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CNG

A Vehicular fuel of the future

Compressed Natural Gas

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1. An Introduction

The demand for natural products in India has been increasing at a faster rate than the increase in domestic supply. This has necessitated an increased amount of revenue being spent on the import of these natural products. The transport sector is the single largest consumer products. There is an urgent need to introduce alternate fuels as substitute for high diesel and petrol in the transport sector.

The continuing pressure on emission control through periodically tightened regulation has compelled the search for alternate fuel. Among the options currently available as alternate to petrol and diesel, COMPRESSED NATURAL GAS (CNG) has received wide spread recognition. CNG is lighter than air. It disperses easily into it and does not form a sufficiently rich enough mixture for combustion to take place. In this respect, CNG is superior to LPG or propane or even petrol. Storage of propane on vehicles is easier compared to CNG, but the cost of propane is higher.

The energy content per kg of CNG is very similar to that of petroleum based fuels, but it has a lower energy content per unit of volume. The excellent knock resisting property of CNG allows for use of a higher compression ratio resulting in an increased power output and greater fuel economy when compared to petrol. CNG can be used in engines with a compression ratio as high as 12:1 compared to normal gasoline (7.5:1 to 10:1). At this high compression ratio, natural gas-fuelled engines have higher thermal efficiencies than those fuelled by gasoline. The fuel efficiency of CNG driven engines is about 10-20% better than diesel engines.

CNG represents a more cost-effective emission reduction measure than the other options available for diesel engines such as catalytic converters, which cannot reduce emission of particulate matter. Particulate trap is a high cost device that is still under development for diesel engines. CNG engines, on the other hand, are a better way to eliminate particulate matter. The importance of a cost

effective, efficient, easy to maintain and user friendly solution to overcome environmental problems cannot be overemphasized, and CNG meets these requirements. CNG also allows the use of catalytic converter more efficiently than diesel. It may emerge as the fuel of the future.

CNG - The Transportation Fuel for Today and the future

Compressed Natural Gas (CNG) as a fuel is clean, economical and has been in use worldwide to power vehicles. There are over 1,200,000 vehicles running on CNG in the world. Existing petrol vehicles can use CNG by installing a bi-fuel conversion kit and the converted vehicle will have the flexibility of operating either on CNG or petrol. CNG is lead free and its use substantially reduces harmful engine emissions and helps keep the environment clean. Besides, operational cost of vehicles running on CNG is approximately one third that of petrol. Due to its relative advantages and superiority over conventional fuels, CNG is the most promising alternative fuel for city transport. This report provides information on CNG to motorists interested in getting their vehicles converted to run on CNG.

What is CNG?

CNG (Compressed Natural Gas) is a mixture of hydrocarbons consisting of approximately 80 to 90 percent methane in gaseous form. Due to its low energy density, it is compressed to a pressure of 200 to 250 Kg/cm^2 (to enhance the vehicle on-board storage in a cylinder) and hence the name Compressed Natural Gas. Natural Gas is colorless, odorless, non-toxic but inflammable and lighter than air. CNG is not a liquid fuel and is not the same as LPG (Liquefied Petroleum Gas) which consists of propane and butane in liquid form. Natural gas is normally transported from the source upto the users by pipelines. Besides widespread industrial use as a clean fuel for applications ranging from electric power generation, feedstock for fertilizer plants to furnaces etc., it is becoming a fuel of choice in domestic and commercial sectors.

- Natural gas compressed to 200 - 250 bars.
- Clean burning fuel.
- Potential for ultra low emission.
- Solution for reducing high levels of urban pollution caused by conventional fuels.

CNG in India, Pilot Program

- Launched in 1992-93 by GAIL in Delhi, Mumbai and Vadodara. It is also available in the cities of Surat, Ankleshwar and Bharuch of Gujarat State.
- Conversions predominantly of petrol vehicles.
- Diesel buses on duel fuel mode tried.

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2. CNG in India - Present Status

CITY	CO.	NO. OF STATIONS	VEHICLES		MONTHLY SALE IN KG.
			Cars	Buses	
Delhi	IGL	56	8,000	133	82,371
Mumbai	MGL	9	10,000	10	1,102,060
Vadodara	GAIL	3	118	0	6,074
Surat	GGCL	3	667	0	21,704
Ankleshwar	GGCL	1	89	0	233

Source: World Bank

3. International Scenario

The concept of natural gas as an automotive fuel started around 1930. Research has proved that it can be used safely.

Many countries are known to be using CNG as an automotive fuel. These include USA, Canada, UK, Italy, Thailand, Iran, Australia and New Zealand. While in most countries, its usage is restricted to private vehicles, in countries like Australia and America, it is the fleet operators who find it useful. More than 50 companies in the US operate their fleet vehicles on CNG. In Italy, about a quarter of a million vehicles are running on CNG, primarily due to the high cost of petrol. France, too, had a taste of CNG as an automotive fuel during World War I. But, not much emphasis was given to CNG, due to the use of LPG and a taxation structure on CNG. Canadian Western Natural Gas Company started a CNG conversion program in 1970 by converting about 100 vehicles in Edmonton City. The Council of Canada participated in the program by introducing three Chevrolet half-ton pickup trucks. However, the increase in the cost of natural gas adversely affected the CNG conversion program. As early as 1937, the Victorian State Electricity Commission of Australia considered the use of CNG for vehicle fuel. Similarly, the South Australian Gas Company converted 17 vehicles of their fleet to operate on CNG, but due to the high costs of kits and cylinders the conversion to CNG could not make much headway.

In New Zealand, a CNG conversion program started in the 1970s and continued till the late nineties. The New Zealand Energy Research and Development Corporation, the Auckland Gas Company and the Wellington Gas Company were the pioneers in introducing the CNG program in New Zealand. A variety of vehicles of vehicles were converted and their performances were monitored. The program severely deteriorated, because of tax adjustments.

In the eighties, other Asian and South American countries embarked upon CNG programmes, namely, India, Bangladesh, Indonesia, Pakistan and Argentina.

4. Benefits

The following are the benefits of CNG:

- Very easy on the engine, giving longer service life and lower maintenance costs.
- Established clean Fuel.
- Regulations already in place in Delhi.
- Large upcoming infrastructure base.
- Potential for ultra low emission
- Safest alternative fuel.
- Dry gaseous fuel does not dilute the lubricating oil, thus saving on oil filters and oil chargers
- Freedom from adulteration

5. Limitations

Presently, in India, the following are the limitations for CNG:

- Driving complaints due to loss of power with CNG. Dynamometer tests indicate that CNG-fuelled vehicles have 10-15% lower power output than petrol engines.
- Increased exhaust-valve wear in CNG-operated vehicles are anticipated due to the drying effect of the gaseous fuel
- Distribution
- Economy
- Dead weight
- Unfair competition from illegal use of LPG and other fuels
- Prime among its disadvantages is the loss of luggage space.
- Inability to make an impression on the common man

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6. Emissions with CNG v/s Conventional Fuels

Reduction in IDC Mass Emission with CNG retrofitted as CERTIFIED BY ARAI/VRDE.

A. PASSENGER CAR (PETROL)

VEHICLE	POLLUTANT (Gm/Km)	PETROL (Gm/Km)	CNG (Gm/Km)	% REDUCTION in Gm/Km
Maruti Omni	CO	19.79	0.55	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 118 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

B. AUTORICKSHAWS (PETROL)

	POLLUTANT (Gm/Km)	PETROL (Gm/Km)	CNG (Gm/Km)	% REDUCTION in Gm/Km
BAJAJ THREE WHEELER	CO	3.26	3.99/1.26*	63.19*
	HC	5.48	1.57	71.35
	CO_2	47.44	27.6	41.82
	NO_x	0.25	0.2	20.00

C. DIESEL BUSES

	POLLUTANT (Gm/Km)	(Gm/Km)	CNG (Gm/Km)	% REDUCTION in Gm/Km
Ashok Leyland	CO	1.68	1.4	16.67
	HC	4.5	3.77	19.37
	NO_x	13.73	8.0	41.7

7. Pollution-Major Cause of Vehicular Pollution

70% of total air pollution comes from Vehicles due to:

- The traffic conditions
- The condition of vehicles
- Fuel used in vehicles

Effects in terms of Pollutants:

SUBSTANCE	HEALTH EFFECTS
CARBON MONO OXIDE	FATAL IN LARGE DOSES, AGGRAVATES HEART DISORDERS EFFECTS CENTRAL NERVOUS SYSTEM, IMPAIRS OXYGEN CARRYING OF BLOOD IRRITATION OF RESPIRATORY TRACT
NITROGEN OXIDES, HYDROCARBONS	DROWSINESS, EYE IRRITATION, COUGHING

Annual Health incidences in Indian cities:

CITIES	PREMATURE DEATHS	HOSPITAL ADMISSIONS	MINOR SICKNESS
Calcutta	5,726	3,022,786	179,479,908
Delhi	7,491	3,990,012	241,958,219
Madras	863	461,966	27,859,487
Mumbai	4,477	2,579,210	156,452,916

Source: World Bank

Health costs due to air pollution (in Indian cities):

NATURE OF EFFECT	NO. OF CLASS	COST VALUATION (US $ MILLIONS)
PREMATURE DEATHS	40,351	170 - 1,613
HOSPITAL ADMISSIONS AND SICKNESS REQUIRING MEDICAL TREATMENT	19,800,000	25 - 50

MINOR SICKNESS (INCLUDING RESTRICTED ACTIVITY DAYS AND RESPIRATORY SYMPTOM DAYS)	1,201,300,000	322 - 437
TOTAL	-	517 - 2,102

Source: WHO

Lowest levels of SO_2 and TSP that effect health (in µg / m3)

Effect	24 hr. exposure			Annual Exposure		
	SO_2	Smoke	TSP	SO_2	Smoke	TSP
Excess Mortality	500	500	100	100		
Increased acute respiratory morbidity (adults), symptoms or illness	250	250				
Decreased Lung function			180			180

Notes: µg / m^3: in micrograms per cubic meter SO_2: Sulfur dioxide

TSP: Total Suspended Particulate matter

Source: WHO

Effects of Vehicular Pollutants on Humans

Substance	Health Effects
CO (from gasoline cars, 2-wheelers, 3-wheelers)	Fatal in large doses; aggravates heart disorders; effects central nervous system; impairs oxygen carrying capacity of blood

NO_x (from diesel vehicles)	Irritation of respiratory tract
Ozone	Eye, nose and throat irritation; risk to asthmatics, children and those involved in heavy exercise
Lead (from petrol vehicles)	Extremely toxic: affects nervous system and blood; can impair mental development of children; causes hypertension
HC (mainly from 2-wheelers and 3-wheelers)	Drowsiness, eye irritation, coughing
Benzene	Carcinogenic
Aldehydes	Irritation of eyes, nose and throat, sneezing, coughing, nausea, breathing difficulties; carcinogenic in animals
PAH (from diesel vehicles)	Carcinogenic

8. Technical feasibility of CNG conversions

What is the running range of vehicles on CNG?

Since CNG is a gaseous fuel, storage capacity for CNG in a vehicle is comparatively less than that of petrol.

The quantity of CNG filled by the dispenser during refueling also depends upon pressure at the dispensing station. At maximum permitted filling pressure (200 barg.), an amount of 8/9/10 Kg CNG is stored in 40/50/60 liter size cylinders respectively which is equivalent (approximately 11.2/12.5/14 liters of petrol equivalent. However the gas quantity depends on ambient condition and actual fill pressure.

A Fuel switch on the dashboard is fitted to enable the vehicle to run on petrol, in case it runs out of CNG.

Characteristics of CNG vis-a-vis Petrol:

CNG has a much higher-octane value than petrol, making it a superior fuel. Due to absence of any lead content in CNG, the lead fouling of plugs is eliminated. Being a gaseous fuel, CNG mixes with air easily even at very low temperatures. Main features distinguishing CNG from petrol are:

Properties	Unit	CNG	Petrol	Diesel
Liquid Specific Gravity	-	-	0.74	0.84
Heat of Evaporation	BTU/lb	-	160	200
Density relative to air	Air = 1	0.6	3.4	3.9
Auto ignition Temperature	°C	540	232 - 282	225

Properties	Unit	CNG	Petrol	Diesel
Flammability Limit	% in Air	5 - 15	1 - 8	0.6 - 5.5
Flame Temperature	^{o}C	1790	1977	2054
Octane No.	-	127	87	-
Cetane No.	-	10	10	45

Can a diesel vehicle run on CNG?

Both the OEM's i.e. TATA and Ashok Leyland have developed CNG buses and can convert the existing buses to run on CNG by changing the engine.

How much time is taken for Kit fitment?

Conversions can be done in a single day.

Gist

- Type approved kits available for most of petrol car models on Indian roads
- Motorists are happy with performance of these kits
- Ten Ashok Leyland CNG buses successfully operating for last one year with BEST Bombay
- Aiam endorses CNG as most technically and environmentally proven fuel.

Difference in performance and power output between CNG and petrol:

It has been experienced that a petrol engine will produce less power on CNG than on petrol and motorists may feel that a car's performance on CNG is inferior. The questions normally asked are:

Why and how much?

It is necessary to consider three separate aspects that can contribute to the performance and power difference.

Fuel related factors:

The space occupied in the engine cylinder by CNG is greater than petrol, with the result that the fuel-air mixture inside the engine chamber contains 8 to 10 percent less air (oxygen) in CNG mode. Less oxygen means less fuel burnt and hence less power produced. Since CNG burns more slowly than petrol it produces less power and slower idle speed for the same ignition timing and throttle position.

The difference in burning rate can be partially compensated by advancing the ignition for CNG. Idling RPM also needs to be increased in the CNG mode to prevent engine stalling. Natural gas also requires much higher ignition temperature to burn in the combustion cylinder.

Differences in available energy are combustion characteristics between petrol and Natural Gas may persist under any condition and are considered unavoidable, even with optimized ignition timing, unrestricted airflow etc..

Petrol / engine-related factors:

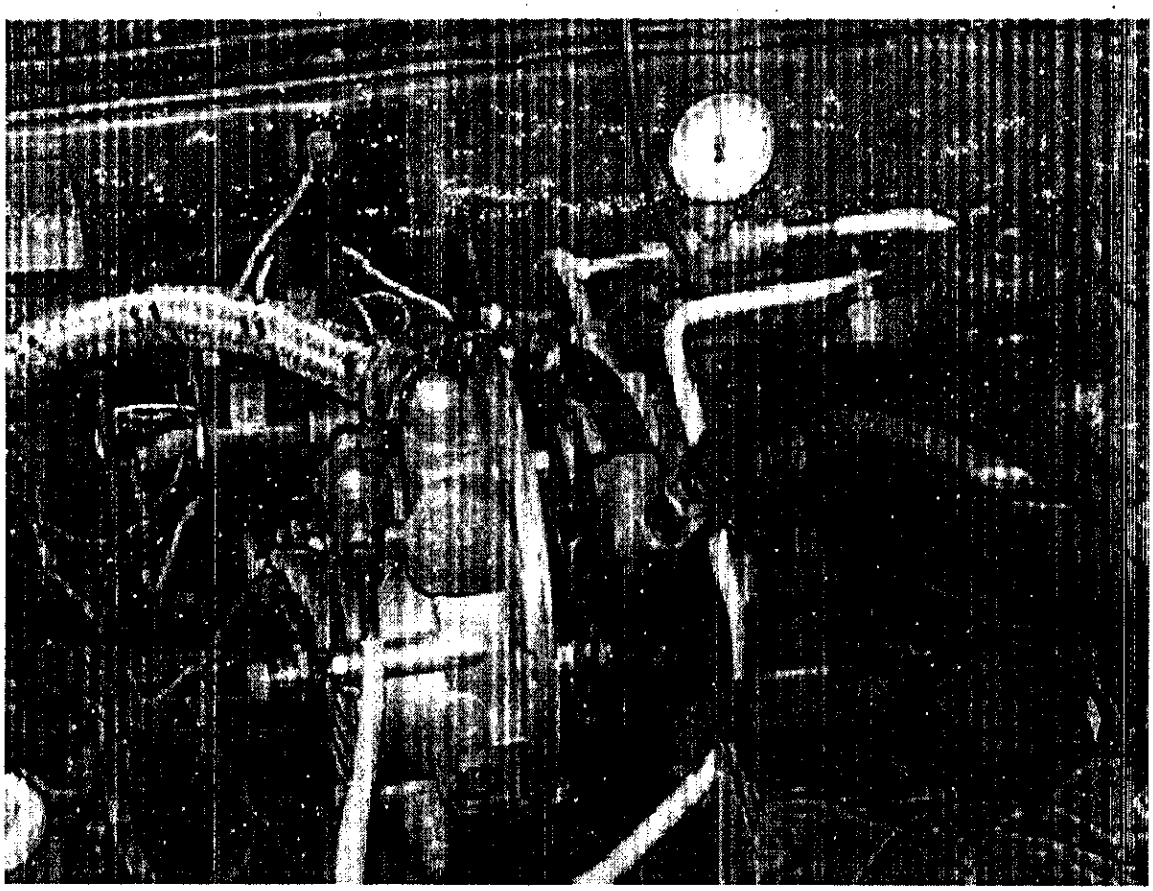
The power output also depends on individual engine design features, particularly in the engine combustion chamber, valve timing, inlet manifold heating and positioning of the air cleaner intake.

In most petrol engines, the air cleaner draws hot air from immediately behind the radiator or in the vicinity of the exhaust manifold. But as the heating of intake CNG charge will cause a reduction in the density of the charge, for maximum power, the intake air should be as cold as possible.

CNG conversion system-related factors:

A major factor in optimal performance of the conversion kit is the quality of kit installation by the workshops. Optimization of the gas mixture and ignition timing and

9. Conversion Kits



Can all vehicles be converted for CNG conversion?

Almost any petrol vehicle can be converted to operate on CNG. However, technical suitability of a vehicle to use CNG can be ascertained only by automobile workshops and service stations familiar with CNG kit fitment. Vehicles with catalytic converters can also be fitted with a CNG kit to use CNG, without any difficulty, as CNG does not contain lead.

What types of Conversion Kits are available?

As per **Motor Vehicle Act**, type approval is carried out by following three Govt. Laboratories:

1. Indian Institute of Petroleum, Dehradun.
2. ARAI, Pune
3. VRDE, Ahmednagar

Type approval certificate then issued to particular model of car on particular make of CNG Kit. Ministry of Surface Transport (MOST) in turn inform the regional transport authorities that so and so make of Kit has been typed approved on so and so make of car.

Based upon the authority letter of MOST, regional transport authority include CNG fuel mode in the vehicle registration book at the time vehicle is presented for inspection alongwith the installation certificate. Installation certificate is issued by respective installer / workshop authorised by Kit supplier in writing to the Regional Transport Authority. The whole process may take 6 to 10 months time.

What does a CNG conversion kit consists of?

Major parts of a CNG retrofit are illustrated below:

1. Pressure Regulator
2. Petrol Solenoid Valve - Stops petrol flow when operating on CNG
3. On-Off valve and refueling connector - Opens or stops gas flow to the regulator and includes a refueling device
4. Control Module/Change-over Switch
   Electronic control component with fuel selection switch
5. CNG level indicator
   Shows CNG quantity on vehicle dashboard.
6. Gas-Air Mixer
7. CNG Cylinder with valve, vapor bags & bracket

8. Petrol hose
9. Low pressure gas hose
10. Ignition advance processor
11. High pressure gas tube
12. Wire harness
13. NRV in petrol return line
14. Pressure gauge

There may be some differences in nomenclature and variations in the kit component from one make to another. For more details, motorists should refer to the conversion manual, packing list / schematic diagram provided by the supplier at the time of purchase of the kit.

CNG Kit Installation

Before conversion to CNG, the vehicle must undergo a pre-conversion check. This is to ensure that the engine is mechanically sound and property tuned to the manufacturer specification.

The check should include audit of the electrical system, ignition, valve clearances, cylinder compressions, exhaust gas analysis and the condition of the air cleaner. It is best to check fuel consumption, power output and vehicle performance on starting, idling and running. Fuel emission should also be checked both before and after conversion on CNG as well as on petrol separately.

Sometimes there can be additional expenses initially for replacing batteries, ignition circuits etc. This is because the ignition temperature for CNG is much higher than for petrol and a much stronger spark is needed to ignite CNG, even though the earlier spark strength may have been acceptable for petrol running.

Also ensure the following:

1. That the workshop is authorised and observes Safety Standards and Code of Practices in kit installation and commissioning.

2. The kit, including the cylinder, must be type approved for the make of the car. Do not buy components from different sources or try to install the kit yourself.
3. Before converting the car for CNG, the tubing must be totally free of debris, dust/sand. After the connections are made, ensure a complete and thorough leak test of the gas system.
4. Collect the installer's certificate from the workshop.
5. Modification or improvisations **should only be done** at an authorised workshop.

CNG Cylinder Installation:

Cylinders are usually mounted in the luggage space of vehicles. In station wagons and hatchback vehicles, they are mounted behind the rear seat or, in some cases underneath the chassis. Cylinders must be located in a protected position to minimize damage in the event of an accident and ***should never be mounted on the roof***.

Specially designed steel clamps, which completely surround and grip the cylinders, are used to mount these on vehicles. These clamps are anchored to the body of the car with suitable stands so as to facilitate the efficient use of boot space.

The payload of the vehicle (shown in the registration book) would be naturally reduced by an amount equivalent to the weight of the gas cylinder and brackets and kit.

Maintenance and Periodical inspection / Testing Schedule of CNG Kit Components:

Although the CNG kit is simple and practically maintenance-free, the following tips can help you to gain the maximum from the use of CNG:

After conversion, the vehicle may have to be brought to the workshop for tuning on gas after 1,000 km to 1,500 km running as diaphragms and other parts require this much usage before settling down.

Cylinder testing:

As per the requirement of Chief Controller of Explosives, the CNG cylinder should be hydrotested at an authorised testing shop every five years.

Rechecking the CNG kit system:

Motorists should take the vehicle for annual inspection to a CNG conversion workshop. The motorist should obtain a certificate from the workshop that the CNG system is found installed properly. Motorists may be required to produce this certificate at the time of CNG filling.

Experience of other countries has shown that life of lubricating oil is extended because CNG does not contaminate and dilute the crankcase oil. The plug life is also extended due to elimination of lead fouling.

STATUS OF TYPE APPROVED CNG KITS FOR VARIOUS CAR MODEL

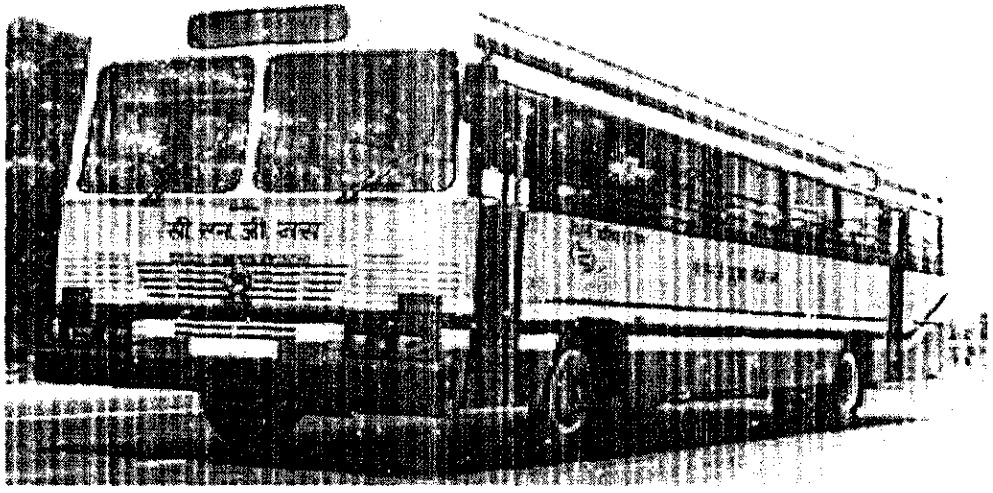
CAR MODEL	LOGICON */LANDI RENZO	GREEN TECH/ BEDINI	PRIMER AUTO ELECTRIC	OFFCINE LOVATO	TRANSENERGY	AG AUTO GAS SYSTEMS HOLLAND
MARUTI 800	Yes	-	-	-	Yes	-
MARUTI GYPSY	Yes	-	-	Yes	Yes	-
MARUTI ESTEEM	Yes	Yes	-	-	Yes	-
MARUTI ZEN	-	Yes	-	-	Yes	-
MARUTI VAN	-	-	-	-	Yes	-
PREMIER PADMINI	Yes	-	Yes	Yes	Yes	Yes
AMBASSADOR NOVA	Yes	-	-	-	Yes	-
AMBASSADOR ISZ 1800	-	-	-	Yes	Yes	-
CONTESSA	-	-	-	-	Yes	-
NE118	Yes	-	Yes	-	-	-
CIELO	Yes	Yes	-	-	-	-

The above-approved Kits are being supplied by the following:

Logicon Engineers Pvt. Ltd. 47/48, Mahavir Centre, Sector - 17, Vashi, Navi Mumbai - 400 703	Tel.: 022-7681662 022-7672349 022-7680778, Fax : 022 - 7632792, E-mail : logicor@bom3.vsnl.net.in	Indian representative of M/s Landi Renzo, Italy
Transenergy Ltd. 185, SIDCO, Indl. Estate Ambattur, Chennai-600 098	Tel : 044 - 6250646 Fax : 044 - 6254722	Kit Supplier
Transenergy Ltd. 10/60,Kirti Nagar, New Delhi - 64	Tel : 5935695	Kit Supplier
Green Tech-Fuel Systems, 503, Ansal Tower, Nehru Place, New Delhi - 110019	Tel : 6294275, 6282175	Kit Supplier
Shrimankar Gas Car Services Pvt. Ltd. 236, Sant Nagar, East of Kailash, New Delhi - 110065	Tel: 6405429	Kit Supplier for Auto Rickshaw
Shrimankar Gas Car Services Pvt.Ltd., 101, Narayan Dhuru Street, 1st Floor, Mumbai - 400 004	Tel : 022 - 3633739, 3615633 Fax : 022 - 3634338	Kit Supplier
J P Autogas India Pvt. Ltd. 505, Prasad Chamber, Opera House, Mumbai - 400 004	Tel : 022 - 3633739, 3615633 Fax : 022 - 3634338	Kit Supplier
Rutu Auto Gas Pvt. Ltd. 9, Parivitinagar Bunglows, B/H 3A Satellite Road, Ahmedabad - 380015	Tel: 079 - 6765926, 6760259 Fax : 079 - 6761701, 6760480	Kit Supplier

SITAC, F-04&05, Triveni Comml. Complex, Shekh Sarai Ph-1, New Delhi - 110017	Tel: 6014949 Fax: 6016841	Kit Supplier
Autogas Conversion India Fairfield, 6th Floor, 204, Savarkar Marg, Mahim, Mumbai - 400016	Tel: 022-4463163 Fax: 022-4458131	Kit Supplier

10. CNG Engine Bus - The technical scenario



10.1 DUAL FUEL ENGINE

The availability of CNG led to the development of CNG - Diesel Duel Fuel engine by the retrofitment of the conversion kit. The advantage of a Duel Fuel system is that engine can operate either on Diesel or on Duel mode and can switch over to 100% diesel, if CNG is not available. The engine starts on Diesel fuel but changes over to CNG after a certain engine speed. While dynamometer trials are satisfactory and show a substitution of diesel as high as 70%, when operating on full throttle across the speed range. Vertical trial show a substitution as low as 30%, when engine speeds are low under typical city operating conditions. Further the reduction in Diesel fuel under dual mode results in injector overheating. The expenditure involved in installation of two separate fuel systems is not commensurate with gains and so that the concept of duel fuel engine, in the context of Diesel bus, is being given up.

10.2 DEDICATED CNG ENGINE

Ashok Leyland is currently manufacturing three varieties of engines - HINO and IVECO with variants to suit various customer requirements. Out of these, **IVECO 6 cylinder naturally aspirated Diesel engine** was chosen for CNG engine development, as this was the latest to be introduced in Ashok Leyland range.

Following choices of basic engine, following design changes were carried for suitability of operation on CNG;

- ✓ Additional machining in cylinder head to accommodate spark plugs
- ✓ Piston was re-machined to reduce the compression ratio
- ✓ Diesel fuel injection system was replaced by CNG fuel system with an end speed governor
- ✓ Compression ignition was replaced by spark ignition

Only the fuel system and ignition systems are imported. The spark plug, end speed governor, gas cylinders and valves have been indigenously developed and produced.

10.3 SPECIFICATION OF ENGINE

FUEL FEED

The pressure is reduced from 200 Bar in the storage cylinder to 6.9 Bar in the first single stage regulator and further reduced to 64 - 120 MMWC by two stage second stage pressure regulator.

FUEL INDUCTION INTO THE ENGINE

The gas from second pressure regulator is received by an air valve type carburetor (Make: IMPCO, USA), where it gets

mixed with filtered air. The mixture is drawn into the inlet manifold through a throttle.

GOVERNING

An Electronic end speed governor which senses engine speed from alternator cuts off the gas supply by means of a solenoid valve when engine speed exceeds 3050 RPM.

IGNITION SYSTEM

Bosch electronic ignition system with **F6DC (Bosch) / U4A MICO** spark plug is introduced.

EMISSIONS

The engine meets 1996 emission norms with considerable margin. During the testing of engine for optimizing performance, it was established that the engine is capable of developing more HP (122 - 131 HP) than the declared maximum power of 107 HP @ 2800 RPM - the requirement for city bus. The maximum torque is 362 NM @ 1000 RPM.

The first CNG bus in India was launched at Mumbai on 15th January 1997.

10.4 EMPIRICAL RESULTS

The buses operated at Mumbai were fitted with 10 Nos. of 50 ltr. Water capacity cylinders with working pressure of 200 Bars and testing pressure of 335 Bars. Subsequently, the numbers of cylinders was raised to 12. They can store 84 kgs of CNG and this ensures a bus run up to 250 kms per filling in Mumbai.

The dedicated CNG engine after preliminary study of engine performance was installed on a chassis and road test. Two buses were inducted in BEST fleet, one in January 1997 and

another in May 1997. The teething problems were quickly resolved. Satisfied with the performance of these two vehicles, BEST ordered another eight buses, which were inducted in to the fleet between July and September 1998. At present, 10 CNG buses being operated by BEST have been covered a cumulative mileage of 7,00,000 kms.

10.5 TECHNOLOGY OPTION

The first phase of the development work confirmed the feasibility of operation of dedicated CNG engine for powering city buses in India. It was therefore decided to examine the technology options available for further development. The findings are as follows;

LEAN BURN

In lean burn option, the exhaust emission control is achieved by diluting the engine inlet change with excess air. The excess air available reduces the combustion temperature and hence NO_X emission. Since the engine operates almost close to the misfire limits, it is necessary to use an oxidation catalyst to reduce CO and HC emission.

The lean burn emission requires close loop control system and since the fuel induction in to the engine is by gas injecting, the engine requires complex controls.

The charge affects the flame propagation speed and it is necessary to incorporate fast burn combustion characteristics.

Even small variation in gas composition can change the engine performance to a large extent.

STOICHIOMETRIC

In stoichiometric option, engine operates closer to certain limits of chemically correct air-fuel ratio, which caters to the usage of a three-way catalytic converter. The three-way catalytic converter along with stoichiometric combustion enables the achievement of ultra low emission levels.

To keep the air-fuel ratio close to the stoichiometric, it is necessary to provide a close loop feedback system, which has an oxygen sensor, planted in the exhaust. It provides signal to the microprocessor, depending upon the availability of oxygen in the exhaust. Based upon the milli-volt output of oxygen sensor, the microprocessor controls the gas control solenoid and varies the gas induction to maintain the air-fuel ratio close to stoichiometric.

The variation in gas composition does not significantly affect the engine performance. The engine can tolerate even a small amount of compressor oil.

For a naturally aspirated engine, the stoichiometric combustion is the only option because the lean burn option reduces the power output considerably.

10.6 DEVELOPMENT OF DEDICATED CNG ENGINE

The salient details are as follows;

The engine capacity is the same as that chosen for the earlier duel fuel development. The modifications carried out are;

✓ Engine Components

- Piston modified to accommodated the bathtub type combustion bowl with 1.5 compression ratio
- Cylinder head modified to introduce sparkplug
- Adaptation of drive arrangement for distributor to replace fuel injection pump

✓ Additional Fitments

- Fuel feeding system comprising of first stage regulator to reduce the storage cylinder pressure to 10 bars and second stage regulator to further reduce the gas pressure to almost atmospheric. The air valve type .carburetor mixes the gas with air and inducts into the intake manifold.
- The ignition system comprises of contact-less distributor, electronic triggering unit, high-energy ignition coil and sparkplugs of suitable heat range for this application
- End speed governing system, comprising of an auto relay to sense the speed and to induce a three way solenoid valve, to reduce the gas supply to the engine at the second stage regulator itself.
- Close loop control system, comprising of oxygen sensor to sense the oxygen in the exhaust, and the signal fed to the microprocessor to control the fuel control solenoid to vary the fuel at speed of 10 Hz to correct the air-fuel ratio closer to stoichiometric.
- Three way catalytic converter having metal coat of 5:1 of **Pt:Rh**.

10.7 ENGINE PERFORMANCE

The CNG engine has been tested on dynamometer and optimized for engine performance and emission levels. AL have carried out necessary modifications to improve the durability of

CNG engines and also introduced fuel system to reduce emission levels considerably.

The naturally aspirated version retained due to its simplicity and adopted stoichiometric combustion. The lean burn version necessitates turbocharging or turbocharging with intercooling to obtain the same rated power of the Diesel engine.

ENGINE RATED POWER

With the close loop control and stoichiometric fuel system, the engine develops marginally higher rated power, whereas the maximum torque remains as high as that of the Diesel engine, which is most desirable for city traffic conditions.

EMISSION

With the rated power marginally above the Diesel engine power, the considerable reduction in emission level achieved with stoichiometric operation with three-way catalytic converter.

The achieved emission results are as given below;

Pollutant	**Achieved Emission (Gms/kwh)**	
	CNG	Diesel
NO_2	3.24	7.721
CO	3.12	1.820
HC	1.30	0.262
MMHC	0.04	
PM	0.014	0.310

The smoke level measured from CNG engine is less than 3 **Hatridge** smoke units all over the operating range.

The unburnt hydrocarbon emission of CNG engine contains mostly methane, which is not, considered a pollutant. Out of the total hydrocarbons emitted, the non-methane hydrocarbon will be only 3-4%.

The particulate measurement system suitable for diesel engines can not measure particulate on a CNG engine.

10.8 CNG CHASSIS / VEHICLES

The major modification to the chassis is the fitment of gas cylinders in place of the conventional fuel tank. Due to the large storage volume, as many as 12 cylinders, each with a 50 ltr water capacity, are required to be provided for an operating range of 250 to 300 kms between refills. The cylinders are interconnected with pipe of 6 mm outside diameter and 4 mm inside diameter. The cylinders are filled with gas to a pressure of 200 bars, but are tested at a pressure of 334 bars as specified in the safety regulation by the Chief Controller of Explosives. Each cylinder weighs 70 kgs when fully charged with 7 kgs of gas. Thus the gas cylinders when filled with gas impose a weight penalty of 840 kgs. Separate filler valve 9/16 dia is provided on the chassis for filling all the cylinders simultaneously when connected to the outlet at the gas filling station. Each cylinder has individual closing valve to cut off the gas supply to the pipeline when required as during bodybuilding and to isolate the cylinder during maintenance and repair.

10.9 VEHICLE PERFORMANCE

The performance of CNG bus is almost identical to that of a Diesel bus. In the crowded traffic of Mumbai, the average speed is 11 km/hr both for Diesel and CNG. The acceleration of CNG bus is same or slightly better than the Diesel bus.

The maximum speed is also the same as that of the Diesel bus.

The various facets of performance are summarized below;

DRIVABILITY

The drivability of CNG bus is equivalent to that of a Diesel bus. The accelerator pedal effort is considerably reduced since it is operating only the throttle of the carburetor. The reduced noise and vibration level of the CNG engine contributes to better driver comfort.

The throttling of air along with gas results in the engine operating with less excess air, compared to Diesel. This give rise to higher exhaust temperatures in part throttle conditions and has to be taken care of by providing proper heat shielding under the bonnet.

FUEL CONSUMPTION

According to Vehicle supplier, the fuel consumption of CNG buses operated at BEST (3.2 kms/kg) with very low average speeds, is equivalent to fuel consumption achieved on Diesel buses (3.2 kms/ltr). While BEST itself confirms Diesel average of 3.2 kms/ltr, it puts CNG average around 3 kms/kg. In other words, the average in Diesel (ltr) to gas (kg) equivalent terms is about 6% lower.

SAFETY

The CNG storage cylinders along with all connectors and pipeline are tested for a minimum 1.5 time working pressure, 200 bars. The rooting of gas pipelines, mounting of cylinders, location of pressure regulators and filler valve selection are carried out as per **New Zealand safety standard 5422, Part-3: 1991**. The vehicle is type approved for compliance to safety standards. Even in the event of an

accident, the tank is only dented and there is no other damage.

As CNG is lighter than air, if there is any leakage, it diffuses into air, unlike LPG or Petrol, which collects in a puddle and is prone to fire.

NOISE

The noise level of CNG engine is much lower than that of the Diesel due to reduction in compression ratio. Reduction in noise level also increases comfort for the driver. The measured passer by level for CNG version is 86 dB (max) as compared to 90 db (max) for Diesel bus chassis.

DURABILITY

The changeover of all the major structural components from a Diesel engine ensures the durability of a CNG engine. The absence of carbon particles due to clean combustion increases the life of such fast wearing parts as liners, pistons and rings, even though the maximum cylinder pressure is almost the same as that of the Diesel.

10.10 FEEDBACK TO CNG ENGINE BUS - "BEST" - MUMBAI

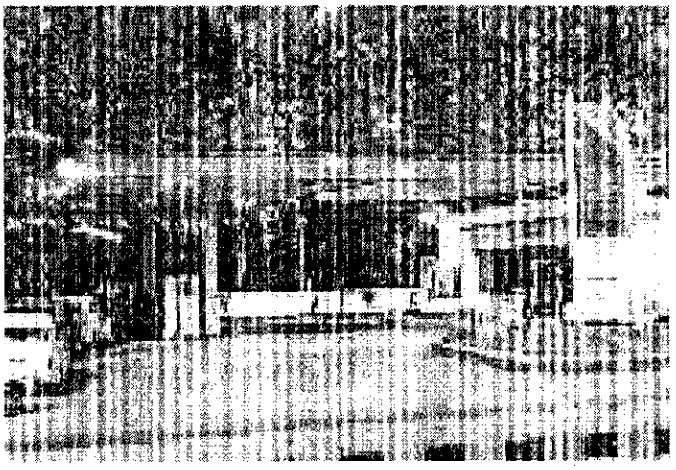
DRIVER PERCEPTION

- The vehicle pick-up (acceleration) is very good as compared to Diesel buses. Can move ahead of cars at the signal start.
- Engine noise level is very low and hence feels less fatigued.

MAINTENANCE TEAM'S PERCEPTION

- The engine is very consistent and such has not given any major problems.
- Engine noise level is very low and hence feels less fatigued.

11. Dispensing Facilities



How is CNG distributed?

CNG STATIONS:

Mother stations are outlets to the CNG pipeline Network running (existing/ proposed) throughout the length & breadth in city / high way. These stations also provide Cascade filling facility, used to fill gas in small cascades and transmitted to Daughter Stations

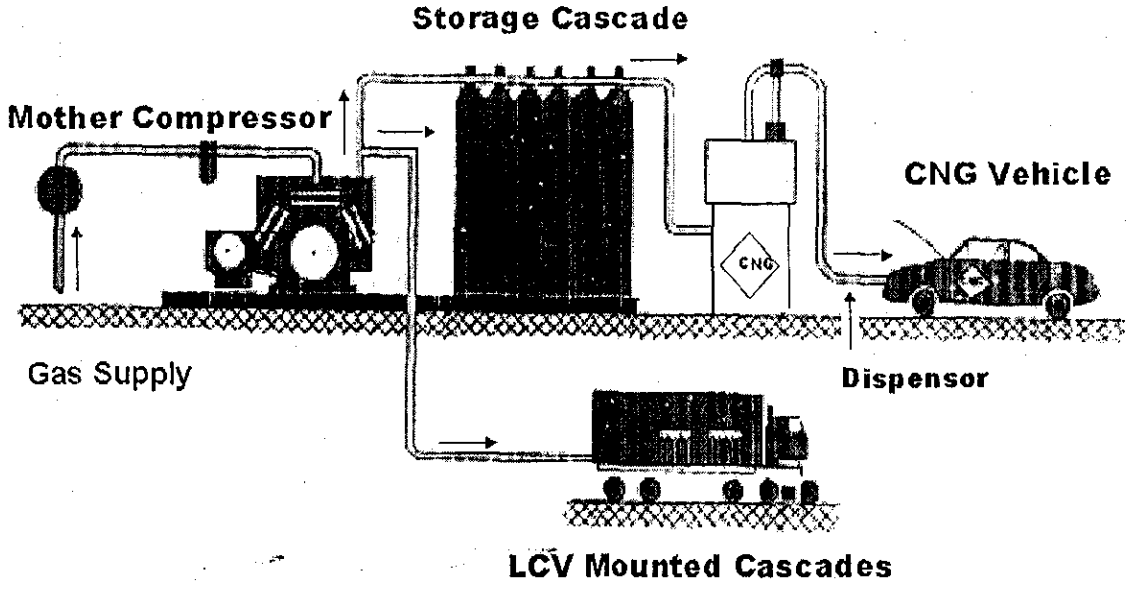
CNG vehicle storage cylinders need to be filled at a pressure of 200 bar "**On-Line stations**" are equipped with a compressor, which compresses low-pressure pipeline gas to the pressure of 250 bar for dispensing CNG to the vehicle cylinder. Online stations are the same as Mother Stations except that they do not have the Cascade filling facility

Daughter Stations are small stations catering to the needs of even those areas where Pipeline cannot reach.

CNG is supplied to consumers mainly through the existing CNG stations. The dispensing units at the stations are supplied through storage cascade (also called "Mother-Stations") in rack-mounted-cascades to the retail outlets called the "Daughter-Stations". The "on-board" cylinder in

the CNG driven vehicle is refueled from the dispensing unit under pressure, in a manner similar to petrol filling.

The vehicle cylinder is not taken out or replaced for refueling. CNG dispensing operates on the principle of equalizing pressure between the storage cascade and vehicle "on-board" cylinder. CNG is sold on retail from the dispenser in Kg. Units using direct mass flow meters while refueling.



There is reduction in storage pressure with each successive filling at a CNG retail outlet not connected to a gas pipeline. Once station pressure drops, the refueling time increases, while the quantity of CNG dispensed to the vehicle decreases. Normally a car with one "on-board" cylinder is refueled in 3 minutes when cascade storage pressure is full.

12. Safety Aspects

Safety guidelines for CNG users :

Immediately check your cylinder/kit safet certificate.

- After the kit fitment, the workshop must issue safety certificate that the conversion kit has been fitted in safe and proper manner.

- Certificate issued by the dealer should have the details of Cylinder Make & No. and Re-testing Date

All CNG users will need to carry their fitment certificate for filling CNG.

- CNG Company will check the kit safety certificate before filling CNG , every time as a safety measure

Use only approved CNG kits.

- Use only CNG kits approved by Automobile Research Association of India (ARAI) Pune, Vehicle Research Development Establishment (VRDE), Ahmednagar or Indi Institute of Petroleum (IIP), Dehradun.
- Install your CNG kit at a workshop authorized by the kit supplier or manufacturer.
- Install CNG cylinders approved only by Chief Controller of Explosives.
- CNG cylinders are required to be tested and certifie for use after every five years.

Do not try to source the kit components separately.

- Do not make the CNG kit yourself..... non-compatibility of components can be unsafe.
- Usage of spurious cylinders is an offence.
- Ensure CNG conversion is authorized by the Regional Transport Authority.

Natural Gas is available in abundance worldwide and is expected to last for several hundred years. Natural Gas worldwide, is an established clean, green fuel for domesti and commercial applications. It is predominantly being used as a versatile fuel in most of the major cities catering t domestic and commercial applications as cooking fuel, fo water heating, space heating, air Conditioning etc.

How safe is CNG as a VEHICLE fuel?

From health and safety points of view, CNG is as good as, or even better than petrol and other alternative fuels. The following properties make it a ***desirable fuel***:

- CNG is **lighter than air**. In the event of a leak, it will rise and disperse in the atmosphere and not form puddles (as in petrol) nor will it spread (as in LPG).
- The ignition temperature of Natural Gas is much higher than petrol making it more difficult to ignite.
- A high gas concentration in the air is needed to ignite CNG, not easy to achieve even in the event of a leak. Natural gas will not bum when its concentration in air is below 5% or above 15%.

Properties which make CNG a desirable fuel:

Natural Gas is:

- **Non-toxic** and cannot be accidentally ingested
- **Non-corrosive** and **non-carcinogenic** (totally free from cancer inducing agents.)
- Will not contaminate the ground water like liquid fuels.

The CNG cylinders have been specially manufactured for use in vehicles. They are made of a special steel alloy and are entirely of a single piece. There are **no welded joints in the cylinder**. Moreover cylinders have been provided with **burst discs** so that in case of inadvertent high-pressure filling or fire, this burst disc is ruptured and no excessive pressure beyond specified level remains inside the cylinder. In the luggage section of the car, CNG

fittings and the cylinder valve are enveloped inside a **vapor bag**, so that if a leak occurs, gas will pass through the bag to outside the vehicle. This reduces the possibility of gas finding its way inside the car.

The safety track record of Natural Gas Vehicles all over the world is found much better than that of other liquid fuels. This is credited to the unique characteristics of Natural Gas.

Note: CNG kit system cannot be used on LPG and CNG cannot be filled in LPG cylinder and vice versa. It is dangerous and illegal to run your vehicle on a Kitchen LPG cylinder or any other fuel not approved under rules.

- As per international data injury and death rate per vehicle mile traveled lowest with CNG.
- CNG cylinders are structurally most sound and have passed every severe test.
- Lighter than air - in case of leak no dangerous puddles.
- Unlikely to ignite as a very narrow range of air to gas concentration & high and narrow range of ignition temperature.

Safety Precautions for CNG Vehicles:

CNG vehicles may be serviced and repaired inside garages and parked provided the following conditions are observed:

- In case of leakage in fuel system, vehicles shall not be parked within 6m of any source of ignition or fire.
- In case of vehicles undergoing repairs involving welding, or heat application to any part (within 1.5 m) of the cylinder, the cylinder should be earptied first.

Dos and Don'ts:

- Always refer to the supplier's kit manual for the trouble shooting guide and do not do it yourself.
- In case of any accident, get the vehicle thoroughly checked at an authorised workshop and obtain re-certification.
- Do not install a LPG, Propane or any other cylinder in the place of a CNG cylinder. It is illegal and unsafe.
- For Emergency Handling of any CNG Leak: Users must be aware of the location and operation of the cylinder valve, master shut-off valve and burst disc in the CNG system. Study the system and ask your mechanic to identify these parts for you.
- For starting on CNG and change over of fuels (switching from petrol to CNG and vice-versa), please carefully follow the instructions of the kit supplier. The auto-workshop doing the kit fitment should be able to demonstrate these operations to your Satisfaction. It is advisable to operate the vehicle occasionally on petrol to ensure that the petrol system remains in good working conditions.

13. Economics

How much does CNG cost?

The present cost of CNG is Rs. 12.21 per kg at IGL Delhi, Rs. 18.00 per kg at GGCL - Surat & Ankleshwar, Rs 11.20 per kg at GAIL Vadodara (in July 2000) and Rs. 18.30 per kg at MGL Mumbai.

What about vehicle Insurance?

The CNG kit installed in the vehicle will have to be insured along with vehicle accessories. The motorist should notify the insurance company to provide insurance on the CNG system, for which additional premium may be charged by the insurance company. Motorists should run their car after installation, only after the risks of the additional CNG kit system are covered by the insurance company.

Gist

- With retrofit kit, higher mileage in case of petrol vehicle
- Lower fuel cost per km. in case of diesel buses
- Lower maintenance cost per km.
- Lowest life cycle cost.

The annual savings in fuel cost on converting CNG will depend on the size and fuel consumption of the vehicle on the annual mileage run on CNG. The typical annual savings calculations are attached as an Annexure 1.

14. CNG Station Cost

Various types of CNG Stations cost break-up are as follows;

MOTHER STATION: Size - 36 Mtr x 30 Mtr

SR. NO.	COMPONENT	COST (Rs.in Mn.)
1	Compressor	20.00
2	Cascade (2 Nos. 200 Liter)	4.00
3	1 Dispenser	3.00
4	2 Power Dispenser	3.00
5	Civil & Other misc. works	7.50
6	Piping & Instrumentation	0.25
7	Fire detection	0.15
8	DG Set	1.00
9	Contingency	0.70
***	**TOTAL**	**39.60**

ON-LINE STATION: Size - 36 Mtr x 30 Mtr

SR. NO.	COMPONENT	COST (Rs.in Mn.)
1	Compressor	7.50
2	1 Cascade	2.00
3	2 Cascade Dispenser	3.00
4	Civil & Other misc. works	7.50
5	Piping & Instrumentation	0.25
6	Fire detection	0.15
7	DG Set	1.00
8	Contingency	0.70
***	**TOTAL**	**22.10**

DAUGHTER STATION: Size – 36 Mtr x 30 Mtr

SR. NO.	COMPONENT	COST (Rs.in Mn.)
1	1 Dispenser	1.50
2	2 Mobile Cascade	3.00
3	Civil & Other misc. works	7.50
4	Contingency	0.70
***	TOTAL	12.70

DAUGHTER BOOSTER STATION: Size – 36 Mtr x 30 Mtr

SR. NO.	COMPONENT	COST (Rs.in Mn.)
1	2 Compressor	3.00
2	1 Cascade	0.15
3	2 Mobile Cascade	4.50
4	Civil & Other misc. works	7.50
5	Contingency	0.70
***	TOTAL	15.85

15. Refueling Station

Building a comprehensive refueling infrastructure for the new century puts ever increasing pressure on the total cost (life cycle cost) of a CNG Station installation. As CNG installations are in competition with conventional fuels for the transportation market, they are benchmarked against them in terms of cost, comfort, reliability, safety and profitability. CNG Stations are inherently more complex than stations for liquid fuels. Hence, stations must become easier to operate & maintain. For the same reason, their level of sophistication may be increased.

The trends for the new station design focus on the main target area to meet the market needs;

1. Safety
2. Minimizing life-cycle cost
3. Rising the comfort level
4. Improving the general performance

General rules for CNG Refueling stations;

1. Design a compressor station for maximum forecasted turnover for achieving lowest CNG price
2. Choose station site where the big NGV-fleets will come and where there can be combined use
3. Schedule a growth scenario to keep up with CNG demands
4. Implement dynamic storage for rush hour and HD refueling
5. Discuss trade possibilities while buying compressor
6. Consider to operate NGV and station together under one responsibility