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| <b>EXXON</b><br>EXXON<br>ENGINEERING | <b>SAFETY IN PLANT DESIGN</b><br><b>FLAMMABLE GAS, TOXIC GAS,<br/>AND FIRE DETECTION SYSTEMS</b><br><br><b>PROPRIETARY INFORMATION</b> - For Authorized Company Use Only | <b>DESIGN PRACTICES</b> |                 |
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#### Revision Memo

|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>12/99</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Page 3        | Updated references.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Page 5        | Added clarification to second bullet on availability of toxic gas detector technologies                                                                                                                                                                                                                                                                                                                                                                                     |
| Pages 5 and 6 | Added "Potential" to the definitions of the H <sub>2</sub> S Hazard Areas. Changed the upper limit of the Low Potential H <sub>2</sub> S Hazard Area and the lower limit of the Medium Potential H <sub>2</sub> S Hazard Area from 1000 vppm to 250 vppm along the lines of the EBSI proposal in report MR.35DQ.97. Clarified definitions of all H <sub>2</sub> S Hazard Areas. Added flowchart to aid in the determination of the potential H <sub>2</sub> S hazard areas. |
| Page 7        | Added section on Application in HF Detection. Updated the perimeter monitoring technology.                                                                                                                                                                                                                                                                                                                                                                                  |
| Page 8        | Updated the catalytic point detector technology. Updated the IR Absorption point detector technology. Updated the Open-Path IR detector technology. Removed the following incomplete and unnecessary sentence: "For a fixed size hole, the amount of gas released at 200 psig (14 barg) is roughly equal to the amount of vapor released from liquid butane at 100°F (38°C)." Added "higher risk" to definition of materials involved.                                      |
| Page 9        | Added fifth bullet: "Control valves operating above 200 psig (14 barg)" to the list of leak sources. Clarified the air monitoring recommendation for "Cooling tower exhaust" (5th bullet) and removed the following statement: "Hydrocarbon analyzers in the return water may be substituted for hydrocarbon vapor detectors."                                                                                                                                              |
| Page 10       | Added "toxic gas" to detectors that are not required.                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Page 11       | Added statements related to plastic tubes that may be used as alternatives to traditional fire-sensing devices.                                                                                                                                                                                                                                                                                                                                                             |
| Page 16       | Added "Flame Detector" to title of <b>Figure 3</b> for clarification and removed the "6 in. (150 mm) Diameter". Also corrected <b>Figure 4</b> distance scale's lowest value to 10 from 1.                                                                                                                                                                                                                                                                                  |
| Page 17       | Corrected the degree signs on the viewing angles shown.                                                                                                                                                                                                                                                                                                                                                                                                                     |



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## SCOPE

This section describes the use of detection systems for flammable or toxic gas releases and for fires. Early detection is a key to controlling a release or fire and mitigating its effects.

## REFERENCES

### DESIGN PRACTICE

X-G Pumps - Shaft Sealing

### INTERNATIONAL PRACTICE

IP 4-3-1, Plant Buildings for Operation and Storage  
IP 4-3-3, Shelters for Process Analyzers  
IP 10-8-1, Combustion Gas Turbines  
IP 15-8-3, Combustible and Toxic Vapor Detection Systems  
IP 16-6-1, Substation Layout

### OTHER LITERATURE

*Outdoor Installation of Flammable Gas Detectors*, ER&E Report No. EE.77E.78.  
*Guidelines on Safety Requirements for H<sub>2</sub>S Monitoring*, ER&E Report No. EE.15E.85.  
*Guidelines for the Use of Fire Detectors*, ER&E Report No. EE.43E.87.  
*Marketing Terminal Fire Detection Systems - Engineering Standard*, ER&E Report No. EE.2M.90.  
*National Fire Alarm Code*, National Fire Protection Association - NFPA 72  
*HF Alkylation Consequence Reduction Technology; Best Proven Reasonable Design for Detection, Automation and Initiation*, ER&E Document No. 99SR37.  
*Hydrogen Sulfide Handling Practices at refineries and Chemical Plants: A Benchmarking Study*, EBSI Report No. MR.35DQ.97.  
*Pump Sealing Technology Manual*, ER&E Report No. TMEE-023.  
*Proof of Principle, Development and Field Test of a New Commercially Available Hydrogen Sulfide Open Path Monitor Using Tunable Diode Lasers*, ER&E Report No. EE.125E.98.

## GENERAL

While the goal in design and operation of refineries and chemical plants is a plant free of gas releases and fires, the risk of a release or fire is never zero. Some areas of the plant have a greater risk than others. The risk is influenced by the material contained, the conditions under which it is contained, and the equipment and procedures used to contain it.

The risk from flammable or toxic gas releases or fires can be reduced by early detection and subsequent mitigating actions. Detection and response to a release or fire, is often effectively provided by the process operators, in conjunction with their daily activities. However, sometimes the nature of the event is such that a more rapid detection and response is required than can be expected from the operator. Additionally, the increased use of remote monitoring and automation can reduce the time operators spend on the unit, possibly increasing the time to detect a leak. When more rapid detection is necessary than can be provided by the process operator, an instrumented monitoring system can be used.

## RISK FROM FLAMMABLE AND TOXIC MATERIAL RELEASES

The risk from a flammable or toxic material release is the combination of the probability of a leak occurring and the potential consequences should the leak occur. In determining the probability of a leak, the type of operation, the operating conditions, and the equipment involved are all considered. In determining the consequences, the material contained, the size of the leak, the proximity of the leak to other equipment or the fence line, and speed with which the leak might be detected without instruments are all considerations.

All releases occur as a result of some failure. These failures can generally be classified as follows:

- Human errors (e.g., failure to close a drain valve, incorrect valve opened).
- Active equipment failures (e.g., pump seal or bearing failure).
- Passive equipment failures (e.g., pipe gasket failure or pipe rupture).

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## RISK FROM FLAMMABLE AND TOXIC MATERIAL RELEASES (Cont)

In addition to this general classification, data on typical refinery and chemical plant manufacturing indicate certain areas which have historically caused release problems. Areas of higher probability include:

- Open sampling or drain points.
- Equipment opened for maintenance.
- Seals on rotating equipment, i.e., pumps and compressors.
- Atmospheric seals on sulfur units.
- Flange gaskets.
- Tanks, due to overfilling.
- Small lines in vibrating service.
- Lines in corrosive/erosive service.
- Plate and frame heat exchangers.

When a leak does occur the consequences may range from inconsequential effect to personnel health effects, fire, or vapor cloud explosion. The severity of the consequences depends on the following factors:

- The material leaked, specifically its toxicity or flammability.
- The mass rate leaked which is a function of the material vapor pressure, the operating temperature and pressure, and the cross-sectional area of the opening.
- The proximity of the leak to in-plant personnel, ignition sources, and the property line.
- The ability to detect the leak and stop or reduce the rate.
- Atmospheric conditions, especially wind velocity and direction.

Toxic gas, flammable gas, and fire detectors can reduce the risk of a release by reducing the severity. Severity is reduced because faster response is possible. The response may be carried out by the operator or through an automated response. Automated responses include stopping and/or isolating equipment and automated foam, water spray, or deluge systems.

While vapor and fire detectors reduce risk by decreasing the severity of a release, other design changes and/or instrumentation may provide equivalent risk reduction by reducing the probability of a release. Designs which reduce the probability of a release may be considered as an alternative to detectors, e.g., pump seal leak detection in place of toxic or flammable vapor detectors. Also see **ALTERNATIVES TO TOXIC AND FLAMMABLE GAS DETECTORS** later in this section.

## TOXIC GAS DETECTORS

Toxic gas often is present in refinery or chemical plant streams. Hydrogen sulfide ( $H_2S$ ) is often present in refinery streams, but hydrogen fluoride (HF), chlorine ( $Cl_2$ ), carbon monoxide (CO), anhydrous hydrogen chloride (HCl), bromine ( $Br_2$ ), and ammonia ( $NH_3$ ) may also be present at a site. Small releases of toxic gas are a threat to personnel working directly where the leak occurs. Medium releases may affect other personnel working on the unit but not directly at the release source. Large releases may produce toxic concentrations outside the unit or even outside the plant fence line.

Toxic releases may be generally classified by the cause of the release as follows:

- Releases resulting from venting or draining equipment, typically for sampling or as part of maintenance. Toxics are not intentionally vented but equipment may not be properly gas freed or the toxic concentration may not be properly identified.
- Releases from "active" equipment. From previous experience, active equipment which is a likely release point includes: pump and compressor seals, sulfur plant seals, and  $H_2S$  incinerators which have lost flame. Since the amount of active equipment is low, the number of likely release points is relatively few and known in advance.
- Releases from "passive," higher integrity equipment, such as pipe flanges and pipe/vessel wall ruptures. These are lower probability release points than for active equipment. Unlike active equipment, the amount of passive equipment is very large and the most likely release points are not easily identified.

Different detection methods are employed for each type of release.

- Since releases which occur from opening equipment immediately expose personnel, the absence of toxics must be confirmed beforehand. Effective control of releases is by training, effective work permits including contractor monitoring, personal or portable gas detectors, and the use of personnel protection like breathing apparatus when appropriate. Sampling systems should be designed for closed transfers whenever possible.

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### TOXIC GAS DETECTORS (Cont)

- Releases from higher potential, active equipment should be monitored with toxic gas detectors. Toxic gas detectors available for use in refineries and chemical plants are based on a wide range of technologies including electrochemical sensors, solid state sensors, ion mobility sensors, and FTIR and laser diode open path systems. Detectors should be located close to the potential leak source. This will signal the problem to those in the general area or those who might enter the area.
- Releases from higher integrity, passive equipment usually do not require monitoring. Because of the lower likelihood of a release and the very large area covered by passive equipment (e.g., pipe flanges) complete monitoring is not possible. Manifolds with a large number of valves and flanges, representing a concentration of leak sources, may be locally monitored if the toxic concentrations are high.

### ♦ S APPLICATION IN H<sub>2</sub>S DETECTION

H<sub>2</sub>S is the toxic gas most commonly handled in refineries. Three hazard levels are defined below for H<sub>2</sub>S operation: high, medium, and low. A flowchart that aids in the determination of the potential hazard areas is also provided.

High potential hazard areas contain **BOTH** a potential release source **AND** high H<sub>2</sub>S concentrations. Examples of potential release sources include floating roof tank seals, pump and compressor seals, sulfur plant seal legs, H<sub>2</sub>S incinerators, vents, drains and sampling connections. High H<sub>2</sub>S concentrations are defined as those where the H<sub>2</sub>S concentration in the vapor phase of the contained stream is above 2 volume%. If H<sub>2</sub>S is dissolved in a liquid, and an isenthalpic flash of the liquid at atmospheric pressure produces a vapor with more than 2 volume% H<sub>2</sub>S, the stream would also be considered high concentration. Typical sources with higher release potential and high H<sub>2</sub>S concentrations include, but are not limited to:

- Amine regenerator overhead pumps.
- Sour water stripper overhead pumps.
- Compressors for H<sub>2</sub>S rich gas.
- Claus plant atmospheric seals.
- Air intakes in Claus plants.
- Burners of H<sub>2</sub>S combustors and incinerators.
- Water seals on flare drums which often have a high H<sub>2</sub>S concentration.

Medium potential hazard areas require **BOTH** a potential release source (see examples under High Potential Hazard Areas) **AND** contained H<sub>2</sub>S concentrations between a minimum of:

- 250 volume ppm, if potential exposure involves possible direct exposure to the vessel vapor space, such as sampling or opening vessels, or
- 500 volume ppm, for dispersed process exposure not involving possible direct exposure to the vessel vapor space and a maximum of 2.0 volume%.

Typical examples for such areas include:

- Sour water drawoff facilities.
- Sour crude tanks and slop tanks.
- Asphalt and heavy fuel oil tanks.

Low potential hazard areas contain **EITHER** a potential release source (see examples under High Potential Hazard Areas) with H<sub>2</sub>S concentrations of between a minimum of 10 vppm and a maximum of:

- 250 volume ppm, if potential exposure involves possible direct exposure to the vessel vapor space, such as sampling or opening vessels, **or**
- 500 volume ppm, for dispersed process exposure not involving possible direct exposure to the vessel vapor space,

**OR**

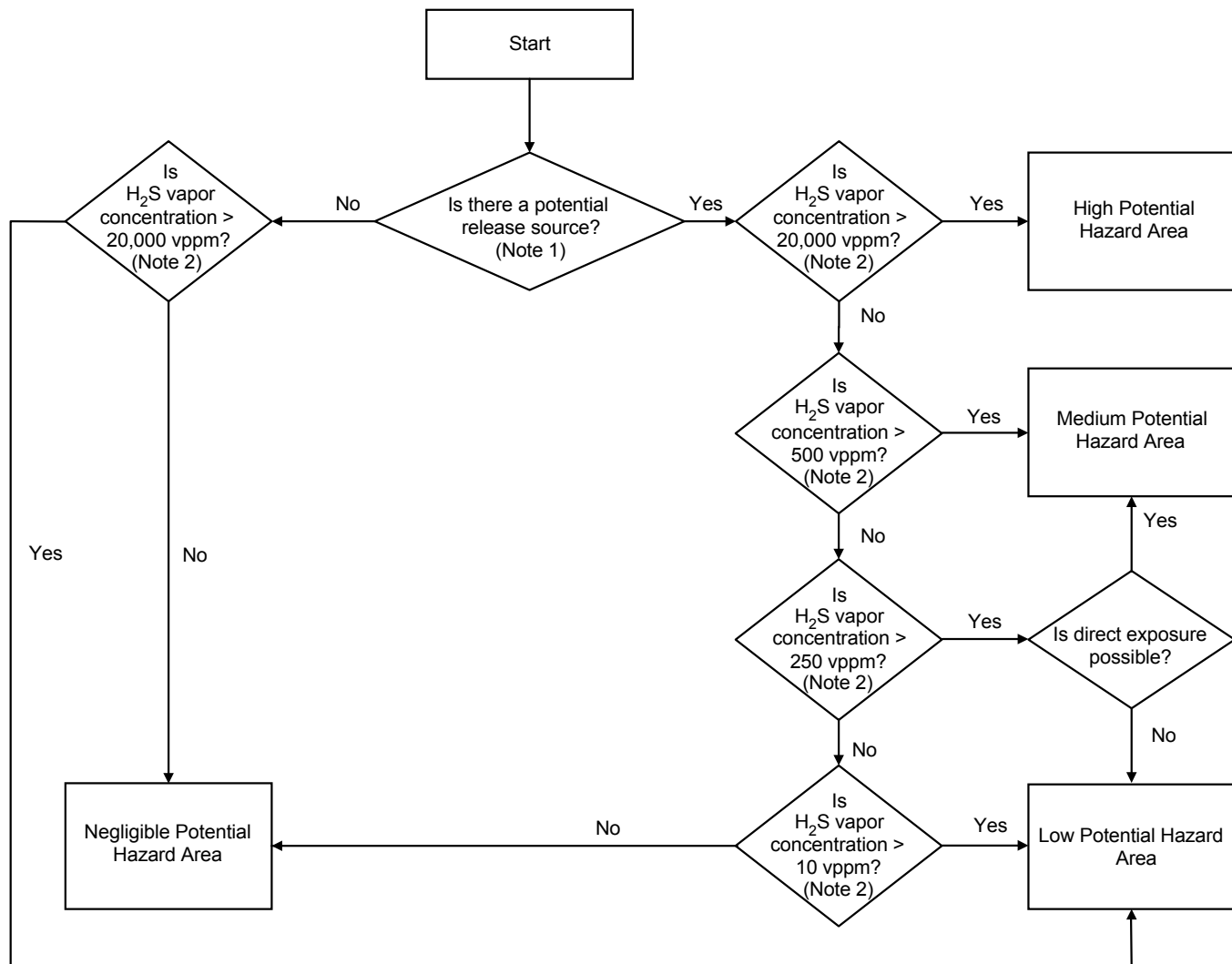
high H<sub>2</sub>S concentrations within passive, high integrity equipment. High H<sub>2</sub>S concentrations are defined as those where the H<sub>2</sub>S concentration in the vapor phase of the contained stream is above 2 volume%. If H<sub>2</sub>S is dissolved in a liquid, and an isenthalpic flash of the liquid at atmospheric pressure produces a vapor with more than 2 volume% H<sub>2</sub>S, the stream would also be considered high concentration. Examples of passive, high integrity equipment includes process vessels, piping, flanges, and other static equipment (no moving parts).

### TOXIC GAS DETECTORS (Cont)

Typical examples of Low Potential Hazard areas include:

- Light ends pumps handling fluids with low H<sub>2</sub>S concentrations (e.g., untreated propane).
- Sour fuel gas at fired boilers as long as the gas contains less than 500 vppm H<sub>2</sub>S.
- Heavy fuel loading.
- Acid gas transfer lines (typically high H<sub>2</sub>S concentration but no potential release source).

#### FLOWCHART TO DETERMINE H<sub>2</sub>S POTENTIAL HAZARD AREAS



Note 1: Potential Release Sources are defined above, under "Application of H<sub>2</sub>S Detection"

Note 2: H<sub>2</sub>S Concentrations are defined above, under "Application of H<sub>2</sub>S Detection"

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Additional information on H<sub>2</sub>S hazard levels may be obtained from the EBSI Report No. MR.35DQ.97, titled "Hydrogen Sulfide Handling Practices at refineries and Chemical Plants: A Benchmarking Study."

**Fixed H<sub>2</sub>S detectors are recommended for use within high potential hazard areas.** The detection points should be located at each high potential release point. Ideally, the detectors should be located within 5 ft (1.5 m) of the leak point, and between the centerline and 2 ft (60 cm) below. Access may require some adjustment to the location. The detector should alarm between 10 and 20 ppm. When multiple sources are located together, e.g., pumps, a single monitor can service two sources, provided the sources are located within 10 ft (3 m) of each other.