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Innovative Gas Utilization Model and Risk Assessment Strategies for Marginal Oil and Gas Fields in Nigeria

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Abstract

Marginal Field Operators (MFOs) in Nigeria are susceptible to multiple systemic problems and fundamental issues which have hampered successful development of the field activities into lucrative ventures. These issues have caused undue delay and huge setback in operational activities, thereby leading to deferred revenue. In order to overcome these challenges, there is a need to explore an exceptionally efficient way that will place these operators in advantageous positions for consistent productivity and proficient service delivery, for overall economic growth and development. Hence, the aim of this study was to overcome some of the systemic problems in the oil and gas industry by creating an "Innovative Gas Utilization Model and Risk Assessment Strategies for Marginal Oil and Gas Fields in Nigeria". This study developed the "Quicksearch" software package which uses a material balance principle to estimate the volumes of gas utilized, that is, the quantity used as fuel gas and quantity converted to liquid products with a simplified Excel-based tool. This resolved production operation challenges through timely reporting of gas utilization and flaring volumes to the regulators. In addition, the operationally safe and user friendly tool prevented frequent shutdown of operations connected to the maintenance of faulty gas transmitters, mostly those without by-pass process lines, and ensured huge savings from OPEX associated with gas meter calibration and maintenance. The paper also, presents evacuation strategy with a robust Risk Assessment Plan (RAP) which is driven by well-articulated Community Affairs, Safety, Health, Environment and Security (CASHES) Policies to ensure unconstrained crude oil production and evacuation. The invention of multiple crude oil movement tracking data sheets deployed in this research work made it possible to predict or forecast accurately, the exportable crude oil volumes that will eventually get to the final export terminal, which ultimately determines the revenue that gets to the operator, after the crude oil lifting process. This is a major improvement, in terms of crude oil shipment to the terminal, when compared with crude oil pipeline that is vulnerable to periodic attacks, in Nigeria.

1. Introduction

Marginal Field (MF) is a field that has been discovered and left unattended for a period of not less than 10 years from the date of first discovery [1]. The term "marginality of a field" is subjective, but whether it is untapped, abandoned or partially depleted reserves, the most important factor is always the degree of profitable production. The Nigerian Association of Petroleum Explorationists (NAPE) defines marginal field as, "non-producing fields whose economics is not considered robust enough using conventional development methods under the prevailing fiscal regime" [2]. However, from an economic stand-point, a marginal field is one that can be developed with marginal profit regardless of the actual size of the oil field, and so require special field development planning and reservoir management strategies in order to yield acceptable returns on investment (ROI). Marginal oil fields in Nigeria are categorized based on surface terrain and the typical range of minimal recoverable reserves required for profitable production as follows:

1. Onshore Land (2 – 5 MMSTB).
2. Onshore Swamp (7 – 20 MMSTB).
3. Coastal Offshore (12 – 25 MMSTB).
4. Continental Shelf Offshore (20 – 45 MMSTB).
5. Deep Offshore (> 40 MMSTB).

This shows that the deeper into water the higher the minimal recoverable reserve. An encouraging progress was recorded when 8 out of the 24 operators, in the 2003 categories, achieved First Oil in their various fields, despite the associated challenges and more operators are now at the verge of first oil. In the grand scheme of things, whether the field is abandoned or has partially depleted reserves, the most important factor is always the degree of profitability [3]. With changes in technological and economic conditions, a field may be brought into production for commercial purposes. The results from the 2003 licensing round fell short of expectations. A vast majority of marginal fields allocated were not able to achieve first oil for several years, with the Department of Petroleum Resources (DPR) threatening to revoke the licenses of 18 marginal field companies in 2015 [4]. The challenges of these MF companies include but not limited to: finance, technology, geological complexity of formations, cost of development and government policies. Other operational challenges include the inadequacy of gas meters at necessary nodal points in the four marginal fields under reference and burden of estimating the volumes of gas utilized by the various gas fired process equipment which necessitated the advent of "Quicksearch" software package. Prior to this innovation, most Marginal Field Operators depended predominantly on Daniel Measurement and Control with Daniel Orifice Meters and Gas Transmitters. In addition, most existing crude oil evacuation philosophy via trucking lack robust Risk Assessment Plan (RAP) and various intervention strategies in event of a mishap. This results into complete shutdown of operations and subsequent downsizing of the workforce, if the shutdown period extends beyond the limit Marginal Field Operators can accommodate, mainly in areas of payment of salary.

A safe tool is required to ensure daily report of gas utilized in terms of fuel gas volume and the quantity converted to liquid products: Liquefied Petroleum Gas (LPG), Propane and Condensate, in line with the regulatory reporting protocols. The frequent failures or breakdown of the Human Machine Interface (HMI) and the gas meters which lead to no gas report to the regulators and periodic shutdown of process due to unscheduled repairs were the major identified gaps. "Quicksearch" resolved these perennial production operations challenges, because it is system based and easily transferable to another system and very safe to operate. Furthermore, cost of maintenance and routine calibrations for data accuracy are saved under OPEX. "Guidelines for the establishment of a natural gas plant facility in Nigeria" now Nigerian Upstream Petroleum Regulatory Commission (NUPRC) [5].

However, there are systemic problems like deferred revenue orchestrated mostly by pipeline attack/vandalism which causes loss of revenues, loss of oil volume and undue exposure of process facility to hazards, to mention a few, need to be avoided to achieve optimal results. Unfortunately, most of these experiences were not published by the affected Marginal Field Operators, but were discreetly managed. See evidence or reference pictures in Plates (1 – 5). This article is expected to change the narrative.

Plate 1: Truck abandoned by pipeline vandals at PROW within OML XY in Niger Delta, undergoing inspection by the asset owner

Plate 2: Carefully vandalized 6" crude oil pipeline within OML XY, by criminals

Plate 3: Carefully installed valves and hoses on Oil Export Pipeline in OML XY, by vandals

Plate 4: Concrete casting after valve installation on crude oil pipeline by pipeline vandals

Plate 5: Valve securely mounted on crude oil export line by pipeline vandals.

2. Materials and Methods

2.1 Case Study – ENR Field

A study of a plant in ENR Marginal Field Flowstation was used as a case study for over a period of time. ENR Field is an onshore field located in the Central Niger Delta approximately 100km north-west of Port-Harcourt, Nigeria. It is a combination of a 10,000 BOPD capacity flowstation as shown in Figure 1 and a 25 MMSCF/D gas processing plant as shown in Figure 2. The measurement of natural gas produced is carried out by orifice meter, at the flowstation.

2.1.1 ENR Flowstation Piping and Instrumentation Diagram

Three major Headers: High Pressure, Low Pressure and Test Manifolds receive crude oil stream at the ENR Flowstation from all the producing Wells on stream from the Wellheads as shown in Figure 1. High Pressure Wells within the line pressure range of (200 – 500psi) are routed to the High Pressure (HP) Separator while Low Pressure Wells within the line pressure range of (50 – 250psi) are routed to the Low Pressure (LP) Separator, at the arrival manifold. Fluctuating well or well under test is routed to the test separator either High or Low Pressure Well from the test header, for stabilization and subsequent data acquisition. The 3 separators function either as 2-phase or as 3-phase separators.

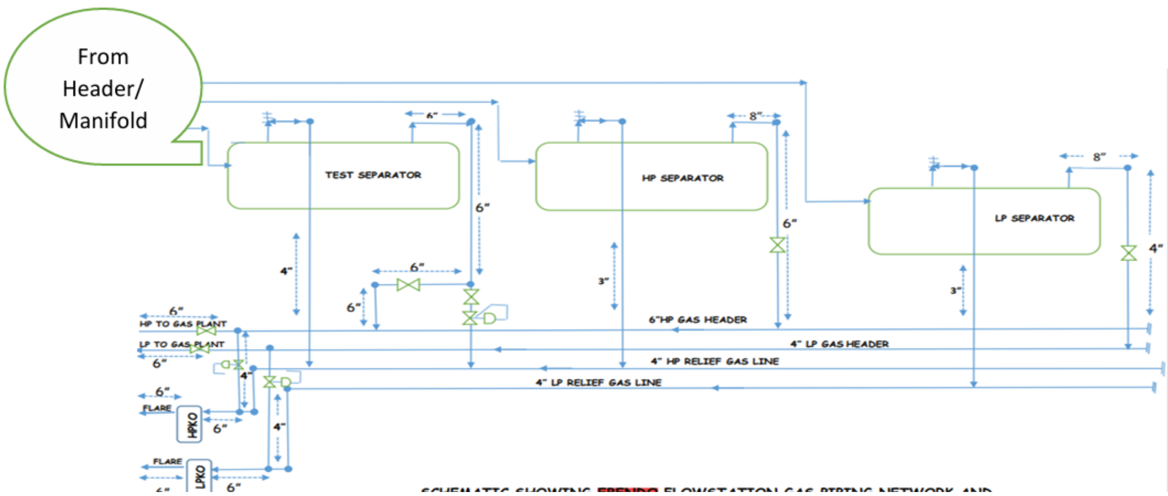

Figure 1: P&ID and Process [6]

2.1.2 Gas Plant Process Schematic

Process Configuration including Piping & Instrumentation Diagrams (P&ID) – 2016 and Process Flow Diagram (PFD), showing the detailed Material Balance and feedstock composition. The Gas Plant receives associated input gas from the ENR Flowstation in the Intermediate Pressure Compressor (IP Compressor #1 & #2) and the Low Pressure Compressor (LP Compressor) through the ENR Flowstation HP Separator and LP Separator Gas Discharge lines respectively as shown in Figure 2.

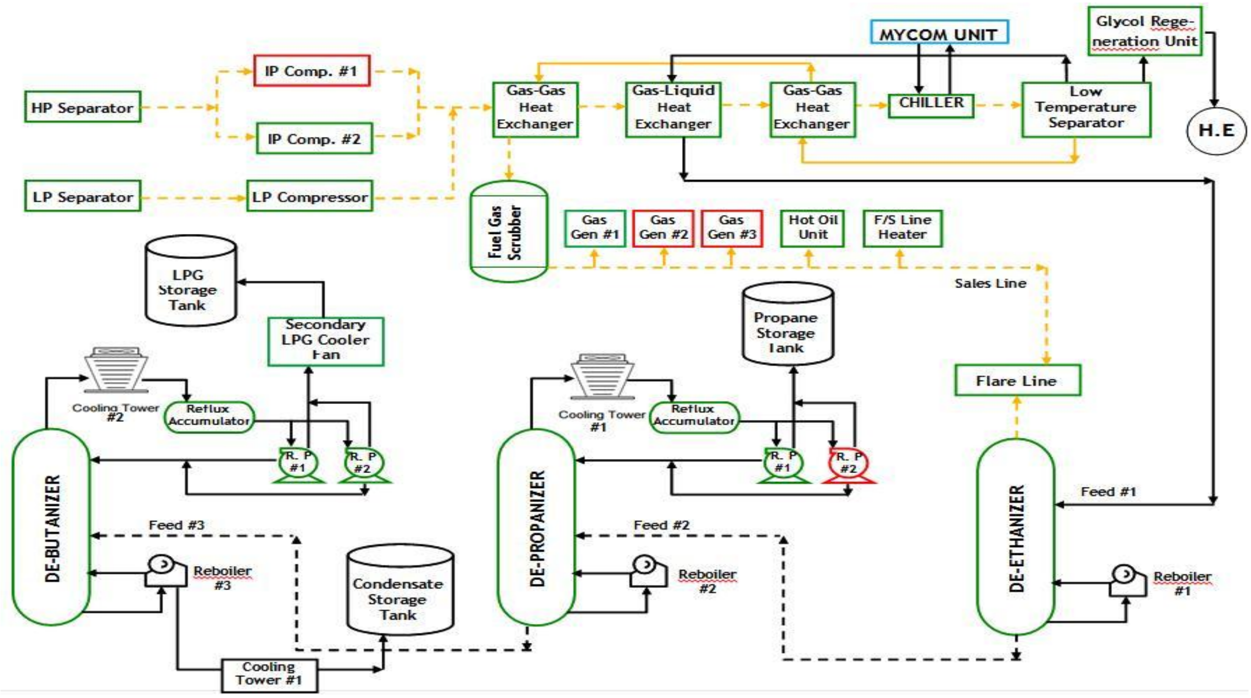

Figure 2: Gas Plant Process Schematic [7]

The IP compressor which is a single stage compressor compresses and discharges the gas into the process area through a 6" line. While LP Compressor compresses and discharges into the same header with IP Compressor through a 2" line, as shown in the Gas Process Schematic (Figure 2). The compressed gas from both compressors are received into the process area through 1st gas to gas heat exchanger, gas to liquid exchanger, 2nd gas to gas exchanger, the chiller and JT valve (where the gas is chilled/Liquefied) and the Liquefied gas is collected at the LTS (Low Temperature Separator). The Liquid Hydrocarbon (LHC) in the LTS is a mixture of Propane, Butane and Condensate. At the LTS Methane and Ethane traces which were not liquefied leave through the 2nd Gas to Gas heat exchanger 1st gas to gas exchanger to fuel gas line. This methane is tapped into the fuel gas scrubber.

From the fuel gas scrubber, Fuel gas is piped to all the gas fired process equipment: Gas gen sets #1, #2, #3, and IP Compressors #1 & #2 as well as the LP Compressor. Liquid Products: LPG, Propane and Condensate are stripped at various stages mainly from C_2 and above while the Lean Gas mostly C_1 is used as fuel Gas and excess flared. Gas composition analysis plays a vital role in the gas constituent distribution. C_1 composition is predominantly methane. This constitutes the greater percentage of the gas composition classified as the lean gas and proposed future plan is for CNG, IPP or Gas Sales Pipeline. The Liquid Products: LPG, Propane and Condensate are stripped at various stages mainly from C2+ and above, as shown in Figure 2. The Flowstation Line Heater is also fired by the same fuel gas from the fuel gas delivery line from the Gas Plant. The Hot Oil Unit at the gas plant also utilizes the same fuel gas. The Liquid Hydrocarbon at the LTS is level controlled through the gas-liquid exchanger into the De-ethanizer tower, at the De-ethanizer tower any carry over ethane is removed while the bottom product of De-ethanizer is also level controlled into the De-Propanizer tower, at the De-propanizer tower, Propane is vaporized, refluxed, condensed and collected at the Propane reflux tank. From the reflux tank it is level controlled into the Propane storage tank. The bottom product of the De-Propanizer tower is also level controlled into the De-Butanizer tower, where Butane is vaporized, refluxed, Condensed and collected at the Butane reflux tank, from the reflux tank it is level controlled into the Butane storage tank. The bottom products of the De-Butanizer tower are condensate, this is also level controlled through the condenser into the condensate storage tank. The condensate tank also serves as Condensate stabilizer. From the condensate tank the condensate is pumped to the flowstation where it is blended with crude oil stream and pumped into the crude oil export line while Propane/LPG offtakers are loaded directly from the storage tanks at the Gas Plant. All the Liquid Products are fiscalized at stabilized condition. Practically, LPG is a mixture of 20% of Propane and 80% of Butane. The computational data sheet for the software is shown in Table 1.

The significance of Table 1 is to keep accurate operating hours of the processing equipment so that Gas utilized by the process equipment can be accurately determined. This will ultimately ensure accuracy in the volume output after 24 hours.

2.1.3 Justification for Data Sheet

Hourly data sheet compilation ensures the accuracy of the final value at the end of 24 hours operations because of the following:

i. Equipment functionality and monitoring is very crucial, the time gas fired equipment is in operation translates to the gas consumption profile for that same period and whenever the equipment goes off line, the accurate time is swiftly compiled for consistency in gas utilization management.
ii. All engines above five 5 years have 12% fuel compensation integrated, in line with CAT chart C1 equipment manual.
iii. Hours Equipment Run is a function of gas utilized as fuel gas.
iv. Gas fired equipment not operational during the period under review have zero hour ascribed to such equipment till it becomes operational.

Table 1: Gas Plant Hours Equipment Run Data Sheet

Gas Plant Process Equipment Running Hours							
Date	No of Hours for IP Comp 1	No of Hours for IP Comp 2	No of Hours for LP Comp	Gas Gen 1 Running Hrs	Gas Gen 2 Running Hrs	Gas Gen 3 Running Hrs	No of Hours for Hot Oil Unit
1/05/17	24.000	0.000	0.000	8.160	0.000	24.000	24.000
2/05/17	24.000	0.000	0.000	0.000	0.000	24.000	24.000
3/05/17	24.000	0.000	0.000	5.000	0.000	24.000	24.000
4/05/17	24.000	0.000	0.000	7.500	0.000	24.000	24.000
5/05/17	24.000	0.000	0.000	8.000	0.000	24.000	24.000
6/05/17	17.000	0.000	0.000	0.000	0.000	24.000	24.000
7/05/17	24.000	0.000	0.000	0.000	0.000	24.000	24.000
8/05/17	24.000	0.000	0.000	0.000	0.000	24.000	24.000
9/05/17	24.000	0.000	0.000	0.000	0.000	24.000	24.000
10/05/17	24.000	0.000	0.000	0.000	0.000	24.000	24.000
11/05/17	9.000	0.000	0.000	0.000	0.500	24.000	24.000
12/05/17	0.000	0.000	0.000	0.000	6.580	24.000	24.000
13/05/17	0.000	0.000	0.000	0.000	8.500	24.000	24.000
14/05/17	0.000	0.000	0.000	7.750	0.000	24.000	24.000
15/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
16/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
17/05/17	0.000	0.000	0.000	0.000	4.500	24.000	24.000
18/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
19/05/17	0.000	0.000	0.000	0.000	3.250	24.000	24.000
20/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
21/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
22/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
23/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
24/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
25/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
26/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000

27/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
28/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
29/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
30/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000
31/05/17	0.000	0.000	0.000	0.000	0.000	24.000	24.000

Table 1 shows the hourly capture of gas fired equipment, within the Gas Plant, that are operational. The hourly computation is fed into the software that produces the total volume utilized.

Table 2: Flow Station Hours Equipment Run Data Sheet

FLOWSTATION PROCESS EQUIPMENT RUNNING HOURS					
Date	Field Daily Gas Production (MMSCF/D)	Flowstation online (HRS)	Line Heater online (HRS)	Gen Set Hrs online (HRS)	REMARKS
1/05/17	21.888	24	24		
2/05/17	21.564	24	24		
3/05/17	22.721	24	24		
4/05/17	24.243	24	24		
5/05/17	25.528	24	24		
6/05/17	23.211	24	24		
7/05/17	27.518	24	24		
8/05/17	28.998	24	24		
9/05/17	32.120	24	24		
10/05/17	31.115	24	24		
11/05/17	28.486	24	24		
12/05/17	23.861	24	24		
13/05/17	18.210	24	24		
15/05/17	22.845	24	24		
16/05/17	22.606	24	24		
17/05/17	20.744	24	24		
18/05/17	21.027	24	24		
19/05/17	21.099	24	24		
20/05/17	22.174	24	24		
21/05/17	24.198	24	24		
22/05/17	24.442	24	24		
23/05/17	24.433	24	24		
24/05/17	24.296	24	24		
25/05/17	25.952	24	24		
26/05/17	22.945	24	24		
27/05/17	20.534	24	24		
28/05/17	20.811	24	24		
29/05/17	21.547	24	24		
30/05/17	21.451	24	24		
31/05/17	28.627	24	24		
TOTAL	741.851				

Table 2 illustrates the hourly reflection of Flowstation gas fired equipment. The Line Heater was the only gas fired equipment in operation at the time of data collation. Though, provision already made for the Gas Generator newly installed. Remarks column is to efficiently track and monitor any operational anomalies capable of affecting the final data.

Table 3: Flowstation Gas Production and Utilization

	GAS PRODUCTION			**FLOWSTATION GAS UTILIZATION**			
Date	Total Gas Produced (mmscf/d)	Line Heater online (Hrs)	Average Hourly Gas Production (mmscf/hr)	Line Heater Gas Utilization (mmscf/d)	Gas Gen Running Hours	Gas Gen Utilization (Vmmscf/d)	Total Gas Utilized at Flowstation (mmscf/d)
1/05/17	21.888	24	0.912	0.095	0.000	0.000	0.095
2/05/17	21.564	24	0.899	0.095	0.000	0.000	0.095
3/05/17	22.721	24	0.947	0.095	0.000	0.000	0.095
4/05/17	24.243	24	1.010	0.095	0.000	0.000	0.095
5/05/17	25.528	24	1.064	0.095	0.000	0.000	0.095
6/05/17	23.211	24	0.967	0.095	0.000	0.000	0.095
7/05/17	27.518	24	1.147	0.095	0.000	0.000	0.095
8/05/17	28.998	24	1.208	0.095	0.000	0.000	0.095
9/05/17	32.120	24	1.338	0.095	0.000	0.000	0.095
10/05/17	31.115	24	1.296	0.095	0.000	0.000	0.095
11/05/17	28.486	24	1.187	0.095	0.000	0.000	0.095
12/05/17	23.861	24	0.994	0.095	0.000	0.000	0.095
13/05/17	18.210	24	0.759	0.095	0.000	0.000	0.095
14/05/17	22.657	24	0.944	0.095	0.000	0.000	0.095
15/05/17	22.845	24	0.952	0.095	0.000	0.000	0.095
16/05/17	22.606	24	0.942	0.095	0.000	0.000	0.095
17/05/17	20.744	24	0.864	0.095	0.000	0.000	0.095
18/05/17	21.027	24	0.876	0.095	0.000	0.000	0.095
19/05/17	21.099	24	0.879	0.095	0.000	0.000	0.095
20/05/17	22.174	24	0.924	0.095	0.000	0.000	0.095
21/05/17	24.198	24	1.008	0.095	0.000	0.000	0.095
22/05/17	24.442	24	1.018	0.095	0.000	0.000	0.095
23/05/17	24.433	24	1.018	0.095	0.000	0.000	0.095
24/05/17	24.296	24	1.012	0.095	0.000	0.000	0.095
25/05/17	25.952	24	1.081	0.095	0.000	0.000	0.095
26/05/17	22.945	24	0.956	0.095	0.000	0.000	0.095
27/05/17	20.534	24	0.856	0.095	0.000	0.000	0.095
28/05/17	20.811	24	0.867	0.095	0.000	0.000	0.095
29/05/17	21.547	24	0.898	0.095	0.000	0.000	0.095
30/05/17	21.451	24	0.894	0.095	0.000	0.000	0.095
31/05/17	28.627	24	1.193	0.095	0.000	0.000	0.095
TOTAL	**741.851**						**2.945**

Table 3 shows the total gas production, from the Daniel Orifice and flowstation gas utilization model.

2.2 Procedure

Quicksearch is a new invention in gas utilization matrix. Similar tools or software are not common. Quicksearch Structure operates by a well-articulated and task-specific algorithm referred to as "instructions for completing a task". The algorithm in the context of gas accounting is not a high level abstracted algorithm but a simplified edition designed to achieve a higher level of accuracy during deployment.

The first step is to capture the gas produced from conventional Daniel Orifice Measurement and hourly computation of all the various gas fired process equipment at the Flowstation and Gas Plant.

The Input Data go through a sequence of routine processing as clearly captured in the algebraic expressions from Equation 1 to Equation 9 below, and Figures 3 and 4 in the flow charts. When each section of the flowchart is completed, the results are generated through the output command. Prior to starting or initiating the command, all the gas fired equipment would be running smoothly on stabilized mode.

Any defective gas fired equipment is isolated and classified as not operational, component has zero gas utilization by default and according to the working mechanism, since the system operates on the Material Balance Principle. The following gas fired equipment were considered in this research:

- Intermediate Pressure Compressor 1
- Intermediate Pressure Compressor 2
- Low Pressure Compressor
- Gas Generators: 1, 2 & 3
- Hot Oil Unit
- Line Heater

2.3 Mode of Operations

Quicksearch is a simplified Excel-based simulator, designed to primarily establish an equilibrium in the Gas Volume of Natural Gas produced, the corresponding volume utilized either as fuel gas or the volume converted to liquid products like Condensate, Propane and liquefied Petroleum Gas (LPG) and the excess volume flared, mostly the lean gas.
The entire concept can be clearly expressed by this algebraic expression:

$$A = B + C + F \quad (1)$$

$$A = D + F \quad (2)$$

$$D = A - F \quad (3)$$

Where, A = Volume of Natural Gas Produced (MMSCF/D)
B = Volume of Gas Used as Fuel Gas (MMSCF/D)
C= Volume of Gas Converted to Liquid Products (MMSCF/D)
D = B + C = Total Volume Utilized (MMSCF/D)
F = Volume of Gas Flared (MMSCF/D)

Recall, $V = BHP \times 8 \times T \quad (4)$

Where, BHP = Brake Horse Power of the gas fired engines
V = Volume of fuel gas (cubic feet) consumed
T = Time (hours), Run hours on Gas Fired Engines

Note that, All Engines used for this research are above 5 years of age, hence, 12% fuel compensation applicable, as captured in the equipment manuals of the gas fired engines.
Flowstation Line Heater:

$$\text{Gas Utilized} = \text{Hrs equipment run} * 3.958/1000 \quad (5)$$

Flowstation Gas Engine

$$\text{Gas Utilized} = (\text{Hrs equipment run}*8*\text{BHP}) + (\text{Hrs equipment run}*8*\text{BHP}) * 0.12/1000000 \quad (6)$$

Table 4: Gas Fired Equipment Parameters

Equipment Parameters	**BHP**	**RPM**
Gas Plant Gen 1	930	1200
Gas Plant Gen 2	830	1200
Gas Plant Gen 3	737	1200
LP Compressor	365	1800
IP Compressor 1	650	1000
IP Compressor 2	650	1000
F/S Gas Generator	930	1200

Equipment parameters are recommended set points by the Original Equipment Manufacturer (OEM) for optimal performance of the equipment while in operation.

From Gas Composition Analysis,

- C1 : Fuel Gas 80% (mostly methane)
- C2 : Higher constituents 20% (mostly ethane & traces C2+)

Gas Flared (F) = IF(X13>W13, X13-W13, X13) (7)
Where, X13 – C1 & C2 Constituents in Gas Produced
W13 (B) – Total Gas used as Fuel Gas AA13 (D) – Total Gas Utilized (B + C)

AB13 (C) – Gas To Liquids = LPG, Propane & Condensate = C2+
Recall Equation (3)

$$D = A - F$$

Where, A is the total volume of Gas Produced and F is volume of Gas Flared.
Therefore,
C = D – C1 Constituent in Gas (8)
C2+ = D – C1 (9)
The equations used is a simple algebraic expression based on material balance.
Gas composition analysis showed C1 = 80% & C2+ = 20%, there was no major change in the gas composition ratio over the period the research was conducted. However, the same principle works at any gas processing plant with simple modification of the gas composition, if necessary.

3. Results and Discussion

Monthly performance of the flowstation and the gas plant processes, was routinely conducted, using the combination of fiscalization/metering approach for the liquid products and calculation/metering for the gas components. The liquid product yields are volumetrically determined. The measured volume is converted to the established contract base condition. Basically, the liquid products are sediments and water free, therefore, Gross Standard Volume (GSV) is the same as Net Standard Volume (NSV). GSV is the volume indicated by the meter, corrected for the meter's performance and the liquid's condition.
The correction to the meter's indicated volume are grouped together into the Combined Correction Factor (CCF). IV represents the Indicated Volume by the meter which is the difference between the Final Meter Reading (FMR) and Initial Meter Reading (IMR)

Therefore,
IV = FMR – IMR (10)
GSV = NSV = IV X CCF (11)
CCF is the product of two correction factors:
1. The correction for the meter's performance (Meter Factor);
2. The correction for the temperature and pressure of a liquid (CTPL Factor converts the density and volume of the liquid to base conditions).

CCF = CTPL X MF (12)

GSV = NSV = IV X CTPL X MF (13)

For the period under investigation,

Total Gas plant liquid yield (GSV = NSV) = 16.38 Bbls

(LPG = 10.1 Bbls, Propane = 3.29 Bbls & Condensate = 2.99 Bbls)

Monthly Volume of Gas to Liquid = 62.250 MMSCF

Technically, the flared volume consistently tracked with the actual gas volume produced when the Gas Plant is not operational. Figure 5 (Gas Utilization Plot) showed the trend explicitly. The meagre fuel gas volume utilized by the process line heater accounted for the difference between the produced and the flared volumes, under the Gas Plant shutdown scenario. Under the same condition, no liquid product is recovered, as shown in Figure 6 (Gas to Liquid Product) Chart.

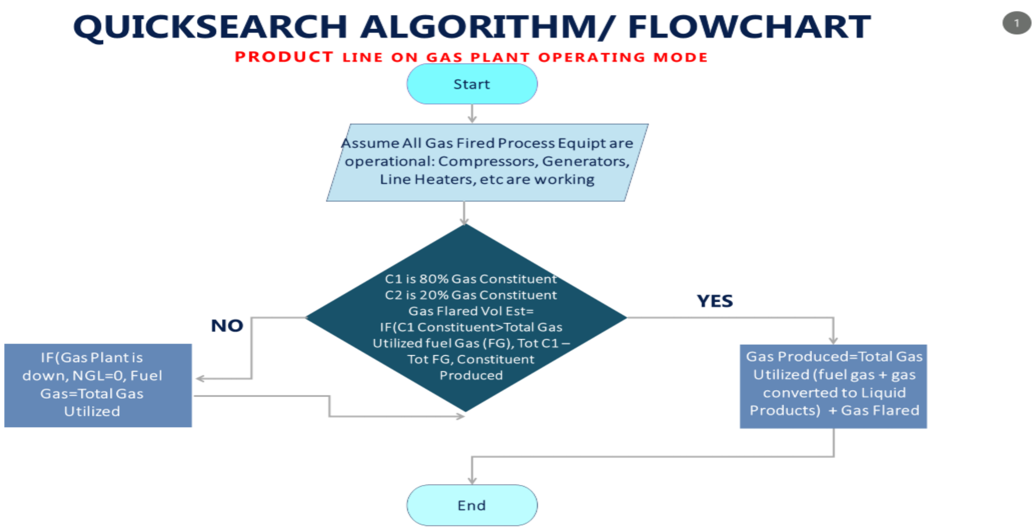

Figure 3: Quicksearch

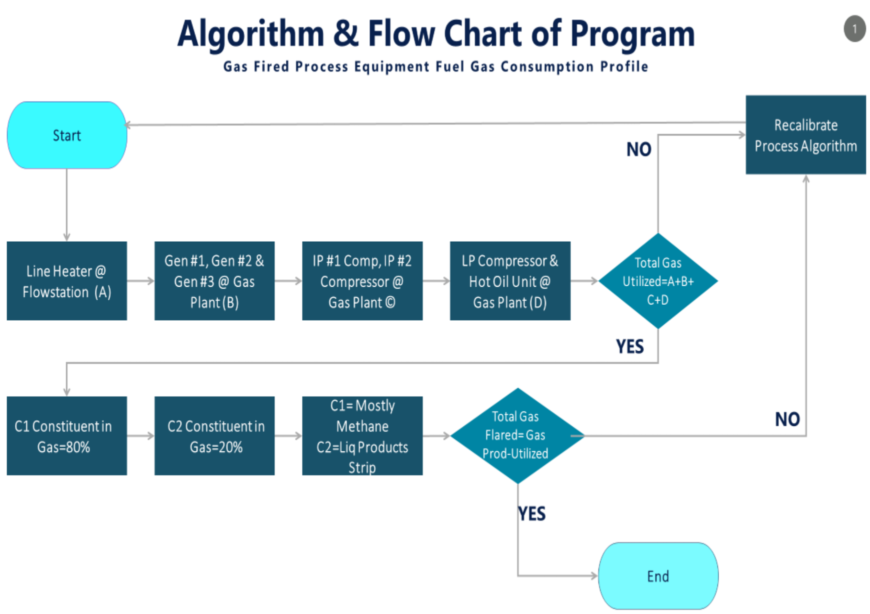

Figure 4: Quicksearch Flow Chart

3.1 Gas Data Acquisition Matrix

Hourly data sheet compilation ensures the accuracy of the final value at the end of 24 hours operations because of the following:

Monitoring and functionality of equipment are crucial, the time gas fired equipment is in operation translates to the gas consumption profile for that same period and whenever the equipment goes off line, the accurate time is swiftly recorded for consistency in gas utilization management. Hours Equipment Run is a function of gas utilized as fuel gas. Gas fired equipment not operational during the period under review have zero hour ascribed to such equipment till it becomes operational. In Figure 5, between 1st May and 13th May, the gas plant was operational and gas fired equipment utilized lean gas which also accounted for the volume of low lean gas flared during the period. When the gas plant went down from 13th May, the flared volume increased and tracked very closely with the total gas volume produced. The difference was as a result of the Line Heater which was the only gas fire equipment in operation when the gas plant was shut down.

3.2 Gas Utilization Results – Quicksearch Model

The conventional method of gas measurement is deployment of gas meters and transmitters. The economic benefit of Quicksearch is that huge OPEX is saved in lieu of routine maintenance, calibration and skilled personnel deployment associated with conventional meters, while the operational benefit of "Quicksearch" is elimination of process shutdown characteristic of conventional meters, without a by-pass loop. The percentage of gas utilized is relatively low (+/-10%), because greater percentage of lean gas is flared. Other utilization options like synergy with Integrated Power Projects (IPP) and Compressed Natural Gas (CNG) should be considered to boost utilization.

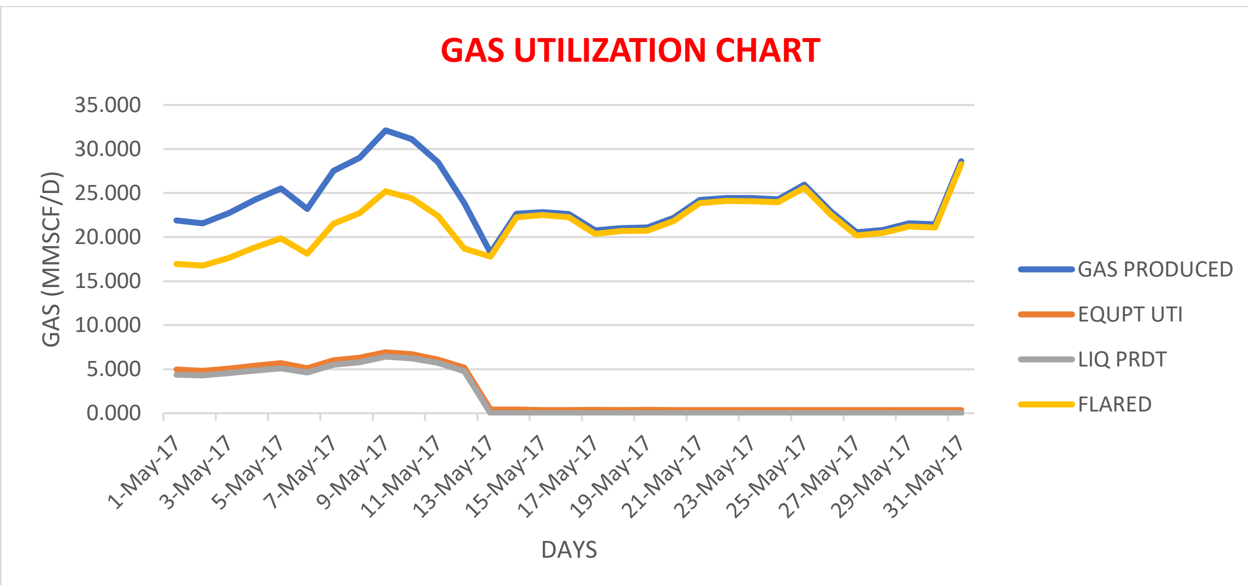

Figure 5: Gas Utilization Plot

Figure 6, clearly illustrates liquid products recovery values when the gas plant was in operation between 1st May - 13th May and how liquid products recovery went to zero when the gas plant was shut down. This further authenticated the liquid product recovery trend in Figure 5 when the gas plant was shut down.

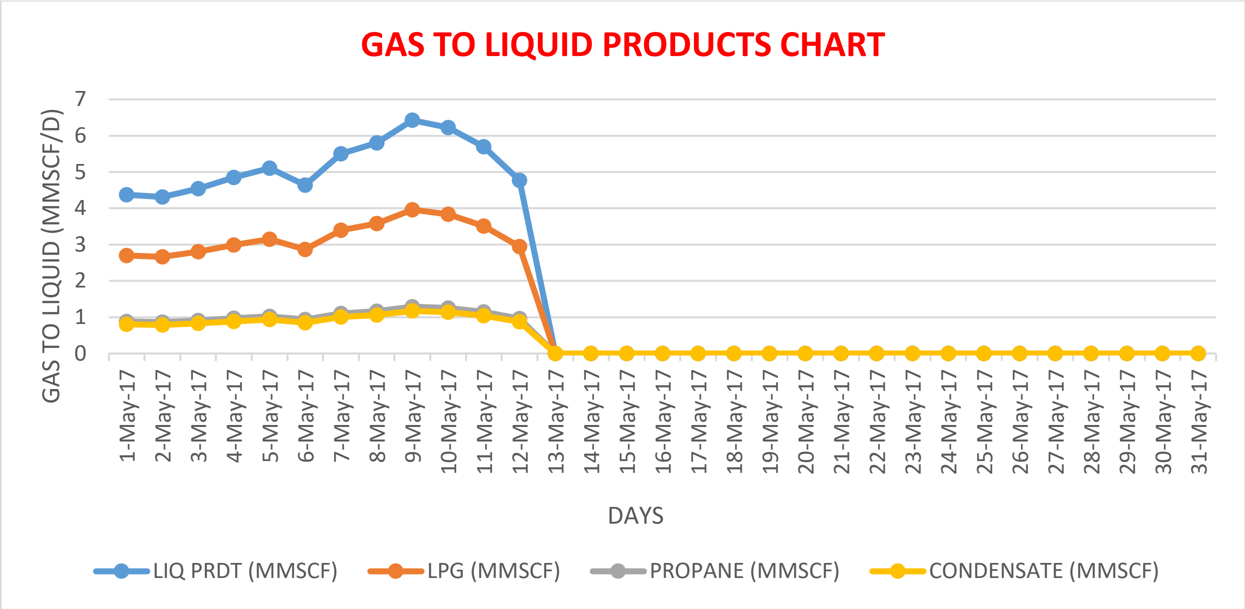

Figure 6: Gas to Liquid Product Chart

Statistical data over a period of 7 months showed the same trend as the daily reviewed above Figures (5 and 6) in terms of liquid products stripped from the gas stream. The flaring increases when most of the gas fired equipment are not in operation.

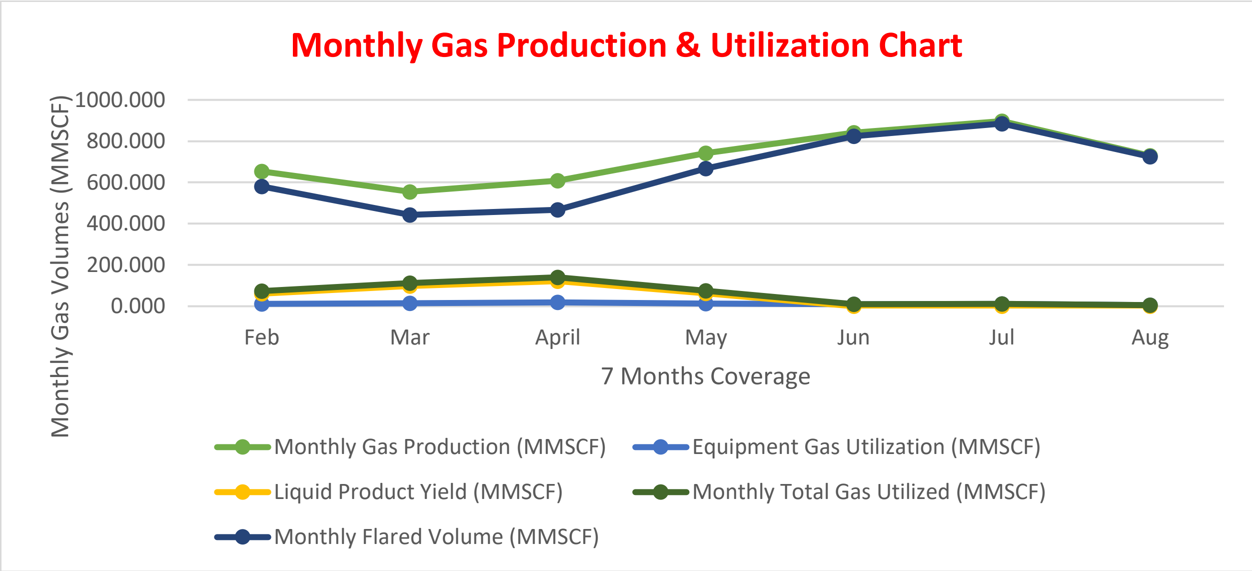

Figure 7: Monthly Gas Production Performance

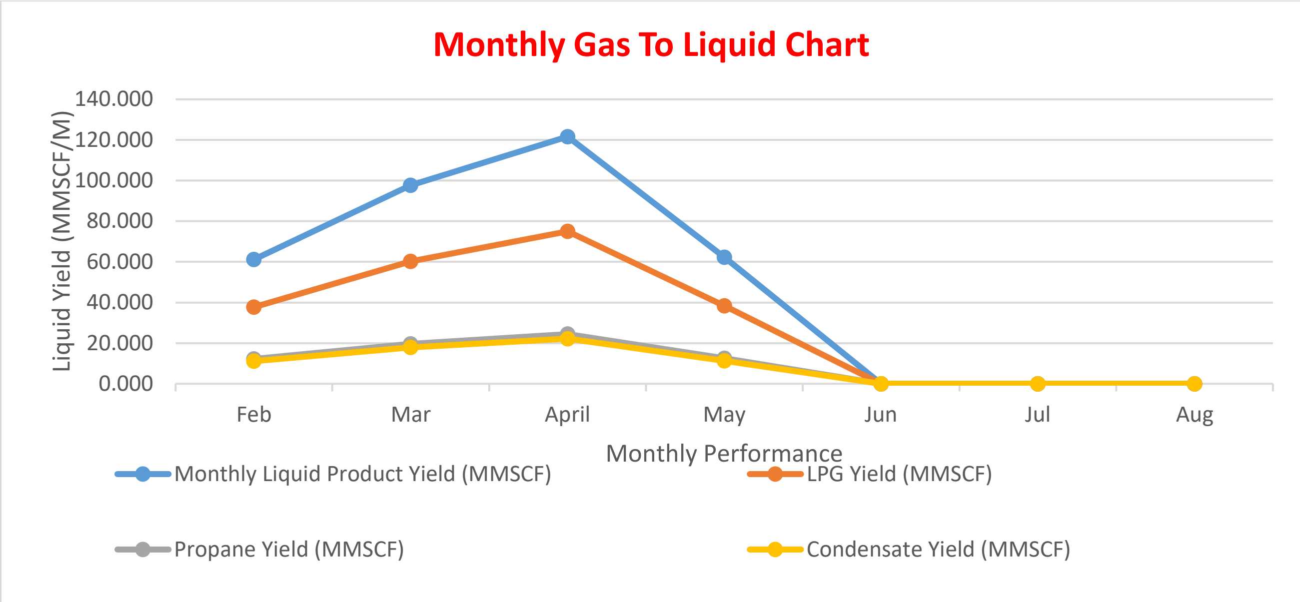

Figure 8: Monthly Gas to Liquid Product Yield for Seven Months

3.2.1 Gas Utilization Model

A Gas Utilization Model was developed for the research work with Microsoft Excel spreadsheet. It is called "Quicksearch" software package. Hourly Data in Tables (1 – 3) are computed in the Quicksearch model to properly account for the gas utilized.

Table 5: Gas Fired Equipment Utilization Schedule

SN	GAS FIRED EQUIPMENT	GAS UTILIZED (MMSCF)	REMARKS
01	LINE HEATER	2.945	
02	IP COMPRESSOR #1	1.409	
03	IP COMPRESSOR #2	0	NOT IN USE
04	LP COMPRESSOR	0	NOT IN USE
05	GENERATOR #1	0.303	
06	GENERATOR #2	0.174	
07	GENERATOR #3	4.900	
08	HOT OIL UNIT	2.937	
09	EQUPT @ F/STATION	2.945	
10	EQUPT @ GAS PLANT	9.732	
11	TOTAL EQUPT CONSUMPTION	12.668	FUEL GAS

Table 6: Gas to Liquid Utilization Schedule

GAS TO LIQUID (MMSCF)	LPG (MMSCF)	PROPANE (MMSCF)	CONDENSATE (MMSCF)
62.250	38.384	12.503	11.363

Equations (7 – 13) provide the entire gas to liquid ratio, in its whole form.

Recall, for the period under investigation, the total gas plant liquid yield = 16.38 Bbls
(LPG = 10.1 Bbls, Propane = 3.29 Bbls and Condensate = 2.99 Bbls

Average Monthly Percentage of Liquid Products Based on calculated volume:

LPG = 38.384/62.251 = 61.7%
Propane = 12.503/62.251 = 20%
Condensate = 11.363/62.251 = 18.3%

Table 7: Monthly Gas Utilization Performance

TOTAL VOLUME OF GAS PRODUCED (MMSCF)	741.851
TOTAL VOLUME OF FUEL GAS (MMSCF)	12.668 (1.7%)
VOLUME OF GAS CONVERTED TO LIQUID (MMSCF)	62.250 (8.4%)
TOTAL VOLUME OF GAS UTILIZED (MMSCF)	74.918 (10.1%)
TOTAL VOLUME OF GAS FLARED (MMSCF)	666.933 (89.9%)

Gas Produced (MMSCF) 741.851 = 74.918 + 666.933

3.3 Findings

In this research work, the findings are explicitly stated as follows:

1. The invention of Quicksearch resolved some perennial production operations challenges caused by defective or malfunctioning gas meters.
2. Timely reporting of gas utilization and flaring volumes in the field to the appropriate authorities or regulators achieved.
3. Elimination of sanctions by the regulatory agencies, triggered by non-conformances linked to late submission of gas utilization reports or no report, in some cases, achieved.
4. Quicksearch deployment improves significantly field data generation, acquisition and ultimately calibration of gas meters. Thereby, saving huge cost, mostly operating cost (OPEX) associated with routine field transmitter calibrations and maintenance.
5. Most existing models of crude oil trucking captured in literature were developed with little or no significant attention to Risk Management Plan of the Health, Safety and Environment (HSE) Plan and crude oil accounting specifics. That clearly explains the fatality recorded in most cases of crude oil trucking campaigns.
6. The invention of multiple crude oil movement tracking data sheets deployed in this research work made it possible to predict or forecast accurately the exportable crude oil volumes that will eventually get to the final export terminal. This is a major improvement when compared with pipeline mode of crude oil evacuation, in Nigeria.

The following areas are recommended for further research:

1. Since trucking is quite laborious and exposure to risk is relatively high. It is recommended that a good Risk Assessment Plan should be in place. Also, good Health, Safety and Environment culture must be established in the corporate operational philosophy and subjected to periodic review based on occurrences as trucking operation progresses.
2. The percentage of gas utilized is relatively low (+/-10%) because greater percentage of lean gas is flared. Other utilization options like synergy with Integrated Power Projects (IPP) and Compressed Natural Gas (CNG) should be considered.

4. Conclusion

New Marginal Field Awardees should, therefore, explore these merits with other notable factors emphasized in this paper. From the research work, the following conclusions were reached:

1. An alternative approach to hydrocarbon evacuation using the trucking method in marginal oil and gas field was safely achieved through the deployment of a robust Health, Safety and Environment Management System (HSE MS), which is a quality management instrument for risks mitigation and protection of people, assets, reputation and environment where such operation is carried out.
2. (Quicksearch) was developed for field gas production reconciliation using Microsoft Excel with algorithm and flow chart programs.
3. The Risk Assessment Plan developed was specifically tailored to hydrocarbon trucking operations with well-articulated risk assessment matrix to preempt hazard and minimize such impact, in event it occurs during the trucking operations, with special emphasis on Community Affairs and Security Management.

The overall insights shared in terms of algorithm for gas reconciliation should be standardized, mostly at the Marginal Field because of cost effectiveness and reliability. Finally, alternative evacuation of crude oil via trucking is a key instrument for production sustainability at Marginal Field level. Hence, the 6 months Trucking Permit usual provision by the NUPRC should be reviewed to 2 years and consideration for modular refinery could be explored by Marginal Field Operators to simply break the midstream monopoly market and guarantee sustainable production across Marginal Fields in Nigeria.

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