EHS RISK ASSESMENT OF M.R.C.S.B PROJECT, L&T, GOA (UNDER CONSTRUCTION) AND DESIGN OF CITY GAS DISTRIBUTION NETWORK BY USING TECHNICAL STANDARDS AND SPECIFICATION INCLUDING SAFETY STANDARDS

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AND
DESIGN OF CITY GAS DISTRIBUTION NETWORK BY USING TECHNICAL STANDARDS AND SPECIFICATION INCLUDING SAFETY STANDARDS

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by

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Supervisors' Certificate

This is to certify that the work presented in the thesis entitled *EHS Risk Analysis Of M.R.C.S.B Project, L&T, Goa (Under Construction) And Design Of City Gas Distribution Network By Using Technical Standards And Specification Including Safety Standards* submitted by *Laxminarayan Nayak*, Roll Number 214CH2553, is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master Of Technology* in *Chemical Engineering With Specialization Of Safety Engineering*. Neither this thesis nor any part of it has been submitted earlier for any degree to any institute or university in India or abroad.

_____

Arvind Kumar
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Declaration of Originality

I, *Laxminarayan Nayak*, Roll Number *214CH2553* hereby declare that this thesis entitled *EHS Risk Analysis Of M.R.C.S.B Project, L&T, Goa (Under Construction) And Design Of City Gas Distribution Network By Using Technical Standards And Specification Including Safety Standards* presents my original work carried out as a M.Tech student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the Thesis. Works of other authors cited in this thesis have been duly acknowledged under the sections "Bibliography". I have also submitted my original research records to the scrutiny committee for evaluation of my thesis.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present thesis.

May 23, 2016

Laxminarayan Nayak

NIT Rourkela

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23rd may

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Abstract

An EHS leader must Fully understand the philosophy of L.I.F.E. & Zero Harm Vision along with Inspire others to behave safely and have due regard for the environment. He must have ability to recognize the connection between good EHS and good business practices and Posses up-to-date EHS knowledge. He must have communication skills to convey and demonstrate leadership to all levels of the workforce and committed to action at all times.
EHS culture has four stages namely pathological, reactive, calculative, proactive and generative stage. Zero harm vision has seven key elements. First element is leadership and commitment so Leaders must promote & demonstrate visual EHS commitment, excellence and lead by example.

Second element is the risk management. Class one risk activity incorporated with working at height, vehicles, plants and equipment, tunneling, excavation, form work, mechanical lifting, work in confined space, work with electricity, working adjacent to public areas and hot work. Third element is setting of objectives and targets which should be measurable, attainable, and relevant and must have time bound. Fourth element is training and competence which includes of evaluation of training needs and periodical training for all personnel. Daily tool box talk to create awareness and propagate the incident and case studies among all the workmen.

Fifth element is the communication and consultation. It includes monthly EHS meeting, EHS notice board, and EHS newsletter. Sixth element is to measure performance by inspection, internal audit and external audit. Seventh element is review and changes .Reviewing & managing changes is designed to expedite control and manage changes to policies, procedures, standards, organizational management and the execution or sequence of EHS related critical activities.

Risk management has four stages namely identifying hazards, access the risk, determine the controls, and implement the controls, monitor, review and update. The approach must passes through a hierarchy of elimination, substitution, engineering control, administrative control, training and Personal protective equipment. In this study I have done risk assessment of different activities of construction of MRCSB Project, L&T, Goa. Then a comparable study between RA and RR has been done. After analyzing all the facts it is found that despite Risk assessment for every activities the KPI are not up to expectation. So to find out the root cause of this nonconformity gap analysis has been done.

Real field data collected along with lagging and leading indicator, discussion with ground people. Fish bone analysis and by studying different laws, code of practices suggest some recommendation to improve site condition.

Keywords*: *EHS risk assessment; Gap analysis; Data collection; Data analysis

Contents

List of Figures

List of Tables

EHS RISK ASSESMENT OF M.R.C.S.B PROJECT, L&T, GOA

(UNDER CONSTRUCTION)

Chapter 1

Introduction

1.1Background

The stringent standard from ILO-OSH, BS OSHAS, IMS and BOCW (1996) succeeded to have a growing awareness among the working group regarding occupational health and hygiene. The standards all together put emphasis on continual improvement of safety standards of organization. But despite of taking all the initiatives, the standards of safety is not improved in recent years as expected. (Vitor Sousa 2014) listed up the key elements for this under achieved safety standards i.e. (1) the inherent risk associated with the construction projects and (2) a negative perspective of financial investment for the additional safety measures to run pro safety drive.

In terms of occupational safety and health at work the construction industry is most dangerous industry as construction workers are three times more likely to die compared to other industry(EASHW, 2003).The risk associated with construction workers mainly divided into three categories(David M. ZALK, 2011). Chemical risks exposed by construction workers are asbestos, solvents, silica, welding fumes, and lead. Physical risks faced by construction workers are hand and arm vibration, full body vibration, ergonomics risks, noise, heat, and cold. The safety risks with construction works are working at heights, working on or under unstable structure, working with energized equipment/machinery, working near power cables. So there is a need of risk management process which can also address to safety with the issues regarding environment and quality.

In low income group countries like India the standards of occupational health and safety rule and regulation implementation is a big challenge. Due to dynamic nature of construction projects, it is a top task to train all the workers. Most of workers have training in a certain field but its nature of construction projects which put force on the worker to do work in which he is not specialized and may or may not have minimum knowledge. So it is very crucial to select the approach of a construction company with regard to occupational health and safety.

EHS Risk Management is an integral part of the IMS and combines technical, consultative, systematic and managerial approaches to identify any foreseeable hazards that have the potential to harm employees, contractors, JV Partners, visitors and members of the public. Risk Management program is has been improved to support the elimination of fatalities & serious injuries .hazard is the Source, situation, or act with a potential for harm in terms of human injury or ill-health or a combination of these. Risk is the Combination of the likelihood of an occurrence of a hazardous event or exposure and the severity of injury or ill-health than can be caused by the event or exposure. Risk assessment includes Routine and Non-routine activities, Activities of all personnel having access to the workplace (including contractors & visitors), Facilities at the workplace (office, canteen, workmen facilities etc.).input of risk assessment includes Project Risk Register, List of work activities, List of machinery and tools used, Records of past incidents and accidents, Relevant legislation, Relevant codes of practice or specifications, Details of existing control measures, Feedback from staff, clients, suppliers, interested parties, Other information such as MSDS, manufacturer's instructions, Copies of any relevant previous risk assessments. Risk assessment has 5 steps. Identification of hazard, evaluate the risk, determine the control, and implement the control, review and update.

1.2 Objectives and scope

It is attempted to do EHS Risk assessment of following activities at Mandovi River cable stay bridge project (Under Construction)

(a) EHS Risk analysis of Pilling activities in marine

(b) EHS Risk analysis of Temporary Cofferdam works

Scope of this work:

(a) Mandovi river cable stay bridge project is chosen for the study
(b) Hazard identification, analysis, determining the control for the risk and revaluating is done for the different activity
(c) Risk management for different activity related to bridge construction is tabulated
(d) A methodology for gap analysis is proposed and it is done for this project

(e) All the finding are analyzed and recommendation given for the improvement of safety standards.

1.3 Organization of the Project Report

This thesis is organized in eight chapters of which this is the first. Chapter two deals with literature review. Chapter three comprises about the MRCSB Project. Chapter four and five describes EHS Risk assessment by matrix method. In chapter six a model for gap analysis proposed while chapter seven manifests the result of the model. Chapter eight concludes the report by summarizing the works done here.

Chapter 2

Literature Review

Unsafe act or unsafe condition or a combination of both leads to an accident(Connor, 1992) and 80% of them are due to unsafe behavior(Choudhry, 2007).

Haslam et al.(2005) analyzed accidents in construction industry and claim that 84% accidents could be predicted well before and can be eliminated by adopting the risk management system.

Individual risks are ‘‘the frequency with which an individual can be expected to bear a certain level of aggression resulting from the materialization of a specific hazard’’ and Societal risks are defined as ‘‘the relationship between the frequency and the number of individuals subject to certain level of aggression resulting from the materialization of a specific hazard’’(IChemE, 1985).

The individual risk and societal risk are to be handled an attempt should be towards to achieve a risk in state of as low as reasonable possible(HSE, 2001). All this theory of ALARP based on three criteria i.e. equality, technology and utility based criteria.

To reduce risk the risk management should undergone in three steps(1) risk identification(2)risk assessment(3)risk mitigation(Zayed, 2008)

Cox et al.(2008) figure out the ambiguous input and output of existing risk matrix so it must be used with ample experience and a good sense of judgement.

Sameh et al.(2008) plotted a probability impact matrix for the construction industries in UAE. In the study it is recommended that the allocation for accident during constructor will be subcontractor.

David et al.(2011) developed a 4 × 4 matrix for pre job hazard analysis. He divided the risk level into 4 categories and specifies the requirement for each risk band to minimize the risk. The activity falls under risk level one basic craft skill is sufficient on job site, for second level hazard

awareness expertise required on job site, for third risk level competent person required on job site and for fourth risk level expert required on job site.

Amir et al.(2011) proposed a risk assessment model for construction industry using the fuzzy TOPSIS method and decision criteria are obtained from the nominal group technique (NGT) and validated the model with an Iranian construction corporation.

Mohamed et al.(2015) identified the risk factors for construction projects. He categorized safety risk factor into five categories and also defined the consequence of this risk in terms of very high to very low. For fatalities the rank is very high, for severe injury it is high, for medical treatment rank is moderate, for first-aid rank is low and for no injury consequence will be very low.

Al-Anbaria et al.(2015) developed risk Assessment of Safety and Health RASH method for building construction. He classified the risk into health risk and safety risk. The accuracy is twice than conventional risk assessment methods and it is also statistically acceptable.

S.X. Jeng et al.(S.X. Zeng 2008) argued in the favor of an integrated standard to deal with safety issue. By integrating ISO 9001, ISO 14001 and the OHSAS 18001, chance of delicacy and resource to implement along national standard will be reduced.

Seok J et al.(2013) claimed that the incident rate decreased by 67% and fatal rate decreased by 10.3% during 2006 – 2011by adopting occupational health safety management system in South Korean construction companies.

In this project, a EHS Risk Assessment for Mandovi river cable stay bridge project (under construction), L&T, Goa developed as per IMS Guideline.

2.1 Problem Statement

Project work has been done in four steps. First attempt is to understand every step for construction of bridge i.e survey, design, planning, resource assembling, pilling, pile cap, cofferdam work, pier and pier cap and erection works. Second step is to develop a 4x4 matrix for risk analysis as per IMS manual, then EHS Risk assesment done by matrix method for every activities. Then gap analysis is done by Data collection, data analysis, Employee survey, EHS walk down, Evaluate findings and suggest improvement.

Chapter 3

About the Mandovi river cable stay bridge project

3.1 project location

L&T – Mandovi River Cable Stay Bridge Project, Goa site is located in the city of Panaji, Goa. The site address is L&T Construction, Mandovi River Cable Stay Bridge Project opposite of KTC bus stand, old Mumbai bus stand, Panaji, Goa - 403005. The overview of project is to Design & Construction of Bridge across River Mandovi at Panaji, Goa including approaches on NH 17 between Pundaliknagar Jn (Porvorim) and Merces Jn.

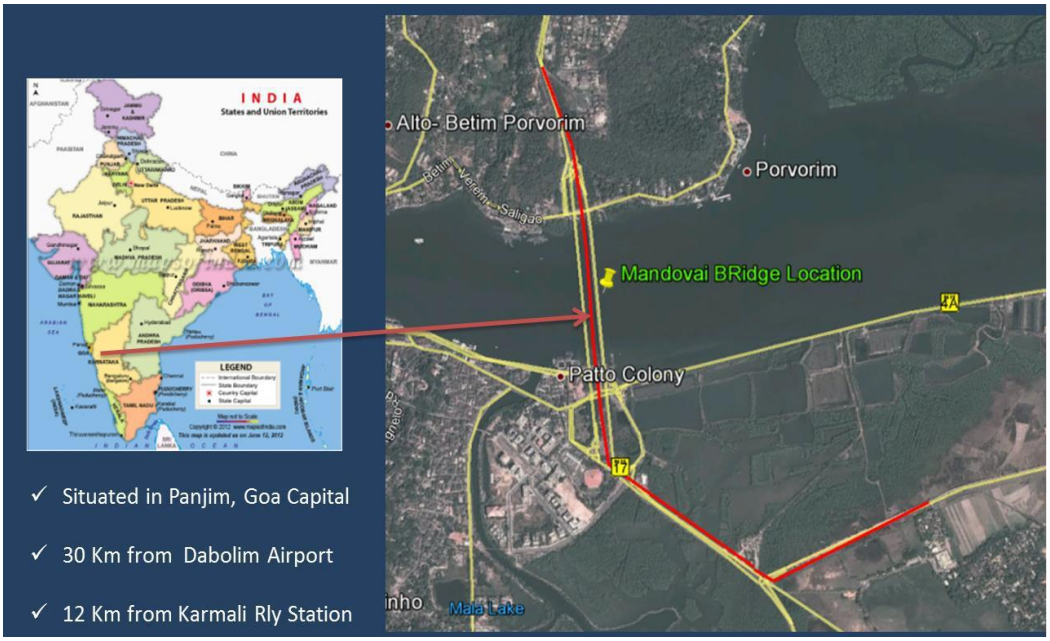


Fig 3.1: Route Map of Mandovi River Project

3.2 Project highlights

Name/ Identity of the project: Mandovi Cable Stay Bridge Including Approaches, GOA

Client	**:** GSIDCL
Client Consultant	**:** S. N. Bhobe & Associates Pvt. Ltd., Mumbai
Contract Type	**:** Design & Build Lump sum
Conditions of Contract	**:** Goa State Contracting Procedures
Duration	**:** 30 Months
Value	**:** 403 Cr

3.3 Step by step of construction of MRCSB project

The construction started by surveying by surveyor, Then soil testing is to be done .With reference to result of soil test designing will be done .Planning for execution will be done and documented by a team of multidisciplinary experts for execution .After legal documentation process resource marching will be done i.e. Human resource, vehicle, machineries etc. Barricading and road diversion will be done as per standard of Indian Road congress. The survey point will be cleared and made it possible for construction works .Then utility trial pit test to be done.

After that three or four point shall be marked around the survey point and center of augar shall be placed and work has to start. As per drawing check whether it will be as per drawing and will be upright or not by sprit leveler. Sprinkle of bentonite solution will be done in the pile. Boring will be done as per design drawing by pilling Rig machine or by winch machine as per requirement. After that cage lowering is to be done followed by trimmie pipe lowering. Next step is Hopper shifting and connect with trimmie pipe and then concreting is to be done by the help of boom placer.

Then excavation will be done as per designing (Generally 1.8m) following by dressing. Level checking will be done by auto leveler .After that plane cement concreting (PCC) is to be done at bottom of pile to join the pile. After that liner cutting will be done and removed from excavated pit. Then pile chipping will be done by chipping machine and reinforcement bar is to be cut as per design. Next step is to pile stump breaking and removing from excavated pit. Survey point, center point and corner point will be marked of pile cap. Then bar binding is to be done at bottom reinforcement, top reinforcement and vertical reinforcement for pier.

Fig 3.2 : Coffer dam at P-22, MRCSB Project

Next step will be shuttering and concreting with vibrator. After that de-shuttering is to be done followed by coal tar or epoxy paint spraying. After curing reinforcement for pier as per designing with help of Doca tower. Then shuttering will be done for pier and concreting will be done and this process will continue till the design height of pier. After that pier cap will be constructed

In marine after surveying Survey Liner Pitching and driving using vibrohammer is to be done. Boring is to be done by using BG28 Rig machine. Then Erection of Piling Gooseneck to be done. After that Winch machine is to be placed. Placing of winch rope in gooseneck boom manually using man basket. Next activity is Launching of chisel in the winch rope and Hammering of chisel is started. After some time interval Replacing of chisel with bailer for removing the broken rock pieces from pile is to be done .The winch mat platform is to be taken back and cage lowering is to be done by help of crane. After that trimmie is to be lowered & concreting is to be done. Transporting/Shifting of liners & other materials from load out jetty to Crane Barge using material barge and Liner pitching and driving for coffer dam is to be done.

Chapter 4

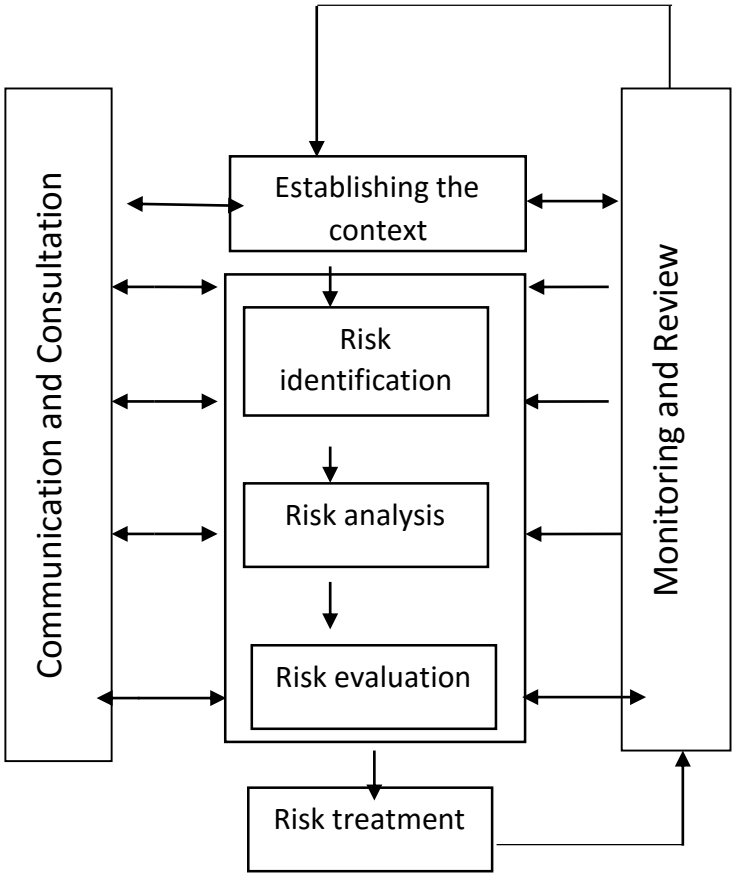
ESH Risk assessment by matrix method

4.1 Risk

The definition of risk and risk management process may vary in different literature, In this thesis I followed Is/ISO 31000:2009(BIS, 2009) and ("IMS Manual," 2014)guideline for the risk assessment of different activity. Indian standard for risk management(BIS, 2009) defines the risk as ‘’the effect of uncertainty on objectives’’ and Risk assessment as’’ the overall process of risk identification, risk analysis and risk evaluation’’.

4.2 EHS Risk management process

EHS Risk management process has five step.(1)Identify Hazards / Aspects(2)evaluate the risk / impact(3)determining controls(4)Implement the controls(5)Review and update



4.2.1 Identify Hazards / Aspects

This step involves the identification of hazards / environment aspects associated with the activity. The source of risk and the consequence also determined in this step which may leads to any adverse effect on project. The points shall be taken into account while identifying the health & safety hazards and environmental aspects are activities of all persons having access to the workplace, human behavior and capabilities along with other human factors, hazards originating outside the workplace having capacity adversely affecting the health and safety of persons under the control of the organization within the workplace, hazards / aspects created in the vicinity of the workplace by work-related activities under the control of the organization, infrastructure and equipment and materials at the workplace irrespective of provided by the organization or others, changes or proposed changes in the organization and can be extend to its activities and materials, modifications to the EHS management system including temporary changes and their impacts on activities and the design of work areas, processes, installations, machinery/equipment, operating procedures and work organization, including their adaptation to human capabilities.

4.2.2 Risk analysis

In this stage method for the evaluation of risk is selected. In this stage the extent of consequence of risk on activities determined along with probability of occurrence. While selecting consequence of any event and probability of occurrence, the present counter measure to minimize the risk can be taken into consideration. One risk can have multiple consequence on multiple events. In this step the level of risk also decided for the particular event and step must be taken to limit the risk within tolerance limit, so that the risk can be as low as reasonable possible.

4.2.3 Evaluate the risk / impact

The risk evaluation shall be done by listing out,the existing risk control measures, the likelihood of occurrence (probability), assessing the potential severity of the health & safety hazards, environmental aspects and ascertaining the risk / impact level based on the likelihood and severity

Existing Risk Control

The presence of existing control measures shall be first identified for each of the Health & Safety hazard, Environment aspect and by considering the effectiveness of the existing controls and the consequences of their failure, the risk / impact level can be assessed.

Likelihood of occurrence (Probability)

Likelihood of occurrence of an incident is classified as per the table given below.

Table no.4.1: Probability Description

Probability Descriptions (The highest category will always be used)		
VALUE	**Status**	**Description**
4	Very Likely	The event is almost certain to occur and has occurred repeatedly in the construction industry
3	Likely	The event will probably occur in most circumstances
2	Unlikely	The event may occur only in exceptional circumstances
1	Very Unlikely	Very unlikely but remotely possible
4	Very Likely	The event is almost certain to occur and has occurred repeatedly in the construction industry

Severity

Severity is the degree or extent of harm that can be caused by the hazards or the environment aspect as a result of an incident. Severity is classified as per the table given below.

Table no 4.2: Severity Description

VALUE	Result of Hazard to Personnel / Environmental impact
4	Fatality
3	Reportable Injury or illness resulting in more than 2 days off work / Permanent Total Disability /Major Pollution
2	Non-Reportable Lost Time Injury or Illness resulting in less than 2 days off work
1	Injury or illness requiring First Aid treatment. Minor Pollution

Matrix for Risk Assessment

Once the likelihood and severity have been established, the risk / impact level can be determined by selecting the appropriate row for Likelihood and by selecting appropriate column for severity; the cell where they intersect indicates the Risk / Impact Level.

Probability (P)	Severity (S) 1	2	3	4
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16

Fig 4.1: Risk assessment matrix

4.2.4 Determine controls

Based on the risk / impact level determined, controls should be selected to reduce it to acceptable level. This can be done by reducing the Likelihood and/or Severity.

Table no 4.3: Risk Prioritization

Risk Rating **(P x S)**	**Risk level**	**Recommended actions**
1 to 3	Low Risk	No additional risk control measures may be needed.
4 to 8	Medium Risk	Work can be carried out with Risk controls in place
9 to 16	High Risk	Don't start work. Risk level must be reduced to Medium / low before commencing work.

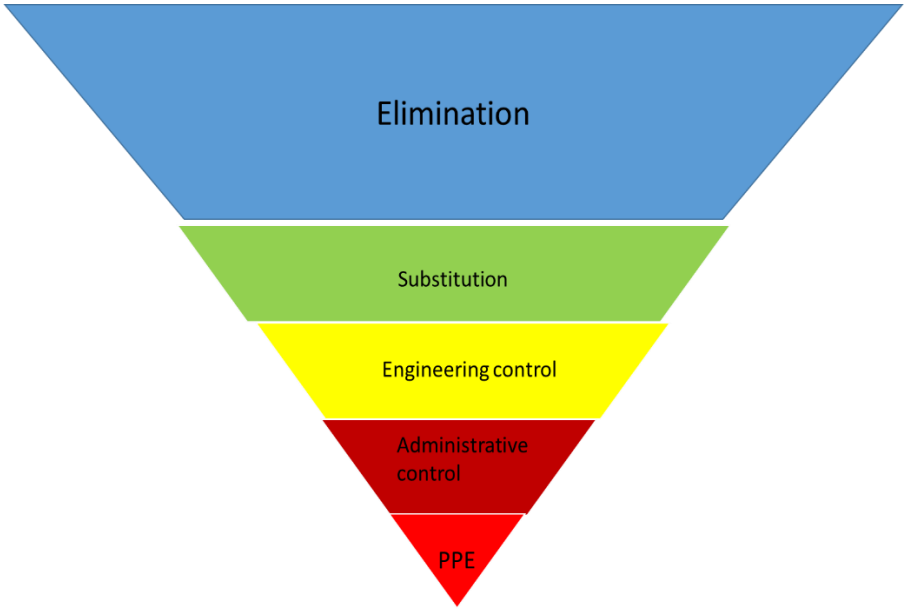


Figure 4.2: Hierarchy of controls

When determining controls, or considering changes to existing controls, consideration shall be given to reducing the risks according to the above hierarchy control.

Residual Risks / Impact

Residual risks / impacts are the remaining risks / impacts, for which the planned controls are not able to effectively remove or control. It shall be ensured that the residual risks / impacts are acceptable and manageable.

4.2.5 Implement controls

Work shall be carried out as per approved safe work method. Adequate resource must be ensured by authority to implement the control.

Work Permit System

Work permit systems shall be implemented for the activities which are required to be performed under controlled environment("IMS Manual," 2014) . The work permits shall be applicable for working at height, confined Space work, hot work, excavation work, work on Plant & Machinery and electrical work.

Daily Pre-start verification and Briefing to workmen

The Engineer In charge shall complete the 'Daily Pre-start verification and Briefing sheet' before starting the work every day. 'Pre-start verification' ensures that the EHS risks involved in the day's task are assessed and site condition verified for compliance in line with the Risk Assessment and SWM. Before starting the day's work, the workforce shall be briefed about the nature of the risks involved and the control measures implemented in line with the Risk Assessment and Safe work method statement. Language of briefing shall be understandable to the workforce.

4.2.4 Review & update

Engineer In charge and Project EHS In charge shall conduct periodic inspections to verify the implementation of controls stipulated in the Safe Work method statement.

The EHS risk management system shall be reviewed periodically taking into consideration of field audit findings, incident reports and feedback from projects. The EHS Risk Assessment shall be maintained up to date.

5.1 EHS Risk assessment of pilling activities in marine

Activities Covered: Pilling activities in marine

Location: Main Bridge

Table no. 5.1: EHS risk assessment of pilling activities

Sl No	Activity	Hazard	Risk Involved	People at risk	Existing Control Measures	Assessment			Additional Control Measures	Re-assessment		
						P	S	Risk Level		P	S	Residual Risk

1	Survey	Drowning, Risk of fall	Injury, drowning, fatal	Site workers and site staff	• Edge protection shall be provided on jack up barge plat form • Hard barricading shall be provided to prevent fall. • Rescue boat with divers shall be deployed at all the time of work.	1	2	2				
2	Liner Pitching & Driving using vibro hammer	Sling failure Crane toppling	Hit Injury Drowning Risk of fall	Site workmen, staffs, operator	• Lifting slings & D shackles shall be inspected daily before taken into use. • Turn buckle should be provided for crane arresting with jack up platform • Monthly joint inspection from P&M dept. and EHS dept. shall be done and fitness certificate shall be displayed.	2	2	4	• Rescue boat with divers shall be deployed at all the time of work. • Work shall be stopped or restricted			

					• ASLI shall be maintained regularly and if not working it shall be repaired. Lifting equipment shall be used unless ASLI rectified. • All limit switches shall be connected through ASLI and if it crosses the limit the lifting equipment's shall get cut off automatically.				during rough wind.			
	Welding & Cutting for liner jointing & welding	Burning, Explosion	Burn Injury, Electro cution	Site work men, staffs, operator	• Hot work permit shall be taken in every shift. • Flashback arrester shall be provided. • Welding cables shall be properly maintained & contact with water to be prevented. • Cylinder stand & shed shall be provided. • Earthing shall be provided with holder.							

3	Boring using BG28	Hit hazard while swinging of rig. Toppling of piling rig.	Hit Injury, Severe injury leading to fatality	Operator, Workmen & Staffs.	• Swing alarm shall be provided • Qualified operator shall be provided for operating piling rig. • Turn buckle should be provided for piling rig arresting with jack up platform. • Qualified foreman are provided for expert supervision	1	1	1				
4	Erection of Piling Goos eneck boom	Snatching of rope, Man Over Board	Injury, drowning, fatal	Site workers and site staff	• Check the condition of rope, tools and tackles before taking to use. • Inspection of lifting tools and tackles as per the site EHS plan and color coding for the same. Only inspected lifting tools and tackles shall be used. • Edge protection shall be provided where ever practicable.	2	4	8	• Separate rigging gang shall be deployed for erection activities. • Lifting plan shall be made for such lifting activities.	1	4	4

					• All workmen shall wear solos approved lifejacket while working over water. • Proper illumination level (minimum 54 lux) shall be maintained while working at night. • Rescue boat with divers shall be deployed at all the time of work. • Work shall be stopped or restricted during rough wind.				• Storage of lifting tools and tackles shall be free from wet and mud. • Suitable number of ring buoy shall be kept near the work area with 30 meter pp rope connected.			
		Toppling of lifting equipment	Injury, Fatal.	Site work men, staffs,	• Lifting equipment shall be inspected daily before taken into use.	1	4	4	• Periodical joint inspection from P&M			

				operator	• 3rd Party test shall be carried out as per requirement. • ASLI shall be maintained regularly and if not working it shall be repaired. Lifting equipment shall be used unless ASLI rectified. • All limit switches shall be connected through ASLI and if it crosses the limit the lifting equipment shall get cut off automatically. • Rescue boat with divers shall be deployed at all the time of work. • Work shall be stopped or restricted during rough wind.				dept. and EHS dept. shall be done and fitness certificate shall be displayed.			
5	Welding/gas cutting	Fire, explosion, electrocution	Burn injury, Electric shock, Fatal.	Site workmen, staffs	• Hot work permit shall be taken for each shift. • The flammable materials shall be removed before start of hot work.	1	4	4				

	works for erecting of goozner and other fittings				• The power supply for all welding machines shall be taken only through RCCBs which have 30mAmps tripping range. • Flash back arrestor shall be fixed at both cylinders in both end i.e., torch end and cylinder end. • All cylinders shall be stored in upright position and shall be secured tightly. • All cylinders shall be procured only with safety cap for protection of damage of cylinder nob.							
6	Placing of winch	Snatching of lifting rope, Man Over Board	Injury, drowning, fatal	Site workers and site staff	• Check the condition of rope, tools and tackles before taking to use. • Inspection of lifting tools and tackles as per the site EHS plan and color coding for the same.	1	4	4				

					Only inspected lifting tools and tackles shall be used. • 3rd Part test for lifting tools and tackles shall be only used. • Storage of lifting tools and tackles shall be free from wet and mud. • Edge protection shall be provided where ever practicable. • All workmen shall wear only approved lifejacket while working in water. • Suitable number of life ring shall be kept near the work area with 30 meter pp rope connected. • Proper illumination level (Minimum 54 lux) shall be maintained while working at night.							

					• Rescue boat with divers shall be deployed at all the time of work.							
7	Placing of winch rope in goose neck boom manually using man basket.	Man Basket failure, Man Basket hitting with other objects, Man over board.	Injury, drowning.	Site workers and site staff	• 3rd party test shall be done for man basket. • Daily inspection shall be done for the man basket. • Man basket shall be guided with guide rope while lifting with lifting equipment. • Workmen entering in the man basket shall wear full body harness and shall be hooked in separate sling. • All workmen shall wear solas approved lifejacket while working in water. • Suitable number of life ring shall be kept near the work area with 30 meter PP rope connected.	1	2	2	Work shall be stopped or restricted during rough wind.			

					• Rescue boat with divers shall be deployed at all the time of work.							
8	Launching of chisel in the winch rope.	Snatching of wire rope, Man over board.	Serious Injury, drowning,	Site workers and site staff	• Check the condition of rope, tools and tackles before taking to use. • Inspection of lifting tools and tackles as per the site EHS plan and color coding for the same. Only inspected lifting tools and tackles shall be used. • 3rd Part test for lifting tools and tackles shall be only used. • Storage of lifting tools and tackles shall be free from wet and mud. • Edge protection shall be provided where ever practicable. • All workmen shall wear only approved lifejacket while working in water.	1	4	4	• Suitable number of ring buoy shall be kept near the work area with 30 meter pp rope connected. • Proper illumination level shall be maintained while working at night. • Work shall be stopped or restricted			

					• Rescue boat with divers shall be deployed at all the time of work.				during rough wind.			
9	Hammering of chisel	Snatching of winch rope, Slipping of winch brake, caught between the rotating parts.	Serious injury, drowning	Site workers and site staff	• Daily pre-inspection check list shall be made for winch machine and inspect before start of work. • The wire rope shall be inspected daily for any damage and if found it shall be replaced. • The rotating parts of the winch machines shall be guarded as per the guarding standards. • The operator shall be competent and he shall not allow extra workmen near the winch.	1	2	2	• Daily pre task maintenance shall be made for winch machine. • The eye made in the wire rope shall be as per standard i.e., minimum 3 nos of dog clamp shall be fixed as per standard.			

10	Replacing of chisel with bailer for removing the broken rock pieces from pile.	Snatching of winch rope, Slipping of winch brake, caught between the rotating parts, rolling of chisel.	Serious injury, drowning	Site workers and site staff	• Daily pre-inspection check list shall be made for winch machine and inspect before start of work. • The wire rope shall be inspected daily for any damage and if found it shall be replaced. • The rotating parts of the winch machines shall be guarded as per the guarding standards. • Guide rope shall be used for placing the chisel in platform level. • Proper support for resting the chisel or bailer shall be made arranged to rest the • Usage of standard chain hook while interchange of chisel and bailor • Double guide rope shall be tied to chisel while lowering	1	4	4	• Daily pre task maintenance shall be made for winch machine. • The eye made in the wire rope shall be as per standard i.e., minimum 3 nos of dog clamp shall be fixed as per standard. • Workmen shall not allowed to position the			

					• Workmen shall not be allowed to hold the chisel till it totally rested over platform				lowered chisel and bailer manually			
11	Cage lowering in inclined position	Sling failure Lifting hooks failure Sudden jerks due to load displacement Working platform failure Stopper rod failure	Serious injury, drowning Hit Injury Burn Injury Falling in water/ pile	Site workers and site staff	• Working platform with handrails • ISA 75x75 stopper boxes are used for resting the reinforcement cage over liner • Standard and certified hooks shall be used for lowering the 3rd reinforcement cage • No person shall handle the pile cages manually • Workmen shall not be allowed to stand on temporary plat form. • Foreman/supervisor shall signal the crane operator for lowering activities	3	2	6	• Gooseneck boom shall be removed during lowering of rebar cage. • Nearby open piles shall be closed to prevent fall			

					• Workmen shall not be allowed near liner/reinforcement cage while lowering • Double guide rope shall be used for handling reinforcement cage							
	Welding				• Hot work permit shall be taken in every shift. • Qualified welder shall be engaged for welding works • Area shall be cleared before doing any welding works • Cable joints shall be avoided	1	4	4				
11	Tremie lowering & Concreting	Fall hazard Rope failure Working platform failure Toppling of Hopper Sling Failure	Serious injury, drowning Hit Injury Falling in	Site workers and site staff	• Working platform with handrails • Damaged wire ropes are replaced with new ones. • Tremie stand shall be provided • ssBall catcher shall be provided.	3	2	6	Slings shall be inspected with color code and periodic inspections shall be carried out.			

		Blow injury during ball pass	water/ pile Fatal		• Authorized rigger and Khalasi shall be deployed for lifting activities							

5.2 EHS Risk assessment of temporary cofferdam works

Activities Covered: Temporary Cofferdam works

Location: Main bridge

Table no. 5.2: EHS risk assessment of temporary cofferdam

Sl No	Activity	Hazard	Risk Involved	People at risk	Existing Control Measures	Assessment			Additional Control Measures	Re-assessment		
						P	S	Risk Le		P	*S*	Residual Risk

								v e l				
1	Trans portin g/Shif ting of liners & other mater ials from load out jetty to Crane Barge using Mater	Crane failure / Fall of materials / Snatching of lifting ropes.	Serious Injury to multipl e people, Fatal, Risk of drowni ng.	Site work men & staffs	• Standing or working below suspended load shall be restricted. • Qualified / competent operator shall be engaged. P&M circular against eligibility criteria for operators & Age bar for hired equipment shall be adhered strictly. • The lifting equipment shall be not overloaded. • Lifting equipment shall be placed in stabilized area and soil condition shall be monitored. • Lifting supervisor shall be deployed. • The lifting equipment, tools & tackles shall be inspected daily	2	4	8	• Operator shall be trained by manufacturer / authorized trainers. • Wind flow shall be monitored and the lifting activities shall be stopped during excessive wind.	1	4	4

	ial barge.				before taking it into work. 3rd Party test shall be done for all lifting equipment, tool & tackles. • The ASLI (Automatic Safe Load Indicator) shall be maintained in working condition. • Edge protection with handrails, mid-rails shall be provided in barges.				• Separate rigging gang shall be deployed for rigging activities. • Dedicated training program on working over water shall be done frequently. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept			

									in appropriate places with minimum 30 mtrs of PP rope.				
		Man over board due to slippery surface.	Risk of drowning	Site work men & staffs	• Proper housekeeping shall be maintained. Oil spillage shall be cleared immediately and the work area shall be clear of restrictions. • Edge protection with handrails, mid-rails shall be provided in barges. • Dip tray along shall be provided during filling of fuel, oil and also at maintenance time.	3	2	6	• Dedicated training program on working over water shall be done frequently. • Housekeeping drive shall be conducted frequently. • Life jacket shall be used	2	2	4

									while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.			
		Snatching of mooring rope	Serious Injury to multiple people, Risk of drowning.	Site work men & staffs	• Competent seamen shall & engineer supervision be deployed for mooring activities. • Proper capacity mooring rope shall be used. • Work shall be suspended while heavy wind flow. • Life jacket shall be used while working in barges, pontoons.	1	3	3				

					• Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope. • Mooring shall be inspected daily before prior to use.							
		Sinking of material barge	Damage to property, Serious Injury to multiple people, Risk of drowning.	Site workmen & staffs	• Safe load shall be displayed over barge • The barges shall not be over loaded. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope. • Competent seamen & engineer supervision shall be deployed for mooring activities.	2	3	6	• Periodical maintenance of barges, pontoons shall be implemented.	1	3	3
2	Liner pitching	Hit by suspended load	Serious Injury, drowni	Site workmen	• Guide rope shall be used for controlling the movement of suspended load.	1	4	4	• Dedicated training	1	4	4

	and driving		ng, fatal.	& staffs	• Load chart of the lifting equipment shall be displayed and load shall be lifted as per load chart. • Experience rigging gang & dedicated lifting supervisor shall be deployed. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope. • Proper housekeeping shall be maintained.				program on working over water shall be done frequently.			
		Snatching of mooring rope	Serious Injury to multiple people, Risk of	Site work men & staffs	• Competent seamen & engineer supervision shall be deployed for mooring activities. • Proper capacity mooring rope shall be used.	1	3	3				

			drowning.		• Mooring shall be inspected daily before prior to use. • Work shall be suspended while heavy wind flow. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.							
		Crane Failure, Fall of materials, Snatching of lifting rope,	Serious Injury to multiple people, Fatal, Risk of drowning.	Site work men & staffs	• Standing or working below suspended load shall be restricted. • The crane shall be arrested with turnbuckle when lifting activity in progress. • Qualified / competent operator shall be engaged. P&M circular against eligibility criteria for operators & Age bar for hired equipments shall be adhered strictly.	2	4	8	• Operator shall be trained by manufacturer / authorized trainers. • A competent lifting supervisor shall be appointed to manage all	1	4	4

					• The lifting equipment shall be not overloaded. • The lifting equipment, tools & tackles shall be inspected daily before taking it into work. 3rd Party test shall be done for all lifting equipments, tool & tackles. • The ASLI (Automatic Safe Load Indicator) shall be maintained in working condition. • Edge protection with handrails, mid-rails shall be provided in barges. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.				lifting operations • Wind flow shall be monitored and the lifting activities shall be stopped during excessive wind. • Separate rigging gang shall be deployed for rigging activities. • Dedicated training			

									program on working over water shall be done frequently.			
		Sinking of crane barge	Damage to property, Serious Injury to multiple people, Risk of drowning.	Site workmen & staffs	• Safe load shall be displayed over barge • The barges shall not be over loaded. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.	2	3	6	• Periodical maintenance of barges, pontoons shall be implemented.	1	3	3
		Man over board,	Serious Injury to	Site workmen	• Proper housekeeping shall be maintained. Oil spillage shall be cleared immediately and the	3	2	6	• Dedicated training program on	2	2	4

		Slippery surface,	multiple people, Risk of drowning.	& staffs	work area shall be clear of restrictions. • Dip tray along shall be provided during filling of fuel & oil and also at maintenance time. • Edge protection with handrails, mid-rails shall be provided in barges. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.				working over water shall be done frequently. • Housekeeping drive shall be conducted frequently.			
		Oil leakage from vibro-hammer,	Minor injury, risk of drowning.	Site work men & Staffs	• Hydraulic hoses shall be free from damage & joints. If joints available it shall be secured with hose clamp. No binding wire shall be used for tying the hose joints. • Proper housekeeping shall be maintained.	3	2	6	• Dedicated training program on working over water shall be done frequently.	2	2	4

					• Edge protection with handrails, mid-rails shall be provided in barges. • Dip tray along shall be provided during filling of fuel, oil and also at maintenance time. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.				• Housekeeping drive shall be conducted frequently.			
3	Platform erection: • Waler beam erec	Snatching of rope, Toppling of crane, Fall of materials, Hit by suspended load.	Injury, drowning, fatal.	Site workmen & Staffs	• Standing or working below suspended load shall be restricted. • The crane shall be arrested with turnbuckle when lifting activity in progress. • Qualified / competent operator shall be engaged. P&M circular against eligibility criteria for operators & Age bar for hired	2	4	8	• Operator shall be trained by manufacturer / authorized trainers. • Wind flow shall be monitored and the			

	tion. • ISMB erection. • Bracing erection • 10HP Dewatering Pump Plat				equipment shall be adhered strictly. • A competent lifting supervisor shall be deployed for lifting activities. • The lifting equipment, tools & tackles shall be inspected daily before taking it into work. 3rd Party test shall be done for all lifting equipment, tool & tackles. • The ASLI (Automatic Safe Load Indicator) shall be maintained in working condition. • Guide rope shall be used for controlling the movement of suspended load. • Edge protection with handrails, mid-rails shall be provided in barges.				lifting activities shall be stopped during excessive wind. • Separate rigging gang shall be deployed for rigging activities. • Dedicated training program on working over water shall be done frequently.			

	for m • Edg e Prot ecti on				• Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.							
		Slippery Surface	Minor Injury, risk of drowni ng.	Site work men & Staffs	• Hydraulic hoses shall be free from damage & joints. If joints available it shall be secured with hose clamp. No binding wire shall be used for tying the hose joints. • Proper housekeeping shall be maintained. Oil spillage shall be cleared immediately and the work area shall be clear of restrictions.	2	2	4				

					• Edge protection with handrails, mid-rails shall be provided in barges. • Dip tray along shall be provided during filling of fuel, oil and also at maintenance time. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.							
		Fire hazard, Explosion, Electrocution,	Burn injury, serious injury to multiple workmen, Risk of	Site workmen & staffs	• The area shall be free from combustible materials. • The compressed gas cylinders shall be kept Upright and secured tightly. • Flash back arrestor shall be provided both in torch end and cylinder end for both oxygen and fuel cylinder.	2	3	6				

			drowning.		• The welding machines shall be covered with canopy for protecting from water. The power terminal shall be covered and no power cables shall be exposed. • All cable joints shall be made with heat sleeve joints of coupler joints. Normal insulation tape joint shall not be permitted. • The welding lead shall be free from joints. If joints available it shall be jointed with welding lugs. The return earth for the welding works shall be given only through welding cables. No reinforcement rods, angles, MS pipes shall be used for the same.							

					• All welding machines shall be provided with body earthing. • The power supply for welding machine shall be taken through circuit breakers with 30mAmps sensation. • Edge protection with handrails, mid-rails shall be provided in barges. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope. • Proper housekeeping shall be maintained.							
		Man overboard,	Risk of drowning.	Site workmen	• Proper housekeeping shall be maintained. Oil spillage shall be cleared immediately and the work area shall be clear of restrictions.	2	2	4				

				& staffs	• Edge protection with handrails, mid-rails shall be provided in barges. • Life jacket shall be used while working in barges, pontoons. • Ring buoy shall be kept in appropriate places with minimum 30 mtrs of PP rope.							

Chapter 6

Gap analysis

The objective of the analysis is to find out the gap between policy planning and implementation on the ground. A sample no of employee are selected for the study. The issue which directly affect occupational safety standards are to be addressed along with the issue which are the indirect contributor like and led to the incident.

A Gap Analysis comprises seven steps. They are:

i. Data collection;

ii. Baseline analysis;

iii. Employee survey;

iv. Walkthrough survey;

v. Evaluate findings and suggest improvements;

vi. Communicate findings; and

vii. Act on recommendations

Data Collection

The first step to conducting a Gap Analysis is the collation of existing data. Existing data may be collected from the various available sources such as in-house incident reporting systems, screening data, first-aid data, statistical data, historical data, current and historical data of diseases and ill health, near misses, dangerous occurrence, minor and major pollution data, sick leave taken by employees at particular time, accident investigation report. In addition to that data can be collected from minutes of meeting of safety meeting and recommendation given by legal authorities at different time. The internal and external audit of the year from commencement of project is a useful document for data collection.

Data Analysis

After data collection all the data are sorted into various groups. For example all the incident are sorted into categories such as gender, experience, field of expertise, root cause, PPE, etc. Then it has to be observed that whether the data reflects any trend or not. The analysis is also done with regard to behavior of worker, risk taking nature and habits like smoking, alcohol, etc.

Employee Survey

In this stage of analysis an attempt is being done to find out the missing stuffs. In this stage brain storming, group discussion, employee interaction done to find out about the issue which is misleading in current data analysis and the issue which is very much subjected with current scenario but having no data.For example the temporary hearing loss can be plotted with current assessment but the permanent hearing loss is practically not possible to show the trends with the data from one under construction projects of winch machine operator. In addition to data some time rescreening is to be done so that a comparable study can be done with current scenario.

EHS walk down

In this process where all the finding are communicated to the concern senior officers and their views are to be documented. In this step it is to be verified the current scenario with the received data. The effectiveness of control measures to be evaluated along with awareness among working group regarding it.

Evaluate findings and suggest improvements

All the out comes from risk assessment, safe working method and outcome of gap analysis from steps 1 to 4 are evaluated and summarized in a report with recommendation.

Communicate findings

It is important to communicate the findings of the gap Analysis to everyone in the organization. It will help to actively participate everyone to improve the situation. It must be communicated in a platform where EHS personnel, execution engineers, working personnel from other supportive departments like quality department, operation and maintenance department, industrial relation department, and human resources department can participate. A group of representative from

clients, subcontractor and other key personnel related to the projects shall be invited. It can also communicate in safety committee meeting and managerial review meeting.The feedback from all the participators are reviewed and documented.

Act on recommendations

After the finding of analysis is communicated to everyone and accepted the outcome of findings by key personnel, it is now to prioritize the recommendation to implement.

6.2Gap analysis for MRCSB Project

Data collection

I have collected the data regarding MRCSB project. All the data can be classified under two categories (1) reactive and (2) proactive. The reactive are lagging key performance indicators and proactive are leading key performance indicator. Reactive (Lagging/Trailing KPI) includes no of fatalities, frequency rate and accident investigation report and Proactive (Leading KPI) includes data of EHS leadership program, EHS audit report, Project inspection report, Project EHS Training record, near miss reporting record, risk assessment for all activity, safe work method of statement, prestart briefing and verification records, work permit system records, mock drill reports, EHS committee meeting reports, review and update of IMS, green card register, health register, instrumentation calibration report, environmental monitoring report, waste management plan, safety Induction report, PPE report, legal Register

Data analysis

The collected data is sorted into various groups such as departments, incident locations, work processes, gender, and age groups.

EHS Walkdown

I talk to Employees, supervisors, works, sub-Contractor to know the extent of implementation and ground level issue regarding issue of safety. I have done Risk management audit of Rebar yard at P-41 under leadership of EHS In charge of MRCSB project, L&T, Goa .The audit is conducted as per guideline described by IMS-12-E. From all the accident data Fishbone analysis has been done for find out the root cause.

Chapter 7

Result of analysis and recommendation

7.1Results of analysis

From the above analysis I found that

- Prestart verification and briefing done as per requirement.
- Permit system implemented successfully
- LOTO system communicated to employees and implemented in Batching plant, it has to be also used everywhere where maintenance work is to be done.
- Before employing safety induction has been done to all
- PPE has been provided to all the workers and used by them as per requirement
- Awareness and signage system has been implemented successfully (Golden safety rule tree)
- All the PPE found as per standard.
- Fire extinguisher has been placed as per requirement
- Emergency mock drill has been done as per plan
- EHS committee walk down by Project manager, construction manager, EHS Head ,Execution engineer has been done regularly
- Weekly and Month EHS meeting done regularly.
- Following the rule of BOCW act 19996 satisfactorily
- EHS leadership program achieved 100% as per project requirement
- All the legal register, Emergency preparedness plan has been found updated and documented as per IMS standard
- All the safety appliance i.e. Dosimeter, Lux meter, Rccb tester, Alcohol tester, Earth pit tester has been found well and fit for use.
- EHS Risk assessment audit has been done as per plan

- Tools and tackles inspection regularly done and color coding system has been implemented
- It is observed that IPV vehicle is used at correct location

7.2 Recommendation

- Step to be taken for actively participation of Execution Engineer in Tool box talk.
- Work permit shall be also implemented for activities like Pre-lifting work permit, Guard rail removal permit, electrical maintenance permit etc.
- Step to be taken for welfare of worker
- Eng. control for reducing the noise level of winch machine shall be done
- Traffic risk assessment has to be reviewed and updated if necessary
- Awareness campion shall be done for alcohols and heat related disease like heat stroke
- Planning for execution shall be strengthened
- Waste management plan to be reviewed
- Incident investigation training shall be given to all EHS personnel.
- Near miss and dangerous occurrence reporting system shall be implement
- Worker shall be trained without attempting shortcuts and follow the standard practice
- Preventive maintenance of Machineries shall be carried out as per planned maintenance matrix
- Housekeeping and material stacking shall be improved
- Root cause of every accident, near miss , dangerous occurrence ,environmental issue has been inspected
- CAPA shall be documented and implemented

Chapter 8

Summary and Conclusions

8.1 Summary

In this project report huge amount of practical related data has been collected. Risk assesment for various activity has been done and gap analysis is done for improving condition of site. Accident investigation report, monthly inspection report, Minutes of meeting, internal audit report, and EHS Risk assessment audit report has been studied.
A comparative study of RA and RR has been done and all statistics, fish bone analysis has been studied during internship training, Gap analysis has been for the project. By communicating with workers, supervisors, execution engineer, and top managerial personnel gathered data regarding implementation of safety policy. By analyzing above facts finds the possible ways to improve safety standard in construction industries and recommended how to implement CAPA

The main contribution of this project report are:

1. Real life data collection of construction Industries
2. EHS risk assessment of different activities
3. Comparison between RA and RR
4. Gap analysis
5. Study of EHS statics. Fish bone analysis during internship
6. Participate in Risk assessment audit of Rebar yard

8.2 Major conclusion

Major Conclusion are as follows

- Zero incident can be achievable
- The movement of zero incident starts from conceptual design itself
- For achieving zero incident policy must be zero tolerance

- Safety starts from commitment towards welfare for the employee from top management
- This is the right time for striving towards from react to act
- The focus shall be developing the system and implement it
- Right tools and tackles for right purpose
- Designing ,Planning and utilization of resources are vital ingredient to have a safe and healthy atmosphere around the premises
- The role and responsibility of safety officer shall be reviewed and updated periodically
- If any incident happens then safety Engineer is also responsible as Execution Engineer.
- Safety is not only a “staff function”. It is a combination of staff and line Function.
- Consequence exaggeration will let you back one step from present and it will act as a hindrance in faith building process
- If the top managerial approach is not towards Pro-safety drive then it is regarded as failure of safety officer
- Whether it is Engineering control, substitution theory, administrative control or imposing of PPE we can’t ignore the theory of “Man behind Machine”
- Despite of all steps like trainings, creating awareness etc. to have a culture of safety failed then we must look forward for the next step i.e. example setting(Safety Engineer in a role of Execution Engineer)

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DESIGNING OF CITY GAS DISTRIBUTION NETWORK BY USING TECHNICAL STANDARDS AND SPECIFICATION INCLUDING SAFETY STANDARDS

Abstract

Present day city gas distribution is one of the important component of hydrocarbon value chain, as it supplies gas to the end consumers. Now the Government of India also put interest on it and marked as a requirement for the smart city project across India. So this project is aimed to design a city gas distribution network for, Lucknow city, U.P.

As to fulfill the demand of customer's city gas distribution industries laid down gas pipeline on an allotted geographical area. The gas pipeline directly deal with public, so highest safety factor is recommended in all the national and international standards for designing, construction, operation and maintenance for the CGD industry. The vulnerability and impact of accident is more than other cases due to its nature and properties of gas it handle.

In this thesis an attempt is being done to design a gas network by using A.S.M.E B31.8 and rule prescribed by PNGRB, India. After calculating basic dimension, modelling of network is done by SynerGEE software .For making the risk as low as reasonable possible, hazard and risk are identified from the designing stage itself and all the measures are incorporated in design. The right of way was selected as per the guideline given by Government of, India. The demand of consumer from the domestic, commercial, industrial sector is determined at peak hour time .The MDPE pipe of grade PE100 selected and the valves are placed in strategic position so that in emergency situation the probability of catastrophic effect is to be minimized. The simulation result shows that all the pressure at different node and facility are under predetermined level and satisfying with flow of demand and supply.

Keywords: ***City gas distribution; CNG; gas network; standards and specification; inherent safety design***

Contents

List of Figures

List of Tables

Nomenclature

D = specified outside diameter, in.

P = design pressure, psig

S = long-term hydrostatic strength at a temperature equal to 73°F, 100°F, 120°F

t = Specified wall thickness, in

e = Pipe efficiency (dimensionless)

f = Darcy-Weisbach friction factor (dimensionless)

G = Gas specific gravity (dimensionless)

L = Pipe length (miles)

P_b = Pressure base (PSIA)

P_1, P_2 = Inlet and out let pressure (PSIA)

Q = Flow rate (SCFD)

T_a = Average Temp.

T_b = Temp. Base

Z_a = Compressibility factor (dimensionless)

N_{re}= Reynold's number (dimension less)

V = fluid velocity (feet/sec)

Chapter 1

Introduction

1.1Background

Planning commission of India predicts that the Indian economic will achieve a GDP growth of around 6.4% during the year 2008-2035. To achieve the stable economic growth, the aspect of energy requirement need to be addressed. In 2011 the share of natural gas in energy basket is 11%, which will be around 20% in 2025 as expected by 'Integrated energy policy of India, 2008'. So to achieve a 20% share in primary energy mix, it is very important to build infrastructure for the same. Natural gas has been used broadly in power sector, industrial segment, and fertilizer sector and city gas distribution. Rising cost of imported coal and unavailability of domestic coal, environment concern and rising cost of crude oil, availability and affordability of natural gas, subsidy burden, food security and infrastructure are key drivers for using of natural gas in different sector.

There are 10,631 commercial consumers, 2974 industrial customers, 15.22 lakh domestic connection and 588 CNG filling stations in India which consume 13.6 MMSCMD of natural gas as per the Petroleum and natural gas governing regulation board, India. The pipe line transport is the most safe, reliable and economical feasible option for gas distribution(Sydney Thomas, 2003). For domestic customer pipe natural gas is the safe than LPG as the inherent safety system like appliance valve and isolation valve installed within consumer premises inside and outside kitchen respectively. The pipe contain gas only at 21mbar, so by stopping the source of gas, the chance of catastrophic effect will be minimized. LPG expands 250 times and settle down near the bottom of surface as it is heavier when leakage occurs. But as CNG lighter than air with adequate ventilation, on leakage it disperse through air. The narrow flammability limit with nontoxic and nonpoisonous, environmental friendly characteristic nature make it one of the most reliable, safest and economically feasible alternate fuel in the world.

Characteristics of natural gas

Natural gas is a safe fuel. It is a non-toxic, non-poisonous, combustible source of energy and it is safe as compared to other hydrocarbons by handling it properly.

Natural gas is composed mainly of methane with minor quantities of ethane, propane, carbon dioxide and traces of higher hydrocarbons and oxygen. It has a specific gravity of 0.60 which means it is only 60% heavy as the air and it will rise under normal atmospheric conditions.

Natural gas within the distribution system will be given a distinctive odour which will be designed to be detectible by the nose at the concentrations of less than 0.1% of gas in the atmosphere. It will burn within the range of 5% and 15% of gas in air, and it is readily ignited by spark or other forms of ignition within this range. It is one of the environmentally friendly fuel and now most of the countries are adopting as alternative energy sources to reduce carbon foot print.

Natural gas can be hazardous in the following ways,

- From asphyxiation – When permissible exposure limit crosses for the natural gas, with inadequate ventilation give rise to a state of asphyxiation. It is usually found in a confined space or mechanical accidental failure of equipment.
- From explosion – When in a confined space accumulation of escaping gas being ignited when mixed with air.
- From fire – When compressed natural gas come into contact with source of fire and air, within the flammability range, leads to fire. It is a usual phenomenon after explosion.
- From overpressure – When it exceeds maximum allowable operating pressure the chance of incident will be more. Rapid crack propagation is a usual phenomenon seen in MDPE pipeline.

Transmission grid

The backbone of the natural gas transmission system in India is the GAIL operated HBJ pipeline. Gas feeding into this pipeline comes primarily from the south basin gas field. The field is located offshore-west of Mumbai. The offshore gas is transported through a 250km

pipeline from Hazira treatment plant in Gujarat. The gas feeder line (8") length shall be approximately 38km from the tap off point to the city gas station near Amousi airport. The CGS is located near Amousi airport. 12" dia. Steel pipeline approximately 27km in length is laid from CGS to Gomti Nagar CNG station.

1.2Objective and scope

It is attempted to

a) Study about use and applicability of CNG and city gas distribution in India
b) The standards and specification for the CGD industry
c) Forecast the demand for the CNG
d) Designing a CGD network by taking care of all standards and specification

Scope of this work:

a) Lucknow city is chosen for this study, and PNG demand for various types of customers i.e. domestic and commercial customers assumed.
b) By the guide line of regulating authority of India and utility distribution system in that area right of way selected
c) A model for the gas network has been proposed and designing of network is done with help of SynerGEE software.
d) By assigning model parameter and demand, supply to the designed network, simulation being done with help of software and validate the model by taking care of predetermine pressure and velocity level for the designed network.

1.3 organisation of the thesis

This thesis is organised in nine chapters of which this is first. Chapter two deals with literature review. Chapter three and four comprise design standards and specification and pipeline network system and components respectively. Chapter five describes designing of network and chapters six comprises of mathematical model. Chapter seven describes designing the network in SynerGee software, while chapter eight contain simulation result. Chapter nine conclude the thesis by summarizing the work done here.

Chapter 2

Literature Review

In this chapter a review of past studies on gas network is presented. After that motivation behind the thesis is proclaimed followed by a problem statement.

Literature review is necessary in two major field to satisfy the objective and scope of the study.one of the area is the mathematical model and simulation for steady and unsteady state of gas flow in pipe. The second phase of literature review is required to study the pressure, flow and other parameter distribution in the pipe network.

Andrzej J.et al. (1989) developed a mathematical model for unsteady state of flow in gas network, comprised of a single pipeline. The partial differential equation are solved by finite element and finite difference method.

S.L. et al.(2000) analyzed gas flow in pipe line network by electronic analogical method in which resistance is combined with theoretical model of capacitance and inductance. It is easy to solve as ordinary differential equation can be solved easily than partial differential equation.

M.Herty et al.(2008) introduced a new model for gas flow in a pipe line network using asymptotic analysis. By using isothermal Euler equation the new model was developed.

A. Herra. Et al.(2009) highlights the dependency of pressure drop with respect to inclination in a distributing duct carrying gas with help of a new model and simulation technique for gas distribution in a ducts.

Jolanta et al.(2010) calculated velocity and over pressure for a gas pipeline network of 4,115 m, filled with $51m^3$ and operated with an over pressure around 2.4kPa in the city of Szczecin, Poland and came into conclusion that flow and velocity in pipeline carrying gas for downstream customers depend upon time of day.

J. Krope. et al.(2011) proposed a mathematical model for loop gas network, in which the linearized equation developed from this low pressure gas network is solved by sparse matrix. The analysis is done by HAPN application.

M. Chaczykowski et al.(2012) predicted temperature and pressure profile for a horizontal pipe under a steady state condition. The equation developed for non-isothermal gas flow which consist of a convective term in momentum equation and kinetic energy term in the energy equation and concluded that temperature distribution cannot be neglected for real gas distribution analytical solution.

Edris. et al.(2012) designed gas network with a result of orthogonal simulation and the set of differential equation is being solve by Runge-Kutta method. This method is can be suited to both isothermal and non-isothermal gas flow in a pipeline network.

Mohd. et al.(2013) analyzed pressure drop of natural gas transmission pipeline in Bangladesh, and find out justification of compressor station installation in the route of pipeline as the rate of pressure drop varies considerable with respect to rate of gas consumption.

Nasr. et al.(2014) designed transmission and distribution gas network by considering gas demand, source pressure, distribution velocity, pipe material, gas quality, maximum allowable operating pressure. For the distribution network stress per hourly distribution plotted for PE 80 grade and PE 100 grade with 50 years of minimum required strength.

A.Ooster. et al.(2015) studied heat transfer between pipe lines to soil for buried pipe line. In the inlet of pipe, the effect of gas mass flow and temperature are studied and simulation results are compared with real data.

Alfredo. Et al.(2015) developed GANESO software. The modelling for the software has two stages. In first stage with help of optimization algorithm decision was taken for the element like compressor station, valves and output of first stage are treated as input of second stage where with help of control theory technique the results of first stage refined so that the accuracy of end result will increase.

2.1 Motivation

The root cause of many incident are design fault and not following the standards and specification by regulating body. From my earlier internship experience at M.R.C.S.B Project (under construction) L&T, Goa my point of view is ‘Safety starts from conceptual design itself’. Inherent safety strategy is the most robust and reliable because it identify and find out the way

to implement the plan to completely eliminate or reducing the hazards, rather than to develop add-on protective system and procedures.

During my second internship at Green Gas Limited, Lucknow (A joint venture of IOCL and GAIL) an incident occurred in PNG supply pipe line adjacent to under construction hospital. During construction a workman from third party drilled the gas pipeline by a jack hammer for providing support to the scaffold from the outside of right of way. Due to which gas escapes from pipe line and on contact with ignition source, it caught fire for hours.

I found that there is no single isolation valve in between DPRS to incident location and beyond the point of incident location in this network. So that the volume of gas in this 4km network of pipeline escapes from pipe so that fire manage to sustain for the hours. Further investigation leads to the fact that there is no such system in the design itself. It was attempted to stop the gas flow by squeezing the pipe nearer to incident location. With help of excavator it was attempted to locate the pipe, but due to unavailability of GIS mapping, the exact location is predicted and wrong judgement on the worksite leads the pipe line rupture by excavator, during this incident gas escapes from that rupture pipe. With this series of event a large volume of gas lost and the supply of gas resumed after 5hrs.So it is found that the violation of rule and regulation is done from design stage itself. In CGD industry it is very difficult to incorporate modification after construction and in operational stage.

Now the design follows active and procedural strategy which includes safety interlocks, automatic shutdown system, standard operating procedural, safety rules, operational training, emergency management technique, so in addition to that I subscribe for the inherent safety design along with considering technical standards and specification including safety standards for the design.

2.2Problem statement

It is aimed to design a city gas distribution network by following all the technical standards and specification including safety standards by governing body of India, for Lucknow city.

Chapter 3

Design standards and specification

The Indian standard by petroleum and natural gas regulatory board (Technical standards and specification including safety standards for city or local natural gas distribution works) regulation, 2008 used for designing the network

The American standard ANSI/ASME B31.8 – gas transmission and distribution piping systems was as the principal international standard for this distribution piping system.

Because of the limited attention given to polyethylene pipe systems in ASME B31.8 additional reference have been made from Australian standards AS 3723 – 1989 –installation and maintenance of plastic pipe systems for gas.

ISO 4437 'buried polyethylene pipes for the supply of gaseous fuels – Metric series – Specifications' has applicability in area of material specification.

The book published by the American Gas Association as volume 111, distribution; book D-1, system design is also used as reference document.

3.1materials

The materials adopted for mains and the underground portion of service pipe in the general distribution in medium density polyethylene (MDPE) Grade 100. This material was selected because of its cost effectiveness, tensile strength and the strength of PE fused joints. The pipeline diameter range for pipe has been 'standardised' at 180, 125, 90, 63 and 32mm for mains, and 32 and 20mm for services.

Properties of polyethylene (PE) pipe

Polyethylene is manufactured by polymerisation of the hydrocarbon ethylene. PE pipe is a general description and covers pipes made of ethylene of different density, molecular weight and molecular weight distribution. The performance of the pipe is directly influenced by the physical properties of the polyethylene resins used. The most commonly used classification of PE is by density, and expressed in kg/m^3, as below Low density, in which the density ranges

between 910-940 kg/m^3 and the product exhibits high flexibility and retention of properties at low temperatures. Medium density, in which the density ranges between 930-940 kg/m^3. The pipe exhibits high flexibility and ductility, slow crack growth resistance and crack propagation resistance. It is extensively used in the installation of gas distribution networks.

High density, HDPE resins are also manufactured by a low-pressure process. The density ranges from 930-960 kg/m^3. HDPE tends to be stiffer than the other classifications has a high application in the electrical and communication industry.

Advantages of PE over steel

- PE is non-conductor and therefore is not subject to galvanic corrosion. It is almost completely resistant to inorganic chemicals and most organic chemicals.
- It is a thermoplastic material and is easily jointed by heating and pressing together two components to form a joint as the parent components.
- Because of its flexibility, small diameter pipe can be coiled into long lengths for easy transport and installation.
- Its flexibility also allows PE in the smaller sizes to squeezed shut in an emergency situation.

Disadvantages of PE over steel

- The pipe is softer and more susceptible to damage during transport, installation and future third party activities in the vicinity of the installed pipe.
- Because of its thermoplastic nature PE is weaker at higher temperatures. At full design pressure it should not operate at temperatures above 50°C or below 0^0C. Its use is therefore restricted to underground only.
- It is only used for secondary and tertiary network having maximum flow velocity of 30 m/sec.

It has a tendency to creep under load. An internal stiffener is required to prevent creep whenever a mechanical joint is employed

3.2Specification of piping material used in CGD network

Plastic Pipes

- ISO 4437 Buried polyethylene (PE) pipes for the supply of gaseous fuels, Metric series Specifications
- IS 14885 Specifications for polyethylene pipes the supply of Gaseous Fuels

Plastic Valves

- ASME B16.40 Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems
- EN 10204 Excess flow check valve
- EN 1555-4 Plastic piping system for supply of gaseous fuels polyethylene - Part 4

Chapter 4

Pipeline network system and components

Petroleum and natural governing regulatory board (PNGRB), India defines city gas distribution network as an interconnected network of gas pipeline and the associated equipment used for transporting natural gas from a bulk supply high pressure transmission main to the medium pressure distribution grid and subsequently to the service pipes supplying natural gas to domestic, industrial or consumer commercial premises and CNG station situated in a specified geographic area.

It classifies three types of network for city gas distribution.

1. Primary network

It is a medium pressure distribution system comprising of pipelines that operates at pressure above 7 bar (100 psig) and below 49(711 psig) bar. It is normally constructed by using steel pipeline and the maximum velocity should be limited to 100 ft/sec (30 m/sec) after pressure regulating instrument. The function of this network is to supply gas from one city gate station (CGS) to one or more distribution pressure regulating station (DPRS) or to the secondary gas network or bulk customers through service line.

2. Secondary network

It is a low pressure distribution system comprising of gas mains or distribution mains that operate at pressure below 7bar (100psig) and above 100mbar (1.5 psig) .It is usually constructed using medium density polyethylene pipe (MDPE) and having maximum flow velocity of 100 ft/sec (30 m/sec). This network is designed for the interconnection from district pressure regulating station to various service regulator at domestic, industrial and commercial consumers.

3. Tertiary network

It is a part of city gas distribution network that operate at a pressure less than 100 mbar (1.5 psig). It is usually constructed using a combination of MDPE piping and GI/Copper tubing. This type of network is designed for the supply of gas to the customers by using service pipeline, service regulators and consumer meter set assemblies.

City gate station

It is point where custodial transfer of natural gas take place from natural gas pipeline to CGD network. Generally CGS comprising of pressure reduction skid, odorization equipment, metering equipment, filter and separator if required.

Distribution pressure regulating station

It is part of CGD networking system which is used for isolation and pressure regulation of gas stream. It is also called as district pressure regulating station and located at different demand point. It comprises of inlet and outlet isolation valve, gas filter, pressure reduction skid with active monitor regulator with 50% redundancy arrangement.

4.1Pipeline

It provide 3 transportation function, namely gathering, transmission (interstate and intra state) and distribution. This thesis only deals with gas distribution within a city.

As per PNGRB, India (T4S), Regulation, 2008 for low pressure CGD network thermoplastic pipe and fittings are recommended and as per schedule 1-D of this standard thermosetting plastic piping is not permitted. As per this standard the thermoplastic pipe shall not be used below 0^0c and above 50^oc and minimum wall thickness shall not be less than 2.3mm.

The nominal wall thickness for a designed pressure shall be determined by the following formula

$$P = 2S* \frac{t}{D-t} * 0.32 \quad (1)$$

Where

D = specified outside diameter, in.

P = design pressure, psig

S = long-term hydrostatic strength at a temperature equal to 73°F, 100°F, 120°F

t = Specified wall thickness, in

Maximum allowable operating pressure in pipe is given by

$$\text{MAOP} = \frac{20*MRS}{C*(SDR-1)} \quad (2)$$

Where

MAOP = Maximum allowable operating pressure in bar

MRS= Minimum required strength of material in MPa at 20°c for 50 years

C = Overall service coefficient

SDR = Standard dimension ratio

As per Is14885:2001 there are 2 type grade of material used namely PE80 and PE100 having minimum required strength at 20°c for 50 years are 8MPa and 10MPa respectively.

As per ISO 4437:1997(E) conventional density of the designed pipeline shall be more than 930 kg/m^3 (base polymer) .All the fitting shall be electrofusion type and conforms to ISP 8085-part3.

4.2Valve

There are different type of valves are used in natural gas industry namely, ball valve, gate valve, plug valve and check valve. The valves are generally used for the purpose of isolation, controlling the flow and relief of pressure at different strategic location.(P. Smith).

Ball valve

It is used extensively in natural gas industry and normally used to provide block function in pipeline. It consist a ball with a hole through it and when it closes the rate of flow decreases as friction increases and as it opens rate of flow increases due to less friction

Gate valve

It is a rectangular gate or wedge used to block the flow by applying force across the flow

Plug valves

It consist a tapered plug which can be forced downwards to provide a tight mechanical seal between the plug and seat. It is quarter turn type valve. When the valve is engaged a cavity formed inside the plug and perpendicular to flow and this can be vented outside for the verification of no flow. So it is generally used where custodian transfer take place.

Check valve

It is unidirectional valve having a flapper which only opens to allow flow in one direction only and it shut down the flow when it tries to flow reverse. It is used in compressor station to avoid backflow.

Seismic automatic gas shutoff valve

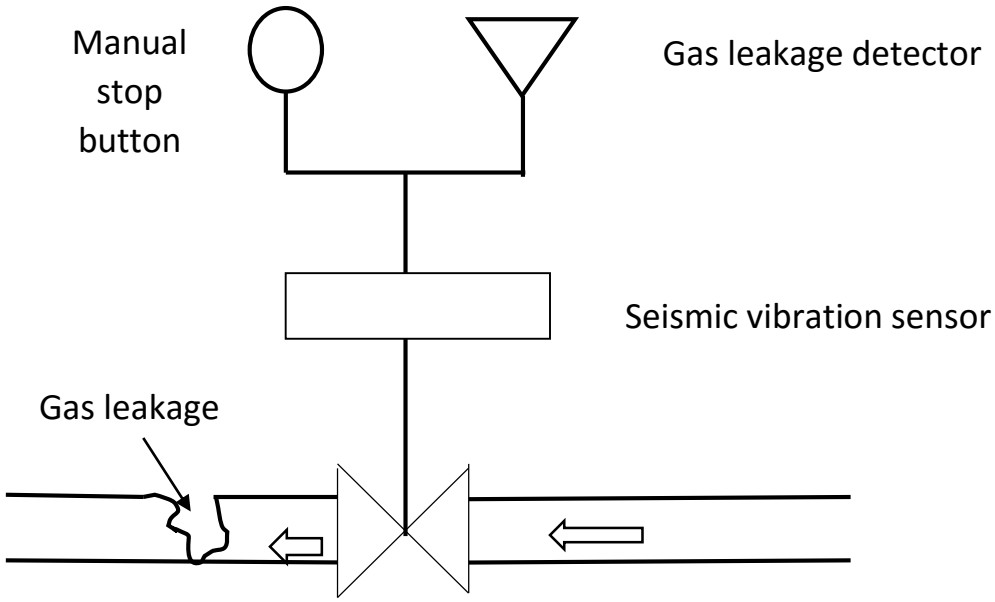


Fig4.1: Seismic automatic gas shutoff valve(G. P. Cimellaro)

In the situation such as manmade or natural disaster (Earth quake) it is able to stop the flow in certain area of network and after the valve closed it can be opened only by manually(G. P. Cimellaro).

Spacing of valves

All the valves are of double block with bleed facility and spacing not more than 1km for high pressure distribution system shall be used(PNGRB, 2008). For the low pressure distribution system it is provided so that the network isolation can be done within short period of time and shall be installed below the ground having accessible facility.

Actuators

These are operated by gas line pressure. The operating principle of the actuator is compressed natural gas introduced in a cylinder which connected to a valve shaft. As the pressure of line increases from a predetermined level it pushes the cylinder and subsequently shaft turns. These are used so that the valve turned closed automatically when the pressure increase and flow stops.

4.3 Supervisory control and data acquisition system (SCADA)

It is a typical system which collects data from different programmable logic controller placed in different strategic position which supervise in real time and in addition to that it also used to control the required parameter. A long pipeline, block valve are generally monitored and controlled by real-time SCADA. This system based on Ethernet and fiber optics. Transducers are distributed across a geographical area with respect to pipeline so that the pipeline operation are monitored and controlled by real time SCADA system. The input signal from measurement system converted into engineering unit in remote terminal unit. It provides the information about Pipeline display, equipment status, and alarm system and network analysis.

Pipeline display

The complete network of pipe can be seen in a single interface with visual feedback of any port56n of network It also include different components of pipeline like compressor and valves.

Equipment status

It can display the parameter associated with the equipment such as temperature, pressure, flow and vibration. SCADA system enable to display of equipment status i.e. whether it is on or off.

Alarm system

If there is an unusual or abnormal operating situation takes place then it always alert operator to take necessary steps. It also reminds the operator about the upcoming operating changes. If the operator doesn't intervene in a predetermined time then the SCADA system will automatically take action, which is appropriate on that situation as programmed by the system.

Analysis

The feature like history, graphical aids are used to assist the operator for making decision during routine and emergency condition.

4.4 Right of way

As in India there is no specific corridor for gas line supply, it relay upon existed right of way used by other facilities. So for the deciding right of way this parameter shall be taken into consideration. An utility survey of the location must needed for this purpose in addition to that care must be taken that so that it avoid railway track crossing, river crossing, major vegetation crossing, heritage and major traffic scenario of that area.

Protection from hazard

Pipe line laid under the area which is keen to flooding shall be provided with anti-buoyancy measures such as anchorages, concrete weight so that the resulting specific gravity of installation equal or more than 1.10

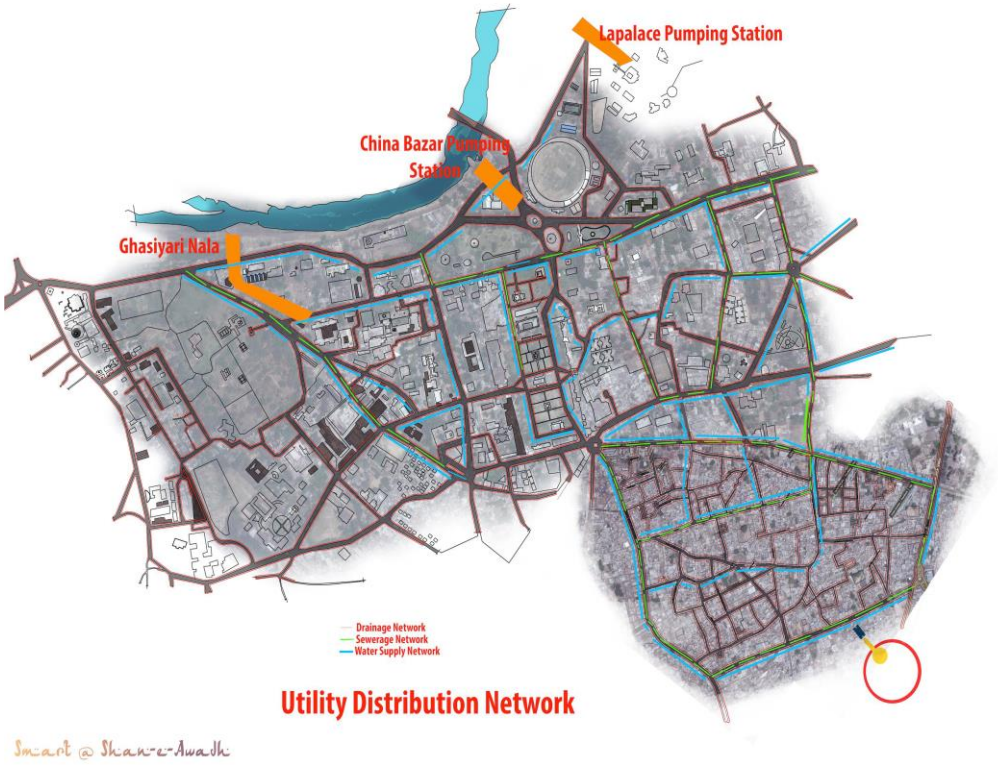
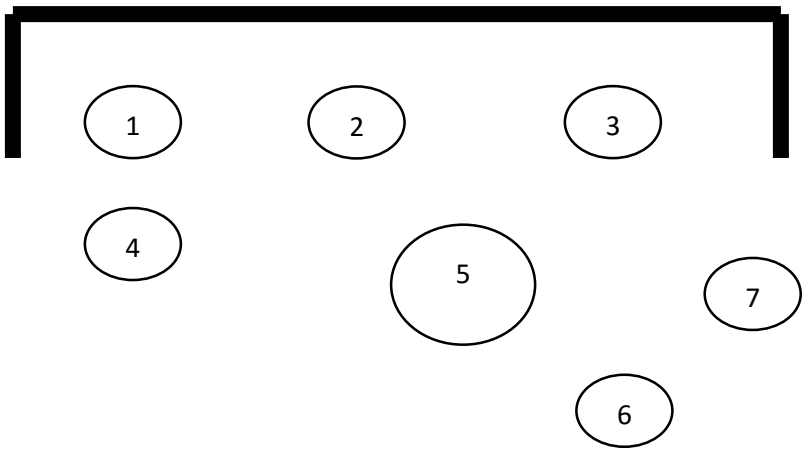


Fig 4:2 Utility distribution map

Road Berm/Foot path



1, 2- Electrical cable (Low voltage), 3 - Telecom cable, 4 - Electric cable (high Voltage)

5 - Gas pipeline, 6-Warer pipeline/sewage line, 7- Other hydrocarbon product pipe line

Fig4.3 Relative position of gas pipeline and distribution mains(PNGRB, 2008)

The gas pipeline shall have minimum clearance of 300mm from the existed utility system and it must have 500mm clearance between two adjacent hydrocarbon lines and should maintain 3meter clearance from industrial sector. While crossing railroad, highway street for PE pipe the casing shall be RCC pipe of minimum NP3 class(PNGRB, 2008).

When open technique is used a warning tape shall laid down 200 mm above the pipeline. For right of way protection pole marker, RCC marker shall be placed in every kilometers. Remote sensing data can also be monitored for gas pipeline along the right of way(K.B. Fung).vibration detector and technique such as Pipeline Damage Prevention Through the Use of Locatable Magnetic Plastic Pipe and a Universal Locator (Jeff Wiese) and software capable of real time data at any instant are to be used for leak detection technique and protection from third party encroachment(Marean, 2013).

Third party interference

Third party intrusion is a very often scenario in CGD industry. It is very difficult to prevent this third party excavation and protect the pipeline within the right of way by adopting conventional method such as patrolling. To deal with that modern technique which are commercial available shall be adopted(T.C. Pharris, 2007).

The NYSEARCH/Northeast Gas, association, American Innovations and Physical Sciences Inc. (M.F. Byl) developed PIGPEN system which consist of an array of sensors, alarms and a system for real-time monitoring for preventing third party encroachment.

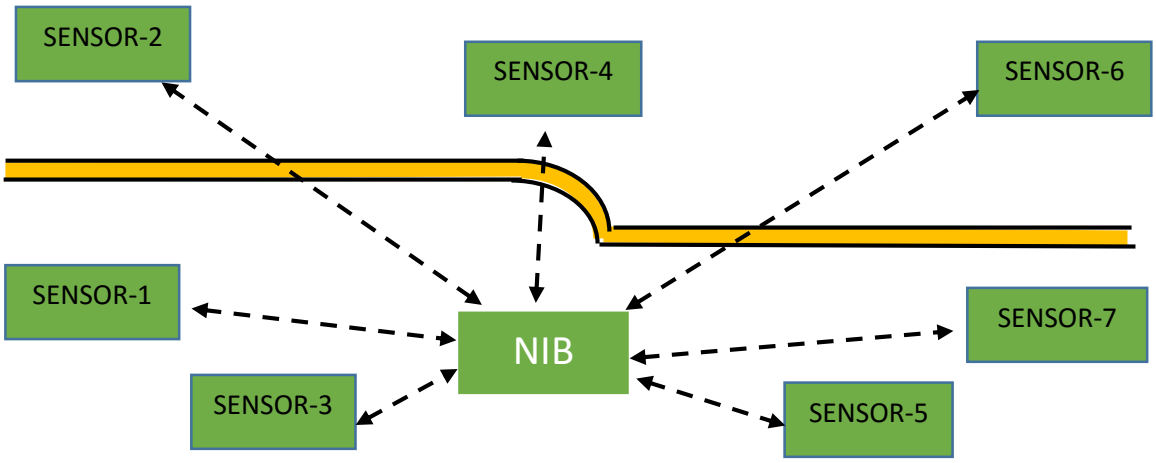


Figure 4.4: Seismic sensors and configuration of array installation.(M.F. Byl)

The seismic sensors are distributed along the way of ROW and the system also capable to distinguish the signal between threats to pipeline from normal one.There are different damage prevention research is going on and due to recent technology advancement most of are commercially available(Jeff Wiese). Under the integrity management system of pipeline S. Shuheng. *et al.(2015)* developed high precession infrasonic sensor based on PVDF. Between the frequency 3 Hz to 30 Hz it perform with high precession.

Leak detection

There are different strategies to deal with this kind of failure. It can be minimized by adopting new technology, correct assessment of gas reconciliation, above ground inspection. Leak can be detected by underground, above ground and airborne system. Airborne leak detection pipeline inspection system(ALPIS) and Intrinsic distributed fiber optic leak detection are two techniques can be used for this purpose(Jim Merritt, 2009). ALPIS consist of a detection system along with digital camera and global positioning system, which is used to detect the presence of hydrocarbon in the atmosphere with a facility of visual survey of area.

Chapter 5

Designing of network

The design procedure of city gas distribution network is divided into three sections: Prediction of demand in different location, design of the basic dimensions of the pipeline system components and the network design.

Design philosophy

The fundamental design objective is the provision of a safe, reliable and economic gas distribution system for the customers which ensures

1. Supply of gas with required flow rate at consumer end , which fluctuate in between predetermined pressure limit
2. Required no of control valve placed to prevent any catastrophic effect.

5.1Prediction of demand at major location

From the past data from Green gas limited, Lucknow, it is assumed the demand for different categories of customers

- Domestic houses = .6 SCMD
- Small hotels = 25 SCMD
- Hotel & Restaurant = 50 SCMD
- Loge = 100 SCMD
- Hospital = 25 SCMD

As peak hour for different categories of customer are different so demand for different customers are computed with respect to their peak hours.

- Domestic houses (6 hrs.) = .1SCMH
- Small hotels (10 hrs.) = 2.5SCMH
- Hotel & Restaurant (12 hrs.)= 4.16 SCMH
- Loge (12 hrs.)= 8.34SCMH

- Hospital (12 hrs.) = 2.08 SCMH

After computing peak hour demand for different categories of customers, now demand for major location to be calculated in peak hour.

- Cantonment Road = (2.5*4)+(4.16*5)+8.314+(5*2.08)+(.1*1000)=149.54 SCMH
- Goutam Budh Marg = (2.5*3)+(4.16*7)+(.1*1000)=136.62 SCMH
- Hewett Marg= (2.5*2)+(4.16*2)+(.1*300)=43.32 SCMH
- V.S Marg= (2.5*4)+(4.16*5)+8.314+(.1*1000)=139.14 SCMH
- Parivartan chowk = (2.5*3)+(4.16*4)+(3*8.314)+(.1*1000)=149.16 SCMH
- M.G Marg = (2.5*2)+(4.16*3)+(2*8.314)+(.1*1000)=134.16SCMH
- Nabiullah road = (2.5*10)+(4.16*12)+(8.314*4)+(.1*1500)=308.28 SCMH
- Jagat Narayan Road = (2.5*12)+(4.16*13)+(8.314*2)+(.1*1980)=318.76 SCMH
- Jagat Narayan to Parivartan Chowk
  =(2.5*13)+(4.16*14)+(8.314*8)+(.1*1500)=307.46 SCMH

5.2 Basic dimension

The pipeline network for city gas distribution is designed according to standard, ASME B31.8: Gas Transmission and Distribution Piping Systems and standard by PNGRB, India.

The nominal wall thickness for a designed pressure (P), with specified outside diameter (D) and Specified wall thickness (t) shall be determined by equation (1)

$$58 = 2*725.189*\frac{t}{110-t}* 0.32 \qquad (3)$$

Or

$$t = 12.23 \text{ mm}$$

For 110 mm nominal outside diameter with standard dimension ration for thermoplastic pipe, minimum wall thickness shall be selected from table no: 4 of PNGRB (T4S) Regulation, India, 2008(PNGRB, 2008)So, Minimum wall thickness = 12.3 mm with SDR 9

Maximum allowable operating pressure in pipe is given by IS 14885:2001 and ISO4437:1997(E) and is determined with help of equation (2)

$$\text{MAOP} = \frac{20*10\ MPa}{2*(9-1)} \quad (4)$$

Or

$$\text{MAOP} = 12.5 \text{ bar}$$

5.3 Pipe line flow

Gas moves through pipeline from high pressure zone to low pressure zone, in which pressure is transmitted by compressor. When gas flows from one distributing pressure regulating station to another it losses pressure due to friction. For CGD, the elevation is assumed as zero. The gas flow follows Boyles law i.e. flow varies inversely with pressure. So when pressure of gas decreases, the volume it increases results the gas spreads out and all the gas molecules moves faster so that friction per kilometer of pipe increases.

As the nature of gas is compressible its flow is complicated. Isothermal flow is usually is taken for flow in long pipelines. In this type, gas is kept in constant temperature.

So the gas law of this condition, such that

$$\frac{P_2}{P_1} = \frac{V_1}{V_2} \quad (5)$$

Isothermal flow

It is the normal flow in most gas gathering lines, Pipelines.

Assumption

1. No mechanical work in system
2. It has a horizontal flow

The general energy equation for this condition can be written as

Change in pressure + change in velocity + Lost work to overcome friction = 0 (6)

$$\text{VdP} + \frac{d(v^2)}{2G} + \text{dR} = 0 \quad (7)$$

Now

$$dR = \frac{fv^2 dl}{2GD} \quad \text{(Drag Law)} \tag{8}$$

Where

l= length of pipe

G = Specific gravity of gas

P = Pressure

V = Volume of gas

D = Diameter of pipe

f = Co-efficient of friction

Substituting the value of dR in equation (7), the equation becomes

$$VdP + \frac{d(v^2)}{2G} + \frac{fv^2 dl}{2GD} = 0 \tag{9}$$

Or

$$\frac{2GVdP}{v^2} + \frac{2dv}{v} + \frac{fdl}{D} = 0 \tag{10}$$

By integrating the equation between point 1 and 2, the equation becomes

$$P_1^2 - P_2^2 = \frac{v_1^2 P_1}{Gv_1}\left[2\ln\frac{v_2}{v_1} + \frac{fl}{D}\right] \tag{11}$$

As $\frac{fl}{D} >> 2\ln\frac{v_2}{v_1}$, so neglecting the term, the equation (11) becomes

$$\frac{P_1^2 - P_2^2}{P_1^2} = \frac{flv_1^2}{GDP_1v_1}$$

Or

$$P_1 - P_2 = P_1\left[1 - \sqrt{1 - \frac{flv_1^2}{GDP_1v_1}}\right] \quad (12)$$

So by changing the equation(12) to unit in which all have a common unit, Hyman. et al.(1975) and Finch. et al.(1988) derived flow in a horizontal pipe given by

$$Q = C\left(\frac{T_b}{P_b}\right) D^{2.5}\, e\left(\frac{P_1^2 - P_2^2}{LGT_aZ_af}\right)^{.5} \quad (13)$$

Where

C = Const. 77.54 (for English unit)

D = Pipe diameter (inches)

e = Pipe efficiency (dimensionless)

f = Darcy-Weisbach friction factor (dimensionless)

G = Gas specific gravity (dimensionless)

L = Pipe length (miles)

P_b = Pressure base (PSIA)

P_1, P_2 = Inlet and out let pressure (PSIA)

Q = Flow rate (SCFD)

T_a = Average Temp.

T_b = Temp. Base

Z_a = Compressibility factor (dimensionless)

Pipe are not usually horizontal and elevation are not too high in CGD industry so a correction of static head of fluid may be incorporated in equation (12) and determined as follows

$$Q = C\left(\frac{T_b}{P_b}\right) D^{2.5}\, e\left(\frac{P_1^2 - P_2^2 - H_c}{LGT_aZ_af}\right)^{.5} \quad (14)$$

Where

$$H_c = \frac{0.0375g(H_2-H_1)P_a^2}{ZT_a} \quad \text{(English)}$$

$$H_c = \frac{0.06835g(H_2-H_1)P_a^2}{ZT_a} \quad \text{(Metric)}$$

Fluid flow may be characterized by dimensionless grouping of variable known as Reynold's number which is defined as:

$$N_{re} = \frac{Dv\rho}{\mu} \tag{15}$$

Where

N_{re}= Reynold's number (dimension less)

D = pipe diameter

V = fluid velocity (feet/sec)

ρ = Fluid density

μ = Fluid viscosity

For a compressible fluid substituting density and velocity in equation (7) can be written as

$$N_{re} = \frac{0.013579QgP_b}{\mu DT_b} \tag{16}$$

Where

g = Gas specific gravity

P_b = Base pressure (PSIA)

Q = Gas flow rate (Standard ft^3/day)

T_b = Base temperature

For gas flow in pipe network, the friction factor can be a function of Reynold's number and relative pipe roughness Moody. et al.(1944)

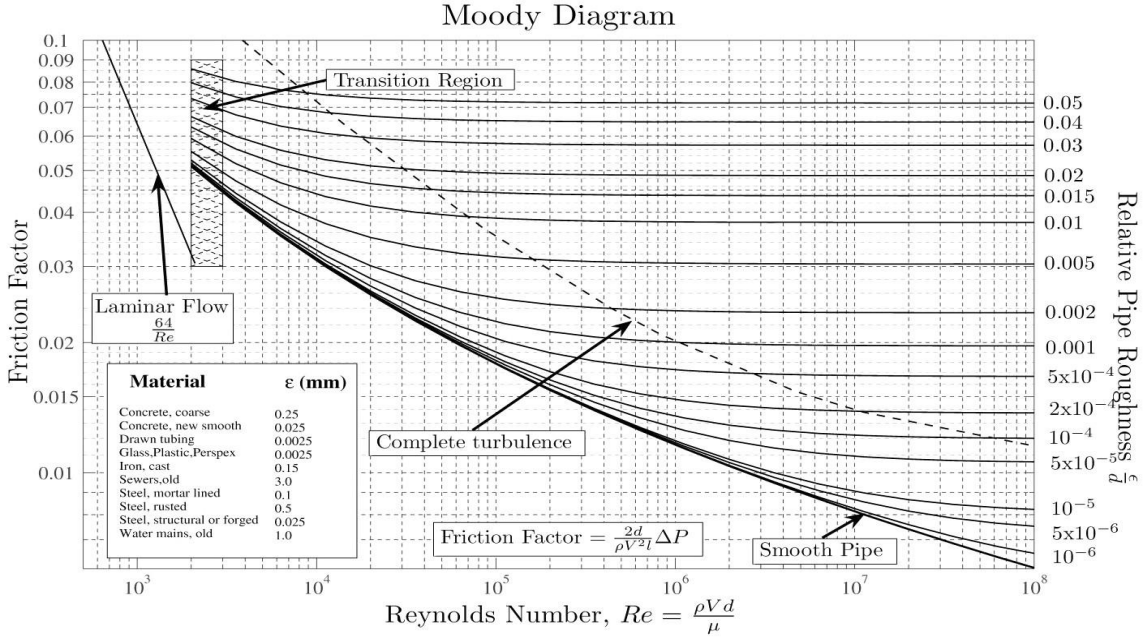


Figure 5.1 Moody diagram (Moody, 1944)

Moody diagram has 4 zones, such as laminar, transition, partial turbulent, full turbulent. In laminar zone fluid has a low flow rate and in fully turbulent zone fluid flows with extremely high flow rate. Moderately high flow rate fluid flows in partially turbulent zone. The friction factor can be determined as a combination of smooth and rough pipe law Colebrook (1937) from Colebrook- White equation is the right method for calculation of friction.

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\epsilon/d}{3.7} + \frac{2.51}{R_e\sqrt{f}}\right) \quad (17)$$

Where

f = Friction factor

R_e = Reynold's number

ϵ = Roughness height

Chapter 6

Mathematical model

Like blood vessel provide blood to every part of human body, city gas distribution network is the interconnection of pipeline to provide the gas to the consumers. It can be treated as an array of connection of branches and nodes .There are two type of network commonly used in natural gas industry i.e. tree type and loop type. For distributing domestic and commercial consumers generally loop type network is used.

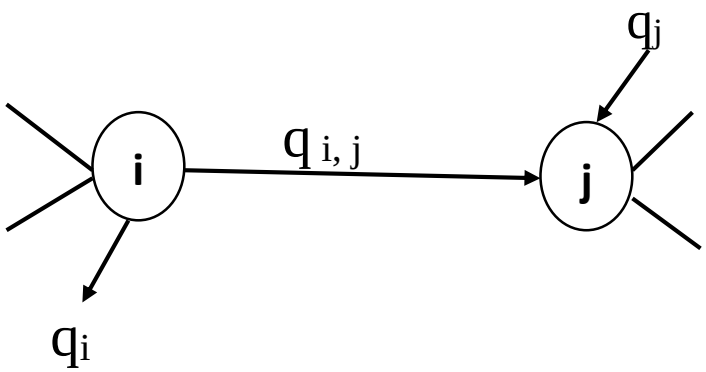


Figure6:1 Diagram of branch with node i and j

6.1Rule for modelling the network

Node:

There are two types of node used in this modelling of network i.e. hydraulic node and graphic node. Hydraulic node are required at the end of all pipes and equipment, wherever pipes and/or equipment is connected, changes in pipe diameter, changes in pipe material, location of point load and elevation extremes. At Graphic node no calculation performed, only it is to be used for providing shape and size of pipe and it can only be applied to pipe and can be added while adding a pipe.

Assigning supply and demand

Most of load are applied to node but it can also applied to pipe. Pipe load is split 50:50 and put on each end node. This technique is very useful for distributed type load i.e. residential

customers. Node flow is the flow into (supply) or out of (load) a node from outside the network, it is not flow through node. Negative node flow is a load and positive node flow is a supply but pipe load are always positive. There is no flow on graphic node and if there is no external flow in a node then that is treated as zero node flow. All the flow must obey Kirchhoff's law i.e. sum of external in flow and out flow must be zero (Kirchhoff's 1st Law)

Rules for unknown

For network topology unknown can be node pressure, node low, pipe diameter, regulator constant, valve constant, compressor power requirement. The number of unknown must be number of nodes. To be solve the network there must be one known pressure along with minimum one unknown node flow of the network shall be assigned. In network the number of unknown flow along with number of unknown node containing external supply shall be equal to number of unknown pressure. For the designing of distribution pipe line as the slope is not too high, it generally ignore the elevation.

Boundary limit

Boundary limit for network topology can be classified under two categories i.e. load limit and supply limit. For load limit boundary constraint are fixed flow and minimum pressure. For supply limit boundary constraint are fixed flow and maximum pressure.

6.2 Kirchhoff's law

Kirchhoff's first law, states that the external inflow and external outflow of a node in a network must sum to zero in order to mass to be conserved.

$$F_j = \sum_{\substack{i=1 \\ adjacent \\ to\ node\ j}}^{facility} Q_i + QN_j \qquad j = 1, 2, 3 \ldots\ldots\ldots NN \qquad (18)$$

In the equation, j represents each node in the network, NN is the number of nodes in the network, Q is the facility flow, QN is the node flow and the summation is for all facilities incident to node j. Thus, from Kirchhoff's first law, a node continuity relationship evolves for the entire network.

Kirchhoff's second law states that the sum of pressure losses in any closed pipe network loop is equal to zero.

$$F_j = \sum_{i=1}^{NN} \Delta P_i = 0 \quad (19)$$

For solving the nonlinear algebraic equation an iterative method shall be used.A Jacobean matrix of differential pressure flow is to be developed for calculating pressure in every node. The nonlinear algebraic equation are solved by Newton-Raphson's iteration method.

6.3 Governing equation

A series of nonlinear equation developed for solve the network

$$\begin{aligned} Y_1 &= f_1(x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_n) \\ Y_2 &= f_2(x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_n) \\ Y_3 &= f_3(x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_n) \\ &\cdot \quad\quad \cdot \\ &\cdot \quad\quad \cdot \\ Y_n &= f_n(x_1, x_{2,\, x3} \ldots\ldots\ldots\ldots x_n) \end{aligned} \quad (20)$$

For solving the set of variable X_i , Taylor series of expansion can be used. Neglecting higher order terms from Taylor series equation can be written as in matrix form

$$f(X + \Delta x) = f(x) + J\Delta x \quad (21)$$

Where J is known as Jacobian

$$\boldsymbol{J} = \begin{bmatrix} \left(\frac{\partial y_1}{\partial x_1}\right) & \left(\frac{\partial y_1}{\partial x_2}\right) \ldots & \left(\frac{\partial y_1}{\partial x_n}\right) \\ \left(\frac{\partial y_2}{\partial x_1}\right) & \left(\frac{\partial y_2}{\partial x_2}\right) \ldots & \left(\frac{\partial y_3}{\partial x_n}\right) \\ \left(\frac{\partial y_m}{\partial x_1}\right) & \left(\frac{\partial y_{m+1,n}}{\partial x_2}\right) \ldots & \left(\frac{\partial y_{m+m,n}}{\partial x_n}\right) \end{bmatrix} \quad (22)$$

$$Y_1 = f_1(x_{1i}, x_{2i}, x_{3i} \ldots\ldots\ldots x_{ni}) + \left(\frac{\partial y_1}{\partial x_1}\right) * \Delta x_1 + \left(\frac{\partial y_1}{\partial x_2}\right) * \Delta x_2 + \ldots\ldots\ldots + \left(\frac{\partial y_1}{\partial x_n}\right) * \Delta x_n$$

$Y_2 = f_2(x_{1i}, x_{2i}, x_{3i} \ldots\ldots x_{ni}) + \left(\frac{\partial y_2}{\partial x_1}\right) * \Delta x_1 + \left(\frac{\partial y_2}{\partial x_2}\right) * \Delta x_2 + \ldots\ldots + \left(\frac{\partial y_2}{\partial x_n}\right) * \Delta x_n$

$Y_3 = f_3(x_{1i}, x_{2i}, x_{3i} \ldots\ldots\ldots x_{ni}) + \left(\frac{\partial y_3}{\partial x_1}\right) * \Delta x_1 + \left(\frac{\partial y_3}{\partial x_2}\right) * \Delta x_2 + \ldots\ldots + \left(\frac{\partial y_3}{\partial x_n}\right) * \Delta x_n$

. .

.

$Y_n = f_n(x_{1i}, x_{2i}, x_{3i} .. x_{ni}) + \left(\frac{\partial y_m}{\partial x_1}\right) * \Delta x_1 + \left(\frac{\partial y_{m+1,n}}{\partial x_2}\right) * \Delta x_2 + \ldots.. + \left(\frac{\partial y_{m+m,n}}{\partial x_n}\right) * \Delta x_n$

To solve Δx such that $f(X + \Delta x) = 0$, the set of equation can be written as

$$\begin{bmatrix} \left(\frac{\partial y_1}{\partial x_1}\right) & \left(\frac{\partial y_1}{\partial x_2}\right) \ldots & \left(\frac{\partial y_1}{\partial x_n}\right) \\ \left(\frac{\partial y_2}{\partial x_1}\right) & \left(\frac{\partial y_2}{\partial x_2}\right) \ldots & \left(\frac{\partial y_3}{\partial x_n}\right) \\ \left(\frac{\partial y_m}{\partial x_1}\right) & \left(\frac{\partial y_{m+1,n}}{\partial x_2}\right) \ldots & \left(\frac{\partial y_{m+m,n}}{\partial x_n}\right) \end{bmatrix} * \begin{bmatrix} -\Delta x_1 \\ -\Delta x_2 \\ \vdots \\ -\Delta x_n \end{bmatrix} = \begin{bmatrix} Y1 \\ Y2 \\ \vdots \\ Yn \end{bmatrix} \quad (23)$$

Solving Δx at iteration k

$$\Delta x_k = -J_k^{-1} f(x_k) \quad (24)$$

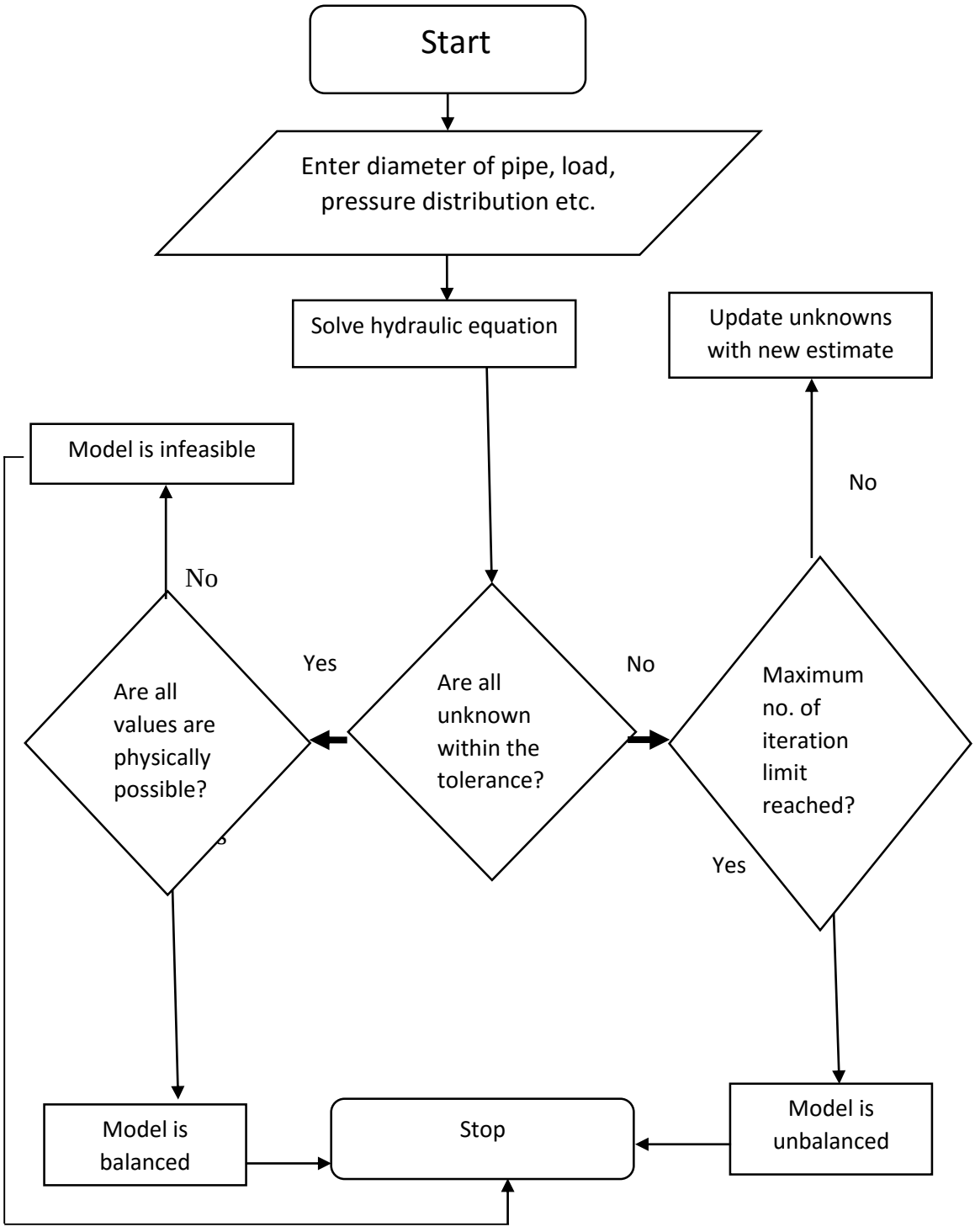
Where Δx is the change in the x vector from previous iteration.

$$\Delta x_k = x_{k+1} - x_k \quad (25)$$

By substituting Δx_k in equation (24) , the equation becomes

$$x_{k+1} = x_k - J_k^{-1} f(x) \quad (26)$$

6.4 Flow chart



Chapter 7

Designing the network in SynerGEE software

After determining the basic dimension it is necessary to model the network by any CAD software. I have used SynerGee gas software of version 4.6.0 for the modeling of the network.

7.1Background work

Base map loading

Base map such as GIS mapping system file, Auto CAD files, Scanned paper drawing and aerial photograph can be loaded and displayed as a new layer with respect to the hydraulic model. This map assist the user to understand of system and its environment by combining physical and geographical attribute and spatial relationship between them. It can digitize the pipe by onto by tracing over map. Base map files falls into two broad categories (1) raster (2) vector.

I have used a raster base map of JPG (joint photographic expert group) type. Since raster file don't contain any scaling and position information, it need to be provided by a supplemental file known as world file. It can be created manually in a program such as Notepad.

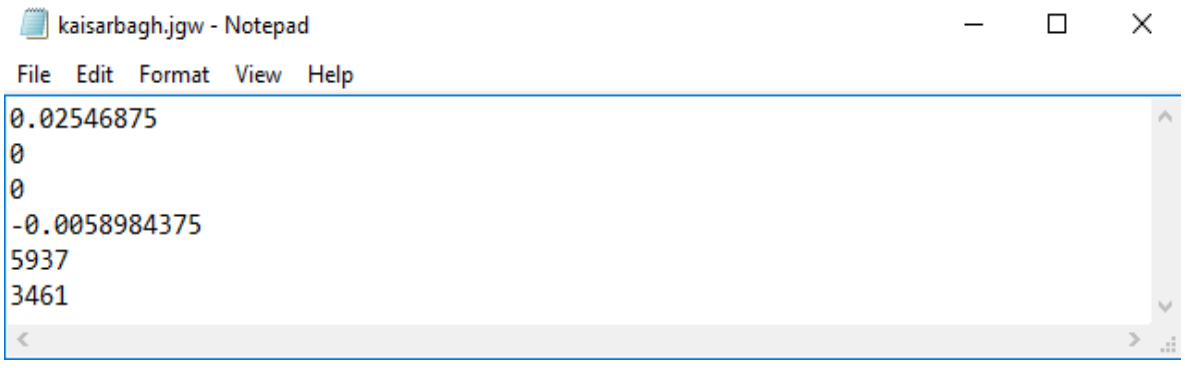


Figure 7.1 scaling position of Kaisarbagh

The first line represents the X scale or width of one pixel in map unit, second and third line represents rotation and should be zero as it is not supported by SynerGee. Next line represents

Y scale or height of one pixel in map unit and always will be negative. The next two line represents X and Y co-ordinate in map unit of upper left hand corner of the image respectively.

Equipment warehouse

The equipment warehouse allows to create a virtual catalog of pipes, valves, regulators, and other equipment that to be used in the model. Figure shows an example equipment warehouse. In this warehouse, pipes have been divided into subtypes based on pipe equations. Each subtype includes several pipes with different diameters.

To add a facility to an equipment warehouse

1. In the model explorer, click the Warehouse tab.
2. Select the equipment type or subtype for adding a facility.
3. Right-click and select New > [Facility Type].
4. Double-click the facility name to open the facility editor. With this editor, edit the name and values for the new warehouse facility.

By following this I have created a warehouse for this model.

7.2Create the model in SynerGee Gas

The detail process of developing of the model is described below

1. Create a new model
    - From the main menu ,select file > open
    - In the opening Assistant , create a new model
    - Under supplementary data source select My workspace.ws.mdb and my warehouse.ws.mdb which saved in my work folder
    - Click ok
2. Open ware house and locate the pipe that closely represent for the required specification of pipe
    - In the model explorer, click on warehouse tab
    - Expand pipes and click on my pipes
    - In the grid , click on My 4'' PE and drag it on the map display

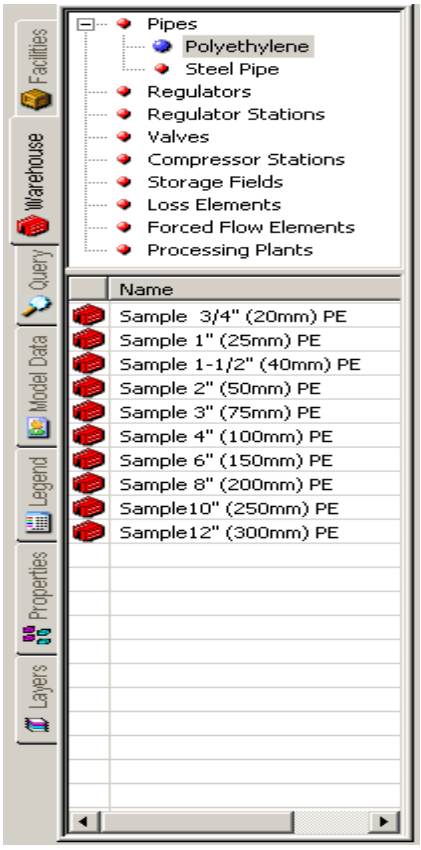


Figure 7.2 Equipmnt ware house

3. Draw the Pipe on the map
    - In the map display, click the starting point of pipe, called from node
    - Move the cursor to the leading location of pipe, called to node and then double click
    - Draw all the pipes with the same procedure and complete the loop
4. Insert vertices on pipe
    - Right click and select graphic edit
    - Click on the facility to select it
    - When the ↕ cursor appears, click on the point on the facility, where to add a vertex
    - Click and hold the left mouse button on the red vertex, as to drag to the new location

- Release the mouse button and click on the pipe, where to add a new vertex
- Drag to the new location and then click anywhere to complete the process.

5. Draw the valve on the map
    - In the model explorer, click the warehouse tab
    - In the tree view click the valves
    - Choose the required the valve and drag it on to the map display
    - Click anywhere in blank space upstream of top source node and then double click on source node to finish the adding the valve
6. Edit the pipe properties
    - In the map display double click on pipe
    - In the pipe editor, click on the physical data tab
    - In the length text box assign the required length and click apply
    - Repeat this process for each pipe

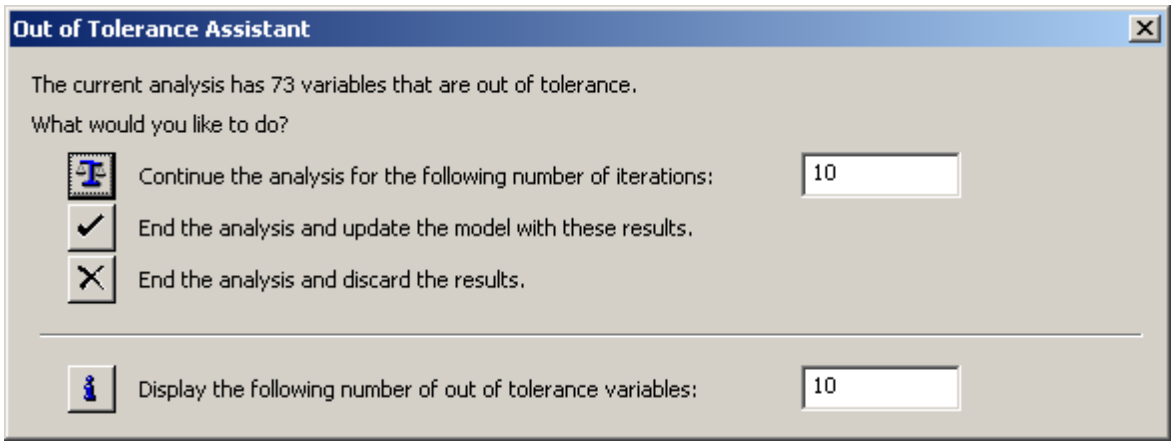


Figure 7.3 Tolerance assistance for iteration method

7. Edit the valve properties
    - In the map display double click on valve
    - In the editor, click on physical data tab
    - In the text box assign the required changes and click apply
    - Repeat this process for each valve

8. Edit the node
    - Double click on the node
    - Under the identification change the name, ex: Keiserbag, Parivartan chowk, etc...
    - Next to control, uncheck the flow and pressure
    - By clicking ok, the unknowns indicate on the status bar
9. Set the pressure on the node
    - Double click on the required node
    - In the node editor, next to control, check the pressure
    - On the pressure tab enter the required data for that specific node
    - Click ok and repeat the same procedure for all the node, whose pressure shall be controlled

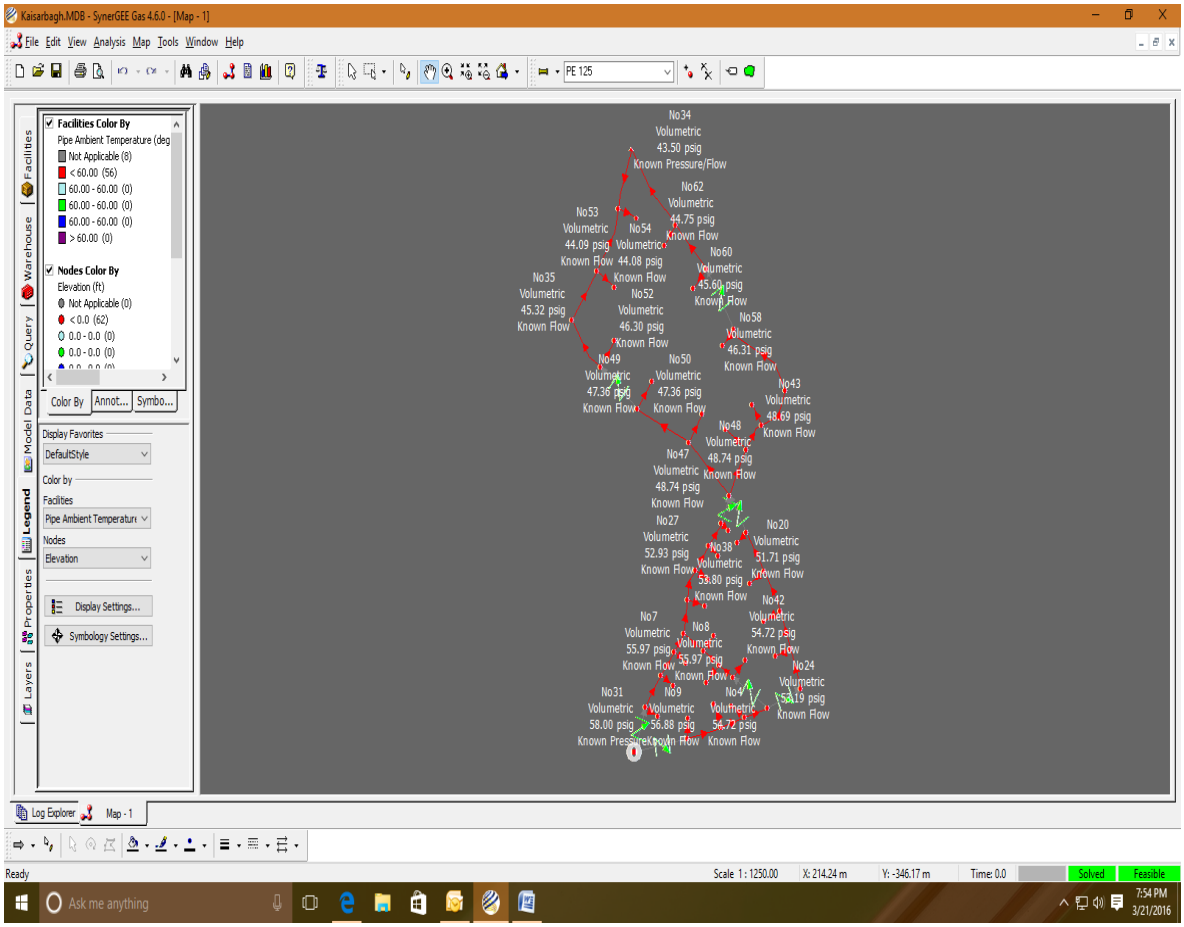


Figure 7.4 Pipe lay out for kaiserbag

10. Set the flow on the node

- Double click on the node
- In the node editor, next to control, check the flow
- On the flow tab enter the required data for the specific node
- For supply it should be positive and for demand it should be negative
- Click ok and repeat the same procedure for all the node, whose flow shall be controlled

11. Run Steady state analysis

- From the main menu select analysis > steady-state
- Out of tolerance assistant helps to find out, how many variable are out of tolerance
- The model is solved by updating the model or by continuing the analysis with more number of iteration.
- After the solving the model save the model

Chapter 8

Simulation Result

In this Chapter simulated results are presented. SynerGEE Gas 4.6.0 software is used to simulate the model.

8.1 Model parameter

For simulating the model proposed in chapter 6, some parameter need to be chosen. This section describes those parameter like pipe length, Pipe size, Pipe material, gas properties.

Table 8.1: System data

Model Parameter	Specification
Specific gravity of gas	0.60
Maximum Gas velocity	100 ft/sec
Minimum pressure in network	30 Psig
Maximum pressure in network	58 Psig
Pipe diameter	4 inch
Total pipe length	8.73 mile
Pipe material	PE100
Total demand	2.064 mmscfd
No of nodes	62
No of facilities	64
Pressure calculation	Fundamental equation with variable friction

As per guide line from Oil industry and safety directorate, the maximum gas velocity is limited to 100 ft/sec and the design pressure limit shall be within 30 Psig to 58Psig. A 4inch MDPE pipeline of material grade 100 s selected for this purpose. The fundamental equation with variable friction is chosen for the calculation.

8.2 Result

The simulated pressure and volumetric flow distribution tabulated below

Table 8.1: Node data

Node name	Pressure psig	Volumetric Flow mmscfd
No1	55.40	0.000
No 10	56.88	-0.007
No11	56.07	0.000
No12	56.07	-0.007
No13	57.05	0.000
No14	57.05	-0.007
No15	51.36	0.000
No16	51.36	-0.009
No17	50.93	0.000
No18	50.93	-0.009
No19	51.71	0.000
No2	55.39	-0.007
No20	51.71	-0.009
No21	52.49	0.000
No22	52.49	-0.009
No23	53.19	0.000
No24	53.19	-0.009
No25	52.11	0.000
No26	52.11	-0.009
No27	52.93	0.000
No28	52.93	-0.009
No29	53.81	0.000
No3	54.72	0.000

No30	53.92	0.000
No31	58.00	2.064
No32	50.14	0.000
No33	47.89	0.000
No34	43.50	0.000
No35	45.32	0.000
No36	54.71	0.000
No37	54.73	0.000
No38	53.80	-0.009
No39	54.72	0.000
No4	54.72	-0.007
No40	54.72	-0.009
No41	54.72	0.000
No42	54.72	-0.009
No43	48.69	0.000
No44	48.69	-0.035
No45	49.24	0.000
No46	49.24	-0.035
No47	48.74	0.000
No48	48.74	-0.035
No49	47.36	0.000
No5	55.26	0.000
No50	47.36	-0.035
No51	46.30	0.000
No52	46.30	-0.035
No53	44.09	0.000
No54	44.08	-0.035
No55	42.70	0.000
No56	38.80	-1.610
No57	46.31	0.000

No58	46.31	-0.035
No59	45.61	0.000
No6	55.26	-0.007
No60	45.60	-0.035
No61	44.76	0.000
No62	44.75	-0.035
No7	55.97	0.000
No8	55.97	-0.007
No9	56.88	0.000

The chart shows the nodal pressure distribution. All the pressure distribution to the various node are under pre-determined limit.

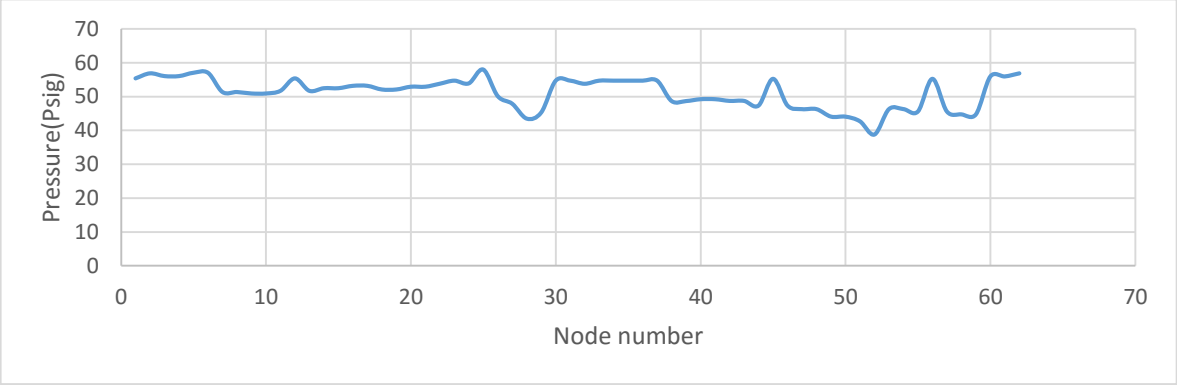


Figure 8.1 Node pressure distribution chart

As node 31 is the supply point for this designed network it designed to supply with highest pressure of 58Psig. Nodes having higher pressure in the network after node 31 are node 13, 14, 9, 10,11,12,7,8 and 1 with pressure of 57.05, 57.05,56.88, 56.07, 55.97, 55.97 and 55.40 in Psig respectively. This due to most of above nodes are nearer to supply point and others are due to junction point of pipe. The node having lowest pressure in the network are node 56, 55, 34, 54, 53, 62, 61, 35, 60, 59 having pressure of 38.80, 42.70, 43.50, 44.08, 44.04, 44.75, 44.76, 45.32, 45.60, 45.61 Psig respectively. Most of the above mention nodes having more consumption demand and located far from supply point.

The simulated flow, velocity and pressure distribution for pipe line are tabulated below

Table 8.2 Pipe data

Facility Name	From	To	Length mile	Flow mmscfd	Velocity ft/sec	Pressure
Pi1	No1	No11	0.12	-0.976	27.22	55.73
Pi10	No9	No10	0.10	0.007	0.22	56.88
Pi11	No11	No13	0.17	-0.983	27.15	56.56
Pi12	No11	No12	0.10	0.007	0.23	56.07
Pi14	No13	No14	0.10	0.007	0.22	57.05
Pi16	No15	No16	0.15	0.009	0.31	51.36
Pi17	No17	No19	0.16	-0.866	25.83	51.32
Pi18	No17	No18	0.15	0.009	0.31	50.93
Pi19	No19	No21	0.16	-0.875	25.79	52.10
Pi2	No1	No2	0.10	0.007	0.23	55.40
Pi20	No19	No20	0.15	0.009	0.31	51.71
Pi21	No21	No23	0.14	-0.884	25.75	52.84
Pi22	No21	No22	0.15	0.009	0.31	52.49
Pi23	No23	No30	0.14	-0.893	25.74	53.55
Pi24	No23	No24	0.15	0.009	0.30	53.19
Pi25	No25	No15	0.10	1.077	31.90	51.74
Pi26	No25	No26	0.15	0.009	0.31	52.11
Pi27	No27	No25	0.11	1.086	31.80	52.52
Pi3	No3	No41	0.08	-0.066	1.87	54.72
Pi31	No32	No45	0.17	0.889	27.22	49.69
Pi32	No33	No57	0.33	0.819	26.29	47.11
Pi33	No34	No55	0.20	0.714	24.38	43.10
Pi34	No35	No51	0.16	-0.931	30.38	45.81
Pi35	No36	No29	0.12	1.104	31.52	54.26
Pi36	No37	No1	0.11	-0.969	27.29	55.06
Pi37	No36	No39	0.11	-0.050	1.42	54.72

Pi38	No27	No28	0.15	0.009	0.30	52.93
Pi39	No29	No27	0.12	1.095	31.67	53.37
Pi4	No3	No4	0.10	0.007	0.23	54.72
Pi40	No29	No38	0.15	0.009	0.30	53.81
Pi41	No39	No3	0.08	-0.059	1.67	54.72
Pi42	No39	No40	0.15	0.009	0.30	54.72
Pi44	No41	No42	0.15	0.009	0.30	54.72
Pi45	No43	No33	0.17	0.819	25.62	48.29
Pi46	No43	No44	0.20	0.035	1.26	48.69
Pi47	No45	No43	0.11	0.854	26.38	48.97
Pi48	No45	No46	0.20	0.035	1.25	49.24
Pi49	No47	No32	0.19	-1.036	31.96	49.44
Pi5	No5	No36	0.08	1.053	29.68	54.99
Pi50	No47	No48	0.20	0.035	1.26	48.74
Pi51	No49	No47	0.20	-1.001	31.58	48.05
Pi52	No49	No50	0.20	0.035	1.29	47.36
Pi54	No51	No52	0.20	0.035	1.31	46.30
Pi55	No53	No35	0.20	-0.931	31.02	44.71
Pi56	No53	No54	0.20	0.035	1.36	44.08
Pi57	No55	No53	0.23	-0.896	30.58	43.40
Pi58	No55	No56	0.20	1.610	68.82	40.77
Pi6	No5	No6	0.10	0.007	0.23	55.26
Pi60	No57	No58	0.20	0.035	1.31	46.31
Pi61	No59	No61	0.21	0.749	24.68	45.18
Pi62	No59	No 60	0.20	0.035	1.33	56.43
Pi63	No 61	No 34	0.33	0.714	24.04	45.60
Pi64	No 61	No 62	0.20	0.035	1.35	44.13
Pi7	No 7	No 5	0.10	1.060	29.64	44.76
Pi8	No 7	No 8	0.10	0.007	0.23	55.61
Pi9	No 9	No 7	0.13	1.067	29.54	55.97

All the pressure and velocity distribution in pipe are under predetermined level

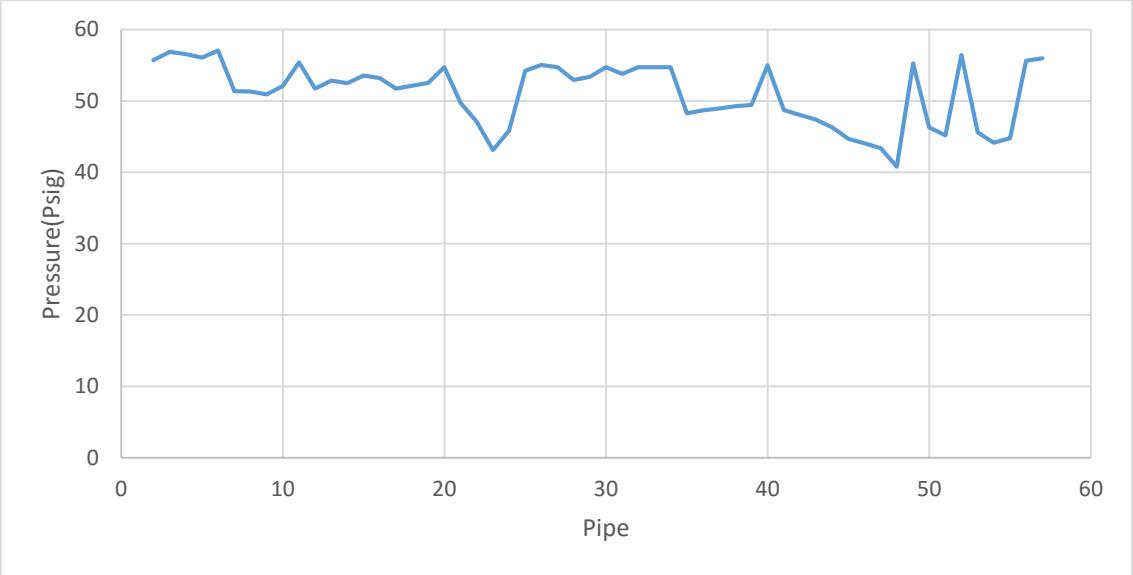


Figure 8.2: Pipe pressure distribution chart

Chapter 9

Summary and conclusion

9.1 Summary

In this thesis the standards and specification for city gas distribution are studied. To reduce the carbon foot print now CNG is widely used. The use of this hydrocarbon is now being popular as it is one of the safe and economically feasible hydrocarbon. Looking for the demand of Lucknow city, the existed network shall be extended. After studying various standards and specification prescribed by both national and international authority, a CGD network has been designed. The designing of network is gone through three stages. In forth stage the demand for the gas in various location has been predicted and peak hour gas consumption calculated, along with the right of way for the gas network has been selected with considering present utility system and demand predicted. In second stage the basic dimension of pipe and its components are calculated which consist of diameter of pipe, material to be used and maximum allowable operating pressure. In the third stage the rule for the network topology proposed and designing of network with simulation is done with help of SynerGEE software.

The main contribution of this thesis are

i. Forecasting the CNG demand in various location of Lucknow city
ii. Selection of right of way
iii. Calculation of basic dimension of pipe and its components
iv. Mathematical model for network topology
v. Designing and simulation of CGD network

9.2 Conclusion

A new City gas distribution network has been designed with taking care of all standards and specification. The valves are strategically placed so that the chances of catastrophic effect could be minimized with minimum response time. The network is consist of 62 nodes having capacity 2.064 mmscfd. So it require a distributing pressure regulating station to control the pressure fluctuation at node 31.

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