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ADAPTATION OF NATURAL GAS FOR MOTOR FUELS IN NIGERIA TRANSPORT SYSTEM

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ABSTRACT

In recent years, as a result of limiting reserve of crude oil and the clamour for the deregulation of the petroleum sector of the nation's economy, there is need to look beyond liquid fuel (gasoline, diesel) as vehicular fuels. The viability of adapting natural gas for motor fuels had been presented. Natural gas as automobile fuel has a multiple of advantages over liquid fuel. These include high octane number, less negative effects on engine parts, low toxicity of effluents. (i.e. low CO, NO_X, and lead emissions.) Experiences of other countries that are presently using natural gas as automobile fuel are reviewed along with the efforts put in place by Nigeria through the Nigerian Gas Company (NGC) Limited to experiment the project. The need of government through the NGC to be fully involved in the planning and execution of a retrofit plan to optimize pipeline network and supply service of natural gas to refueling and refilling stations is also emphasized. The public on the other hand requires enlightenment on the need to convert their vehicles to gas/gasoline powered, and incentives given for patronizing natural gas filling stations. A cohesive interplay of both national and corporate interests in policy formulation and implementation will harness effective distribution and utilization of natural gas within the Nigeria socio-economic sector.

Key words: Gas, Fuel, Automobile, Technology, Project.

INTRODUCTION

Nigeria has been identified as one of the biggest gas flaring nations in the World. Out of a total of 1.45 Billion cubic metres of gas produced in 1986, 4.08% was used to operate various machines and equipment, 9.82% was used by chemical industries, 8.74% was re-injected into reservoirs for pressure maintenance and secondary oil recovery mechanism while a whooping 73.82 % was flared (Appah et al, 1999). Nigeria's proven gas reserve currently stands in excess of 145 trillion cubic feet (an equivalent of over 20 billion barrels of oil) and a potential (unexplored reserve) of about 300 trillion cubic feet with a life span of over 50 years (Nigasco, 2000). Current estimates put flared gas statistics in Nigeria at over 75% of produced natural gas. This great waste of resources caused by lack of optimization of natural gas potentials has been a source of concern to the federal Government. Therefore the directives to the oil producing companies to discontinue gas flaring by the year 2008 came as no surprise.

In order to meet the Federal Government deadline of 2008 to end gas flaring, many oil producing companies had initiated various projects aimed at utilizing the flared gas. Some of these projects are however directed at re-injecting the produced natural gas back into the oil wells which invariably does not and cannot end gas flaring. A greater volume of this flared gas will however be utilised by the Nigeria Liquefied Natural Gas (NLNG) project which had just be-gone production. Still the need to look at additional economic areas of natural gas utilization will not be overemphasised.

The recent clamour for deregulation and unbundling of the down stream sector of the nation's oil industry as a result of incessant

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scarcity of liquid fuels (Petrol, diesel etc.) has made it imperative to source for an alternative motor fuel. Natural gas with its abundant reserve readily comes to mind.

Gaseous motor fuel has already obtained widespread application in automobile and marine transport and also in stationary internal combustion engines (ICE). The use of natural gas in ICEs does not require deep chemical processing of the feedstock, but rather is largely connected with methods of their preparation for utilization. Gaseous fuels possess such dignified qualities as high octane number lower emission of ecologically unfriendly substances in the effluent/exhaust gas than gasoline and diesel fuels and higher motor resource energy for the engine. Usual gasoline (Petrol) or diesel engines can be easily adapted or modified.

Terentyev et al (1989) has classified alternative fuels applied in automobile transport according to the following structural cycle of energy utilization:

1. In the sphere of production of fuel, i.e according to the nature of raw material used, the technological variant of obtaining the fuels and their component structure and important physico- chemical properties.
2. In the sphere of transportation of the fuel; i.e. according to the method of supply to the user position.
3. In the sphere of exploitation and transport; i.e. by methods of fuel application in engines, storage and transportation on the auto vehicles, organization of their refueling stations and the spheres of application according to the nature of automobile transport.

By application, the last structure suggests a possible differentiation of refilling stations into three groups, namely-:

- The usual type
- The modified type for servicing vehicles with alternative fuels.
- Specialized type – filling stations for gaseous cryogenic fuel.

In this paper we review the possibility of adapting Compressed Natural Gas CNG) as motor fuels. The viability and technologies involved in such a project are fully analysed.

COMPOSITION AND PROPERTIES OF NATURAL GAS

The principal components of Natural Gas (NG) are the volatile components of the saturated hydrocarbon series. In particular, methane CH_4) is always present at a prevailing concentration, followed by ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) on the order. Some non-hydrocarbon components, like hydrogen (H_2), nitrogen (N_2), carbon dioxide (CO_2), hydrogen sulphide (H_2S), moisture (H_20), are usually present at variable but limited extents. Although CH_4 remains in all cases the primary component, its concentration may vary within a broad range, approximately 99.5% to 70%.

If hydrocarbon components less volatile than C_3H_8, usually up to C_8H_{18}, are present at an

TABLE 1 AVERAGE NATURAL GAS COMPOSITION FROM A GAS WELL IN EGBEMA WEST FIELDS (DRY BASIS) (Commerint, 198?.)

COMPOSITION	FORMULAR	MOLES %
Methane	CH_4	87.52
Ethane	C_2H_6	5.72
Propane	C_3H_8	3.41
Butane	C_4H_{10}	1.52
Pentane	C_5H_{12}	0.51
Hexane +	C_6H_{14}+	0.50
Nitrogen	N_2	0.27
Carbon dioxide	CO_2	0.55

appreciable extent, as it happens for associated gas, NG is said to be "Wet". If the presence of such components is negligible, NG is said to be "dry". Table 1 shows the typical composition of NG from a well in Nigeria.

Depending on its source composition, NG may require various treatments in order to remove components not admitted by commercial specification or recover specifically desired components. Several treating processes have been developed in this sense. Besides the simple removal of CO_2 and moisture, the recovery of gasoline from wet gases and the conversion of hydrogen sulphide to sulphur are treatment processes that are often undertaken..

Natural gas is a mixture of a limited number of components, however, since the relative amounts of these components vary from one source to another, no general values of its properties can be established. For each specific situation, unless directly measured, the mixture properties can be evaluated by suitably combining the corresponding properties of the single components. A good knowledge and understanding of this method of evaluation is of primary importance for designing and operating NG installations.

From the chemical point of view, the behaviour of all components is quite uniform. In fact, saturated hydrocarbons are characterised by a high energy level of the bonds between the forming atoms. This makes them highly stable and hardly reactive even against strong inorganic chemicals. Besides combustion, therefore, they undergo very few chemical transformations. which is of particular advantage in terms of their storage and transportation.

The situation is different with respect to their physical and thermodynamic properties, whose values vary appreciably from one component to another. For the hydrocarbon series, however, such variations obey to certain continuity rules as functions of the molecular weight as can be noted observing the sets of data summarised in Table 2,

For each individual component, physical properties are generally not constant but depend on both temperature and pressure, the former parameter being the most effective.

The vapour pressure curves, reported in figure 1 allow one to identify the physical state – liquid, vapour or gas – at which the component exists at a given temperature (T) and pressure (P) . In this respect, it must be remembered that a liquid starts boiling or a vapour starts condensing when the vapour pressure equals the total pressure acting over the system. Therefore any combination of temperature and pressure values which can be represented on the diagram by a point lying on the left of the vapour pressure curves (Ps < P) indicates liquid state; any point on

TABLE 2: PHYSICO-CHEMICAL PROPERTIES OF NATURAL GAS CONSTITUENTS (Commerint, 1981)

COMPONENTS	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	N_2	CO_2
MOLECULAR WEIGHT	16.04	30.07	44.09	58.12	72.15	28.02	44.01
Density at (NTP) (kg/m^3)	0.716	1.342	1.967	2.593	3.219	1.250	1.966
Density relative to air	0.555	1.041	1.523	2.011	2.495	0..970	1.523
Freezing Poin (^0C)	-182.5	-183.6	-189.9	-135.0	-129.7	-210.0	-56.6
Normal Boiling Point (^OC)	-161.7	-88.6	-42.6	-0.5	36.1	-195.8	-78.5
Heat of Vapourisation at NTP ((KJ/kg)	512.0	491.0	427.6	386.8	358.7	200.3	575.4
Critical Temperature Tc (^OC)	-82.5	35.0	96.8	153.2	197.2	-147.1	31.1
Critical Pressure Pc (atm)	45.3	48.8	42.0	36.0	33.0	33.5	73.0
Ignition Temperature (^OC)	650 - 750	520-630	510	490	550	-	-
Heat of Combustion at 25°C(KJ/kg)	55713	52080	50539	49728	49203	-	

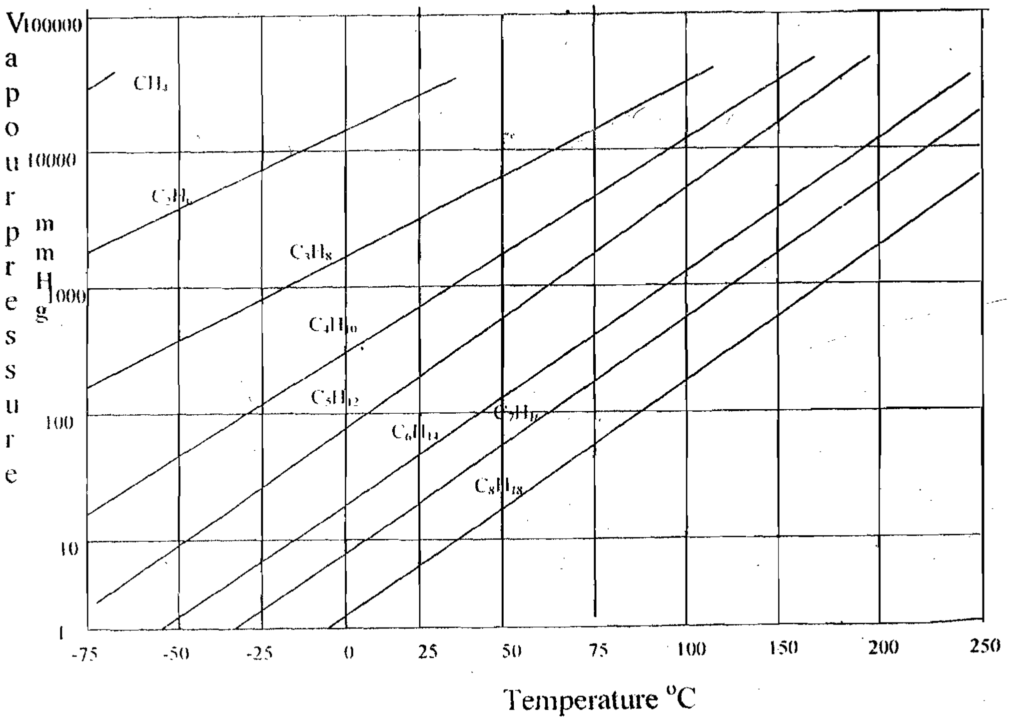

Figure 1 Vapour pressure of light hydrocarbons.

the right of the curve (Ps > P) indicate vapour state and any point on the curve itself (Ps = P) identifies the combination of temperature and pressure values at which the changes of state occurs. Each vapour pressure curve ends on the right hand side at a characteristic point called the "critical point". The corresponding critical temperature (Tc) and critical pressure (Pc) are reported in Table 2. At all temperatures greater than Tc the physical state is more properly defined as "gas" which conceptually differs from "vapour" in that no condensation is anymore possible by simple pressure adjustment. For volatile components like CH_4 the possibility of liquefaction thus implies a preliminary cooling far below room condition.

Table 2 also reports the density values of single components at normal T and P (i.e at 0°c and 1 atm. This property is strongly dependent on both parameters; it can be calculated at any conditions by applying a real gas state equation.

$$\rho = P.M/ZR.T. \quad (1)$$

.erived from the ideal gas law

$$PV = nRT \quad (2)$$

Where

M = Components molecular weight (m/n)
m = mass
n = number of moles
V = volume (m /ρ)
ρ = density
p = pressure
R = Universal gas constant
Z = compressibility factor.

The compressibility factor ,Z, a characteristic of real gas, is a function of reduced temperature (Tr) and pressure (Pr)

i.e

$$Z = f (Tr, Pr) \quad (3)$$

Where

Pr = P/Pc
Tr = P/Pc
Pc = Critical pressure
Tc = Critical temperature

The critical parameters (Pc, Tc) are conditions beyond which the gas cannot exist any longer as a gas.

COMPRESSED NATURAL GAS (CNG)

Compressed Natural Gas (CNG) is presently being used in automobile transport in Italy, France, New Zealand, Canada, U.S.A., Russia etc. Early experiments on the application of CNG for transport in Russia dates back to the 1950s. Interest was rekindled in the 1980s with the institution of complex programmes to ensure creation of a network for the supply of CNG to vehicles.

By 1991, about 540,000 vehicles were CNG operative worldwide, with Italy accounting for 50%,New Zealand 20%, Russia 13%, U.S,A. 5%, Canada 3% and Argentina 3% (Yusuf 1993).

. An experiment on the use of CNG in Nigeria has been carried out by the Nigerian Gas company (NGC), a subsidiary of the Nigeria National Petroleum Corporation (NNPC).

COMPARISON BETWEEN CNG AND LIQUID FUELS.

Compressed Natural Gas (CNG) offers operational advantages over liquid fuels. It requires no heat of vapourisation, mixes readily with air in an engine even under low temperatures. CNG also reduces engine wear and exhaust emission problems:

Table 3 gives comparative characteristics of CNG and other competing fuels.

Gaseous fuel, however, contains less energy per volume than gasoline or diesel fuels. On Kilo joules per cubic meter basis, natural gas at 25MPa, a pressure more likely to be used in vehicles, the equal volume energy content of NG is about 25% of gasoline and 20% of diesel fuels. Consequently, a substantial volume of CNG stored in relatively heavy pressure cylinders is required to give CNG vehicles the same range as a similar gasoline and diesel vehicles. For this reason a CNG fueled vehicle will weigh between 17 and 39% more, depending on vehicle type (Ikeano 1991)

Table 4 gives the comparison between the weight of CNG fueled vehicles and liquid fueled vehicles for different ranges of vehicles.

The major problem of CNG fueled vehicles as can be seen from Table 4 is the weight. Research (Yusuf, 1993) is however under way to reduce the weight of CNG cylinders either through new materials ranging from steel to wrapped aluminum and composite materials or the use of absorbent technology which could increase the amount of gas stored in a given volume and pressure.

CNG DISPENSING TECHNOLOGIES.

At automobile gas filling station, natural gas coming through gas pipelines from the fields is stripped from liquid droplets and mechanical particles in separators and filter, then the flow is metered as the gas is fed to compressor station

TABLE 3 : CHARACTERISTICS OF NATURAL GAS AND OTHER COMPETING FUELS (Gainullin et al, 1986)

PROPERTIES	UNLEADED GASOLINE	DIESEL FUEL	NATURAL GAS
Primary Hydrocarbon	C_4-C_{10}	C_{12}-C_{20}	C_1
Energy output (KJ/Litre)	31798	36052	5505
Energy output. KJ/m^3 of Mixture*	3732	3787	3400
Octane Number	87.94	N/A	120
Stoichiometric Ratio Air/Fuel	14.5 – 15.5	14.2 – 15.1	17.2

*At stoichiometric gaseous air/fuel ratio, 14 psi, 60^{o}F lower net heating value.

TABLE 4: COMPARISON BETWEEN CNG AND OTHER COMPETING FUELS (Gainullin et al. 1986)

TYPE OF CAR	CURB WEIGHT (CB) FOR SAME DRIVING RANGE		DRIVING RANGE (KILOMETERS) FOR SAME CURB WEIGHT	
	GASOLINE	CNG	GASOLINE	CNG
PASSENGER CAR	1588	1755	722	143
LIGHT DUTY TRUCK 5.0L ENGINE 2500kg GROSS VEHICLE WEIGHT (GVW)	1760	2305	1078	212
MEDIUM DUTY TRUCK 7.4L ENGINE, 5448kg GVW	3392	3987	579	114
MEDIUM DUTY TRUCK 6.0L ENGINE 13556kg GVW	3832	5340	885	201

containers. Compressed to 25MPa pressure, the gas is directed to a drying or dehydration plant, then to accumulator vessels, and then through a series of valves and regulators to gas filling station columns.

Expenditure on erecting structures for automobile gas filing compressor stations is substantially higher than that of traditional petrol filling stations, as a result of complexity of equipment and high energy spending for compressing the gas. Energy spending is shown to be determined by the pressure of the gas coming into the compressor from the pipeline. For example, an increase of inlet pressure from 0.5 to 4 MPa lowers the specific spending of electrical energy on compression of the gas 2.3 times.

Although CNG is known to be cheaper in terms of cost to end users, and great improvements have been made in converted vehicle performance, a deficient dispensing network may cause fuel supply problems along normal routes and long waits in service stations (Bellini et al, 1986). In order to make the natural gas dispensing network more attractive to users and rationalize the service, CNG dispensing terminals can be installed in existing petrol stations. This will allow various station components to be made more compact.

Modern technologies have been put in place for rationalizing the network of automotive fuel dispensing points. Hypotheses and methods have been presented for planning a natural gas dispensing network to be parallel to, but independent of the traditional fuel system.

In order to make smaller plants cost effective, new models are being designed to cut station installation and running costs.

A very up-to-date solution is the package modular units, comprising all gas compression components and related cooling, control and electric power supply and distribution systems. All module components are skid mounted and the unit they form can be enclosed in a cab (cubogas) that protects it from atmospheric agents and reduces noise level.

The industrialized cubogas solution offers the following advantages:

* Lower cost due to mass-production, almost total elimination of station engineering costs, the need for less ground, no special foundations being necessary.
* Faster installation and practically immediate use, meaning investment cost can be amortized earlier.
* Greater safety achieved by grouping all equipment in a well-defined self protected space.
* Greater reliability, since stations are assembled and tested at the factory prior to shipment.
* Easier fitting into surroundings, especially in urban areas, because it is self-sufficient

- needs no cooling water storage tanks or external piping: It is not noisy.

A typical station for fleets that can also easily fit into urban areas is a Cubogas unit, which is connected with a series of delivery terminals. These systems are easy to install and guarantee immediate use with the minimum of infrastructures. Stations can be formed of several modular units with a limited unitary capacity matching the delivery terminals. The only parts shared by the various modular units are the metering and station electrical systems. The modular solution means:

* Components can be standardized for different sized stations intended as multiples of the basic model formed of at least one compression system and two terminals
* A station can be enlarged by adding other modules, thus spreading an investment out over a period of time to suit demand.

NIGERIA'S CNG PILOT PROGRAMME

The Compressed Natural Gas (CNG) pilot scheme was embarked on in 1989 by the Nigerian Gas Company (NGC), a subsidiary of the Nigerian National Petroleum Corporation (NNPC) to promote CNG as an automotive fuel as part of the company's efforts at promoting natural gas utilization in the country and expanding the revenue base of the company.

In order to realize this objective, the company established a CNG conversion workshop with cylinder test rig in Warri and two mini-sized refueling stations each with a capacity for refueling six cars per day, one each in Warri and Egbin, respectively. The company also took up membership of the International Association for Natural Gas Vehicles (IANGV) to avail itself of up-to date information and other benefits on the development/commercialization of CNG.

Since the commencement of the pilot scheme, the company has succeeded in converting twenty-three vehicles of various brands, including a diesel truck of the company's fleets and twenty of SPDC, to run on CNG.

INVESTMENT OPPORTUNITIES IN THE CNG PROJECT.

Investment opportunities abound in the CNG industry. The options available includes:

* Joint venture agreements between NGC and foreign and local partners
* Build operate transfer (BOT) scheme
* Build operate own (BOO) scheme
* Partial or full privatization of NGC for mobilizing private sector funds for additional investment in the CNG project.

Vehicle Conversion Process

A converted vehicle consists of the following components

* Cylinder and brackets
* Regulator
* Solenoid valves (gas and petrol)
* Mixer
* Wire braided hose
* Hot and cold water hoses
* High pressure tubing for gas
* Power valve
* Manual shut off valve
* Change over switch
* Level gauge
* Electrical wires and connectors.

The conversion of vehicles involves the installation of a cylinder in the booth compartment, from where the high pressure tubing is piped through the underneath of the vehicle to the manual shut-off valve in the engine compartment. All the piping works from the solenoid valve to the regulator and to the mixer fixed on top of the carburetor are carried out in the engine compartment. The change over switch is fixed on the vehicle dash board. Other electrical connections are also carried out.

CONCLUSION

Compressed Natural Gas (CNG) is the ideal alternative fuel for automotive services. Its amply illustrated ecological, economic and strategic advantages are incentives for the sector to pick up in Nigeria. The possibilities of this actually happening depend on the overall competitiveness of natural gas in relation to traditional fuels.

The Federal Government, through the NGC, should set in motion machinery aimed at encouraging individuals and corporate bodies to enter into the CNG project. This can be done by giving incentives to entrepreneurs ready to set up vehicle conversion workshops and vehicle refueling outlets. Vehicle owners on the other hand can be encouraged by subsidizing the cost of converting their vehicles to gas/petrol.

The NGC should take the lead by establishing CNG refueling stations in areas with proximity to natural gas reticulation infrastructures, beginning with Escravos – Lagos Pipeline between Warri and Lagos. Companies with gas supply infrastructures can also be encouraged to convert their operational vehicles and establish CNG refueling facilities within their premises.

Though the initial capital outlay of the project may be high, it is, however, anticipated that the viability of the project is realizable in the shortest possible time. It is hoped that the decades ahead will witness a great increase in the number of motor vehicles as a result of improved living conditions of the inhabitants. This will invariably lead to optimization of the CNG filling/refueling stations.

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