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"CNG STATION DESIGN"

A Project Report

BY

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M.Tech (Gas Engineering)

In Partial Fulfillment of the award of the degree

Of

M.Tech (Gas Engineering)

Undergone Training at

Green Gas Limited,

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Acknowledgement

This is to acknowledge with thanks the help, guidance and support that i have received during the training.

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ग्रीन गैस लिमिटेड
(गेल (इंडिया) लिमिटेड एवं इंडियन ऑयल का संयुक्त उद्यम)
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(A joint venture of GAIL (India) Ltd. & Indian Oil)
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TO WHOMSOEVER IT MAY CONCERN

It is to certify that Mr. Rohit Gupta a Student of M.Tech(Gas Engineering) IInd year of University Of Petroleum & Energy Studies, Dehradun has successfully completed his project on "CNG STATION DESIGN" from 11th March 07 to 2nd May 07 at Green Gas Limited, Lucknow.

During training period he shown keen interest in the project assigned.

We wish him all success in life.

For & On Behalf Of Green Gas Limited

(Dileep Kumar)
Dy. General Manager (HR)

UNIVERSITY OF PETROLEUM & ENERGY STUDIES

CERTIFICATE

This is to certify that the project work entitled on **"CNG Station Design"** submitted to the by **Rohit Gupta** in partial fulfillment of the requirement for the award of degree of Masters of Technology (Gas Engineering), at College of Engineering, University of Petroleum & Energy Studies, Dehradun is a record of the work carried out by him under my supervision and guidance.

The work is comprehensive of sufficient standard and here by recommended for the award of the degree of M.Tech. in Gas Engineering.

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Abstract

Considering the necessity and need of the hour for mitigating the environmental pollution, CNG infrastructure is the important step towards achieving the pollution free environment. The unavailability of Natural Gas Vehicle (NGV) refueling stations (i.e. CNG Station) constitutes one of the major barriers to the wide spread utilization of natural gas in the transportation market.

The purpose of this project is to provide the methods and best practices for designing and construction of Compressed Natural Gas station.

In this project total gas consumption has been calculated, to size station equipment appropriately to meet the fleet's needs and specify the right equipment in a way that meets all code requirements and the fueling needs.

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Chapter 1
About Company

Green Gas Limited (GGL) is a Joint Venture of GAIL (India) Limited [GAIL] and Indian Oil Corporation Limited [IOCL]. The "**Joint Venture Agreement**" was signed on May 11, 2005 and was **incorporated** on October 07, 2005. It has been incorporated for the implementation of City Gas Projects for supply of Piped Natural Gas (PNG) to domestic, commercial and industrial Consumers and Compressed Natural Gas (CNG) to automobile consumers in the cities of Lucknow and Agra.

Vision:

To make Green Gas Limited an unparalleled natural gas distribution company, providing eco-friendly and clean fuel to transport, domestic, commercial and industrial sectors, with a total commitment to provide quality service to its customers.

Mission:

- To provide safe, convenient and reliable gas supply to their customers in transport, domestic, commercial and industrial sectors.
- To provide a cleaner and environment friendly auto fuel to their clientele.
- To facilitate conversions of commercial and private vehicles to CNG through external agencies by
    1. Making available the quality kits; and
    2. Creating a network of workshops to undertake reliable and speedy conversion to CNG.

Future Plans

GGL will have UPSRTC as one of its major customers. With this in view, they are setting up CNG Mother stations right in the bus depots of UPSRTC in Lucknow and Agra so that on one hand CNG could be made available to UPSRTC buses through dedicated dispensing facilities and on the other, CNG can be dispensed to public vehicles - cars, autos, tempos, Mini buses, etc.

Recognizing the fact that vehicle owners will not convert their vehicles to CNG until and unless CNG has been made available in adequate quantity and at many locations across the city, GGL decided to make CNG available at multiple places and to ramp up the availability of CNG both in terms of quantity and geographical spread. This will help in kicking off the conversion process as well as developing the CNG demand.

They are currently focusing on:

1. Conversion of UPSRTC buses to CNG in Lucknow and Agra. For this, follow up is being done at various levels in UP Government, Lucknow and Agra Division

Commissioners, Transport Ministry, UPSRTC, UPSIDC, Ministry of Environment, etc.

2. Creating awareness among the public about the benefits that they can derive by switching over to CNG fuel from the liquid fuels.

3. Creating infrastructure for supplying Piped Natural Gas (PNG) to domestic, commercial and industrial establishments.

Business Spread

Presently, the company has taken up city gas distribution projects in the cities of Lucknow and Agra. The operations of the company will spread to other cities of western Uttar Pradesh and Uttaranchal, in line with the directive of Ministry of Petroleum and Natural Gas.

Chapter 2
Introduction

2.1 CNG

CNG is the short form of Compressed Natural Gas. The Natural Gas has less energy density as compared to Liquid Fuel and hence it is compressed to over 200 Kg/cm² (g) to 250 Kg/cm² (g) pressure to make it CNG for use in the automobile sector. In its natural form it is colourless, odourless, non-toxic and non-carcinogenic. However, this natural gas is mixed with an odorant to add flavor similar to the odor of LPG from a domestic cylinder so as to facilitate detection of its leakage. The typical composition and physical properties of CNG (i.e. Compressed Natural Gas) is as follows:

Typical Composition:

Methane	:	88%
Ethane	:	5%
Propane	:	1%
CO_2	:	5%
Others	:	1%
Total	:	100%

2.2 Physical Properties:

Non-toxic – Natural gas being lead/sulphur free, its use substantially reduces harmful engine emissions. When natural gas burns completely, it gives out carbon dioxide and water vapour - the very components 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 a leakage.

Colourless – Natural Gas is available in the gaseous state, and is colourless.

Odourless – The gas in its natural form is odourless, however, ethyl mercaptan is later added as odorant so as to detect its leakage.

2.3 Advantages and Disadvantages of CNG:

The advantages of CNG include:

- Very low particulate emissions
- Low emissions of airborne toxins
- Negligible emissions of oxides of sulfur (SOx)
- More quiet operation, having less vibrations and less odor than the equivalent diesel engines.

Disadvantages of CNG are:

- Much more expensive distribution and storage
- Higher vehicle cost
- Shorter driving range
- Much heavier fuel tank

2.4 Pollution reduction in CNG fueled vehicle:

The use of CNG in vehicles has lead to considerable reduction in air pollution as is evident from the following data:

A. Autorickshaw – Three wheelers:

(Emission in gram/Km)

Bajaj Three wheeler	Pollutants	Petrol	CNG	% Reduction
	HC	3.26	1.26	63.19
	CO	5.48	1.57	71.35
	CO2	47.44	27.60	41.82
	NOx	0.25	0.20	20.00

Source: Bajaj Auto, the manufacturer of three wheelers

B. Passenger Cars:

(Emission in gram/Km)

	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 Padmini	CO	18.38	0.94	95
	HC	2.83	2.03	28
Premier 118NE	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 tests conducted by GAIL (India) Ltd., one of the promoter companies of IGL and the supplier of Natural Gas

C. Diesel Buses:

(Emission in gram/KWH)

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

** In gm / km*

Source: Ashok Leyland, the manufacturer of buses

Table 1

2.5 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 Type 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.

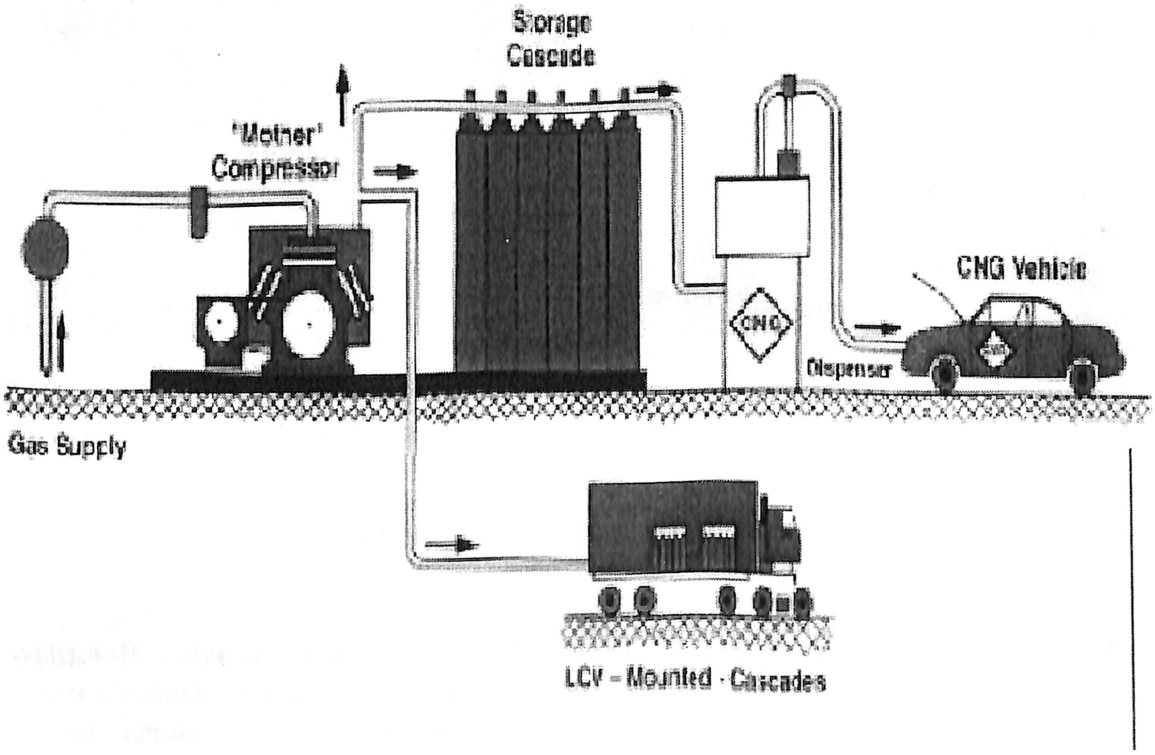

Figure1. Mother CNG Station

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.

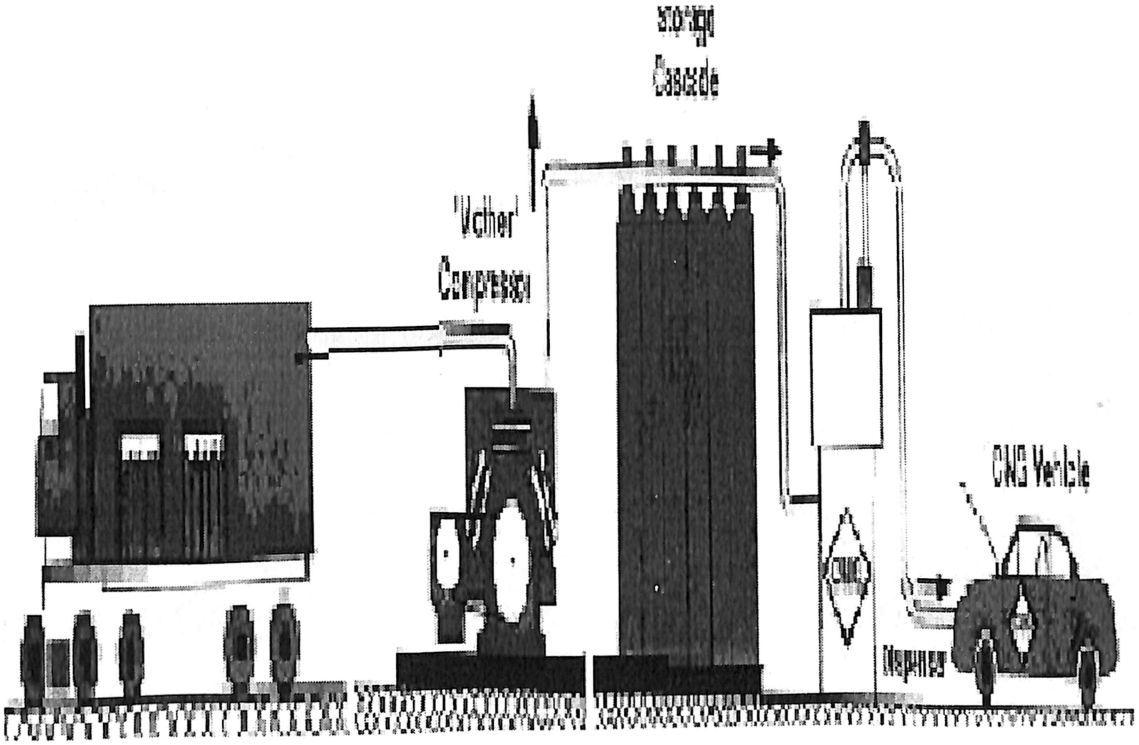

Figure2. Daughter CNG Station

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.

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.

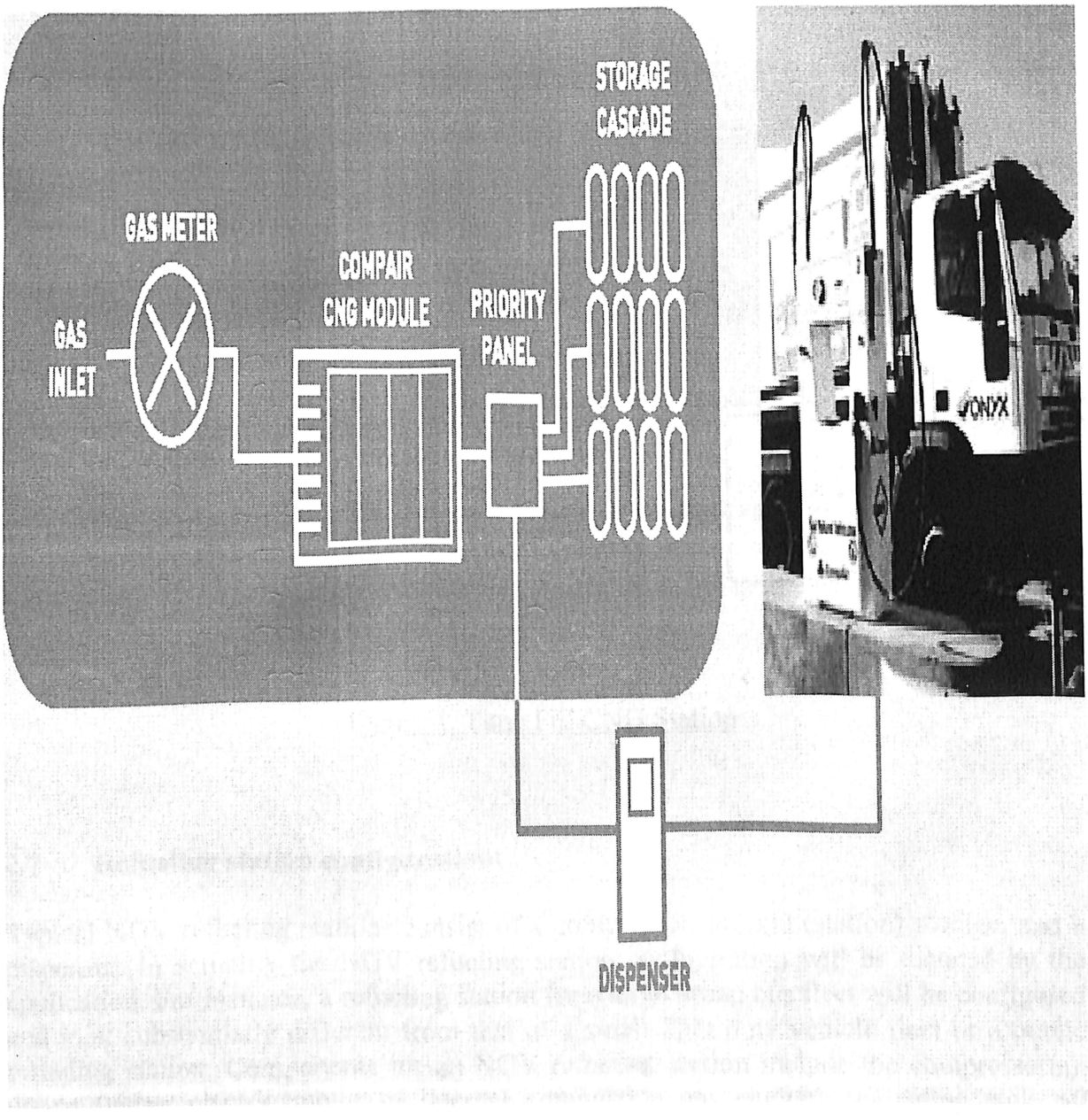

Figure3. Fast Fill CNG Station

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.

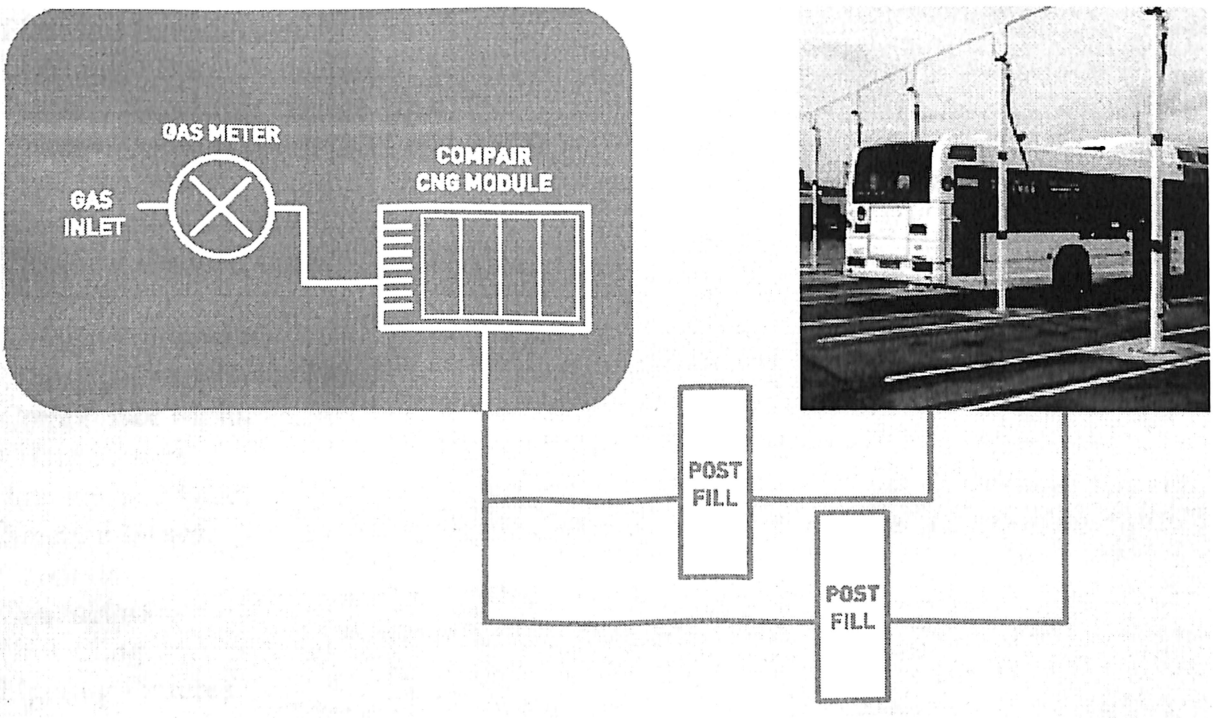

Figure 4. Time Fill CNG Station

2.7 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 in Table 2.

Table 2. 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.

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 1, a separate crosshead linked to the connecting rod is used with a piston rod linked to the piston.

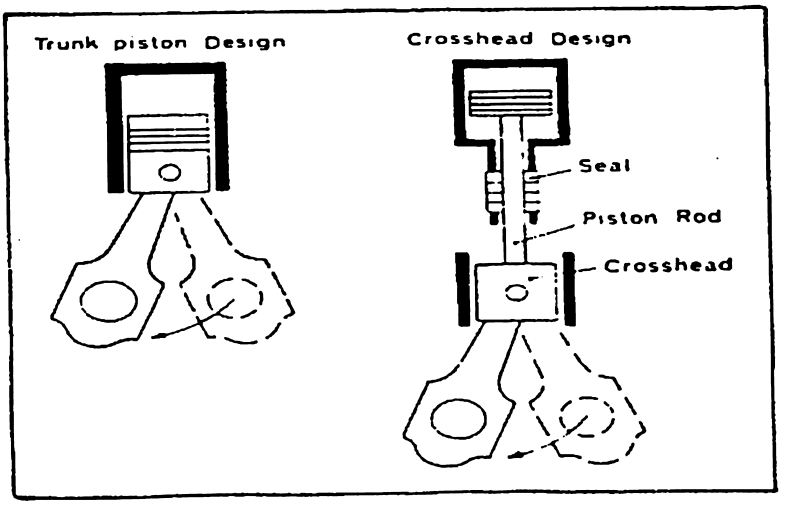

Figure 5. Trunk and crosshead design compressor

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.

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.

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.

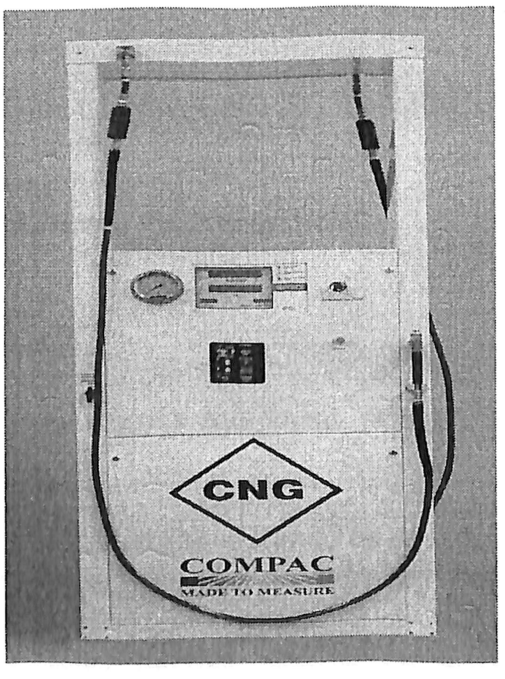

Figure 6 Dispenser

Chapter 3
Codes and Regulations

3.1 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 relief 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 II.

Table 3

TABLE -I

INTER DISTANCES

FROM BUILDINGS AND OUTER BOUNDARIES TO GAS STORAGE UNITS

Total capacity of gas storage units (In liters) (1)	Min. distance from buildings and boundaries (In Meters) (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 4

TABLE - II

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 (Min-3)	T-1 (Min-3)	T-1 (Min-3)	T-1 (Min-3)	6	-

NOTES :

i) T-I denotes Table-I

ii) Distances shown as "–" shall be any distance necessary for operational convenience.

iii) A suitable curbing platform shall be provided at the base of the dispensing unit to prevent vehicles from coming too near the unit.

iv) 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.

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 refuelling 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.

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 there on, shall be placed with easy access and egress on a low platform or hard compacted ground, which shall extend to atleast 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.

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.

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.

Valves

- A minimum of four shut off valves shall be fitted between the gas storage unit and vehicle refuelling 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 refuelling is not being done.

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

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 atleast 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.

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 atleast once a year and records maintained.

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 atleast 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.

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.

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.

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.

3.2 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.

Note: Not universally adopted.

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 5

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 6

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 7

3.3 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.

3.4 Other Codes

AGA NGV 1, 2, 3, and 4

NGV 1 Requirements for Natural Gas Vehicle (NGV) refueling connection devices.

NGV 2 Basis requirements of type 3 natural gas fuel containers (vehicle cylinder).

NGV 3 Natural Gas Fuel System components and conversion system.

NGV 4 Fueling station Equipment.

AGA NGV 4

AGA NGV 4.1
NGV Dispensing Systems.

AGA NGV 4.2
Hoses for Natural Gas Vehicles and Dispensing Systems.

AGA NGV 4.4
Breakaway Devices for Natural Gas Dispensing Hoses and Systems.

AGA NGV 4.6
High Pressure Manually Operated Valves for Natural Gas Dispensing System

AGA NGV 4.7
Automatic High Pressure Operated Valves for Natural Gas Dispensing System

AGA NGV 4.8
Natural Gas Vehicle Fueling Station Compressor Guidelines.

Chapter 4
Design Methodology Adopted

4.1 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.

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

4.2 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 m * 36 m.
(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.

Difficulties 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.

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.

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.

Chapter 5
Civil Infrastructure

5.1 Requirements for Design and Installation:

- For CNG filling station, the corresponding safety distances shall be taken into account.
- Basements are prohibited. Higher floors shall only be allowed for vehicles parking purposes.
- In the case of open to the public service stations, permitted vehicle accesses and direction of flow of traffic shall be taken into account.
- It shall count with the approval of the national, provincial or municipal authority having jurisdiction as may correspond.
- 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".
- Elements not related to the business activity shall not be stored in the service station facilities.
- 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.
- A CNG dispensing outlet may be added to a typical service station, only if the site dimensions allow the compliance with the minimum safety.

5.2 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 8

5.3 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.

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:

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

b) 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.

c) 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.

d) It shall have two labyrinthine 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.

e) 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.

f) 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.

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

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

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

j) 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.

k) 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.

l) 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.

m) 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.

n) 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.

o) Main staircase shall 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.

p) 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.

q) 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.

5.4 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.

5.5 Fast Fill Stations :

General Aspects:

5.5 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.

5.6 For refueling vehicles shall preferably be oriented towards the street.

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

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

5.9 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.

5.10 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.

5.11 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 .

5.6 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.

Chapter 6
Design calculations for CNG Station

Here the following calculations are done for the proposed CNG Station:-

Compressor capacity required.
Compressor power required.
Temperature of the outlet gas and amount of cooling water.
Valve sizing (Flow coefficient)
Number of hoses and dispensers required for the
- **a) Buses.**
- **b) Three wheelers.**

Pipe diameter required.
Pipe thickness required.

Following data are taken:

Specific Gravity of Natural Gas (SG) = 0.6
Mole Ratio (M) = 16.7 kg/ k mol
$k = C_p / C_v$ = 1.31
P1 = Inlet pressure to the compressor = 19 bar
P2 = outlet pressure from the compressor = 250 bar
R = Universal Gas constant = 8.314 kJ/ k mol ^oK

6.1 Compressor Capacity

Per day requirement of gas = 39987 kg. (From annexure 1)
= 39987/ 16*3600
(Operating time for compressor per day is 16 hrs)
= 0.69422 kg/ sec

Density of natural gas (as calculated earlier) = 0.768 kg/ m^3

Volumetric flow rate = 0.69422/ 0.768
= 0.90393 m^3/ sec
= 1949.1 cfm

Therefore compressor capacity required = 0.90393 m^3/ sec.

6.2 Compressor Power

Is given by,

$$W = m/M\, RT_1 \left(\frac{k}{k-1} \right) \left(\left\{ \frac{P_2}{P_1} \right\}^{k-1/k} - 1 \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

m = mass flow rate (kg/ sec) = 0.69421875 kg/ sec (from annexure 1)

M = mole Ratio (kg/ K mol) = 16.7 kg/ k mol

R = Universal Gas constant = 8.314 kj/ k mol ^{o}K

T_1 = Inlet Temperature = 293.15 ^{o}K

$K = C_p / C_v = 1.31$

P_1 = Inlet pressure to the compressor = 19 bar

P_2 = outlet pressure from the compressor = 250 bar

From Eq. 1:-

W = 361.96 kW

Taking compressor efficiency = 0.8
Therefore, actual compressor power required = 361.96/ 0.8 = 452.45 kW
Assuming motor drive and taking transmission efficiency of the belt = 0.8
Power of electric motor required = 565.56 kW

6.3 Temperature of the outlet gas

$T_2 = T_1 (P_2/ P_1)^{k-1/k}$

$= 539.43\ ^{o}K$

Therefore, cooling of the outlet gas to the ambient temperature is required.

From, $Q = m C_p (T_2 - T_1)$
Where,
m = mass flow rate
C_p = specific heat at constant pressure
T_2 & T_1 = inlet and outlet temperature.

From above equation:-

$m_g C_{pg} (T_{2g} - T_{1g}) = m_w C_{pw} (T_{2w} - T_{1w})$

$0.69422*0.5136*(539.43 - 293.15) = m_w* 0.99974*(313.15 - 293.15)$
(assuming outlet temperature of water be 313.15 ^{o}K)

Gives, m_w = 4.392 kg/ sec

Hence, water required for cooling will be 4.392 kg/ sec.

6.4 Specification for the compressor and electric motor

Required capacity of single compressor shall be **1949.1 cfm** at maximum discharge pressure of **250 bars.**

Power of the electric drive motor shall be **565.56 kW.**

6.5 Valve Sizing

$C_v = (Q / 23.2*Y) (T_1* SG/ P*P_1)^{1/2}$ ..... (2)

And

$Y = 1 - ½ (P/P_1)$ ..... (3)

Where,

C_v = flow coefficient
Q = gas flow rate (scfm)
T_1= absolute temperature just upstream (^oF)
SG = specific gravity of gas
P = pressure drop
P_1 = upstream pressure (psi)

SG = 0.6
Density of air = 1.28 kg/ m^3
Therefore, density of gas = 0.6*1.28
= 0.768 kg/ m^3
Mass flow rate of gas = 41.65 kg/ min
Therefore volumetric flow rate of gas, Q = 41.65/ 0.768
= 54.2358 m^3/ min
= 1949.07 scfm

T_1 = 20 ° C = 68 ° F
P = 5% (assumed)
P_1 = 250 bar = 3625 psi

From Eq. 3:-

Y = 0.999993403

From Eq. 2 and 3:-

C_v = 37.44

6.6 Hoses and Dispenser

(a) For Buses

Station working hours = 960 min.

Filling time for buses (capacity = 96 kg) = 10 min

Filling time for mini buses (capacity = 48 kg) = 6 min

Time required to fill buses = no. of buses* time to fill each bus
= 32*10 (from annexure 1)
= 320 min

Time required to fill mini buses = no. of mini buses* time to fill each mini bus
= 15*6 (from annexure 1)
= 90 min

Therefore time required to fill all the buses = 320 + 90 = 410 min

Therefore, no. of hoses required = 410/960 = 0.427

Since no. of hoses should be a whole number, therefore, no. of hoses required for all buses = 1.

Therefore, no. of dispensers required = 1/ 2 = 0.5 (one dispenser has 2 hoses)

Again, no. of dispensers should be a whole number, therefore, no. of dispensers required for all buses = 1.

(b) For Three wheelers

Filling time for auto (capacity = 3 kg) = 2.75 min

Filling time for vikram (capacity = 4 kg) = 3.75 min

Time required to fi' auto = no. of auto* time to fill each auto
= 1615*2.75 (from annexure 1)
= 4441.25 min

Time required to fill vikram = no. of vikram * time to fill each vikram
= 1647* 3.75 (from annexure 1)
= 6176.25 min

Therefore time required to fill all the three wheelers (auto+vikram) = 4441.25+6176.25
= 10617.5 min

Therefore, no. of hoses required = 10617.5/960 = 11.05

Since no. of hoses should be a whole number, therefore, no. of hoses required for all three wheelers = 12

Therefore, no. of dispensers required = 12/ 2 = 6 (one dispenser has 2 hoses)

6.7 Specification for the dispenser

Dispensing System design pressure shall be 300 bars (5000 psi) and operating pressure shall be 200 – 250 bars (3000 – 3500 psi) at ambient temperature of 20 °C.

Minimum gas flow rate from each dispenser hose should be 1000 cfm.

6.8 Pipe Diameter

Pipe Diameter required for the flow rate of up to **2000 cfm** is 1 inch for the maximum allowable operating pressure of 3800 psi (approx. 260 bars).
(From "CNG Station Design" By Leo B. Thomson II)

6.9 Pipe Thickness

As per ASME B 31.8

$P = (2*S*T/ D) *E*F*T$ ..... (4)

Where,

P = Maximum allowable operating pressure (psi)
= 260 bar
= 260 * 14.5 (1 bar = 14.7 psi)
= 3770 psi.

S = maximum specified yield stress
= 70000 psi (for X70)

F = Design Factor
= 0.72
(From ASME B 31.8, Table 841.1 A)

E = Longitudinal join factor
= 1
(From ASME B 31.8, Table 841.1 B)

T = Temperature degradation factor
= 1

(From ASME B 31.8, Table 841.1 C)

D = Pipe dia.
= 1 inches.

t = thickness of pipe in (inches)

From Eq. 4:-

3770 = (2*70000*t/ 1)*1*.72*1

Gives, t = .0374 inches.

6.10 Specification for the Pipe

As per **API 5 L.**

Conclusion

Hence, for the CNG station:

Compressor Capacity	=	1949.1 cfm
Compressor Power	=	452.45 kW
Electric motor power	=	565.56 kW
Temperature of the outlet gas	=	539.56 ^{o}K
Cooling water for outlet gas	=	4.392 kg/ sec
Valves with flow coefficient (C_v)	=	37.44

Number of Hoses and Dispenser for:

(a) For Buses

Number of Hoses	=	1
Number of Dispensers	=	1

(b) For Three wheelers

Number of Hoses	=	12
Number of Dispensers	=	6

Pipe Diameter	=	1 inch
Pipe Thickness	=	0.0374 inch

REFERENCES CITED

McAllister E. W., 2005, *Pipeline Rules of Thumb*, Handbook, Sixth Edition, Gulf Production Publication, Page 86 to 90, Page 189 to 190, Page 290 to 295.

Kumar Sanjay, 1997, "*Natural Gas Production*", Volume 4, Gulf house Publication, Page 39 to 57.

Thomson ll Leo B., "*Compress Natural Gas Fueling Station*", Online Resources.

Blazek Christopher, Biederman Richard, Jasionowski Walter, Kinast John, Paper Presente at Institute of Gas Technology Continental Conference Norman, Oklahoma June 4- 6, 1991 on "Natural Gas Vehicles", Page 2 to 23

Green Gas Limited, Vehicles Data Report.

	Buses		Three Wheelers		Gas Consumption				
Year	UPRTC Buses (96 kg)	Mini Buses(	Auto(3 kg)	Vikram(4 kg)	UPRTC Buses	Mini Buses	Auto	Vikram	Total Consumption
2007	32	15	1615	1647	3072	720	9690	13176	26658
2008	38	18	1938	1976	3686	864	5814	7906	18270
2009	46	22	2326	2372	4424	1037	6977	9487	21924
2010	55	26	2791	2846	5308	1244	8372	11384	26309
2011	66	31	3349	3415	6370	1493	10047	13661	31571
2012	80	37	4019	4098	7644	1792	12056	16393	37885
2013	96	45	4822	4918	9173	2150	14467	19672	45462
2014	115	54	5787	5901	11008	2580	17361	23606	54554
2015	138	64	6944	7082	13209	3096	20833	28327	65465
2016	165	77	8333	8498	15851	3715	24999	33993	78558
2017	198	93	10000	10198	19021	4458	29999	40791	94269
2018	238	111	12000	12237	22825	5350	35999	48949	113123
2019	285	134	14400	14685	27390	6420	43199	58739	135748
2020	342	160	17279	17622	32868	7704	51838	70487	162897
2021	411	193	20735	21146	39442	9244	62206	84585	195477
2022	493	231	24882	25375	47330	11093	74647	101501	234572
2023	592	277	29859	30450	56796	13312	89576	121802	281486
2024	710	333	35831	36541	68156	15974	107492	146162	337784
2025	852	399	42997	43849	81787	19169	128990	175395	405340

Annexure 1

Projection of Vehicles upto Year 2025
and total gas consumption

Year	UPRTC Buses	Time to fill	No. of hoses	Mini buses	Time to fill	No. of hoses	Total hoses	Actual No.	No. of Dispenser
2007	32	320	0.33333	15	90.00	0.094	0.427	1	1
2008	38	384	0.40000	18	108.00	0.113	0.513	1	1
2009	46	461	0.48000	22	129.60	0.135	0.615	1	1
2010	55	553	0.57600	26	155.52	0.162	0.738	1	1
2011	66	664	0.69120	31	186.62	0.194	0.886	1	1
2012	80	796	0.82944	37	223.95	0.233	1.063	2	1
2013	96	956	0.99533	45	268.74	0.280	1.275	2	1
2014	115	1147	1.19439	54	322.49	0.336	1.530	2	1
2015	138	1376	1.43327	64	386.98	0.403	1.836	2	1
2016	165	1651	1.71993	77	464.38	0.484	2.204	3	2
2017	198	1981	2.06391	93	557.26	0.580	2.644	3	2
2018	238	2378	2.47669	111	668.71	0.697	3.173	4	2
2019	285	2853	2.97203	134	802.45	0.836	3.808	4	2
2020	342	3424	3.56644	160	962.94	1.003	4.570	5	3
2021	411	4109	4.27973	193	1155.53	1.204	5.483	6	3
2022	493	4930	5.13567	231	1386.63	1.444	6.580	7	4
2023	592	5916	6.16281	277	1663.96	1.733	7.896	8	4
2024	710	7100	7.39537	333	1996.75	2.080	9.475	10	5
2025	852	8519	8.87444	399	2396.10	2.496	11.370	12	6

Annexure 2

Projection of Hoses for buses upto Year 2025

	Three Wheelers						
Year	Auto	Vikram	Total	Time to fill	No. of hoses	Actual No.	No. Of Dispensers
2007	1615	1647	3262	12233	12.7422	13	6
2008	1938	1976	3914	14679	15.2906	16	8
2009	2326	2372	4697	17615	18.3488	19	10
2010	2791	2846	5637	21138	22.0185	23	12
2011	3349	3415	6764	25365	26.4222	26	13
2012	4019	4098	8117	30438	31.7066	32	39
2013	4822	4918	9740	36526	38.0480	39	20
2014	5787	5901	11688	43831	45.6576	46	23
2015	6944	7082	14026	52598	54.7891	54	27
2016	8333	8498	16831	63117	65.7469	66	33
2017	10000	10198	20197	75740	78.8963	79	40
2018	12000	12237	24237	90888	94.6755	95	48
2019	14400	14685	29084	109066	113.6106	114	57
2020	17279	17622	34901	130879	136.3327	137	69
2021	20735	21146	41881	157055	163.5993	163	82
2022	24882	25375	50258	188466	196.3192	196	98
2023	29859	30450	60309	226160	235.5830	236	118
2024	35831	36541	72371	271392	282.6996	283	142
2025	42997	43849	86845	325670	339.2395	340	170

Annexure 3

Projection of Hoses and Dispenser for Auto/ vikram upto Year 2025