

Fire and Gas Detection and Control in the Process Industry

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Abstract

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. This paper describes various fire and gas detectors, such as flame, smoke, heat, gas, and the typical actions taken by fire and gas systems. Also described are current system architectures: hard-wired, addressable, redundant and others; the integration of fire and gas into overall control systems; regulations and codes. To SIL (assign an IEC61508 Safety Integrity Level) or not to SIL will also be addressed.

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1 Introduction

Fire and gas detection systems have been around for many years.

A childhood memory is of being taken by my late father to the Mines Rescue Station at Boothstown, Lancashire. There I saw walls of canaries in cages. Canaries were then a mandatory requirement in coal mines. They were used to detect the presence of Carbon Monoxide.



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Illustration 1: Canary in a cage

The coal industry has a continuous possibility of fire-damp (methane) emanating from the strata. Great efforts are made not only to detect combustible and toxic gases but also to ensure that equipment is safe for use in potentially explosive atmospheres.

The process plant should be designed to be safe. However there will always be residual risks. Layers of protection need to be designed in, to detect any anomalies that the process control system hasn't taken care of. These additional layers should make the process safe. The fire and gas detection system provides an extra layer of protection to mitigate the consequences when the other safeguarding layers have not been sufficient.

The gas detection system can detect a discharge of combustible or toxic gas and take action to minimise the leak and prevent it turning into a fire or explosion. If a fire should result, systems can be attached to extinguish the fire and protect other areas from the actions of the fire. The same system, usually with different detectors and principles, can be used to detect toxic gases, give warning to personnel and provide the possibility of taking automatic actions.

Fires in process plants may be either like any other industrial fires, for example electrical fires in utility areas, smouldering waste bins, etc., or an ignited leak of a product from the process.

Some companies use separate gas and fire detection systems. This particularly applies to the fire and gas systems designed to GOST codes (Russia and former Soviet Union states). Generally, the fire detection system and gas detection system is combined into one fire and gas system. A separation that may be made is to have one fire and gas system for the 'process' areas and another sub-system for the utility or office/accommodation areas.

Systems can be single, duplicated or triplicated. Redundant systems are not new. Systems in the early 1980's were being delivered with dual, diversely located controllers, dual detectors, and dual control outputs.

Simple logic controllers have fallen out of general use in the fire and gas context. Systems

tend to offer a redundant solution and/or high levels of diagnostics.

A current issue is the application of IEC61508/IEC61511 'SIL levels' to fire and gas systems and products, applying these to detection, actions and annunciation.

2 System Choices

Before technology choices can be made a risk analysis has to be undertaken. The resulting risk analysis and mitigation reports can be used to establish the integrity requirements for the fire and gas system. This is normally performed by a competent, multidisciplinary team. The documents produced should be reviewed at regular intervals. They may be revised based on an evaluation of available detection and protection solutions. These documents are part of the project life-cycle documentation.

Several companies offer a service for '3D modelling' of the plant so that the placement of detectors can be confirmed in relation to the modelled fire and gas scenarios.

Below are some of the issues that need to be considered when choosing a system and/or detectors:

- Codes, standards and regulations. Which are required for the installation? Attention should be paid to variations in national codes and orders of precedence.
- Codes, standards and regulations are various including:
 - Certification bodies, ABS, DNV and Lloyds Register etc.
 - Company codes of practice.
 - Insurance based; FM, LPC, and UL etc.
 - International standards, IEC 61508 IEC 61511 and SOLAS etc.
 - Local fire authorities, State Fire Marshall etc.
 - National and multinational codes, EN54, API, GOST, ISA S84, KOST and NFPA 72 etc.
 - Project specific specifications.
- What is likely to produce the risk event? What are the plant's raw materials, by-products and final product?
- What are the chances of a fire or gas release?
- How big would the release be? i.e. what size gas cloud or fire do you need to detect?
- How do you split the process plant into fire zones or fire areas?
- Are they called fire zones or fire areas?
- Should you use a fire zone number as part of device tag numbers?
- Can the fire zone naming or numbering hierarchy form part of the overall plant naming or numbering system?
- Should you abbreviate fire area naming so that they fit into the length and presentation restrictions of the Operator Interface?
- Is there a project-agreed list of abbreviations?
- Speed of detection response (not forgetting that speed of response can be a trade off against unwanted alarms. Unwanted alarms can cause plant shut-down, which is costly and itself increases risk.)
- Are there company preferences, such as vendor preference, existing stocks, spares holding requirements, commonality needs?

- Considerations for offshore systems – they must be self-contained; i.e. must have no need for service from onshore as the fire brigade can't be called out and there is nowhere to run to.
- How localised should the alarm be? Time saved locating the fire can reduce escalation and life threatening circumstances.
- How will detectors be tested? Which tests need to be performed manually? Which tests can be carried out automatically? What frequency of testing is needed? Choosing equipment that needs to be tested less often can mean shorter test periods and longer test intervals Longer and predictable test intervals reduces staff presence, thus lowering exposure to risk to the staff on the process plant.
- What level of detail is required from the detector? Intelligent use of diagnostic information can be used to determine why unwanted alarms happen and enable predictive maintenance, again reducing plant exposure.
- Consider detection types that offer a view and a recording of alarm events – sending staff towards a risky situation seems counter-intuitive.
- Consider what information is needed by the operator and what is needed by maintenance personnel. Are there other users?
- Carry out an alarm handling study, including alarm discrimination to avoid flooding an operator during a time of crisis.
- What symbols should you use on the operator graphics display – should they be the same as on any detection layout drawings? Do they translate well from paper to screen?
- Which language to use? Or multi-language?
- Consider the level of integration (if any) the system is to have with other plant systems, and the Operator Interface. Is it to be standalone, partially integrated or fully integrated? Is the 'integrated' system you are considering really integrated?
- Do the systems and devices chosen have a proven track record?
- What actions do you want the system to take?
- Where will the equipment be located? Is it indoors, outdoors, will there be rain, fog, or pollutants obscuring the detector or causing it to false alarm? Is there anything in the detection area that will reduce its effectiveness? What IP (ingress protection) ratings are required? Will sunlight, background heat or vibrations have an impact on the performance?
- Hazardous area ratings – consider not just normal circumstances but, for example, exposure during gas releases.
- One detection system will not cover all situations. Even if detectors are bought through the system supplier, they may not be the manufacturer of all the devices. So you need to make sure all the elements will work together.

3 Initiating Devices

This section covers fire, gas, leak detection, manual activation and other inputs to the fire and gas detection system.

The choice of detection type is determined by using the optimum detection for the application, National and International code requirements, and custom and practice. Code requirements may call for specific detector technologies. Purchase price and life cycle costs are also considerations.

3.1 Fire Detection

Fires can be detected from flame, smoke or heat. A combination of devices may be needed for best results. There is no perfect fire detector.

3.1.1 Flame Detectors

Flame detectors should not be confused with flame monitors. The function of a flame monitor is to alarm in the absence of a flame, for example to cut the gas supply to a furnace if the flame is extinguished. Flame monitors are normally wired to a dedicated burner control system, not the fire and gas detection system.

A flame detector should alarm on the presence of a flaming fire and ignore normal phenomena that are not flames.

●Infra-red (IR) Flame Detectors

These are currently a popular choice. The detector relies on infra-red radiation produced by flames. The level and wavelength of infra-red radiation varies depending on the fuel of the flame being detected. The detector detects a flame within a cone of vision. The shape and length of the cone of vision varies between different models and manufacturers of flame detectors. In some detectors, more than one wavelength of infra-red radiation is used. Flame pattern recognition can be used to distinguish between constant sources of infra-red and flames. Background infra-red radiation can lead to reduced sensitivity and reduced effective detection distances. Careful placement is needed.

Example uses: General flame detection applications



Picture courtesy of Draeger Safety

Illustration 2: Example flame detector

● **Camera-based Flame Detectors**

Camera-based flame detectors use visual pattern recognition techniques to recognise flame shapes. They can relay a picture of the area under detection to the control room operator, thus minimising the need to send staff towards a risk. Also a recording of events leading to incidents may be made. These records can be used to review the circumstances of an incident. Areas of the display that could cause false alarms (e.g. a flare or reflections of a flare) can be masked from the detection area, whilst still being visible to the operator. In addition, a camera-based detector can give the operator information about the current state of the fire, whereas a traditional flame detector can only indicate limited alarm levels. These detectors require that a flame is visible.



Picture courtesy of Micropack Engineering

Illustration 3: Example camera-based flame detector

Example uses: top decks of floating production vessels and external areas where flare reflections are a problem.

● **Combining IR or UV flame detectors and cameras**

Some manufacturers combine flame detectors and cameras into one housing or product. Other solutions are to have the fire and gas system connected to the overall plant control system and CCTV (closed circuit TV) system to automatically direct a CCTV camera at the detection area. This principle can be extended to all forms of detection.

● **Ultra-violet (UV) Flame Detectors**

These detectors rely on the effective detection of ultra-violet radiation produced by flames. This is the original type of flame detector and has been largely superseded by other technologies. Detection of hydrogen fires, which used to mandate UV detectors, can also now be done by some infra-red flame detectors.

Example uses: Speciality applications where speed is paramount, hydrogen fires.

● **Combined UV/IR Flame detectors**

These detectors have both UV and IR detectors in one unit.

Example uses: Where there is a combination risk; when minimising unwanted alarms is paramount; where determined by code requirements.

3.1.2 Smoke Detection

Smoke detection technology ranges from the battery-powered detectors on sale generally to sophisticated visual, camera-based detection systems.

●Point Smoke Detectors

Point detectors detect smoke at a fixed point. They need to be placed where smoke realistically could travel in the event of a fire.

The majority in use rely on smoke accessing a chamber containing the detector element. These detectors therefore have a low IP rating and cannot be used in external areas. With the use of addressable systems, each location can be pinpointed.

Example uses: Offices, corridors, switch rooms, accommodation.



Picture courtesy of Autronica Fire and Security A/S

Illustration 4: Example point smoke detector

-Ionisation Point Smoke Detectors

This used to be the predominant smoke detection technology. It has been largely superseded by optical or combined optical smoke /heat detectors.

These detectors use a small radioactive source and detect decreased conduction caused by the ionisation of smoke particles in a detection chamber. For this reason they are susceptible to alarming in areas of high humidity.

Example uses: High energy fires, where codes require.

-Optical Point Smoke Detectors

These detectors generally detect smoke particles inside a chamber by an increase of light

scatter caused by smoke particles or by the smoke particles obscuring a light beam.

Example uses: general; early warning with high sensitivity versions.

-Combined Optical Smoke/Heat Point Detectors

Uses a heat sensor to sense a rapidly rising temperature caused by a high energy fire. Heat detectors are described in the next section.

Example uses: general; ionisation detector replacement.

-Laser Point Smoke detector

Laser point detectors offer increased sensitivity over general purpose optical point smoke detectors at the expense of increased cost per location. They use the same principles as the optical point smoke detectors.

Example uses: Early warning in telecommunications and similar areas.

-Beam Smoke Detectors

A beam of light is interrupted by smoke particles.

Example uses: monitoring of large areas e.g. atria, machinery spaces, areas where it is impractical or impossible to mount other detection types.

•Aspiration Smoke Detectors

Established technology provides early warning of fires, often before smoke is visible. Provides area coverage by the use of sampling tubes and continuous detection for smoke particles drawn through the tubes into the detection unit. Requires power in field. Generally can only be used in a safe area. The normal configuration of one unit is a single point of failure.

Example uses: Instrument rooms, telecommunications rooms, control rooms.

•Camera-based Smoke Detectors

Detectors that monitor the characteristic shape of smoke. Continuous light is essential for smoke detection.

3.1.3 Heat Detection

Heat detection is used where ambient temperatures or environment preclude the use of smoke detection. Linear heat detectors offer wide area coverage, with some linear heat detectors discriminating alarms both by temperature and location.

•Point Heat Detection

These detect high temperatures at a given point. Descriptions have changed over time. EN54 describes A1, A2, B, C, D, E, F and G types. They are still commonly described as “Rate of Rise, and Fixed heat detectors”.

Rate of Rise Detectors respond to a sudden increase of temperature whilst fixed detectors are set to a fixed temperature.

Example uses: Kitchens; turbine hoods; where codes mandate usage.

“Rate Compensated” describes a proprietary product extensively used in harsh environments.

Example uses: pump buildings, generator hoods etc.



Picture courtesy of Cooper MEDC Limited

Illustration 5: Example rate compensated heat detector

•Linear Heat Detectors

These detectors detect heat somewhere along the length of the device. They vary from the simple destructive types that burn through and signal an alarm to sophisticated systems that monitor the actual temperature at a particular point.

Example uses: Tank rim seals; large process vessels; cable tunnels.

3.2 Gas Detection

In general, gas detection is divided into combustible gas detection and toxic gas detection. This is a broad separation that breaks down in some cases, e.g. some gases are both toxic and combustible in the concentrations expected. Historically there has also been a separation in technology between combustible and toxic detection.

Below are some of the issues you need to consider when choosing gas detectors.

- Most devices used in the oil and gas industry are set to detect methane (CH_4) or hydrogen sulphide (H_2S).
- Many detectors show cross-sensitivity; i.e. a detector for detecting one gas will also detect another, at different readings. So at the time of purchase it is important to specify the gas that is to be detected and consider other gases that may be present that may affect the readings.
- The nature of the gas should be considered – e.g. H_2S is heavier than air, methane rises, propane sinks. However they may not behave like that under a high pressure discharge.
- Altitude affects the readings of some detectors.

- Portable personal gas detectors, set for multiple gasses may be used in areas where toxic gases may be present.

3.2.1 Combustible Gas Detection

Two mainstream technologies are available – infra-red absorption and catalytic types. Other types are available and in development; e.g. metal oxide semiconductor sensors. Detection methods from the field of analysers may cross over to meet gas detection needs.

Point detectors are calibrated against the lower explosive limit (LEL) of a certain gas, frequently methane. The lower explosive limit for methane mixed in air is achieved at a 5% concentration. Typical alarm settings are 20% LEL and 60% LEL. Confusion can arise as these levels are traditionally labelled low gas and high gas, whereas control instrument engineers would use the term high alarm and high-high alarm.

Open path gas detectors are calibrated in LEL metres (LELm). This setting has evolved as an analogue with the LEL range used in point detectors.

•Infra-red Absorption Combustible Gas Detection

The technology uses the absorption characteristics of the hydrocarbon molecules to infra-red light. The more hydrocarbon molecules are present, the higher the absorption of infra-red radiation. More than one type of hydrocarbon gas may be detected.

This technology is more expensive than catalytic detection, but it is used for many applications as it doesn't need field calibration and proof test intervals are considerably better (longer) than for catalytic types. Speed of response is quicker than for catalytic types. The measured value doesn't drift unlike catalytic detectors. And unlike catalytic types, the detector doesn't need oxygen for operation,

-Point infra-red gas detectors

Point detectors record the gas concentration at the detector location. They need to be placed where a release of gas is considered possible. They can be placed remotely and connected to the sampling location by tubes, with air sucked across the detecting chamber. Consideration needs to be given to the extra detection time added by the transit time down the tube.

Example uses: Detection in confined spaces, specific locations, air inlets etc.



Picture courtesy of Detector Electronics

Illustration 6: Example point infra-red gas detector
-Open path infra-red gas detectors

Open path gas detectors have a separate transmitter and receiver. Manufacturers quote up to 200m range, but in practice smaller distances are used, due to climatic and practical mounting arrangements.

Detectors should be mounted rigidly to avoid misalignment between the transmitter and receiver, both statically and due to vibrations.

Current devices will detect more than one hydrocarbon gas. New devices are in development that are tuned to a particular gas. Different versions of these can also detect H₂S.

Example uses: Migration detection, pipe rack monitoring.

•Catalytic Gas Detectors

Catalytic detectors rely upon burning gas in a sintered chamber. For this reason they are only available as a point detector or as part of a multi-point aspirating system.



Picture courtesy of General Monitors

Illustration 7: Example catalytic gas detector

They require periodic checking, calibration and replacement and are liable to poisoning by chemicals. For these reasons, despite their lower cost than infra-red detectors they have fallen out of general use in the process industries.

Example uses: Hydrogen leaks.

3.2.2 Toxic Gas Detection



Picture courtesy of General Monitors

Illustration 8: Example point toxic gas detector

Various technologies are available – chemical cell and semiconductor point detectors; open path (Laser) gas detection is in development.

Many different types of gas can be detected. Cross-sensitivity to different gases other than those being looked for needs to be given careful attention.

Response times of detecting and testing frequencies need careful attention.

Chemical cell types require sensor replacement at intervals determined by the environment. Semiconductor cells are also affected by their environment and may need to be ‘kept awake’ by exposure to the detected gas. New products are in development that are less susceptible to these limitations.

Infra-red single gas open path detectors are at an advanced stage of development. These offer the important advantages of fast response and high reliability.

Example uses: H₂S from sour oil wells or processing plant; carbon monoxide from burning products and CO₂ (Carbon Dioxide) build up



Picture courtesy of Senscient Inc

Illustration 9: Example toxic open path laser detector

3.2.3 Oxygen Depletion detection

The detection methodology is different from the other gas detection applications – an alarm is indicated when the oxygen setting falls to a low level.

3.3 Leak Detection

Leak detection may not be considered to be part of the fire and gas detection system. Leak detection is often regarded as a supervisory or maintenance facility, or an adjunct to the fire and gas system by using them in conjunction with other detection methods.

3.3.1 Point Leak detectors

Devices are available for detecting the sound of leaks at ultrasonic frequencies and have more general application. They do not detect a specific gas but detect the characteristic sound of gas or vapour leaking from the plant. Time delays are built into the detection system or detectors to aid in differentiating between normal process emissions and leaks.

Example uses: Leaks from valves, flanges and joints in pipe-work.



Picture courtesy of Groveley Instruments

Illustration 10: Example point leak detector

3.3.2 Camera-based Leak Monitoring Systems

These are in development with some systems installed. They offer a video picture, overlaid with a computer-generated representation of the leak.

They are more expensive than point or open path detectors and generally fall into the category of site surveillance systems.

Example uses: Overall surveillance of plants for leaks.

3.4 Manual Initiation

Manual initiation of fire and gas systems can play an important part in warning of events on the plant. It should be decided what the function of a manual alarm. Is it to advise of a fire or gas leak or initiate a general alarm?

The alarm can be raised by a plant operator, manager, or by staff in the field.

Various names are used for manual initiation field devices: Pull Stations/Manual Call

Points/Manual Alarm Call points/Manual Fire Stations.

Alarms can be manually initiated by:

- breaking glass
- pushing button
- lifting flap and pushing button
- lifting flap and breaking glass
- lifting and pulling handle
- Other combinations.

Consider the local customs and usages when choosing the type of device.

Various colours and combinations of colour are used but red is most common for manual fire alarms

Other colours may be used for shut-down or extinguishant initiation.



Picture courtesy of Cooper MEDC Limited

Illustration 11: Example manual initiation devices

3.5 Other Signals

Other signals that may be received by the fire and gas system could include:

- Fire dampers closed
- Fire dampers open
- Extinguishant discharged
- Extinguishant system status e.g. low air pressure, system isolated, main/reserve status

- Fire-water pump status
- Fire-water Ring Main pressure
- Fire Door status

4 Mitigating Actions

Actions may range from alerting a control room operator, release of extinguishants to a complete plant shut-down to sounding an evacuation alarm.

The control room operator may be part of the control loop – perhaps by being required to decide whether to initiate a general alarm or plant shut-down.

The ozone depleting effects of Halon 1301 and its almost complete ban has led to a review of the general use of automatically released extinguishants and an increase in emphasis on early warning of fire and manual interventions. This emphasis is, however, company and country specific.

4.1 Start Water Fire Pumps

Frequently fire pumps are started as a precautionary measure on detection of fire or on a manually initiated fire indication.

Fire pumps can normally only be stopped locally to the fire pump.

Fire pump control logic – sequencing, etc. is sometimes performed by a fire and gas system. It can also be implemented in dedicated fire pump controllers supplied by a fire pump supplier.

A manual start fire pump push-button should be provided in the control room wired directly to the fire pump control panel.

4.2 Initiate Plant Alarms

Plant alarms can be automatic or manual and can be wired directly from the fire and gas system or form part of a general, high integrity public address system.

Consideration should be given to an alarm hierarchy and local zoning. For example is it necessary to evacuate a complete site based on a local alarm in an instrument room?

Visual repeats of audible alarms may be needed in noisy areas. Some jurisdictions require all audible alarms to be accompanied by a visual indication such as an integrated flashing beacon (strobe). Colours of visual indications need to be established at an early stage to ensure that they don't clash with other visual indicators. The choice of colour affects the distance covered by a device of given power.



Pictures courtesy of Cooper MEDC Limited

Illustration 12: Example notification devices

For audible alarms, consideration needs to be given to how many different sounds are required, and how many sounds the plant personnel can distinguish. Voice messages offer greater flexibility in conveying messages, but may not be so effective in multilingual projects or comprehensible to off-site personnel.

If alarm signalling is via another system, it needs to be established which system has control over facilities such as system resetting, inhibiting and silencing.

Choice of interface could be hard wired, secure serial or a combination using remote I/O (inputs and outputs) co-located at the alarm signalling system.

Audible and visual alarms can be initiated in the following ways:

- Automatically on detection of fire, perhaps requiring more than one fire detector to operate (voting)
- Automatically on detection of gas, perhaps voted
- Automatically after a delay to allow for manual intervention
- Manually by the control room operator
- Manually by manual call point in the field
- Other combinations of the above

4.3 Local indication

This can be achieved by local display panels, hard-wired from the fire and gas system or serially.

A simple form of local annunciation may be made by connecting remote indicators from some types of detectors – for indicating alarms on hidden detectors below floors or above ceilings, etc. Care should be taken if using this approach that enough power is available in intrinsically safe versions of detectors to illuminate the indicator.

Addressable systems can provide a very cost effective solution for local indicator panels.



Picture courtesy of Autronica Fire and Security A/S

Illustration 13: Example local panels

4.4 Close Fire Doors and allow egress

Automatic fire doors can be closed on detection and exits unlocked to allow easy escape. Be aware that opening exit doors automatically may also allow ingress by unauthorised personnel.

4.5 Control Ventilation Systems

Fire dampers should be fitted at the air inlet to a building to prevent ingress of gas or smoke from outside areas. Gas detectors can be fitted in or to the inlet duct. In some circumstances detection of gas outside the area can augment internal detection systems. Consideration should be given to the transit time of the air in the duct. In other words, time should be allowed for the detection to work, signal the fire and gas system and for the fire and gas system to close the damper completely.

In applications where detection of fire or gas is life critical, such as in air inlets to temporary refuges; the consequences of an event is multiplied by the number of people affected, so that the risk reduction capability of these applications needs to be examined carefully. SIL 3 requirements may arise.

Closing fire dampers will lead to a change in the heating, ventilation and air-conditioning state – perhaps changing to re-circulating mode or stopping. Consideration should be given to how long the building can keep operating within its specifications and whether to selectively load-shed to prolong this time. Also consider whether additional fire and gas detectors should be used to protect an inner core for life or process critical systems.

Fire dampers should be fitted at extract ducts to prevent ingress of fire or smoke when the

building is un-pressurised.

Smoke dampers can be fitted, together with extraction facilities to expel smoke.

In areas with potential toxic gas releases toxic gas detectors should be fitted to air intakes to ensure that re-opening the dampers doesn't admit toxic gas into the building. Care needs to be taken to ensure the detectors are correctly located in relation to any filters fitted to the air ducts. If smoke detectors are fitted, attention should be given to the temperature and humidity specifications as they are normally designed for use in heated buildings.

Frequently, fire-damper status signals are connected to the plant control system. A signal may be sent to the control system from the fire and gas system to shut down the ventilation system to reinforce the effects of closing the fire dampers.

4.6 Isolate Ignition Sources

Detection of gas in an area can be used to isolate potential ignition sources; for example welding and utility sockets.

It has been argued that if gas is present in, for example in a switch room, sparks created by opening circuit breakers could in themselves constitute an ignition source.

4.7 Unit Control Panel (UCP) trips

In order to make electrical isolations it may be necessary to interface to a unit control panel. These systems can have some unusual interface requirements for fire and gas systems. Outputs are often de-energised outputs, energising to trip. Often the trip switches 110V or 220V AC contactors. These may be outside the system suppliers' specifications for current switched. If the trips are normally de-energised, then line monitoring would normally be needed. If interposing relays are to be fitted, then is it acceptable for any line monitoring to finish at the interposing relay coil? Or the circuitry can become complex to work round these limitations.

4.8 Initiate Active Fire Protection

Extinguishants are chosen depending on the risk being protected.

They can be water deluge, water spray, foam, 'Halon replacements' such as Inergen or Argonite, CO₂, water-mist etc.

Extinguishant systems can be initiated locally, near the risk being protected, at a central control point or automatically on detection of fire.

CO₂ should not be used in manned areas due to its asphyxiating properties.

In some extinguishant systems a warning will be given and the extinguishant released after a delay to allow personnel to leave the area.

4.9 Trip Plant

This can be either a local trip – shutting down a local section of the plant that won't immediately stop the whole process a major shut-down or a process blow-down or other shut-down. The trip can be hard-wired directly to the equipment under control. The trip command would usually be initiated by an emergency shut-down system. The signalling can be a hard-wired or safe, serial communications. Generally, the connection will be wired so that it trips under power failure.

4.10 Other Actions

If other devices are to be interface to then consideration needs to be given to the nature of

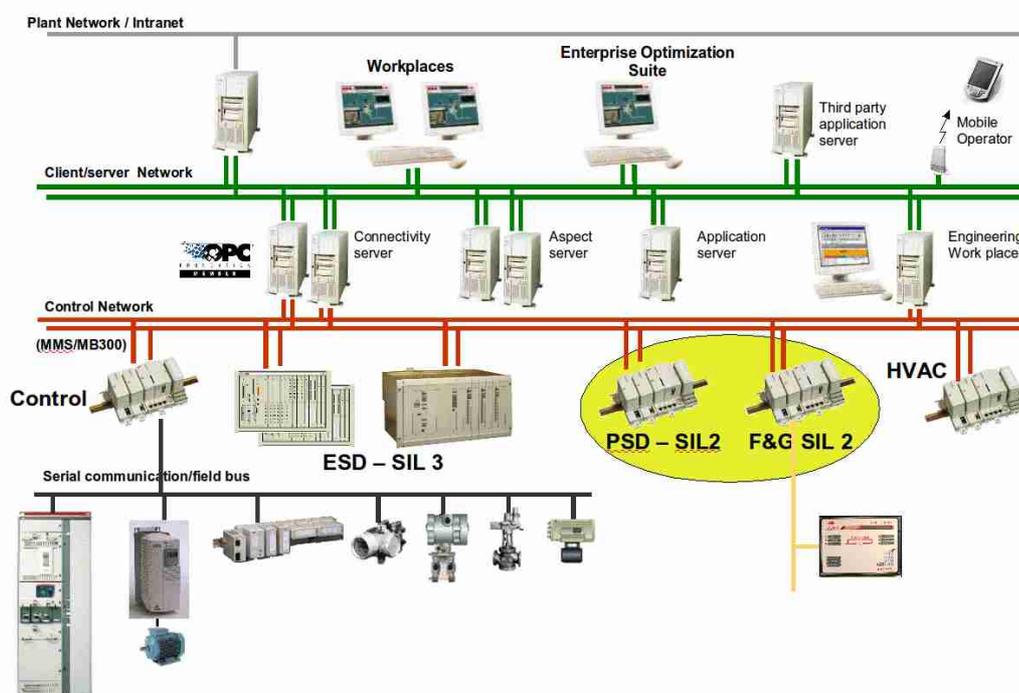
the device connected to.

- Should the output be normally energised or de-energised to carry out the action?
- Does the circuit need line monitoring?
- Do any of the considerations given above also apply to these other actions?

5 System Architecture

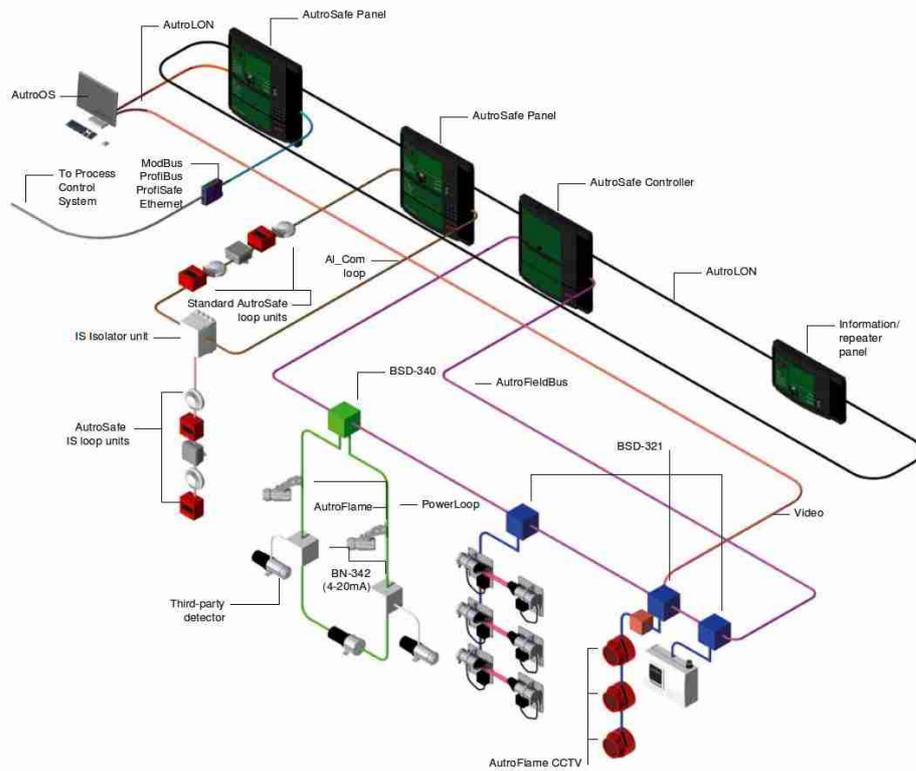
Previous sections have covered what may initiate an action, and what actions could be taken by the fire and gas system. This section describes the rest of the fire and gas system.. A logic solver facilitates, amongst others, automatic functions, operator interaction and interfaces to other systems.

In the past there were a number of independent suppliers, who specialised in fire and gas systems and services. The trend in recent years has been for larger corporations to supply fire and gas systems as part of their portfolio. These companies may be suppliers of safety systems that can also act as fire and gas systems. Fire alarm suppliers who also add gas detection capability to their systems, and fire and gas detection companies who also supply automatic systems.



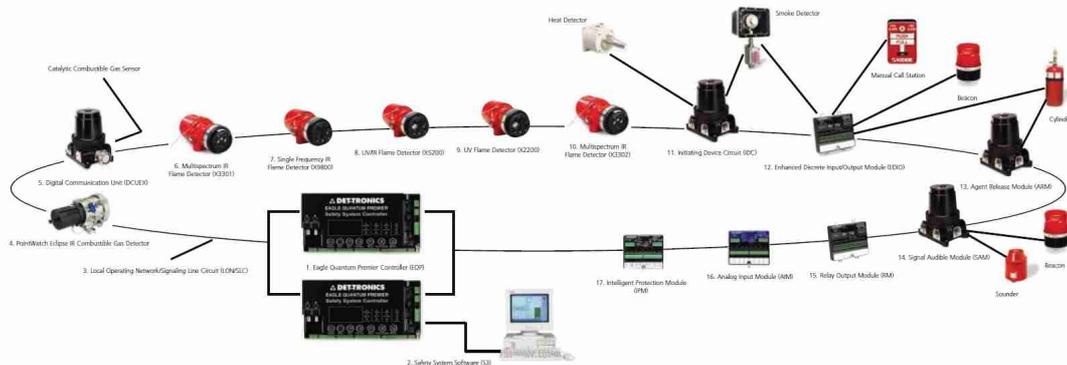
Picture courtesy of ABB Ltd UK

Illustration 14: Example integrated fire and gas system



Picture courtesy of Autronica Fire and Security A-S

Illustration 15: Example integrated fire and gas system



Picture courtesy of Detector Electronics

Illustration 16: Example integrated fire and gas system

The fire and gas system is generally required to be independent of the control system. This is consistent with the fire and gas system normally having a higher integrity requirement than the control system. Some fire and gas systems have been integrated with emergency shut-down systems. This remains a contentious point.

As already mentioned, no single company can supply all the ‘best in show’ products for all the items described in this paper. There are therefore normally interfaces between different suppliers. Minimising interfaces, document sets and inspections can be achieved by

procuring all products from one source at the cost of reducing choice of initiating devices and possibly increasing the initial purchase cost.

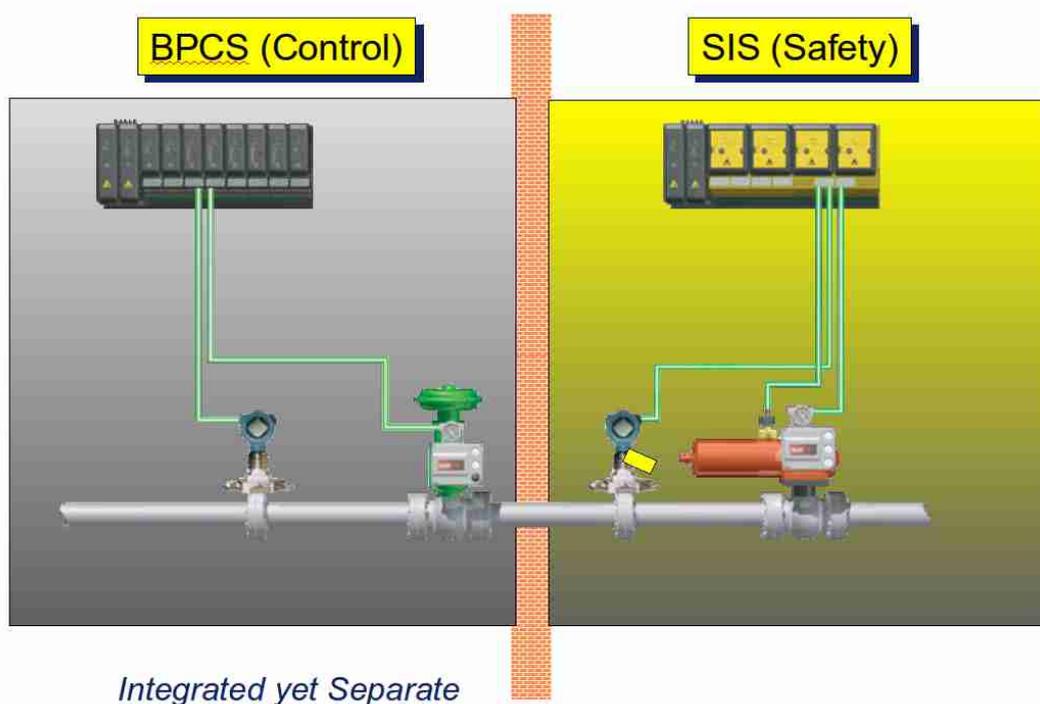
5.1 Logic Solver

The larger systems architectures have divided into two main types: distributed and networked controller-based systems and addressable systems. Some manufacturers have both types of system in their product ranges.

The contents of the 'black box' that contains the fire and gas logic have become somewhat homogeneous, with less use of proprietary and 'fire and gas specific' hardware and software.

Some installations use a combination of serial systems and hard-wired field device interfaces.

Sensible use of diagnostic data can offer increased safety by providing maintenance data, which can be used to plan service visits thus minimising staff exposure to the process plant.



Picture courtesy of Emerson Process Management

Illustration 17: Example logic controllers

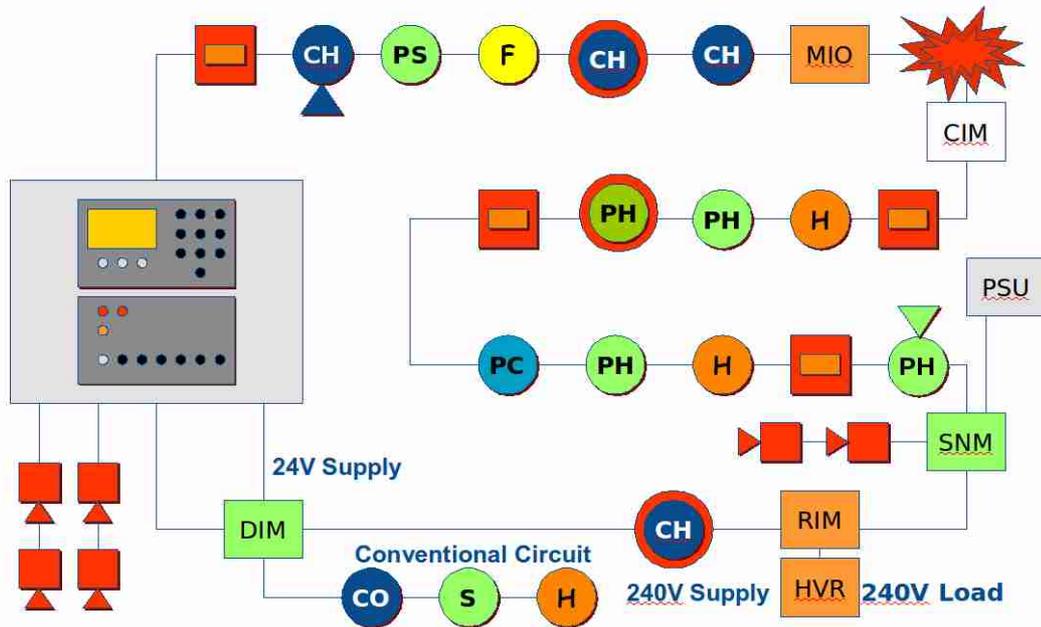
5.1.1 Initiating (Input) Device interfaces to the logic solver

4-20mA interfaced devices are common, enabling standard or modified process control interfaces to be used.

Field interfaces for smoke detectors, heat detectors and manual call-points are generally two wires with modifying components in the control system or marshalling cabinets to allow a 4-20mA interface to be used. The modified interface provides open circuit monitoring, short circuit monitoring and diagnostic reporting without using dedicated fire and gas hardware.

5.1.2 Serial (addressable) device interfaces

Addressable detector systems have been available for many years. Addressable systems are generally proprietary designs, which require proprietary interfaces. They considerably pre-date Hart and FieldBus systems.



Picture courtesy of Tyco Integrated Systems

Illustration 18: Example addressable system

Addressable systems, Hart and FieldBus offer the possibility of detailed detector information. Hart is an enhanced 4-20mA signalling system. Addressable systems and FieldBus also offer two-wire interfaces for multiple devices, potentially saving field cabling and I/O costs.

Addressable systems can offer sufficient diagnostic information and alarm and fault indication for the needs of a fire and gas system. This can be at a reduced cost and infrastructure commitment than Hart and FieldBus types. However the power requirement of some detectors mean that two wire operation isn't always possible.

FieldBus based fire and gas products are becoming available. Hart based devices are available from a significant number of manufacturers. Interfacing Hart and FieldBus devices can involve considerable extra hardware and space requirements. Hart based data is not used for safety actions.

This is an area of active development, several 'safety busses' are available but they have so far seen limited application for fire and gas detection.

5.1.3 Mitigating (Output) device interfaces

Mitigating device interface outputs are generally 24V DC, normally de-energised circuits. For these circuits, line monitoring technology is well established. Line monitoring is used where safety related circuits are normally de-energised. A number of techniques are used: a small current is passed through the device to check continuity, a pulse is periodically applied to a device – not enough to activate the device but long enough to check continuity; or the output is periodically disconnected from the system and a reverse polarity monitoring current applied. This technique has the advantage that a complete loop of devices may be monitored.

Normally energised devices generally do not need to be line monitored, as open circuits will be detected by activation of a device and short circuits would generally have the same effect.

Addressable solutions are available to reduce the mitigation device wiring. Another solution is to fit 'remote I/O' in distributed field equipment rooms.

5.1.4 Fire and Gas System – application programming

Applications programming can be in proprietary Boolean logic-based systems, versions of IEC 61131 part 3 languages, ladder logic, Cause and Effects, etc.

There can be considerable variations between suppliers in how they implement application logic. Some provide 'standard' fire and gas functions. These may have been tested with specific field devices or can be generic. Frequently these functions are repackaged versions of function blocks developed on earlier projects. In any case it should be made clear which devices and applications have been tested by the system supplier. For example, usage of diagnostic data using the 4-20mA interface varies between manufacturers: some use 2mA to mean "dirty optics"; some use 3mA to represent the same state. For some detectors "dirty optics" doesn't degrade the operation of the device, whilst for others it may put the detector out of service and prompt a maintenance visit.

Cause and effect diagrams remain the usual method of specifying fire and gas logic to the system supplier. Some suppliers have developed dedicated cause and effect utilities to program their systems. For best effects these should be used by the system specifiers, in concert with the system suppliers, so that the specifier's requirements are met in the most efficient fashion.

It should be established and disseminated what needs the cause and effect charts are meeting:

- A definition of the system logic
- A record of the system logic
- Programming instructions for the system implementer
- An operational tool
- An FAT (factory acceptance test) record document – a 'tick sheet'

Illustration 19: <<Example cause and effect diagram here>>

Substantial proportions of system logic cannot be readily implemented as an X on a cause and effect chart – this is frequently called "the note problem".

Voting (coincidence logic to reduce unwanted alarms) is normally a 2 out of n system (2oon). Some implementations of voting use a fault signal to change the voting from 2oon to 1oon.

Off line simulation allows the application logic to be tested before being implemented on the running system. A difference facility showing the changes between two versions of the configuration can provide evidence that only the changes that were intended were those actually made.

5.2 Indicating equipment

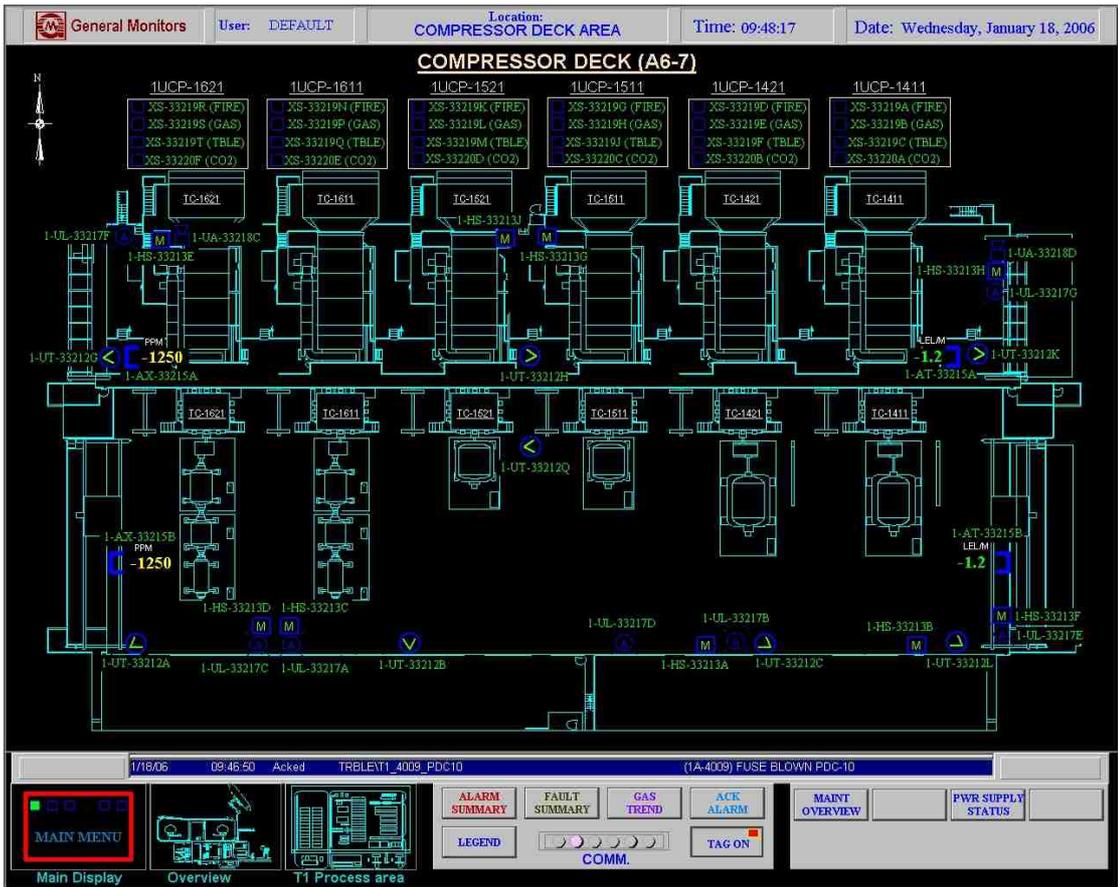
Operator interfaces are normally in the form of PC graphics displays.

5.2.1 PC Graphics



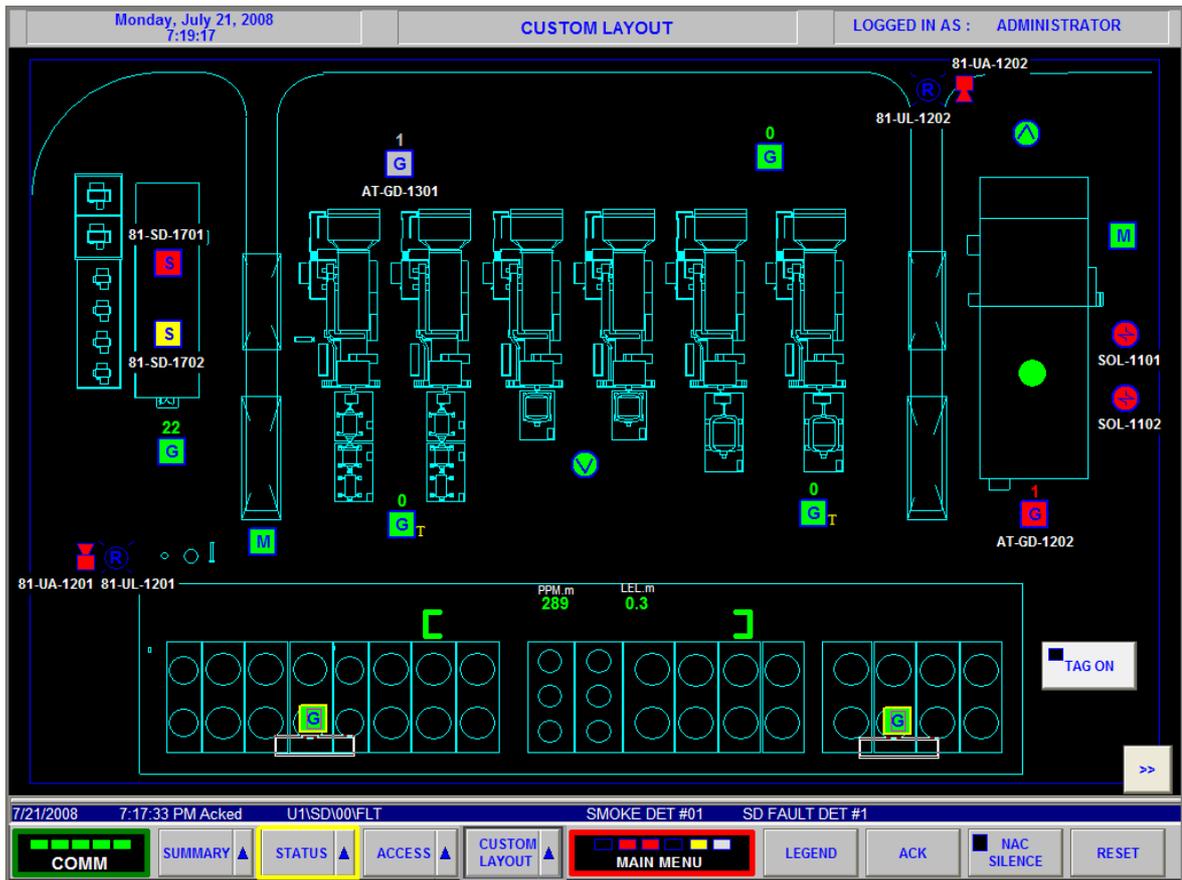
Picture courtesy of General Monitors

Illustration 20: Example PC Graphic Display



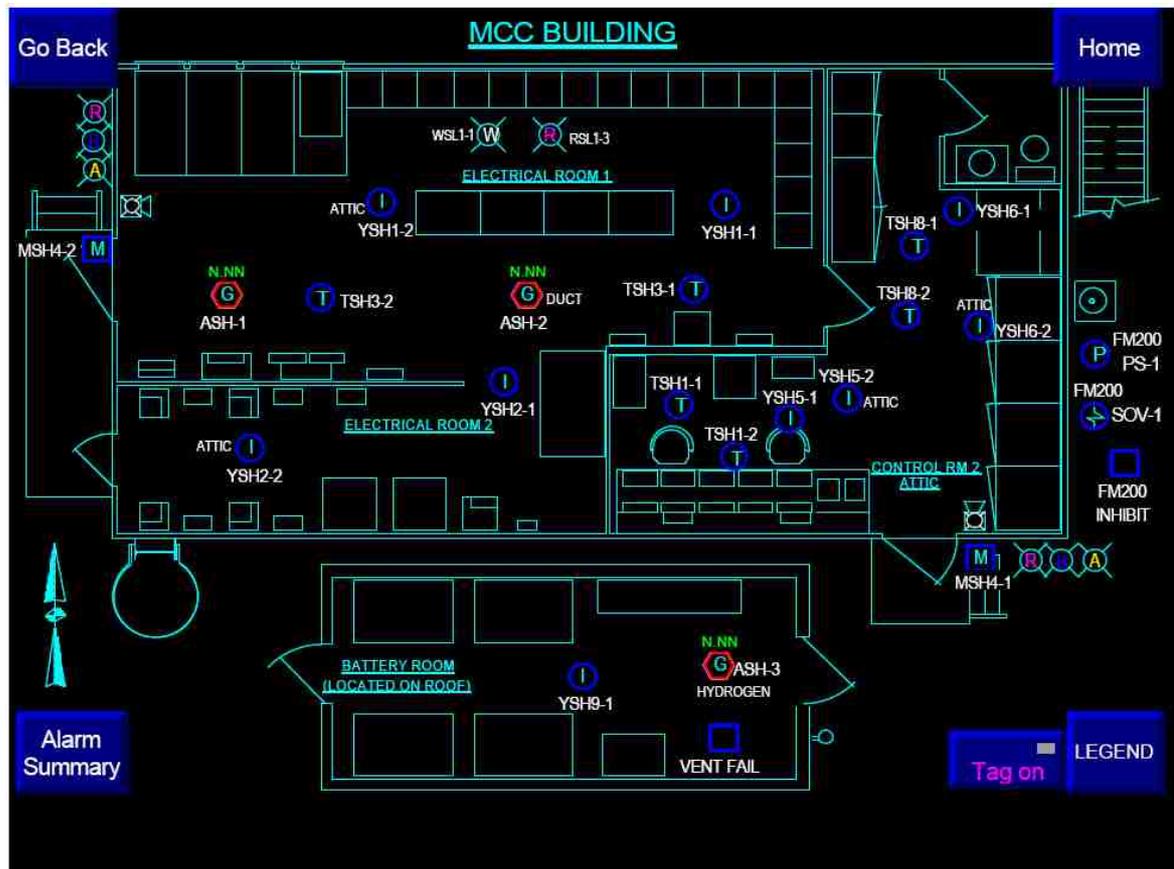
Picture courtesy of General Monitors

Illustration 21: Example PC Graphic Display



Picture courtesy of General Monitors

Illustration 22: Example PC Graphic Display



Picture courtesy of General Monitors

Illustration 23: Example PC Graphic Display

These graphics normally fit into a hierarchy with navigation between elements of the hierarchy. Despite the processing power of modern PC's there has been little development taking into account the graphic power available either in the form of 3D graphics or smooth scrolling site plans

5.2.2 Hard-wired displays

Some form of hard-wired indicator panel is normally provided to give an independent display system to be used in the event of start-up or total shut-down.. The panel can also give an overview of the fire and gas status. Hard-wired facilities may be provided to release extinguishants, start fire pumps, indicate maintenance override status, remove overrides in the event of other displays being available, etc.

5.2.3 Addressable Displays

Addressable systems offer the possibility of low cost display systems being added to a system network.

5.2.4 Diversity of display

There is frequently a desire for a control room operator (CRO) to use a single window to the process plant. There is a dichotomy between the benefits of a fire and gas display that is fully integrated with the facilities of the control system and the need for separateness so that a failure of the control system doesn't threaten the integrity of the fire and gas system. For these reasons a system may be used where the fire and gas system may have a simple, dedicated display. This display would be used in the unlikely event of the main operator interface not being available. As this display would be rarely used, there are often pressures for this display to be used for other purposes than a backup fire and gas display system.

5.2.5 Access and Security

The author suggests that users can be in any of the following categories: management, operator, maintenance, technician, engineer or super-users.

A strict security system should be set up for access to parts of the fire and gas systems. These access levels should meet the needs of the user or dangerous work-around may be made. One person may perform the function of more than one of the users listed. The access levels include physical access and keying systems. Passwords should be changed from the default values supplied with the system. Use of cabling bundled with other services should be carefully planned to avoid disconnection of the safety system by other disciplines. Access levels should be integrated with the permit to work system.

5.2.6 Specialised Fire and Gas Operator Functions

•Alarm Resets

It is usual for fire and gas alarms to 'latch' in a fire and gas system; i.e. they stay in alarm until a responsible person removes the alarm.

The latching may be stored in the fire and gas system and/or the display system. This is an important design decision as the display system may not have the same level of integrity as the rest of the system.

Multiple levels of alarms are usually available to provide prioritisation and discrimination.

It is usual to reset (silence) site alarms once the cause of an alarm is established. If an

alarm still exists on a system reset then a choice can be made to silence the alarm for a period or to re-initiate it.

• **Inhibit, bypass, override, disable, isolate, defeat etc.**

The above functions involve disconnecting something from an automatic system. Disconnecting the automatic system means that it is not available on demand. There therefore need to be restrictions on how many inhibits etc. are applied, in which combination and for how long. Examples are restricting inhibits to one device in a voting group; assigning a time period to an inhibit, perhaps one shift period. And a means should be provided to remove all inhibits in the event of the operator interface being unavailable.

Applying an inhibit to a device in a voting group can be treated as an alarm – such that a voting group changes from 2 out of n (2oon) to 1oon. Should inhibits be applied to manually initiated functions? Being too restrictive in the rules for applying inhibits may mean that there is a temptation to ‘block’ items at an engineering level. This could be dangerous as the device status could then be invisible. There may need to be restrictions on the total number of inhibits that may be placed on a system at any one time.

The meanings of these words and their functions should be described very clearly.

• **Additional Maintenance Functions**

In addition to the above functions, facilities can be provided for:

- Calibrating catalytic gas detectors
- Monitoring proof tests
- Listing devices that require maintenance, e.g. cleaning
- Other forms of inhibits/overrides.

These facilities may be devolved to other systems, such as an asset management system.

5.3 Interfaces to other Systems

The following interfaces may be required.

- Addressable fire detection system
- Asset management system
- DCS
- ESD system
- Sequence of events recorder
- Fire brigade call-out
- Paging system
- Public address systems
- SCADA system
- etc.

In an ‘integrated system’ these interfaces may not be readily visible in the system architecture. They may be hard wired or serial, depending on integrity requirements, costs, performance, client preferences, custom and practice. Serial interfaces generally need to be dual, full duplex. OPC (OLE for Process Control) is seen by some as becoming standard interface method. A ‘safe’ version of OPC is in development.

6 To SIL or not to SIL?

A development that is gathering pace is the application of IEC61508 and IEC61511 to fire and gas products and systems. The phrase ‘should we SIL it?’ has come into parlance. Using SIL as a verb means to assign an IEC61508 Safety Integrity Level (0-4) to a loop or function in a system. The higher the SIL number, the lower the probability of the system to fail on demand; i.e. a SIL 2 system is less likely to fail when required than a SIL 1 system.

The application of IEC61508/11 started with the application to safety control systems. Generally these are systems that are used in various safety-related applications – emergency shut-down, fire and gas, turbine surge control, burner management, etc. These systems have varying levels of compliance with the relevant codes and standards for fire (and gas) detection systems – EN54, NFPA72 etc.

A consensus has not yet emerged concerning the application of IEC 61508 to Fire and Gas systems. The ISA has a working party¹ investigating the applicability of IEC61511 to fire and gas systems. It is unlikely therefore that a definitive regime will be in force for some years to come.

There are also dedicated fire (and gas) detection systems with IEC61508 certification.

There are features in systems designed for fire and gas applications that are not to be found in systems designed for generic 'process' and safety applications. A conflict arises between a need for a single view of the process, simple maintenance and the built-in features of dedicated fire and gas systems.

Manufacturers are producing field equipment with IEC61508 documentation. So it is possible to ‘tick the boxes’ and get a SIL’ed fire and gas system.

Purchasing SIL certified components a solution does not make, a probability of the detectors actually detecting the alarm, taking into account voting logic, field conditions; the weather, view obstruction etc can be assessed. The effectiveness of mitigative actions need to be incorporated. Some companies have significant databases of installed devices providing in service data.

For the immediate future it is the authors opinion that Fire and Gas systems , “if SIL'ed” at all will largely fall in the low SIL areas; Certain applications, such as temporary refuge air supplies having a higher integrity requirement will require multiple fire and gas devices and frequent testing. This of course means that an analysis will have been carried out. of the overall requirement is made to ascertain which parts require specific levels of integrity and choose systems to suit.

There is a danger of a dilution of importance if a ‘SIL 3’ system is specified when only a small proportion of the system requires that integrity level. The additional life cycle costs associated with the SIL 3 systems should also make an incentive to apply the relevant SIL levels.

It is also the authors opinion that new fire and gas systems for the process industry will converge towards IEC61508, not least as a defensive action – “what happens if we didn't use the standard ? “

¹ISA-TR84.00.07 Technical Report The Application of ANSI/ISA 84.00.01-2004 Parts 1-3 (IEC 61511 Parts 1-3 Modified) for Safety Instrumented Functions (SIFs) in Fire & Gas Systems

7 Abbreviations and references

Abbreviation	Meaning
ABS	American Bureau of Shipping
AC	Alternating Current
API	American Petroleum Institute
CCR	Central Control Room
CCTV	Closed Circuit Television
CH ₄	Methane
CO ₂	Carbon Dioxide
DNV	Det Norske Veritas
EN	European Norm
ESD	Emergency Shutdown
FM	Factory Mutual
GOST	Gosudarstvenii Standart – Russian National Standards Body
H ₂ S	Hydrogen Sulphide
Hart	Highway Addressable Remote Transducer
HVAC	Heating, Ventilation and Air Conditioning
I/O	Inputs and Outputs
IEC	International Electrotechnical Commission
IEC61131 part 3	Programmable controllers -Part 3: Programming languages
IEC61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC61511	Functional safety: Safety instrumented systems for the process industry

Abbreviation	Meaning
	sector
Inergen	A mixture of Nitrogen, Argon and CO ₂ . Developed for replacing Halon 1301.
IR	Infra-red
ISA	Instrument Society of America
KOST	Kazakh National Standards Body
LEL	Lower Explosive Limit
LELm	Measure of gas concentration used by open path gas detectors
LPC	Loss Prevention Council
mA	milliamp
NFPA	National Fire Protection Association
OPC	OLE for Process Control (OLE = Object Linking and Embedding)
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SO ₂	Sulphur Dioxide
SOLAS	Safety of Life at Sea
UCP	Unit Control Panel
UL	Underwriters Laboratories
UV	Ultra-violet