# DESIGN AND NETWORK ANALYSIS FOR PIPELINE SYSTEM OF CGD FOR ELURU TOWN

By

SARADHI MEDAPUREDDY

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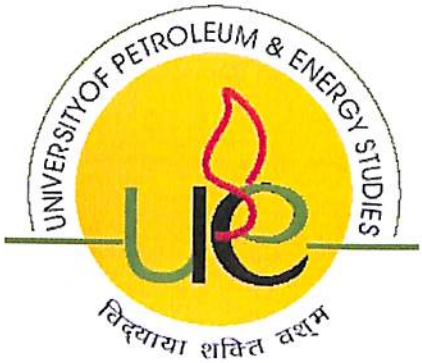


College of Engineering

University of Petroleum & Energy Studies

Dehradun

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# DESIGN AND NETWORK ANALYSIS FOR PIPELINE SYSTEM OF CGD FOR ELURU TOWN

A thesis submitted in partial fulfillment of the requirements for the Degree of

Master of Technology

(Pipeline Engineering)

By

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Under the Guidance of

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May, 2011

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During this period he was found to be sincere, hardworking and diligent. His character and conduct during the training period were found to be good.

We wish him the Best of luck in his future endeavours.

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## CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "DESIGN AND NETWORK ANALYSIS FOR PIPELINE SYSTEM OF CGD FOR ELURU TOWN" by "SARADHI. MEDAPUREDDY" in partial fulfillment of requirements for the award of degree of M. Tech. (Pipeline Engineering) submitted in the Department of at UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN is an authentic record of my own work carried out during a period from 1ST Feb, 2010 to 21ST APR, 2010 under the supervision of VIJAY MANE, MANAGER (PROJECT) BAGYANAGAR GAS LIMITED. The matter presented in this thesis has not been submitted by me in any other University / Institute for the award of M. Tech Degree. *Due to the confidentiality of data, the original name, location and identity of the data has been changed.*

SARADHI MEDAPUREDDY

## ACKNOWLEDGEMENT

There are many people to acknowledge when a report like this is completed. My sincere thanks goes to all those who are directly or indirectly involved in this project and took time out of their busy schedules to pour insights into my report.

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The University of Petroleum & Energy Studies must be credited for letting me do a project in my area of interest. I sincerely thank **Mr. Adarsh Kumar arya** for keeping faith in me and letting it happen.

Last and most assuredly not least, I am deeply indebted to many people including my present class-mates, who have helped and extended their support to me directly and indirectly in this project.

SARADHI MEDAPUREDDY

# ABSTRACT

The present work study explains the feasibility of setting up a City Gas Distribution (CGD) network in Eluru Town and designing pipeline system for the same. Later the Natural gas demand for the Eluru town is estimated with the help of past executions taken place at Lucknow & Hyderabad. For this demand, the CGD system is designed. The study also includes route surveying with the help of maps obtained from town planning department.

The study includes Network Analysis of the steel pipeline grid, which was performed for balancing the flows and pressures. Finally, the cost analysis for the entire CGD system is done to ascertain the economic feasibility.

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## NOMENCLATURE

| | |
|---|---|
| CGD | City Gas Distribution |
| CGS | City Gate Station |
| DRS | District regulating station |
| MRS | Meter regulating station |
| MMSCMD | Million Metric Standard cubic Meter per Day |
| CNG | Compressed Natural gas |
| R-LNG | Regasified Liquefied Natural gas |
| PNG | Piped Natural gas |
| RPD | Rotary Positive Displacement meter |
| MDPE | Medium Density Polyethylene |
| LCV | Light commercial vehicle |
| PNGRB | Petroleum and Natural gas regulating board |
| LDO | Light Diesel Oil |
| SDR | Standard Dimension ratio |
| MRS | Minimum required strength |
| MOP | Maximum operating pressure |
| TCP | Temporary or Sacrificial anode cathodic protection |
| PCP | Permanent or Impressed current cathodic protection |
| TLP | Test lead point |
| EBIT | Earning before interest and Tax. |

# DESIGN AND NETWORK ANALYSIS FOR PIPELINE SYSTEM OF CGD FOR ELURU TOWN

# SUMMARY

## Summary of the project

This Study presents the results and conclusion of the report for the technical and commercial viability of supplying piped natural gas and/ or R-LNG to the domestic, commercial, industrial and CNG for vehicle transportation sections in the Eluru town with in the municipal limits.

This study includes a Market survey for Natural gas, Route survey for possible pipeline routes, System design, Network analysis and Economic model deals with the capital and operating cost.

The demands of Eluru town in different categories for 10th year are as follows.

| | Domestic | Commercial | Industrial | Automobiles | Total |
|---|---|---|---|---|---|
| Demand for 10 years | 54069 | 885.44 | 18086.90 | 239781.69 | 312823.03 |

CGS is proposed to be located near the NH5 at Duggirala village.

The demand for 10 years is now deemed for systems modeling of main steel grid gas pipeline network and for analysis of the pipeline system. The question in the individual categories is envisaged for the development of structures and calculation CAPEX.

The distribution system was set up with Flow parameters based on different literature. A distribution pressure of 14-19 bar is the intention after city gate station. Pressure after district regulate station shall be 4 bar, with a system of not less than 1,5 bar.

An attempt is made to verify the feasibility of the Pipeline Network by Newton Nodal Method which results in the divergence, hence a detailed investigation has to be carried out further to balance the network.

CNG infrastructure started with the facilities to meet the first year CNG demand. Subsequently, the facilities shall be augmented every year as per demand projections.

A summary of the capital cost is presented in the following table

| S.No | CATEGORIES | Cost in Crs. |
|---|---|---|
| 1 | City Gate Station & Steel grid pipeline | 25.83 |
| 2 | CNG Station | 35.46 |
| 3 | District Regulating Station | 3.66 |
| 4 | Total Connection Cost (Inds, Dom, Commercial) | 2.91 |
| 5 | Others | 0.20 |
| 6 | **Total** | **68.06** |

Total Estimated CAPEX is Rs. 68.06 Crores

An economic model is considered for further clarification of the capital and investment, based on operating capital and operating expenditure financial analysis has to be done. As a result of the confidentiality of information and time constraints analysis has been forgotten and illustrated by for example..

**(Note: Due to confidential of the information by the owner company, some of the information may be hidden and assumed are nearly taken to the actual data)**

# INTRODUCTION

# 1. INTRODUCTION

Energy is a widely recognised as one of the most significant input for economic growth and human development. The growth of a nation covers all sectors of economy and all parts of the society is dependent on meeting its energy requirements sufficiently. coal, oil and gas, the three primary commercial energy sources.

The dominant source of energy in India are still being coal with a 54.5% share followed by oil (31.7%), natural gas (7,7%), and hydro (5,1%) and nuclear (1%). The most developed countries on the other hand, there are more dependent on oil and natural gas resources for their energy requirements. India ', and the balance recoverable reserves of crude oil and natural gas.

Natural Gas has experienced the fastest rate of increase of any fuel in India's primary energy supply. It now supplies about 7% of India's energy, with that share expected to double by 2020.

Gail (India) Limited (gail) is responsible for transport and marketing of natural gas. setup in 1984 owner over 4200 km pipeline 2300 including HBJ km long pipeline that has a capacity of 60 MMSCMD. Alongside the HBJ system, the company has regional grids in Andhra Pradesh, Assam, Gujarat, Maharashtra, Rajasthan, Tamil Nadu and Tripura.

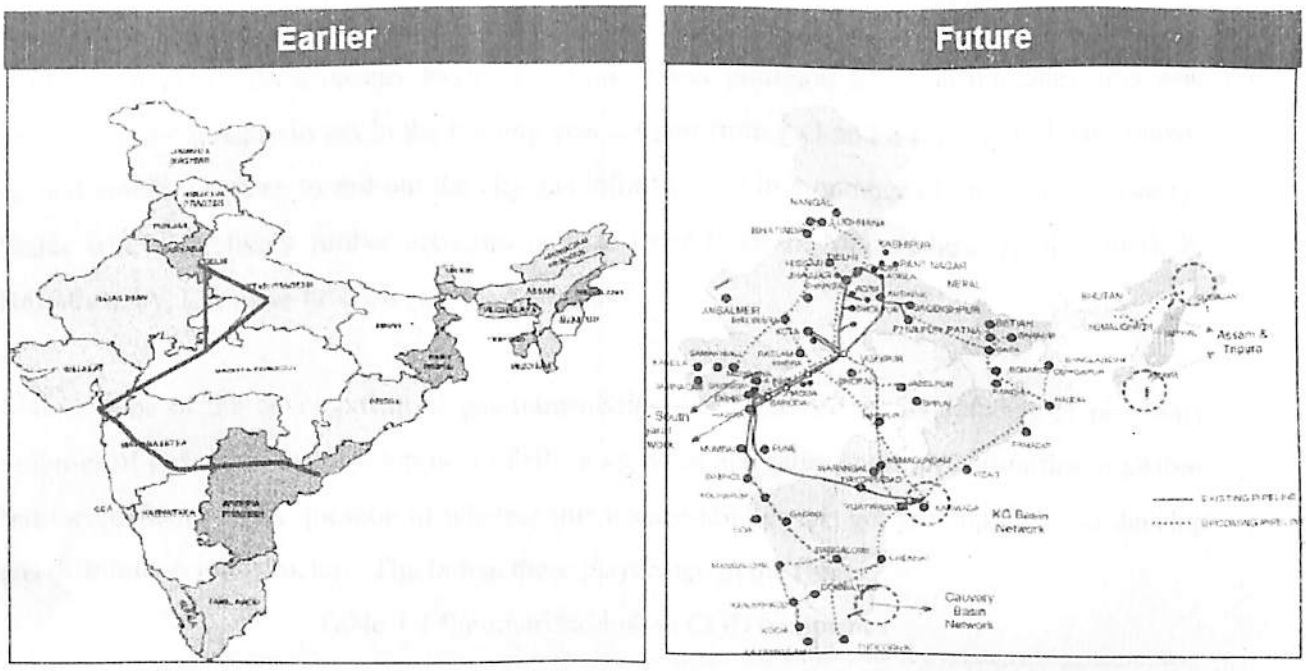



**Figure 1.1 Comparison of Earlier and Future Natural gas Pipelines**

## 1.1 CITY GAS DISTRIBUTION

Town gas distribution network means an interconnected network of gas pipelines transporting gas from a high pressure transmission line to the main medium pressure distribution network and later to the service pipes supply of natural gas to domestic, industrial and commercial premises and compressed natural gas (NG) stations on vehicles for transport.

The city gas distribution accounts for 6-10mmscmd in our country. This is probably to increase to a degree of 20mmscmd in the next 5 to 10 years. The city gas distribution in India is increasingly on a rapid express rate for the use of piped natural gas (Papua-New) for the domestic, commercial, industrial and CNG for transport. The two factors that will drive this growth are

1.) Increase in gas production (from the KG basin)

2.) Development of infrastructure.

## 1.2 HISTORY OF CGD IN INDIA

With the emphasis on a cleaner environment and lower pollution levels in the cities, this was expected more quickly to get in the coming years. Apart from gail and a few players have drawn up and ambitious plans to roll out the city gas infrastructure in a number of cities in the country. States which are likely further activities include Uttar Pradesh, Maharashtra, Andhra Pradesh, Rajasthan, by, Kerala as Pradesh and West Bengal.

Main engine of the development of gas transmission and these are the availability of necessary volumes of gas. With the development of ril ' s kg basin and other areas. opportunities available, but the challenge is the question of whether this licence-holders can get gas supplies and develop gas distribution infrastructure. The Indian these players are in the figure.

Table-1.1 Summarized Indian CGD companies

| Year | City | Company |
|---|---|---|
| 1880 | Calcutta | Calcutta Gas company |
| 1900 | Mumbai | Bombay Gas company |
| 1972 | Vadodara | Vadodara Municipal Corporation |
| 1980 | Delhi | Delhi Municipal Corporation |
| 1982 | ONGC colony- Mehsana, Sibsagar | ONGC |
| 1985 | Duliajan | Assam gas company |
| 1986 | Sibasagar | Assam gas company |
| 1989 | Surat, Ankleshwar, Bharauch | Gujarat gas company Ltd. |
| 1994 | Mumbai | Mahanagar Gas Ltd. |
| 1995 | Delhi | Indraprastha Gas |
| 2004 | Vadodara, Ahmedabad | Adani |
| 2006 | Kanpur, Lucknow | CUGL & GGL |
| 2006 | Gandhinagar, Kadi, Mehasana, Rajkot, Vapi, Morbi | GSPC/ SGL |
| 2007 | Hyderabad | Bhagyanagar gas |

Source: Dimple singh, City gas Distribution [13]

Few years ago CGD was limited to only Mumbai and Delhi, but today we have25 cities where the infrastructure for CGD has been developed. Some of the major cities are Delhi. Mumbai, Ankleshwar, Baruch and Surat, Vadodara, Agartala, Vijayawada, etc. For the year 2007-08 CGD contributed 7% of the gas demand in India.

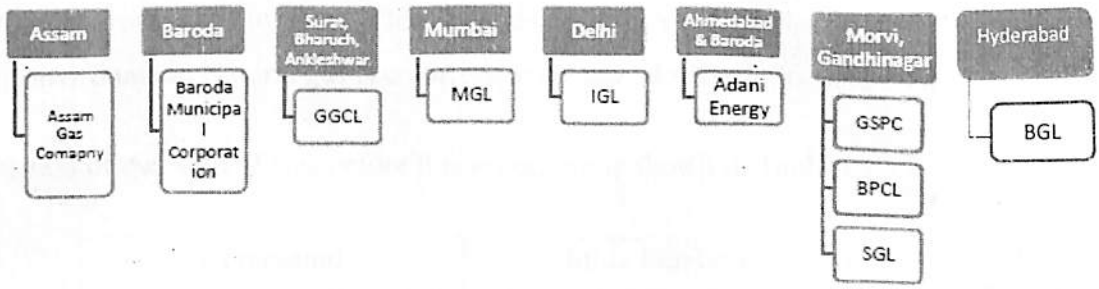



Figure-1.2 CGD's in India

With the expected improvement in the availability of gas and related infrastructure, a number town gas distribution projects can find some in the near future. New Delhi & Mumbai have witnessed significant improvement in the gas quality after the Court made mandatory use of CNG in public vehicles for the control of emissions.

A typical layout of City Gas Distribution system is shown in Figure1.3

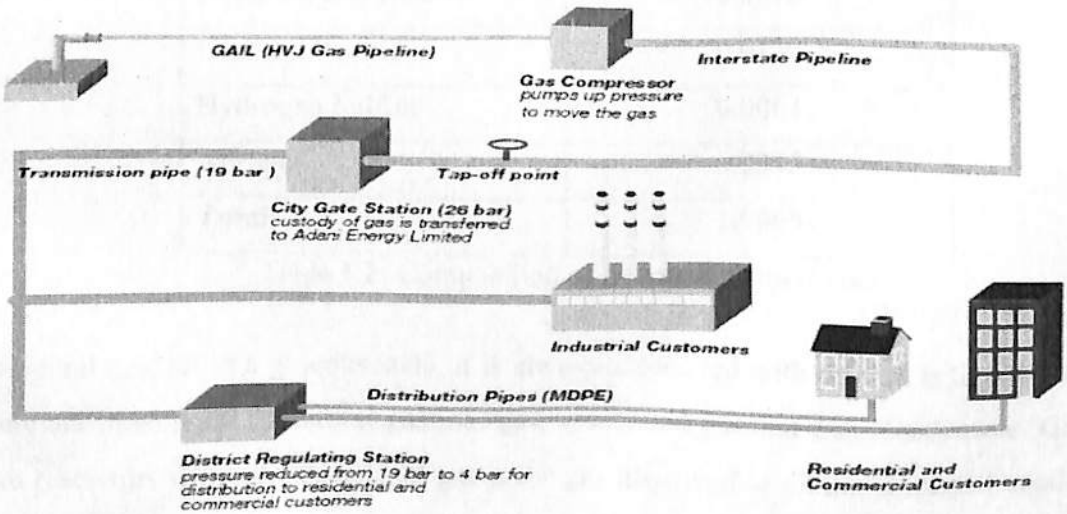



Figure 1.3: Example for city gas distribution

## 1.3 NATURAL GAS

Natural gas is a subcategory of oil that is, naturally occurring, complex mixture of hydrocarbons, with a limited amount of organic compounds. Methane is a major component of the gas mixture; it also includes ethane, propane, butane and pentan. The composition of natural gas varies from place to place. That depends on the characteristics of the soil and the surrounding environment. Natural gas is colorless, was, and odorless in its pure form.

The composition of the Natural Gas before it is processed is shown in Table 1.1.

| Compound | Mole Fraction |
|---|---|
| Methane | 0.8407 |
| Ethane | 0.0586 |
| Propane | 0.0220 |
| i-Butane | 0.0035 |
| n-Butane | 0.0058 |
| i-pentane | 0.0027 |
| n-Pentane | 0.0025 |
| Hexane | 0.0028 |
| Heptanes and Heavier | 0.0076 |
| Carbon Dioxide | 0.0130 |
| Hydrogen Sulfide | 0.0063 |
| Nitrogen | 0.0345 |
| **Total** | **1.0000** |

Table 1.2: Composition of a typical Natural Gas

As natural gas, oil in a gaseous state, it is always associated with oil that is liquid petroleum. There are three types of natural gas; not gas, associated gas and Gas Condensate. Gas is not form reservoirs with oil. Associated gas is the gas dissolved in oil under natural conditions in the oil reservoir. Gas Condensate refers to gas with a high content of liquid hydrocarbons at reduced pressure and Temperature.

### 1.3.1 NATURAL GAS PROPERTIES

Natural gas is colorless, odorless, tasteless, SAT, and lighten than air. The natural gas following appropriate treatment for acid gases reduction, odorization, and hydrocarbon and moisture dewpoint point adjustments would then be sold within the limits of pressure, calorific value, and possibly Wobbe index (often referred to as the Wobbe number).

**Physical Properties of Natural Gas:**

| Sl. No | Property | Unit | NG |
|---|---|---|---|
| 1 | Density relative to air | Air=1 | 0.6 - 0.9 |
| 2 | Auto ignition Temperature | $^0$C | 540 |
| 3 | Flammability Limit | % in air | 5-15 |
| 4 | Flame Temperature | $^0$C | 1790 |
| 5 | Octane No. | - | 127 |
| 6 | Cetane No. | - | 10 |

Table 1.3: Physical Properties of Natural Gas

## 1.4 Compressed Natural Gas (CNG)

CNG is a fossil fuel, Deputy substitute for petrol (gasoline), diesel, or propane fuel. It is a more environmentally friendly clean, much safer than other fuels in the case of a spill (natural gas is lighter than air, but when released quickly disperses).

CNG is made by together natural gas (mainly composed of methane (CH4]), to less than 1% of the volume at normal atmospheric pressure. It is usually stored in cylindrical or spherical shapes of hard containers and used for distribution, on a normal pressure of 2900-3600 PSI.

CNG is used for gasoline combustion-engine cars which have been converted into bi-Fuel Vehicles (petrol/CNG). Natural gas vehicles are widely used in the whole world, in response to high environmental concerns and fuel prices..

CNG is a relatively clean fuel with lower emission levels of emissions of SO2, NOx and spm. it is, therefore, be promoted by the Government of India as fuel for transport. CNG as a car engine fuel improves efficiency. The current cost of CNG is lower in comparison with diesel and petrol. The energy content per kg of CNG is very similar to that of oil based fuels, but it has a lower energy content per unit of volume.

CNG can be used in engines with a compression ratio as high as 12:1 compared to normal gasoline (7.5:1 to 10:1). At this high compression ratio, natural gas- fuelled engines have higher thermal efficiencies than those fuelled by gasoline. The fuel efficiency of CNG driven engines is about 10-20% better than diesel engines.

CNG is least polluting:

Table-1.4 Summarization of fuel emission compared to CNG

| (gm/100 KM) | | | | | |
|---|---|---|---|---|---|
| Fuel/ Emissions | $C0_2$ | CO | NOx | SOx | PM |
| Petrol | 22,000 | 634 | 78 | 8.3 | 1.1 |
| Diesel | 21,000 | 106 | 108 | 21 | 13 |
| LNG | 18,200 | 168 | 37 | 0.4 | 0.3 |
| CNG | 16,275 | 22 | 26 | 0.2 | 0.3 |

Source: Dimple Singh, City Gas Distribution 2010 [13]

### 1.4.2 Benefits of CNG:

1. Environment friendly and hence better health
2. Safer & Economical as compared to liquid fuels
3. Very low particulate emission & air borne toxins

4. Negligible emission of oxide of sulphur($SO_X$)
5. Increases Engine Life & reduces maintenance cost
6. Non Toxic and Non Corrosive

### 1.4.3 Limitations of CNG

1. Non availability at all locations.
2. Higher conversion cost of vehicles.
3. Higher Infrastructure cost.
4. Lack of knowledge about CNG.
5. Boot space occupied by cylinder.
6. High vehicle cost

*The above described details about CNG are taken from reference* [3].

## 1.5 Piped Natural Gas (PNG)

The second category of the gas in the City Gas Distribution (CNG) is PNG. The major difference between the CNG & PNG is that, the PNG which is supplied through the MDPE pipes from DRS.

The demand for natural gas in the country is more than the availability. In order to bridge the gap between demand and supply of natural gas, Government has adopted a multi pronged strategy. These cover:-

i. Exploitation of unconventional sources like Coal Bed Methane (GBM)
ii. Underground coal gasification
iii. LNG imports & Gas sourcing through transnational gas pipelines.

### 1.5.1 Applications of PNG

Applications of PNG are as follows

1. Cooking purpose
2. Heating/ furnace
3. Air conditioning
4. Hotels, restaurants, hospitals.
5. Industrial

# CGD SYSTEM

## 2. CITY GAS DISTRIBUTION SYSTEM

In City Gas Distribution System natural gas will be drawn from high pressure transmission line by keeping a tap-off point at near location. And this gas will be compressed from 19- 255 bar pressure in City Gate Station and will be sent to the customers with required pressure using MDPE system. A typical layout of City Gas Distribution system is shown in Figure 2.1

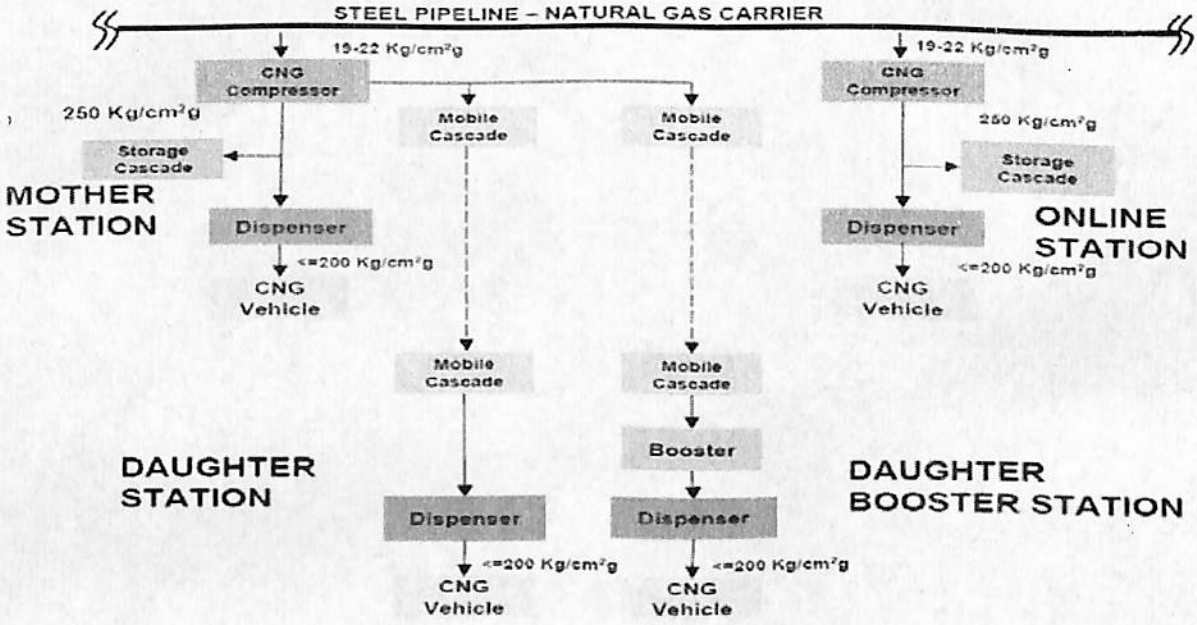



Figure-2.1 Typical layout of City gas Distribution

Source: ACMIIL Company report[ 14]

The city gas distribution system consists of

1. City Gate Station (CGS)
2. District Regulating Station (DRS)
3. Service regulator
4. Meters
5. Pipeline system
6. CNG station

## 2.1 City Gate Station

The Natural Gas which was received from CGS is passed through cleaners to remove impurities in gas. CGS is the starting point of the city gas distribution system. The primary function of CGS is to measure the amount (Volume) of incoming gas. Another function is to reduce the pressure of the gas to be sent for distribution. as the distribution system requires much lesser pressure than that in long distance transmission. CGS consists of configuration.

1. Filter skid
2. Regulating skid
3. Metering skid.

### 2.1.1 Filtration skid

In Filtration skid has high efficiency filter separators are used for the removal of impurities from the incoming gas. The outlet gas from the processing industry is cautiously maintained at free of impurities; the filtration skid ensures the pure gas to be distributed to the line. The filter is normally designed to withstand a pressure in the range of 30-49 bar.

### 2.1.2 Pressure Reduction skid

The pressure reduction skid is installed to reduce the pressure of the incoming gas from the source from the range of 30-49barg to 26barg.

### 2.1.3 Flow metering skid

Flow meters are installed for a single stream. The normal flow meters used in the CGS is orifice plates. Orifice flow meters find its use as a large pressure drop is required. The various parameters such as temperature in the various sections of the line, pressure at the inlet and outlet joints, flow inlet and outlet are controlled by the SCADA systems in the control room

Therefore the gas is passed through the filter for removal of liquid and solid particles and then it is passed through the regulating skid to reduce the pressure of the gas from 26-30 to 19 bar,

after this the gas with this pressure is sent to the main metering skid for the purpose of measuring.

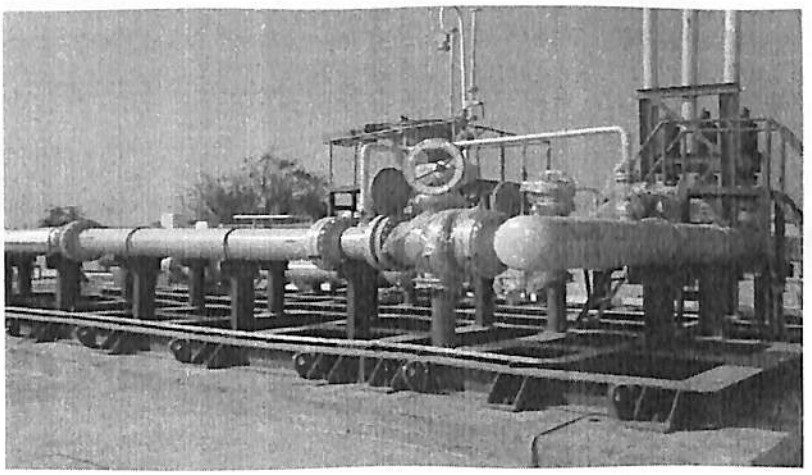


Figure 2.2: Filter, Regulating & Metering Skid

Source: Bagyanagar Gas Limited.

**2.2 Odorization unit**

At the CGS, the odorization of the natural gas takes place. One of the measure safety factors in natural gas distribution is Odorization of the natural gas. For the safe distribution of the gas some smelling identification is required for leak detections. Different types of odorants are used, so that the "smell" makes the presence of the escaping, un-burnt gas recognizable at very low concentrations. This serves as a warning well before the gas accumulates to hazardous levels.. The unit consists of a pressure vessel filled with odorant and a special injection pump which pumps these chemicals into the natural gas line by considering flow rate. The odorant generally used is ethyl mercaptant. The odorizer injected should be of 12PPM as per the Indian standards.

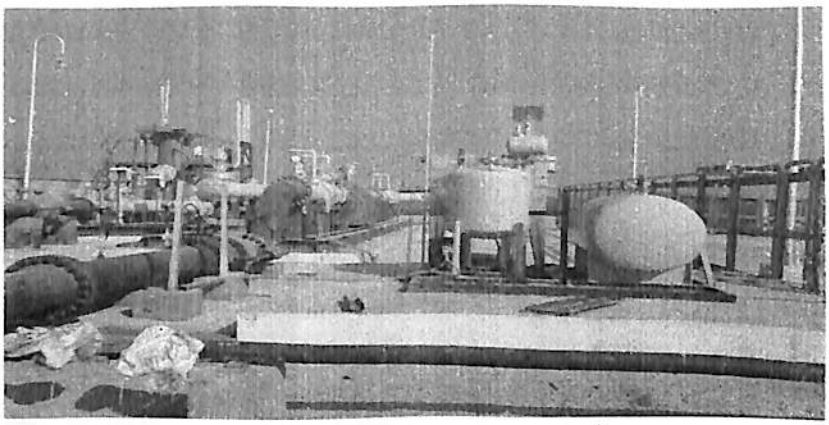


Figure 2.3: Odorization unit

Source: Bhagyanagar Gas Limited, Hyderabad.

## 2.3 District Regulating Station

DRS is the next setup of the CGD. It is a device used to reduce the pressure from 19 barg to 4barg. It is the interface between the steel grid network and the medium pressure network. The location of the District Regulation Station mainly depends on the requirements and demand. The various components in the DRS includes

- Slam shut valves for controlling the flow.
- Filtering skid
- Pressure reduction skid

The normal range of pressure in the District Regulation System is inlet: 19-26barg, outlet: 2-4barg. The maximum allowable flow inside the DRS is in range of 5000-10000SCMH. The inlet to the DRS is from the steel line and the outlet is also the steel line, where its joined to the PE line using the Steel – PE converter.

## 2.4 Service regulators

The NG regulators play several roles in the safe operation and use of Natural Gas appliances. The regulator accepts signals from the thermostat on when to turn off heat manufacture and flow. It also monitors and controls the pressure of the natural gas running through the appliances in keeping with its design and manufacturer's specifications. It also has a safety features that if no flame produced, the regulator cuts off the flow of NG so that unburnt fuel does not come into the home.

These are installed in front of tertiary PE lines, generally located at customer premises for maintaining supply pressure and designed to maintain safe condition even in the event of rupture in the regulator downstream section. It reduces the pressure from 4 bar to 110 mbar to the service line. The types of regulators that are used generally depend on the number of connections. According to this various types of regulators are available as shown in Table 2.4.

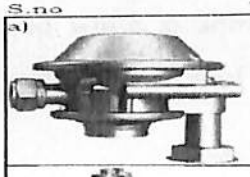
| S.no | Type | Flow rate | Max. Capacity |
|---|---|---|---|
| a)  | B-6 | 6m3/hr | 1-8 domestic connections |
| b)  | B-10 | 10m3/hr | 1-20 domestic connections |
| c)  | B-25 | 25m3/hr | 1-30 domestic connections |
| d)  | B-50 | 50m3/hr | 1-75 domestic connections |

**Table 2.4: Types of service regulators**

## 2.5 Meters

Meters are important part of the CGD. It decides or gives the details about the amount of gas used by the customer. Billing of gas is usually done based on the standard conditions i.e. SCM. Meters are used based on the type of the customer and his requirements.

Meter used for the domestic customer is of diaphragm meter having a flow range of 0.017 to 2.6 $m^3$/hr. with a maximum operating pressure of 0.1bar and the typical diagram is shown below. A typical layout of Diaphragm meter is shown in Figure 2.5.

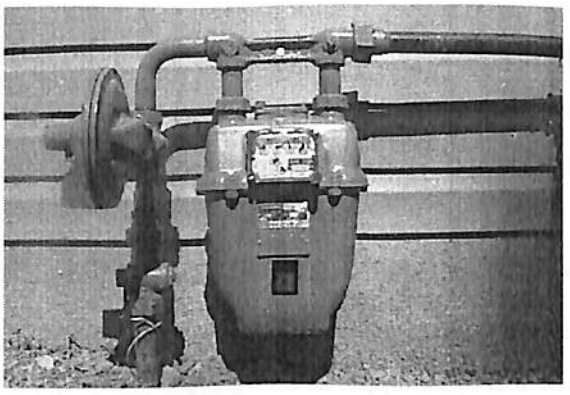


**Figure 2.5: Diaphragm Meter**

Source: Meters Applications, Maintenance & Installation by Paul G.Honchar

For Industry purpose both diaphragm and RPD (Rotary Positive Displacement Meter) or turbine meters are used which is shown below. It depends on the demand and accuracy needed for billing. A typical diagram of RPD meter is shown in Figure 2.6.

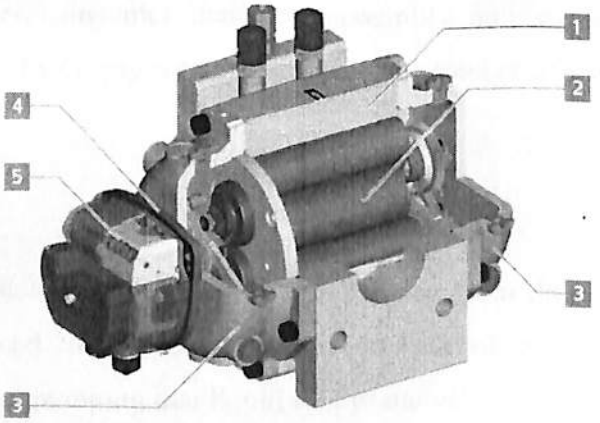



**Figure 2.6: RPD meter**

Source: Meters Applications, Maintenance & Installation by Paul G.Honchar [4]

## 2.6 Pipeline System

Pipeline network consists of steel pipeline. polyethylene pipeline. galvanized iron pipeline and finally copper pipeline.

A typical CGD network should consist of the following

**Primary network:** A medium pressure distribution system comprising of pipelines, gas mains or distribution mains normally constructed using steel pipes and connects one or more transmission Pipeline to respective CGS or one or more CGS to one or more DRS.

**Secondary Network:** A low pressure distribution system comprising of gas mains or distribution Mains usually constructed using thermoplastic piping (MDPE) and connects DRS to various service regulators at commercial, industrial, and domestic consumers.

**Tertiary Network:** A service pressure distribution system comprising of service lines, service regulators and customer /consumer meter set assemblies constructed using a combination of thermoplastic (MDPE) piping and GI /copper tubing components.

**Tube / Hose pipe for connecting consumer meter set assembly and consumer appliance:** The connection between consumer meter set assembly and gas appliance (provided by consumer) may be made by GI pipes or copper tubing or steel reinforced rubber hose.

## 2.7 CNG Station:

Natural gas vehicle refueling stations differ significantly from their conventional liquid fuel counterparts. As opposed to the relatively simple task of storing a liquid fuel at near atmospheric pressure and pumping that liquid fuel to the vehicle, natural gas refueling stations are able to take a relatively low pressure gas and compress that gas to high pressures for storage at the refueling station and/or on the vehicle. Older CNG refueling stations were typically designed to deliver gas for on-board storage applications up to 2400 psig. Newer refueling stations typically operate at pressures greater that 3600 psig to service vehicles with maximum on-board storage pressures of 3000 psig.

There are four types of CNG Station:

**Mother Station:** CNG facility connected to natural gas pipeline and having a compressor meant primarily to fill mobile cascades for 'daughter' stations. Such facilities, in addition to act as 'mother' station can also fill stationary cascades for CNG dispensing into vehicles. A typical layout of CNG mother station is shown in Figure 2.5

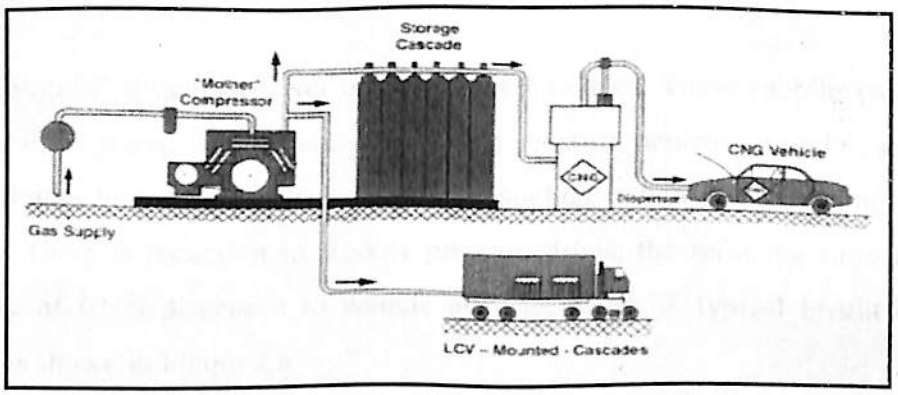



**Figure 2.7: Mother CNG Station**

Source: Bagyanagar gas Limited, Hyderabad

The following units have been envisaged in mother station:

**Main equipments**

i. Mother compressor along with auxiliaries
ii. Dispensers for buses
iii. Dispensers for car and three wheelers
iv. Stationary cascades & Mobile cascades
v. Loading facility for mobile cascade
vi. DG sets, UPS and Battery bank, Electronic control panel
vii. Instruments for air and water facilities
viii. Fire fighting equipment and safety side

**Online Station:**

CNG vehicle storage cylinders need to be filled at a pressure of 200bars. "On line Stations" are equipped with a compressor of relatively small capacity, which compresses pipeline gas to the pressure of 250 bars for dispensing CNG to the vehicle cylinder. The investment in a station is midway between daughter station and mother station.

**Daughter Station:**

The "Daughter Station" dispenses CNG using mobile cascades. These mobile cascades at daughter station are replaced when pressure falls and pressure depleted mobile cascades is refilled at the "Mother Station". The investment in a daughter station is least among all types of CNG station. There is reduction in storage pressure drops, the refueling time increase, while the quality of CNG dispensed to vehicle also decreases. A typical layout of CNG daughter station is shown in Figure 2.6

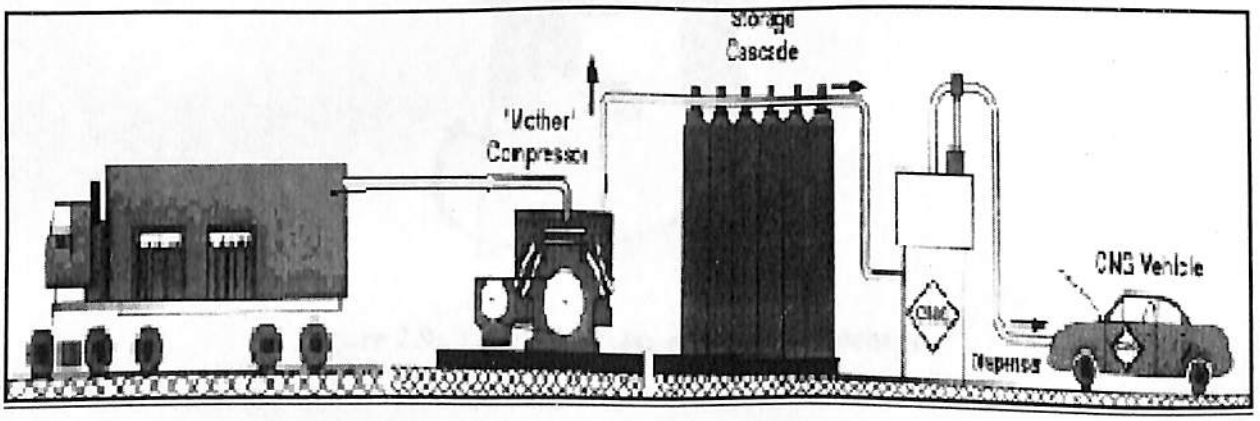



**Figure 2.8: Daughter CNG Station**

Source: Bagyanagar gas Limited, Hyderabad

**Daughter-Booster Station:**

Installing a booster compressor can eliminate drawbacks of daughter stations. The mobile cascade can be connected to the dispensing system through a booster. Daughter booster (compressor) is designed to take variable suction pressure and discharge at constant pressure

of 200 bars to the vehicle being filled with CNG. The investment in daughter booster station is slightly higher than that of daughter station

**Detail Description of Facilities in Different Stations**

## 2.8 Dispensers

Compressed natural gas from compressor or cascade is dispensed to NGVs (Natural Gas Vehicles) such as cars, 3-whelers, buses, etc, through dispensers. The Following are the two types of dispense

**Three wheeler and Car Dispenser**

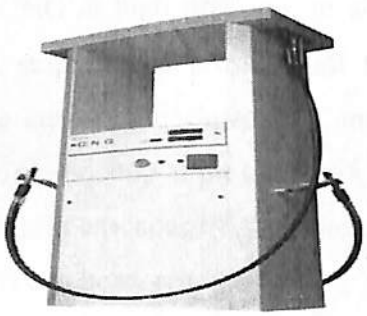


**Figure 2.9: Three Wheeler and Car Dispenser**

Source: Bagyanagar Gas Limited

To meet the requirement of car and three wheeler filling at mother, and daughter stations, double arm type car/auto dispenser each with a capacity of 15 kg/min have to be installed. A typical diagram of three wheeler dispenser is shown in Figure 2.9

**Bus dispenser**

To meet the requirement of bus filling at mother stations, single arm bus dispenser, each of capacity 80 kg/min has to be installed.

## 2.9 Cascades and there types

This is a group of gas cylinders with a total water capacity not exceeding 4725 Liters. contained within a length of 5.5M, a height of 1.6M and a width of 1.2M in case of cylinders kept vertical, or 5.5M, 1.6M and width of 1 cylinder up to 2M in case of horizontal cylinders. Both arrangement used is interconnected by high-pressure piping to form a single gas storage unit referred as stationary cascade and, the cascade which is used for transportation of CNG in the structural container having facility for lifting and placement is called as mobile cascade.

Following are the two types of cascades

### 2.9.1 Stationary cascade

Cascades are used to store the CNG at high pressure, to absorb the surge of reciprocating compressor, frequent start and stop of compressor and to supply additional gas when dispensing rate is more than the compressor capacity. Compressor will start if pressure in cascade falls below 210 $Kg/cm^2$ (g) and stop at pressure 255 $kg/cm^2$ (g). For a pressure range of 220 $kg/cm^2$(g) to 255 $kg/cm^2$(g), in cascades of 4500 liter & 2200 liter capacity, about 135 Kg & 65 Kg respectively, of CNG can be stored.

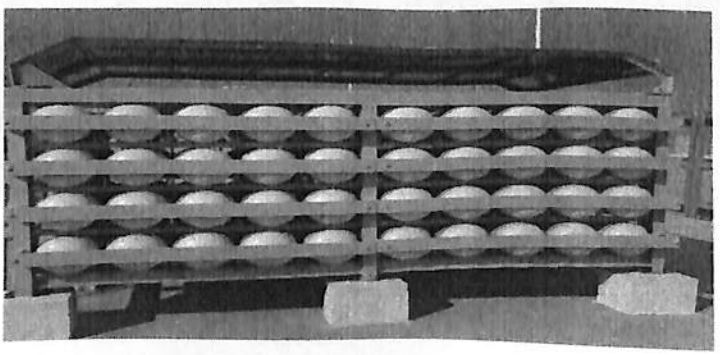


**Figure: 2.10: Stationary Cascade**

Source: Bhagyanagar Gas limited.

The cascade shall supply gas to bus as well as car/auto dispensers. A diagram of basic stationary cascade is shown in Figure 2.11

Main specification/Features of Cascade are

- Cascade is made of group of cylinders fixed with structural steel frame having facility of lifting placement.
- The cylinder and their neck threading are designed as per IS: 7285-1988 and IS: 3224-1979, respectively and approved by chief control of explosives (CCOE).
- The cylinder shut off valve is fitted with fusible disc confirming to requirements of IS: 3224-1979 and are CCOE approved.
- All end connections for quick release couplings, pressure gauges, valves and fittings of cascade are within a tamper proof enclosure. This is on one side of the cascade for ease of operation.

### 2.9.2 Mobile cascade

**Figure 2.11: Mobile Cascade mounted on LCV**

Source: Green Gas Limited, Lucknow [1]

A 2200 liter water capacity cascade is fitted on light commercial vehicle (LCV). The mobile cascade is filled at mother station up to 255 kg/cm$^2$ (g) pressure. Mobile cascade at pressure 255 kg/cm$^2$ (g) is sent to the daughter booster station (DBS) for gas dispensing up to a

pressure of 30 kg/cm$^2$ (g) at DBS. Empty mobile cascade at pressure lower than 30 kg/cm$^2$ (g) come to mother station for refilling. Approximately 335 kg/cm$^2$ (g) gas is transported from this cascade. The entire assembly is to be approved by CCOE. A simple diagram of mobile cascade is shown in Figure 2.10

## 2.10 Other Facilities to be installed at CNG station

**DG set**

To meet the requirement of emergency power in case of grid power failure, one DG set of capacity 7.5KW to be installed at each station. The DG set starts automatically in case of grid power failure. Emergency loads are connected to DG set.

**UPS and Battery Backup** A one hour UPS and Battery Backup system should be provided at each station.

**AVS** A suitable automatic voltage stabilizer based on local supply shall be provided.

**Electrical system**

The electrical system comprises of conduit work including junction boxes, wiring for lighting and power; fittings and accessories, cables, mains and sub-mains; LT panel, main and sub-distribution panels, capacitor panels; cable trays, galvanized iron conduits; earthing system; area lighting, canopy lighting, signage lighting and control room illumination etc.

**Instruments for air and water facilities**

Air is required for starting the mother compressor, so an air compressor has been installed. Water is used in intercoolers and after coolers for cooling the natural gas, so water supply network from the available sources has been installed.

**Firefighting equipment and safety sign**

Portable fire extinguishers should be provided in each station.

# METHODLOGY

# 3. METHODOLOGY OF STUDY

The present study includes facilities for steel grid line, CNG Network & City Gas Distribution for industrial, commercial and domestic consumers. For this purpose, the gas is planned to be tapped off from the CS-2 Station near Koppaka village from RIL's East-West pipeline.

Design of city gas distribution system includes estimation of gas demand for Eluru town, detailed route selection for pipeline network, design and network analysis of pipeline. Also cost estimation for setting up of the system is done for checking economic feasibility.

## 3.1 TOPOLOGY OF CITY

Eluru is a town and municipal corporation in the state of Andhra Pradesh. It is a headquarters and has a population of 2,85,900 approximately of 140924 males and 144976 females. Eluru is situated on the national highway NH5 connecting Vijayawada and Visakhapatnam and about 333 KM east of state capital, Hyderabad.

This project of the design of city gas distribution system for Eluru city covers the whole system requirements for the distribution system.

The city having 2,85,900 of population and 67,395 households out of which 17441 rural and 49954 households of urban, according to population census 2011.

## 3.2 MARKET SURVEY AND DEMAND ASSESSMENT

The objectives of market survey were to:-

i) Asses Compressed natural gas (CNG) demand for various types of vehicles in the city.

ii) Asses the Piped natural Gas (PNG) demand for domestic, commercial and industrial sectors in the town.

iii) Asses the requirements of various facilities to satisfy the demand of various category of consumers. The facilities may include laying of adequate sizes of pipeline from the

nearest source of gas supply, installation of different types of CNG dispensing stations, providing connections to individual PNG consumers etc.

## 3.3 MAPS USED FOR STUDY

The following maps were studied for the optimum route selection.

a) Planning maps of Eluru Development Authority.

b) Satellite imageries from Google earth and Google maps.

## 3.4 ROUTE SELECTION CRITERIA

Route study carried out keeping the following factors into account:

a) Shortest length of grid pipeline.

b) Minimum rail, major road and river/ major canal crossing.

c) Availability of space for right-of-way.

d) Least contour variations.

e) Least stretch through slushy, rocky and cultivable terrain.

f) Avoiding High tension transmission lines.

g) Minimum ecological impacts.

h) Minimum number of turning points.

i) Easy access to the route during construction phase.

## 3.5 SELECTION OF TAP-OFF POINT AND CGS

For selection of a suitable tap-off point, proximity to Eluru town is the prime consideration, as this shall minimize the total cost of project. Considering this, The proposed City Gate

Station meant for catering to the demand of various sectors in Eluru has been selected for the purpose.

## 3.6 SELECTION OF CNG-MOTHER, ONLINE AND DAUGHTER BOOSTER STATIONS

The selection criteria for CNG mother stations' location is based on the following:

i) Location either at the center of city (for city residents) or proximity to highway (for buses plying to-and-from Eluru).

ii) Likely availability of a plot of size 40m x 30m (1200m2).

iii) Proximity to proposed Daughter Booster Stations.

The selection criteria for CNG On-line stations location is based on the following:

i) Location at population centers in the city. Proximity to Vehicular traffic and major roads.

ii) ii) Availability of sufficient area at existing petrol/diesel retail outlets.

iii) Willingness of existing petrol/diesel retail outlet owners to install CNG stations at their premises.

Considering the above, CNG On-line stations have been envisaged at existing petrol/ diesel retail outlets and along the city ring main at an average distance of 3 km from each other.

The selection criteria for CNG Daughter Booster Stations' location are based on the following:

i) Location at population centers in the city but away from the proposed main grid line.

ii) ii) Availability of sufficient free space at existing petrol pumps.

iii) Willingness of existing petrol pump owners to install CNG stations at their premises.

## 3.7 SELECTION OF SECTIONALIZING VALVES (SV) STATIONS

The selection criteria for SV stations' location is based on the following:

i) Primary consideration shall be given to locations that provide continuous accessibility to valves

ii) ii) Inter distance between two successive stations shall be about 3.0km

iii) Conservation of gas

iv) Time to blow down the isolated section

v) Continuity of gas service

vi) Operational flexibility

vii) Expected future expansion between two sectionalizing valves

viii) Operation and security of the line

ix) Availability of a plot of minimum size 5m x5m

Considering the above. SV stations shall be provided in the main grid line at critical areas and also at regular interval of approx. every 3.0 km to facilitate isolation of mainline sections.

The spacing between SV stations shall be adjusted to permit a SV station to be installed in a more accessible location depending upon the availability of land during project execution.

## 3.8 SELECTION OF DISTRICT REGULATING STATIONS

The selection for DRS location is based on the following:

a) Primary consideration shall be locations at those residential and commercials areas of the city where likelihood of conversions is maximum.

b) Easy and convenient accessibility.

# MARKET SURVEY

# 4. MARKET SURVEY

## 4.1 MARKET SURVEY AND DEMAND ASSESSMENT

### 4.1.1 Objective of Market analysis

The market survey for natural gas demand has been undertaken to meet the objectives and scope of study for Eluru.

This study relates to the supply of natural gas to domestic, commercial and industry sectors and for CNG automobile vehicles in Eluru.

The objective of market analysis was to:-

1. Assess CNG demand for various segments of vehicles in the city.
2. Assess natural gas demand for industry.
3. Assess commercial consumer demand for natural gas.
4. Assess the domestic consumers demand for natural gas.

## 4.2 ENERGY SCENARIO

Energy is consumed by various consumers in the form of electrical energy, petroleum products like, piped gas, CNG and LPG, Kerosene, petrol, diesel, LDO, furnace oil, and coal/coke. Sector wise consumption of various form of energy shows that domestic and commercial sectors mainly consume LPG for cooking and electrical energy for lighting and water & space heating. In addition kerosene and coal are also being used for cooking, but their consumption is very nominal. Industry sector is mainly the consumer of electrical energy and petroleum products like furnace oil, LDO, LSHS, coal / coke and rice husk etc,. They are likely to switch over to natural gas in view of pollution control norms being stipulated by Govt. Authorities. Automobiles sector is the consumer of petrol and diesel but in view of the stringent norms for pollution control being stipulated by Supreme Court for various cities, they are likely to switch over to CNG/LPG.

## 4.3 DEMAND OF NATURAL GAS

For this project the demand of various sectors like domestic, commercial, transportation and Industrial sector customers are covered. Following are the details of the consumers in and around the Eluru city.

- Domestic – 67,395 households
- Commercial Sector
- Transportation (vehicle population profile)

### Total Gas Required by the City

The total gas required by the city considering all customers is as follows

## 4.4 Demand estimation for domestic customers

The total number of Households in each zone was arrived upon on the basis of Census Survey 2011.

Consumption of LPG in KG per Year was calculated based on the field survey. Equivalent PNG requirement was estimated region wise based on the calorific value for natural gas at 8300 Kcal/SCM (gross) and for LPG the gross calorific value as taken as 11750 kcal/kg (gross)

Once the household likely to convert in each scenario was estimated it was multiplied by the consumption of NG per year to estimate the demand in each region.

The consumption of natural gas by individual house is calculated based on following considerations/assumptions that,

- Each individual house is using one LPG cylinder per month
- Each LPG cylinder is having capacity of 14.7kgs
- Calorific value of natural gas is 8300 kcal/$m^3$

- Calorific value of LPG is 11750 kcal/$m^3$
- Density of Natural gas in form of gas is 0.9 kg/$m^3$

Detailed calculation of gas quantity consumed by a domestic customer is given below

Assuming each house consumes one LPG cylinder per month, and then amount of gas used per day by a house will be

$$= \frac{14.7}{30} \text{ kg/day} = 0.49 \text{ kg/day}$$

Therefore, Equivalent amount of natural gas used per day by a house will be

$$= 0.49 * \left( \frac{Calorific\ value\ of\ LPG}{C.V\ of\ Natural\ Gas} \right)$$

$$= 0.49 * (11750/8300)$$

$$= 0.693 \text{ kg/day of Natural Gas}$$

$$= \frac{0.693674}{Density\ of\ N.G}$$

$$= 0.771111 \text{ } m^3\text{/day of N.G}$$

Therefore, it is calculated that the total requirement of Natural Gas for domestic customers is **0.051969 MMCSMD**.

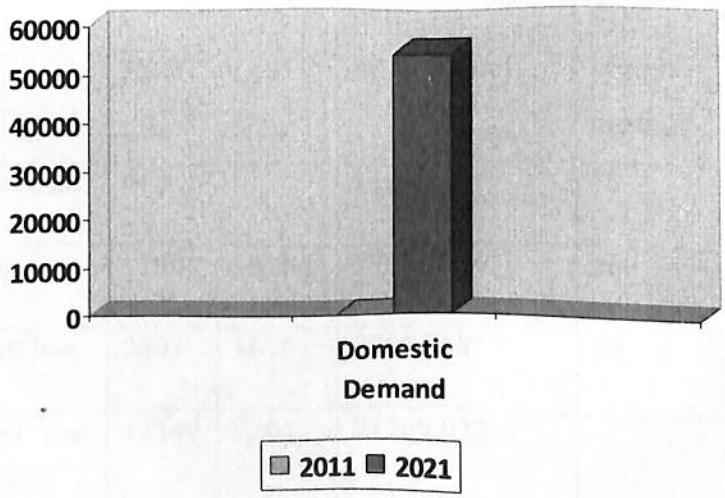
The projected demand of natural gas for domestic purpose for next 10 years tabulated below.

Table-4.1 Year wise gas volume demand for Domestic sector

| YEAR WISE GAS VOLUME - Domestic sector | |
|---|---|
| Year | Gas Volumes (SCMD) |
| 1 | 0 |
| 2 | 3060 |
| 3 | 9860 |
| 4 | 16660 |
| 5 | 22141 |
| 6 | 25800 |
| 7 | 25800 |
| 8 | 51969 |
| 9 | 53008 |
| 10 | 54069 |

**Demand of Natural gas Domestic sector**

**(Figure in SCMD)**



## 4.5 Commercial Sector

### Commercial Consumers

The broad categories of commercial consumers considered are hotels, restaurants, canteens/ club, hostels/ guest houses, hospitals, nursing houses and bakeries.

Unlike the domestic sector, there is wide variation between the major energy users like large hotels and hospitals and small users such as restaurants, canteens, bakeries etc. Therefore, almost all major hotels and hospitals were covered in survey

### Consumption of Natural Gas in Commercial Sector

The following table gives us a rough idea of the potential demand for PNG in Eluru commercial sector. The Total Potential Demand for PNG in both the areas was calculated to be around **708.9685 SCMD** (Considering 30 working days in a month)

The total Commercial sector demand in for eluru is calculated and estimated as **885 SCMD.**

Table-4.2 Gas demand calculation for commercial sector

| Conversion Factor | | 1.153 | 1.353 | Equivalent NG consumed in unit SCM/Month | Avg no. of working days per Month in the unit | Equivalent NG consumed in the Unit SCMD |
|---|---|---|---|---|---|---|
| | | Monthly fuel consumption | | | | |
| S.no | Description | HSD Ltrs | LPG Kgs | | | |
| 1 | Movie Halls- 32 no. | 960 | | 1106.88 | 30 | 36.896 |
| 2 | Hotels-48 nos. | 11000 | 3528 | 17456.384 | 30 | 581.8795 |
| 3 | Restuarants-19 nos. | 380 | 1676 | 2705.768 | 30 | 90.193 |
| Total consumption of fuel per month | | 12340 | 5204 | 21269.032 | | 708.9685 |

Note: The monthly wise consumption of HSD and LPG are assumed values.They may vary according to there consumption.

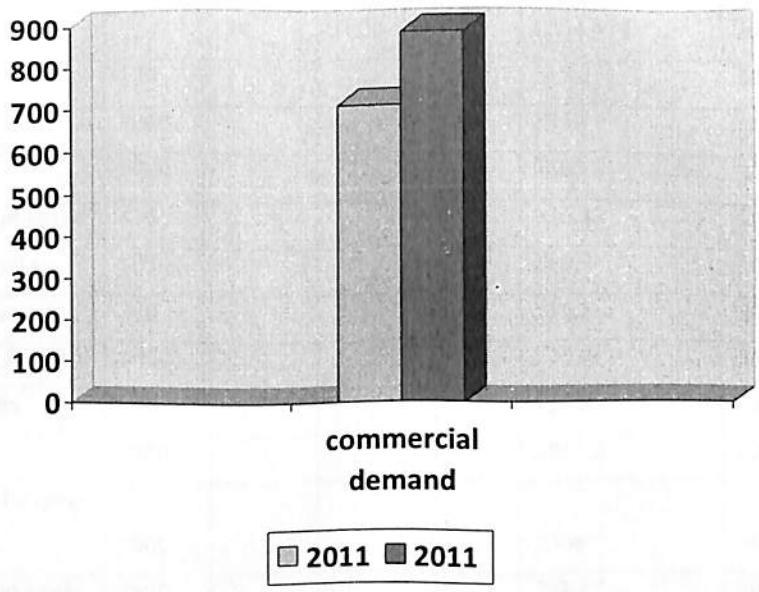
The projected demand of natural gas for commercial sector for next 10 years is tabulated below.

Table-4.3 Year wise gas demand for Commercial sector

| YEAR WISE GAS VOLUME - Commercial sector | |
|---|---|
| Year | Gas Volumes (SCMD) |
| 1 | 709 |
| 2 | 727 |
| 3 | 745 |
| 4 | 764 |
| 5 | 783 |
| 6 | 802 |
| 7 | 822 |
| 8 | 843 |
| 9 | 864 |
| 10 | 885 |

**Demand of Natural gas for commercial purpose**

**(Figures in SCMD)**




### 4.5 Industrial Sector

During discussion with representatives of Industries and fuel consumptions per month indicated by them during the survey it has emerged that 27 units are major units.

Table-4.4 Detailed Natural gas consumption of Natural gas for Industries in Eluru.

| Conversion Factor for NG | | 1.153 | 1.353 | 1.153 | 417 | | | |
|---|---|---|---|---|---|---|---|---|
| | | Monthly Fuel Consumption | | | | Eqivalent NG consumed in the unit SCM/Month | AVG. no. of working days per month in the unit | Equivalent NG consumed in the unit SCMD |
| S.no | Unit Name | Diesel Ltrs | LPG KG | FO Ltrs | Coal MT | | | |
| 1 | Ambica | 1400 | | 3000 | | 5073.2 | 30 | 169.10667 |
| 2 | Sai swarna Motors | 1000 | | | | 1153 | 30 | 38.433333 |
| 3 | Kumar Industries | 300 | | 40000 | | 46465.9 | 30 | 1548.8633 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4 | Pratap poly pack Industries | | 38 | 1000 | | 1204.414 | 30 | 40.147133 |
| 5 | Mahesh Pvt. Ltd | 100 | | | | 115.3 | 30 | 3.8433333 |
| 6 | srinu ceramics | 3000 | | | | 3459 | 30 | 115.3 |
| 7 | A.P Drug house | 2500 | | | | 2882.5 | 30 | 96.083333 |
| 8 | Raja chemical Industries | 110 | | | | 126.83 | 30 | 4.2276667 |
| 9 | Maheswari industries | 100 | | | | 115.3 | 30 | 3.8433333 |
| 10 | Kalyani Industries | 100 | | | | 115.3 | 30 | 3.8433333 |
| 11 | Siddhi Vinayaka Pvt. Ltd | 10000 | | | | 11530 | 30 | 384.33333 |
| 12 | AP steel industries | 100 | | | | 115.3 | 30 | 3.8433333 |
| 13 | uniplast Pvt. Ltd | 2500 | | | | 2882.5 | 30 | 96.083333 |
| 14 | Mallikarjuna forgings Pvt. Ltd | 2000 | | | | 2306 | 30 | 76.866667 |
| 15 | Durga steel rolling Mills | 2500 | | | | 2882.5 | 30 | 96.083333 |
| 16 | Ashok transtech pvt. Ltd. | 300 | | | | 345.9 | 30 | 11.53 |
| 17 | Kalyan Rubber Products | | | 600 | | 691.8 | 30 | 23.06 |
| 18 | Star steel industries | | | 90000 | | 103770 | 30 | 3459 |
| 19 | Sri Venkateswara Steel & allied Industries | | | 45000 | 90 | 89415 | 30 | 2980.5 |
| 20 | Aryan Expoters Pvt.Ltd. | | | 4800 | | 5534.4 | 30 | 184.48 |
| 21 | Poornima Steels | | 1650 | | 75 | 33507.45 | 30 | 1116.915 |
| 22 | Cheerys Auto Ancillaries Pvt Ltd | 690 | 3240 | | | 5422.83 | 30 | 180.761 |
| 23 | Tara Industries | | | | 21 | 8757 | 30 | 291.9 |
| 24 | Manjunadha Motors | 100 | | | | 115.3 | 30 | 3.8433333 |
| 25 | Mangalagiri Traders | | 90 | | | 121.77 | 30 | 4.059 |
| 26 | Avadh Rubbers | 6000 | | | | 6918 | 30 | 230.6 |
| 27 | Avanthika steels | 100 | | | | 115.3 | 30 | 3.8433333 |
| Total consumption of fuel per month | | 32900 | 5018 | 184400 | 186 | 335141.794 | | **11171.3931** |

**Demand for Industrial Sector**

The demand for the industrial sector has been projected based on the above information collected during market survey.

The gas demand for the Industry works out to **0.011171 MMSCMD**

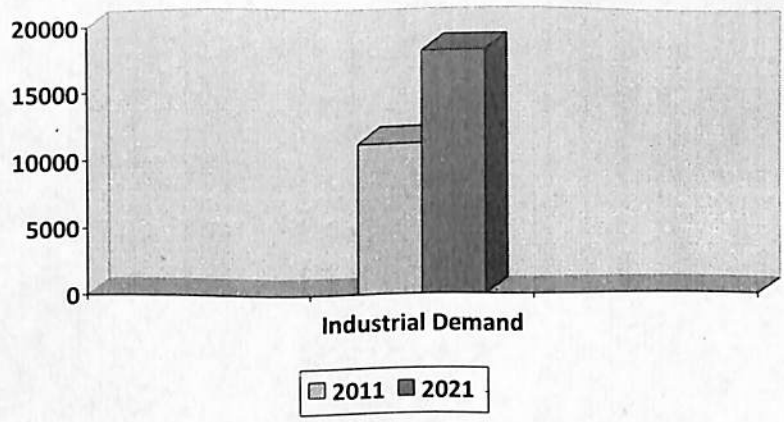
The projected demand of natural gas for Industrial sector for next 10 years is tabulated below.

Table-4.5 Year wise gas volume demand for Industrial sector

| YEAR WISE GAS VOLUME- Industrial sector | |
|---|---|
| Year | Gas Volumes (SCMD) |
| 1 | 11171 |
| 2 | 11785 |
| 3 | 12434 |
| 4 | 13118 |
| 5 | 13839 |
| 6 | 14600 |
| 7 | 15403 |
| 8 | 16250 |
| 9 | 17144 |
| 10 | 18087 |

**Demand of Natural gas for Industrial sector**

**(Figure in SCMD)**




## 4.6 Automobile - CNG Sector

### Vehicle Categories

Automobile sector has been broadly divided in to petrol driven vehicles and diesel driven vehicles. Further the segment is subdivided into three wheelers, cars (private & taxies), jeeps, buses etc. based on the information available from RTO. Latest information from RTO has been collected and utilized for demand projection.

The current price differential of petrol and CNG is very high and it is easy and cheaper for petrol vehicles to be converted to CNG. Also, the potential for conversion to CNG for petrol driven vehicles is very high as compared to diesel driven vehicles even without compulsion by Government / Supreme Court. Other factor which will influence conversion is annual run in km. Therefore private owned petrol run vehicles are less likely to be converted to CNG as compared to Taxies as payback period for cost of conversion for private vehicles is much longer as they run very less distance. However, in view of very stringent norms being adopted by various State Governments, all commercial vehicles like city buses, LCV, taxies though run on diesel are considered for conversion to CNG.

In order to divide three wheelers, taxies and cars into petrol and diesel driven vehicles subjective judgment based on the discussion with RTO office has been used. Different categories of vehicles so derived are shown below:

**Petrol driven:**

Table-4.6 Total number of petrol driven vehicles

| | |
|---|---|
| Taxies | 100 |
| Three wheelers | 154 |
| Cars | 725 |
| **Total** | **979** |

**Diesel driven:**

Table-4.7 Total number of diesel driven vehicles

| | |
|---|---|
| Taxies | 538 |
| Three wheelers | 738 |
| Cars | 128 |
| Jeeps | 118 |
| Buses | 355 |
| School Buses | 150 |
| **Total** | **2027** |

Consumption norms for petrol and diesel for different categories of vehicles had been derived from the market survey feedback and given below:

**Petrol driven**

Table-4.8 Total consumption of petrol

| | **Litres/ Month** |
|---|---|
| Taxies | 200 |
| Three wheelers | 190 |
| Cars | 50 |

**Diesel driven**

Table-4.9 Total consumption of Diesel

| | **Litres / Month** |
|---|---|
| Taxies | 225 |
| Three wheelers | 190 |
| Cars | 60 |
| Jeeps | 225 |
| Buses | 800 |
| School Buses | 250 |

**Demand for Automobile – CNG Sector**

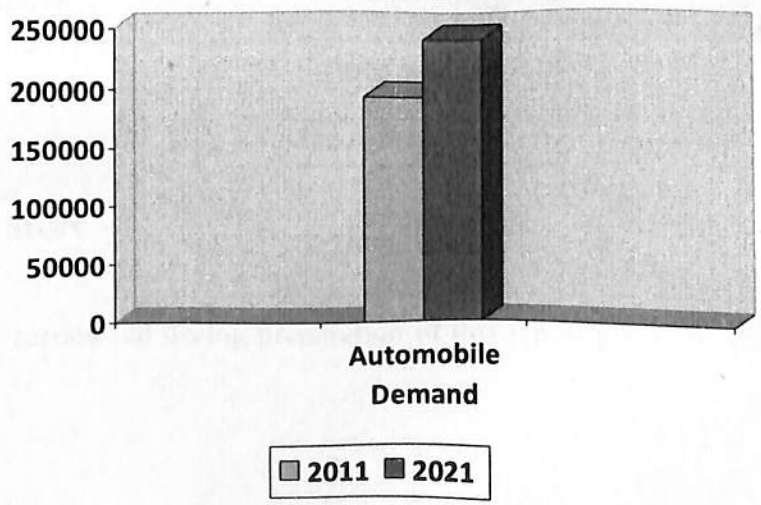
Based on the consumption norms as derived from the original market survey and switching norms and growth rate as adopted above, total demand of petrol & diesel driven vehicles for CNG has been estimated as **0.192 MMSCMD.** The projected demand of Natural gas for automobile sector for next 10 years is tabulated below.

Table-4.10 Year wise consumption of gas volume for Automobile sector

| YEAR WISE GAS VOLUME - Automobile sector | |
|---|---|
| Year | Gas Volumes (SCMD) |
| 1 | 192000 |
| 2 | 196800 |
| 3 | 201720 |
| 4 | 206763 |
| 5 | 211932 |
| 6 | 217230 |
| 7 | 222661 |
| 8 | 228228 |
| 9 | 233933 |
| 10 | 239782 |

Demand of Natural gas for Automobile sector

(Figures in SCMD)



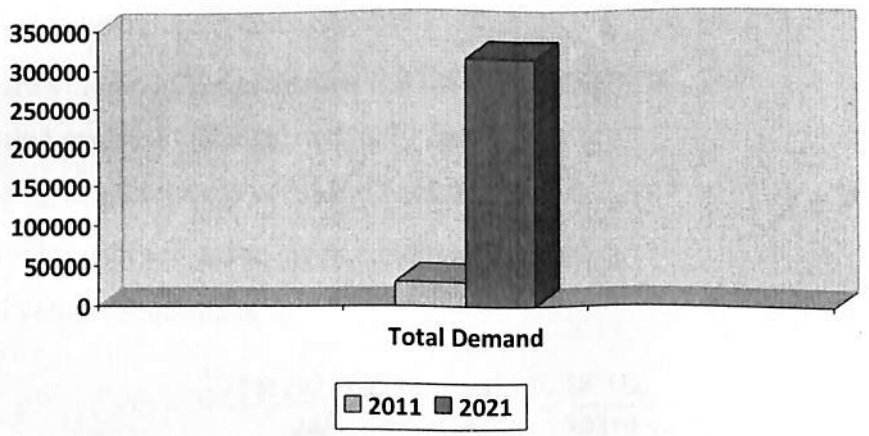
Consolidated total Demand of Eluru for City Gas Distribution Project for period of 10 years including Domestic, Commercial, Industrial and Automobile sectors is 312823.0323SCMD.

Table-4.11 Total gas demand for various sectors

| Sector | 2011 | 2021 |
|---|---|---|
| Domestic | 0 | 54069 |
| Commercial | 709 | 885.44 |
| Industrial | 11171 | 18086.90213 |
| Automobile | 19200 | 239781.6902 |
| Total | 31080 | 312823.0323 |

**Total Demand of Natural gas**

**(Figures in SCMD)**




## 4.7 SYSTEM DESIGN

### Demand Pattern

The market study carried out during preparation of this report gives gas demand in different sectors.

| Sector | 2011 | 2021 |
|---|---|---|
| Domestic | 0 | 54069 |
| Commercial | 709 | 885.44 |
| Industrial | 11171 | 18086.90213 |
| Automobile | 19200 | 239781.6902 |
| Total | 31080 | 312823.0323 |

This is the standard volume of gas required by the city.

The Actual volume of gas required can be calculated by using the below given formula

$$\frac{P_{standard}\, Q_{standard}}{T_{standard}} = \frac{P_{actual}\, Q_{actual}}{T_{actual} \times Z}$$

The standard pressure is considered as 2 bar

The standard temperature is considered as 15 °C

The standard volume of gas estimated is **312823.0323 SCMD**

The operating pressure is considered as 19 bar

The operating temperature is considered as 30 °C

Compressibility factor Z at the given conditions is 0.97

The actual volume required is

$$\frac{2*312823.0323}{288} = \frac{19*Q_{act}}{303*0.97}$$

$$Q_{actual} = 71314.144\ m^3/day$$

$$= 0.51858743 m3/sec$$

**4.8 Pressure Reigme:**

Depicting the Pressure regime in CGD

The below figure depics the consolidation of pressure regime for normal CGD layout, which was regulated by the PNGRB board.

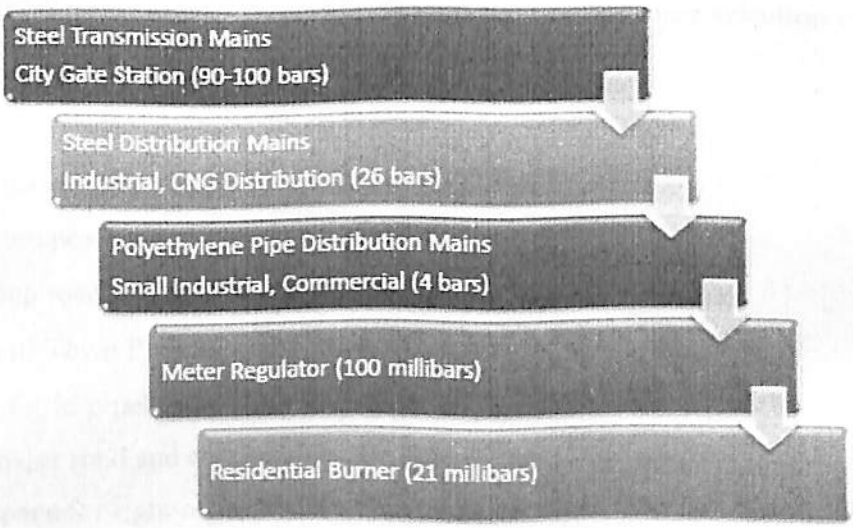



Figure 4.1 Consolidated Pressure regime of CGD layout

Source: Dimple singh, City Gas Distribution 2010 [ ]

# 5. PIPELINE ROUTE SURVEY

Pipeline route survey report based on Table Top Study.

## 5.1 Basis for Route Selection

The route survey is based on the desktop study of Eluru town maps. Map identification numbers are indicated in the respective tables. The feeder pipeline route selection is based on the following principles.

- Major demand areas to be preferably serviced through loops
- To cover maximum possible potential customers
- Follow the existing road or highway to the extent possible
- Eluru City maps of Town Planning Department
- Shortest length of grid pipeline
- Minimum rail, major road and river/major canal crossings
- Availability of space for right of way
- Least stretch through slushy, rocky & cultivable terrain
- Avoiding HT transmission lines
- Minimum number of turning points
- Minimum ecological impact
- Easy access to the route during construction phase
- Availability of infrastructure facility e.g. land

The salient features of the each route are as follows.

1. Shortest Distance achieved
2. Covered all Demand load centers
3. Routed the pipe line network covering all the charged areas.

### 5.1.2 Total Steel Grid Network

1. NH -5 Road Crossing–1 at Opposite of CGS
2. Road Crossing – 28.
3. Main Canal -1
4. Rail Crossing – 1
5. Flyover – 1 (Parallel to pipeline)

## 5.2 Conclusion and Recommendation

The steel grid pipeline route selection based on demand centre. Approximately 24 km of steel grid survey is conducted in Eluru. Eluru upcoming industrial town as well as it is an district Head quarters and its demand mainly industrial units and commercial units situated in Industrial Area at zone-2 & Industrial Area at zone-3, Zone-2. The domestic and commercial demand are also along / adjacent of NH-5 Road. Hence, the pipeline routes are selected along the NH-5 and inter connecting Roads of the town for maximum utility of pipeline.

# DESIGN

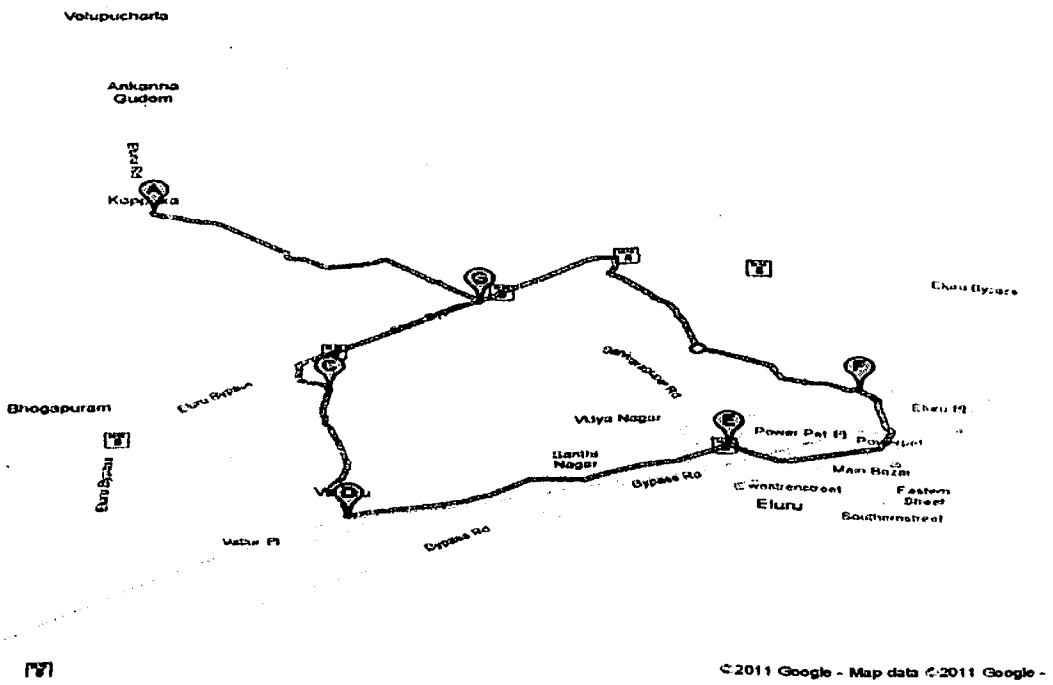
# 6. DESIGN CALCULATION

The actual design of City Gas Distribution for Eluru town is carried in different phases. Here in this case the design is carried out by selecting the 4 distribution points, as two kinds of pipe lines are considered. The design calculations are carried out as following:

- Design of Steel Pipe for CGD
- Design of MDPE Pipe for CGD

## 6.1 Design of Steel Pipe for CGD

**Introduction**: In order to accomplish the design of steel pipeline for Eluru town, the town map of the city is considered as per Figure 6.1. In the whole town 5 distribution points are considered for the optimum design. Further network analysis is carried to analyse the section wise losses, and optimise the design. *(The following contour maps obtained from Reference [3]*



DESIGN ANALYSIS:

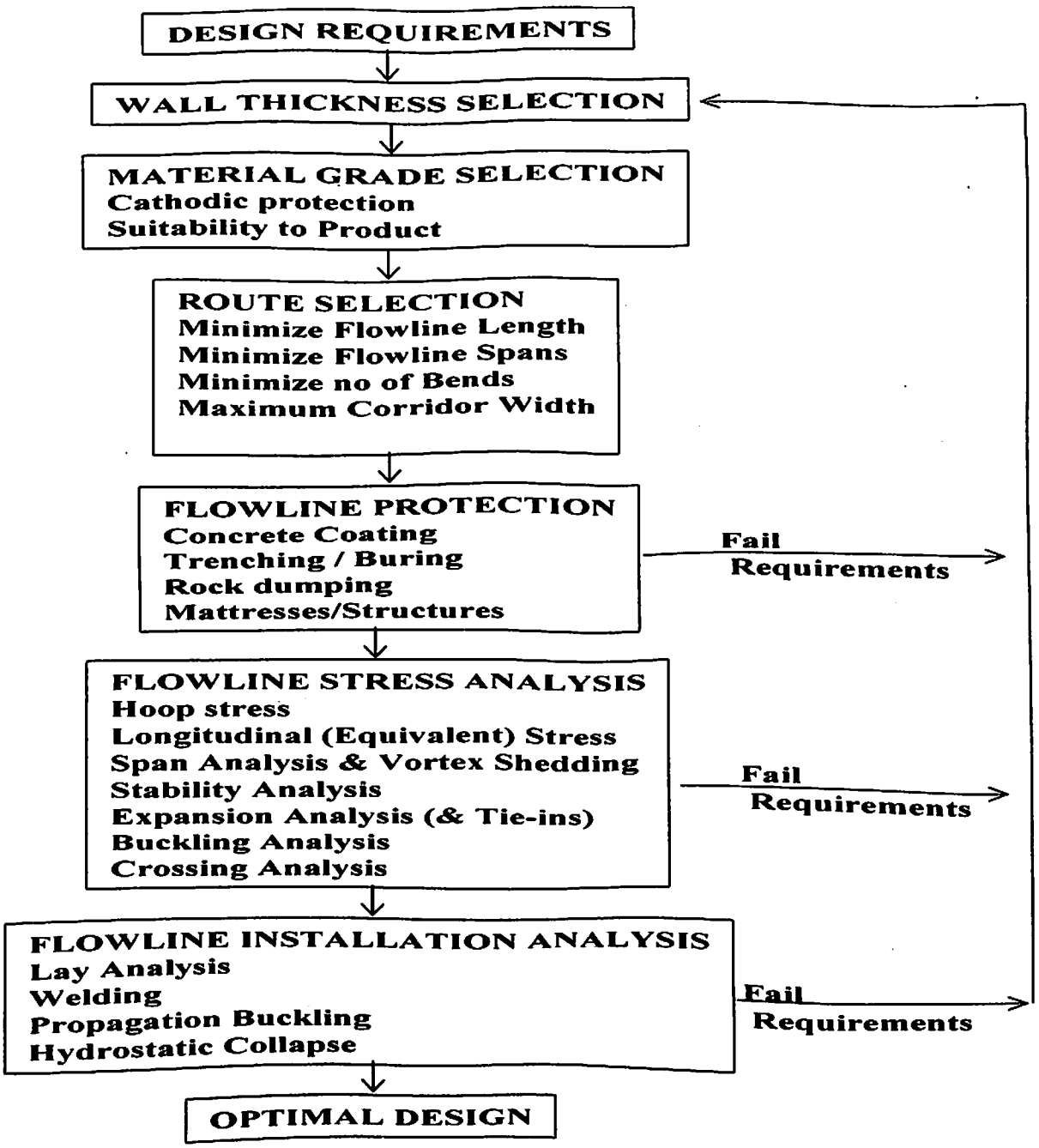



**Figure 6.2 Algorithm for pipeline design analysi**

**Pipeline Size determination**

Considering the above geographical potential demand distribution, the main steel grid size has been calculated by

The allowable stress value S to be used for design calculation for new pipe of known specifications is given by the following equation.

S= 0.72 X E X specified minimum yield strength of the pipe

Where,

0.72 = Design factor based on nominal wall thickness,

E = Weld joint factor.

**Design parameters of Steel pipe diameter for CGD**

| | |
|---|---|
| Length | 24 km |
| Flow rate of gas at standard conditions | 0.31282344 MMSCMD |
| Operating pressure of pipeline $P_1$ | 19 bar |
| Operating temperature of pipeline | 25°C = (298k) |
| Compressibility factor at operating conditions | 0.97 |
| Viscosity of gas | $1.2 \times 10^{-5}$ pa-sec |
| Specific gravity | 0.58 |
| Molecular weight of the gas | 16.8026 |
| Density of gas | 0.9 kg/m$^3$ |
| Velocity of gas (assumed) | 8 m/s |

The design calculations for the subsequent sections are carried out in excel Programming and results are summarized.

**Pressure drops in various sections of steel main line**

| Section | $Q_{std}$ | $Q_{act}$ | D | $R_e$ | F | $P_1$ | $P_2$ | $\Delta P$ |
|---|---|---|---|---|---|---|---|---|
| AB | 312823.44 | 0.51858 | 12.750 | 1664544867 | 0.01279 | 19 | 18.74 | 0.2608 |
| BC | 66301.022 | 0.11143 | 6.625 | 678954613.1 | 0.01461 | 18.74 | 18.38 | 0.3592 |
| CD | 78961.922 | 0.13531 | 6.625 | 808609166.8 | 0.01461 | 18.38 | 17.86 | 0.5219 |
| DE | 77257.238 | 0.13624 | 6.625 | 791151577.3 | 0.01461 | 17.86 | 17.35 | 0.5143 |
| BF | 90303.258 | 0.51778 | 6.625 | 924749147.8 | 0.01461 | 18.74 | 18.07 | 0.6721 |
| FE | 77257.238 | 0.13740 | 6.625 | 791151577.3 | 0.01461 | 17.71 | 17.19 | 0.5188 |

Also thickness of the pipe by section wise and velocity of the gas in respective sections are calculated and shown in below table.

**Thickness of pipe in various sections**

| Section | T<br>mm | U<br>m/sec |
|---|---|---|
| AB | 6.35 | 4.721 |
| BC | 6.32 | 4.763 |
| CD | 6.35 | 4.563 |
| DE | 6.34 | 4.594 |
| BF | 6.32 | 5.178 |
| FE | 6.32 | 4.633 |

**Summary**

The results obtained from calculations for actual volumetric flow rate, velocity, pressure drop for various diameters are presented in the following table

**Recapitulation of steel pipeline design**

Table – 6.1 Recapitulation of Steel pipeline design

| Section | $Q_{act}$ $m^3/sec$ | D in | T mm | U | ΔP |
|---|---|---|---|---|---|
| AB | 312823.44 | 12.750 | 6.35 | 4.721 | 0.2608 |
| BC | 66301.022 | 6.625 | 6.32 | 4.763 | 0.3592 |
| CD | 78961.922 | 6.625 | 6.35 | 4.563 | 0.5219 |
| DE | 77257.238 | 6.625 | 6.34 | 4.594 | 0.5143 |
| BF | 90303.258 | 6.625 | 6.32 | 5.178 | 0.6721 |
| FE | 77257.238 | 6.625 | 6.32 | 4.633 | 0.5188 |

## 6.2 DESIGN OF POLYETHYLENE PIPE

Design of a polyethylene piping system is generally no different than the design undertaken with any ductile and flexible piping material. Polyethylene pipeline has different grades. The allowable grades for the city gas distribution for piped natural gas (PNG) are PE 80 and PE 100, mainly the Medium Density Polyethylene (MDPE). PE 100 is the standard pipe used due to its characteristics of regaining its shape after squeezing.

The two available grades of polyethylene pipes are PE80 & PE100. The design of both these grades is based strength of the respective materials known as Minimum Required Strength (MRS).

**Classification:** There are two types of MDPE pipes are majorly employed in the CGD works. They are PE100 with MRS-10 and PE 80 with MRS-8. pressure.

**Merits:** The PE 100 having the minimum required strength of 10 which is greater than PE80 is selected for the Outlet from the DRS at each zone. The various other reasons for the selection of the pipe grade PE 100 are as follows:

- First, it's lightweight, flexible and availability in long coils there by making it easy for installation and minimizing the numbers of joints in the piping system.

- PE is approximately $1/8^{th}$ weight of steel pipe when compared, and with integral and robust joining methods, installation is simpler.

- One important trend in the market for PE gas pipes is the emergence of PE 100 as an ideal material choice for gas pipeline systems.

- The main field of application for PE gas pipe has traditionally been city gas distribution with operating pressures 1 bar to 4 bar and in some cases even 5 bar.

- However, it has been proven in service that long distance lines with operating pressures of 10 bar can be produced from PE100. PE gas pipes have gained more importance in recent years because of their low cost and technical advantages over other pipes

**Design of MDPE Pipe Line :** The final aim of this design is to evaulvate Maximum allowable operating pressure, thickness of the pipe. If the SDR is calculated, the MAOP can be calculated and from the standard pipe specification, the MAOP can checked for safety limits.

**Standard Dimension Ratio:** It refers to the geometry of the pipe. It is defined as the ratio of nominal outside diameter of pipe to nominal wall thickness of the pipe.

$$SDR = \frac{dn}{en}$$

$d_n$ = nominal outside diameter of the pipe.

$e_n$= nominal wall thickness of the pipe (minimum).

Higher SDR indicates a thinner walled pipe at any given diameter.

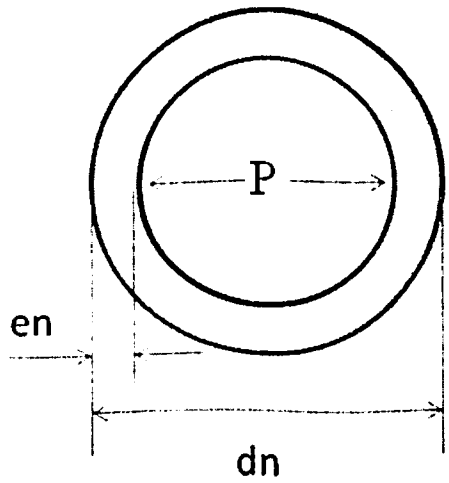



**Figure 6.3: Geometry of MDPE pipe**

$$S = \frac{P\,(dn - en)}{2\,en}$$

By rearranging

$$S = \frac{P\,(SDR - 1)}{2}$$

Where,

S = maximum hoop stress; P = internal Pipe pressure.

The hoop stress is the design stress for the pipe material, which is MRS (Minimum required strength), divided by the overall design service coefficient "C" which is of value 2 to 3.

$$\frac{MRS}{C} = \frac{P\,(SDR - 1)}{2}$$

$$p = \frac{2 * MRS}{SDR - 1} * \left(\frac{1}{cm * ca * ct}\right)$$

Where

Cm – Material Coefficient ( Cm-1.25 as per ISO)

Ca- Application Coefficient ( Ca – 1.6)

Ct- Temperature coefficient ( Ct- 1.3)

The pressure P is defined as the maximum operating pressure in the pipe.

$$MOP = 2 \times \frac{MRS}{C\,(SDR - 1)}$$

Where MOP and MRS are in Megapascal, so

$$MOP = 20 \times \frac{MRS}{C\,(SDR - 1)}$$

So required MOP for the different SDR for PE 100 pipe and MRS of polyethylene **(10barg)**

Table – 6.2 Recapitulation of MOP for different SDR for MDPE pipe

| SDR | MOP |
|---|---|
| 21 | 17.09 |
| 17 | 13.68 |
| 11 | 8.54 |
| 9 | 6.83 |
| 8.3 | 6.24 |
| 7.3 | 5.38 |

Hence the maximum operating pressure of the PE100 **of** various SDR pipes is tabulated; hence we choose the required ine for a pressure rating of maximum **4 barg.**

**Summary:**

From calculation it is found that Medium Density Polyethylene pipe of grade PE100 with different SDR is having different maximum operating pressure hence we choose the required MDPE line which is suitable for the actual line pressure.

# NETWORK ANALYSIS

# 7. NETWORK ANALYSIS

In most countries gas transportation and distribution systems consist of a large set of highly integrated pipe networks operating over wide range of pressures. The ever growing demand for gas necessitates the development of gas transport systems and distribution networks and these create further problems associated with the rational operation of the system to ensure, on the one hand proper supply of gas to the consumers, on the other hand, low system operating costs.

Simulation of gas networks makes use of models of gas flow in pipes that have been developed based on the physical laws controlling the processes of flow. However, in view of the complexity of the problems (formulation of the equations, dimension of the problem, complexity of the model) in most cases we cannot do without a computer.

As has already been mentioned, simulation allows us to predict the behavior of gas network systems under different conditions. Such conditions can then be used to guide decisions regarding the design and operations of the real system. At the stage of designing a network, simulation helps us to select a structure for the network, as well as the geometric parameters of the pipes in the case of given parameters of gas supply and demand. Simulation also facilitates the selection of sites where non-pipe elements should be installed. The control of a gas system also requires simulation in order to obtain information about the pressures and flow rates at given points of the network. Depending on the character of gas flow in the system we distinguish steady and unsteady states. The steady states in gas networks are described by systems of algebraic- in general non linear –equations. Steady state simulation is relatively simple to deal with and is far easier to understand; in some cases, however, the dynamics of the flow cannot be neglected without committing a serious error, it is then necessary to use a dynamic model which leads to simulation which is computationally much more complicated.

## 7.1 NEWTON LOOP-NODE METHOD (MULTI DIMENSIONAL)

The Hardy-Cross nodal method solves the set of nodal equations ,i.e, the set of equations. An Initial approximation is made to the nodal pressures. In turn this approximation is corrected for each node to be a better approximation. This process is repeated until all the nodal errors are less than a specified tolerance.

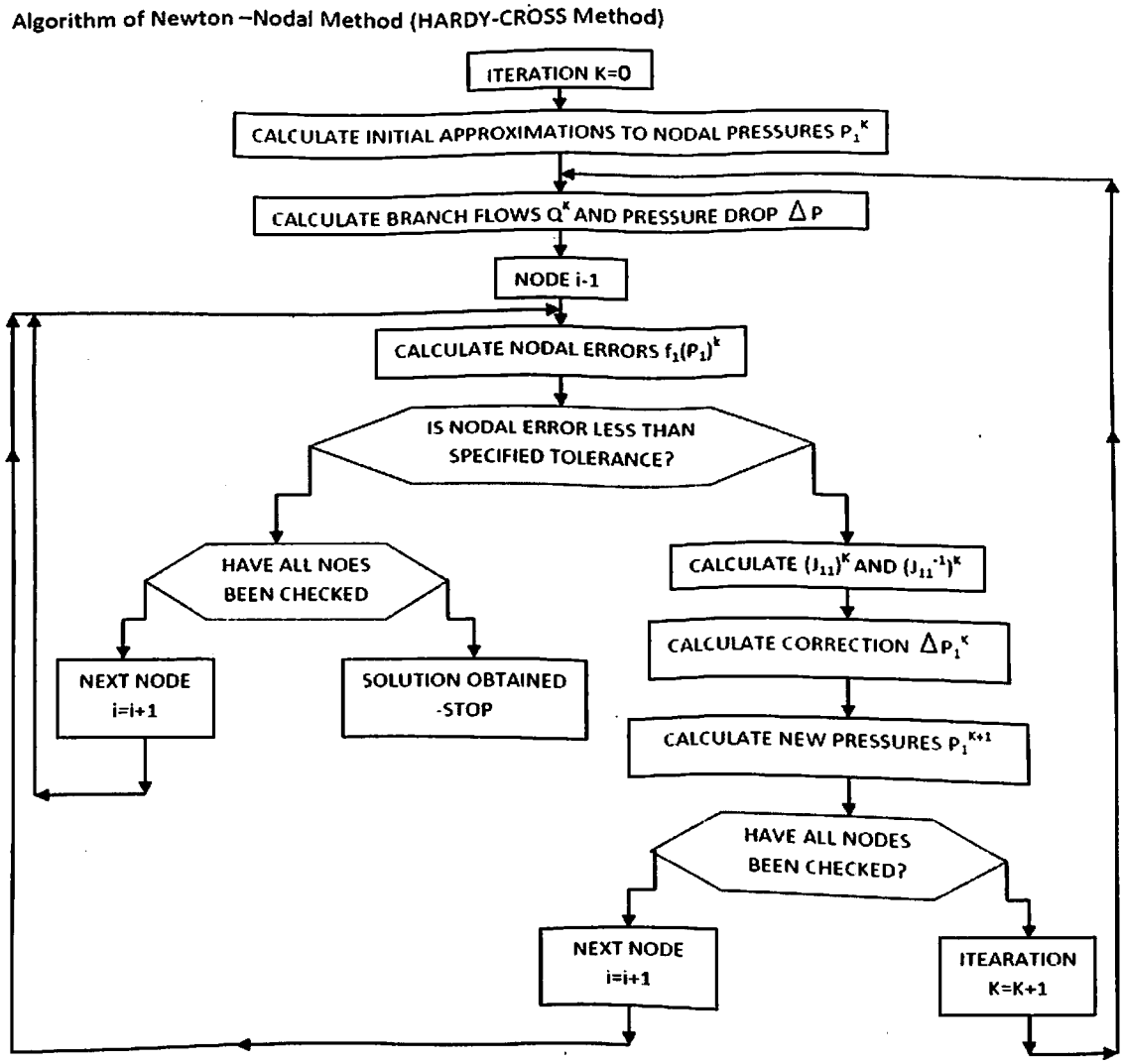
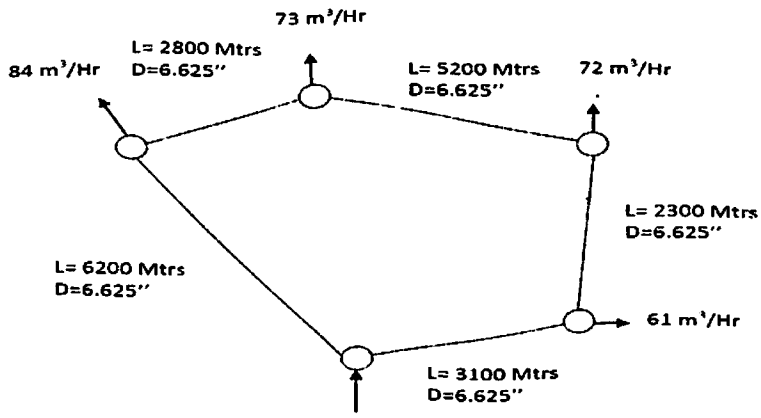



Figure: 7.1

Source: Andrzej J. Osiadacz Simulation And Analysis Of Gas Networks [25].

The results are simulated in the Excel sheets and the results are tabulated below.




## 7.2 Summary:

An attempt is made to verify the feasibility of the pipeline Network by Newton Nodal Method which results in the divergence; hence a detailed investigation has to be carried out further to balance the network.

Recapitulation of the Flow rates after every iteration.

Table: 7.1 Summarization of the flow rates after every iteration.

| Q (Initial) | Q (After 1st iteration) | Q (After 2nd iteration) | Q (After 3rd iteration) |
|---|---|---|---|
| 84 | 107.42 | 164.215 | 446.532 |
| 61 | 88.44 | 96.535 | 283.404 |
| 72 | -18.53 | -95.860 | -44.538 |
| 73 | 91.37 | 212.538 | 1969.075 |
| | -69.87 | -90.487 | 831.177 |

# PROJECT DETAILS

## 8. CITY GAS DISTRIBUTION DETAILS

### 8.1 City Gate Station and Steel Grid Pipe Line

The City Gate Station has been proposed in Industrial Area No.3. Natural Gas from the CGS is fed into single pipeline supplying gas to the city network. The pressure at the downstream of CGS shall be 19 bar. A Primary network of steel pipeline shall connect the various CNG stations and District Regulating Stations (DRS) for further gas supply distribution to automotive and and PNG consumers.

The network of steel Pipeline is marked in the route map identified. The main grid line is laid alongside roads and highways. SV Stations are installed at approx every 2.5 km distance. As far as possible, SV Stations are planned to be installed near CNG stations for prompt maintenance response. Network modelling has established the following parameters of the ring main grid pipeline.

(a) Design Pressure - 50 kg/cm2
SMYS - 290 N/mm2
Negative tolerance - Zero mm (0 mm)
Design factor - 0.6 for Location Class 2

(b) P/L Size & Length (indicative)
Primary P/L 10"/12" - 4200 Mtrs
Secondary P/L 6" - 19800 Mtrs

(c) Material - API 5 L X 42
Class - ANSI Class 300

(d) Thickness - 6.4 mm

(e) Corrosion Allow. – 0.5 mm

**Design pressure of Steel Pipeline Network**

Proposed steel pipeline system is designed for 50 kg/cm2. However operating pressure for the proposed CGD will be 19 kg/cm2.

**8.2 District Regulating Stations**

DRS are the installation which work as pressure reduction equipment and meters the gas passing through. The DRS comprises of pressure reduction, metering system, condensate removing facility and cold venting facility.

Filter separator shall be provided at the inlet of each DRS. Filtering efficiency shall be 99.9% for the removal of all particles above 3-micron size. The flow measurement meter shall be Turbine Meter type with error of + 0.2%. The regulating assembly shall be a dual run assembly with each run designed for the full flow capacity required of the station and manual isolating valves provided to facilitate servicing of each run without shutdown of the station.

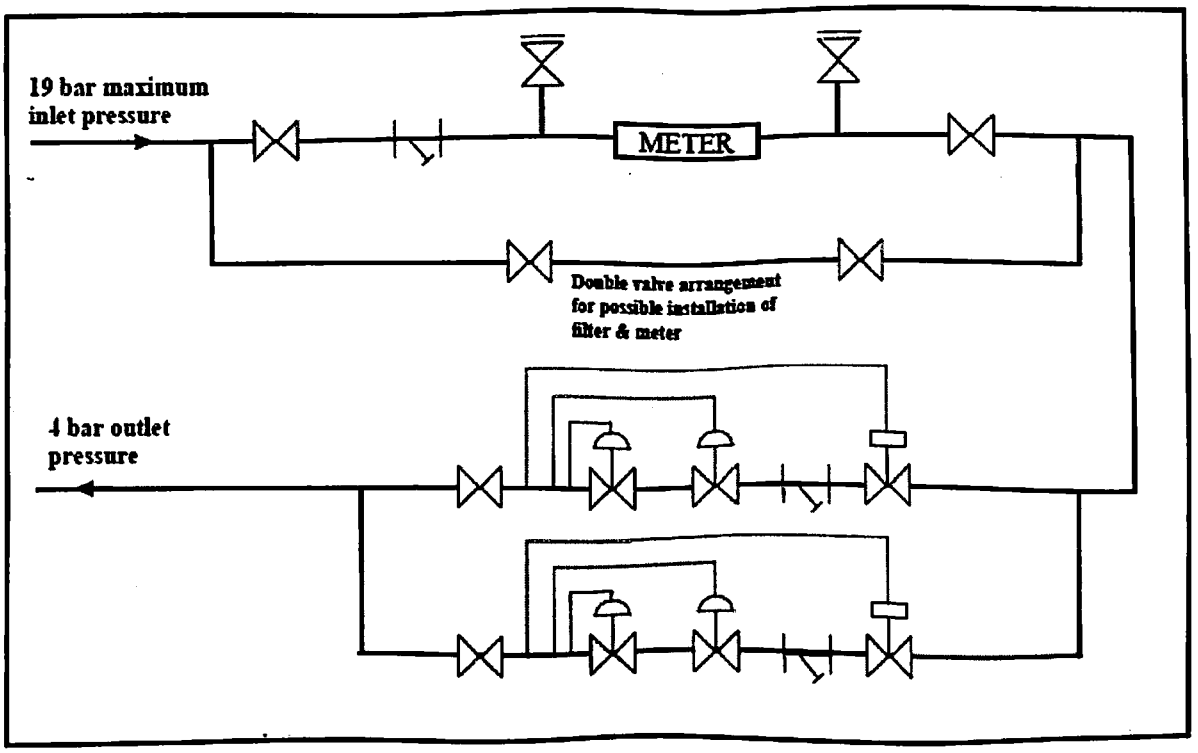



**Figure 8.1 Schematic diagram of District regulating station**

Source: Green Gas Limited, Lucknow[1]

The DRS will have inlet pressure of 11-19 bar and outlet pressure of 4 bar.
Following capacities of DRS will be installed as per demand profile of various clusters.

- 2000 SCMH
- 3000 SCMH
- 5000 SCMH
- 10000 SCMH

10,000 SCMH DRS is installed close to industrial demand centres. DRS of 5000, 3000 & 2000 SCMH are mainly for commercial and domestic application

**8.3 MDPE Network**

MDPE pipes shall be installed downstream of District Regulation Station (DRS).

Distribution Mains

To standardise the distribution system, it is proposed to install only five sizes of OD pipes – 180mm, 125mm, 63 mm, 32mm and 20 mm. All pipe joining is by electro fusion couplings. Distribution mains will be buried at 1.0 metre cover. All MDPE pipe will be back filled with sand around it to protect the plastic material.

It is a standard practice to install warning mats 300mm directly above the MDPE gas pipe, because of the large amount of gas that is released should a 125 mm or 63 mm pipeline rupture at 4 bar. The warning mats are typically 300 mm wide and 1.0 mm thick for Steel/distribution mains and 0.25mm thick for service lines.

Where the gas main crosses another service the plastic warning mats could be omitted and a concrete slab nominated instead. Emphasis will be placed on utilising modern construction

techniques to install the distribution system in line with international trends. This will include, wherever possible, avoiding disruption/damage to roads and footpaths, by boring and drilling.

It is proposed to have valves on the distribution and transmission networks at strategic locations to ensure security of supply. Based on previous experience, an allowance was made to install two valves per 5 kilometers of distribution main.

To ensure system integrity and safety, prior to commissioning, the MDPE pipes shall be air tested as per applicable standards.

Distribution Services

Distribution services are used to connect customers from the mains. As most services must cross roads / footpaths, to reach the customers, they are often installed by boring, to reduce reinstatement costs. Open excavation is then only needed at the connection to the main and at the service. Where open excavation has taken place, Marker tape is installed.

A typical service is diagrammatically shown below:

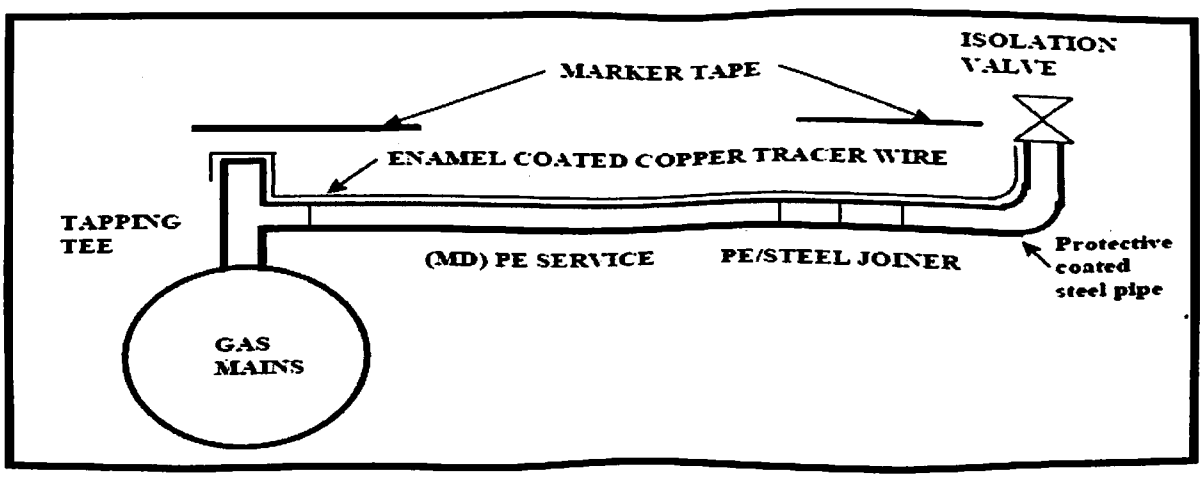



**Figure 8.2 Schematic Diagram of Distribution system**

**Source: Green gas limited, Lucknow[1]**

*Typical 15 mm/20 mm / 50 mm Service*

To standardize materials, it was assumed that 15 mm services will be used to supply domestic consumers, 20 mm services for small commercial consumers or and 50 mm services for most large commercial consumers and industrial consumers.
In addition, it is recommended to install PE emergency shut-off valves outside the large consumer's premises.

## 8.4 Meter/Regulator Assemblies

Domestic Consumer Service/Meter/Regulator

The domestic household gas in Eluru is essentially for cooking. Natural gas for water heating and/or space heating may also be required by more affluent consumers considered; however, this requirement is likely to be minimal and hence not considered. Accommodation also consists of multiple households in apartment-type premises. This means a number of households can be supplied with gas from a single service.

The combination of multiple households per site, low quantity gas requirements, and high-pressure gas supply results in a requirement for a single service/single regulator supplying gas to a block of householders with individual metering for households.

It is proposed that over the life of the project, a service line supplies to an average of three households. Each service line will include a main isolating valve and a regulator, reducing the pressure to 21 mbar. This is shown in figure below.

Such an arrangement will not affect meter measurement accuracy within the nominated meter accuracy range of ± 1% to 2%. The accuracy will not be compromised because the gas flow rates are low and therefore the pressure drop across a meter will be within the manufacturer's specifications.

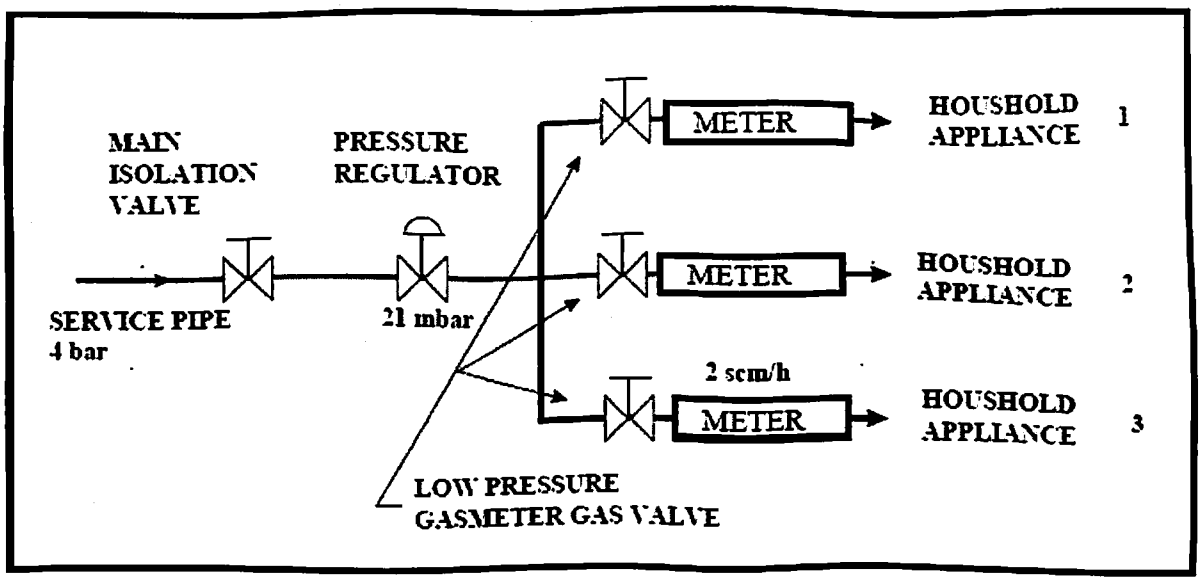



**Figure 8.3** ***Schematic diagram of Domestic Consumer Service/Meter/Regulator Arrangements***

Source: Green gas limited, Lucknow [1]

Commercial Meter/Regulator Assemblies

The service pipeline to commercial consumers will depend on the load required. For large commercial users (e.g. Big hotels), pipe sizes will be considerably larger than domestic and small commercial premises, and a higher gas supply pressure also may be required.

To enable maintenance of meters while ensuring continuity of gas supply, bypass systems may need to be incorporated. Since the costs of these gas supply facilities are chargeable to the consumer, various options can be made available, depending on the customers' service level requirements.

Basic meter/regulator assemblies are shown in Figures:

Where security of supply is paramount, dual regulator systems may be necessary.

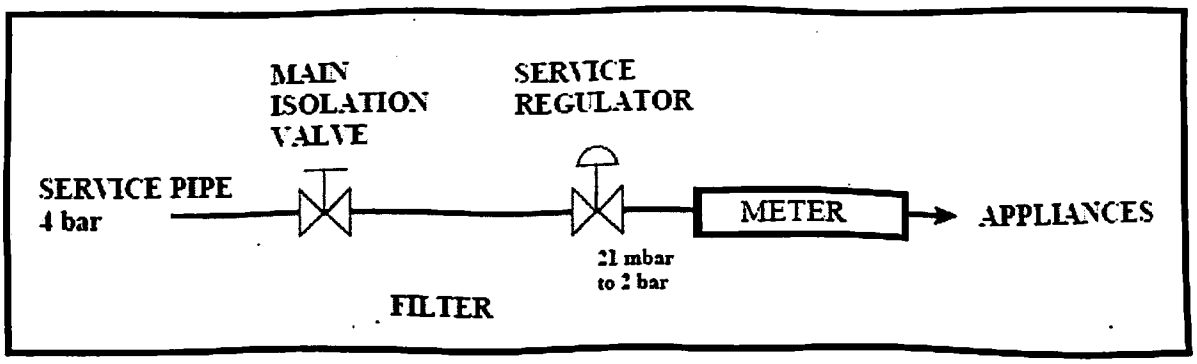



*Figure 8.4 Schematic diagram of Small Commercial Meter/Regulator Service*

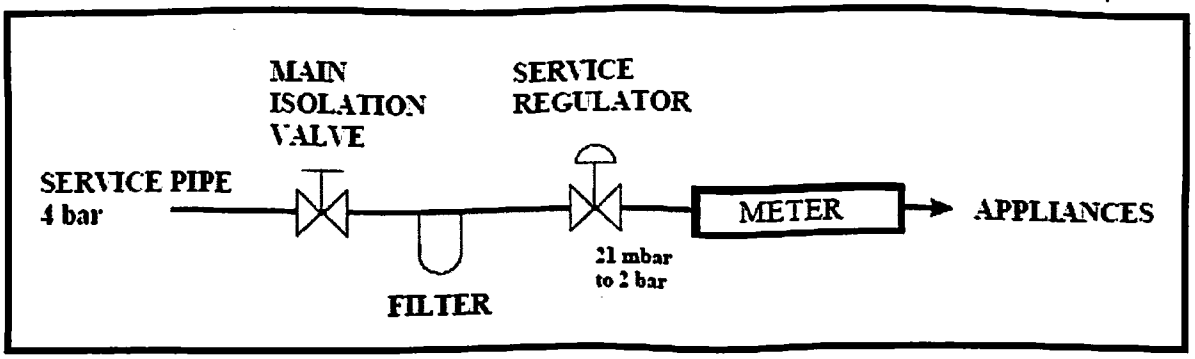



*Figure 8.5 Schematic diagram of Typical Commercial Meter/Regulator Service*

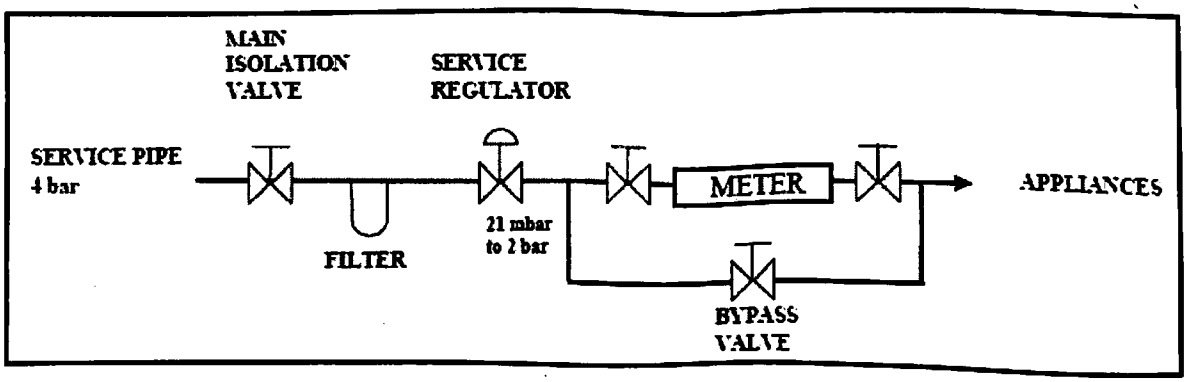



*Figure 8.6 Schematic diagram of Commercial Meter/Regulator Service with By-pass*

## 8.5 SELECTION CRITERIA

### Selection of CNG - Mother, On-line and Daughter Booster Stations

The selection criteria for location of CNG stations should be based on the following:

i) Suitability for catering CNG requirements of Buses through dedicated CNG stations.

ii) Location at population centres in the city

iii) Should cover major routes of heavy traffic movement

iv) Availability of sufficient area at existing petrol/diesel retail outlets.

v) Stations locations should provide an optimum spread of CNG network in the city

**Selection of District Regulatory Stations (DRSs)**

The selection criteria for DRS location is based on the following:

i) Proximity to areas having a high concentration of large and medium commercials

ii) Proximity to those residential areas of the city where likelihood of conversion is high.

iii) Locations shall be such that there is possibility of forming closed loops of the MDPE network.

iv) Easy and convenient accessibility

**System Descriptions**

**CNG Stations**

The following types of CNG stations may be planned for catering to the demand of automobile sector:

**Mother Station**

The following units have been envisaged in Mother Station:

A. Main Equipment

i) Electrical/Gas Engine driven Mother Compressor of 1200 SCMH capacity along with auxiliaries

ii) Dispensers for buses

iii) Dispensers for cars and three-wheelers (autos)

iv) Loading Facility for Mobile Cascades

v) Stationary Cascade of 4500 WL capacity

vi) DG Set, UPS & Battery Bank, AVR, Electrical Control Panel

vii) Instrument Air and Water Facilities

viii) Fire Fighting equipment and safety sign

B. Other Facilities as per requirement of the station

i) Office-cum-Control Room

ii) RCC forecourt, canopy over dispenser island and signages

iii) Stainless steel tube connecting compressor, dispenser & cascades laid in U/G trenches

iv) U/G drainage and sewerage network

v) Approach/ exit road, boundary wall etc.

**On-line Station**

The following units have been envisaged in each On-line station:

A. Main Equipment

i) On-line Compressor (Electrical/Gas Engine driven) of 1200 SCMH capacity along with auxiliaries

ii) ii) Dispensers for buses (as required)

iii) Dispensers for cars and three-wheelers (autos)

iv) Stationary Cascades of 2200 WL to be mounted over the compressor.

v) DG Set, UPS & Battery Bank, AVR, Electrical Control Panel

vi) Instrument air and Water Facilities

vii) Fire Fighting equipment and safety sign

B. Other Facilities as per requirement

i) Office-cum-Control Room

ii) ii) RCC forecourt, canopy over Dispenser Island and signage's

iii) Stainless steel tube connecting compressor, dispenser & cascades lay in U/G trenches

iv) U/G drainage and sewerage network

v) Approach/ exit road, boundary wall etc.

**Note:** Depending on development of the On-line Station at green field location or at Retail Outlets of Oil Company, the facilities as listed above shall be considered.

**Daughter Booster Station**

The following units have been envisaged in each Daughter Booster station:

A. Main Equipment

i) Booster Compressor along with auxiliaries

ii) ii) Dispensers for cars and three-wheelers (autos)

iii) Stationary Cascades

iv) DG Set, UPS & Battery Bank, AVR, Electrical Control Panel

v) Instrument Air and Water Facilities

vi) Fire Fighting equipment and safety sign

vii) Unloading facility from mobile cascades

B. Other Facilities

i) Office-cum-Control Room

ii) RCC forecourt, canopy over Dispenser Island and signage's

iii) Stainless steel tube connecting compressor, dispenser & cascades lay in U/G trenches

iv) U/G drainage and sewerage network

v) Approach/ exit road, boundary wall etc.

**Note:** Depending on development of the Daughter Booster Station at green field location or at Retail Outlets of Oil Company, the facilities as listed above shall be considered.

## 9. CATHODIC PROTECTION & COATING

### Impressed Current Cathodic Protection System

The following Impressed Current Cathodic Protection System (PCP) is envisaged. It is also proposed to provide sacrificial anode cathodic protection system (TCP) to provide protection during construction phase.

The following electrical equipments/systems are envisaged for TCP & PCP:

a. Power Source with Battery Back-up Transformers Rectifier unit, Anodes-Temporary Cathodic Protection Mg, Ribbon Anodes.

b. Anodes-Impressed Current Cathodic Protection (ICCP) for permanent Cathodic Protection (PCP) Mixed Metal Oxide (MMO) Anodes.

c. Cables

d. Polarization Cell

e. Half Cell Reference Copper Sulphate Electrodes

f. Test Lead Points (TLP)

g. Insulation Mono Blocks

h. Polarization Coupons

i. Design Life of TCP system &PCP system has been considered one(1) year and thirty(30) respectively.

# FINANCIAL SUMMARY

## 10. ECONOMIC MODEL

The economic model for the project is taken for the existing CGD projects in India. The total expenditure is divided into two expenditure i.e. CAPEX and OPEX and nominal rate of interest is considered for the capital recovery. The economic model may vary from time to time with respect to the duration of the completion of the project and inflation rate available. Further a detailed cost recovery methodology has to be worked to return the project cost.

The following facilities have been envisaged for the project:-

Table 9.1 Facilities that are envisaged for the Project

| SL.NO | DESCRIPTION | DETAILS |
|---|---|---|
| I) | **Grid Line** | |
| | 12'' X 6.5 mm Steel Pipeline | 6.4 Km |
| | 6'' X 6.4 mm Steel Pipeline | 8.0 Km |
| | 4'' X 6.4 mm Steel Pipelline | 9.2 Km |
| II) | **CNG Stations** | |
| | **Mother Station** | |
| | - Gas Driven Compressor 1900 SCMH | 3 |
| | - Cascade 4500 Ltrs | 2 |
| | - Dispensers for Car & Bus | 8 |
| | **On-Line Station** | |
| | - Gas Driven compressor 600 SCMH | 2 |
| | - Cascade 2200 Ltrs | 2 |
| | - Dispenser for Bus | 2 |
| | **Daughter Station** | |
| | - Booster Compressors 250 SCMH | 6 |
| | - Dispenser for car | 12 |
| | - Cascade 2200 Ltrs | 6 |
| III) | **City Gas Distribution Network** | |

| | | |
|---|---|---|
| | Domestic Connections | 67395 |
| | Commercial Connections | 36 |
| | Industrial Connections | 27 |

## 9.1 BREAK FOR CAPITAL EXPENDITURE:

## SUMMARY OF CAPEX FOR ALL FACILTIES OF ELURU CITY GAS PROJECT

Table-9.2 Summary of CAPEX for each facility that are envisaged in the project.

| SL.NO | CATEGORIES | COST IN Crs |
|---|---|---|
| 1 | City Gate station & steel grid pipeline | 25.83 |
| 2 | CNG Stations | 35.46 |
| 3 | District Regulating Stations | 3.66 |
| 4 | Total Connection Cost (Inds, Dom, Commercial) | 2.91 |
| 5 | Others | 0.20 |
| 6 | **Total** | **68.06** |

Total estimated capital cost is 68.06 Crs (Assumed)

**General**

A preliminary capital cost estimate has been prepared for supplying Natural Gas to Eluru City. This comprises steel grid pipeline from City gate station to Eluru city covering various clusters i.e Domestic/ Commercial/ Industrial/ automobile.

The estimated capital cost for putting up the City Gas Distribution project in Eluru works out to **Rs 68.06 Crores.**

**Basis of Cost estimate**

Capital cost based on the facilities as elaborated in earlier chapters for steel gridline, CNG station and city gas distribution network and the following considerations.

**Pipe line**

The Cost for the Primary and Secondary Steel pipe line has been considered.

**Survey & Soil Investigation**

Cost provisions for survey & soil investigation includes the detailed Steel Grid pipeline route survey for the proposed City Gas Project.

**Line Pipe**

Line pipes of specifications **API 5L GR-42** has been considered. Following distribution of area classification has been considered:

Class 4 - With a Design factor of 0.40

A provision of 3% has been considered an account of detouring and failure during hydro testing. ERW pipes are considered indigenous upto 16".

**Line Materials**

Line materials like flow Tee, Insulating Joints, Sectionalizing valves and LR Bends, Scrappers have been included and covered in the above unit rate.

**Pipe Line Coating**

The underground pipe line is proposed to be coated externally with three layer PE coating and epoxy for internal coating.

**Pipe line Laying**

The land along the pipe line route is normal Terrain.

**Cathodic Protection**

Cost of temporary as well as permanent CP system for Steel grid Pipe line for sacrificial anode type, impressed current type and including cost of power source.

**Piping**

The cost of the piping has been estimated based on the factor basis.

**Electrical**

The cost of electrical is based on site requirement.

**Instruments**

The cost of instrument is based on the site requirement.

**Spares**

Provision for spares required for 2 years normal operation has been made equivalent to 5% of equipment cost excluding steel grid pipeline.

**Erection works**

Cost of erection works for equipment and bulk materials is based on percentage of the respective material cost.

**Civil works**

The cost of the civil work is based on site requirement.

**Design, Engineering, Procurement & Construction Supervision**

A cost provision has been made for Design, Engineering, Procurement and Construction supervision charges on percentage basis.

**Start up & commissioning**

Provision has been made for startup & commissioning.

**Contingency**

Contingency provision of 5% for **CGD** project, direct & indirect cost excluding financing charges, working capitals margin and contingency cost has been made.

**CAPEX Phasing-Year Wise**

The Year wise Capital Phasing (in amount & Percentage) is summarized:

Table-9.3 Estimated Year Wise Capital Phasing

| Year | Capital Phasing (in Rs) | Capital Phasing (%) |
|---|---|---|
| 2011 | 24.5016 | 36 |
| 2012 | 20.418 | 30 |
| 2013 | 3.403 | 5 |
| 2014 | 3.403 | 5 |
| 2015 | 4.0836 | 6 |
| 2016 | 3.403 | 5 |
| 2017 | 1.3612 | 2 |
| 2018 | 2.0418 | 3 |
| 2019 | 1.3612 | 2 |
| 2020 | 2.7224 | 4 |
| 2021 | 1.3612 | 2 |
| **Total** | **68.06** | **100** |

## 9.3 OPERATING EXPENSES

The model for the operating expenses has to be further divided into fixed operating expenses and variable operating expenses. At the starting of the project the fixed operating costs will be

more and at the later stage the expenditure will be flat. The variable operating cost will increase with the life of the machinery. Individual cost recovery models has to calculated in case of compressors to replace with the new ones with which the variable operating costs can be reduced. A detailed cost program has to be carried out with the manufacturer once the engineering model is constituted.

### 9.4 Break up for the OPEX

Individual break up for the operating expenditure is not evaluated at this stage, but an average percentage factor of the CAPEX is considered as OPEX at this moment. All necessary escalation factors are considered in order to achieve a better economic model.

### SUMMARY OF OPEX FOR THE FACILTIES OF ELURU CGD

Table-9.4 Summary of CAPEX for each facility that are envisaged in the project.

| SL.NO | CATEGORIES | COST IN Crs |
|---|---|---|
| 1 | City Gate station & steel grid pipeline (@ 15 % of the CAP_CGD) | 3.89 |
| 2 | CNG Stations @ 15% of the CAP_CNG | 5.32 |
| 3 | District Regulating Stations @ 12% of CAP_DRS | 0.44 |
| 4 | Total Connection Cost (Inds, Dom, Commercial) @ 7% of CAP_CON | 0.29 |
| 5 | Others | 0.20 |
| 6 | **Total** | **10.14** |

*(Itemized breakup of the above CAPEX is truly confidential and is a integral part of BGL, hence cannot be provided)*

## 9.5 Fixed operating Expenses:

**Escalation Factors Considered for Operating Costs**

Operating Cost parameters have been inflation indexed.

**Salary & Wages**

Direct cost on account of manpower has been taken as Rs. 2.2 lakh per person on average basis. Indirect cost towards overheads has been considered as 20% of the operating cost. It is estimated that 19 Persons would be required to operate the facilities.

Based on the cost to company, the Salary/ Wages for each employee of the Project have been assumed on per annum basis. The Salary/ Wages have been assumed to increase at the rate of Domestic Inflation as measured by the Consumer Price Index (CPI).

The following Annual salary is assumed value Rs.2750000 has been considered for different category of personnel.

**Insurance**

Insurance cost at the rate of 0.12% of the capital cost has been considered in the operating cost estimates.

## 9.6 Variable operating Expenses

**Repair & Maintenance Expenses**

Repairs & Maintenance Expenses have been considered as5% of the CAPEX and the same have been escalated at the rate of Domestic Inflation as measured by the WPI.

**Power Tariff**

The Power Tariff has been considered at Rs 5.00/ KWHr during the first year of operations and the same has been assumed to escalate at the rate of Domestic Inflation as measured by the Wholesale Price Index (WPI).

Note: This value is taken from the APCPCDL power tariff plan 2010-2011

**Diesel**

Cost towards procurement of diesel for DG sets has been considered under this head at the rate of Rs. 32.79/litre.

**Total Operating Cost Year Wise**

Table 9.5 Summarized total estimated year on year Operating cost

| Year | Capital Phasing (in Rs) | Capital Phasing (%) |
|---|---|---|
| 2011 | 1.2168 | 12 |
| 2012 | 1.521 | 15 |
| 2013 | 1.8252 | 18 |
| 2014 | 1.9266 | 19 |
| 2015 | 0.7098 | 7 |
| 2016 | 0.4056 | 4 |
| 2017 | 0.6084 | 6 |
| 2018 | 0.507 | 5 |
| 2019 | 0.4056 | 4 |
| 2020 | 0.507 | 5 |
| 2021 | 0.507 | 5 |
| **Total** | **10.14** | **100** |

The overall operating expenditure comes around 15 percent of the capital expenditure, which is allowable. Further this cost parameter subjected to market conditions and inflation rates.

### 9.7 Cost recovery rates for the project:

The following are the cost recoveries rate proposed for the projects that are prevailing in other gas distribution project in Delhi. A safety factor of 20% can be considered for the present project for the cost recovery calculations. For all the below calculations a continuous supply of gas for the GAIL is considered at Administrative Pricing Mechanism with is currently at 4.2 $ / MMBtu.

| CNG Pricing details as on February 2011 | | |
|---|---|---|
| **Particulars** | **Unit** | **Delhi** |
| Gas Cost (A) | ₹/Kg | 12.85 |
| Network charges (B) | ₹/Kg | 4.6 |
| Compression Charges (C) | ₹/Kg | 8.66 |
| Corporate Tax (D) | ₹/Kg | 0.23 |
| Marketing Margin (E=F-A-B-C-D) | ₹/Kg | 0.85 |
| Selling Price (F) | ₹/Kg | 25.29 |
| Excise 14.42% | ₹/Kg | 3.66 |
| Consumer Price (charged to customers) | ₹/Kg | 29.00 |
| Source: IGL, ACMIIL Research | | |
| (Note: Refer Annexure-1 for details on Network charges and Compression charges) | | |

| Economics for CNG Station for company owned company operated model | | |
|---|---|---|
| | IGL | New Entrants |
| Cap-ex (₹ Mn For 1 CNG Station) | 100 | 180 |
| EBIT at 20% ROCE (₹ Mn) | 20 | 36 |
| (+) Depreciation (₹ Mn) | 8.8 | 18 |
| (+) Cost of Gas (₹ Mn) | 36.5 | 41.9 |
| (+) Operating Costs (₹ Mn) | 15 | 20 |
| Sales (₹ Mn) | 87 | 120 |
| Sales (Mn Kg/yr) | 3 | 3 |
| Required Selling price (₹/Kg) | 29 | 40 |

Source: Company, ACMIIL Research

| Month | Old price | New price | Reason |
|---|---|---|---|
| Mar-10 | 21.20 | 21.90 | Due to rise in input costs |
| Jun-10 | 21.90 | 27.50 | Increase in APM prices from $1.79 to $4.2 per MMBTU |
| Oct-10 | 27.50 | 27.75 | In light of Exchange Volatility |
| Jan-11 | 27.75 | 29.00 | To pass on the incremental price of high cost R-LNG |

Source: IGL, ACMIIL Research

IGL also raised price of Piped natural gas in Delhi by Rs 2.10 per SCM for domestic households, is a very price sensitive segment with a view to protect its margin. The new consumer proce of PNG to households in Delhi has been raised to Rs 18.95 per SCM from Rs.16.85 per SCM for consumption up to 90 SCM in four months. Beyond 90 SCM of consumption in four months, the applicable rate in Delhi would be Rs. 26 per SCM. We except the PNG prices to increase supported by pending deregulation of LPG prices. However we have factored the same in our projections.

# CONCLUSION

In this endeavor Design of main steel pipeline, polyethylene pipeline, and cost estimation were carried out. Due to confidentiality of the data, only summarized values of the cost estimations are presented

- The total natural gas requirement for Eluru city estimated for around 10 years as 312823.032 SCMD, with 54069 SCMD for domestic purpose, 885.44 SCMD for commercial sector, 239781.6902 SCMD for transportation sector and 18086.90213 SCMD for industrial sector.
- A steel pipeline of varying diameter from 8 to 14 inches is proposed from RIL's compressor station-2 located at Koppaka village considering future demand and mandatory regulations by the PNRGB board are considered.
- An attempt is made to verify the feasibility of the pipeline Network by Newton Nodal Method which results in the divergence; hence a detailed investigation has to be carried out further to balance the network.
- From calculation it is found that Medium Density Polyethylene pipe of grade PE100 with different SDR is having different maximum operating pressure hence we choose the required MDPE line which is suitable for the actual line pressure.
- An Economic model is constructed to explain the feasibility city gas distribution for eluru town in it the total expenditure is divided in to CAPEX and OPEX. The cost recoveries rate proposed for the projects that are prevailing in other gas distribution project in Delhi is considered.

# APPENDIX

## Appendix-A

Table-1

Values of Design Factor F

| Construction Type | Design Factor F |
|---|---|
| Type A | 0.72 |
| Type B | 0.6 |
| Type C | 0.5 |
| Type D | 0.4 |

Reproduced From ANSI/ASME Code B31-8-1982, Table 841.1A

Table-2

Temperature derating factor T for steel Pipe

| Temperature $^0$F | Temperature Derating factor T |
|---|---|
| 250 or less | 1.000 |
| 300 | 0.967 |
| 350 | 0.933 |
| 400 | 0.900 |
| 450 | 0.867 |

Reproduced From ANSI/ASME code B31-8-1982, Table841.1C

Table-3

Longitudinal Joint Factor E

| Spec. Number | Pipe class | E Factor |
|---|---|---|
| ASTM A53 | Seamless | 1.00 |
| | Electric resistance welded | 1.00 |
| | Furnace Welded | 0.60 |
| ASTM A106 | Seamless | 1.00 |
| ASTM A134 | Electric Fusion Arc welded | 0.80 |
| ASTM A135 | Electric resistance welded | 1.00 |
| ASTM A139 | Electric Fusion welded | 0.80 |
| ASTM A211 | Spiral welded steel pipe | 0.80 |
| ASTM A381 | Double submerged -arc-welded | 1.00 |

| | | |
|---|---|---|
| ASTM A671 | Electric Fusion welded | |
| | Classes 13,23,33,43,53 | 0.80 |
| | Classes 12,22,32,42,52 | 1.00 |
| ASTM A672 | Electric Fusion welded | |
| | Classes 13,23,33,43,53 | 0.80 |
| | Classes 12,22,32,42,52 | 1.00 |
| API 5L | Seamless | 1.00 |
| | Electric resistance welded | 1.00 |
| | Electric Flash welded | 1.00 |
| | Submerged Arc welded | 1.00 |
| | Furnace Butt welded | 0.60 |
| API 5LX | Seamless | 1.00 |
| | Electric resistance welded | 1.00 |
| | Electric Flash welded | 1.00 |
| | Submerged Arc welded | 1.00 |
| API 5LS | Electric resistance welded | 1.00 |
| | Submerged Welded | 1.00 |

Reproduced From ANSI/ASME code B31-8-1982, Table841.1B

TABLE-4

PLAIN END LINE PIPE DIMENSIONS, WEIGHT PER UNIT LENGTH, AND TEST PRESSURE FOR SIZES 2 $^{3}/_{8}$ THROUGH 5 $^{9}/_{16}$

| SIZE | SPECIFIED OUT SIDE DIAMETER | SPECIFIED WALL THICKNESS | PIPE-END WEIGHT PER UNIT LENGTH | CALCULATED INSIDE DIAMETER | Maximum test Pressure | |
|---|---|---|---|---|---|---|
| | d (In) | t (in) | w (lb/ft) | d (in) | Grade X42 Std | Alt |
| 4[c] | 4.000 | 0.083 | 3.48 | 3.834 | 1050 | 1310 |
| 4[c] | 4.000 | 0.109 | 4.53 | 3.782 | 1370 | 1720 |
| 4[c] | 4.000 | 0.125 | 5.18 | 3.750 | 1580 | 1970 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4[c] | 4.000 | 0.141 | 5.82 | 3.718 | 1780 | 2220 |
| 4[c] | 4.000 | 0.156 | 6.41 | 3.688 | 1970 | 2460 |
| 4 | 4.000 | 0.712 | 7.04 | 3.656 | 2170 | 2710 |
| 4 | 4.000 | 0.188 | 7.66 | 3.624 | 2370 | 2960 |
| 4 | 4.000 | 0.226 | 9.12 | 3.548 | 2850 | 3560 |
| 4 | 4.000 | 0.250 | 10.02 | 3.500 | 3000 | 3040 |
| 4 | 4.000 | 0.281 | 11.17 | 3.438 | 3000 | 4430 |
| 4 | 4.000 | 0.318 | 12.52 | 3.364 | 3000 | 5010 |
| 4 1/2[c] | 4.500 | 0.083 | 3.92 | 4.334 | 930 | 1160 |
| 4 1/2[c] | 4.500 | 0.125 | 5.85 | 4.250 | 1400 | 1750 |
| 4 1/2[c] | 4.500 | 0.141 | 6.57 | 4.218 | 1580 | 1970 |
| 4 1/2[c] | 4.500 | 0.256 | 7.24 | 4.188 | 1750 | 2180 |
| 4 1/2 | 4.500 | 0.172 | 7.96 | 4.156 | 1930 | 2410 |
| 4 1/2 | 4.500 | 0.188 | 8.67 | 4.124 | 2110 | 2630 |
| 4 1/2 | 4.500 | 0.203 | 9.32 | 4.094 | 2270 | 2840 |
| 4 1/2 | 4.500 | 0.219 | 10.02 | 4.062 | 2450 | 3070 |
| 4 1/2 | 4.500 | 0.237 | 10.80 | 4.026 | 2650 | 3320 |
| 4 1/2 | 4.500 | 0.250 | 11.36 | 4.000 | 2800 | 3500 |
| 4 1/2 | 4.500 | 0.281 | 12.67 | 3.938 | 3000 | 3930 |
| 4 1/2 | 4.500 | 0.312 | 13.97 | 3.876 | 3000 | 4370 |

REPRODUCED FROM APL-5L X SPECIFICATION FOR LINE PIPES, TABLE 6B

TABLE-5

PLAIN END LINE PIPE DIMENSION, WEIGHT PER UNIT LENGTH AND TEST PRESSURES FOR SIZES $6\,^{5}/_{8}$ THROUGH 80

| SIZE | SPECIFIED OUT SIDE DIAMETER | SPECIFIED WALL THICKNESS | PIPE-END WEIGHT PER UNIT LENGTH | CALCULATED INSIDE DIAMETER | Maximum test Pressure | |
|---|---|---|---|---|---|---|
| | d | t | w | d | Grade | X42 |
| | (In) | (in) | (lb/ft) | (in) | Std | Alt |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 5/8 | 6.625 | 0.562 | 36.43 | 5.501 | 3000 | 5340 |
| 6 5/8 | 6.625 | 0.625 | 40.09 | 5.375 | 3000 | 5940 |
| 6 5/8 | 6.625 | 0.719 | 45.39 | 5.187 | 3000 | 6840 |
| 6 5/8 | 6.625 | 0.750 | 47.10 | 5.125 | 3000 | 7130 |
| 6 5/8 | 6.625 | 0.864 | 53.21 | 4.897 | 3000 | 7260 |
| 6 5/8 | 6.625 | 0.875 | 53.78 | 4.875 | 3000 | 7260 |
| 8 5/8 [c] | 8.625 | 0.125 | 11.36 | 8.375 | 910 | 910 |
| 8 5/8 [c] | 8.625 | 0.156 | 14.12 | 8.313 | 1140 | 1140 |
| 8 5/8 | 8.625 | 0.188 | 16.96 | 8.249 | 1370 | 1370 |
| 8 5/8 | 8.625 | 0.203 | 18.28 | 8.219 | 1480 | 1480 |
| 8 5/8 | 8.625 | 0.219 | 19.68 | 8.187 | 1600 | 1600 |
| 8 5/8 | 8.625 | 0.250 | 22.38 | 8.125 | 1830 | 1830 |
| 8 5/8 | 8.625 | 0.277 | 24.72 | 8.071 | 2020 | 2020 |
| 8 5/8 | 8.625 | 0.312 | 27.73 | 8.001 | 2280 | 2280 |
| 10 3/4 [c] | 10.750 | 0.156 | 17.67 | 10.438 | 1040 | 1040 |
| 10 3/4 [c] | 10.750 | 0.188 | 21.23 | 10.374 | 1250 | 1250 |
| 10 3/4 [c] | 10.750 | 0.203 | 22.89 | 10.344 | 1350 | 1350 |
| 10 3/4 | 10.750 | 0.219 | 24.65 | 10.312 | 1450 | 1450 |
| 10 3/4 | 10.750 | 0.250 | 28.06 | 10.250 | 1660 | 1660 |
| 10 3/4 | 10.750 | 0.279 | 31.23 | 10.192 | 1850 | 1850 |
| 10 3/4 | 10.750 | 0.307 | 34.27 | 10.136 | 2040 | 2040 |
| 10 3/4 | 10.750 | 0.344 | 38.27 | 10.062 | 2280 | 2280 |
| 12 3/4 [c] | 12.750 | 0.172 | 23.13 | 12.406 | 960 | 960 |
| 12 3/4 [c] | 12.750 | 0.188 | 25.25 | 12.374 | 1050 | 1050 |
| 12 3/4 [c] | 12.750 | 0.203 | 27.23 | 12.344 | 1140 | 1140 |
| 12 3/4 [c] | 12.750 | 0.219 | 29.34 | 12.312 | 1230 | 1230 |
| 12 3/4 | 12.750 | 0.250 | 33.41 | 12.250 | 1400 | 1400 |
| 12 3/4 | 12.750 | 0.281 | 37.46 | 12.188 | 1570 | 1570 |
| 12 3/4 | 12.750 | 0.312 | 41.48 | 12.126 | 1750 | 1750 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 [c] | 14.000 | 0.188 | 27.76 | 13.624 | 960 | 960 |
| 14 [c] | 14.000 | 0.203 | 29.94 | 13.594 | 1040 | 1040 |
| 14 [c] | 14.000 | 0.210 | 30.96 | 13.580 | 1070 | 1070 |
| 14 [c] | 14.000 | 0.219 | 32.26 | 13.562 | 1120 | 1120 |
| 14 [c] | 14.000 | 0.250 | 36.75 | 13.500 | 1280 | 1280 |
| 14 [c] | 14.000 | 0.281 | 41.21 | 13.438 | 1430 | 1430 |
| 14 | 14.000 | 0.312 | 45.65 | 13.376 | 1590 | 1590 |

REPRODUCED FROM API -5L X SPECIFICATION FOR LINE PIPES, TABLE 6C

TABLE-6

PIPE SIZE DATA FOR COPPER TUBES

| Nominal Pipe size (mm) | PIPE LENGTH (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3.0 | 6.0 | 9.0 | 12.0 | 15.0 | 20.0 | 25.0 | 30.0 |
| | GAS FLOW RATES ($m^3/s$) | | | | | | | |
| 15 | 0.00079 | 0.00054 | 0.00043 | 0.00035 | 0.00032 | 0.00027 | 0.00025 | 0.00024 |
| 22 | 0.00244 | 0.00165 | 0.00126 | 0.00102 | 0.00110 | 0.00079 | 0.00070 | 0.00063 |
| 28 | 0.00495 | 0.00330 | 0.00260 | 0.00220 | 0.00197 | 0.00165 | 0.00142 | 0.00134 |

REPRODUCED FROM ASTM B88M STANDARD SPECIFICATION FOR SEAMLESS COPPERTUBE

TABLE-7

DIMENSIONS OF COPPER TUBES

| NOMINAL SIZE OUTSIDE DIAMETER .(mm) | Wall thickness (mm) | TOLERANCE +/- MAXIMUM DEVIATION AT ANY POINT (mm) | WEIGHT (Kg/m) |
|---|---|---|---|
| 6 | 0.90 | 0.08 | 0.12 |
| 8 | 0.90 | 0.09 | 0.18 |
| 10 | 0.90 | 0.09 | 0.23 |
| 12 | 1.20 | 0.10 | 0.36 |
| 115 | 1.20 | 0.10 | 0.47 |
| 18 | 1.20 | 0.10 | 0.57 |
| 22 | 1.60 | 0.15 | 0.92 |
| 28 | 1.60 | 0.15 | 1.19 |
| 35 | 1.60 | 0.15 | 1.50 |
| 42 | 1.80 | 0.20 | 2.03 |
| 54 | 2.10 | 0.20 | 3.06 |
| 67 | 2.40 | 0.25 | 4.35 |
| 79 | 2.80 | 0.30 | 5.99 |
| 105 | 3.40 | 0.35 | 9.70 |
| 130 | 4.00 | 0.40 | 14.20 |
| 156 | 4.80 | 0.50 | 20.30 |
| 206 | 6.80 | 0.70 | 38.00 |
| 257 | 8.50 | 0.85 | 59.30 |
| 308 | 10.30 | 1.00 | 86.10 |

REPRODUCED FROM ASTM B88M, STANDARD SPECIFICATION FOR SEAMLESS COPPER TUBES

TABLE-8

PRESSURE RATED MDPE YELLOW PIPES

| IPS PIPE SIZE | O.D ACTUAL | | IPS DR 7 | IPS DR 9 | IPS DR 9.3 | IPS DR 10 | IPS DR 11 | IPS DR 11.5 | IPS DR 13.5 |
|---|---|---|---|---|---|---|---|---|---|
| 1/2" | 0.840 | Min. wall thickness | 0.12 | 0.09 | 0.09 | | 0.08 | | 0.06 |
| | | Wt. per 100 | 11.80 | 9.70 | 9.50 | | 8.30 | | 7.10 |
| 3/4" | 1.050 | Min. wall thickness | 0.15 | 0.12 | 0.11 | | 0.10 | | 0.06 |
| | | Wt. per 100 | 18.20 | 15.00 | 14.60 | | 12.70 | | 7.10 |
| 1" | 1.315 | Min. wall thickness | 0.19 | 0.15 | 0.14 | | 0.12 | | 0.08 |
| | | Wt. per 100 | 28.50 | 23.10 | 22.50 | | 19.70 | | 10.80 |
| 1-1/4" | 1.660 | Min. wall thickness | 0.24 | 0.18 | 0.18 | 0.17 | 0.15 | | 0.10 |
| | | Wt. per 100 | 45.30 | 36.60 | 35.50 | 33.40 | 30.90 | | 16.50 |
| 1-1/2" | 1.900 | Min. wall thickness | 0.27 | 0.21 | 0.20 | | 0.17 | | 0.12 |
| | | Wt. per 100 | 59.40 | 48.00 | 46.60 | | 40.30 | | 26.00 |
| 2" | 2.375 | Min. wall thickness | 0.34 | 0.26 | 0.26 | 0.24 | 0.22 | | 0.14 |
| | | Wt. per 100 | 92.80 | 75.10 | 72.90 | 68.60 | 62.90 | | 33.80 |
| 3" | 3.500 | Min. wall thickness | 0.50 | 0.39 | 0.38 | | 0.32 | 0.30 | 0.26 |
| | | Wt. per foot | 2.02 | 1.63 | 1.58 | | 1.37 | 1.30 | 1.13 |
| 4" | 4.500 | Min. wall thickness | 0.64 | 0.50 | 0.48 | | 0.41 | 0.39 | 0.33 |
| | | Wt. per foot | 3.33 | 2.69 | 2.62 | | 2.30 | 2.20 | 1.87 |

REPRODUCED FROM ASTM D2513 , STANDARD SPECIFICATION FOR TERMOPLASTICS GAS PRESSURE PIPE, TUBING AND FITTI

## APPENDIX B

## LIST OF PIPING SPECIFICATIONS USED IN CGD NETWORKS

**STEEL PIPES**

| | |
|---|---|
| API 5L: | Specification for line pipes. |
| ASTM:A106 | Seamless Carbon Steel Pipe which is for High Temperature Service. |
| ASTM:A333 | Seamless and Welded Steel Pipe which is for Low-Temperature Service. |

**MDPE PIPES FOR U/D GAS SERVICES**

| | |
|---|---|
| ASME B 31.8: | Gas Transmission and Distribution Piping systems |
| ISO 4431: | Buried polyethylene (PE) pipes for the supply of gaseous fuels. |
| ASTM D2513 | Standard specification for thermoplastics gas pressure pipe, tubing and fittings. |

**COPPER TUBES**

| | |
|---|---|
| BS EN 1057: | Copper and copper alloys. Seamless, round copper tubes which are used for water and gas in sanitary and heating applications. |

**VALVES**

| | |
|---|---|
| API 6D: | Pipeline Valves |
| ASME B16.34 : | Flanged valves, threaded and welding end |
| BS 5352: | Specification for globe valve, steel wedge gate and check valves 50 mm & smaller for the petroleum, petrochemical and allied industries |
| BS 5351: | Specification for steel ball valves for the petrochemical, petroleum and allied industries |
| BS 1873: | Specification for steel globe, globe stop and check valves (flanged and butt-welding ends) for the petrochemical, petroleum and allied industries. |

**FITTINGS**

| | |
|---|---|
| ASME B16.9: | Factory-Made Wrought steel butt welding fittings. |
| IS 1239: | Steel tubes, tubular and other wrought steel fittings. |

**Pressure safety equipment**

| | |
|---|---|
| EN 334: | Gas pressure regulators for inlet pressures up to 100 bar. |
| EN 14382: | Safety devices for gas pressure regulating stations and installations. |
| API 526: | Flanged steel pressure relief valves. |

**Copper fittings**

| | |
|---|---|
| BS EN 1254: | Copper and copper alloys. Fittings with ends for capillary soldering or capillary brazing to copper tubes. |

**Plastic Valves**

| | |
|---|---|
| ASME B16.40 : | Manually operated thermoplastic gas shutoffs and valves in gas distribution systems. |

**Brass Ball Valves**

| | |
|---|---|
| BS EN 331: | Manually operated ball valves and closed bottom taper plug valves for gas installations in buildings. |

## Appendix – C

## Model Calculations

### Diameter of pipe, Discharge Pressure, Average velocity of gas, Reynold Number, & Friction factor calculation

| S.no | Inputs | | Units | | |
|---|---|---|---|---|---|
| 1 | Demand or $Q_{standard}$ | 312823.44 | SCMD | | |
| 2 | Inlet Pressure $P_{actual}$ | 19 | bars | 1900 | Kpa |
| 3 | Operating Temperature $T_{actual}$ | 30 | $^0C$ | 303 | K |
| 4 | Base Pressure $P_{standard}$ | 2 | Bars | 200 | Kpa |
| 5 | Base Temperature $T_{standard}$ | 15 | $^0C$ | 288 | K |
| 6 | Compresibility Factor | 0.97 | | | |
| 7 | Viscosity | 0.000012 | Pa-sec | 0.00012 | Poise |
| 8 | Length of the Pipeline | 24 | KM | | |
| | AB | 4.5 | KM | | |
| | BC | 3.1 | KM | | |
| | CD | 2.3 | KM | | |
| | DE | 5.2 | KM | | |
| | BF | 6.1 | KM | | |
| | EF | 2.8 | KM | | |
| 9 | Friction factor | 0.01 | | | |
| 10 | Gas gravity G | 0.58 | | | |
| 11 | Density of Natural Gas | 0.9 | $Kg/m^3$ | | |
| | $\frac{P_{standard}\,Q_{standard}}{T_{standard}} = \frac{P_{actual}\,Q_{actual}}{T_{actual} \times Z}$ | | | | |
| 12 | $Q_{actual}$ | 33604.50923 | $m^3/day$ | 0.51858811 | $m^3/sec$ |
| | | | | | |
| 13 | **Calculation of Diameter of the Pipe** | | | | |
| | Q=A*V | | | | |
| | Velocity of gas (Assumed) | 8 | m/sec | | |
| | Area of the pipe | 0.064823513 | $m^2$ | | |
| | Diameter of the pipe | 0.28729055 | m | 11.3106516 | Inches |
| | **Assumed Diameter of the Pipe be** | **0.32385** | **m** | **12.75** | **Inches** |
| | | **323.85** | **mm** | | |
| 14 | **Calculation of Average Velocity of gas in the pipe** | | | | |
| | $u = 14.7349\left(\frac{Q_b}{D^2}\right)\left(\frac{P_b}{T_b}\right)\left(\frac{ZT}{P}\right)$ | | | | |
| | $u$ = gas velocity, m/s<br>$Q_b$ = gas flow rate, measured at standard conditions, $m^3/day$<br>$D$ = pipe inside diameter, mm<br>$P_b$ = base pressure, kPa<br>$T_b$ = base temperature, K(273 + °C)<br>$P$ = pressure, kPa<br>$T$ = average gas flowing temperature, K(273 + °C)<br>$Z$ = gas compressibility factor at the flowing temperature, dimensionless | | | | |
| | Velocity of gas | **4.72124945** | | | |

| | | | | | |
|---|---|---|---|---|---|
| 15 | **Calculation of Reynold Number** | | | | |
| | $Re = 0.5134\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right)$ | | | | |
| | Where | | | | |
| | $Re$ = Reynolds number, dimensionless<br>$u$ = average velocity of gas in pipe, m/s<br>$D$ = inside diameter of pipe, m<br>$\rho$ = gas density, kg/m³<br>$\mu$ = gas viscosity, kg/m-s | | | | |
| | Reynold Number | **1664544867** | | | |
| | | | | | |
| 16 | Calculation of Friction factor | | | | |
| | $\frac{1}{\sqrt{f}} = 1.14 - 2\log\left(e_D + \frac{21.25}{N_{Re}^{0.9}}\right)$ | | | | |
| | e/D | **0.000141176** | | | |
| | 1/√f | **8.839819092** | | | |
| | √f | **0.113124487** | | | |
| | f | **0.01279715** | | | |
| 17 | **Calculation of Discharge Pressure** | | | | |
| | $Q = 1.1494 \times 10^{-3}\left(\frac{T_b}{P_b}\right)\left[\frac{(P_1^2 - P_2^2)}{GT_f LZf}\right]^{0.5} D^{2.5}$ | | | | |
| | Where | | | | |
| | $p_1$ | upstream pressure, kPa | | | |
| | $p_2$ | downstream pressure, kPa | | | |
| | $T_f$ | average gas flowing temperature, K (273+$^0$c) | | | |
| | L | pipe segment length, km | | | |
| | D | Inside diameter in mm | | | |
| | (G*$T_f$*L*Z*f)^0.5 | 3.133170709 | | | |
| | ($p_1^2$-$p_2^2$)^0.5 | 313.7544593 | | | |
| | ($p_1^2$-$p_2^2$) | 98441.8607 | | | |
| | $p_2^2$ | 3511558.139 | | | |
| | $p_2$ | 1873.91519 | Kpa | | |
| | **Change in pressure** | **26.08481** | Kpa | | |
| | | | | | |

## Wall Thickness calculations

| | | | | | |
|---|---|---|---|---|---|
| **A) PRESSURE CONFINEMENT CRITERIA :** | | | | | |
| Nominal wall thickness | t = | PD / 2S FET | | ( As Per Cl 841.11 of ASME B 31.8) | |
| P - | Design pressure | | = | **5** | MPag |
| D - | Nominal outside diameter | | = | **219.075** | mm |
| S - | SMYS of pipe material (API 5L X-42) PSL2 | | = | **290** | Mpa |
| F - | Design factor as per table 841.114A | | = | **0.6** | |
| | **(For class 2)** | | | | |
| E - | Longitudinal joint factor as per table 841.115A | | = | **1** | |
| T - | Temperature derating factor as per table 841.116A | | = | **1** | |
| | **( For Design temp = 60°C )** | | | | |
| t - | Nominal wall thickness | | = | 3.15 | mm |
| CA - | Corrssion allowance | | = | **0.5** | mm |
| Nominal wall thickness | | t + CA | = | 3.65 | mm |
| Closest Higher Wall Thickness as per API 5L(Table E-6B) | | | = | 6.35 | mm |
| Selected wall thickness as per API 5L(Table E-6B) | | | = | **6.35** | mm |
| | | | | | |
| **B) At public road crossings without casing** | | | | | |
| ( Adjoining higher class thickness as per GSPL Minimum Functional Specifications) | | | | | |
| Design factor, F | | | = | 0.5 | |
| Wall thickness, t | | | = | 3.78 | mm |
| Closest Higher Wall Thickness as per API 5L(Table E-6B) | | | = | 6.35 | mm |
| Selected wall thickness as per API 5L(Table E-6B) | | | = | **6.35** | mm |

## Newton NOdak Network Analysis

*INITIAL CONDITIONS*

| | | | | | DEL P | P1 | 19 |
|---|---|---|---|---|---|---|---|
| Q1 | L4 | 84 | K1 | 0.000529 | 3.732298 | P5 | 15.27 |
| Q2 | L1 | 61 | K2 | 0.0002688 | 1.000252 | P2 | 18 |
| Q3 | L2 | 72 | K3 | 0.0001994 | 1.033905 | P3 | 16.97 |
| Q4 | L3 | 73 | K4 | 0.0004509 | 2.402907 | P4 | 14.56 |
| Q5 | | | K5 | 0.0002428 | | | |

| **literation-1** | | | | | |
|---|---|---|---|---|---|
| **BRANCH** | **1** | **2** | **3** | **4** | **5** |
| Q | 84 | 61 | 72 | 73 | 53.876512 |
| DELP | 3.732298 | 1.000252 | 1.03391 | 2.402907 | 0.7047658 |
| Q/DELP | 22.50624 | 60.98466 | 69.6389 | 30.37987 | 76.445976 |
| | | | | | |
| **NODE-2** | | | | | |
| DISCREPENCY | $f_2^0$ | $J_{22}^0$ | $(J_{22}^0)^{-1}$ | DEL $P_2^0$ | $P_2^1$ |
| | -72 | -65.31177 | -0.01531 | -1.1024 | 16.897344 |
| Q2 | 88.44216 | | | | |
| Q3 | -18.53258 | | | | |
| NEW BRANCH QUANTITIES | | | | | |
| **BRANCH** | **1** | **2** | **3** | **4** | **5** |
| Q | 84 | 88.44216 | -18.5326 | 73 | 53.876512 |
| DELP | 3.732298 | 2.102656 | 0.0685 | 2.402907 | 0.7047658 |
| Q/DELP | 22.50624 | 42.06211 | -270.551 | 30.37987 | 76.445976 |
| | | | | | |
| **NODE-3** | | | | | |
| DISCREPENCY | $f_3^0$ | $J_{33}^0$ | $(J_{33}^0)^{-1}$ | DEL $P_3^0$ | $P_3^1$ |
| | -163.5326 | 120.0854 | 0.00833 | 1.361803 | 18.327646 |
| Q4 | 91.37347 | | | | |
| NEW BRANCH QUANTITIES | | | | | |
| **BRANCH** | **1** | **2** | **3** | **4** | **5** |
| Q | 84 | 88.44216 | -18.5326 | 91.37347 | 53.876512 |
| DELP | 539402.8 | 2.102656 | 0.0685 | 20062.14 | 0.7047658 |

| | | | | | |
|---|---|---|---|---|---|
| Q/DELP | 0.000156 | 42.06211 | -270.551 | 0.004555 | 76.445976 |
| | | | | | |
| **NODE-4** | | | | | |
| DISCREPENCY | $f_4^0$ | $J_{44}^0$ | $(J_{44}^0)^{-1}$ | DEL $P_4^0$ | $P_4^1$ |
| | 72.24999 | -38.22527 | -0.02616 | 1.890111 | 16.453047 |
| Q5 | -69.8714 | | | | |
| NEW BRANCH QUANTITIES | | | | | |
| **BRANCH** | **1** | **2** | **3** | **4** | **5** |
| Q | 84 | 88.44216 | -18.5326 | 91.37347 | -69.8714 |
| DELP | 4972.828 | 2.102656 | 0.0685 | 3.76471 | 1.185345 |
| Q/DELP | 0.016892 | 42.06211 | -270.551 | 24.27105 | -58.94604 |
| | | | | | |
| **Node-5** | | | | | |
| DISCREPENCY | $f_5^0$ | $J_{55}^0$ | $(J_{55}^0)^{-1}$ | DEL $P_5^0$ | $P_5^1$ |
| | 69.8714 | 29.46458 | 0.03394 | -2.37137 | 12.896333 |
| Q1 | 107.4204 | | | | |
| NEW BRANCH QUANTITIEs | | | | | |
| **BRANCH** | **1** | **2** | **3** | **4** | **5** |
| Q | 107.4204 | 88.44216 | -18.5326 | 91.37347 | -69.8714 |
| DELP | 8132.386 | 2.102656 | 0.0685 | 3.76471 | 1.185345 |
| Q/DELP | 0.013209 | 42.06211 | -270.551 | 24.27105 | -58.94604 |

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