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Layout Planning, Execution, and Testing of City Gas Distribution (CGD) Network of Pipelined Natural Gas (PNG)

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1. Abstract

PNG (Pipelined Natural gas) pipeline for city gas distribution network is a promising future for Indian cities. The Methane gas which flows through these pipes is the main contributer of natural gas in this network. This paper discusses the procedure and steps in the planning and execution for the natural gas network . In this paper, we have computerized the flow of the natural gas into a network of PE and GI pipeline provided into the phase - 1 of its laying i.e., for MCV – 1. CFD analysis for the methane gas has been the main focus of this paper in our project of laying the network of PE and GI pipeline through the given apartment. After Simulation the results are analyzed based on the pressure drop through the network for proper flow of the gas

I. Introduction

As information provided by COP of MNGL (Maharashtra Natural Gas Limited), Natural gas mainly contains of Methane which occurs naturally as a mixture while extraction. This Natural Gas is provided in Nashik City with the help of MNGL as a distributer which is the Joint venture of Gail India and BPCL. As Natural Gas is 40 percent Lighter than air and has high ignition temperature above 1000 degree C it becomes much safer to use than LPG which is regularly used in the Indian households. The mixture of natural gas contains (Ethane, Methane and Propane) it becomes vital to understand the flow and pressure of the gas throughout the pipeline. This study focusses on the pressure drop of the methane gas neglecting the outer conditions or any other effects.

CFD is known as Computational fluid dynamic, it is a modern software related to the fluid mechanics numerical analysis and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.[1]

I. Problem Statement

During this process various factors need to be considered to maintain required pressure and velocity at consumer end with minimal losses. The factors which need to be taken into account consist of dimensions of the pipe, material roughness, various joints and fitting to be used, environmental conditions, space constraints etc.

- Achieving less pressure drop and velocities across the laid network into the provided area of the society.
- Development of Pipeline Network in a pre-defined geographical spread
- Maintaining Different Levels of Gas Pressure to meet the Demand of various segments of gas users
- Designing a high pressure and medium pressure network such that supply to any consumer is possible from either side.
- Consider Health, Safety & Environment at all stages

II. Objectives

To achieve optimal pressure and flow rate at consumer end and to avoid leakages at fittings. Also, to utilize minimum no. of fittings for minimal losses.

III. Expected Outcomes

Minimum of 21 mbar pressure shall be achieved from 30 m/sec inlet velocity by maintaining length of the laid network of GI (Galvanized Iron) and PE (Polyethylene) pipes.

IV. Literature Review

Many researches have contributed to the Study of Natural Gas Pipeline and its Planning and Laying, some of the Papers are summarized below:

1. CFD investigation of natural gas leakage and propagation from buried pipeline for anisotropic and partially saturated multilayer soil Javad Bezaatpour Esmaeil Fatehifar in the present study, the 3-D model of natural gas leakage from a buried damaged pipeline in the soil is studied numerically by utilizing the finite element method under unsteady-state condition until it reaches the soil surface. The characteristics of the porous media are considered in accordance with the actual soil conditions. As a novel idea the employed soil is considered completely anisotropic, stratified with variable moisture content for each layer. The weight effect of soil layers is also considered in the model[2]

2. Miguel Ferreira Santos in 'Analysis of transient flow in natural gas transmission network' presents a mathematical model and its numerical implementation for the simulation of complex gas networks in transient state, including the mathematical formulation, the experimental validation and the application to relevant case studies for the Portuguese natural gas transmission network. The mathematical formulation is based upon the principles of conservation, applied to the gas flow in a pipe, which will be simplified depending on the assumptions made. The numerical implementation is based on the conservation of mass in a node, by two different numerical methods: finite difference and finite elements. Two existent computer programs were improved to perform the numerical calculations. Two case studies were analyzed. It is concluded that the developed numerical methods simulate the behavior of complex networks, with no preference for either method. It is verified that if pipes are non-horizontal the elevation term might be nonnegligible. It can also be concluded that the Portuguese gas network has the capacity to meet the gas demand in near future.[3]

3. R. Kiš, M. Malcho, M. Janovcova in 'A CFD Analysis of Flow through a High-pressure Natural Gas Pipeline with an Undeformed and Deformed Orifice Plate' aims to present a numerical analysis of the natural gas which flows through a high-pressure pipeline and an orifice plate, through the use of CFD methods. The paper contains CFD calculations for the flow of natural gas in a pipe with different geometry used for the orifice plates. One of them has a standard geometry and a shape without any deformation and the other is deformed by the action of the pressure differential. It shows the behavior of natural gas in a pipeline using the velocity profiles and pressure fields of the gas in both models with their differences. The entire research is based on the elimination of any inaccuracy which should appear in the flow of the natural gas measured in the high-pressure pipelines of the gas industry and which is currently not given in the relevant standard.[4]

4. Z.A. Majid a, R. Mohsin a, Z. Yaacob a, Z. Hassan in 'Failure analysis of natural gas pipes 'Study was performed to identify the most probable cause of the pipe's failures. The study conducted by reviewing the existing design and construction data, visual physical inspection, pipe material analysis, structural analysis using NASTRAN and Computational Fluid Dynamics analysis (CFD) using FLUENT. Investigations revealed that high pressure water jet from leaked water pipe had completely mixed with surrounding soil forming water soil slurry (high erosive properties) formed at a close vicinity of these pipes. Continuous impaction of this slurry upon the API LX42 pipe surface had caused losses of the pipe coating materials. Corrosion quickly ensued and material loss was rapid because of the continuous erosion of oxidized material that occurred simultaneously. This phenomenon explains the rapid thinning of the steel pipe body which later led to its failure. Metallurgical study using photomicrograph shows that the morphology of the steel material was consistent and did not show any evidence of internal corrosion or micro fractures. The structural and CFD simulation results proved that the location, rate and the extent of erosion failures on the pipe surfaces can be well predicted, as compared with actual instances.

Materials Used for CGD

A. *Medium Density Polyethylene Pipeline (MDPE)*

1. *Specification of MDPE Pipe*

Fig 1: Medium Density Polyethylene Pipeline

The Medium density Polyethylene (MDPE) Pipe that has been used has some of the specifications as follows:

- Tech Spec: IS 14885:2001 & ISO 4437
- Material Grade & Color: Internationally approved resins of PE 100 grade of orange color
- Minimum Required Strength (MRS) of PE 100 grade pipe: 10 MPa
- Pressure Class: SDR 9 (dia 20 mm), SDR 11 (dia 32 & 63 mm) and SDR 17.6 (dia 90, 110, 125 and 160 mm).
- Operating pressure: 4 bar (g)
- Operating temperature range: - 10°C to + 40°C.
- Density: > 930kg/m^3
- Tensile Strength at Yield elongation: 15MPa

A. Galvanized Iron Pipes

1. Specification of GI Pipe

Fig 2: GI Pipe

The Galvanized Iron (GI) Pipe that has been used has some of the Specifications as follows:

- Tech Spec: IS 1239 (Part 1)
- Types used: Medium Class and Heavy Class
- Pipes shall be screwed with Taper threads
- Threads: Tapered and conforming to BS 21
- Galvanizing: IS 4736
- Coating requirements: Mass of coating is 400 g / m2
- Test Pressure: 5 MPa
- Powder Material: Pure Polyester
- Application: Electrostatic spraying (40 – 90 KV, Manual / Automatic)

V. Design

B. For MDPE Pipe

The length of the MDPE pipe that needs to be used is calculated on the basis of the Weymouth equation.

The Weymouth Equation for MDPE is:

Q = 0.11672 * (d)*2.664 * {(p12-p22)0.544 / (S * L)1/2}

Where,

d = diameter of pipe

p12=inlet Pressure

p22=outlet Pressure

S = specific density of Natural Gas

L = length of pipe laid

Velocity, V = Q / A

Note: Velocity for filtered gas to be 30 m/s & unfiltered gas to be 20 m/s.

C. For GI Pipe

The length of the GI pipe that needs to be used is calculated on the basis of the Weymouth equation.

The Poly flow Equation for GI is:

Q = 1.522786 * 10-3 * (d)2.623 * {(h/L)0.541}

Where,

d = diameter of pipe

h = height of building

L = length of pipe laid

Being a standard PNG Connection, we have standardized the design of PNG Network as follows;

• Peak Gas flow is assumed @ 0.5 SCMH for one house

• ½” GI pipes up to G + 4 apartments OR 5 connections in case of row house.

•1” GI Pipe above 5th Floor apartment OR above five connections in row house.

VI. Pipe Laying Procedure

A. For MDPE Pipe

1. Route Planning

Route Planning is the first Process when it comes to the MDPE pipe laying Process. Route Planning Ensures that the Process of trenching is smooth. It avoids any obstacles that are laid under the planning area.

2. Trenching

Trenching Is the Process of making a 0.4m wide trench and 1.2m deep for laying of MDPE pipeline with the help of trenching tools. It can be done either manually with labors or by the help of bulldozers if necessary.

3. Laying

In the laying process the MDPE pipe is laid into the trench with proper orientation and backfilling is done. A warning mat is laid on top of the laid pipe as a warning symbol for safety purposes.

4. Joining

The joining Process is Done with the help of a fusion machine. The fusion machine used is of GF. It is connected to two end pieces of the connection point where it needs to be joined. The time taken for joining MDPE pipe is 315 sec.

5. Backfilling.

Backfilling is carried out from the extracted material for the laying of the pipeline. the ends of the laid pipe are kept open for the testing and purging.

6. Testing

Testing is carried out for detection of any Leakages throughout the laid pipe. The testing is done for the pressure of 6.2 Kg/cm2 for about 24 Hrs. No leakages were detected during the testing.

7. Restoration

Restoration is a process of installation of the tiles and PCC during the Excavation of the ground for which the pipe has been laid. PCC is used in the ratio of 1:2:4 for the restoration purpose

8. Marker Installation

As the laid Pipeline need to be identified for the operation and maintenance purpose route markers are installed for this reason. The laid Pipeline was then marked by using proper route markers

B. For GI Pipe

1. Route Survey

Route survey is carried out in order to plan for the installation of the GI pipe. We have surveyed the building and found out the appropriate route that the GI pipe needs to be installed. Obstacles such as wires waterflow pipes are need to be properly studied in order to carefully plan the surveying process.

2. GI Installation

As per the planning drawings the GI installation is carried out into the building for the Krushna Chaya building. This is done by the overhanging plumbers with proper tools and machines such as Drilling machines. Proper use of the safety equipment's is necessary for the installation of these pipes.

3. Testing of GI pipe.

For GI Pipeline the Flushing is done at 250 mbar. The Flushed pipeline is Kept under pressure (250-300 mbar) for 15 min. Then it is Checked for any Leakage. If any Leakage is found it is rectified or else the pressure is released. Painting with yellow color is done after the testing.

VII. Computer Aided Drawing Using Solid Works

After a design has been selected, the next step in designing process is 3D model. The design is separated into part by part and the dimensioning process is firstly sketched on the paper. After dimensioning, the drawing of the design is drawn using computer software Solidworks. At this stage, solid modelling method is used. Part by part solid modelling creates according to the dimension done before, after all part create, the 3D model is assembled with each other base on the design.

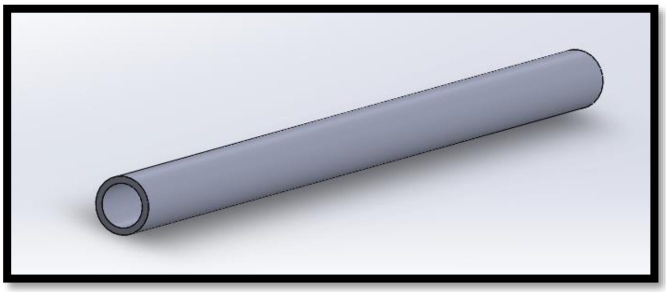

Fig 3: Low Pressure Pipe

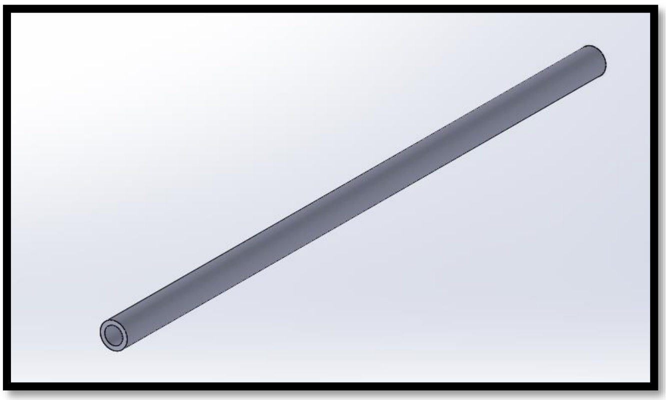

Fig 4: Galvanized Iron Pipe

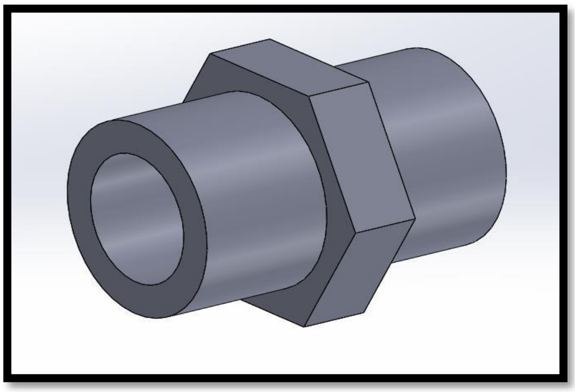

Fig 5: Union for GI pipe

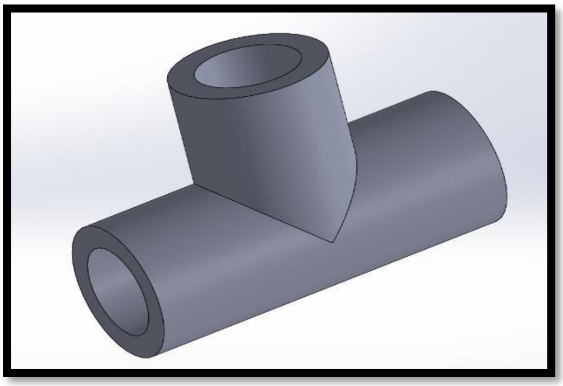

Fig 6: ½ inch Tee for GI pipe

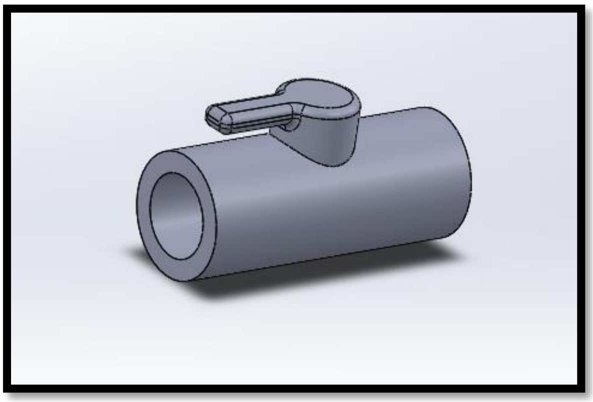

Fig 8: ½ inch valve

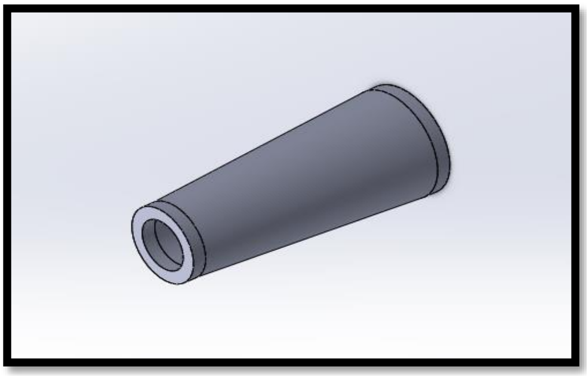

Fig 7: Reducer

Table 1: Material Required

A. Boundary Conditions

The Boundary conditions for the analysis were considered for the given data. Methane at ambient temperature (300K) was used as the working fluid. Simulations were carried out by specifying velocity at the inlet of the horizontal pipeline. Which is taken to be 30 m/s. Another Boundary condition was the Pressure at each outlet of the GI valve. The Pressure was taken to be at Environmental Pressure which is 101.325 Kpa

Type	Inlet Velocity
Faces	LID5-1/Imported1//Face
Coordinate system	Face Coordinate System
Reference axis	X
Flow parameters	Flow vectors direction: Normal to face Velocity normal to face: 30.000 m/s Fully developed flow: No
Thermodynamic parameters	Approximate pressure: 101325.00 Pa Temperature type: Temperature of initial components Temperature: 293.20 K
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 0.466 m
Boundary layer parameters	Boundary layer type: Turbulent

Table 2: Boundary Conditions

B. Results

As observed in table given below the pressure drops across the designed pipeline are:

Name	Unit	Value Pa	Progress	Criteria	Delta	Use in convergence
GG Minimum Static Pressure 1	Pa	2560.14	100	3989.96046	2769.84706	On
GG Average Static Pressure 2	Pa	11461.73	100	31126.8986	30445.6276	On
GG Maximum Static Pressure 3	Pa	24801.65	100	61193.7212	47063.3654	On

Table 3: Results

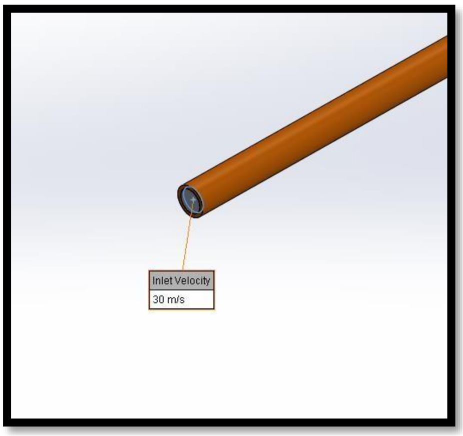

Fig 9: Inlet Flow Velocity

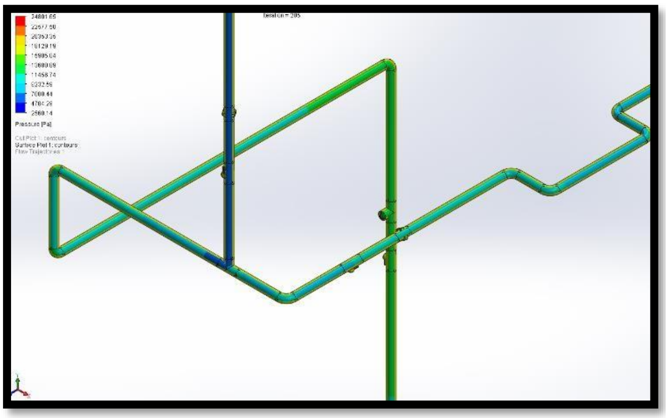

Fig 11: Pressure Surface Plot across the planned pipe of Krushna Chaya

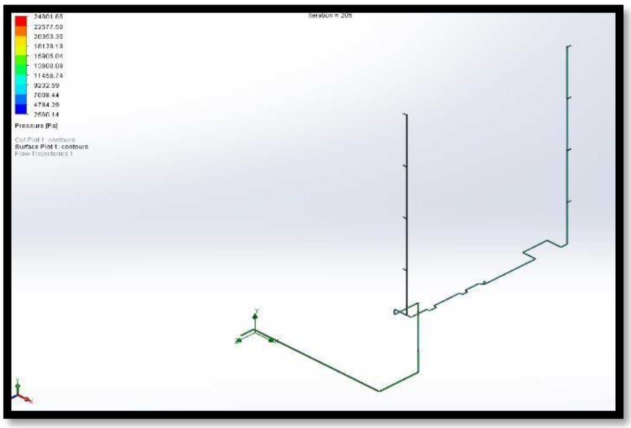

Fig 10: Pressure Surface Plot across the planned pipe of Krushna Chaya

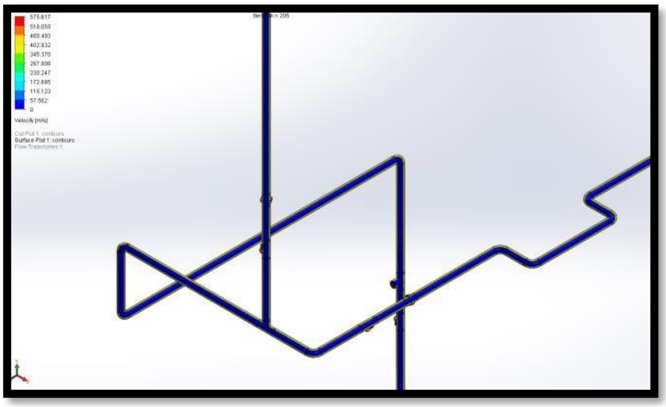

Fig 12: Velocity Surface Plot across the Planned pipe of Krushna Chaya

VIII. Conclusions

Using CFD analysis the minimum pressure throughout the constructed pipeline was observed to be 2560.14 Pa which was found at the outlet of the constructed pipeline. The average Pressure is maintained is 11461.73 Pa for the constructed pipeline. It reaches its maximum value at the inlet.

To achieve the required pressure at the consumer end, the major affecting factor for the laid network are the pipe dimensions.

To avoid leakages in the network, fittings must be properly fused and fitted using proper material and equipment.

To avoid major head losses caused in laid networks we should use a minimum no. of fittings and also, we need to ensure that the laid network has minimum no. of joints.

References

[1] Rasel A Sultan, Houssemeddine Leulmi 21st March, 2016. CFD Simulation Investigation of Natural Gas Components through a Drilling Pipe.Reserach Gate Publication, 4-5,12 https://www.researchgate.net/publication/299616522_CFD_Simulation_Investigation_of_Natural_Gas_Components_through_a_Drilling_Pipe

[2] Ali Rasoulzadeh, Javad Bezaatpour,, Esmaeil Fatehifar – 2016 CFD investigation of natural gas leakage and propagation from buried pipeline for anisotropic and partially saturated multilayer soil – 1-10

[3] Miguel Ferreira Santos - Analysis of transient flow in natural gas transmission network https://fenix.tecnico.ulisboa.pt/downloadFile/395142220603/resumo_51565.pdf

[4] R. Kiš, M. Malcho, M. Janovcová - World Academy of Science, Engineering and Technology International Journal of Mechanical and Mechatronics Engineering Vol:8, No:3, 2014 A CFD Analysis of Flow through a High-Pressure Natural Gas Pipeline with an Undeformed and Deformed Orifice Plate

https://publications.waset.org/9997799/a-cfd-analysis-of-flow-through-a-high-pressure-natural-gas-pipeline-with-an-undeformed-and-deformed-orifice-plate

[5] Zulkifli Abdul Majid, Rahmat Mohsin, Z. Yaacob, Zulkafli - June 2010 Hassan Failure analysis of natural gas pipes https://www.researchgate.net/publication/245161740_Failure_analysis_of_natural_gas_pipes

[6] Development of natural gas flow rate in pipeline networks based on unsteady state Weymouth Equation-Hossein Amani, Hasan Kariminezhad, Hamid Kazemzadeh,2016, sciencedirect.com