AZERBAIJAN BUSINESS UNIT

(AzBU)

Safe System of Work:

Hydrogen Sulphide

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1 INTRODUCTION

1.1 DOCUMENT PURPOSE

This Safe System of Work contains the information and guidelines necessary to assist in reducing the risks encountered when working with Hydrogen Sulphide to as low as reasonably practicable.

1.2 DOCUMENT SCOPE

The contents of this Safe System of Work apply to all BP owned and managed sites and installations in Azerbaijan and Georgia where Hydrogen Sulphide is present or has a potential to be present. For detailed procedures to be followed during drilling, well testing and well servicing operations, refer to the BP Drilling Operations Guidelines (EUR-D-001), Hydrogen Sulphide (H_2S) Procedures. 1120/GEN.

Note: All personnel working on BP owned sites and installations in Azerbaijan and Georgia where Hydrogen Sulphide could be present must be made aware of the contents of this document.

The following Safe Systems of Work may also be relevant to this one, depending upon the circumstances:

- UNIF-HSE-PRO-103 Permit to Work
- UNIF-HSE-PRO-108 Confined Space Entry

2 RESPONSIBILITIES

2.1 SITES

Sites shall be responsible for:

- Operating in accordance with this document assuring them of compliance.
- Establishing a sampling programme to detect any onset of H_2S at producing sites where H_2S is not currently present in the well fluids.
- Maintaining a recorded system of training for all personnel working in areas with an H_2S hazard.

2.2 UPSTREAM TECHNOLOGY GROUP

Upstream Technology Group (UTG) shall be responsible for the provision of authorities advice on all aspects of H_2S during drilling and well operations.

2.3 CUSTODIAN

The Health Manager is custodian for this document and will:

- Maintain this document and co-ordinate any updates
- Provide a risk assessment and advisory service, in conjunction with UTG, on the adequacy of proposed H_2S detection and protection methods.
- Disseminate relevant lessons learned, within and out with BP

2.4 SITE MANAGER / OIM

Site Managers / OIMs are responsible for:

- the assessment and management of health risks on the site / installation
- reviewing the Risk Assessment findings and recommendations
- ensuring systems are in place to implement and track the actions resulting from the Risk Assessment
- Ensure sufficient monitoring systems and equipment is in place and there is adequate equipment available on site e.g. Oxygen equipment.
- ensuring that mechanisms are in place to communicate the findings, recommendations and requirements of the Hydrogen Sulphide Risk Assessment to all relevant personnel (including contractors, visitors, etc).

2.5 AREA AUTHORITIES

Area Authorities shall ensure that:

- Hydrogen Sulphide Risk Assessments are carried out before any related tasks are undertaken or begun
- Personnel working under their supervision are aware of the risks involving Hydrogen Sulphide and are aware of the necessary precautions.
- Personnel working under their supervision are trained in the use of monitoring devices and other protective systems.

2.6 SAFETY ADVISORS

Safety Advisers are responsible for providing technical support, guidance and advice, whenever required.

2.7 HEALTH MANAGER

The Health Manager is responsible for:

- maintaining this Safe System of Work
- ensuring Company training programmes comply with the requirements of this Safe System of Work.

3 HYDROGEN SULPHIDE DESCRIPTION

3.1 WHERE HYDROGEN SULPHIDE CAN OCCUR

Hydrogen Sulphide can occur naturally:

- in crude oil and gas
- during the decomposition of organic materials, including sewage
- in de-oxygenated seawater, which encourages the growth of Sulphate-reducing Bacteria (SBR)

In addition, Hydrogen Sulphide can be produced as a by-product:

- while processing hydrocarbons that contain Sulphur
- from the chemical action of acids on metallic sulphides; for example, during the chemical cleaning of equipment containing Iron Sulphide deposits.

H_2S is generated by bacteria in seawater, which thrives in conditions of oxygen deficiency and, together with organic materials as a nutrient, reduces the sulphate in seawater to hydrogen sulphide

3.2 PROPERTIES AND CHARACTERISTICS OF HYDROGEN SULPHIDE

Characteristics of H_2S

Principle characteristics of H_2S are:

- Highly toxic, colourless, flammable gas which, in relatively low concentrations, can quickly cause unconsciousness
- Approximately 20% denser than air and therefore can accumulate inn depressions around an area where the gas is present
- Has an auto-ignition temperature of 260^{o} C, is flammable in the range of 4.3% to 45% volume in air and burns with a blue flame to produce sulphur dioxide, which is also toxic
- Is highly corrosive to certain metals. In particular, materials containing copper should never be used due to the possibility of an explosive reaction with H_2S
- In air, concentrations are measured in parts per million (ppm) on a volume-to-volume basis. In water, concentrations are measured in milligrams per litre (mg/l)

Toxicity

Warning: Hydrogen Sulphide is highly toxic and can cause unconsciousness and death at quite low concentrations.

Hydrogen Sulphide is an irritant and an extremely toxic gas, between five and six times as toxic as Carbon Monoxide. After exposure to Hydrogen Sulphide, symptoms usually begin immediately:

- **Low level exposure** causes irritation of the eyes, nose and throat
- **Moderate exposure** levels can cause headaches, dizziness, nausea and vomiting as well as coughing spasms and breathing difficulties within 15 minutes
- **Higher exposure** levels can cause shock, convulsions, coma, and damage to the heart, brain damage and death.

Very low concentrations of Hydrogen Sulphide can be detected by the offensive odour of rotten eggs. However, personnel working in areas where Hydrogen Sulphide is present may become accustomed to the smell because prolonged and repeated exposure will cause the sense of smell to tire (not being able to smell it, may mean that concentration of H_2S has increased, not decreased). Higher concentrations of Hydrogen Sulphide can paralyse the sense of smell immediately and rapid loss of consciousness. Death may result within minutes unless the casualty is moved to fresh air and resuscitated.

Note: Recent evidence indicates that long-term exposure to relatively low concentrations of H_2S (10 to 30ppm) may affect respiratory efficiency by interfering with oxygen uptake (anaerobic respiration).

Corrosiveness

Hydrogen Sulphide is highly corrosive, especially in association with moisture or oxidizing gases such as Oxygen and Carbon Monoxide. Iron and steel are particularly vulnerable.

Corrosion mechanisms associated with Hydrogen Sulphide include:

- general corrosion
- pitting
- crevice corrosion, including Sulphide Stress Corrosion Cracking which can lead to sudden and catastrophic failure
- Hydrogen induced cracking, also known as hydrogen embitterment

Any equipment likely to be exposed to Hydrogen Sulphide must be made of appropriate materials, constructed and operated to take account of these corrosion problems.

Pyrophoric Scale

Carbon steel lines and equipment that carry gas or liquids containing hydrogen sulphide may develop a layer of pyrophoric scale (iron sulphide) on their internal surfaces. When these lines or equipment are opened up to atmosphere, oxygen from the atmosphere will react with the pyrophoric scale to produce spontaneous burning. If hydrocarbons or other combustible substances are present during this

reaction, an explosion may result.

Warning: A by-product of this oxidising process is Sulphur Dioxide, which is also toxic.

Whenever such lines and equipment are opened up to atmosphere, their internal surfaces should be doused thoroughly with water or blanketed by steam in order that any pyrophoric scale is rendered harmless.

Warning: Equipment and pipe work that has been on sour-gas duty (i.e. contains more than 0.5% by weight of H_2S) should only be opened in one place at a time unless the pyrophoric scale has been thoroughly wetted. Opening the system in more than one place can cause through drafts capable of igniting the scale.

If the introduction of water is not permissible, either due to corrosion potential or the risk of freezing, a nitrogen purge followed by a further purge with a mixture of 5% oxygen in nitrogen will allow controlled oxidation.
Pyrophoric scale that has been removed from lines and equipment shall be placed in a drum and immediately covered with water. It must then be disposed of by:

- burying or burning in a suitable area as determined by legislation (onshore situations)
- slurrying with water and storing in sealed drums, clearly marked 'PYROPHORIC SCALE', and manifested as dangerous goods and sent ashore (offshore situations).

Apart from the hazards to personnel, H_2S also poses a risk of sulphide corrosion and hydrogen embrittlement to metals. Protection methods for metals are detailed in BP Hydrogen Sulphide Technical Safety Aspects Guidance Note GN 91/30 (refer to BP Engineering Standard GS 136-1.

4 HYDROGEN SULPHIDE DETECTION KNOWN H_2S AREAS

4.1 KNOWN H_2S AREAS

In cases where H_2S is known to be present or may be present in well fluids, appropriate measures shall be provided to prevent exposure of personnel to this hazard.

Procedures, especially those relating to breaking of containment, confined space entry and gas testing, shall be the principle means of protecting personnel. Portable instruments may be used together with procedures to monitor a potentially hazardous are in which personnel are present.

The personnel using and relying on the detection equipment shall be trained in its use.

4.2 HYDROGEN SULPHIDE FIXED DETECTION SYSTEM

Note: It is BP policy that the protection of site personnel is primarily achieved by the safe working practices defined in this document, not by the use of fixed detectors. However, fixed detection methods may be installed for other reasons.

Areas where an accumulation of H_2S is possible may be monitored by use of **fixed detectors** that react to H_2S and give early warning of its presence. However, these should not be relied on to prove the area is clear of an H_2S hazard. Personnel should not approach an area where such a suspected release has taken place unless they are wearing self-contained breathing apparatus.

Warning: There may also be a risk of ignition and explosion in such a scenario; if the lower explosive limit (LEL) on H_2S or the LEL of other process gasses has been exceeded, then personnel should not approach the area. Isolations should be applied remotely.

4.3 HYDROGEN SULPHIDE PORTABLE DETECTION EQUIPMENT

Where a specific risk of H_2S has been identified, personnel are recommended to use **portable detectors** or wear **personal electronic detectors** that alarm when H_2S level reaches 5 PPM.

Portable Hydrogen Sulphide monitors must be provided so that in the event of a Hydrogen Sulphide escape, the extent of the danger can be established.

Chemical sampling methods of Hydrogen Sulphide detection are preferred, because they are much more reliable than instruments. it is important to ensure that the detector tubes used to monitor Hydrogen Sulphide are always within the test expiry date.

Note: Chemical sampling methods are not suitable in certain circumstances; for example, for confirming that clean air has been reached when escaping from a Hydrogen Sulphide hazard.

4.4 AREAS NOT CURRENTLY PRODUCING H_2S

In cases of producing sites, which at present do not have H_2S in their well fluids, sampling shall be undertaken at defined intervals in order that any onset of H_2S is established early.

4.5 OTHER AREAS

Appropriate measures shall be provided for non-process systems/areas, which have the potential to produce H_2S. These measures shall be determined by suitable risk assessment.

4.6 GAS TESTER LEVEL 1

An Authorised Gas Tester Level 1 is authorised to test for the presence of flammable gas or vapour, toxic gas and oxygen, and in particular to test atmospheres in 'Confined Spaces' as defined in *UNIF-HSE-PRO-108 - Confined Space Entry*.

5 HYDROGEN SULPHIDE PRECAUTIONS

5.1 CLASSIFICATION OF H_2S RISK AREAS

Warning: Notices warning of the presence of H_2S and stipulating access requirements must be posted at the perimeter of medium and high-risk areas, and at every access point.

High Risk Areas

High risk areas are those areas where Hydrogen Sulphide is likely to be continually present above the 8 hour Time Weighted Average Long Term Exposure Limit of 5 PPM (see *Appendix A*) for long periods during normal operations and where routine monitoring is mandatory.

Note: It is usual BP practice to paint pipe work and vessels containing hazardous concentrations of Hydrogen Sulphide yellow, or with yellow bands.

In areas where H_2S is likely to be encountered, sufficient self-contained (positive pressure) breathing apparatus sets (working sets) shall be kept for all persons normally working in that area. Two full spare air cylinders for each set shall be held in reserve in an open-air safe area. Adequate numbers of 10-minute duration escape sets shall also be provided.)

If the presence of H_2S in the air is suspected or alarm activated, personnel must leave the area immediately, if possible heading into the wind.

Entry into such areas shall be permitted only under a planned entry procedure and a work permit. Personnel, working in pairs, must wear self-contained positive pressure breathing apparatus or an airline. A standby rescue team should be in attendance.

Consideration should be given to the installation of wind direction indicators (windsocks or flags) in high-risk areas, to aid direction of escape upwind/across wind.

Medium Risk Areas

Medium risk areas are those areas where Hydrogen Sulphide may occur during certain planned operations and maintenance activities and where monitoring is carried out during these operations.

Only authorized persons should enter these areas. Work shall be carried out under permit to work procedures that should list precautions to be taken. The area should be monitored with portable Hydrogen Sulphide detection equipment during these

activities.

In both the above cases, it is vital that the source of any H_2S is clearly identified and an assessment made of any potential for deterioration.

Low Risk Areas

Low risk areas are those areas where Hydrogen Sulphide is not likely to occur in normal operations, and if it does occur it will exist only for a short time, e.g. system malfunction.

Personnel entering low risk areas must be made aware of the possibility of the presence of Hydrogen Sulphide and the emergency arrangements in force at the site.

Notices warning of the presence of Hydrogen Sulphide and stipulating access requirements must be posted at the perimeter of medium and high-risk areas, and at every access point to them.

5.2 BREATHING APPARATUS TRAINING

All personnel who are likely to work in an environment where there could be potential exposure to Hydrogen Sulphide shall be given **positive pressure breathing apparatus training** (self-contained and air-line sets). Only fully trained personnel shall be permitted to wear breathing apparatus and they must receive local refresher training every six months.

Personnel should be trained where and when to remove breathing apparatus after completing a job since there may still be Hydrogen Sulphide present. They should either remove the set at a remote location or test the atmosphere adjacent to the job first.

Training shall also be given in mouth-to-mouth resuscitation and the use of resuscitation equipment.

On plant where high concentrations of Hydrogen Sulphide are likely, consideration should be given to the use of escape breathing apparatus sets. These can either be carried by personnel or located at various parts of the plant.

5.3 CONTINGENCY PLANNING

It is not feasible to provide a single plan for every contingency at every site. Plans must prepared on a site by site basis, and should cover:

- planning for a Hydrogen Sulphide release
- personnel training
- Hydrogen Sulphide monitoring.

In addition, sites that have a Hydrogen Sulphide risk must have an alarm system that is understood by all personnel.

If the presence of H_2S in the air is suspected, personnel must leave the area immediately. The Area Authority, accompanied by one other person shall don

breathing apparatus and investigate, by using suitable test equipment, the concentrations of H_2S in the air.

Upon recognition of an H_2S gas hazard (e.g. by smell) or on activation of personnel H_2S detectors. As a minimum, the following steps should be incorporated into any response to a Hydrogen sulphide release:

1. Evacuate the area, moving across wind if possible.
2. If necessary, don an emergency BA escape set to effect safe escape.
3. Do not attempt to rescue other personnel from the H_2S area unless equipped with BA set (leave it to the rescue team).
4. A person outside the H_2S risk area should oversee personnel working in an H_2S atmosphere or on equipment where H_2S is present.

Reference should be made to Appendix B, for what to do on discovery of an H_2S leak or finding a victim of H_2S exposure. (Any accidents/incidents shall be reported in accordance with Accident and Incident Investigation and Reporting Procedure).

Planning for a Hydrogen Sulphide Release

A **site action plan** should be prepared showing the location of safe areas according to prevailing wind conditions. For onshore sites usually three safe Areas will be defined:

- Two areas will be in the open air on opposite sides of the site (so that at least one will be upstream of any incident). These areas shall be used for mustering essential personnel.
- The third area (at a remote off-site location) will be used to muster all non-essential personnel.

On offshore Installations, there should be one suitable Temporary Safe Refuge (TSR) where personnel can withdraw to in the event of a release of H_2S. This area of module should have shutoff dampers on the Heating, Ventilation and Air Conditioning (HVAC) system to prevent the ingress of H_2S.

Protective / emergency equipment should be stored or located near to the two Safe Areas used for essential personnel. In addition, in areas where H_2S is likely to be encountered, sufficient self contained positive pressure breathing apparatus sets shall be kept for all persons normally working in that area. Two full spare air cylinders for each set shall be held in reserve in an open-air safe area. Adequate numbers of escape sets shall also be provided.

A **trained rescue team** should be established.

Where operations are being carried out in a known Hydrogen Sulphide area, and where personnel may be required to wear breathing apparatus, it should be ascertained that personnel have no obvious medical conditions that might endanger their health or performance prior to breathing apparatus training.

Training of Personnel

Al personnel shall be informed of the hazards relating to Hydrogen Sulphide and they shall receive instruction in the correct use of any personal safety equipment,

Hydrogen Sulphide detectors, warning systems and evacuation procedures.

Information relating to Hydrogen Sulphide safety measures shall be prominently displayed at strategic points around the site / installation.

All personnel working in the crew and rescue team should be instructed in basic first aid procedures applicable to victims of Hydrogen Sulphide exposure.

All ERT and rescue team members should be instructed in basic first aid procedures applicable to victims of H_2S exposure. Training exercises and drills must be carried out on a regular basis.

Monitoring for Hydrogen Sulphide

See paragraph *4.2 Hydrogen Sulphide Portable Detection Equipment*.

6 HYDROGEN SULPHIDE FIRST AID

Symptoms of acute Hydrogen Sulphide poisoning reduce rapidly when inhalation of the gas ceases. It is therefore vital to get casualties into fresh air and to summon medical aid immediately.

Casualties should be kept at rest. If their breathing is slow, laboured or impaired, artificial resuscitation (mouth to mouth or by the use of a mechanical resuscitator) may be necessary.

Note: Before commencing mouth-to-mouth resuscitation, any gas in the casualty's lungs should be first expelled by pressing down on the chest.

Warning: Rescuers must wear positive pressure self-contained breathing apparatus (BA).

Monitoring the Presence of H_2S

Portable H_2S monitors must be provided so that, in the event on an H_2S escape, the extent of the danger area can be established.

H_2S monitors should be set to current occupational exposure limits i.e. 5ppm.

APPENDIX A

Classification of Physiological Responses to Hydrogen Sulphide Classification of Physiological Responses to Hydrogen Sulphide

Occupational Exposure Standards (OESs) for airborne substances hazardous to health are controlled by either Long Term Exposure Limits (LTELs) or Short Term Exposure Limits (STELs) or both. These are normally expressed as Time Weighted Average (TWA) concentrations and are calculated in the case of the long term exposure limit, to restrict the total intake of H_2S by inhalation over one or more work shifts, and to control the effects due to brief exposure of H_2S at higher levels in case of the short term exposure limit. In the case of Short Term Exposure Occupational Exposure Limits for H_2S are defined as follows:

Time Weighted Average Concentrations
The limits refer to the maximum exposure concentration when averaged over an 8-hour day or a 15-minute period respectively.

Long-term exposure limit (the 8 hour Time Weighted Average value) for H_2S = 5 PPM (7mg/m^3).

In case of the standard 12 hour shift, the long term exposure limits for H_2S would therefore be 8/12 of 5 PPM = 3.3PPM.

Short-term exposure limit (the 15 minute Time Weighted Average value) for H_2S = 10 PPM (14mg/m^3).

The way H_2S affects people depends on the level and timescale of exposure and individual susceptibility to the gas (alcohol in the bloodstream enhances the effects of H_2S poisoning).

It should be noted that the nose is much more sensitive to H_2S than detection equipment.

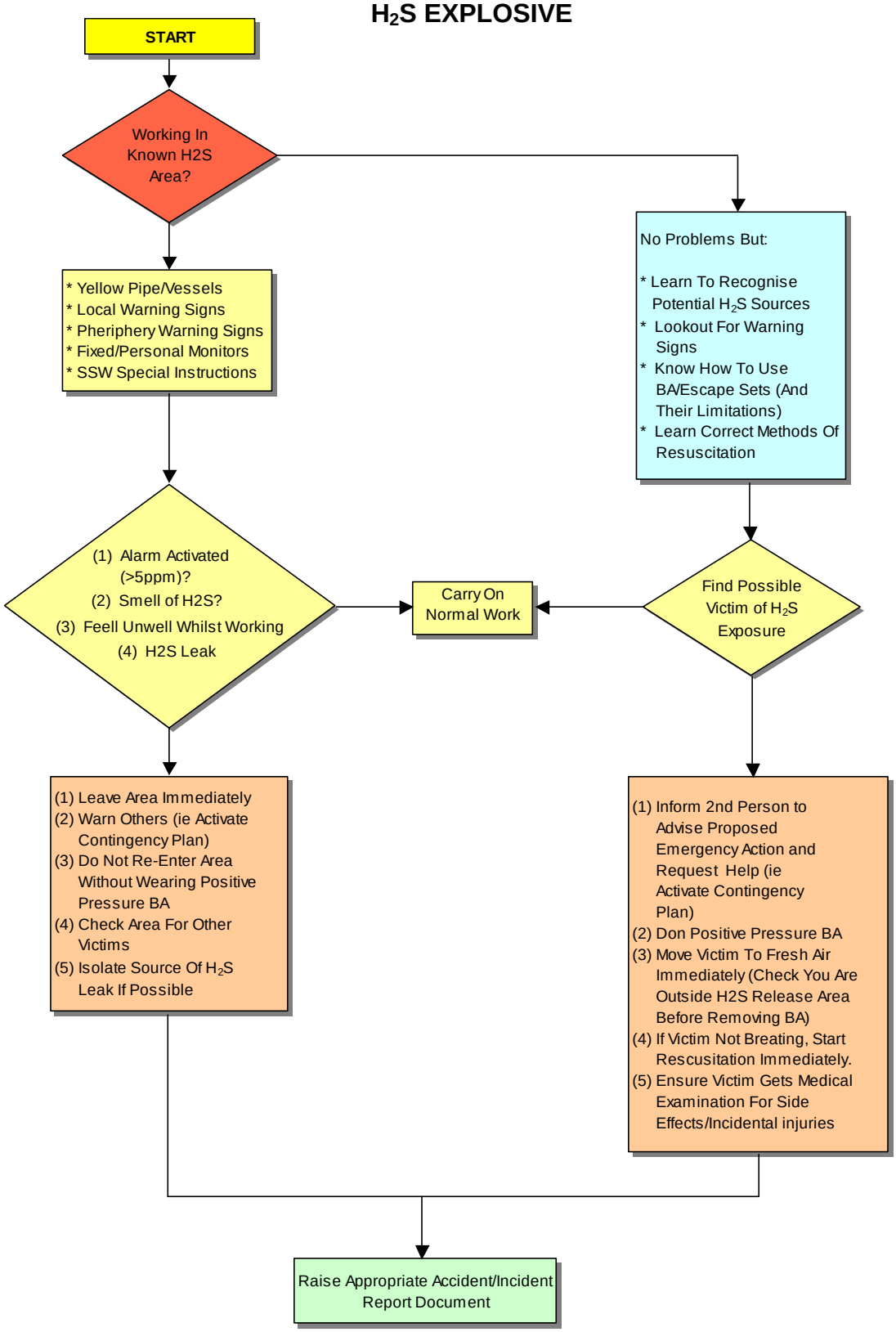
However, it is less proficient at determining the difference between a small amount and an amount large enough to impair the sense of smell, therefore the nose should not be relied on other than as an initial alert to the presence of the gas.

A summary of physiological responses to various concentrations of H_2S is given in Table 1.

Table 1 - Physiological Response to H_2S

Physiological Response	Concentration (ppm)
Detectable by smell	0.0025
LTEL (the 8-hour TWA value)	5
STEL (the 15-minute TWA value)	10
Low concentration: possible reparatory effects and eye irritation	About 30
Loss of sense of smell	About 100
Medium concentration: dizziness, headaches, nausea, abdominal pains after 15 minutes, dangerous after 30 minutes exposure, rapidly produces unconsciousness and death if effective resuscitation is not applied	About 500
Rapid unconsciousness followed by death within minutes	Over 1000

APPENDIX B DISCOVERY OF AN H_2S LEAK OR FINDING A VICTIM OF H_2S EXPLOSIVE



APPENDIX C

Central Azeri

The potential for H_2S to be present in the reservoir fluids has been identified; therefore H_2S detectors are installed at the shale shaker on Central Azeri. The H_2S Alarm consists of GPA audible alarm with Yellow Beacons in high noise areas. In addition two Red Toxic Gas beacons will be triggered in the effected zone.

There is no voting for these detectors therefore a single low-level detection gives alarm at fire and gas panel only. While a single high level detection alarms at fire and gas panel and sounds a H_2S alarm via the PA system. Activates Toxic Gas beacons in the affected fire zone and isolates all plug and sockets in naturally ventilated areas.

In the event of the activation of the H_2S detectors personnel must leave the area immediately, moving across or up-wind if possible. If necessary don emergency BA escapes set to effect safe escape. Only personnel with suitable breathing apparatus are allowed to re-enter the area