A REPORT ON

CNG

As

AN ALTERNATE FUEL

FOR

RAILWAY TRACTION

CNG as an alternate fuel for Railway Traction

G K Gupta
Dy.CME/Dsl

1.0 Introduction

The financial position of Indian Railways is under extreme pressure due to ever increasing expenditure in comparison to revenue earnings. About 22% of total expenditure i.e. approximately Rs. 7,382 Crores is incurred over fuel per annum out of which Rs. 2,827 crores is on diesel.

A small reduction in fuel consumption through use of alternate cheaper fuel, efficient engine and improved technology can result in substantial savings in fuel bills. Besides cost aspects, the alternate fuel needs to be environment friendly, clean & green and without major input requirements in the existing system.

As on date, more than one million vehicles are running with CNG in the world. Even in our country, realising the adverse impact of increased environmental pollution, CNG has been adopted for public transportation in a big way and as on date all the public transport vehicles including buses, taxis, auto rickshaws etc. have been converted into CNG powered vehicles. This has improved the air quality in major cities substantially.

Realising the importance of CNG as an alternate fuel, the concept of retro fitment of CNG kit in the present engine of DEMU without any major changes in the existing system was studied in association with M/s CUMMINS in April 2004. The feasibility study through simulation was carried out and a decision was taken to develop proto type CNG retro fitment kit. It was also decided to carry out structural modifications in one of the existing DPCs to accommodate CNG carrying gas cylinders and other associated parts of the kit.

The work of implementation of this concept in the DEMU was started in Nov. 2004 at SSB shed. RDSO clearance was taken for implementation of this project. Simultaneous clearance from Chief Controller Of Explosives(CCOE), Nagpur was taken for use of CNG in DEMUs.

M/S IGL was associated to supply cascade for carrying CNG cylinders inside DPC, high pressure gas pipe line and associated fittings, all of which were approved by CCOE. They also agreed to supply CNG for pilot project free of cost.

2.0 Structural changes carried out in DPC

In order to implement the concept of dual fuel engine in DEMU, a lot of structural changes have been carried out, which are summarised as follows :-

a) Shifting of Air Inlet filters for Traction Motor from coach Floor to side wall through ducting.

b) Fitment of LTA radiators
c) Fitment of LTA pump
d) Removal of 30 seats for provision of CNG cascade in DPC
e) Fitment of cross channels on the floor for mounting CNG cascade
f) Roof cutting of DPC to insert CNG cascade
g) Fitment of CNG cascade
h) CNG pipe line routing and fitment

3.0 Components of CNG conversion kit

A brief description about important components of CNG kit are as follows:-

- **DFM-100 Dual Fuel Controller -** Controls the supply of Diesel/Gas proportion through diesel and gas actuators independently.
  - **Diesel Actuator -** Controls the diesel fuel proportionately.
  - **Gas valve Actuator -** Controls the gas fuel proportionately.

- **ESD-5300 Speed Governor -** Controls the speed of engine and is provided with enhanced features, which makes it capable to control any dynamic situation.

- **Special LCC Speed & Load Control Unit –** An electronic load control device which sends the signals to DFM controller and speed governor for speed and load control functions.

- **Electronic Knock Control-DF 16 -** Detects engine knocking through knocking sensors and controls the supply of gas proportion to arrest the knocking.

- **Exhaust Temperature Sensor -** Senses the Exhaust gas temperature and sends the signal to DFM Controller, which controls the proportion of gas in air/blender.

- **Knocking Sensor -** Knocking sensors are fitted in each cylinder of the engine. They sense the knocking tendency and send the signals to the Anti knock controller.

- **Engine Speed Sensor -** Senses the speed of engine and gives signal to the engine speed governor through LCC control unit.

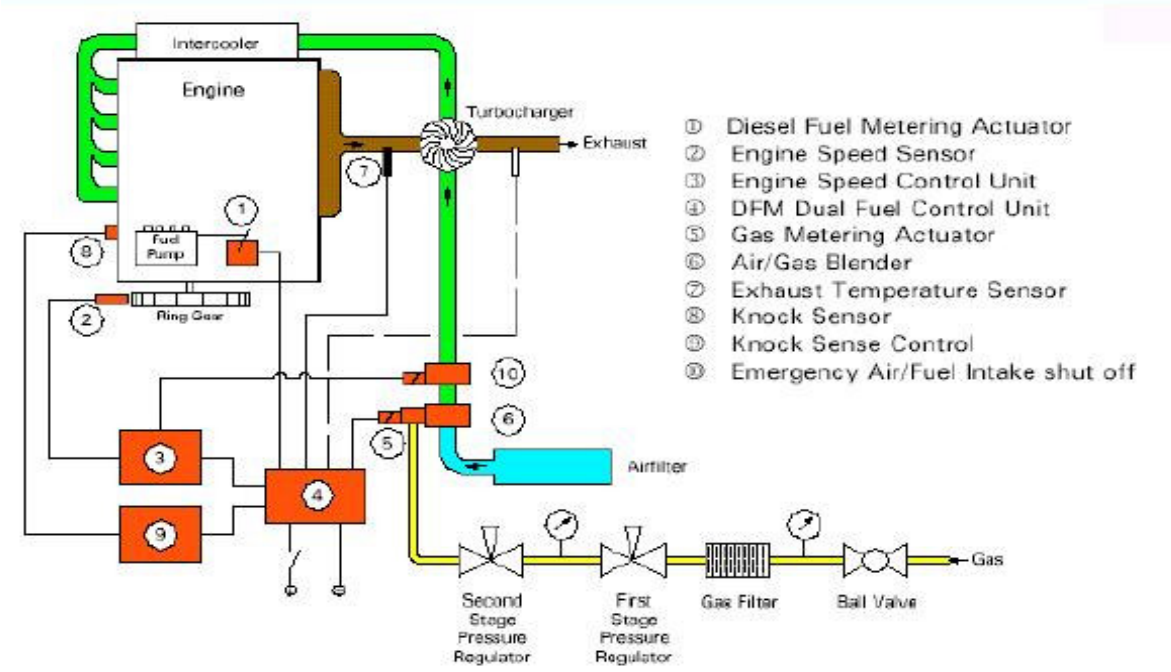
- **Flame Arrester -** Prevents the back travel of the flame from engine to the gas cylinders in case of any mal functioning in the engine.

Other Components

- **Air Gas Mixture**

- **Gas filter**
- **Pressure Regulator**
- **Pressure Gauge With Valve**
- **Electric Gas Shut off Valve**
- **Manual Shut-off Valve**

Schematic diagram of Dual Fuel Engine



4.0 Basic principle of operation of dual fuel engine

In dual fuel engine, the CNG gas is mixed with air by an air gas blender and is injected in the combustion chamber of engine. This air-gas mixture is compressed in the engine at high pressure and high temperature.

Thereafter the diesel fuel is injected, which auto ignites and in turn ignites natural gas. Thus the power is generated by burning mixture of natural gas and diesel in the combustion chamber of engine.

Normally the natural gas and diesel is mixed in the ratio of 50:50. However it varies according to the load. At lower loads, use of diesel fuel tends to be higher, where as at higher load the gas proportion is higher.

Dual fuel control unit (DFM controller) controls the proportion of natural gas and diesel as per requirement. It sets the amount of injected diesel fuel via the

diesel actuator with position sensor. Simultaneously, the amount of gas into the air/gas blender is also regulated by it.

The air/gas mixture then passes through the turbo charger, through the intercooler into the engine. The required engine speed is controlled by the governor control, which measures the engine speed at the engine ring gear via speed sensor.

Whenever there is a tendency of knocking, the knock sensors send signal to knock controller, which in turn sends signal to DFM Controller and thereby regulates the supply of CNG and diesel to control knocking tendency.

Similarly, temperature sensors control the exhaust gas temperature by regulating ratio of CNG and Diesel.

5.0 Safety Features

Although CNG is a flammable gas, it has a **narrow flammability range,** making it an inherently safe fuel. CNG also disperses rapidly, minimizing ignition risk relative to air and will not pool as a liquid or vapor on the ground. In the event of a spill or accidental release, CNG poses no threat to land or water. CNG is primarily Methane, however, which is a greenhouse gas that could contribute to global climate change if leaked. Strict safety standards make CNG vehicles as safe as Diesel-powered vehicles.

Dual fuel DEMUs shall be having following safety features to safeguard against fire in case of accident:

5.1 Pressure relief devices (PRDs)

PRDs are provided to protect against the possible explosion of a CNG cylinder if it were involved in fire. They are designed to fail and release the cylinder contents before the cylinder walls rupture. They are incorporated with fusible elements which are designed to soften and release gas at predetermined temperature and prevent the chance of explosion even in worst possible scenario.

5.2 Flame Arrester

It prevents any backward travel of flame in case of malfunctioning of valves in combustion chamber of engine.

5.3 Fire Alarm System

It detects any smoke and fire through optical smoke detectors and will give fire alarm in the driver cab who can take necessary action to shutdown the engine.

5.4 Separate Storage

CNG cylinders shall be stored in separate chamber, completely isolated from engine room, thus making the system free from fire hazard even in case of any leakage.

5.5 Gas leak detector

Gas leak detector senses leakage of CNG inside storage area of CNG and gives signal to cut off the supply of CNG from cascade to the engine and thus prevents any consequential damage.

5.6 Anti Climbing Couplers

DEMUs shall be equipped with anti climbing couplers which will prevent the climbing of coaches over one another in case of accident, thus further minimizing the chance of fire due to collision.

6.0 Benefits of CNG

Emissions - Pure CNG engine as compared to conventional Diesel engine reflect the following potential reductions:-

- Reduction in **Carbon monoxide emissions by 90 to 97%.**
- Reduction in **Carbon dioxide emissions by 25%.**
- Reduction in **Nitrogen oxide emissions by 35 to 60%.**
- Reduction in **non-Methane hydrocarbon emissions by 50 to 75%.**
- **Fewer toxic and carcinogenic pollutants.**
- **No particulate matter produced.**

Cost - Cost of CNG is approximately **60 % less** than diesel for generating equal amount of power.

Less Lub-Oil Change - The oil in a CNG vehicle does not need to be changed frequently as CNG burns cleanlier than diesel, producing less deposit in the oil. In addition, cleaner burning characteristics of natural Gas and the absence of particulates often reduce engine wear and tear. CNG engine **run more efficiently** than a Diesel powered vehicle, **thereby extending the life of the vehicle**.

Less noisy - CNG engines are less noisy than diesel engines.

Availability - Abundant, underused resources are available in many developing countries including India.

Other Benefits

Besides cost benefits and the improvement of environment due to reduced harmful emissions, the CNG based dual engines have following benefits;-

- Natural gas is lighter than air and mixture of air and natural gas are inflammable only in a fairly narrow range of gas concentration between 5% to 15% by volume, thus small leaks of natural gas are unlikely to result in fires, since the gas normally disperses upwards before reaching a flammable concentration.

- Decreased engine wear that comes with the use of cleaner fuel. Due to a reduction of carbon soot build-up and cleaner lube oil, longer intervals between service maintenance can be expected, sometimes doubled.

- The DFM will continuously govern along the knocking threshold if necessary. This feature helps to increase efficiency.

- Smaller size of effluent treatment plant.

- Reduced Lube oil consumption to the extent of 30%

- Longer economic life for the engine and a better overall return on investment.

- Dual fuel engine have the advantage of not being totally dependent on natural gas for fuel supply. Thus, if a dual fuel engine runs out of natural gas or is away from an available CNG source, it is able to operate solely on diesel.

7.0 Storage of CNG

For DEMU operation, the storage space and the number of CNG gas cylinders has to be sufficient for minimum twenty hours of operation so that frequent refueling is not required en-route. For dual fuel engine, the consumption of CNG is 40 CUM per hour, hence for twenty hours of un-interrupted operation, a total of 800 CUM of natural gas will be required. A cascade of 40 cylinders each with capacity of 14 Kg can store the required amount of 560 Kg of CNG, which comes to more than 900 CUM at a density of 0.6 Kg./CUM. The natural gas is stored in cylinder at 255 bar. The cylinders used confirm to the following specifications:

Water capacity - 50 lt.
Outer diameter - 232 mm
Wall thickness - 7.0 mm
Length - 1515 mm

Steel grade - Seamless Chrome Molybdenum Steel

Cylinders in cascade are firmly secured in their position to prevent any movement during run.

8.0 Cost Benefit Analysis

Cost of conversion kit of CNG per DEMU shall be Rs.27,50,000/- and the cost of CNG cascade along with 30 cylinders shall be Rs.6,50,000/-. Thus the total cost of conversion for Dual Fuel Engine including taxes, excise duty, freight and insurance charges comes to be Rs.36,00,000/- approx. The cost has been worked out based on detailed discussions with M/S CUMMINS INDIA LIMITED, who is a worldwide, reputed and established player in the field of Diesel and CNG engines.

CNG costs Rs. 10/- per CUM in comparison to the cost of Diesel of Rs.22.10/- per liter. And one cum of CNG produces approximately same energy as is produced by one liter of Diesel. Thus, use of CNG in its pure form may result in savings of 60% of fuel consumption. However, in dual fuel engine, since CNG has been proposed to replace only 50% of Diesel, therefore, the total savings have been worked out after considering the fuel cost, lube oil cost and the maintenance cost of Dual Fuel Engine as compared to Diesel Engine which are indicated as below:-

CALCULATION FOR 1400 HP DEMU CONVERTED TO DUAL FUEL OPERATION

DESCRIPTION	DIESEL	DUAL FUEL
DIESEL: GAS RATIO	100	50-50
RATING KVA	1250	1250
RATING KW	1000	1000
COST OF CONVERSION	N.A.	3600000
FUEL COST		
GAS CONSUMPTION - CUM/HR	0	42.2
DIESEL CONSUMPTION - LITRE/HR	80	40
GAS RATE - RS./CUM	N.A.	10
DIESEL RATE - RS./LITRE	26.28	26.28
FUEL COST FOR GAS - RS./HOUR	0	427
FUEL COST FOR DIESEL - RS./HOUR	2102	1051
TOTAL FUEL COST - RS./HOUR	**2102**	**1478**
LUB OIL COST - 6000 HOURS (Oil Change Periodicity)		
LUB OIL RATE RS./LITRE	80	80
LUB OIL CONSUMPTION LITRE/HOUR	0.25	0.25
LUB OIL CONSUMPTION IN 6000 Hr.(Lt.)	1500	1500
LUB OIL CONSUMPTION COST IN 6000 Hr	120000	120000

(Rs.)		
LUB SYSTEM CAPACITY – LITRES	177	177
LUB OIL CHANGE PERIOD – HOURS	300	500
NO. OF CHANGES FOR 6000 HOURS	20	12
TOTAL LUB OIL CHANGE IN 6000 Hr.(Lt.)	3540	2124
LUB OIL CHANGE COST RS.	283200	169920
TOTAL LUB OIL COST - RS.	403200	289920
LUB OIL COST/HOUR	**67**	**48**
ROUTINE MAINTENANCE COST - 6000 HOURS		
COST OF SPARES - RS.	359724.28	266906.04
MAINTENANCE COST /HOUR	**59.95**	**44.48**
TOTAL OPERATION COST - RS./HOUR	**2229**	**1571**
SAVING/HOUR - RS.		**658**
Loss of passengers (S+S)		**30+30**
Loss in Railway earning Rs/hr		**210**
NET SAVING/HOUR - RS		**448**
PAYBACK PERIOD – IN HOURS		**7258**
AVERAGE RUNNING HOURS / MONTH		**400**
PAYBACK PERIOD –IN MONTHS		**18**

From the above calculations it is noticed that the introduction of dual fuel engine in DEMUs results in saving of Rs.496/- per Engine hour running as compared to diesel engine. Considering average Engine running of 400 Hrs per month, **total savings per DEMU per annum comes to be Rs.23.8 lacs**. **Thus, the cost of CNG conversion kit shall be recovered in 18 month only giving annual rate of return of 66%.**

9.0 Environmental Improvement

Use of CNG in Railways will go a long way to improve our environmental concerns as the emission gases of CNG engine contains the harmful SO_x, CO_2, CO, NO_x, and particulate matter in considerably reduced quantity which are mainly harmful for health hazards. The particulate matter is primarily responsible for smog conditions prevailing during winter over most of the cities in Northern India, which is the main cause for growing incidences of Asthama. The particulate matter would reduce to nil in case of CNG engine and thus the incidence of this disease is expected to come down.

Substantial reduction in SO_x, & CO in the emission of the CNG engine will help in reducing the green house effect and thus general improvement in Air quality. The reduction in green house effect will improve the global warming scenario.

Similarly, reduction in NO_x in exhaust will also improve the air quality. CNG being a simple molecule of methane, it burns completely and therefore exhaust gases do not contain any amount of un-burnt hydrocarbons, which has a very significant and positive impact on environment.

10.0 Future Suggestions and recommendations

- After successful trial on DEMU, all the existing DEMUs can be converted into Dual fuel engine through retro fitment on a programmed basis.

- All new DEMUs to be manufactured with pure CNG engine, which will further reduce the fuel cost and improve the environment.

- Development and retro fitment of CNG kit for existing fleet of Diesel Locomotive.

- All new locomotive to be manufactured with pure CNG engines

- Existing stationary DG sets to be converted into Dual fuel engine through retro fitment of CNG kit and new DG sets to be procured with pure CNG engines.

- Exclusive CNG storage systems to be developed over Indian Railways on the pattern of existing RDI.

- Use of CNG to be extended in manufacturing and maintenance activities of different units over Indian Railways.

- CNG engines may be planned as future fuel for complete traction over Indian Railways.

11.0 Conclusion

- Use of CNG engine is established in transport sectors worldwide and its popularity is growing because of its properties of clean fuel.

- It is possible to use CNG in a dual fuel engine through retro fitment of CNG kit in the existing system without any major modification in the existing system.

- Cost of CNG is less than half as compared to that of diesel for developing same amount of energy and thus the operating expenses of CNG engine shall be lowered by approximately 30% in dual fuel engine.

- Introduction of CNG has a definite impact on environment improvement. Reduction in CO and SO_X shall result in reducing

green house effect and thereby improving global warming scenario. Reduction in particulate matter to almost nil in pure CNG engine and by approximately 50 % in dual fuel engine shall result in reduced smog effect and thereby minimizing the health hazards.

- CNG is much lighter than air and disperses quickly and rises upward. Hence the chances of fire hazard are minimized.

- The investment on CNG kit is paid back in 18 months, thereby expected annual rate of return is 66%.

- The benefits shall further multiply by manufacturing new DEMUs and Locomotives with pure CNG engines.

CNG has the potential of not only bringing down our fuel bill, but also reduce dependence of nation on imported crude. CNG is the fuel of future and therefore technology is in state of evolution.

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Annexure – I

Technical Data of Diesel Engine of DEMU

Engine Model	KTA50L
BHP at 1500 RPM	1400
No. of Strokes	4
No. of Cylinders	16
Configuration	60 Deg Vee
Aspiration (TA – Turbocharged Aftercooled)	TA
Engine Firing Order	1R-8L-1L-8L-3R-6R-3L-6L-2R 7R-2L-7L-4R-5R-4L-5L
Engine Rotation	Clockwise
Bore – mm	159
Stroke	159
Displacement – litres	50.3
Compression Ratio	13.9:1
Dry Weight	4858
Wet Weight	5180
Engine Dimensions	
Length (Less Cooling system)	2978
Width (Less Cooling system)	2080
Height (Less Cooling system)	1798
Air Intake System	
Number of Air Cleaner	2 Nos.
Number of elements per air cleaner	1 inner & 1 outer
Exhaust System	
Recommended exhaust pressure – mm Hg	50-63
Exhaust Gas Temp – Deg C	490
Coolant System	
Coolant capacity (engine) – litres	161
System Pressure	7 PSI
High Water temp safety limits – Deg C	93-95
Lub Oil System	
Lub Oil sump capacity – litres	145
Total lub oil sump capacity inclusive of bypass filters – litres	177
Min Lub oil pressure @ idele speed – Kg/square Cm	1.8
Lub oil pressure @ rated speed – Kg / square Cm	3 – 4.9
Fuel system	
Type of Injection system	Cummins PT
Fuel Filter quantity per engine	2 Nos.
Recommended Fuels	HSD as per ASTM D2

Specific Fuel Consumption	151 gms/bhp/hours

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SAVINGS FOR 1400 HP DEMU WITH DUAL FUEL(CNG+DSL) OPERATION

DESCRIPTION	DIESEL	DUAL FUEL
DIESEL: GAS RATIO	100	50-50
RATING KVA	1250	1250
RATING KW	1000	1000
COST OF CONVERSION	N.A.	41.26 lac
FUEL COST		
GAS CONSUMPTION - CUM/HR	0	42.2
DIESEL CONSUMPTION - LITRE/HR	80	40
GAS RATE - RS./CUM	N.A.	10.80
DIESEL RATE - RS./LITRE	28.45	28.45
FUEL COST FOR GAS - RS./HOUR	0	456
FUEL COST FOR DIESEL - RS./HOUR	2276	1138
TOTAL FUEL COST - RS./HOUR	**2276**	**1594**
LUB OIL COST - 6000 HOURS (Oil Change Periodicity)		
LUB OIL RATE RS./LITRE	80	80
LUB OIL CONSUMPTION LITRE/HOUR	0.25	0.25
LUB OIL CONSUMPTION IN 6000 Hr.(Lt.)	1500	1500
LUB OIL CONSUMPTION COST IN 6000 Hr (Rs.)	120000	120000
LUB SYSTEM CAPACITY – LITRES	177	177
LUB OIL CHANGE PERIOD – HOURS	300	500
NO. OF CHANGES FOR 6000 HOURS	20	12
TOTAL LUB OIL CHANGE IN 6000 Hr.(Lt.)	3540	2124
LUB OIL CHANGE COST RS.	283200	169920
TOTAL LUB OIL COST - RS.	403200	289920
LUB OIL COST/HOUR	**67**	**48**
ROUTINE MAINTENANCE COST - 6000 HOURS		
COST OF SPARES - RS.	359724.28	266906.04
MAINTENANCE COST /HOUR	**60**	**45**
TOTAL OPERATION COST - RS./HOUR	**2403**	**1687**
SAVING/HOUR - RS.		**716**
Loss of passengers (S+S)		**30+30**

Loss in Railway earning Rs/hr	**210**
NET SAVING/HOUR - RS	**506**
AVERAGE RUNNING HOURS / DAY	**15**
AVERAGE SAVINGS PER ANNUM	**27,70,350**