

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUALS

FIRE, GAS AND SMOKE DETECTION SYSTEMS

PTS 32.30.20.11

OCTOBER 2009



© 2010 PETROLIAM NASIONAL BERHAD (PETRONAS)

All rights reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the permission of the copyright owner.

PTS Circular 2009	PETRONAS 
PTS No:	32.30.20.11
Publication Title:	Fire, Gas and Smoke Detection Systems
Base PTS Version:	Revision 13

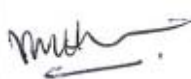
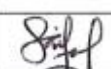
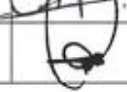
This revision of **PTS 32.30.20.11- Fire, Gas and Smoke Detection Systems** has been updated incorporating:

1. PETRONAS Lessons Learnt
2. Best Practice
3. New information issued by relevant industry code and standards.
4. Incorporate PTS 20.176 - Fire & Gas Detection & Protection System

All updates in the document are highlighted in *italic* font.

The previous version of this PTS September 2002 will be removed from PTS binder/ e-repository from herein onwards.

Document Approval

	Name	Designation	Date	Signature
Initiator	Chua Kien Kek	Principal Engineer		
Reviewed		SKG 14 TPs	PTS Challenge Session 1 and 2 (FY08/09). PTS Challenge Session 1 and 2 (FY09/10)	
Approved	V.R. Harindran	Custodian Engineer (Technical Authority), Instrument & Control, PA&O - GTS	13/10/09	
Verified	Saifol Mualim B Ahmad Yahaya	Senior Manager, Engineering - GTS	20/10/09	
Verified	Pau Kiew Huai	General Manager, Engineering - GTS	23.10.09	
Endorsed	Pramod Kumar Karunakaran	Senior General Manager, GTS	28.10.09	

Revision History

Date	Version	Description of Updates	Author

Summary of Changes

Section	Changes
1.1 Scope	Adding the following The fire suppressing agent should be non-CFC based e.g. FM 200, CO₂, INERGEN, Water Mist, NOVEC 1230 etc. which when specified should be delivered come with Material Safety Datasheet (MSDS)
2.2.4 Enclosed buildings	Adding the following "Gas monitor settings should generally be at 20% LEL high alarm and 60% LEL high-high alarm. "
Table 1 to 5	Changes were made to these tables to accommodate current requirement for offshore applications e.g. changing the BCF to other clean agent in accordance to current regulatory requirements.
2.2.5 Engines	OCMA requirement were replaced with "EEMUA 107" requirements.
2.2.7 Helidecks	Adding new clause on "Helideck". These requirements were extracted from deleted PTS 20.176.
2.3 Onshore Facilities	Adding the following statement "For manned on-shore process facilities, the need to trip the process facilities on gas and/or fire detection shall be upon recommendation of both the HAZOP studies and IPF studies, with optional QRA studies and fire & gas mapping studies."
Section 3 Item 2	The following statement were added <u>"Ventilation fans</u> For ventilation of more than one compartment, the dampers shall be installed on each individual inlet to each compartment. Note: The fire damper shall not be located in the common header as inadvertent closure of the damper would cause the air blower to run against closed end which may cause integrity/reliability issue with damper itself and the ducting due to pressure difference and pressure build-up. On the fan itself it might experience stall."
Section 3 Item 3	Adding new clause as follows: "3a) CO₂ system The design philosophy shall follow as the minimum NFPA12. 1. Description The system, of the fixed type, is made up of piping normally empty, connected to a set of CO₂ storage cylinders. Nozzles of the open type, distributed and orientated in accordance with the applicable standards installed onto the piping, release the gas within the protected area to contain and extinguish the fire. The intervention of the system is activated automatically by means of the fire detection system which will power up the electric controls located on the pilot cylinder, and/or manually, on site, by means of suitable handle controls acting exclusively on the pilot cylinder of the CO₂ storage set. The intervention of the pilot cylinder will control the opening of all other slave cylinders. The release of gas will activate, by means of a pressure device, the alarm signals, which will then be displayed as the intervention on the control panel CO₂ system alarm panels are installed at strategic location e.g. at door entrance of the gas turbine enclosure to warn the personnel related to the CO₂ system operations. As the minimum, status to display are System "Auto", "Inhibited" and "CO₂ Discharge in progress" The system is activated by a detection system which will actuate, by means of the electrical control the pilot cylinders, the CO₂ discharge (the start discharge is normally delayed of 20-30 seconds). Part of the gas, by means of the pneumatic circuit of the check valve, will pressurise the pneumatic pistons; which in turn, by means of their levers pull the opening control bars of all the remaining cylinders in the cylinder bank.

Section	Changes
	The actuation manual control by means of a push button will follow the above described logic of intervention. To signal the intervention of the system, on the discharge pipe is installed a pressure sensor connected to the system alarm panel. For the emergency, there shall be manual mechanical control by means of a pull handle on the cylinder rack, which upon pulled will initiate the gas discharge. 2. CO2 Cylinder The fire is extinguished thanks to the release within the protected areas of a calculated quantity of carbon dioxide stored on cylinders placed in a safe position, on a suitable rack. The quantity of carbon dioxide is calculated in accordance NFPA 12. The cylinders are made of special carbon steel and tested up to 250 Kg. / cm². Every cylinder is equipped with a special quick release valve and siphon, and complete with a safety disk against over-pressure. The bursting pressure of the safety disk is equal to 250 bar. Each cylinder is further provided with a mechanical weighing device, which indicates that the contents of the cylinders are maximum 10% below their nominal charge. All the cylinders are connected to a manifold by means of flexible hoses. On the connections of the manifold, suitable check valves are installed. These allow the performance of the system even in the case of one or more disconnected cylinders for maintenance purposes. For cylinder unit controlled with pneumatic devices, the pilot cylinder check valves are supplied with a lateral coupling, for the connection of the pressurisation circuit of the pneumatic operator which controls the intervention of the system of levers of all the slave cylinders. 3. The piping network The distribution network is made of piping preferably AISI316L of calculated thickness to cope with the pressure of the gas, connected by means of fittings junctions. Discharge nozzles preferably AISI316L, supplied with purposely calculated drills, are installed onto the piping in the ideal position. The quantity and the location of these nozzles are established according to the type of protection, the discharge time and the characteristics of the area and/or the protected equipment. The nozzles designed are based on the CO2 quantity that must be discharged at the pressure that there is at the nozzle. 4. Sizing The nos of CO2 cylinders shall depend on the volume coverage, size of individual cylinders and the projected concentration. There shall be two sizing based on: - QUICK DISCHARGE of which the project concentration shall be 37% for the 1st one minute. - SLOW DISCHARGE of which the project concentration shall be 30% for 30 min. 5. Test All CO2 systems testing should successfully accomplish the following: • Check the integrity of the piping distribution including cylinders rack, supports and anchors. • Verify detector operation. • Verify audible and/or visual alarm operation. • Verify manual release operation. • Verify that all interlock and shutdown functions operate and occur at the appropriate time in the system discharge sequence.

Section	Changes
	• Actuation sequence conforms to the intended design and pre-discharge time delays (if provided), operates correctly and with the correct time delay period. • All pressure operated devices function as intended at the correct point in the firing sequence. • All safety and warning features are in place and operate satisfactorily. • Design concentration is attained within the appropriate time in accordance with NFPA 12. As per NFPA12 requirements, each carbon dioxide system must be tested with full gas discharge in order to make sure that the project characteristics are observed, causing the intervention of the systems with the distribution of the extinguishing agent in the considered area. Smoke test shall be conducted prior to the actual CO2 discharge test to ensure zero leakage of the enclosure. The OPU Fire Safety Dept. shall be consulted on the requirement for conducting the CO2 discharge test. If conducted, the execution of the test must be entrusted to trained personnel, who are also provided with appropriate tools CO2 analyser recorder, safety equipment etc 3b) FM200 or other system The test philosophy shall be similar to CO2 testing with some variations depending on the MSDS (Material Safety Data Sheet)." Because the high airflow volume of the ventilation system causes a considerable dilution of the gas concentration in the event of a leak, higher gas detector sensitivity shall apply with the following settings: - o 5% LEL for Alarm - o 10% LEL for 2oo3 Trip
Section 4 - Firewater Mains, Pumps and Applications	Added the following clause: "Foam solution application rates, injection times, storage quantities and system design criteria shall be as specified in NFPA 11. 3% foam concentrate shall be used and the foam concentrate injection rate will be 5 or 6 litres/min/m² of tank surface area depending on the product stored." "The helideck foam system shall be capable of providing a blanket coverage of at least 6 litres/min of 3% AFFF foam solution per square metre of helideck prescribed area for a minimum period of 5 minutes."
6.0 Fire Damper Control	No difference in control philosophy is made between fire dampers or a halon damper except that frangible bulls operations is not provided on halon dampers. Replace with No difference in control philosophy is made between fire dampers or a floodingsystem damper except that frangible bulls operations is not provided on floodingsystem dampers.
9.0 Fire, Gas and Smoke Detector Selection	Adding as highlighted in italic The hardwired interface between the detector or control unit and the FGS IPS shall be 4-20 mA, with option for 0-20 mA, where 0-4 mA is used for diagnostics, 4-20mA for the signal and detectors shall be configured individually for alarm purposes, unless zone monitoring is approved or specified by the Principal.

Section	Changes
10.2.1 Selection of Point Gas Detector	Removal of following notes Gas ingress/egress thresholds for gas turbine protection vary widely throughout the Group. Gas ingested is offset by that drawn from the fuel gas supply, and provided detection is prompt and large quantities of fuel rich gas are not ingested, then over-speeding should not result. The danger is turbine runaway, but this requires large quantities of gas which should be detected by the gas detection system installed to protect the area where the leakage occurred. 10 % LEL and 50 % LEL should therefore be the low/high detection thresholds for gas turbines. Adding new note 3: 3. For the outlet ventilation fan, the threshold for outlet ventilation, because the high airflow volume of the ventilation system causes a considerable dilution of the gas concentration in the event of a leak, higher gas detector sensitivity has been introduced as one of the latest standards on new units: ▪ 5% LEL for Alarm ▪ 10% LEL for Trip
10.2.3 Catalytic type detectors	New note added as follows: “4. Infrared type detector will not response to the presence of H₂ gas. In this case, a catalytic type detector shall be used.”
15.7 Requirements for Circuit Integrity	Added new clause: “Note: Line monitoring shall be achieved by serial and parallel resistors at the initiators. The resistors shall be placed as close as practicable to the initiator and should form an integral part of the detector. The resistors shall be of encapsulated type.”
	Changes (strikethrough and italic bold) - field initiators should be individually wired to the control module or to the FGS IPS. Normally closed contacts shall be applied. Line monitoring shall be installed. achieved by serial and parallel resistors at the initiators. The resistors shall be placed as close as practicable to the initiator and should form an integral part of it. - zoning of initiators may be applied in buildings. Zoned circuitry shall be achieved by parallel (normally open contacts) configuration of the initiators. The line monitoring shall be installed achieved by a resistor in series with the initiator which should form part of that initiator, and by terminating the circuit by an encapsulated end of line (EOL) resistor which shall be located furthest away from the control module and which should form an integral part of the last initiator in the chain.
16. Installation Practices for Detectors and Associated Equipment	Adding new clause “However, for detecting gas heavier than air, e.g. H₂S, the sensors may be installed lower than 1m above grade or ground level.”

PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

The right to use PTS rests with three categories of users:

- 1) PETRONAS and its affiliates.
- 2) Other parties who are authorised to use PTS subject to appropriate contractual arrangements.
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) and 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, PETRONAS disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any PTS, combination of PTS or any part thereof. The benefit of this disclaimer shall inure in all respects to PETRONAS and/or any company affiliated to PETRONAS that may issue PTS or require the use of PTS.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, PTS shall not, without the prior written consent of PETRONAS, be disclosed by users to any company or person whomsoever and the PTS shall be used exclusively for the purpose they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of PETRONAS.

The copyright of PTS vests in PETRONAS. Users shall arrange for PTS to be held in safe custody and PETRONAS may at any time require information satisfactory to PETRONAS in order to ascertain how users implement this requirement.

TABLE OF CONTENTS

1.	INTRODUCTION	1
1.1	SCOPE	1
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY	1
1.3	DEFINITIONS	2
1.4	CROSS-REFERENCES	2
2.	APPLICATION	3
2.1	GENERAL.....	3
2.2	OFFSHORE FACILITIES	3
2.3	ONSHORE FACILITIES	13
3.	GAS TURBINES.....	14
3.1	GENERAL.....	14
3.2	FIRE DETECTION SYSTEM.....	14
3.3	FIRE PROTECTION	15
5.	TEST.....	16
3.4	GAS DETECTION:-	17
3.5	DRIVEN EQUIPMENT.....	17
3.6	PORTABLE FIRE EXTINGUISHERS.....	17
4.	FIREWATER MAINS, PUMPS & APPLICATIONS	18
4.1	FIREWATER SUPPLY	18
4.2	FIREWATER PUMPS.....	18
5.	FOAM SYSTEMS	20
5.1	DESIGN REFERENCES	20
5.2	FLOATING ROOF TANK FIXED FOAM RISERS-SYSTEM	20
5.3	SUB-SURFACE FOAM INJECTION SYSTEM	20
5.4	HELIDECK FOAM SYSTEM	21
5.5	FUSIBLE PLUGS	21
6.	FIRE EXTINGUISHERS	22
6.1	DESIGN REFERENCES	22
7.	DELUGE AND SPRINKLER SYSTEM.....	23
7.1	DESIGN REFERENCES	23
7.2	SUPPLEMENTARY-REQUIREMENTS	23
8.	FIRE DAMPER CONTROLS	24
9.	FIRE, GAS AND SMOKE DETECTOR SELECTION.....	25
9.1	GENERAL.....	25
10.	FLAMMABLE GAS DETECTOR SELECTION.....	26
10.1	GENERAL.....	26
10.2	SELECTION OF POINT GAS DETECTORS	27
10.3	SELECTION OF OPEN PATH GAS DETECTORS	28

11.	ACOUSTIC LEAK DETECTION	29
12.	OIL MIST DETECTION	30
13.	TOXIC GAS DETECTOR SELECTION.....	31
13.1	GENERAL.....	31
13.2	H ₂ S GAS DETECTORS.....	31
13.3	OTHER TOXIC GAS DETECTORS	32
13.4	TOXIC GAS DETECTION THRESHOLDS	32
14.	FIRE AND SMOKE DETECTOR SELECTION	34
14.1	DETECTOR TYPE SELECTION.....	34
14.2	GENERAL.....	34
14.3	DETECTION BY PERSONS	34
14.4	OPTICAL TYPE FIRE DETECTORS	34
14.5	CCTV FLAME DETECTORS.....	35
14.6	SMOKE DETECTORS	35
14.7	ULTRA-HIGH SENSITIVITY SMOKE DETECTORS	36
14.8	HEAT DETECTORS.....	36
14.9	COMBINED HEAT AND SMOKE DETECTORS.....	36
15.	SYSTEM ENGINEERING, SPECIFICATION AND INSTALLATION PRACTICES.....	37
15.1	GENERAL.....	37
15.2	FIRE AND GAS SYSTEMS (FGSS).....	37
15.3	HUMAN-MACHINE INTERFACE (HMI)	38
15.4	DETECTOR STANDARDS.....	43
15.5	CONTROL MODULES	44
15.6	ALARM LEVEL SETTINGS	44
15.7	REQUIREMENTS FOR CIRCUIT INTEGRITY	45
15.8	EXTINGUISHING SYSTEMS	45
15.9	PURCHASING REQUIREMENTS.....	45
16.	INSTALLATION PRACTICES FOR DETECTORS AND ASSOCIATED EQUIPMENT	47
16.1	GENERAL.....	47
16.2	PERFORMANCE DEFINITIONS.....	47
16.3	PERFORMANCE REQUIREMENTS FOR F&G SYSTEMS	48
16.4	MINIMUM REQUIREMENT FOR ESTABLISHING THE PERFORMANCE OF A SET OF DETECTORS	48
16.5	LOCATION OF FLAMMABLE GAS DETECTORS	49
16.6	LOCATION OF TOXIC GAS AND NH ₃ GAS DETECTORS.....	50
16.7	LOCATION AND POSITIONING OF SMOKE AND FIRE DETECTORS.....	51
16.8	POSITIONING OF BEACONS	52
16.9	POSITIONING OF MANUAL CALL POINTS	53

17.	INSPECTION AND TESTING	54
17.1	FACTORY INSPECTION AND TESTING	54
17.2	SITE INSPECTION AND TESTING	54
18.	MAINTENANCE	55
18.1	GENERAL.....	55
18.2	PRECAUTIONS DURING CONSTRUCTION, SHUTDOWNS AND COMMISSIONING.....	55
18.3	INITIAL CALIBRATION	56
18.4	CALIBRATION/TESTING OF FLAMMABLE GAS DETECTORS	56
18.5	CALIBRATION/TESTING OF H ₂ S GAS DETECTORS.....	56
18.6	CALIBRATION/TESTING OF FIRE AND SMOKE DETECTORS.....	57
19.	TESTING FREQUENCIES	58
20.	REFERENCES	59

APPENDICES

APPENDIX I	HEAT DETECTOR CLASSIFICATION	1
APPENDIX II	TYPICAL CAUSE AND EFFECT MATRIX	2
APPENDIX III	TYPICAL HARDWIRED MIMIC PANEL LAYOUT	3
APPENDIX IV	FIRE & GAS DETECTION MAPPING	4

1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the type selection, specification and installation of fire, gas and smoke detection systems (FGSs).

FGSs shall detect at an appropriately early stage:

- the presence of flammable and toxic gases;
- the presence of a fire;
- the presence of smoke from smouldering or incipient fires.

In order to quickly assess the overall situation in the event of an alarm in highly hazardous and low-manned areas with limited direct visibility, the addition of remote plant surveillance by means of Closed Circuit Television (CCTV) may also be considered. For further information on CCTV technology, refer to PTS 32.71.00.10.

- NOTES:
1. Pattern recognition techniques are now being combined with CCTV technology providing an alternative to conventional optical flame detectors. CCTV technology has the potential to overcome many of the shortfalls experienced with optical detectors such as reflections from welding and friendly fires.
 2. CCTV flame detection based on monochrome and full colour technology is available from a number of Manufacturers. Manufacturers' early results with full colour systems seem encouraging as they provide a clear viewable image. This technology may well be ideally suited for unmanned or remote installations where early intervention or operator conformation is required. However, the Principal's approval should be required for the use of CCTV technology as a replacement for conventional optical detection.

For situations that are not covered in this PTS, the codes of the USA National Fire Protection Association (NFPA) should be consulted.

The fire suppressing agent should be non-CFC based e.g. FM 200, CO₂, INERGEN, Water Mist, NOVEC 1230 etc. which should be delivered with Material Safety Datasheet (MSDS).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETROANS or managed by a Group company, and to Contractors and Manufacturers nominated by them.

It is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in onshore and offshore exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The Contractor is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The Manufacturer/Supplier is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The Principal is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word shall is a requirement.

The word should is a recommendation.

1.3.2 Abbreviations

ALARP	As Low As Reasonably Practical
AFFF	Aqueous Film Forming Foam Concentrate
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
DCS	Distributed Control System
ESD	Emergency Shut Down
FGS	Fire and Gas System
GPA	General Platform Alarm
HSE	Health, Safety and Environment
IPF	Instrumented Protective Function
IPS	Instrumented Protective System
LED	Light Emitting Diode
LOS	Line of Sight
MFAP	Main Fire Alarm Panel
OEL	Occupational Exposure Limit
PFD	Probability of Failure on Demand
QRA	Qualitative Risk Assessment
SFR	Safe Failure Robustness
SIL	Safety Integrity Level
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
UPS	Uninterruptible Power Supply

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in [\(20\)](#).

2. APPLICATION

2.1 GENERAL

- 2.1.1 It should be noted that the standard caters for only one incident at a time.
- 2.1.2 The level of Protection advocated by this standard should be regarded as the minimum, with each new installation critically examined on its own merits.
- 2.1.3 On offshore complexes, an individual protected area shall be defined as a complete installation separated from any other installation by an adequate distance (e.g. Platform Bridge) or part of an installation segregated from adjacent parts of areas by a firewall(s). Individual decks on the production, drilling, riser and living quarter platform may thus form single risk areas.
- 2.1.4 Area classification shall be as specified in PTS 80.00.10.10.

2.2 OFFSHORE FACILITIES

2.2.1 Unmanned Stations

Minimum requirements for fire and gas detection and protection system for unmanned stations are stipulated in [Table 1](#).

2.2.2 Manned Oil Stations

Minimum requirements for fire and gas detection and protection system for manned oil stations are stipulated in [Table 2](#).

2.2.3 Manned Gas Producing/Processing Station

Minimum requirements for the fire and gas detection and protection system for manned gas producing/process stations are stipulated in [Table 3](#).

2.2.4 Enclosed Buildings

Minimum requirements for fire and gas detection and protection system for enclosed buildings on offshore platforms are stipulated in [Table 4](#).

Ventilation and/or pressurization fresh air intakes of all enclosed buildings shall be provided with three (3) gas detectors.

Totally enclosed areas within hazardous areas shall be made safe by pressurization. Semi/totally enclosed buildings on platform which do not process live hydrocarbons do not require to be fitted with gas detectors.

All semi enclosed safe areas on platforms which process live hydrocarbons shall be fitted with a minimum of three (3) gas detectors.

All totally enclosed safe areas which are deemed to be inadequately ventilated on platforms which process live hydrocarbons shall be fitted with a minimum of three (3) gas detectors.

Gas monitor settings should generally be at 20% LEL high alarm and 60% LEL high-high alarm.

For both manned and unmanned platforms, if two or more gas detectors are activated within the same zone, the platform shall initiate an automatic ESD of that unit.

**TABLE 1 - MINIMUM REQUIREMENTS FOR FIRE AND GAS DETECTION AND PROTECTION
SYSTEMS FOR UNMANNED PLATFORMS**

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Wellhead	Fusible Plugs	N/A	Dry powder extinguishers Foam extinguishers	(a) Melting of a fusible plug shall cause platform ESD. (b) Foam extinguishers for drip pan area
Other Process areas e.g. separators, hydrocarbon pumps, launchers/receivers	Fusible Plugs	N/A	Dry powder extinguishers Foam extinguishers	(a) Melting of a single fusible plug, confirmed high level gas or flame shall cause platform ESD. (b) Foam extinguishers for drip pan areas.
Gas Compressor area	Fusible Plugs, Flame and Gas	N/A	Dry powder extinguishers Foam extinguishers	(a) Foam extinguishers for drip pan areas only (b) Melting of a single fusible plug, confirmed high level gas or flame shall cause platform ESD.
Glycol regenerators	Fusible plugs Flame and Gas	N/A	Powder extinguishers	(a) Gas detection for air intake system. (b) Coincident high level gas or flame detection shall cause ESD. (c) Fusible plugs to be at entrance of firebox and vent stack (if applicable). (d) Melting of a single fusible plug shall cause platform ESD.
Internal Combustion Engines				See 2.2.5 – Engines
Enclosed Premises				See Section 2.2.4 – Enclosed buildings
Helidecks	Gas	N/A	Foam Extinguishers Powder extinguishers	(a) Gas detection is only required if gas compressors or other major gas equipment are located below the helideck (b) Coincident high level gas detection shall cause ESD.
Air compressor	Gas	N/A	Powder Extinguishers	(a) Gas detection for air compressor inlet. (b) Coincident high level gas detection shall cause ESD.

NOTE:

- In addition to the fire and gas detection methods, "Kill Knob" (emergency button) shall be provided at appropriate locations, e.g. all escape routes, boat landings, etc. on the platform. The "Kill Knob" will initiate ESD when activated manually.
- H₂S gas detector may be required at the area where the H₂S concentration >10 ppm.

TABLE 2 - MINIMUM REQUIREMENTS FOR FIRE AND GAS DETECTION AND PROTECTION SYSTEMS FOR MANNED OIL PLATFORMS

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Wellhead	Fusible Plugs	Water/foam deluge	Hydrants and fire hose. Powder extinguishers. Foam extinguishers.	(a) Melting of single fusible plug shall cause platform ESD and activate deluge systems. (b) Foam extinguishers for drip pan areas.
Other Process areas e.g. separators, hydrocarbon pumps, launchers/receivers	Fusible Plugs Flame and Gas	Water/foam deluge	Hydrants and fire hose. Powder extinguishers. Foam extinguishers.	(a) Melting of single fusible plug shall cause platform ESD and activate deluge systems. (b) Coincident high level gas detectors shall cause ESD. (c) Foam extinguishers for drip pan areas.
Gas Compressor	Fusible Plugs Flame and Gas	Water/foam deluge	Hydrants and fire hose. Powder extinguishers. Foam extinguishers.	(a) Melting of single fusible plug shall cause platform ESD and activate deluge systems. (b) Coincident high level gas detectors shall cause ESD. (c) Foam extinguishers for drip pan areas.
Internal Combustion Engines				(a) See section 2.2.5 .
Enclosed Buildings				(b) See section 2.2.4 .
Air Compressor	Gas	N/A	Powder Extinguisher	(a) Gas detection for air compressor inlet. (b) Coincident high level gas detectors shall cause ESD..
Glycol Regenerators	Fusible plugs Flame and Gas	N/A	Powder extinguishers Hydrant and firehose Foam hose reels.	(a) Gas detection for air intake system. (b) Coincident high level gas detectors shall cause ESD.. (c) Fusible plugs to be at entrance of firebox and vent stack (if applicable). (d) Melting of a single fusible plug or confirmed high level flame shall cause ESD.

Note:

1. In addition to the fire and gas detection methods, "Kill Knob" (emergency button) shall be provided at appropriate locations, e.g. all escape routes, boat landings, etc. on the platform. The "Kill Knob" will initiate ESD when activated manually.
2. If venting is required during ESD, it shall be manually activated from the control room.
3. H₂S gas detector may be required at the area where the H₂S concentration >10 ppm.

TABLE 3 - MINIMUM REQUIREMENTS FOR FIRE AND GAS DETECTION AND PROTECTION SYSTEMS FOR MANNED GAS PRODUCING/PROCESSING PLATFORMS

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Wellhead manifolds, Production coolers.	Fusible plugs Flame	Water deluge	Hydrants, fire hose, powder extinguishers.	Melting of a fusible plug or confirmed flame will activate water deluge and cause ESD.
Production/test separators, coalescers, skimmers, contactor tower, glycol storage tank, condensate flash separator, condensate dryer tower.	Fusible plugs Flame and Gas	Water deluge	Hydrants and fire hose, foam hose reels, powder extinguishers.	(a) Melting of a single fusible plug or confirmed flame will activate water deluge and cause ESD. (b) Coincident high level gas detection shall cause ESD.
Glycol regenerators	Fusible plugs Flame Gas	N/A	Hydrants and fire hose, foam hose reels, powder extinguishers.	(a) Gas detection to be at the air intake system. (b) Melting of a single fusible plug or confirmed flame shall activate water deluge and cause ESD. (c) Coincident high level gas detection shall cause ESD. (d) Fusible plugs to be at the entrance of fire box and vent stack.
Launcher/Receiver	Fusible plugs, gas or flame	Water deluge	Hydrant and hose reels, foam hose reels.	(a) Melting of a single fusible plug will activate water deluge and cause ESD. (b) Coincident high level gas detection shall cause ESD.
Vent stacks	IR/ Thermocouples	CO ₂	N/A	(a) IR/Thermocouples detection to alarm only. (b) CO ₂ is to be manually activated.
Fuel Gas/Vent scrubbers	Fusible plugs, Gas/Flame	Water deluge	Hydrants and hose reels, powder extinguishers.	(a) Melting of a single fusible plug will activate water deluge and cause ESD. (b) Coincident high level gas detection shall cause ESD.
Hydrocarbon pumps, lube oil coolers, diesel storage tank, methanol storage tank, brine/LCM/ Condensate tankage area	Fusible plugs, Gas/Flame	Water deluge	Hydrants and hose reels, Foam hose reels.	(c) Melting of a single fusible plug will activate water deluge and cause ESD. (d) Coincident high level gas detection shall cause ESD..
Gas Compressors	Fusible plugs, Gas/Flame	Water deluge	Hydrants and hose reels, powder extinguishers.	(a) Melting of a single fusible plug will activate water deluge and cause ESD. (b) Coincident high level gas detection shall cause ESD..

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Air compressors	Gas	N/A	Powder extinguishers	(a) Three (3) gas detectors to cover air compressor air intake and to shutdown air compressor coincident gas detection.
Enclosed buildings				(a) See section 2.2.4 – Enclosed buildings
Internal combustion engines				(a) See section 2.2.5 – Engines
Gas turbines				(a) See section 2.2.6 – Gas Turbines

Note:

1. In addition to the fire and gas detection methods, "Kills Knob" (emergency button) shall be provided at appropriate locations, e.g. all escape routes, boat landings, etc. on the platform. The "Kills Knob" will initiate ESD when activated manually.
2. If venting is required during ESD, it shall be manually activated from the control room.
3. H₂S gas detector may be required at the area where the H₂S concentration >10 ppm.

TABLE 4 - MINIMUM REQUIREMENTS FOR FIRE AND GAS DETECTION AND PROTECTION SYSTEMS FOR OFFSHORE ENCLOSED BUILDINGS

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Generator room	Flame Gas	Flooding system subjected to Principal approval	Powder Extinguishers	(a) Confirmed flame detection, gas supply line to the room shall shutdown and blowdown and should initiate the start of the auxiliary diesel generator (if in different location) (b) Three (3) nos of gas detectors for air compressor air intake and to shutdown air compressor upon coincident gas detection.
Electrical or electronic room e.g. control rooms, switch rooms, radio room, inverter/UPS room, SCADA room, termination room, transformer room, etc.	Smoke Gas	Only for remote location require total flooding system. Such system is subjected to Principal approval.	Powder extinguishers	(a) Where applicable, smoke detectors to be in the room plus false floor and false ceiling for flooding system activation. (b) Smoke detection to give GPA only. (c) Confirmed high level gas shall activate ESD.
Battery room	Smoke Gas	N/A	Powder extinguishers	(a) Gas detection is not required if all equipment in the room are certified for use in Zone 2, gas group IIC environment. Confirmed gas detection shall stop of ventilation inhibits boost charge. (b) Smoke detection to give GPA only.
Equipment rooms/workshop	Smoke	Automatic water sprinklers	Powder extinguishers	Smoke detection to activate GPA only.
Gas compressor room	Flame, Gas, Heat	Water deluge	Powder extinguishers	Standard manufacturer detectors for confirmed gas, flame or heat will shutdown the compressor.
LIVING QUARTERS				
Corridors and stairwells	Smoke	Automatic water sprinklers	Hose reels, water extinguishers	Air conditioning shutdown on smoke detection.
Ceiling voids	Smoke	N/A	Hose reels (available from corridor)	(a) Smoke detectors shall only be located in ceiling voids should a significant fire hazard be deemed to exist. (b) Each detector shall have a remote indicator light unit located in the corridor directly in line with the detector.
Cabins	Smoke	Automatic water sprinklers	Hose reels (available from corridor)	Smoke detection to activate GPA only.

AREA	DETECTION METHODS	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
Dining/Recreation rooms	Smoke	Automatic water sprinklers	Hose reels, water extinguishers	Smoke detection to activate GPA only.
Galley	N/A	Automatic water sprinklers	Powder extinguishers, Fire blanket Fire blanket	Sprinklers shall not spray onto a deep cooking oil fryer.
Galley hood/duct	Heat	N/A	Powder extinguishers	Heat detection to activate GPA only.
AHU Room	Gas Smoke	N/A	Powder extinguishers	(a) Gas detection to monitor air inlets. Confirmed High level gas shall activate ESD. (b) Smoke detection to trip fans.
Radio Room	Smoke	N/A	Powder extinguishers	(a) Where applicable, smoke detectors to be in false floor and false ceiling. (b) Smoke detection to activate GPA only.
Laundry room/ Locker room/ Store Room	Smoke	Automatic water sprinklers	Powder extinguishers Water extinguishers	(a) Powder or water extinguishers as appropriate. (b) Smoke detection to activate GPA only.

Notes:

1. Remote smoke indicator units shall be installed in the corridors for all detectors except the corridor or ceiling detectors which have integral indicators already visible from the corridor.
2. Multiple smoke detection loops (minimum 2) should be utilised for the ceiling detectors. The grouping of these should be on an alternate detector basis thus maximising coverage in the event that one loop is isolated for maintenance or is faulty.
3. Manual fire alarms stations at each exit from the floor plus at strategic points on the floor, e.g. entrance to stairwell should be installed. These shall not be installed more than 30 m apart.

2.2.5 Engines

Generally, the only form of fire detection/protection for the internal combustion engines can consist of the various types of fire and gas detection system such as fusible plug loop, UV, IR and other fire detection devices.

Precautions shall be taken to ensure that any engine installed in an enclosed area which is required to run in an emergency situation, when normal platform ventilation would be shutdown, is provided with adequate air supply from a non-hazardous area for both combustion and cooling requirements.

Any engine located in a hazardous (classified) zone which is fitted with automatic start-up facilities, shall be protected by gas detectors to both alarm and inhibit the engine start-up sequence if a hazardous environment is monitored. Engines of firewater pumps shall not be located in a hazardous (classified) zone.

All internal combustion engines when operating in a classified zone shall be protected and maintained in accordance with EEMUA 107. Additionally gas engines shall have shielded ignition systems which are 'grounded' by the engine over speed device. (Rig saver is thus not a mandatory requirement for gas engines).

2.2.6 Gas turbines – Refer to [Section 3](#).

2.2.7 Helidecks

2.2.7.1 Manned Installation

The following equipment shall be provided on all helidecks at manned installations:

Fire Fighting Equipment

- (1) Two (2) non-CFC based extinguishers with capacity of 12.0 kg each.
- (2) Four (4) DCP dry powder extinguishers with capacity of 12.0 kg each.
- (3) A low expansion foam application system capable of discharging foam solution onto the landing area at a rate of not less than 6 liters per minute per square meter over an area of 498 sq. m.

Sufficient foam compound to enable the rate prescribed above shall be continuously maintained for a period of not less than 5 minutes.

- (4) 2 fire hydrants shall be installed, one at each side of the deck, adjacent to the access points. Each hydrant shall be fitted with 2 x 0.065m (2½") individually valved instantaneous couplings and a hose box containing 2 x 0.043m (1 ¾") hose and 2 fyrex branch pipes.
- (5) Four low profile foam monitors located one on each side of the helidecks shall be required.

Rescue Equipment

The following rescue equipment shall be provided and contained in a steel box:

- (a) 1 axe - aircraft type
- (b) 1 crowbar, 1 m (3'6") long
- (c) 1 heavy duty hacksaw c/w blade
- (d) 2 spare hack saw blades
- (e) 1 fire blanker (fibre glass type)
- (f) 1 grappling hook with line
- (g) 1 quick release safety knife (Bristol type)
- (h) 1 0.60m (24") bolt croppers

Fireman's Equipment

Every helidecks at manned offshore installation shall be provided with four sets of fireman's equipment.

The sets of equipment shall be kept in pairs, and one pair shall be kept at a place which is readily accessible from the helicopter landing area, while the other is worn by operators during helicopter operations.

Each set of equipment above shall comprise the followings:

- (1) a protective outfit, including gloves, boots, a face mask or hood and helmet;
- (2) a self-contained breathing apparatus;
- (3) a portable battery operated safety lamp capable of functioning efficiently for a period of not less than 3 hours;
- (4) a fireman's axe; and
- (5) a safety harness and lifeline.

2.2.7.2 Unmanned Installation

The following equipment shall be provided on all helidecks at unmanned platforms:

Fire Fighting Equipment

- (1) Two non-CFC based extinguishers with capacity of 12.0 kg each.
- (2) Four DCP dry powder extinguishers with capacity of 12.0 kg each.

Rescue Equipment

For unmanned installation the following rescue equipment are provided and-contained in a fibre glass box:-

- (1) 1 crowbar, 1m (3'-6") long
- (2) 1 axe, aircraft type
- (3) 1 pair of fire proof hand gloves
- (4) 1 quick release safety knife (Bristol type)
- (5) 1 0.60m (24") bolt croppers

Other than stated in Para [2.2.7.1](#) and [2.2.7.2](#), the system requirement for Helidecks should comply with Department of Civil Aviation requirements as specified in CAP437.

2.2.8 Barges

1. Fire Detection and Alarm Systems:-

An automatic fire detection and alarm system shall be provided in all accommodation and service spaces. Service spaces are those used for galleys, main pantries, stores, workshops other than those forming part of machinery spaces, etc.

Detection and alarm are to be the same as those outlined in [2.2.4](#).

2. Fire Protection:-

Sprinklers are to be installed in the accommodation and service spaces, and manual equipment is to be available, similar to those outlined in [2.2.4](#).

Hydrants and fire hoses are to be available on the decks. Machinery spaces also shall be provided with fire hoses.

CO₂ system shall be installed in the engines room.

Gas Detection:-

Gas detection is required in the ventilation inlets to alarm and shutdown the ventilation/air conditioning upon 2 or higher level operation of any two gas detectors.

3. Alarm Panels:-

All fire and gas alarms shall be relayed to the main fire control station which shall be manned or equipped as to ensure that any alarm from the system is immediately received by a responsible member of the crew. Such alarm system shall be constructed to indicate if any fault occurs in the system.

2.2.9 Drilling Rigs

[Table 5](#) gives a summary of the fire/gas detection/protection system required on drilling rigs. For accommodation modules of the rigs, detection and protection systems are to be per [2.2.4](#).

TABLE 5 DRILLING RIGS FIRE/GAS DETECTION/PROTECTION

AREA	DETECTION	FIXED CONTROL AND EXTINGUISHING SYSTEMS	HAND, PORTABLE AND MOBILE EQUIPMENT	COMMENTS
DRILLING RIG				
Drill floor and substructure	N/A	Water monitors	Hydrants & Fire Hose Powder Extinguishers	Gas detection may be incorporated within enclosed substructures where applicable.
Shake Shaker and Active mud tanks	Gas	Water/Foam Deluge	Hose Reel Powder Extinguishers Hydrants & Fire Hose	Deluge system with manual operation from a safe area.
Mud pumps	Gas Smoke	N/A	Hydrant & Fire Hose Powder Extinguishers Hose Reel	
Sack storage	Heat	N/A	Hose Reel Powder Extinguishers	
Bulk storage	Heat	N/A	Hose Reel	
Rig Emergency Room	Smoke	N/A	Powder Extinguishers	
Cement Unit	Gas	N/A	Hydrants	
Mud Laboratory	Gas Smoke	N/A	Powder Extinguishers	Gas Detection to monitor air inlet and on detection shutdown ventilation and electrical equipment and close dampers.

2.3 ONSHORE FACILITIES

The onshore facilities are to be protected by the types of gas and fire detection/protection systems as stipulated by the following documents:-

PTS 80.47.10.30 "Assessment of Fire Safety of Onshore Installation"

This PTS gives the minimum requirements for the design and engineering of fire detection/protection and related facilities for application in onshore oil and gas processing and petrochemical installations, storage facilities, jetties, terminals, loading and unloading facilities. It also stipulates the fire detection/protection requirements for buildings and these requirements shall be additional to those stipulated in the Malaysia Uniform Building By-Laws and BOMBA.

The on-shore facilities manned buildings are additionally covered by :-

Local regulatory by-laws, such as, Malaysia Uniform Building By-Laws

This document spells out the statutory requirements of fire detection/protection of buildings. All buildings shall be built to meet the minimum requirements stipulated by this document.

For manned on-shore process facilities, the need to trip the process facilities on gas and/or fire detection shall be upon recommendation of both the HAZOP studies and IPF studies, with optional QRA studies and fire & gas mapping studies.

3. GAS TURBINES

3.1 General

Turbines provide both sources of fuel and ignition in close proximity and have a high incident rate of fires.

Thus they require a fire and gas detection/protection system. They require large quantities of air both for combustion and for cooling and they are generally installed within acoustic enclosure which allows effective extinguishing of turbine fires and provides containment and segregation of hazards. The fire and gas detection/protection system shall cater for the following hazardous situations:-

- (a) Fire inside the turbine enclosure
- (b) Fire outside the turbine enclosure
- (c) Combustible gas in the turbine combustion/ventilation air intake
- (d) Combustible gas under the acoustic hood

3.2 Fire Detection System

3.2.1 Turbine Enclosure:-

The fire detection system inside the turbine enclosure is to consist of the following:-

- (i) Primary (main) detection using U.V or UV/IR or Triple IR detection or manufacturer's recommendation subjected to approval by Principal;
- (ii) Secondary (back-up, due activation based on prolonged fire occurrence) detection using fixed heat detection.

Sufficient numbers of primary detectors are to be provided to oversee the interior of the gas turbine enclosure. Care shall be taken with location of primary detectors to ensure that they monitor the fuel gas and combustion chamber areas without obstruction by ducts, piping, etc. Heat detectors of appropriate temperature rating shall be incorporated to monitor those areas not seen by primary detectors, e.g. behind inlet and exhaust plenum, lubrication oil systems, heat sources and air flow. Nevertheless, the primary detectors shall ensure maximum detection coverage. The setting and location of the heat detectors shall be determined with the turbine vendor considering temperature profiles in the enclosure. Each compartment may be considered as one zone with at least two out of three (2oo3) voting logic for tripping. One primary detector sensing fire shall alarm and additional one more detectors shall be required to trip the machine. The tripping action generally comprises shut down enclosure ventilation fans and close dampers, isolate and blowdown fuel gas line of the particular turbine, isolate the fuel supply and release CO₂/FM 200 or other equivalent clean agent as per NFPA2001. The actual required tripping action shall be determined by the turbine vendor.

(iii) Ventilation fans

For ventilation of more than one compartment, the dampers shall be installed on each individual inlet to each compartment.

Note: The fire damper shall not be located in the common header as inadvertent closure of the damper would cause the air blower to run against closed end which may cause integrity/reliability issue with damper itself and the ducting due to pressure difference and pressure build-up. On the fan itself it might experience stall.

- (iv) Outside the Turbine Enclosure the fire and gas detection requirements shall follow the appropriate process facilities requirements

3.3 Fire Protection

The gas turbine enclosure is to be provided with an automatic total flooding e.g. CO₂, FM200, water mist system or other equivalent clean agent as per NFPA2001 for fire extinguishment.

3.3.1 CO₂ system

The design philosophy shall follow as the minimum NFPA12.

1. Description

The system, of the fixed type, is made up of piping normally empty and connected to a set of CO₂ storage cylinders. Nozzles of the open type, distributed and orientated in accordance with the applicable standards installed onto the piping, release the gas within the protected area to contain and extinguish the fire.

The intervention of the system is activated automatically by means of the fire detection system which will power up the electric controls located on the pilot cylinder, and/or manually, on site, by means of suitable handle controls acting exclusively on the pilot cylinder of the CO₂ storage set.

The intervention of the pilot cylinder will control the opening of all other slave cylinders. The release of gas will activate, by means of a pressure device, the alarm signals, which will then be displayed as the intervention on the control panel.

CO₂ system alarm panels are installed at strategic location e.g. at door entrance of the gas turbine enclosure to warn the personnel related to the CO₂ system operations. As the minimum, statuses to display are System "Auto", "Inhibited" and "CO₂ Discharge in progress".

The system is activated by a detection system which will actuate, by means of the electrical control the pilot cylinders, the CO₂ discharge (the start discharge is normally delayed of 20-30 seconds). Part of the gas, by means of the pneumatic circuit of the check valve, will pressurise the pneumatic pistons; which in turn, by means of their levers pull the opening control bars of all the remaining cylinders in the cylinder bank.

The actuation manual control by means of a push button will follow the above described logic of intervention.

To signal the intervention of the system, on the discharge pipe is installed a pressure sensor connected to the system alarm panel.

For the emergency, there shall be manual mechanical control by means of a pull handle on the cylinder rack, which upon pulled will initiate the gas discharge.

2. CO₂ Cylinder

The fire is extinguished thanks to the release within the protected areas of a calculated quantity of carbon dioxide stored on cylinders placed in a safe position, on a suitable rack. The quantity of carbon dioxide is calculated in accordance NFPA 12.

The cylinders are made of special carbon steel and tested up to 250 Kg. / cm².

Every cylinder is equipped with a special quick release valve and siphon, and complete with a safety disk against over-pressure. The bursting pressure of the safety disk is equal to 250 bars.

Each cylinder is further provided with a mechanical weighing device, which indicates that the contents of the cylinders are maximum 10% below their nominal charge.

All the cylinders are connected to a manifold by means of flexible hoses. On the connections of the manifold, suitable check valves are installed. These allow the performance of the system even in the case of one or more disconnected cylinders for maintenance purposes. For cylinder unit controlled with pneumatic devices, the pilot cylinder check valves are supplied with a lateral coupling, for the connection of the pressurisation circuit of the pneumatic operator which controls the intervention of the system of levers of all the slave cylinders.

3. The piping network

The distribution network is made of piping preferably AISI316L of calculated thickness to cope with the pressure of the gas, connected by means of fittings junctions. Discharge nozzles preferably AISI316L, supplied with purposely calculated drills, are installed onto the piping in the ideal position. The quantity and the location of these nozzles are established according to the type of protection, the discharge time and the characteristics of the area and/or the protected equipment. The nozzles designed are based on the CO₂ quantity that must be discharged at the pressure that there is at the nozzle.

4. Sizing

The nos of CO₂ cylinders shall depend on the volume coverage, size of individual cylinders and the projected concentration. There shall be two sizing based on:

- a) QUICK DISCHARGE of which the project concentration shall be 37% for the 1st one minute.
- b) SLOW DISCHARGE of which the project concentration shall be 30% for 30 min.

5. Test

All CO₂ systems testing should successfully accomplish the following:

- Check the integrity of the piping distribution including cylinders rack, supports and anchors.
- Verify detector operation.
- Verify audible and/or visual alarm operation.
- Verify manual release operation.
- Verify that all interlock and shutdown functions operate and occur at the appropriate time in the system discharge sequence.
- Actuation sequence conforms to the intended design and pre-discharge time delays (if provided), operates correctly and with the correct time delay period.
- All pressure operated devices function as intended at the correct point in the firing sequence.
- All safety and warning features are in place and operate satisfactorily.
- Design concentration is attained within the appropriate time in accordance with NFPA 12.

As per NFPA12 requirements, each carbon dioxide system must be tested with full gas discharge in order to make sure that the project characteristics are observed, causing the intervention of the systems with the distribution of the extinguishing agent in the considered area.

Smoke test shall be conducted prior to the actual CO₂ discharge test to ensure zero leakage of the enclosure.

The OPU Fire Safety Dept. shall be consulted on the requirement for conducting the CO₂ discharge test. If conducted, the execution of the test must be entrusted to trained personnel, who are also provided with appropriate tools CO₂ analyser recorder, safety equipment etc.

3.3.2 FM200 or other system

The test philosophy shall be similar to CO₂ testing with some variations depending on the MSDS (Material Safety Data Sheet).

3.4 Gas Detection:-

3.4.1 Enclosure ventilation and combustion air intakes detection system:-

The ventilation and combustion air intakes should preferably be located at the same position and three gas detectors shall be installed at this common intake.

Low (10% LEL) or high (50% LEL) level operation of a single detector will annunciate at the local turbine control panel and at the main Fire and Gas Panel. 2 or more higher level operation of any two detectors will automatically initiate an alarm and shutdown the turbine.

3.4.2 Ventilation air exhaust detection system:-

Three gas detectors shall be installed under the acoustic hood to monitor the ventilation air exhaust. The actions are as in 4(a) for the combustion/ventilation air intake, except on 2 or higher level operation of any two detectors, the fuel lines shall be shut off and blown down.

Gas detectors are preferably to be installed at the ventilation outlet but the exhaust temperature of the turbine will determine the location of gas detectors.

Because the high airflow volume of the ventilation system causes a considerable dilution of the gas concentration in the event of a leak, higher gas detector sensitivity shall apply with the following settings:

- o 5% LEL for Alarm
- o 10% LEL for 2oo3 Trip

3.5 Driven Equipment

Driven units transferring hazardous fluids (e.g. oil pumps, hydrocarbon compressors) will normally be situated outside any enclosed turbine room. Heat or flame detection should be installed to initiate a process shutdown and system depressurisation as appropriate. See also [2.2.5](#).

3.6 Portable Fire Extinguishers

50-kg wheeled powder extinguishers shall be installed in the vicinity of the gas turbine enclosures.

4. FIREWATER MAINS, PUMPS & APPLICATIONS

4.1 Firewater Supply

4.1.1 Design References

PTS 80.47.10.30 "Assessment of Fire Safety of Onshore Installation", PTS 80.47.10.31 "Active Fire Protection Systems and Equipment for Onshore Facilities" and API RP 14G "Recommended Practice for Fire Prevention on Open Type Offshore Production Platforms".

Quality, reliability and storage of firewater supply shall be designed to the requirements outlined in these **standards**.

4.2 Firewater Pumps

4.2.1 Design references

4.2.1.1 NFPA 20 - Centrifugal fire Pumps"

Pumps for use in fire-fighting water service shall comply with the requirements of NFPA 20.

4.2.1.2 PTS 80.47.10.30. "Assessment of Fire Safety for Onshore Installation".

This PTS shall be used to supplement NFPA 20 in the design of firewater pumps.

1. Firewater Ringmain

Design References

PTS 80.47.10.30. "Assessment of Fire Safety of Onshore Installation".

Design, installation and material selection of firewater ringmain should meet the requirements outlined in this PTS.

2. Water Application Rates

Design References

PTS 80.47.10.30. "Assessment of Fire Safety of Onshore Installation".

This PTS shall be used in determining the required water rates for designing the firewater system.

3. Hydrants

The theoretical water flow rate from a hydrant can be calculated from the equation -

$$Q = C * A * \text{SQRT} (2 * P_e / \rho)$$

where

Q = discharge rate (m³/S)

C = nozzle discharge coefficient (typically 0.9)

A = nozzle area (m²)

P_e = system pressure (Pa)

ρ = fluid density (kg.m³) = 1000 kg/m³ for water

SQRT = square root

Supplementary Requirements:

On offshore platform, two outlets per hydrant are usual. The hydrant valve outlet shall be provided with a 2.5 inch (63.5 mm) instantaneous female connection. The coupling shall point downwards and be fitted with a chained cap. On offshore platforms, hydrant spacing should generally be such that each fire risk area can be reached from two separate hydrants with a single (75 feet) length of hose.

4. Hoses

In general, hoses are not required to be located at hydrants at onshore locations as the fire brigade will carry the necessary hoses for fire fighting. On offshore locations, each hydrant shall have one length of 75 feet hose of 1.5 inch diameter with combination type jet/fog nozzles stored in suitable weather-proof boxes adjacent to the hydrant. Rubber hose is preferred. Hoses handling sea water or for offshore use shall have couplings of copper nickel alloys.

5. Hose Reels

Hose reels for buildings (including offshore living quarters) shall be of the pivot round type. Each hose reel shall have a 30 meter long, 25 mm diameter bore non-kink braided rubber hose. The minimum bursting pressure of the rubber hose shall be 40 bars. The hose reel shall be capable to deliver 24 litres per minute and one hose reel should be provided to cover every 800 m² of floor space or part thereof.

Where foam/water hose reels are required, each hose reel shall have a 30 meter long 1.5 inch diameter bore non-kink braided rubber hose complete with combination type jet/fog nozzles. The nozzle shall deliver a flow rate of not less than 96 GPM. Each foam/water hose reel station should be provided with a 50-60 gallon stored volume of foam concentrate which is picked up by an eductor. The hose reel stations should be designed to provide foam solution or water using a selector valve.

6. Monitors

Design References

PTS 80.47.10.30 "Assessment of Fire Safety of Onshore Installations ".

This PTS should be used in determining the type and capacity of water monitors for protection of specific areas such as general process and storage areas.

Supplementary Requirements

Fixed foam/water monitors may also be employed for fire fighting, like those on offshore platforms. Maximum flow shall be 1100 USGPM at maximum inlet pressure of 360 psi. The monitors shall have a horizontal travel of 360 degrees and a vertical travel of 45 degrees below horizontal and 90 degrees above horizontal (mini). Minimum inlet pressure of 50 psi must be maintained at the nozzles.

5. FOAM SYSTEMS

5.1 Design References

- a) NFPA 11 "Low Expansion Foam and Combined Agent Systems".

5.2 Floating Roof Tank Fixed Foam Risers-System

A fixed foam riser system to NFPA 11 shall be installed for floating roof tanks.

Foam application rate shall be 12.2 litres/min/m² of annular ring area between the foam dam and tank shell using 6% or 3% foam concentrate according to location. The minimum spacing between discharge points should be 30 m of tank circumference. The foam concentrate supply should operate the system for 1 hour and 1 hour foam supply shall be kept to replenish the system.

Foam concentrate shall be supplied by a foam tanker. Foam proportioning will be by a mobile foam proportioning unit. The mobile foam proportioning unit shall be furnished with foam proportioner, foam pumps with driver and starter, interconnecting piping, valves pressure sensors and balancers, connections for foam inlet, water inlets and solution outlets, etc. to provide a complete and operable system all mounted on a trailer.

The foam outlet nozzles shall be in accordance to PTS reference drawing S88.010 while the solution feed will terminate outside the bund wall.

5.3 Sub-Surface Foam Injection System

Fixed cone roof oil storage tanks shall be fitted with a system to manually inject foam subsurface in these tanks. Fixed roof tanks of diameter less than 18m need not be protected by the sub-surface injection system.

Foam solution application rates, injection times, storage quantities and system design criteria shall be as specified in NFPA 11. 3% foam concentrate shall be used and the foam concentrate injection rate will be 5 or 6 litres/min/m² of tank surface area depending on the product stored.

Foam concentrate will be supplied via hoses from a foam tender to a trailer mounted proportioning unit. The proportioning unit shall have a diesel driven foam concentrate pump, a foam proportioner and portable high back pressure generators (HBPG). Finished foam is to be supplied to pipe work manifold via hoses.

Line work and equipment in contact with foam concentrate shall be stainless steel and line work in contact with foam solution shall be carbon steel.

The method of injection into the tank shall be by nozzles above the maximum water level.

The system shall incorporate a locked open valve on the tank wall and a flanged connection upstream of it to allow for system test without injection into the tank. A non-return valve and bursting disc shall be incorporated outside the tank wall valve to facilitate leaving the tank valve being locked open. The lines to the tank shall be fitted with a drain at the lowest point.

5.4 Helideck Foam System

The helidecks foam system shall be capable of providing a blanket coverage of at least 6 litres/min of 3% AFFF foam solution per square metre of helidecks prescribed area for a minimum period of 5 minutes. This shall be capable of being supplied from two independent fixed foam systems located below the helidecks. One system will supply foam solution to at least four low profile foam monitors located one on each side of the helidecks. The second system shall supply foam solution to hand hose stations located at the stairway landings or an adjustable foam monitor.

The fixed monitors systems shall be fed from a pressure proportioner foam storage tank or bag tank system. Water feed to the proportioner shall be manually operated. pelton-wheel method of foam pump drive may also be considered and oscillating monitors may be used.

The foam hand hose system shall consist of a diaphragm pressure proportioner foam tank or pelton-wheel system containing 3% AFFF foam concentrate. This tank shall be kept constantly pressurised via the fire water system, the tank diaphragm acting as the foam/water interface. Foam from the tank shall be mixed with fire water via an inline proportioner and the line to the hand hose reel hydrants kept constantly pressurised.

5.5 Fusible Plugs

The detection system shall consist of fusible plugs distributed in zones connected to small diameter tubing which is pressurised with instrument air or gas. The zones are to be located above process equipment in such geometry that any likely fire will have an acceptably high probability of quickly melting a nearby plug considering API RP 14C recommended spacing.

Plugs with different melting points are to be used taking into consideration the ambient conditions and equipment generating heat. The temperature values chosen are to give fast response to actual fires and yet avoid false response to normal solar radiant heating and equipment produced heat.

Each zone is to be separated into branches, isolated from each other by check valves. This is to improve response time (maximum 45 seconds) by reducing the total volume of pressurised field which must bleed through an open (melted) plug.

The fusible plug system shall include the following features:-

- a. An orifice to allow the pressurised piping to breathe with day/night thermal expansion and contraction and allow toleration of small leaks but still ensure that melting of one plug will trip the system.
- b. A shutdown override and signal to the control room to indicate system isolation for Test maintenance purposes. When override is engaged, the alarms shall all remain functional.
- c. A means whereby a small loss of system supply pressure given a fault signal to the control room.
- d. Activation/melting of any single fusible plug shall initiate a platform shutdown with Blowdown (ESD). On onshore installations, shutdown of the plant on fusible plug melting should be reviewed on a case by case basis.

6. FIRE EXTINGUISHERS

6.1 Design References

PTS 80.47.10.32 "Portable and Mobile Equipment for Fire Fighting".

The above PTS shall be used for specifications of fire extinguishers.

7. DELUGE AND SPRINKLER SYSTEM

7.1 Design References

- a) NFPA 16 "Deluge Foam - Water Sprinkler System and Foam - Water Spray System".

The water/foam deluge system shall be designed in accordance to this standard.

- b) NFPA 15 "Water Spray Fixed Systems for Fire Protection".

The water deluge system shall be designed in accordance to this standard.

- c) Fire Offices' Committee (FOC) Rules "Automatic Sprinkler Installations".

The water sprinkler system shall be designed in accordance to this standard.

7.2 Supplementary-Requirements

Water Deluge Systems

Depending on the size of the risk areas, the water deluge heads are to be divided into 'deluge zones' each having a deluge system. The risk area should be fitted with a stainless steel tubing loop connected to fusible plugs. Detection of fire in one deluge zone of any single risk area will only cause the deluge system in that specific deluge zone to be activated. Automatic operation of the deluge systems should only be activated by the fusible plugs.

Water is to be supplied to the spray nozzles through a pneumatic operated deluge valve held closed by instrument air pressure. Each deluge system is to be provided with its own local deluge valve panel to perform all of the necessary logic and to process signals to/from the MFAP.

Water Sprinkler Systems

Where the installation to be protected by the sprinkler system is of mixed occupancy, e.g. an office building with car park on the ground floor, the higher class of hazard shall be adopted. The frangible bulb of each sprinkler head will shatter when the ambient temperature reaches a preset level and cause the sprinkler head to discharge water. This pre-set level shall be 68°C except in the galley and laundry room on offshore living quarters where the bulbs shall be rated at 141°C.

Operation of a sprinkler system shall annunciate at normally manned fire/gas panel showing the presence and location of a fire.

Water/Foam Deluge System

The deluge valve should be a tight shutoff fail open block valve equipped with a local manual reset 3-port solenoid valve. A bypass should be installed around this valve for manual operation.

A manual start button should be provided on the fire panel inside control room. Logic failure shall not initiate foam pump start. Once started remotely, the pump shall run until stopped locally.

8. FIRE DAMPER CONTROLS

Fire dampers provided for a building should be pneumatically operated and shall fail closed. A fire in the duct shall cause closure of the individual dampers by causing operation of a three way valve operated directly by a frangible bulb located in the damper duct section. An override shielded latched pushbutton should be provided on the MFAP for override of automatic ventilation shutdown/fire damper closure. Operation of this override shall initiate indication on the MFAP. The closed position of the individual fire dampers should be displayed on the MFAP.

No difference in control philosophy is made between fire dampers or a flooding system damper except that frangible bulls operations is not provided on flooding system dampers.

9. FIRE, GAS AND SMOKE DETECTOR SELECTION

9.1 General

FGSs and their related detection systems shall comply with the requirements of instrument protective functions as specified by PTS 32.80.10.10. This includes determining the required SIL: the required degree of fault tolerance and the maximum probability of failure on demand for the defined set of detectors that are to detect the identified fire or gas release. The Contractor, in consultation with the Principal, shall demonstrate that such requirements are met.

The exact number and location of FGSs and their associated equipment (horns, beacons, etc.) shall be determined by the Contractor in consultation with the Principal during detailed engineering, and such detectors and their location shall be indicated on the master plan of fire safety systems.

The make and specific type of FGSs shall be stipulated in the project specification.

Determining the correct location to site fire and gas detectors is not straightforward, particularly in congested areas. Special software has been developed for this purpose, and such software has the potential to optimise the effectiveness of the FGSs. It does this by enabling an engineer to consider different detector locations and evaluate different voting strategies. The result is a compliance (performance) map that shows if the chosen detector locations reduce the identified risks to ALARP.

Such software is commonly referred to as "Fire & Gas Detection Mapping" and is available from a number of sources.

NOTES: 1. Fire & Gas Mapping software may not be required for all designs. For example, where designs are small or for limited detection refurbishment, where the additional cost may not be justified. However, Fire & Gas Mapping shall be considered, and the Principal shall be consulted.

The hardwired interface between the detector or control unit and the FGS IPS shall be 4-20 mA, with option for 0-20 mA, where 0-4 mA is used for diagnostics, 4-20mA for the signal and detectors shall be configured individually for alarm purposes, unless zone monitoring is approved or specified by the Principal.

NOTES: 1. Individual (point) monitoring
Each detector is considered on an individual basis in order to provide a one-to-one alarm/message presentation to the operator, i.e. each alarm/message represents one detector only.

This can be achieved by applying:

- a serial pulse-code type data transmission (bus) between the detector and the rest of the system, in which case a number of detectors are interconnected in series and terminated to one system input. Serial pulsed coded detectors are not allowed for SIL 1 and higher unless TUV certified for higher SIL rating;
- an analogue data transmission (typically 0 – 20 mA) between the detector and the rest of the system, in which case each detector is connected to an individual system input (star configuration).

2. Zone monitoring

A number of detectors are connected to one system input only, to provide an 'n' to one alarm / message presentation to the operator, i.e., one common zone alarm / message represents any one of these detectors.

The design of the detector(s) should allow them to be calibrated and verified by a single person.

10. FLAMMABLE GAS DETECTOR SELECTION

10.1 General

In open process plants, the hydrocarbon-containing equipment is so designed that, should leaks of flammable material occur, they should not escalate into fires or explosions within the confines of the plant. This is achieved by optimising the lay-out during the design stage so that the probability of coincidence of a flammable vapour-air mixture and known electrical or other sources of ignition is reduced to an acceptable level.

Nevertheless, significant hydrocarbon releases with a potential for such escalation shall be detected promptly. Instrumented detection is indispensable if detection by personnel or by other means is likely to be too late to prevent escalation of the incident.

The correct choice of flammable gas detector is most important if early detection is to be achieved. It is equally important that the detector is correctly positioned, and properly mounted. The appropriate type of detector, point or Line-of-Sight (LOS), is best determined in the light of the heat and material balance statistics for the process. For example, heavier than air gases may well be neutrally buoyant if released under pressure, and LOS detectors may well be the most appropriate choice.

Catalytic (pellistor type) gas detectors can provide reliable detection providing environmental conditions are not challenging and stoichiometric conditions (the gas concentration is between the lower and upper flammable limits) exist. The latter is necessary because catalytic detectors determine gas concentration through oxidization which results in heat, and this is sensed by a bridge circuit. It follows that catalytic gas detectors under-read in the low oxygen atmospheres which exist with gas rich releases. This shortfall is compounded by the fact that catalytic gas detectors have a response time of typically 20 to 30 seconds i.e. if they fail to respond whilst the release is dispersing, they may well be unable to respond subsequently if the release is large and over-rich. This characteristic makes catalytic gas detectors difficult to site.

NOTE: Infrared-based detectors are now available as drop-in replacements for catalytic (pellistor) detectors. The Principal should be consulted for advice.

Infrared gas detectors are preferred to catalytic detectors because they provide rapid response to gas, and they do not under-read in oxygen-reduced atmospheres. They also show improved sensitivity to higher order hydrocarbons, (which is desirable) and the technique is immune from poisoning by airborne pollutants such as silicones, lead compounds and H₂S.

Infrared gas detectors make use of the properties of hydrocarbons and other gases to absorb infrared energy at certain wavelengths, but not others. For hydrocarbons, the absorption peak occurs around 3.4 μm . A reference measurement is normally made close to the measurement wavelength that is not absorbed by expected gases. Gas at the measurement head causes energy to be removed at the measurement wavelength, but not from the reference wavelength. The ratio from the two measurements gives the gas concentration free from variations in signal intensity and detection sensitivity.

10.2 Selection of point gas detectors

10.2.1 General

Flammable gas detectors shall be selected from the following types, which are listed in order of preference:

- Infrared absorption type;
- Catalytic gas detection (see 10.2.3);
- Acoustic leakage detection (see 11).

Where point IR gas detectors are chosen, 20 % LEL and 60 % LEL should be used as respective thresholds to indicate Low/High level gas. Where a single detection threshold is used as an alarm function, this should be set at 50 % LEL.

NOTE: For gas turbines:

1. the gas detection thresholds, for gas turbine inlet filter house, the gas turbine protection should be set to 25% LEL and 50% LEL respectively to indicate low/high level gas. This is a relaxation over previously specified settings and is possible due to faster and more reliable gas detection and due to improved turbine regulation.
2. the inlet ventilation fan gas detection, threshold should be set at 10% LEL and 50% LEL.
3. the outlet ventilation fan, the threshold for outlet ventilation, because the high airflow volume of the ventilation system causes a considerable dilution of the gas concentration in the event of a leak, higher gas detector sensitivity has been introduced as one of the latest standards on new units:
 - 5% LEL for Alarm
 - 10% LEL for Trip

10.2.2 Infrared type detectors

Infrared type gas detectors have distinct advantages with respect to:

- faster response time;
- poison resistance;
- they do not under-read in oxygen reduced atmospheres;
- reduced maintenance load;
- a higher degree of fail-safety;
- self-diagnostic features.

Infrared type gas detectors respond to a limited group of hydrocarbons, and may therefore not cover all situations. For example, infrared detectors cannot be used to detect hydrogen.

Otherwise, infrared absorption is the preferred technology for detecting flammable gas releases.

10.2.3 Catalytic type detectors

The use of catalytic gas detectors requires approval from the Principal. Where catalytic combustion type detectors are selected, these shall be poison resistant. The use of non-poison resistant sensors requires the approval of the Principal, who shall be made aware of the restricted lifetime of non-poison resistant sensors.

NOTES: Point gas detection

1. Catalytic gas detectors suffer from both short-term and long-term drift. Short-term drift may result from temperature variations at the head, and from the control card itself – the latter is typically +/- 3 % LEL. Long-term drift results from ageing of the pellistor, and this ageing is accelerated by the presence of gas.
2. Infrared gas detectors also suffer from both short-term and long-term drift, but this is small when compared to that of catalytic-type detectors.
3. If catalytic gas detectors are used, 20 % LEL and 60 % LEL should be set as respective Low/High detection thresholds to avoid unwanted alarms.
4. Infrared type detector will not response to the presence of H₂ gas. In this case, a catalytic type detector shall be used,

10.2.4 Aspirated gas detection

Aspirated gas detection systems are available for detecting gas in difficult working environments such as high temperatures or those requiring special apparatus for access, or where general access is difficult. Examples are gas turbine enclosures or below raised floor. Such systems function by drawing air mixtures from the measurement volume, which are then directed to the measuring detector.

10.3 Selection of open path gas detectors

10.3.1 General

Open path or Line-of-Sight (LOS) gas detectors make use of the properties of gases to absorb infrared energy at certain wavelengths but not others. This property, coupled with high-energy sources, enables LOS gas detectors to sense gas over relatively long distances.

To enable reliable operation, LOS gas detectors require rigid supports that do not vibrate. Manufacturers of LOS gas detectors provide misalignment data for their products. This information shall be followed.

LOS gas detectors are ideally suited for detecting gas accumulations or gas cloud migration in open facilities. They are preferred over point type gas detectors for this purpose.

LOS gas detectors for non-flammable gas shall only be used with the approval of the Principal, as insufficient experience has been gained with this type of instrument.

10.3.2 Area/perimeter monitoring

LOS gas detectors can be used to monitor a complete area or to monitor the perimeter of a process unit. These optical-type instruments monitor a given area or perimeter for the presence of flammable gas.

For area monitoring, at least two open path instruments shall be applied. For monitoring a jetty or, for example, the border between an existing operating process unit and a unit under construction or shutdown, one (1) monitor is normally sufficient.

NOTES: Open path gas monitors:

1. typically have a (recommended) minimum alarm level setting of 0.5 LELm (50 % LEL extended for one metre). That is, it can be set to give an alarm if there is a flammable gas cloud of 5 % LEL over a distance of 10 m or, 0.5 % LEL over a distance of 100 m. Recommended alarm thresholds for open path (line-of-sight) gas detectors are: 1 LELm & 3 LELm respectively for Low/High level alarm;
2. are available covering distances from 4 m to 200 m. However, an optimum distance for offshore facilities is 20 m to 30 m, and 30 m to 60 m for onshore facilities. When an open path gas monitor is used over much longer distances, they may give nuisance alarms (these are true alarms but are a nuisance because clouds of a very low concentration of flammable gas may not constitute hazardous situations). But it is likely that if gas fills a significant proportion of the open path, this may well be due to a large leak at some other point on the plant.

11. ACOUSTIC LEAK DETECTION

Acoustic leak detection technology is not proven and therefore not recommended for leak detection.

12. OIL MIST DETECTION

Oil mist detectors are optical beam detectors and should be considered for all enclosed applications where there is a potential of a pressurised leak of flammable liquid such as high pressure stabilised crude oil, because such leaks are unlikely to be detected by gas detectors.

Oil mist detectors are considered sufficiently robust for executive action to be taken if they are employed in closed applications, i.e., free from interfering particles such as rain and fog, provided a number of detectors are used so that their outputs may be combined logically to form a voted output.

13. TOXIC GAS DETECTOR SELECTION

13.1 General

Release of toxic gases, e.g., carbon monoxide or hydrogen sulphide, into the atmosphere will generally create a health hazard rather than an explosive hazard, although ultimately the latter situation may develop. Generally the concentrations at which toxic gases need to be detected are far lower than for flammable gas detection. Flammable gas detectors shall therefore not be used for the detection of toxic gas, even if the latter coexists with a flammable gas of a different compound, e.g. H₂S in conjunction with a hydrocarbon mixture, unless authorised by the Principal; see limitations (4.5.2).

Toxic gas detectors are prone to poison by other chemicals. Therefore, such detector shall be poison resistance.

Detectors for toxic gases may be considered in two major categories as follows:

Category 1:

Detectors for gases which create an immediate health hazard (danger to life), e.g. hydrogen sulphide, carbon monoxide, hydrogen fluoride, hydrogen chloride, chlorine gas. These gases usually have a STEL that is slightly higher than the TLV.

The following applies to the selection of detectors in category 1:

- detection shall be fast and reliable and preference shall be given to speed of response over precision;
- all aspects of HSE shall be included in the design study.

Category 2:

Detectors for gases that create a health hazard on long-term exposure, e.g., carcinogenic gases such as vinyl chloride, benzene, toluene, formaldehyde, ammonia, etc.

To detectors in this category the following applies:

- detection shall be reliable and precise;
- TLV (threshold limit values for an 8 hour working day) shall be monitored;
- HSE aspects shall be included in the design study;
- a logic control system with capabilities such as statistical analysis and a data base to enable the collection and storage of long-term exposure data is very important. This is a legal requirement in certain countries, and shall be considered.

13.2 H₂S gas detectors

Flammable gas detectors may be considered (used) to detect the presence of H₂S in the production process, provided the amount of H₂S present in the gas phase at equilibrium after flashing to atmospheric pressure does not exceed 500 mL/m³. This decision requires approval by the Principal.

Flammable gas detectors shall not be used to detect the presence of H₂S when concentrations of H₂S in the production stream exceed 500 mL/m³ (in the gas phase at equilibrium after flashing to atmospheric pressure).

If flammable gas detectors are used to indicate the presence of H₂S, the coverage must be adequate and, if necessary, include coverage at low level to accommodate accumulation of heavy vapours.

If H₂S detectors are installed, they should be typically mounted at 1.2 m above grade.

H₂S gas detectors shall be selected from the following types:

1. The electrochemical cell-type.

Currently, electrochemical detection is preferred to the semi-conductor type. Both sensing mechanisms have strengths and weaknesses, but the electrochemical sensor has proved to be more reliable in wet and humid atmospheres.

This type is based on an electrochemical cell, developed to react exclusively to H₂S. As a result of the chemical reaction of the cell organic electrolyte with H₂S, an electric current is generated that is proportional to the H₂S concentration in the sample gas.

Electrochemical cells have a restricted lifetime of typically two years from the date of installation, but life is not adversely affected by ambient conditions.

2. The semi-conductor type.

The semi-conductor type is based on the adsorption of H₂S molecules on the surface of a solid-state semi-conductor crystal, which causes a change in resistance of the electrical circuit of which the semi-conductor forms part. The change in resistance is proportional to the H₂S concentration in the sample gas.

Semi-conductor type sensors theoretically have an infinite lifetime. However, their life is adversely affected when exposed to poisonous contaminants (e.g. paint solvents) or to humid atmospheres (even for periods of less than 24 hours) or when not regularly exposed to small H₂S concentrations (causing a loss of speed of response, which effect is usually reversible).

Experience of semi-conductor type H₂S detectors in dry climates is generally good. Experience in humid or wet conditions is generally poor.

13.3 Other toxic gas detectors

For the detection of most other toxic gases such as ammonia of Category 1 (2.5.1) electrochemical sensors are most commonly used.

NOTE: Carbon monoxide is sometimes measured with infrared type instruments. Point detectors are available, and so are aspirating systems requiring aspirating compressors and sampling systems etc.

13.4 Toxic gas detection thresholds

The occupational exposure limits (OEL) for H₂S detection are set by governing regulatory authorities, and may be different, country to country. The detection thresholds shall reflect local regulations, but the following example may be used as a guide.

The Health & Safety Executive (HSE) for the UK define H₂S occupational limits as follows:

- 1) OEL – Time Weighted Average (TWA) for an 8 hour day, 40 hour week as 5 mL/m³
- 2) STEL – Short Term Exposure Limit ((4) x 10 minutes exposures per day) as 10 mL/m³.

H₂S threshold limits shall reflect legislation but the emphasis should be on controlling exposure.

The use of low alarm thresholds may result in increased maintenance and spurious alarms in the more challenging environments. A better alternative may be the use of personal H₂S monitors which are more easily maintained backed-up by fixed detection.

If fixed H₂S detection is installed (UK), should the alarm threshold for safeguarding personnel from the dangers of H₂S should be set at 5 mL/m³ as a minimum, with 10 mL/m³ considered appropriate for fixed detection if personal H₂S monitors with thresholds set at 5 mL/m³ (ppm by volume) are worn by personnel entering or working in areas where H₂S may be present.

If a second (high level) alarm threshold is used, threshold should be set at 10 mL/m³ (ppm by volume) as a minimum, and 15 mL/m³ (ppm by volume) if personal monitors are worn.

14. FIRE AND SMOKE DETECTOR SELECTION

14.1 Detector type selection

If jet fires are likely, rapid response and good space detection are necessary detection characteristics. Infrared flame detectors shall be considered for such applications.

14.2 General

People are acknowledged as good detectors of incidents and their contribution should not be overlooked. If detectors are employed, they shall be selected from the following list, depending on their specific properties and their specific field of application:

- Detection by persons (with manual call points);
- Infrared (IR) flame detectors;
- CCTV flame detectors;
- Smoke detectors, such as:
 - scattered-light type detectors;
 - ionisation-type detectors.

Other types of detectors may be considered for specific applications, such as:

- Heat detectors, for example:
 - quartzoid bulbs;
 - fusible alloy links or plugs;
 - heat sensitive cable;
 - rate-compensated heat detectors;
 - a combination of fixed temperature and rate-compensated heat detectors;
 - fire detection tubing.

Ultraviolet (UV) flame detectors shall only be employed, following approval by the Principal, in restricted high temperature applications e.g. inside turbine acoustic enclosures.

For general information on heat detectors, refer to (Appendix I) of this PTS.

14.3 Detection by persons

Manual call points shall be of the break-glass, auto-release type.

The complete housing of manual call points installed outdoors shall be constructed in accordance with requirements for the classified hazardous areas, and shall be corrosion-resistant and fully weather-proofed. For identification, they shall be coloured red to 04E33 of BS 4800, (DIN Standard RAL 3000), or equivalent.

14.4 Optical type fire detectors

Optical detectors shall have automatic self-checking facilities.

1) Infrared type fire detectors

These shall be solar blind, i.e. unaffected by sunlight, and should be applied where fast detection of a hydrocarbon fire, or of other flammable products with high hydrocarbon content, is of prime importance.

The design of the detectors is based on the flame-flicker principle, i.e. the detector responds to the flickering of most hydrocarbon fires. They are not suitable for the detection of smouldering fires.

Infrared flame detection is the preferred technology for detecting hydrocarbon fires.

- NOTES:
1. IR type fire detectors have an upper ambient temperature limit of 75°C.
 2. Triple-band IR flame detectors are available that employ more advanced signal processing techniques. Triple-band flame detectors have the advantage of improved false alarm rejection and improved sensitivity to flame.

2) UV type fire detectors

Ultraviolet light type detectors are extremely fast in detecting fire, but they should not be applied in dusty environments or in environments where airborne oil droplets are likely or where fires are expected to produce heavy smoke.

- NOTES:
1. UV detectors are subject to interference from welding activities, X-rays used in non-destructive testing, direct sunlight and lightning.
 2. These detectors have an upper ambient temperature limit of 150 °C.

14.5 CCTV flame detectors

CCTV technology and suitable software can deliver robust fire detection for a wide range of combustion products. CCTV technology has the potential to differentiate friendly fires from those of interest, and in principle is solar blind. CCTV technology also enables the detector's field-of-view to be matched to the application, and the technology has the potential to issue a warning when this is changed.

CCTV based fire detectors provide visual confirmation of an event, thus eliminating the need to send personnel into potentially hazardous situations to investigate an alarm. This subsequently reduces the time required to initiate appropriate safety measures.

14.6 Smoke detectors

Smoke detectors should be employed in closed areas only. Their use in open areas shall be subject to approval by the Principal.

There are two basic types of smoke detector, each having its own characteristic strengths and weaknesses.

1) Optical smoke detectors

Optical smoke detectors employ light scattering by smoke particles to detect the presence of smoke. Optical smoke detectors are more sensitive to smoke particles having a diameter greater than 0.5 µm. This characteristic makes them particularly sensitive to incipient and smouldering fires.

Cable fires and hydrocarbon fires are examples that produce smoke consistent with the larger particle size range. Optical smoke detectors are recommended for electrical areas and areas containing hydrocarbon products.

Open path (IR) smoke detectors also employ light scattering techniques to detect the presence of smoke. Open path smoke detectors typically have a working range of 30 m and are set to alarm when the visibility changes by 0.5 dB (11 %) over the path length.

Open path smoke detectors have sensitivities similar to those of point smoke detectors for a working range of approximately 4 m. At longer path lengths, open path smoke detectors are more sensitive than point smoke detectors.

Open path smoke detectors employ a combined transmitter and receiver (transceiver), and a retro-reflector to return the infrared beam. Smoke entering the beam at any point is detected and differentiated from optical fouling and beam interruption.

Open path smoke detectors, like other smoke detectors, are sensitive to fog.

2) Ionisation-type smoke detectors

Ionisation-type detectors may be considered when optical (scattered light type) detectors are not suitable for the application. If ionisation-type detectors are selected, they shall be not be of radioactive type as this requires proper disposal of faulty sensor as scheduled waste. Ionisation-type smoke detectors are more sensitive to the smaller (less than 0.3 μm) smoke particles produced by fully developed fires, which release fine aerosols. If used for the detection of smouldering fires in buildings, ionisation-type detectors should be applied only in conjunction with heat detectors.

NOTE: The application of this type of detector may be restricted due to the fact that the detection principle employs a small radioactive source and faulty detectors need to be disposed of properly.

14.7 Ultra-high sensitivity smoke detectors

Ultra-high sensitivity smoke detectors (also called high sensitivity smoke detection systems) are used for the early detection of incipient fires in control buildings, system cabinets, computer rooms and similar. They are usually configured around an aspirated system. The Principal shall be consulted for the selection of this type of equipment.

If ultra-sensitive smoke detection systems are installed, the detection threshold should not be set too low, otherwise, nuisance alarms are likely. All alarms need to be investigated, and the use of low detection thresholds makes the task of confirming the presence of early combustion products difficult.

14.8 Heat detectors

Heat detectors should be applied for the detection of fires that are expected to build up quickly and generate much heat. They generally have a low spurious alarm rate, but are slow in detecting fires. They may also be applied as a backup for fire detectors in, for example, gas turbine enclosures (Appendix I).

If heat detectors are applied in open areas for general fire detection, they should be spaced so that one detector covers approximately 25 m^2 , and heat shields should be installed to encourage heat build-up where detectors are more than 8 m above potential fire sources.

The Principal shall be consulted for the selection of this type of equipment.

14.9 Combined heat and smoke detectors

Combined heat and smoke detectors are compact devices, and typically incorporate a temperature sensitive element and an optical smoke detector.

Most commonly, the temperature sensitive element is a thermistor, producing a linear response against temperature. Variations exist, but combined heat and smoke detectors are normally fixed temperature devices with a set point at 60 °C.

Smoke detection is typically optical light-scattering from visible smoke particles – see (4.6.1.5).

Combined heat and smoke detectors can offer benefits where a large number of combustion processes are likely. For example, some fires (fast burning and some liquid fires) produce little or no visible smoke, but they do produce significant heat. Combined heat and smoke detectors may well be suited to such applications, but the Principal shall be consulted on their use.

15. SYSTEM ENGINEERING, SPECIFICATION AND INSTALLATION PRACTICES

15.1 General

- 15.1.1 In the event of conflict between this document and its referenced standards, then this document shall be followed.
- 15.1.2 In the event of conflict between two referenced international or national -standards, then the more stringent of the two shall apply unless the applicable standard is referenced in the text of this document in regard to the point of the conflict.
- 15.1.3 In the event of conflict between a referenced international or national standard and this PTS, then this PTS shall apply.
- 15.1.4 All equipment associated with fire and gas detection and control should be certified suitable for the environmental conditions which may prevail during any emergency.
- 15.1.5 It should be possible to test the integrity of a detection system without taking the whole system out of service or without shutting down processes.
- 15.1.6 Facilities should be provided which allow the sequential inhibition of automatic executive control actions from individual detectors for use during maintenance and testing.
- 15.1.7 The total fire and gas detection and alarm systems shall be commissioned and tested on basis of realistic tests prior to commissioning. The tests must, as far as possible, simulate the type of fire or gas release which can arise in the protected area under normal operating circumstances, and reflect the design intent. These system tests are additional to the usual component commissioning, and shall be included in the commissioning reports.
- 15.1.8 Total fire and gas detection and alarm system shall be periodically tested as per Clause [15.2](#).

15.2 Fire and Gas Systems (FGSs)

FGSs are typically used to initiate the following functions automatically or manually:

- audible and visual alarms/messages in the control centre and/or in the plant. Additional alarm/message presentation and/or control shall be provided when specified, e.g. in the gate-house, storage area and jetty, loading facilities etc.;
- messages of emergency situations to local community services, e.g. fire brigades, etc.;
- starting of fire fighting equipment, e.g. fire water pumps, water spray and fog systems, etc.;
- activation of safeguarding and depressurising (blowdown systems);
- automatic closure of air ventilation inlets;
- personnel evacuation systems (barriers, howlers, etc.).

For each project a cause and effect matrix shall be prepared. For a typical cause and effect matrix refer to (Appendix II). The final cause and effect matrix shall be submitted for approval by the Principal.

The design of an FGS shall be in compliance with PTS 32.80.10.10. Additionally:

- initiators of FGSs shall be normally closed contacts unless otherwise specified by the Principal;

- when gas/fire detection is provided for specific plant equipment, such as turbine which is equipped with its own dedicated control/safeguarding system, the output of the gas/fire detection system shall be used as a (shut-down) initiator for the control/safeguarding system of that piece of equipment as appropriate. This may also be the case for batch processes, where the output of the FGS shall be fed as a (shut-down) initiator to the logic controller of the batch process.

NOTE: In particular, packaged units, e.g. gas turbines, may be fully self-contained and separate from the general signal processing control module.

Because the FGS is required to have an availability in case of power failure different from that of the control and IPSs, and because the operator may be one link in the IPF chain (for

Fire and Gas IPFs up to SIL 2), the operator interface shall be via:

- DCS video display units; and
- hardwired mimic panel if the Fire & Gas IPF is SIL 1 or higher, and the confirmed fire or gas does not initiate the actions automatically (i.e. where the correct actions depend on the operator responding to the alarm).

At locations where colour coding of visual alarms and arrangements for audible alarms, different from those described below, already exist the Principal shall decide which coding system will be applied to any extensions or new FGSs.

15.3 Human-Machine Interface (HMI)

15.3.1 Hardwired mimic panels

For any new project, dedicated HMI mimic panel instead of hardwired mimic panel shall be used. However, for existing installation using hardwired mimic panel, plant has to ensure that the following design applies:

The hardwired mimics shall contain simplified geographical lay-outs of the plant area which is to be monitored, showing hydrant location, traffic access gateways, roads and major plant equipment for each process unit. The lay-out shall be in accordance with the plot plans. The indications on the mimic panel shall be driven via hard-wired signals from the FGS IPS.

The mimic panel shall be ergonomically integrated with the DCS console. The size of the panel requires the approval of the Principal.

The mimic panel shall incorporate separate confirmed (voted) fire, flammable gas and toxic gas alarms as well as system fault alarms. Alarms associated to individual detectors (non-voted) may be incorporated in the DCS (see [15.3.2](#)).

The FGS IPS shall group together all types of FGS inputs for a single zone, unit or equipment item(s). If any zone is in the confirmed alarm state, a zone or unit alarm LED on the mimic panel shall operate. Separate 'zoned' indications shall be provided for fire, flammable gas, toxic gas and system alarms.

Detector types shall be identified by means of coloured LEDs. The colour code shall be as follows:

- | | |
|----------------------------------|-----------|
| - toxic gas | : yellow, |
| - flammable gas | : blue |
| - fire | : red, |
| - system fault | : white, |
| - fire-water pump running lights | : green, |
| - other alarms | : red. |

Flammable gas visual alarms should distinguish between low alarm and high alarm values by assigning one LED for low alarm and one LED for high alarm.

The LEDs shall be mounted so that they protrude at least 3 mm above the surface of the panel to enable an alarm to be recognized from various angles.

The following plant common alarms shall be grouped in the top left-hand corner to facilitate quick appraisal by operating personnel. Each alarm shall be presented by means of a coloured lamp and the corresponding text as appropriate.

- fire,
- flammable gas,
- toxic gas,
- fire-water pump auto-start stand-by indication,
- system fault,
- utility fault,
- UPS fault.

The normal situation shall be indicated by extinguished LEDs and lamps on the mimic. In the event of an alarm, the relevant LEDs and lamps shall start flashing. After acknowledgement the flashing shall stop and change to a steady light, but it shall be reactivated on the recurrence of any alarm condition. Return to the normal situation, after acknowledgement, shall extinguish the LEDs and lamps.

The audible alarm shall be annunciated in the control room by means of a buzzer mounted at the rear of the mimic having an intermittent tone at 2000 Hz, which shall stop when the operator acknowledges the alarm by means of a button on the mimic. An all-clear signal shall not be provided in the control room.

A wind speed and direction indicator shall be mounted in the top right-hand corner. Plant North shall be indicated on the mimic by an arrow.

For a typical layout of a mimic panel refer to ([Appendix III](#)).

The mimic panel shall have a scratch-proof, non-reflective plastic surface. A 'mosaic', e.g., multi-tile, lay-out shall be provided to facilitate future modification of the panel. The layout and design shall be provided by Contractor.

The following controls, mounted in the bottom section of the mimic panel, shall be available to the operator:

- Lamp Test: a non-latching push button to test all indication lights on the mimic.
- Acknowledge: a non-latching push button to change all alarm lights (except for the plant beacons) from flashing into steady and to silence the audible alarm in the control room.

NOTE: Pressing this acknowledge button will not acknowledge the DCS alarm. The operator has to acknowledge the DCS alarm separately.
- Reset: a non-latching push button to reset all visual and audible alarms, provided that all initiators have returned to normal.
- All-Clear: a non-latching push button to initiate an all-clear signal in the buildings and in the plant.
- Fire Alarm: a non-latching push button to manually initiate a fire alarm with effects similar to the activation of a break glass push button.

- Toxic Gas Alarm: a non-latching push button to manually initiate a toxic gas alarm in the relevant unit.
- Flammable Gas Alarm: a non-latching push button to manually initiate a flammable gas alarm in the relevant unit.

Start Fire-water Pumps: one or more non-latching push buttons to manually start the fire water pump(s) start sequence.

NOTE: It shall not be possible to stop the fire water pumps from the mimic panel.

- Close Dampers: latching push buttons to manually close the dampers.
- Water spray valves: three-position switches with the positions and related text: open, auto and isolate. The positions of the deluge valve switches shall be monitored so that if a switch is not in the auto position an alarm is presented at the DCS.
- Water spray valve reset: non-latching push buttons to reset the water spray valves. Fire, toxic gas and flammable gas alarm push buttons shall be of the illuminated type to indicate that fire, toxic gas and flammable gas alarms have been initiated from the mimic panel. The start fire water pump(s) push button shall also be of the illuminated type, and the lamp shall be on when the fire water pump(s) start sequence has started.

Depending on the purpose of the FGS, operator controls in addition to those indicated above may be required (e.g. remote release of extinguishing agent), and will be indicated by the Principal on the preliminary cause and effect matrix.

Where the controls mentioned above are non-latching push buttons, the fire and gas detection system shall be able to accept the pulse input from these switches. All manual operator controls with their related effects shall be indicated in the project cause and effect matrix.

15.3.2 Distributed Control System

The operator interfaces shall be grouped together to form a dedicated FGS DCS operator console. All individual FGS alarms shall be presented to the operator via a FGS DCS operator console.

The number of operator stations in the console shall be at least two. It shall be possible to use each of the operator stations as a back-up for the other(s), thus providing redundancy. The hierarchy of displays shall be as follows:

- Area Overview Display - This shall show the relevant plants as a simplified plot plan. If there is any fire, smoke, flammable gas, toxic gas or system fault alarm present in a plant, the plant box shall fill red (yellow for revealed failure robust initiators with only one of the initiators in alarm), flash until the alarm is accepted, and remain steady until all abnormal states are healthy again. A flashing message shall be displayed indicating whether a fire, smoke, flammable gas, toxic gas or system alarm has been detected. The message shall steady upon acceptance and clear when the initiator(s) return to normal. The boxes and message shall re-flash if a new condition of the same type occurs in that plant, according to the same basic principles as for the mimic panel. Wind speed and direction shall be shown on this display. It shall be possible to call up the plant displays from each box via touch screen or equivalent method.

- Plant Overview Displays - One plant overview display shall be provided for each plant. This shall show the various units in that plant as a simplified plot plan. If there is any fire, smoke, flammable gas, toxic gas or system fault alarm present in a unit, the unit box shall fill red (yellow for revealed failure robust initiators with only one of the initiators in alarm), flash until the alarm is accepted, and remain steady until all abnormal states are healthy again. A flashing message shall be displayed indicating whether a fire, flammable gas, toxic gas or system alarm has been detected. The message shall steady upon acceptance and clear when the initiator(s) returns to normal. The box and message shall re-flash if a new condition of the same type occurs in that unit, according to the same basic principles as for the mimic panel. Wind speed and direction shall be shown on each of these displays. It shall be possible to call up the unit displays from each box via touch screen or equivalent method.
- Unit Detailed Displays - A unit detailed display shall be available for each process unit, building, substation and analyser house. In addition, a detailed display shall be available for the FGS, utility and UPS fault conditions. In the case of process units, the displays shall consist of a simplified unit layout showing the approximate physical locations of individual sensors. For buildings, all fixed fire protection and fire control systems shall be shown on the geographical lay-out (including fire walls, smoke doors and dampers). When an initiator is in alarm, the symbol shall turn red and flash until it is accepted whereupon it shall steady until it returns to normal. A similar method showing the FGS layout shall be used for presenting FGS, utility and UPS fault alarms.

All FGS alarms shall be presented via the standard DCS alarm displays and be logged and printed via the standard DCS alarm logging facilities. A standard DCS audible warning shall be provided.

For analog inputs, trending shall be undertaken by means of the standard DCS trend facilities.

Historical data shall be archived by means of the standard DCS archiving facilities.

A dedicated printer shall be available to print out all fire and gas alarms, system faults and other events in order of occurrence. The alarm message shall contain time, tag number, description, process data and type of alarm.

15.3.3 Sequence of events recorder (SER)

A dedicated FGS SER should be provided.

15.3.4 Means of communication

Telecommunication facilities such as telephone, plant radio, public address system etc. shall be provided on the FGS console.

15.3.5 Buildings

Fire, gas and smoke alarms in buildings, including auxiliary rooms and offices, shall be annunciated in the buildings themselves by means of a bell with an intermittent ring having a mark-space ratio of 1:1 and a cycle time of 2 s. Duration of the annunciation after initiation shall be fully adjustable over a range of 1 min to 10 min. and not be affected by the reset on the mimic.

The all-clear signal in the control centre shall be a continuous ring of the bell. The duration of the all-clear shall be adjustable between 10 s and 120 s. The same arrangements should also be applied in satellite buildings, gate house and fire station.

The number and location of the bells shall be specified in the requisition of the FGS of the building, which is usually supplied by the Civil Contractor.

15.3.6 Field

If specified by the Principal the detection of a fire shall be announced by audible means in the field.

Detection of toxic and flammable gas shall be indicated by stroboscopic beacons and shall be announced by audible means in the field.

All detectors, manual call points, horns, beacons and loudspeaker positions shall be clearly indicated on the plot plan of the FGS lay-out drawing(s).

The beacons shall have the same colour coding as the related LEDs on the mimic, to ensure that the correct action is taken in the event of an emergency.

The beacons shall be located so that they will be visible in the area for which they are to provide a warning and are accessible for maintenance. Suggested locations are pipe racks, top corner of analyser houses, the main passages inside auxiliary buildings and on field-mounted panels. Attention shall also be given to the rigidity of supports and the routing and clamping of cables. Tag numbers shall be assigned and be clearly visible from accessible locations.

Toxic and flammable gas alarms shall be audibly annunciated in the plant by means of two separate audio-amplifiers. Line and distribution audio-amplifiers shall be suitable to provide the required output levels as specified and should have a balanced line impedance of 600.

The loudspeaker annunciation for toxic gas shall be by means of an interrupted tone, having a mark-space ratio of 1:1, a cycle time of 2 s. and a frequency of 1000 Hz. The all-clear signal shall be a continuous tone of 1000 Hz.

The loudspeaker annunciation for flammable gas shall employ two different frequencies, having a mark-space ratio of 1:1, a cycle time of 1 s and frequencies of 1000 Hz and 2000 Hz. The all-clear signal shall be a continuous tone of 2000 Hz.

If the Principal specifies that there shall be audible fire alarms in the field, then motor-driven sirens shall be provided. The motor-driven siren annunciation for fire shall be by means of an on-off modulated tone with a frequency of 520 Hz, the on-time adjustable between 3 s and 10 s and the off-time adjustable between 1 s and 5 s.

Duration of the annunciation after initiation shall be fully adjustable over a range of 1 min to 10 min. and not be affected by the reset on the mimic. The duration of the all-clear shall be adjustable between 10 s and 20 s.

The sound level of loudspeakers and sirens shall be at least 6 dB(A) above the area noise in all areas, but not more than 120 dB(A) at 1 m distance on the main axis. The number of loudspeakers and sirens shall be selected accordingly. During the engineering stage, it may be possible to utilise a computer noise simulation to optimise the number and the location of horns and loudspeakers. Sirens and loudspeakers shall be installed in accordance with PTS 31.10.00.31.

If a piping model is available, the detectors, horns, beacons and loudspeaker positions should also be finalised on the model after the model review. Instrument and safety engineers shall contribute to this choice.

Manual call points with the facility of an electronic location code should be wired into loops so that the resulting alarm indication will direct fire appliances and personnel to the specific spot, road or building from where the call was initiated.

Local fire-water pump start and stop buttons shall be provided near to the fire water pumps. These buttons shall be wired directly to the electrical switchgear and not via the IPS.

Functional checks shall be carried out before plant commissioning, noise levels shall be checked and the number of horns and loudspeakers increased or reduced as found necessary.

With DCS:

With other systems:

With local community services:

15.3.8 Overrides

Operational overrides shall not be used for FGSs.

15.4 DETECTOR STANDARDS

15.4.1 Standards of construction and performance

- Heat detectors EN 54
- Flame and ionisation-type detectors EN 54
- Combustible (flammable) gas detectors EN 61779 Parts 1 through 5

The housing of detectors for use in process areas shall be stainless steel AISI 316. Use of other materials requires the approval of the Principal.

15.4.2 Standards of certification

- non-certified (general purpose) detectors may be used only for fire, toxic gas and smoke detection in non-hazardous areas;
- fire, smoke and gas detectors for use in process areas shall be certified for use in zone 1 areas as a minimum;
- flammable gas detectors for use in all areas shall be certified for use in zone 1 areas as a minimum.

15.5 CONTROL MODULES

Transmitter or unitised types of sensors do not usually require a control module. This section applies to control modules for other types of gas detectors.

The failure of a circuit in a multiple detector input/output module should not affect other circuits. If so, the circuit concerned shall be redundant.

Control modules should be suitable for single man calibration.

The control module shall contain as a minimum the following self-diagnostic features:

- open loop detection (input and output);
- short circuit (input and output);
- earth fault(s);
- power supply failure, e.g. low battery voltage (of UPS);
- control unit failure;
- system fault;
- detector malfunction;
- end of sensor life (if applicable).

Any of the above failures shall generate a system fault at the FGS IPS, thereby forcing a failure alarm for each affected function. Detectors forming part of a 0 mA – 20 mA monitoring loop shall be configured so that specific current levels between 0 mA and 4 mA shall reflect specific conditions.

Modern FGSs are capable of diagnosing other non-terminal faults such as dirty optics, beam blocked, misalignment etc., and normally signal such occurrences by outputting a 2 mA signal (typically). Such fault or warning signals are not attributed to detector failure and need to be identified and discriminated from detector faults. However such faults need to be rectified promptly, otherwise this may lead to a dangerous situation.

Alarm level settings shall be protected against changes by unauthorised persons, e.g. by means of a key lock.

15.6 ALARM LEVEL SETTINGS

Alarm levels for gas detectors for personnel protection should not be set at levels higher than the STEL levels. For the current recommendations on STEL levels refer to the HSE executive assigned to the project.

For flammable gas detectors the alarm level setting shall be:

- 10 % LEL as minimum for point detectors, see [\(10.2.1\)](#) for recommended alarm thresholds;
- 1 LELm typically for open path detectors, see [\(10.3.2\)](#) for recommended LOS alarm thresholds.

NOTE: The typical long-term random drift of flammable gas detectors is in the order of 3 % LEL. Setting the alarm level at 10 % LEL as a minimum should prevent false alarms.

For H₂S gas detectors, the recommended alarm level setting shall be 10 mL/m³ H₂S, see [\(13.2\)](#) for additional information.

NOTE: The typical long term random drift of H₂S gas detectors is in the order of 5 mL/m³ H₂S. Setting the alarm level at 10 mL/m³ minimum should prevent false alarms.

15.7 REQUIREMENTS FOR CIRCUIT INTEGRITY

FGSs shall be robust against spurious activation.

When normally de-energised actuating circuits are applied via pneumatic systems, e.g. for the activation of valves, they shall be connected to a secured instrument air system comprised of fire resistant components, e.g., AISI 316 tubing instead of copper tubing. Refer to PTS 31.37.00.11.

Critical instrument and electric cabling shall be installed so that they are protected against direct heat radiation and flame impingement. If this is not possible, special fire-resistant cables shall be used which have a minimal 30 min. fire rating.

Exposed field cables shall be of a fire resistant type, with a minimal 30 min. fire rating, if they are required to function when exposed to fire.

Electric circuitry shall be enhanced with line monitoring facilities. Line monitoring shall be able to discriminate between safe condition, alarm condition, open loop and short circuit.

Note: Line monitoring shall be achieved by serial and parallel resistors at the initiators. The resistors shall be placed as close as practicable to the initiator and should form an integral part of the detector. The resistors shall be of encapsulated type.

Digital inputs from the initiators shall comply with the following:

- field initiators should be individually wired to the control module or to the FGS IPS. Normally closed contacts shall be applied. Line monitoring shall be installed.
- zoning of initiators may be applied in buildings. Zoned circuitry shall be achieved by parallel (normally open contacts) configuration of the initiators. The line monitoring shall be installed by terminating the circuit by an encapsulated end of line (EOL) resistor which shall be located furthest away from the control module and which should form an integral part of the last initiator in the chain.

15.8 EXTINGUISHING SYSTEMS

Normally de-energised actuating circuits may be applied if a spurious release of extinguishing agent will result in unnecessary damage to the plant or unacceptable hindrance to the operation of the plant. The risks, including the risk to personnel, of such a spurious release shall be assessed.

If carbon dioxide is used as extinguishing agent, 20 s notice shall be given before the actual release of extinguishing agent in an enclosed room or cubicle. Annunciation shall be by the same means as specified in [\(15.3\)](#) – refer to PTS 80.47.10.30 and PTS 80.47.10.31 for these systems. These PTS's refer to applicable NFPA-12 or other codes covering these devices.

15.9 PURCHASING REQUIREMENTS

15.9.1 Detector specification

For detectors used with rotating equipment that are fitted with 'noise hoods', high temperature resistant detectors shall be specified and the cable between the detector and junction boxes shall be of the fire resistant-type.

15.9.2 Calibration and testing facilities

Where special test equipment is specified for calibration, testing and checking the instrument, such test equipment shall be made part of the order.

Calibration gas cylinders with the appropriate calibration gases and all necessary equipment such as pressure regulators, sensor head connections, fittings, etc., shall be part of the order.

A certificate shall be supplied with every cylinder, stating the composition of the contained gas, the date of filling, and the expiry date.

15.9.3 System requirements

15.9.3.1 Self-diagnostics and error messages

For detector and control module self-diagnostics, see [\(15.9.3\)](#).

15.9.3.2 Electro Magnetic Compatibility (EMC)

The design of the FGS shall be such that it is not adversely affected by electromagnetic interference as defined in IEC 60801.

15.9.3.3 Electricity supply

Electricity supply for FGSs shall meet the requirements of PTS 33.64.10.10.

15.9.3.4 Tagging of sensors

A unique number shall be assigned to each detector, manual call point, horns, beacons, etc., in accordance with PTS 32.10.03.10.

16. INSTALLATION PRACTICES FOR DETECTORS AND ASSOCIATED EQUIPMENT

16.1 General

Sensor heads shall have safe access for maintenance, e.g. from grade or from a platform. Access shall be possible without the need for scaffolding.

Sensors shall not be installed lower than 1 m above grade or ground level, and they shall be positioned so that they are not adversely affected by sand, dust, water spray, direct rain, salt spray, strong winds or high velocity flows, e.g. in ducting. Therefore, they should not be installed inside ducting. Instead, they may be installed at the inlet or outlet openings, but with sufficient protection, e.g. by wind protection hoods or equivalent.

This is particularly true for catalytic gas detectors that have flame arrestors, or IR detectors that have filters fitted inside their weather baffle.

However, for detecting gas heavier than air, e.g. H_2S , the sensors may be installed lower than 1m above grade or ground level.

Protective filters should not be used on IR gas detectors as such filters can lead to reduce response to gas and eventual failure to respond if not properly maintained.

- NOTES:
1. Detectors may be positioned at approximately the same elevation as the potential source of leakage, but should not be less than 1 m above grade level to avoid damage by ingress of splash water. If catalytic gas detectors are employed, their correct positioning is most important as otherwise they are likely to under-read.
 2. LOS gas detectors are generally the preferred technology for detecting gas leaks in open areas.
 3. Gas detectors should be positioned so that they are easily accessible for calibration and maintenance. Where this is not possible, they shall be equipped with a permanent calibration/test connection that is accessible from grade or from an existing platform (such detectors will require periodic maintenance).
 4. Power supply and electronic measuring circuits shall be located in a non-hazardous area, e.g. the auxiliary room of the control centre or field auxiliary room.

16.2 Performance definitions

Before detectors can be located, the degree of safeguarding needs to be understood. For F&G detection, the following definitions are appropriate:

Performance (fire detection)	The probability that an assigned set of detectors in a zone will detect a fire of a defined minimum size in a defined area (zone) within a defined time period with the defined safe failure robustness assuming that all detectors work properly (i.e. the likelihood of detecting a fire as confirmed fire).
Performance (gas detection)	The probability that an assigned set of detectors in a zone will detect a gas leak of a defined minimum size in a defined space (zone) within a defined time period with the defined safe failure robustness assuming that all detectors work properly (i.e. the likelihood of detecting a gas leak as confirmed gas).
Performance target	The minimum acceptable performance of a fire or gas detection system.
Fault tolerance	Ability of a fire or gas detection system to continue to perform a required function in the presence of faults or errors.

Minimum degree of fault tolerance	If the minimum degree of fault tolerance is T, (where T is a specified number of detectors), this means that any combination of T detectors shall not cause the detection performance to drop below the performance target.
Probability of Failure on Demand (of a fire or gas detection system)	The fraction of time during which a defined set of detectors is not able to meet the defined performance target (assuming that the occurrence of a gas leak or fire is independent of the failure of the detection system – see (Appendix IV)).
Definition of failure	A failure of a set of fire or gas detectors is defined as its inability to meet the minimum performance target. This implies that a minimum performance target has to be set. Where this is not the case, the performance target shall be 85 %.

Multiple failures shall also be considered – see (Appendix IV) for additional information.

16.3 Performance requirements for F&G systems

For fire detection, the performance of a fire detection system is defined as the calculated probability (using a fire detector mapping methodology) that a fire of a defined minimum size in a defined area will be detected within a defined time period with the defined safe failure robustness (e.g. a fire in area ABC of at least 50 kW will be detected by 2 detectors with at least 94 % probability).

For gas detection, the performance is defined as the calculated probability (using a gas detector mapping methodology) that a gas leak of a defined minimum size in a defined space will be detected within a defined time period with the defined safe failure robustness (e.g. a gas leak in a space ABCD of at least 1 kg/s will be detected by 2 detectors with at least 90 % probability).

16.4 Minimum requirement for establishing the performance of a set of detectors

Fire and Gas detectors are continually evolving, often resulting in performance improvements. It is therefore most important to understand how a detector will respond to a fire or gas leak. For example, Manufacturers of flame detectors commonly quote detector performance in terms of the detector's ability to detect a 10 kW (1 ft²) gasoline pan fire, but the detector's performance in response to other fuels will be very different. It may also be true that the detector's Field-of-View (FOV) will be significantly different, and this needs to be considered when determining what a detector "can" and "cannot" detect.

The above is even more difficult in congested plants where fires or gas leaks may be concealed. In such cases, the "if in doubt, add more" syndrome commonly prevails, leading to over-engineering and higher maintenance costs.

Software tools have been developed to help site F&G detectors in congested plants, and such tools shall, as a minimum:

- enable the user to perform the required F&G detector compliance modelling using the performance envelope for the intended set of detectors. The performance envelope shall cover the intended use and this shall be supported by Manufacturer test data or by data obtained via in-house evaluation testing;

- enable the user to evaluate the effectiveness of the intended set of detectors at any position within the 3D modelled volume;
- enable the user to determine the detection coverage (performance target) with one or more detector(s) in fault – see definition of failure ([16.2](#));
- enable the user to consider the effect of congestion shadowing on flame detection coverage, and consider the effect of gas releases impacting on equipment;
- enable the user to evaluate/compare different logic voting combinations;
- enable the user to produce detector performance (coverage) maps at multiple (user defined) elevations;

enable the Probability of Failure on Demand to be calculated for the intended set of detectors; considering differing failure scenarios – see ([Appendix IV](#)).

Fire and Gas detector mapping software is available from a number of sources. The Contractor shall use Fire and Gas detector mapping software from an acknowledged source to demonstrate that the intended set of detectors meets the required safety performance; unless determined otherwise by the Principal.

16.5 Location of flammable gas detectors

The type of detector and its location should be based on typical leakage calculations (kg/s), taking into account plant and equipment lay-out and the heat and material balance statistics for the process. Prevailing wind speed and direction and local atmospheric conditions should be considered.

The location of flammable gas detectors shall be defined on the basis of an auditable study for each individual application in consultation with the Principal. General guidelines and requirements are given below.

Detectors with shutdown action are typically located where air is 'normally' free from flammable gas, such as:

- air inlets for HVAC (heating, ventilation and air conditioning);
- air outlets of enclosed hazardous areas/modules, ventilated gas turbine compartment etc.;
- air inlets to analyser houses;
- the suction of instrument air compressors;
- inlets to furnaces in gas plants;
- inlets to air compressors in gas plants;
- inlets to breathing air systems.

For flammable gas detection in ducting, the sensor(s) shall be installed at the inlet air opening. This ensures the fastest possible response time and obviates the need for sampling systems.

In process units, suitable flammable gas detectors may be installed near the seals of centrifugal process gas compressors and pumps and in LPG bottling facilities - see ([16.5](#)) on locating catalytic gas detectors. But siting detectors close to potential leakages sources may not always give the best performance. Gas clouds disperse and may collide with plant structures increasing the probability of detection. Therefore locating detectors at some distance from potential leak sources may improve detection probability.

The elevation at which the flammable gas detectors are mounted shall reflect the presence of heavier or lighter-than-air gases; such releases may well be neutrally buoyant if released under pressure - see ([Appendix IV](#)).

NOTE: 1. Both the temperature and molecular weight of a gas have an impact on buoyancy. In particular, the temperature of a gas following a release may differ significantly from the initial process conditions (due to J-T cooling etc.).

Clearly, detection shall be focused on specific locations that are potential sources of a release, or areas where potential hazards would arise if a release occurs (as listed above). Adequate detection shall also be provided in all areas where a hazardous accumulation of gas could occur. Areas should be identified in which the local ventilation rate is likely to be significantly below that of the general area. In particular, such areas often have inherent characteristics in which the local flow regime is one of 'recirculation' rather than ventilation. In these areas, significant gas clouds can persist, even when the size of the initial release is relatively small.

The ultimate test of how effectively a gas detection system can control potential incidents relates to the size of gas cloud that could exist in a sensitive area without being detected (the size of a cloud is directly related to the potential consequences in terms of explosion overpressure). Given that confirmed detection (by two detectors) is usually required before executive shutdown actions are taken, the size of the largest gas cloud that can exist while only one detector is triggered is an important measure of the 'worst case' incident that could occur without shutdown being initiated. This worst case scenario shall be determined.

16.6 Location of Toxic Gas and NH₃ Gas Detectors

16.6.1 Toxic gas detectors - point detection

Detectors should be located near to potential sources of leakage such as at pump and compressor seals, and also at some distance to detect further dispersion of gas. But toxic gas detectors shall not be sited too close to potential leakages sources, otherwise spurious operation may result from very small leakages which may not be detected on follow-up inspection.

If high toxic gas containing equipment has been grouped in the smallest area, a fixed number of detectors around and/or within this area should give effective coverage.

16.6.2 Toxic gas detectors - area monitoring

The location of toxic gas detectors shall be based on a careful study of the particular plant/project in which all the relevant factors such as process equipment type, potential sources of leakage, concentration of toxic gas in the process streams and plant lay-out, etc., have been considered.

As H₂S-containing vapours are often heavier than air and tend to disperse downwards, detectors should be located at levels lower than the expected leak source (but not lower than 1 m above grade). However, if the vapour is lighter than air (possibly due to a higher temperature), detectors should be located at levels above the expected leak source.

Detectors shall be placed along logical entrance routes to an H₂S-containing process area. Prevailing wind directions shall be taken into account in selecting locations for toxic gas detectors.

16.7 Location and positioning of smoke and fire detectors

16.7.1 Smoke detectors

1) General

Ionisation-type and scattered light type smoke detectors shall be used for enclosed spaces and buildings such as offices, archives, store rooms, medical centres, computer rooms and instrument auxiliary rooms, etc. - see [\(14.6\)](#).

2) Diffusion-type detectors

The following shall be taken into account when selecting the actual location:

- room ventilation patterns, i.e. draught due to air conditioning;
- the diluting effects of air conditioning and ventilation systems.

Detector spacing shall be in accordance with national/local fire protection standards and the Manufacturer's recommendations. Closer spacing shall be applied wherever the characteristics of the protected hazard would impair the effectiveness of detection.

3) Smoke aspirating type detectors

These are generally used for aspirating smoke from the following locations:

- under elevated floors in computer rooms, auxiliary rooms, and inside electrical and instrumentation cabinets in auxiliary rooms;
- on cable trays in buildings.

A typical aspirating type smoke detector features a detector cabinet containing up to 5 detectors connected to sample points via sample lines. The detectors share a common aspirating pump, drawing the sample through the lines to the detectors.

16.7.2 Fire detectors

1) Heat detectors

Maximum spacing of detectors shall be according to national fire protection standards, taking into account the Manufacturer's recommendations and requirements. Closer spacing shall be applied where the characteristics of the protected hazard would otherwise impair the effectiveness of detection.

Heat detectors shall respond promptly to the development of a fire. Response times depend on the amount of heat transferred from the fire to the detector. Therefore, the following factors shall be taken into account for the positioning of detectors:

- height of ceiling and depth to which the detector projects below the ceiling;
- ventilation patterns in the building/room;
- objects possibly blocking the heat flow to the detector, e.g. system cabinets.

Where heat detectors are installed in open areas, heat shields shall be installed to improve early detection.

2) Fire detection tubing

Fire detection tubing shall be positioned near the potential fire source of the equipment to be protected, taking consideration of the need to safeguard the tubing against mechanical damage. Fire detection tubing shall be black, flame retardant polyethylene which is resistant to ultraviolet light; for example, "Polyflo 44-PF". Such tubing is supplied by Imperial Eastman or by Samuel Moore; however, an equivalent may be used following approval by the Principal.

The instrument air in the tubing shall be maintained at an appropriate pressure, typically 1.5 bar (ga), for the transmitter it is to operate, as this relates to rupture temperature.

NOTE: The instrument air lines for inter-connections and for connecting the tubing to the instrument air header shall be of plastic-sheathed copper tubing.

For a typical application of fire detection tubing, refer to Standard Drawings S 88.020 and S 88.021.

Systems based on fire detection tubing are vulnerable and prone to failures induced by exposure to chemicals or by mechanical damage. The Principal shall be consulted on the use of fire detection tubing.

A sturdy alternative, although possibly slower to respond to fire, is a point detection system with frangible bulb detectors in AISI 316 tee fittings interconnected by AISI 316 tubing and mounted at two-metre intervals. Fusible plugs may be used instead of frangible bulbs.

3) Optical type fire detectors

Optical type fire detectors are line-of-sight devices and shall therefore be positioned so that they can see the entire section to be protected. They shall be mounted so that they are free from the effects of vibration and shock, and spaced in accordance with the detection objectives, see ([Appendix IV](#)).

Infrared (IR) lenses shall be protected against the effects of water and the possibility of freezing.

NOTE: Certain hydrocarbons and other gases, e.g., carbon dioxide, may interfere with the signal to the IR detector.

Ultraviolet (UV) detectors shall be protected from possible fouling of their windows / lenses but such protection shall not impair their operation.

The preferred type of UV detector is solid state photo diode. All photo tube type shall not be used as it can potentially cause nuisance alarms.

Optical type fire detectors provide rapid response and good space detection - see ([14.4](#)).

16.8 Positioning of beacons

Beacons shall be positioned so that they will be visible in the area for which they are to provide a warning, but they should be accessible for maintenance. Suggested locations are pipe racks, top corners of buildings and the principal passages inside auxiliary buildings.

16.9 Positioning of manual call points

Manual call points shall be positioned (see PTS 80.47.10.30) so that they stand out against the background, i.e. they shall be clearly recognisable from a distance. If necessary they shall be provided with signs to enhance their visibility from access roads.

Manual call points should be positioned as follows:

- along roads in the plant area at intervals not exceeding 100 m, preferably at or near to lamp posts;
- along roads in storage / tank areas not exceeding intervals of 200 m;
- near or at locations having a higher risk such as remote pump floors, oil catchers, manifolds, motor control centres, jetty heads;
- on offshore locations, at escape routes (entrance to bridges and staircases);
- inside buildings, office entrance, canteens, warehouses, medical centres, gate and guardhouses, etc.;
- inside the plant and positioned:
 - outside power station(s);
 - outside analyser house(s);
 - outside control room(s);
 - outside utility buildings;
 - outside hazardous enclosed areas;
 - along logical escape routes.

16.10 Detector Voting

Detector voting is one method of ensuring that fire or gas detector configurations are robust against failure and robust against spurious alarms. But detector voting may not be required; for example, where detectors or detector systems themselves are robust, or where appropriate actions are taken by experienced operators.

Clearly, combining detectors to vote logically in any configuration requires additional detectors to provide the same degree of coverage. Generally, the number of detectors required increases as the voting architecture become more complex – ([Appendix IV](#)) lists possible configurations.

An architecture finding widespread use is that referred to as 1oo2D. This strategy requires 2 detectors for confirmed Fire or Gas as with 2ooN, except that under detector fault conditions, e.g. if a detector has failed, the logic reverts to 1ooN (i.e. the logic considers failed detectors as alarms, which is the equivalent of voting High on detector fault). This has the major advantage that detection coverage is not lost if a detector has failed, as with 2ooN - in fact coverage is increased. The concept, however, is slightly less robust against spurious trips when alarms are produced from F&G zones that have failed detectors, but this lower robustness does not affect the entire facility. Furthermore, modern detectors have a typical MTBF of 10 years or more, so this drawback is marginal and inconsequential when judged against the improvement in safety performance. Nevertheless, this highlights the need for prompt action to repair faulty instruments.

The main reason for adopting 1oo2D detector voting is that the required performance (coverage) is delivered with the minimum number of detectors. Other detector voting configurations may be required to achieve identified safety or economic needs, but such configurations will require a greater number of detectors.

17. INSPECTION AND TESTING

17.1 FACTORY INSPECTION AND TESTING

17.1.1 General

Inspection and testing at the Manufacturer's works shall be carried out in accordance with PTS 62.10.08.11 and the Manufacturer's own procedures.

If specified by the Principal, the Principal shall be invited to witness the Factory Acceptance Test (FAT).

17.1.2 Acceptance test

The detectors and their associated hardware shall be tested prior to shipment at the Manufacturer's works to demonstrate that the system performs as specified.

Testing shall comprise a full check on the operational requirements and on proper functioning of all hardware and, where applicable, software in the system.

Serial communications, if any, shall be demonstrated.

17.2 SITE INSPECTION AND TESTING

17.2.1 General

Inspection and testing shall be carried out on site in accordance with the requirements of PTS 62.10.08.11 and the Manufacturer's own procedures.

Prior to the site inspection and test, the detectors shall have been calibrated, see [\(19.3\)](#).

17.2.2 Acceptance test

A full site acceptance test shall be performed to demonstrate that the FGS functions correctly. A test manual shall be supplied by the system Manufacturer/Supplier for this purpose. If assistance by the system Manufacturer is required, this shall be specified in the requisition.

The complete FGS and control system shall be commissioned on the basis of realistic tests prior to start-up. The tests shall, as far as is practical, simulate fire, smoke and gas detection which can arise in the protected area under normal operating conditions, e.g. smoke detectors shall be commissioned with the heating, ventilating and air conditioning system in operation with a smoke source at ground level. This should ensure that the response time of the system is measured reliably.

18. MAINTENANCE

18.1 General

Maintenance, calibration and testing of fire, smoke and gas detectors can be carried out by the site service organisation or by an outsider under a service contract.

18.2 Precautions During Construction, Shutdowns and Commissioning

Gas detectors other than the optical types are in general sensitive to environmental conditions. The Manufacturer's recommendations on how to store new sensors shall be followed.

Sensors installed in the field as part of new projects should be installed at the latest possible moment, and sensors should not be left without power supply once installed. Proper protection as recommended by the Manufacturer shall be applied to the sensors if powering-down is unavoidable, e.g. during shutdowns. It may be considered to remove the sensors from their housing or cover the sensor and store them at an appropriate location if such conditions are severe.

Pellistor-type flammable gas detectors are sensitive to a variety of poisoning agents such as silicon compounds, volatile vapours from drying paint, welding fumes, lead compounds as found in leaded gasoline, etc. Their sensitivity depends on the type and make.

Semi-conductor type H_2S sensors are sensitive to ingress of moisture that will eventually lead to permanent damage. They should therefore not be left exposed to atmospheric air, unless under powered conditions. If it is unavoidable to switch off the power from the sensors, they should be capped off using the caps with which they were supplied from the factory. If it is expected that power-off conditions may be of a long duration, the sensors should be disconnected and stored in a clean atmosphere with caps on.

Semi-conductor type H_2S sensors are easily poisoned by welding fumes and other poisoning contaminants like paint solvents.

Semi-conductor type H_2S sensors tend to lose their speed of response when not exposed to H_2S for a prolonged period of time. Once powered up the sensors should therefore be exposed to H_2S concentrations not exceeding 200 mL/m^3 H_2S at intervals not exceeding one month.

NOTE: The speed of response can often be restored by carrying out calibrations (at low and high span levels). A recovery period may last approximately one week.

Electro-chemical type sensors have a limited shelf-life, necessitating a well thought out stocking policy. Also, since these sensors are easily damaged they should only be installed shortly before commissioning.

Some ionisation-type smoke sensors are sensitive to airborne dust. The aspirated, ultra-sensitivity types are most susceptible to this condition. Commissioning should therefore be done at the latest possible moment in order to allow the atmosphere in newly constructed buildings to settle down.

18.3 Initial Calibration

Initial calibration shall be in accordance with the Manufacturer's recommendations.

Initial readings (output values and response times) shall be recorded.

Initial calibration of semi-conductor type of H₂S detectors shall only be started after the sensor has been powered on for a period of 24 hrs as a minimum. At the start of that period, the sensor shall have been exposed to an H₂S concentration not exceeding 200 mL/m³ in air.

18.4 Calibration/Testing of Flammable Gas Detectors

Flammable gas detectors should be calibrated to local standards with a certified, suitable test gas mixture of the prevailing gas in air. Test gas mixtures with a LEL concentration exceeding 60 % LEL shall not be used.

NOTE: Air/methane mixtures are normally used for natural gas applications, while propane is more common for refinery applications where catalytic gas detectors are still common. Concentrations ranging from 20 % to 60 % LEL equivalent are normally used.

Point IR gas detectors are least sensitive to methane. Therefore if general gas detection is required, detectors shall be calibrated using methane.

When the performance of a detector is tested, adjustments should be carried out only if the difference between the value of the output signal and that of the value of the test gas exceeds 5 % LEL. On these occasions, the speed of response should also be tested. A sensor is suspect if it fails to read higher than the value of the test gas minus 5 % LEL once the accepted response time has lapsed.

NOTE: Catalytic gas detectors need to be replaced when the mV or mA output signal per % LEL exceeds a certain level as advised by Manufacturer.

The performance of open path gas detectors should be verified using Manufacturer approved 1 LELm and 3 LELm test filters.

18.5 Calibration/Testing of H₂S Gas Detectors

18.5.1 General

When the detector is tested to ensure performance, adjustments should be carried out only if the difference of the output signal from the value of the test gas mixture exceeds 5 mL/m³ H₂S. On these occasions, the speed of response should also be tested. A sensor is suspect if it fails to read higher than the value of the test gas minus 5 mL/m³ H₂S once the accepted response time has lapsed.

NOTE: Gas detectors need to be replaced when the mV or mA output signal per mL/m³ H₂S exceeds a certain level as advised by Manufacturer.

H₂S gas detectors can be calibrated using either:

1. calibration chambers and calibration ampoules, or
2. a cylinder with H₂S-in-nitrogen.

NOTES: 1. Response times during calibration/validation/testing are faster when calibration chambers are used than when gas under flowing conditions is used.
2. H₂S-in-air mixtures are not stable.

18.5.2 Electrochemical type H₂S gas detectors

This type of detector can be calibrated with bottled air for zero adjustment, and with a test gas mixture containing 15 mL/m³ H₂S in nitrogen for sensor response.

18.5.3 Semi-conductor type H₂S gas detectors

Calibration shall be carried out with at least 2 different mixtures as recommended in the manual of the sensor. Normally, the following procedure is applicable:

- A glass ampoule containing a known concentration of H₂S is inserted in a slip-on calibration chamber of a known volume. This chamber is slipped over the sensor head, after which the ampoule is broken by turning a screw on the side of the chamber. The sensor head is thus exposed to a known concentration of H₂S and the detector can be calibrated. Glass ampoules with concentrations of 4, 10, 20, 50, 100 mL/m³ are available from Manufacturers of H₂S gas detectors.

18.6 CALIBRATION/TESTING OF FIRE AND SMOKE DETECTORS

18.6.1 General

The preferred method of testing a detector is to expose it to a source of heat, smoke or fire as the area classification allows. Otherwise test conditions should simulate the actual hazard as closely as possible.

Testing of fire and smoke detection systems may also depend on the application. Reference is made to the Manufacturer's proposed procedures or applicable International recognised codes and standards (e.g. NFPA or BS)

18.6.2 Testing of ultra sensitivity smoke detectors

If the response time of a smoke detector is not sufficiently fast, the air ventilation conditions should be improved.

NOTE: Some standards on testing the performance of smoke detectors specify unrealistically fast response times. It should be realised that response times cannot be faster than the ambient air velocity and also depend on the airflow pattern in the atmosphere. Response times should be calculated from data on airflow velocities in ambient atmosphere, air flow velocities in aspirating tubes or diffusion velocities of smoke detectors and detector response times as quoted by Manufacturer.

19. TESTING FREQUENCIES

The testing frequencies shall comply with the IPF requirements (also see PTS 32.80.10.10) and should take into account the Manufacturer's recommendations as well as OPU/Site Maintenance Philosophy.

- NOTES:
1. Gas detectors (catalytic) may be considered to have an acceptable performance when the Mean Time Between Adjustments is equal to or greater than one month. The period advised by the Manufacturer is normally better than 2 months. This period can sometimes not be met due to adverse ambient atmospheres at site.
 2. For record purposes, a specific calibration record should be completed after each calibration, and a test sheet after each test. These sheets should include the date, the name of the technician and the type of calibration or test.
 3. In some countries (e.g. the Netherlands) the testing frequencies are dictated by legislation.

20. REFERENCES

In this PTS reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

PETRONAS STANDARDS

Index to PTS publications and standard specifications	PTS 00.00.05.05
Index to Standard Drawings	PTS 00.00.06.06
Noise control	PTS 31.10.00.31
Instrument air supply	PTS 31.37.00.11
Symbols and identification system - Instrumentation - Part 1 - Process (engineering) flow schemes	PTS 32.10.03.10
Instruments for measurement and control	PTS 32.31.00.32
On-line process stream analysis - Analysers	PTS 32.31.50.12
Plant telecommunication	PTS 32.71.00.10
Classification and implementation of instrumented protective functions	PTS 32.80.10.10
Electrical engineering guidelines	PTS 33.64.10.10
Inspection and functional testing of equipment	PTS 62.10.08.11
Assessment of the fire safety of onshore installations	PTS 80.47.10.30
Active fire protection systems and equipment for onshore facilities	PTS 80.47.10.31

STANDARD DRAWINGS

Note: The latest issue dates of standard drawings are identified in PTS 00.00.06.06.

Arrangement of polyethylene tubing for fire detection of pumps below pipe racks	S 88.020
Arrangement of polyethylene tubing for fire detection of pumps outside pipe racks	S 88.021

AMERICAN STANDARDS

Carbon dioxide extinguishing systems	NFPA 12
Standard for the storage and handling of liquefied petroleum gases	NFPA 58

BRITISH STANDARDS

Paint colours for building purposes	BS 4800
-------------------------------------	---------

EUROPEAN STANDARDS

Components of automatic fire detection systems	EN 54
Electrical apparatus for the detection and measurement of flammable gases. Part 1: General requirements and test methods	EN 61779-1
Electrical apparatus for the detection and measurement of flammable gases. Part 2: Performance requirements for group I apparatus indicating a volume fraction up to 5 % methane in air	EN 61779-2

Electrical apparatus for the detection and measurement of flammable gases. Part 3: Performance requirements for group I apparatus indicating a volume fraction up to 100 % methane in air EN 61779-3

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 EN 61779-4

Electrical apparatus for the detection and measurement of flammable gases. Part 5: Performance requirements for group II apparatus indicating a volume fraction up to 100 % gas EN 61779-5

INTERNATIONAL STANDARDS

Electrical Apparatus for Explosive Gas Atmospheres IEC 60079

Electromagnetic compatibility for industrial process measurement and control equipment IEC 60801

APPENDIX I HEAT DETECTOR CLASSIFICATION

Heat detectors are classified as follows:

1) Fixed temperature detectors

These detectors are either of the linear type, such as fire detection tubing and heat sensitive cable, or spot type, such as quartzoid bulb and fusible alloy links and plugs.

- Fire detection tubing is often applied in process areas or around equipment which is to be protected such as pumps, vessels, loading platforms, etc., handling flammable products, and other potential fire hazards such as flanges and drains.

Fire detection tubing shall be black (UV light resistant), fire retarding polyethylene, in accordance with Standard Drawings S 88.020 and S 88.021.

- Heat sensitive cable consists of two conductors held apart by heat sensitive insulation covered with an outer protective wrapping. The insulation melts at a predetermined temperature allowing the conductors to contact and initiate events.

Later developments of this type use insulation whose electrical resistance changes with temperature. If corrective action is taken quickly the cable will not be damaged and will not need replacing.

- Quartzoid bulbs can be applied in spray heads to combine detection with executive action, i.e. upon detection of a fire the bulb bursts and an extinguishing agent is released from the spray heads.
- Fusible alloy detectors use alloys of bismuth, lead, tin and zinc to solder links together or to form plugs which melt rapidly at a predetermined temperature. The links and plugs form the operating elements of the heat detector. These detectors can also be applied to combine detection and executive action.

2) Rate-of-rise heat detectors

These detectors are designed to function when the temperature of their operating element rises at a rate exceeding a predetermined amount, regardless of the temperature level.

They are typically used in those applications where, under normal circumstances, appreciable variations in ambient temperature may be expected, for example during the start up and normal operation of gas turbines. The use of such detectors shall only be considered following approval from the Principal, as they are unlikely to detect slowly developing fires.

3) Combination-type detectors

Combination-type detectors may employ more than one operating principle. A typical example is a combination of fixed temperature and compensated rate-of-rise detector, which is capable of responding accurately to both slow and fast temperature rises. They should therefore be applied where a combination of the circumstances described under fixed and compensated rate-of-rise detectors are expected.

4) Rate compensated type detectors

Rate-compensated detectors have the inherent ability to operate whenever the surrounding air temperature reaches the set point under all conditions of rate of rise in temperature.

Where the above detectors are used in open areas, consideration shall be given to installing heat shields to encourage the build-up of heat.

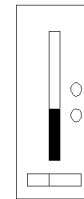
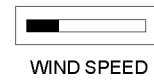
APPENDIX II TYPICAL CAUSE AND EFFECT MATRIX

CAUSE	EFFECT											
	Audible alarm in control room	Visual and audible alarm on DCS	Visual alarm on mimic panel	Audible alarm in building	Visual alarm in building	Audible alarm in plant 1)	Visual alarm in plant 1)	Close fresh air intake 1)	Close fire tight dampers 1)	Start fire-water pump 1)	Open waterspray valves 1)	Activate gaseous extinguishing system 1)
GENERAL ALERT												
Manual call point (in building)	X	X	X	X	X			X				
Manual call point (in open plant)	X	X	X			X	X			X ²		
HEAT												
Space	X	X	X	X	X							
Rate of rise	X	X	X	X	X			X				X
Polyethylene tube	X	X	X							X ²	X	
Frangible quartzoid bulb	X	X	X							X ²	X	
FIRE / FLAME												
Infra red	X	X	X	X	X			X	X			X
Ultra violet	X	X	X	X	X				X			
Building air intake high temperature	X	X	X	X				X				
SMOKE												
Ionisation	X	X	X	X	X			X	X			
Scattered light	X	X	X	X	X			X	X			
Ultra sensitive	X	X	X	X	X			X	X			X
GAS												
Toxic gas	X	X	X	X	X	X	X	X				
Flammable gas Low	X	X	X					X				
Flammable gas High	X	X	X	X	X	X	X	X				X

NOTE: 1. Where revealed failure robust initiators are implemented, action shall only be performed when 2 out of 'n' initiators are In Alarm.
2. The automatic starting of firewater pumps is not always necessary.

APPENDIX III TYPICAL HARDWIRED MIMIC PANEL LAYOUT

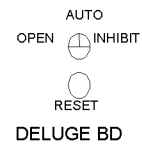
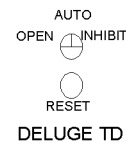
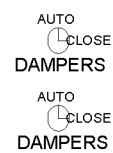
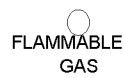
- ☐ FIRE
- ☐ FLAMMABLE GAS
- ☐ TOXIC GAS
- ☐ FWP AUTO-START STAND-BY
- ☐ SYSTEM FAULT
- ☐ UTILITY FAULT
- ☐ UPS FAULT



FIRE WATER
PRESSURE



- ☐ LAMP
- ☐ ACKNOWLEDGE
- ☐ RESET
- ☐ ALL CLEAR



APPENDIX IV FIRE & GAS DETECTION MAPPING

1. Introduction

Determining how many fire and gas detectors are required to safeguard an area is not straightforward, and it is even more difficult to determine the best place to site them. Clearly the number and type of detectors required is related to the potential risks, and understanding those is an essential first step. The following numbered points introduce the concepts that should be considered when optimising fire and gas detection systems, together with more detailed information on Fire & Gas Detection Mapping:

1. Identification of credible loss of containment/leak scenarios in each process area;
2. Development of a detailed list of release scenarios, e.g., a release of high pressure gas from pipe A, a release of pressurised liquid from tank B, etc.;
3. A quantification/estimate of the hazard consequence for each scenario, (e.g. gas cloud leading to explosion if ignited in congested area, burning back to jet fire, or pool fire if liquid release ignited). For this the heat and material balance statistics for the involved processes are required;
4. A quantification/ranking of the likelihood of realising the scenario (based on own plant history or generic data);
5. A quantification/ranking of the escalation potential of each scenario and final outcomes (e.g. loss of life, loss of asset, loss of reputation, damage to environment);
6. Combine 3, 4, & 5 to provide an overall risk rating for the scenario. In a typical QRA study, this would be a frequency (per annum) of getting the outcomes in 5;

Based on the outcomes in 6, optimise gas and fire detection.

2. Fire & Gas Detection Mapping

It is common practice with F&G detection systems to set performance targets, and such targets are generally based on detecting hazardous accumulations. And whilst there is no evidence that such accumulations have gone undetected on Shell facilities, it is likely from the evidence that high-pressure leakages may do so particularly in open areas.

High-pressure leakages may form significant releases outside the area protected by the installed gas detection system and whilst it may be argued that such releases are unlikely to pose a significant overpressure threat if ignited, they may pose a significant radiation hazard. It is important therefore, that fire & gas systems demonstrate that they are capable of responding to the highest practicable proportion of genuine demands. At the heart of this requirement is the need for appropriate mapping of fire & gas systems to ensure that their coverage can be demonstrated to provide an acceptable likelihood of detection.

3. The role of fire & gas systems

The role of a gas detection system is to detect accumulations of gas or gas migrating between areas, and to do this sufficiently early for shutdown actions to be initiated before flammable concentrations reach key ignition sources. It is very rare for a gas detection system to be able to respond in time to limit the instantaneous size of the resulting flammable cloud. However, if provided that process shutdown is initiated before the cloud has grown to such a size that its ignition could threaten the shutdown devices, the system can be considered to have performed its function. It is not the role of the gas detection system to detect fugitive leaks, but leakage detection systems set at an appropriate level can provide early indication of a significant gas release.

The role of a fire detection system is, in comparison, much simpler: it is to detect fires sufficiently early so that shutdown actions can be taken which minimise the risk to personnel and damage to plant. As with gas detection, fire detection is unlikely to be able to act quickly enough to reduce the size of the initial event, but provided that shutdown is initiated promptly, the shutdown devices themselves should be capable of operating as required, and the potential for escalation should be reduced.

4. Gas leakage detection

Gas detectors (IR or other technologies) are best sited observing any QRA risk predictions for the facility and the need to minimise the threat to life that may follow from gas leaks that ignite, as these may result in hazardous explosion overpressures or escalating fires. The threat from any toxic gas release should be addressed through similar consideration of the hazard and its potential effects. The discussion that follows specifically addresses the issue of flammable gas detection, but similar criteria apply to the detection of toxic gas.

The choice of detector type should be determined in the light of the most probable leak scenario and depending on whether dispersion will be pressure driven or will result from evaporation or migration of gases at low pressure, or some combination of these mechanisms. For the latter low-momentum releases, buoyancy (positive or negative) is a consideration dependent on both molecular weight and temperature. For high momentum releases, the effect of buoyancy will be negligible until the momentum of the release starts to dissipate – the resulting concentration and therefore the plume buoyancy is highly dependent on the relative congestion of the area and the ventilation rate. If a module is relatively uncongested and has a high level of ventilation, then the effects of buoyancy will be small. If a module is highly congested with relatively low ventilation rates, then the effects of buoyancy will be increased as a result of collisions.

Experience from full-scale tests and computational fluid dynamics (CFD) simulations has shown that there is a wide range of possible cloud sizes and concentrations. The traditional 'rule of thumb' approach to the positioning of (predominantly) flammable gas detectors has led to designs of differing complexity and generally indifferent performance. Improvements to the design process are therefore required in which a combination of the most effective detector types and a rigorous approach to layout design are combined with an effective understanding of the hazards.

The software estimates the probability of a given release being detected, and can accommodate both point and LOS gas detector configurations.

The software considers leak scenarios on a grid basis throughout the facility, and at each postulated leak location, gas dispersion is considered for different wind directions and speeds. For a given configuration of detectors, the software then determines the probability that the specified gas cloud or leak rate will be detected, together with the probability of detecting the leak with any single detector or multiple detectors in fault – this is a requirement of IPF methodology. The software also determines if the target gas cloud could exist undetected, anywhere within the modelled area.

Some of the limitations of this methodology are that:

- releases and their profiles are considered only within the modelled volume, and that releases that extend outside the modelled volume are not (currently) considered;
- gas plumes impacting on smaller obstacles are not considered – although this effect is thought to be small for distant obstacles;
- ventilation rates in the vicinity of the release may be higher or lower than the (average) rate for each given wind speed that is assumed in the model.

Modelling complex gas dispersion scenarios is complicated but it provides a repeatable and auditable screening tool to test alternative configurations against a consistent set of rules.

Depending upon the type of installation and the extent of available CAD data, CFD modelling is likely to be more representative. However the information needs to be interpreted, and this inevitably introduces a degree of subjectiveness.

Whatever method is used to map the proposed location of gas detectors, the size of gas cloud that could occur between detectors is a fundamental measure of detection capability (the size of a cloud is directly related to the potential consequences in terms of explosion overpressure). As outlined in Section 6.4, the size of the largest gas cloud that can exist while only one detector is triggered is an important measure of the 'worst case' incident that could occur without shutdown being initiated. This is a key element of the mapping software, and compliance shall be demonstrated.

The mapping of acoustic leak detectors has very different criteria to the mapping of gas detectors. The process is much simpler from the point of view that the ultrasound signal from a release radiates uniformly and is not sensitive to local ventilation characteristics, but the reflection of ultrasound is important and needs to be considered. There is however, in the case of acoustic leak detection, a greater complexity associated with measuring (or predicting) the ambient ultrasound 'noise'.

If an area is to be covered by voted systems that include both gas and acoustic leak detection, then appropriate mapping of both systems is required, and any mapping process shall consider the contribution from each technology where detector voting is required.

5. Flame detection

The mapping of flame detectors is a more straightforward process than that described above for gas and leakage detectors, in that the source (fire) radiates uniformly and there are rarely any ambient sources of radiation to provide a spurious signal. However, in this case, the complexity arises from the potential screening associated with equipment congestion, and the differing sensitivity requirements for pool and jet fires.

To assist in the mapping of detectors, software is available to precisely determine if a fire of specified size, 50kW for example, anywhere within the facility can be seen from a particular detector position. This does not mean that a fire smaller than 50kW will not be detected, and output from the program highlights the proportion of the module in which the fire could be seen by 1, 2 or more detectors. In brief, the flame detection algorithm determines the points at which a fire could be hidden by the objects within the module and identifies the optimum locations to site detectors to maximise their performance. This process is repeated until the facility is adequately safeguarded, with the minimum number of detectors – see (6.5).

It is most important when undertaking a mapping exercise that the performance envelope for the respective set of detectors is accurately modelled. The characteristics of detectors vary considerably, and this needs to be considered.

6. General

The above is a brief overview of the techniques that can be applied in the mapping of fire & gas detector locations. Many of the techniques require a 3D model to operate on, and this is most commonly acquired as a Drawing File Output from the CAD package. If this is not available, a skeleton model can be produced from plot plans and digital images taken at site.

Mapping software is available from third party vendor. Methodologies used shall provide evidence that the required degree of safety as described in PTS 80.47.10.30 has been achieved and, that designs have the required number of fire and gas detectors to meet the requirements of PTS 32.80.10.10.

PTS 32.80.10.10 requires all failure scenarios to be considered, and the Probability of Failure on Demand to be calculated. Details are given below.

7. Failure scenarios

Typically there will be multiple fire or gas detectors serving the area under surveillance. Therefore there will be multiple scenarios (unique sets of detectors showing a dangerous failure) entailing inability to meet the target. The scenarios shall take into account whether SFR is required or not.

The failure scenario is not a simple NooM equation since not all detectors will contribute equally to the overall detection performance. Therefore each scenario that leads to a 'failure' needs to be separately defined and its PFD assessed.

Each failure scenario shall consider a unique set of detectors that need to fail dangerously in order to have the performance drop below the target, i.e. all combinations of detectors whose failure will cause an overall detection failure.

It can be seen that the number of failure scenarios can grow dramatically if there are many detectors and/or if the performance of the system with all detectors working properly is only slightly higher than the target.

Detectors of the same type will be exposed to common cause failures that will cause all detectors to fail. Obviously failure of all detectors of the same type shall be part of the failure scenario analysis. Failure of all detectors of all types shall be considered as well. The probability of that scenario will be determined following the consideration of failures that have a dangerous effect on all detectors at the same time (e.g. power supply).

Calculation of the Probability of Failure on Demand

The Probability of Failure on Demand (PFD) of a set of fire or gas detectors shall be calculated with account being taken of the following:

- The SIL of the overall function (detection, logic solver and final elements). From the SIL of the overall function, the target PFD of the detection shall be established. The SIL is to be established in accordance with PTS 32.80.10.10. If no SIL is established, the overall function shall comply SIL 1 requirements or the detection PFD shall be better than 4.5E-2.
- The probability of occurrence of each of the failure scenarios. This probability is to be calculated with account being taken of at least:
 1. the dangerous failure rate of each detector;
 2. the diagnostic coverage for dangerous failures of each detector;
 3. the safe failure rate of each detector;
 4. the routine maintenance and calibration interval of each detector;
 5. the repair time of each detector;
 6. the time each detector is off-line when it is routinely maintained or calibrated;
 7. the proof test interval of each detector;

8. the proof test duration of each detector;
 9. common cause failure rate of identical and for diverse instruments (Common cause failures may be treated as a special failure scenario);
 10. the PFD of each failure scenario results from the PFD of each of the detectors that need to fail as part of the failure scenario.
- The overall PFD of the detection is the sum of the PFDs of all individual failure scenarios. In addition the safe failure rate of the fire or gas detection shall be calculated to ensure that the spurious alarm rate or trip rate is acceptably low.

If this is done, the diagnostic coverage for safe failures shall be taken into account if diagnosed architectures are used.

In diagnosed architectures a diagnosed failure (safe or dangerous) will cause the architecture to degrade from $NooM$ to $Noo(M-1)$ or $(N-1)oo(M-1)$ where $N-1 \leq 1$ and $M-1 \leq 1$ and $N < M$ or $N = M = 1$.

See Table 1 for architecture degradations. Subsequent degradations are ignored (i.e. the likelihood of a diagnosed safe or dangerous failure of more than one detector at the same time is not considered except for common cause failures).

Table 1 Degradation of detector voting upon diagnosed safe or dangerous failures

Initial architecture	Degraded architecture
2oo6	2oo5
2oo5	2oo4
2oo4	2oo3
1oo2D	1oo(N-1)
2oo3	1oo2
1oo2	1oo1
3oo6	3oo5
3oo5	3oo4
3oo4	2oo3

A spurious trip/confirmed alarm occurs if:

1. $NooM$ detectors show an undiagnosed safe failure or,
2. In the case of a degraded architecture $(N-1)oo(M-1)$ (or $Noo(M-1)$), the detectors show an undiagnosed safe failure or
3. All detectors show undiagnosed safe failure as caused by common cause failures.

Considering the very low probability of $(N-1)oo(M-1)$ (or $Noo(M-1)$) detectors showing an undiagnosed safe failure during the fraction of time the architecture is degraded already, case 2 may be ignored in the calculation of the spurious trip/confirmed alarm rate.