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Qualitative Risk Assessment and HAZOP Study of a Glass Manufacturing Industry

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Abstract*: In the recent years, many industries have realized that maintaining good occupational health and safety is as equally important in accordance with production requirement. Hence there has been much scope for the risk assessment in order to protect the workers' health and safety at workplace. Risk assessment is a process where the Identified hazards are evaluated to determine the potential cause of an accident and further to reduce to the lowest reasonable risk level to protect worker's health and safety. It is a part of risk management. Risk assessment can be categorized into Qualitative and Quantitative risk assessment which is being carried out using different techniques. In this paper, an attempt has been made to carry a Qualitative risk assessment i.e. Hazard Identification and Risk Assessment and HAZOP study for the identified critical areas of a glass manufacturing industry. From the results obtained from this study, Physical Hazard is 47%, Ergonomic Hazard is 10%, Chemical Hazard is 9%, Electrical Hazard 2%, Biological Hazard 3%, Thermal Hazard is 29% etc. Risks are also categorized into Low, Medium and High risks which 12.09%, 45.05% and 42.06% respectively. Hazard analysis from the design intent for Silane and ethylene gas station is also studied using a HAZOP technique. Some of the control valves are suggested to install before the gas filter. ALOHA is also used to simulate the model to analyse the impact due to leakage from the various potential whole area in the natural gas pipeline. Leakage from the larger hole of about 324.51 sq.cm has shown the high hazardous zone - death to human beings i.e.12m down the line in the wind direction. However, periodical maintenance and monitoring of the Natural gas distribution pipelines along with Gas detection system and fire hydrant system with sprinklers can prevent the disaster.

***Keywords:* Risk Assessment, HAZOP, HIRA, ALOHA, Threat Zone, and Thermal Radiation**

I. INTRODUCTION

Emerging new technology and social development in the industrial sector has led to increase in the size and complexity of industrial operations especially at Pharmaceutical and Chemical manufacturing industries including automotive sectors. Industries has gained a substantial attention in the recent years because of significant benefits to the society, such as extensive use of raw materials for fertilizer, shelter and clothing. Although there are many benefits from the industries, any mislead in the critical operation can also lead to the tragic event like Bhopal Gas tragedy (1984), Jaipur oil depot fire (2009), Chasnal Mining Disaster (1975) and Bombay Docks Explosion (1944) etc. According to the "International Labour Organization" for every 15 seconds, nearly 153 worker dies from a work related accident or diseases. One of the report published in the year 2015 from International Labour Office say that, the incident rate of injury/ illness per 10,000 full time workers in glass manufactures is high (118.9) compared to all other private manufacturers (102.6) for the year 2012 in United State. To avoid these accidents in an industry and for it to be successful, there is a need for identifying Hazard/Risk associated with their complexity of the operation and brings back the risk to the tolerable risk level. This approach is termed as Risk Assessment where hazard can be defined as "Source or the Situation, or act with a potential for harm in terms of human injury or ill-health, or combination of these" and Risk is defined as a combination of the likelihood of an occurrence of a hazardous event or exposure and severity of injury or ill health that can be caused by the event or exposure [1]. The main objective of this study is to evaluate safety through Risk Assessment and Hazard Analysis using HAZOP technique of the critical areas at the workplace of Glass Manufacturing Industry. The specific objectives are, to carry out Qualitative Risk Assessment for the activity of the critical area using risk rating scale technique, to analyse the hazards using HAZOP technique and Quantitative Risk Analysis using ALOHA Software with recommendations.

II. LITERATURE REVIEW

Risk assessment is the first step in risk management and a process used to evaluate hazards that can cause great harm to the workers from the hazardous operation and mitigate it to a tolerable risk [2]. It is defined as a systematic procedure for analysing systems to identify and evaluate hazard and safety characteristics and helps in determining qualitative or quantitative values of risk for identified threat. Some of the risk assessment process are very complex and are best used in formal situations for specific purposes e.g. fault tree analysis, failure mode and effects analysis irrespective whether it is a qualitative or quantitative risk assessment. One of the simplest types of risk assessment is "hazard identification and risk assessment" which assists to identify the possible hazards and risks of a potential threat with options to reduce or mitigate the risk. Hazards are identified by various mean like walking around the workplace, interaction with the workers, reviewing the work instructions and also previous incident reports. While conducting the HIRA, it is necessary to consider both routine and Non-routine activity and conditions of the job like Normal, abnormal and emergency [3]. One of the author Shrivatsava et al., (2015) has carried out HIRA in Thermal Power Plant. He has identified and evaluated some of the hazards from the critical operations like Coal handling plant, D.M plant, Boiler, Generator, turbine and switch hazard in thermal power plant and classified the risk into low risk, medium risk, moderate –high risk and high-risk event. 27 hazards were identified from the above operations by the author where the major risk event was from Generator and turbine operation i.e. Fire and explosion on hydrogen tank. Further, Vivek et al., (2015) have improved or extended the same methodology by evaluating the effectiveness of the implemented controls for determining hazard from which people are exposed to injury in the workplace of Cold and Mill in Steel Industry. This methodology has been described as "Workplace Risk Assessment and Control (WRAC)". About 40 hazards have been identified, amongst low risk is 2 and 36 before and after the implementation of control measures. In addition to this, Shamsuddin et al., 2015 have included one more element in this study with respect to HIRA known as "Hierarchy of Controls" and Intolerable risks are recommended for additional controls with hierarchy.

HAZOP is a type of Hazard identification technique which is commonly used in chemical Industry and now successfully extended its application in various other types of industry. Some of the other Hazard identification techniques are Fault Mode Effective Analysis (FMEA), Fault Tree Analysis (FTA), Hazard and Operability Study (HAZOP) and Energy Trace and Barrier Analysis (ETBA) [6] and [7]. Subsequently, Kotek et al., (2012) have defined HAZOP as a "systematic safety study, based on the systemic approach towards an assessment of safety and operability of complex process equipment, or the production process". Data required for the HAZOP study are drawing, procedure and flow chart of the process [8]. The main advantage of HAZOP study is a thorough examination, finding the new dangerous situations and increased efficiency of the operation and the drawbacks are long time needed, knowledge and skills of the HAZOP participants [6].

Habibi et al., (2008) has conducted HAZOP studies on water treatment plant in one of the power station. Water treatment plant is compiled with Dual media Filter, RO, Storage tank, transfer pump, Deionizer, DE gasifier, Deionizer (Anion) and mixed bed of the design intent, More than Quantitative increase, Less than Quantitative decrease, As Well As Qualitative increase, Part of Qualitative decrease, Reverse Logical opposite of the intent, Other than Complete substitution or the operational procedures occur abnormally. From authors result, there were 14 nodes, 126 deviations, 293 causes of deviations. The categories of risk 10.4% - Not Acceptable, 35.7% - Undesirable, 24.6% - Acceptable with reconsideration, 29.3% - Acceptable. Suggestions were mainly related to the modification and improvement of equipment's or processes (42%), regular maintenance of the equipment (35%), and the use of correct operational methods (23%). 175 Suggestions were given by the author. Large No. of risks/hazards – Entry of raw water to sand filter (Node) and the Highest level of Risk: - deviations from acid and alkali. In this way, many authors have studied using different risk assessment techniques with some improvements for the conventional approach. In this study, an attempt has been made to analyse the hazards of a glass manufacturing industries through three different techniques.

III.MATERIALS AND METHODOLOGY

An industry which was selected for Qualitative Risk Assessment is a Glass manufacturing Industry located in North India. The main function of this industry is to manufacture the glass, where the raw materials of a glass are melted in the hot end with a temperature ranging from 1000^0C to 300^0C. The fuel which is used for furnace operation is natural gas. They also use a chemical like Silane and Ethylene gas for coating on the glass which would act as a reflector for the UV sunlight. In this study, there are three different risk assessment techniques used to assess the safety at the industry. The critical area identified for three different risk assessment technique is Furnace area – Hazard Identification and Risk Assessment, Ethylene and Silane Gas station – HAZOP study and Impact from potential leakage of natural gas from the distribution pipeline is also simulated with models using ALOHA software. The steps involved in each risk assessment technique is as follows,

A. **Hazard Identification and Risk Assessment**

This is a simple method with 6 major steps in the process which starts with the identification of hazard and associated risks for both routine and non-Routine activities, Identification of conditions and direct or indirect (Normal, Abnormal and Emergency), Evaluation of Hazard/Risk using the guidelines, Estimation of residual risk, Identification of significant and non-significant and hierarchy of risk control which includes elimination, substitution/modification, engineering barrier, Administrative Control and PPE. Documentation of process, monitoring, and review of the process.

Evaluation is performed using the guidelines with pre-defined risk scale rating from one to five for severity and probability of different levels. The table 2 and 6 reveals the risk scale rating for different levels of severity and probability in this study. Risks are also classified into High risk, Medium, and Low Risk. The criteria for identifying significant hazard\risk in this study are Severity >

= 3, Residual Risk Score >= 12, High Risk and Emergency. Equation 1 and 2 are used for calculating residual risk and percentage reduction in the risk level. From the table 1, All ***RED*** colour boxes are termed as High Risk, ***ORANGE*** Color – Medium Risk and ***YELLOW*** color – Low Risk.
Formula for Estimating the Residual Risk,
Residual Risk = SxPOCxPC ………………..(1)
Where,
S = Severity, POC = Probability of Occurrence, PC = Present Control

Percentage Reduction Risk level = Q / R – 1 …………(2)
Where Q = Residual risk rating before implementation of proposed controls.
R = Residual risk rating after implementation of proposed controls.

Table 1: Classification of Risk

Severity\ Probability	5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

Table 2: Risk Rating Scale for Probability of Occurrence

Probability of occurrence (POC)	Present control (pc)	Rat. pc
Very rare occurrence. Can occur only in exceptional circumstances. Requires sequential / multiple system failures	Control applicable, available and effective	1
Less likely. Can occur once / twice a year.	Control applicable, fully or partially available and not effective	2
May be possible. Exposure occurs few times in a month, but not every week.		
Likely occurrence. Exposure occurs few times in a month. Consistent week after week.	Control not provided	3
High probability. Occurs very frequently, many times in a working shift/month. Highly certain, Constant and continuous exposure exists		

B. **HAZOP TECHNIQUE FOR A CHEMICAL PLANT – GLASS MANUFACTURING INDUSTRY**
The critical area selected for HAZOP study is chemical gas station i.e. Silane and Ethylene Gas Station. These gas along with N_2 are mixed at a desired ratio in Mass Flow Control Room for glass coating which acts as a reflector for sunlight. Silane is spontaneously flammable in the air in its pure form and Ethylene gas is also flammable if they are exposed to a source of the fire. The Fig. 1 shows the flow diagram of the Silane and production area,

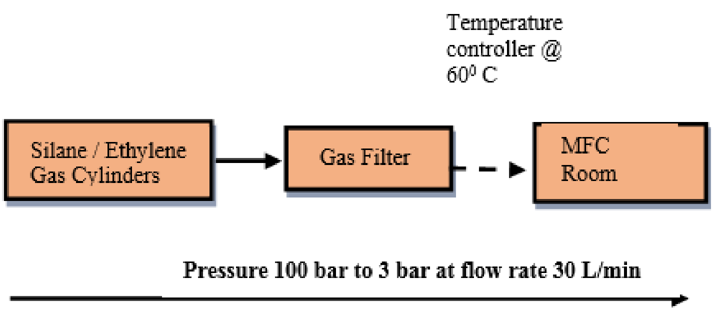


Fig 1. Flow Diagram of Silane and Ethylene Gas to Mass Flow Control Room

HAZOP Procedure adopted for this study is as followed:

1. Divide the system into sections
2. Choose a study node
3. Describe the design intent
4. Select a process parameter
5. Apply Guide-word
6. Determine the cause, consequences and safe guard
7. Evaluate the consequences/problem
8. Provide risk rating in terms of S & L and calculate S x L = RR
9. Recommend action and Record Information Including Action by
10. Repeat procedure (from step 2).

Guide words used for this study is shown in the table. 3. Deviations for the parameter identified are derived. Causes and consequences are identified for respective deviations with safeguards.

Table 3: GUIDEWORDS USED FOR THIS STUDY

SI. No	Guide Word	Meaning
1.	No or Not	Complete negation of the design Intent
2.	More/High	Quantitative Increase
3.	Less/More	Quantitative decrease
4.	Reverse	Logical Opposite of the design Intent

Identified risks are evaluated and classified the risk into High Risk, Medium Risk and Low Risk using the guideline as shown in table 4 and 5.

Table 4: Classification of Risk

Severity\ Probability	1	2	3	4	5
1	25	20	15	10	5
2	20	16	12	8	4
3	15	12	9	6	3
4	10	8	6	4	2
5	5	4	3	2	1

Table 5: Risk rating scale for HAZOP study

Risk Rating	Severity	Probability
1	Serious	High
2	High	Moderate
3	Medium	Medium
4	Low	Low
5	None	Very Low

C. **Simulation of model on Potential Leak of Natural gas from the pipeline**

ALOHA software is used in this study to anticipate the impact due to the release of natural gas from the pipeline under "Burning" and "Not Burning" condition. Natural gas is supplied from the GAIL station, located on the campus of the industry in the main branch pipeline of "8inch" diameter and pressure within the pipeline is 21 bar. All the atmospheric data are obtained from the weather forecast website of the location.

Table 6: Risk Rating Scale for Severity

Severity of Risks								
Rate Scale	**Noise Pollution**	**Physical Injury**	**Burn Injury**	**Heat (Temp.)**	**Illness**	**Lighting**	**Exposure To Radiation effect**	**Ergonomics**
1	< 40 dB	Small cuts/injury requiring first aid and person can return back to work immediately	Burns with immediate recovery and person can return back to work immediately	Work environment shows normal ambient temperatures. Efforts related to work carried out results in average sweating. No impact to health conditions.	Momentary discomfort/ Nuisance, sneezing, cough	Illumination is adequate for the given activity	Not Applicable	Stress / Strain / Frustration / Depression
2	40 to 75 dB	Injury requiring Nurse or doctors attention and person can return back to work within 24-48 hours	Burns with recovery within 2 weeks and person can return back to work	Work environment shows higher than normal ambient temperatures. The difference is due to lack of ventilation/air flow and not because of the process.	Prolonged discomfort/ nuisance/ temporary Headache, eye or respiratory tract irritation.	Illumination is moderate for the given activity	Exposures to Nonionizing radiation - mainly thermal effects	Effect on vision / Mild ache
3	76 to 90 dB	Injury / internal injury requiring hospitalization and person can return back to work within 1 weeks	Burns with recovery within 5 weeks and person can return back to work.	Frequent change of exposures from Hot - Cold environment expected. The process also generates heat/cold to affect the work environment. Temporary discomfort, Irritation, Heat rashes can be expected.	Un consciousness, Faint or Collapse, blurred Vision, Vomiting and requires immediate medical attention.	Illumination is not assessed / Very low lux levels / working areas are darker / Activity can cause eye strain or can cause injuries.	Exposures to Nonionizing radiation - (no thermal impacts) Microwaves, Radio waves, Mobile phones, low-frequency radiations	Upper limb disorder / repetitive strain Injury (RSI)
4	91 to 105 dB	Major Injury / Internal injury requiring hospitalization and person can return	Burns with recovery within 2 months and person can	Hot / very cold envy, Uncomfortable to work for long durations. Can lead to	Major Health impact, which leads to chronic Respiratory	No Lightings at all	-	Blood pressure / Heart disease / Nervous

RESULTS AND DISCUSSION

This results obtained from the study with respect to each risk assessment technique used for the selected critical areas are as follows,

A. Hazard Identification and Risk Assessment – Furnace Area

		back to work within 8 weeks	return back to work	Cramps, muscular pains a headache, excessive sweating, vomiting, etc.,	, Dormitory Illness or any other long –term occupation al illness.			breakdown / Sprain
5	>=106 dB	Major oral/internal injury requiring hospitalization and person can return back to work > 8 weeks / Could result in Fatality	Burns with 20% burns and recovery within 6 months to return back to work	Very Hot / extremely cold atmosphere. Not possible to work for long durations. Uncontrolled exposures seen could lead to death or permanent alteration to health conditions	Over exposure which may lead to immediate death.	Lux level is more than the standard limits	Exposures to ionizing radiation effects - Alpha-Rays, Beta-Rays, Gamm-rays, and X-rays	Tolerable residual occupational ergonomic risk

Total numbers of activities identified from the furnace area are 36. Hazard/Risks were identified for all routine and non-routine activity. Major hazards identified from the furnace area are thermal hazard like exposure to heat, chemical hazards like NG leakage and some physical hazards. There was nearly 47% of the physical hazard, 10% of ergonomic hazard, 9% of the chemical hazard, 2% of electrical hazard, 3% of a biological hazard and 29 % of Thermal Hazard. Risks are further classified as high risk, medium risk and low risks with 42.83%, 48.35%, and 8.79% respectively from furnace area. The Fig. 2 shows the percentage of classification of risk. There were nearly 63 significants identified which is 69% among all other hazards. Some of the major recommendations are to provide shut-off valve for NG pipeline, Provide adequate lighting and ISI mark PPEs where ever applicable.

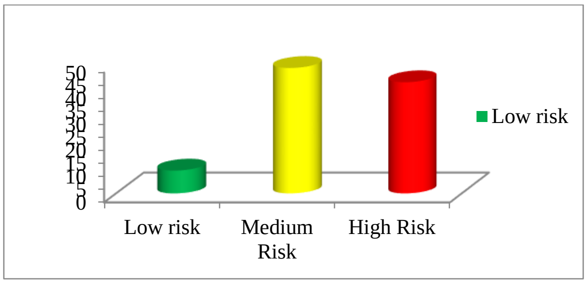


Fig 2: Classification of Risk

B. HAZOP Study – Silane and Ethylene Gas

The Silane pipeline with control device/equipment is considered as a single node for which causes, consequences are derived along with respective safeguard. The design intention for the Silane and Ethylene node is mentioned in Table 7. Guide words, parameter, and deviations remain same for an identified node of both Silane and Ethylene gas station however consequences will alter. Hazards with causes and consequences that are identified are evaluated using risk rating scale between 1 to 5 for both severity and likelihood. In addition to this, the Tables 8 to10 and Figures 3 to 5 divulge the number of low/medium/high risk for flow, pressure and temperature parameter of Node 1 from Silane and Ethylene Gas Zone. Although the medium risk is more with respect to all parameters of Silane and Ethylene node1, the prominence is given to high risk for recommendations. There are overall 42 and 34 numbers of consequences from Node 1 for Silane and Ethylene Gas Zone respectively.

Table 7: Node with Design Intention for both Silane and Ethylene Gas Zone

Node. No	Node	Silane Gas Zone - Design Intention
1	Silane Pipeline	A silane of purity 99.95% is transferred from the carbon steel cylinder under pressure of 100 bar – 3 bar at the flow rate of 30 L/min and temperature of 60^0C which is controlled using the cooling/heating system max. at a temperature of 60^0C in the output of the pipeline.
Ethylene Gas Zone – Design Intention		

1	Ethylene Pipeline	Ethylene gas of purity 99.95% is transferred from the carbon steel cylinder under pressure of starting from 100 bar to 3 bar at the flow rate of 30 L/min which is controlled using the cooling/heating system max. at a temperature of 60^0C in the output of the pipeline.

The Table 4.4 and Fig. 4.4 shows that there is more number of high and medium risk for Silane gas zone compared to Ethylene gas zone because of its high hazardous nature than ethylene gas. Some of the recommendations are, Installation of pressure relieve valve along with the air vent system before the Gas filter for both Ethylene and Silane Gas pipeline, Provide cooling system for filled Silane and Ethylene cylinders under storage condition, Installation of ambient temperature measuring

Table 8:-Flow - Node 1 (Silane & Ethylene Gas Cylinders)

Gas Zone	High	Medium	Low
Ethylene	4	11	2
Silane	6	13	2

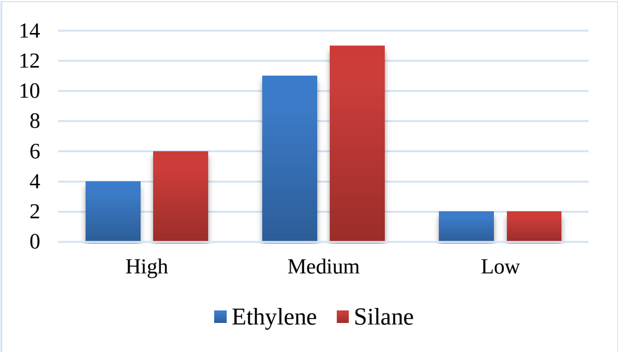


Fig 3: Flow parameter of silane

Table 9: TEMPERATURE OF NODE 1 - SILANE & ETHYLENE GAS ZONE

Gas Zone	**High**	**Medium**	**Low**
Ethylene	3	6	1
Silane	4	5	2

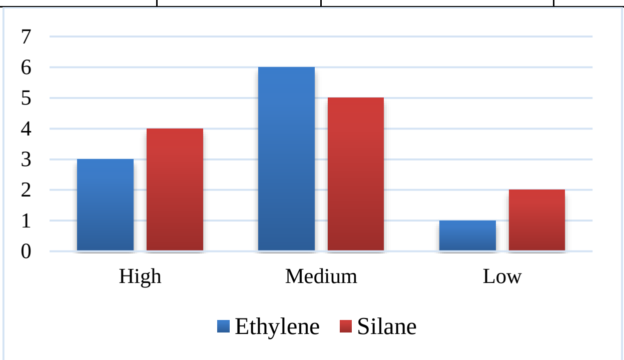


Fig 4: Temperature of Node 1 - Silane & Ethylene Gas Zone

Table 10: PRESSURE OF NODE 1 - SILANE & ETHYLENE GAS ZONE

Gas Zone	High	Medium	Low
Ethylene	1	5	1
Silane	2	8	0

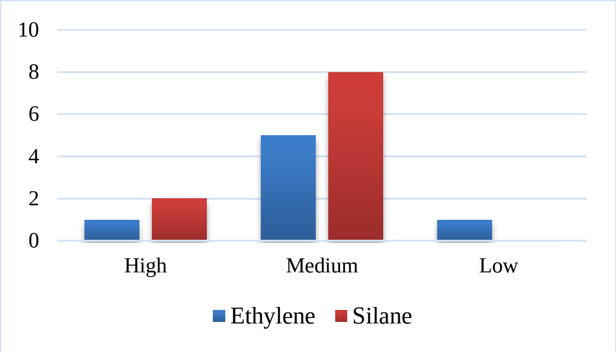


Fig 5: Pressure of Node 1 - Silane & Ethylene Gas Zone

C. Quantitative Risk Analysis – ALOHA

NG is used as fuel for glass melting in the furnace as well as for some of the domestic purpose. From initial risk assessment i.e. HIRA, NG is considered as significant due its flammable nature which could lead to an explosion in case of leakage from the distribution pipeline. Hence NG distribution line is subjected to further studies in terms of Quantitative Risk Analysis using ALOHA software. It has the capability to draw the model in both the cases "Not burning" and "Burning" condition either for flammable liquid or flammable gases. In this study, natural gas which contains nearly 90% of the methane is flammable in nature and has been modeled for the both the conditions "Not Burning" as well as "Burning" and also "source and its strength" is estimated. Table 11 gives the various Hazard analysis that was performed considering both the cases.

Table 11: Different Scenarios for potential leak of NG from the pipeline

Source	Toxic	Fire Scenario	Explosion Scenario
NG Pipeline			
Not Burning	Toxic Vapour Cloud	Flammable Area (Flash Fire)	Vapour Cloud Explo sion
Burning (Jet Fire)	NA	Jet Fire(Thermal Radiation)	NA

Source Strength for potential hole area of NG pipeline - Not burning - Source strength predicted by the Gas pipeline source will change over. For the below scenario (Not Burning) i.e. release of the chemical into the atmosphere, ALOHA averages the series of time steps into between one and five release rates that are each for a time period of at least 1 minute. Max. Average releasing rate for the potential hole area of 324.51 sq.cm, 15 sq.cm and 10 sq.cm remains same as 407 grams/sec for the duration of 1 min. However, for the potential hole area of 5 sq.cm releasing rates is 24 kg/min for the duration of 3 min. The Table 12 and Plates 1 to 2 explain the release duration and Max. Average sustained release rate for various potential hole area of natural gas pipeline while not burning.

Table 12: Source Strength of "8-inch" diameter with "21 bar" pressure under "Not burning" condition.

Scenario: Pipeline of a flammable gas (Not Burning)				
SI. No	**Hole Area**	**Release Duration**	**Max. Average sustained release rate**	**Total Amount Released**
1	324.51 sq.cm	1 min	407 grams/sec	24 kg
2	15 sq. cm	1 min	407 grams/sec	24 kg

3	10 Sq.cm	1 min	407 grams/sec	24 kg
4	5 Sq.cm	3 min	24 kg/min	24 kg

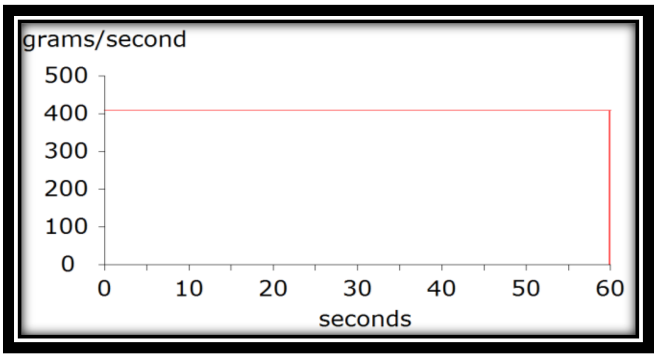


Plate 1: Source Strenght for pipeline of hole area 324.51 sq. cm, 10 sq. cm and 15 sq. cm

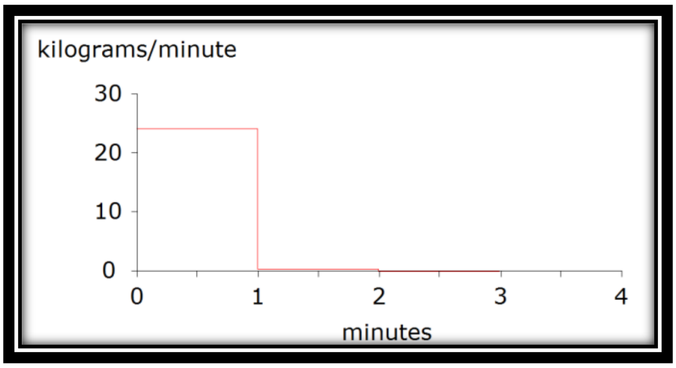


Plate 2: Source Strenght for a pipeline of hole area 5 sq. cm

Hazard Analysis on Natural Gas when "Not burning"-

The table 13, 14 and 15 gives values of the Toxic area, Flammable area, and over-pressure of the vapour cloud. This has been computed for various potential hole area of the NG pipeline. Red threat zone, Orange threat zone and Yellow threat zone in case of Toxic Area of vapour cloud are within 10m. Since ALOHA has limitations of not modeling with threat zone less than 10m. Model is not performed.

Table 13: Hazard Analysis: Toxic Area of Vapour Cloud

Scenario	**Toxic Area of Vapour Cloud**			
Hole Area	**324.51 sq.cm**	**15 sq. Cm**	**10 sq.cm**	**5 sq. cm**
Red Threat Zone	<10m	<10m	<10m	<10m
Orange Threat Zone	<10m	<10m	< 10m	<10m
Yellow Threat Zone	<10m	<10m	< 10m	<10m

Table 14 gives us the flammable area for various potential hole area of NG pipeline. However, this was computed by ALOHA using 60% of Level of Exposure limit by default. As shown in the table. 14, the estimation of Red Zone and the Yellow zone is by default as per the exposure limit guideline selected by ALOHA (i.e. Red Zone – Upper exposure limit and Yellow Zone – Higher exposure limit). Red Zone of 19m length and yellow zone of 45m remains same for all potential hole areas in the natural gas pipeline. Orange zone is not estimated, as there are no exposure limits available in ALOHA by default. Model or the threat zone was not drawn because the effect of near – field patchiness makes dispersion predictions less reliable for short distance.

Table 14: HAZARD ANALYSIS: FLAMMABLE AREA OF VAPOR CLOUD

Scenario	**Flammable Area of Vapour Cloud**			
Hole Area	**324.51 sq.cm**	**15 sq. Cm**	**10 sq.cm**	**5 sq. cm**
Red Threat Zone	19m	19m	19m	18m
Orange Threat Zone	Nil	Nil	Nil	Nil
Yellow Threat Zone	45m	45m	45m	45m

For Blast of vapour cloud hazard analysis, level of concentration (LOC) is never exceeded as shown in table 15. The LOC is never exceeded for almost all potential hole areas of NG pipeline i.e. LOC lies within the exposure limits for Red zone, Orange zone, and Yellow zone - 8.0 psi, 3.5psi, and 1.0 psi respectively which cannot be modeled by ALOHA software. This indicates that potential hazard due to this blast when not burning is very less.

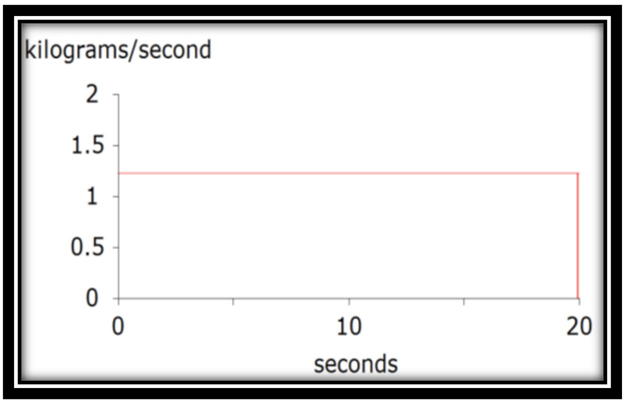
Table 15: HAZARD ANALYSIS: OVER PRESSURIZED OF VAPOUR CLOUD

Scenario	Over pressurized of Vapour Cloud			
Hole Area	**324.51 sq.cm**	**15 sq. Cm**	**10 sq.cm**	**5 sq. cm**
Red Threat Zone	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded
Orange Threat Zone	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded
Yellow Threat Zone	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded	LOC Never Exceeded

Further to this, ALOHA has been considered for modeling thermal radiation due to the burning of Natural Gas (Jet Fire).
Source Strength of NG (Burning) - Source strength in case of Natural gas – Burning (Jet Fire) includes computation of Flam length, Burn rate, Burn Duration, Total amount burned. Table 16 and plates 3 to 6 shows the above-said parameter for various potential hole areas of the natural gas pipe line of 8-inch diameter with 21 bar pressure.

Table 16: Source Strength of "8-inch" diameter with "21 bar" pressure under "Burning – Jet Fire" condition.

Scenario: Pipeline of a flammable gas (Burning – Jet Fire)				
Hole Area/Source Strength	**Flame Length**	**Burn Rate**	**Burn Duration**	**Total Amount Burned**
324.51 sq.cm	16 m	107 kg/Sec	20 Sec	24.4 kg
15 sq. cm	3 m	4.97 kg/sec	50 sec	24.4 kg
10 sq.cm	3 m	199 kg/min	1 min	24.4 kg
5 sq.cm	2 m	99.4 kg/min	2 min	24.4 kg



Plates 3 : Source Strenght for 324.51 sq.cm of Pipeline hole area.

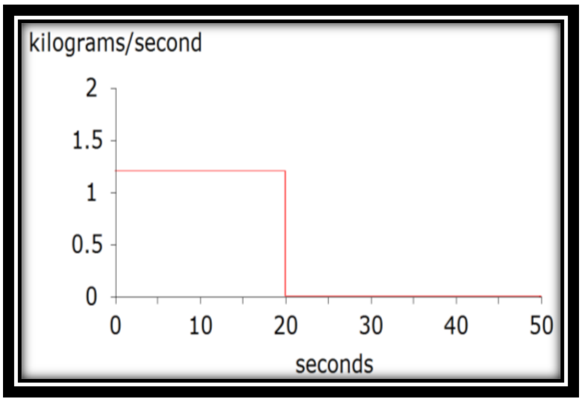


Plate 4: Source Strenght for 15 sq.cm of Pipeline hole area.

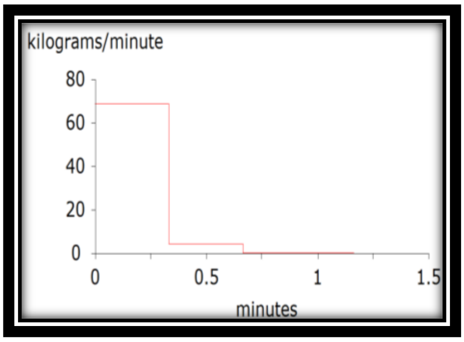


Plate 5: Source Strenght for 10 sq.cm of Pipeline hole area.

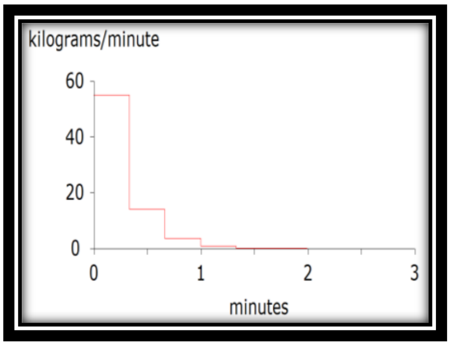


Plate 6: Source Strenght for 5 sq.cm of Pipeline hole area.

Table 17 denotes the values of the zone area of thermal Radiation for various potential hole area of Natural Gas Pipeline. These values are modeled which indicates different categories of Hazard Zone i.e. Red (lethal for 60 sec), Orange (2nd-degree burn for 60 sec) and Yellow zones (Pain for 60 sec) in the plates 7, 8 and 9. Threat zone for 5 sq.cm potential area remains same as the threat zone for 10 sq.cm potential hole area as shown in plate 9. It is the area where the thermal radiation is predicted to exceed the corresponding level of concentration at some point in the hour after release begins.

Table 17: Hazard Analysis: Thermal Radiation from Jet Fire

Scenario	**Thermal Radiation from Jet Fire**			
Hole Area	**324.51 sq.cm**	**15 sq. cm**	**10 sq.cm**	**5 sq. cm**
Red Threat Zone	10 m	10m	< 10 m	< 10 m
Orange Threat Zone	14 m	10m	<10 m	<10 m
Yellow Threat Zone	25 m	16m	15 m	12 m

Threat Zone

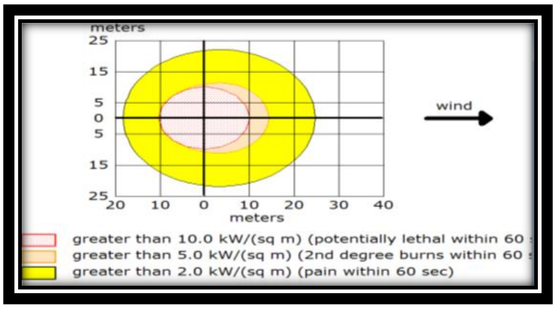


Plate 7: Threat Zone for Thermal Radiation of Natural Gas of Hole area 324.51 sq.cm.

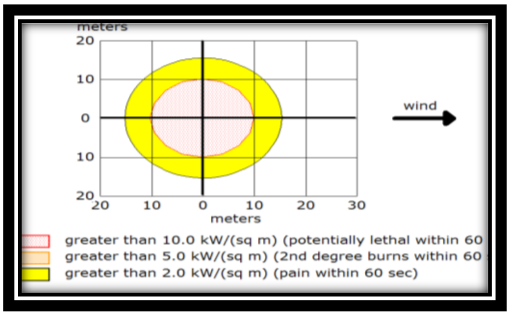


Plate 8: Threat Zone for Thermal Radiation of Natural Gas of Hole area 15 sq.cm

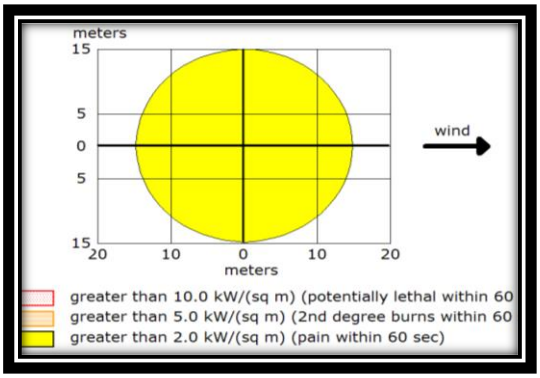


Plate 9: Threat Zone for Thermal Radiation of Natural Gas of hole area 10 sq. cm and 5 sq.cm

CONCLUSION

Now a day, industries are growing to a vast range to achieve high economic growth at national level. New technologies are implemented for accurate and fast outcome in terms of good quality product. The other phase of this new technology also leads to criticality in the operations which result in the accidents in case of negligence in the safety. This is a preliminary attempt to evaluate the safety aspects in one of the glass manufacturing industry located in North India. Mainly three Risk Assessment techniques are applied for safety evaluation i.e. Hazard Identification and Risk assessment, HAZOP study and Quantitative risk analysis using ALOHA software for the critical areas identified in glass manufacturing Industry. The conclusions from this study are as discussed below,

Hazard Identification and Risk Assessment technique are a preliminary stage assessment which was used for furnace area. Most of the medium and high risks from the furnace area are chemical and thermal hazards. Some of the recommendation is to provide shut off valve to the Natural gas pipeline to avoid potential explosion and adequate lightings at some of the areas etc.

Hazard and Operability Study is a specialized technique which highlights the causes and consequences for the deviations from process perspective i.e. deviation from the standard operating procedure. This technique is usually applied for highly hazardous operations. In this study, this technique was applied for a chemical plant i.e. Silane and Ethylene gas plant where most of the risk are medium risk, however, prominence is given to high risk with recommendations as suggested to install pressure relieve valve before the filter and cooling system for the cylinders on storage condition etc. Maximum numbers of high risks are found from Silane gas zone compared to Ethylene gas zone because of high reactive nature of the Silane with air under high pressure.

Although the studied techniques are qualitative which is only subjective, this study was further extended to quantitative risk analysis (QRA) using ALOHA software which helps us to analyse the catastrophic event from Natural gas leakage and its impact on the human being and environment. This software was applied for various potential hole area in the distribution pipeline of Natural gas as shown and concluded as comparing the various models of potential hole areas in the natural gas pipeline (Refer Plates 7 to 10), 324.51 sq.cm which is the rupture of whole diameter of the pipeline exhibits high hazardous zone which can also lead to death of human beings i.e. more than 12m from the point source down the line in the wind direction. The Hence larger diameter of rupture in the pipeline, more severe will be a loss in terms of the environment, society, workers, residents etc. depending on nature and operating conditions of the chemicals. However, frequent maintenance and monitoring of the Natural gas distribution pipelines along with Gas detection System and Fire Hydrant System can prevent the disaster.

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