CNG STATION DESIGN

By

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"CNG STATION DESIGN"

A thesis submitted in partial fulfilment of the requirement for the Degree of
Master of Technology
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UNIVERSITY OF PETROLEUM & ENERGY STUDIES
(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled **"CNG Station Design"** has been carried out by Utkarsh Vikram Singh under my/our supervision during March/April 2008 and has not been submitted elsewhere for a degree.

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ABSTRACT

Project aims at giving details regarding the design parameters and various civil as well as mechanical aspects of a CNG Station design.

This topic Design of a CNG Station includes discussions on various parts and equipments involved at a CNG Station viz; the compressor, diesel generator, dispenser, the gas meter, storage cascade, pipes, valves & fitting, control panel , safety accessories etc.

It also deals with the basis of design (civil aspects) of a CNG Station and primarily the selection of the compressor. A 3-stage double cylinder reciprocating compressor is concluded to be the most efficient and suitable under the present scenario.

Along the pipeline network CNG stations shall be established to service to the fuel needs of the transport sector. CNG Stations shall directly get connected to the pipeline network so that it receives gas at a minimum pressure of 19 bar(g). Where the pipeline connectivity is not established, the stations shall be operated as "Daughter-Booster" stations. Dedicated stations shall be established for the bulk CNG users such as the Local City Bus service, State Transport buses, etc. Land for the CNG station is assumed to be provided by the state government / local government.

The present invention is a dual-service compression and refueling system providing refueling capability and flexibility that were neither previously known nor available to either refueling station owners or vehicle operators. Using the system and method of the invention, one can use a single compressor installation and control system to compress, store and dispense methane or natural gas, or variable mixtures of methane or natural gas at pressures and densities that are appropriate for an intended use.

ACKNOWLEDGEMENT

At the very outset, I would like to thank Mr.B.P.Pandey, the Dean of U.P.E.S. for giving me the opportunity to undergo this major project.

I am happy to acknowledge our mentor Mr.R.P.Shriwas, Senior Adjunct Professor for the guidance and help that he provided to me during our project and helping me in all respect in bringing out this report. I am also very grateful to Mr. Rakesh Kumar Singh (Senior Manager, Projects) who despite many pressure on his time, readily agreed to my request.

Lastly I would like to express my heartfelt thanks to all staff members of Adani Energy Limited who gave me unending support right from the initial stage of our project.

Utkarsh Vikram Singh

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NOMENCLATURE

AGA: American Gas Association.

ANSI: American National Standards Institute.

API: American Petroleum Institute

ASME: American Society of Mechanical Engineer

CGS: City Gate Station.

CNG: Compressed Natural Gas.

DCEP: Direct Current Electric Power.

GAIL: Gas Authority of India.

GI: Galvanized Iron.

IPRS: Industrial Pressure Regulating Station.

ISO: Indian Standards Organization.

LNG: Liquefied Natural Gas.

MDPE: Medium Density Polyethylene.

MMSCMD: Million Metric Standard Cubic Meters per Day

MAOP: Maximum Allowable Operating Pressure.

ND: Nominal Diameter.

OISD: Oil Industry Safety Directorate.

PCV: Pressure Control Valve.

PNG: Piped Natural Gas.

PSV: Pressure Safety Valve.

ROW: Right of Way.

ROU: Right of Use

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Compressed Natural Gas (CNG) has been identified as one of the alternate fuels to liquid petroleum fuels, which has added environmental benefits. This fuel is being used internationally with the proven success as an automotive fuel.

CNG is a mixture of hydrocarbon gases and vapours consisting of principally methane in gaseous form which are compressed to a pressure of 200 to 250 Kg/ Sq.cm.g. for use as a vehicular fuel. Besides, installation of conversion kit in an Automotive system, two major installations need to be erected i.e.

1) Compressors station for either on-line operation or to serve as mother station
2) Refuelling station either with on-line facility or with moveable cascade.

These facilities may be either co-located in the MS/HSD dispensing stations or at dedicated stations.

Safety at these installations is most important factor in view of the operating conditions such as pressure, storage of other flammable materials etc. The provisions in this standard shall provide a reasonable level of safety and protection from loss of life and property from fire and explosion. This is primarily the reason why I chose to work on this topic.

Along the pipeline network CNG stations shall be established to service to the fuel needs of the transport sector. CNG Stations shall directly get connected to the pipeline network so that it receives gas at a minimum pressure of 19 bar(g). Where the pipeline connectivity is not established, the stations shall be operated as "Daughter-Booster" stations. Dedicated stations shall be established for the bulk CNG users such as the Local City Bus service, State Transport buses, etc. Land for the CNG station is assumed to be provided by the state government / local government.

SCOPE

This topic lays down the minimum safety requirements at installations discussed above, handling Natural Gas for dispensing into vehicles and minimum checks required in the vehicles by Refuelling stations. It is not intended that requirements should be applied rigidly to existing installations duly approved by Chief Controller of Explosives, where for a variety of reasons it may not be practicable to comply with.

Approval.

The following systems and system components shall be listed or approved:

(1) Pressure relief devices, including pressure relief valves
(2) Pressure gauges
(3) Pressure regulators
(4) Valves
(5) Hose and hose connections
(6) Vehicle fueling connections
(7) Engine fuel systems
(8) Electrical equipment related to CNG systems

The present invention is a dual-service compression and refueling system providing refueling capability and flexibility that were neither previously known nor available to either refueling station owners or vehicle operators. Using the system and method of the invention, one can use a single compressor installation and control system to compress, store and dispense methane or natural gas, or variable mixtures of methane or natural gas at pressures and densities that are appropriate for an intended use.

The methodology followed for Chronological Set Up Of CNG Stations include:

(a) Survey And Projection Of Vehicles
(b) Implication Dependence Of CNG Infrastructure:

In the design methodology I have throw light on the civil infrastructure with focus on installations site and minimum safety distances. Mounting of CNG stations so as to avoid concentration of excessive load on the supports is another important parameter. Also discussion on the Design For Maneuvering Area Of CNG Filling Stations, Fast fill stations, Slow fill stations, Pavement for Vehicle Circulation and Special Distribution of Refueling and Maneuvering Area and Circulation and Maneuvering Areas have been done.

Taking a serious view of the Supreme Court directives and the reports of Lucknow being counted among the most polluted city in the country. State govt. has worked out plan to combat the pollution. The progress of CNG infrastructure in Lucknow till date was excruciatingly painful due to non implication of CNG as mandatory for Lucknow city. With the SC's directive and NOC from state govt. for CNG infrastructure development, GGL and AEL have taken pace in full swing for the implication of city gas distribution system.

1.2 OVERVIEW OF CITY GAS DISTRIBUTION IN INDIA

Oil India Limited (OIL) was first to start distribution of gas in Assam in the 60s. In Gujarat, Oil and Natural Gas Corporation (ONGC) started selling its associated gas to the neighboring industries in the 70s. 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 bassein of Mumbai shores, the first cross country pipeline in India was conceptualised 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 this pipeline, which ran from Hazira to Jagdishpur via Bijaipur. This pipeline supplied gas to the fertilizer and power sector. Thereafter, entire existing assets of ONGC and development of new networks were transferred to GAIL.

Gujarat Gas Company Ltd. (GGCL) was the first commercial city gas distribution project in India. GGCL currently under British Gas management developed distribution network in the 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 of surplus cater to the industrial demand.

Similarly in 1998, Indraprastha Gas Company Limited (IGL) started city gas distribution in Delhi. The focus of IGL was to provide CNG to the transport sector in view of Supreme Court judgment making CNG compulsory.

In addition to these, city gas distribution in limited scope is present in Sibsagar (Assam) and Agartala (Tripura) mainly for the domestic users.

With the successes of IGL & MGL, CNG has become the most sought after fuel in the transport sector. Use of CNG not only checks the air pollution but also provides immense savings to the user.

Internationally as well as domestically, the use of natural gas has been increasing steadily for several reasons viz. price advantage, environmental concerns, fuel diversification and/or energy security issues, market deregulation (for both gas and electricity) and overall growth in the economy.

1.3 OVERVIEW OF CITY GAS DISTIBUTION IN LUCKNOW

Lucknow, the capital of Uttar Pradesh is situated 123 Mts. above sea level. It is situated on 26.30 & 27.10 North latitude and 80.30 & 81.13 East longitude. Lucknow covers an area of 2544 sq.km. River Gomti flows through the city. Sai river flows from the south of the city and in the east enters district Raebareli.

Lucknow has a population of approx. 23.0 Lacs having a literacy rate of 68.63%. It is the second largest urban centre in Uttar Pradesh after Kanpur. Being capital of the State, the district has well knit rail and road links with other districts in the state and also with some important parts of the country.

Modern Lucknow, spread evenly on both sides of river Gomti, is a perfect blend of the ancient with the modern, as many glitzy shopping arcades coexist with the old monuments. Lucknow has also emerged as a "Science City", and numerous national level laboratories, premier medical colleges, two universities along with an engineering college and Management institute are present here. An educational and cultural center, it has varied industries, including food processing and handicrafts. The city is a major transportation hub and has an important agricultural market.

In order to promote biotechnology based industries in the state, biotechnology city, one each at Lucknow and Noida, are proposed to be established jointly with UPSIDC with partial financial support from Govt. of India. It is expected that the proposed biotechnology cities shall provide opportunity for scientists, engineers, consultants and entrepreneurs looking for the development of biotechnology industries in the State.

Being the capital of UP, it is an important urban centre of North India. It has a good mix of industrial units, commercial establishment, vast population and large number of vehicles. Lucknow therefore offers a great opportunity to develop the gas distribution project.

Looking to the vast opportunities in city gas distribution projects, Adani Group has been working on developing the city gas distribution project in various cities in the country since 1998. It secured NOC from Government of Gujarat to develop city gas distribution projects in Ahmedabad and Vadodara. Adani Group formed a separate company - Adani Energy Limited (AEL) for implementing these projects. Today Adani Group is proud to claim successful implementation of the projects in a record time of less than 2 years.

Adani Group has been recently awarded the rights to develop the City Gas Distribution project in Faridabad (Haryana) which is also part of the NCR. With this it is the only Group in the country to be involved with City Gas Distribution projects in multiple cities in the country.

Example of City Gas Distribution

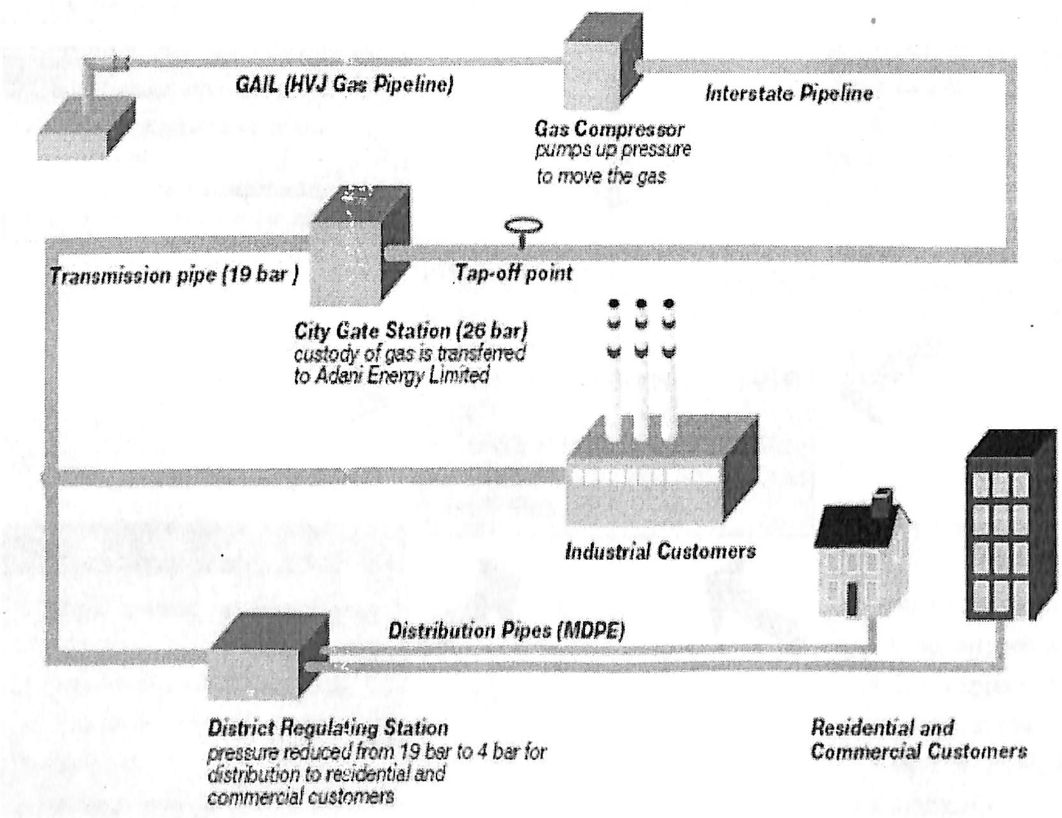
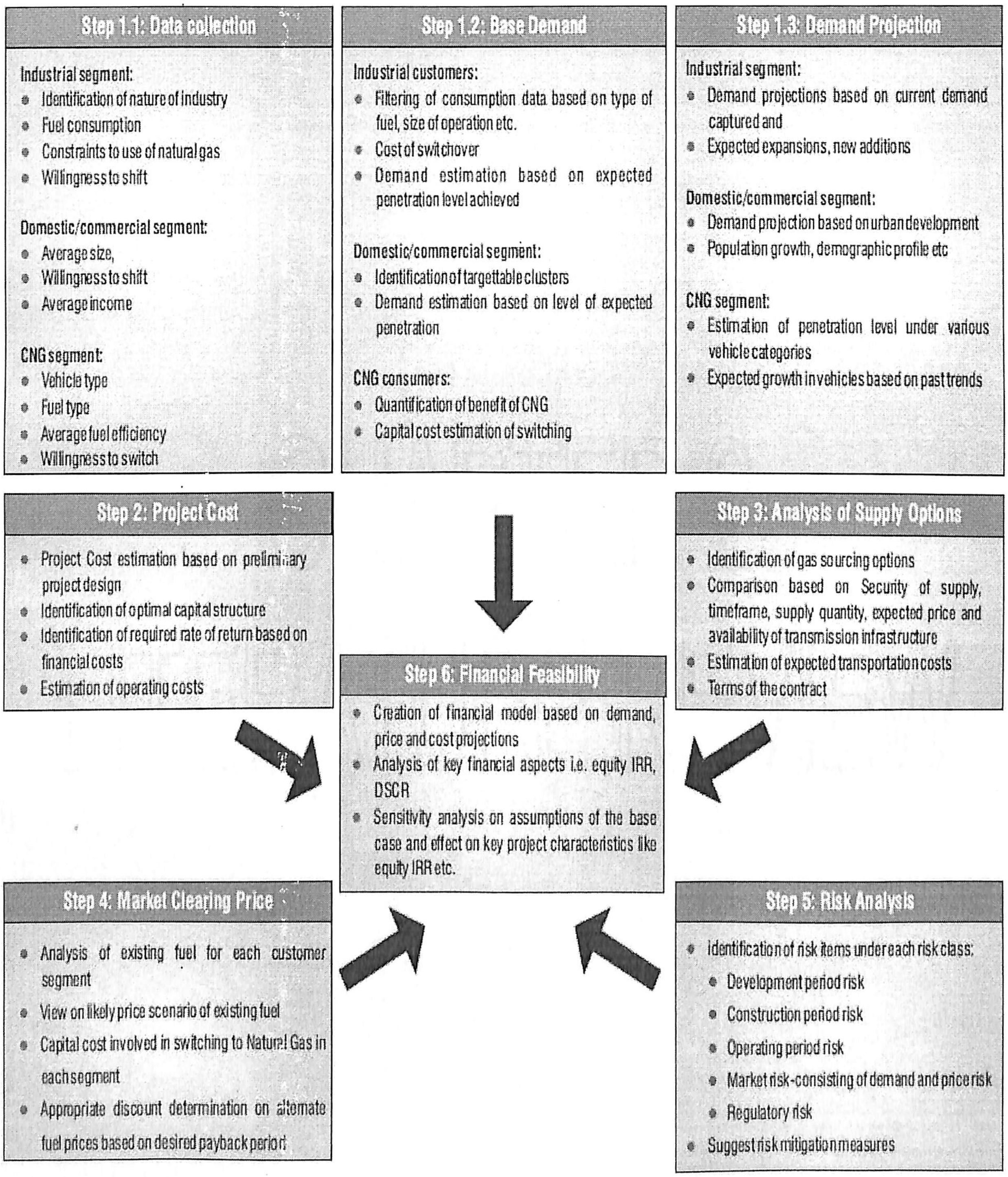


Figure 1

1.4 Feasibility of City gas distribution project:



CHAPTER 2
LITERATURE REVIEW

2.1 NATURAL GAS – FUEL OF THE CENTURY

Globally natural gas is the fastest growing component of the total energy consumption. Use of Natural gas is increasing around the world for a variety of reasons including economy, environmental friendliness, fuel diversification and energy security issues, market deregulation for gas & electricity, etc.

Global Natural gas consumption which stood at 87 trillion cubic feet in 2001 is expected to double to 182 trillion cubic feet by 2020 with an average annual growth rate of 3.2 %. Significant rise in gas consumption is expected in Central and South America and Asia. The share of natural gas in the energy basket is likely to go upto 28 % by 2020 from the current levels of 16%

Gas consumption is expected to grow by 2.4 % per year in the industrialized countries. Natural gas is likely to account for largest increase in energy use for power generation over next two decades as compared to others. In developing countries also similar trends are likely for the natural gas consumption. As per estimates natural gas consumption would grow by an average of 5.2%, more rapidly than any other fuel, up to 2020.

The increase in usage of natural gas can be attributed to the increasing sensitivity to environment issues and need to improve the environment performance. Besides the environment advantage, natural gas also provides efficient combustion, economy and convenience.

India is a large country with a population of over one billion (16% of world population). To provide a better quality of life for the people, the energy needs are enormous. Continued economic development and population growths are driving energy demand faster than India can produce it. India consumes 12.18 quadrillion Btu (Quads) of energy, or roughly 3% of the world's total energy consumption. During the last 50 years the Government of India through National Oil Companies has developed a reliable energy production and distribution system. However, energy consumption in India, despite growing at a rapid pace, is still much below the world average.

Natural gas in India is increasingly becoming more popular as a primary energy source since the last two decades. It is primarily used in power, fertilizer, petrochemicals and steel sector. Consumption of natural gas rose from 628 billion cubic feet (bcf) per year in 1995, to 800 bcf in 2004. Natural gas will become a bigger part of the energy picture for India, primarily as a way to reduce dependence on foreign oil and also to meet the stringent environmental regulations because of the absence of sulfur dioxide and reduced levels of carbon dioxide and nitrogen oxide.

As per the Hydrocarbon Vision 2025 of Government of India, share (%) of natural gas in future Energy Supply in India will be as follows : **Table 2**

Year	*Coal*	*Oil*	*Gas*	*Hydel*	*Nuclear*
1997-98	55	35	7	2	1
2001-02	50	32	15	2	1
2006-07	50	32	15	2	1
2010-11	53	30	14	2	1
2024-25	50	25	20	2	3

Source: HYDROCARBONS VISION – 2025, GOI

Over the last one and half decade the Indian gas market has made significant advancements and is now ready of take off on much wider coverage of the country the next 10 years or so. The Indian gas market, at present, is supply constrained, however number of supply side initiatives have been taken by Govt. of India to increase the gas supply to the market from the domestic resources as well as through imports. The policy framework has been put in place to support development of gas import projects as well as to intensify exploration in the country to improve the base of recoverable gas reserves in coming years. Similarly major steps have been taken to undertake study and commercial exploitation of unconventional gas resources.

Gas Demand

	Terminal Year of Plan 2006-07
Gas Linkage Committee allocations + Potential Demand by Existing Market	180 MMSCMD
Hydrocarbon Vision-2025	231 MMSCMD
ADB'S Gas Master Plan	185 MMSCMD

Initial Assessment by User Ministries + Other Sectors	135 MMSCMD

Source: Tenth Five Year Plan **(Table 3)**

Some of the recent initiatives of Government of India for augmenting the gas supplies are: Iran-India gas pipeline project, Myanmar-India gas pipeline, Petronet LNG Project, Coal Bed Methane projects and attracting private capital for exploration and production of the Oil & Gas fields.

The predominance of Natural Gas as a fuel for city energy purpose internationally is primarily due to three reasons. Firstly, Natural Gas is a more **economical** alternative. Comparing Natural Gas with fuels against which it will be competing in various customer segments within cities namely FO/LSHS for industrial segment, Petrol/Diesel for transport and LPG for commercial and domestic segments, this can be clearly bought out. In the transport segment (Refer Figure 1) the fuels are compared based on running cost, CNG is almost three times as economical as the traditional fuels.

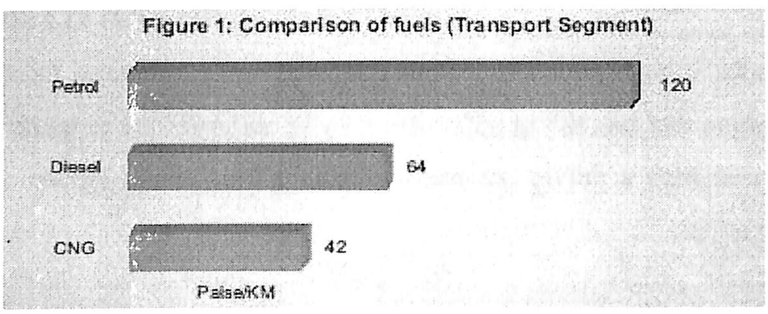


Figure 2: Comparison of fuels (Transport Segment)

For the Industrial, commercial and domestic segments the fuels are compared on the basis of total expenditure incurred to create one million Kilocalories of energy (Refer Figure 2).

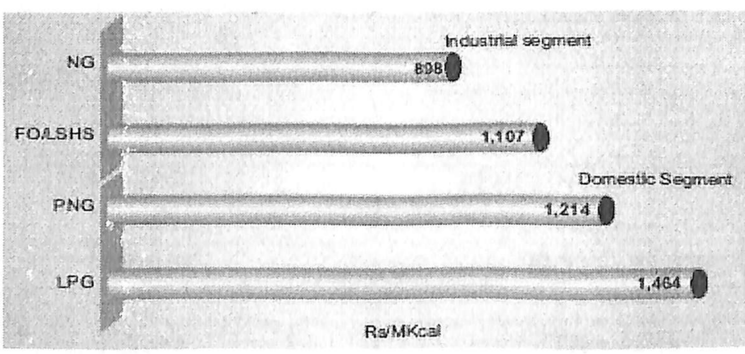


Figure 2: Comparison of fuels

For industrial customers Natural Gas offers a 20% cost benefit in energy terms while for the domestic segment Piped Natural Gas (PNG) presents a savings opportunity of almost 17% on the monthly bill. Secondly, Natural Gas is a 'clean' fuel. When Natural Gas burns it creates lesser pollutants as compared to traditional fossil fuels (Refer Table 1).

	Natural Gas	Diesel	Oil	Coal	Petrol
Carbon Dioxide	117000	135250	164000	208000	285700
Nitrogen Oxide	92	1632	448	457	4081
Sulphur Oxide	0.6	1121	1122	2591	204
Particulates	7	1021	8.4	2744	40.8

(Pounds of Air pollutants produced per Billion BTU of energy)
Source: Energy Information administration

TABLE 4 : Environmental comparison of fuels

2.2 COMPRESSED NATURAL GAS (CNG)

CNG is a compressed natural gas that is widely used in INDIA in bus, trucks, auto etc. At low pressure it is too bulky to be stored or be of much value to car and bus engines compressed at high pressure, the energy stored in the vehicle increases, giving a vehicle a reasonable range between refills.

CNG – Making difference.

In the past, gas fuelled automobiles used LPG. Today it is compressed natural gas that is in use. Methane is the prime component of CNG while LPG is a blend of Propane, Butane and some other chemicals.

2.2.1 Typical composition of CNG:

COMPONENT	PERCENTAGE RANGE
Methane	90.5% – 91.5%
Ethane	3% - 4.2%

Propane	0.3% - 0.5%
CO_2	3.5% - 4.2%
Others	0.012% - 0.212%
Total	100%

TABLE 5: Typical composition of CNG

2.2.2 Physical properties:

Non-toxic --- natural gas being sulfur/lead free, its use substantially reduce harmful engine emission. When natural gas burns completely, it gives out carbon dioxide and water vapour- the very component we give out while breathing.

Lighter than Air --- natural gas being lighter than air, will rise above ground level and disperse in the atmosphere, in the case of leakage.

Colourless --- natural gas is available in gaseous state, and is colourless.

Odourless --- the gas in its natural form is odourless, however, ethyle mercaptan is later added as odorant so as to detect the leakage.

2.2.3 Benefits of CNG.

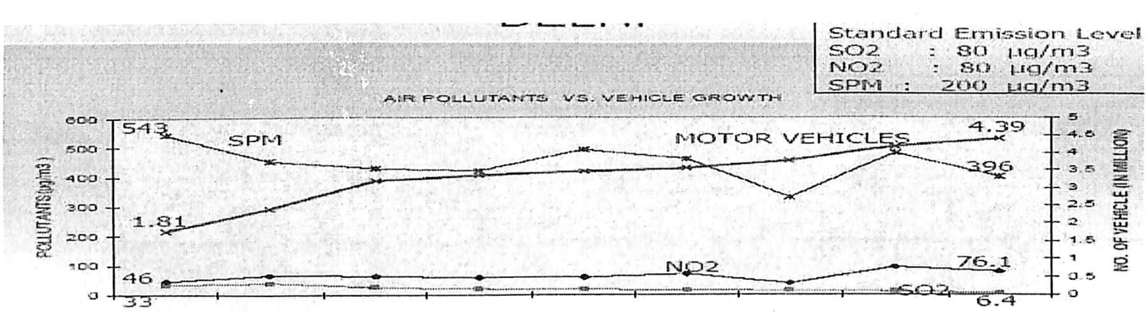
- Environment friendly and hence better health
- Economical.
- Safer
- Very low particulate emission
- Low emission of air borne toxins
- Negligible emission of oxide of sulphur(SO_X)
- More quiet operation, having less vibrations and less odour than the equivalent diesel engines.

FUEL/ EMISSIONS	CO2	UHC	CO	NOx	SOx	PM
PETROL	22,000	85	634	78	8.3	1.1
DIESEL	21,000	21	106	108	21	12.5
LPG	18,200	18	168	37	0.38	0.29
CNG	16,275	5.6	22.2	25.8	0.15	0.29

(gm/100km)

Source: US energy department

TABLE 6: Fuel vs. Emissions



SOURCE: CPCB

TABLE 7: Air pollutants vs. Vehicle growth

(Typical ex. of air quality in Delhi)

2.2.4 Limitations of CNG

- Non availability at all locations.
- High conversion cost of vehicles.
- High Infrastructure cost.
- Lack of awareness about CNG.
- Requires high pressure to increase storage energy density.
- Requires heavy high pressure cylinder for storage-the weight of car which is increased by the cylinder.
- Shorter autonomy (but there is dual fuel option available).
- Boot space occupied by cylinder.

- Movement of vehicles confined to city only.
- Much more expensive distribution and storage
- Higher vehicle cost
- Shorter driving range
- Much heavier fuel tank.

2.3 Pollution reduction in CNG fuelled vehicle:

The use of CNG in vehicle leads to considerable reduction in air pollution as is evident from the following data: **(Table 8)**

A. Auto rickshaw --- Three wheelers

Bajaj Three wheeler	Pollutants	Petrol	CNG	% Reduction
	HC	3.26	1.26	63.19
	CO	5.48	1.57	71.35
	CO_2	47.44	27.60	41.82
	NO_X	0.25	0.20	20.00

Source: Bajaj auto manufacturer of three wheelers.

B. Passenger car:

	Pollutants	Petrol	CNG	% Reduction
Maruti Omni	CO	19.79	.55	97
	HC	1.14	1.02	11

Maruti Gypsy	CO	4.94	0.59	88
	HC	1.86	1.42	24
Premier Padmani	CO	18.36	0.94	95
	HC	2.83	2.03	28
Premier NE	CO	15.6	2.04	87
	HC	2.57	1.92	25
Ambassador	CO	52.16	0.78	98
	HC	6.37	4.33	32

Source: Emission test conducted by GAIL (INDIA) Ltd., one of the promoter company of IGL and supplier of Natural Gas.

C.Diesel Buses:

	Pollutants	Diesel	CNG	% Reduction
Ashok Leyland	HC	1.68	1.4	16.67
	CO	4.5	3.77	19.37
	NO_X	13.73	8.0	41.77
	Particulate Matter	0.125	0.0029	97.68

Source: Ashok Leyland the manufacturer of buses.

2.4 Critical aspects of City Gas Distribution projects

With a growing demand base and increasing supply options City Gas Distribution networks offer a tremendous investment opportunity. However in order to tap this opportunity the developers need to analyze several critical aspects of the project.

- Demand build-up - For a city gas distribution project the industrial segment provides the "base load" demand, which can be captured in a shorter time frame. In contrast, build-up of demand in the commercial, transport and residential segments provides better margins but has a higher gestation period. The project roll out must therefore be planned to capture an optimal mix of demand from these segments.

- Supply - Input gas price and its terms and conditions are critical for the viability of the city gas distribution project. Existence of Natural gas networks passing by or in proximity of the supply sources from the city limit enhances the project feasibility by reducing the capital and input gas costs.

- Pricing of delivered gas - The delivered gas must be priced in such a manner so as to secure a minimum level of profitability for the promoters; while providing adequate incentive to induce targeted customers to shift to Natural Gas. Keeping this in mind Gas should be priced using the 'alternate fuel linked pricing' methodology where Gas is priced at an appropriate discount to alternate fuel prices. For example in PNG the fuel should be priced at a discount to LPG so as to provide the customer with a payback period of less than three years on the expenditure on setting up the connection.

- Risk factors- The feasibility of a city gas project is highly sensitive to the demand the company is able to capture, and is thus exposed to **demand risk.** The project is also exposed to **price risk** due to the probable mismatch in the movement of input gas price and selling price. Moreover as the Indian Gas sector does not have a well-developed regulatory framework. Uncertainty exists over issues such as licensing for setting up distribution networks, exclusivity of operator within a distribution zone and role of regulator in pricing of gas. This exposes projects to **regulatory risk**. The project could also be exposed to the residual risk created by the difference in terms and conditions of contracts with the suppliers and the buyers.

2.5 CHALLENGES FOR IMPLEMENTATION OF CITY GAS PROJECTS

- Availability of Gas.
- Long build up period.
- Trunk line connectivity.
- Capital intensive – high initial investment as cities are geographically dispersed.
- Huge infrastructure required.
- Support from Authorities.

2.6 CNG Station:

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

2.6.1 Types of CNG Station:

There are four types of CNG Station:

Mother Station: Mother Stations are connected to pipeline and have high compression capacity. These stations supply CNG to both vehicles and daughter stations (through mobile cascades). Typically they have the facility of filling all types of vehicles- buses/autos/cars. In mother station there is heavy investment towards compressor, dispensers, cascades, pipelines, tubing etc.

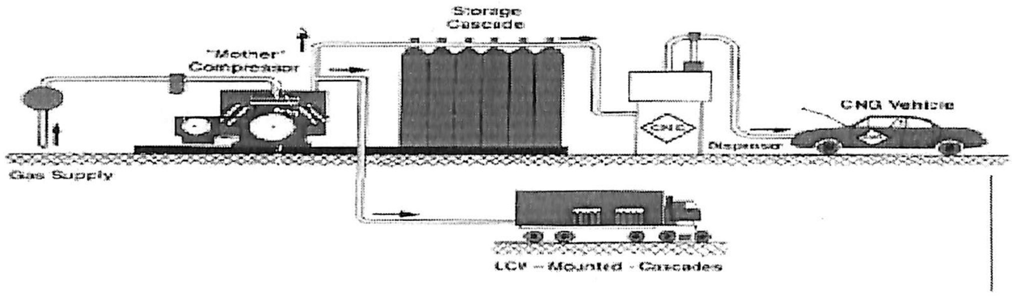


Figure 4: Mother CNG Station

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

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

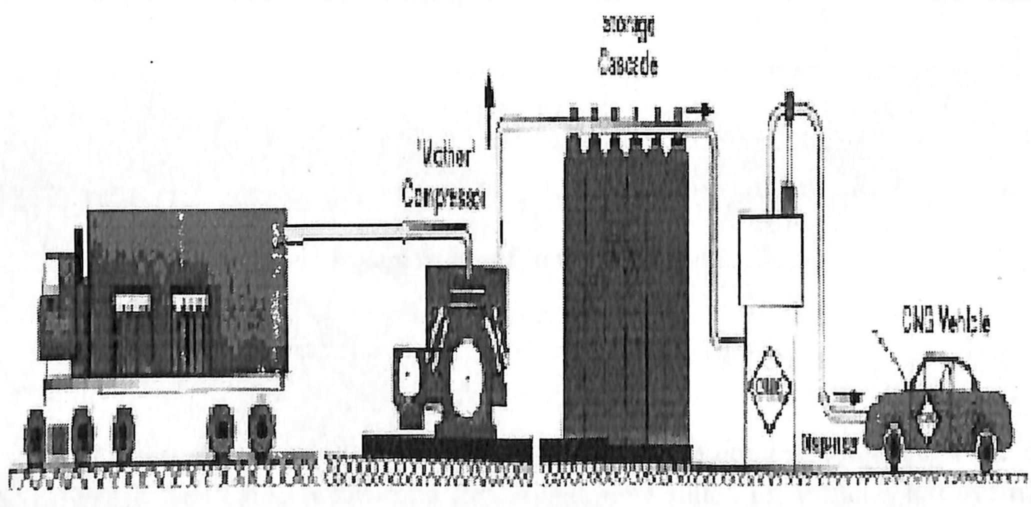


figure 5: Daughter CNG Station

Daughter-Booster Station: Installing a booster compressor can eliminate drawbacks of daughter stations. The mobile cascade can be connected to the dispensing system through a booster. Daughter booster (compressor) is designed to take variable suction pressure and discharge at constant pressure of 200 bars to the vehicle being filled with CNG. The investment in daughter booster station is slightly higher than that of daughter station.

2.6.2 Another Classification:

Fast Fill:

Fast Fill stations primarily utilize gas drawn from a storage bank previously filled by the compressor, rather than direct from the compressor. The speed of fill is comparable to petrol or diesel and is typically found on public forecourts. This method is always used where the exact volume of gas in each vehicle must be quantified.

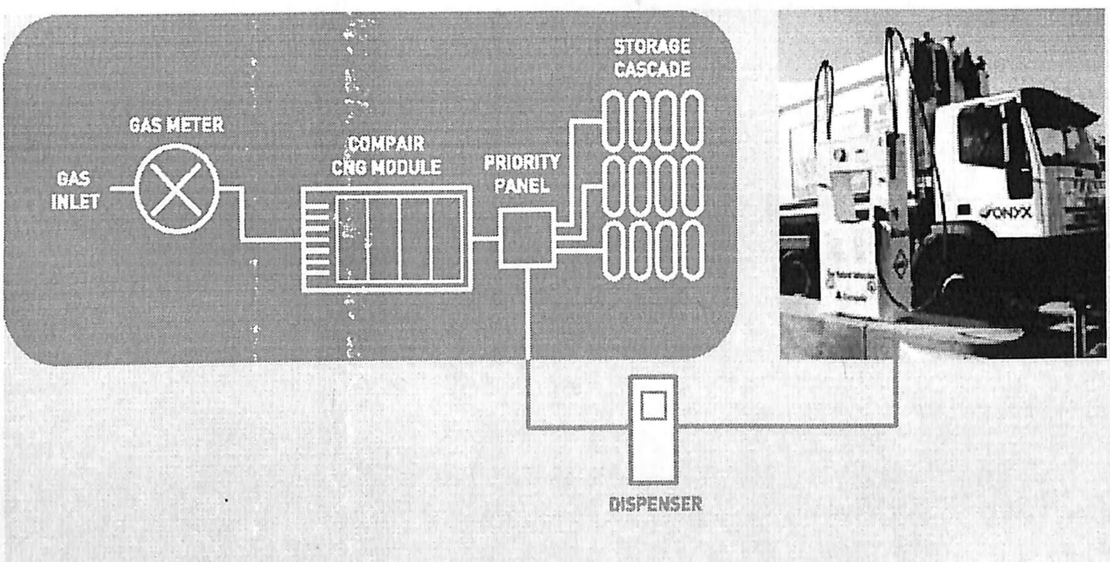


Figure 6. Fast Fill CNG Station

Time Fill:

With time fill posts the vehicle is refuelled directly from the compressor without the need for storage cylinders. Refuelling is therefore slower and more suited for vehicles left overnight at a depot, such as buses. With time fill posts the quantity of fuel dispensed into each vehicle is not easily monitored and therefore time fill is unsuitable for public refuelling stations.

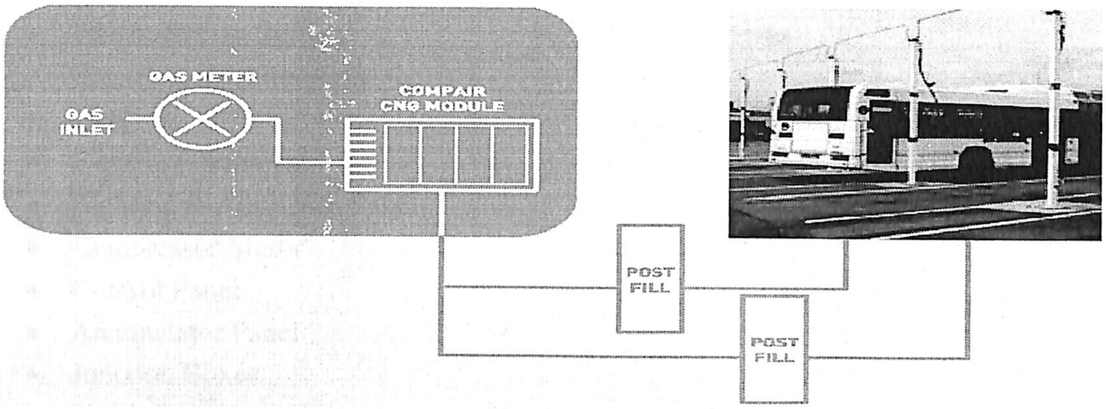


Figure 7: Time Fill CNG Station

2.6.3 Refueling station configuration:

Typical NGV refueling stations consist of a compressor, ground (station) storage, and a dispenser. In actuality the NGV refueling station configuration will be dictated by the application. For instance, a refueling station for a large urban bus fleet will be configured and look substantially different from that of a small light duty vehicle fleet or a public refueling station. Components for an NGV refueling station include the compressor(s), drives (either electric motor or internal combustion gas engine), unloading tank, all piping, fittings, valves, gas conditioning, control elements, ground storage and the refueling dispenser. A more complete components list for a typical NGV refueling station is presented below.

Typical NGV Refueling Station Components

- Compressor(s)
- Drive(s), Electric or Gas IC Engine
- Fast-Fill Dispenser and Slow-Fill Dispensers
- Fast-Fill Fully Metered
- Pipe, Valves & Fitting
- Ancillary vessels
- Instrumentation
- Electrical Interconnect
- Lightning / Static Protection
- Pressure Regulators (Dome Load)
- Storage Cascades (Both DOT and ASME)

- Flow Limiters
- Fire Detection System
- Electrical Requirements
- General
- Electric Equipment
- Lighting & Appliance Panel
- Compressor Motor
- Control Panel
- Annunciator Panel
- Junction Boxes
- Conduits
- Conductors
- Grounding
- Lighting Fixtures

Design specifications requirements must be taken into consideration all applicable codes and standards from organizations such as OISD, NFPA, DOT, ASME and ANSI for refueling stations.

2.7 Compressor:

Compressors are the largest single cost item in the refueling system. Compressors used for high pressure ratio service are almost exclusively of the reciprocating type. The basic reciprocating compressor is a single cylinder compressing gas on only one side of the piston, referred to as single-acting. Double-acting reciprocating compressors use both sides (strokes) of the piston to perform alternating compressions in the same cylinder per crankshaft revolution. Reciprocating compressors used for high pressure natural gas service can be defined further as crosshead or trunk-piston compressors. The trunk piston design, as shown in Figure 1, relies solely on the piston rings to prevent the escape of high pressure gas to the crankshaft/connecting rod casing. In a crosshead design as presented in Figure 8, a separate crosshead linked to the connecting rod is used with a piston rod linked to the piston.

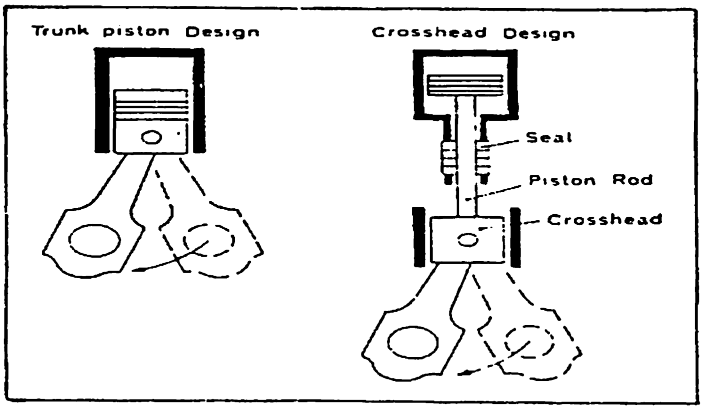


Figure 8. Trunk and crosshead design compressor

This provides a straight-line motion to the piston rod and simplifies sealing. This arrangement minimizes the likelihood of combustible gas leakage to the crankshaft/connecting rod housing. Other design characteristics of reciprocating compressors include lubricated and non-lubricated designs, as well as air-cooled and water-cooled designs. At high output pressures (above 3000 psig) lubricated compressors are typically specified. For reciprocating units designed for high pressure service, multiple stages are required. The compression ratio per stage is generally limited to 4, although small-sized units are designed with compression ratios of 8 or higher. Compressors designed for compressed natural gas service (< 3,600 psig) typically have 4 or 5 stages. In some machines, double-acting pistons are used in the first stages and single-acting in the higher pressure stages.

Compressors are also classified in terms of duty cycle. Typically, only moderate and heavy duty machines would be used for CNG refueling station service. Moderate duty machines are designed for reliable service over a reasonable service life where continuous, full-load, long-duration service is not required. Although moderate duty machines may be capable of operating under these conditions, their maintenance costs will increase dramatically over time, compared to use in their intended duty. Moderate duty machines can be of the trunk piston or crosshead design. Vertical or "Y" type trunk piston units are most often lubricated from the crankcase, air cooled, and operate at higher speeds than heavy duty machines. These factors contribute to higher operating temperatures and more rapid wear and deposit formations on valves and other parts. Larger moderate duty machines are typically of the crosshead variety. The principle distinguishing factor between these and heavy duty machines is that they operate at higher speeds. Heavy duty machines are typically of the crosshead type with entirely separate and well-controlled cylinder lubrication, water-cooled cylinders, and low operating speeds.

Distinguishing between moderate and heavy duty machines is an important factor in determining station compressor life and operating and maintenance costs. For example, a heavy-duty, crosshead reciprocating compressor operating at low speed may have a rated capacity of 300 SCF/min. That same compressor operating at a higher speed could have a capacity of 500 SCF/min. However, in this application that same machine would have a reduced service life and higher operating costs and would as such be rated a moderate duty machine.

Specifying a compressor for refueling station application is much more difficult than just specifying the input and output pressures, type and service rating. A typical partial detailed compressor specification as prepared by the Brooklyn Union Gas Co. is presented below.

"Vendor shall furnish a natural gas compressor capable of compressing natural gas from an inlet pressure of 5 psig to a discharge pressure of 3600 psig at 70°F. Compression shall take place in various stages and after each stage gas shall be cooled and condensate removed prior to delivery to the next stage or final discharge.

Vendor shall specify method of cooling the gas after each compression stage. For a water cooled compressor, the coolant system shall be of a closed loop design, since no continuous water supply will be available.

Compressor shall operate in an environment whose design temperature is 0°F to 100°F. The system will be installed outdoors with suitable weather protection and shall be unmanned. Each cylinder shall be protected for overpressure by means of a pressure relief valve set at no more than 10% above the design pressure of the cylinder. The discharge of the relief valve shall be piped to a common vent stack. Each relief valve shall be tagged with its rated setting. The vent stack shall conform to NFPA Std #68 latest edition Guide for Explosive Venting.

As a minimum, the compressor shall be equipped with check valves for the discharge, inlet solenoid-operated shut off valve, hand operated valve, pulsation cylinder suction with a pressure relief valve, low pressure drop filters and an approved stainless steel braided flexible connector between the inlet gas piping and the compressor inlet pulsation cylinder. The solenoid valve shall be of explosion-proof design rated for service intended.

All solenoid valves shall be UL approved. The compressor shall also be equipped with a condensate collection tank capable of collecting all condensate removed after each compression stage. The condensate tank shall be equipped, as a minimum, with a level indicator, drain valve, regulator, solenoid valves, and relief valves. The tank contents shall also be protected against freezing of condensed liquid.

Condensate blow down shall be of a closed loop design. The compressor package shall be equipped with a methanol injection system (or approved equivalent), including but not limited to storage tank with sight glass, tubing, valves, and drip injector to prevent formation of hydrates in the gas.

All drive belts shall be of the antistatic design and shall be equipped with OSHA approved belt guards. The compressor shall be equipped with inlet pressure and temperature gauges and gauges to indicate the suction pressure and final discharge pressure gauge. The pressure gauges used shall be oil-filled, calibrated in pounds per square inch gauge and equipped with a pulsation damper and a valve to facilitate removal for calibration. The gauge valve shall be rated for the applicable pressure service. The temperature gauges shall be calibrated in degrees Fahrenheit.

The compressor shall also be equipped with a crankcase oil pressure switch to prevent over pressurization of the crankcase. The pressure switch shall be set to automatically shut down the system in the event that pressure in the crankcase exceeds the design pressure.

The compressor shall also be equipped with the following automatic shut down features:

Low suction pressure High suction pressure High oil temperature Low oil pressure High motor temperature High discharge pressure High discharge temperature High crankcase pressure

Vendor shall specify in the proposal the limits of the aforementioned settings. Local visual shutdown fault indications for each shall be provided in the central panel. Contacts for remote indications shall also be provided. Compressor shall also be equipped with a "run time" hour meter on the control panel. Control panel shall include all local indications including all gauges.

Vendor shall hydrostatically proof test the compressor at one and one half times the maximum operating pressure for a period of not less than thirty (30) minutes. If feasible, an engineer designated by the Utility shall witness this test. Vendor shall submit to the Utility a notarized affidavit attesting to such a satisfactory proof test. All electrical components shall be as specified in the Electrical Section of this specification."

The compressor and drive unit represents the most expensive single component within the refueling station. Figure 3 presents compressor capital cost estimates for units in the 250 to 2000 SCF/min size range. This size range is representative of the largest compressor stations which would service heavy duty applications such as large urban bus fleets.

Natural gas engines used to drive compressors are generally two to three times more costly than equivalently sized electric motors. Capital costs for natural gas engines become more competitive with electric motors as horsepower requirements increase, while lower horsepower applications strongly favor electric motors. Depending on local electric and gas rates as well as environmental factors, gas engine drives would become competitive in applications requiring more than 100 HP.

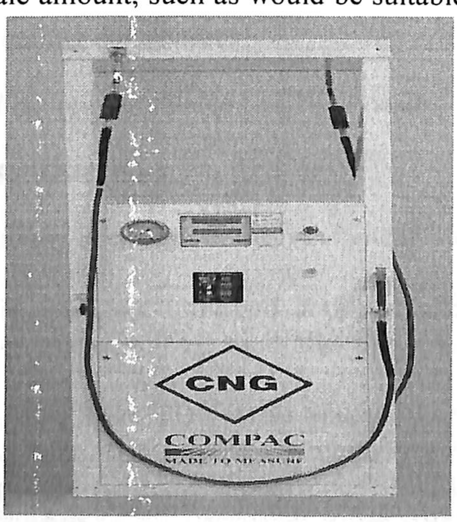
2.8 Ground Storage:

Refueling stations which utilize ground storage of compressed gas often do so in a cascade manner. Storage operation by cascade involves individually-actuated storage vessels controlled by valves switched in sequence. Cascade storage works on the principle that multiple independent banks of vessels can more efficiently fill a vehicle than bulk storage, or operation of total storage capacity as a unit at a common pressure. In cascade storage operation the compressor fills the ground storage vessels, which in turn fill the vehicle storage cylinders, drawing in order from the lowest to the highest pressure ground storage vessels, as the pressures vary with time. A single maximum pressure can be set for the storage facility, or each bank's maximum pressure can be individually defined. Refueling station storage of compressed gas is an option for fleets that wish to reduce compression requirements.

Ground storage vessels can be constructed to either DOT or ASME code. DOT ground storage vessels typically have a 500 SCF capacity at 3600 psig. Typical large ASME type storage vessels have storage capacities of over 10,000 SCF each. These seamless pressure vessels are designed for natural gas service and do not require any periodic recertification as would be the case for DOT type ground storage vessels.

2.9 Dispenser:

Dispenser costs for NGV applications vary according to the number of hoses and the necessity for metering. For example, a two-position fill post assembly without metering is roughly $1000. State-of-the-art in high pressure natural gas metering is represented by Coriolis mass flow meters. A two-hose dispenser with mass flow metering approaches $20,000.This increases the total cost for a two-hose dispenser with mass flow metering and readouts for total quantity, unit price, and total sale amount, such as would be suitable for a public refueling station, to as much



as $25,000. F

Figure 9: Dispenser

2.10 Codes and Regulations

OISD (Oil Industry Safety Directorate) 179

Scope

This standard lays down the minimum safety requirements at installations handling Natural Gas for dispensing into vehicles and minimum checks required in the vehicles by Refuelling stations. This standard does not certify the fitness of vehicles either for CNG use or otherwise. Further, this standard only supplements the existing statutory regulations and in no way supercedes them. The statutory regulations must be followed as applicable.

Approval Required

The systems and components of CNG facility(s) are required to be certified for CNG use and marked accordingly by applicable statutory authority or his agent. The various components of the CNG system which need such certification/ approval are given below:

a) Cylinders

b) Pressure relicf devices including pressure relief valves

c) Pressure gauges

d) Pressure regulators

e) All parts under pressure carrying CNG/NG including valves.

f) Hose and hose connections

g) Vehicle fuelling connections

h) Electrical equipment related to CNG systems

Layouts and Inter Distances

- Inter-distances between various equipment, storage cylinders/ cascade etc. shall be as per Table - I, II.
- Safety distances not indicated above should be as approved by Chief Controller of Explosives on case to case basis after due consideration of all influencing factors.
- When inside a MS-HSD Service Station, the CNG storage and dispensing facilities shall be located in an isolated area not interfering in the vehicular movement on the drive way and not coming within the hazardous areas of petroleum facilities as prescribed in the Fourth schedule of the Petroleum Rules, 1976. The CNG facilities shall not be located beneath electric power lines or where exposed by their failure.

- The fencing may be limited up to the dispensing unit to avoid obstruction in the driveway if the required clear space is available thereafter within the service station premises. The dispensing unit may also be located farther from the fence enclosure on a separate pedestal observing the minimum safety clearance mentioned in Table 10.

Table 9

INTER DISTANCES

FROM BUILDINGS AND OUTER BOUNDARIES TO GAS STORAGE UNITS

Total capacity of gas storage units (In liters)	Min. distance from buildings and boundaries (In Meters)
(1)	(2)
Upto 4500	2.5
4500 to 10000	4.0
10000 to 100000	10.0

NOTE: If on the side (s) towards the boundary of the installation, the clearance as above is not available, the same may be reduced to 2 meters provided a 4 H-FRR RCC wall of adequate height and length covering the cylinder cascades is constructed at the boundary and adequate clear space is available on the other side of the wall.

Table 10

INTER DISTANCES BETWEEN VARIOUS FACILITIES OF NATURAL GAS HANDLING AT INSTALLATION

Distance from (In meters)	1	2	3	4	5	6	7	
1. CNG Compressor	-	3	2	3	6	6	T-1 (Min-3)	
2. CNG Dispensing unit	3	-	2	4	6	4	-Do-	
3. Storage Cascade	2	2	-	T-1	T-1 (Min. 6)	T-1 (Min. 4)	-Do-	
4. Outer boundary Wall/ CLF	3	4	T-1	-	6	4	-Do-	
5. MS/ HSD Dispenser	6	6	T-1 (Min. 6)	6	-	6	-Do-	
6. Vent of MS/ HSD u/ g storage tank	6	4	T-1	4	6	-	6	
7. Filling point of MS/ HSD	T-1 (Min-3)	T-1	T-1 (Min-3)	T-1	T-1 (Min-3)	6	- (Min-3)	(Min-3)

Notes :

- T-I denotes Table-I
- Distances shown as "–" shall be any distance necessary for operational convenience.
- A suitable curbing platform shall be provided at the base of the dispensing unit to prevent vehicles from coming too near the unit.
- A CNG cascade having cylinders of total water capacity not exceeding 4500 liters can be mounted on top of the compressor super structure. The assembly shall observe 3-meter clearance around and also from the dispensing unit. This can be reduced to 2 meter as per Note- I of Table – I.

Design For Maneuvering Area Of CNG Filling Stations

Definition:

- **Maneuvering and refueling area**: It is the area of the filling station reserved for vehicles maneuvering for refueling. It includes entry, refueling and exit lanes.

- **Area limits**: means the physical elements for limiting the space reserve for maneuvering and circulation in the refueling area. To these effects borders shall be the site party walls or the property lines if any all existing construction within the service station site and the front property line.

- **CNG dispensing Island**: area above ground level adequately protected from maneuvering area on which vehicle circulation shall not be allowed. There CNG dispenser its shut-off valves and if necessary support column of dispensers, refueling areas canopies and compressors enclosure shall be located.

- **Entry Lane**: It is the maneuvering area that extended from the street and internal driveway up to the refueling lane in case in case of indirect access to it . On this lane vehicles shall maneuver fro entering the station and approaching the refueling zone.

- **Refueling Lane**: It is the area strip located at each side and align to the dispensing island. On it vehicles shall make the minimum essential maneuvers for approaching the dispensing island and shall stop for refueling.

- **Exit Lane**: It is the maneuvering area strip extending from the refueling lane up to the street or internal drive way, in case of indirect exit. On it vehicles shall maneuver for exiting the station. It is considered as the exit path in case of emergency.

- **Internal Driveway:** It is the corridor that communicates the street with the refueling and maneuvering area fro entering and exiting the station .Its minimum value shall be of 4 m for up to hoses and 6 m for more than 6 hoses.

- **Dispensing island direction angles:** they are the E or Ex formed by longitudinal axis of entering and exiting lane respectively. Based on the corresponding angle of refueling lane.

- The inner urban space (common space between buildings) shall in no case be occupied by the drive way area; if there is no municipal permit expressly authorized it.

2.11.1 CNG Storage system (Static)

- The cascade having horizontal cylinders and sited parallel to other cascade, cylinder fittings should be arranged so that they do not face cylinder fittings of other cascade.

- Cylinder installed horizontally in a cascade shall be separated from another cylinder in the cascade by a distance of not less than 30 mm.

- Cascade with horizontal cylinders shall have the valves fitted on the same side within the cascade opposite to the refueling point and arranged in a manner that any gas leakage is discharged upwards.

- Cascade/bulk units shall be installed on a firm, compacted, well-drained non-combustible foundation. This foundation may be in the form of a plinth with the raised edge at 2 M from the front and sides of the cascade forming a kerb upto which vehicles should be permitted. The cascade shall be securely anchored to prevent floating in case flooding is anticipated.

- Gas storage facility shall be protected from the effects of the weather by a roof or canopy designed to facilitate the dispersion of free or escaped gas and shall not permit gas to be trapped.

- Adequate means shall be provided to prevent the flow or accumulation of flammable or combustible liquids under containers such as by grading, pads or diversion curbs.

2.11.2 CNG Storage system (Mobile):

- Only dedicated trailer, truck or any other vehicle to be used for transportation of CNG storage units. These units should have lugs fitted for lifting and in no case magnetic device to be used for lifting purposes.

- The vehicle with the cascade thereon, shall be placed with easy access and egress on a low platform or hard compacted ground, which shall extend to at least another one meter on all sides and this platform or hard ground shall be under a light roof or canopy.

- For other inter-distances refer Table I, II, above.

- The trailers/ vehicle carrying CNG should be made immovable by application of brake and wheel choke prior initiation of filling or dispensing operation.

2.12 CYLINDERS

- The cylinders and their fittings for CNG use shall be designed, manufactured, tested including hydrostatic stretch test at a pressure in full conformity to IS:7285 and Gas Cylinder Rules, 1981, considering the maximum allowable operating pressure of 250 kg/ Sq.cm.g.

- These cylinders are to be permanently and clearly marked for "CNG only" and also labeled "CNG ONLY" in letter at least 25 mm high in contrasting colour in a location which shall be visible after installation.

- The cylinder shall be fabricated from steel. However, cylinders with composite materials may be considered after the establishment of its suitability and approval of the Chief Controller of Explosives.

- The cylinders shall be re-examined and re-tested every five years and in accordance with Gas Cylinder Rules, 1981 by a competent person with due markings. No cylinder shall be used which has not been duly re-tested as indicated.

- Cylinders shall be painted white to reduce solar heating effect and protect it from atmospheric corrosion.

2.13 CNG Piping

- All rigid piping, tubing, fittings and other piping components shall conform to the recommendations of ANSI B 31.3. All the elements of piping should be designed for the full range of pressures, temperatures and loading to which they may be subjected with a factor of safety of at least 4 based on the minimum specified tensile strength at 20 deg. C.
- Gaskets, packing and any other materials used shall be compatible with natural gas and its service conditions.

- All the piping and tubing shall have minimum turns with adequate provision for expansion, contraction, jarring, vibration and settling. Exterior piping may be either buried with suitable corrosion protection or installed 30 cm. above the ground level with supports and protection against mechanical and corrosive damage.

- Rigid pipelines shall have welded joints between their respective components.

- All the piping and tubing shall withstand a pressure equal to that of safety relief device and tested accordingly after assembly. The testing to be done by inert gas, in case natural gas is used the suitable safety measures to be adhered to.

2.14 Valves

- A minimum of four shut off valves shall be fitted between the gas storage unit and vehicle refueling filling nozzle as explained below:

  a) Each CNG storage unit to have quick action isolation valve in the steel supply pipe immediately adjacent to such storage unit to enable isolation of individual storage unit. These valves shall be within fencing of storage unit.

  b) Master shut off valve with locking arrangement in close position, shall be installed in steel outlet pipe outside but immediately adjacent to the gas storage unit to isolate all downstream equipment from the gas storage unit. This valve shall be outside the fencing.

  c) A quick action emergency and isolation shut off valve shall be installed near dispensing unit with easy approach and to remain closed when refueling is not being done.

d) A vehicle refueling shut off valve shall be installed for each flexible vehicle refueling hose to control the refueling operation and shall have venting provision to allow for the bleeding of the residual high pressure gas after refueling is complete.

- All these valves and other elements of piping shall be suitable for the full range of pressure and temperature to which they may be subjected. These valves are to have permanent marking for service rating etc.

2.15 CNG Hoses

- Internally braided, electrically continuous, non-metallic and metallic hoses resistant to corrosion and suitable to the natural gas service may be used for CNG service in the downstream of emergency and isolation shut off valve.

- These flexible hoses and their connections shall be suitable for most severe pressure and temperature service condition expected with a burst pressure of at least four times the maximum working pressure.

- The flexible hoses with their connections shall be tested after assembly and prior to use to at least two times the working pressure and also tested to a pneumatic pressure of atleast 400 bar under water. Thereafter, all the hoses shall be examined visually and tested for leaks with soapsuds or equivalent at an interval not exceeding one year. Hoses shall be rejected and destroyed in the event of any leakage. These tests are to be recorded and such records shall be available at installations at all times.

- Flexible hoses shall have permanent marking indicating the manufacturer's name/ identification, working pressure and suitability for use with CNG.

2.16 Pressure Gauges

- Every CNG storage unit including each cascade or bulk storage tank shall be provided with a suitable pressure gauge directly in communication with them.

- The CNG storage unit shall have an opening not to exceed 1.4-mm diameter at the connection where pressure gauge is mounted.

- The pressure gauge shall have dial graduated to read approximately double the operating pressure but in no case less than 1.2 times the pressure at which pressure relief valve is set to function.

- All pressure gauges in the installation shall be tested and calibrated at least once a year and records maintained.

2.17 Compressor Station

- The piping and its fittings upto the battery limit of CNG installation shall conform to ANSI B 31.8 or equivalent.

- Compressor shall be designed for use in CNG service and for the pressures and temperature to which it may be subjected under normal operating conditions conforming to API 618/ API 813 or equivalent standard and Flame proof electric motor and associated fittings should conform to IS:2148 suitable for class I division I group II area.

- Compressor shall be fitted with the following minimum devices :

a) Pressure relief valves on inlet and all stages to prevent pressure build up above the predetermined set point.

b) High discharge temperature shut down

c) High cooling water temperature switch fitted to cooling water return line to shut the compressor in the event of a fault.

d) High, inlet, inter stage & discharge pressures shut down.

e) Low lube oil pressure shut down.

f) Low cooling water flow switch fitted to the cooling water return line to shut the compressor in the event of fault.

g) A remote isolation switch for emergency shut down to be provided with manual reset at control panel.

- Compressor shall be provided at least the following clear and permanent markings readily accessible and easy to read in the installed position :

  a) Manufacturer's name

  b) Model

  c) Serial No./ month & year of manufacture

  d) Certificate of approval no.

  e) Rated capacity (cubic meter per hour)

  f) Operating speed (RPM)

g) Required driving power(in kW)

h) Maximum & minimum supply pressures

i) Maximum outlet pressure

j) Certification for Natural Gas use

- A compressor and its all fittings shall be tested for compliance of relevant standard suitable for CNG use by a competent person/ agency prior to installation.

2.18 Pressure Relief Devices

- Safety Relief Devices may consist of either burst disc or safety relief valve and should conform to the requirements of OISD-STD-132.

- Safety relief devices shall be installed with unobstructed full size discharge to a safe place on bulk tanks and cylinders in the vertical position with suitable rain caps. These devices should have their outlet arranged in a manner so that in case of emergency a high-pressure gas escapes from these should not directly hit on operators/ persons in the close vicinity.

- Cylinder should have safety relief devices fitted in conformity to the Gas Cylinder Rules.

- Piping shall be protected by safety relief devices in conformity to OISD-STD-132.

- Safety relief valves shall have a locking arrangement to prevent tempering by unauthorized persons. Any adjustments to the safety relief valve shall be made by manufacturer or a competent person. These valves should have a permanent tag indicating pressure setting, date of re-setting/ setting and capacity.

- All safety relief devices shall be tested at least once a year for proper operations and records to be maintained.

- All the safety relief devices shall have manufacturer's permanent marking indicating following :
  - a) Set pressure to start discharge
  - b) Discharge capacity in CuM / min.

- No shut off valves shall be installed between the safety relief device and the gas storage unit or bulk tank.
- All natural gas devices not otherwise specifically mentioned shall be constructed and installed to provide a safety equivalent to those other parts of the system.
- Gas detectors interlocked with compressor cut out switch in the electrical system of the compressor are to be installed which would automatically switch off the unit in case of major gas leak.

2.19 Dispensing Unit

- Dispensers shall be installed on a suitable foundation observing the minimum safety distances etc. as given in 6.0 above. Dispensing unit to be protected against possible damage by vehicular movement.
- The flexible hoses fitted on the dispenser shall be mechanically and electrically continuous. The design, material and construction of hoses shall be suitable for CNG and shall withstand not less than four times the maximum working pressure of the system.
- The dispensing unit shall be of a type approved by the Chief Controller of Explosives / Statutory Authorities.

2.20 Electrical Equipment

- All electrical wiring and equipment, gas storage dispensing unit located in hazardous area Division I and II shall be in accordance with the Indian Electricity Rules, Gas Cylinder Rules, IS:5572 (Part 1), NFPA - 52.
- The earthing at the installation, protection against ignition arising out of static, lightning and stray currents shall be as described in OISD-STD-110 and further maintained as per the guidelines given in OISD-STD-137.

2.21 National Fire Protection Association (NFPA) 52

Scope

- Most widely used standards in the CNG industry.
- Deals with siting and setback issues.
- Establishes electrical rating requirement.
- Defines the boundary of hazardous areas.

Electrical Installations

Location	Division	Extend of classified area
Containers (Other than mounted fuel supply containers)	2	Within 10 ft. of container.
Area containing compressor and ancillary equipment		
outdoors	2	Up to 15 ft. from equipment
indoors	2	Up to 15 ft. from equipment

Table 11 (a)

Location	Division	Extend of classified area
Dispensing equipment		
Outdoors	1	Inside dispenser enclosure.
	2	From 0 to 5 ft. from the dispenser.
Indoors	1	Inside dispenser enclosure.
	2	Entire room with adequate ventilation

Table 11(b)

Location	Division	Extend of classified area
Discharge from relief valve or vents.	1	5 ft. in all direction from point source
	2	Beyond 5 ft. but within 15 ft. in all directions

		from point of discharge.
Valves, flanges or screwed fittings.	none	Unclassified.
Discharge from relief valves within 15 degrees of the line of discharge.	1	15 ft.

Table 11(c)

2.22 National Fire Protection Association (NPFA) 70

Scope

- Classifies according to the likelihood of a particular hazardous or flammable material being presented in a given location.
- Gives equipments electrical classification.
- Gives electrical wiring requirements.
- Defines the classification of hazardous area.

Hazardous Locations – classes

Class 1: Flammable liquids, gases or vapor.

Class 2: Combustible or electrically conductive dust.

Class 3: Easily ignitable fibers or flyings.

Hazardous Locations – Division

Division 1:

A location where flammable mixture exists in the atmosphere under normal operating conditions, or exists frequently because of repair or maintenance, or as a result of a faulty operation.

Division 2:

A location where risk of explosion is reduced because the flammable material is confined with in a close containers or systems. The flammable mixture may be present infrequently in the atmosphere under abnormal operating conditions, or as a result of equipment malfunction.

Hazardous Locations – Groups

Group A

Atmosphere containing acetylene.

Group B

Atmosphere containing butadiene, ethylene oxide, hydrogen (or gases or vapor equivalent in hazard to hydrogen, such as manufactured gas) or propylene oxide.

Group C

Atmosphere containing acetaldehyde, cyclopropane, diethyl ether, ethylene, unsymmetrical dimenthyl hydrazine or other gases or vapor of equivalent hazard.

Group D

Atmosphere containing acetone, acrylonitrile, alcohol, ammonia, benzene, benzol, butane, ethylene dichloride, gasoline, hexane, isoprene, lacquer solvent vapors, naphtha, natural gas, propane, propylene, styrene, or other gases or vapor of equivalent hazard.

Class 1, Division 1, Group D

A location where natural gas is present all the time, or which may be present as a result of faulty operation of the equipment. It is assumed that the equipment releases the enough gas into the surrounding atmosphere to create the ignitable mixture. Although the ignitable mixture is usually not present in the actual practice but the designer is forced to assume that this is true, and design accordingly.

Class 1, Division 2, Group D

A location where natural gas is normally contained in tanks, pipes, etc. and can only escape into the surrounding atmosphere under abnormal circumstances such as equipment failure.

General Purpose

An area is classified as general purpose in an area that cannot have a concentration of natural gas present that can form an ignitable mixture. As a result no extraordinary means need to be include in the design of any electrical systems in the area.

CHAPTER 3
THEORETICAL DEVELOPEMENT

3.1 Inputs Required:

Available Throughput:

As per the agreement made in Contract, where Ministry of Petroleum (MoP) and Natural Gas (NG), vide letter no. **L12011/2/00-GP(Vol- II)** dated **16.01.01** allocated **0.1 MMSCMD** of Gas for City Gas Distribution in Lucknow, subject to condition that out of above allocated quantity, upon the limit of **30%**, there of may be utilised for supply to small industrial consumers within the city.

Present Demand Pattern (as per updated DFR):

Sector	**NG consumption (MMSCMD)**	**No. Of Consumers**
Domestic	0.0007	1000
Commercial	0.0050	30
Industrial	0.0340	01
Automotive	0.1000	15100
Total	**0.1397**	

Table 12

Present consumption rate:

S.No	**CNG based operating vehicle as on 10.09.07 as per RTO**	**Additional conversion**	**Total No. Of CNG vehicle**
Tempo / Taxi	1592	512	2104
Autorickshaw	3500	9	3509
Nagar Bus	2	82	84
Bus(UPSRTC)	32	75	107
School Bus	50	511	561
Personal service	37	32	69

vehicle			
Total	**5213**	**1221**	**6434**

Table 13

3.2 Proposed Network

Based on the above Network Design philosophy, following is proposed:

1. Gas shall be drawn through a 8" pipeline connecting at the tap-off point on GAIL's HBJ pipeline at Mulawan about 38 Kms away from Lucknow city. City Gate Station (CGS) shall be established at a convenient location in Lucknow /Mulawan. The broad operating specifications of CGS shall be:

Inlet Pressure = 30-35 bar(g)

Outlet Pressure = 26 bar(g)

Flow rate = Initially 35,000 SCMH (to be expanded with increasein volume)

2. District Regulating Stations (DRS) shall be provided at various demand centers to reduce the gas pressure from 19-bar(g) to 4 bar(g) to supply industrial and large commercial consumers. The broad operating specifications for DRS shall be :

Inlet Pressure = 26 – 19 bar(g)

Outlet Pressure = 4 bar(g)

Flow-rate = 15,000 SCMH

3.The 4 bar (g) MDPE pipeline grid shall originate from the DRS. A loop shall be provided on each of these DRS to provide security of gas supply in case of a shut down of any section of the gas grid.

4.Domestic Regulators shall reduce the pressure from 100-mbar(g) to about 21-mbar(g) before the burner tip in the domestic kitchen. The specifications of Domestic regulators are:

Inlet Pressure = 4 – 1 bar(g)

Outlet Pressure = 100 mbar(g) - 21 mbar(g)

Flow-rate = 0.23 SCMH

5.Sectionalising valves shall be provided at all pipe junctions to enable the isolation of the particular sections. The sectionalising valves shall be manually operated valves.

6.CNG stations shall be designed so as to achieve maximum equipment efficiency. Initially 6 CNG stations are planned for Lucknow. Dedicated stations shall be established for the State Transport Buses in their depots. Where the pipeline connectivity is not established the station shall be operated as "Daughter Booster" station. The specifications for the compressors shall be:

Inlet Pressure = 26 – 19 bar(g)

Outlet Pressure = 240 bar(g)

Capacity = 1200 SCMH

7.The pressure regime of the proposed distribution network shall be :

Sr. No.	*Network Component*	*Inlet from*	*Inlet Pressure*	*Outlet Pressure*	*Outlet to*
1	CGS	Transmission line	49 – 28 bar(g)	26 bar(g)	Steel Grid
2	Steel pipeline	CGS	26 bar(g)	26 – 19 bar(g)	DRS / CNG station
3	DRS	Steel pipeline	26 – 19 bar(g)	4 bar(g)	MDPE pipeline
4	MDPE pipeline	DRS	4 bar(g)	4 – 1 bar(g)	DRS or IPRS or Industrial / Domestic Meters
5	IPRS	MDPE pipeline Steel pipeline	4 – 1 bar(g) 26 – 19 bar(g)	1.5 bar(g) 4 - 1.5 bar(g)	Industrial internal pipeline
6	Domestic Regulators	MDPE pipeline	4 – 1 bar(g)	100mbar(g) – 21 mbar(g)	Copper / GI pipeline

Table 14

Schematic of the proposed network:

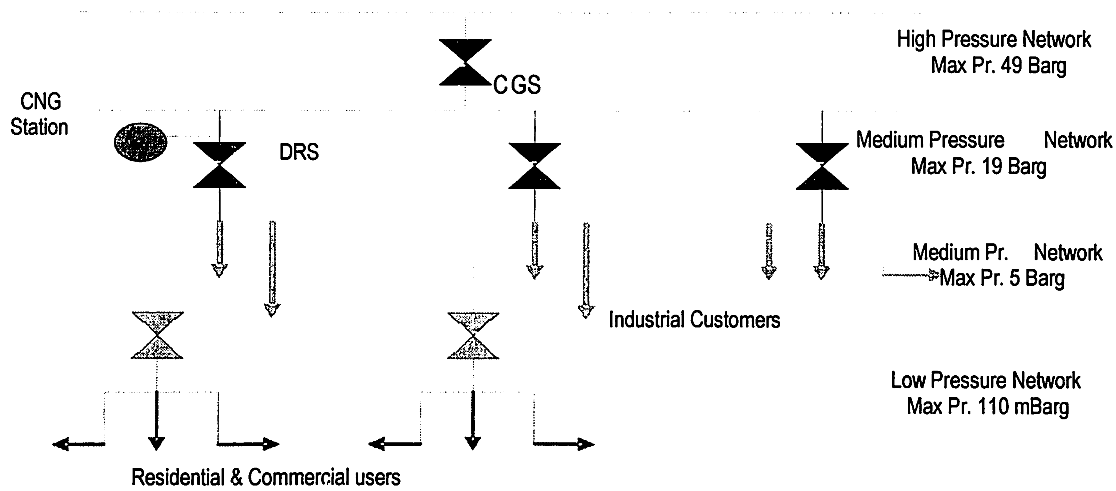


Figure 10

3.3 Design Methodology Adopted:

The proposed CNG stations will be specified to Indian standard OISD 179 or equivalent.

3.3.1 Assumptions:

(1) The CNG station in all options is based on three lines, fast fill system.
(2) The area of each proposed CNG site is assumed to be approximately 30*36m.
(3) The extension of steel grid to a CNG is assumed to be not more than 1 km.

(4) Based on the existing local operation and conditions , it is assumed that station Compressors will operate 16 hrs/day.

(5) The gas supply to the station is taken from the steel grid pipeline at 26 to 15 barg.

(6) It has been assumed that the proposed CNG station would require associated station infrastructure which includes shelter over the dispensers, station attendant's building with amenities, concrete apron and driveways.

3.3.2 Constraints for Developing CNG Infrastructure:

The following difficulties are faced in developing CNG infrastructure:

- Limited natural gas allocation leading to delay in management decisions on expenditure commitment.
- Uncertainty about conversion of vehicles & CNG demand.
- Lack of indigenous technology.
- Capital intensive project – a mother station cost would be 5-6 times the cost of a petrol pump & pipeline need to be placed in place
- Infrastructural constraints (Electricity, land etc.)
- Delay in getting permission from statutory authorities
- Objection from local people , encroachment
- Low storage capacity of on board cylinders, thus requiring frequent refills.

3.3.3 Factors influencing the success of CNG Project:

- Government commitment to the program.
- Sustainable economic advantage over liquid fuels.
- Appropriate CNG technologies.
- Appropriate program management.
- OEM support.
- Safety of CNG vehicles and CNG economic are key factors that determine the success of CNG program.

3.3.4 Factors That Cause Delays / Uncertainty In The Project Plan:

(1) CNG Demand

All project plans are based on the demand of the product . The CNG expansion plan may become unviable if the predicted or assumed demand does not materialize.

(2) Gas Allocation

Natural gas is the basic feedstock for CNG. Unless there is firm gas allocation, no project plans can be drawn out.

(3) Land Allocation

CNG stations require land for installing the equipment like compressors, dispensers, cascades and the maneuvering area. The land acquisition requires multi-stage approvals combine with site surveys etc. Additionally there may be unforeseen problems like encroachment/ land not available in area / size of land not appropriate location/ inappropriate location / public objection etc.

(4) Delayed Permission or Approvals

CNG stations being run on Natural Gas need to follow certain safety guidelines. Central committee on explosives is the approving agency for this purpose. The mother stations need to be connected to the pipeline for which the permission for right of way is required from the concerned authorities such as PWD, RAILWAYS, LMC etc.

(5) Foreign Suppliers

Majorities of suppliers of CNG related equipments are in foreign countries. Moreover the equipment is not available of the shelf; it is custom made according to the requirement if the customer. The commissioning of the CNG station is heavily dependent on the timely delivery of this equipment.

(6) Capital Intensive Project

A mother station cost would be 5-6 times the cost of petrol pumps and pipelines need to be in place.

3.3.5 Chronological Set Up Of CNG Stations:

(a) Survey And Projection Of Vehicles :

- For survey and market study for the projection of vehicles, average forecasting method has been incorporated .(see annexure 1)
- Based on the NGV projections gas consumption scenario has been calculated. (annexure 1)

(b) Implication Dependence Of CNG Infrastructure :

Taking a serious view of the Supreme Court directives and the reports of Lucknow being counted among the most polluted city in the country. State govt. has worked out plan to combat the pollution. The progress of CNG infrastructure in Lucknow till date was excruciatingly painful due to non implication of CNG as mandatory for Lucknow city. With the SC's directive and NOC from state govt. for CNG infrastructure development GGL has taken pace in full swing.

3.4 Civil Infrastructure

Requirements for Design and Installation:

Location:

(1) Installations at the Site:

a) For CNG filling station, the corresponding safety distances shall be taken into account.
b) Basements are prohibited. Higher floors shall only be allowed for vehicles parking purposes.
c) In the case of open to the public service stations, permitted vehicle accesses and direction of flow of traffic shall be taken into account.
d) It shall count with the approval of the national, provincial or municipal authority having jurisdiction as may correspond.
e) It shall comply with the Industrial Hygiene and Safety law Nr. 19587 and P.E.N (National Executive Power) Decree Nr. 2407/83 "safety standard for service station and other fuel dispensing outlets".
f) Elements not related to the business activity shall not be stored in the service station facilities.
g) Service station party walls shall be of solid masonry with at least 3m. Height and 0.30 m thickness. Rural service stations located not populated areas may not require those walls (near building located as of 100 m from service station perimeter), provided there is no regulation in force in that respect.
h) A CNG dispensing outlet may be added to a typical service station, only if the site dimensions allow the compliance with the minimum safety stated in 1-2.

(2) Minimum Safety Distances :

Installation shall be located within safety distances according to the following minimum distances. According to the maximum allowed height for the building construction in the district of the premises but, if the building next to it is higher, then the latter case applies.

Note: Masonry or concrete wall, 0.50 m higher than compressor and / or storage and more than 1.00 m, length exceeding each and with a minimum 3 hour resistance shall be constructed. It shall count with labyrinthine accesses. Distances shall be measured from the outer border of its parameter wall.

References	Distances (in meters) Storage Volume (water liters)		
	Upto 4000	**From 4000 – 10000**	**For >=10000**
Storage and compressor Enclosures			
Site party walls and own facilities	5	5	10
Ground floor front property wall	3	3	3
Upper floor front property line			
- 4 or more storey building for More than 150 persons	10	10	10
- Dispensers	5	5	5
- Open flames	3	3	3
Dispensers			
Front property line	4	4	4
High way and Road side	6	6	6
Own premises	3	3	3
Side party wall and own premises entrance	5	5	5
Open flame	5	5	5
Liquid fuel storage			
(Loading and / or discharge outlets)	5	5	5

Table 15

(3) Installation Components And Equipments :

General Aspects:

(a) CNG storage shall be installed within the compressor enclosure or in the similar enclosure.
(b) Equipment installation for avoiding hydrate formation in very cold areas shall be analyzed.
(c) CNG storage tanks shall be capable of operating at a working pressure of 250 bars and shall comply with the requirements of A.S.M.E Code SECTION VIII, Div. I (American Society of Mechanical Engineers code) or any other code accepted by gas Del Estado. They shall be approved by a certification entity recognized by the authorities having jurisdiction. They shall include a safety valve which pressure is set to discharge at 15% to 20% above maximum working pressure. Safety valve shall have the capacity of releasing the maximum flow rate supply, either from the suction regulator valve or from the compressor as the case may be. Connection unions and flanges shall be suitable for tank operating pressure and their installation shall be fitted to the requirements of the construction standard or code applied. The tank exposed to internal pressure shall neither be welded nor altered. Only support plates or brackets may be welded. Interconnections between tanks and compressors shall have differential movement and vibration compensation.

(4) Mounting of CNG tanks:

Tanks mounting shall be such as to avoid concentration of excessive load on the supports. Tank supports shall be made of reinforced concrete, steel of solid masonry. Metal supports may be used only if they are adequately fire protected; thus, being capable of resisting the action of directs fire during not less than 3 hours without collapse. Mounting or supports shall allow free expansion and contraction of the tank and piping connected thereto. Adequate means for avoiding corrosion of the tank parts in contact with the support shall be provided. Once the tanks are mounted they shall be adequately cleaned and then protected with 2 coats of anti corrosive paint and 2 of white synthetic enamel. During these operations special care should be taken for not covering the identification plate that shall be readily visible and permanently affixed on every approved tank. When used or tanks unused for 1 year or more are utilized the following shall be previously considered.

As a general rule, it is stipulated than new tank shall be used in any new installation or expansion thereof. Utilization of used tank or tanks unused for 1 year or more shall only be allowed if a new permit is obtained by the review procedures according to the respective manufacturing standard which shall be certified by a certifying entity recognized by Gas de Estado.

Cylinder Storage Unit:

Provisions include in point 7.4 of GE 1-141 standards for compressors apply to this storage type. It shall be considered that the support structure of each storage unit will be constructed with corrosion resistant material or treated adequately for corrosion preventions. Its construction shall allow a fixed and non-displaceable way of mounting of the cylinder, in order to preserve the connection however they shall be able to be easily disassembled for maintenance purposes. All the operating valves shall always allow there operation from the storage unit perimeter. Each storage level shall have its corresponding pressure gauge with a valve and purge. The design pressure of cylinders used in the storage unit shall depend upon the operating pressure that shall not exceed 250 bars.

Compressors and Storage Enclosures and Gas Dispensers:

i) Compressors, storage unit and gas dispensers shall comply with GE Nr. 1-141 Standards.

j)Compressors and storage unit shall be installed in appropriate enclosures. Enclosures used to house a compressor and / or storage facility shall not be used for any other purposes.

k)Compressors and storage equipment shall be surrounded by a perimeter wall at least 50 cm higher than the highest component subject to high pressure and shall have a minimum height of 3 m.

l)It shall have two iabyrinthine accesses diagonally opposed with free circulation width of at least 1.10 m. If those accesses have doors, they shall open outwards and shall have iron fittings and non-panic latching and devices admitted by Gas del Estado.

m)Labyrinthine accesses previously defined in 2-2-d shall lead to corridors or common alleys that will be used for exiting in case. Free circulation path shall extend up to the refueling area or street and it shall not be obstructed by convenience stores or other shops. If needed, exit signs shall be posted.

n)Perimeter wall defined in 2-2-c shall be made of at least 3 hrs fire resistance rating 15 cm. thickness reinforced concrete , 1113 quality (130 kg/cm2) or higher according to CIRSOC . Two meshes with 10 mm-diameter steel bars per each 15 cm. 4200 kg/cm2 steel equivalent quality one at each face shall be the reinforcement of the wall. For ensuring higher safety against wall fragmentation in case of explosion or impact, mesh reinforcement phase out is convenient. Original poured concrete surface shall be kept and plastering is not allowed.

o)Ground floor walls shall be erected on reinforced concrete walls footings according to the calculation based on the pertinent soil bearing analysis.

p)The storage or compressor enclosure shall have an easily eject able light fastened roof. It must not be joined to party walls.

q)Non packaged compressor enclosure shall be roofed except when the equipment is weather proof and when noise attenuation is guaranteed.

r)Storage or compressor enclosure shall be perfectly ventilated under roof level and 50 cm above the last pressurized element, and the opening shall be correctly distributed with surfaces that shall not less than 100cm2 / m3 of enclosure volume. In case lower opening are needed the construction criteria to be applied shall consider prevention of outward fire protection or blunt objects ejection in an emergency situation.

s)An adequate flow of cooling air shall be provided. It is advisable that the enclosure temp. Shall not exceed more than 10 deg. Celsius above the outside temp.

t)Inside the compressor enclosure a circulation corridor of at least 0.90 m. clearance among compressors and among them the enclosure wall shall be foreseen. Such corridor shall be free from obstacle and its clearance shall be measured from the compressor bases or projected parts. If for maintenance a wider corridor is needed for the equipment houses in the enclosure such corridor and entries in the enclosure shall be widened.

u)Vibration damper systems required for avoiding transmission of unacceptable vibration levels to neighbor constructions shall be implemented. To this effect there shall be no attachment to party walls transmitting unacceptable vibration or noise to them. Non-combustible or self extinguishing soundproof material is required.

v)For construction of storage or compressor located at upper floor enclosures the following guidelines shall be considered: If vehicle traffic flow is allowed under the elevated floor enclosure, it least it shall be 5 m free height from the ground floor level.

w)Main staircase shail be readily accessible through common passages leading to means of exit, completely in accordance with the stipulation of 2-2-e). It shall have rigid guardrails or handrails well secured at each side. Minimum free width shall be of 1.10 m measured between baseboards. If the handrail projects more than 7.5 cm beyond the baseboard projection, it shall be taken into account when measuring free width. Passage height shall be at least 2.3 m measured from the paving of landing or from the step to the ceiling or any other lower roof projection. It shall be constructed of non-combustible, fire resistant material in straight section, preferably without landing direction changes. Staircase section shall not have more then 21 subsequent treads between landings. In each section all steps shall be of the same size and shall comply with the following formula:

$2t + r = 0.06$ m. to 0.63 m.

Where,

t = (riser), shall not be higher than 0.18 m.

r = (tread) shall not be lower than 0.26 m.

x)Landing shall not be less than ¾ of the staircase width and need not exceed 1.10 m. and an equal width of the staircase. There shall be a secondary staircase from the storage or compressor enclosure to the exits located at the ground floor, to be used in case fire reaches the higher floor exits or main staircase. Access to the secondary staircase shall be independent from the main one. It shall be constructed of non-combustible materials and it may be a vertical or cat ladder and in this case distance from the wall face shall not be less than 0.15 m. It shall be practical and safe.

y) If the site is located in non-urban areas concrete wall is not necessary for the compressor or the enclosures. In this case the enclosure wall shall be fenced with the wire mesh with two access gate diagonally opposed. Wire fence shall be at least 3 m high. When related to compressor or storage enclosure twice the minimum distance included in the table shall be considered. Should be neighborhood area become urbanized the enclosure shall be adapted according to the specific guidelines to that effect.

(5)Fast Fill Stations :

General Aspects:

i)Distribution of dispensing islands on the area shall enable a fast entry and exit of vehicles. When they are parked for refueling they shall not hinder the entry or exit of other vehicles for maneuvers nor occupy public streets.

j)For refueling vehicles shall preferably be oriented towards the street.

k)For refueling vehicles should be parked parallel to the dispensing island. Their positioning against it shall not be allowed.

l)Vehicles shall not be allowed to drive in reverse for approaching or exiting the refueling position.

m)If 2 or more dispensing islands are to be installed, they shall preferably be parallel as this distribution is the best one for a faster evacuation in case of emergency. Up to 4 single or double hose dispensers shall be installed aligned.

n)Entry and exit direction angle value E Ex to dispenser islands as well as the angle formed by the entry and exit lanes with the street shall favor vehicle movement.

o)Turning angle greater than 90 deg. shall not be allowed as the vehicle initial position shall be based on the highway/road traffic direction except in those cases in which greater turning radius is required.

Pavement for Vehicle Circulation:

a) Entry refueling and exit lane lanes pavement shall be made of materials that cannot be altered by the action of atmospheric agents (heat, cold, rain) hydrocarbons (fuels and lubricants spills). Their surfaces should be solid and non-skidding. Exposed natural soil pavement utilization shall not be allowed.

b) Refueling lanes shall be horizontal. Slopes for favoring rain drainage shall be gradual enough so as to prevent vehicle involuntary skidding during refueling.

Dispensing Island:

a) Distribution of aligned dispenser (on one or more dispensing islands) shall not prevent simultaneous use of all the filling hoses. Minimum distance among them shall be 10 m. Installation of two dispensers at 0.5 to 1 m. distance between them provided they only contain one filling hoses shall be allowed . Dispensers shall be located in the open air. Refueling area canopy shall be at least 5 m. height from the floor. Columns from which dispensers are suspended are considered as dispensers components.

b) Dispensing island shall bear a built in manhole for housing the dispenser's shut-off valve. It shall have a removable or hinged lid with embedding handles and without cutting edges and its wait shall not be higher than 5 kg. Shut-off valve depth according to the island level shall not exceed 0.40 m. manhole dimension allow easy activation of those valve. Finishing of there internal surfaces shall comply with art rules. In case of under ground manhole it shall optionally have.

c) Its bottom connected to the piping ditch so as to enable drainage through them.

d) A permeable bottom mechanical protection at both ends of dispensing island shall be installed when there height related to the refueling lane level is lower than 0.20 m. They shall be designed to withstand the impacts at a speed of up to 10 km/h. Their height shall not be lower than the user's vehicle bumpers. Connections to dispensers shall be flexible so as to absorb vibration and potential impacts. Dispensers external cover may be metal or self-extinguishing plastic material as well as for the area of dispensing indicators.

Annexes and Ancillary Areas:

When the filling station counts with the parking areas or the car wash , greasing , tire shop services or sales of vehicles elements , convenience stores etc. they shall be located in such a way that vehicles using them shall not maneuver or park on refueling or exit lanes .

If the station provide other services apart from fuel dispensing (as for example sale of food, entertainment area etc or meeting places), they shall be directly accessed from the street. Pedestrians shall not circulate along the refueling and maneuver area.

Special Distribution of Refueling and Maneuvering Area:

Quadratic Dispensing Island:

When the dispensing islands are squarely distributed that is to groups of two parallel and aligned dispensing islands, the following minimum distance shall be applied between parallel dispensing islands, 10 m. A 4 m. central strip for vehicle movement along other vehicles parked in refueling positions has been included in the 10 m. width refueling lane; therefore parked vehicle shall not occupy such central strip. For this layout. a group of more than four dispensing islands is not recommended.

Other Layouts:

When dispensing islands distribution is a combination between aligned parallel and other non regulated layouts space for vehicle circulation and maneuvers shall be analyzed , isolated some parts of the area or dispensing island groups, and applying specific provisions that may correspond to GAS DEL ESTADO criteria.

(6) Slow Filling Station :

Slow fill is the process for CNG refueling in which the fill up time is so long that it prevents permanent presence of dispensing operators and vehicle drivers next to the vehicle. Thos refueling mode shall be used only for refueling captive or own fleets.

General Aspects:

a) For refueling effectiveness vehicles may be placed against the dispensing island. Therefore driving in reverse for approaching or exiting refueling position shall be allowed. Nevertheless a fast evacuation from the installation in case of emergency shall be foreseen.

b) Vehicles in refueling position shall not impair maneuver of other station users.

c) During refueling vehicles shall remain with there doors unlocked and keys in the ignition switch.

d) If a slow fill station has installation for open to the public dispensing, refueling and maneuvering area in each of them shall be clearly separated.

Circulation and Maneuvering Areas:

The areas of refueling lanes when vehicles are parked opposite the dispensing island , shall be the sectors occupied by the vehicle in its refueling normal position and their size compared to the vehicle shall be such that ::

There length is at least m. greater than the user vehicles. Their width is at least 1 m. greater than the user vehicles.

The area to the corresponding to the entry or exit lanes hall have the minimum width , resulting from :

G	=	a+ L sine α + B cosine α
A	=	5m
L	=	Vehicle length
W	=	Vehicle width
α	=	entry/exit angle related to the island longitudinal axis

Width of entry or exit lanes allowing two way circulations shall be increased by at least 5m.

Refueling lanes must be perfectly leveled.

Dispensing Islands:

a) For mechanical protection of CNG dispensers, guardrails not lower than user vehicle bumper shall be installed. Rails shall be located opposite the dispensers with at least 0.30m. Clearance.

b) Minimum distance between CNG dispensers and opening through which gas can accidentally enter into own premises, construction or buildings are set at 5m. Minimum distance between dispensers and own premises walls site lines or party walls shall be 5m.

Safety Devices and Fire Extinguishers:

a) 10 kg capacity pressurized tri-class chemical powder fire extinguisher (IRAM 3569/75 standard), with IRAM seal of approval, shall be loaded with 50 gm of such product per each surface square meter of refueling and parking area. At least 2 fire extinguishers adequate distributed in the refueling area shall be installed such that the operator does not have to walk more than 15 m.

b) Further more wheeled fire extinguishers with pressurized tri class chemical powder according to what is set firth in point 5.3 with IRAM seal of approval shall be installed. They shall be loaded with 50 g of such product per each surface sq. meter of refueling and parking area. At least 1 fire extinguisher shall be installed in the refueling area.

c) Safety signs shall be posted in the refueling area according to the stipulations of part 2 items 1-5 of these standards at one set of signs per each 10 filling hoses. The installation of the sign with the legend "Warning for drivers: ___________" may be omitted.

d) Emergency shut down palm buttons shall be installed on the dispensing island or dock, on one out of five filling hoses. They shall be identified with a sign stating "EMERGENCY SHUTDOWN" Likewise emergency shut down button shall be installed with the same requirement in the sector of the shift or night personnel and general access to the filling stations.

e) Emergency shut down shall automatically interrupt compressor, servo valve and dispensers.

f) When the refueling area is located in door zenithal ventilation with natural damper for enabling adequate air renewal shall be foreseen.

g) Vehicles shall not be refueled with people abroad.

3.5 Design specifications of the major components at the CNG Station

CNG Fueling Station

CNG Fueling Station Operation:

- Gas is supplied from City Gate Station at 26-19 barg.
- Gas is compressed from 19 bar to 250 bar.
- Gas is cooled, filtered, and moisture and oil are removed during compression.
- Gas is stored in high pressure tanks.
- Gas is then dispensed from the station.

Steel Pipeline:

12 inches = 32 Km

08 inches = 07 Km

04 inches = 06 Km

Total = 45 Km

Compressor

- Horizontally Opposed CNG Compressor
- 121 hp
- 3 Stage reciprocating compressor
- Direct coupling rated up to 1800rpm
- Capacity: 5*1200 SCMH ------ Mother Station Compressor
- Capacity: 1*1200 SCMH ------ On-Line Station Compressor
- Capacity: 5*250 SCMH ------ Daughter Station Compressor
- Pressure: 19 bar to 250 bar

Dispenser

High-Flow Bus CNG Dispensers (5 No.)

- Dispenser flow rates from 2,000 to 5,000 SCFM (3,200 to 8,00 Nm^3/hr)
- Single line (buffer) and 3-line cascade filling schemes
- Nominal filling times of 3-5 minutes for even the largest buses .
- High-flow bus nozzles.
- Stand-alone high-flow hose breakaway post available .
- Custom design of high flow systems to suit specific applications .

Fast-Fill Car CNG Dispensers (2 No.)

- Flow rate 100 to 200 SCFM (20 to 40 KG/min)
- Emergency Shut Down (ESD) system available with single or dual button activation
- Standard in-line breakaways on all dispenser models
- High-flow bus nozzles
- Easy-to-read backlit displays and 4 inch pressure gauge
- High flowing 10 micron filters on each inlet line
- Convenient preset keypad for both volume and currency entry options

Cylinder

Cylinder Cascade (One set)

Manufacturing standard:	BS5045
Working Pressure	25 Mpa = 250 bar
Cylinder capacity/pc	50WL
Nos. of Cylinder	40
Total Capacity	4500 Litres * 8 No.
Total Capacity	2200 Litres * 5 No.
Overall size	2,250 x 1,700 x2,150
Weight	4.2 ton

Generator:

Diesel Generator
Range 10 kVA up to 4000 kVA

Valves

Line valves are used as isolation valves. The type of line valve used is specified as V-4913 is having brass forged body and metallic seat. It is suitable for high pressure application i.e. 200 barg to 250 barg.

Safety relief valves

The V-7713 is having metal to metal seat and is suitable for high level application up to 200 Kg/cm2.

we can supply safety relief valves for all types of gases. The material of construction depends on the nature of media/ gas for which it is to be used.

Pressure Regulators

40 micron filter

A heat exchanger

A solenoid shut-off valve

The maximum rated inlet pressure is 80 bar

The outlet pressure ranges from 3.4 bar to 10 bar.

Flow 75 KG/hr

Wide range of fittings for gas inlet, outlet and heat exchanger connections.

CNG Pressure Gauge

Parameters:

1) Pressure gauge: dia.: 50mm, 54mm, 63mm, 75mm
2) Fixing way: radia or axial direction
3) cover material: ABS, stainless steel 304
4) Connection part material: HPB59-1 brass, or stainless steel SUS316
5) Connection thread: G1/4 (PF1/4); M14 x 1.5, ZG1/4 (PT1/4); NPT1/4
6) Scale on the meter: 0 - 400Bar / 6,000PSI
7) Accuracy Grade: 2.5

Pressure piping systems

Pressure piping systems covered are:

(a) between the termination of the utility's piping, usually at the meter, and the inlet to the compressor assembly at a CNG refuelling station, if the design pressure exceeds 4.14 bar (60 psi); and

(b) from the inlet to the compressor assembly through to the dispenser nozzle, except for the mechanical parts of the compressor and any subsystems designed for 4.14 bar (60 psi) or less.

Laying of MDPE Polyethylene (Mild Density Polyethylene)

180 mm = 3.00Km

125 mm = 4.45 Km

063 mm = 6.00 Km

032 mm = 10.00 Km

020 mm = 10.00 Km

Total = 33.45 Km

3.6 Compressor selection

Several factors must be considered in selecting a compressor for a particular application. a multistage compression system may use different compressor types for its stages in order to optimize performance or enable more desirable operating features. This discussion is limited to the two principal types of compressors used most commonly for handling natural gas: reciprocating and centrifugal dynamic compressors. In some cases the analysis can be quite complex and these general guidelines may not be sufficient. It is best in such cases to discuss the particular situation with the compressor manufacturers themselves.

- GAS CHARECTERISTICS
  Gas characteristics such as ratio of specific heats, compressibility significantly affects the centrifugal compressors—many more stages are required if the inlet gas density is low. Positive displacement compressors are not much affected by the gas molecular weight, specific gravity or inlet density.

- FLOW RATE

For higher flow rates , centrifugal machines may be used for the lower compression stages, and reciprocating for the higher pressure stages. For relatively lower flow rates, the reciprocating compressor can be used for all the stages.
Flow-rate variation is another factor. Reciprocating compressors can handle enormous flow-rate variations with little loss in efficiency. Centrifugal compressors, however, do not perform efficiently below 50-90% of their rated capacity. In general, reciprocating compressors are more flexible in handling various types and sizes of gas flow streams than centrifugal compressors.

- COMPRESSION RATIOS and OPERATING PRESSURES

Low compression ratios with moderate capacities favor centrifugal compressors. High compression ratios and higher pressures favor reciprocating compressors.
Variations in inlet and discharge pressures are important to consider also. In reciprocating compressors, if the inlet (suction) pressure is lowered while maintaining the same discharge pressure, the overall horsepower is lowered, the differential pressure of all but the last stage is lowered, and the pressure differential and the temperature rise of the last stage are increased. If the suction pressure to the first stage is increased, horsepower of the complete system increases, pressure differential across all but the last stage is increased, while the pressure differential and the temperature rise in the last stage are lowered.
In centrifugal compressors, if the suction pressure is raised, the discharge pressure will increase, frequently beyond the design point, and horsepower will also increase. If the suction pressure is lowered, the centrifugal compressor will not compress to the desired discharge pressure.

- OPERATING TEMPERATURES

Centrifugal compressors are less affected by high or low temperature extremes than reciprocating compressors in which temperature limitations are imposed by the lubricants. However, the maximum discharge temperature must generally be kept within some limit to avoid operating problems such as cracking of the lubricating oils. None of the compressors has any significant advantage in this respect; intercoolers are required to be used between stages to overcome high-temperature problems. Where lubricating-oil cracking and contamination problems are particularly severe, special partially-lubricated or non lubricated reciprocating compressors may be more suitable than the centrifugal compressors.

- COMPESSOR DRIVER

The power source to be used for driving the compressor also influences the choice. Generally, the driver is selected based upon available power source(s), the heat balance or utilization, waste gas use, and other factors. Centrifugal compressors are always preferred if the driver must be a turbine; reciprocating type are preferred if the driver must be a turbine; a reciprocating type are preferred if the driver must be an electric motor. This is so because motor-driven reciprocating compressors can be directly driven by the motor, whereas motor-driven centrifugal compressors require gears for increasing the speed. The opposite is true for turbines.

- FOUNDATION AND FLOOR SPACE.

The centrifugal compressor is usually favourable from the point of view of floor space and foundation requirements. Reciprocating compressors generally produce some unbalanced forces during their operation, requiring a foundation that will support their dead weight plus maintain alignment of the compressor and driver by absorbing the unbalanced forces that may be present.

- CONTINUITY OF OPERATION

The value of lost production usually exceeds the actual cost of repairs, and continuity of operation or availability becomes an important factor. Dynamic compressors can operate uninterrupted for a longer period of time and their malfunctioning (stoppage) is more predictable than reciprocating compressors. However, the average yearly availability of both compressor types is very high and quite similar.

- CAPITAL COSTS

It is difficult to compare the cost of centrifugal compressors versus reciprocating compressors. For the same volume, pressure, and other compression factors, gas specific gravity influences the cost of the centrifugal compressor but not the reciprocating compressor. Often, the cost of the driver is used as a cost criterion. As stated earlier, if the power source is conductive to turbine operations, then the centrifugal compressor will be cheaper.

- OPERATING COSTS

The operating cost, consisting mainly of the cost of power, throughput the service life of a compressor far exceeds the capital costs and is therefore a more important consideration. The reciprocating compressor is inherently more efficient than the centrifugal compressor; expect at very low compression ratios. Very large volumes, low compression ratios, and low discharge pressures favour the centrifugal compressor from an operating cost viewpoint.

➢ MAINTENANCE COSTS

It is generally accepted that for the same gas that is clean, non-corrosive, and under the same terminal pressure conditions, maintenance is less on the centrifugal compressor than the reciprocating compressor. For more difficult compression problems, maintenance requirements for both compressor types increase, and become more nearly equal, though the centrifugal compressor will frequently require a little less maintenance.

3.7 Compressor Design Fundamentals

From the perspective of compressor users such as gas engineers, compressor design involves only the determination of compressor capacity and power requirements for a given application, in order to select the type and size of compressor required.

Multistaging

There are practical limits to the permissible amount of compression for a single compression stage. The limitations vary with the type of compressor, and include the following:

1. Discharge temperature—all types.
2. Compression efficiency (energy requirements)—all types.
3. Mechanical stress (rod loading) problems—all types.
4. Pressure rise or differential—dynamic units, and most positive-displacement units.
5. Compression ratio—dynamic units.
6. Effect of clearance—reciprocating units.

Whenever any limitation is involved, it becomes necessary to use multiple compression stages (in series). Furthermore, multistaging may be required from a purely optimization standpoint. For example, with increasing compression ratio r, compression efficiency decreases and mechanical stress and temperature problems become more severe. Therefore, if a greater compression ratio is desired, multiple compression stages must be used. Intercoolers are generally used between the stages to increase compression efficiency as well as to lower the gas temperature that may become undesirably high (as given by the following equation: especially for high compression ratios.

$$T_2/T_1 = (p_2/p_1)^{n-1/n} = r^{n-1/n}$$

Where,

P1, p2 = pressure at stages 1 and 2, respectively.

T1, T2 = temperatures at stages 1 and 2, respectively

R = pressure ratio, equal to p2/p1
N = polytropic exponent

3.8 Compressor Design Methods

The design of each compression stage is best considered separately because of pressure losses and temperature changes in the intercoolers and piping between the stages, condensation (if any) of water vapor from the gas, and the consequent volume changes of the gas.

The three methods used for compressor design calculations are:

1. Analytic expressions derived from basic thermodynamic relationships;
2. Enthalpy versus Entropy charts, commonly known as Mollier Diagrams, for ideal isentropic compression process;
3. Empirical "quickie" charts, frequently provided by compressor manufacturers for quick estimates.

The method to use depends upon the accuracy desired and the amount of data available. In many cases, very great accuracy is not required: compressors are rarely chosen to satisfy a given requirement very precisely. Overdesign is quite common in order to provide an operating safety factor and to ensure that expensive compression equipment is not required to be enhanced or replaced for relatively small capacity increases in the flowing system. All three methods, therefore, find application in determining the compressor to use.

Governing Equations

1. **Piston Motion**

The distance between piston and top of cylinder h depending on time t can be determined using the properties of the crank mechanism. We use the length of the crank lever r, the length of the piston rod l, the smallest distance between piston and cylinder top $h0$ an the present angle of the crankshaft φ to obtain

$$h = r + l + h_0 - r\cos\varphi - l\sqrt{1 - \left(\frac{r}{l}\right)^2 \sin^2\varphi}\,, \qquad (1)$$

where $\varphi = 2\pi nt$. Here, n denotes the speed of the crankshaft.

2. **Flow Field**

The governing equations for the flow of gas are obtained by taking the mass and momentum balance over a cross section. The variables ρ, u, p have their usual meaning, density, velocity and pressure, respectively.

$$\frac{\partial \rho A}{\partial t} + \frac{\partial(\rho u A)}{\partial x} = 0\,, \qquad (2)$$

$$\frac{\partial \rho u A}{\partial t} + \frac{\partial(\rho u^2 A + pA)}{\partial x} = p\frac{\partial A}{\partial x}\,. \qquad (3)$$

Assuming isentropic flow conditions we have

$$p\rho^{-\kappa} = \text{const}\,, \qquad (4)$$

where, κ denotes the ratio of specific heats. Note that eq. (3) is not of conservation form. The right hand side of equation (3) constitutes a momentum source of the flow due to a variation of the cross section. Since the cross section A may vary rapidly at the transition from the cylinder to the valve pocket, the derivative dA/dx may become large causing numerical problems. Using the isentropy condition (4) for smooth solutions the momentum equation becomes

$$\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}\left(\frac{1}{2}u^2 + \frac{\kappa}{\kappa - 1}\frac{p}{\rho}\right) = 0 \qquad (5)$$

We remark that equation (5) is equivalent to equation (3) for smooth solutions only. Discontinuous solutions corresponding to shocks or to sudden changes of the flow cross section are associated with an increase of entropy and thus are not described correctly by (5). However, it turns out that the increase of entropy in the considered cases is small and thus has been neglected.

3. Pipeline Flow Equtaions

3.1 MAOP = 2*S*T*F / D_0 (Maximum Allowable Design Pressure)

Where,

T = wall thickness

F = Factor of Safety

D_0 = outer diameter

3.2 Design Pressure D_p = 2*S*T*(F*L*J*T) / D_0

Where,

L = location factor

J = joint factor

T = temperature factor

3.3 The Gas Velocity,

$$U = 0.002122 * \left[Q_b / D_i^2 \right] \left[P_b / T_b \right] \left[ZT/P \right]$$

Where,

Q_b = Throughput

P_b = Base Pressure

T_b = Base Temperature

Z = Compressibility Factor

T = Gas Temperature

P = Gas Pressure

3.4 Erosional Velocity is calculated in the following manner:

$U_{max} = 100 \sqrt{ZRT/29GP}$

Where, Z = Compressibility Factor = 0.954

R = Universal Gas constant = 10.732 KJ/Kg mol K

T = Gas Temperature = 546 Rankine

G = Specific Gravity = 0.612

4. Valve Dynamics

The state of a valve is specified by the distance between valve plate and seating (valve lift) *xv*. The motion of the valve plate is determined by the forces acting on it. We consider the following three contributions to the resulting force: the pressure difference across the valve acting on an effective force area *Av* of the valve plate, the springing and thirdly a contribution due to viscous forces in the initial stages of valve opening. Denoting the pressure in front of the valve *p1* and behind the valve *p2* we obtain the equation of motion for thevalve plate

$$m_v \ddot{x}_v = (p_1 - p_2)A_v - k(x_v + l_1) - F_{adh}. \qquad (6)$$

Here *mv* stands for the mass of the valve plate. The constants k and *l1* denote stiffness of springing and initial deflection of the springs. An initial sticking effect is modelled by the force *Fadh.* It is caused by the viscosity of the gas in the valve gap resulting in a small time delay when the valve is opening. It reads as follows (Flade4)

$$F_{adh} = f_1 \frac{\dot{x}_v}{x_v^3}. \qquad (7)$$

The factor *f1* depends on geometric features of the valve and properties of the gas. It also takes lubrication oil at the valve plate into account.

2.2.4 Flow through the valve

The flow through the valve is considered as the (stationary) outflow of a gas from a pressurized container through a convergent nozzle. Thus this model takes the pressure loss due to separation into account. The mass flow .through the valves is given by St.Venant and Wantzell6,

$$\dot{m} = \phi \rho_1^0 \left(\frac{p_2}{p_1^0}\right)^{\frac{1}{\kappa}} \sqrt{\frac{2\kappa}{\kappa - 1}\frac{p_1^0}{\rho_1^0}\left(1 - \left(\frac{p_2}{p_1^0}\right)^{\frac{\kappa-1}{\kappa}}\right)}.$$

(8)

where 0

*p*1 is the totel pressure before and

p2 is thepressures after the valve, respectively.

The effective flow cross section φ of the valve is assumed to be a function of the position of the valve plate *xv* only. It has to be determined empirically.

4.1 Valve losses

In figure 15 the computed mean pressure *p* is shown in the p,V-diagram. The shaded area corresponds to losses at the discharge valve.

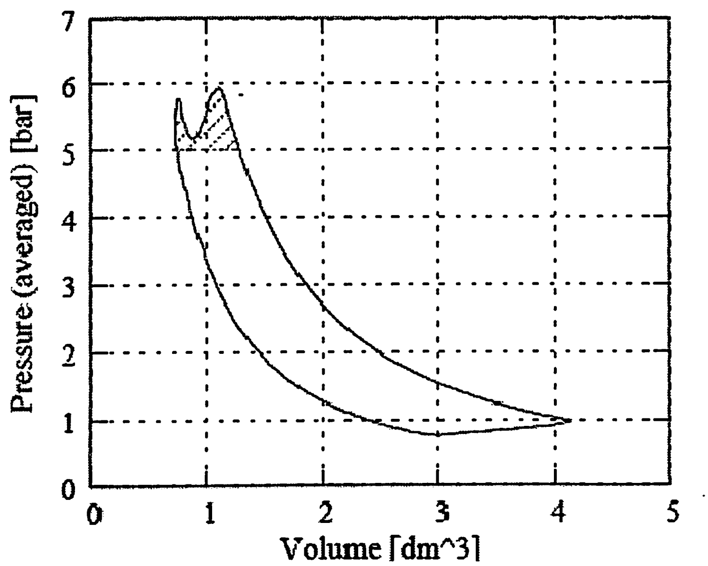


Figure 15: p, V-diagram, valve losses

5. Pressure Regulator:

The governing equations are the following three:

- continuity equation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial r} + \frac{\rho u}{r} + \frac{\partial (\rho w)}{\partial z} = 0$$

- momentum equation:

(r-component)

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial r} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial p}{\partial r} + \frac{1}{r}\frac{\partial}{\partial r}(r\,\tau_{rr}) + \frac{\partial \tau_{rz}}{\partial z}$$

(z-component)

$$\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial r} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \frac{1}{r}\frac{\partial}{\partial r}(r\,\tau_{rz}) + \frac{\partial \tau_{zz}}{\partial z}$$

- energy equation:

$$\frac{\partial}{\partial r}\left(k_r \frac{\partial T}{\partial r}\right)+\frac{1}{r}k_r\frac{\partial T}{\partial r}+\frac{\partial}{\partial z}\left(k_z \frac{\partial T}{\partial z}\right)$$
$$+\eta\gamma^2-\rho C_p\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial r}+w\frac{\partial T}{\partial z}\right)=0$$

6. Compressor Cylinder Design

Two compressor cylinder designs have been proven. One is a cylinder suitable for gas transmission and storage applications. The second is a compressor cylinder designed primarily for gas gathering applications.

Gas transmission cylinders are unique in their design. These cylinders are capable of large flows at very low ratios of compression (typically 1.2-1.8 ratios). At these low ratios, the designer needs to be concerned with unobstructed gas flow passages. Consequently, these flow passages tend to be large. Likewise, compressor valving is selected to maximize the flow with very low compressor valve power losses. These cylinders are usually designed without water jackets for cylinderbore cooling.

Designing cylinders for higher rota - tive speeds generally results in shorter stroke cylinders. For this cylinder design, both 7.25-inch and 8.5-inch compressor strokes had to be considered. Higher rotative speeds have the designer concerned about total recipro - cating weight. The governing equations for inertia load for a slider-crank mech -anism are shown here:

F = m r ω^2 cos ωτ + m(r / l) r ω^2 cos 2 ωτ

Becomes a maximum when τ = 0

F = m r ω^2 (1 + r / l)

Where:
τ = time (secs.)
F = Inertia Load (lbs)
m = mass (Total reciprocating mass)
r = crankshaft radius (inches)
ω = angular velocity (rad/sec)
l = connecting rod length (inches)

This equation points out the inertia load considerations. As the rotative speed increases, the inertia load goes up by thesquare of the speed. Reciprocating mass (primarily the mass of the crosshead, piston and rod weight) and crank radius increase the inertia load linearly.

Therefore, for shorter-stroke, higherspeed compressors units, it is desirable to have piston and rod weights which are as light as possible so as not to inertia overload the unit when gas is not being compressed.

7. Capacity Regulation

Compressor capacity control is key, particularly in gas transmission and gas storage applications of compression equipment. It is less of a factor in routine gas gathering applications, but

occasionally a load step is required, involving a pneumatically operated clearance pocket or manually adjusted variable volume outerhead.
For the purposes of this discussion, automatic systems for capacity control will be discussed. These systems require a control system, but do not require the intervention of a compressor station operator due to the logic built into these types of control systems.

8. Dispenser

Using standard principles of fluid energy, a fluid can possess energy in three forms (disregarding thermal energy)--pressure, kinetic, or potential energies. Bernoulli's equation is basically an energy conversation equation. The total energy of a fluid flowing without losses in a pipe or chamber cannot change. According to Bernoulli's equation--total energy possessed by a fluid is the sum of its pressure, kinetic and potential energies.

$$p_1/\rho + v_1^2/2g_c + z_1 = p_2\rho + v_2^2/2g_c + z_2$$

p=pressure
ρ=density
v=velocity
g_c=gravitational constant
z=height above datum

In fluid dynamics, energy conservation principles based on Bernoulli's equation are derived to include the frictional loss in the system as well as other internal losses. The frictional loss generally refers to the restricting properties of the materials through which the fluid flows. The other loss properties include obstructions in the flow, changes in direction, and changes in flow area. The losses lower the efficiency of a system, and are described as:

$$(p_1/\rho + v_1^2/2g_c + z_1) + h_A = (p_2/\rho + v_2^2/2g_c + z_2) + h_E + h_f$$

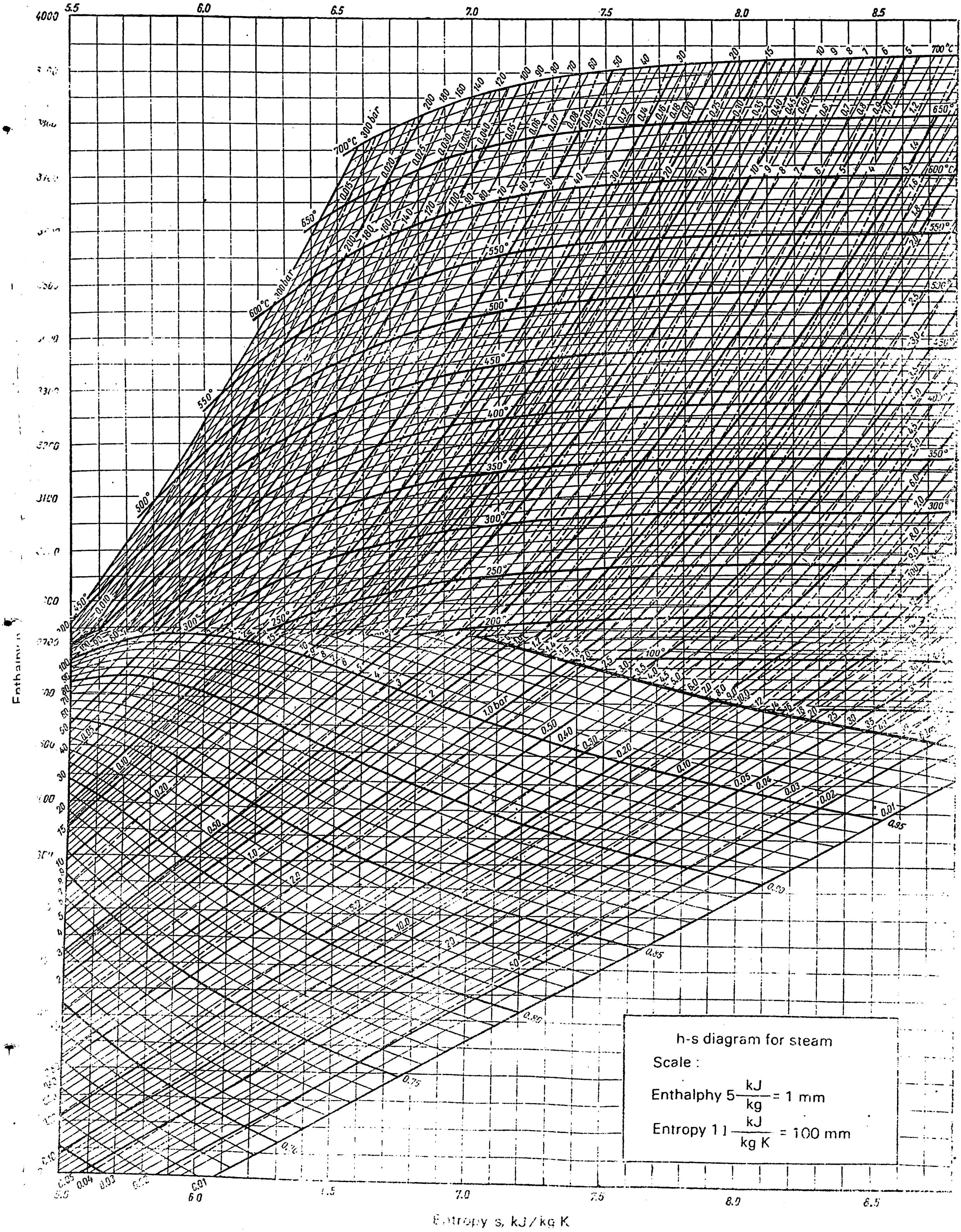
h_A=Fluid height, head, depth--Added

h_E=Fluid height, head, depth--English, extracted

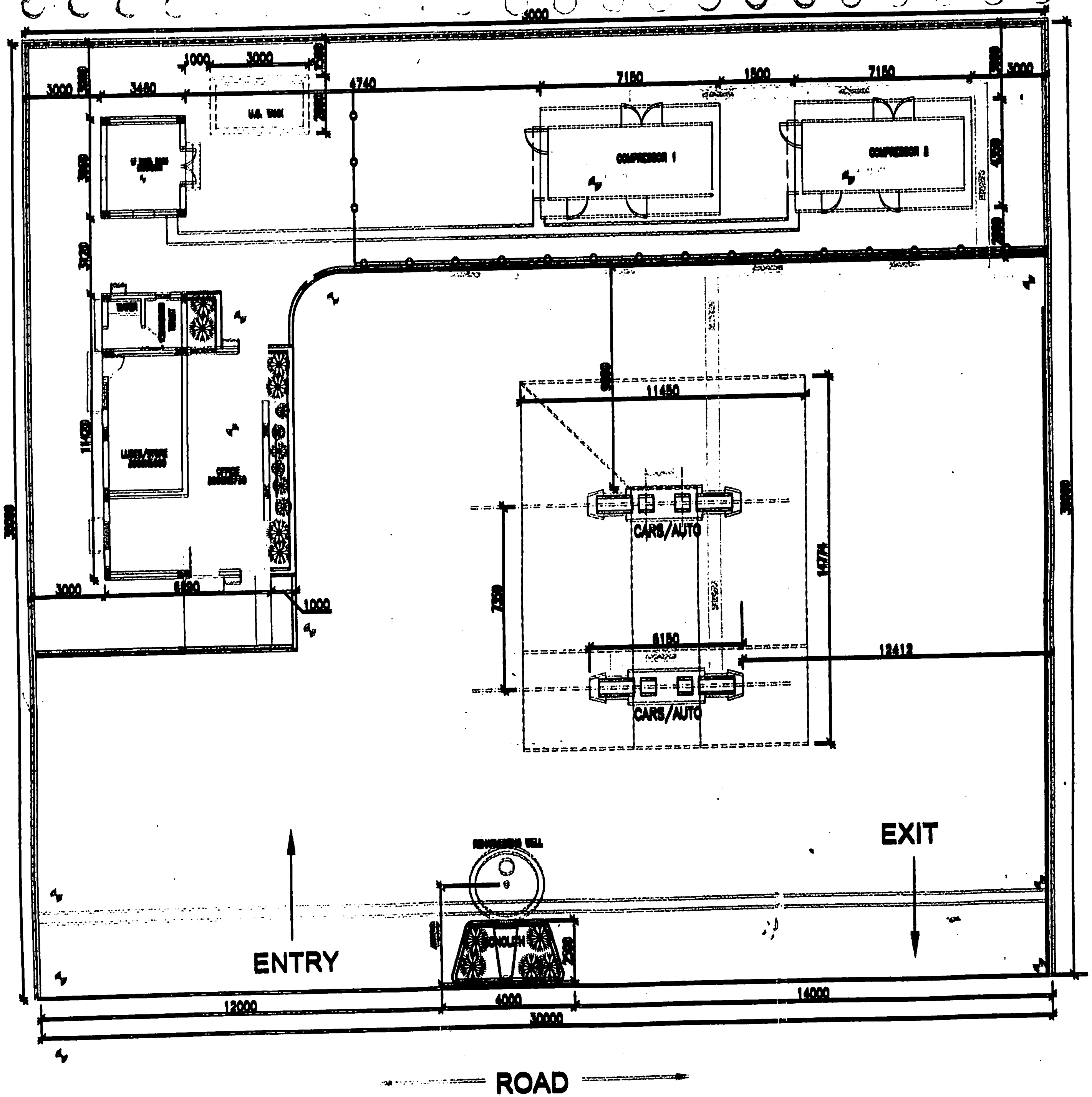
h_f=Fluid height, head, depth--friction, flow

In the liquid dispenser systems, losses decrease the operating efficiency of the dispenser, and require a greater input force to counter these losses. There are inherent losses attributable to all dispensers and refer to the material used in the dispenser design. There are also losses that can be reduced for obstructions and dimensional restrictions. Furthermore, properly designed fluid paths reduce the inefficiency attributable to turbulence.

The dispenser hoses have to account for huge pressure variations and also should have the capacity to sustain high pressures. This is the reason why the dispenser hoses are made of strong material so as to resist the varying high pressures.



Mollier diagram

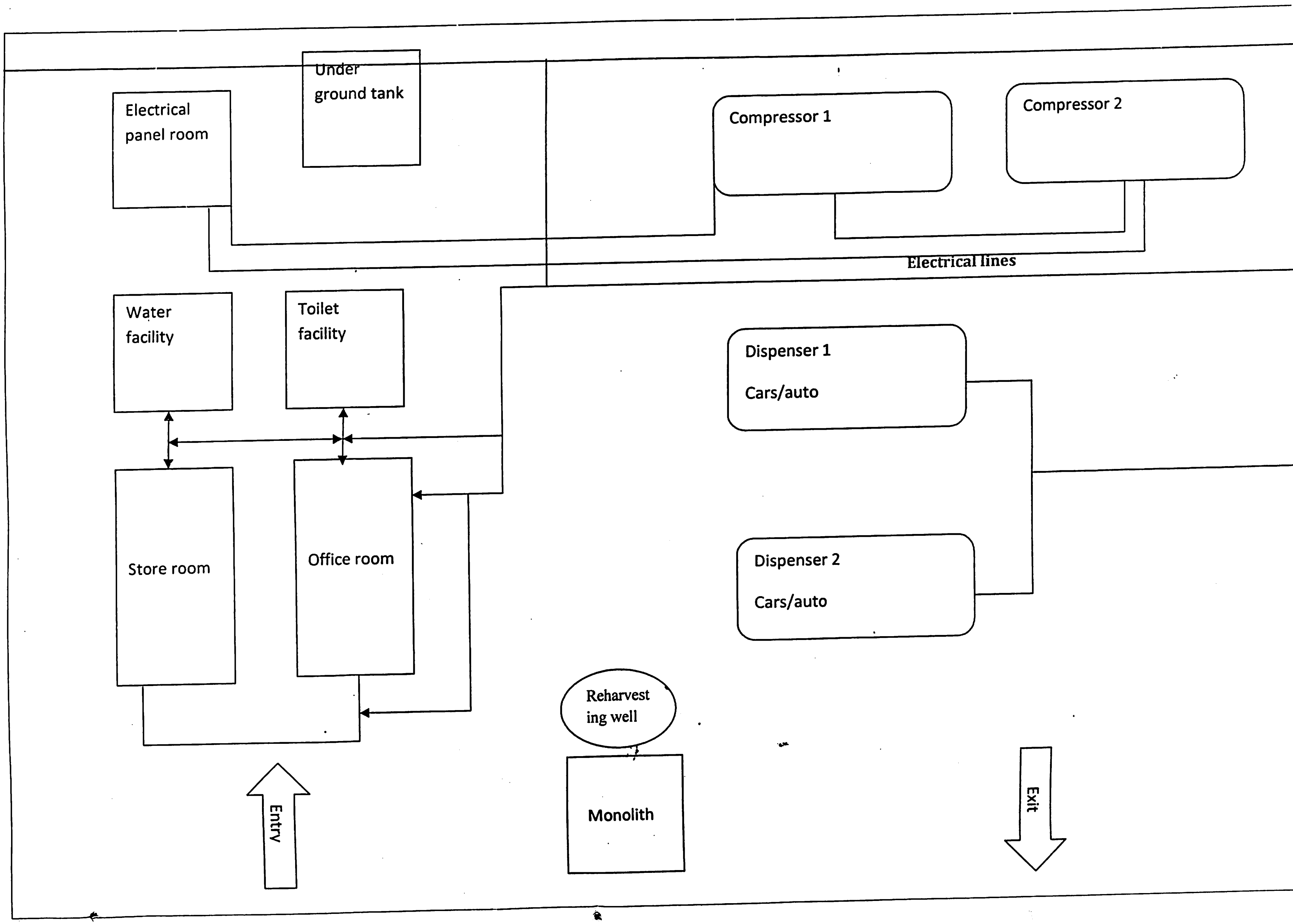


PLOT AREA : 900.00 SQ. MT.

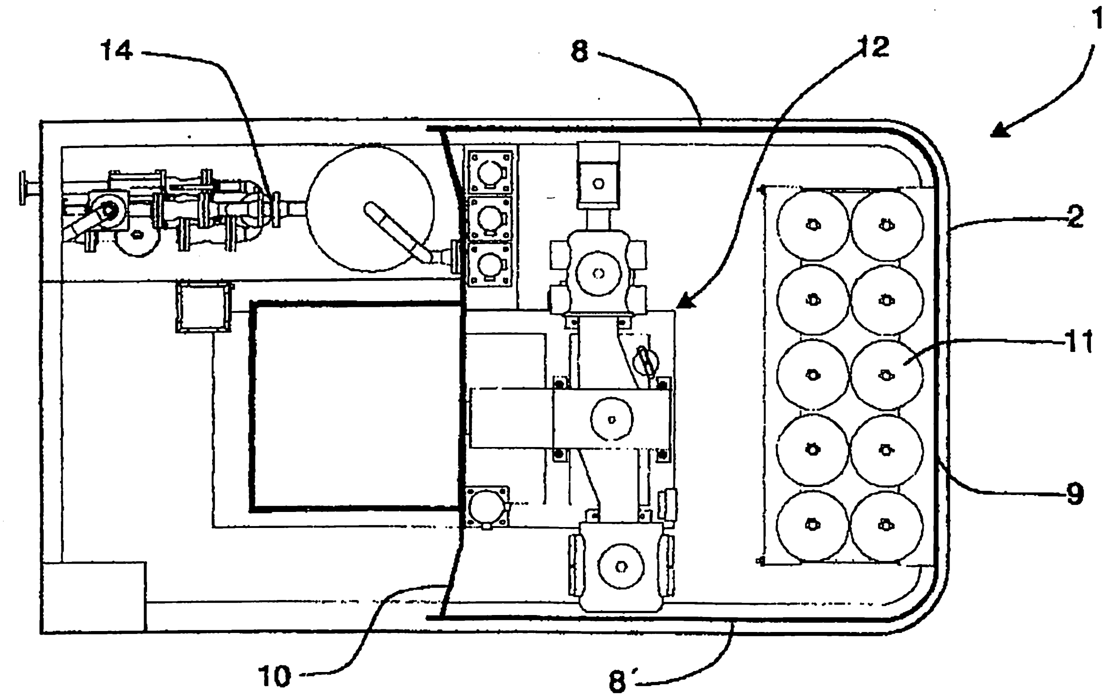
Drawing Title:
TRENCH LAYOUT

Drwg Number:
ADN-LUCK-01

Adani Energy Ltd.
ADANI GROUP
A-1/11, Sector-B, Aliganj, Lucknow.



Electrical panel room
Under ground tank
Compressor 1
Compressor 2
Electrical lines
Water facility
Toilet facility
Dispenser 1
Cars/auto
Store room
Office room
Dispenser 2
Cars/auto
Reharvesting well
Entry
Monolith
Exit



14
8
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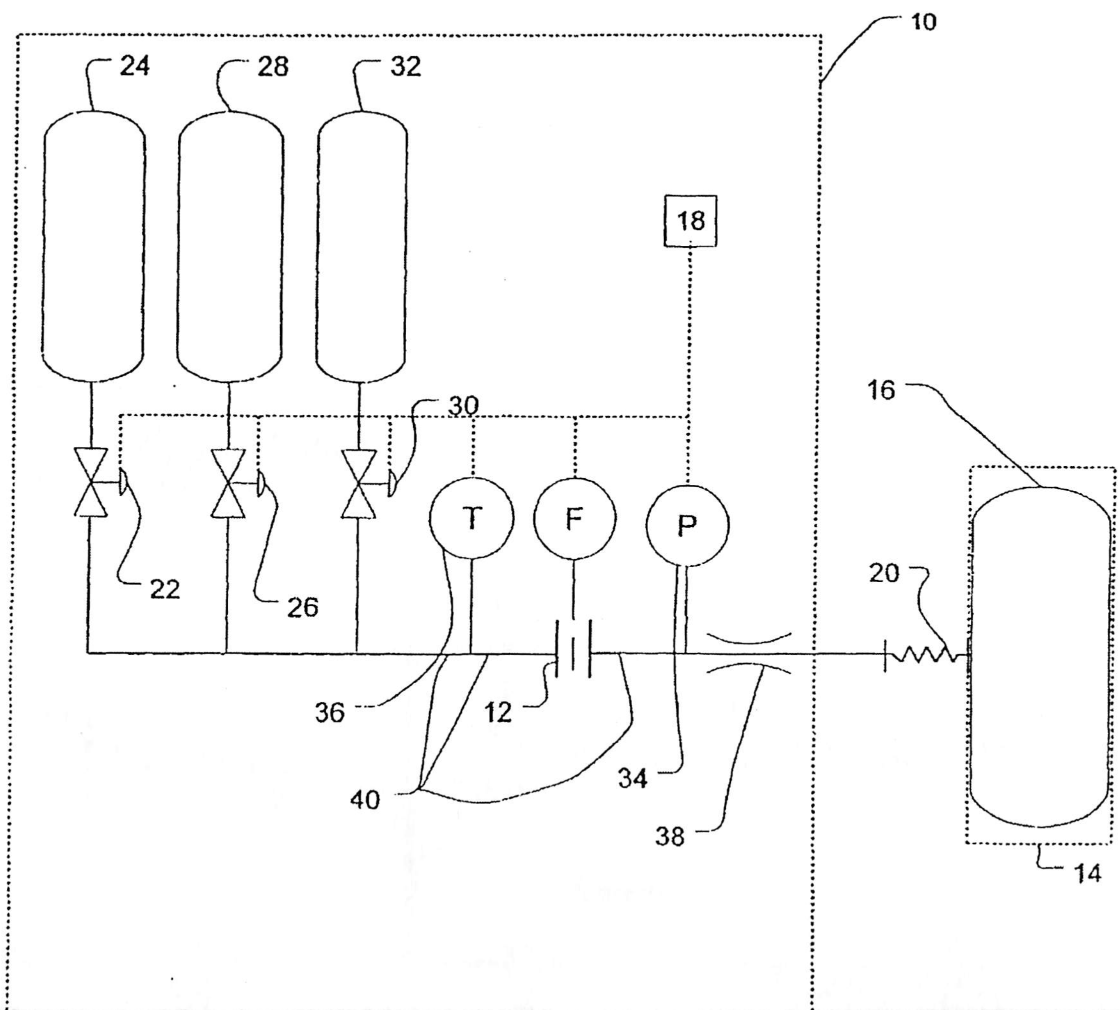

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1, 10------ CNG station Layout

2------Outer boundary of the CNG Station

9------Storage Cascade

10-----Dispenser

12----Battery

11, 24, 28, 32-----Storage Cylinders

14-----Reciprocating Compressor

22----Isolation valve

26----Safety valve

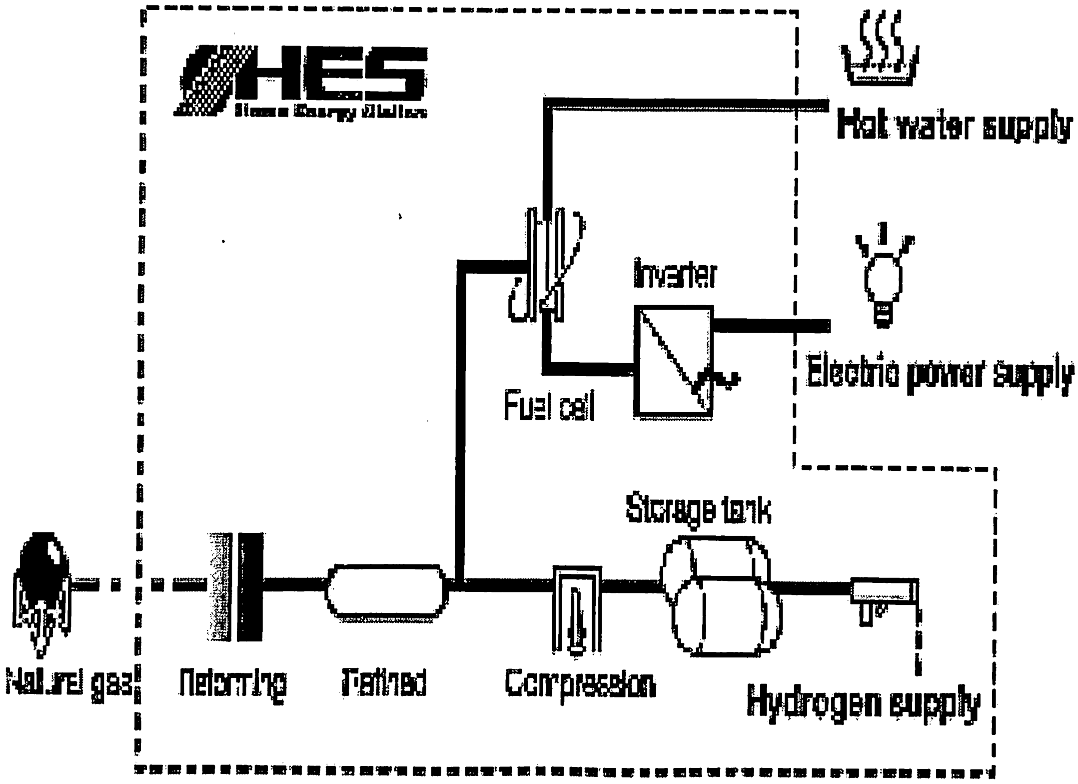
30-----Emergency valve

36----Temperature Indicator

40----Flow meter

34----Pressure Indicator

16----Compressor



Typical Layout

CHAPTER 4
COMPUTATIONAL CALCULATIONS

4.1 Compressor Power Required

For the compressor selection we calculate the compression ratio (r) so as to compress the gas from 19 bar pressure to 250 bar pressure. This can be done as under:

R opt $= (p_d/ p_s)^{1/n_s}$

$= (250 \text{ bar}/ 19\text{bar})^{1/n_s}$

$= (3625.943 \text{ psia}/ 275.5717 \text{ psia})^{1/n_s}$

$= (13.158)^{1/n_s}$

Now, for $n_s = 1$; $r_{opt} = 13.158$ which is too high.

for $n_s = 2$; $r_{opt} = 3.628$ which is not very high and may be acceptable.

for $n_s = 3$; $r_{opt} = 2.361$ which is not very high and may be acceptable.

We have, for first stage :

$p_2/p_1 = r_{opt} = 13.158$

Therefore, $p_2/19 = 13.158$

$P_2 = 250.002$ bar(guage)

And the power required can be calculated in the following manner:

Work done by the compressor for **single** stage is given as

$W = n/n\text{-}1\ P_1V_1\ (\ (P_2/P_1)\text{^}n\text{-}1/n - 1)\ )$

$W = 1.3\text{-}1/1.3\ 19*10\text{^}5\ ((250/19)\text{^}1.3\text{-}1/1.3\ \text{-}1)\ )$

W = 6693.1378 KJ

And **power** required is given as

$P = WN_w/60$

P = 6693.1378*N/60

P = 111.552 KW

Now taking the compression ratio as 3.628 and number of stages equal to two we calculate the pressure at each stage and the power required in the following manner:

We have, for first stage :

$p_2/p_1 = r_{opt} = 3.628$

Therefore, $p_2/19 = 3.628$

$P_2 =$ 68.932 bar(guage)

And , for second stage :

$P_3/p_2 = 3.628$

$P_3/68.932 = 3.628$

$P_3 = 250.08$ bar(guage)

And the power required can be calculated in the following manner:

Work done by the compressor for **double** stage is given as

W = 2n/n-1 P_1V_1 ((P_2/P_1)^n-1/n – 1))

W = 2*1.3-1/1.3 19*10^5 ((68.932/19)^1.3-1/1.3 -1))

W = 5709.620 KJ

And **power** required is given as

$P = WN_w/60$

P = 5709.620*N/60

P = 95.16 KW

Now, taking the compression ratio as 2.361 and number of stages equal to three we calculate the pressure at each stage and the power required in the following manner:

We have, for first stage :

$p_2/p_1 = r_{opt} = 2.361$

Therefore, $p_2/19 = 2.361$

$P_2 =$ 44.859 bar(guage)

And , for second stage :

$P_3/p_2 = 2.361$

$P_3/44.859 = 2.361$

$P_3 = 105.9121$ bar(guage)

And , for third stage :

$P_4/p_3 = 2.361$

$P_4/105.9121 = 2.361$

$P_3 = 250.058$ bar(guage)

And the power required can be calculated in the following manner:

Work done by the compressor for **three** stage is given as

W = 3n/n-1 P_1V_1 ((P_2/P_1)^n-1/n – 1))

W = 3*1.3-1/1.3 19*10^5 ((44.859/19)^1.3-1/1.3 -1))

W = 5415.832 KJ

And **power** required is given as

$P = WN_w/60$

P = 5415.832*N/60

P = 90.264 KW

Here we see that the same output pressure is achieved if we compress the gas in three stages with better efficiency and power requirements than in a single or double stage.

The reasons being:

- The compressor size increases.
- The compression cost increases.
- The temperature increases and hence a lot of heat is generated.
- The overall power required for compression also increases.
- The maintenance cost as well as the overall maintenance of the compressor increases.

From the above calculations we get the power required = **90.264 kW**

We know that the number of stages of compression in the CNG station is three. Therefore, the power in each single compression stage will be = 90.264/ 3 = **30.088 kW**. (Theoretical)

Taking the efficiency to be as 80%, the actual power required will be = 30.088 / 0.8

= **37.61 kW**.

This was the **actual power** required by our compressor to compress the natural gas, now we calculate the **break horse power** required by the compressor at each compression stage. This is done in the following way:

4.2 Break Horse Power Calculations:

The gas has the following composition (expressed as mole fraction):

Composition	y_i	M_i	p_{ci}	T_{ci}	c_{pi}
C_1	0.9216	16.043	667.8	343.1	8.95
C_2	0.0488	30.070	707.8	549.8	13.78
C_3	0.0185	44.097	616.3	665.7	19.52
$I-C_4$	0.0039	58.124	529.1	734.7	25.77
$N-C_4$	0.0055	58.124	550.7	765.4	25.81
$I-C_5$	0.0017	72.151	490.4	828.8	31.66

$M = Ey_iM_i = 17.737$ lbm/lbmole

Therefore, $Y_g = M/28.97 = 17.737/28.97 = 0.612$

$P_{pc} = Ey_ip_{ci} = 667.313$ psia

$T_{pc} = Ey_iT_{ci} = 363.831\ ^0R$

Therefore, $p_{pr} = p/p_{pc} = 100/667.313 = 0.150$

And $T_{pr} = T/T_{pc} = (460+150)/363.831 = 1.677$

The gas Z factor at suction is taken as unity.
$C_p^0 = Ey_ic_{pi} = 9.578$ Btu/lbmole-^{0}R

For $p_{pr} = 0.150$ and $T_{pr} = 1.677$, $\hat{}c_p = 0.15$ Btu/lbmole-^{0}R

Therefore, $c_p = c_p^0 + \Delta c_p^0 = 9.578 + 0.15$

$= 9.728$ Btu/lbmole-^{0}R
$= 0.548$ Btu/lbm-^{0}R

From the equation, $k = c_p/c_v = c_p/c_p - 1.986$
$k = 9.728/(9.728-1.986)$
$k = 1.2565$

Now, the Brake Horse Power required at each stage can be given by the following two procedures:

- The Analytical Approach
- Mollier Diagram Method

I have followed the Mollier Diagram Method to calculate the BHP at each stage.

For a V_g= 0.612, the enthalpy-entropy diagram is approximately applicable. Use of this diagram results in:

Point	Process	p(psia), T(^{0}F)	Enthalpy, h (Btu/lbmole)
1	Entering gas	275, 100	880
2	After isentronic compression	870, 474	3600
3	After isobaric cooling	870, 100	750
4	After isentropic compression	1740, 614	5650
5	After isobaric cooling	1740, 100	-450
6	After isentropic compression	3480, 613	5500
7	After isobaric cooling	3480, 100	-900

Using the Gas Law, the number of moles is given by

$N_g = pV/ZRT = 275\ (1.02\text{x}10^{\wedge}6)\ /\ (1)(10.732)(460+100)$

$= 46{,}672.83425$ lbmoles/day

The ideal compression horse power required, IHP is given by the following equation:

IHP = (1hp/33,000 ft-lbf/min) (778.2 ft-lbf/min/Btu/min) (n_g (h_2-h_1)/t Btu/day / 1440 min/day)

= 1.6376 x 10^-5 n_g (h_2-h_1) / t

Substituting the values in the above equation one by one,

We get the IHP required for each stage of the compression process as follows:

IHP for 1st stage = (1.6376 x 10^-5)(46,672.83425)(3600-880) / 1

= 2078.935 hp

IHP for 2nd stage = (1.6376 x 10^-5)(46,672.83425)(5650-750) / 1

= 3745.140235 hp

IHP for 3rd stage = (1.6376 x 10^-5)(46,672.83425)(5500+450) / 1

= 4547.670285 hp

Thus, BHP for the first stage = 2078.935 / 0.80

= 2598.66875

= 2599 hp (approx)

Similarly, BHP for the second stage = 3745.140235 / 0.80

= 4681.425294

= 4682 hp (approx)

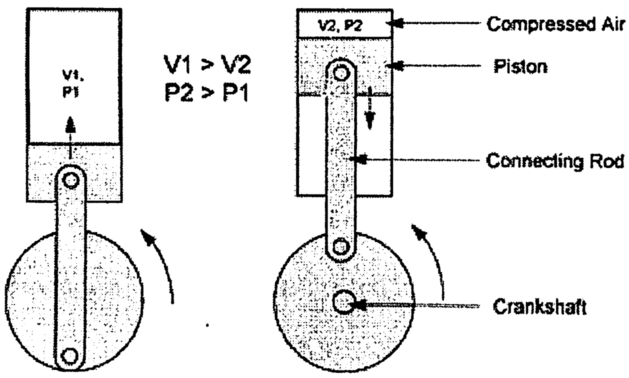
And, BHP for the third stage = 4547.670285 / 0.80

= 5684.587857

= 5685 hp (approx)

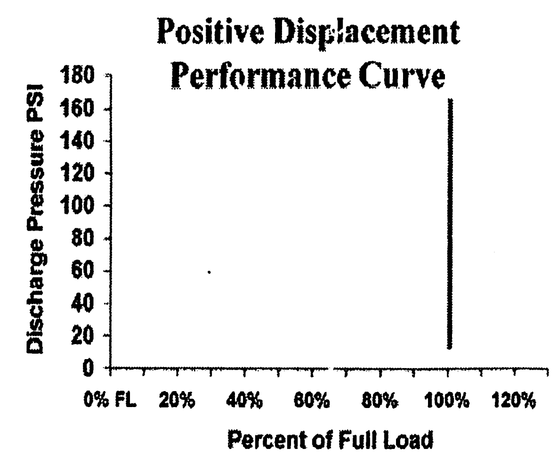
4.3 Reciprocating Compressors

Reciprocating compressors are positive displacement machines, meaning that they increase the pressure of the air by reducing its volume. The relationship between pressure and volume is illustrated in the figure below. This compressor has a crankshaft, connecting rods, and pistons. Single-stage and two-stage reciprocating compressors are commercially available. Single-stage compressors are generally used for pressures in the range of 70 psig to 100 psig. Two-stage compressors are generally used for higher pressures in the range of 100 psig to 250 psig.



Reciprocating Compressor Schematic

A performance curve for a positive displacement machine is provided in the figure below. It can be seen that despite compressor discharge pressure, load remains constant. Load reduction is achieved by unloading individual cylinders. Typically, this is accomplished by throttling the suction pressure to the cylinder or bypassing air either within or outside the compressor. Capacity control is achieved by varying speed in engine-driven units through fuel flow control.



Positive Displacement Performance Curve

4.4 Calculation of Gas Velocity

MAOP = 2*S*T*F / D_0

T = wall thickness = 6.5 mm = 0.2599 inches

F = Factor of Safety = 0.4

D_0 = outer diameter = 8 inches

Substituting the above values in the previous equation,

We get, the MAOP (maximum allowable operating pressure);

MAOP = 1092 psi

And the Design Pressure D_p = 2*S*T*(F*L*J*T) / D_0

Where, L = location factor = 0.8

J = joint factor = 1.0

T = temperature factor = 1.0

Substituting the above values in the previous equation,

We get, the **D_p = 873.6 psi**

The Gas Viscosity is given as = 0.0008 centipoise

= **0.000008 lb/ft/sec**

The Gas Velocity,

$$U = 0.002122 * \left[Q_b / D_i^2 \right] \left[P_b / T_b \right] \left[ZT/P \right]$$

Where, Q_b = Throughput = 0.9836 MMSCMD

= 983600 SCMD

= 34734850.4 SCFD

P_b = Base Pressure = 14.7 psia

T_b = Base Temperature = 520 Rankine

Z = Compressibility Factor = 1

T = Gas Temperature = 546 Rankine

P = Gas Pressure = 277.38 psia

Substituting the above values in the previous equation,

we get, the Gas Velocity = 73.14546 ft/sec

= **22.2947 m/sec**

Likewise the Erosional Velocity is calculated in the following manner:

$U_{max} = 100 \sqrt{ZRT/29GP}$

Where, Z = Compressibility Factor = 0.954

R = Universal Gas constant = 10.732 KJ/Kg mol K

T = Gas Temperature = 546 Rankine

G = Specific Gravity = 0.612

($M = Ey_iM_i$ = 17.737 lbm/lbmole

Therefore, $Y_g = M/28.97 = 17.737/28.97 = 0.612$)

P = Gas Pressure = 277.38 psia

Substituting the above values in the previous equation,

we get, the Erosional Velocity = 109.0999 ft/sec

= **33.2536 m/sec**

Number of Hoses / Dispensers required for buses:

Station working hours = 16 hrs. = 960 min.
Filling time for UPRTC buses (96 kg) = 10 min.
Filling time for mini buses (48 kg) = 6 min.

Number of Hoses / Dispensers required for Auto/ Vikram:

Time to fill an auto/ Vikram = 3.75 min.
The exact number is then calculated based on the current requirement within the city, though it is evident that the number of hoses required in case of buses will be less in comparison to that required for three wheelers.

CHAPTER 5
RESULTS & DISCUSSION

5.1 RESULTS

The area of each proposed CNG site is taken to be approximately 30 m * 36 m.

Compressor shall be designed for use in CNG service and for the pressures and temperature to which it may be subjected under normal operating conditions conforming to API 618/ API 813 or equivalent standard.

Hence the result of the compressor selection and the number of stages as per the above calculations is that:

- A **3-stage** Reciprocating compressor is used for natural gas compression.
- The initial pressure p_1 being 19 bar (guage).
- The pressure in between after first compression p_2 being 44.859 bar (guage).
- The pressure in between after second compression p_3 being 105.9121bar (guage).
- And the final pressure after two compression stages p_4 being 250 bar (guage).

CNG storage tanks shall be capable of operating at a working pressure of 250 bars

The design pressure of cylinders used in the storage unit shall depend upon the operating pressure that shall not exceed 250 bars.

The cylinders and their fittings for CNG use shall be designed, manufactured, tested including hydrostatic stretch test at a pressure in full conformity to IS:7285 and Gas Cylinder Rules, 1981, considering the maximum allowable operating pressure of 250 kg/ Sq.cm.g.

All rigid piping, tubing, fittings and other piping components shall conform to the recommendations of ANSI B 31.3

A minimum of four shut off valves shall be fitted between the gas storage unit and vehicle refueling filling nozzle

Internally braided, electrically continuous, non-metallic and metallic hoses resistant to corrosion and suitable to the natural gas service may be used for CNG service in the downstream of emergency and isolation shut off valve.

The pressure gauge shall have dial graduated to read approximately double the operating pressure but in no case less than 1.2 times the pressure at which pressure relief valve is set to function

The piping and its fittings upto the battery limit of CNG installation shall conform to ANSI B 31.8 or equivalent.

Piping shall be protected by safety relief devices in conformity to OISD-STD-132.

Dispensers shall be installed on a suitable foundation observing the minimum safety distances.

All electrical wiring and equipment, gas storage dispensing unit located in hazardous area Division I and II shall be in accordance with the Indian Electricity Rules, Gas Cylinder Rules, IS:5572 (Part 1), NFPA - 52.

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

6.1 Conclusion

This topic Design of a CNG Station includes discussions on various parts and equipments involved at a CNG Station viz; the compressor, the diesel generator, the dispenser, the gas meter, storage cascade, pipes, valves & fitting, control panel , safety accessories etc. Apart from all the other equipments which are all important in their own perspective, the compressor selection is the most challenging job for the company.

Hence, for the CNG station here at Adani Energy Limited:

At Present,

Compressor power required = 90.264 kW.

Gas is compressed in three stages in the following way:

Gas is compressed from

- ✓ 19 bar(g) to 44.859 bar(g) in the first compression stage.
- ✓ 44.859 bar(g) to 105.9121 bar(g) in the second compression stage.
- ✓ 105.9121 bar(g) to 250.058 bar(g) in the third compression stage.

6.2 Recommendations

The entire CNG Station set up can be built in a safer manner as safety has to be the prime consideration when dealing with exhaustible products. Both human safety as well as damage to property should be taken care of.

The CNG Stations should be built in a more spacious manner so that it is easy for movement.

The compressor selection work can be more appropriately worked upon to get the best of results and efficiencies.

Good quality intercoolers can be used which effectively decrease the gas temperature in between stages and provide for better gas compression by reduction in volume.

Hence , by more carefully and properly meeting the required specifications; one can further

- ➢ Reduce the power required for compression.
- ➢ Can go for higher capacity compression.
- ➢ Upgrades the material class from 150 class to 300 class to increase the MAOP.
- ➢ Thereby, reduce the overall compression cost.

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