DIESEL VEHICLE OPERATION ON CNG

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by

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- improvements in fuel consumption that may be obtained by increasing the compression ratio above 11:1 have been proven to be only marginal.

- in a city bus application, reliability is of paramount importance. From the foregoing discussion it is apparent that reliability of the converted engine may be affected should we increase the compression ratio above 11:1 for this CNG engine.

3.0 VEHICLE FUEL STORAGE SYSTEM

3.1 Number and Size of CNG Cylinders

In selecting the number and size of CNG cylinders for bus operation, a number of considerations must be satisfied. These include the fuel consumption and required range of the bus between fills, the weight distribution on each particular vehicle type and the physical space available for cylinder mounting.

Various configurations have been used in conversions undertaken by Welgas.

The rear engined Hino buses (RK 176) for example, were fitted with five 80 litre water capacity cylinders, with a total full weight of 450 kg. The buses have a driving range of between 280 and 350 kilometers.

On the mid-engined Hino buses (BX341) the customer requested a driving range of up to 350 kms, and so five 90 litre cylinders were fitted. These will give the vehicle a range of between 310 and 380 kms per fill.

3.2 Load Distribution of CNG Cylinders

The cylinder locations on the Hino buses were selected to ensure axle loadings were kept within manufacturers tolerances and legal limits for New Zealand roads.

The BX341 chassis has a total gross vehicle weight of 13,176 kg, some 424 kg less than the Manufacturers Gross Rating of 13,600 kg. Both front and rear axle weights are below the Manufacturers Gross Rating. The additional weight of the CNG equipment is 600 kg, after deducting the weight of the diesel fuel tank, fuel system, fuel pump and fuel, which are discarded in the conversion to CNG.

3.3 Filling Time

Filling time for CNG vehicles varies depending on the filling stations used. However, typically the Hino RK-176 rear engined bus will fill from empty in 6 to 7 minutes and the Hino BX341 mid engined bus takes 8 to 9 minutes.

Trickle filling is also used on some of these vehicles. This allows filling during idle time, and overnight, avoiding the need for any down time for refuelling.

4.0 ENGINE DYNAMOMETER TEST RESULTS

The graphs presented are for the following 3 cases:-

a) Diesel - Manufacturers Published Data
b) Diesel - Corrected Data based on tests conducted by Transgas.
c) CNG - Corrected Data based on tests conducted by Transgas.

The results obtained are compared with the manufacturer's published data, as this shows the design limits for power and torque output for this engine type.

The difference between the diesel figures (manufacturer's data versus tested data) is quite typical of production engines and is not a cause for concern.

However, CNG test data should be compared with the manufacturer's published data as this gives the upper limit imposed by the engine manufacturer for the particular engine type.

As can be seen from Fig. 1, CNG power and torque output is within 6% of the manufacturer's published data over the entire engine speed range.

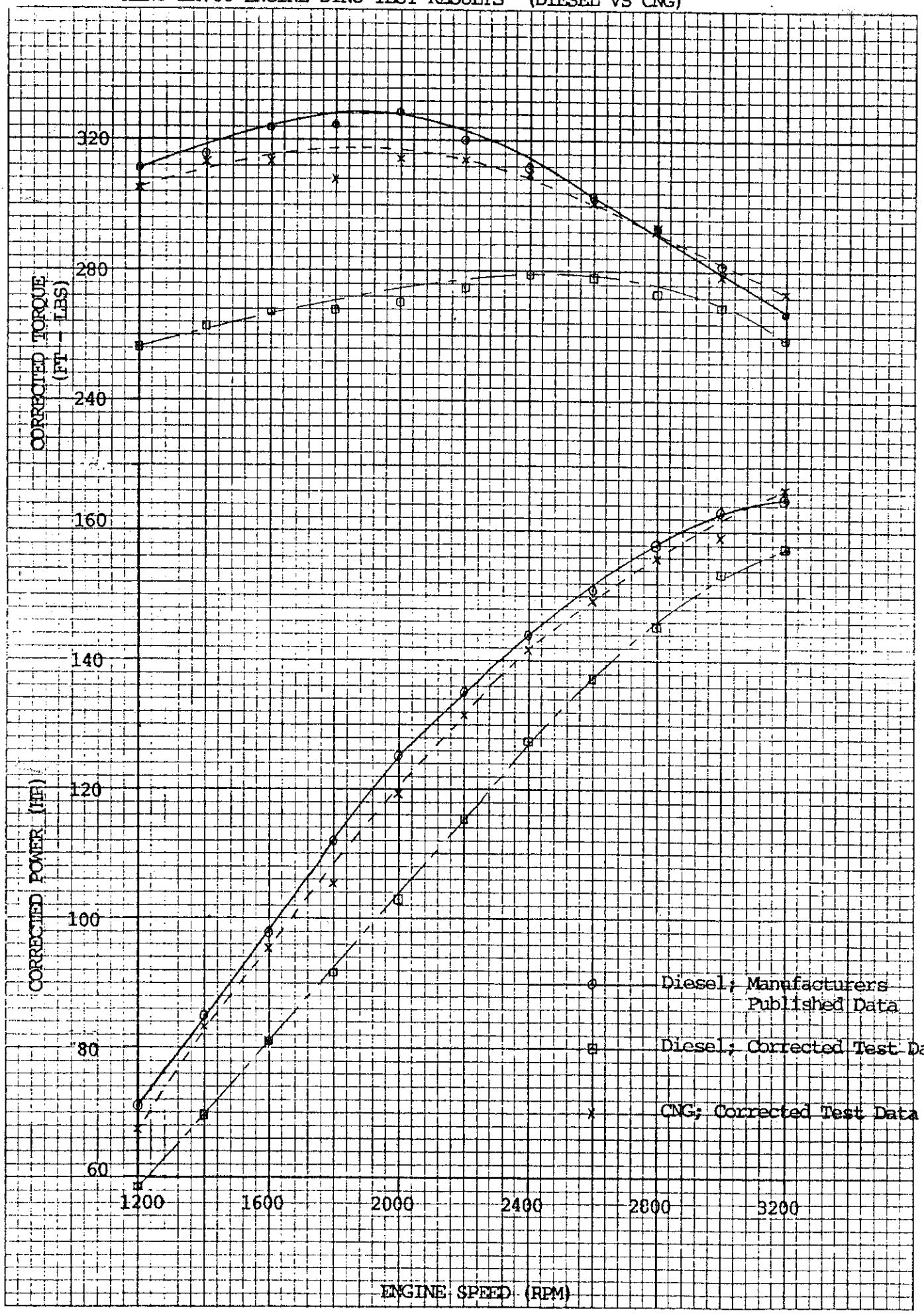
Figure 2 shows the power and torque output percentage differences for the CNG and diesel test cases when compared with the diesel published data. It can be seen that the power and torque output of the engine on CNG is substantially better than that on diesel.

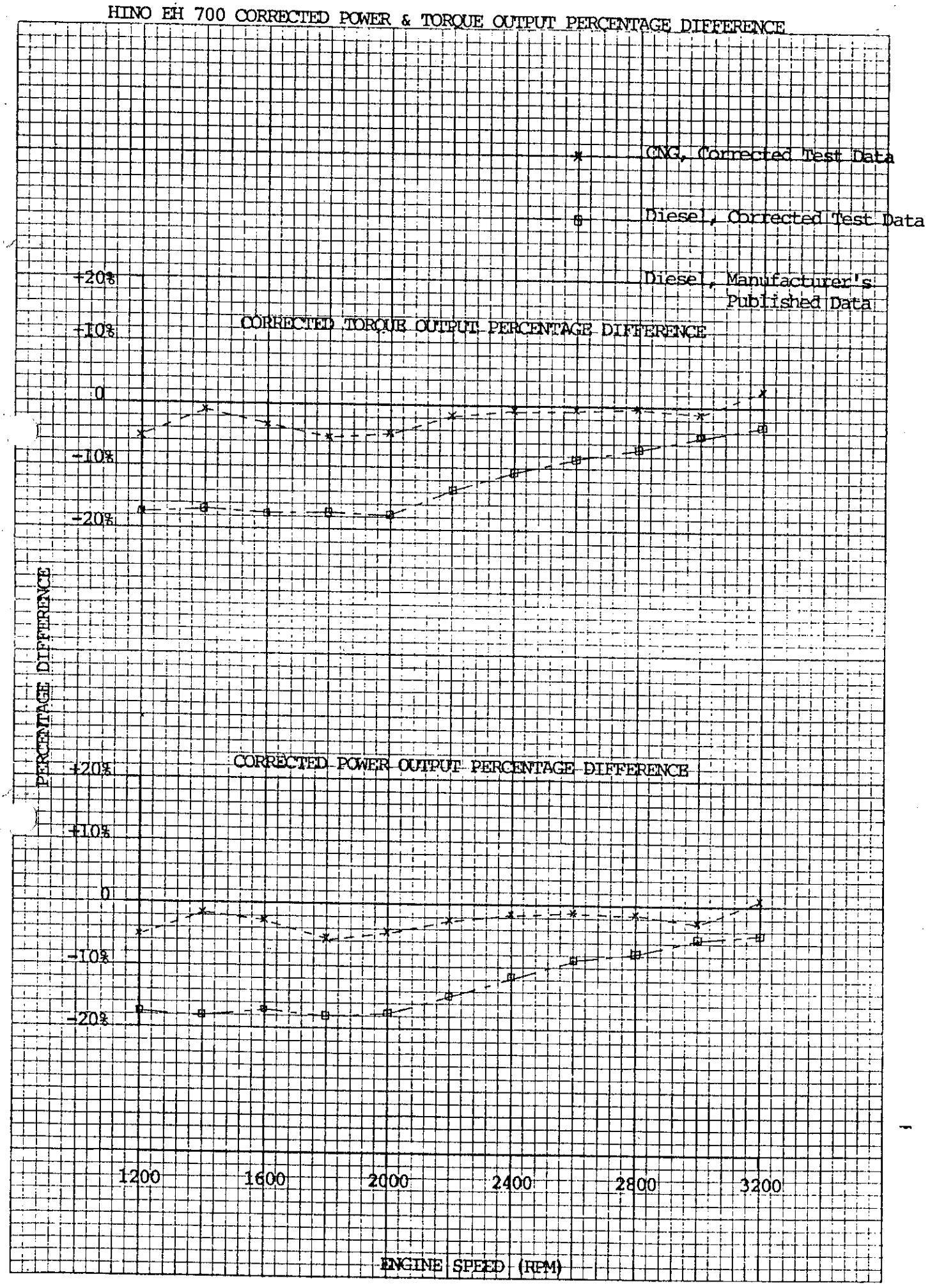
The improvement on CNG is more pronounced between 1200-2500 rpm engine speed, whereas this improvement is present over the entire speed range up to 3200 rpm.

This improvement on CNG when compared to the diesel test case is immediately noticeable when driving the bus and is particularly beneficial in city stop-start driving conditions.

FIG. 1

HINO EH700 ENGINE DYNO TEST RESULTS (DIESEL VS CNG)




HINO EH 700 CORRECTED POWER & TORQUE OUTPUT PERCENTAGE DIFFERENCE
CNG, Corrected Test Data
Diesel, Corrected Test Data
Diesel, Manufacturer's Published Data
CORRECTED TORQUE OUTPUT PERCENTAGE DIFFERENCE
+20%
+10%
0
-10%
-20%
CORRECTED POWER OUTPUT PERCENTAGE DIFFERENCE
+20%
+10%
0
-10%
-20%
PERCENTAGE DIFFERENCE
1200
1600
2000
2400
2800
3200
ENGINE SPEED (RPM)

5.0 ECONOMICS

In order to calculate the economic benefits of using CNG in diesel vehicles, we need to establish a fuel consumption equivalence between CNG and diesel.

5.1 CNG - Diesel Fuel Consumption Equivalence

A Fuel Performance Drive was carried out to establish the fuel consumption equivalence between CNG and diesel.

Two city buses with identical bodies, one operating on CNG and the other on diesel, were used for the test. Both buses, owned by the Palmerston North City Corporation, were identical except for the fuel systems and engines.

Both buses are built on the Hino RK-176 chassis. One was in the standard diesel configuration and the second in a CNG configuration with five 80 litre water capacity CNG cylinders fitted. The diesel bus had a tare weight of 7940 kgs and the CNG bus 8300 kgs. The diesel bus carried 21 people and the CNG bus 23 people during the test.

A total distance of 356 kilometres was covered, with both buses approximately half loaded. They travelled in convoy at all times to ensure identical road, traffic, and weather conditions.

Accurate measurements were recorded for each fuel type before starting and at each refuelling. Both vehicles were filled with fuel to capacity at the commencement of the run, in Palmerston North. Refuelling took place in Hastings after 195 kms and again at Palmerston North after 356 kms.

A direct comparison has been made between the total amount of fuel used by each bus to establish the fuel equivalence factor, as shown below:-

1.	Diesel consumption for 356 kms	90.90 litres
2.	CNG consumption for 356 kms	79.57 kgs

Therefore

90.90 litres of diesel = 79.57 kgs of Kapuni CNG

i.e. 1 litre of diesel = 0.875 kgs of Kapuni CNG.

5.2 Fuel Cost Savings

Based on the equivalence factor established above, we now calculate fuel cost savings for the bus operator.

1.	Diesel price	$ 0.67/litre
2.	CNG price	$ 0.51/litre equiv.
3.	Fuel cost savings	$ 0.16/litre equiv. or 23.9%

Annual distance travelled (kms)	40,000	60,000	80,000
Fuel consumption (kms/l)	3.3	3.3	3.3
Annual fuel usage (litres)	12,121	18,181	24,242
Annual fuel cost savings	$ 1,939	$ 2,909	$ 3,879

NOTE:

1) Diesel price is the current average retail price as of August 1987, exclusive of GST.

2) CNG price is the current average retail price as of August 1987, exclusive of GST. Excise Duty is not applicable for diesel vehicles and has been deducted from the CNG price.

CNG price equivalent to a litre of diesel has been calculated as below:-

CNG retail price (incl. GST)	$ 0.80/kg
Less GST @ 10% ($0.073/kg)	$ 0.727/kg
Less Excise Duty ($0.141/kg)	$ 0.586/kg
CNG equiv. litre price (x 0.875)	$ 0.512/l.eq

6.0 CONCLUSIONS

From the information presented in the preceding sections, and practical experience, it can be concluded that:-

1. The technical aspects of the conversion of a diesel engine to spark-ignited dedicated CNG operation have been well proven in service over a number of years in a wide variety of applications.

2. The practical experience gained in the operation of these dedicated CNG vehicles (buses and trucks) show that the CNG engine is very reliable in service.

3. Black smoke emission, as in the case of diesel vehicles, is completely eliminated with the use of CNG. Other constituents of exhaust emissions are greatly reduced and so is engine noise and vibration.

4. The life of the CNG engine is expected to be longer than the original diesel version because of the reduction in compression ratio and hence reduction in mechanical stresses on the engine components.

5. CNG fuel storage systems can be sized to suit the range required by a vehicle operator between refills. Typically, city buses are able to travel between 250 and 350 kms per fill of CNG, with 5 or 6 CNG cylinders.

6. The economics of conversion to CNG are attractive at the present time. With the inevitable increase in the prices of imported oil in the future, the economics will become even better.

   Furthermore, gas utilities are very keen to market CNG to commercial vehicles operators, and are prepared in many cases to offer incentives. Similarly, CNG Stations are also prepared to offer discounts to commercial vehicles operators because of the large volume of CNG they consume.

It can therefore be concluded that CNG as a fuel for diesel vehicles is available today, with technology that is well proven, safe, clean, reliable, and economical.