GENERAL SPECIFICATION

SAFETY

GS EP SAF 312

Fire and Gas detection systems

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<tr>
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1. Scope

1.1 Purpose

This General Specification sets out the requirements governing the design, selection, installation, location and logic of (automatic) fire and gas detection equipment and systems. The intent is to detect a potentially flammable, explosive or toxic gas concentration resulting from a leak or to detect a fire as quickly as possible, locate it and initiate:

- Alarms
- Fire-fighting actions
- Automatic safety process actions (shutdown/blow down) to limit escalation of the hazardous event.

1.2 Application

This specification is applicable to onshore and offshore oil and gas production and processing facilities, including technical and residential buildings which are part of the facility. This specification does not cover the design and functional requirements of the associated automated Fire & Gas safety system(s), which are covered by GS EP SAF 261, GS EP INS 134 and GS EP INS 198.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.
## Standards

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<td>BS EN 61779-4</td>
<td>Electrical apparatus for the detection and measurement of flammable gases - Part 4: performance requirements for group II apparatus indicating a volume fraction up to 100% lower explosive limit</td>
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<tr>
<td>ISO 10418</td>
<td>Petroleum and natural gas industries - Offshore production installations - Analysis, design, installation and testing of basic surface process safety systems</td>
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<tr>
<td>ISO 13702</td>
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<tr>
<td>NF S 61-950</td>
<td>Fire detection equipment. Linear heat and multipoint smoke detectors and intermediate elements</td>
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<td>RAL – Color Standard</td>
<td>Reichsausschuß für Lieferbedingungen und Gütesicherung</td>
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### Professional Documents

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<tr>
<td>API RP 14C</td>
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<td>API RP 14G</td>
<td>Recommended Practice for Fire Prevention and Control on Fixed Open-type Offshore Production Platforms</td>
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<td>ASTM E 1002</td>
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<td>NFPA 329</td>
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### Regulations

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### Codes

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3. Terms and definitions

There are three types of statements in this General Specification: “shall”, “should” and “may”. They shall be understood as follows:

**Shall**  
Is to be understood as mandatory. Any deviation from a “shall” statement requires a derogation approved by the Company.

**Should**  
Is to be understood as strongly recommended to comply with the requirements of the specification. Alternatives shall provide a similar level of protection and this shall be documented.

**May**  
Is used where alternatives are equally acceptable.

For the purpose of this document only, the following terms and definitions apply.
Failure of equipment  Malfunctioning of equipment, hardware or software related to an external factor (power cut, mechanical damage, cable rupture, etc.) (Company).

Fault of equipment  Malfunctioning of equipment, hardware or software related to an internal factor (device breakdown, error, drifting, virus, etc.) (Company).

FES (Fire and Explosion Strategy)  Results of the process that uses information from the fire and explosion evaluation to determine the measures required to manage these hazardous events and the role of these measures (ISO 13702).

Fire & Gas (F&G) System  A centralised electronic programmable safety instrumented system comprising I/O cards, relays, CPU, logic, voting, human machine interface, etc. in accordance with GS EP SAF 261, and GS EP INS 134. Objectives are:

- To provide continuous automatic monitoring functions to alert personnel of the presence of a hazardous fire or gas condition.
- To allow executive actions to be initiated manually or automatically in order to minimize the likelihood of escalation. (Company from ISO 13702)

Fire loop  Pneumatic control line containing temperature-sensing elements which, when activated, will initiate control actions in response to a hazardous situation. Examples of temperature-sensing elements are: fusible plugs, synthetic tubing, etc. (ISO 10418).

IMO  International Maritime Organisation

LEL (Lower Explosive Limit)  Concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed (IEC 60079-10-1).

Manual (Alarm) Call point (MAC)  Device for the manual initiation of an alarm (ISO 7240-1)

PFD  Probability of Failure on Demand (Company).

Safe State of equipment  No hazardous condition, i.e. the detection equipment is working correctly, no fire is detected, or gas concentration is below trip threshold value (Company).

Safety Action  Executive actions by the Fire & Gas System as per Cause & Effect matrix (Company).

Trip State  Hazardous condition, i.e. fire is detected, or gas concentration is at/above trip threshold value, causing an automatic executive action (Company).
4. Installation and design requirements

4.1 Environmental conditions

A dedicated specification for each project shall define the indoor and outdoor environmental characteristics of the site, equipment and installations to be monitored. All fire & gas equipment (i.e. detectors, system, final elements) shall be certified for use in the specific environmental conditions.

A special attention shall be paid concerning the temperature in which the equipment shall be installed: the F&G detectors shall be used within their temperature of ATEX or IECEx certification as per GS EP ELE 079 requirements.

Materials of construction shall be in accordance with GS EP INS 101.

4.2 Electrical supply

In principle, all fire and gas detectors shall be hard-wired and shall be loop-powered from the F&G System at 24 V DC, in accordance with GS EP INS 101 and GS EP INS 134. Other operating voltages shall not be used, and the impact of the detectors total power consumption on the F&G System shall be carefully assessed.

In any case, indoor & outdoor gas detection and outdoor fire detection shall be hardwired.

The F&G System itself shall be powered by a redundant and reliable UPS power source in accordance with GS EP SAF 261.

Although 2-wire detectors are preferred, the use of 3 and 4 wire detectors is permitted when required (e.g. for heating, anti-condensing, etc.).

The output signals of any detector (incl. push buttons) shall be either:

- analogue 4-20 mA output signal whenever possible, or else
- discrete (on-off) contact output signal.

In case fail-safe configurations are unsuitable for discrete signals (e.g. push buttons, smoke detectors) then a line-monitoring resistor shall be installed in combination with a line-monitoring device in the F&G System (line failure = safety action).

Pressure switches for fusible loop systems shall not be used; analogue pressure transmitters shall be used.

Any indoor or outdoor electrical or signal cable related to the F&G System shall be fire-resistant as per IEC 60331 and be in accordance with GS EP ELE 161.

4.3 Area classification and electrical certification

All electronic F&G sensors and final elements installed in a hazardous area shall be certified ATEX or IECEx as per GS EP ELE 079 requirements for use in:

- Zone 1, Gas Group IIA, Temperature Class T3, by default, or more stringent Gas Groups if required by hazardous area classification
- Zone 1, Gas Group IIC, T3, in case of hydrogen (e.g. battery rooms).

Fire and gas equipment installed in a Zone 0 application (e.g. retention ponds, vent stacks) shall be certified for use in Zone 0, and is limited to intrinsically safe equipment only.
Refer to GS EP INS 101 for more details on permitted Ex types and ATEX / IECEx categories.

In principle, for reasons of standardisation, indoor F&G detection equipment shall be identical brand & model as the Ex-certified F&G detection equipment installed outdoors, with the exception of that smoke and fire detectors installed in living quarters and being part of an addressable fire detection system may be non-Ex-certified.

4.4 SIL Certification

All F&G detection equipment (including push buttons) and final elements (e.g. relays, solenoid valves, etc.) connected to the main F&G system shall be minimum SIL-2 certified by a company approved third party (e.g. TUV, EXIDA, SIRA). SIL requirement for F&G loop shall be assessed during Basic Engineering.

Refer to GS EP SAF 261 for more details on reliability requirements.

4.5 Detector status indication

All F&G detectors shall have an illuminated means of status indication (alphanumeric or coloured LED(s), or illuminated LCD screen), visible at minimum 3 m distance, to indicate:

- Safe state
- Trip state
- Fault state (when available).

Pressure transmitters for fusible loop systems shall have a standard build-in LCD screen, providing indication of actual pressure or fault state.

4.6 Detector failure output value setting

When this feature is present, the switch (often called burn-out protection) inside the detector which forces the output signal to high or low value in case of detector failure shall be set to:

- High-output signal for analogue F&G detectors
- Low-output signal for analogue pressure transmitters in fusible loop systems
- Open contact for fail-safe discrete output signals
- Close contact for non fail-safe discrete output signals.

4.7 Application limit of addressable type detection systems

Only non-addressable type detectors/systems shall be used for (automatic) executive actions by the main F&G/ESD systems. Therefore fire detected by an addressable type system shall be interfaced with the main F&G/ESD systems, which further controls (automatic) executive actions (via hardwired links exclusively).

Addressable type detectors/systems shall only be used for fire detection in residential buildings (e.g. living quarters or technical building inside residential buildings), in which case the addressable system shall be SIL-2 certified as per GS EP INS 134. In case of floating production facilities for which the IMO classification rules stipulate the installation of an addressable fire detection system in any room part of the living quarters or hull, then an additional certification by the applicable IMO classification body shall be provided.
Addressable type systems shall have their own dedicated operator panel, but shall also be connected to the PCS (Process Control System) system for alarm announcement on the CCR (Central Control Room) operator work stations and for event recording (via hardwired or redundant serial communication link). It shall not compromise reliability (see section 4.4) and availability.

5. Selection of detectors

5.1 General

The type of F&G detectors shall be selected upon the characteristic phenomena of combustion and of the predictable initial leak in the monitored zone.

Detection of toxic gases is intended to protect personnel. The main concern is H2S.

Detectors shall be selected primarily on the basis of the characteristic phenomenon likely to afford the most certain, most rapid detection, i.e.:

For detectors in a closed space with normal ventilation:

- Smoke or gas from combustion
- Flame
- Heat
- Flammable gas
- Toxic gas
- Oil Mist.

For detectors in the open air or in the presence of strong ventilation:

- Flame
- Heat
- Flammable gas
- Toxic gas
- Ultrasonic.

because, in principle, smoke cannot be detected in this case.

Regarding gas detectors, the choice of sensor shall be made on the basis of which gas is to be detected and whether it comprises toxic or flammable/combustible gas. The flammable gas detection function shall be totally separated from the toxic gas detection function.
### Table 1: Classification and type of detectors

<table>
<thead>
<tr>
<th>Classification of detectors</th>
<th>Type of detectors</th>
<th>Standard abbreviations</th>
<th>Standard abbreviations on lay-out and/or P&amp;IDS</th>
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<tr>
<td>Heat detector</td>
<td>Frangible bulb (Sprinkler)</td>
<td>SP</td>
<td>SP</td>
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<tr>
<td></td>
<td>Fusible plug</td>
<td>FP</td>
<td>RDFP</td>
</tr>
<tr>
<td></td>
<td>Linear fusible tube</td>
<td>FT</td>
<td></td>
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<tr>
<td></td>
<td>Thermostatic</td>
<td>TS</td>
<td>RDH [F]</td>
</tr>
<tr>
<td></td>
<td>Rate-of-rise</td>
<td>TV</td>
<td>RDHR [ROR/RC] [1]</td>
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<td>Linear Heat detector (heat sensitive cables)</td>
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<td>Fusible links [2]</td>
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<td>RFD</td>
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<td>Smoke detectors</td>
<td>Optical (scattered light or transmitted light)</td>
<td>RDOS</td>
<td>RDOS</td>
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<td>Detector - Aspirating Smoke Detector</td>
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<tr>
<td>Oil Mist detector</td>
<td>Optical oil mist detector</td>
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<td>Infrared</td>
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<td>Flammable gas detector</td>
<td>Catalytic (flammable gas including H\textsubscript{2} detection)</td>
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<td>Infrared point Gas Detector</td>
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<td>Open path detector (Infrared) [4]</td>
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<tr>
<td>Manual detection</td>
<td>Manual Alarm Call Point</td>
<td>MAC</td>
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</table>
Note 1: with or without ambient temperature compensation: rate compensated

Note 2: Fusible links (RFD) are also mentioned in this specification for detection and actuation of fire dampers

Note 3: as a complement to other type of detectors

Note 4: equivalent to Line Of Sight (or LOS detection).

5.2 Heat detectors

Detectors reacting to temperature rise shall be used, the sensing element of which shall be one of the following:

- An eutectic metal alloy (melting pellet/fusible plug)
- A determined volume of gas or liquid (bursting of a frangible bulb)
- A thermocouple
- A thermistor
- A bimetallic strip.

5.2.1 Definitions

Fusible Plug (RDFP)

A fusible element consisting of a metal alloy installed on a stainless steel loop (generally ½” AISI 316L or 904 as per GS EP INS 107) pressurized with instrument air (or nitrogen) and melting at a pre-set temperature (79°C to 96°C). The low loop pressure is used to initiate various actions. At least 3 PT (analogue pressure transmitters) shall be installed on the fusible plug system to provide a 2oo3 voting logic which shall automatically activate ESD-1 actions (as per section 7 and GS EP SAF 261).

Fusible loop systems shall at least contain the elements as shown in figures 1 & 2, noting the particular element:

- An analogue pressure transmitter for low supply pressure alarm in case of nitrogen or instrument gas.

The fusible loop itself shall be a closed loop; the T-point shall be located at less than 5 m distance from the fusible loop control panel to avoid long depressurization times.

When instrument air is not available, nitrogen may be used to pressurize fusible plug loop. In this case, additional hazard of loss of pressurized gas containment shall be assessed. Precaution to minimise these risks are as a minimum (see Fig. 1 and 2):

- the loop is pressurised (charged) and then isolated from its supply by isolation valve
- provide a pre-alarm PT on the supply loop
- provide back-up bottles (in case of N₂ use).

Should fuel gas or hydraulic oil for fusible loop be required on remote installations, a formal derogation shall be sent to HSE/SEI.

All components of the fusible loop systems (e.g. fittings, valves, supports, panels, cabinets, instruments, etc) shall be fully AISI 316 and tubing material shall be as per GS EP INS 107.
Figure 1: Fusible loop schematic

Note 1: Accumulator may be optional

Note 2: Low supply pressure mandatory in case of instrument gas or nitrogen gas (optional for instrument air)

Figure 2: Nitrogen supply schematic for fusible loops
**Linear Fusible Tube (FT)**

FT consists of fusible tube, made of plastic or any other equivalent material, filled with air (or nitrogen) at 2 or 3 bars and connected to an analogue pressure transmitter(s). They may be an alternative to networks of fusible plugs, where general area detection is more suitable than multi-spot detection. Automatic ESD-1 actions shall be based on 2oo3 voting logic. Linear fusible tube shall be certified for UV resistance when installed in UV-exposed areas. They are not recommended by the Company.

**Frangible bulbs/Sprinklers (SP)**

The Frangible bulbs or Sprinklers consist in a bulb bursting when the fluid it contains expands and allowing water to flow.

**Thermostatic detector (RDH)**

A detector which is tripped when a predetermined or preset temperature threshold is reached. The threshold normally lies between 50°C and 80°C. This technology may not be used for automatic ESD-1 or SD-2 actions.

**Thermovelocimetric (rate-of-rise) detector (RDHR)**

This detector trips when a predetermined or preset temperature rise is reached. The criterion of rate-of-rise is normally more than 5°C/min. Rate compensation rate-of-rise detectors shall be used in areas where the ambient temperature is high and where temperature variation can occur in normal operating conditions, in order to have more reliable heat detection while avoiding false alarms (i.e. turbine enclosures).

Company recommends using a combination of fixed temperature and compensated rate-of-rise detector, the rate-of-rise heat method detects fires that rapidly grow in intensity and quickly responds to abnormally fast temperature increases, and the fixed-temperature method detects fires that build temperatures to a high level at a slow rate which responds to a specific temperature setting. Rate compensated bimetallic blade type detectors shall be used.

**Heat sensitive cables**

The heat sensitive cables design consists in a sensor cable with integrated sensors and a processor unit.

- The sensor cable is comprised of two steel conductors individually insulated with a heat sensitive polymer. The insulated conductors are twisted together to impose a spring pressure between them, then wrapped with a protective tape and finished with a UV resistant outlet jacket suitable for the environment in which the detector is installed.

- The processor unit registers and analyses the temperature readings values from temperature sensors. Whenever the preset threshold readings are exceeded, the system generates an alarm or an action. A minimum of +11°C between maximum normal ambient and minimum alarm temperature shall be allowed in order to avoid any potential false alarm conditions.

As they usually have a measuring temperature range from -55°C up to 180°C maximum, they shall not be used in ambient temperature above 100°C. If the heat sensitive cable conductor continuity is broken, an open circuit fault condition shall always be signaled, i.e. they shall be equipped with line monitoring. Heat sensitive cables shall be certified for UV resistance when installed in UV-exposed areas.
Company does not recommend the use of heat sensitive cables.

5.3 Flame detectors

Optical flame detector selection shall be based on detector performance criteria for each application and not by detector technology. Only detectors approved for use with the specified fuel and verified by an independent third party approval body shall be considered.

Flame detectors, such as UV/IR and MIR detectors, shall be equipped with an automatic optical testing system to verify the integrity of the optical system (including the transparency of the lens) that shall be checked on an automatic and regular basis. Detectors shall be provided with UV/IR and/or IR test lamp, which shall be certified as per Directive 94/9/EC – ATEX with the same use as the detectors.

Any flame detection response by the detector shall be maintained for at least 10 seconds before tripping the alarm to prevent unwanted trips from spurious radiation.

These detectors shall be protected against solar radiation, dirt and water from rain and deluge with a weather protection.

It shall be required to prove the insensitivity of the IR detectors to light sources at a flicker frequency of 10 Hz and higher.

Imaging based flame detection

Imaging-based flame detection is a CCTV (Closed Circuit Television) system integrating camera and signal processing system (with specific software) showing in the control room the live video image of the camera cone of vision and interpreting the flame characteristics. Software algorithms shall be used to discriminate between genuine fire conditions and other radiant sources causing false alarms.

The cameras may be installed as a complement to other type of flame detection. They may generate a fire detection alarm, but they are not allowed for automatic executive ESD actions. Typically, they are connected to a dedicated large CCR wall screen providing multiple images simultaneously.

5.4 Smoke detectors

Smoke detectors shall generally not be used in the open air. Smoke detectors should be employed in closed areas only. Their use in open areas shall be subject to approval by the Company. Smoke detectors are sensitive to fog.

Two types of smoke detectors may be used:

Optical detectors (scattered-light type or transmitted-light type detectors)

Optical smoke detectors employ light scattering by smoke particles to detect the presence of smoke. Optical smoke detectors are more sensitive to starting and smouldering fires, they are recommended for electrical areas and areas containing hydrocarbon products, as these fires produce smoke consistent with the particle size range.

Open path (IR) smoke detectors consist of at least one transmitter and one receiver and may include reflector(s), for the detection of smoke by the attenuation and/or changes in attenuation of an infrared beam. They usually have a working range of 30 m and are set to alarm when the visibility changes by 11% over the path length. ISO 7240-12 specifies requirements, test
methods and performance criteria for line-type smoke detectors for use in fire detection systems installed in buildings.

**Early warning smoke detection system (aspirating smoke detection)**

The early warning detection system aspirates ambient air in the monitored zone into a pipe network through orifices and then pumps it to an analysis chamber. When smoke particles are present, light is reflected to the optical cell and alarms are activated. The European Standard EN 54-20 specifies the requirements, test methods and performance criteria that shall be followed for aspirating smoke detectors for use in fire detection and fire alarm systems installed in buildings.

This system may be used to monitor instrumentation and electrical cabinets, as a complement to optical detection or conventional smoke detectors of the room, but it is not allowed for automatic executive ESD actions.

**Ionization detectors**

These detectors shall not be used, unless proper transportation, storage and disposal procedures for radioactive sources are put in place, following current local regulations.

5.5 Manual initiation

Local fire, gas and emergency detection by operators shall be achieved by the installation of Manual Alarm Call Point(s) (MAC). This equipment shall be installed in accordance with ISO 7240-11 and with requirements for classified hazardous area (explosion proof type according to IEC 60079-0 if required). Manual (Alarm) Call Points are divided into two types depending on the method of operation:

- **Type A**: direct operation: in which the change to the alarm condition is automatic (i.e. without the need for further manual action) when the frangible element is broken or button/handle displaced.
- **Type B**: indirect operation: in which the change to the alarm condition requires a separate manual operation of the operating element by the user after the frangible element is broken or button/handle displaced (i.e. breaking glass or lifting protective cap/ flap).

Generally they are located at identified strategic exit points from areas and at designated potential fire points, near doors of buildings, on main escape routes, on escape stairs and in corridors of accommodation and machinery spaces.

Outdoor-mounted MACs shall be of the double action (type B) and be red colored (equivalent to RAL - Color Standard 3000). When activated they shall raise an alarm in the central control room. Protective cap or flap shall be used instead of breaking glass, in order to avoid unnecessary debris (potentially plugging draining systems) and replacement works.

Normally personnel shall not have to travel more than 20 meters on a same level to access to a MAC. At least two MACs shall be provided at each level of the installation in two opposite locations.

In addition of MACs generating only alarms, a limited number of outdoor-mounted (E)SD and deluge handles/buttons, generating a direct (E)SD or deluge activation, may be installed in addition of the CCR emergency panel. Pull-to-activate handles/buttons are commonly used for ESD-1 and (E)SD-2/3 and deluge activation. ESD pull handles/buttons shall be yellow colored (equivalent to RAL – Color Standard 1003) and deluge pull handles/buttons shall be light
blue colored (equivalent to RAL – Color Standard 5012). All ESD/SD/deluge pull handles/buttons shall be latching type, equipped with line-monitoring and associated resistance when not fail-safe, and ESD-1 push handles/buttons shall be key-switch reset type (except inside CCR).

For existing facilities, existing colour codes shall be maintained to avoid confusion by operators. All MAC, ESD, and deluge handles/buttons installed outdoors and inside machinery spaces/enclosures shall have AISI 316 metallic housing, installed under a protective shade in order to avoid spurious activation due to water ingress from rain, cleaning or deluge water.

All MAC, ESD, and deluge handles/buttons shall be directly hardwired to the associated safety systems: addressable type, daisy-chaining or voting configurations are not permitted.

Push buttons for manual activation of inert gas fire extinguishing systems shall be black colored (equivalent to RAL – Color Standard 9005 - flap type, latching and key-resettable) and be in compliance with GS EP SAF 331.

5.6 Flammable gas detectors

5.6.1 General

The gas detection sensors shall be based on the principle of catalytic (with catalytic beads- kept at high temperature, which also continuously dissipate humidity and dry the sintered shield/flame arrestor - the catalytic sensors shall have a sintered shield to prevent the propagation of combustion outside the sensor- connected to a control module based on Wheatstone Bridge principle) or on the principle of point infrared detection when catalytic is not applicable (oxygen free or corrosive atmospheres, air duct, etc.), or linear Infrared detection.

IR point detectors shall be checked for ambient temperature as above 70/75°C they are not suitable. Thus, in machinery spaces, at more than 75°C, IR point detectors are not suitable (operating and certification T°).

For flammable gas (HC) point detectors:

- The alert threshold shall be set at 20% LEL
- The alarm threshold shall be set at 50% LEL.

For flammable gas (HC) point detectors in machinery enclosures or building containing a continuous or primary grade of release, as per GS EP SAF 221:

- The alert threshold shall be set at 15% LEL
- The alarm threshold shall be set at 25% LEL.

For flammable gas (H₂) point detectors:

- The alarm threshold shall be set at 5% LEL
- The control action threshold shall be set at 10% LEL.

Open-path detectors typically consist of a radiation source and a physically separate, remote detector. The detector measures the average concentration of gas along the path of the beam.

The unit of measurement is the concentration multiplied by path length,% LEL x m and ppm x m.

The maximum open-path distances shall not exceed 25 m (offshore) and 50 m (onshore), taking into account obstacles and temporary equipment storage for maintenance and operations.
Company recommends a misalignment tolerance not less than 0.5% (integrated alignment capability shall be provided).

The minimum alarm level shall be set at 0.5 LEL x m (50% LEL extended for one meter): it gives an alarm if there is a flammable gas cloud of 5% LEL over a distance of 10m.

For open path (line-of-sight) gas detectors:
- The low level alarm shall be set at 0.5 LEL x m
- The high level alarm shall be set at 1 LEL x m.

Semi-conductor type sensors are not permitted. Sensors based on catalytic oxidation shall not be used in low oxygen atmospheres, in high air flow-rates, or in high gas concentrations.

5.6.2 Minimum characteristics

The characteristics to be defined shall be:
- The temperature of the filaments in Fresh Air (for catalytic sensor)
- The electrical power supplied to the sensor
- The zero stability as a percentage of the LEL, per year
- The drift of the full-scale sensitivity as a percent LEL, per year
- The guaranteed life of the sensor under operating conditions shall never be less than three years. The Contractor shall guarantee this life in the presence of Freon, silicones and tetraethyl and tetramethyl lead.

- The use of physical or chemical filters before the sensors shall only be accepted if the sensors’ sensitivity and detection speed are not altered by them.

The enclosure for each sensor and its connection box shall be a safety enclosure. A weather-protecting cone shall be supplied for detectors located outdoors.

The sensor shall be able to operate at least in the -50°C to +90°C range for catalytic sensor and to 70°C for IR point sensor.

With the point detectors placed initially in clean air and subjected to a sudden increase of the gas concentration from 0% to 100% of the LEL, the detection system shall be required to initiate its highest alarm level in less than 10 seconds. This test shall be made on detectors equipped with their accessories, such as active filters, collector cones and so on.

5.6.3 Optical Oil Mist Detection

It is to be reminded that oil mist is spontaneously flammable above auto-ignition point. The interest of this detection is to prevent the occurrence of a fire in case of oil mist.

Therefore oil mist detection should be considered for all enclosed applications with a potential of pressurised leakage of flammable liquid, when such leaks are unlikely to be detected by gas detectors. Turbine enclosures for instance have forced ventilation and both gas and oil mist detection should be installed in the enclosures exhaust ducting.

5.6.4 Ultrasonic Gas Detection

Ultrasonic gas leak detectors detect leaking pressurized gas and differ from conventional gas detectors by not having to be in physical contact with the gas itself.
In outdoors ventilated areas, the leaking gas is very often carried away, or diluted before it reaches the conventional gas detectors and therefore ultrasonic gas leak detection is an important detector technology that should be used in all outdoor (onshore and offshore) pressurized gas installations.

Ultrasonic detection may be considered for leaks from pressurized gas systems to the atmosphere (>10 barg), but not for liquids or multiphase leaks. The ultrasonic detectors pick up the airborne acoustic ultrasound generated by pressurized gas leaks. These detectors shall be based on the microphone technology sensitive to high frequency sound (25 kHz to 70 kHz range).

When a pressurized gas is emitted through an orifice or a crack, this leak produces an ultrasonic sound in the audible and ultrasonic frequency range associated with the leakage rate (quantity of gas emitted per second in kg/s). The unit shall be fitted with a built in acoustic integrity test device to check that the microphone is within the correct tolerances.

Whilst these detectors theoretically have an instantaneous response, a delay time shall be incorporated in order to reduce spurious alarms to an acceptable level. It is noted that this delay is typically of the order of 20-30 seconds and therefore ultrasonic gas detection shall not be used alone for toxic gas detection. They shall not be used for low pressure process but value is depending on the background noise, or for gas cloud resulting from HC evaporation, or gas accumulation as they cannot detect any sound. Ultrasonic detectors can usually detect at the performance standard leak rate of 0.1 kg/s (ref: methane) or 0.01 kg/s (ref: hydrogen) within a radius of 9-12m in normal process areas and 5-8 m in compressor areas.

The unit shall be fitted with an integrated piezo-based acoustic (non-mechanical) integrity test. In intervals, an external transducer transmits an acoustic test signal to check that the microphone is within the correct tolerances.

The ASTM E 1002 test method covers procedures for calibration of ultrasonic instruments, location, and estimated measurements of gas leakage to atmosphere by the airborne ultrasonic technique.

Company recommends using ultrasonic detector with auto test capabilities. The detector shall be based on electret condenser microphone technology, which has minimal drift and maximum temperature stability. A traceable Test/Calibration portable unit, certified as per Directive 94/9/EC – ATEX, shall be provided. At commissioning live leak simulation (with substitute gas) can be considered to verify detection coverage. This technology may be a complement to other type of field-proven point detectors in outdoor and windy areas, but shall not be used for automatic executive actions.

5.7 H₂S detectors

5.7.1 General characteristics
For fixed and portable H₂S detectors, there are two types of field-proven technologies:

1. Electro-chemical
   - Chemical reaction principle
   - Sensible to wear/aging
   - Sensible to humidity (20% to 80% RH)
   - Sensible to temperature (maxi 40°/45°C)
• Sensibility to other gases (false alarms)
• Response time increasing with temperature
• Typical T50 at 30 seconds for a full-range (20 ppm) equivalent concentration gas
• Life time: 1 to 2 years
• Sudden failure of the detector (no self-monitoring).

2. Semi-conductor Thin film(TGD)
• Physical reaction principle: adsorption
• No wear/aging
• Not sensible to ambient humidity (0 to 99%RH)
• Not sensible to ambient temperature (-40°C to 90°C)
• Constant response time
• Typically T50 at 2 minutes for a full-range (20 ppm) equivalent concentration gas
• Loss of speed of response / calibration to be done
• Theoretical life time: 4 to 6 years
• Slow end of life
• Insensitivity to other gases.

Semi-conductor type detectors shall be preferred to electro-chemical, taking into consideration that electro-chemical type detectors have a lifetime adversely affected when exposed to poisonous contaminants (e.g. paint solvents) or to humid atmospheres (even for periods of less than 24 hours) or to continuous background of H₂S.

When not regularly exposed to H₂S concentrations, semi-conductor H₂S detectors may lose their speed of response for low concentrations, whose effect is usually reversible; therefore they shall be exposed to H₂S every 3 months.

The characteristics of the probe shall be clearly specified as a function of changes to the environmental conditions (hygrometry, temperature and pressure).

The H₂S detector semi-conductor shall work at a stable temperature defined by the Manufacturer (not varying more than 1°C) which also protects the sensitive element from surrounding humidity and it shall be systematically isolated from the atmosphere through a flame guard and a sintered element. Fouling in the sintered element can cause an increase in the response time of detection system.

5.7.2 H₂S threshold values

H₂S detectors shall be used mainly for alarms purposes and personnel protection actions.

The thresholds shall be 5 ppm of H₂S at level 1 and 10 ppm of H₂S at level 2.

The first threshold (5 ppm) shall serve to instruct personnel to the muster point.

The second threshold (10 ppm) shall serve to instruct personnel to abandon the facility.

In some cases H₂S detection may be used for automatic executive actions on a 2oo3 voting basis in particular in air inlets/airlocks for buildings (technical rooms and living quarters).
5.7.3 Minimum characteristics

The characteristics to be defined shall be:

- Response time
- Suitability for low concentrations
- Suitability for high concentrations
- Cross sensibility to other gases
- The zero stability in ppm per month with the conditions, i.e. hygrometry, temperature and pressure held constant
- The zero drifts in ppm per month as a function of the hygrometry at 20°C and 1013 mbar. The deviations between 20% and 100% of the Relative Humidity (RH) shall be stated.
- The zero drift in ppm per month as a function of the temperature at 50% RH and 1013 mbar. The deviations between -20°C and +40°C shall be stated.
- The zero drift in ppm per month as a function of the pressure at 50% RH and 20°C. The deviations at 1013 ± 50 mbar shall be stated
- The sensitivity drifts in ppm in the above conditions
- The sensitivity drifts when the probe has not been in contact with the gas to be detected for three months
- The sensitivity drift when the probe has been in contact with the gas to be detected at 50% of the mean allowable concentration for one month
- The guaranteed operating life of the sensor shall not be less than two years, even in the presence of Freon, silicone and tetraethyl and tetramethyl leads (TEL and TML)
- Use of physical or chemical filters before the sensors shall only be accepted if the sensors’ sensitivity and detection speed are not altered by same
- The detectors shall be able to operate at least in the -20°C to +45°C range or up to 85°C (depending on the maximum temperature according to the local outdoors design conditions).

6. Detectors’ location

As per ISO 13702, a F&G system shall be provided in accordance with the requirements of the FES. The FES shall describe the basis for determining the location, the number and the types of detectors. This requires a process of identifying and assessing the possible F&G hazardous events in each area and evaluating the requirements to reliably detect these events. As a guideline, detectors selection and location are shown in Appendix 1 – table 9.

Alarm conditions requiring muster of personnel shall be identified by acoustic signals, supplemented by visual signals in high noise areas. The F&G information required at the temporary refuge and control stations shall be considered during the design of the system. The F&G control system shall be designed, located or protected so that it is available in all emergencies.

The flare shall not be provided with heat or flame detection except for burner flame monitoring (PCS system).
Non-accessible detectors, e.g. detectors installed higher than 2.0 m elevation or detectors installed above false ceilings or under false floors or inside ventilation air plenum of ventilation unit should be equipped with a calibration facility at direct accessible point between 1.5 m and 1.8 m elevation. The purpose is that no special measures (scaffolding, mobile stairs, displacing ceilings/floor panels, etc.) are required for test and calibration.

The detectors shall be positioned taking into account any accumulation or ingress of sand, dust, water, rain, etc. and also within the operating limits of the equipment given by the Manufacturer (wind speed, maximum temperature, relative humidity, acceptable vibration, etc.). For instance, a “roof” on top of the flame detector can prevent pollution and failure in outdoor applications. When necessary to prevent ignition of a gas release in non-hazardous areas, the air intakes to these areas, or the areas themselves, shall be fitted with gas detection if gas can realistically reach these areas. Unless specifically designed for this application (such as extended point gas detector suitable for gas turbine ventilation extract ducts or HVAC inlets), gas detectors shall not be installed inside ducting but at the inlet or outlet air openings in order to avoid malfunctioning and pollution from high velocity flows.

During Detailed Engineering phases of new projects, specific lay-outs (flammable gas detectors or F&G detectors layout) showing the location of the detectors shall be made and shall give all necessary indications for the installation of the detection. Especially for each detector located on the lay-out, the following information shall be given:

- Gas to be detected: HC, H₂S or type of detection for fire prevention (heat detector, smoke detector, fusible plugs). Usually this information is included in the symbolization of the detector.

- The exact sitting on the drawing: this is generally indicated with an arrow or a point showing where is located the detector. If it is not precise enough a supplementary note shall give more information.

- Detector elevation: it shall be at the same elevation as the potential source of leakage indicated either with:
  - General note if all the detectors are all located at the same height (example detector of gas heavier than air located at 300 to 500 mm above the ground)
  - Particular notes if elevation are different for each detector.

Well-placed detectors do improve the performance of a detection system and this emphasizes the need for knowledge of dispersion, the processes being undertaken in a module and the equipment layout when deciding detector placement. Table 2 shows typical application of fire/gas detectors in oil & gas installations.
Table 2: Typical applications of fire/gas detectors (from ISO 13702)

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Type of detector</th>
<th>Typical application</th>
<th>Typical actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>Heat</td>
<td>Pneumatic</td>
<td>Alarm, ESD, EDP, closure of the SSSV, active fire protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electric</td>
<td>Alarm, ESD, EDP, active fire protection</td>
</tr>
<tr>
<td>Flame</td>
<td>Process, wellhead utilities, generators, gas turbines</td>
<td>Alarm, ESD, EDP, active fire protection</td>
<td></td>
</tr>
<tr>
<td>Smoke</td>
<td>Control rooms, electrical rooms, computer rooms, accommodation</td>
<td>Alarm, isolate power, active fire protection (if present)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air intakes to TR (^{(1)}) and control stations</td>
<td>Alarm, isolate ventilation</td>
<td></td>
</tr>
<tr>
<td>Flammable gas</td>
<td>Process, wellhead utilities areas (^{(2)}), engine rooms (^{(2)})</td>
<td>Alarm, ESD, EDP, isolate power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air intakes</td>
<td>Alarm, ESD, EDP, isolate power</td>
<td></td>
</tr>
<tr>
<td>Oil mist</td>
<td>Enclosed areas handling low GOR liquid hydrocarbons</td>
<td>Alarm, ESD, EDP, isolate power</td>
<td></td>
</tr>
<tr>
<td>Manual call point</td>
<td>All areas, escape routes, muster points, TRs(^{(1)})</td>
<td>Alarm, start of fire pumps</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Process areas include drilling areas

**Note 1:** Temporary Refuge

**Note 2:** Only for rooms containing essential safety systems

### 6.1 Heat detectors’ location

It is recommended that the spacing of heat release detectors comply with following table.

Table 3: Sitting of thermal detectors and thermal rate of rise detectors

<table>
<thead>
<tr>
<th></th>
<th>Maximum ground area covered by a detector</th>
<th>Maximum distance between detectors</th>
<th>Maximum distance from a continuous obstruction wall, etc.</th>
<th>Maximum height above the potential hazard location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detectors placed in naturally ventilated open spaces</td>
<td>15 m(^2)</td>
<td>5 m</td>
<td>2.5 m</td>
<td>4.5 m</td>
</tr>
<tr>
<td>Detectors placed in mechanically ventilated closed spaces (air change rate &lt; 12)</td>
<td>20 m(^2)</td>
<td>6 m</td>
<td>3 m</td>
<td>5 m</td>
</tr>
</tbody>
</table>

A minimum distance of 0.5 m shall also be respected from a continuous obstruction wall.
Heat transfer is the key point for thermal detectors; therefore the following factors shall be taken into consideration for location of detectors: enclosed spaces, height of ceiling, ventilation in the enclosed space.

Potential thermal barrier effect like a hot wall (e.g. of a shed warmed by sunlight) or objects possibly blocking the heat flow to the detectors can have an adverse impact on the operation of the detectors.

They shall not normally be used in battery rooms, electrical rooms and instrumentation rooms. They may be used in workshops, HVAC rooms, HPU and essential diesel generator rooms (with Multi Frequence IR), for instance.

For gas turbine and diesel engine enclosures, UV type flame detectors combined with RDHR (rate compensated) type detector shall be used. RDHR (rate compensated) heat detectors shall be provided in kitchen areas.

**Fusible plug**

For fusible plugs, the minimum recommended spacing also applicable to onshore on the table 4 taken from of ISO 10418.
Table 4: Guidelines for fusible-plug installation

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Fusible Plug Arrangement</th>
<th>Minimum Number of Plugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellheads</td>
<td>3 around each wellhead at 120°(1)</td>
<td>3</td>
</tr>
<tr>
<td>Headers</td>
<td>one for each 3m of header length, or: n = L[m]/3 (1)</td>
<td>2</td>
</tr>
<tr>
<td>Pressure vessels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD: Outside diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L: Length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical Vessel</td>
<td>n = OD[m]/0.3 with a maximum of 5 plugs</td>
<td>1</td>
</tr>
<tr>
<td>Horizontal vessel</td>
<td>If OD ≤ 1.2m</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>n = L[m]/1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If OD ≥ 1.2m</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>n = 2x L[m]/1.5 in 2 parallel rows</td>
<td></td>
</tr>
<tr>
<td>Atmospheric vessels</td>
<td>1 for each process inlet, outlet and hatch</td>
<td>-</td>
</tr>
<tr>
<td>Fired vessels and exhaust</td>
<td>Same as pressure vessels. Additionally, 1 outside of the flame arrester on fired components.</td>
<td>-</td>
</tr>
<tr>
<td>heated components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat exchangers (shell-tube)</td>
<td>1 for each end of heat exchanger</td>
<td>2</td>
</tr>
<tr>
<td>Pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reciprocating</td>
<td>1 over rod packing</td>
<td>-</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>1 over each packing box</td>
<td>-</td>
</tr>
<tr>
<td>Compressors</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Reciprocating</td>
<td>1 for each cylinder (2)</td>
<td>-</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>1 over compressor case</td>
<td>-</td>
</tr>
<tr>
<td>Engines</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Spark ignition</td>
<td>1 over each carburettor or fuel injection valve (2)</td>
<td>-</td>
</tr>
<tr>
<td>Diesel</td>
<td>1 for pump supplying injectors (2)</td>
<td>-</td>
</tr>
<tr>
<td>Combustion turbines</td>
<td>1 for each fuel solenoid, governor valve and PTO pump</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: when fusible tubing or other devices (such as UV/IR flame detectors, etc.) are used instead of fusible plugs, they should provide at least the same coverage as outlined above.

Note 1: not applicable to underwater wellheads or headers.

Note 2: or equivalent coverage.

For gas wells (high pressure) it is recommended to install FPs and UV/IRs or MIRs detectors. The duplication is particularly useful during operations on the well as the FP network linked to the well control cabinet is in override mode when the F&G system electronics are still on.
6.2 Flame detectors' location

For flame detectors, the Manufacturer's data shall be taken into account for sitting the detectors, especially:

Cone of vision. Flame detectors are sited such that their vision cone covers areas where fire may occur. The cone of vision of the flame detector is three dimensional and is not necessarily perfectly round. The horizontal angle of vision and the vertical angle of vision often differ, as shown example below (Figure 3 and Figure 4) (example of cone of vision -or field of view-: 90° on horizontal plane, 75° on vertical plane, at 70% minimum of detection distance in central axe).

![Figure 3: Example of cone of vision at the indicated distance (m) for a Methane fire](image1)

![Figure 4: Example of vertical cone of vision with detector set at 45° with vertical](image2)

Detection range to the application’s specified fuel with common false alarm sources present, taking into account any obstacles that might create a screen and thus reduce device efficiency. The shadow effect shall also be considered (see Figure 5). It can be minimized by mounting a second flame detector in the opposite of the first detector.
The detector shall have an unobstructed view of the protected area. Obstructions such as grids, scaffolding, bars, supports, tackle and any other solid object blocks the cone of vision and restricts the access for maintenance purposes. These data shall be validated by the final acceptance tests on site during commissioning of the new detection system. A good location on the layout may be, in fact, a bad place in reality that is why a site survey is necessary to check a right location of the detector and its complete coverage of the protected area. Especially all the areas with high potential of fire ignition shall be covered by flame detection system. Location of detectors is critical whenever voting is employed, as the detectors implemented in the voting shall cover the same area, taking account of obstacle (see Figure 6).

### 6.3 Smoke detectors’ location

Smoke detectors shall not be used in heavily ventilated areas.

Smoke detector spacing shall be according to following table 5.
Table 5: Smoke detectors’ location

<table>
<thead>
<tr>
<th>Maximum ground area covered by a detector</th>
<th>Maximum distance between detectors</th>
<th>Maximum distance from a continuous obstruction (wall, etc.)</th>
<th>Maximum height above the potential hazard location</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 m²</td>
<td>8 m</td>
<td>5 m</td>
<td>7.5 m</td>
</tr>
<tr>
<td>20 m² in false floor and false ceiling</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A minimum distance of 0.5 m shall also be respected from a continuous obstruction wall.

Such detectors shall not be situated more than 60 cm from the ceiling.

A smaller area of coverage may be selected, depending to the hazard to be protected against and the speed of alarm sought. The detectors shall be evenly distributed about the premises, with particular attention given to friezes and dropped girders, to ventilation air inlet and outlet ducts and to temperatures near the ceiling. In premises where the air change rate is more than 12, a special study shall be required.

Scattered light type smoke detectors shall be used for enclosed spaces and buildings such as offices, archives, store rooms, medical centres, computer rooms and instrumentation rooms, LQ air inlets, etc.

**Early warning smoke detection system (e.g. VESDA)**

This system may be used to complement to optical type detection for protection of the following locations: under elevated floors in computer/technical/control rooms, inside electrical and instrumentation cabinets and on indoor cable trays.

### 6.4 Flammable gases detectors’ location

The location of detectors shall be based on study about typical leakage calculations, taking into account the lay-out of the installation, the heat and the material balance of the process, the environmental condition (prevailing wind speed and direction, local atmospheric conditions), and the structural arrangements (walls, partitions, etc.) which could allow gas to accumulate. The possible ignition source shall be considered.

Gas detectors with shutdown safety actions shall by default be installed in the following locations:

- In the air inlets of pressurized and/or ventilated premises (ducts, airlocks, etc.)
- Air inlets of HVAC systems (with specific detector adapted to flowing air application)
- Inside the premises in the case of vital premises, e.g. control room, main instrument room, in a highly congested environment (offshore platform)
- In turbine combustion air and ventilation air inlets (on turbo-compressors and turbo-generators) and in air inlets for diesel engines (emergency power generators and fire pumps)
- Inside of turbine hoods according to the configuration of the fuel gas network
- In or around the air inlets of furnaces, heaters, e.g. of a glycol reboiler, and analyser buildings (but not large fire boilers which are safe by location)
Outside rotating machinery such as:
  - all HC gas compressors
  - all HC pumps.

Outside when there is a heavy concentration of control valves in a small space (e.g. wellhead flow-line manifold on a process platform where the pressure is dropped from WHSP to the processing pressure)

Air outlets of enclosed hazardous areas/modules, etc.;

Outdoor in liquid gas (LNG/LPG) trenches, impounding basins and tank roofs, and cooling water discharges (LNG plant).

Elevations of flammable gas detectors shall be in accordance with the kind of flammable gas release (heavier or lighter than air) and also shall give the best probability of detection taking into account:

- Gas cloud dispersion
- Gas cloud collision with plant (obstruction)
- Potential hazardous accumulation of gas/low ventilation rate (where significant gas cloud can persist).

The worst scenario shall be determined by estimating the size of the flammable gas cloud that could exist in the sensitive area without being detected.

Open path gas detectors shall be positioned so that they see the section to be protected, they are not recommended in highly congested areas.

For HC storage facilities and containment, the “Buncefield” recommendation MIIB n°13 shall be assessed, as per HSE-TD-PS-12020-001/5; therefore measures shall be analyzed to detect hazardous conditions arising from loss of primary containment, including the presence of high levels of flammable vapors in secondary containment. An evaluation to identify suitable and appropriate measures shall be undertaken in order to consider:

- Installation of flammable gas detection in bunds containing vessels or tanks into which large quantities of highly flammable liquids or vapors may be released
- Relationship between the gas detection system and the overfill prevention system. Detecting high levels of vapor in secondary containment is an early indication of loss of containment and so should initiate action, for example through the overfill prevention system, to limit the extent of any further loss
- Installation of CCTV equipment to assist operators with early detection of abnormal conditions. Operators cannot routinely monitor large numbers of passive screens, but equipment is available that detects and responds to changes in conditions and alerts operators to these changes.

### 6.5 H₂S detectors’ location

Location of H₂S gas detectors shall be based on hazard studies taking into account the lay-out, the process equipment type, the potential sources of leakage and H₂S release, the concentration of H₂S in the process streams, the environmental condition (prevailing wind directions, etc.), etc. They shall be installed at some distance to potential leakages sources to
detect further dispersion and to avoid spurious operations. H₂S detectors shall be installed as a minimum:

- In the air inlets to pressurized and/or ventilated premises (ducts, airlocks, etc.)
- In the air inlets and inside the premises in the case of vital premises or occupied buildings e.g. control room, living quarters, main instrument room, analyser buildings, etc.
- Along escape and evacuation routes and at the muster areas. They shall be located 500 to 750 mm from the ground
- Around the flanges of equipment used to remove H₂S from the gas (e.g. amine treatment, sulphur units) and along the flow path of H₂S-laden effluent (typically at valves and connecting flanges)
- Near to potential sources of leakages such as pump and compressor seals
- In open areas, generally close to sources around vessels and equipment where gas containing H₂S may be released, and along access to an H₂S-containing process area.

H₂S gas is heavier than air and sinks to the lowest lying area. The detectors shall be located at levels lower than expected source of leak, but not higher than 0.75 m above grade, except for escape routes.

### 6.6 Acoustic leak detectors' location

As the acoustic leak detectors are complement to traditional gas detectors, there is no specific requirement for their location. Furthermore their detection range is function of the background noise (see Figure 7), which prevent from having a good and reliable coverage of the area.

Where acoustic leak detectors are installed, their performance shall be considered by an appropriate mapping methodology: location of acoustic detectors is based on identifying the potential sources of leaks, e.g. all joining parts in high-pressure gas installations; an ultrasound map of the background noise shall be determined to decide the alarm level and the optimal location. Care has to be taken to avoid acoustic reflections that can trigger false alarms.

The sensitivity of the detector microphone is adjusted above the ultrasonic background noise. In practice, process zones can be divided into two categories:

- High-level noise: 70 to 80 dB
- Low-level noise: 40 to 60 dB.

The dynamic measurement scale of an ultrasonic detector of gas leaks is usually between 58 dB and 104 dB. The detectors may not require calibration over time, but only a setting of the alarm threshold adapted to the area to be protected.
7. Detection logic

7.1 Detection logic matrix

The safety logic, to be implemented in the F&G system logic solver(s), shall be specified in a dedicated document called ‘Fire & Gas Cause & Effect Matrix’.

The C&E (Cause and Effect) matrix shall consist of a set of tables, one set for each fire zone (refer to GS EP SAF 253), sub-divided in a consistent manner for facility units, equipment, deck, living quarters, etc. and be compiled on the basis of detector/MAC/etc layout drawings.

Multiple dedicated matrices are typically created in case of separate F&G systems, for example:

- A F&G system for floating production facility is typically split up in a topsides and a hull F&G system, with an additional dedicated IMO-certified fire detection system for living quarters
- Packaged equipment may be supplied with their own F&G system/panel
- Onshore facilities are split up in process units, buildings, geographic areas, etc.

Although the F&G matrix for package equipment is typically in the scope of work of the package vendor, the evaluation and approval remains the responsibility of Company.

The layout of C&E matrix tables shall be organized in the industry’s standard way (e.g. the matrix layouts adopted in API RP 14C) as follows:

- On the vertical axis: the causes or initiating events, e.g. all the different detectors in the zone (sub-divided area/unit) including possible combinations (voting blocks), alarm/trip threshold values, or signals from other matrices/systems
- On the horizontal axis: the effects or consequences divided clearly in three main groups, i.e. alarms (local and remote), extinguishing and emergency shutdown actions (process, electrical, ICSS, packages, refer to GS EP SAF 261)
The interaction with other systems (PCS, PSS, ESD, HVAC, packages, etc) shall be clearly addressed using tag/equipment numbers, interconnection signal tags, ESD safety bar references, and listing associated reference documents.

Particular functions such as the manual activation push button (field and CCR), MACs, manual deluge/foam start/stop, CCR push buttons, etc. being related to programming the F&G safety logic shall clearly appear on the F&G C&E matrices as well, because it is the key document used for programming the F&G system(s) and for safety assessments (e.g. HAZOP).

7.2 Fire and Gas detectors not permitted for executive actions

Referring to section 5, the following list summarizes which detectors shall not be used for automatic executive actions (i.e. they can be used for alarm only):

**Gas detectors**
- Acoustic type
- Open path type
- \(\text{H}_2\text{S}\) detectors (except for air inlets and airlocks of buildings and technical rooms).

*Note:* open path type gas detectors may be added as a complementary detection to point gas detectors in a voting configuration for automatic executive action, but may not entirely replace point type gas detectors.

**Fire detectors**
- Imaging based (CCTV) flame detectors
- Manual Alarm Call Points (MAC) (except ESD/Deluge buttons/handles)
- Early warning smoke detection systems
- Addressable type sensors/systems.

Imaging based (CCTV) flame detectors shall also not be used as a complementary detection to other flame/fire detectors in a voting configuration.

7.3 Maintenance inhibits

Maintenance inhibits can be set for reasons of periodic calibration or faulty detectors.

Maintenance inhibits are considered the equivalent of a detector fault, meaning a non-availability of that detector.

In case of voting configurations:
- It results into a degraded mode with reduced availability
- It shall only inhibit the particular detector, hence not the output of the voting block.

A sufficient number of spare detectors and spare parts shall be kept locally at the production facility to ensure that the duration of any maintenance inhibit is reduced as much as possible (i.e. less than 1 day).

7.4 Detection and voting principles for executive actions

All fire and gas detectors which may cause a main process or platform shutdown (i.e. ESD-1 or essential SD-2 as per GS EP SAF 261) shall be redundant or have triplicate sensors in
acCORDANCE WITH THE TABLE HEREAFER, IN ORDER TO OBTAIN BOTH RELIABILITY AS WELL AS AVAILABILITY. THE FOLLOWING VOTING PRINCIPLES SHALL BE IMPLEMENTED IN ACCORDANCE WITH GS EP INS 198.

### Table 6: Voting configuration principles

<table>
<thead>
<tr>
<th>ESD-1</th>
<th>2ooN (N≥3)</th>
<th>By default, all fire &amp; gas detection used for ESD-1 level executive actions shall be installed in a 2ooN (with N≥3) voting configuration minimum.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2oo2</td>
<td>The use of a 2oo2 voting configuration for ESD-1 level executive actions is not permitted for gas detection applications. It is only permitted for smoke detection if it is done between 2 separate loops and if each loop has multiple (3 or more) detectors (e.g. 2 separate smoke detection loops for a technical room).</td>
</tr>
<tr>
<td></td>
<td>1oo2</td>
<td>The use of a 1oo2 voting configuration for ESD-1 level executive actions is not permitted in any case, because the degraded mode in case of one faulty or inhibited detector would increase the risk of spurious shutdowns due to the reduced number of healthy detectors, and it would also reduce the effective safety integrity level (SIL) of the entire loop.</td>
</tr>
<tr>
<td></td>
<td>1oo1</td>
<td>The use of a single fire or gas detector for ESD-1 level executive actions is not permitted (except for heat sensitive cables see note here after) because it is considered too unreliable to avoid a spurious ESD-1 activation.</td>
</tr>
<tr>
<td>SD-2/3</td>
<td></td>
<td>Single detectors are permitted, but voting configurations shall be installed when an increased reliability and/or availability is required for a particular (essential) equipment, package, area or zone (e.g. following FERA, SIL review, etc.).</td>
</tr>
</tbody>
</table>

Note: the 2oo3 voting configuration for ESD-1 level executive actions also applies to the pressure detection of a fusible plug loop, meaning that a single pressure sensor for a fusible plug causing ESD-1 level actions is not permitted. For heat sensitive cables, a specific risk assessment shall define whether this technology may be used for automatic ESD-1 actions, and if voting logic (i.e. multiple cables) is required.

The maximum number of detectors used in a single voting block shall be carefully assessed, following GS EP INS 134, detectors used in XooY voting logic shall be spread over Y input cards in order to avoid common cause failures. Considering that a limited number of input cards can be placed in one rack (e.g. 8, 10, 12 depending on brand and model), using more detectors in voting block than available input cards may result in unnecessary additional racks (and therefore cabinets) for the F&G system. Instead, voting blocks with large amount of detectors shall be split in multiple voting blocks to optimize the use of input cards and racks of the F&G system (e.g. 3 times 2oo8 instead of 2oo24, using only 8 input cards shared by 3 voting blocks).

### 7.5 Fault handling principles for voting configurations

A detector fault (detector breakdown or maintenance inhibit) is not considered the equivalent of exceeding a trip threshold value, otherwise a detector fault would reduce unnecessary the availability of the safety instrumented function (SIF) and it would increase the risk of spurious shutdowns due to the reduced number of healthy detectors.

Therefore, in case of faulty detectors, the initial voting configuration shall automatically be reconfigured in accordance with the tables provided here after.

The ‘executive action’ means the trip activation as per C&E matrix for the initial voting configuration, while ‘alarm’ means a CCR operator work station announcement with event recording by the ICSS. A fault alarm shall only be removable from the ICSS alarm pages once that fault has been restored to healthy conditions.
Table 7: Fault handling principles for gas detection

<table>
<thead>
<tr>
<th>Flammable or Toxic Gas Detection</th>
<th>Voting Configuration</th>
<th>1 Fault</th>
<th>2 Faults</th>
<th>3 Faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>2oo2</td>
<td>2oo2 = not permitted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2oo3</td>
<td>1oo2 + Alarm</td>
<td>1oo1 + Alarm</td>
<td>Executive Action</td>
<td></td>
</tr>
<tr>
<td>2ooN (N&gt;3)</td>
<td>1oo (N-1) + Alarm</td>
<td>1oo(N-2) + Alarm</td>
<td>Executive Action</td>
<td></td>
</tr>
</tbody>
</table>

Note (1): Executive action in case of hydrogen gas detection in battery rooms shall comprise: inhibiting UPS boost charger and increase air extraction of battery room.

Table 8: Fault handling principles for fire detection

<table>
<thead>
<tr>
<th>Fusible Plug Loop (pressure sensors)</th>
<th>Voting Configuration</th>
<th>1 Fault</th>
<th>2 Faults</th>
<th>3 Faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>2oo3</td>
<td>1oo2 + Alarm</td>
<td>1oo1 + Alarm</td>
<td>Executive Action</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Smoke Detection</th>
<th>2oo2 + Alarm</th>
<th>1oo1 + Alarm</th>
<th>Executive Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2oo3</td>
<td>1oo2 + Alarm</td>
<td>1oo1 + Alarm</td>
<td>Executive Action</td>
</tr>
<tr>
<td>2ooN (N&gt;3)</td>
<td>1oo (N-1) + Alarm</td>
<td>1oo(N-2) + Alarm</td>
<td>Executive Action</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Fire Detection Technologies</th>
<th>2oo2</th>
<th>2oo2 = not permitted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2oo3</td>
<td>1oo2 + Alarm</td>
<td>1oo1 + Alarm</td>
<td>Executive Action</td>
</tr>
<tr>
<td>2ooN (N&gt;3)</td>
<td>1oo (N-1) + Alarm</td>
<td>1oo(N-2) + Alarm</td>
<td>Executive Action</td>
</tr>
</tbody>
</table>

Note (2): 2ooN (with N>3) is not recommended for applications other than technical rooms.

Note (3): Pressures sensors for fusible plug loops shall be analogue pressure transmitters; on-off pressure switches shall not be used (in some standards the word ‘switches’ shall be read as ‘threshold values’ and not ‘mechanical switches’).

Reminder: Voting may not be performed by addressable type detectors/systems.

7.6 Smoke detection requirements for technical rooms

It is highly recommended to install multiple (two or more) loops, with a voting configuration between loops, instead of connecting all individual smoke transmitters to one single voting block. In case multiple loops are applied, each loop shall have 'mixed' locations within the technical room, meaning that each loop shall have at least one detector under the false floor,
one detector in the room and (when applicable) one detector above the false ceiling, hence creating a total room coverage by each loop. Voting shall then be between the loops.

This requirement may be altered when individual cabinets are equipped with individual smoke detectors and/or individual fire extinguishing (e.g. electrical switchboards). It is reminded that early warning smoke detection systems shall not be used for automatic executive actions.

This requirement may also be modified for very large rooms where a very large number of smoke detectors per loop would be required, in which case a room partition approach may be more practical.

In any case, the fire detection philosophy for technical rooms shall be clearly identified in the Safety Concept.

8. Testing

The indicator panels shall have been subjected to a first test in the Manufacturer’s factory prior to shipping. The detectors shall be tested at the site. Each detection point and its module shall be tested, as well as its associated logic. Detectors shall be tested in their final configuration on the site (e.g. with splash guard and other protective shelters if any), with test devices allowing the test gas to flow through the detector via the same course: all necessary test and calibration equipment, as per Manufacturer’s design and above requirements, shall be supplied for each brand & type of detector as part of the initial order.

Detector operation shall be checked using:

- Test lamps for the UV/IR detectors
- CH4 standard gas bottles for gas detector
- Calibrated H2S bulbs for H2S detector
- Spray cans for smoke detectors.

Final acceptance shall take place at the site, under operating conditions. For this purpose, a standard flame or a smoke source shall be used.

Heat detectors and UV/IRs shall be tested with an alcohol flame (typical seat is 20 cm²).

Concerning electrical cable fire hazards the standard flame source used shall be electrical cable of the same type as that installed.

The response times of combustible gas detectors, whether catalytic or IR, are set out in standard BS EN 61779-4. They concern the minimum performance expected from the apparatus to be certified. For this standard, T₅₀ is 10 s and T₉₀ is 30 s.

T₅₀ = the detector initially being in clean air, this is the time interval between the moment when it is subjected to a gaseous atmosphere and the moment when the indication reaches 50% of the final indication.

T₉₀ = ditto for 90% of the final indication.

Response time, i.e. the time interval between the start of the phenomena (fire-smoke-gas) and the time when the response reaches a stated indication, shall be:

- For heat detectors ≤ 5 minutes
- For smoke detectors ≤ 2 minutes
• For flame detectors ≤ 30 seconds.
• For H₂S detectors < 30 seconds
• For gas detectors in HVAC < 60 seconds
• For flammable gas detectors < 10 seconds

The associated automatic discharge systems shall be individually tested for correct operation.
### Appendix 1 Detectors’ selection and location

**Table 9: Fire detectors (API RP 14G)**

<table>
<thead>
<tr>
<th>Classification of Detectors</th>
<th>Type of Detector</th>
<th>Operating Principle</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flame Detectors</td>
<td>(a) Infrared (IR) Detectors</td>
<td>Responds to radiant energy from a flame</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Ultraviolet (UV) Flame Detectors</td>
<td>Responds to wave length of light emitted from flame</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) Combination IR/UV</td>
<td>Responds to both UV and IR</td>
<td>Eliminate some of the false alarm problems of the individual IR or UV flame detectors</td>
</tr>
<tr>
<td>2. Heat Detectors</td>
<td>(d) Fusible Plugs or links</td>
<td>Melts at predetermined temperature</td>
<td>Used in compressor and equipment buildings and areas around production equipment and wellheads</td>
</tr>
<tr>
<td></td>
<td>(e) Heat-pneumatic or Thermistor Sensors</td>
<td>Detect a high temperature along a length of tubing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(f) Rate of Rise Detectors</td>
<td>Detect a rapid rate of temperature rise</td>
<td>Not recommended for use near outside doorways in heated or air conditioned buildings</td>
</tr>
<tr>
<td>3. Products of Combustion Detectors</td>
<td>(g) Ionization Detector</td>
<td>Detect temperature above a predetermined value Products of combustion activate an ionization chamber</td>
<td>Normally used in living quarters and control rooms</td>
</tr>
<tr>
<td></td>
<td>(h) Photoelectric Detector</td>
<td>Activated by interruption of a beam of light by smoke particles</td>
<td></td>
</tr>
</tbody>
</table>