' in design standards and/or directives always mean public buildings (offices, hospitals etc.) The design guidelines in these national design standards and directives are typically suitable for point smoke detectors. In public buildings flame detectors are hardly applied. Flame detectors are used in a versatile range of applications. The detection system design of flame detectors in an Alcohol storage in a Hospital differs significantly from the detection system design of flame detectors utilized for monitoring a Generator Room. When designing the flame detection system it is necessary to follow the instructions of the manufacturer, rather than following the guidelines of the national design directive and frequently ask for the assistance of the manufacturer or his representative. The supplier considers in its design guidelines also the features of the application, such as monitoring of the contamination of the detector window, sensor self-test, and the aspects of detection of e.g. non-hydrocarbon fires.

It is possible to get an EN 54-10 approval for a simple UV flame detector in the highest sensitivity class, which is NOT suitable for 90% of the applications.

UV flame detectors are typically used for the detection of light- or non-hydrocarbon fires. UV flame detectors are not suitable for applications with the following false alarm and inhibitor risks: arc welding, unshielded halogen lamps and e.g. Corona. Blinding of the UV flame detector can take place by occurrence of Smoke, Gases, Vapors, Oil films, Silicones and Salt films. These limitations are not mentioned in the standard EN 54-10. A certificate of conformity with the standard EN54 part 10 however, is not a guarantee that the UV flame detector is the right choice for a certain application. For industrial objects a thorough analysis is necessary of the object and of the fires to be expected, the possible fire alarm sources and false alarm sources and also from pollution sources, which might negatively influence the sensitivity of the flame detector. In industrial applications in which hydrocarbon fires can occur in oily environments an IR flame detector, which is sensitive for radiation in the 4.3 micron range, are more suitable than a UV flame detector. Whilst the IR flame detector might be classified in the lowest sensitivity class (3) and the UV flame detector in the highest (1). Therefore the sensitivity class in the standard EN54-10 is not a guarantee for a proper performance in a certain application.

The sensitivity classification in the standard EN54-10 might suggest that a flame detector in the highest sensitivity class is automatically the best flame detector in all applications.

There is only a limited number of applications in which a very high sensitivity flame detector is important. Often the most sensitive flame detector is recommended, presuming this is always the right choice. There are more important factors, determining type and quantity of the detectors for a certain project. Important factors are for example the shadow effect and zone classification. For industrial projects the design guidelines of the manufacturer should be obeyed and the know-how of the supplier should be involved. For the project the supplier can make a project description of the application including a justification of the choice of the flame detector type. The national design standards and directives and the standard EN 54-10 do not add to a design of flame detection systems in industrial applications.

4 Developments in Flame Detection

Development of sensors

End of the sixties the development of automatic fire alarm sensors began. Electro-mechanical sensors already existed, such as temperature- and pressure-transmitters. The first automatic fire sensors were based on bimetals and determined a fire by measuring the (rising) temperature gradient of a fire.
For the measurement of light, smoke, gas and so on, specific sensors are necessary. Because of the developments in semiconductor components the new sensors could determine physical phenomena from the background. Complex electrical integrated circuits (ICs) enabled the product developers to transform the signals of the sensors into a useful alarm.

Miniaturization

End of the seventies the themes „unwanted alarm suppression“ and „miniaturizing“ were important. The sensors were able to measure, but were not very selective. With help of miniaturizing the sensors became cheaper and this initialized an increase in the demand. Because of the high production volumes the sensors became even cheaper and the market was saturated with a wide range of sensors; not all of them had the same high quality. The consequence was a high amount of unwanted alarms and the demand for regulation for product requirements, planning projecting, and maintenance of fire alarm systems.

Intelligent signal processing and multi-sensors

End of the eighties the intelligent signal processing was introduced. This was made possible by the quick developments in the processor industry. Algorithms gave the possibility to process the signals in a complex way and therewith enhance the reliability. The technique became nice names like “Fuzzy Logic”. “Self-learning software” (“neural networks”) were able to suppress unwanted alarms in a spectacular way. Next to the use of multi-sensors was the border between the suppression of unwanted alarms and the neglect of real fires however unpleasantly small. It occurred that real fires were not detected, because the presented themselves in a way, which was not expected by the product developers.

New sensors technology

End of the nineties the industry understood that the sensors did lack an insufficient intelligence and did not fully utilize the capabilities of the powerful processors. A human being observes events by means of the senses, like feeling, hearing, seeing, smelling and tasting. From these the visible information is the most important for the diagnose of the size of a fire. The alternative for the human eye is the camera. By processing the image material one has a wide variety of sensors. Each pixel is in fact a sensor. With the information of these pixels the processor can make its calculations. The video technology has had an significant progress and compression techniques are improving very fast. The first camera detection observed unwanted persons, without the necessity to let the security guard focus on the monitor continuously. By means of movement analysis of the pixels in the camera image, one can even determine if a person is moving in a suspect way through a crowd. Face recognition is today very common, and also traffic management systems with cameras and computer. The human being at highest makes the decisions.

Alarm verification

Today, there is demand for quick verification of alarms with human causes, because the systems are not (yet) able to make their decisions independently. And may-be this is undesirable. The decisions should be taken in your organization. The rise of (mobile) internet enables sending images, sound and even video real-time all over the world. Alarms can be sent to smart phones, to enable the expert (for example a fire fighter) to judge, what is the right response.

5 Test fires for Flame Detectors

SENSE-WARE manufactures flame detectors for Industrial applications.
After installing a flame alarm system the design may be checked by means of a test fire but preferably one should in advance check the design in an actual situation. One should take changing circumstances into account and also, if necessary, seasonal influences.

Test fire with Heptane:

A. 33 x 33 cm (10 kW) approx. 650 ml Heptane
B. 50 x 50 cm (25 kW) approx. 1500 ml Heptane
C. 100 x 100 cm (100 kW) approx. 6000 ml Heptane

Laboratory:

It is almost impossible to simulate 100% laboratory-conditions at the site of the end-user (or in facility). If the purpose of the test is to observe the behavior of the fire relative to the behavior of a well-known test-fuel such as Heptane, then a description of the testing conditions is sufficient. By doing simulations of fires to be expected at the site of the end-user one can design a tailor made design of the flame detection system. The certificates (ATEX, FM) solely provide the legitimization of the design of the flame detector and the organization of the manufacturer of the flame detector.

In fact, preferably, one should test at the outdoor application of the end-user itself, because then the system is tested in the actual conditions. Weather influences can only partly be predicted. The manufacturer and his re-sellers, however, are able to provide a thorough advice about the possible spurious factors and how to deal with them.

Detection distance:

It is also possible to held a test on half of the detection distance with a quarter of the fire size. If a flame detector must be able to detect a fire of for example 100 x 100 cm Heptane on a detection distance of 60 meters one may, as an alternative, also test with a fire size of 50 x 50 cm at a distance of 30 meters. For more information see also the section "**square law**" on this web site The square law, however, is not infinitely valid.

Be aware:

the pan for the pan fire should be well positioned horizontally and should have a bottom clearance. The best solution is to reinforce the pan with help of ribs on the bottom of the pan, to avoid deformation of the pan, cause by the heat. For a design of the pan consult SENSE-WARE.

- after every test the pan for the test fire should be sufficiently cooled down to avoid boiling of the next batch of test fuel.
- extinguishing agents (for example CO_2) should be well vented after a test because the agent can significantly influence the results of a next test.
- at indoor applications, in between the tests, the room should be well vented to avoid accumulation of gases and fumes which can influence the results of the next tests.

Be aware of your one safety and that of others. Preferably a fire fighter should attend the fire tests and sufficient fire extinguishing devices should be available. In case of emergencies the victims should be quickly treated.

6 Physical Background

7.1 Fire Type

When analyzing the object that needs protection one has to determine what Fire Type (FT) is involved before selecting the right detector: Flame detectors are generally only suitable for flames so only type FT4, FT5 and FT6 fires can be detected. An Optical Smoke detector is only useful for FT3 (smoldering) Fires.

Not every Flame Detector is the same based on the sensors property. E.g. Flame detectors with a single frequency 4.3 micron IR sensor (CO2) is only suitable for FT5 and FT6 fires.

FT1: Sparks or Embers.
No visible flames or smoke.
Example:
FT1-1 Mechanical sparks
-Metal parts in a mill
-Nails in a timber shop
FT1-2 Electric sparks
-Short circuits
-Static electricity

FT2: Latent fire.
The fire is not visible yet and there is no smoke.
Example:
-Chemical reaction
-Heat Combustion (fermentation)
-Overheating (electrical) equipment

FT3: Smoldering fire.
No flames but smoke is present.
Example:

-Smoldering wood, plastic, cotton

FT4: Open fire, flames with little or no Carbon.
Example:
-FT3-1 Hydrogen fire, Methanol fire
-FT3-2 Metal fire such as burning Magnesium

FT5: Open fire, flames with Carbon and little or no smoke.
Example:
-Methane
-Acetone

FT6: Open fire, flames with Carbon and lots of smoke.
Example:
-Diesel
-Transformer oil
-Wood
-Plastic

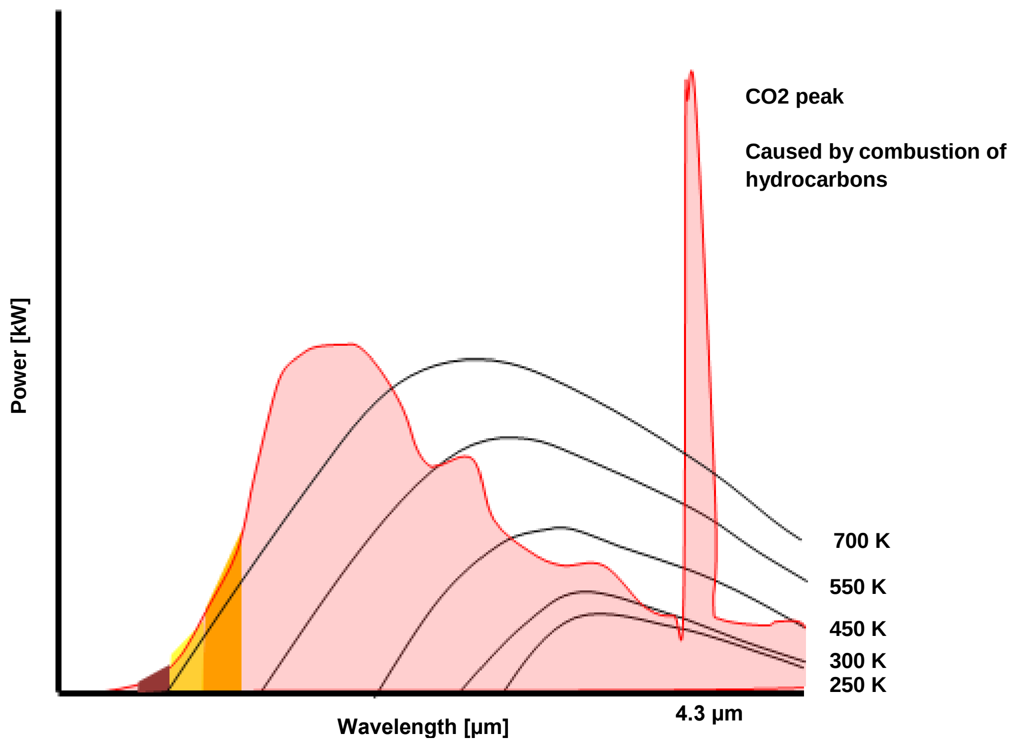
Also the physical state of the fuel needs to be recorded:
-Solids (S)
-Liquids (L)
-Gas (G)

Some special aspects of the expected fire needs to recorded:
-Spill Fire (SF)
-High Pressure Liquid (HPL)
-Low Pressure Liquid (LPL)
-High Pressure Gas (HPG)
-Low Pressure Gas (LPG)

Example:
Generator room in a Hospital:
Non-hazardous area; Fuel: Diesel and lube oil.

-Fire type: FT6, Spill Fire (SF for the Diesel tank and Lube Oil tank) and Low Pressure Liquid (LPL) for the fuel pump.
-Detector selection: Flame detector, Multi IR or UV/IR (+/- 1 meter below the ceiling).
-Design: 2 Flame detectors, diagonal, ensure that the spill area is in the field of view of the Flame detector.

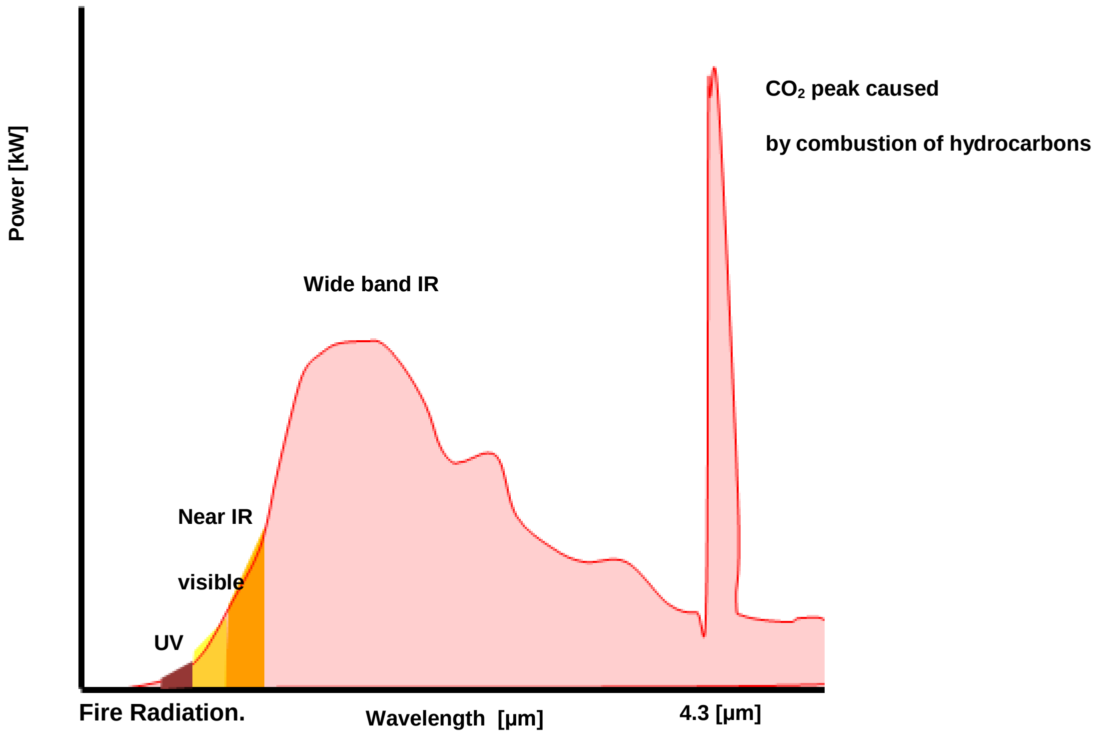
7.2 Black body radiation



Black body Radiation.

Infrared sensors are also effected by Infrared Radiation that is not coming from a fire. The fire can be masked by this Black body Radiation. Every object that has a temperature higher than the absolute minimum (0 Kelvin or -273 ºC) radiates energy and at room temperature the energy is already detectable for the most sensitive Infrared sensors. Some flame detectors have the feature that a moving hand close to the sensor of the detector is sufficient to generate an alarm. At 700 Kelvin a hot object already emits visible light energy (glowing). Dual or Multi Infrared detectors suppress the effects of Blackbody Radiation by sensing energy just besides the CO_2 radiation peak e.g. on 4.1 or 3.9 micron. The principle works on the fact that a real Hydrocarbon fire causes a difference between the sensors. See S1 and S2 in the picture above. A drawback is that there must be a larger difference in sensor output than the background radiation present. In other words, the detector gets insensitive when Black body Radiation is present. Every multi IR Flame Detector based on IR frequencies around 4,3 micron deals with this problem, no matter what the price of the device is.

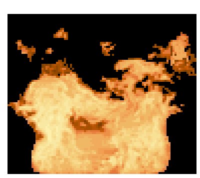
7.3 Fire radiation



Fire Radiation.

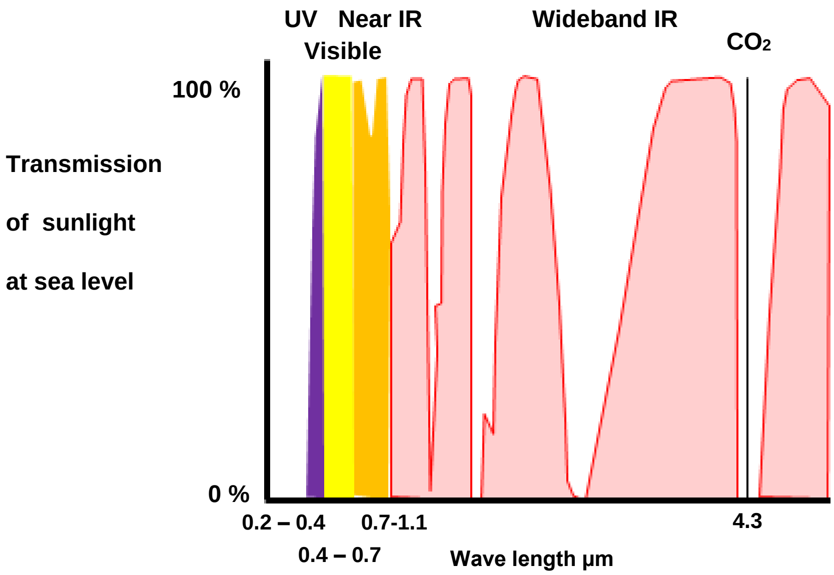
A fire emits an enormous amount of energy of which only a small part is light, which is visible to the human eye. As can be seen in the picture above most of the energy is invisible. The part that can be seen is mostly red-yellow in color caused by the carbon in a fire. The invisible IR part of the fire is experience as heat. A non-Hydrocarbon such as Hydrogen burns light blue-transparent because there is no Carbon in the flame. It also doesn't have the CO_2 peak at 4.3 μm and can therefore only be detected with a UV detector.

The CO_2 peak in the fire represents less then 2% of the total fire energy. A multi sensor Flame Detector that uses sensors such as UV, near IR, wide band IR etc. has much more sensor input and can therefore be more specific or less effected by false alarms.



It looks rather static but in reality the fire energy fluctuates rapidly. The Fuel and Oxygen in the uncontrolled fire constantly burn as in small explosions and then sucks new Fuel and Oxygen to the flames. This process causes the flame flicker. The typical frequency is between 1 and 20 Hz. Most Infrared Flame Detectors use the flicker frequency as an extra criterion in order to make the detector more reliable.

7.4 Sunlight transmission

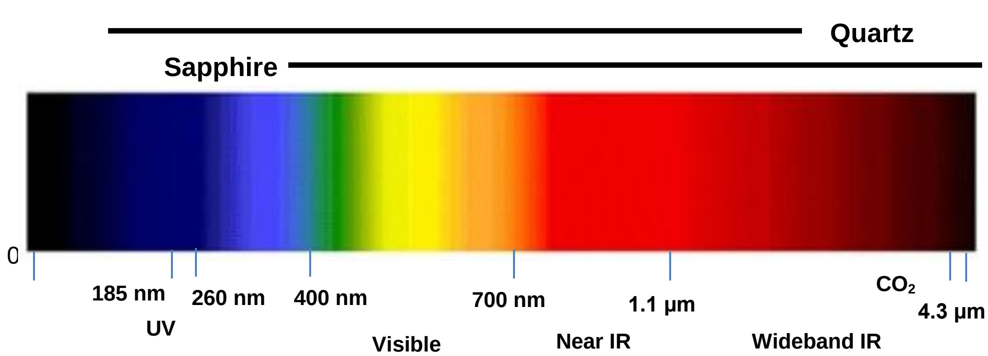


Sunlight transmission.

The sun is a powerful source of energy that also can be very harmful. However, most gases and vapors in the atmosphere such as water (clouds) and Ozone absorb sufficient radiation to protect us. In the picture above you can very well see that the sunlight is filtered around the 4.3 micron. The cold CO_2 in the air absorbs 4.3 micron energy and therefore Infrared flame detectors that use the 4.3 micron are Solar blind. The filter that covers the IR sensor of a flame detector must be very accurate (narrow) because it should not respond to IR radiation over and under 4.4 micron and therefore unfit for outdoor applications.

Between 0.7 and 3 µm a significant fraction of the sunlight is absorbed by the atmosphere. This frequency range is therefore used by some manufacturers for Flame Detection in combination with e.g. UV, Visible or Near IR. The economic advantage is that in this case an expensive Sapphire lens is not needed. It also makes it possible to detect non-Hydrocarbon fires such as burning Hydrogen, Sulfur, Magnesium etc. and still be false alarm resistant.

7.5 The Spectrum



The Spectrum.

The electromagnetic spectrum includes high frequencies (high energy) such as γ-rays and X-rays, ultraviolet, visible light, infrared and to low energy waves like radio waves and microwaves. Flame detectors typically detects a fire with help of UV, IR and sometimes visible light. A human being uses his/her sensors to "detect" a fire by visible input, heat sensors in the skin and even detect smoke gases by smelling. Our brain uses a natural algorithm to recognize it and respond to a fire situation. A flame detector also uses sensors and logic to generate an alarm. The more sensors we can make and the more processing power we have to calculate the algorithms the more reliable the detector is.

A Ultraviolet (UV) sensor for a flame detector is made for radiation input of 185 to 260 nm. This range is least effected by natural sources such as cosmic radiation and sunlight. Gases, vapor and smoke in the atmosphere filter the sunlight but also oil and grease on the window blocks the detector. Beware of these inhibitors because you won't know that they are there. Virtually every fire emits UV radiation and therefore the UV flame detector is a good "all round" detector. False alarm sources for UV detectors are Halogen and Quartz lamps without the protective glass, Arc welding, Corona and Static Arcs.

A Visible light sensor (0.4 to 0.7 micron) is able to produce a signal that people can understand and process. Visual Flame Detection is based on analyzing pixels using sophisticated algorithms. Still the camera detector can be blinded with smoke or fog. It is also possible to mix the images of the visible camera with a UV camera. The Corona camera is an example of this technology. It is used for sensing defects in high voltage installations and also makes fire detection possible over large distances under ideal conditions.

A Near Infrared sensor (0.7 to 1.1 micron) is less effected by water and water vapor. Used for the detection of e.g. munition fires or embers in air ducts. This sensor is not solar blind.

A Wide band IR sensor (1.1 micron and higher) looks at the heat of fire. A special frequency is 4.3 micron. This is the resonance frequency of CO_2. When burning a Hydrocarbon such as Wood, Gasoline or Natural Gas this energy is released. It causes a peak in the spectrum that can be easily detected. When the CO_2 cools down it starts absorbing the 4.3 micron energy. This is typical for all elements: when they are hot send out radiation in their resonance frequency and when they are cold they absorb energy in that same frequency. The cold CO_2 filters the sunlight away (at sea level) and makes the IR detector Solar blind. By analyzing the flicker frequency of a fire (1 to 20 Hz) IR detectors can be more false alarm resistant. Multi IR detectors use algorithms to suppress the effects of blackbody radiation. This always makes the detector less sensitive since the blackbody radiation masks the fire. Sunlight has the same effect.

A disadvantage of IR detectors based on 4.3 micron (appr. 3.5 micron and higher) is that some energy in that range may be absorbed by water (ice and water on the detector window). I.e Fog, snow or water spray decrease the sensitivity of the detector. By correctly aligning the detector in many applications the contamination of the detector window with water or ice can be avoided. Also a part of the problem can be solved by a “through the lens” self-test of the detector window so you know that the transmission through the window has decreased by the absorption. In severe environments heating can be included the detector window to vaporize the water.

A sensor must be protected from the environment by a housing with a window. That window must be able to transmit the radiation you are looking for. Different materials have different filter properties. Quartz can be used for UV detectors but not for 4.3 micron IR flame detectors. Sapphire is suitable for IR (up to appr. 6 micron) flame detectors but only for UV radiation when the window is less than 3 mm thick and it is much more expensive. In the picture above you can see the ranges that are involved with the transmission of the Quartz and Sapphire windows.

7 Glossary of Terms

Term	Definition
Air shield	Device to avoid deposition of debris on a detector window of a flame detector with help of pneumatic air.
ATEX	European standard for explosion protection.
Automatic fire detector	Fire detector based on the measurement of physical fire phenomena, like emitted light, particles or heat
Cone of vision	
Detection distance	The distance between the fire source and the fire detector.
(Detection) zone	A geographical sub-division of the protected premises in which one or more points are installed and for which a common zonal indication is provided.
Detector group	A (virtual) group of detectors, monitoring a detection zone.
Detector loop	A hardware cable, on which detectors are connected.
Detector window	Transparent window of the flame detector, to enable relevant radiation of a fire to enter the flame detector
Dual IR	IR Flame detector with 2 different IR sensors
False alarm	Alarm, without a physical reason
Field of view	
Fire control panel	Equipment to centralize inputs and outputs in a fire detection installation.
Fire detection installation	
Fire size	Pan fire dimension in sqrft or cm^2
Flame detector	A detector which responds to the radiation emitted by the flames from a fire.
Heat detector	A detector which responds to an increase in temperature.
Infrared flame detector	Flame detector, responding to infrared radiation of a fire.
IR flame detector	Flame detector, responding to infrared radiation of a fire.
Latching / non latching	Synonyms to self-resetting/non self-resetting. Self-resetting detector: A resettable detector which will automatically restore itself to its normal state of readiness to detect.
Manual call point	A component of a fire detection and fire alarm system which is used for the manual initiation of an alarm.
Mast mounting	
Multiband detector	a flame detector having two or more sensing elements, each responding to radiation in a distinct wavelength range and each of whose outputs may contribute to the alarm decision.
Performance requirement	
Point detector	A detector which responds to the phenomenon sensed in the vicinity of a fixed point.
Protected area	
Reset	
Sensitivity	a measure of the ability of a flame detector to detect fires
Shadow effect	The effect that the light of a light source is obstructed by objects between the light source and the observer.
Shielding	
Smoke detector	A detector sensitive to particulate products of combustion and/or pyrolysis suspended in the atmosphere (aerosols).
Square law	The law saying that the intensity of the light of a flame is inverse proportional to the square of the distance from the light source to the observer.
Test lamp	Device for functionally testing the
Triple IR flame detector	
Ultraviolet flame detector	Flame detector, responding to ultraviolet radiation of a fire.

Undesired alarm	Alarm, caused by a physical phenomenon, which is used to detect a fire, but nevertheless is from a “friendly fire”.
UV flame detector	Flame detector, responding to ultraviolet radiation of a fire.
UV/IR flame detector	Flame detector, responding to ultraviolet and infrared radiation of a fire.
Video flame detection	Flame detection by means of a video camera and firmware.
Visual light sensor	Sensor in a flame detector, responding to visual light.
Wall mounting	Mounting of the detector to a wall.

Remark: for a part of the definitions we refer to the standard EN54 parts 1, 2 and 10.