

A
Project Report
On

**“HYDROGEN SULFIDE (H₂S) MANAGEMENT AND
CONSERVATIVE & CONSEQUENCE ANALYSIS OF
HYDROGEN SULFIDE GAS RELEASE DISPERSION MODEL
FROM DHDS UNIT”**

By

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Roll No: R070208008



College of Engineering
University of Petroleum & Energy Studies
Dehradun
May, 2010

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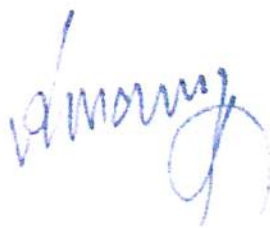
“HYDROGEN SULFIDE (H₂S) MANAGEMENT AND CONSERVATIVE & CONSEQUENCE
ANALYSIS OF HYDROGEN SULFIDE GAS RELEASE DISPERSION MODEL FROM DHDS
UNIT”

A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
Health, Safety & Environment Engineering.

By

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Under the guidance of



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May, 2010



CERTIFICATE

TO WHOM SO EVER IT MAY CONCERN

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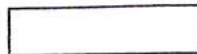
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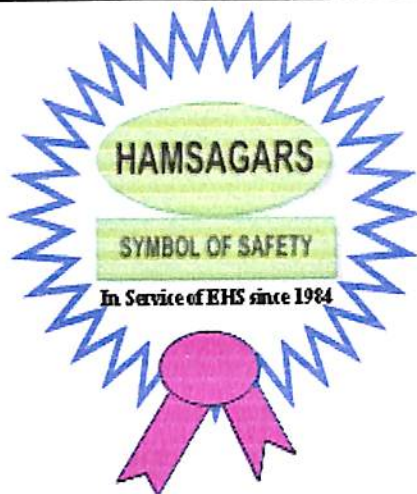
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HYDROGEN SULFIDE GAS RELEASE DISPERSION MODEL FROM DHD'S
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This is to certify that the work contained in this thesis titled **“HYDROGEN SULFIDE (H₂S) MANAGEMENT AND CONSERVATIVE & CONSEQUENCE ANALYSIS OF HYDROGEN SULFIDE GAS RELEASE DISPERSION MODEL FROM DHDS UNIT”** has been carried out by M.MALLA REDDY under our supervision and has not been submitted elsewhere for a degree.

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ACKNOWLEDGMENT

With immense pleasure, I would like to present this Project report related to **“Hydrogen sulfide (H₂S) management and Conservative & Consequence Analysis of Hydrogen sulfide Gas Release Dispersion model from DHDS Unit”**. It was really a great pleasure for me to get such a wonderful opportunity to learn from the Technical staff of Essar Oil Ltd. for 6 weeks.

First of all, I would like to offer heartfelt thanks to **Mr. Upendra Mistri Manager Safety Dept., Mr. J. Mahadik Head, Safety Dept., and Mr. P. Palanivelu, Head, Fire Dept., Essar Oil Ltd.** whose keen interest and excellent knowledge base helped me to finalize the topic of the Project. His constant support and interest in the subject equipped me with a great understanding of different aspects of the required material for this project work.

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SCOPE OF THE PROJECT

Consequence models are used to predict the size, shape, and orientation of hazard zones that could be created by release of hazardous materials

Dispersion calculation is often performed assuming a one-hour exposure to the gas. This is particularly true with air pollution studies since these studies are typically concerned with long term exposure to low concentration levels. For accidental release of toxic gases, shorter exposure time may be warranted since durations of many accidental releases are less than an hour

In this present work, 5 min & 15 min's of exposure to H₂S gas release is taken into consideration and their respective fatality rate at different Effective Locations are calculated for different probable failures of process equipments in the DHDS unit.

So, effective Management of H₂S is required and its technical management principles are covered.

To obtain a better understanding of the risk posed to people who live or work near hazardous materials facilities, and to aid them in preparing effective emergency response plans.

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1. OVERVIEW OF ESSAR GROUP

1.1 Company Profile:

ESSAR is one of India's largest corporate houses with leadership position in the high-growth infrastructure sectors of Steel, Energy, Power, Communications, Shipping & logistic, Construction and other like Agrotech, Exploration.

Group has Asset value of US\$ 60 billion in services and manufacturing. With a firm foothold in India, the Essar group has been focusing on global expansion with projects and investments in Europe, North America, the Caribbean, Africa, the Middle East and South East Asia. Privately owned and professionally managed, the Group is judiciously invested in the commodity, annuity and service business. Forward and backward integration, as well the use of state-of-the-art technology and in-house research and innovation have made Essar Group a leading player in each of its businesses. EGL's abiding philosophy is to be a low cost, high quality, technology driven group with innovative customer offering.

1.2 Vision and Mission

Vision: "We will be a respected global entrepreneur, through the power of Positive Action."

Mission: "We are committed to innovative growth, through our personal passion, reinforced by a professional mindset, creating value for all those we touch."

1.3 History:

The Essar Group was founded in 1969 by brothers Shri Shashi Ruia and Shri Ravi Ruia. The Ruia family's origins are in Rajasthan. Sometime in the 19th century, it moved to Mumbai and set up its own business. In 1956, Shri Nandkishore Ruia, father to Shri Shashi and Ravi Ruia, moved to Chennai, capital of the south Indian state of Tamil Nadu, to begin independent business activities. He mentored his two sons in the intricacies of business. When Shri Nandkishore Ruia passed away in 1969, the brothers laid the foundation of the Group.

The Essar Group began its operations with the construction of an outer breakwater in Chennai port. It quickly moved to capitalise on every emerging business opportunity, becoming India's first private company to buy a tanker in 1976. The Group also invested in a diverse shipping fleet and oil rigs, when the Government of India opened up the shipping and drilling businesses to private players in the 1980s.

Then, in the 1990s, Essar began its steelmaking business by setting up India's first sponge iron plant in Hazira, a coastal town in the western Indian state of Gujarat. The Group went on to build a pellet plant in Visakhapatnam and eventually a fully integrated steel plant in Hazira.

Through the 1990s, with the gradual liberalisation of the Indian economy, Essar seized every opportunity that came its way. It diversified its shipping fleet, started oil & gas exploration and production, laid the foundation of its oil refinery at Vadinar, Gujarat, and set up a power plant near the steel complex in Hazira. The Construction business helped the Group build most of its business assets. Essar also entered the GSM telephony business, establishing India's first mobile phone service in Delhi (branded Essar Cellphone) with Swiss PTT as the joint venture partner.

2. ESSAR GROUP OF COMPANIES

1. Essar Steel Ltd.
2. Essar Oil Ltd.
3. Essar Power
4. Essar Construction Ltd.
5. Essar Shipping and logistic
6. Essar Telecom
7. Essar BPO (Agies Ind Ltd.)
8. Essar Agro Tech

2.1 Essar Steel:

Essar Steel is a global producer of steel with a footprint covering India, Canada, USA, and Asia. It is a fully integrated flat carbon steel manufacturer--from iron ore to ready-to-market products. Its products find wide acceptance in highly discerning consumer sectors, such as automotive, white goods, construction, engineering and shipbuilding. It is India's largest exporter of flat steel products and aims to reach 25 MTPA capacity.

2.2 Essar Energy:

Energy - Essar Oil operates a fully integrated oil company. Its assets include development rights in proven exploration blocks, a 12.5 MTPA refinery in the west coast of India and over 1,000 oil retail stations across India. Plans are under way to increase its exploration acreage in various parts of the globe, expand its refinery capacity to 34 MTPA and open 5,000 retail outlets.

2.3 Essar Power

Essar Power has five power plants with a combined capacity of 1,200 MW. This includes two gas-based plants, of 500 MW and 515 MW capacities, and one liquid fuel based 32 MW plant in Hazira, a 120 MW co-generation plant in Vadinar and a 25 MW coal-based plant in Visakhapatnam. Work has started on three new plants that will take total capacity up to 6,000 MW.

2.4 Essar Shipping:

Essar Shipping Ports & Logistics Ltd. is an end-to-end logistics provider with sea and surface transportation services, oilfield drilling services, dry and liquid terminals, tankage and associated pipelines. It provides complete supply chain management services to clients in oil & gas, steel and power generation industries..

2.5 Essar Communication:

Essar Communications operates in four business segments: Telecom, telecom retail, telecom infrastructure and IT-enable services. It has a joint venture with Vodafone, a chain of telecom retail outlets, a nationwide telecom tower network and a presence in IT enabled services.

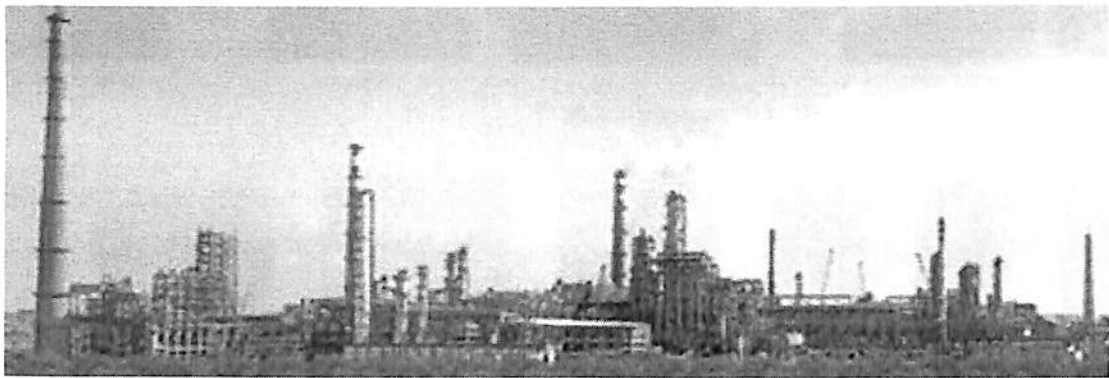
2.6 Essar Oil & Gas

ESSAR Oil & Gas is an integrated oil company operating in three divisions:-

- 1- Exploration & Production
- 2- Refinery
- 3- Marketing
- 4- Petrochemicals

3. ESSAR OIL REFINERY- OVERVIEW

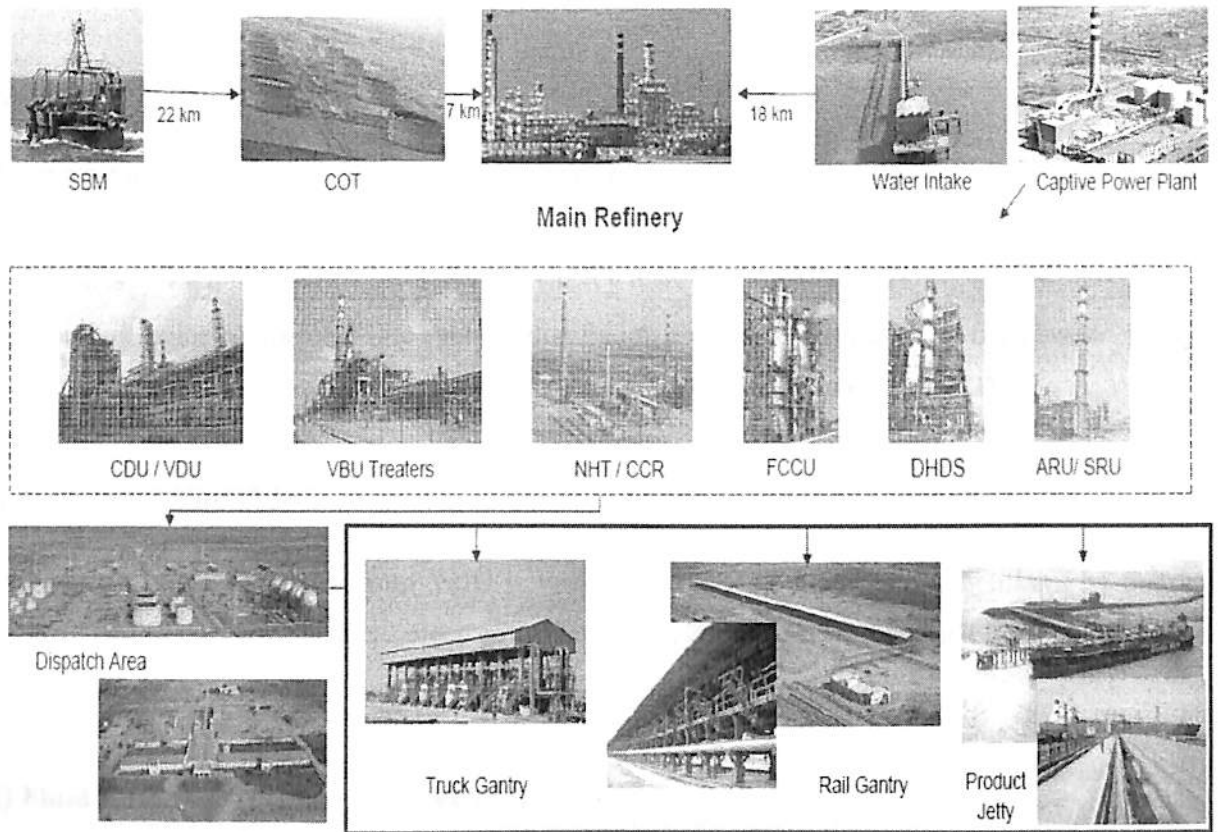
Essar's oil refinery at Vadinar in Jamnagar, Gujarat, is ideally located on India's West Coast in close proximity to the crude rich Gulf States. Vadinar is an all-weather deep-draft natural port. About 70% of India's crude imports land in and around this region. Besides, the refinery's location enables access to the fast growing markets in the north and western region of India through product pipelines. The eastern and southern parts of India will be serviced through the coastal route circling the country.



The refinery is operating at a capacity of 240,000 barrels per day (12 MTPA) with an investment of close to USD 2.2 billion. Essar Oil is in the process of increasing this refining capacity to 680,000 barrels per day (34 MTPA). The refinery has been built with state of the art technology with technical and project assistance from the world's leading consultants and equipment suppliers in the field. It is designed to handle a diverse range of crude mixes. The world-class refinery produces middle distillates like aviation turbine fuel, kerosene oil and high-speed diesel, as well as LPG and transport fuels conforming to Euro III and Euro IV product quality standards. Post expansion the refinery will have a Nelson Complexity of 12.8 with capability of processing tougher crudes and producing petroleum products of very high quality, meeting Euro V standards. The refinery is fully integrated with its own dedicated 120 MW co-generation power plant, port and terminal facilities. It includes rail-car and truck loading facilities and a Single Point Mooring (SPM) capable of handling vessels up to 350, 000 DWT with a marine product dispatch capacity of 14 MTPA.

The refinery has built-in environment friendly technologies for pollution management. A self-sustainable, 700-acre greenbelt, with over 3 lakh saplings, has been developed to ensure a green corridor around the entire refinery complex.

3.1 Essar Refinery ISBL Units



Administration

Existing Infrastructure to reduce expansion cost

Fig NO.1 Existing Infrastructure of Refinery

(a) Crude Distillation Unit (CDU)

This is a mother unit in which crude oil is fractionated into different product like light naphtha, heavy naphtha, L kero, H kero, LGO and HGO (heavy gas oil) by distillation process. The unit has measure equipment like world's tallest crude distillation column, fired heater, network of heat exchanger and air coolers, pumps, compressors and vessels. The unit operations are fully automated with advanced instrumentations.

(b) Vacuum Distillation Unit (VDU)

The main purpose is to upgrade atmospheric oil, received from CDU through distillation process carried out under vacuum and derive product like vacuum distillate LVGO (low vacuum gas oil), HVGO(heavy vacuum gas oil) and HHVGO (heavy heavy vacuum gas oil).

The unit has major equipments like vacuum distillation column, ejector system, fired heater, pumps, vessels and integrated network of heat exchangers, coolers and air coolers with CDU.

(c) Visbreaker Unit (VBU)

The vacuum residue received from VDU is further upgraded to derive more distillates by thermal cracking process. Cracking takes place in furnaces and distillates are obtained through two stage distillation in atmosphere and vacuum distillation column.

(d) Fluid Catalytic Cracking Unit (FCCU)

The LVGO and HVGO (received from VDU) as well as gas oils obtained from VBU are further upgraded into useful products like LPG, gasoline, diesel through catalytic cracking process carried out in specially designed reactor. The catalyst is also continuously regenerated and reused in the unit to reduce product cost.

(e) Saturated Gas Unit (SGU)

Refinery gases and light naphtha streams are processed in this unit to recover LPG components and reduce gaseous losses such as to maximize LPG production.

(f) Naphtha Hydrometer And Continuous Catalytic Reformer Unit

This is an integrated block that handles the naphtha produced from various units like CDU, VBU, and FCCU. Naphtha is hydro treated in NHT to remove sulphur and then catalytically reformed in CCR to improve octane number of gasoline as required for production of various grades of gasoline.

(g) Treating Units

The products such as LPG, gasoline, kerosene ATF, diesel etc. obtained from various units are the refinery undergoes finishing treatment to highest quality standard for these products mainly with respect to sulphur and olefins contents.

Following are the treating units

- (a) Diesel Hydro desulphurization (DHDS)
- (b) Kerosene Treating unit
- (c) Gasoline Treating unit
- (d) LPG Treating unit

(h) Environmental Unit:

Following are the environment units

- (a) Sulphur recovery unit
- (b) Amine wash and regeneration unit
- (c) Sour water stripping unit
- (d) Spent caustic treatment unit
- (e) Waste water treatment unit

(i) Support Services Units:

The refinery operation can be safe and sustained efficiently mainly through following units:

- (a) Desalination and Demineralization water unit
- (b) Cooling towers
- (c) Nitrogen generation unit
- (d) Air generation unit (for plant and instrument air)
- (e) Fire water system
- (f) Tempered water system
- (g) Steam generation unit
- (h) Captive power plant
- (i) Crude oil storage
- (j) Products storage
- (k) Products loading, unloading and dispatch facilities

4. INTRODUCTION TO HYDROGEN SULFIDE (H₂S)

One of the most common hazards associated with production and processing of oil & gas is the potential for exposure to Hydrogen sulfide. Hydrogen sulfide is present in oil & gas reserves in free state as well as in dissolved phase. Hydrogen Sulfide gas is presents in the upstream oil and gas facility. The typical sources of H₂S are the original reservoir, as a result of the hydrocarbon source material and the conditions under which it was converted to oil and gas. If this is the case then H₂S will be produced with the process fluids. Stagnant seawater systems, by the action of sulphate reducing bacteria (SRB). The reservoir after prolonged injection of water with oxygen (seawater, brackish, formation water) which may result in 'souring' of the fluids within it due to the action of SRB introduced during the injection process.

Any H₂S will be subsequently produced with fluids. Upon a leak from the processing stream, depending upon the concentration, the released H₂S will pose toxic risk to the operating people as well as the nearby public offsite to the facility. Although very pungent at first, H₂S quickly deadens the sense of smell, so potential victims may be unaware of its presence until it is too late to escape. Accidents and incidents involving H₂S can be prevented by good engineering practice, job planning and the proper use of personal protective equipments.

4.1 Personnel Exposure to H₂S

The risk to personnel on a facility where H₂S is present in the process fluids arises:

1. During an accidental release.
2. During normal maintenance operations,
e.g.: sphering (to enclose in or as if in a sphere), vessel entry, instrumentation or valve maintenance.
3. During venting from tanks

The level to which personnel could be subjected depends upon the concentration of H₂S in the process fluid and the dispersion and dilution under local conditions. All facilities potentially exposed to H₂S must be designed to resist the harmful effects of H₂S at the anticipated operating temperatures and pressures.

4.2 Properties and Characteristics of H₂S

4.2.1 H₂S Characteristics:

1. Highly toxic, flammable gas Colourless
2. At low concentrations, it is detectable by its characteristic rotten-egg odour. At higher concentrations (above 100 ppm), H₂S rapidly paralyses the sense of smell Odour shall not therefore be used as a warning measure.
3. Normally present as a gas and not as a liquid
4. Soluble in both water and hydrocarbon liquids. Pools of water or sludge at the bottom of a tank may thus contain concentrations of H₂S and if agitated or heated will release the gas
5. Pure H₂S is heavier than air and can collect in low-lying areas, especially pits and sumps which are closed-in and have poor ventilation. However, the gas density will depend on the molecular weight of the gas (Methane rich gas is lighter but will be heavy when mixed with higher hydrocarbon)
6. It can burn when mixed with air and when an ignition source is available

7. It burns with a blue flame and gives off sulphur dioxide (SO₂), which also provides a health hazard
8. It can form pyrophoric iron sulfide on the internal surfaces of carbon steel equipment containing H₂S. Pyrophoric iron sulfide can auto-ignite when coming into contact with air.
9. It is corrosive in the presence of water
10. It causes cracking and embrittlement of metals under certain conditions but steels of the correct quality, which are resistant to these forms of attack can be used.

4.3 Physical effects of H₂S

H₂S in the absence of free water can be considered to be non-corrosive, conversely when free water is present, especially during abnormal situations, such as start-up/shut-down, drilling or circulating out a kick, general corrosion will most probably take place. If carbon dioxide, oxygen, chloride ions, elemental sulphur are presents either individually or together then severe corrosion may take place within a very short period.

Pyrophoric iron sulfide can be formed on the internal surfaces of carbon steel equipment containing H₂S. Iron oxide present on the internal surfaces will react with the H₂S and form pyrophoric iron sulfide which, on exposure to oxygen can auto-ignite. Although pyrophoric iron sulfide can form and collect on all internal surfaces of carbon steel equipment, likely places of accumulations are Wire line lubricators, Filters, Vessels, Pipelines, spheres and pig receivers, Vent and flare systems, Storage tanks etc. Whilst steps can be taken to reduce the formation of pyrophoric iron sulfide it must never be assumed that there can be an absolute prevention of the reaction.

Therefore any equipment constructed of carbon steel which is in contact with sour hydrocarbons should be treated as if it contained pyrophoric iron sulfide. Great care must be taken on opening equipment likely to contain pyrophoric iron sulfide, for its removal, disposal.

4.4 Occupational Exposure Limits

TLV - TWA	: 10 ppm
STEL	: 15 ppm
CEILING VALUE	: 20 ppm
IDLH	: 100 ppm

NOTE:

It should be noted that where the source is rich in H₂S, gas or liquid, the transition from low to very high exposure may be instantaneous.

4.5 Sour Service Classification

Generally, the Oil & gas facilities are classified as 'Sweet facility' if the H₂S concentration in the gas phase, resulting from reducing the process fluid or process gas to atmospheric pressure, is up to 49ppm. If concentration is between 50ppm and 499ppm, it is termed as 'low risk sour facility' and the facility is termed as 'High risk sour facility' if the concentration exceeds 500ppm.

4.6 Toxic effect of H₂S

4.6.1 Concentration Effect

0.12 ppm	Odour threshold in humans
1 ppm	Odour of rotten eggs can be clearly detected.
10 ppm	Unpleasant Odour. Possible eye irritation. TLV for an 8-hour workday, 5 days per week.
15 ppm	STEL averaged over 15 minutes.
20 ppm	Burning sensation in eyes, irritation of the respiratory tract after one-hour exposure.
50 ppm	loss of sense of smell after about 15 minutes exposure.
100 ppm	loss of sense of smell after 3-15 min. coughing altered respiration, drowsiness after 15 min. 100 ppm conc. Is considered Immediately Dangerous to Life & Health (IDLH).
500 ppm	Unconscious after short exposure, breathing will stop if not treated quickly. Victims need prompt artificial and/or cardiopulmonary resuscitation (CPR) techniques.
700 ppm	Unconscious quickly. Breathing will stop and death will result if not rescued promptly.
>1000 ppm	Unconsciousness at once. Permanent Brain damage or death may result.

4.6.2 Health hazard

1. Vapour Inhalation

H₂S produces headache and dizziness, strong irritation, sour throat, irritation of upper respiratory tract. Pulmonary edema may result if the exposure is prolonged. At higher conc., nervous system may get affected and may be fatal.

2. Eye contact

Exposure to conc., varying from 20 – 150 ppm irritates eyes, causing severe pain & redness. Repeated exposure to low conc., cause conjunctivitis, photophobia and blurred vision

3. skin contact

H₂S produces irritating effect on skin. This is because hydrogen reacts with the alkali present in moist surface producing sodium sulfide on alkali. Causes frostbite if contact with liquid.

Systems of exposure

1. Eye, nose, throat irritation,
2. Suffocation,
3. Headache,
4. Dizziness.

4.7 Fire Hazard, First Aid and Personal Protective Measures

1. Fire Hazard, First Aid and Personal Protective Measures refer to the MSDS provided.

4.8 Evacuation procedures

Upon detection of an emergency event by Alarm system, announcement regarding the emergency shall be made manually on the public address system speakers and flashing beacons situated at strategic locations will glow with alarming. Security, fire and Evacuation team should rescue the plant personnel

4.9 General safety precautions

1. Even if there is no confined space, no person is allowed to work alone in H₂S prone areas.
2. Upon knowing high concentration of H₂S around, immediately escape from that area and do not try to find the source of leak without SCBA set.
3. Personnel performing jobs such as sampling, draining, inspections etc., in the vessels, pipelines containing H₂S must stay upwind and wear the recommended personal protective equipments.
4. Before entry & during the course of the work to a confined space that contain H₂S, the space should be purged and the H₂S concentration should be determined at regular intervals. Under no circumstances should the reliance be placed on the sense of smell to detect the presence of gas.
5. Where the presence of H₂S has been detected, the person entering the confined space should wear respiratory protective equipment of self contained type, a safety belt, full body harness and should be observed from the outside by a standby person.
6. Only Authorised & trained personnel having the H₂S entry I-cards & gate passes should be permitted in the H₂S prone areas.
7. Do not eat, drink or smoke during work at H₂S prone areas.
8. Naked flames should be prohibited in the areas where H₂S is handled or stored.

5. RISK MANAGEMENT OF H₂S HAZARDS

5.1 Hazards & Effects Management Process

The H₂S Risk Management System shall be applied to the consideration of H₂S throughout the design process and facility life. The Hazard and Effects Management Process (HEMP) for H₂S facilities shall consist of the following four basic steps:

1. Hazard Identification
2. Risk Assessment Qualitative/Quantitative
3. Risk Reduction, Control & Mitigation Recovery
4. Emergency preparedness planning.

5.2 Basic HSE Design philosophy for Sour service

The HSE design philosophy for sour facility shall be developed on three levels of Controls viz.

1. Preventive measures (reducing likelihood of hazards)
2. Mitigatory measures and
3. Recovery or recovery preparedness measures (reducing the chain of consequences arising from a top event).

5.3 The main aspects to be considered in design stage

1. **Minimizing process stream H₂S levels.** At concept and front end design stages, process selection should seek inherent safe design concepts to minimize H₂S levels, and avoid generation of process streams with very high levels of H₂S.
2. **Ensuring that risks associated with H₂S is quantified and recorded.**
3. **Minimizing exposure of operational and maintenance personnel to H₂S risk, e.g. by designing for unattended plant operation and minimum maintenance requirements.**
4. **Ensuring that detailed design minimizes the risk of H₂S release.**
5. **Ensuring that adequate personnel protection is provided.** This includes consideration of training, access control, gas detection, personal protective equipment, and escape.

6. H₂S RISK MITIGATION MEASURES

6.1 Design considerations to prevent H₂S release

The following guidelines shall be followed where a facility is classified as High Risk Sour or Low Risk Sour, to minimize the probability of H₂S release. All design considerations should consider the potential for the increase of H₂S concentration in process streams over the life of the plant and the probability that the classification may change from Low Risk to High Risk Sour over the production life cycle.

6.2 Material of Construction

Recommended Materials of Construction for sour service are CS, LTCS, SS316L, CS + Epoxy lining, CS clad with 825 Alloy, 625 Alloy, GRP etc. Materials & Piping department shall be consulted for selecting any particular material for sour service application.

6.3 Piping

1. To minimize corrosion, piping should be designed and installed in such a way those dead ends and areas of intermittent flow are eliminated.
2. Double block and bleed isolation shall be provided for High Risk Sour facilities.
3. Screwed fittings shall not be used in Sour Service. Flanges on piping in Sour Service should be minimized wherever practical, to reduce the number of potential leak sources.
4. To avoid flanged connections, welded valves are recommended.
5. Butt weld joints shall be used for high pressure sour service. Socket welds are not recommended.
6. Small bore connections shall be kept away from positions vulnerable to damage.
7. Small bore connection rating shall use higher flange rating from the systems (e.g. closed drains up to interface will use ratings same as of parent system) Valves preferably with less leak path, i.e., and top entry valves shall be considered.
8. Efforts shall be made to minimize the number of valves without affecting the maintenance requirements (review and assess during P&ID review, design reviews and HAZOP)
9. Higher size small bore fittings (preferably 2" size) are recommended for instrumentation connections. Material testing procedure shall be established to ensure the quality of fitting.
10. Drain line should not be less than 2" size. Consideration shall be given to reduce as much as possible leak sources without creating future problems during maintenance (to be reviewed during design review & HAZOP).

6.4 Sampling system

1. The location of sampling points necessary for future monitoring of facility classification shall be determined in consultation with Operations during design.
2. Samples should be taken from the areas of process plant expected to contain the highest concentrations of H₂S.
3. Typically 3 sample points would be expected to cover high, low and atmospheric pressure levels. Where possible these sample points have to be combined with sample points for other purposes.
4. Closed system bomb sampling systems shall be used in High Risk Sour service. Sample return lines should be routed back into a lower pressure process stream. Where this cannot be achieved, the sample return line shall be flared or vented.

6.5 Vents and drains

1. Depressurizing of equipment and process lines in Sour Service should be routed to a flare system.
2. Where this is not possible, venting may be allowed but shall be designed such that personnel cannot be exposed to H₂S concentrations above 10 ppm.
3. Special attention should be paid to the vents from Glycol Regenerator vapour outlets, which may contain very high levels of H₂S.
4. All liquid in sour service shall be piped into a closed drains system.
5. Vents and drains, which are for hydro testing, shall have their outlets blocked-off by blind flanges.

7. EQUIPMENT DESIGN CONSIDERATIONS

7.1 Centrifugal compressors

7.1.1 Shaft seals:

The following mechanical seal types shall be considered:

1. Dry gas seals (most preferred) for design pressure below 120 bar
2. Conventional oil film seals for design pressure above 120 bar
3. Mechanical seals (restricted by speed/pressure) used typically in refrigeration systems and small machines.
4. Dry gas seals shall be provided with a sweet buffer gas (e.g. nitrogen).

7.1.2 Seal vent

A seal leak detection system shall be installed. Seal vent gas shall be directed to flare. If a flare system does not exist, then local venting may be allowed. Reciprocating compressors seal leak detection system shall be installed. Blanket gas shall be used for distance piece venting. Vent gas shall be discharged to flare. If a flare system does not exist, then local venting may be allowed.

The compressor vendor shall provide process engineering flow schemes of lubricating and seal oil systems, seal gas and flare and drain connections, which clearly shows how the above sour service requirements have been incorporated into the design.

7.2 Gas turbines and gas engines

It is not recommended to use Sour gas should as fuel gas wherever possible. If sour gas is used then:

1. 1 Turbine engine materials and pipe work shall be compatible with the sour fuel.
2. 2 Duplex filters shall be installed on the fuel gas inlet to ensure removal of ferrous sulfide (fine black dust). These filters shall have water-flushing connections to avoid auto-ignition of pyrophoric iron when they are opened.
3. Turbine enclosures shall be ventilated to ensure a safe working atmosphere. Stack height shall be determined based on dispersion of exhaust gas to ensure that ground level concentrations of SO₂ do not exceed 5 ppm.

7.3 Centrifugal and positive displacement pumps

If Sour gas can be released in the event of a seal leakage, a seal leakage detection device should be installed. This device may be a seal pot with a level switch or pressure transmitter with switch, vented to a flare.

7.4 Instrumentation Design Considerations

1. Sour gas shall not be used as instrument gas. Pneumatic instruments in Sour Service shall use instrument air or sweet gas.
2. High reliability shall be ensured for all instrumentation systems for monitoring process over pressures through structured safety reviews like Safety Integrity Level.
3. Flexible connections shall be minimized, wherever possible.
4. Instrument tubing shall be replaced with hard piping in vulnerable locations and bracings shall be provided for small bore piping.
5. Instrumentation tapping shall be minimized using electronic indicators on transmitter loops, instead of additional pressure/temperature gauges.

8. DESIGN CONSIDERATIONS TO MINIMIZE EFFECT OF H₂S RELEASE

The following guidelines shall be followed to minimize the effect of an H₂S release.

8.1 Facility Layout

In selecting a facility site, consideration should be given to taking advantage of the prevailing wind direction, climatic conditions, terrain, transportation routes, and the proximity of populated or public areas. Clear entrance and exit routes should be maintained and confined areas within the facilities should be avoided. Location, spacing, and height of flares or vent stacks should be determined based on acceptable gas dispersion calculations.

8.2 Plant layout and spacing

Gas containing H₂S may be heavier or lighter than air, and so can accumulate in low or high places. Areas of restricted ventilation (both high and low), should be avoided so as to allow sour gas releases to disperse. Equipment handling sour fluid shall not be placed inside a totally enclosed area. The seals of rotating and reciprocating equipment which are a potential cause of High Risk Sour releases shall be given special consideration in plant layout and spacing to avoid trapping concentrations of H₂S and to take fullest advantage of the natural atmospheric dispersal effects. All working locations should be equipped with at least two escape routes in separate directions. These shall be located as far apart as possible. Elevated platforms shall use stairs only so that there is no hindrance when carrying breather sets or rescuing H₂S affected personnel.

8.3 Fences

Fences referred to in this document are all to stop personnel accidentally entering H₂S areas. The H₂S concentration at the facility fence during normal operation shall not exceed 10 ppm. Dispersion calculations shall be performed for all normal or operational vents.

8.4 Emergency escape exits

Emergency escape exits in Low Risk Sour and High Risk Sour facilities shall be provided such that escape is possible upwind of (or at worst, perpendicular to) the prevailing winds direction. As a minimum, escape gates shall be provided on opposite sides of the facility.

8.5 Warning signs

It is important that all equipment containing H₂S is clearly marked, with vessels and pipelines individually identified. This is in addition to area warning notices which should be in all working languages. If available, Country specific regulatory requirements shall be referenced for color coding of process equipment and pipe work containing H₂S in hazardous concentrations. H₂S designated areas should be identified by signs at each point of access. Any areas identified as being of particularly high risk, requiring special precautions or a higher level of training also be marked by appropriate signs and markers. Signs with pictorial content are preferred to text only. The codes ISO 3864, BS 5499, API RP 49 etc. may be used as Reference for developing proper safety signage layouts.

8.6 Windsocks

Each Sour Service designated facility shall have sufficient windsocks located so that they may easily be observed from any position within the station.

8.7 Temporary Refuge

Temporary refuge is a place where control room personnel will be adequately protected from relevant hazards following a major incident, and from where they will have access to the communications, monitoring and control necessary to ensure a safety and from where, if necessary, safe and complete evacuation can be effected. For High sour facilities, Temporary Refuge is recommended to be a part of Control room. The TR facility shall have an integrity against any Fire, smoke or toxic release for two hours. All cable entries to the TR shall be provided with gas tight transit blocks to minimize any penetration of gas.

On confirmed H₂S detection, the normal HVAC system of TR room shall shut down and fresh air inlets and exhausts shall close through motorized dampers. Following this, fresh air supply shall be reinstated through emergency HVAC system equipped with stand alone oxygen generator/ system. TR shall be kept under positive pressure to prevent any H₂S ingress. First aid medical facilities shall be available within TR room.

8.8 Assembly Points

The preparation of a comprehensive Emergency Evacuation Plan, including consideration of requirements for assembly points, shall be incorporated in the design of all High Risk and Low Risk Sour facilities. H₂S concentration during the worse credible accidental hydrocarbon release does not exceed 10 ppm. Where this would result in an assembly point location at an excessive distance from the facility (which might create additional problems of access and communication), a relaxation to a local concentration no greater than 20 ppm at the assembly point may be allowed provided that operations agreement is obtained. Where the possibility exists for an H₂S concentration greater than 10 ppm at an assembly point, local emergency procedures shall highlight that personal H₂S Gas Detectors may continue to alarm at the assembly point.

Dispersion calculations shall be performed for all Sour Service facilities to verify that assembly points are suitably located. Maps showing "worst case" H₂S concentrations contours shall be included in the Facility HSE Case and be displayed in the facility Control Room. The maps should include 50 ppm and 10 ppm contours.

8.9 H₂S Detection

The primary objective of fixed H₂S detection is to provide a warning to prevent entry of personnel into a known hazardous area. A fixed system does not in itself provide personnel protection and shall not be considered a substitute for entry precautions, personal H₂S detection or personnel protective equipment. A Fixed H₂S detection system should be provided around all sour process plant facilities.

8.9.1 Fixed detectors in open air

There are two approaches that can be applied to fixed H₂S detection in open areas:

- **H₂S Leak Detection:** A sensor is installed to detect leakage from a single source where the H₂S concentration in the fluid is relatively high and/or there is a relatively high probability of a leak. This may be applied on equipment for which an alternative design measure to minimize the probability and/or quantity of a release, or to direct it to a safe location, is not readily available.

- **H₂S Area Monitoring:** Sensors are installed to detect H₂S dispersed into the plant area from any source, and thus also cover less likely sources of release. This system may be applied in areas where the installation of individual detectors for each potential source cannot be justified. All fixed detectors shall have a range of 0 - 20 ppm, and shall alarm at 10 ppm.

8.9.2 Fixed detectors in enclosed areas

Buildings and enclosures where personnel can enter during normal operations (except well cellars), located adjacent to or in High Risk Sour or Low Risk Sour designated facilities, shall contain fixed H₂S detectors set to activate alarms at 10 ppm. For control rooms and other buildings with central air conditioning systems, which duct the chilled air throughout the building, one fixed H₂S detector shall be installed in the air conditioning inlet. The air conditioning unit shall be shutdown on H₂S detection. For High Risk Sour facilities, gas tight dampers should be installed on the inlet to the air conditioning unit, to close on detection of H₂S. For buildings where the air conditioning system does not duct air throughout the building (such as standard gathering station control rooms), fixed H₂S detectors shall be installed; one inside the main entrance and others in the principal rooms (e.g. the control room and the rest room).

8.9.3 Personal H₂S Monitors

H₂S personal monitors are available with plant operation persons. They are advised to keep H₂S personal monitor continuously with them while performing works like sampling, draining e.t.c., apart from this one must enter to H₂S prone areas with escape masks and personal monitors. H₂S personal monitors measures the gas between 0-100 ppm range and gives preset low alarm at 10 ppm and high alarm at 15 ppm. High alarm can be cleared only when the gas concentration drops below 15 ppm.

8.10 Alarms

Fixed H₂S detectors shall alarm audibly and visually at the:

- (1) Station control room panel.
- (2) Main entrance to the station.
- (3) H₂S detector location.
- (4) Remote monitoring centre, if telemetry is installed.

The alarm shall also be audible throughout the facility under all normal operating conditions. These detectors should be designated for H₂S alarm only, and should not normally be connected to the plant shutdown, due to the risk of spurious shutdown. Consideration may be given to a shutdown action on H₂S detection for High Risk Sour facilities, as part of an overall Safeguarding Philosophy. The alarms accept button shall be on the station control room panel. This alarm shall be distinguishable from the station fire alarm. On acceptance of alarm at control room, only the audible alarm in the control room should silence; the visual indication should remain on.

8.11 Ventilation Systems

8.11.1 Local ventilation

1. Contain and exhaust hazardous substances.
2. Use properly designed hoods.
3. Use hoods for charging and discharging.
4. Use ventilation at drumming station.
5. Use local exhaust at sample points.
6. Keep exhaust systems under negative pressure.

8.11.2 Dilution ventilation

1. Design ventilation systems to control low-level toxics
2. Design locker rooms with good ventilation and special areas or enclosures for contaminated clothing.
3. Design ventilation to isolate operations from rooms and offices.
4. Design filter press rooms with directional ventilation

8.12 Environmental Considerations

1. Emission controls should be set to protect offsite people from toxic risks and avoid public nuisance. There are no known health effects associated with long-term exposure to H₂S at concentrations at or below the point where short-term symptoms (for example eye or respiratory irritation) are observed.
2. SO₂ is one of the products formed when H₂S is burned in the atmosphere and is also formed when pyrophoric iron sulfide oxidises. It is also often present in combination with H₂S.
3. Sulphur dioxide is a colourless, non flammable gas (or liquid) with a strong suffocating odour. It is a respiratory irritant and causes coughing, an increase in sputum production and broncho constriction at low concentrations.
4. Recommended occupational exposure limits for Sulphur dioxide have been set in order to prevent these acute symptoms. The ACGIH Threshold Limit Value based on an 8- hour time weighted average is 2 ppm. The 15-minute Short Term Exposure Limit is 5 ppm. The air quality in respect of allowable concentrations of H₂S varies considerably from country to country.
5. Allowable emission concentrations can be as low as 1ppm H₂S with a Corresponding air quality of 0.02 ppm H₂S over a 30 minute period. These levels do not present a toxic risk although they can result in a pungent odour. The odour threshold for H₂S depends upon the individual and can be as low as 0.02 ppm.
6. Country regulations shall be referenced while developing the control strategy for environmental emissions for H₂S and SO₂ for a particular project.

9. SAFETY PROGRAMS

A successful safety program requires several ingredients,

These ingredients are

- System
- Attitude
- Fundamentals
- Experience
- Time
- You

“Safety must be given importance equal to production.”

The most effective means of implementing a safety program is to make it everyone's responsibility in a chemical process plant. The older concept of identifying a few employees to be responsible for safety is inadequate by today's standards. All employees have the responsibility to be knowledgeable about safety and to practice safety.

It is important to recognize the distinction between a good and an outstanding safety program.

1. A good safety program identifies and eliminates existing safety hazards.
2. An outstanding safety program has management systems that prevent the existence of Safety hazards.

A good safety program eliminates the existing hazards as they are identified, whereas an outstanding safety program prevents the existence of a hazard in the first place. The commonly used management systems directed toward eliminating the existence of hazards include safety reviews, safety audits, hazard identification techniques, checklists, and proper application of technical knowledge.

10. REALISTIC RELEASE INCIDENTS

10.1 Process pipes: Rupture of the largest diameter process pipe as follows:

1. For diameters smaller than 2 in, assume a full bore rupture.
2. For diameters 2-4 in, assume rupture equal to that of a 2-inch diameter pipe.
3. For diameters greater than 4 in, assume rupture area equal to 20% of the pipe cross-sectional area.

10.2 Vessels:

1. Assume a rupture based on the largest diameter process pipe attached to the vessel. Use the pipe criteria.
2. **Worst-case incidents: Quantity** Assume release of the largest quantity of substance handled on site in a single process vessel at any time. To estimate the release rate, assume the entire quantity is released within 10 min.

10.3 Wind speed: stability Assume F stability, 1.5 m/s wind speed, unless meteorological data indicate otherwise.

10.4 Ambient temperature/humidity:

Assume the highest daily maximum temperature and average humidity.

10.5 Height of release: Assume that the release occurs at ground level.

10.6 Topography:

Assume urban or rural topography, as appropriate. At EOL we assume Rural Topography.

10.7 Temperature of release substance: Consider liquids to be released at the highest daily maximum temperature, based on data for the previous 3 years, or at process temperature, whichever is highest. Assume that gases liquefied by refrigeration at atmospheric pressure are released at their boiling points.

11. CONSERVATIVE ANALYSIS

All models, including consequence models, have uncertainties. These uncertainties arise because of

- (1) An incomplete understanding of the geometry of the release (that is, the hole size),
- (2) Unknown or poorly characterized physical properties,
- (3) A poor understanding of the chemical or release process, and
- (4) Unknown or poorly understood mixture behavior.

Uncertainties that arise during the consequence modeling procedure are treated by assigning conservative values to some of these unknowns. By doing so, a conservative estimate of the consequence is obtained, defining the limits of the design envelope. This ensures that the resulting engineering design to mitigate or remove the hazard is over designed. Every effort, however, should be made to achieve a result consistent with the demands of the problem.

For any particular modeling study several receptors might be present that require different decisions for conservative design. For example, dispersion modeling based on a ground level release will maximize the consequence for the surrounding community but will not maximize the consequence for plant workers at the top of a process structure.

To illustrate conservative modeling, consider a problem requiring an estimate of the gas discharge rate from a hole in a storage tank. This discharge rate is used to estimate the downwind concentrations of the gas, with the intent of estimating the toxicological impact. The discharge rate depends on a number of parameters, including (1) the hole area, (2) the pressure within and Outside the tank, (3) the physical properties of the gas, and (4) the temperature of the gas.

The reality of the situation is that the maximum discharge rate of gas occurs when the leak first occurs, with the discharge rate decreasing as a function of time as the pressure within the tank decreases. The complete dynamic solution to this problem is difficult, requiring a mass discharge model cross-coupled to a material balance on the contents of the tank. An equation of state (perhaps non-ideal) is required to determine the tank pressure given the total mass. Complicated temperature effects are also possible. A modeling effort of this detail is not necessarily required to estimate the consequence.

A much simpler procedure is to calculate the mass discharge rate at the instant the leak occurs, assuming a fixed temperature and pressure within the tank equal to the initial temperature and pressure. The actual discharge rate at later times will always be less, and the downwind concentrations will always be less. In this fashion a conservative result is ensured.

For the hole area a possible decision is to consider the area of the largest pipe connected to the tank, because pipe disconnections are a frequent source of tank leaks. Again, this maximizes the consequence and ensures a conservative result. This procedure is continued until all the model parameters are specified.

Unfortunately, this procedure can result in a consequence that is many times larger than the actual, leading to a potential over design of the mitigation procedures or safety systems. This occurs, in particular, if several decisions are made during the analysis, with each decision producing a maximum result. For this reason, consequence analysis should be approached with intelligence, tempered with a good dose of reality and common sense.

During an accident, process equipment can release toxic materials quickly and in significant enough quantities to spread in dangerous clouds throughout a plant site and the local community. A few examples follow

- Explosive rupture of a process vessel as a result of excessive pressure caused by a runaway reaction,
- Rupture of a pipeline containing toxic materials at high pressure,
- Rupture of a tank containing toxic material stored above its atmospheric boiling point, and rupture of a train or truck transportation tank following an accident.

Serious accidents (such as Bhopal) emphasize the importance of planning for emergencies and of designing plants to minimize the occurrence and consequences of a toxic release. Toxic release models are routinely used to estimate the effects of a release on the plant and community environments.

An excellent safety program strives to identify problems before they occur. Process Safety Engineers, Chemical engineers, HSE Engineers and Safety Officers must understand all aspects of toxic release to prevent the existence of release situations and to reduce the impact of a release if one occurs.

This requires a toxic release model. Toxic release and dispersion models are an important part of the consequence modeling procedure. The toxic release model represents the first three steps in the consequence modeling procedure. These steps are

1. Identifying the release incident (what process situations can lead to a release?).
2. Developing a source model to describe how materials are released and the rate of release.
3. Estimating the downwind concentrations of the toxic material using a dispersion model (once the downwind concentrations are known, several criteria are available to estimate the impact or effect).

Various options are available, based on the predictions of the toxic release model, for example:

1. Developing an emergency response plan with the surrounding community,
2. Developing engineering modifications to eliminate the source of the release,
3. Enclosing the potential release and adding appropriate vent scrubbers or other vapour removal equipment,
4. Reducing inventories of hazardous materials to reduce the quantity released, and
5. Adding area monitors to detect incipient leaks and providing block valves and engineering controls to eliminate hazardous levels of spills and leaks.

12. PARAMETERS AFFECTING DISPERSION

Dispersion models describe the airborne transport of toxic materials away from the accident site and into the plant and community. After a release the airborne toxic material is carried away by the wind in a characteristic plume, or a puff.

The maximum concentration of toxic material occurs at the release point (which may not be at ground level). Concentrations downwind are less, because of turbulent mixing and dispersion of the toxic substance with air.

A wide variety of parameters affect atmospheric dispersion of toxic materials:

- wind speed,
- atmospheric stability,
- ground conditions (buildings, water, trees),
- height of the release above ground level,
- Momentum and buoyancy of the initial material released.

12.1 Wind speed:

As the wind speed increases, the plume becomes longer and narrower; the substance is carried downwind faster but is diluted faster by a larger quantity of air. At EOL the average wind speed is 2.33 m/s (this data taken from ESSAR weather report). In EOL the prevailing wind direction is always Southwest to Northeast. I have considered there wind directions (SW-NE, W-E & NW-SE). So ARU/SRU, Product and Intermediate Tankage (PIT), Ware House and Dispatch Areas fall under this Wind Directions.

12.2 Atmospheric stability:

Atmospheric stability relates to vertical mixing of the air. During the day, the air temperature decreases rapidly with height, encouraging vertical motions. At night the temperature decrease is less, resulting in less vertical motion. Sometimes an inversion occurs. During an inversion, the temperature increases with height, resulting in minimal vertical motion. This most often occurs at night because the ground cools rapidly as a result of thermal radiation.

Atmospheric stability is classified according to three stability classes: unstable, neutral, and stable.

1. For unstable atmospheric conditions the sun heats the ground faster than the heat can be removed so that the air temperature near the ground is higher than the air temperature at higher elevations, as might be observed in the early morning hours. This results in unstable stability because air of lower density is below air of greater density. This influence of buoyancy enhances atmospheric mechanical turbulence.
2. For neutral stability the air above the ground warms and the wind speed increases, reducing the effect of solar energy input, or insolation. The air temperature difference does not influence atmospheric mechanical turbulence.
3. For stable atmospheric conditions the sun cannot heat the ground as fast as the ground cools; therefore the temperature near the ground is lower than the air temperature at higher elevations. This condition is stable because the air of higher density is below air of lower density.

12.3 Effect of Buoyancy:

The influence of buoyancy suppresses mechanical turbulence.

12.4 Ground conditions:

Ground conditions affect the mechanical mixing at the surface and the wind profile with height. Trees and buildings increase mixing, whereas lakes and open areas decrease it. There is a Change in wind speed versus height for a variety of surface conditions.

13. WORST-CASE CONDITIONS

For a plume the highest concentration is always found at the release point. If the release occurs above ground level, then the highest concentration on the ground is found at a point downwind from the release.

For a puff the maximum concentration is always found at the puff center. For a release above ground level the puff center will move parallel to the ground and the maximum concentration on the ground will occur directly below the puff center. For a puff isopleths the isopleths is close to circular as it moves downwind. The diameter of the isopleths increases initially as the puff travels downwind, reaches a maximum, and then decreases in diameter.

If weather conditions are not known or are not specified, then certain assumptions can be made to result in a worst-case result; that is, the highest concentration is estimated. The weather conditions in the Pasquill-Gifford dispersion equations are included by means of the dispersion coefficients and the wind speed. By examining the Pasquill-Gifford dispersion equations for estimating the concentrations, it is readily evident that the dispersion coefficients and wind speed are in the denominator. Thus the maximum concentration is estimated by selecting the weather conditions and wind speed that result in the smallest values of the dispersion coefficients and the wind speed. The smallest dispersion coefficients occur with F stability. Clearly, the wind speed cannot be zero, so a finite value must be selected. The EPA suggests that F stability can exist with wind speeds as low as 1.5 m/s. Some risk analysts use a wind speed of 2 m/s or data should be collected from the local weather report department. The assumptions used in the calculation must be clearly stated.

14. LIMITATIONS TO PASQUILL-GIFFORD DISPERSION MODELING

1. Pasquill-Gifford or Gaussian dispersion applies only to neutrally buoyant dispersion of gases in which the turbulent mixing is the dominant feature of the dispersion.
2. It is typically valid only for a distance of 0.1-10 km from the release point.
3. The concentrations predicted by the Gaussian models are time averages. Thus it is possible for instantaneous local concentrations to exceed the average values predicted, this might be important for emergency response.
4. The models presented here assume a 10-minute time average. Actual instantaneous concentrations may vary by as much as a factor of 2 from the concentrations computed using Gaussian models.

ADVANTAGES OF CONSEQUENCE ANALYSIS

1. Safety
2. Assessment of risk in formal risk assessment studies
3. Improved design and operation
4. Improving the Overall Asset Integrity by Safety and Mechanical Integrity Levels
5. Supporting decision making
6. Transfer of knowledge
7. Cost benefit

15. PROBABLE CAUSES OF FAILURE

I. Design and Operational Deviations

1. Metal selection
2. Wrong welding
3. Overloading and bypassing the design parameters
4. High temperature and pressure
5. Material faults
6. Corrosion
7. Runaway reaction
8. Liquid and gas thermal expansion
9. Vibration
10. Ageing
11. Foundation collapse
12. Improper maintenance
13. Inadequate training
14. Horse play
15. Work pressure

16. DISPERSION MODEL (PLUME) OF H₂S RELEASE FROM DHDS UNIT

16.1 Piping Leakage

Release of H₂S from Various piping streams leakage (Aprox) in DHDS unit

Area of leakage A = $2.027 \times 10^{-3} \text{ m}^2$

Table NO. 1: Release rate (Aprox) of H₂S from various piping streams leakage in DHDS unit

Sl.NO.	Stream no	Internal pressure (Pa)	Temperature (K)	Mass fraction of H ₂ S	Release rate Kg/sec
<u>1</u>	<u>15</u>	<u>5643802.5</u>	<u>372</u>	<u>0.02</u>	<u>1.586</u>
2	16	5643802.5	372	0.02	1.586
3	17	5643802.5	372	0.15	11.89
4	18	5643802.5	372	0.15	11.89
5	21	4555575	336	0.05	3.36
6	22	4494834	343	0.03	1.97
7	40	860497.5	313	0.4345	5.73
8	42	1518525	313	0.42	9.77

In table 1 Stream 15 and 16 are having the least probable leakages and so as to proceed further I have taken this least release rate for Calculating the Concentrations at ARU/SRU, PIT, WARE HOUSE, DISPATCH.

Stream no data is given in Table NO. 2

Table NO 2: Stream No. Data

SL.NO.	STREAM NO.	FROM	TO
1	15	Reactor Effluent Air Cooler (40EA-001)	Reactor Effluent Trim Cooler (40E-003 A/B/C/D).
2	16	Reactor Effluent Trim Cooler(40E-003 A/B/C/D).	H.P.Separator Drum (40V-002)
3	17	H.P.Separator Drum 40V-002	Recycle Compressor K.O. Drum (40V-004)
4	18	H.P.Separator Drum 40V-002	Amine H.P.Absorber (40C-001)
5	21	Amine H.P.Absorber (40C-001)	L.P.Amine Absorber (40C-004)
6	22	Recycle Compressor K.O. Drum (40V-004)	Recycle Compressor (40K-001-N)
7	40	Stripper Reflux Drum (40V-007)	L.P.Amine Absorber K.O. Drum (40V-009)
8	42	L.P.Amine Absorber K.O. Drum (40V-009)	L.P.Amine Absorber (40C-004)

16.2 Consequence of Piping Leakage (Plume type)

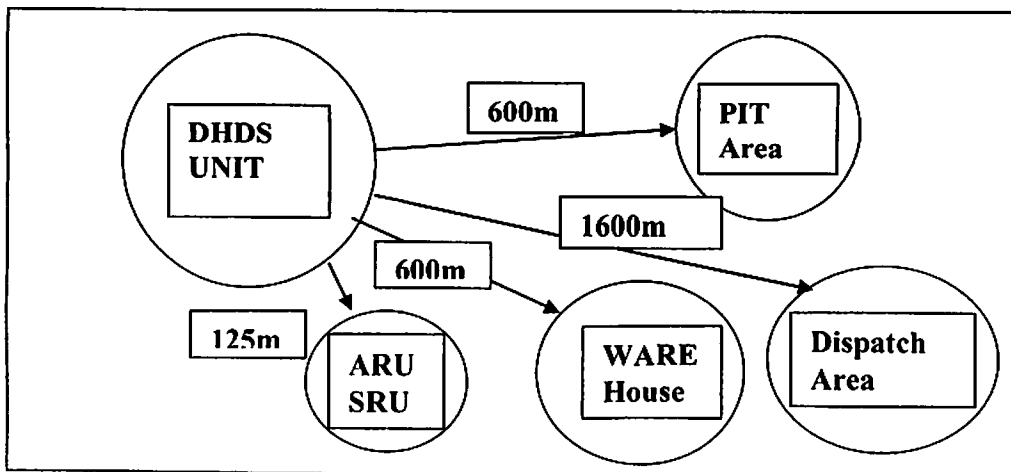
A probable loss of life due to the leakage of H₂S

Piping Failure name : Stream no 15 (40EA-001 to 40E-003 A/B/C/D)
 Release rate : 1.586 kg/sec.

Table NO. 3: Loss of life at different Areas due to Stream No. 15 failure.

SL.NO.	Unit affected	Conc. ppm	% Fatality of people working in that area for different exposure time	
			5 min	15 min
1	ARU/SRU	11050.42	99	99
2	PIT/WARE HOUSE	728.05	2-3	21
3	DISPATCH	166.7	0(minor injury)	0(minor injury)

Fig. NO. 2 Distances from DHDS Unit



16.3 Process Vessel Leakage

Release rate (Aprox) of H₂S from various process vessels leakage in DHDS unit

Release of H₂S from Various vessels leakage (Aprox)

1. Assumed Area of leakage $A = 0.164 \text{ m}^2$ because the largest connection attached to any vessel is 36in Man Hole so on an average 18in diameter connection is selected.
2. Partial Pressure of H₂S is $1.3 \text{ kg/cm}^2\text{g}$ is assumed in all the process vessels

Table NO. 4: Release rate (Aprox) of H₂S from various process vessels leakage in DHDS unit

Sl.NO.	UNIT NAME/NO	Internal pressure (Pa)	Temperature (K)	Release rate H ₂ S Kg/sec
1	H.P.Separator /40V-002	5643802.5	372	128.32
2	H.P. Amine Absorber / 40C-001	5643802.5	387	125.8
3	Compressor K.O. Drum / 40V-004	4494834	343	159.6
4	M.P. Separator / 40V- 003	1933588.5	372	43.96
5	L.P. Amine Absorber /40C-004	1295808	322.7	31.63
6	<u>Stripper/40V-007</u>	<u>860497.5</u>	<u>313</u>	<u>22.35</u>
7	L.P.Amine K.O.Drum/40V-009	1518525	313	37.64
8	Stripper Drum Reflux/40V-007	860497.5	313	21.33

In table 4 Stripper (40V-007) and stripper reflux drum (40V-007) is having the least probable leakages and so as to proceed further I have taken Stripper release rate as least release rate for calculating the Concentrations at ARU/SRU, PIT, WARE HOUSE, and DISPATCH

16.4 Consequence of Process Vessel Leakage (Plume type)

A probable loss of life due to the leakage of H₂S

Process vessel failure name : STRIPPER (40C-002)
Release rate : 22.35 kg/sec

Table NO. 5: Loss of life at different Areas due to Stripper failure (40C-002)

Sl.NO.	Unit affected	Conc. ppm	% Fatality of people working in that area for different exposure time	
			5 min	15 min
1	ARU/SRU	155703.55	99	99
2	PIT/WH	10822.07	99	99
3	DISPATCH	2349.95	58	91

17. DISPERSION MODEL FOR A PUFF TYPE BEHAVIOR

17.1 Consequence of Vessel leakage

Process vessel failure name : Recycle compressor K.O. Drum(40V-004)
 Release amount : 7.4872 kgs (Q* Instantaneous Release)

Table NO. 6: Loss of life at different Areas due to K.O. Drum (40V-004)

Sl.NO.	Unit affected	Conc. ppm	% Fatality of people working in that area for different exposure time	
			5 min	15 min
1	ARU/SRU	377293.29	99	99
2	PIT/WH	7306.37	99	99
3	DISPATCH	589.52	No	9

17.2 Consequence of piping leakage

Piping Failure name : Stream no 15. (40EA-001 to 40E-003 A/B/C/D)
 Release amount : 1.586 kgs (Q* Instantaneous release)

Table NO. 7: Loss of life at different Areas due to Stream No. 15 failure.

Sl.NO.	Unit affected	Conc. ppm	% Fatality of people working in that area for different exposure time	
			5 min	15 min
1	ARU/SRU	79931.43	99	99
2	PIT/WARE HOUSE	1547.89	28	69
3	DISPATCH	124.89	0(minor injury)	0(minor injury)

18. DISTANCE TRAVELED BY THE TOXIC CLOUD

18.1 PLUME MODEL:

1. Pipeline failure (stream 15) (40EA-001 to 40E-003 A/B/C/D)

Table NO. 8

SL.NO.	Distance	Conc. mg/m ³	Conc. ppm
1	10 km	17.52	12.5
2	5 km	44.78	31.98

2. Vessel failure (Stripper) (40C-002)

Table NO. 9

SL.NO.	Distance	Conc. mg/m ³	Conc. ppm
1	10 km	247.02	176.44
2	5 km	631.04	450.74

18.2 PUFF MODEL

1. Pipeline failure: (stream 15) (40EA-001 to 40E-003 A/B/C/D)

Table NO. 10

SL.NO.	Distance	Conc. mg/m ³	Conc. Ppm
1	10 km	2.86	2
2	5 km	12.43	8.87

2. Vessel failure: (Stripper) (40C-002)

Table NO. 11

SL.NO.	Distance	Conc. mg/m ³	Conc. Ppm
1	10 km	40.31	28.79
2	5 km	175.19	125.13

3. Vessel failure: (K.O. Drum) (40V-004)

Table NO. 12

SL.NO.	Distance	Conc. mg/m ³	Conc. Ppm
1	10 km	13.5	9.64
2	5 km	58.69	41.92

19. CONSEQUENCE ANALYSIS

This consequence analysis is According to Backward Calculation method

Table NO. 13: Hazardous Hydrogen Sulfide Concentration levels for various Exposure times and Fatality Rate

Sl.NO.	Exposure time (min)	Fatality rate (%)	Corresponding probability value	Hazardous H ₂ S Concentration levels					
				D.J.Finney Probit		Perry and Articola Probit		GASCON2 Probit	
				ppm	mg/m ³	ppm	mg/m ³	ppm	Mg/m ³
1	5	1	2.67	618	865	897	1255	375	525
		<u>25</u>	<u>4.33</u>	<u>1481</u>	2073	1320	1848	496	694
		50	5	2107	2950	1543	2160	556	778
2	15	1	2.67	346	484	416	582	242	338
		25	4.33	830	1162	612	856	320	448
		50	5	1181	1653	715	1001	359	502
3	30	1	2.67	240	336	256	358	183	256
		25	4.33	576	806	377	527	242	338
		50	5	821	1149	441	617	272	380
4	60	1	2.67	167	233	158	221	139	194
		25	4.33	400	560	232	324	184	257
		50	5	569	796	271	380	206	288

➤ The relation between Fatality rate and Probability value is shown in Table NO. 15

19.1 H₂S Release Rate at DHDS unit irrespective of piping or vessel

A Maximum Probable Release Rate of H₂S at DHDS unit which can cause 25 % Fatality at various units under its vicinity for exposure of 5 min & 15 min is shown in Table 2

Table NO. 14: H₂S Release Rate at DHDS unit Q (kg/sec)

Sl.NO.	Unit/Area where 25 % Fatality	25 % Fatality-Release Rate in kg/sec at DHDS Unit for Exposure time of					
		5 min			15 min		
		D.J.P	Perry.P	Gascon2.P	D.J.P	Perry.P	Gascon2.P
1	ARU/SRU	<u>0.212</u>	0.18	0.071	0.118	0.087	0.046
2	PIT/Warehouse	3.058	2.726	1.024	1.714	1.263	0.661
3	Dispatch	14.08	12.559	4.716	7.897	5.817	3.044

- Here Q = 0.212 kg/sec is calculated from its corresponding concentration of 1481 ppm (see Table NO.14 for conc. value)

20. GENERAL RELEASE MITIGATION APPROACHES

20.1 Inherent safety

- Inventory reduction: Less chemicals inventoried or less in process vessels
- Chemical substitution: Substitute a less hazardous chemical for one more hazardous
- Process attenuation: Use lower temperatures and pressures

20.2 Engineering design

- Plant physical integrity: Use better seals or materials of construction
- Process integrity: Ensure proper operating conditions and material purity
- Process design features for emergency control: Emergency relief systems
- Spill containment: Dikes and spill vessels

20.3 Management

- Operating policies and procedures
- Training for vapour release prevention and control
- Audits and inspections
- Equipment testing
- Maintenance program
- Management of modifications and changes to prevent new hazards
- Security personal deployment

20.4 Early vapour detection and warning

- Detection by sensors and Analysers
- Detection by personnel

20.5 Countermeasures

- Water sprays
- Water curtains
- Steam curtains
- Air curtains
- Deliberate ignition of explosive cloud
- Dilution
- Foams

20.6 Emergency response

- On-site communications
- Emergency shutdown equipment and procedures
- Site evacuation
- Safe havens
- Personal protective equipment and Medical treatment
- On-site emergency plans, procedures, training, and drills

21. EMERGENCY CONTROL MEASURES FOR H₂S GAS RELEASE

I. Engineering controls

1. Standard Operating Procedures (SOP)
2. Periodic testing and maintenance
3. Oxygen- air source control
4. Energy- ignition source controls
5. Equipment and design controls
6. Detection and suppression systems
7. Operating plans and practices
8. Internal and external audits

1. Standard Operating Procedures (SOP):

A Well defined SOP's are kept in practice and regular updating of SOP's are carried out by consulting with the Field Operators, Technical Services, Area Managers, Shift-Incharge and Contract Employee's and the problems faced in performing their regular job's are taken into the consideration.

2. Periodic testing and maintenance:

All the critical equipment i.e. pressure relief valves, pumps, temperature and pressure controllers are periodically maintained by the maintenance department. Lubrication, Cleaning, Tightening and Corrosion monitoring is done using the CBM Techniques very regularly.

3. Oxygen- air source control:

1. Inert gas purging
2. Seals and gaskets
3. Ventilation
4. Inert gas blanket

4. Energy- ignition source controls:

1. No mobile phones are used
2. Spark arrestors are fixed at all ignition sources
3. Authorised vehicles movement with spark arrestor.
4. Grounding and bonding
5. Elimination of open flames
6. Flame Proofing the high Temperature parts
7. Explosion proof electrical equipment
8. Area classification.

5. Equipment and design controls:

1. Equipment design specifications
2. Equipment layout
3. Access control
4. Emergency shutdown and controls

6. Detection and suppression systems:

1. Gas and fire detection equipment
2. LEL sensors
3. Warning and alarm system
4. Fixed fire protection systems
5. Manual Call Point

7. Operating plans and practices:

1. Site specific operating procedure
2. Codes of practice
3. Worker training and education
4. Pre- start up safety review
5. Safe work permit system
6. Management of change

8. Internal and external audits:

Internal audits are conducted by internal auditing teams and external audits are conducted by third party

II. Toxic gas release, Fire Prevention & Protection Measures

1. Water sprays
2. Water curtains
3. Steam curtains
4. Air curtains
5. Dilution
6. Fire water sprinkler system
7. Toxic gas venting system
8. Breathing Apparatus

III. Emergency controls:

1. On Site Emergency Management plan
2. Emergency fire control equipment
3. Emergency escape equipment
4. emergency escape routes

22. Sample Calculations

Release rate:

$$Q_m = C_o A P_o \sqrt{\frac{\gamma g_c M}{R_g T_o} \left(\frac{2}{\gamma + 1} \right)^{(\gamma + 1)(\gamma - 1)}}$$

$$Q = 0.02(1 * 2.027 * 10^{-3} * 5643802.5 \sqrt{((1.3 * 9.8 * 0.034) / (8.314 * 372)) (2 / (1.3 + 1))^{(1.3 + 1)(1.3 - 1)}})$$

$$= 1.586 \text{ kg/sec}$$

- C_o** is Orifice coefficient (= 1)
A = 2.027 × 10⁻³ m² is Area of Leakage, m²
P_o = 5643802.5 is internal pressure, Pa
g = 1.3
g_c = 9.81 m/sec²
M = 0.034 Kmol
R_g is in M K.S units of Ideal Gas const
T_o = 372° K
Y = 0.02 mass fraction.

Down wind Concentration:

$$(C)(x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u}$$

$$C = 1.586 / (3.14 * 2.33 * 5.16 * 2.712)$$

$$= 15470.5 \text{ mg/m}^3$$

$$= 11050.42 \text{ ppm}$$

Where down wind distance x=125m
 at x=125m
 sy = 5.16 , sz = 2.712
 wind speed u = 2.33 m/sec
 "F" Stability.

Probit analysis

$$Y = -11.15 + \log_{10}(11050.42^{1.9}(5))$$

$$= 8.32$$

$$= 99\% \text{ Fatality Rate}$$

23. DATA AND FORMULAE

Table NO.15 Transformation of Probit to % Fatality Rate

%	0	1	2	3	4	5	6	7	8	9
0	—	2.67	2.95	3.12	3.25	3.36	3.45	3.52	3.59	3.66
10	3.72	3.77	3.82	3.87	3.92	3.96	4.01	4.05	4.08	4.12
20	4.16	4.19	4.23	4.26	4.29	4.33	4.36	4.39	4.42	4.45
30	4.48	4.50	4.53	4.56	4.59	4.61	4.64	4.67	4.69	4.72
40	4.75	4.77	4.80	4.82	4.85	4.87	4.90	4.92	4.95	4.97
50	5.00	5.03	5.05	5.08	5.10	5.13	5.15	5.18	5.20	5.23
60	5.25	5.28	5.31	5.33	5.36	5.39	5.41	5.44	5.47	5.50
70	5.52	5.55	5.58	5.61	5.64	5.67	5.71	5.74	5.77	5.81
80	5.84	5.88	5.92	5.95	5.99	6.04	6.08	6.13	6.18	6.23
90	6.28	6.34	6.41	6.48	6.55	6.64	6.75	6.88	7.05	7.33
%	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
99	7.33	7.37	7.41	7.46	7.51	7.58	7.65	7.75	7.88	8.09

Release of H₂S

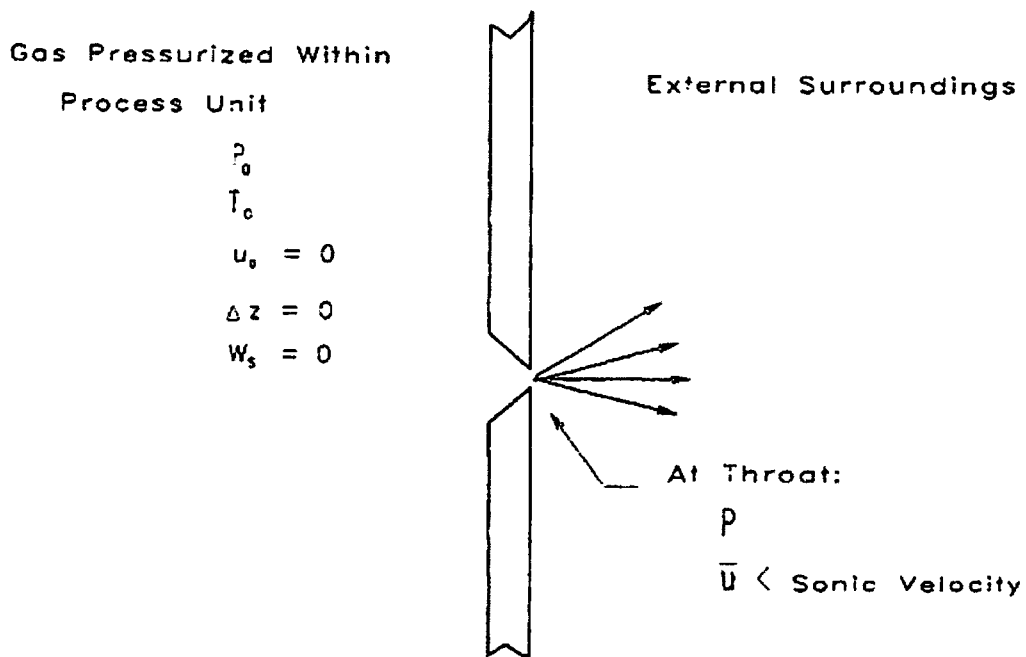


Fig. NO.3 Release of H₂S

1. Area of Leakage for Pipe Failure of 2" diameter is considered
2. Area of Leakage for Vessel Failure of 18" diameter is considered

GAMMA VALUES (γ)

‘ γ ’ values for $H_2S = 1.3$ from the table below

Table NO.16 List of γ values for some common Gases

Gas	Chemical formula or symbol	Approximate molecular weight (M)	Heat capacity ratio $\gamma = C_p/C_v$
Acetylene	C_2H_2	26.0	1.30
Air	-	29.0	1.40
Ammonia	NH_3	17.0	1.32
Argon	Ar	39.9	1.67
Butane	C_4H_{10}	58.1	1.11
Carbon dioxide	CO_2	44.0	1.30
Carbon monoxide	CO	28.0	1.40
Chlorine	Cl	70.9	1.33
Ethane	C_2H_6	30.0	1.22
Ethylene	C_2H_4	28.0	1.22
Helium	He	4.0	1.66
Hydrogen chloride	HCl	36.5	1.41
Hydrogen	H_2	2.0	1.41
Hydrogen sulfide	H_2S	34.1	1.30
Methane	CH_4	16.0	1.32
Methyl chloride	CH_3Cl	50.5	1.20
Natural gas	-	19.5	1.27
Nitric oxide	NO	30.0	1.40
Nitrogen	N_2	28.0	1.41
Nitrous oxide	N_2O	44.0	1.31
Oxygen	O_2	32.0	1.40
Propane	C_3H_8	44.1	1.15
Propene (propylene)	C_3H_6	42.1	1.14
Sulfur dioxide	SO_2	64.1	1.26

Release rate is determined by this Equation NO. 1

$$Q_m = C_o A P_o \sqrt{\frac{\gamma g_c M}{R_g T_o} \left(\frac{2}{\gamma + 1} \right)^{(\gamma + 1)(\gamma - 1)}}$$

Where

- Q_m** is Release rate, kg/sec,
- C_o** is Orifice coefficient (= 1)
- A** is Area of Leakage, m²
- P_o** is Internal pressure, Pa
- γ** is ratio Cp/Cv (= 1.3)
- g_c** is 9.81 m/sec²
- M** is Molecular weight, Kmol
- R_g** is Ideal Gas const
- T_o** is Gas Temperature, K

Table NO. 17 At any Down wind Distant 'x' (100m-10km), coefficients in 'y' & 'z' direction can be known for Plume type.

Pasquill-Gifford stability class	σ_y (m)	σ_z (m)
Rural conditions		
A	$0.22x(1 + 0.0001x)^{-1/2}$	0.20x
B	$0.16x(1 + 0.0001x)^{-1/2}$	0.12x
C	$0.11x(1 + 0.0001x)^{-1/2}$	$0.08x(1 + 0.0002x)^{1/2}$
D	$0.08x(1 + 0.0001x)^{-1/2}$	$0.06x(1 + 0.0015x)^{-1/2}$
E	$0.06x(1 + 0.0001x)^{-1/2}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-1/2}$	$0.016x(1 + 0.0003x)^{-1}$
Urban conditions		
A-B	$0.32x(1 + 0.0004x)^{-1/2}$	$0.24x(1 + 0.0001x)^{1/2}$
D	$0.22x(1 + 0.0004x)^{-1/2}$	0.20x
D	$0.16x(1 + 0.0004x)^{-1/2}$	$0.14x(1 + 0.0003x)^{-1/2}$
E-F	$0.11x(1 + 0.0004x)^{-1/2}$	$0.08x(1 + 0.0015x)^{-1/2}$

Where

σ_x = Dispersion co-efficient in X-direction

σ_y = Dispersion co-efficient in Y-direction

σ_z = Dispersion co-efficient in Z-direction

Table NO. 18 At any Down wind Distant 'x' (100m-10km), coefficients in 'y' & 'z' direction can be known for Puff type.

Pasquill-Gifford stability class	σ_y (m) or σ_x (m)	σ_z (m)
A	$0.18x^{1.92}$	$0.60x^{0.75}$
B	$0.14x^{1.92}$	$0.53x^{0.73}$
C	$0.10x^{1.92}$	$0.34x^{0.71}$
D	$0.06x^{1.92}$	$0.15x^{0.70}$
E	$0.04x^{1.92}$	$0.10x^{0.65}$
F	$0.02x^{1.89}$	$0.05x^{1.61}$

Concentration in Downwind direction for Puff type can determined by this Equation NO.2

$$(C)(ut, 0, 0, t) = \frac{Q_m^*}{\sqrt{2\pi^3} \sigma_x \sigma_y \sigma_z}$$

Concentration in Downwind direction for Plume type can determine by this Equation NO.3

$$(C)(x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u}$$

Graphical way to find, coefficients in 'y' direction can be known for Plume type at any Down wind Distant 'x' (100m-10km)

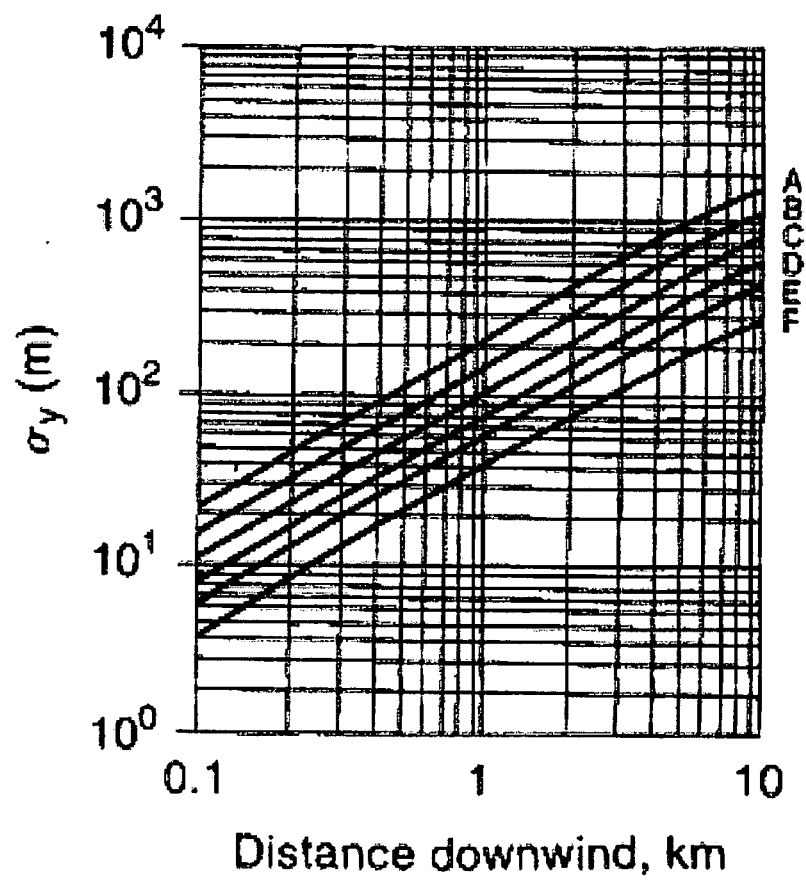


Fig. NO.4

Graphical way to find, coefficients in 'z' direction can be known for Plume type at any Down wind Distant 'x' (100m-10km)

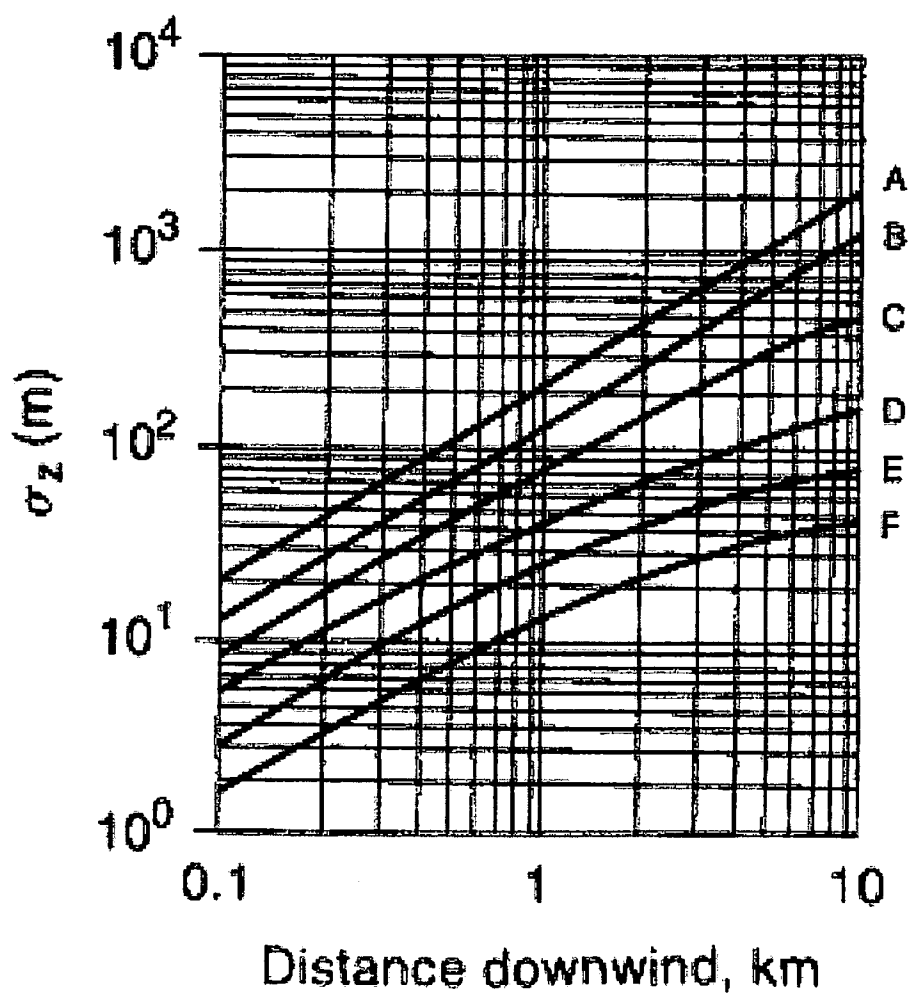


Fig. NO.5

**Graphical way to find, coefficients in 'y' & 'x' direction can be known for Puff type at any
Down wind Distant 'x' (100m-10km)**

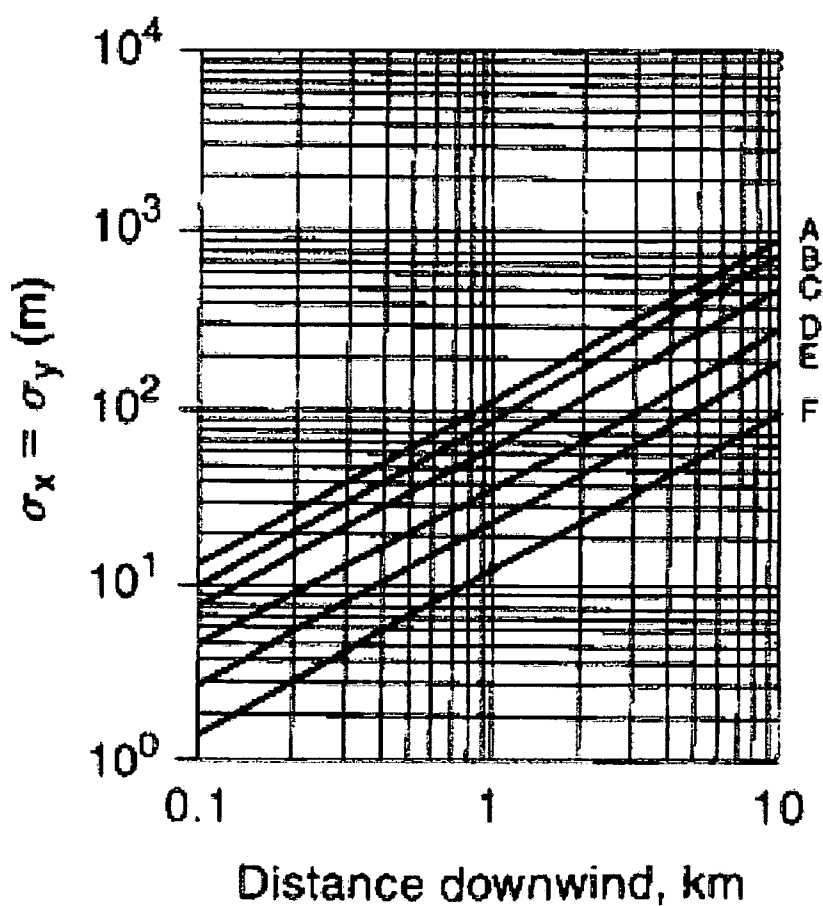


Fig. NO.6

Graphical way to find, coefficients in 'z' direction can be known for Puff type at any Down wind Distant 'x' (100m-10km)

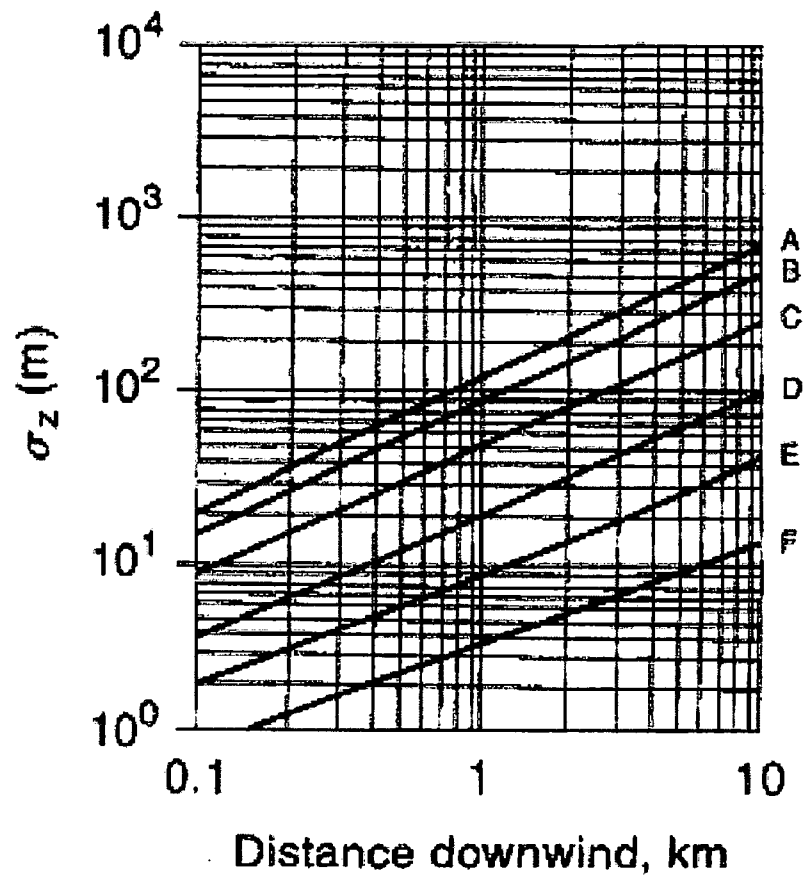


Fig. NO.7

24. CONCLUSION

H₂S risks are always present in majority of oil & gas operations. The key components of effective management of high H₂S risks consists of good Engineering practice to prevent the H₂S release & reduce the effects, operational & administrative controls, emergency preparedness planning and training to the personnel.

So the industries have to be ready with their consequence analysis for effective contribution to the Inherent safer design concepts, risk assessment and Emergency planning.

In the ESSAR Refinery Complex a well defined Engineering Control Measures are adopted in the Design Stage. In addition to this “On Site Emergency Management Plan” (OSEMP) is in place and put in to practice for the mitigation of all types of emergencies.

25. REFERENCE

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2. A text book of "Chemical process safety Fundamental and Application" by - Daniel A Crowl and Joseph F Louvar – Chapter 4 & 5.
3. A text book of "Loss Prevention in Process Industries" by – Frank P Lees Vol 1 & 3 chapters on Dispersion Model and Toxic Release.
4. Perry's Chemical Engineering Handbook- Chapter on PSM
5. Environmental Control Engineering by C.S.Rao- Chapter on Gaussian Dispersion Model.
6. MSDS and H₂S handling provided by Essar Oil Ltd.

26. MATERIAL SAFETY DATA SHEET OF H₂S

Hydrogen Sulfide (H₂S) Material Safety Data Sheet (MSDS)

1. CHEMICAL PRODUCT

PRODUCT NAME : HYDROGEN SULFIDE
SYNONYMS : Dihydrogen sulfide, hydrosulfuric acid, sulfuretted hydrogen

2. COMPOSITION, INFORMATION ON INGREDIENTS

- Formula H₂S
- CAS# 7783-06-4
- Concentration 99+%

Exposure Limits (PPM)

- ACGIH TLV 10
- OSHA PEL 20 (c)*
- MAC 10
- Other STEL 15

*(c) = ceiling

3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Poisonous, flammable liquid and gas under pressure.
May be fatal if inhaled.
Can form explosive mixtures with air.
May cause respiratory tract and central nervous system damage.
Can cause eye irritation.
Gas deadens sense of smell.
Symptoms of exposure may be delayed.

POTENTIAL HEALTH EFFECTS

ROUTES OF ENTRY: Inhalation

ACUTE EFFECTS: Irritation to the eyes, mucous membranes, and upper respiratory tract. May cause pulmonary edema, headache, dizziness, bronchitis, and respiratory paralysis. High concentrations may cause collapse and death.

CHRONIC EFFECTS: May cause conjunctivitis, photophobic, corneal bullae, tearing, pain, and blurred vision.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Persons with impaired pulmonary function or pre-existing eye problems may be at increased risk from exposure.

OTHER EFFECTS OF OVEREXPOSURE: None

CARCINOGENICITY (US ONLY):

NTP – No

IARC MONOGRAPHS – No

OSHA REGULATED – No

4. FIRST AID MEASURES

INHALATION: Immediately remove victim to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.

EYE CONTACT: Immediately flush with copious amounts of water for at least 15 minutes.

SKIN CONTACT: Immediately flush with copious amounts of water for at least 15 minutes while removing contaminated clothing.

INGESTION: None

IN EVENT OF EXPOSURE, CONSULT A PHYSICIAN

NOTE TO PHYSICIAN: None

5. FIRE FIGHTING MEASURES

FLASH POINT: -60 deg.C

AUTOIGNITION TEMPERATURE: 260 deg.C

FLAMMABLE LIMITS: Vol.%
LOWER: 4.4
UPPER: 46

EXTINGUISHING MEDIA: Dry chemical or carbon dioxide. The only safe way to extinguish a H₂S fire is to stop the flow of gas.

SPECIAL FIRE FIGHTING INSTRUCTION AND EQUIPMENT: Wear self-contained breathing apparatus and full protective clothing. Keep fire exposed cylinders cool with water spray.

HAZARDOUS COMBUSTION PRODUCTS: Toxic carbon monoxide and sulfur dioxide may be given off during combustion.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Cylinder rupture may occur under fire conditions. Vapors may travel a considerable distance to the source of ignition and flash back. Emits toxic fumes under fire conditions. Fight fire from maximum possible distance.

6. ACCIDENTAL RELEASE MEASURES

CLEAN UP PROCEDURES: Evacuate and ventilate area. Remove leaking cylinder to exhaust hood or safe outdoor area. Shut off source if possible and remove source of heat.

SPECIALIZED EQUIPMENT: None

7. HANDLING AND STORAGE

PRECAUTIONS TO BE TAKEN IN HANDLING: Secure cylinder when using to protect from falling. Use suitable hand truck to move cylinders.

PRECAUTIONS TO BE TAKEN IN STORAGE: Store in well ventilated areas. Keep valve protection cap on cylinders when not in use. Store away from heat, flame, and sparks

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS: Provide adequate general and local exhaust ventilation to maintain concentrations below exposure and flammable limits.

EYE / FACE PROTECTION: Safety glasses

SKIN PROTECTION: None

RESPIRATORY PROTECTION: In case of leakage, use self-contained breathing apparatus.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: Colorless

ODOR: Rotten egg smell.

PHYSICAL PRESSURE: Gas

VAPOR PRESSURE: @20 deg.C: 18.5 atm

VAPOR DENSITY (AIR=1): 1.175

BOILING POINT (C): -60

SOLUBILITY IN WATER: Soluble

SPECIFIC GRAVITY (H₂O=1): Gas

EVAPORATION RATE: Gas

ODOR THRESHOLD: 0.06 to 1.0 ppm

10. STABILITY AND REACTIVITY

STABILITY: Stable under normal storage conditions.

CONDITIONS TO AVOID: Storage in poorly ventilated areas. Storage near a heat source.

MATERIALS TO AVOID: Oxidizing materials, rubber, lead, silver, alkali metals, mercury, brass and copper.

HAZARDOUS POLYMERIZATION: Will not occur.

HAZARDOUS DECOMPOSITION: Sulfur oxides.

11. TOXICOLOGICAL INFORMATION

LETHAL CONCENTRATION (LC50): 712 ppm, rat 1 hour.

LETHAL DOSE 50 (LD50): N/Ap

TERATOGENICITY: N/Ap

REPRODUCTIVE EFFECTS: N/Ap

MUTAGENICITY: N/Ap

12. ECOLOGICAL INFORMATION

No adverse ecological effects are expected.

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD: Dispose of non-refillable cylinders in accordance with federal, state and local regulations. Allow gas to vent slowly to atmosphere in an unconfined area or exhaust hood. If the cylinders are the refillable type, return cylinders to supplier with any valve outlet plugs or caps secured and valve protection caps in place.

14. TRANSPORT INFORMATION

CONCENTRATION: 99+%

DOT DESCRIPTION (US ONLY):
PROPER SHIPPING NAME: Hydrogen sulfide
HAZARD CLASS: 2.3 (poison), Hazard Zone B
IDENTIFICATION NUMBER: UN1053
REPORTABLE QUANTITIES: 100 lb.
LABELING: POISON GAS, FLAMMABLE GAS

ADR / RID (EU Only): Class 2,2TF

SPECIAL PRECAUTIONS: Cylinders should be transported in a secure upright position in a well ventilated truck.

15. REGULATORY INFORMATION

OSHA: Process Safety Management: Material is listed in appendix A of 29 CFR 1910.119 as highly hazardous chemical.

TSCA: Material is listed in TSCA inventory.

SARA: The threshold planning quantity for this material is 500 lb.

EU NUMBER: 231-977-3

NUMBER IN ANNEX 1 OF DIR 67/548: Material is listed in annex 1.

EU CLASSIFICATION: N/Av

R: 13-26

S: 7/9-16-45

16. OTHER INFORMATION

OTHER PRECAUTIONS: Protect containers from physical damage. Do not deface cylinders or labels. Cylinders should be refilled by qualified producers of compressed gas. Shipment of a compressed gas cylinder which has not been filled by the owner or with his written consent is a violation of federal law (49 CFR).