Gastech 76

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GASTECH 76

INTERNATIONAL LNG & LPG CONFERENCE

TIMETABLE

Co-ordinating *Chairman: Dr. John J. McKetta, The E.P. Schoch Professor, Chemical Engineering Department, The University of Texas, Austin, Texas.

CONFERENCE PRESENTATIONS

Tuesday, October 5, 1976
Session 1.

1. A role for LNG in the USA energy system	Leonard W. Fish, Senior Vice President, Planning, American Gas Association, Arlington, VA
2. The natural gas industry in Nigeria	Dr. T.I. Obiaga & G.N. Bhat, Department of Chemical & Petroleum Engineering, University of Benin, Nigeria.
3. Export policy for Canadian natural gas	Rolfe L. Colpitts, Vice President, Energy, Lalonde, Girouard, Letendre and Associates, Montreal, Canada.
4. LNG for California	R.G. Terry & J. Aspland, Pacific Lighting Corp., Los Angeles, California.

Wednesday, October 6, 1976
Session 2.

	Chairman: William R. Connole, Connole & O'Connell, Washington D.C.
5. The need for an effective policy on US gas imports	Panel Session: Speakers from Federal Power Commission; Gorman C. Smith, Federal Energy Administration; State Department; George D. Carameros Jr., El Paso LNG Co.
6. US gas shipbuilding — present and future prospects	Panel Session: Chairman: Edwin J. Hood, President Shipbuilders Council of America, Washington DC. Keynote Speaker: Robert J. Blackwell, Assistant Secretary for Maritime Affairs, Maritime Administration, Department of Commerce, Washington DC.

* Dr. McKetta will be assisted in co-ordinating the meeting by the individual session chairmen. All chairmen and speakers named in this schedule are listed in good faith but the Organisers reserve the right to designate substitute speakers and/or presentations if necessitated by unforseen circumstances.

Introduction

History and Development

The natural gas industry in Nigeria is inseparably linked with the development of the oil industry; however, whereas the latter has, in recent years, experienced unprecendented growth in capital input and productivity, the gas industry has remained relatively underdeveloped and even neglected.

The search for oil in Nigeria began in 1938 when Shell - d'Arcy Petroleum Development Company of Nigeria, later to become Shell-BP Petroleum Development Company of Nigeria Limited, obtained the first mineral oil concessions covering the entire area (928,200 sq km) of Nigeria. The Company operated without interference from competitors until 1955 when it was joined in the search for crude oil by Mobil Exploration Nigeria Limited, an affiliate of the American Socony - Mobil Oil Company. Since then, the number of oil companies granted exploration and mining concessions has greatly increased, and the search for oil in Nigeria has today become internationalized. Table 1 summarizes the distribution of concession areas among individual companies operating in Nigeria as of March 1971, while Figure 1 is an oil concession map of Nigeria for the same period. Since 1971, at least two more oil companies have joined in the search for oil and the Federal Government of Nigeria has since formed a national oil company which itself is directly involved in oil prospecting and mining. Thus, today, there are at least fifteen oil companies engaged in Nigeria both on the mainland and in the continental shelf in oil exploration and production.

December 1957 marked the beginning of commercial crude oil production in Nigeria. With it, natural gas development commenced because of the positive correlation between natural gas development and crude oil production, as until the present time all the natural gas produced in Nigeria is a by-product of crude oil production. Table 2 summarizes crude oil and natural gas production in Nigeria in the years 1958 to 1975. Starting with an annual production of 1.8 million barrels of crude, the figure climbed rapidly and by 1966, 152 million barrels of crude oil were produced. The crisis in Nigeria between mid 1967 and 1970 temporarily reduced the rate of production in 1967 and 1968. However, by 1969, spurred by new oil discoveries in the Midwestern region of Nigeria, and in off-shore wells, oil production quickly bounced back, to continue the spectacular upward trend. By 1974, oil production had reached an all time high of 795 million barrels annual production, placing Nigeria as the fifth largest oil producer among the OPEC countries. The growth of oil and natural gas production in the period 1958 to 1975 is illustrated graphically in Figure 2.

In Table 2 we see that the proportion of gas associated with crude oil is relatively high in Nigeria. The gas to oil ratio averaged 150 cubic meters per cubic meter of crude oil, or roughly 800 cubic feet per barrel of crude. Thus, at the present rate of crude oil production of 1.8 million barrels a day, 40 million cubic meters (approximately 1.4 billion cubic feet) of natural gas are produced daily as associated gases in Nigeria's oil fields. In 1974, with an annual crude oil production of 795 million barrels, natural gas produced in association with the crude amounted to 21 billion cubic meters or 730 billion cubic feet. According to the latest U. S. government report issued by the Federal Power Commission on world natural gas production, Nigeria is the eighth of the world's largest natural gas producers. Among the OPEC nations, Nigeria ranked third after Iran and Saudi Arabia.

Nigerian Natural Gas Potential

A study of the geological structure of Nigeria reveals, as Figure 3 shows, two principal components, the sedimentary formations of the Cretaceous, Tertiary and Quaternary Ages, and the crystalline rocks of Precambrian Age. Igneous and metamorphic rocks cover half the surface areas of Nigeria. Of these 80% is from Precambrian Age and the remaining 20% is younger intrusive rock and volcanic lava. These are rock formations not potentially productive of mineral oil and natural gas.

The other half of the surface area of Nigeria is covered with extensive marine and continental sedimentary rocks, the greater part of which is of marine origin. They occur principally in the southern part of Nigeria as well as along the Niger and Benue troughs. Of the three sedimentary types, the Tertiary sediments of the Niger delta which occur both onshore and offshore have formed the principal formations of oil discoveries. Strata of Cretaceous cycles, the oldest of the sedimentary rocks, have also yielded shows of oil and gas both in outcrops and in wells, and so the existence of Cretaceous oil and gas formations in southern Nigeria is a clear possibility, particularly in view of the fact that in Gabon and Senagal, crude oil has been discovered in similar geological formations.

On the other hand, Quaternary formations which occur as sands, clay and boulders in the Niger delta, and are found in Sokoto Province and the Chad basin in the North are not looked upon as potential formations for oil and natural gas.

From this brief review of the geology of Nigeria, it is apparent that there exists in that country abundant geological formations potentially productive of mineral oil and natural gas. The present prolific productivity, about 2 million barrels of crude oil a day accompanied by about 57 million cubic meters of associated gas, tends to support this view. One recent estimate of the country's petroleum reserves has been placed at between 11 - 14 billion cubic meters. According to this estimate, and at the average gas/oil ratio of 150, associated natural gas reserves is between 1,650 - 2,100 billion cubic meters. The U. S. Federal Power Commission report (Table 3) places the natural gas reserves at 1,422 billion cubic meters.

In a 1963 report to the United Nations, the Nigerian Ministry of Mines and Power grossly underestimated Nigeria's natural gas reserves at about 280 billion cubic meters. Significantly, however, that report attributed 80% of the total to gases not associated with crude oil. If this ratio remains correct today, then the actual Nigerian natural gas reserves would more properly be about 8 trillion cubic meters, which according to the U. S. FPC report (Table 3) would rank Nigeria as possessing the third largest share of the world's reserves, after the U.S.S.R. and Iran. Obviously, Nigeria's natural gas potential reserves are vast indeed.

Role of Natural Gas within the Energy Framework of Nigeria

(a) Total Energy Resources

Nigeria possesses an enviably large energy base in the form of almost all commercial forms of energy considered necessary for a dynamic economic prosperity and growth. These energy forms include crude oil, natural gas, coal, lignite, hydro power and radio-active minerals. Only rough approximations of the total energy potential are possible at the present time since the country's total potential has not been fully assessed; estimates derived from several independent sources are sometimes contradictory, and in many cases are deemed out of date. Nevertheless, relative orders of magnitude can still be established.

Table 4 is a summary of the estimated primary energy reserves of Nigeria. The total non-renewable energy resources (coal, lignite, crude oil, natural gas, radio-active minerals) amount to about 30 billion tons equivalent of coal, t.e.c., in addition to about

19 million t.e.c. per year of hydroelectric power. Crude oil and natural gas command a dominant position in the reserve potential, accounting for 55 and 36 per cent respectively of the total (Figure 4). On a per capita basis,Nigeria, with an estimated population of 65 million, has energy reserves of 460 t.e.c. At present the yearly per capita energy consumption is about 0.03 t.e.c. and we see that the natural gas energy reserves alone are enough to sustain Nigeria's energy requirements for the next 60 years, even if energy consumption suddenly jumped 100 times the present values.

(b) Past and Present Role

Although, as we have seen, Nigeria possesses vast natural gas potentials and produces billions of cubic meters of it annually as associated gases from the oil fields, only a small percentage of that produced is utilized on a productive basis. Starting from 1963, natural gas consumption in Nigeria increased continuously from 28 million cubic meters to 574 million cubic meters in 1974. This represents 4.5% and 2.11% respectively of the total produced, the rest being flared (Table 5). In 1963, 90% of the total gas utilized was converted into electricity, but by 1974, only 37% of the gas being utilized was converted into commercial electric energy, most of the rest being used as fuel by the oil producers in the field. The 1974 natural gas utilization amounted to 28.5% of the total Nigerian electric energy production. The remaining 71.5% is shared between hydro-power (46%) and other thermal (coal, oil, diesel) forms (25.5%). In 1963, energy costs per kwh of generated electricity were, natural gas 0.2¢, and coal and fuel oil 0.45¢. It would appear that there should hardly be any competition between natural gas and other fossil forms of energy. No comparative energy costs between natural gas and hydro-power are available at present, but Nigeria is presently laying emphasis on hydro-power (46%) as a source of electric energy.

(c) Future Role

The role of natural gas in Nigeria's future energy framework will depend primarily on the development of a coherent and detailed energy policy, and to a lesser degree on the impulse to satisfy immediate energy needs resulting from increased economic activity. The National Electric Power Authority, NEPA, is the body charged exclusively to generate and distribute electricity in Nigeria and its choice of the use of primary energy resource to achieve its aim will govern the share of electric energy production from natural gas. In its ten year development programme starting from 1975, NEPA plans to greatly increase the total generating capacity to meet rapidly growing demands. It envisages, at the end of that plan period, to be able to generate about 6,500 MW of power. Only about 1000 MW or 15 per cent will be produced in gas turbines fired with natural gas. 5000 MW will accrue from hydro-power and the rest from other fossil thermal plants. The total natural gas consumption for electric power generation will probably quadruple the present values, but it will still be a meagre 8% of the total production at today's production rates.

It would appear therefore, that natural gas will play a diminishing role in the electric power production in future while hydro-power will supercede. This may be a delibrate policy designed to free natural gas to be used elsewhere in other sectors of the Nigerian economy.

Natural Gas and Industrialization in Nigeria

If natural gas is underutilized in the energy producing sector in Nigeria, its level of utilization in the industrial sector for process energy is dismal, while its use as feedstock energy is non-existent. At present, only eight industrial plants, including Nigeria's only refinery in Port Harcourt, derive their process energy from natural gas. In 1974, the combined consumption of natural gas in this manner amounted to about 37 million cubic meters, just about one day's total production and represents only 6% of the total natural gas consumption. The industries are supplied through a network of gas pipelines whose total length measures less than 100 kilometers as they are found in three locations (Aba, Port Harcourt and Ughelli) all within 30 kilometers of oil producing wells.

As we have seen, there is in Nigeria a competition between the various energy forms. An analysis of this competition in 1966 showed the extent of the market open to natural gas to be at least 280,000 m^3 a day, if natural gas could be distributed by pipeline. The largest industrial centres are in western Nigeria and Lagos which lie about 320 kilometers from the nearest oil wells. The problem is, therefore, justifying the construction of a pipeline from the fields to where the market exists.

In a 1963 report to the Nigerian government, the Canadian Industrial Gas Limited suggested a well head gas price of 5k per 1000 ft^3 (about 3.3¢, per 1000 ft^3) in order to ensure profit to energy-intensive industrial consumers. On a price per ton equivalent of coal basis, this works out to ₦1.34/ t.e.c. or $2.01/ t.e.c. This price structure appears quite low considering that the cost of natural gas at that time to the industrial consumers was 6 to 7 times higher.

In the same year, another report by Arthur D. Little Inc. suggested the following as viable transportation costs for transporting natural gas over great distances by pipeline (costs in pence; 120 pence = ₦1.00 = $1.50).

10^6 ft^3 per day	Miles/Costs			
	20	50	100	200
1	102.5	102.2	102.1	101.5
10	25.7	20.1	16.8	14.75
100	13.7	10.2	8.33	6.75

Assuming an industrial demand for natural gas of

280,000 m^3 per day as previously suggested, and assuming pipeline distribution to the markets of Lagos and western Nigeria, the added cost due to transportation by pipeline would be 101.5 pence or 0.045k (0.03¢) per t.e.c. It is very probable that transportation costs would have risen since the time of that report to ten times as much, but that still adds only 0.45k to the cost of gas delivered to industries in Lagos.

Taking the well head price of natural gas at 50k per 1000 cubic feet, that is ten times the price recommended in the Canadian study, and assuming ten times higher transportation costs, the price of natural gas delivered by pipeline to Lagos from the oil fields of mid-western Nigeria would amount maximally to ₦15.00 ($22.50) per t.e.c. This is to be compared with the present price of electricity to industries which averages to about ₦53.29 ($79.94) per t.e.c. It is obvious, therefore, that the real bottleneck in the more intensive utilization of natural gas process energy is the inadequacy of pipeline network in Nigeria.

In addition to energy utilization, the value of Nigerian natural gas can be significantly upgraded if used as the raw material feedstock for the manufacture of petrochemicals. The range of end uses which can be developed based on natural gas utilization as feedstock is indeed very vast, as demonstrated by the U.S. petrochemical industry, but in the initial stages of development, petrochemical manufacture will probably be restricted only to the bulk chemicals. Chief among these are ammonia for fertilizer manufacture, vinyl chloride monomer, ethylene and their polymers.

In 1969, a Japanese report to the Nigerian government recommended the setting up of nitrogenous fertilizer manufacturing facility to be rated at 339,900 tons of urea per year. The choice of urea was on the premise that most of the product would be for the export market (projected demanded for urea in Nigeria 60,000 tons/year to 1980) and urea has high marketability as an export. Of the three possible raw materials available, that is natural gas, naphtha and LPG, natural gas is favored because of its abundance and relative low cost. A plant of the size contemplated would require natural gas supply of 680,000 m^3 a day, hardly a dent on the daily production.

The same report recommended a natural gas based petrochemical complex which would produce PVC (30,000 tons/year) and low density polyethylene (20,00 tons/year) using the ethane and propane components. The Nigerian natural gas has a chemical composition which is well suited for this (Table 6).

The ethane and propane contents average 6.2% and 4.7% respectively. These are comparable to the United States natural gas (Table 7) which has so successfully been used as petrochemical feedstock.

Such a plant as envisaged here would require about 2 million cubic meters of natural gas per day about 5% of the total daily production. After extraction of the heavier components, the stripped natural gas could be supplied in part as raw material to the ammonia (urea) plant.

The abundant natural gas resources available in Nigeria if properly utilized, can thus give a big impetus to industrialization in Nigeria, supplying both feedstock energy to petrochemical industries as well as processes energy to all other industries including such heavy and necessary industries as steel production.

Markets and Marketing of Nigerian Natural Gas

The internal markets available to the Nigerian natural gas have been discussed in terms of energy production, process energy and feedstock energy. Natural gas production from the oil wells is so prolific that there is more than enough to satisfy all of Nigeria's internal needs with a great deal more left for export, if markets could be found for it.

It is for this reason that two 1 billion cubic feet per day LNG plants are now being negotiated for construction at Bonny, a port near the oil fields.

Nigerian natural gas export appears destined for the American market. For European markets, Libya and Algeria are clearly at an advantage especially in Southern Europe; in the northern parts, the discovery of North Sea gas sealed hopes of supplying that market and in the eastern part the 'Friendship pipelines' now bring natural gas from the U.S.S.R. The long haul to Japan makes natural gas supply to that country economically unattractive and in South America, Venezuela is well poised geographically to deliver not only LNG but also pipeline gas (Figure 5).

Alternatively, therefore, Nigeria's natural gas could be upgraded by producing liquid ethylene locally and exporting it to Europe where there is a well coordinated network of ethylene pipeline. This arrangement will greatly compliment LNG exports and enhance the value of Nigeria's natural gas.

Another viable option is the conversion of the methane component, by microbial action, to single cell proteins (SCP). Nigeria, like most developing countries, is protein defficient. The manufacture of SCP would