Fire & Gas Detection in Process Industry

Topics Covered

- Hazard Management and Requirement of F&G Detection in Industry
- Working Principles of Fire, Heat & Gas Detectors
- Detectors There Coverage
- Comparison of Fire & Gas Detectors
- Detector Selection and their Applications
- Cause and & Effect
- Comparing QRA Results, Hazardous Area and F & G Layout
- Exercise Selection and Placement of Fire & Gas Detectors
- Considerations when placing F& G Detectors and Areas of Concerns
- Working of F & G Safety Systems
- Fire, Smoke and Gas Detection Selection and Application Guide
- Sample Layouts of Fire, Smoke and Gas Detectors
- Detector Voting Logic – Not Covered
- F&G 3-D Mapping – Not Covered

Presentation Part - 1

Hazard Management and Requirement of F & G Detection in Industry

F&G Applications in Process Industry

Wide range of process industries use and manufacture Hydrocarbon and Toxic Liquids and Gas:

- ❑ Gas Compressor Stations
- ❑ Pipelines
- ❑ Gas Turbine Power Plants
- ❑ Oil and Gas Terminals
- ❑ Refineries
- ❑ Oil and Gas Storage Tanks
- ❑ Oil and Gas Platforms

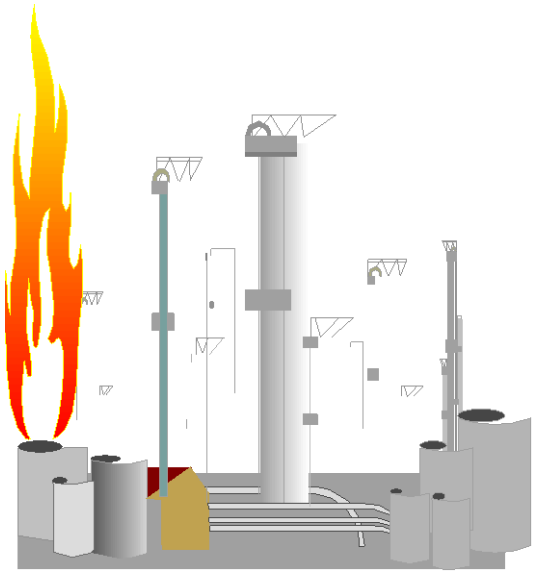
Intro Movie Clip

Type of Hazards in Process Industry

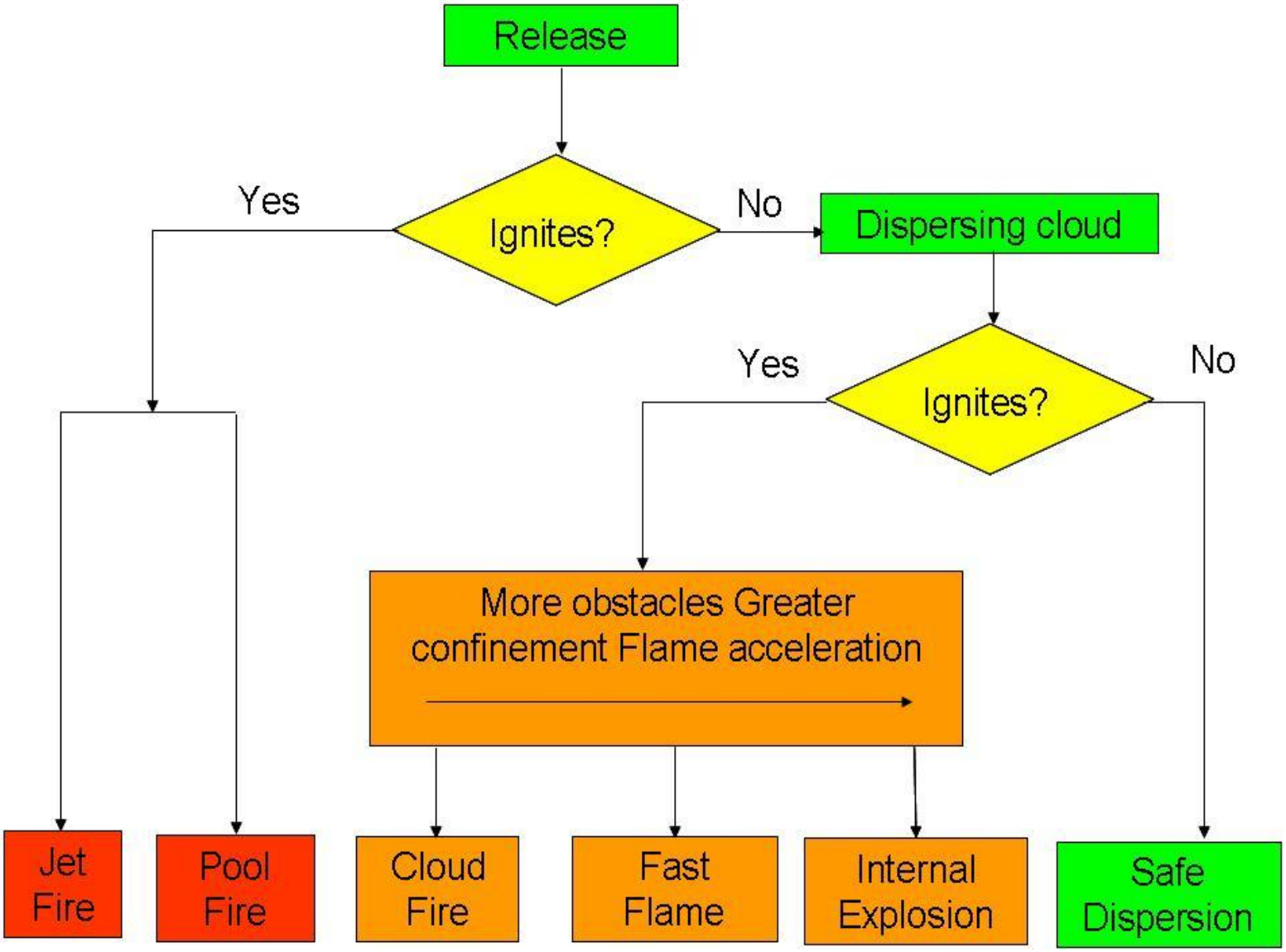
- Hazard :
  - Toxicity
  - Flammability
  - Reactivity

Chemical Hazard Examples:

- Hydrocarbon (flammable gas and liquids)
- Sulfuric Acid (toxic and reactive)
- Chlorine (toxic and reactive)
- Hydrogen Peroxide (unstable and reactive)



Hazardous Material Release

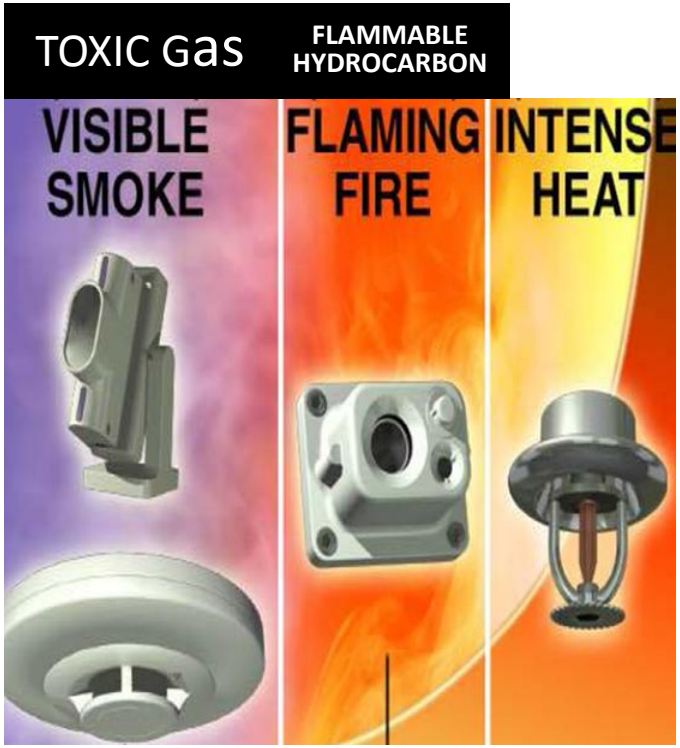


Hazardous Scenarios of Concern

- **combustible**
  - methane (CH_4); hydrogen (H_2)

- **toxic**
  - carbon monoxide (CO); hydrogen sulphide (H_2S)

- **asphyxiant**
  - nitrogen (N_2); carbon dioxide (CO_2)



Hazard Management

System Safeguards:

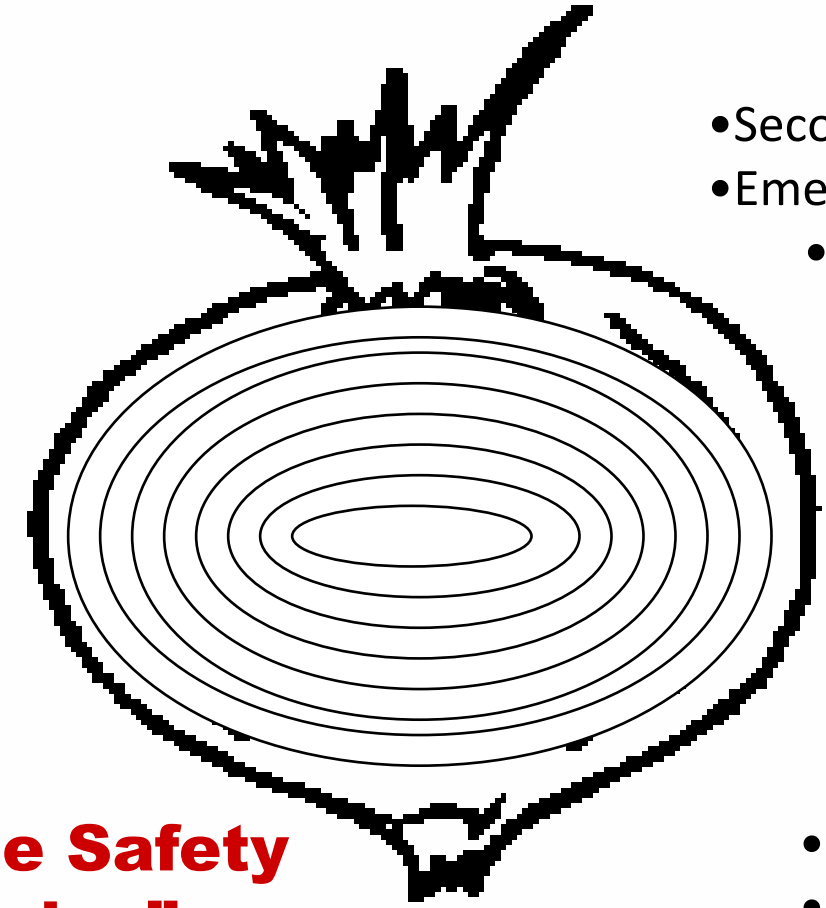
Preventions:

- Passive → •Hypochlorite instead of chlorine; •Water instead of xylene
- Active → •Procedures and Training; •Alarms and Actions

Mitigations:

- Passive → •Containment Dikes; •Equipment Spacing
- Active → •Personal Protective Equipment; •Interlocks and Emergency Relief

Multi Layer Safeguards



The Safety "Onion"

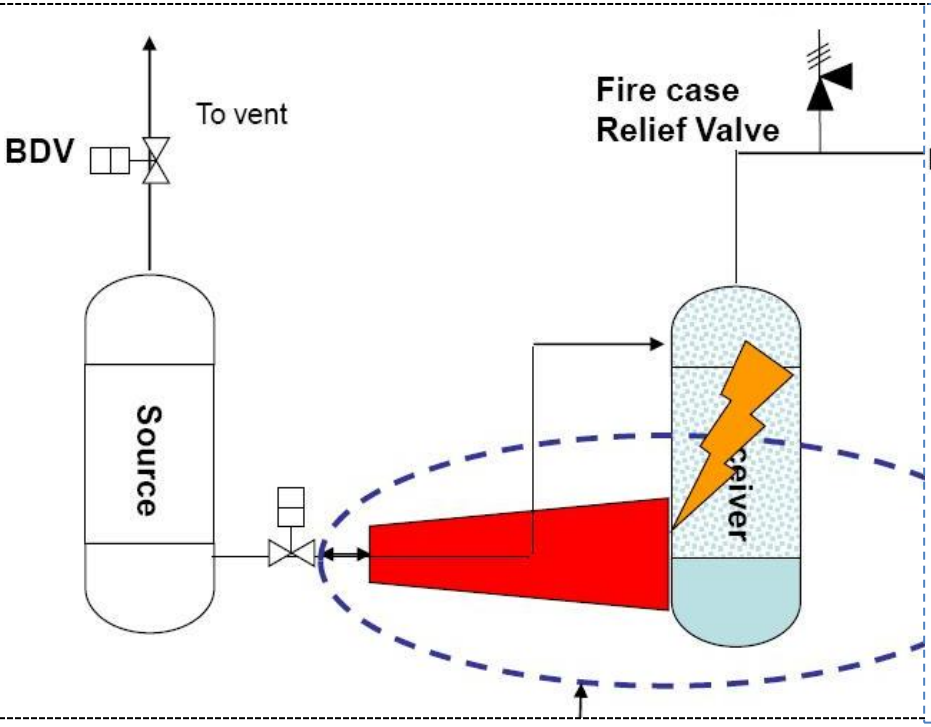
- Secondary Containment
- Emergency Relief Systems (ERS)
  - Safety Instrumented Systems (SIS)

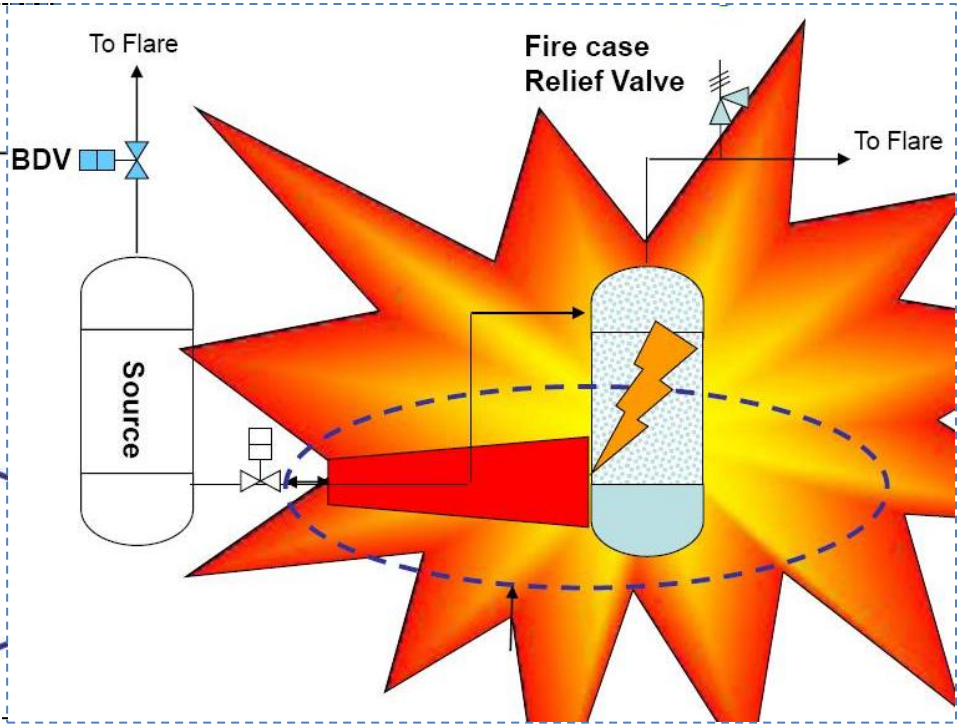
- Emergency Shutdown Systems
- Alarms & Operator Action
- Process Control System

- Operating Procedures & Training

- Mechanical Design
- Process Design

Layers of Protection and Failures

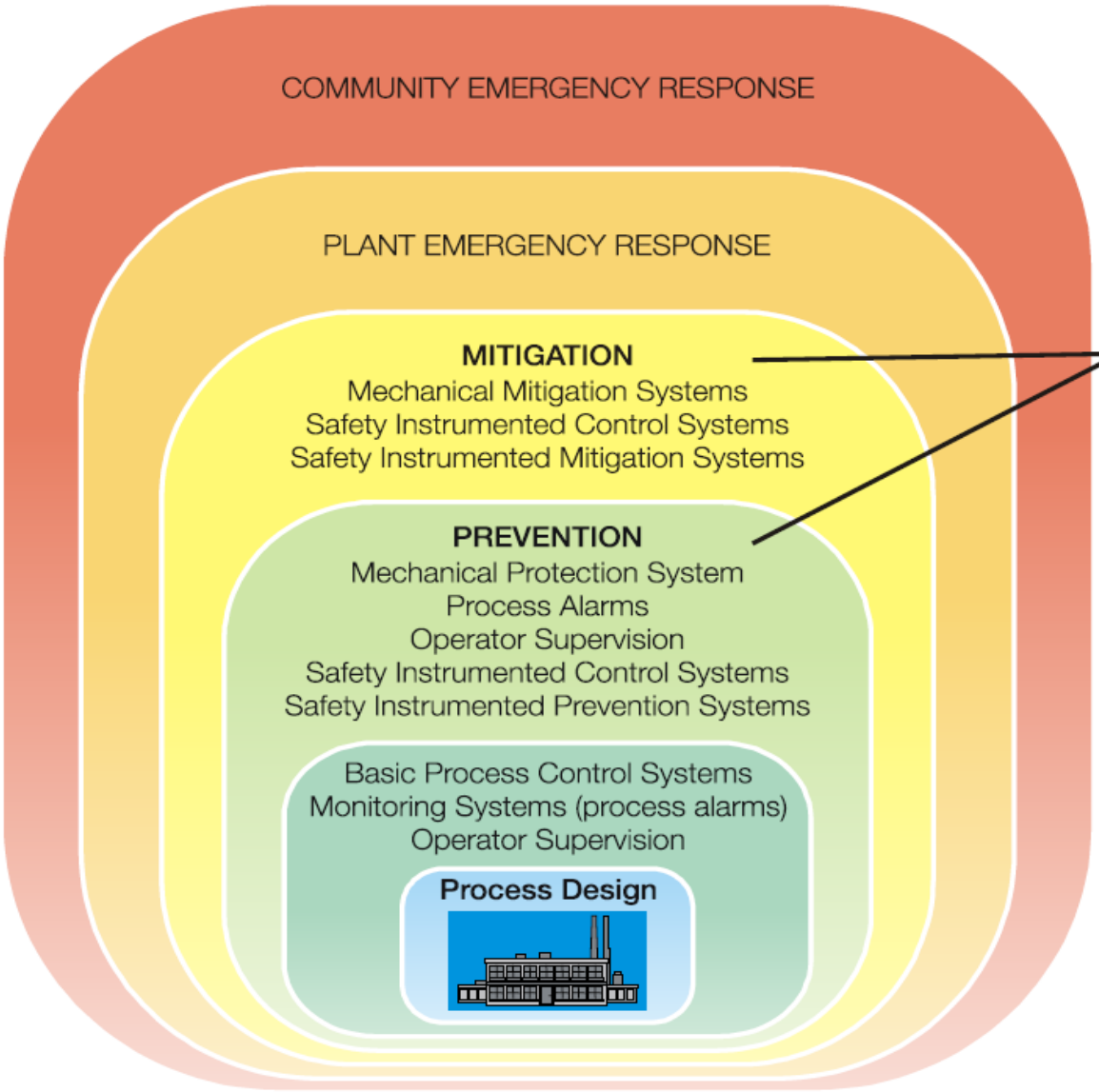




Fire case relief valve on Receiver opens to protect against overpressure. Following relief liquid level decrease in receiver and vapour part of vessel is exposed to jet fire.

If Receiver is not protected by passive fire protection it will fail in less than 15 min and cause BLEVE.

Multi Layer Safeguards



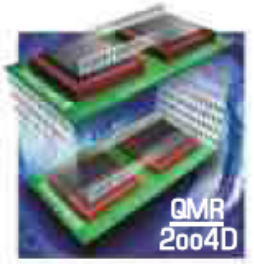
Safety Layer(s)

Mitigation

e.g. Fire & Gas Safety System

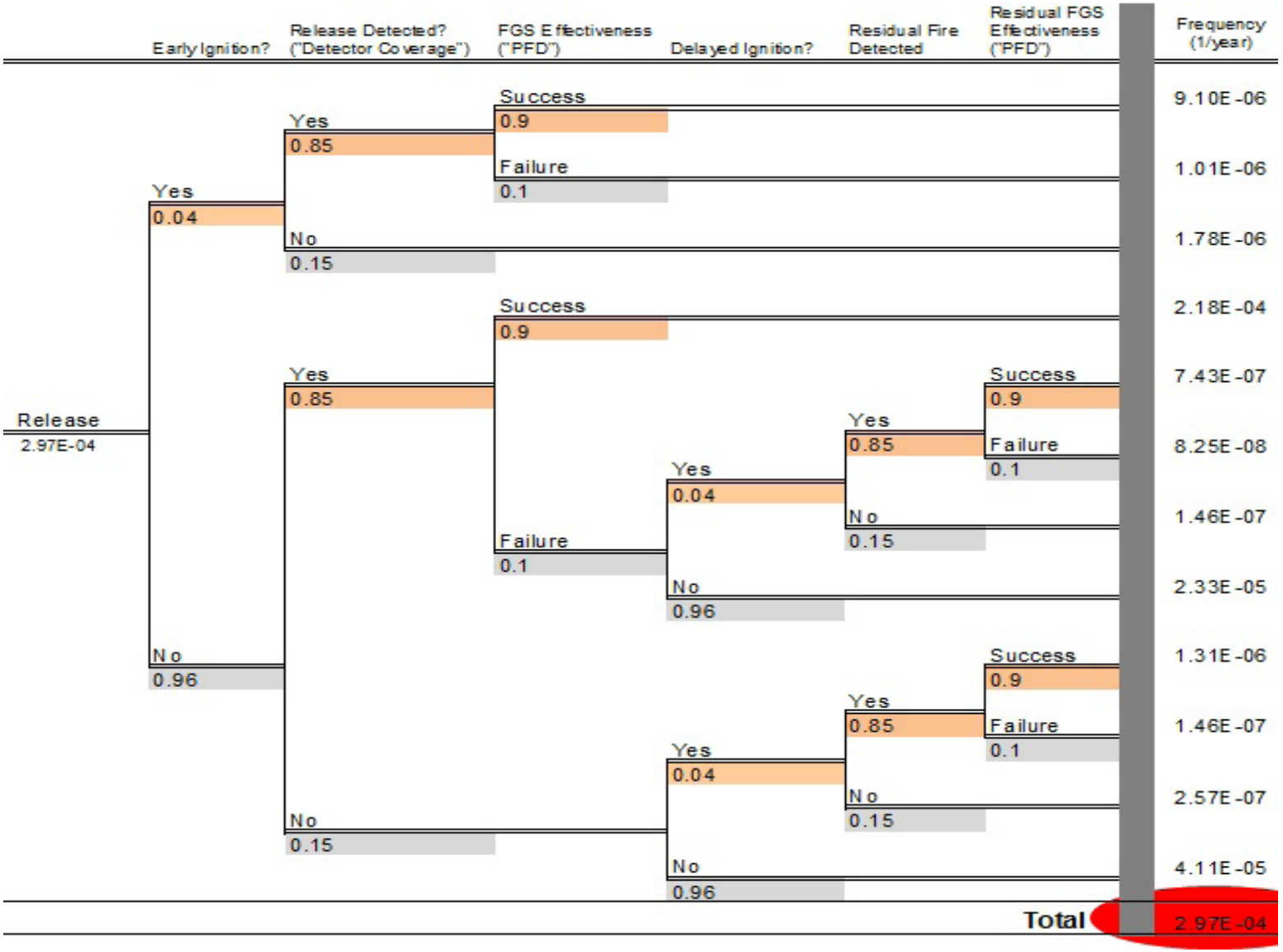
Prevention

e.g. ESD Safety System



Protection layers specified in IEC 61511

Risk Calculation Using Event Tree for an Release Scenario



Risk = Consequence X Likelihood. Risk associated with scenarios in each zone can be modeled by a event tree as shown in Figure. The risk posed by each scenario will be modified taking into account various mitigating factors, such as ignition probability, explosion probability, occupancy probability, and mitigation effectiveness.

Financial Analysis of F&G

Jet or Pool fire Consequence, Frequency & Loss

Hole Size	Release	Personnel Impact	Asset Loss	Production loss	Release Frequency	
25 mm	0,1 Kg/Sec	Serious Injury	$10 MM	1 Months	1.2E-02	1 in 80 years
75 mm	0,9 Kg/Sec	Single Fatality	$30 MM	2 Months	1.4E-05	1 in 70 000 years

Summary of FGS Effectiveness

	Unmitigated		Mitigated with F&G System	
Serious Injury Frequency	1.3E-04	1 in 7,600 years	2.1E-04	1 in 4,733 years
Single Fatality Frequency	1.5E-04	1 in 6,846 years	8.7E-05	1 in 11,518 years
Annualized Financial Risk	$ 172,000	(US Dollars)	$ 85,000	(US Dollars)

International Safety Code: RequirementS of Fire Detection Device

Location Facility	Hazard	Fixed Detector Types	Reference
Control Room	Electric Fire	MAC / Smoke	NFPA 75, Section 6.2
Switchgear Room	Electric Fire	MAC / Smoke	NFPA 850, Section 5.5
Turbine Package	Electric & HC Fire	Heat / Optical	NFPA 30, Section 5.5.5.1
Process Units	Hydrocarbon Fire	MAC / Heat / Optical	NFPA 30, Section 5.5.5.1
Pump Stations	Hydrocarbon Fire	MAC / Heat / Optical	NFPA 30, Section 5.5.5.1
Loading Facilities	Hydrocarbon Fire	MAC / Heat / Optical	NFPA 30, Section 5.5.5.1
Tank or Vessel Storage	Hydrocarbon Fire	MAC / Heat / Optical	NFPA 30, Section 5.5.5.1

Working Principles
of
Fire, Heat & Gas Detectors

FIRE SIGNATURES

When fire begins - changes occur in the surrounding environment, which are termed “fire signatures” (smoke, heat, light, and gas).

F & G Detectors - Types

- Sensors for HC's
- Toxic Gas Detectors
- Point/Open Path Detectors
- Flame Detectors
- Ultrasonic Gas Leak Detectors
- Heat and Smoke Detectors
- Integrated Fire and Gas Detection Systems

Fire and gas detection systems are designed to mitigate unexpected events. Designers need to know what is available in order to choose the correct systems for their plants

Hydro Carbon Detector Types

F & G Display Panel

Alarm LED's

Optional Sounder

Detector Sensor Inputs

Sonic Leak

Infrared

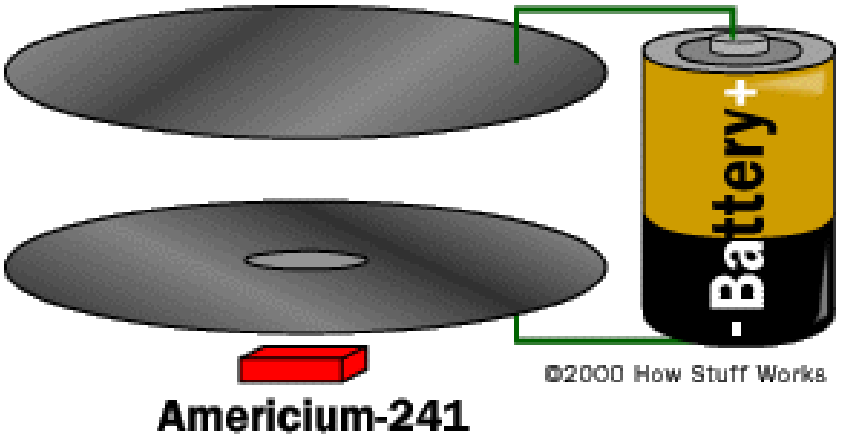
Toxic HC

Catalytic Type

Electrochemical Type

HC/H_2S Sensors

WORKING PRINCIPLE - SMOKE DETECTORS (Ionization Type)

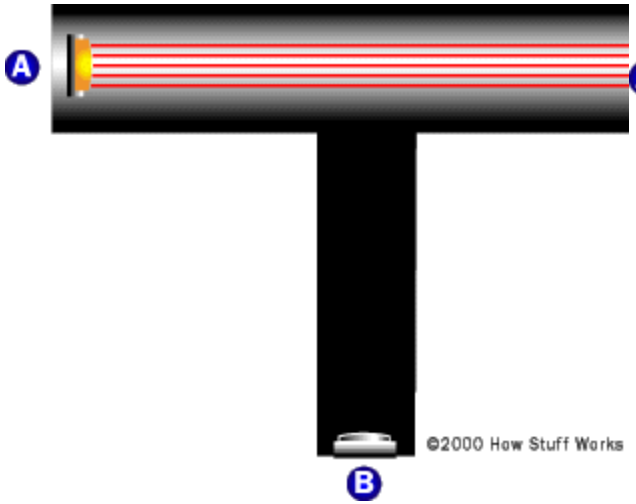


Ionization Type Detectors:

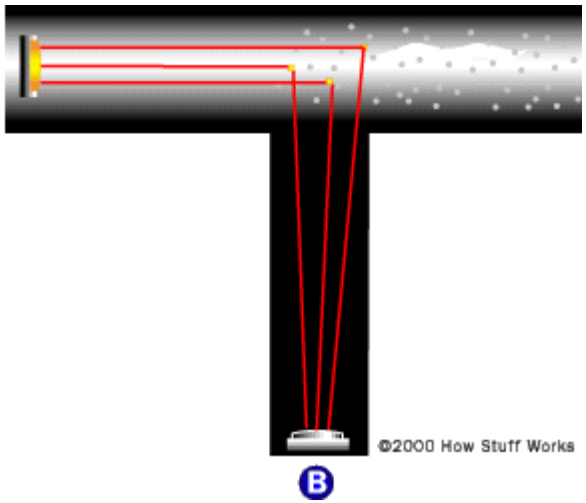
- Ionization detectors operate by using a small amount of radioactive material to ionize (electrically charge) the air within a sensing chamber in the detector. The ionization of the air permits the air to conduct electricity between two electrodes. As smoke enters the chamber, the smoke particles become ionized and reduce the conductivity of the air between the electrodes.

- These detectors also have the greatest false alarm rate of smoke detectors from cooking and other non-fire sources.

WORKING PRINCIPLE - SMOKE DETECTORS (Photoelectric)



A – Light Source



B – Photo Sensor

Photoelectric Type Detectors:

- Photoelectric detectors operate on one of three different principles:
- 1) Light obscuration principle
- 2) Light scattering principle
- Light obscuration principle photoelectric detectors operate by projecting a light beam onto a photosensitive device.
- As smoke particles enter the chamber the light intensity diminishes
- As smoke particles enter the sensing chamber, light is reflected (scattered) from the smoke particles onto the photosensitive device

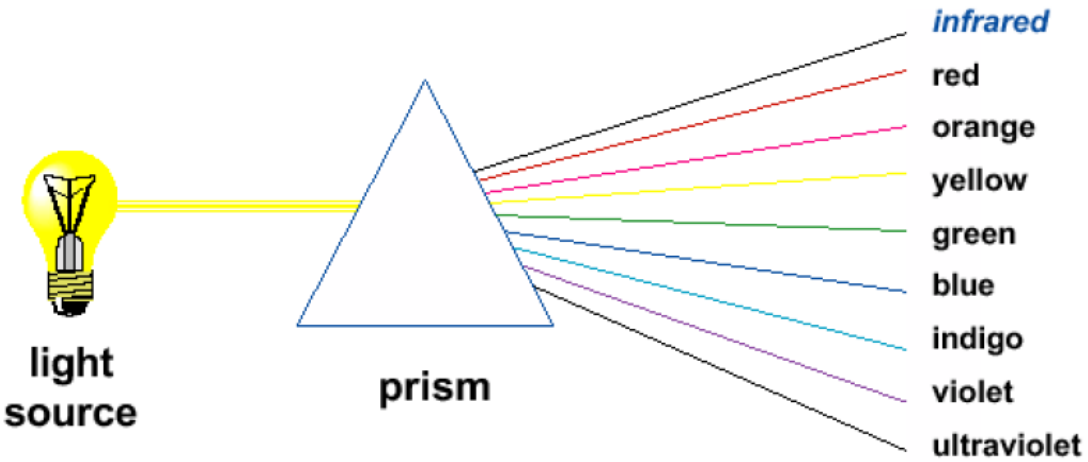
WORKING PRINCIPLE - FIXED HEAT DETECTORS

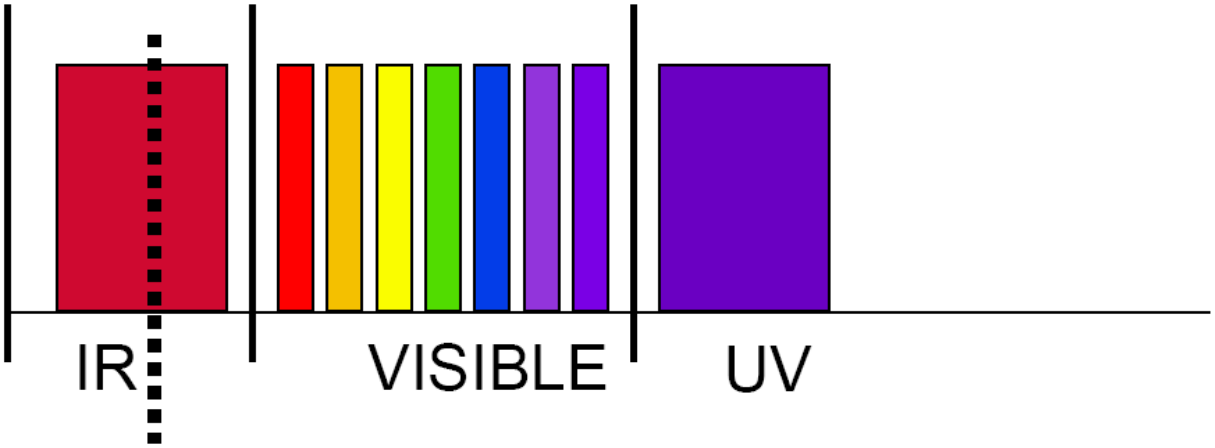
FIXED TEMPERATURE / HEAT DETECTORS
Fixed temperature heat detectors - designed to alarm when the sensing element reaches a predetermined temperature. Type: fusible element type, continuous line/ wire type and bimetal type.

The continuous line type - parallel wires, with heat resistive insulation. Insulation melts away at a predetermined temperature (from a fire), the wires come into contact. The bimetal type of heat detectors relies on two joined metals with different coefficients of expansion. Fusible element type operates similar to a sprinkler head where a eutectic metal melts at a predetermined temperature releasing a spring under tension and initiates an alarm signal

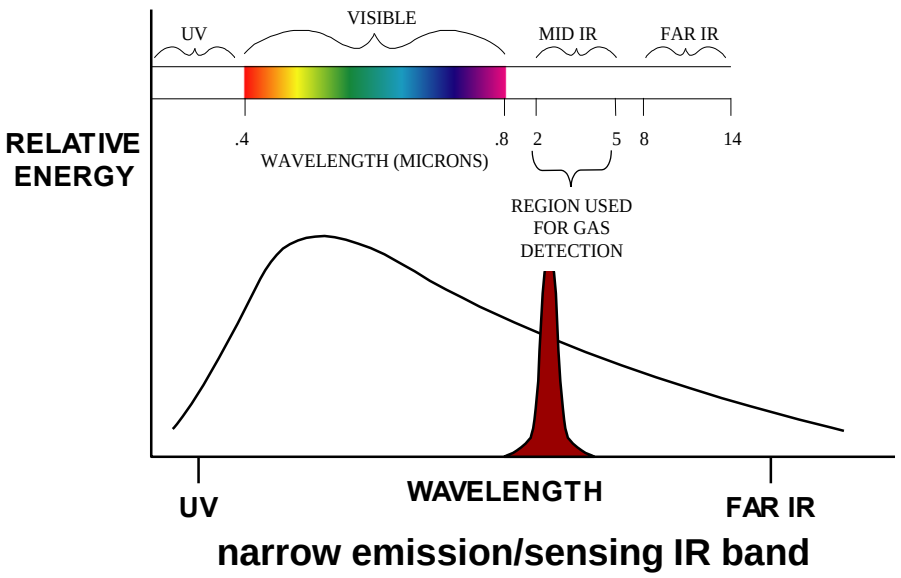
WORKING PRINCIPLE- Gas detection IR -Band

Infrared combustible gas detector



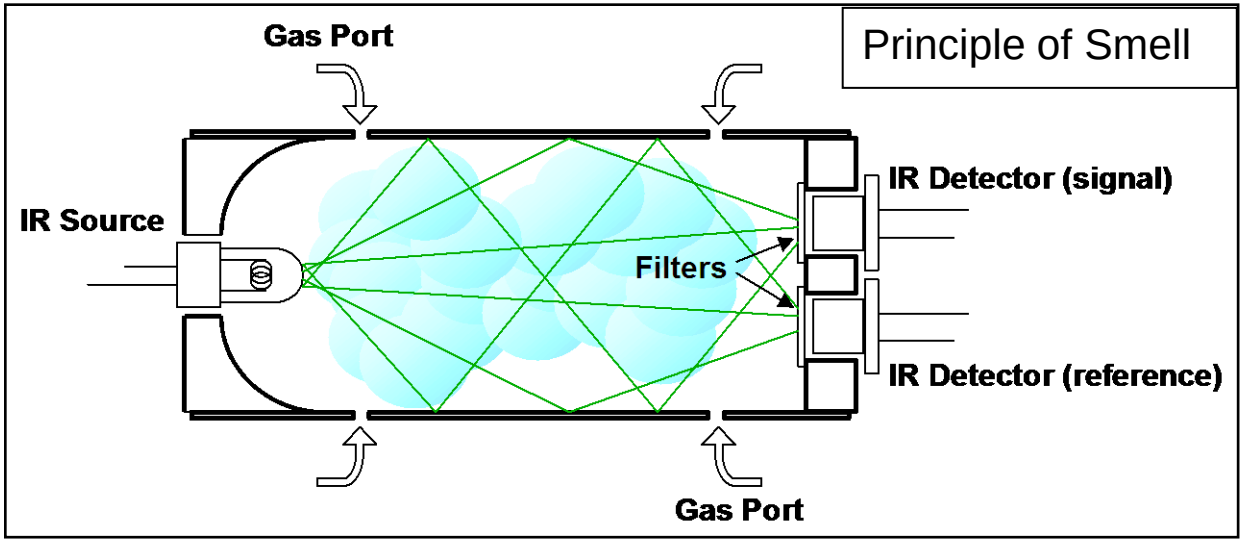


WORKING PRINCIPLE- Point IR Gas Detector



Infra-red (IR) gas detection is based on the absorption of energy by hydrocarbons. The bond between hydrogen and carbon absorbs proton energy at a wavelength of 3.3m m.

In practice, most modern sensors use light at two different wavelengths, one is absorbed by the gas (sample), and the other is not absorbed (reference).

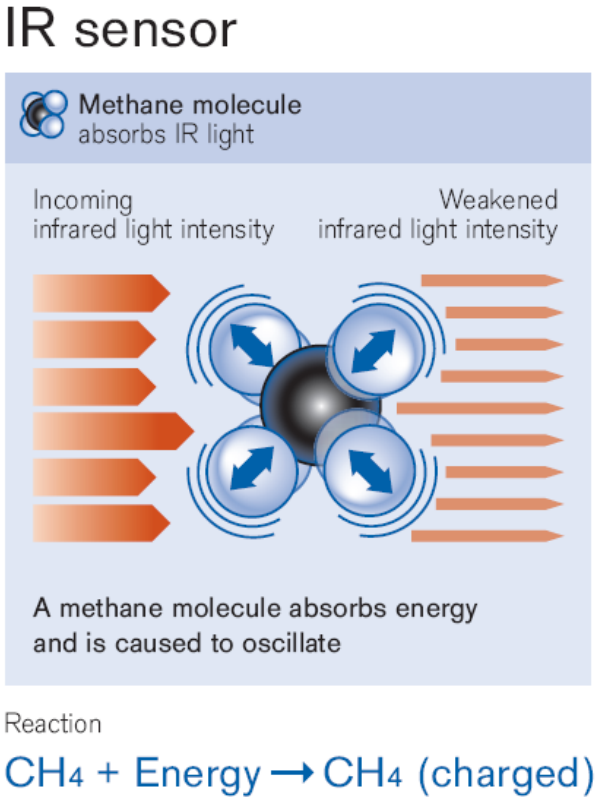


Organic substances are ionized and subjected to the electrical field between the electrodes in the measuring chamber. The strength of the resulting current is directly proportional to the concentration of ionized molecules inside the chamber

WORKING PRINCIPLE-Infra-red(IR)gas detection

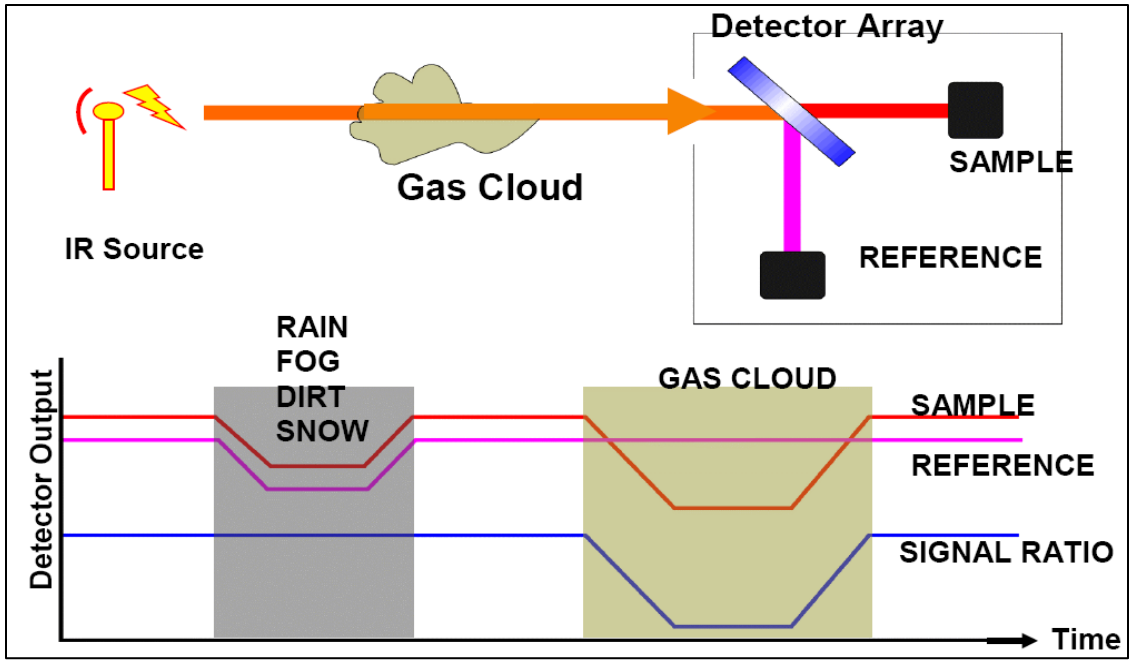
Every gas absorbs light in a particular way; some even absorb visible light (wavelength of 0.4 to 0.8 micrometers), which is why chlorine is yellowish green, bromine and nitrogen dioxide are brown, iodine vapor is violet.

Hydrocarbons, on the other hand, absorb light in a certain wavelength range, from between about 3.3 and 3.5 micrometers – and that can be utilized for detection purposes, since the main components of air (oxygen, nitrogen, and argon) do not absorb radiation in that range.

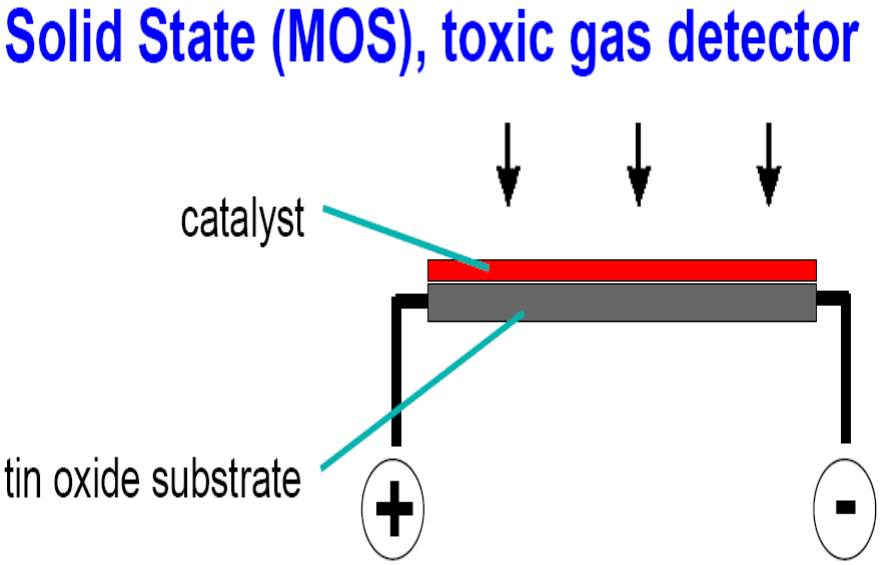


Working Principle Line of Site (IR type)

- Gases Wide range of hydrocarbons can be detected based on the fact that they absorb light in a certain wavelength range. Example: Alkane series from methane to hexane, propylene, ethanol and methanol.
- Factory calibration Methane or propane, selectable. Other hydrocarbon gases on request
- Operating distance 30 - 120 m or 100 - 200 m separation of transmitter & receiver



Working Principle Metal oxide – Gas Detector



☺ lifetime typically 5 to 10 years

☺ ppm level detection

☹ large cross sensitivity to other gases

☹ non linear ouput, can “go to sleep”

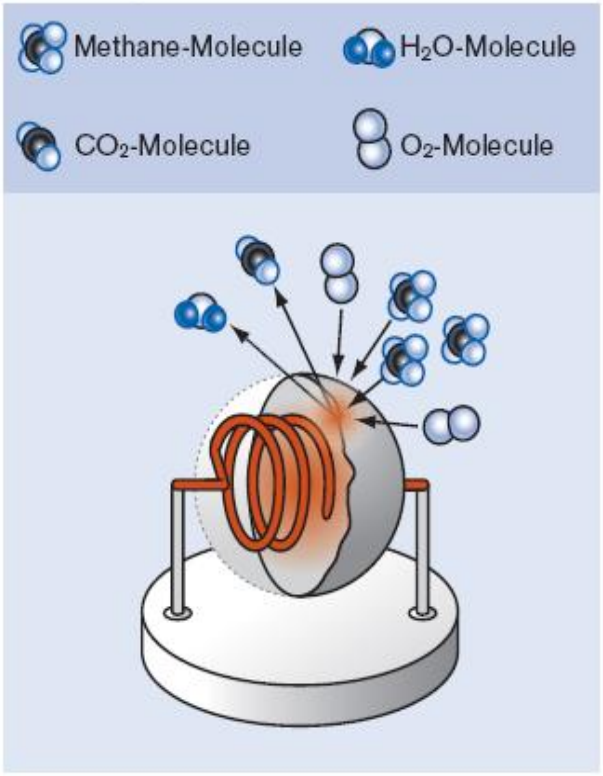
Solid-state sensors are made of a metal oxide that changes resistance in response to the presence of a gas; the instrument measures this resistance change and translates it into concentration.

Advantages:. Solid-state sensors have a very long lifetime, typically 10 years

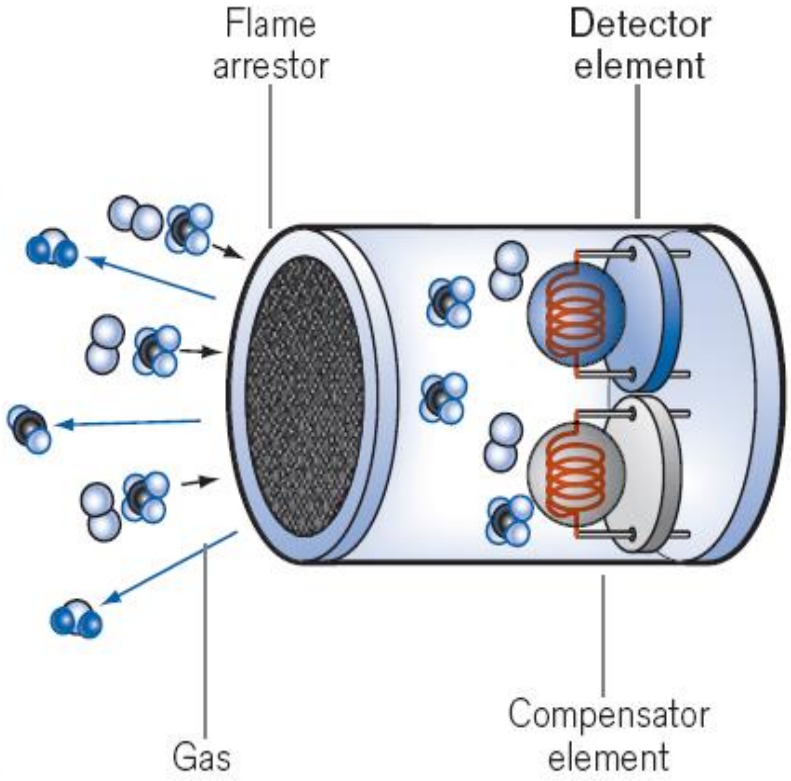
Because they are fairly inexpensive, solid-state instruments typically are used to detect gas at the source, so response to leaks is quick and monitoring is continuous.

Point Catalytic HC Detector

Catalytic bead sensors

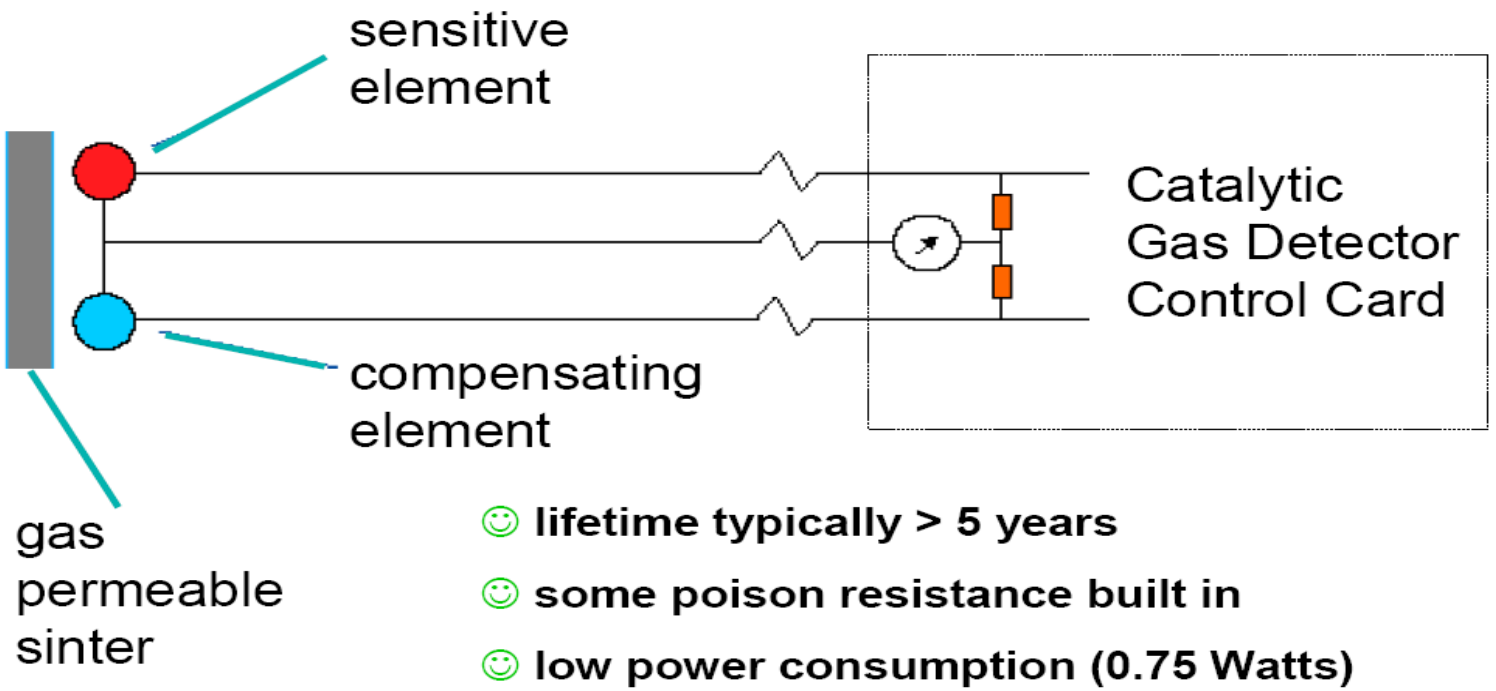


Reaction



Principle of Smell

Catalytic combustible gas detector



- The catalytic sensor is a coil of platinum wire, which is heated to around 400oC by passing a current through it. The coil is coated with a catalyst that enables a reaction to occur at this relatively low temperature - the reaction being one between the combustible gas being detected, and oxygen from the air.

- This reaction is exothermic, that is, it gives off heat. This causes the platinum coil to heat up further, which in turn changes the electrical resistance of the coil. This change of resistance is measured.

Different Hydrocarbon Detection Capability

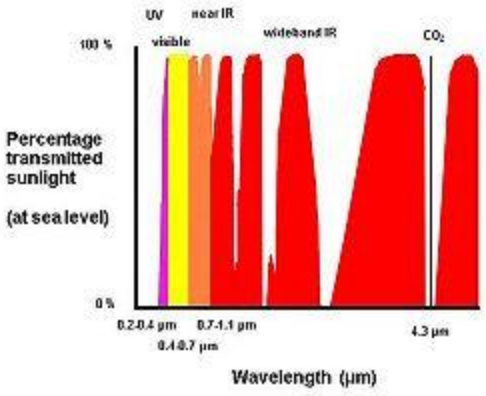
Gas Type	LEL (%vol)	Ranges Available: Flamgard Plus
Acetylene (C_2H_2)*	2.3 (2.4)	0-100% LEL
Ammonia (NH_3)	15	0-100% LEL
Butane (C_4H_{10})	1.4 (1.8)	0-100% LEL
Ethane (C_2H_6)	2.5 (3)	0-100% LEL
Ethylene (C_2H_4)	2.3 (2.7)	0-100% LEL
Hexane (C_6H_{14})	1.2	0-100% LEL
Hydrogen (H_2)	4	0-100% LEL
LPG	2	0-100% LEL
Methane (CH_4)	4.4 (5)	0-100% LEL
Pentane (C_5H_{12})	1.4 (1.5)	0-100% LEL
Petrol	1.3	0-100% LEL
Propane (C_3H_8)	1.7 (2.2)	0-100% LEL

Different Gas Detection Capability

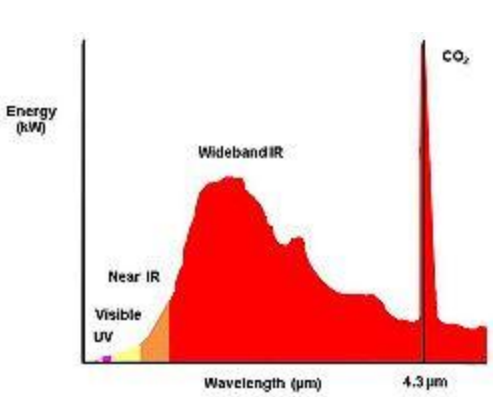
Type	Explosion proof transmitter		
Gases and Ranges	Toxic gases and oxygen in discrete pre-set values, user selectable		
Display	3-digit LCD		
FSD (Full Scale Deflection)	O_2		25 vol%
	CO		50 / 100 / 200 / 300 / 500 ppm
	H_2S zero-bias		10 / 20 / 50 / 100 ppm
	H_2S LC		10 / 20 / 50 / 100 ppm
	H_2S HC		100 / 200 / 300 / 500 ppm
	H_2		500 ppm
	Cl_2 **)		5 / 10 / 20 / 50 ppm
	EO *)		20 / 50 / 100 ppm
	NH_3 LC **)		50 / 100 ppm
	NH_3 HC **)		300 / 500 ppm
	NO *)		50 / 100 ppm
	NO_2 **)		5 / 10 / 20 / 50 / 100 ppm
	SO_2 **)		5 / 10 / 20 / 50 / 100 ppm
	H_2O_2 LC **)		5 / 10 / 20 / 50 / 100 ppm
Electrical data	Signal Output	Normal operation	4 to 20 mA
		Maintenance	4 mA ± 1 mA 1 Hz modulation, or steady 3 mA; user selectable
		Fault	< 2 mA
	Supply Voltage		16 to 30 VDC, 2-wire
Ambient conditions (see also sensor data sheet)	Temperature		-40 to + 150 °F / - 40 to + 65 °C
	Pressure		20.7 to 38.4 inch Hg / 700 to 1300 mbar
	Humidity		0 to 100 %RH, non-condensing
Enclosure	Transmitter housing		epoxy-coated copper free aluminum or 316L st
	Sensor housing		316L stainless steel

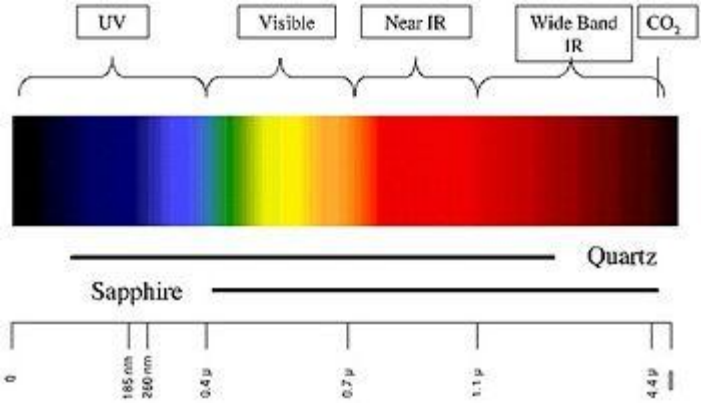
Working Principle of Optical Fire Detectors

Sunlight



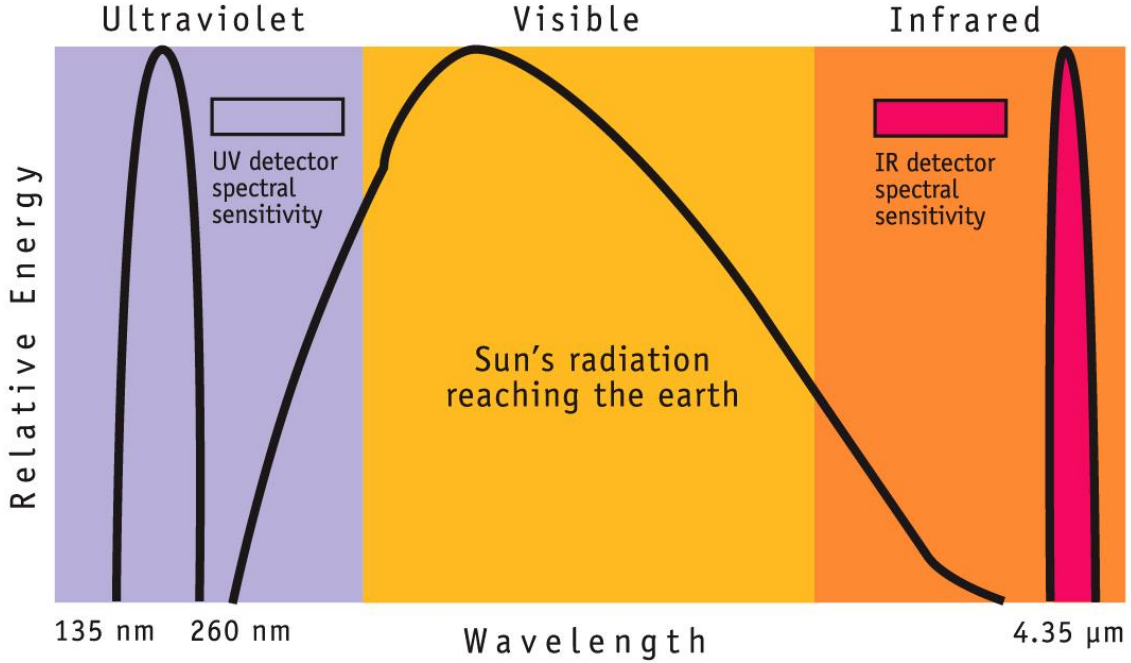
Emission of Fire Radiation



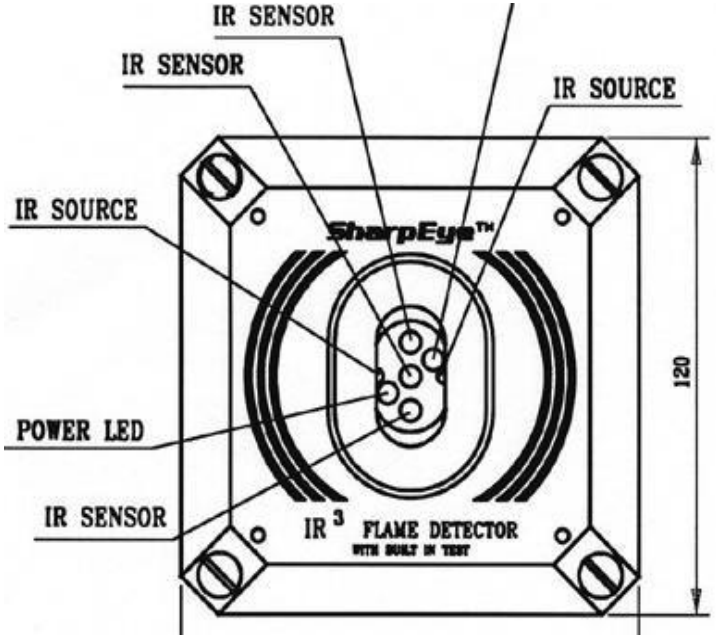


During a fire relatively sparsely UV energy and visible light energy is emitted, as compared to the emission of Infrared radiation. A none-hydrocarbon fire, from for example hydrogen, does not show a CO2 peak on 4.3 µm. A multi-frequency-detector with sensors for UV, visible light, near IR and/or a little bit wideband IR thus do have much more "sensor data" to detect these fires like: hydrogen, methanol, ether or sulphur.

Spectral Range & UV / IR Detectors



Emission Energy Spectrum



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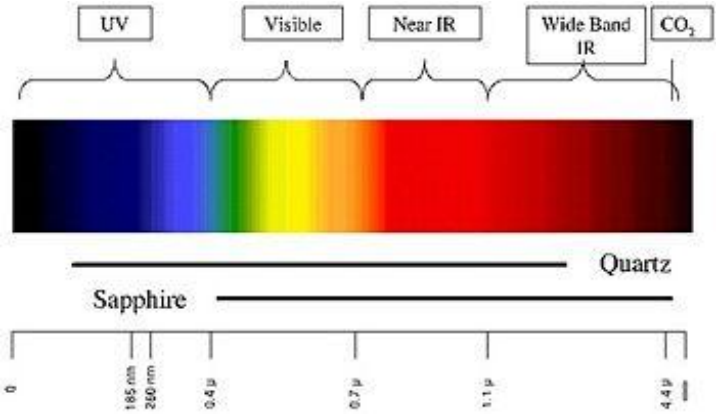
Working Principle
Flame Detectors-Optical



Ultraviolet

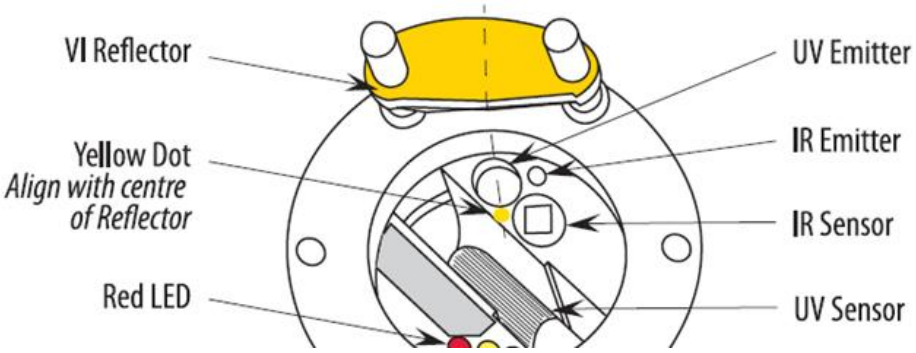
- Ultraviolet (UV) detectors work with wavelengths shorter than 300 nm. These detectors detect fires and explosions within 3–4 milliseconds due to the UV radiation emitted at the instant of their ignition. False alarms by UV sources such as lightning, arc welding, radiation, and sunlight. To reduce false alarm a time delay of 2-3 seconds is included UV detector design.

Infrared

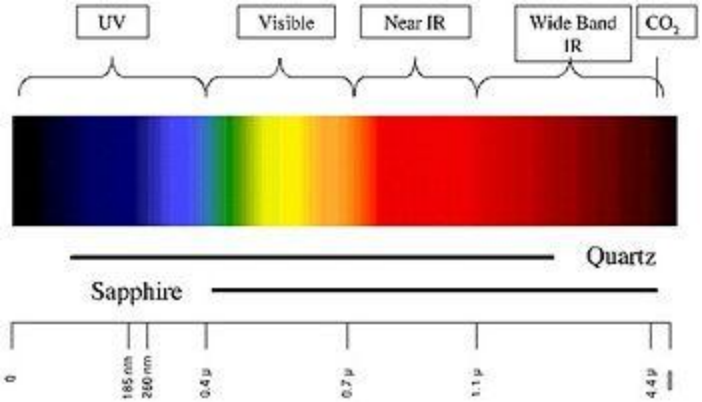
- Infrared (IR) flame detectors work within the infrared spectral band. Hot gases emit a specific spectral pattern in the infrared region, which can be sensed with a thermal imaging camera (TIC) a type of thermographic camera. False alarms can be caused by other hot surfaces and background thermal radiation in the area as well as blinding from water and solar energy. Typical frequency fo single IR flame detector is 4.3 micrometer. Typical response time is 3-5 seconds.

UV/IR

UV and IR flame detectors compare the threshold signal in two ranges in "AND" configuration and their ratio to each other to confirm the fire signal and minimize false alarms.

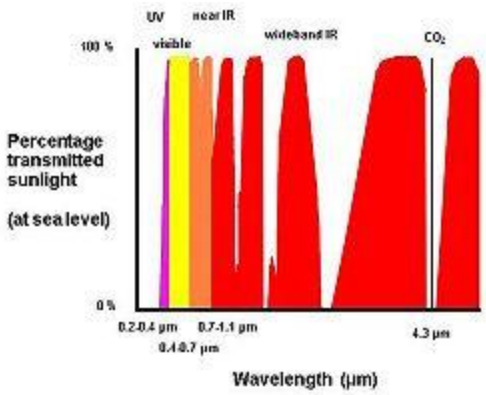


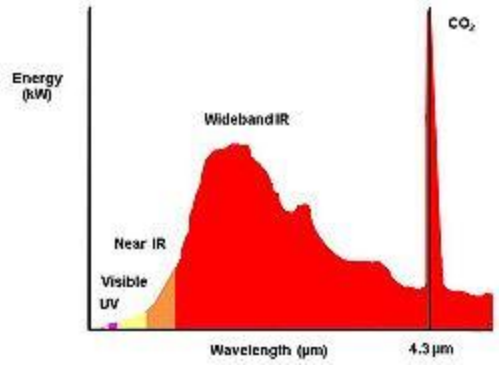
Working Principle
Flame Detectors-Optical



3-IR flame detection

Triple IR flame detectors compare three specific wavelength bands within the IR spectral region and their ratio to each other to reliably detect flames while attempting to reduce false alarms. In this case one sensor looks at the 4.4 micrometre range and the other sensors at reference frequencies above and below. Triple IR detectors are also susceptible to blinding by water and reduced sensitivity from sunlight. False alarms can be caused by other hot surfaces and background thermal radiation in the immediate area.





Working Principle Flame Detectors-Optical

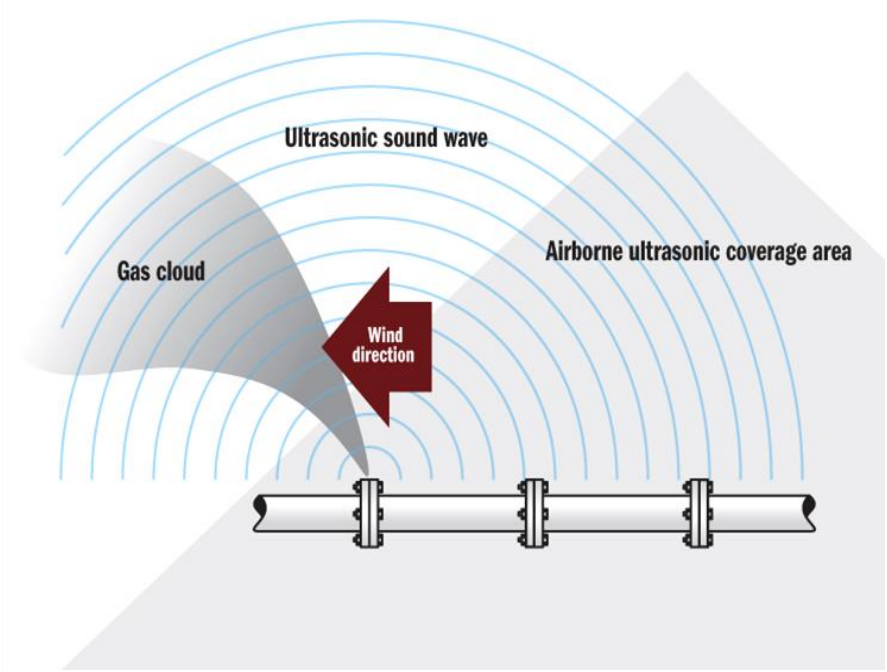
Visible sensors

- In some detectors a sensor for visible radiation is added to the design in order to be able to discriminate against false alarms better or improve the detection range. Example: UV/IR/vis, IR/IR/vis, 3-IR flame detectors.

Video

- Closed-circuit television or a web camera can be used for video detection (wavelength between 0.4 and 0.7 µm). Like humans, the camera can be blinded by smoke or fog.

Ultrasonic Gas Leak Detection



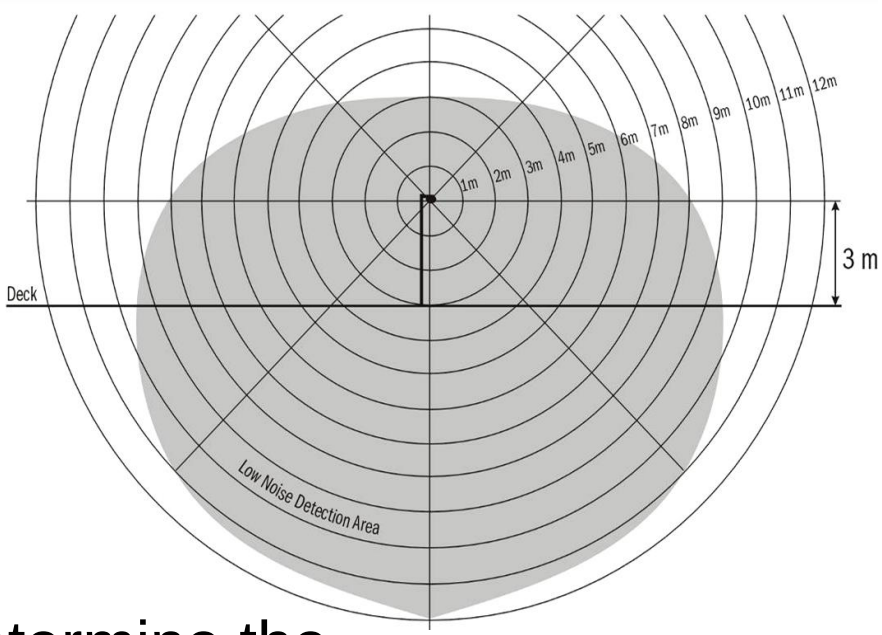
Main Characteristics:

- Instant acoustic gas leak detection
- Detects gas leaks at a leak rate of 0.1 kg/s
- Detection radius up to 20 meters away

Leak Detection Range

The detection range of an ultrasonic gas leak detector depends on these variables:

- Leak size
- Pressure
- Ultrasonic background noise



Leak size and gas pressure determine the acoustical ultrasonic noise level generated from the leak.

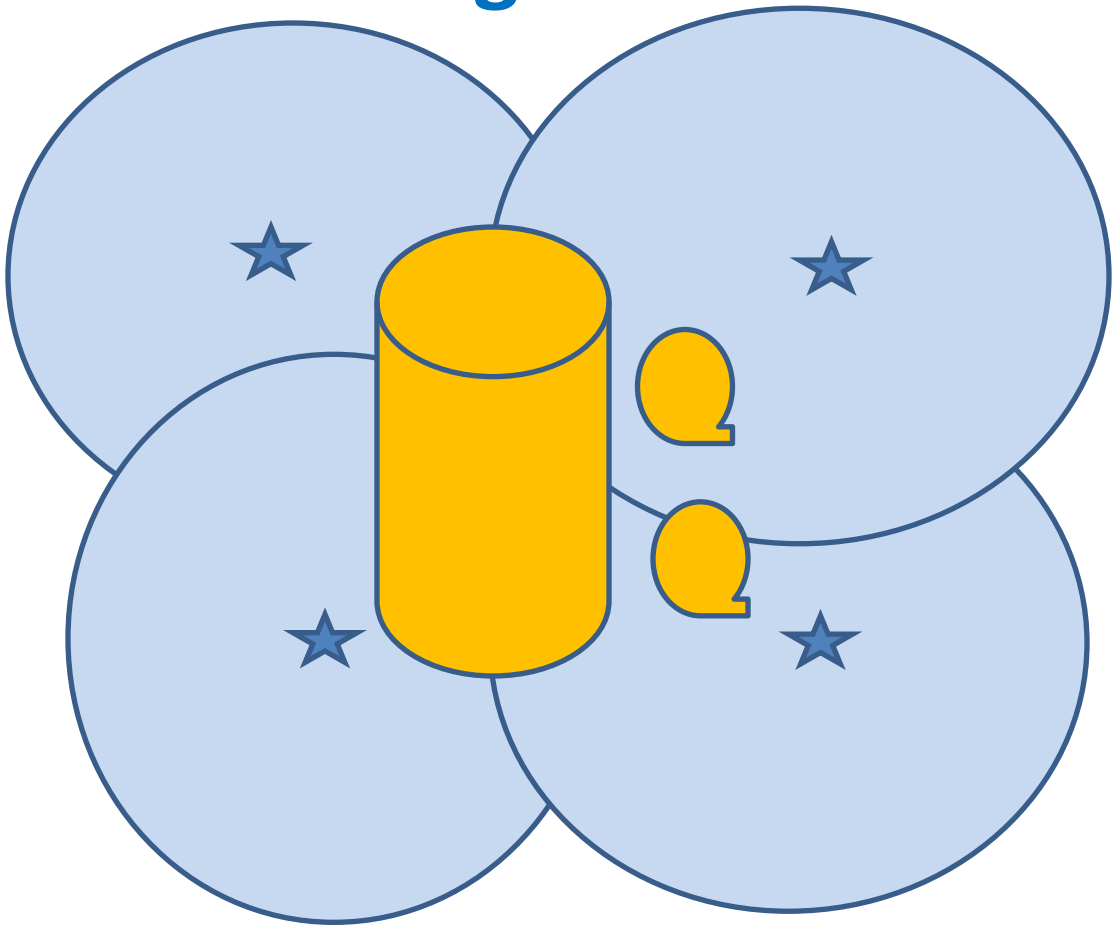
Different Detectors
&
There Coverage

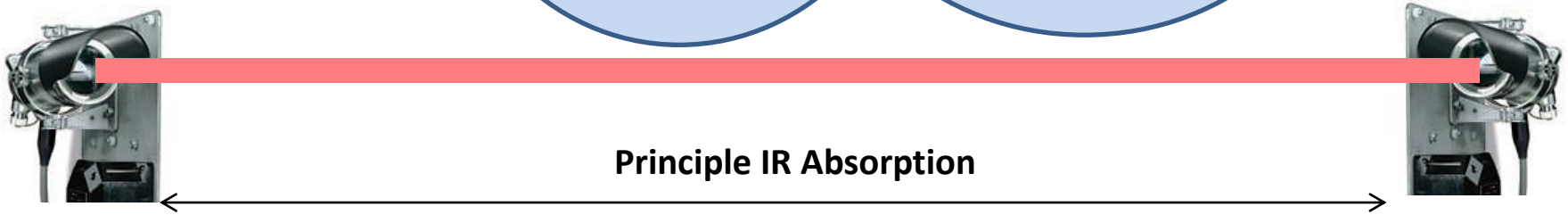
Point & Line Hydrocarbon Detector Coverage

Detector

Coverage Area

Principle of Smell

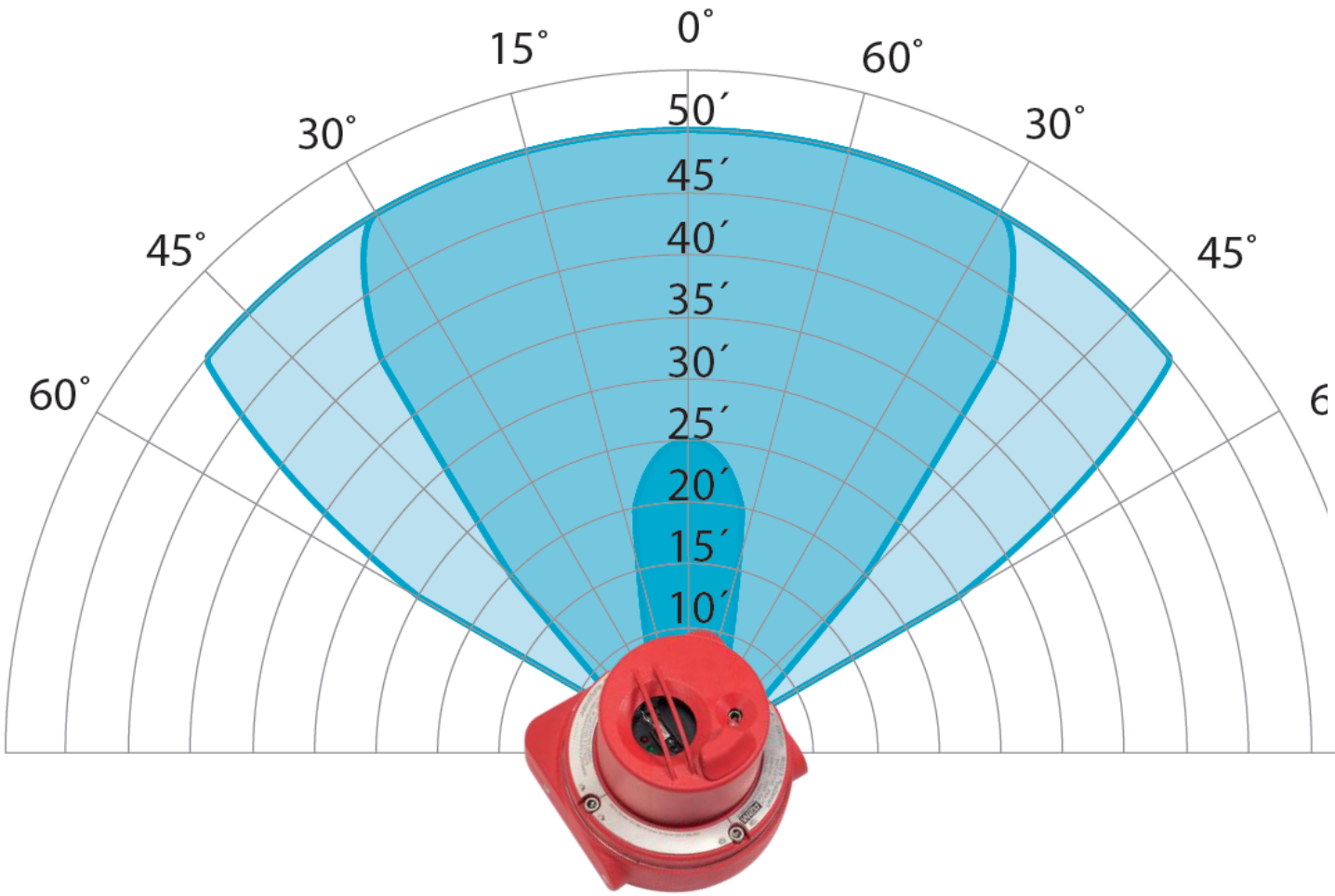


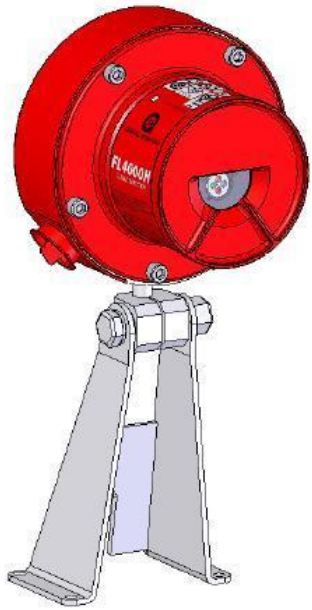


Principle IR Absorption

Coverage Path - 50 Meters

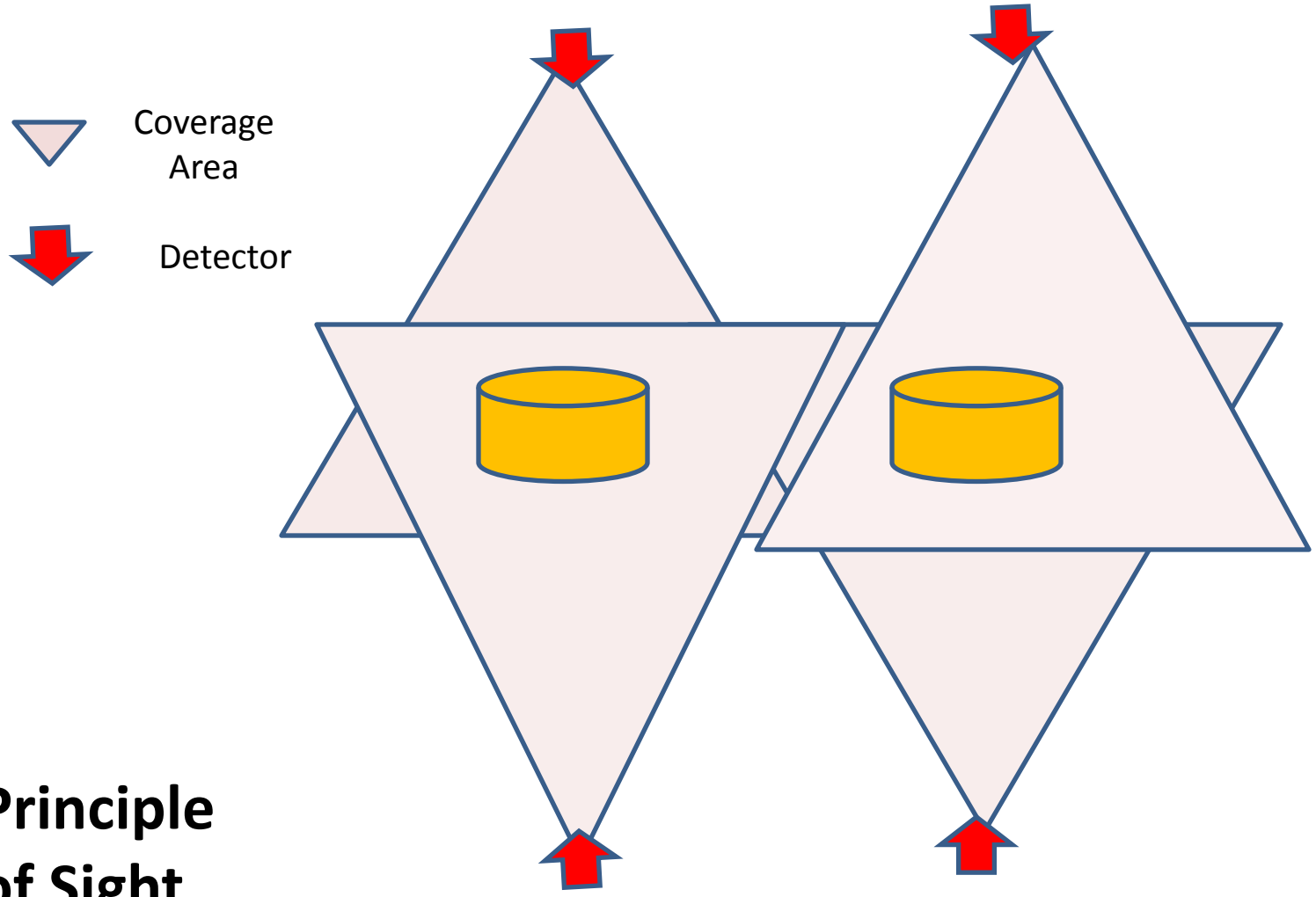
Field of View / Cone of Vision Flame Detector





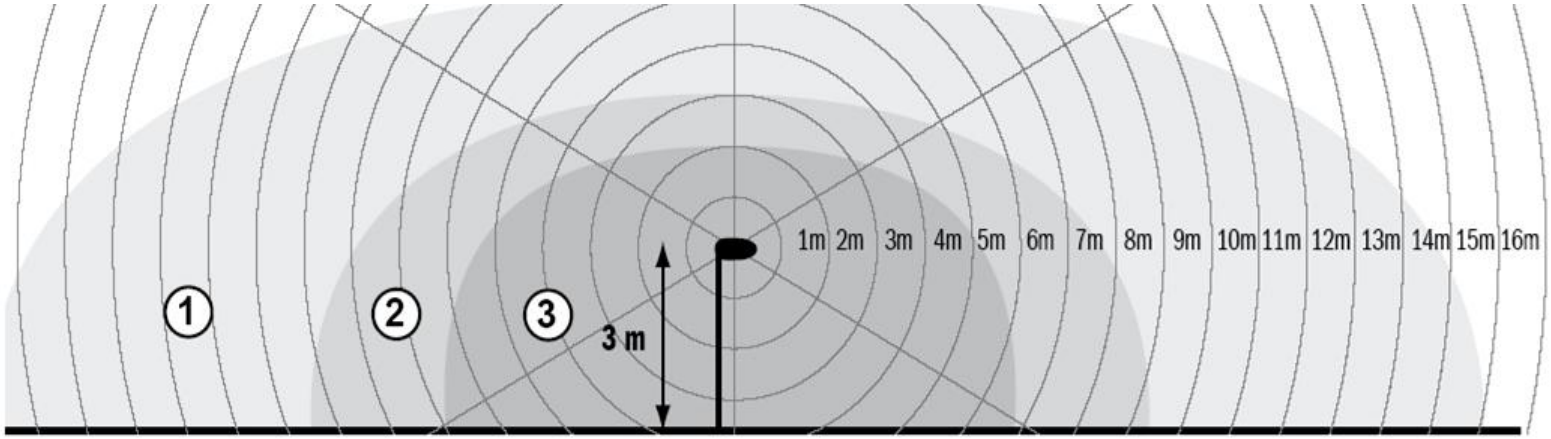
Field of View, View Angel, Line of Site, Mounting Height

UV / IR Flame Detector Coverage



Principle of Sight

Directional Characteristics



(1) Very low-noise areas
In "very low-noise areas", where background noise is less 58dB, the trigger level must be set at 64 dB. This corresponds to a detection radius of 13-20 Metres.

Typical areas:
- Onshore wellhead areas in calm environment
- Salt dome gas storage facilities in calm environment

(2) Low-noise areas
In "low-noise areas", where background noise is less than 68dB, the trigger level must be set at 74 dB. This corresponds to a detection radius of 9-12 Metres.

Typical areas:
- Areas with no machinery
- Areas with low frequency machine made noise

(3) High-noise areas
In "high-noise areas", where background noise is above 78dB, the trigger level must be set at 84 dB. This corresponds to a detection radius of 5-8 Metres.

Typical areas:
- Turbo compressor areas
- Complete open offshore weather deck
- Next to very noisy machinery

Comparison of
F & G Detectors
&
F & G Detector Applications

Hydrocarbon Gas Detection Technology Compared

Gas	Advantages	Disadvantages
Catalytic	Simple, Measures flammability of gases. Low cost, proven technology	Can be poisoned by chlorine, lead. Requires O2 to work. Limited to Spot Detection
Electrochemical	Measures Toxic gas at low concentration. Wide rage of gases. Industry Standard	Poisoning. Failure mode not easily revealed. Limited to Spot Detection
Point -Infrared	Use physical rather then chemical tech. less sensitive to calibration errors. No unseen failure. Can be used in inert atmosphere. Ideal for areas where gas is likely to collect, Can be used in conjunction with line of sight. Very fast response, Limited maintenance	Flammable gas in % range. Measure on the concentration , which has to be related to flammability of gas. Only measures at a particular point. Cannot measure non hydrocarbons eg., hydrogen.
Open Path- IR	Covers large Area, can be used Boundaries Pump Alleys, Perimeters. Best to seek leak path. No unseen failures. Can detect low concentrations. Poisoning not critical. Very fast response. Toxic and flammable versions	Higher initial cost. Requires Clear view, Detection path can be obstructed. Unsuitable for hydrocarbons which have various compositions ie., if one day the leak could be Methane and the next Propane the readings will change and will not be representative. Cannot measure H2.
Semiconductor	Mechanically robust, work well in constant humidity	Susceptible to contaminants and changes in environment. Non liner response. Affected by complexity. Limited to Spot Detection

Comparison of Fire Detectors

Comparison of Fire Detectors				
Detection	**Detector Type**	**Speed**	**Cost**	**Detection Range**
Human	Human	Moderate	Expensive	Wide Area
Smoke	Ionization	Fast	Moderate	Area
	Photo-Electric	Fast	Moderate	Area
	VESDA	Very Fast	High	Area
Heat	Fusible Link	Low	Moderate	Wide /Line
	Plastic Tube	Low	Low	Wide /Line
	Fusible Plug	Low	Low	Local
	Quartzoid Bulb	Low	Moderate	Local
	Bi-Metallic	Low	Low	Local
Optical	IR/ UV/ 3-IR	Very Fast	High	Wide /Line
	Video Camera	Fast	Expensive	Wide

FIRE DETECTOR PARAMETERS AND APPLICATIONS

Detector Type	Advantages	Disadvantages	Application	Environmental Resistance
Ultra Violet Detectors	- Fast response - Large coverage - Unaffected by wind	- Need a clear “cone of sight " - Ultraviolet radiation absorbed by heavy smoke	- In general areas where flames are expected to be one of the prime indications of fire. - Hydrocarbon & Fuel areas - Open outdoor areas	- Very good. - Unaffected by rain, wind etc. - Solar blind if sensitivity below 2800
Infra Red Detectors	- Fast response - Large coverage - Unaffected by wind - Infrared radiation not absorbed by smoke	- Need a clear “cone of sight " - Radiation from sun and hot vibratory machinery may give rise to false alarms	As for UV, however, not recommended in outdoor areas and areas where vibrating machinery operates	- Good. - Unaffected by rain, wind etc. Solar radiation may give rise to false alarms
Heat Detectors	- Reliable	- Relatively slow response	1. Areas where ambient conditions are too rough for smoke detectors. 2. Back-up for flame detectors in high hazard areas.	- Good, although response affected by wind, making them less suitable for open outdoor areas.
Smoke detectors	- Very sensitive - Detect smoldering fires at early stage	Require relatively clean atmosphere	- Clean areas not associated with flammables - Control room - Switchgear room - Void ceiling spaces / false floors	- Not suitable for open outdoor areas or naturally ventilated areas.