e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:03/Issue:06/June-2021 Impact Factor- 5.354 www.irjmets.com

"RISK MODELING AND ITS MONITORING IN NATURAL GAS TRANSMISSION PIPELINES OF CITY GAS DISTRIBUTION NETWORKS"

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ABSTRACT

Risk assessment is adequate methods followed by oil and gas industries in functioning of gas pipelines helps limits the results of disasters. Risk assessments are administered at various phases of the strategy industry from conceptual stage, design stage, construction stage, operational stage, decommissioning stage.

Keywords: Gas Distribution Network, Risk Assessment; Gas Safety.

I. INTRODUCTION

There is an imminent must transport huge quantity of gas from source to consumption center economically and this can be possible only through building pipeline infrastructure within the country. Considering the importance of use of fossil fuel in various industrial and automotive sectors, major developments in transportation & distribution of fossil fuel through pipeline systems are trendy. The use of piped gas (PNG) for household, commercial (Hotel, restaurants etc.) and industrial supply in cities is gaining increased importance as an alternate fuel. The PNG network consists of receiving fossil fuel from suppliers at City Gate Stations, Steel Mains, Pressure Regulating Installations (PRI), Medium Density Poly Ethylene (MDPE) Mains and provides System to finish users. There's "five step" approach to safety risk management as (i) Planning, (ii) Hazard Identification, (iii) Analysis, (iv) Assessment and (v) Decision.

II. METHODOLOGY

Safety in PNG distribution is critical seeable of the highly inflammable nature of the gas and densely populated areas during which the network is installed. This study aims to confirm safe design; construction, operation & maintenance of PNG distribution so on provide level of safety and protection of life and property. Hazard Identification could be a systematic process of examining each work area and work task for the aim of identifying all the hazards which are 'inherent' within the activity/job. Risk Analysis could be a systematic process of appreciating the risks related to each of those hazards identified in order that the character of risk is understood. This includes the character of the damage/harm that will result from the hazard, the severity of that damage/harm and therefore the likelihood of this occurring. Risk Control details out taking actions to eliminate safety and health risks as far as in all fairness practicable. Where risks cannot be eliminated, then implementation of control measures is required, to attenuate risks as far as is fairly practicable. Hazard: Anything (condition, practice, behavior etc.) that has potential to cause harm, including injury, disease, death, environmental, property and equipment damage.

Methodology in brief is as under:

Explanation of HIRA Concept, Purpose, Methodology, Keywords, Risk Matrix

Detailed interaction on entire CGD operations.

Listing out key Operation and Maintenance activities.

Identification of possible/potential hazards in these identified activities.

Analysis of these hazards using a dedicated Hazard Identification Sheet covering the hazard, severity, probability and overall risk.

Decide Control Measures and check if existing control measures are adequate or additional control measures are required.

Check the residual risk level after considering all control measures.

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III. MODELING AND ANALYSIS

The Risk Matrix defines various levels of Severity and Probability of Occurrence upon various levels as under:

Table No 1: Categorization of Probability of occurrence: Probability of occurrence

Categorization of Probability of occurrence: Probability of occurrence	Rating
Once in a year	1
Once in six months	2
Once in three months	3
Once in a month	4

Table No 2: The Overall Risk Matrix

FREQUENCY	4	Moderate	High	Unacceptable	Unacceptable
	3	Acceptable	Moderate	High	High
	2	Acceptable	Moderate	Moderate	High
	1	Acceptable	Acceptable	Acceptable	Moderate
		1	2	3	4
	SEVERITY				

Table No 3: Categorization of Severity: Severity

Categorization of Severity: Severity	Rating
No injury only material loss	1
Minor to moderate injury or health effects OR Minor asset damage	2
Moderate to severe injury or health effects OR Major asset damage	3
Permanently disabling injury or fatality OR complete loss of asset	4

Table No 4: The Overall Risk Ranking is as under: Risk Ranking

The overall Risk Ranking is as under: Risk Ranking	Rating
1-3	Acceptable
4-7	Moderate
8-12	High
13-16	Unacceptable

Table No 5: The Residual Risk Ranking is as under: Risk Ranking

The Residual Risk Ranking is as under: Risk Ranking	Rating
1-4	Tolerable
5-16	Intolerable

Implementing Existing Control Measures and Additional Control Measures, if the Risk Ranking decreases to less than 4, the Residual Risk will be treated as Tolerable. Even implementing Existing Control Measures and Additional Control Measures, the Risk Ranking decreases but remains in the range of 4-16, the Residual Risk will be treated as Intolerable. However, as 'Fatality' is considered as the most serious consequence, hence, if there is an Overall Risk of 4 wherein 'Fatality' is involved, such risk will still be treated as 'Intolerable'.

Intolerable risks have been classified as having potential for single or multiple fatalities. For such risks where the hazard involves loss of human life, remedial action of some kind has to be undertaken. There are four ways of handling any type of risks:

•Terminate

•Treat

•Tolerate

•Transfer

HAZARD IDENTIFICATION & RISK ANALYSIS

PROBABILITY RATING-(1-Yearly, 2-Halfyearly, 3-Quarterly, 4-Monthly)

SEVERITY RATING-(1-No injury,2-Minor,3- Moderate,4-Fatality)

RISK RANK (A-Acceptable/ M-Moderate/ H-High/ U-Unacceptable)

OVERALL RISK= Probability X Severity

RESIDUAL RISK- (T- Tolerable, I- Intolerable)

Table No 6: HAZARD IDENTIFICATION & RISK ANALYSIS

ACTIVITY	**HAZARD**	**IMPACT EXPLANATION**	**PROBABILITY RATING**	**SEVERITY RATING**	**OVERALL RISK**	**RISK RANK**	**EXISTING CONTROL MEASURES**	**ADDITIONAL CONTROL MEASURES**	**RESIDUAL RISK**
Odorisation	1.1 Spillage	-Air pollution -Being highly toxic, health gets affected.	1	2	2	A	1. SOP for handling and disposal is available. 2. Chemical Suit and required PPE available. 3. Safety Shower and Eyewash available.	1. Inspection of dosing unit should be done periodically. 2. Designated person for handling Odorisation System to be identified. 3. Sodium Hypochlorite as neutralizer or other chemicals should be available.	T
		Being highly flammable, fire may occur, asset damage, human injury	1	4	4	A	1. Fire extinguishers available. 2. Fire Fighting Training imparted to concerned personnel. 3. MSDS should be displayed at the unit. 4. Emergency contact number should be displayed for use in case of emergency	1. Periodic maintenance of the fire extinguisher to be done.	T

Gas transmission	2.1 Leakage	-Minor asset damage - Environment gets affected	1	2	2	A	1. Routine Patrolling is done. 2. Periodic Awareness campaign for general public is done. 3. ERV Vehicle is available for any emergency. 4. SOP for Steel Pipeline Network in place. 5. O&M team available for leak repair.	1. Maintenance of isolation valve should be done to ensure its operation during leakage. 2. The pit maintenance should be done. 3. Adequate number of markers should be installed at specified intervals for identification of the pipe line. 4. Training to contractors of other utility companies sharing the same corridor should be imparted to avoid third party damage.	T
	2.2 Fire	-Human injury -Major asset damage - Environment affected	1	4	4	M	1. Routine Patrolling is done. 2. Periodic Awareness campaign for general public is done.	1. Maintenance of isolation valve should be to ensure its operation during fire. 2. The pit maintenance should be done. 3.Adequate number of	
							3. ERV Vehicle is available for any emergency. 4. SOP for Steel Pipeline Network in place. 5. O&M team available for leak repair.	markers should be installed at specified intervals for identification of the pipe line. 4.Liaison with local authority should be done to tackle such emergency.	T

	2.3 Third Party Damage	-Asset damage, gas leakage, fire, human injury	1	4	4	M	1. Routine surveillance is done. 2. Periodic Meeting with local bodies. 3. Periodic Awareness sensitization campaign is done. 4. Availability of Route Markers along the pipelines. 5. Emergency Telephone numbers have been displayed at various places in the city. 6. Availability of Warning Tapes above pipeline in place. 7. Odorisation system in place. 8. ERV Vehicle is available for any emergency.	1. GIS Mapping should be carried out. 2. Effectiveness of patrolling frequency to be periodically reviewed. 3.Training to contractors of other utility companies sharing the same corridor should be imparted to avoid third party damage.	T
	2.4 Corrosion	Pipeline integrity gets affected, leakage, fire, asset damage, human injury	3	4	12	H	1.Regular monitoring of PSP and TR Units. 2. CIPL and Pearson Surveys carried out.	1.Coating Health Survey to be carried out. 2.DCVG Survey to be carried out. 3.Pipeline thickness measurement to be carried out. 4.Moisture content in gas composition to be monitored regularly.	T

	2.5 Leakage	-Minor asset damage - Environment gets affected	1	3	3	M	1. Routine Patrolling is done. 2. Periodic Awareness campaign for general public is done. 3. ERV Vehicle is available for any emergency. 4. SOP for MDPE Pipeline Network in place. 5. O&M team available for leak repair.	1. Maintenance of isolation valve should be done to ensure its operation during leakage. 2. The pit maintenance should be done. 3. Adequate number of markers should be installed at specified intervals for identification of the pipe line. 4. Training to contractors of other utility companies sharing the same corridor should be imparted to avoid third party damage.	T
	2.6 Fire	- Human injury -Major asset damage - Environment affected	1	4	4	M	1. Routine Patrolling is done. 2. Periodic Awareness campaign for general public is done. 3. ERV Vehicle is available for any emergency. 4. SOP for MDPE Pipeline Network in place. 5. O&M team available for leak repair.	1. Maintenance of isolation valve should be to ensure its operation during fire. 2. The pit maintenance should be done. 3. Adequate number of markers should be installed at specified intervals for identification of the pipe. 4. Liaison with local authority should be done to tackle such emergency.	T

	2.7 Third Party Damage	-Asset damage -Gas leakage -Customers gets affected -Fire may take place.	4	3	12	H	1. Routine surveillance is done. 2. Periodic Meeting with local bodies regarding gas pipeline network is done. 3. Periodic Awareness sensitization campaign is done. 4. Availability of Route Markers along the pipelines. 5. Emergency Telephone numbers have been displayed at various places in the city. 6. Availability of Warning Tapes above pipeline in place. 7. Odorisation system in place. 8. ERV Vehicle is available for any emergency.	1. GIS Mapping should be carried out. 2. Effectiveness of patrolling frequency to be periodically reviewed. 3. Training to contractors of other utility companies sharing the same corridor should be imparted to avoid third party damage. 4.Awareness program for general public should be conducted at regular intervals	T
Filtration	Choking of filters	Leakage due to failure of gaskets, asset damage	1	2	2	A	1.Overpressure protection available at DRS. 2. Pressure Gauge available for monitoring.	1. Calibration of Differential pressure gauge should be done. 2. Calibration of PSV should be done	**T**

Pressure Reduction	High pressure at downstream due to failure of PCV	Consumer gets affected, PSV pup up, gas loss	1	3	3	A	1. Dual Active Monitor with dual redundancy available. 2. Slam Shut-Off Valve with UPSO and OPSO and PSV available d/s of Active Monitor Regulator.	1. Calibration of PSV should be done.	T
Gas flow	Leakage & Fire	Loss of gas, property damage, human injury environment affected.	1	4	3	M	1. Isolation valve provided at inlet && out let for isolation 2. Contact numbers displayed for passing the information. 3.Fire extinguishers available	1. Preventive Maintenance of isolation vaalve should be done. 2. Training should be imparted for safe operation & maintenance & handling of emergency to the O&M team.	T
Isolation	Isolation Valve is passing	Affected part of pipeline cannot be isolated, gas loss.	1	2	2	A	1. Dual Active Monitor with dual redundancy available. 2. Slam Shut-Off Valve with UPSO and OPSO and PSV available d/s of Active Monitor Regulator.	1. Preventive Maintenance of the isolation valve should be done.	T

Compression	7.1 Leakage	Gas loss, Human injury	1	3	3	A	1. Gas Leak Detection & Shutdown System in place. 2. SOP for CNG Package available. 3. Emergency Shutdown system for Individual Arm, Dispenser and compressor available.	1. Implementation of Preventive Maintenance Schedule to be ensured. 2. Safety interlock system should be checked periodically. 3. Periodic maintenance of the compressor package & leakage test should be done. 4. Periodic testing/ calibration of pressure relief valves,	
								PG, PT, TT should be done. 5. Training should be imparted to compressor operators for safe operation.	T
	7.2 Fire	Human injury and asset damage	1	4	4	M	1. Flame Detection &Shutdown System in place. 2. Fire Suppression System (CO2 Flooding System) in place. 3. SOP for CNG Package available.	1. Preventive Maintenance of CO2 Flooding, fire Detection should be done to ensure its availability. 2. Training should be imparted to compressor operators for safe operation & emergency handling.	T

Dispensing	8.1 Leakage while dispensing	Gas loss, human injury	3	3	9	H	1. Emergency Shutdown system for Individual Arm, Dispenser and compressor available. 2. Portable LEL Detector available. 3. Periodic maintenance of dispensers done. 4. Odorisation System in place. 5. SOP for Dispenser operation available. 6. Dos & Don'ts are displayed near dispensing area. 7. Excess Flow interlock for tripping of dispenser.	1. O-rings of dispensing nozzle to be checked periodically. 2. Leakage testing of the tubing & fittings of dispenser should be done. 3. Periodic maintenance of pressure relief valves. PG & other measuring instruments should be done. 4. Safety precautions should be followed during dispensing.	T
	8.2 Fire	Asset damage, loss of sale, Human injury	1	4	4	M	1. Fire Extinguishers available 2. Regular training to Dispensing staff. 3. Awareness Training to CNG consumers. 4. SOP for Dispenser operation available.	1. Training should be imparted at regular intervals to dispenser operators for safe operation & emergency handling.	T

Mobile Cascade filling	9.1 Movement of LCV during cascade filling	Asset damage	1	3	3	A	1.Comprehensive Safety Checklist for LCV is available and being followed. 2. Wheel Chokes are available. 3. SOP for LCV filling in place.	1. Safety Checklist for LCV filling to incorporate Safety briefing. 2. Crash guard to protect the equipment around the LCV filling point to be provided wherever LCV filling facility is available.	T
	9.2 Damage of hose pipe, tube and fittings	Damage of hose pipe, tube and fittings	1	3	3	A	1. Wheel Chokes are available. 2. SOP for LCV filling in place. 3. Leak Test is done before filling	1. Awareness training to the LCV drivers should be imparted periodically. 2. Crash guard around the LCV filling point can be provided to protect the equipment	T
	9.3 Leakage from hose pipe, tube and fittings	Leakage from hose pipe, tube and fittings	1	3	3	A	1. Portable LEL Detector available for leak test. 2. Periodic maintenance of hose and coupling is done. 3. Odorisation System in place.	1. Safety Checklist for LCV filling to incorporate Safety briefing. 2. Periodic calibration of measuring instruments should be done. 3. Periodic leakage survey should be done.	T
Power generation through Diesel Generator	Electrocution	Fatal	1	4	4	M	1. PPE and tools for safe electrical operation available.	1. Electrical isolation procedure should be followed. 2. Work instruction should be followed 3.Proper tools should be used 4.Inspection of tools should be done before using 5.Damaged tools should be replaced with new one 6.Deployment of trained personnel 7.PPE should be used during work	T

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IV. RESULTS AND DISCUSSION

After implementing Existing Control Measures and Additional Control Measures, if the Risk Ranking decreases to less than 4, the Residual Risk will be treated as Tolerable. Even after implementing Existing Control Measures and Additional Control Measures, the Risk Ranking decreases but remains in the range of 4-16, the Residual Risk will be treated as Intolerable. However, as 'Fatality' is considered as the most serious consequence, hence, if there is an Overall Risk of 4 wherein 'Fatality' is involved, such risk will still be treated as 'Intolerable'.

Table No 7: The Overall Risk Matrix

FREQUENCY	4	Moderate	High	Unacceptable	Unacceptable
	3	Acceptable	Moderate	High	High
	2	Acceptable	Moderate	Moderate	High
	1	Acceptable	Acceptable	Acceptable	Moderate
		1	2	3	4
	SEVERITY				

Intolerable risks have been classified as having potential for single or multiple fatalities. For such risks where the hazard involves loss of human life, remedial action of some kind has to be undertaken. There are four ways of handling any type of risks:

- Terminate
- Treat
- Tolerate
- Transfer

All operational risks fall under these four categories. Suitable mitigating measures are devised and implemented to contain the risks. For the risks which are intolerable, an Incident Management Plan is prepared and activities are carried out in case of an incident, the Incident Management Plan is activated. In no case, an activity related to intolerable risks are stalled merely because they are intolerable as there is a well-defined Incident Management Plan in place.

Table No 8: Action required for reducing the risk to ALARP level

S.No	Risk	Action required for reducing the risk to ALARP level
1	Odorisation of gas	1. Checking of dosing unit should be done periodically. 2. Designated person for handling Odorisation System to be identified. 3. Sodium Hypochloriteas neutralizer or other similar chemicals should be available at the odorizing storage system for neutralization in case of leakage. 4. MSDS should be displayed at the unit. 5. Emergency contact number should be displayed for use in case of emergency. 6. Fire extinguishers should be available at site. 7. PPE should be available 8. Eyewash system should be installed near the unit.
	Fire & leakage in Pipe lines	1. Periodic maintenance of the isolation valves & pits should be done so that the affected section can be isolated easily. 2. Awareness program for the general public should be conducted at regular intervals to spread awareness among the general public. 3. Liaison with local authority should be done so that necessary help can be obtained during any major emergency.

	Third party damage	1. Awareness program for the general public should be conducted at regular intervals to spread awareness among the general public. 2. Liaison with local authority should be done so that necessary help can be obtained during any major emergency.
	Corrosion	1. DCVG Survey to be carried out to monitor corrosion in Steel Pipeline network. 2. Instant Pipe to Soil Off Potential measurement for entire pipeline. 3. Pipeline thickness measurement to be carried out.
	Leakage & fire in compressor	1. Leak test should be done periodically 2. Periodic maintenance of the compressor package should be done. 3. Calibration of measuring instruments & safety valves should be done periodically 4. Checking of fire detection & alarm & firefighting systems should be done periodically. 5. O&M procedures should be followed for operation & maintenance of the compressor. 6. Training should be imparted to compressor operators to handle the emergency in the incipient stage.
	Leakage & fire in dispenser	1.Leak test should be done periodically 2. Periodic maintenance of the dispenser should be done. 3.Calibration of measuring instruments & safety valves should be done periodically 4.O&M procedure should be followed for operation & maintenance of the compressor. 5. Training should be imparted to dispenser operators to handle the emergency in the incipient stage. 6. Awareness training program for CNG customers should be conducted are regular intervals.
	Leakage &Fire in GEG	1. Overloading should be avoided. 2. Leak test should be done on the inlet gas pipe line. 3. Training should be done for the CNG staff to handle the emergency.
	Earthing& electrocution	1. Electrical isolation procedure should be followed during job on the electrical system. 2. Proper tools should be used while working on the electrical system. 3. Trained personnel should be engaged for any work on electrical system. 4. PPE should be used 5. Periodic maintenance of the earth pit should be done & records should be maintained.
	Vehicle & Passenger movement in the CNG station	1. Safety awareness program for public coming to the CNG station should be conducted at regular intervals. Distribution of safety leaflets to the general public to create safety awareness. 2. Vehicle marshalling should be done in a way that the vehicles should come in a row & exit after filling. 3. It is to be ensured that, no passengers are present while the filling is under progress.
	Working at height	1. Working platform or stable ladder should be used for working at height.

		2. Personal protective equipment should be used while working at height. 3. Work permit system should be followed.
	Calibration of measuring instrument	1. Calibration of the measuring instrument should be done periodically.
	Leakage & fire in customers' premises.	1. Leakage survey should be done to detect the leakage. 2. Safety awareness campaign should be conducted for the customers. 3. Display of emergency contact number should be done so that the customer can contact in case of any emergency.

V. CONCLUSION

For further studies, it is recommended to specifically identify risk present in a gas transmission pipeline of city gas distribution industry. Also, it is recommended to determine whether the risks present city gas distribution industry is the same with the other city gas distribution industry in different locations in India. The conclusion of this research work investigation of the effects, cause, and safety issues in city gas distribution industry and noted recommendations to the improvement of city gas distribution industry safety. Section

ACKNOWLEDGEMENTS

The authors of this paper are relatively obliged to the Dept. of Fire Technology and Safety Engineering, Institute of Engineering and Science, IPS Academy, Indore. Authors are grateful to the Principal, Head of the Department and the different body of workers of the Institute. Authors would like to express their deep sense of gratitude toward Prof. Manish Dubey for their treasured instruction and feedbacks. The authors can acknowledge professor, friend or family member who help in research work in this section.

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