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THE DEVELOPMENT OF COMMERCIAL CNG-DIESEL DUAL FUEL SYSTEMS

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INTRODUCTION

For compressed natural gas (CNG) to be an effective supplemental fuel in the diesel engine, it must be successful from both a combustion and economic standpont. CNG cannot be used as the sole fuel for an unmodified diesel engine; instead, at each engine speed and load, a certain percentage of energy can be supplied by CNG. The optimum schedule for CNG addition is complex, requiring little or no gas at low loads and high gas supply (limited by engine knocking) at high loads. Thus, satisfying the CNG-diesel combustion requirement involves more engineering effort than in the CNG-petrol engine case.

The economic benefit obtained from using CNG-diesel is less clear than that for CNG-petrol. Economic advantage is obtained through the substitution of a less expensive fuel (CNG) for diesel fuel. The percentage of diesel fuel that can be effectively replaced varies with engine type, metering system, vehicle power/weight ratio and type of driving. To date, Transport Fuels has modified eight vehicles to operate with CNG-diesel. While these vehicles are looked upon as prototypes and not the final word in dual fuel conversions, it does appear that overall cost savings can occur. The high average mileage of a typical diesel fleet vehicle can result in a system payback period of about eighteen months.

The following three sections will briefly explain the developed CNG-diesel fuel system, show some results to date and give some of the conversion and operating costs. It should be emphasised that the overall replacement levels of diesel with CNG are low, but may be raised as more is known of combustion requirements and effects on engine component life.

THE SYSTEM

The Transport Fuels-Tartarini CNG-diesel system is a development of an original simple supplementation design.

In the early system, a 3-stage regulator reduces cylinder pressure to atmospheric pressure. A venturi mounted in the induction tract draws gas proportional to engine airflow, i.e. if an unthrottled diesel runs twice as fast then twice the air volume is inducted and twice the gas will be inducted also. In practice, the flows do not exactly double, since volumetric efficiency, fluid friction and regulator capacity all contribute to flow losses. However, these will be small if components are correctly sized for the application.

Diesel engines, unlike spark ignited engines, are unthrottled and therefore at a given r.p.m. induct the same amount of air regardless of load. If the supplementation system has only a venturi and regulator fitted, the percentage of the energy supplied by CNG at low load will be very high, since a fixed amount of gas is inducted and very little diesel fuel is injected. Conversely, at high loads with the same r.p.m. the percentage of energy supplied by CNG would be low, as again a fixed amount of gas is inducted but much more diesel fuel is injected.

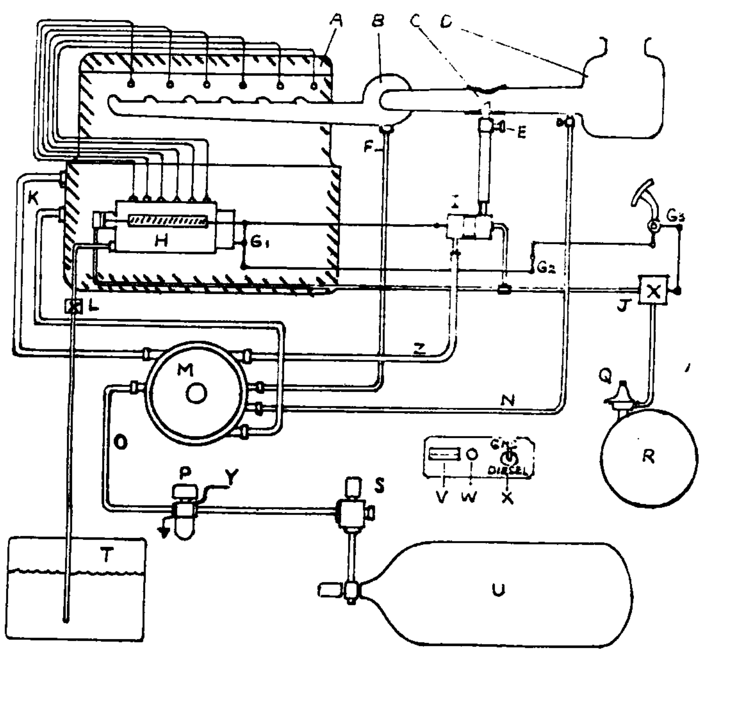
The Transport Fuels-Tartarini CNG-diesel system differs from the simple venturi/regulator system described by the mounting of an additional gas control valve between a similar venturi and regulator.

The additional gas fuel valve is controlled by the diesel injection pump load mechanism, through the rack, fuel pressure or electronically. The valve remains shut at idle and low engine loads but opens as engine load increases. This valve enables gas to be metered proportionally with engine speed and load, a prime requirement where improved efficiencies are being sought.

The original versions of this system generally metered gas from 50%-100% load and the conversion units were predominantly confined to vehicles running at heavy load over 50% of the trip distance.

As a result of further development in valve design and a better understanding of the adjustments needed, current versions of the system allow greater substitution percentages at lower loads.

Progress is continually being made in gas metering systems for a wide range of diesel engine types. Pending the perfection of electronic control units, Transport Fuel is installing units using compressed air, mechanical and electrical controls. These are mounted in a conveniently small container which, when locked, can only be adjusted or serviced by qualified personnel.



KEY

A	Engine
B	Turbocharger
C	Gas/air mixer
D	Air cleaner
E	Power adjustment
F	Boost signal to reg.
G1	
G2	Two gas control systems
G3	
H	Injection pump
I	Gas valve
J	Air control valve
K	Regulator heat pipes
L	Diesel shut down
M	CNG regulator
N	Boost bleed from reg.
O	High press. gas
P	Electrovalve
Q	Air regulator
R	Vehicle air tank
S	Filling valve
T	Diesel tank
U	CNG cylinder
V	CNG contents gauge
W	CNG indicator lamp
X	Switch for either system
Y	Connection to gas switch
Z	Low press. gas

Fig. 1 - Layout of CNG-diesel system

CONVERSION AND OPERATING COSTS

The most important factor in CNG-diesel conversions is the availability and cost of the CNG. Other cost factors include the average trip length, load carried and the weight and volume of CNG tankage that can be mounted. The gas composition appears less critical in CNG-diesel applications than in CNG spark ignition vehicles. Vehicles tuned to Kapuni gas and fuelled with Maui gas lose maximum horsepower and some range but are otherwise unaffected. The move towards one fuel across the North Island will overcome this problem.

There is currently a wide differential in retail price per megajoule between CNG and diesel fuel. Diesel fuel is 58.5c. per litre and CNG is approximately 39.5c. for the energy equivalent, i.e. on current retail prices CNG costs 67% of diesel fuel. The difference in wholesale fuel price is less well defined, particularly if there is existing excess gas compressor output available. It is not unlikely that wholesale CNG can be obtained at 50% of the price of diesel fuel, provided that sufficient volumes of gas are required.

Hypothetically, a vehicle operating on 50% CNG and travelling 100,000 km per year with an economy of 2 km/l could save over $7,000 per year in fuel cost at current retail prices. The savings may be decreased if additional labour time is required for refuelling. Fuel cost savings will generally increase with increasing percentages of CNG supplementation, other factors being equal.

The cost of converting a diesel engine to supplemental fuelling with CNG is higher than that of a CNG-petrol vehicle. Heavy duty vehicles require more than 120 litres of cylinder capacity to have acceptable range and all installation hardware must be robust. Current price for a conversion is approximately NZ$2,000.00 plus CNG tankage. However, only small numbers of any specific diesel model are converted at present and the cost may decrease somewhat with higher conversion numbers. New vehicles are less expensive to convert to CNG supplementation than vehicles having high hours, but this is dependent on the condition of the individual vehicle. At present, there is little likelihood that original engine manufacturers will provide engines suitable for part gas operation as their priorities lie elsewhere. Hence, for CNG-diesel applications, local conversions will continue to be necessary in the future.

RESULTS

This section shows some of the results obtained with CNG supplementation on diesel trucks. The overall percentage of gas used to replace diesel was kept relatively low while reliability of the units was assessed.

The engines that have been converted at the time of this report are listed in Table 1.

Table 1

	Engine	Type	Displacement	H.P.	Vehicle Weight
(1)	Isuzu KT25	4 cyl. IDI	3.3 L	86	5,600 Kg
(2)	Fiat 8280	V8 DI	17.2 L	352	36,000 Kg
(2)	Cummins NTC-290	6 cyl. DI	14.0 L	290	40,000 Kg
(1)	Cummins NTC-335	6 cyl. DI	14.0 L	335	31,000 Kg
(1)	Cummins NTC-350	6 cyl. DI	14.0 L	350	32,000 Kg
(1)	Cummins 504	V8 DI	8.2 L	210	9,700 Kg

With the exception of the Isuzu KT25 all vehicles have direct injection engines, and six of the eight vehicles operate with over 30,000 Kg GVW.

Table 2 lists results obtained for some of the converted vehicles. CNG-diesel consumption is reported as equivalent diesel consumption on the basis of 1 cubic metre CNG = 1.085 litres diesel fuel (same energy value).

Table 2

Engine	Length of Test	Diesel Range	CNG-Diesel Range	% CNG Overall
Isuzu KT25	1,782 km	-	6.00 km/l	25.4
NTC-290	640 km	1.23 km/l	1.17 km/l	41.3
NTC-335	9,801 km	1.78 km/l	1.69 km/l	24.2
NTC-350	52,000 km	1.99 km/l	1.83 km/l	26.6
V8-504	11,565 km	3.99 km/l	3.97 km/l	17.9 *

* First test vehicle

Generally consumption (expressed on an energy basis) was slightly increased in the CNG-diesel mode, although it remained well below a comparable petrol engine consumption.

FURTHER DEVELOPMENTS

Although fuel savings of the order of 16%-20% in retail dollar terms are the norm today, future developments such as turbo air by-pass valves may improve efficiencies and subsequent savings by a few percent. A recurring problem with CNG systems - the siting of the bulky gas cylinders - is also the subject of attention. Pilot trials are to be commenced shortly where cylinders are carried over the trailer axles and a flexible hose (now under D.S.I.R. test) will carry gas to the tractor. This is important where front axle weights are at the limit.

Where total all-up weights are a concern, it must be remembered that removal of a diesel fuel tank and its contents will often compensate for the increased CNG cylinder package. This is an easy solution where normally two tanks are installed. Also, bulk gas purchasing by fleet operators may help also secure the future of this method of extending diesel usage.

CONCLUSION

No deficiencies in vehicle performance occur with CNG-diesel use and no unit to date has had problems within the engine or in the injection system. Several minor problems with solenoids, corrosion in high pressure fittings and oil accumulation in the CNG regulator have occurred. The problems are not serious but indicate that very sturdy installations are needed in heavy duty trucks. As the vehicle has two fuel systems, an aggressive maintenance programme is essential.

To date, two manufacturers have indicated the possibility of transferring warranties to CNG-diesel but the intentions of the majority are unclear.

CNG in the diesel engine can meet both combustion and economic requirements and is a viable option for reducing fuel costs.

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