

Gas Detection

A basic guide

Agenda

- **Types of Hazard**
- **Gas Detection Techniques**
- **Certification & Approvals**
- **Gas Detector Selection**

Types of Hazard

General.

The presence of gases and vapours other than air can pose a threat to human life. The exact nature of this threat depends on the gas that is present, but in general we divide gas hazards into three main categories:

- combustible,
- toxic and
- asphyxiant.

Types of Hazard



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



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



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

Types of Hazard *See slide 3.*

Combustible gases can burn or explode, possibly causing extensive damage to plant and personnel. (The words flammable and inflammable are sometimes used in place of combustible. Commonly encountered examples of such gases are ethane, butane and acetylene, although the complete list of combustible gases is extremely large.

Toxic gases have an adverse affect on human health, ranging from symptoms such as mild headache, through various illnesses, to death. The effect varies with the nature of the gas concerned, and are usually also dependent on the concentration and time of exposure. Common toxic gases include carbon monoxide and hydrogen sulphide.

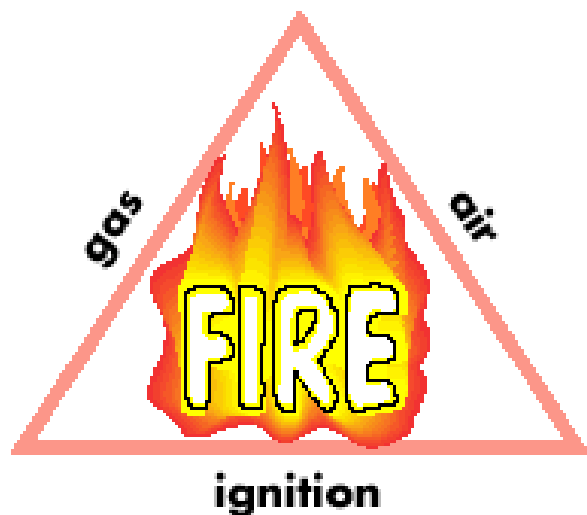
Asphyxiate gases prevent the body from taking in sufficient oxygen for its needs. Usually this is simply by replacing the air, but sometimes by preventing the body using the oxygen, which is present, as for example, in the case of hydrogen cyanide. Almost all gases can be asphyxiates.

Note that many gases fall into all three-hazard categories. For example, carbon monoxide is combustible, toxic and asphyxiate in nature.

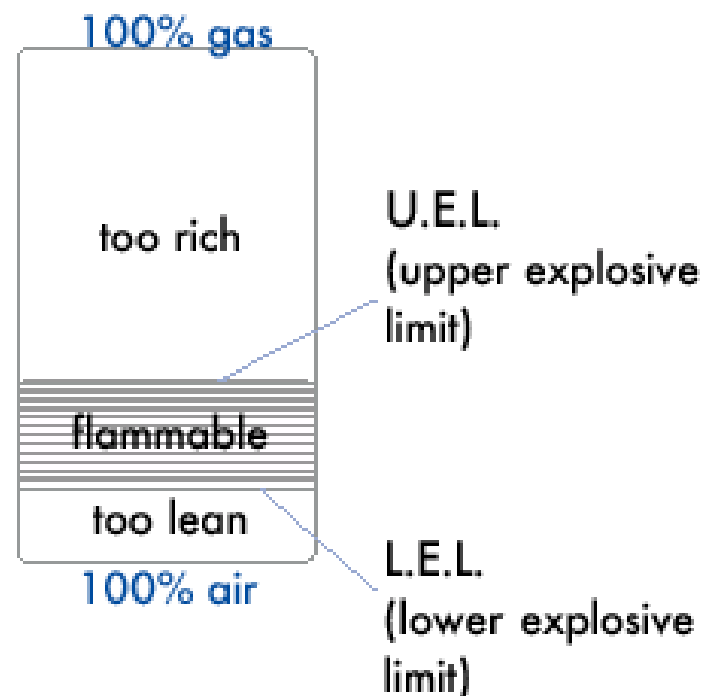
Types of Hazard

Combustible gases

combustion triangle



explosive limits



Combustible Gas *See Slide 4.*

For a combustible gas to ignite, three conditions are needed:

- the presence of gas in sufficient quantities
- the presence of air, or oxygen, in sufficient quantities
- the presence of a source of ignition.

These are the three sides of the traditional Combustion Triangle.

Note that the gas must be present in a high enough concentration to ignite. The minimum concentration needed is called the Lower Explosive Limit or LEL. If the gas concentration goes high enough, then the gas starts to displace the oxygen, and eventually there is insufficient oxygen for combustion to occur. The gas concentration at this point is called the Upper Explosive Limit or UEL. Some gases, such as ethylene oxide, need no external oxygen to ignite, and so have a UEL of 100%.

Types of Hazard

Toxic gases – toxic limits

time weighted average concentration (**TWA**)

units = parts per million (**ppm**), or

mg/cubic metre (mg/m³)

long term exposure limit (**LTEL**) - (8 hours)

short term exposure limit (**STEL**) - (10 mins)

Toxic Gases

See Slide 5.

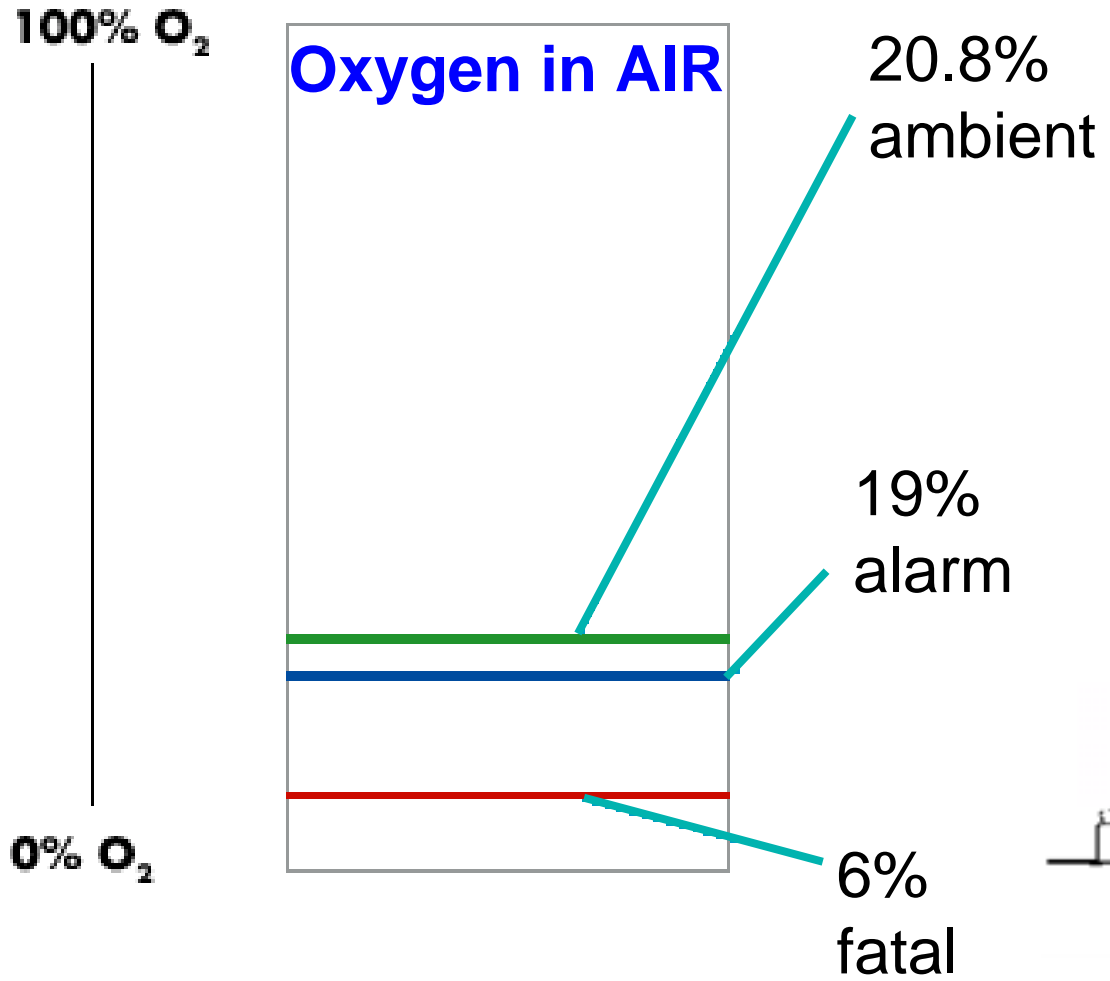
Toxic gases pose a completely different type of hazard from combustible gases. Usually the hazard is present at much lower concentrations than the LEL. Because of this, the concentration is measured in different units. The part per million (ppm) is often used: one ppm is one molecule in a million molecules. An alternative is the milligram per cubic metre (mg/m^3). The relationship between ppm and mg/m^3 is not straightforward - it depends on the molecular weight of the gas, as well as the temperature and pressure.

Each toxic gas will have a different effect on the human body. Some of these effects can be fatal. The severity of the effect is usually dependent on both the concentration of the gas present, and the time of exposure. For example, a five minute exposure to 2,500 parts per million of carbon monoxide causes no effect on man (although it will kill a canary!), whereas a 160 minute exposure to 500 parts per million may kill a man (whilst leaving the canary quite happy).

Therefore acceptable limits of toxic gases are usually quoted in terms of a Time Weighted Average. That is, an average concentration over a given time. The Long Term Exposure Limit (LTEL) is the acceptable concentration for an eight-hour working period, and the Short Term Exposure Limit (STEL) is the acceptable concentration for a short ten-minute period. The LTEL is usually, but not always, higher than the STEL.

Types of Hazard

Asphyxiant gases



Asphyxiate gases *See Slide 6.*

The problem of Asphyxia is caused by a lack of oxygen for the body to use. Rather than measuring the concentration of unwanted gas, it is more usual to measure the oxygen level to check that it is between acceptable limits.

Normal air contains around 20.8% of oxygen, by volume. It is generally accepted that no adverse affects are observed down to 18%. At 16% headaches and other symptoms become apparent, and there is a risk of death at around 14%, which increases until at 6% you have little chance of surviving.

Alarm levels are generally set at 19%. This is less than 2% below normal levels, so it is important that sensors are stable in order to avoid false alarms. Another cause of asphyxia is when toxic gases have the effect of preventing the body from using the available oxygen. Carbon monoxide is one gas that has this effect. For these gases, oxygen monitors will, of course, be of little practical effect, and it is important to monitor for the asphyxiate gas itself.

Vapour density

is the relative density of a gas or vapour when air = 1.0

- vapour density <1 , gas will rise
- vapour density >1 , gas will fall

examples

methane.....	0.55
carbon monoxide	0.97
hydrogen sulphide	1.19
petrol vapour (approx)	3.0

Vapour Density *See Slide 7.*

The vapour density of a gas is a measure of how heavy it is relative to air. Gases, which are heavier than air, tend to fall towards the ground, whereas those that are lighter than air will tend to rise upwards.

This has obvious implications as regards the best positioning of a sensor in order to detect any gas leaks. If no other factors apply, then sensors for lighter than air gases should be positioned high, and those for heavier than air, low. However, other factors often do intrude. Standards such as BS 6959 1989 should be referred to for detailed information, but it is normally wise to consider such things as:

- wind direction and strength
- ground topology - does the site slope in any particular direction?
- where are the likely sites of any leaks?
- where are the likely sites where gas could accumulate?
- is there any plant or machinery which may be hot enough to cause convection
- currents? and so on...

In addition, for toxic gases, it is quite common to position sensors in the breathing zone of personnel working in the area, which can often provide more effective protection than relying on vapour density considerations alone.

Other considerations

flash point (FP)

the lowest temperature at which 100% LEL can exist

auto ignition temperature(AIT)

the temperature which ignites a flammable concentration without a separate ignition source

examples

gas/vapour	FP(° C)	AIT(° C)
methane	< -20	595
kerosine	38	210
bitumin	270	310

Flash Point and Auto Ignition Temperature

See Slide 8.

At all normal temperatures liquids (and, in fact, solids) will give off a vapour. The concentration of vapour given off increases as the temperature goes up. Eventually, if the temperature is high enough, the concentration of vapour will reach the LEL concentration. At this temperature, called the flash point, the vapour can ignite if the other necessary conditions (oxygen; source of ignition) are present.

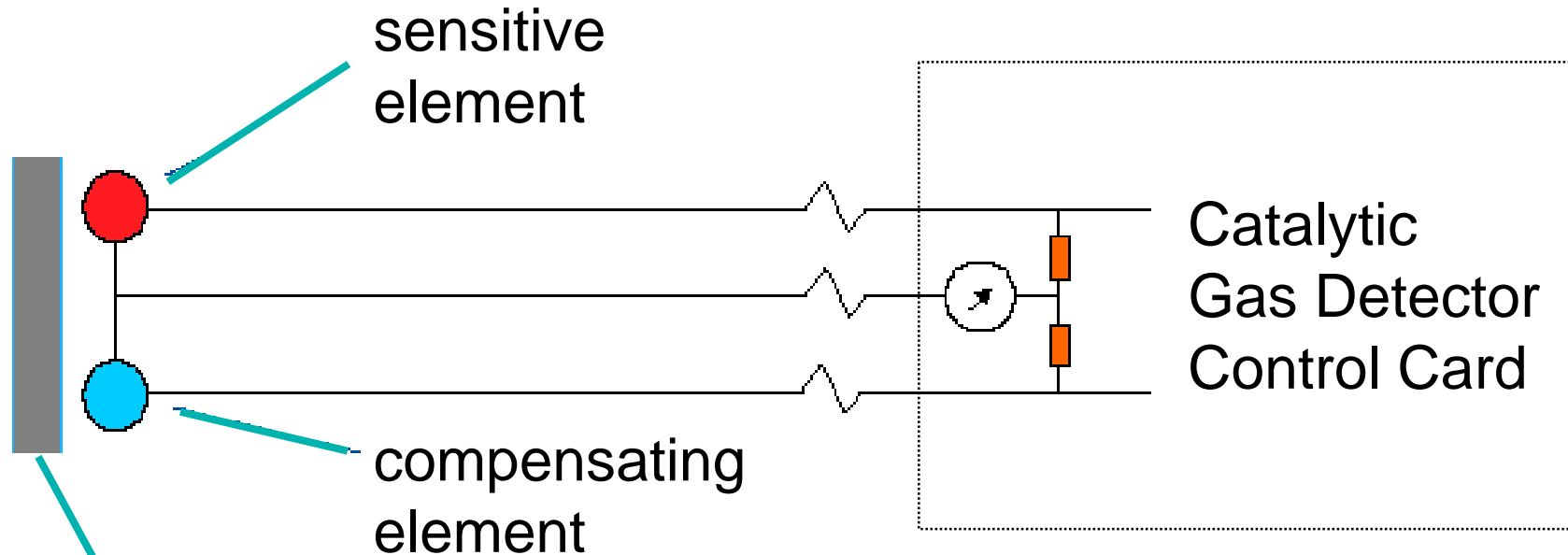
Some substances, such as methane, have such a low flash point that they are capable of ignition at all normal temperatures. Others, such as diesel or kerosine, have a flash point above normal ambient temperatures. This means that however large the release, the concentration of vapour will never reach explosive levels - unless, of course, there is a source of heat in the area.

The other implication of this is that any sensor will not detect LEL concentrations, however large the spill - this is, of course, because an LEL concentration is not present, again unless the temperature is elevated. This has obvious implications as regards the setting of alarm threshold values for leak detection. For the detection of high flash point vapours it may be worth considering a sensor with a lower range than the normal 0 - 100% LEL, and a common range in these cases is 0 - 10% LEL.

The Auto Ignition Temperature of a gas is the temperature at which it will ignite without the need for a flame or spark. An example of this would be ignition on contact with a soldering iron or hotplate. This has implications as to the permitted T rating (see certification) of any certified equipment used with a particular gas. It is essential that the T rating is high enough to prevent the equipment reaching temperatures, which may ignite any gas that is present.

Types of Detection

Catalytic combustible gas detector



gas permeable sinter

- 😊 lifetime typically > 5 years
- 😊 some poison resistance built in
- 😊 low power consumption (0.75 Watts)
- 😞 not fail-safe

Catalytic Instruments See *Slides 9 & 10.*

At the heart of the catalytic sensor is a coil of platinum wire, which is heated to around 400°C 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, and is proportional to the amount of gas that is present.

The circuit to measure this change in resistance is based on the classic "Wheatstone Bridge" network. The change in resistance of the sensitive element causes an imbalance that leads to a current flow down the centre wire. The compensating element is carefully constructed to mimic the thermal properties of the sensitive element. In this case it is coated in glass to make it insensitive to gas.

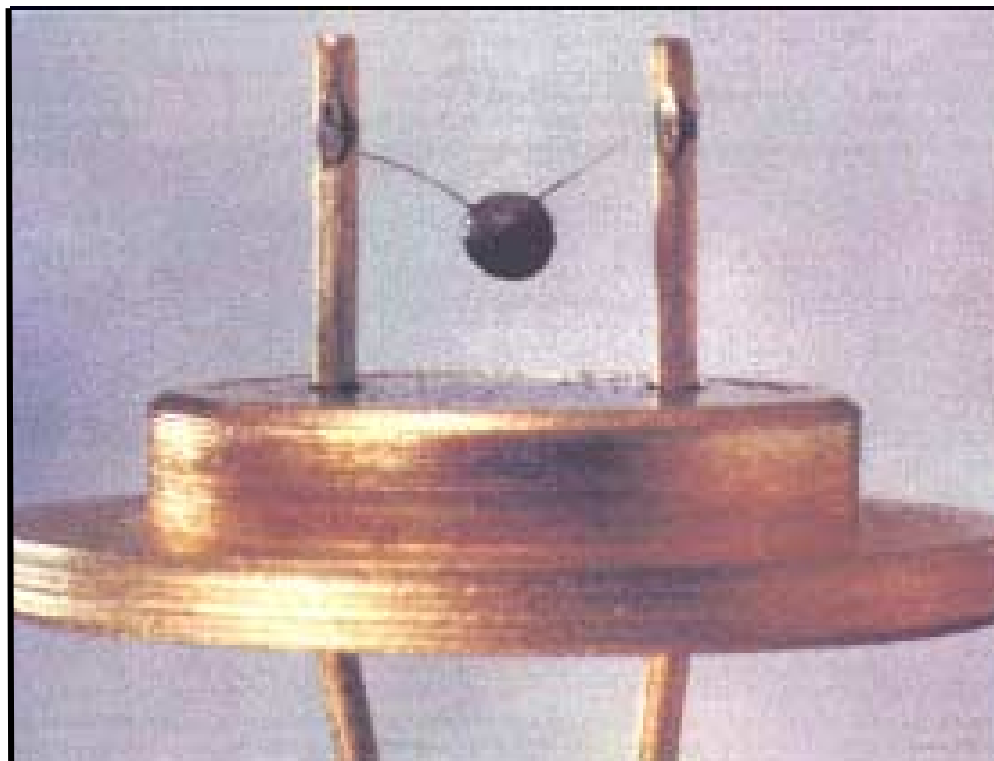
Any normal changes in ambient temperature; humidity, etc. result in near identical changes in resistance of the sensitive and compensating elements, thus no imbalance is created, and the zero remains stable.

As an alternative to the glass coated compensating element, some applications are better met by the use of the pinhole compensator. In this case, two identical beads are used, but one is covered by a cap with only a very, very small pinhole in it. This means that although the bead is open to the ambient air - and so able to act as compensation for changes - the amount of combustible gas entering through the pinhole is insufficient to produce any significant output.

The other bead has a cap with a larger hole, and so has a much greater change in output in the presence of combustible gas. Thus the gas still produces an imbalance in the Wheatstone Bridge network.

Types of Detection

Catalytic combustible gas detector

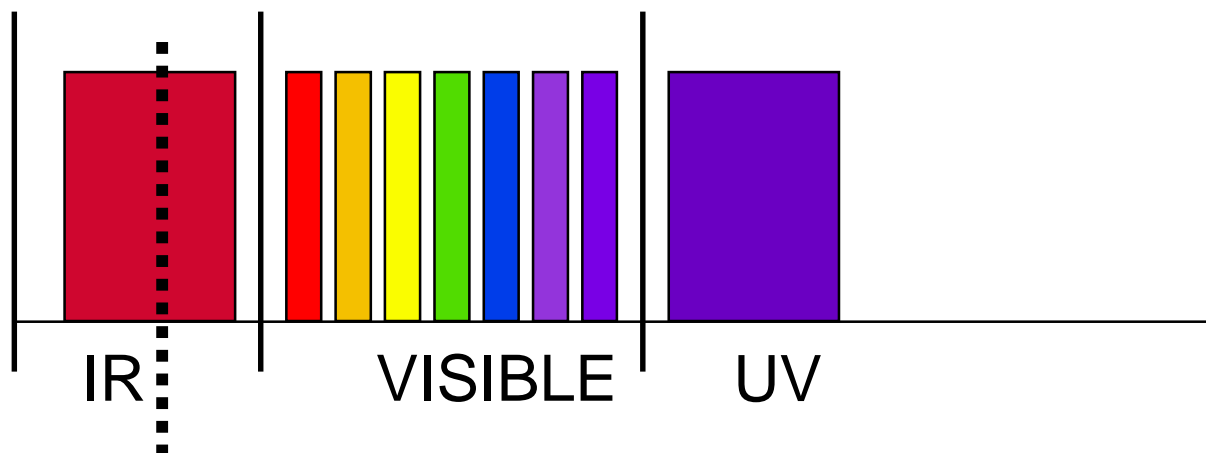
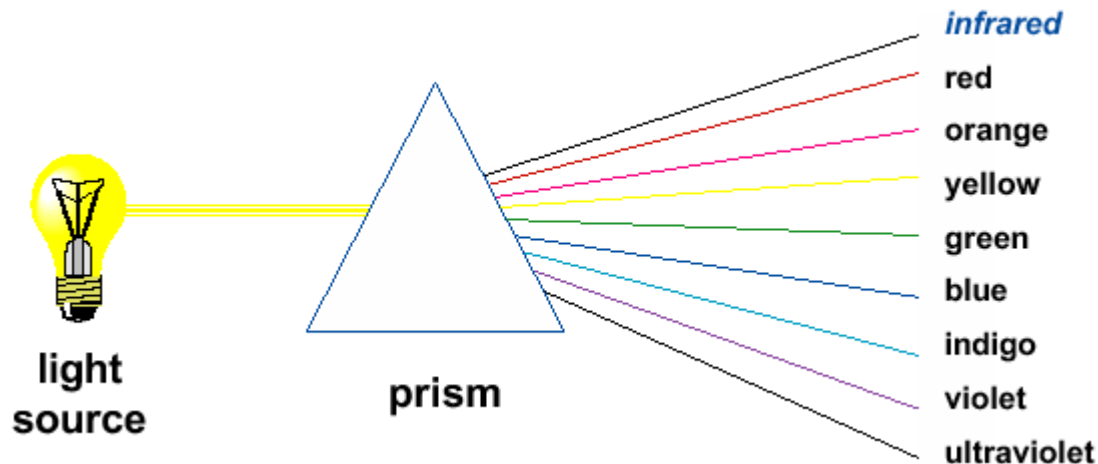


Catalytic Instruments (cont'd)

Catalytic sensors are subject to attack by contaminants, which can poison the catalyst and reduce the sensor output. Modern catalytic sensors are designed to be highly poison resistant, but it is recommended that the calibration be checked at regular intervals, around six months depending on conditions. Provided this is carried out, then years of trouble free service should be obtained.

Types of Detection

Infrared combustible gas detector



Infrared Instruments

See Slide 11 & 12.

Infrared sensors use an entirely different technique.

You are probably aware that white light is made up of many different colours, which can be split up by passing them through a prism. The human eye can see colours from red to violet, but beyond the red colour is the invisible infrared light, and it is this that is used in sensors.

The reasons that infrared light is chosen is that certain colours, or wavelengths, of infrared light are absorbed by the gases that we want to detect. If we shine a beam of light, of the correct wavelength, through an area, then if gas is present the amount of light arriving at the other side will decrease in proportion to the amount of gas that is present.

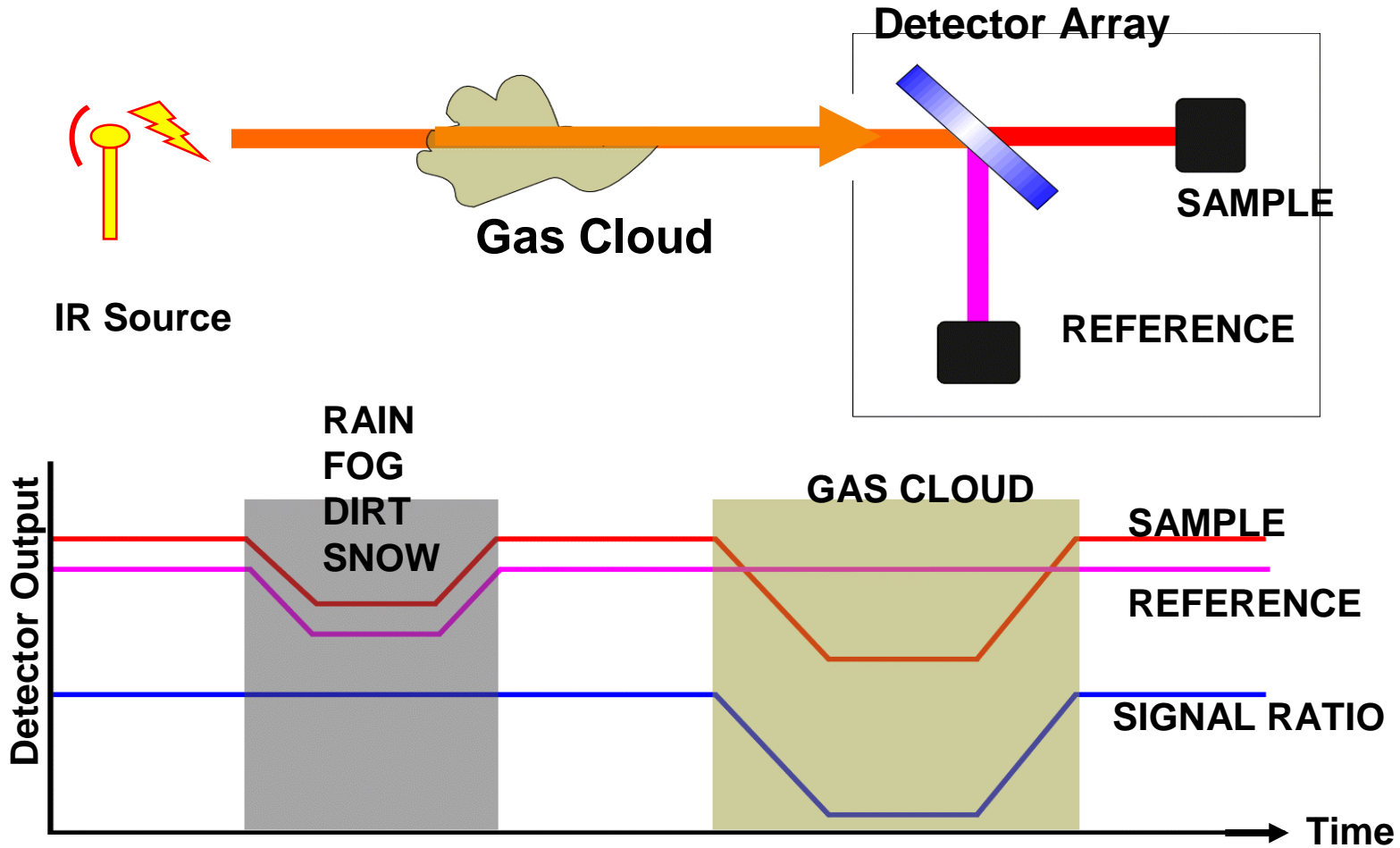
In practice, most modern sensors use light at two different wavelengths, one is absorbed by the gas (sample), and the other is not absorbed (reference).

Under gas-free conditions both beams of light are affected by normal ambient changes, such as humidity, dirt particles, and so on. Because both beams are affected equally, there is no differential output from the system and the zero remains stable. This system also enables the system to self-compensate for potential zero drift, thereby reducing maintenance requirements.

Should gas be present then the gas absorbs the sample beam. The reference beam, however, remains unaffected, and a differential output is obtained, which is proportional to the amount of gas that is present. The amount of light absorbed by a given quantity of gas is a percentage of the light present before absorption. This means that the system can retain its calibration; even if the original light source changes it's properties over time.

Types of Detection

Infrared combustible gas detector



Infrared Instruments (cont'd)

In practice, the distance that the beam of light can cover ranges from a few centimetres (a point detector) to hundreds of metres (an open-path detector). One other major advantage of infrared sensors is that if any part of the system fails, this can be detected electronically, and a warning signal generated. Systems with this feature are by custom called fail-safe, although arguably not in the true meaning of the word.

Types of Detection

Electrochemical cell toxic gas detector

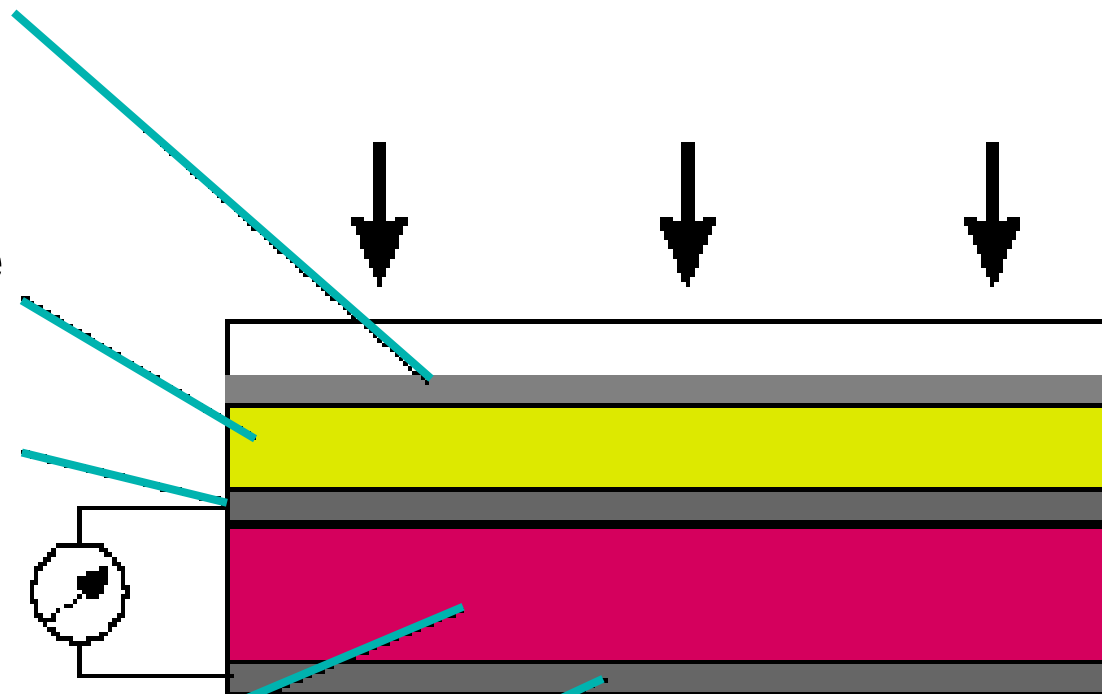
semi permeable
membrane

thin film electrolyte

sensing electrode

bulk electrolyte

reference electrode



Electrochemical Instruments *See Slide 13 & 14.*

Electrochemical sensors are highly sensitive, and so are ideal for the detection of low levels of toxic gases. They work on a principle similar to that of a battery, and so are generally called fuel cells. When the gas permeates into the cell, a reaction occurs which releases electrons, which can flow round an external circuit and between the sensing and working electrodes, so generating a very small electrical current, which is directly proportional to the amount of gas present.

Often a third electrode is added, to which a bias voltage is applied, which can be used to make the cells more selective to particular gases.

Electrochemical Cells have excellent zero stability, and a very consistent output throughout their lifetime, which is normally of the order of several years. Regular calibration checks should, however, be carried out, particularly towards the end of cell life, as the final cell failure mode is not fail-safe.

Types of Detection

Electrochemical cell toxic gas detector

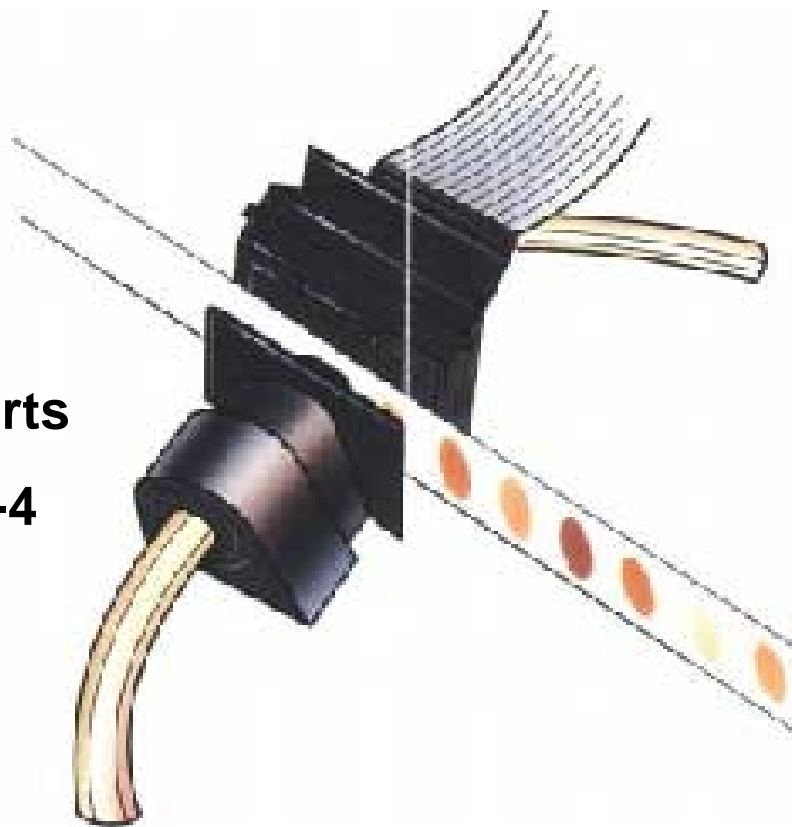
- 😊 lifetime: 1 to 3 yrs
- 😊 “ppm” level detection
- 😊 gas specific
- 😞 not usually fail-safe



Types of Detection

Chemcassette, toxic gas detector

- 😊 very low level “ppb” detection
- 😊 gas specific
- 😞 requires mechanical moving parts
- 😞 must change cassettes every 3-4 weeks.



Chem-Cassette Instruments See Slide 15.

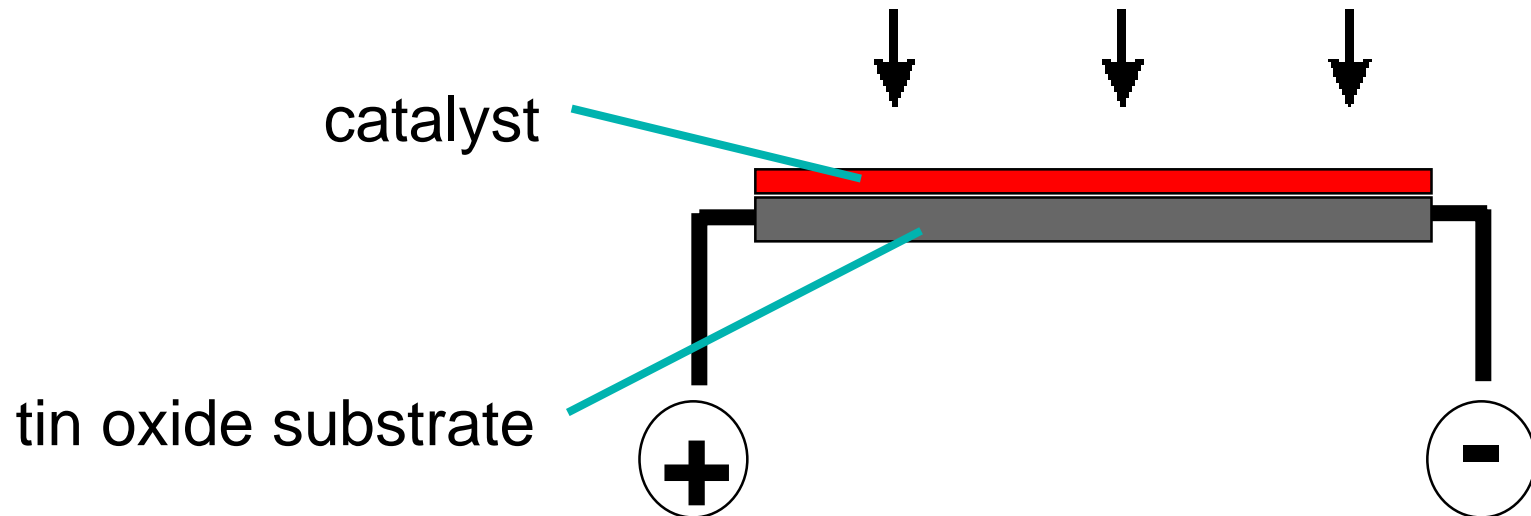
For the detection of low levels of toxic gases, with a very high level of specificity, Chemcassette ® technology can often provide the answer.

The heart of the system is a porous paper tape that is impregnated with a chemical which has a specific reaction with the gas being detected, which results in a colour change on the tape. (Probably the best-known example is the use of lead acetate for the detection of hydrogen sulphide - a dark brown colour results). The sample being monitored is passed through a section of the tape.

The colour change can be measured electronically, and the depth of colour is proportional to the concentration of gas present. By using carefully selected flow rates and times of exposure, levels from ppm down to ppb can accurately be measured.

Types of Detection

Solid State (MOS), toxic gas detector



- ☺ lifetime typically 5 to 10 years
- ☺ ppm level detection
- ☹ large cross sensitivity to other gases
- ☹ non linear output, can “go to sleep”

Solid State Instruments

See Slide 16.

Solid-state sensors are made of a metal oxide (typically tin-oxide) material 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. They can detect a wide range of gases, including many that electrochemical and paper tape instruments are unable to see.

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. In addition, they have no moving parts that can cause mechanical failure.

Disadvantages. While solid-state sensors can detect a wide range of gases, they have very low selectivity — so the possibility of “false alarms” is significantly higher than with other technologies. In addition, when they have not been exposed to gas for some time, some solid state sensors oxidize and “go to sleep,” meaning that they will not respond to real gas leak.

Solid-state sensors also provide a non-linear output, so calibration is more difficult and time-consuming than it is with electrochemical sensors (which have a linear output).

Design Standards

quality	ISO 9001
electrical equipment.....	EN60079
in hazardous areas	
safety	EN50014
performance.....	EN50054
EMC	EN50081/82
low voltage.....	EN61010
combustible sensor location	BS6959

Hazardous Zones

See Slide 17.

It is often vital that equipment for the detection of gas, particularly combustible gas, is not capable of igniting any gas that may be present. Areas of a plant where combustible gas may be present are usually zoned in order to give an indication of the degree of hazard likely to be present.

European standards define three levels of combustible gas hazard:

Zone 0, where the gas is present continuously, or for long periods, under normal operation,

Zone 1, where the presence is only for short periods under normal operation, and

Zone 2, where combustible gas is unlikely to be present for long periods, and only under abnormal conditions.

North American standards use Divisions rather than zones, and combine European zones 0 and 1 into Division 1. The degree of safety built into a product suitable for use in the various areas increases as the hazard increases.

Safety Certification

E Ex ia II C T6

European
(CENELEC)

explosion
protection

type of
protection

apparatus
group

gas
group

temperature
class

Safety Certification

See Slide 18.

To confirm that equipment is safe to use in areas where combustible gas may be present (so called hazardous areas) such equipment is usually certified as safe by a responsible test authority. Equipment that has successfully met the relevant safety standards is then marked to show what standard of certification it meets.

A typical European mark is shown here. It is divided into different parts:

The first "E" indicates a European approval. "Ex" shows it is protected against causing explosions.

The next group of letters shows the type of design criteria used to ensure that it is safe - the type of protection. This is explained further on later pages. The Apparatus Group shows whether the equipment is suitable for mining or other industrial use, again this is explained later.

The Gas Group indicates just which combustible gases it can be used with. (Some gases are easier to ignite than others, and equipment used with these gases needs a higher degree of safety protection built in).

The Temperature Rating indicates how hot the surfaces of the product may become under normal or fault conditions. Clearly it is not safe to use a product whose surface temperature can go above the auto ignition temperature of any combustible gas that may be present.

Types of Protection

Zone 0

Ex iaintrinsically safe

Ex sspecially certified

Zone 1, Zone 0 protection plus:

Ex dflameproof

Ex ibintrinsically safe

Ex ppressurized /
continuous dilution

Ex eincreased safety

Ex sspecial

Ex mencapsulation

Zone 2, Zones 0 & 1 protection plus:

Ex nnon-sparking

Ex ooil immersion

Ex qpowder / sand filled

Types of protection

See Slide 19.

Different methods of protection may be used in the different zones. The actual design and manufacture to these standards is very complex, but a brief description of the techniques is given here.

Intrinsically safe 'ia' the electrical circuit is designed so that nowhere in it is enough energy to create a spark that may ignite the gas, even with two faults on the circuit.

Intrinsically safe 'ib' as 'ia' but with one fault on the circuit.

Flameproof 'd' the equipment is housed in a strong enclosure which is designed so that any explosion is contained within the enclosure, and the resulting gases that are exhausted are cooled sufficiently so that they do not ignite the gas outside the enclosure.

Pressurised 'p' the equipment is housed in an enclosure that is kept above ambient pressure. The potentially explosive gases from the outside cannot enter because of this higher pressure.

Increased safety 'e' the equipment is very simple (e.g. a terminal strip) and of high quality (e.g. built so that cable connections cannot easily work loose and contact other connections). The enclosure is designed to at least IP54.

Special 's' any method of protection not covered by other standards, but proven to be safe. In gas detection this invariably means a sintered flashback arrestor.

Encapsulation 'm' the equipment is put into an enclosure which is then filled with, e.g., a resin compound which sets so that the gas never comes into contact with any hot surfaces.

Non-sparking 'n' not met in gas detection. Oil immersion 'o' not met in gas detection Powder/sand filled 'q' not met in gas detection.

Apparatus and Gas Group

Group	Typical Gas	Ignition Energy
I	mining products.....	
IIA	propane	180 μ J
IIB	ethylene	60 μ J
IIC	acetylene & hydrogen	20 μ J

Apparatus and Gas Groups

See Slide 20.

When it is tested, equipment is certified for particular gas groups. Different gases need differing amounts of energy to start the combustion reaction. Clearly the ones that need the lowest energy need the highest standards of protection in order to remain safe. In European standards the gas groups can be summarized as follows:

Group I mining products only. (The gases found in mines are well defined, and protection standards are designed specifically for those gases).

Group IIA gases with an ignition energy of 180 μ J or more. The typical gas in this group is propane.

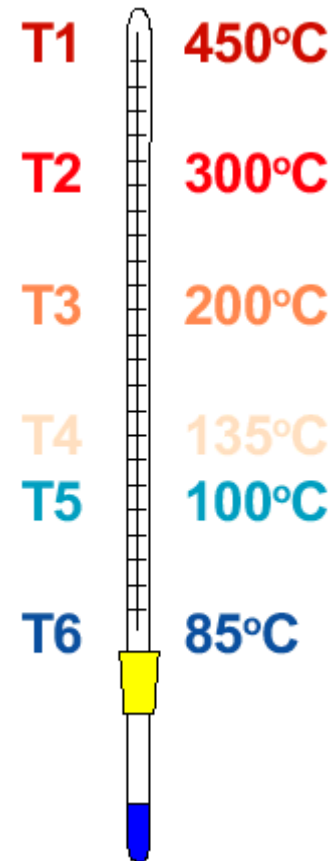
Group IIB gases with an ignition energy of 60 μ J or more. The typical gas for this group is ethylene. Equipment approved for use with group IIB gases is also suitable for use with gases in group IIA.

Group IIC gases with an ignition energy of 20 μ J or more. There are very few gases in this group, and they should be regarded as highly dangerous. The commonly encountered gases are hydrogen, and acetylene. Acetylene is often found in potentially oxygen enriched situations (e.g. oxy-acetylene cutting / welding) which still further increases the hazard.

Temperature Class

...the maximum surface
temperature that a
device could reach
under fault condition

based on an ambient of 40° C



"T" Rating

See Slide 21.

Finally in certification, the equipment is given a temperature classification.

Each gas or vapour has an Auto Ignition Temperature that is a temperature at which it will spontaneously ignite, without the presence of a spark or flame. It is important that any equipment likely to come into contact with a gas never reaches this temperature.

Equipment is given a "T" rating, which indicates the maximum temperature that will be reached - both in normal operation, and, for example, when an explosion occurs inside an Exd enclosure. The higher the 'T' rating, the lower the surface temperature. It is important to note that these tests are carried out at an ambient temperature of 40° C, unless stated otherwise (e.g. T amb = 60° C).

Ingress Protection Ratings

I P ratings... solids IPXX

- 0** no protection
- 1** solid bodies >50mm diameter (e.g. a hand)
- 2** 12mm diameter; 80mm long (e.g. a finger)
- 3** 2.5mm diameter (e.g. a piece of wire)
- 4** 1.0mm diameter (e.g. a small piece of wire)
- 5** dust: ingress allowed, but not enough to prevent operation
- 6** complete protection: no ingress of dust

"I.P." Rating

See Slide 22 & 23.

The I.P. rating system provides a means of classifying the degree of protection of an item from dust and water afforded by electrical equipment and enclosures. The system is recognized in most countries and is set out in a number of standards including IEC 60529

The format for the I.P. rating is indicated by two numbers.

The first numeral indicates access to dangerous parts and protection of internal equipment against the ingress of solid foreign objects.

The second numeral indicates protection of internal equipment against harmful ingress of water.

Ingress Protection Ratings

I P ratings... liquids... IPXX

- 0** no protection
- 1** vertical drops of water
- 2** 15° drops of water
- 3** 60° rain or spray
- 4** splashing water from any direction
- 5** water jets from any direction
- 6** heavy seas or powerful jets
- 7** immersion under 1metre for 30 minutes
- 8** indefinite immersion

Sensor selection and location

Points to consider:

- indoors or outdoors
- environment (temperature; humidity; pressure)
- air movements
- potential sources of leaks
- potential ignition sources
- type of gas
- vapour density
- areas where gas could build up

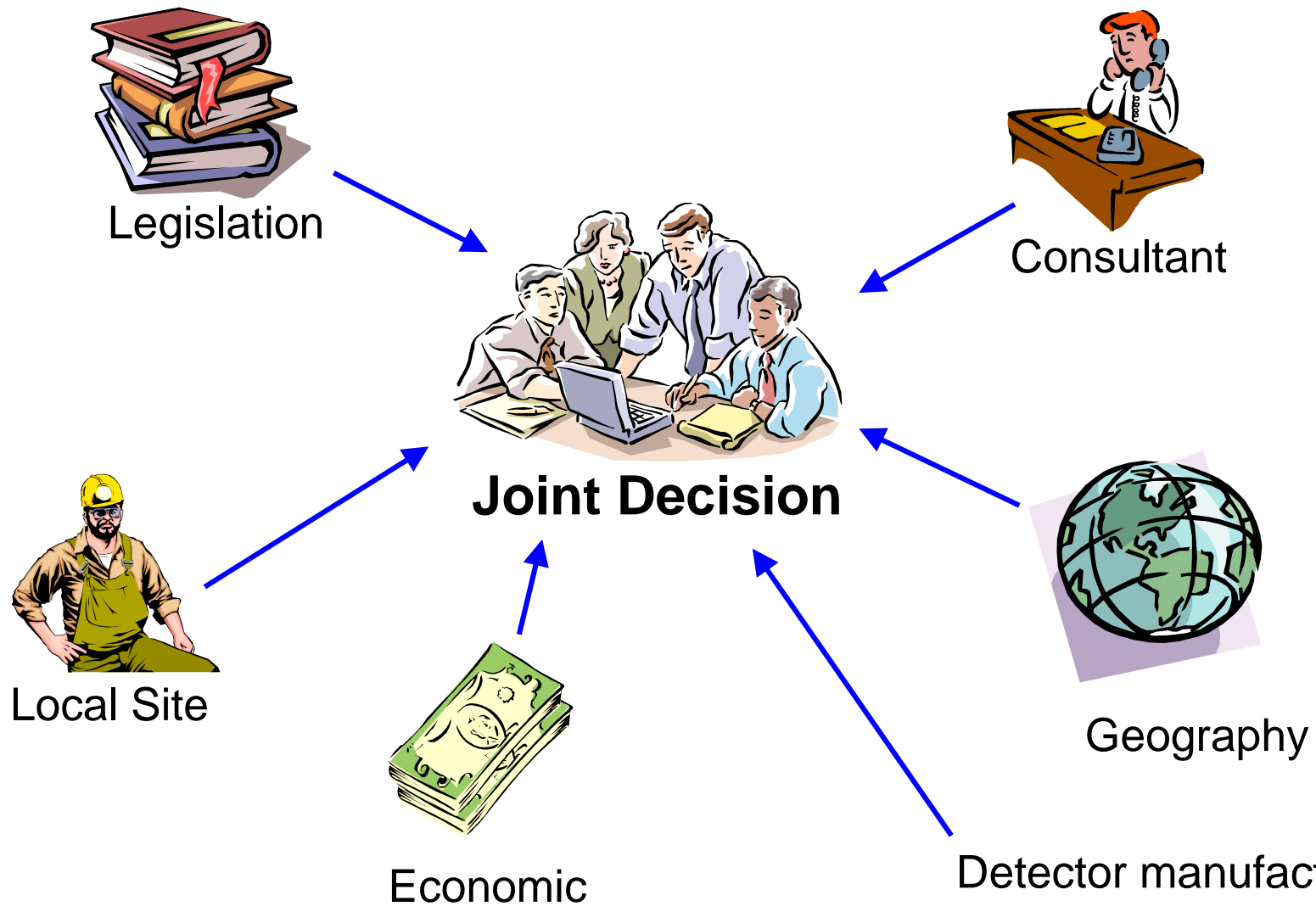
Sensor Selection and Location See *Slide 24 to 29*.

Even the best gas detection systems are of little use if the sensors are incorrectly positioned. There are a great many factors that have to be taken into account, and these are laid out in BS6959, or local regulations.

It is important to note that any one person or organisation is highly unlikely to have all the expertise and knowledge necessary to decide on sensor positioning. Not only is a knowledge of detector function and design needed, but also air movement, gas and vapour behavior, ambient weather and climatic conditions, and detailed plant operation to the extent of knowing the content of every pipe and reaction vessel together with their pressure and likely points of leakage - and more!

The positioning of gas detectors is, for these reasons, best decided by a joint decision from all involved.

Sensor selection



Sensor Selection and Location *See Slide 24 to 29.*

With such a wide range of technologies, regulations and other factors to consider, it is fortunate that Zellweger Analytics have fifty years experience to call upon, and probably the widest choice of gas detection products available in the market today. Gas detection systems usually fall into three categories:

Portable detectors: carried by an individual or group of individuals. Often subjected to some of the harshest treatment of any gas detectors - such as being dropped from great heights, submerged under contaminated water and covered in dirt of various sorts. High quality design and construction is essential for equipment subjected to such treatment.

Fixed systems: permanently attached to a given location. Such systems vary widely in their requirements, from simple, single sensor installations on relatively clean locations, to systems of several hundred detectors with complex control requirements.

Addressable systems: the use of data highways for the data acquisition and control functions associated with gas detection and other functions are now very common. Use of experienced engineers minimises the possibility of problems associated with such systems, and their interface with other devices.

Gas Detector Selection



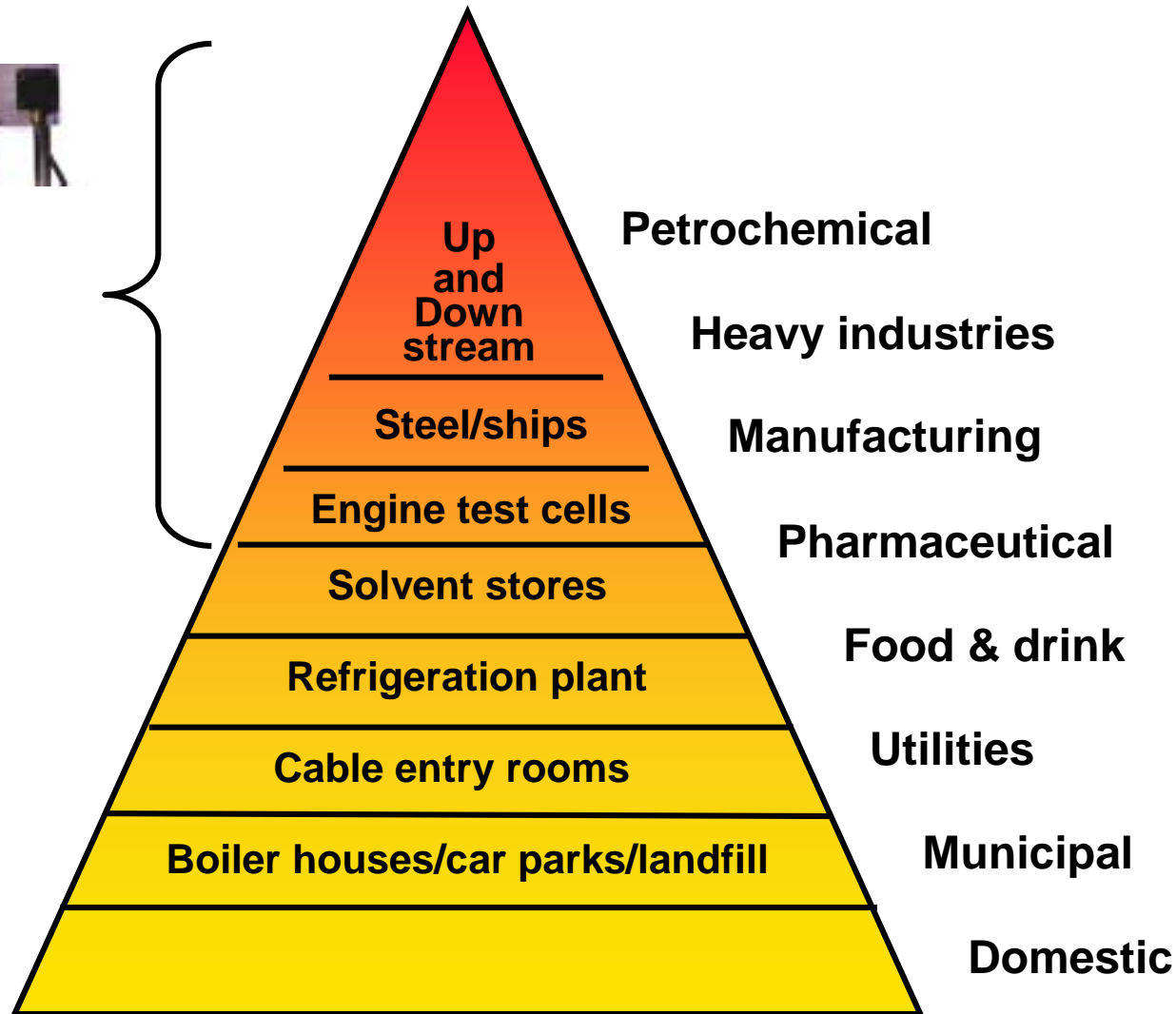
Searchline Excel



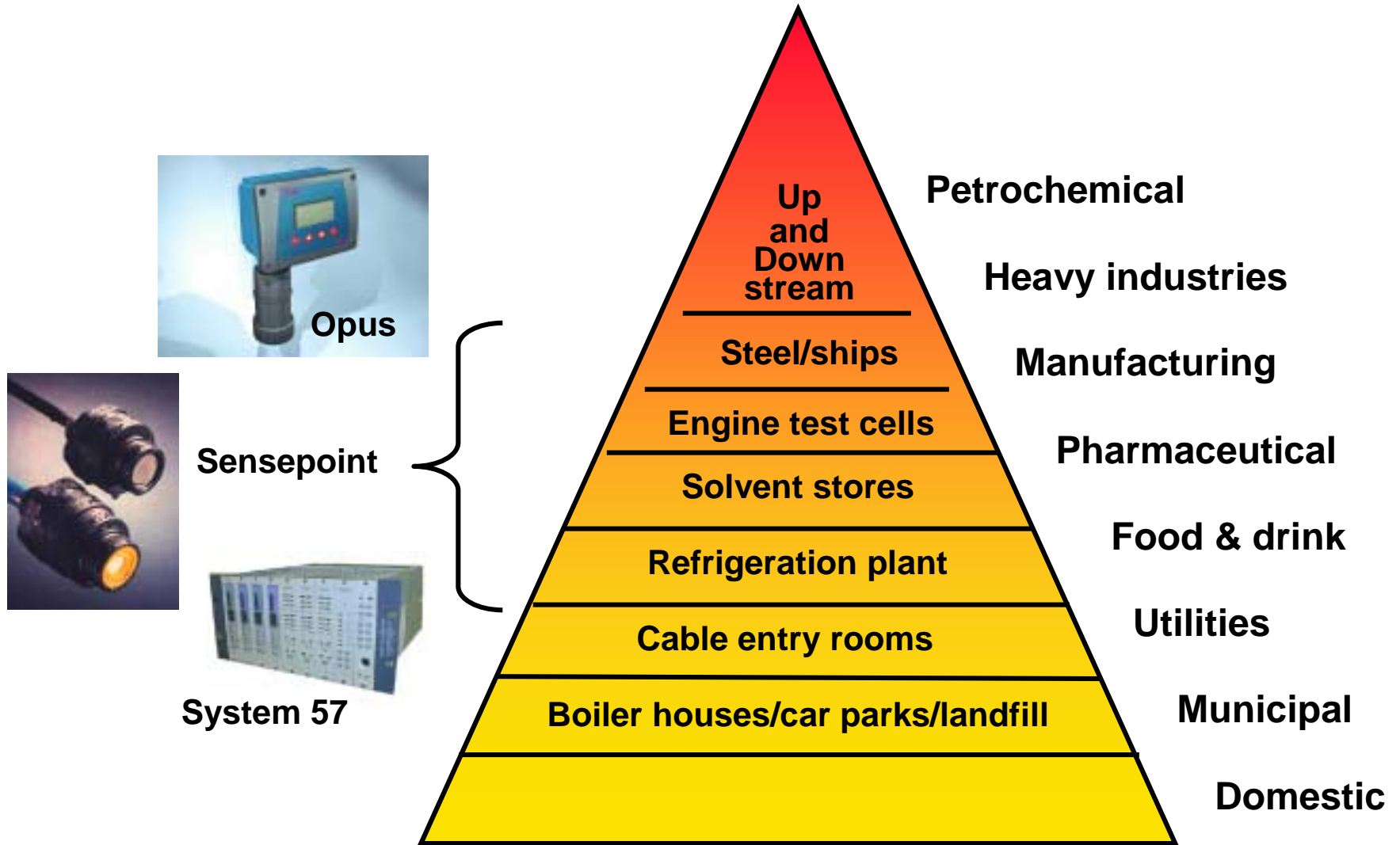
Optima Plus



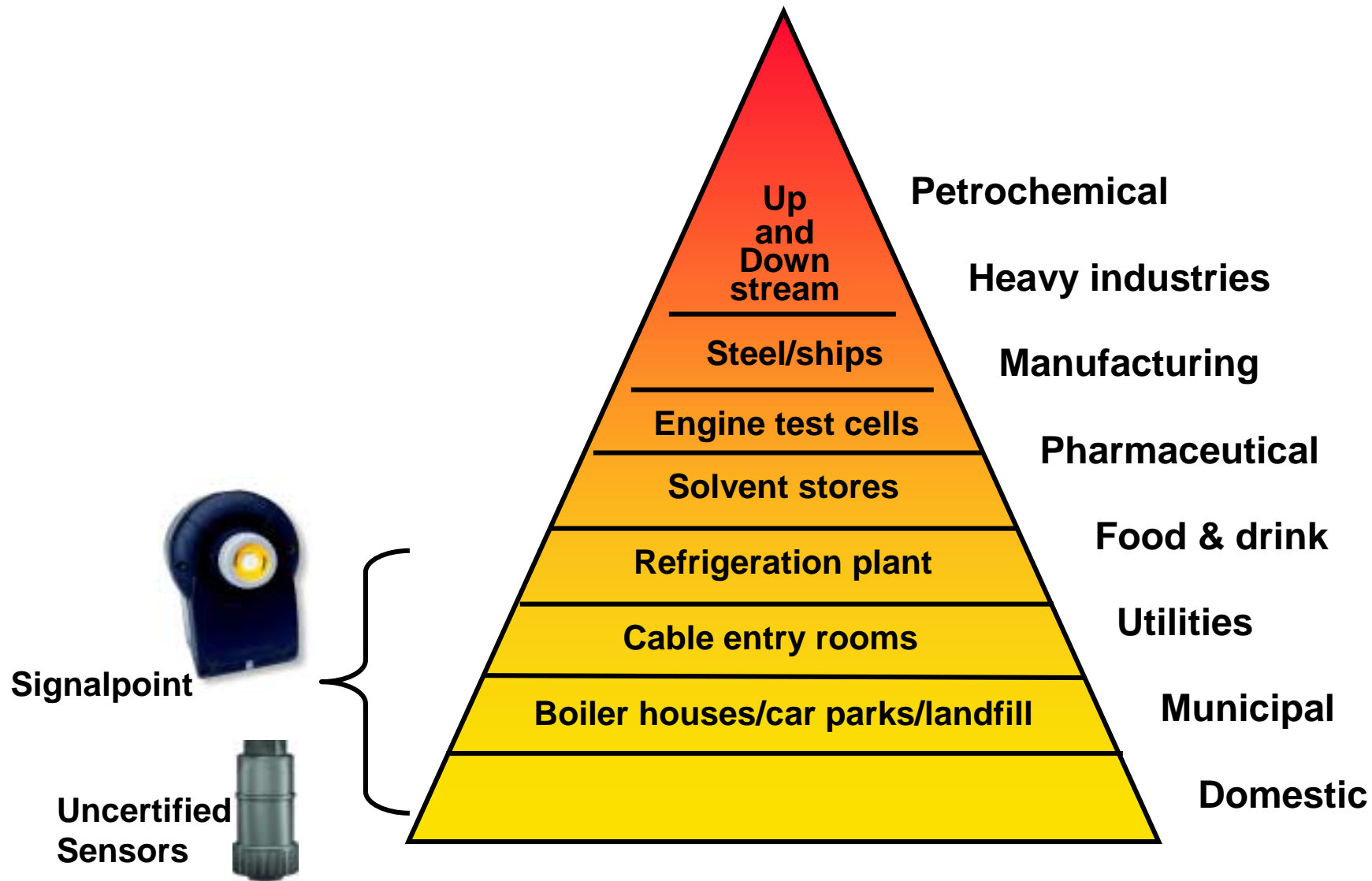
Apex



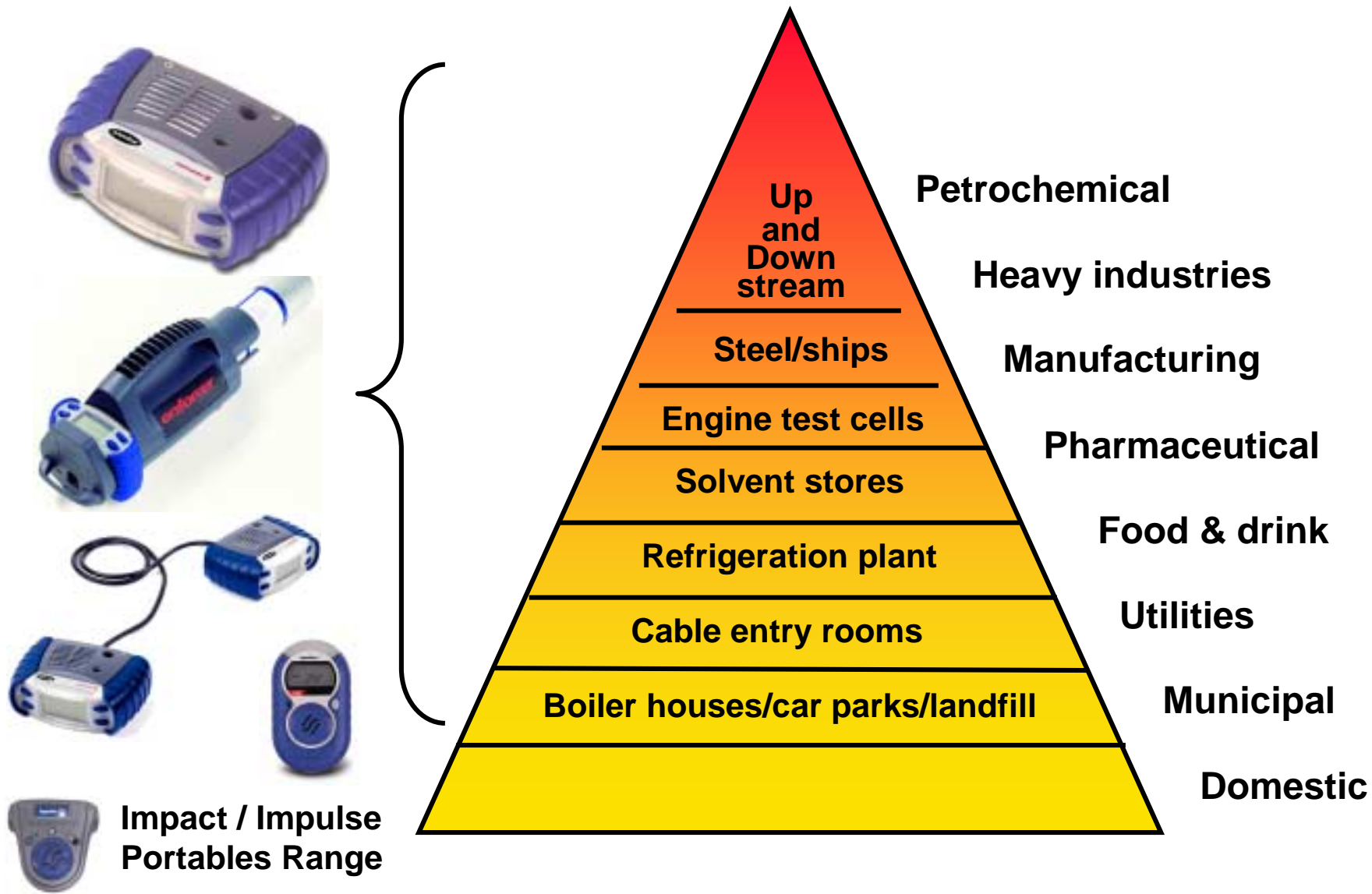
Gas Detector Selection



Gas Detector Selection



Gas Detector Selection



End.