Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 8, August - 2015

Natural Gas Transmission And Distribution In Nigeria

Anyadiegwu C.I.C.
Department of Petroleum Engineering
Federal University of Technology, Owerri
Nigeria
drcicanyadiegwu@yahoo.com

Ohia N.P.
Department of Petroleum Engineering
Federal University of Technology, Owerri
Nigeria

Ukwujiagu C.M.
Department of Petroleum Engineering
Federal University of Technology, Owerri
Nigeria

***Abstract*—Natural gas as a raw material is produced in large quantities in oil and gas wells in Nigeria. Although produced in large quantities, the lack of effective transmission and distribution systems results in a greater percentage of this energy source being flared, thereby resulting in wastage of valuable and scarce foreign exchange for the country. In an attempt to curtail this colossal wastage of energy and valuable raw material, the Federal Government of Nigeria passed a law on gas flaring. This yielded little or no result since the oil producing companies found it more convenient and economical to flare the produced gases. Based on the above premises, a pipeline network for natural gas transmission and distribution for Owerri city was designed with the aid of pipeline simulation software, PIPEPHASE™. In this work, the gas distribution network was designed to convey gas to at least four district regulatory sections, DRS1, DRS2, and DRS3 & DRS4 respectively. DRS1 would supply 168.062 psi pressure gas to Amakohia/Akwakuma regions, DRS2 supplies gas to Ikenegbu/Awaka areas, DRS3 would then take gas Naze/Ihiagwa communites whereas DRS4 supplies Obinze terminal. The distribution network was designed to have a capacity of 12.52MMscf/D based on an estimated gas supply/demand for twenty years in Owerri city. The distribution pattern to the residential areas was based on population density of the city. The total length of the network was 73.94 miles (119 km). The maximum and minimum pressures specified at any point in the main pipeline were 200 and 99.94 psi respectively. The design was also carried out within diameter range 6.625-in and 4.5-in of the transmission and distribution pipeline. The design was performed for inlet pressures of 637.09 psi.**

Keywords—PIPEPHASE, natural gas, transmission, distribution, pipeline.

I. INTRODUCTION

Natural gas is a vital component of the world's supply of energy. It is colourless, shapeless and odourless in its pure form. The principal compositions are methane, ethane, propane, butane and pentane. The non-hydrocarbon gases that may be associated with natural gas include water vapour, carbon dioxide, helium, hydrogen sulphide and nitrogen [1].

Natural gas is one of the cleanest, and most important of all energy sources. Around three quarters of the natural gas deposit is found separate from crude oil or non-associated gas. The rest is found in association with crude oil or associated gas [2].

Natural gas, a fossil fuel comprised mostly of methane, is one of the cleanest burning alternative fuels [3].

Worldwide demand for clean, reliable and affordable energy has been on the increase. Natural gas has played an important role in the supply of daily energy requirement for industrial and domestic use. The total global to annual gas consumption is forecasted to rise to 2.9 trillion cubic meters by 2015 accounting for approximately 27% of the total primary energy supply [1].

Wells drilled specifically for natural gas production are referred to as natural gas wells. The composition of these wells contains little or no oil. There are three main types of conventional natural gas wells [4]. They are:

(i) - Associated gas well in which oil and gas exist,

(ii) - Non-associated or dedicated gas well which is drilled specifically for natural gas and contains little or no oil,

(iii) - Condensate wells which are wells that contain natural gas, as well as liquid condensate. This condensate is a liquid hydrocarbon mixture that is often separated from the natural gas either at the wellhead, or during the processing of the natural gas.

Depending on the type of wellbeing drilled, completion may differ slightly based on the circumstances associated with the well. Natural gas, being lighter than air, will naturally rise to the surface of a well.

Nigeria is home to Africa's largest gas reserves. Nigeria's gas sector holds significant potential. It has huge gas reservoir which is reputed to be the 7th largest reserve in the world. The estimated proved plus proven reserve is 185tcf and combined total of proved, probable and possible reserve is 300tcf [5]. The gas resources are largely unexploited with total gas production estimated at 4.6bcf/d with nearly 55% being flared and the balance split between reinjection, NLNG feedstock, and internal fuel usage and a small percentage marketed as LPG. Nigeria gas is concentrated in the Niger delta which covers an area of about 41000 square miles. Of the total Nigeria's proven reserves, 70% is located on land while 30% can be found off-shore. About 60% is located east of the Niger while the rest are west of the river Niger. Experts estimate that the reserves locked in the Nigerian soil is enough to last as long as 500 years, fuelling our industries, homes and international airports [6].

Although produced in large quantities, the absence of adequate infrastructure and effective transportation and distribution systems results in a significant percentage of this gas been flared off, thereby resulting in wastage of valuable foreign exchange for the country. Nigeria gas sector is still at its infancy with significant opportunity for transformation if it is to deliver economic growth. Several barriers have delayed the pace of the sector's growth. Some of these barriers include; Weak/low pricing framework, Fiscal terms, Institutional/infrastructural arrangements, Legal and regulatory framework.

Izombe is a very rich oil and gas settlement with several matured and new oilfields being developed by Shell, Chevron and ADDAX. These 3 oil companies have been producing from several oil fields in this community since 1970. The processing of the produced crude oil is done locally at Izombe Flow Station before shipment to the international export terminal via several networks of pipelines. OML 124 covers an area of 74100 acres (300km^2) and contains two producing oil fields; Ossu and Izombe, which are operated as a common production area.

The prolific Chevron's JISIKE Oilfield that has produced hundreds of millions barrels of oil in the past 30 years is located in Izombe and is less than 10 km south of Abiaziem. Recently, several pool of oil reserves have been discovered in neighboring Awa and Awo communities thereby making nearby Abiaziem community to be highly prospective for oil and gas exploration. Based on historical drilling and production data published by Shell, Chevron and ADDAX, oil bearing formations in this region generally occurs between 900 m to 2500 m (i.e., approximately 2700 ft to 8000 ft) [7].

Flaring of gas is turning a beneficial asset into a wasting resource. More than half of the associated gas produced in this region is flared. Why are these associated gases been flared? The various oil producing companies in this region has been compelled by a combination of historical, economic, and geographical factors to flare gas. They include the following:

- - Limited numbers of appropriate reservoirs conducive for gas reinjection/storage and the economies of doing so.
- - Huge cost of developing major and inter-connecting network of gas pipelines.
- - Low technological and industrial base for energy consumption in the country
- - Limited regional gas market.
- - Inadequate fiscal and gas pricing policies to encourage investment.
- - Difficult terrain of the region which hinder the gas gathering process.

2. DESIGN OVERVIEW

The transport of natural gas from a gas well to our homes and businesses mainly requires an extensive network of interconnected pipelines, designed to move natural gas quickly and effectively, sometimes over great distances. Pipelines are one of the safest means of distribution of energy because the pipeline system is fixed and underground. There are essentially three main types of transportation pipelines: gathering pipelines, transmission pipelines, and distribution pipelines.

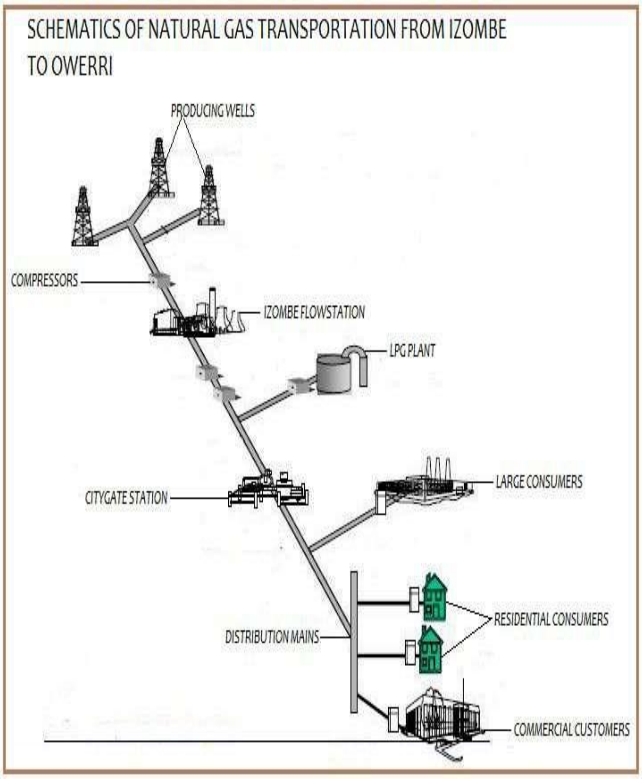

Figure 1: Schematics of Natural gas transport

From figure 1, raw natural gas produced from wells is collected through a series of low-pressure pipelines referred to as a gathering system. Gathering pipelines, in turn, link natural gas production areas to central collection points. The pipelines in a gathering system start out small. Then, as gathering lines from different wellheads converge, the downstream lines become larger, to transport the growing volume of gathered gas. A complex gathering system can consist of thousands of miles of pipes, networking upwards of 100 wells in an area. Sometimes natural gas from a particular well may have a high sulphur and carbon dioxide content, as mentioned previously, being very corrosive. If so, special gathering pipes must be installed to ensure its safe transportation to a gas processing facility.

Then from the gas processing plant, natural gas is gathered into increasingly larger pipelines, almost always underground, until it reaches the large transmission pipelines where it is often transported over large distances. Natural gas transmission pipeline systems are generally the middle transportation link between gathering systems and distribution systems. They transport large volumes of natural gas from production and gathering areas to processing and treatment facilities and from there sometimes thousands of miles to other areas where it is provided to electric power generating stations or to local distribution companies.

Finally, from the transmission pipelines, the gas flows into a low-pressure distribution system. Local natural gas distribution pipelines are usually smaller in diameter than natural gas transmission pipelines and many are constructed out of plastic rather than steel. They consist of smaller service lines that are normally installed underground, usually along or under streets and roadways.

Consequently, according to Ikoku C. U (1984), there are varying factors that affect the design of a gas transmission network. Some of these factors include;

- ✓ Optimum pipeline diameter
- ✓ Pumping horsepower
- ✓ Nature and volume of gas to be transported
- ✓ Transmission area
- ✓ Type of terrain to be crossed
- ✓ Maximum elevation of the route
- ✓ Location of the producing field
- ✓ Gas inlet and outlet pressure
- ✓ Pipeline specification- relative roughness, yield strength

3. DATA PRESENTATION

The properties and chemical compositions of the gas from Izombe field are shown in Tables 1 and 2.

TABLE 1: STOICHIOMETRIC PROPERTIES OF GAS FROM IZOMBE FIELD.

Properties	Value
Relative molar mass	18
Carbon content, weight %	73.3
Hydrogen content, weight %	23.9
Oxygen content, weight %	0.4
Hydrogen/carbon atomic ratio	3.0
Relative density, 15◦C	0.72
Boiling point, ◦C	−162
Auto ignition temperature, ◦C	540–560
Octane number	120–130
Methane number	69–99
Stoichiometric air/fuel ratio, weight	17.2
Vapor flammability limits, volume %	5–15
Flammability limits	0.7–2.1
Lower heating/calorific value, MJ/kg	38–50
Stoichiometric lower heating value, MJ/kg	2.75
Methane concentration, volume %	80–99
Ethane concentration, volume %	2.7–4.6
Nitrogen concentration, volume %	0.1–15
Carbon dioxide concentration, volume %	1–5
Sulfur concentration, weight %	ppm <5
Specific CO2 formation, g/MJ	38–50

TABLE 2: DETAILED CHEMICAL COMPOSITION OF THE GAS

Component	Mole fraction (*y*)	Ppc (psi)	Tpc (K)
Methane	0.847	667.8	343
Ethane	0.0586	707.8	549.8
Propane	0.022	616.3	665.7
Butane (i)	0.0035	550.7	734.7
Butane (n)	0.0058	529.1	765.3
i-Pentane	0.0027	490.4	828.8
n-Pentane	0.0025	464.0	781.11
Hexane	0.0028	436.9	913.4
Heptanes	0.0028	396.8	972.5
Nitrogen	0.0345	493	227.3
Carbon (iv) oxide	0.0130	1071	547.6
Hydrogen sulfide	0.0000	1306	672.4

4. GAS TRANSMISSION DESIGN

Calculation of key parameters of the transmission gas

4.1 Specific gravity (y_g) - The specific gravity is given by

$$Y_g = \frac{M}{M_{air}} \text{---(I)}$$

Where;

M-molecular weight of the mixture and is given by;

$$M = \sum_{i=1}^{n} M_i y_i \text{-------------------------------(II)}$$

M_i - molecular weight of component
iy_i - mole fraction of component I
n- Total number of components.
M_{air} – Molecular weight of air ≡ 28.97
Thus the specific gravity of the transmission gas is 0.707

4.2 Pseudocritical Properties (P_c, T_c)

$$P_c = \sum_i^n P_{ci} y_i \text{-------------------------------(III)}$$

$$T_c = \sum_i^n T_{ci} y_i \text{-------------------------------(IV)}$$

Where;

P_{ci}, T_{ci} - critical pressure and critical temperature of component i, respectively;
The reduced pressure and reduced temperature are defined as stated in equation V and VI

$$P_r = \frac{P}{P_c}\text{---(V)}$$

$$T_r = \frac{T}{T_c}\text{---(VI)}$$

Where;
P_r , T_r- reduced pressure, reduced temperature
P_c , T_c - critical pressure, critical temperature of the gas

4.3 Determination of Design Capacity

Contrary to popular opinion, natural gas is not sold per unit volume but rather per unit energy that can be produced by burning the gas. End-use consumers of gas are interested in the heat energy that combusting the gas will generate. The heat energy of a particular gas stream is measured by units of calorific value, which is defined by the number of heat units released when a unit volume of the gas burns. Typical units of calorific value are British thermal units (Btu), joules (J), and kilocalories (kcal).
Natural gas demand has increased rapidly recently. In many sectors of everyday life, natural gas proves its significant importance through a number of uses, making it a vital component of our lives. Natural gas is used today:

- Residentially- cooking fuel, refrigerant, water heating
- Commercially- liquefied petroleum gas
- Industrially- cement production, fertilizer and steel industries.
- In electricity generation- independent power projects (IPP)
- Other applications, mainly including the transportation sector (LNG)

But for the purpose of determination of the overall design throughput of the gas network, only Gas for domestic utilization is considered. The reason for this is to allow for a time-lag for other key sectors to start utilizing natural gas as their principal fuel source.

4.4 Population Project

The gas demand/supply forecasts are based on the population census figure 2006 of 401,873 persons in Owerri and growth rate of 7%.
The multiplying factor MF, can be estimated using equation VII

$$MF = e^{\frac{rn}{100}} \qquad (7)$$

Where; MF- multiplying factor
r- Rate of growth n- Current period of forecast
Population projection of 20years = MF × 401,873

Current period of forecast, n = current year + projection year – census year

$= 2014+20-2006=28yrs$

Rate of growth, r =7%

$MF = e^{\frac{7*28}{100}} = 7.099$
Population of Owerri in 2034 = 401,873 × 7.099
= 2,852,896 persons

4.5 Gas Demand/ Supply

* 12.5Kg of gas is consumed by a family unit of 4 in 1month

* Number of family units in Owerri = $\frac{2{,}852{,}896}{4}$

= 713,224 ≅ 713,000
Family units * 713,000 family units consumes – 12.5 × 713,000 = 8,900 MT of LPG per month
Conversion factors:

1MT of LPG = 42.84×10^{6} BTU

6,600MT of LPG = 3.81×10^{11} BTU
But 1000BTU = 1SCF of gas

3.81×10^{11} BTU = 381 MMSCF
713,000 family units consumes 381 MMSCF natural gas per month
Conversion per day;

$$381\,\frac{MMSCF}{month} = 381\,\frac{MMSCF}{month} \times \frac{1\ month}{30.42\ days} = 12.52MMscfd$$

*- Assumptions arbitrarily assigned

4.6 Pressure Drop Estimation Using Weymouth Equation

$$Q = 18.062\,\frac{T_b}{P_b}\left(\frac{P_1^2 - P_2^2}{yZTL}\,D^5\right)^{0.5} \qquad (8)$$

Q- 12.52 mmcfd = 522,000 ft3/hr

D =$6\,{}^{5}/_{8}$ in, T_{avg} = 60°F, T_b, P_b = 60°F, 14.7psia

L = 22miles, Z=0.998, y= 0.707

Calculating for ($P_1^2 - P_2^2$) yields;

$$P_1^2 - P_2^2 = 365{,}878$$

Pressure required at the city gate station 200psi, i.e. P_2 = 200psi

$$P_1 = (365{,}878 + 200^2)^{0.5} = 637.09\ psi$$

Requirec VII sure at Izombe flow station = 637.09 p..

5. RESULTS AND DISCUSSIONS

Figure 2 is a map that shows the proposed transmission pipeline from Izombe to city gate station.

Figure 2: Proposed transmission pipeline from Izombe to City Gate Station. {Google maps}

5.1 GAS DISTRIBUTION

From the city gate station, gas of pressure 200psig flows through the distribution mains to 4 district regulatory station (DRS) that would in turn supply gas to 2 dispatch stations located in minor estates and towns. The district regulatory stations are labelled DRS1, DRS2, DRS3 and DRS4. The gas throughput for each regulatory station is given in table 3.
NB- DRS1 & DRS2 were assigned higher gas volumes due to the relatively high demand for gas in these regions.

TABLE 3: DISTANCE OF EACH DRS FROM THE CGS AND THE GAS THROUGHPUT FOR THE REGULATORY STATIONS

DISTRICT REGULATORY STATION	DISTANCE FROM CITY GATE STATION	GAS THROUGHPUT
DRS1	17Km	3,017 MCFD
DRS2	22Km	2,640 MCFD
DRS3	25Km	2,074 MCFD
DRS4	20Km	1,690 MCFD

To obtain the diameter of pipeline to be used and pressure available at each District Regulatory Stations, PIPEPHASE™, pipeline simulation software was utilized. The diameters are presented in Table 4. Result from PIPEPHASE™ shows;

TABLE 4: DIAMETERS OF THE PIPELINES AND THE PRESSURE DROPS ACROSS THEM.

DISTRICT REGULATORY STATION	DIAMETER OF PIPELINE	PRESSURE DROP ALONG LINE
DRS1	6.625-in	31.938psi
DRS2	6.625-in	31.62 psi
DRS3	4.5-in	89.354 psi
DRS4	4.5-in	100.06 psi

5.2 Network Configuration Using PIPEPHASE™

PIPEPHASE™ provides a comprehensive and rigorous modelling capability for steady state, multiphase flows in oil and gas gathering networks and pipeline systems. It offers the power and flexibility to model applications ranging from single well sensitivity analyses of key parameters, to a multi-year planning study for an entire production field. The configuration of the network of lines using PIPEPHASE is as shown in Figure 3.

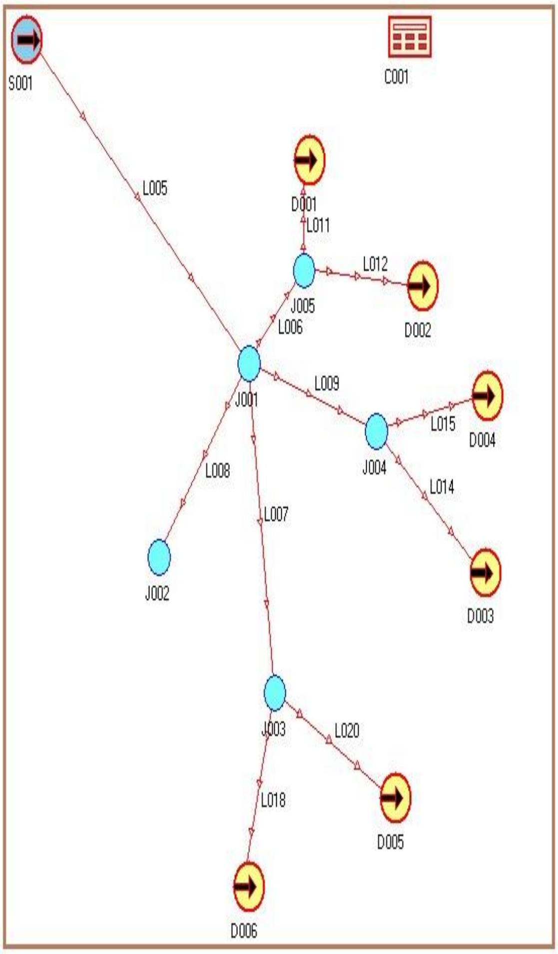

Figure 3: Network Configuration using PIPEPHASE

5.3 Network Summary

The network summary for the gas transmission and distribution lines is shown in table 5.

TABLE 5: PIPEPHASE SIMULATION RESULT

Node	Pressure available, psi	Pipeline	Length, km
S001	528.49 psi	L005	35
J001	200 psi	L006	17
J002	99.94 psi	L007	25
J003	110.646 psi	L008	20
J004	168.38 psi	L009	22
J005	168.062 psi		

5.4 Linear Representation of Pressure Drop with Distance

The linear representation of pressure drop with distance is as shown in Figure 4.

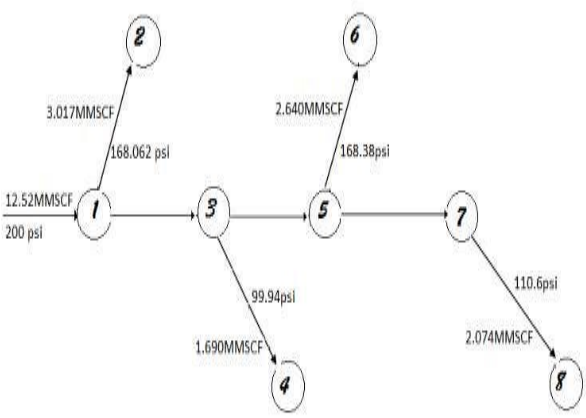

Figure 4: Linear Representation of Pressure Drop with Distance

5.5 Technical Considerations

The volume of gas allocated to each region is proportional to the comparative gas demand for each of the four main district considered for gas distribution in this project. As seen from the network configuration in figure 5, about 32% of the total gas throughput is delivered to DRS 1, whereas DRS2, DRS3 and DRS4 receive about 28%, 22% and 18% respectively.

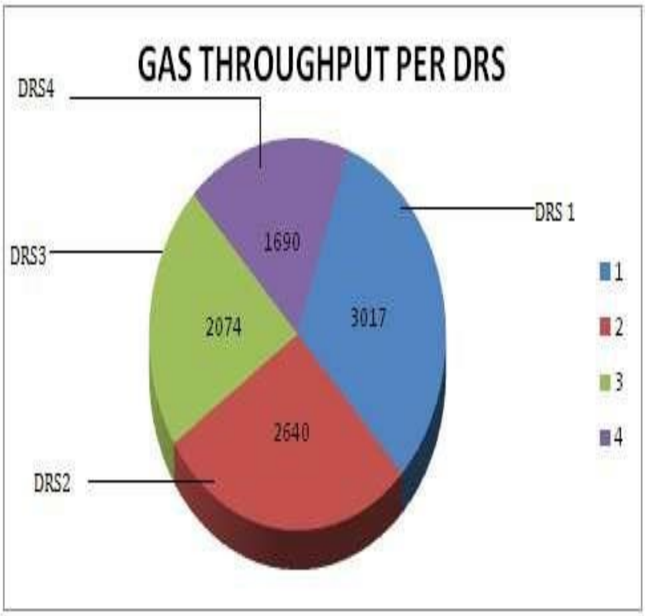

Figure 5: Gas throughput for each District Regulatory Station

6. CONCLUSION

Technical feasibility of the project is established when the gas reserves at the various wells in Izombe field is sufficiently capable of meeting the gas demand for transmission over the next 20years. Also the gas inlet pressure available must be enough to take the gas through the network to the various district regulatory stations. Furthermore, the gas properties at the field should be moderate and require very little conditioning to meet sales gas specification.

Result from calculations of domestic gas capacity reveals that approximately 713,000 family units in Owerri would need approximately 12.52MMSCF of gas daily. Current daily production of associated gas at OML 124, Izombe flow station is at 50,734MMSCFD. This implies that only about 25% of the current daily gas production would be enough for our transmission project. Secondly, over the span of 20 years, a total of 91,440MMSCF of gas would be consumed by 713,000 family units in Owerri. Current proved reserve for the field is about 2,000,000MMSCF of associated gas. This translates to mean that the volume of gas produced would be sufficient to feed the transmission network for over 200 years assuming a fixed demand of 4600MMSCF per annum.

The gas is presently produced as associated gas and is characterized by 0.707 specific gravity and 0.998 compressibility factor. The gas pressure at wellhead is presently at 3500 psi and 110^{0}F. With this pressure, the gas can be transported to over 500miles without a booster station. Thus for Owerri at only 22miles from the field, regulators are required to reduce the pressure to the pipeline inlet pressure of 350psi.

REFERENCES

[1] Anyadiegwu C.I.C. (2012): Development and Conversion of Depleted Reservoirs for Underground Natural Gas Storage in Nigeria. Thesis submitted to the Postgraduate School for the award of Ph.D. in

Petroleum Engineering with Federal University of Technology, Owerri.

[2] Natural Gas Supply Association (2004): Natural Gas Council Statement on NERC Natural Gas-Electric Interdependency Assessment, Washington DC.

[3] United States Department of Energy (USDOE) (2013): Transmission, Distribution and Storage, Retrieved from http://en.wikipedia.org/wiki/Natural_gas_storage.

[4] Ikoku C.U. (1984): Natural Gas Production Engineering, John Wiley and Sons, New-York, U.S.A.

[5] Excel U.T.O (2010). Nigeria gas master plan; strengthening the Nigeria gas infrastructure blueprint as a base for expanding regional gas market. NLNG, Bonny Island, Nigeria.

[6] Igwe G. (2011): Natural Gas Transmission and Distribution in Nigeria. Daily Trust, 24th July, 2011. Retrieved www.dailytrust.com.ng.

[7] Addax Petroleum (2009). Annual information form for the year ended December 31, 2008. March 4, 2009.

NOMENCLATURE

Bcf/d = billion cubic feet
BTU = British thermal unit
D = diameter
DRS = district regulatory section
Ft = foot
ft^3/hr = cubic foot per hour
g/MJ = gram per thousand joules
i = component
in = inch
IPP = independent power projects
K = kelvin
Kg = kilogram
Km = kilometre
km^2 = square kilometre
L = length
LPG = liquefied petroleum gas
m = metre
M_{air} = molecular weight of air
MCFD = million cubic feet per day
M_i = molecular weight of component
MF = multiplying factor
MJ/kg = thousand joules per kilogram
MMscf = million standard cubic feet
MMscf/d = million standard cubic feet per day
MT = thousand tonne
n = total number of components
n = current period of forecast
NLNG = Nigerian Liquefied Natural Gas
P_1 = Required inlet pressure at Izombe flow station
P_2 = Pressure required at the city gate station
P_b = base pressure
P_c = critical pressure
ppm = parts per million
P_r = reduced pressure
psi = pound per square inch
Q = flow rate
r = rate of growth
scf = standard cubic foot
tcf = trillion cubic feet
T_b = base temperature
T_c = critical temperature
T_r = reduced temperature
US DOE = United States Department of Energy
y = mole fraction
y = specific gravity
Yg = gas specific gravity
Z = gas deviation factor
% = percent
◦C = degree Celsius
^{0}F = degree Fahrenheit