DEVELOPMENT OF GAS DISTRIBUTION SYSTEM IN INDIA

A thesis submitted in partial fulfilment 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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CERTIFICATE

This is to certify that the work contained in this thesis titled "**DEVELOPMENT OF GAS DISTRIBUTION SYSTEM IN INDIA**" has been carried out by **NEELIMA ALFRED** under my/our supervision and has not been submitted elsewhere for a degree.

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Date 7-5-10

ABSTRACT

Natural Gas is fast emerging as the most important energy source of the future. The abundance of natural gas, worldwide as well as in India, coupled with its environmental soundness and multiple applications along several sectors, signifies its increasingly important role in the near future for meeting energy demand. Natural Gas is now being quoted as the fuel of the 21st century.

Increasing costs for petroleum products and the volatility of prices have now lead many customers to look for more sophisticated ways to understand and control their demand in real time. These increasing costs and pollution by petroleum products have lead different customers to find a replacement for the existing fuels. These consequences have found to be overcome by Natural Gas, which has lead to gas distribution in various cities of the country catering all essential segments targeting mainly on transport segment.

Various cities in different states of India have already implemented City Gas Distribution. And it is found to catch a great pace in other states of the country in the upcoming years. Segments such as industrial, commercial, transport and Domestic are being supplied Piped Natural Gas and Compressed Natural Gas respectively as clean fuel.

ACKNOWLEDGEMENT

I am greatly indebted to my guide **Mr. Prabodh Kr. Bahl** for providing me an opportunity to work under his guidance. His unflinching support, suggestions and directions have helped me in smooth progress of the project work. He has been a constant source of inspiration in all possible ways for successful completion of my project work.

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NEELIMA ALFRED

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AGA: American Gas Association

ANSI: American National Standard Institute

API: American Petroleum Institute

ASME: American Society of Mechanical Engineers

BTU: British Thermal Unit

CCOE: Chief Controller of Explosives

CGS: City Gas Station

CGD: City Gas Distribution

CNG: Compressed Natural Gas

DRS: District Regulatory Station

GI: Galvanised Iron

IPRS: Industrial Pressure Regulating Station

ISO: Indian Standard Organization

LNG: Liquefied Natural Gas

MAOP: Maximum Allowable Operating Pressure

MDPE: Medium Density Polyethylene

MMSCMD: Million Metric Standard Cubic Meters per Day

MMTPA: Million Metric Tones per Annum

MRS: Meter Regulating Station

ND: Nominal Diameter

OISD: Oil India Safety Directorate

PVC: Pressure Control Valve

PNG: Piped Natural Gas

PNGRB: Petroleum & Natural Gas Regulatory Board

PSV: Pressure Safety Valve

ROU: Right of Use

CHAPTER - 1

INTRODUCTION TO CGD SYSTEM

1.1 Overall View

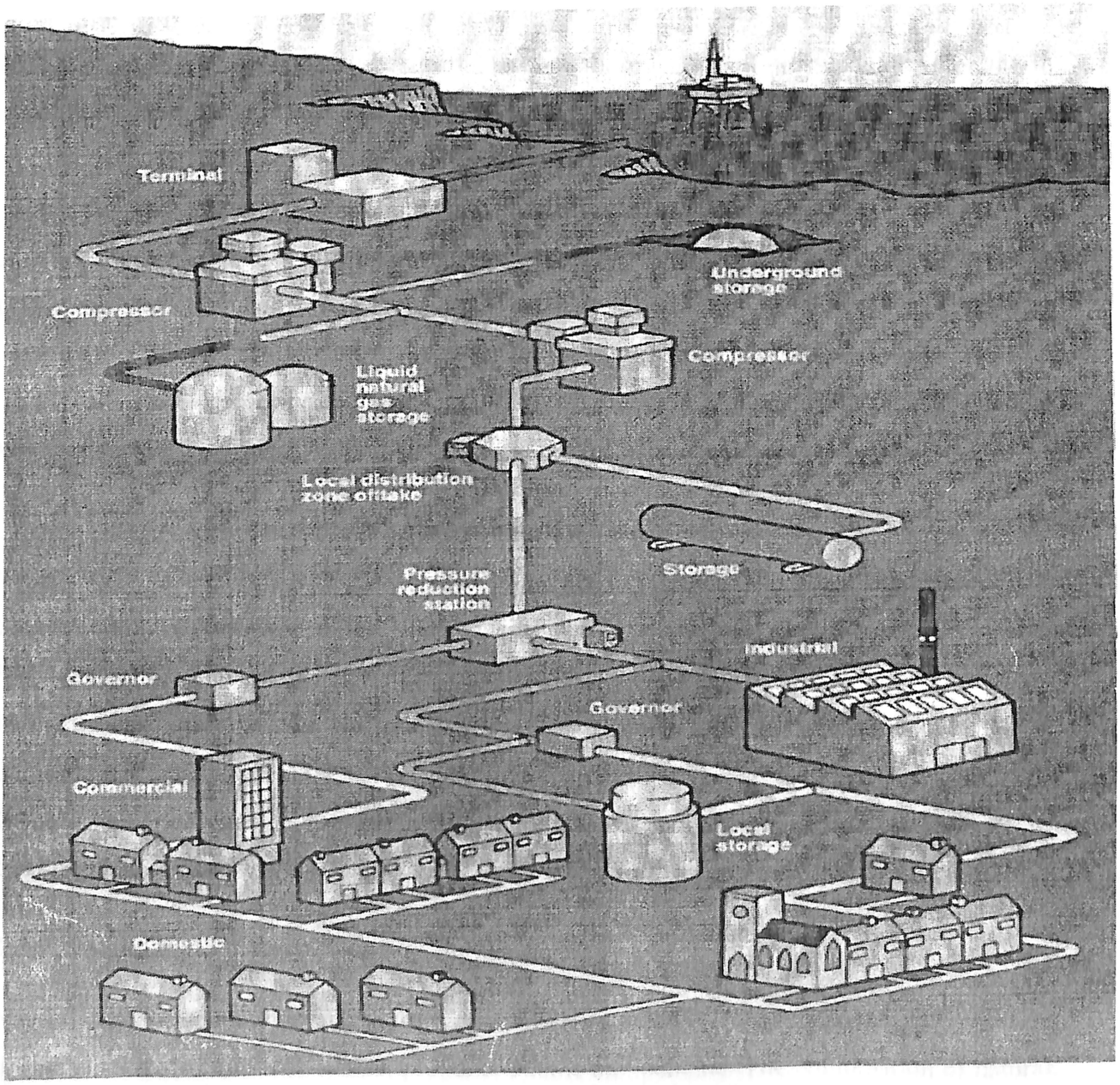


Figure 1. Overall View of gas distribution system

1.2 City Gas Distribution In India

Oil India Limited was first to start distribution of gas in Assam in 1960's. In Gujarat, Oil and Natural Gas Corporation (ONGC) started selling its associated gas to the neighbouring industries in 1970's. With the find of Oil / Gas at Mumbai high, supply of gas commenced to industrial consumers around Mumbai like MSEB, Tata and RCF. The gas pipeline networks were laid / owned by either ONGC or the customers.

With the gas discovery in south basin of Mumbai shores, the first cross country pipeline in India was conceptualized with Hazira as the landfall point in Gujarat. Gas Authority of India (GAIL) was formed in 1984, to act as a nodal agency for natural gas in India. Gail constructed and operated the pipeline, which ran from Hazira to Jagdishpur via Bijaipur. The pipeline supplied gas to the fertilizer and power sector. Thereafter, entire existing assets of ONGC and development of new networks were transferred to GAIL. As a pilot project city gas distribution project was taken up with the help of ONGC at Vadodara city in 1972. Historically due to scarcity of natural gas vis a vis demand, the supply to other cities like Mumbai and Delhi, projects did not take off in absence of adequate gas allocation.

Gujarat gas Company Ltd. (GGCL) was the first commercial city gas distribution company in India. GGCL currently under British Gas Management developed distribution network in Bharuch and Ankleshwar cities. Subsequently, they expanded their network to Surat. Mahanagar Gas Limited (MGL) started city gas distribution to domestic, commercial and industrial customers in Mumbai in 1995. The focus of the company was to supply gas to domestic households and in an event to surplus cater to the industrial demand. Indraprastha Gas Limited (IGL) started city gas distribution to domestic, commercial and transport sector customers in Delhi in 1998. The focus of the company was to supply gas to transport sector.

1.3 Introduction to Natural Gas

Natural gas is a flammable mixture of hydrocarbon gases. Natural gas is primarily composed of methane; it also includes ethane, propane, butane and pentane. The composition of natural gas is different at different places. It depends on the characteristics of the soil and the surrounding environment. The chart below shows the composition of the Natural Gas before it is processed. Natural gas is colourless, shapeless, and odourless in its pure form.

Table 1.Composition of Natural Gas

Typical Composition of Natural Gas		
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	trace

Natural gas is considered to be 'dry' when it is almost pure methane, with commonly associated hydrocarbons removed. The natural gas is 'wet' when other hydrocarbons are present.

Natural gas is considered to be 'sweet' when the sulphur content in the gas is low and 'sour' when the sulphur content is high.

Volume of gas is measured in ft^3 in USCS units and m^3 in SI units. Other units for volume include thousand ft^3 (Mft3) and million ft^3 ($MMft^3$) in USCS units and thousand m^3 (km^3) and million m^3 (Mm^3) in SI units. When referred to standard conditions (also called base conditions) of temperature and pressure (60°F and 14.7 psia in USCS units), the volume is stated as standard volume and, therefore, measured in standard ft^3 (SCF) or million standard ft^3 (MMSCF). It must be noted that in the USCS units, the practice has been to use M to represent a thousand, and therefore MM refers to a million. While measuring by volume is useful, natural gas can also be measured as a source of energy. Like other forms of energy, natural gas is commonly measured and expressed in British thermal units (Btu). One Btu is the amount of natural gas that will produce enough energy to heat one pound of water by one degree at normal pressure. Roughly 0.02832 cubic meters of natural gas contains about 1,027 Btus.

1.4 How Natural Gas is formed

Many thousand years ago, the remains of plants and animals decayed buried in the soil built up in thick layers. This decayed and spoilt matter of plants and animals is called organic matter. Over time, the soil changed to rock and covered the organic matter and trapped it under the rock. The variation in Pressure and Temperature changed the organic material into coal, some into oil (petroleum), and some into natural gas. The main composition of natural gas is methane (CH_4).

Natural gas is found deep underground like other fossil fuels. A formation of rock called "gas trap" causes the natural gas to form and collect. A trap contains three kinds of rock. The fossilized rock that produces the natural gas is called "source rock". The porous rock through which the natural gas seeps as it rises above is called the "reservoir rock". The layer of very dense rock above the reservoir rock that prevents the gas from escaping to the surface is called the "cap rock".

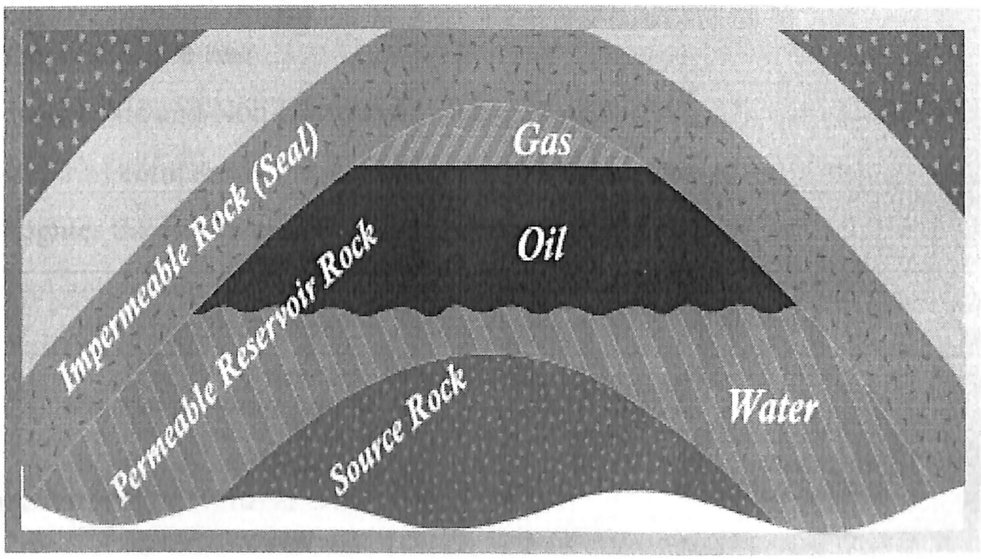


Figure 2. Natural Gas under Earth's Crust

Gas sometimes escapes from small gaps in the rocks into the environment, if there is sufficient source of ignition present in the form of lightning or a fire, it burns. In earlier days when people saw these flames out of curiosity they started experiments and learnt that they could use the gas that caused these flames for heat and light. Hence the exploration and utilization of Natural Gas began. Now, we have very sophisticated technologies that enable us to explore for Natural Gas in an efficient and environmentally friendly manner.

1.5 Priority Sector of Natural Gas Usage

- Power
- Fertilizer
- Industrial
- City gas (Commercial and Domestic)Transport

The transport sector uses natural gas as Compressed Natural Gas (CNG), while the Domestic, Commercial and Industrial sectors use it as Piped Natural Gas (PNG).

1.6 Why Natural Gas

- Eco-friendly fuel
- No Adulteration
- No Pilferage
- Increases Engine Life & reduces maintenance cost
- Cost Effective fuel
- Non Toxic and Non Corrosive
- Safer as compared to liquid fuels
- Lighter than air in case of leak no dangerous puddles
- Unlikely to ignite highest ignition temperature
- Safer than LPG
- No delivery problems unlike LPG

1.7 Indian Scenario of Natural Gas

The natural gas sector in India has gained importance, particularly over the last decade, and is being termed as the Fuel of the 21st Century. Production of natural gas, which was almost negligible at the time of independence, is at present at the level of around 87 million standard cubic meters per day (MMSCMD). The main producers of natural gas are Oil & Natural Gas Corporation Ltd. (ONGC), Oil India Limited (OIL) and JVs of Tapti, Panna-Mukta and Ravva. Under the Production Sharing Contracts, private parties from some of the fields are also producing gas. Government have also offered blocks under New Exploration Licensing

Policy (NELP) to private and public sector companies with the right to market gas at market determined prices

Out of the total production of around 87 MMSCMD, after internal consumption, extraction of LPG and unavoidable flaring, around 74 MMSCMD is available for sale to various consumers.

Most of the production of gas comes from the Western offshore area. The on-shore fields in Assam, Andhra Pradesh and Gujarat States are other major producers of gas. The KG basin is another major of natural gas, having a potential of 40MMSCMD which will go up to 80 MMSCMD in the near future. Smaller quantities of gas are also produced in Tripura, Tamil Nadu and Rajasthan States. OIL is operating in Assam and Rajasthan States, whereas ONGC is operating in the Western offshore fields and in other states. The gas produced by ONGC and a part of gas produced by the Joint Venture (JV) consortiums is marketed by the GAIL (India) Ltd. The gas produced by OIL is marketed by OIL itself except in Rajasthan where GAIL is marketing its gas. Gas produced by Cairn Energy from Lakshmi fields and Gujarat State Petroleum Corporation Ltd. (GSPCL) from Hazira fields is being sold directly by them at market determined prices.

Natural gas has been utilised in Assam and Gujarat since the sixties. There was a major increase in the production & utilisation of natural gas in the late seventies with the development of the Bombay High fields and again in the late eighties when the South Basin field in the Western Offshore was brought to production.

The gas produced in the western offshore fields is brought to Uran in Maharashtra and partly in Gujarat. The gas brought to Uran is utilised in and around Mumbai. The gas brought to Hazira is sour gas which has to be sweetened by removing the sulphur present in the gas. After sweetening, the gas is partly utilised at Hazira and the rest is fed into the Hazira-Bijaipur-Jagdhishpur(HBJ) pipeline which passes through Gujarat, MadhyaPradesh, Rajasthan, U.P., Delhi and Haryana. The gas produced in Gujarat, Assam, etc; is utilised within the respective states.

Natural Gas is currently the source of half of the LPG produced in the country. LPG is now being extracted from gas at Duliajan in Assam, Bijaipur in M.P., Hazira and Vaghodia in Gujarat, Uran in Maharashtra, Pata in UP and Nagapattinam in Tamil Nadu. Two new plants

have also been set up at Lakwa in Assam and at Ussar in Maharastra in 1998-99. One more plant is being set up at Gandhar in Gujarat. Natural gas containing C2 C3, which is a feedstock for the Petrochemical industry, is currently being used at Uran for Maharashtra Gas Cracker Complex at Nagothane. GAIL has also set up a 3 lakh TPA of Ethylene gas based petrochemical complex at Auraiya in 1998-99.

1.8 Liquefied Natural Gas (LNG)

Natural gas at **minus 161^{0}C** transforms into liquid. This is done for easy storage and transportation since it reduces the volume occupied by gas by a factor of 600. LNG is transported in specially built ships with cryogenic tanks. It is received at the LNG receiving terminals and is regassified to be supplied as natural gas to the consumers. LNG projects are highly capital intensive in nature. The whole process consists of five elements:-

- # Dedicated gas field development and production.
- # Liquefaction plant.
- # Transportation in special vessels.
- # Regassification Plant.
- # Transportation & distribution to the Gas consumer.

LNG supply contracts are generally of long term nature and the prices are linked to the international crude oil prices. However, the LNG importing countries in recent times had started asking for medium/short term contracts with varying linkages.

1.9 Gas Pricing

The country has traditionally operated under an Administered Pricing Mechanism (APM) for petroleum products. This system is based on the retention price concept under which the oil refineries, oil marketing companies and the pipelines are compensated for operating costs and are assured a return of 12% post-tax on net worth. Under this concept, a fixed level of profitability for the oil companies is ensured subject to their achieving their specified capacity utilisation. Upstream companies, namely ONGC, oil and GAIL, are also under retention price concept and are assured a fixed return.

The administered pricing policy of petroleum products ensures that products used by the vulnerable sections of the society, like kerosene, or products used as feed stocks for production of fertilizer, like naphtha, may be sold at subsidized prices.

Gradually, the Government of India is moving away from the administered pricing regime to market-determined, tariff-based pricing. Free imports are permitted for almost all petroleum products except petrol and diesel. Free imports are permitted for almost all petroleum products except petrol and diesel. Free marketing of imported kerosene, LPG and lubricants by private parties is permitted. It is contemplated that in a phased manner, all administered price products will be taken out of the administered pricing regime and the system will be replaced by a progressive tariff regime in order to provide a level playing field for new investments in a free and competitive market

Prior to 1987, gas prices were fixed by ONGC/OIL. The price is being fixed by Government w.e.f. 30.1.1987. The price of APM gas of ONGC and OIL was last revised effective 1.7.2005.

1.10 Feasibility of City Gas Distribution project

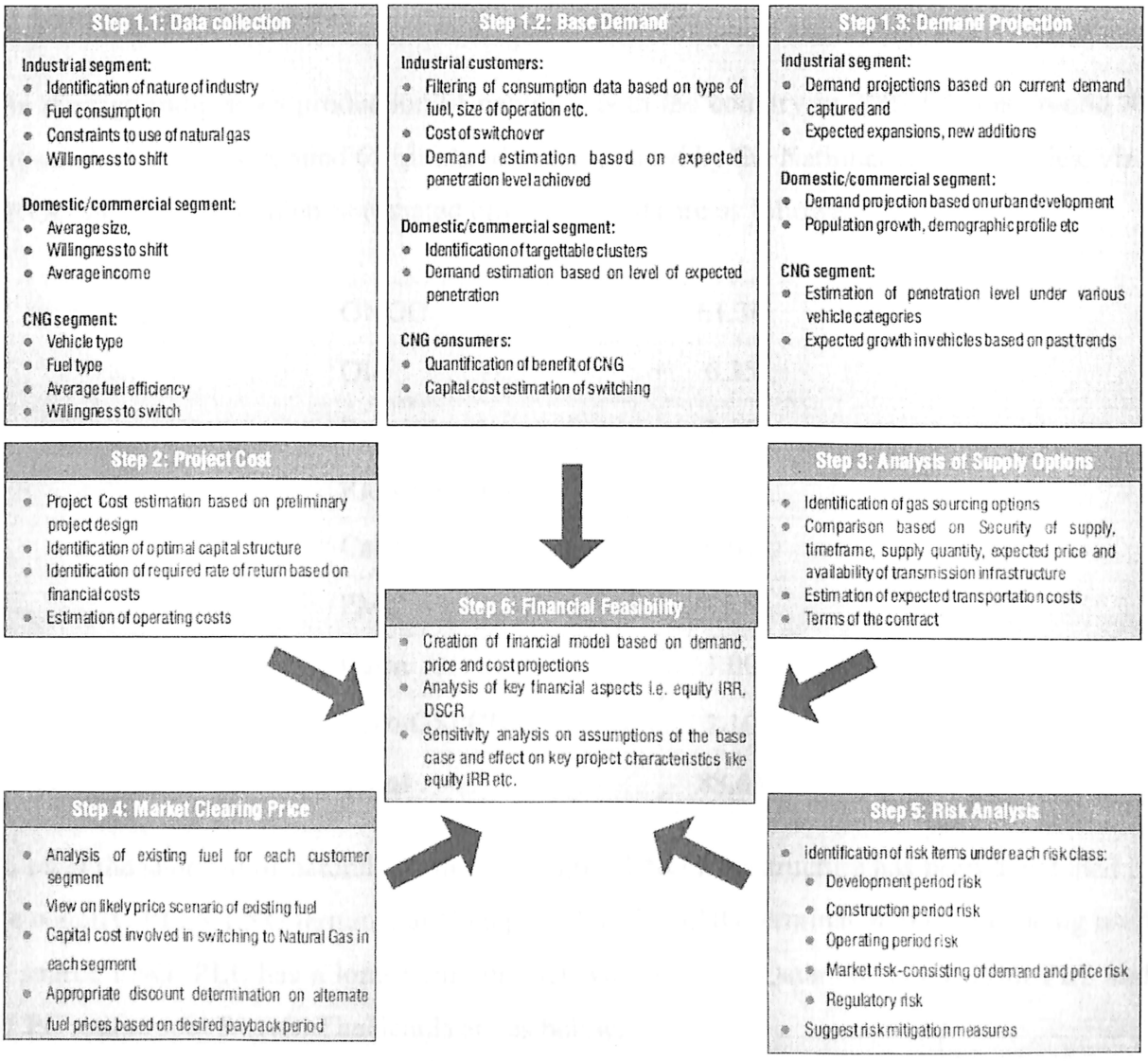


Figure 3. Feasibility Diagram of CGD Project

CHAPTER - 2

AVAILABILITY, DEMAND AND SUPPLY

2.1 Natural Gas Availability

The average indigenous production of natural gas in the country in 2007-08 was around 89 mmscmd. Out of this, around 68 mmscmd was produced by the National Oil Companies, viz., ONGC and OIL, from their nominated blocks. Details are as follows:-

ONGC	61.30
OIL	6.35
Ravva 1	1.05
Ravva Satellite	1.02
Canaro	0.01
PMT	15.8
Cairn	1.00
Niko/GSPCL	2.10
Total	**88.63**

To meet the shortfall of natural gas in the country, LNG infrastructure has been developed in the country. PLL's LNG terminal at Dahej and HLPL's LNG terminal at Hazira is being used to source LNG. PLL has a long term contract with RasGas, Qatar for LNG. Both PLL and HLPL source spot RLNG. The details are as below:-

PLL RLNG	20.41
PLL Spot RLNG	3.20
Shell LNG	2.50
Total	**26.11**

So the total natural gas available in the country is 114.74 mmscmd. After internal consumption and flaring, the natural gas available for distribution in the country is 102.68 mmscmd as follows:-

Sector wise breakup	Avg Supply (in mmscmd)	Percentage
Power	36.52	36
Fertilizer	29.66	29
Sponge Iron	5.33	5
PC + LPG + IC	10.20	10
City Gas & CNG	4.43	4
Industry & others	16.54	16
Total	**102.68**	**100**

2.2 Natural Gas Supply Demand Scenario

Demand

As per the "Natural Gas Working Group for the Tenth Five-Year Plan", in 2006-2007, the domestic gas demand is of the order of 197MMSCMD. This will imply that the domestic production of natural gas along with the imported LNG will match the domestic demand.

Consolidated Sector wise gas Demand Projection in XI Plan

Table 2. Consolidated Sector wise gas Demand Projection in XI Plan

Sector	2007-08	2008-09	2009-10	2010-11	2011-12
Power	79.70	91.20	102.70	114.20	126.57
Fertilizer	41.02	42.89	55.90	76.26	76.26
City Gas	12.08	12.93	13.83	14.80	15.83
Industrial	15.00	16.05	17.17	18.38	19.66
Petrochemical / Refineries / Internal Consumption	25.37	27.15	29.05	31.08	33.25
Sponge Iron / Steel	&00	6.42	6.87	7.35	7.86
Total	**179.17**	**196.64**	**225.52**	**262.07**	**279.43**

Supply

Natural gas is generally used by various industries for fuel requirement as well as feedstock in the manufacturing process. The major industries identified as natural gas consumers are the power plants and the fertilizer companies. In addition, chemical and petrochemical units, glass manufacturers, textile process houses, sponge iron units are also natural gas consumers in the state.

Natural gas scores high over the competing fuels such as naptha, furnace oil, LDO, SKO, etc on account of being a clean fuel, non polluting and economical. Gas being easy to handle, the handling cost of gas is comparatively lower. Usage of gas also improves efficiencies. As a result of the above gas is a preferred fuel.

Domestic Gas Supply Outlook in XI Plan

Table 3. Domestic Gas Supply Outlook in XI Plan

(MMSCMD)

Sources	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**
ONGC	47.28	48.42	45.69	44.67	41.08
OIL	10	10	10	10	10
ONGC + OIL	57.28	58.42	55.69	54.67	51.08
Pvt. / JVs (As per DGH)	23.26	61.56	60.28	58.42	57.22
Projected Domestic Supply - Conservative	80.54	119.98	115.97	113.09	108.3
Additional Gas Anticipated	-	-	74	84	94
Total Projected Supply - Optimistic	**80.54**	**119.98**	**189.97**	**197.09**	**202.3**

LNG Supply Outlook in XI Plan

Table 4. LNG Supply Outlook in XI Plan

(MMSCMD)

LNG Supply Source	2007-08	2008-09	2009-10	2010-11	2011-12
Dahej	5	5	7.5	10	10
Hazira	2.5	2.5	2.5	2.5	2.5
Dabhol	1.2	2.1	5	5	5
Kochi	-	-	-	2.5	5
Mangalore	-	-	-	-	1.25
Total LNG Supply (MMTPA)	**8.7**	**9.6**	**15**	**20**	**23.75**
Total LNG Supply (MMSCMD)	**30.45**	**33.6**	**52.5**	**70**	**83.13**

Overall Demand Supply Balance - XI Plan

Table 5. Overall Demand Supply Balance - XI Plan

(MMSCMD)

	2007-08	2008-09	2009-10	2010-11	2011-12
Total Supply I -Conservative	110.99	153.58	168.47	183.09	191.42
Total Supply II -Optimistic	110.99	153.58	242.47	267.09	285.42
Demand (MMSCMD)	179.17	196.64	225.52	262.07	279.43
Demand Supply Gap I - Conservative	68.18	43.06	57.05	78.98	88.01
Demand Supply Gap II - Optimistic	68.18	43.06	-16.95	-5.02	-5.99

CHAPTER - 3

SYSTEM DESIGN

3.1 Selection of the Route

In consideration of the Environment requirements, construction methodology, design and engineering factors, availability of the logistic support during construction, operation and maintenance of pipelines various feasible alternatives are identified based on the desktop study of the relevant topographic maps of the area.

After the desktop study of the route, reconnaissance study of the route is carried out for the collection of the various details of the route. After collection of the field data once again desktop analysis of data is carried out for arriving at the optimum route. For the fmal route selections following factors are considered:

- Maximum reach to potential demand centres with minimum length
- Use of existing defined pipeline corridors by respective authorities.
- Minimum disturbance to Agricultural land
- Compliance with environmental regulations
- Safety of people and property
- Shortest possible route
- Minimum number of Bends
- Favourable ground profile for construction
- Accessibility of the pipeline for the operation and maintenance
- Location of pipeline facility and access there to
- Avoidance mining area as far as possible
- Avoidance forest area as far as possible
- Minimum number of Road, Canal crossing
- Avoidance of rocky terrain
- Flexibility for future expansion
- Avoidance of the notified forest as well as thick plantation area
- Avoidance of the area reserved for the future development

- Avoidance of archeological and sensitive area
- Safe distance from the village
- Proximity to the existing pipeline for selection of tap-off point at S.V. Station

On completion of the above exercise final route is selected for the pipeline network. After selection of the route, detailed survey for the final route is carried out. During the detailed survey pipeline alignment is decided. The main purpose of the detail survey is to prepare drawings and report for the pipeline construction.

Reconnaissance survey is conducted for the city with the objective of identifying suitable routes for laying pipelines. The survey is done on the specified routes with the recommendation of the best possible route for laying of gas pipeline for PNG and CNG distribution.

The details of the topography along the identified routes is surveyed and marked on the base map. The running distance from the starting point is also indicated. The main obstructions like culvert, road cuttings, nala/ drain, power line, pylons and buildings are recorded. Areas like flyover / canal crossings are avoided wherever possible. Main consideration is given for position of CNG filling station for sketching the position of DRS and CNG station. Suitable sites for PNG and CNG are selected specially on road bends. The feasible routes are marked on the existing base map and the best possible route amongst them are indicated.

The following documents are studied for the optimum route selection:

- City Maps
- City Development Plan
- Industrial & commercial unit's availability.

The route is optimum based on the following factors:

- Shortest length of the pipeline grid
- Least topographical variations and minimum obstacles in the form of rail/road/river/canal crossings
- Minimum cost of the system layout
- Density of traffic flow

- Minimum number of turning points
- Availability of sufficient space on both sides of the road.

Design Philosophy:

The design philosophy is:

- Optimize the use of each component of the overall system (i.e. do not make uneconomical decision on one component to compensate for another).
- Conserve available energy to distribute the gas (i.e. fewer pressure regulating stations).
- Generally minimize the use of mechanical components in the system (i.e. stations, regulators, meters, and valves which are high capital cost, high maintenance and generally reduce pressure availability for distributing natural gas).

3.2 System Planning Assumptions

The high gas pressure which is available for city gas distribution network is generally above 30 bar (g). This high pressure is regulated to a medium pressure of 26-19 bar (g) at facility called City Gate Station (CGS). This CGS also serves the purpose of custody transfer of gas from gas Transmission Company to gas Distribution Company. The network pressure downstream of the CGS is be in the range of 19-26 bar (g).

Major Industrial customers are supplied directly from this steel system, as the pressure above 4 bar makes it an unsafe pressure for direct reticulation to domestic consumers. For the purpose of Piped Natural gas distribution to Domestic, Commercial & Industrial customers, the medium pressure is further regulated to low pressure though the facilities called District Regulating stations (DRS). The distribution network downstream of DRS comprises of Medium Density Polyethylene (MDPE) pipelines network which is laid right up till the customer premises. MDPE material, apart from having commercial benefits over steel pipeline network also has the advantage of laying in city like conditions. To connect customers, service network is required. These are installed by fusing a tapping saddle at the top of the distribution main for supply of gas to consumer's premises. At the end of each

service, a metal up stand is installed upon which an isolation valve, regulator and meters will be connected. The principal international standards proposed for the distribution project is ANSI / ASME B 31.8, Gas Transmission and Distribution Piping Systems'. Four principal design variables are nominated for the safety and reliability of a gas distribution system; these are:

Use of a looped or radial system: It is proposed to have, as far as practical, a looped distribution design such that back-feed can be supplied during interruptions. As the distribution system expands, it is proposed to expand the transmission system, effectively completing the loop around city.

Placement of Valves: It is proposed to have approximately one valve buried every 2.5 kilometres of distribution main and at every branch off. These valves will be normally open, but will be made accessible from the surface, such that they can be utilized as emergency isolation valves.

Layout of services (single and branched): To save on infrastructure cost, it is proposed, where ever practical, to have one gas service to supply up to three domestic customers. This will, however, have a minor negative impact on the reliability of the system, in that should the service be interrupted, three customers will be affected.

System Basic Concept

Pressure levels

The concept is based on the pressure levels given in the following sections.

High-Pressure: This applies to the pipelines connecting the Gas transmission System to the "City Gates".

During the detailed design phase of the project, these routes are refined and selected in detail, to ensure safety, ease of construction and minimal obstruction of other buried services. In addition, during the detailed design the exact location of the CGS and DRS will be nominated, as well as issues such as "Risk Factors with respect to third party system" and "Interruption management".

Medium pressure: This applies to the pipelines connecting City Gate Station to DRS

Low pressure: This applies to the pipelines connecting DRS to customers

City gates are interfacing the High-Pressure system by lowering the pressure to medium pressure level. Pressure reducing stations (DRS) are interfacing MP to LP.

Application to Projects

The project development considers both Medium Pressure and Low Pressure networks. Major industrial consumers will be directly fed through connection in MP network. CNG On-line/ mother stations will be connected to MP network. Small scale industrial customers in industrial sector will be provided through connections in LP network.

3.3 Pipeline Network

The primary network of steel pipelines will provide the core backbone connecting CGS to various DRS. The design of the primary network is based on the demand forecast to be catered. MDPE pipeline network is planned for cluster of industrial units at low pressure. The design of the MDPE pipelines is based on the demand forecast to be catered.

Method of Supply:

Supply Method

Using the domestic / small commercial quantity and large commercial quantity values, and additional information, including location of customers, pressure requirements at major customers, availability of existing supply, and geographic features, optimum method of supply was determined.

Supply Facilities

The supply facilities includes the following:

- High pressure Steel pipeline main
- Medium pressure Steel pipelines
- Low pressure MDPE mains
- Low pressure MDPE services
- CGS/ DRS / Hot Taps
- Service Connections
- Odorisation Facilities

CHAPTER - 4

IDENTIFIED SECTORS FOR CITY GAS DISTRIBUTION IN A CITY

The four major sectors identified for the city gas distribution are:

1. Transport Sector
2. Domestic Sector
3. Commercial Sector
4. Industrial Sector

Domestic, Commercial and Industrial Sectors use Piped Natural Gas (PNG) where as the Transport Sector use Compressed Natural Gas.

4.1 CNG - Transport Sector

The market research for CNG demand in the transport sector is carried out for the following segments:

- Private vehicles comprising of petrol based cars
- Commercial vehicles comprising of auto's, taxis and buses

The following activities were undertaken:

- Traffic survey to establish density and flow of traffic across different routes
- Analysis and optimization of CNG station locations

Studies indicate that CNG demand is dependent on court orders/legislation. The major motivators to switch to CNG are 'un-adulterated', `less expensive' and `environmental friendly properties'. The issues that emerged as causes for concern were the high initial investment for conversion and the technology constraints in converting diesel auto's/ taxis.

4.2 PNG - Domestic Sector

The sector demand for the city is identified based on a field survey and mapping exercise. Each city is classified into four density clusters based on the plot size (Dl D4). The density of population was minimum for Dl and maximum for D4.

The overall satisfaction with LPG is high as currently there is no alternative fuel to LPG. Therefore initial incentives are required to facilitate consumers switchover to PNG. The motivators to shift to PNG are convenience factors such as 'continuous tampering'.

These findings indicate that the perception on the safety of PNG should be emphatically addressed in the advertising campaigns, along with the benefits of PNG. In terms of target customers, new constructions and upcoming colonies in the D3 density segment should be targeted on a priority.

4.3 PNG - Industrial Sector

The major areas where PNG could be used as an alternative fuel in industry are forging, direct-contact water heaters, industrial combined heat and power and industrial co-firing. The main motivators that emerged for the switch to the PNG are its economical usage, no fuel inventory requirement and its environment friendly properties. Most of the survey respondents felt that natural gas would replace bulk of the solid and liquid fuels. The cost involved in replacing solid fuels is very high when compared to liquid fuels and this may act as a barrier for the replacement of solid fuel. In addition, the concern on the initial investment cost should also be addressed.

4.4 PNG - Commercial Sector

PNG can be used in commercial segment in a larger number of establishments. The commercial segment is divided into three major domains horizontally. They are

- Eateries includes Restaurants, Bakeries, Sweet Shops
- Medical includes Hospitals and Nursing Homes
- Entertainment includes Hotels, Shopping malls and Clubs
- Typically the vertical domain can be classified into: clubs, bakeries, sweet shops etc. The average consumption of fuel is in the range of 25-50 SCMD.

Medium commercial includes 3 star hotels, hospitals and shopping complex. The average consumption of fuel is in the range of 50-150 SCMD.

Large commercial includes , big hospitals and shopping malls. The average consumption of this sector is above 150 SCMD.

CHAPTER - 5

STANDARDS AND STATUTORY REQUIREMENTS

5.1 Permissions Required

The permission required from various authorities are given in following table.

Table6: Permissions from Departments

S.No	Department / ministry
1	City Authority
2	Local municipal Corporation
3	RWA's (if applicable)
4	Ministry of Railways (if applicable)
5	Ministry of Environment & Forests
6	State Pollution Control Board
7	Telephone Department (if applicable)
8	National Highway Authority of India (if applicable)
9	Jal Board / Water Board
10	Fire Department
11	Chief controller of explosives
12	Department of Forests / Horticulture
13	Labour Department

5.2 Regulations & Standards

The Petroleum Rule 1976

The rule gives broad guidelines for the import, transport and storage of petroleum products including compressed natural gas (CNG) and natural gas. The Chief Controller Of Explosives (CCOE) enforces the petroleum rule. Agencies proposing projects shall submit to CCOE a project report, necessary drawings, calculations and recognized codes along with security

fees. Project approvals are essential prior to the start of construction activities. The constructed installation must also be approved before the commissioning.

Factory Act

Building havingfactory equipment/machinery require approvals from the Inspectorate of Factories. Approvals are required before construction, and subsequent to the installation before commissioning.

Highway Authorities

For installations requiring and approach from a highway or for crossing of highways, approval from Highway Authorities would be required.

Railway Authorities

For crossing Railway Property/track, approval from Railway Authorities would be required. Apart from these Statutory Authorities, Oil Industry Safety Directorate (OISD) has prepared OISD Standard-141 " Construction requirements for cross country hydrocarbon pipelines" Part-II of this standards addresses gas transportation and distribution system including gas pipeline, gas compressor station, gas metering and regulation station, gas main and service lines upto the outlet of the customers meter set assembly. OISD-141 standard incorporates major clauses from ANSI/ASME B31.8, 1986 addition. (Gas transmission and distribution pipe system) with certain modification.

As a general comment, for each and every local distribution company to install an alternate supply or local storage capacity to deal with continuity of gas supply (i.e. from GSPC / GSPL / Petronet etc.) & Transport (i.e. from GAIL) will result in high economic costs. Further, if redundancy is required, it may be better created nearer to the source supply of supply rather than near the point consumption. In that way the benefit may be more than single community and a lower economic cost.

5.3 Statutory Requirements

The various environmental legislations applicable to the proposed project facilities in India are:

- The Environment (Protection) Act, 1986
- The Environment (Protection) Rules, 1986
- Environment (Protection) Third Amendment Rules, 2002
- The Public Liability Insurance Act, 1991
- The Public Liability Insurance Rules, 1991
- The Water (Prevention and Control of Pollution) Act, 1974 as amended upto 1988
- The Water (Prevention and Control of Pollution) Rules, 1975
- The Water (Prevention and Control of Pollution) Cess Act, 1977 as amended upto 1991
- The Water (Prevention and Control of Pollution) Cess Rules, 1978 as amended upto 1992
- The Air (Prevention and Control of Pollution) Act, 1981 as amended upto1987
- The Air (Prevention and Control of Pollution) Rules, 1982
- Hazardous Wastes (Management and Handling) Rules, 2000
- Gas Cylinder Rules – 1981
- Static & Mobile Pressure Vessels (Unfired) Rules, 1981 (with latest amendments abbreviated as SMPV) Rules
- Following Organisations/ Departments/ Agencies need to be contacted for obtaining Clearances/Permissions for the proposed System:
    - Ministry of Environment and Forests
    - Office of Chief Conservator of Forests
    - Department of Environment
    - State Pollution Control Board
    - Office of Chief Controller of Explosives
    - Public Works Department
    - Local Self Government Bodies
    - State Police
    - State Fire Department

CHAPTER - 6

VARIOUS STATIONS INVOLVED IN THE CGD NETWORK

The various stations involved in the network are:

- City Gate Station (CGS)
- Industrial Pressure Reduction Station (IPRS)
- District Regulating Station (DRS)

The City Gate: interface between High Pressure and Medium Pressure;

The Pressure Reducing Station: interface between Medium Pressure and Low Pressure

The Service Connection: interface between network and end-user pressure.

6.1 City Gate Station (CGS)

CGS for the network is located at Tap off point of the transmission line. The CGS would have inlet supply mains from the transmission pipeline, a pressure reduction system with two stages, a filtering unit, gas chromatograph and orifice metering or Turbine metering, odorant injection system and associated piping. The filtering unit would remove entrained particles of size 5 microns and above and with final filtration efficiency of 99.9%. This unit would comprise of borosilicate fibreglass cartridge. The unit also provides for a drain with a manual drain valve. The filter vessels are designed in accordance with industry norms and shall be constructed with carbon steel.

The pressure reduction facility comprises two full capacity Class 600 regulator runs, each having an active /monitor regulator, each fitted with 'slam-shut' protection facilities. In addition, allowance was made for natural gas preheaters, for future requirement. The pressure reduction and metering equipment can be fitted in a single self-contained skid-mounted cabinet. It is recommended that a CGS be located in a fenced off secure area. To supply the remainder of the distribution system from the 26 bar maximum transmission pressure system, a Class 300 'DRS' will be required. The DRS will be similar in design to the City Gate with different capacity, except no allowance is made for future gas heating and metering.

Facilities in City Gate Station

The main purpose of the city gate station is to transfer the custody of gas from GAIL to AEL. "City Gates" are the key door to a Medium Pressure Network. It assures the basic interface between the High-pressure System and the Medium Pressure Network by offering the main following functionality:

- Terminate the High-pressure up-stream pipeline (Main line or Connecting line)
- Filtration;
- Metering (may be optional); Pre-heating (recommended)
- High Integrity Pressure Reduction and Control (HIPPS);
- Dispatch in the down-stream network.

The main parts are detailed hereafter:

Pigging facilities

Notwithstanding the up-stream High-pressure Main is piggable by design; "Pigging" is rarely to be performed, if ever in MP Steel Network. Permanent Pigging Facilities being space consuming due to "Safety Distances" as well as expensive, no permanent pigging facilities is provided for MP Steel Network. However, inlet-piping design shall consider for each main line branch at starting and ending a valve and a blind flange to allow connection of temporary removable pigging facilities when necessary. Valve stations are provided at MP lines crossing to allow connection with temporary pigging facilities.

Inlet Service Operating Valve

A main Inlet Valve (with pressurizing by-pass) is installed on the station main piping before inlet header. That valve serves in normal operation to isolate the station from up- stream. The valve at the City Gates will be actuated and remotely controlled through SCADA.

Filtration & Liquid Catchers

Equipment like regulators and metering are quite sensitive to dirt. Metering requires no particles above 5 microns. Whatever have been the precautions taken during construction and at final clean-up before commissioning, no pipeline is perfectly clean and small quantities of

residual dirt may always still exists. Residual dirt will move along with the gas depending on gas speed and pipeline geometry. The experience shows that for such a fully new important High-pressure system, the probability of clogging the Inlet Filters to "City gates" is important during the first months of operation. Specially careful follow-up by "Maintenance Team" shall be provided during this "critical" stage. Small K-O drum will be installed in front of the filtration skid. Filter-separators (the Filters) shall be installed for 5 microns maximum particles for the specified flow range. The Concept is based on two filters (plus one stand-by) able to handle 50 % of the consumption forecasted without provisions for future and the later addition of one similar filter when ramp-up of consumption shall justify.

Heating

The gas will then travel to the City Gate through the High pressure Transmission network. During this travel, the gas temperature will tend to reach the soil temperature. Depending on the operating conditions, after the let-down to 19 barg of the city gate we may face condensation or not. Given the natural gas origin (LNG Terminals), the risks of condensation are relatively low. The Polyethylene (material used in the downstream network) is not foreseen to be used with condensates and only upset but certainly no permanent situation could be accepted for mechanical design. Of course, gradually, the gas flowing in the downstream system will warm up to ground temperature and condensate will re-evaporate. However, the first gas consumers installed on the network could still receive dual phase gas given combustion problems at the Burner. Due to the high pressure that may potentially exists upstream the CG, the pressure let-down may lead (by Joule-Thomson cooling effect) to unacceptable gas temperature in Polyethylene network. For all these reasons, it is recommended to install heaters within the City Gate. By achieving this temperature, the final temperature after any further downstream letdown up to atmospheric pressure at ultimate End-users appliance remains at acceptable level with no danger for PE gas lines as well as for Condensate production.

Pressure Control System

The pressure control system shall be of High Integrity type (HIPPS) combining from up to down stream. Slam-shut valve mechanically actuated to close in case of downstream pressure increase above safe level; it needs local manual reset: Fail-safe is to close; a Pressure Control Valve (PCV) which shall take over control in case the Active PCV fails to maintain downstream pressure below required maximum pressure: Fail-safe is to open. Active Pressure

Control Valve (PCV) that regulates the downstream pressure as required: Fail-safe position is to open. Such concept is called "Non Venting Pressure Safety" and allows avoiding the "Safety Relief Valves" more common in industrial plants. Indeed, large relieves as may be needed by the "Venting Pressure Safety" is then avoided and relevant hazards suppressed.

Some suppliers may offer the combination of the above "Slam-shut" valve and "Monitor" in one single integrated device. This may be allowed for so far extremely strict Certification is produced. All piping and station components that are located up-stream to first valve of the "Metering Facility located downstream the HIPPS shall be designed 49 barg, that valve included.

Metering

Metering shall be provided at the City Gate. High accuracy Metering is a usual feature for such purpose. Metering shall be based on orifice/Turbine type flow metering with associated flow computer, retrieving information on gas pressure, temperature and composition. Accurate gas composition shall be derived from data from Gas Chromatographs in order to determine the consumption. A stand-by line will be therefore installed to allow maintenance and assure a continuous flow rate measurement. The Concept is based on one line (plus one stand-by meter-run) able to handle 100 % of the consumption forecasted without provisions for future.

Supplying gas to a domestic/CNG area, large swings are to be expected. Considering that gas flow / volume is to be reconciled with transporter, the metering philosophy adopted here is same as of the transporter. The Conical Strainer is not aiming to filter as commonly understood. It is a device of conical form that is inserted in front of a delicate expensive equipment to serve as ultimate mechanical protection before the meters against such dirt that may have passed through true filtration installed upstream or against heavy dirt remaining between upstream filtration and the delicate equipment or even, as already experienced a rupture of up-stream filter cartridge and flying debris. Its concept is to stop flying objects dragged by gas speed in the upstream. It is:

- relatively inexpensive;
- rough: holes are of some millimetres (3..5 mm);
- Able to withstand large differential pressure if blocked,
- Installed immediately before the metering-line.

Odorisation

Natural gas is, by nature, odourless what makes detection of leaks impossible without special gas detection tool. End-users connected to a Natural Gas Distribution System being not supposed to have adequate skill for gas handling, it is mandatory to add an odorant to the gas before it enters the Medium Pressure Distribution System. Odorisation shall be based on the injection of suitable sulphur component in adequate proportion (in function of actual flow) on the Medium Pressure side. The flow signal is provided by a dedicated flow measurement system.

Two main products may be considered:

- "Tetrahydrothiophene" (in short THT)
- "Tetrabutylmercaptan" (in short TBM).

TBM is often presented as being cheaper than THT. It is about 3 times more smelly (needs 3 times less product) and more volatile. However, the control-system is more delicate. Moreover, THT presents the major advantage to eliminate slower; in other words, the system remains smelly during longer time should the injection become defect or (losing the flow-control signal). Both Systems have been used on the networks operated by world wide Gas Distribution Companies. Experience has shown that on the long term TBM based systems are requiring more maintenance and present more defects. The Operators are presently strongly examining to remove TBM based systems and replace by THT.

Check Valve (Non-return Valve)

Having in mind the same functionality as for the "Fire Brigade" Inlet valve, a check valve ("Non-return valve") shall be installed before the distribution header dispatching gas to the down-stream multiple departure. This allows guaranteeing no back-flow from distribution network to a potential defect in the station and avoids the necessity of downstream "Fire-brigade" valve outside the station. The "Check-valve" shall be either "fireproofed" if installed above ground or better be buried together with the distribution header.

Outlet Valve

The outlet isolating valve may be dispensed with if there is no possibility of reverse flow.

Distribution Header & Departs

All downstream depart(s) shall be connected to a main "Distribution Header" that assures the dispatch of the gas to the downstream network. Each Depart shall be equipped with an isolating valve and pressurizing by-pass. As far as feasible, the "Distribution Header" and departs shall be buried.

Safety

Safety must remain the main topic in the concept of a Natural Gas Facility. Safety must be considered under the following aspects:

Internal:

By considering careful design with adequate Design Factors in the mechanical equipment & piping: the Design Factor shall be 0.4 as suitable for Location Class 4: Area Classification as per API 500 RP; a zone 2 (Division 2) of 7.5 m shall be considered around flanges on the high pressure side for full out-door equipment.

External:

From External hazards except if otherwise adequately protected, High-pressure equipment shall be located at reasonable distance from outside fences in order to prevent the communication of a fire from outside the fencing to regulator and shutting-off the gas flow equipment. To External Environment : a pressure-regulating station being not equipped with vessels with sophisticated piping, and considering the increased safety in the piping design by adopting the Design factor of 0.4 as above, a major gas leak is not considered as credible (extremely low probability). Safety distances as per Area Classification are usually considered as adequate for normal operation & maintenance. However, where feasible outdoor High-pressure equipment that is not buried should not be closer than 15 m from domain freely accessible to the public. Special safety precautions shall be implemented during exceptional hazardous activities (e.g. pigging - etc.).

6.2 District Regulating Station (DRS)

DRS for the network will be located at strategic locations which are known as field regulating stations to meet various demand centers for Domestic/ Industrial segment. It would have

pressure reduction system, a filtering unit, Turbine metering system, valves etc. Based on the consumption profile of cluster of users, customized arrangements are designed with online metering arrangement. The filtering unit would remove entrained particles of size 5 microns and above and with final filtration efficiency of 99.9%. This unit would comprise of borosilicate fiberglass cartridge.

The DRS would have slam shut valves, pressure regulating valves, creep relief valve and vent, isolation valves and no-return valves.

Basically there are three sections that describe the purpose and different component of stations located at a pressure levels interface

Pressure Reduction Station:

Pressure reducing stations interface MP with LP networks.

6.3 Industrial Pressure Reduction Stations (IPRS)

IPRS for the network is located in major industries. It would have pressure reduction system, a filtering unit, Turbine metering system, valves etc. Based on the consumption profile of the user , customized arrangements are designed with online metering arrangement. The filtering unit would remove entrained particles of size 5 microns and above and final filtration efficiency of 99.9%. This unit would comprise of borosilicate fibreglass cartridge. The IPRS would have slam shut valves, pressure regulating valves, Creep relief valve and vent, isolation valves, non-return valves and pressure gauges.

Pigging facilities (Not provided)

"Intelligent Pigging" being a "non sense" for PE based networks and cleaning pigging being forbidden in PE networks, no provision is made for pigging.

Inlet Service Operating Valve

A main Inlet Valve is installed on the station main piping before inlet header. That valve serves in normal operation to isolate the station from up-stream. This valve is purely manual and not remotely controlled nor monitored from a Central Control Room through SCADA. The inlet valve will be followed by transition fitting PE/steel and an insulating joint.

Filtration

On the other hand, residual dirt from pipeline installation being quite limited in a PE based system correctly and carefully constructed; Filters (with no liquid separator) shall be conventional cartridge filters. Special monitoring of cartridge dirtiness shall be achieved during first months of operation.

Basic Concept:

- Conventional cartridge filters designed for 0.01 bar pressure drop when perfectly clean with cartridge replacement when pressure drop is above 0.05 bar at full flow; Installed within the "Trains".

Pressure Control System

To the contrary to "City Gates", one single "Pressure Safety Device" is mandatory in addition to the "Active Regulator".

The "Pressure Safety Device" is of "Non Venting" type and may be either of the following types;

- "Slam-shut Valve" like for the "City gates";
- "Monitor".

The "Slam-shut Valve" solution is simple and relatively cheap. For large End-users, or crucial users where continuity of gas supply is vital for the appliances, the "Monitor" solution might be preferred. "Monitor" alone as single "Pressure Safety", the Operators from our Consultant's Group always considers this as not sufficient and always adds a "Slam-shut Valve" in front or integrated in the "Monitor". This gives guarantees that a "Monitor" shall not be working unknown for long period of time in place of the defect "Active Monitor" without a clear and definite cut-off of flow for ultimate safety. Active PCV shall be of "Low Noise" type. Buffering capacity of downstream facilities up to End-users appliances being usually limited and End-users being most probably operating valves that may suddenly shutdown, transients may develop that may lead the pressure downstream to reach levels unacceptable for the equipment downstream the HIPPS.

Therefore, a small "Pressure-relief' is added on the HIPPS lines to limit the transient over-pressure to acceptable levels so to avoid the trip-off of the "Slam-shut" valve.

- Pressure regulator provided with Safety shut-off valve.
- Pressure safety relief valve for transient phenomena.

Outlet Header

The outlet of the pressure reducing station outlet will be provided with a steel header of sufficient diameter in order not to create a bottleneck in case of capacity increase in MP network. Steel tees will be supplied and transition pieces steel/PE shall be welded on the tees.

Service Connection

This Service Connection is the interface between the LP MDPE network operated at 4 barg and the gas end-user.

Residential Connection

This connection applies to the majority of the clients that have a design flow rate lower than say 10 Sm3/h. A Diaphragm Meter will be used for the measurement of the gas flow.

Commercial Connection

This connection applies to a limited number of big clients that have a design flow rate higher than say 10 Sm3/h. A Rotary Meter will be used for the measurement of the gas flow.

Industrial Connection

Industrial customers within industrial areas shall be supplied from LP network through a central Pressure reducing station OR directly through MP network, in case of more pressure & flow requirement. Industrial customers with high consumption and located outside industrial estates shall be supplied directly from MP steel network.

CHAPTER - 7

EQUIPMENT DESCRIPTION

I. CNG Distribution Network

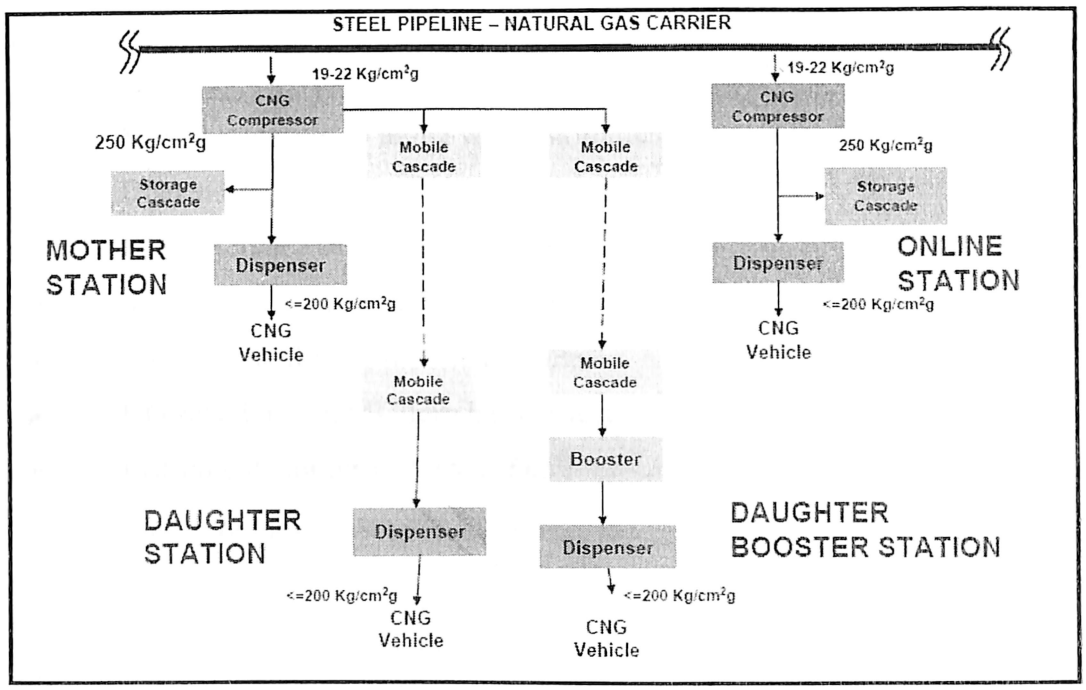


Figure 4. CNG Distribution Network

7.1 CNG Mother Station

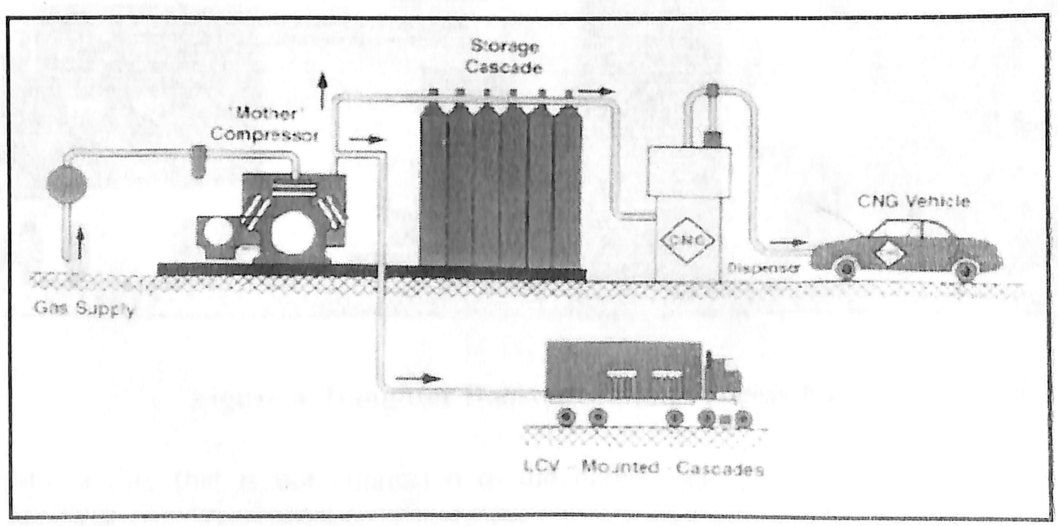


Figure 5. CNG Mother Station Process Flow

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.

The following units have been envisaged in mother station:

Main equipments

- Mother compressor along with auxiliaries
- Dispensers for buses
- Dispensers for car and three wheelers
- Stationary cascades & Mobile cascades
- Loading facility for mobile cascade
- DG sets, UPS and Battery bank, Electronic control panel
- Instruments for air and water facilities
- Fire fighting equipment and safety side

7.2 CNG Daughter Booster Station

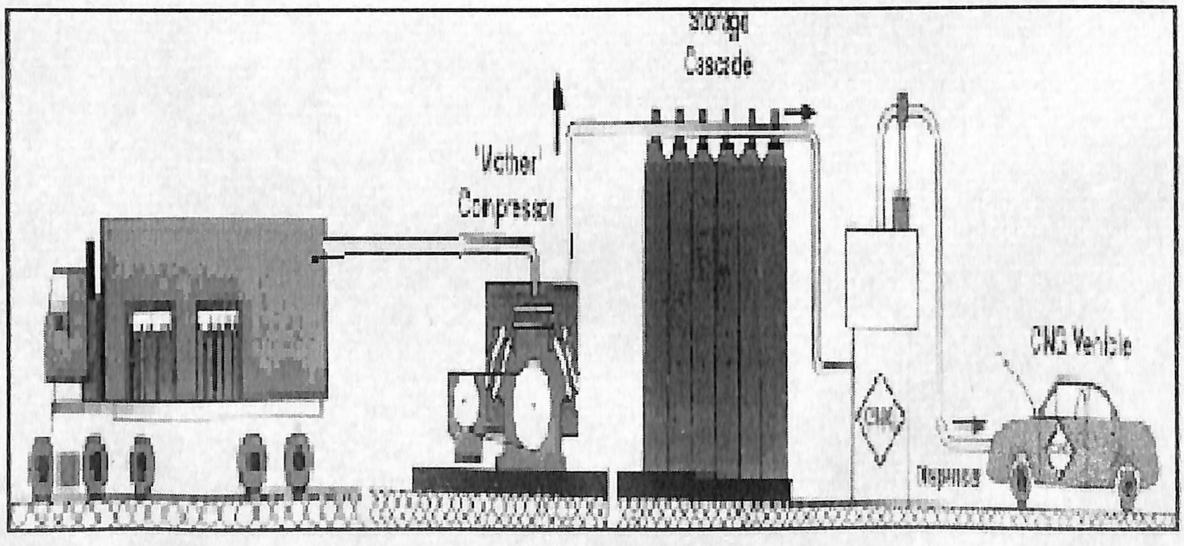


Figure 6. Daughter Booster Station Process Flow

The CNG facility that is not connected to the natural gas pipeline and has facilities for dispensing CNG to vehicles (s) from mobile cascades after boosting the gas pressure using booster compressors. The following units are installed in the Daughter Booster Station

Main Equipments

- Booster compressor
- Dispensers for Cars and Three wheelers
- Stationary cascades and Unloading facility from mobile facility
- Dg Set, UPS & Battery Bank, AVR Electrical Control Panel
- Instrument air and water facilities and Fire Fighting equipment

7.3 CNG Online Station

CNG facility connected to the natural gas pipeline and having a compressor primarily to fill stationary cascades and for dispensing CNG to vehicles. In case the 'on line' station has enough space to accommodate mobile cascades filling, it can be used to act as mother compressor station.

The following units are installed in the Online Station

Main equipment

- On-line Compressor along with auxiliaries
- Dispenser for Buses
- Dispenses for Cars and Three Wheelers
- Stationary Cascades
- DG Set, UPS & Battery Bank, AVR, Electrical Control Panel
- Instrument air and Water Facility
- Fire Fighting Equipment and safety sign

Detail Description of Facilities in Different Stations

(A) 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 dispensers

Car dispenser

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 been installed.

Bus dispenser

To meet the requirement of bus filling at mother stations, single arm bus dispenser, each of capacity 80 kg/min has been installed. The system is designed in such a way that when compressors are in operation, the bus dispenser takes about 65 kg/min gas from cascade and about 15 Kg/min gas from compressor.

(B) Cascades

This is a group of gas cylinders with a total water capacity not exceeding 4725 litres, contained within the 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. Either 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 or placement is called as mobile cascade.

Following are the two types of cascades.

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 litre & 2200 litre capacity, about 135 Kg & 165 Kg respectively, of CNG can be stored. The cascade shall supply gas to bus as well as car/auto dispensers.

Mobile Cascade

A 2200 litre 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 CCOE approved.

Suitable loading facility at mother station and unloading station at DBS has been installed along with sun/rain protection shed.

Other Installed Facilities in Different Stations

(C) DG Set, UPS & Battery Back-up & AVR

DG set: To meet the requirement of emergency power in case of grid power failure, one DG set of capacity 7.5KW has been 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 has been provided at each station.

AVR: A suitable automatic voltage stabilizer based on local supply has been provided.

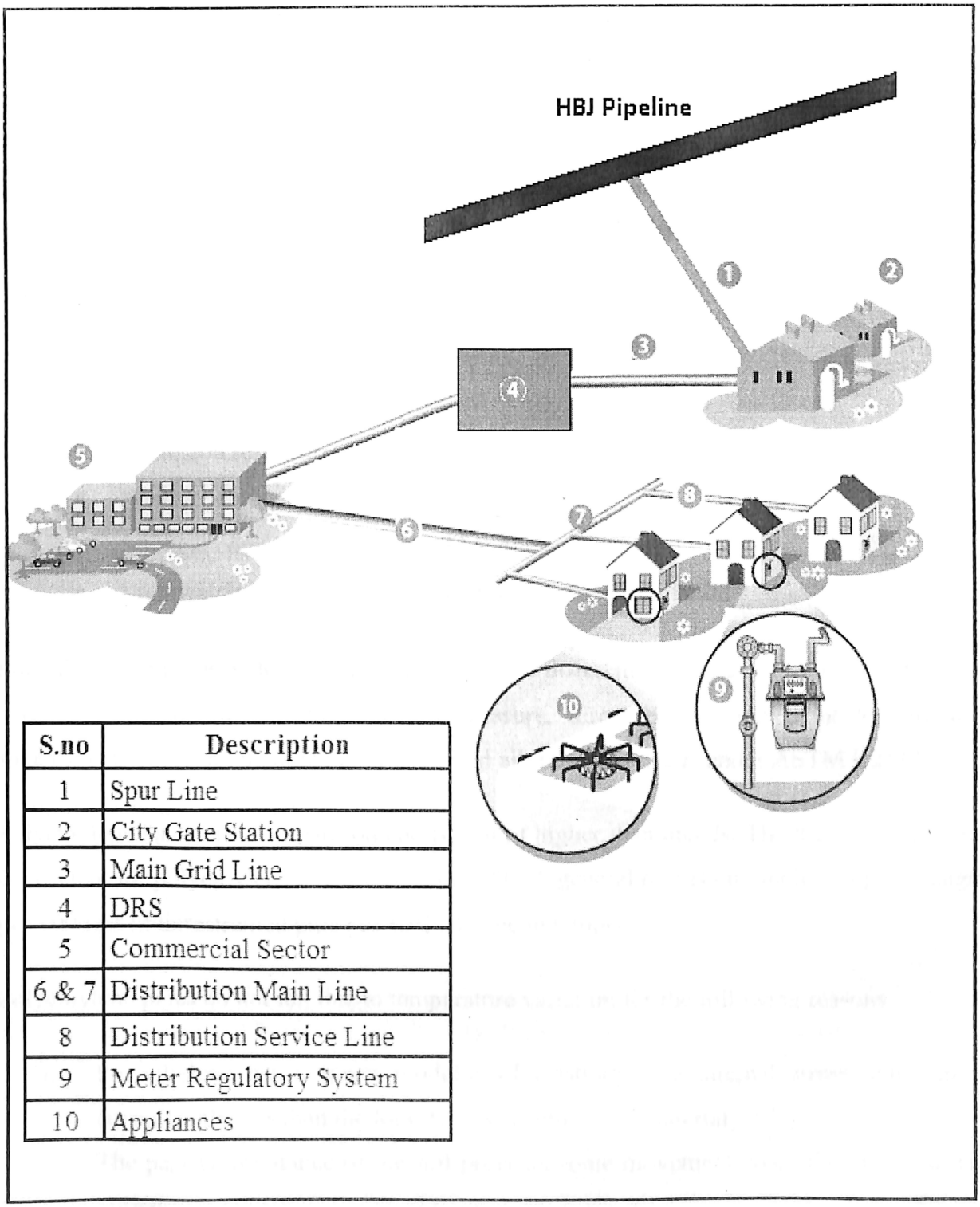
Electrical system

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, galvanised iron conduits; earthing system; area lighting, canopy lighting, signage lighting and control room illumination etc.

Stainless Steel Tubing

Running underground in concrete or/masonry trenches for conveying the compressed gas from compressor to priority panel to dispenser and priority panel to stationary cascade to dispenser. Generally these are 1/2", 3/4" or 1" size tubes of SS 316 grade.

II. PNG Distribution Network



S.no	Description
1	Spur Line
2	City Gate Station
3	Main Grid Line
4	DRS
5	Commercial Sector
6 & 7	Distribution Main Line
8	Distribution Service Line
9	Meter Regulatory System
10	Appliances

Figure 7. PNG Distribution Network

7.4 MDPE Pipeline

A high pressure gas distribution system requires high strength and reliability from the pipe. These all qualities are associated with the Polyethylene pipes. So, these are extensively used for gas distribution applications.

The MDPE and HDPE gas distribution pipes are specially designed and produced for natural gas distribution system applications. The properties that favour their usage are

- Crack resistant
- Impact resistant
- Chemical resistant
- Corrosion resistant,
- Weather ability
- Strength combined with ease of handling
- Lightweight, flexible and heat fusible for easy installation

Polyethylene pipe provides long-term resistance to different service conditions like abrasion, temperature variation, bending, internal pressure, direct burial, and point loading and squeeze-off. These are manufactured to exceed all industrial needs under ASTM D2513.

Polyethylene has thermal expansion coefficient of higher than metals. The thermal expansion coefficient for polyethylene is 1.0 x 10-4 in/in/°F. A general rule is one-inch change in length per 100 feet of unrestrained pipe per 10°F change in temperature.

Polyethylene pipes do not fail due to temperature variation for the following reasons

i. Polyethylene has a lower modulus of elasticity; the internal stress build up is considerably less than the long-term strength of the material.
ii. The passive resistance of the soil prevents some movement when the pipe is direct buried.

Bending Radius

The advantage of Polyethylene is that it is flexible and resilient. The minimum bending radius depends upon the Dimension Ratio (DR) of the pipe. This radius is determined by multiplying the outside diameter of the pipe by the radius factor for the corresponding DR.

When pipe is used in pressure applications, the longitudinal stress created by the sum of the bending radius, internal pressure and other stress loads on the pipe should not exceed the material's design stress rating. Severe but acceptable bends in polyethylene pipelines should be buried or properly restrained.

Joining

Polyethylene pipes can be joined by different of methods.

- Heat fusion
- Mechanical fittings

Heat fusion

The widely used method is heat fusion. The different types of heat fusion are butt fusion, saddle fusion, socket fusion and electro fusion. The joints done by heat fusion will offer a completely leak-proof and restrained joint.

Mechanical Fittings

PE gas piping and fittings can be used in underground gas distribution systems only. These are manufactured by Computer controlled extrusion techniques are utilized and continuous wall monitoring during manufacture results in dimensional consistency.

Different tests are conducted on the manufactured pipes to confirm short and long-term performance. Long-term hydrostatic testing is also performed according to ASTM D1598, ASTM D2837 and Plastics Pipe Institute (PPI) TR-3 to get the products continuity.

MDPE pipeline network is used to supply gas to the domestic and commercial sectors generally. The PNG network is discussed in detail in the following text.

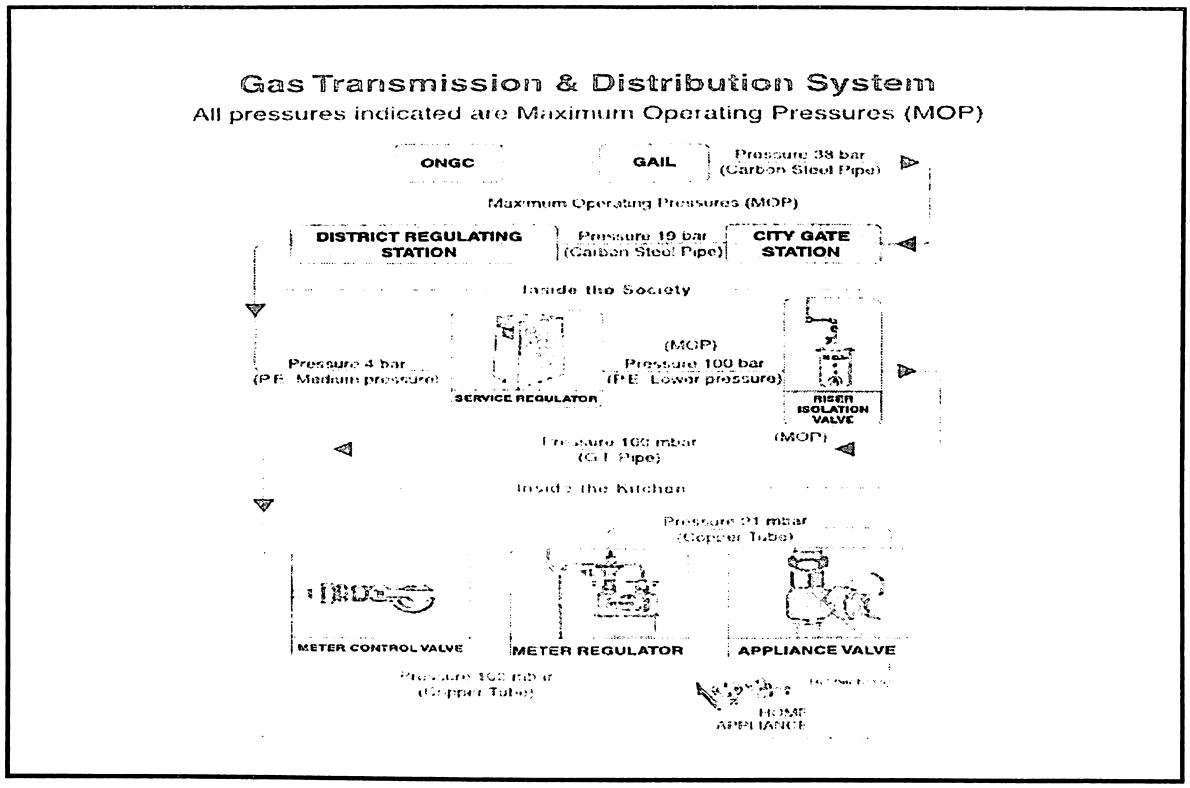


Figure 8. MDPE Service Line

For commercial and domestic consumers it is recommended that low pressure [4kg/cm2(g)] underground network is provided for safety reasons, as it is safe for inhabited areas, easy to lay and economical.

It is recommended that the distribution system in the city be constructed from MDPE at 4bar pressure. The polyethylene fused joints are as strong as the parent pipe, ensuring the integrity of the pipe system. The polyethylene compound used in the manufacture of pipes shall be free from cadmium & visible water and shall confirm to the weathering requirements for thermal stability and hydrostatic strength. The pipeline shall have 180mm, 125mm, 63mm, 32mm and 20mm diameter pipes to form the complete distribution reticulation system.

The regimes that shall be followed for the system design are

- Distribution/Service Line (Medium Pressure System): 4 – 1.5 bar, MDPE
- Domestic Connection (Low Pressure System) : 21 mbar, GI Installation
- Supply pressure large commercial consumer : 2 bar
- Supply pressure small commercial consumer : 300 mbar

The system is divided in two broad categories, namely

i. Distribution mains
ii. Distribution Services

Distribution Mains

Distribution Mains shall be responsible for carrying the gas to the colonies for further distribution by Distribution Services.

To standardise the distribution system, it is proposed to install only four sizes of pipes - 32mm, 63mm, 125mm and 180mm (OD). MDPE pipes shall be fused by electro fusion coupling. The distribution pipe is proposed to be of SDR11, PE100 Grade SDR is defined as the normal outside diameter (DN) divided by the minimum wall thickness.

All MDPE pipes shall have minimum cover of one meter and shall be back filled with sand around it to protect the plastic material. Emphasis shall be placed on utilizing modern construction techniques to install the distribution system. This shall include, wherever possible, avoiding disruption / damage to road and footpaths by boring and drilling. Large crossing, such as canals, major roads, etc., shall be carried out using Horizontal Directional Drilling (HDD).

It is proposed to have valves on the distribution and transmission networks at strategic locations to ensure security of supply (two valves for every 5 KM of distribution mains).

It is proposed to install plastic protection strips (warning tapes) 300mm above the MDPE pipe, to warn any agencies digging the area well ahead of reaching depth of MDPE pipe.

To ensure system integrity and safety, prior to commissioning, the MDPE pipes shall be pneumatically tested.

Distribution Services service lines are laid underground to connect customers from the Distribution Mains up to the customer premises, then laid vertical to rise above the ground level just below the proposed regulator point. The few centimetres of the MDPE pipeline that rises above ground shall be protected by GI pipe sleeve. Since most services must cross roads/footpaths to reach the customers, they are usually installed by boring to reduce restoration costs. Open excavation is required only at the connection to the main as well as at the service. Warning tapes shall be installed all along the route where open cut is used for pipe laying.

A typical service diagram for 20mm MDPE Service pipeline is shown below

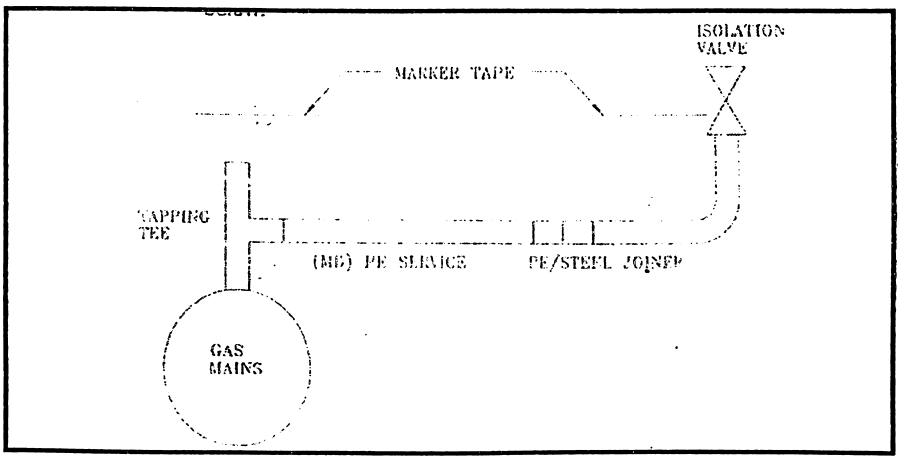


Figure 9. MDPE Service Line

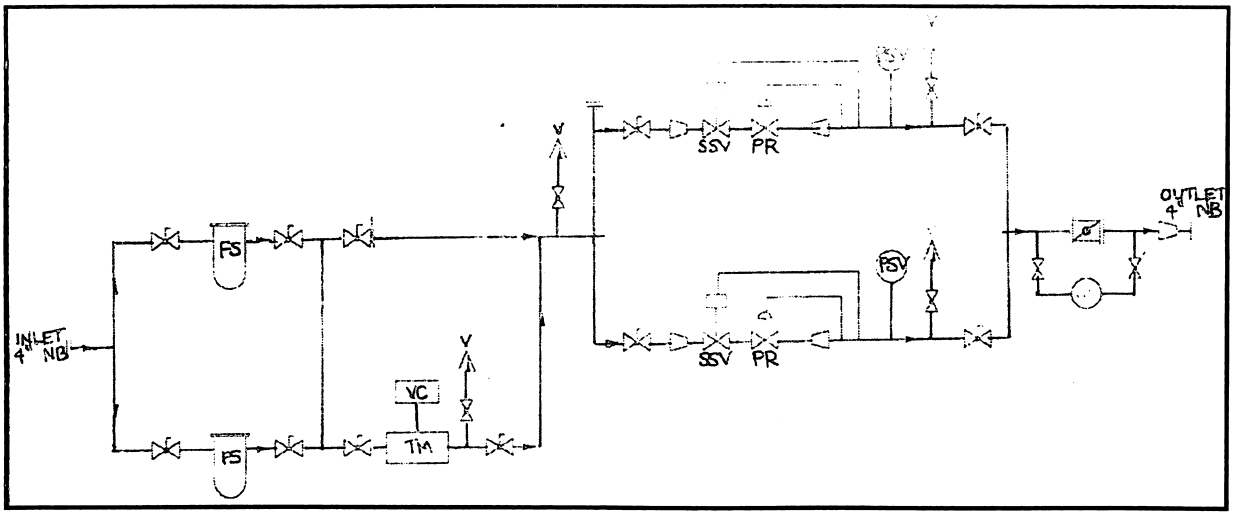


Figure 10. Process Flow Diagram of DRS

The DRS shall control the flow of gas to the distribution network after reducing the pressure to suit the MDPE pipe.

In a DRS the pressure reduction and meeting equipment is fitted in a single self-contained skid-mounted cabinet.

The DRS shall work as pressure reducing and gas metering facility. The DRS shall comprise of pressure reduction, metering system, condensate removing facility and cold venting facility. Filter separator shall be provided at the inlet of each run of the pressure reduction metering assembly. Filtration efficiency shall be 99.9% for the removal of all particles from 3 micron size onwards. The flow measurement meter shall be of Turbine type. The error limits shall be ± 2% in the range between Qmin and 0.2Qmax and ± 1% in the range between 0.2Qmax and Qmax. The regulating assembly shall be a dual run assembly with each run designed for the full flow capacity required for the station and manual isolating valves provided to facilitate servicing of each run without shutdown of the station.

Meter / Regulator Assemblies

Domestic Consumer Services

The MDPE shall be connected to GI network inside the consumer premises through a transition joint. A pressure regulator shall reduce pressure from 4 bar to 21mbar. This GI pipe shall reach the burners through the shortest possible route with minimum bends. A typical domestic consumer service pipe / meter / regulator arrangement is shown below

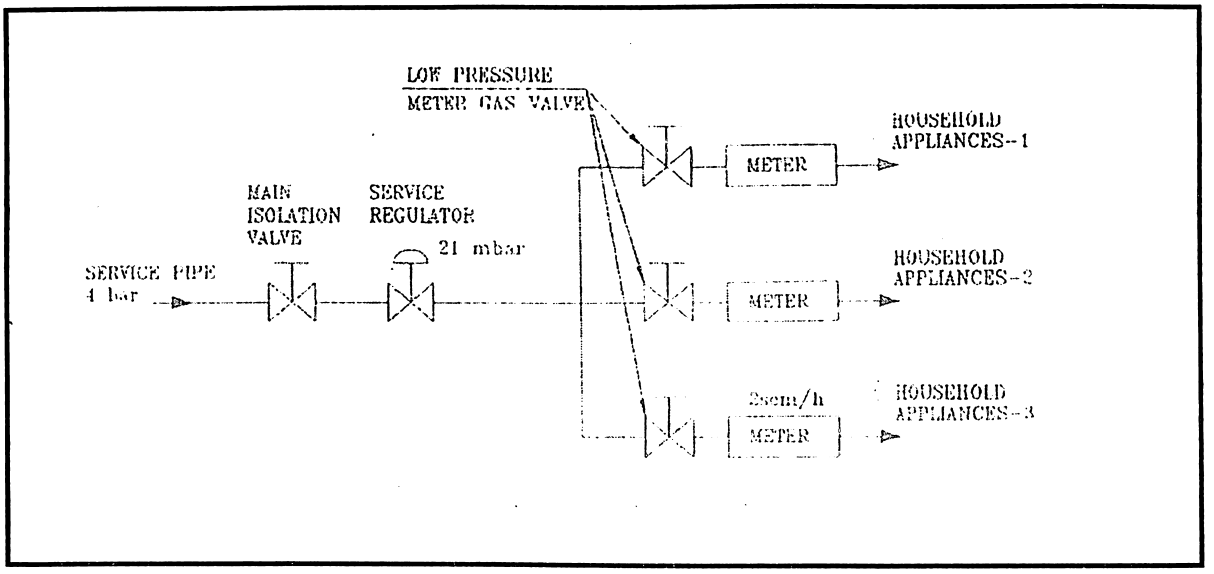


Figure 11. Domestic Consumer Regulator Arrangement

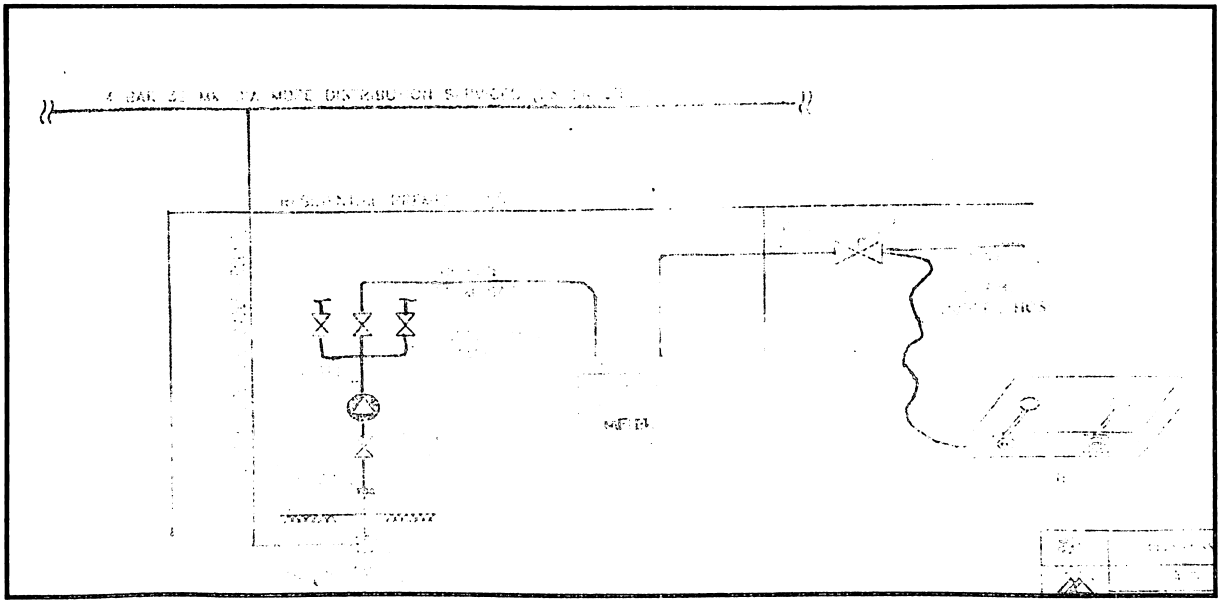


Figure 12. Domestic Connection

In apartment type premises, a number of households can supplied with gas from a single service line. A single regulator shall supply gas to a block of three households with individual metering for each. Each service line shall include a main isolation valve and a regulator, reducing the pressure to 21mbar.

Commercial Meter / Regulator Assemblies

The service pipeline to commercial consumers shall depend on the load required. For large commercial user, pipe sizes shall be considerably larger than domestic & small commercial premises and a higher gas supply pressure shall be required.

Commercial Meters shall be of two different categories catering to small and large consumers with output pressure in the range of 300mbar to 2bar.

Some typical commercial meter / regulator service arrangements are shown below

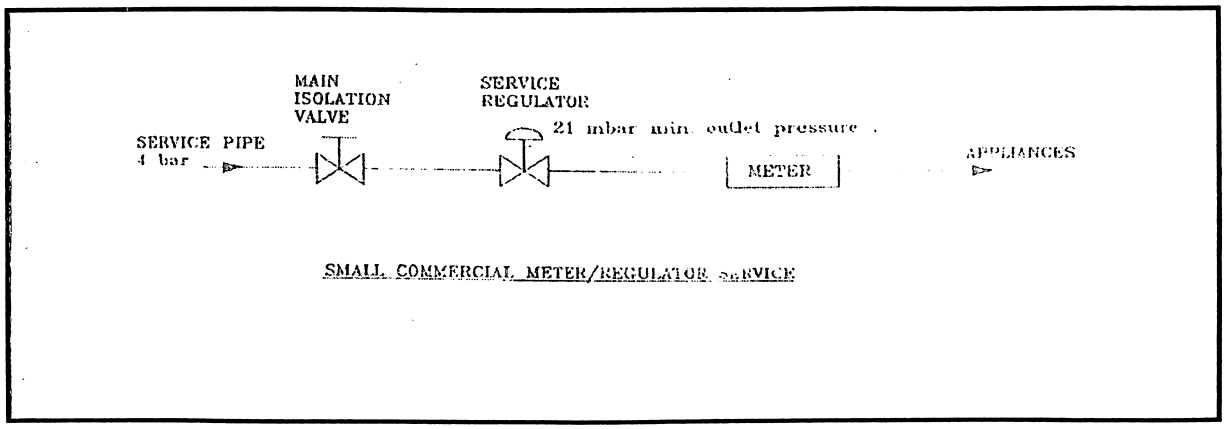


Figure 13. Small Commercial Meter /Regulator Service

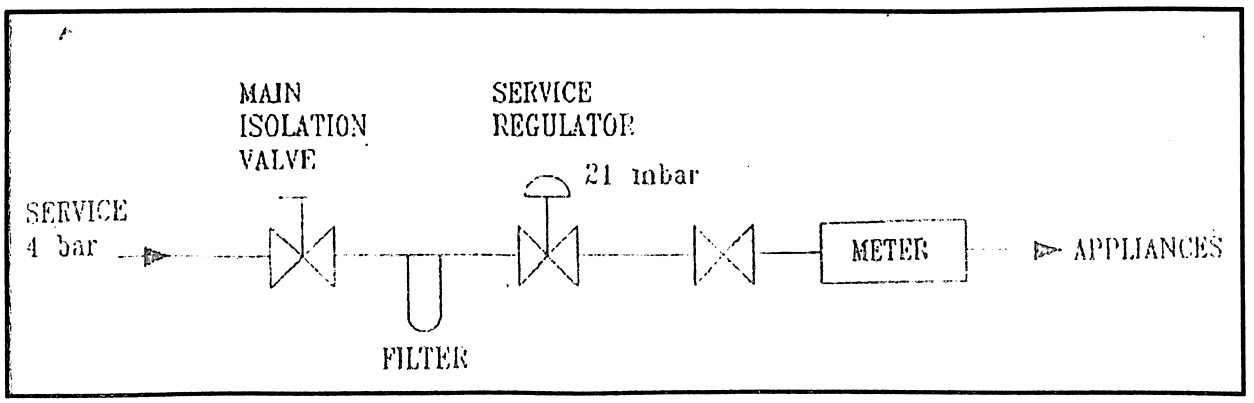


Figure 14. Typical Commercial Meter /Regulator Service

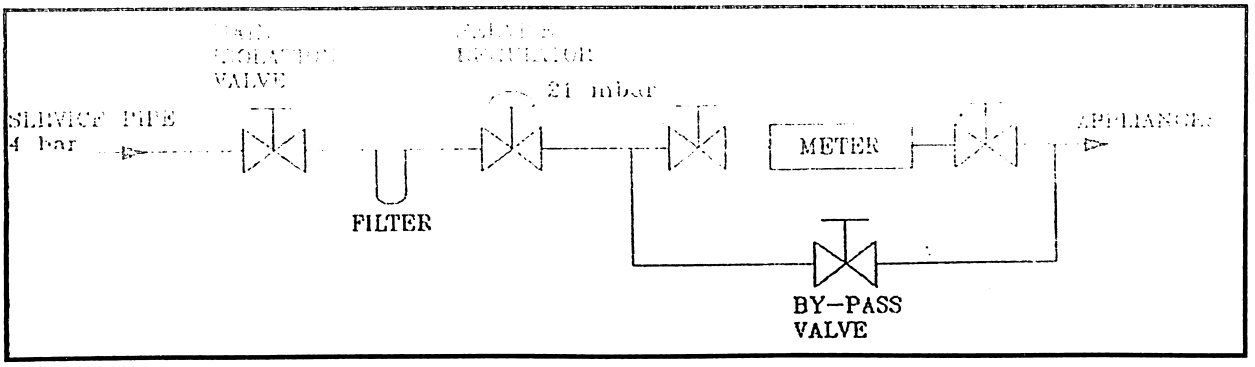


Figure 15. Commercial Meter /Regulator Service with By Pass

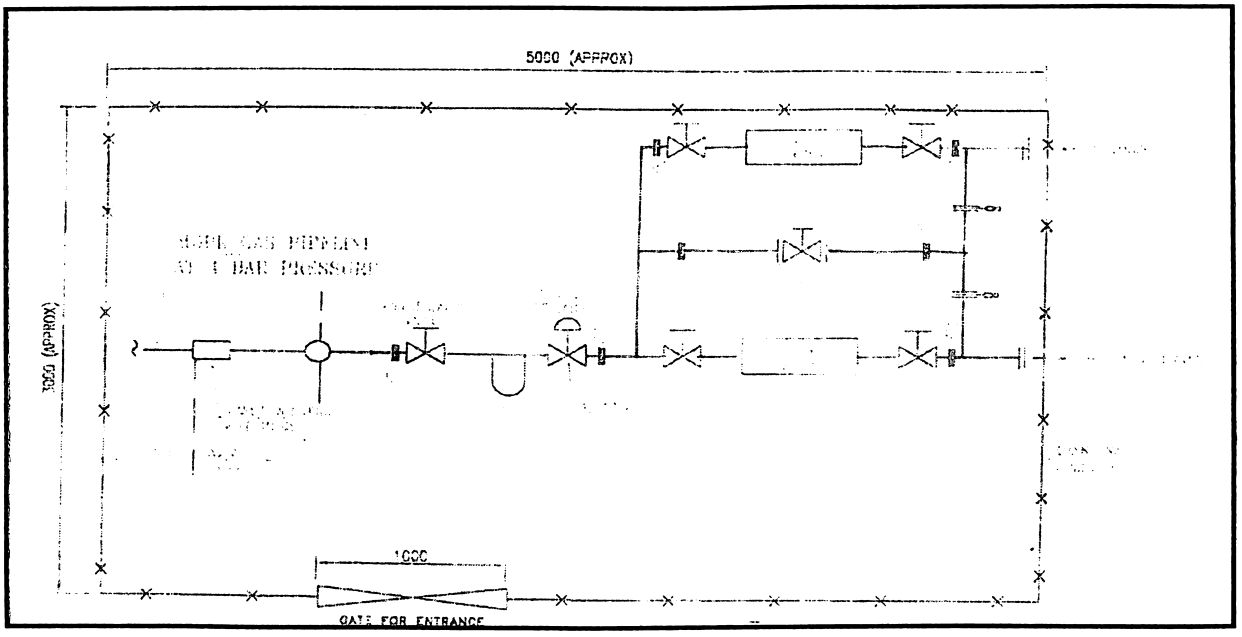


Figure 16. Commercial Connection

Nomenclature

V – Vent

PSV – Pressure Safety Valve

FS – Filter Separator

TM – Turbine Meter

VC – Volume Corrector

SSV – Slam Shut Valve

PR – Pressure Regulator

OS – Odorizing System

CHAPTER – 8

POLYETHYLENE PIPE JOINING METHODS

An integral part of any pipe system is the method used to join the system components. Proper engineering design of a system will take into consideration the type and effectiveness of the techniques used to join the piping components and accessories, as well as the durability of the resulting joints. The integrity and versatility of the joining techniques used for polyethylene pipe allow the designer to take advantage of the performance benefits of polyethylene in a wide variety of applications.

Polyethylene pipe or fittings are joined to each other by heat fusion or with mechanical fittings. Polyethylene may be joined to other materials by means of compression fittings, flanges, or other qualified types of manufactured transition fittings. There are many types and styles of fittings available from which the user may choose. Each offers its particular advantages and limitations for each joining situation the user may encounter.

Thermal Heat Fusion Methods:

There are three types of heat fusion joints currently used in the industry; Butt, saddle, and Socket Fusion. Additionally, there are two methods for producing the socket and saddle heat fusion joints.

The principle of heat fusion is to heat two surfaces to a designated temperature and then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion. When fused according to the pipe and/or fitting manufacturers' procedures, the joint area becomes as strong as, or stronger than, the pipe itself in both tensile and pressure properties. As soon as the joint cools to near ambient temperature, it is ready for handling. The following sections of this chapter provide a general procedural guideline for each of these heat fusion methods.

8.1 Butt Fusion

The most widely used method for joining individual lengths of polyethylene pipe and pipe to polyethylene fittings is by heat fusion of the pipe butt ends as illustrated in Figure. This technique produces a permanent, economical and flow-efficient connection. Quality butt

fusion joints are produced by using trained operators and quality butt fusion machines in good condition.The butt fusion machine should be capable of:

- Aligning the pipe ends
- Clamping the pipes
- Facing the pipe ends parallel with each other
- Heating the pipe ends
- Applying the proper fusion force that results in fusion

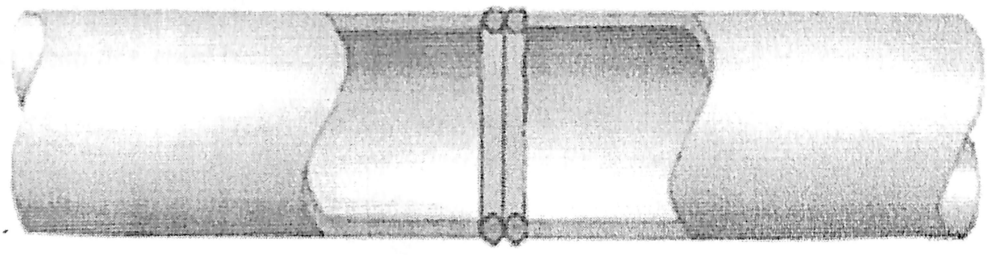


Figure:17 Standard Butt Fusion joint

The six steps involved in making a butt fusion joint are:

1. Clamp and align the pipes to be joined.
2. Face the pipe ends to establish clean, parallel surfaces.
3. Align the pipe profile.
4. Melt the pipe interfaces.
5. Join the two profiles together by applying the proper fusion force.
6. Hold under pressure until the joint is cool.

Optional Bead Removal

In some pipe systems, engineers may elect to remove the inner or outer bead of the joint. External beads are removed with run-around planing tools, which are forced into the bead,

and then drawn around the pipe. Power planers may also be used, but care must be taken not to cut into the pipes outside surface.

It is uncommon to remove internal beads, as they have little or no effect on flow, and removal is time-consuming. Internal beads may be removed from pipes after each fusion with a cutter fitted to a long pole. Since the fusion must be completely cooled before bead removal, assembly time is increased slightly.

8.2 Saddle/Conventional Fusion

The conventional technique to join a saddle to the side of a pipe, illustrated in Figure consists of simultaneously heating both the external surface of the pipe and the matching surface of the "saddle" type fitting with concave and convex shaped heating tools until both surfaces reach proper fusion temperature. This may be accomplished by using a saddle fusion machine that has been designed for this purpose.

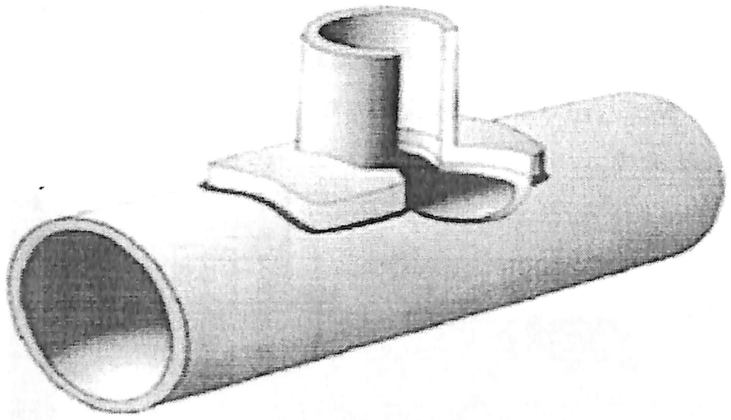


Figure:18 Saddle/Conventional fusion

Saddle fusion, using a properly designed machine, provides the operator better alignment and force control, which is very important to fusion joint quality. The Plastics Pipe Institute recommends that saddle fusion joints be made only with a mechanical assist tool unless hand fusion is expressly allowed by the pipe and/or fitting manufacturer. There are eight basic sequential steps that are normally used to create a saddle fusion joint:

1. Clean the pipe
2. Install heater saddle adapters

3. Install the saddle fusion machine on the pipe
4. Prepare the surfaces of the pipe and fitting
5. Align the parts
6. Heat both the pipe and the saddle fitting
7. Press and hold the parts together
8. Cool the joint and remove the fusion machine

8.3 Socket Fusion

This technique consists of simultaneously heating both the external surface of the pipe and the internal surface of the socket fitting until the material reaches fusion temperature, inspecting the melt pattern, inserting the pipe end into the socket, and holding it in place until the joint cools. Figure illustrates a typical socket fusion joint. Mechanical equipment is available to hold the fitting and should be used for sizes larger than 2 inch CTS to attain the increased force required and to assist in alignment.

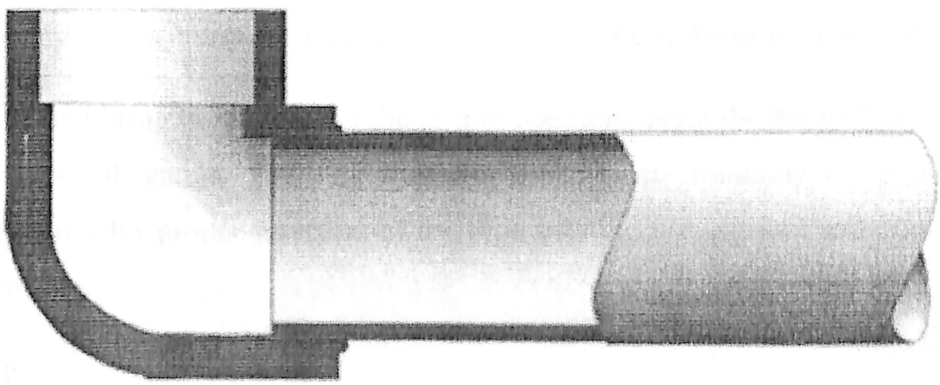


Figure:19 Socket Fusion

General steps to be followed while performing socket fusion:

1. Select the equipment
2. Square and prepare the pipe ends
3. Heat the parts
4. Join the parts
5. Allow to cool

Equipment Selection

Select the proper size tool faces and heat the tools to the fusion temperature recommended for the material to be joined. For many years, socket fusion tools were manufactured without benefit of any industry standardization. As a result, variances of heater and socket depths and diameters, as well as depth gauges, do exist. ASTM F1056 describes standard dimensions for these tools. Therefore, mixing various manufacturers' heating tools or depth gauges is not recommended unless the tools are marked F1056, indicating compliance with the ASTM specification and, thereby, consistency of tooling sizes.

Square and Prepare Pipe

Cut the end of the pipe square. Chamfer the pipe end for sizes 1 1/4 -inch diameter and larger. Remove any scraps, burrs, shavings, oil, or dirt from the surfaces to be joined.

Clamp the cold ring on the pipe at the proper position, using the integral depth gauge pins or a separate depth gauge. The cold ring will assist in re- rounding the pipe and provide a stopping point for proper insertion of the pipe into the heating tool and coupling during the fusion process.

Heating

Check the heater temperature. Periodically verify the proper surface temperature using a pyrometer or other surface temperature measuring device. If temperature indicating markers are used, do not use them on a surface that will come in contact with the pipe or fitting. Bring the hot clean tool faces Into contact with the outside surface of the end of the pipe and with the inside surface of the socket fitting, in accordance with pipe and fitting manufacturers' instructions. Procedures will vary with different materials.

Simultaneously remove the pipe and fitting from the tool using a quick snap action. Inspect the melt pattern for uniformity and immediately insert the pipe squarely and fully into the socket of the fitting until the fitting contacts the cold ring. Twisting of the pipe or fitting should not be done during or after the insertion

Cooling

Hold or block the pipe in place so that the pipe cannot come out of the joint while the mating surfaces are cooling. Cooling times will be listed in the pipe or fitting manufacturer's instructions.

8.4 Electrofusion

This technique of heat fusion joining is somewhat different from the conventional fusion joining thus far described. The main difference between conventional heat fusion and electrofusion is the method by which the heat is applied. In conventional heat fusion joining, a heating tool is used to heat the pipe and fitting surfaces. The electrofusion joint is heated internally, either by a conductor at the interface of the joint or, as in one design, by a conductive polymer. Heat is created as an electric current is applied to the conductive material in the fitting. Figure illustrates a typical electrofusion joint, and Figure (b) illustrates an electrofusion control box and fitting.

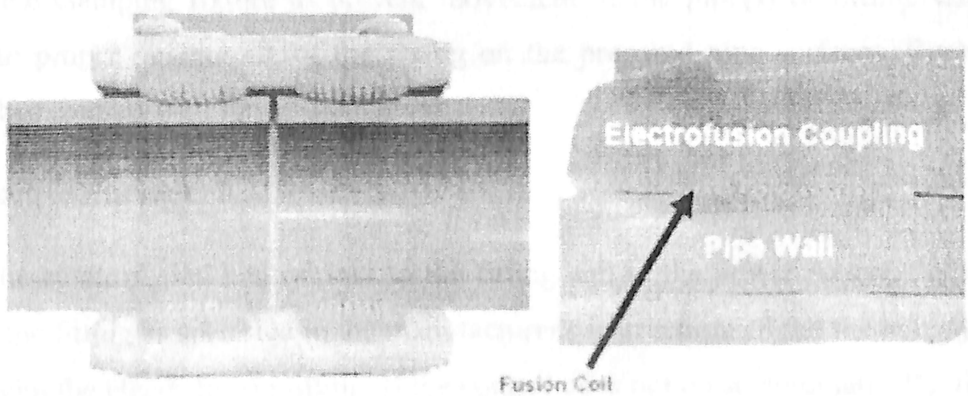


Figure:20 Electrofusion

General steps to be followed while performing electrofusion joining are:

1. Prepare the pipe (scrape, clean)
2. Mark the pipe
3. Align and restrain pipe and fitting
4. Apply the electric current
5. Cool and remove the clamps
6. Document the fusion procedures

Prepare the Pipe (Clean and Scrape)

Assure the pipe ends are cut square when joining couplings. The fusion area must be clean from dirts or contaminants. This may require the use of water or 90% isopropylalcohol.

Scraping: The pipe surface in the fusion area must be removed to expose clean virgin material. This may be achieved by a various manufactured tools.

Mark the Pipe

Mark the pipe for stab depth of couplings and proper fusion location of saddles. (Caution should be taken to assure that a non-petroleum marker is used.)

Align and Restrain Pipe or Fitting per the Manufacturer's Recommendations

Align and restrain fitting to pipe per manufacturer's recommendations. Place the pipes and fitting in the clamping fixture to prevent movement of the pipe(s) or fitting. Give special attention to proper positioning of the fitting on the prepared pipe surfaces. Rerounding of pipe may be required with larger diameters.

Apply Electric Current

Connect the electrofusion control box to the fitting and to the power source. Apply electric current to the fitting as specified in the manufacturer's instructions. Read the barcode which is supplied with the electrofusion fitting. If the control does not do so automatically, turn off the current when the proper time has elapsed to heat the joint properly.

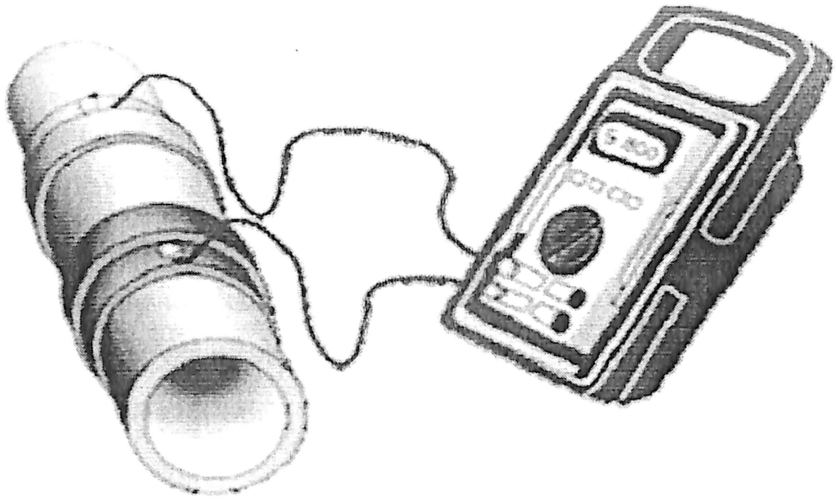


Figure:21 Electrofusion joint control box and leads with clamps and fittings

Cool Joint and Remove Clamps

Allow the joint to cool for the recommended time. If using clamps, premature removal from the clamps and any strain on a joint that has not fully cooled can be detrimental to joint performance.

Consult the fitting manufacturer for detailed parameters and procedures.

Documenting Fusion

The Electrofusion control box that applies current to the fitting also controls and monitors the critical parameters of fusion, (time, temperature, & pressure). The control box is a micro-processor capable of storing the specific fusion data for each joint. •This information can be downloaded to a computer for documentation and inspection of the days work.

CHAPTER – 9

CASE STUDY

Brief Description of the Project

The projected demand of natural gas in the tenth year forms the basis of the total conceptual design and providing facilities thereof in automobile, industrial, commercial and domestic sectors. However, the implementation has been planned in two phases as explained below.

Phase-I shall cater to the needs up till the end of third year demand for automobile sector and some limited facilities for other sectors i.e. domestic & commercial. Certain facilities such as steel pipe network CNG Stations, MDPE Network and DRS etc., shall be installed to meet the total demand up till 3rd year under Phase-I.

Phase-II shall include the augmentation of steel pipeline network, MDPE network, DRS and CNG Stations to cater to 10th year demand for automobile sector and planned demand of other sectors.

9.1 Summary of Demand of Natural Gas

(Realistic Scenario)

Table 7. Demand Scenario in a city

(MMSCMD)

Sl.No.	Years --->	1	2	3	4	5	6	7	8	9	10
A	Domestic	0.0256	0.0409	0.0631	0.1272	0.1730	0.2059	0.2250	0.2295	0.2341	0.2388
B	Industry	0.1212	0.2141	0.3178	0.3850	0.4336	0.4596	0.4872	0.5164	0.5474	0.5802
C	Commercial	0.0143	0.0191	0.0227	0.0265	0.0273	0.0281	0.0290	0.0298	0.0307	0.0316
D	Automobile	0.0389	0.0895	0.1342	0.1686	0.1951	0.2053	0.2114	0.2179	0.2243	0.2310
	Total A To D	0.2020	0.3638	0.5578	0.7073	0.8290	0.8989	0.9526	0.9935	1.0365	1.0816

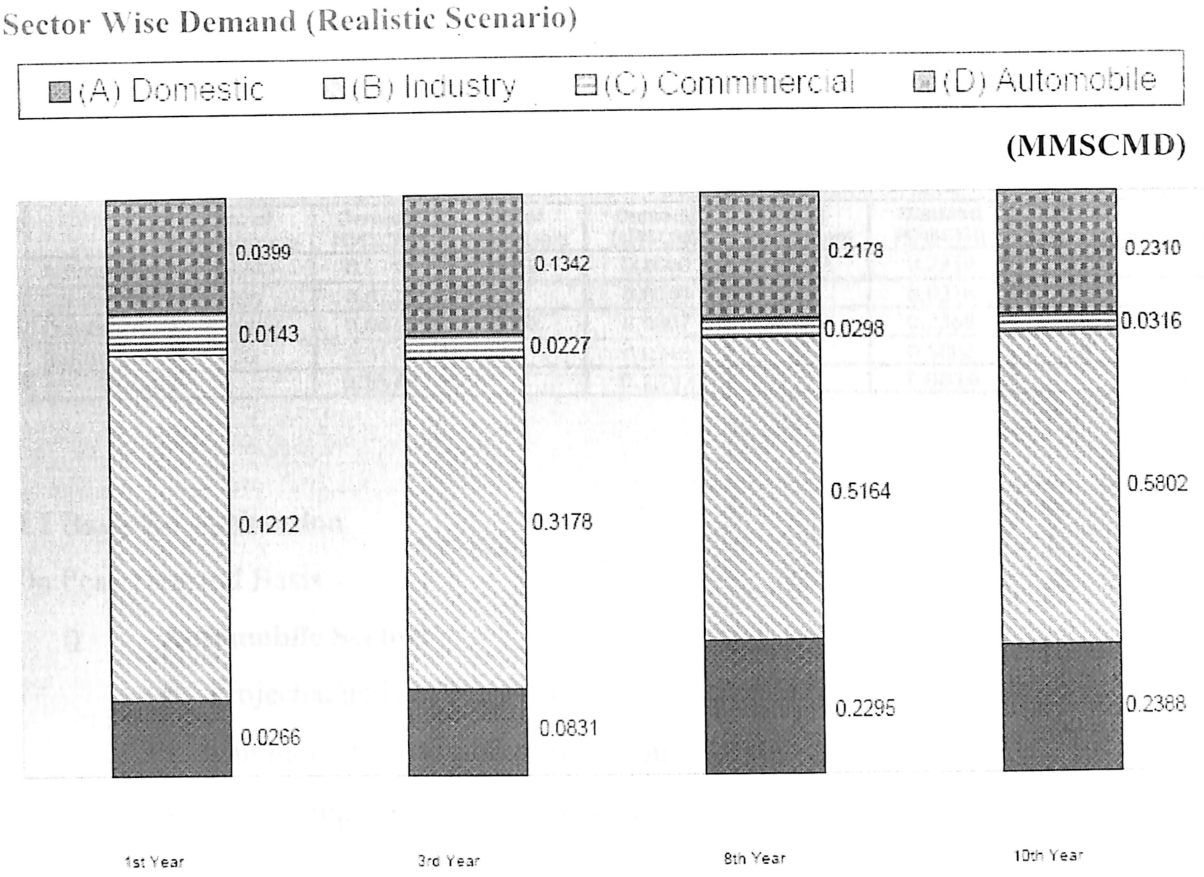


Figure 22. Sector wise Demand

Projected Demand Pattern

Table 8. Projected Demand Pattern

Sector	Phase-I (3rd Year)		Phase-II (10th Year)	
	Qty. (MMSCMD)	Percentage (%)	Qty. (MMSCMD)	Percentage (%)
Automobile	0.1342	24.06	0.2310	21.36
Commercial	0.0227	4.07	0.0316	2.93
Domestic	0.0831	14.90	0.2388	22.07
Industrial	0.3178	56.97	0.5802	53.64
Total	**0.5578**	**100.00**	**1.0816**	**100.00**

Gas Demand Considered for Distribution

Table 9. Gas Demand Consideration For Distribution

SECTOR	Phase-I (3rd Year)				Phase-II (10th Year)			
	Projected Demand		Gas Distribution Plan		Projected Demand		Gas Distribution Plan	
	No. of Consumers	Demand MMSCMD	No. of Consumers	Demand MMSCMD	No. of Consumers	Demand MMSCMD	No. of Consumers	Demand MMSCMD
Automobile	33240	0.1342	15100	0.1000	48240	0.2310	25300	0.1828
Commercial	400	0.0227	30	0.0050	580	0.0316	300	0.0201
Domestic	135400	0.0831	1000	0.0007	388900	0.2388	150000**	0.1050
Industrial	50	0.3178	01	0.0340	70	0.5802	8	0.3340
Total		**0.5578**	-	**0.1397**		**1.0816**		**0.6419**

9.2 Basis for Estimation

On Peak Demand Basis

i) Automobile Sector:

- Projected daily average 10th year = 182800 SCM
- Duration (2 shifts working) = 16 hrs working in a day
- Estimating Sixty percent of daily demand is required in 8 hrs (MHQ).

MHQ, Peak hourly demand = (182800 x 0.6) / 8 = 13710 SCMH ----------(A)

Forty percent of 182800 SCM is required in remaining 8 hrs.

Hourly demand = (182800 x 0.4) / 8 = 9140 SCMH ----------(B)

Select larger of (A) and (B),

Peak Hourly demand in automobile sector = **13710 SCMH** ---- (i)

ii) Industrial Sector :

- Projected daily average, 10th year = 334000 SCM
- Duration : 24 hrs working in a day

Peak hourly demand = 334000 / 24 = **13917 SCMH** ---------- (ii)

iii) Commercial Sector :

- Projected daily average, 10th year = 20100 SCM
- Duration : 12 hrs working in a day

Hourly demand = 20100 / 12 = **1675 SCMH** ---------- (iii)

Domestic Sector :

- Projected daily average. 10th year = 105000 SCM
- Duration : 8 hrs working in a day

Hourly demand = 105000 / 8 = **13125 SCMH** ---------- (iv)

TOTAL PEAK HOURLY DEMAND (MHQ) = (i) + (ii) + (iii) + (iv) = **42427 SCMH**

9.3 Main Grid Design Parameters

Considering the demand load, supply pressure and future requirements for all consumer sectors and inlet pressure at City Gate Station (CGS), the City Grid has been designed.

The main grid line has been designed based on the following design parameters

Table 10. Main Steel Grid Line Parameters

Design Pressure	19kg/cm^2
Specific Gravity of Natural Gas	0.65
Density of Gas	0.788 kg/SCM
Design Temperature	
Buried	45^{0}C
Above Ground	65^{0}C
Design Factors	
Joint Factor	1
Temperature Factor	1
Population Density Factor	Class - IV
Design Life	30 Years
Pipeline Specifications	
Pipeline Material	
For 8" size P/L	API 5L Gr.B, 7.0 mm WT
For 4" size P/L	API 5L Gr.B, 6.4 mm WT
Corrosion Allowance	0.5mm
Pipeline Efficiency	0.9

9.4 Industrial Assessment For Fuel Consumption

Surveys are conducted to assess the potential demand for PNG as an alternative fuel for the existing source of energy the industries are using to fulfil their requirements.

The relations used for calculations are as follows

Liquid Fuels

$$NG_{eq} = Q_f * 10^{-3} * d_f * CV_f / CV_g$$

Solid Fuels

$$NG_{eq} = A_f * CV_f / CV_g$$

Where:

NG_{eq}	-	Equivalent Amount of Natural Gas in SCM.
Q_f	-	Quantity of Fuel to be replaced in litres.
A_f	-	Quantity of Fuel to be replaced in kg.
d_f	-	Density of the fuel to be replaced in kg/m^3
CV_f	-	Calorific Value of the fuel to be replaced in kcal/kg
CV_g	-	Calorific Value of Natural Gas in kcal/SCM

Model Calculations

Assuming Values for Liquid Fuel

Parameter	Value
Q_f	5 litres
d_f	850 kg/m^3
CV_f	10500 kcal/kg
CV_g	8300 kcal/SCM

$$NG_{eq} = (5 * 10^{-3} * 850 * 10500) / (8300)$$

$$= 5.3765 \text{ SCM}$$

Therefore the **5 Litres** of fuel with a calorific value of 10500 kcal/kg is equivalent to **5.3675 SCM** of Natural Gas.

Assuming Values for Solid Fuel

Parameter	Value
A_f	5000 kg
CV_f	4440 kcal/kg
CV_g	8300 kcal/SCM

$$NG_{eq} = (5000 * 4440) / 8300$$

$$= 2674.69 \text{ SCM}$$

Therefore the **5000 kg** of Solid fuel is with Calorific Value of 4440 kcal/kg equivalent to **2674.69 SCM** of Natural Gas.

Energy Equivalence of NG Compared with Other Fuels

Table 11. Energy Equivalence of NG Compared with Other Fuels

Fuel Unit	Natural Gas 1 SCM	LPG 1Kg	HSD 1Kg	LDO 1Kg	FO 1Kg	Kerosene 1 Kg	Coal 1Kg	Wood 1 Kg	Coke 1 Kg	Charcoal 1 Kg
Cal Value in Kcal.	8300	11750	10500	10050	9670	10420	5550	4440	666	6780
Heating transfer efficiency in %	85%	80%	55%	45%	40%	40%	25%	15%	15%	20%
Net Cal. Value in Kcal/Kg	7055	9400	5775	4523	3868	4168	1388	666	999	1356

Natural Gas Equivalence – Quantitative Analysis

1 KG of fuel based on Table12. is equivalent to

Table 12. kg Fuel Equivalent Natural Gas SCM

Fuel	Quantity	Equivalent Natural Gas SCM
LPG	1 Kg	1.4156
HSD	1 Kg	1.2651
LDO	1 Kg	1.2108
FO	1 Kg	1.165
Kerosene	1 Kg	1.2554
Coal	1 Kg	0.6686
Wood	1 Kg	0.5349
Coke	1 Kg	0.08024
Charcoal	1 Kg	0.81686

9.5 Financial Analysis

Capital Expenditure Summary Till 2030 including Taxes & Duties

Expenditure on	Amount in lakhs
Capital Work In Progress	4,288.56
Incidental Expenses During Construction	234.30
Plant & Machinery	1,969.75
Land Cost	1,919.19
Cost of CNG Station	17,911.60
Capital Cost of Steel Gridline	9,174.05
Capital Cost - MDPE (CGD)	41,555.88
Planned Total CAPEX till 2030	**77,053.33**

Taxes & Duties

S.No	Taxes & Duties	%
1	Inland freight	0.50
2	Excise (14.42 %)	14.42
3	CST (2%)	2.00
4	Works Contract Tax	3.00
5	Insurance	1.00
6	Any other applicable tax and duty (give details)	12.36

BREAK UP OF CAPEX FOR STEEL PIPELINE GRID CNG STATIONS TILL 2030

(Rs. in Lacs)

BREAK UP OF CAPEX FOR STEEL PIPELINE GRID (Rs. in Lacs) CNG STATIONS TILL 2030		
A	**Equipment**	**Amount in lacs**
1	Steel Pipes - Main Gridline PE Coated	2895.17
2	CS Valves, Fittings, Transition Fittings	121.94
Subtotal-A		**3017.11**
B	**Erection**	
1	Mechanical (CS)	2220.31
2	Laying Permission for CS pipe line	1541
3	Detailed engineering, procurement, construction, supervision and project management	728.48
Subtotal-B		**4489.79**
C	**Taxes and Duties**	
1	Inland Freight	15.09
2	Excise	435.07
3	CST	60.34
4	Works Contract Tax	134.69
5	Insurance	30.17
6	Service Tax	554.94
7	Contingency	436.86
Subtotal-C		**1667.16**
	Total Cost (Subtotal A + B + C)	**9174.05**

BREAK UP OF CAPEX FOR CNG STATIONS TILL 2030 (Rs. in Lakhs)

CAPITAL COST OF CNG STATION FOR CNG (CASCADES) (Rs in Lacs) TILL 2030		
Sr. No.	**Description**	**Amount in lacs**
A	**CNG Station**	
1	Cascades- 4500 WL	368
2	Dispensers – BUS	171
3	Dispensers – CAR	378
4	Tubing & Fittings	325
	Subtotal – A	**1242**
B	**Capital Spares**	62.1
	Subtotal – B	**62.1**
C	**Erection**	
1	Erection	395
2	Detailed engineering, procurement, construction, supervision and project management	193.22
	Subtotal – C	**588.22**
D	**Taxes and Duties**	
1	Inland Freight	6.52
2	Excise Tax	188.05
3	CST	0
4	Works Contract Tax	17.65
5	Insurance	12.42
6	Service Tax	72.7
7	Contingency	110.79
	Subtotal – D	**434.21**
	Total (A to D)	**2326.53**

CAPITAL COST OF CNG STATION FOR CNG (COMPRESSOR) (Rs in Lacs)

CAPITAL COST OF CNG STATION FOR CNG (COMPRESSOR)		
Sr. No.	**Description**	**Amount in Lacs**
A	**CNG Station**	
1	Online Compressor	8405.76
2	DG Set AND Control Panel	512
3	Fire Fighting System	18.2
4	UPS or Battery Banks	260
	Subtotal	**9195.96**
B	**Capital Spares**	459.8
	Subtotal	**459.8**
C	**Erection**	
1	Mechanical	124.16
2	Electrical	520
3	Instrumentation	416
4	Civil Work	632.95
5	Detailed engineering, procurement, construction, supervision and project management	1307.46
	Subtotal	**3000.56**
D	**Taxes and Duties**	
1	Inland Freight	48.28
2	Excise	1392.36
3	CST	193.12
4	Works Contract Tax	90.02
5	Insurance	91.96
6	Service Tax	370.87
7	Contingency	742.15
	Subtotal	**2928.75**
	Total (A to D)	**15585.07**

BREAK UP OF CAPEX FOR CITY GAS DISTRIBUTION TILL 2030 (Rs. in Lacs)

CAPITAL COST OF CITY GAS DISTRIBUTION (Rs in lakhs)		
Sr. No.	**Description of facilities**	**Total**
A	**Equipment**	
1	Pipe MDPE / HDPE	2079.57
2	MDPE/ HDPE Valves, Fittings, Transition Fittings	4890.89
3	DRS	840
4	TCP / PCP	0
	Subtotal	**7810.46**
B	**Erection**	
1	Mechanical (MDPE / HDPE)	15557.68
2	Laying Permission (MDPE)	9875.9
3	Detailed engineering, procurement, construction, supervision and project management	3548.36
	Subtotal	**28981.95**
C	**Taxes & Duties**	
1	Inland Freight	340.78
2	Excise and CST(MDPE)	692.62
3	Customs Duty (MDPE)	1184.99
4	Works Contract Tax	106.45
5	Service Tax	438.58
6	Insurance	21.21
7	Contingencies and escalation	1978.85
	Subtotal	**4763.48**
	Total (A+B+C)	**41555.88**

OPERATING COST:

Operating cost is 5% of the capital cost and can vary from 5% to8%

So the Operating Cost comes out to be = 3852.67 (Rs. in Lacs)

Gas Selling Pricing Model

CNG Pricing Model at 14% Post Tax IRR		
	APM	RLNG
Basic price - for CNG @14% infrastructure cost as per PNGRB	7.74	7.74
Gas price	7.81	14.80
Total gas price	15.55	22.54
Exicise duty (14.42%)	2.24	3.25
Total gas price inclusive tax	17.79	25.79
VAT (13.5%)	2.40	3.48
Total gas price (per scm)	20.19	29.27
Conversion factor into kg	1.44	1.44
Selling price (per kg)	29.08	42.15

Calculation Of Selling Price of Domestic Sector (INR)	
LPG price	309.75
Price per kg	21.81
Calorific Value of LPG	11000
Calorific Value of NG	8300
Energy Equivalent	16.459
10% Discount	1.646
Selling price	14.813 PER SCM

Calculation of Selling Price of Commercial Sector (INR)	
LPG Price	797.64
Price per kg	41.54
Calorific Value of LPG	11000.00
Calorific Value of NG	8300.00
Energy Equivalent	31.35
10% Discount	3.13
Selling Price	28.21PERSCM

Calculation of Selling Price of Industrial Sector (INR)	
Delivered price of furnace oil	27.50
Calorific Value of F.O.	9700.00
Calorific Value of NG	8300.00
Energy Equivalent	23.53
10% Discount	2.35
Selling price	21.18 PERSCM

CHAPTER 10

OPERATION AND MAINTENANCE

10.1 Basic Requirements

Each operating company having gas transmission or distribution facilities should have the following basic requirements in acceptance with the respective codes.

- To have a written plan covering operating and maintenance procedures in accordance with the scope and intent of the code.
- To have a written emergency plan covering facility failure or other emergencies.
- Operating and maintaining the facilities in conformance with the plans.
- Modifying the plans periodically as experience dictates and as exposure of the public to the facilities and changes in operating conditions require.
- Providing training for employees in procedures established for operating and maintenance functions. The training should be comprehensive and should be designed to prepare employees for service in their area of responsibility.
- Keeping records to administer the plans and training properly.
- The written plan should include detailed plans and instructions for employees covering operating and maintenance procedures for gas facilities during normal operation and repairs.
- Particular attention should be given to those portions of the facilities presenting the greatest hazard to the public in the event of any emergency or because of construction or extraordinary maintenance requirements.

10.2 Pipeline Failure Investigation

This investigation will establish procedures to analyze all failures and accidents for determining the cause and to minimize the possibility of a recurrence. This plan shall include a procedure to select samples of the failed facility equipment for laboratory examination when necessary.

10.3 Prevention of Accidental Ignition

Smoking and all open flames shall be prohibited in and around structures or areas containing gas facilities (such as compressor stations, meter and other gas handling equipment), where possible leakage of gas constitutes a hazard of fire or explosion.

The following steps should be taken to minimize the danger of accidental ignition of gas:

- When a hazardous amount of gas is to be vented into open air, each potential source to ignition shall first be removed from the area and adequate fire extinguishers shall be provided. All flashlights, lighting fixtures, extension cords, and tools shall be of a type approved for hazardous atmospheres. Blow down connections that will direct the gas away from any electrical transmission lines must be installed or used.
- Suitable signs and flagmen or guards, if necessary, shall be posted to warn others approaching or entering the area of the
- To prevent accidental ignition by electric arcing, an adequate bonding cable should be connected to each side of any piping that is to be parted or joined, and any cathodic protection hazard. rectifiers in the area shall be turned off. When plastic pipe is being parted or joined, a spray of water or use of wet rags is advised to cover the surface to prevent static arcing.
- When cutting by torch or welding a thorough check shall first be made for the presence of a combustible gas mixture in the area outside of the pipeline. If found the mixture shall be eliminated before starting welding or cutting. Monitoring of the air mixture should continue throughout the progress of the work.
- Before cutting by torch or welding on a line that may contain a mixture of gas and air, it shall be made safe by displacing the mixture with gas, air, or an inert gas. Caution must be taken when using an inert gas to provide adequate ventilation for all workers in the area.

10.4 Pipeline Maintenance

Periodic Surveillance of Pipelines

In order to maintain integrity of pipeline system, procedures for periodic surveillance of facilities should be implemented. Studies shall be initiated and appropriate action shall be taken where unusual operating and maintenance conditions occur, such as failures, leakage history, drop in flow efficiency due to internal corrosion or substantial changes in cathodic

protection requirements. When such studies indicate the facility is in unsatisfactory condition, a planned program shall be initiated to abandon, replace, or recondition and proof test. If such facilities cannot be reconditioned or phased out, the maximum allowable operating pressure shall be reduced.

Pipeline Patrolling

It will maintain a periodic pipeline patrol program to observe surface conditions on and adjacent to each pipeline right-of-way, indications of leaks, construction activity other than that performed by the company, natural hazards, and any other factors affecting the safety and operation of the pipeline. Main highways and railroad crossings should be inspected with greater frequency and more closely than pipelines in open area.

Maintenance of Cover at Road Crossings and Drainage Ditches: This activity includes determining by periodic surveys if he cover over the pipeline at road crossings and drainage ditches has been reduced below the requirements of the original design. If the normal cover provided at the time of pipeline construction has become unacceptably reduced due to earth removal or line movement, then protection done by providing barriers, culverts, concrete pads, casing, lowering of the line, or other suitable means.

Maintenance of Cover in Terrain

As a result of patrolling if it is known that the cover over the pipeline in terrain does not meet the original design or the cover has been reduced to an unacceptable level then there should be provision for additional protection by replacing cover, lowering the line, or other suitable means.

Leakage Surveys

A transmission line should be provided for periodic leakage surveys of the line in its operating and maintenance plan. The types of surveys selected shall be effective for determining if potentially hazardous leakage exists. The extent and frequency of the leakage surveys shall be determined by the operating pressure, piping age, class location, and whether the transmission line transports the gas without an odorant.

Pipeline Leak Records

Records shall be made covering all leaks discovered and repairs made. All pipeline breaks shall be reported in detail. These records along with leakage survey records, line patrol records, and other records relating to routine or unusual inspections shall be kept in the file of the operating company, as long as the section of line remains in service.

Pipeline Markers

- Signs or markers shall be installed where it is considered necessary to indicate the presence of a pipeline at road, highway, railroad, and stream crossings. Additional signs and markers shall be installed along the remainder of the pipeline at locations where there is probability of damage or interference.
- Signs or markers and the surrounding right-of- way shall be maintained so markers can be easily read and are not obscured.
- The signs or markers shall include the words "Gas (or name of gas transported) Pipeline," the name of the operating company, and the telephone number (including area code) where the operating company can be contacted.

10.5 Distribution Piping Maintenance

Patrolling

Distribution mains shall be patrolled in areas where necessary to observe factors that may affect safe operation. The patrolling shall be considered in areas of construction activity, physical deterioration of exposed piping and supports, or any natural causes, which could result in damage to the pipe. The frequency of the patrolling shall be determined by the severity of the conditions that could cause failure or leakage and the subsequent hazards to public safety.

Leakage Surveys

As a part of operating and maintenance plan provision for making periodic surveys on the system should be adopted The types of surveys selected should be effective for determining if potentially hazardous leakage exists. The following are some procedures that may be employed:

- Surface gas detection surveys
- Subsurface gas detector survey (including bar hole surveys)
- Vegetation surveys
- Pressure drop tests
- Bubble leakage tests
- Ultrasonic leakage tests

The extent and frequency of leakage surveys shall be determined by the character of the general service area, building concentrations, piping age, system condition, operating pressure and any other known condition (such as surface faulting, subsidence, flooding, or an increase in operating pressure) that has significant potential to either initiate a leak or to cause leaking gas to migrate to an area where it could result in a hazardous condition. Special one-time surveys should be considered following exposure of the gas distribution system to unusual stresses (such as those resulting from earthquakes or blasting). The leakage survey frequencies shall be based on operating experience, sound judgment and a knowledge of the system. Once established, frequencies shall be reviewed periodically to affirm that they are still appropriate. The frequencies of the leakage survey should at least meet the following

- Distribution systems in a principal business district should be surveyed at lest annually. Such surveys shall be conducted using a gas detector and shall include test of the atmosphere that will indicate the presence of gas in utility manholes, at cracks in the pavement and sidewalks, and at other locations that. provide opportunities for finding gas leaks.
- The underground distribution system outside the areas covered above should be surveyed as frequently as experience indicates necessary, but not less than once every 5 years

Inspection and Testing of Relief Valves

All pressure relieving devices in compressor stations should be inspected and/or tested and all devices except rupture disks shall be operated periodically to determine that they open at the correct set pressure. Any defective or inadequate equipment found shall be promptly repaired or replaced. All remote control shutdown devices shall be inspected and tested at least annually to determine that they function properly.

Isolation of Equipment for Maintenance or Alterations

The company should establish procedures for isolation of units or sections of piping for maintenance and for purging prior to returning units to service and shall follow these established procedures in all cases.

Storage of Combustible Materials

All flammable or combustible materials in quantities beyond those required for everyday use or other than those normally used in compressor buildings shall be stored in a separate structure built of noncombustible material located at suitable distance from the compressor building. All aboveground gasoline storage tanks shall be protected in accordance with the ANSI/NFPA 30.

Maintenance and Testing of Gas Detection and Alarm Systems

Each gas detection and alarm system required by this code shall be maintained to function reliably. The operator shall develop maintenance and calibration procedures to periodically verify the operational integrity of the gas detection and alarm systems installed.

10.6 Maintenance of Pressure Limiting and Pressure Regulating Stations

All pressure limiting stations, relief devise, and other pressure regulating stations and equipment should be subject to systematic, periodic inspections and suitable tests, or reviewed to determine that they are in good mechanical condition. Visual inspections should be made to determine that equipment is properly installed and protected from dirt, liquids or other conditions that might prevent proper operation. The following shall be included in the inspection where appropriate:

- station piping supports, pits and vaults for general condition and indications of ground settlement
- station doors and gates and pit vault covers to determine that they are functioning properly and that access is adequate and free vault maintenance.
- ventilating equipment installed in station buildings or vaults for proper operation and for evidence of accumulation of water, ice, snow or other obstructions
- control, sensing and supply lines for conditions that could result in a failure

- all locking devices for proper operation.
- station schematics for correctness

If acceptable operation is not obtained during the operational check, the cause of the malfunction shall be determined, and the appropriate components shall be adjusted, repaired or replaced as required. After repair, he component shall be again be checked for proper operation.

At least once each calendar year, a review shall be made to ensure that the combined capacity of the relief devices on a piping system or facility is adequate to limit the pressure at all times. This review should be based on the operating conditions that create the maximum probable requirement for relief capacity in each case, even though such operating conditions actually occur infrequently and /or for only short periods of time. If it is determined that the relieving equipment is of insufficient capacity, steps shall be taken to install new or additional equipment to provide adequate capacity.

Whenever abnormal conditions are imposed on pressure or flow control devices, the incident shall be investigated and a determination shall be made as to the need for inspection and/or for only short periods of time. If it is determined that the relieving equipment is of insufficient capacity, steps shall be taken to install new or additional equipment to provide adequate capacity.

An inspection and/ or test of stop valves should be made to determine that the valves will operate and are correctly positioned. The following should be included in the inspection test:

- station inlet, outlet, and by pass valves
- relief device isolating valves
- control, sensing and supply line valves

The final inspection procedure shall include the following:

- A check for proper position of valves. Special attention shall be given to regular station by pass valves, relief device isolating valves and valves in control, sensing and supply lines
- Restoration of all locking and security devices to proper position

Every distribution system supplied by more than one pressure regulating station shall be supplied with telemetering or recording pressure gages to indicate the gas pressure in the district.

- On distribution systems supplied by a single pressure regulating station, the company shall determine the necessity of installing such gages in the district. In making this determination, the company should take in to consideration the operating conditions such as the number of customers supplied, the operating pressures, the capacity of the installation, etc.
- If there are indications of abnormal high or low pressures, the regulator and the auxiliary equipment shall be inspected and the necessary measures shall be employed to rectify any unsatisfactory operating conditions. Suitable periodic inspections of single pressure regulation stations not equipped with telemetering or recording gages shall be made to determine that the pressure regulating equipment is functioning properly.

10.7 Recommended Inspection Procedures

The certificate of fitness holder should make regular inspections and patrols of the assigned area of responsibility to make sure that fire protection systems, storage containers, and related equipment are in good condition. Defective components (e.g., leaking faucets) should be replaced promptly. The certificate of fitness holder must notify the fire department and his or her supervisor when major defects are discovered (e.g., when the sprinkler system is inoperative). Violations may be issued and enforcement action taken against the certificate of fitness holder when major defects are not reported. Although the inspections will

CONCLUSION

Natural gas is the fastest growing primary energy source amongst fossil fuels. It is projected to grow around 3-4 times in the next 20 years. It is also necessary to safeguard our environment by reducing pollutants. Natural Gas with its clean burning property compared to all the other fuels is the key to the future.

City Gas Distribution is seen as the sunlight of the future in providing energy efficient and clean fuel to the cities in India. Natural Gas usage in Indian cities has been limited primarily due to the scarcity of supply. However this scenario is undergoing change with several LNG projects/transnational pipelines under implementation, which together with new domestic Gas finds are expected to shore up the supply deficit in the next few years. Meanwhile the market for city gas distribution is also set to grow at an accelerated pace. The CNG demand is in the increase as the Supreme Court has passed a directive on pollution reduction in 12 major cities in India. The domestic segment is also expected to grow with the government's intentions to remove the subsidy on LPG cylinders in a phased manner in 3-5 years making piped gas even more economical. There is a tremendous investment opportunity in City Gas Distribution Industry.

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