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DETERMINATION OF THE EFFICIENCY OF HYDROCARBON FLOW IN THE ONSHORE TSHIENDE-07 WELL OF THE COASTAL BASIN OF THE DEMOCRATIC REPUBLIC OF THE CONGO

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ABSTRACT

The general objective of this work is to determine the efficiency of the flow of hydrocarbons in the Tshiende 07 Well. To do this, we have set ourselves the following specific objectives: To carry out a study of the performance of Tshiende 07 wells; Calculate the productivity index of the Tshiende 07 well; Calculate the maximum flow rate in the Tshiende 07 well; Draw the Inflow Performance Relationship (IPR) curve; Determine the hydraulic parameters of the flow of hydrocarbons in a well; Draw the Tubing Performance Relationship (TPR) curve; Apply nodal analysis in the TS-07 well. As we have developed the different mathematical approaches for the optimization of the flow of hydrocarbons in a producing well, we exploited the Poettman-Carpenter mathematical approach, and since iterative calculations of this approach are tedious, we used the Poettmann-carpenter BH-xls software to know the evolution of the pressure in the tubing as a function of depth and Botthom Oil Nodal BH-xls to draw the Tubing Performance Relationship (TPR) curve and to determine the operating points between the curve IPR and TPR during nodal analysis.

Keywords: Coastal Basin, Determination of The Efficiency,Hydrocarbon Flow,Inflow Performance Relationship (IPR)

1. INTRODUCTION

Production from the Tshiende field in the Vermelha sand reservoir dating back several years has already exceeded the production plateau phase, which greatly decreases the reservoir pressure, leading to the closure of several wells [8]. In the huge production system, hydrocarbons flow in places from high to low pressure, knowing that this system is based on the principle of continuity [1,2]. The flow efficiency of hydrocarbons depends on the different factors: pressure difference, liquid flow, fluid type (GLR, GOR and WC), hydraulic properties of the fluids, tubing size and diameter, total well depth etc.Focusing on the aspects such as whether the efficiency of the flow of hydrocarbons influences the productivity of the Tshiende 07 well and also whether the size of the production tubing of the Tshiende 07 well responds positively to the production of the expected hydrocarbons, whether the determination of the operating point between the IPR and TPR curve of the Tshiende 07 well would give a profitable flow rate or desired by the operating company;Thus, we estimated that from the point of intersection or operation from the Inflow Performance Relationship (IPR) – Tubing Performance Relationship (TPR) curves could give a pressure torque at the bottom of the well and the flow rate that the Tshiende 07 well can produce and thus determine the flow efficiency.

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2. MATERIALS AND METHODS

Our research method is based on:

- Documentation technique;
- The collection of oil production data from the TS-07 well;
- Data processing and interpretation of results.

We used some software such as:
Microsoft Excel to plot curves and do statistical calculations;
The arc-Gis to develop the geographical map of our study area;
BottomHoleNodaleOil-HB.xls to find the operating point between the IPR and TPR curve;
Poettman-Carpenter BHP.xls to determine the hydraulic parameters of the well.

3. RESULTS AND DISCUSSIONS

3.1. Geographical Location of The Tshiende Field

The Tshiende field is located westeast of the Onshore concession of the Congolese Coastal Basin, in Kongo Central, off the Atlantic Ocean. It is bounded to the north by the Malongo village, to the west by the Mibale field, to the east by the Tshiende village and to the south by the Kongo village, it is located at a distance of 24 km from the coastal city of Moanda presented in Figure I.3 below.Its geographical coordinates are as follows:12° 57' 36" latitude; 05° 40' 24" longitude.

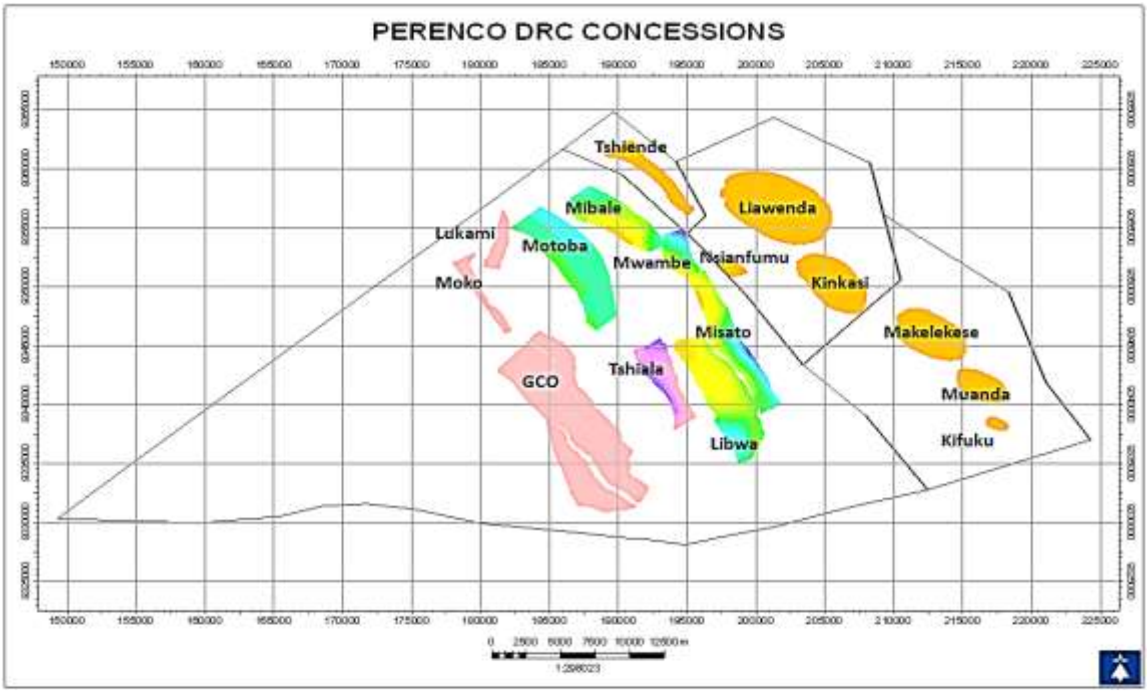

Figure 1. Geographical location map of the Tshiende field [3]

3.2. Geological context

The Tshiende field is part of marginal basins, the Bucomazi formation made up of shale includes the source rock that generated the hydrocarbons.

3.3. Structure of the Tshiende field

The Tshiende field is a faulted anticline structure, divided into two main compartments by a listric fault. These listric faults take root in the Aptian anhydrite, the Loeme Formation and stop at the summit of the Lower Cenomanian presented in Figure I. [4].

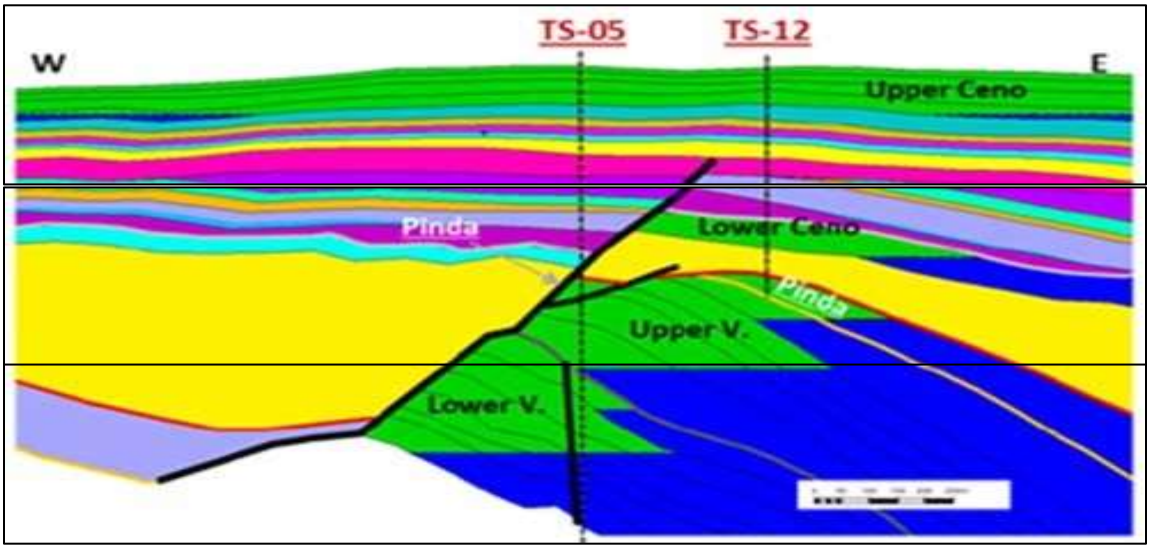

Figure 2. Structure du champ Tshiende [8].

3.4. The Reservoirs
3.4.1. Le Vermelha

a) Reservoir zoning

Vermelha is of Albian age, of the Lower Cretaceous period and of the secondary era. It is composed of a classic alternation of dolomites and sands with a porosity that varies between 15-22% and the water saturation is 40-60% [4].
The division of the zones is based on facies encountered and usually the roofs of the zones are represented by filling clays, which marks the beginning of a period of sea level flooding.
The succession of facies encountered from above and below: Clay (clogging and no tank); Sand (primary production tank); Dolomite (degraded and compact tank).
The Upper Vermelha has a continuous sequence of its facies, on the other hand the Lower Vermelha is marked by a great contrast between the good reservoirs of the sands encountered in the G and H zones on the one hand and the old zones I and M where the quality of the reservoir is decreasing. On the other hand, dolomite is the lithology found in Figure 2.

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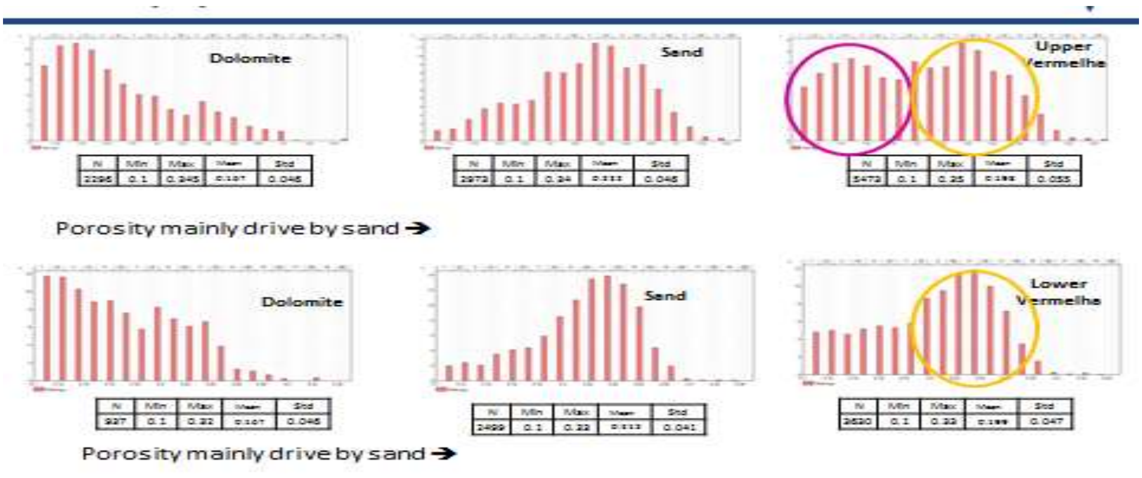

Figure 3. Different facies sequences in the Vermelha [5, 6, 7,]

The geological context has made it possible to divide the Vermelha into several layers called zones from A to M, of which the following are as follows:

- ✓ Zone B: V4 – V6: Thicker dolomitic beds and sandy-clay intercalations;
- ✓ Zone C: V6-V8: dolomitic series;
- ✓ Zone A: from top Vermelha to V4, clay-dolomitic series, locally truncated by the Vermelha Pinda unconformity;
- ✓ Zone D: V8 –V13: dolomitic series interspersed with clay beds;
- ✓ Zone E: V13- V16.1: clay-sandy series, strongly dolomitic at the base; the V16.1 horizon is a new marker and corresponds to the base of a ban; dolomitic whose top has been defined by V16;Figure 3.
- ✓ Zone F: V16.1 – V18: sands, clays and dolomites;
- ✓ Zones G: V18 – V20: detrital at the top, clay-carbonate at the base;
- ✓ Zone H: V20-V22: very sandy and dolomite;
- ✓ Zone I: V22- V23.1: clay and dolomite;
- ✓ Zone J: V23.1- v23.2 dolomitic clay;
- ✓ Zone K: V23.2 -V25: ends in a sandy level found in the good number of the wells;
- ✓ Zone L: V25- V27: dolomite;
- ✓ Zone M: V27 – Mavuma: at the top characteristic sandy levels.

b) **Stratigraphy of the Vermelha Reservoir**

The Vermelha is a mixed carbonate and clastic silica formation with the majority of sand from the reservoir deposited as an insular barrier. Sands and sandy dolomites are considered to be the main producing reservoirs, while dolomites and limestones contribute secondarily or almost not to oil production.
It is overburdened by the Pinda Formation and rests on the Mavuma Formation, subdivided into two parts, the Upper Vermelha with A, B, C, D, E and F as layers and the Lower Vermelha comprising the layers G1, G2, G3, H1, H2, H3, I, J, K, L and M see Figure 4.

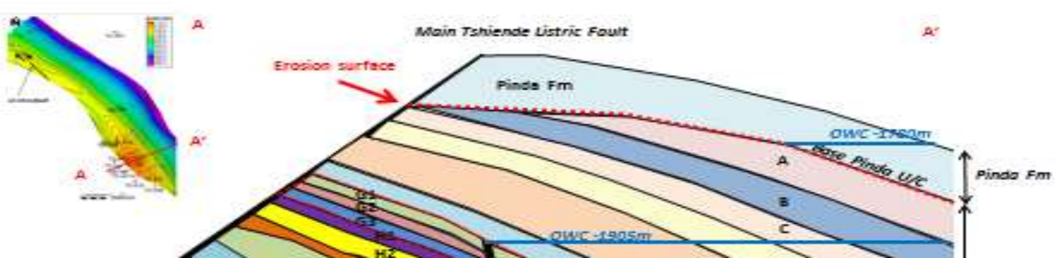

Figure 4. Vermelha Reservoir Areas [4].

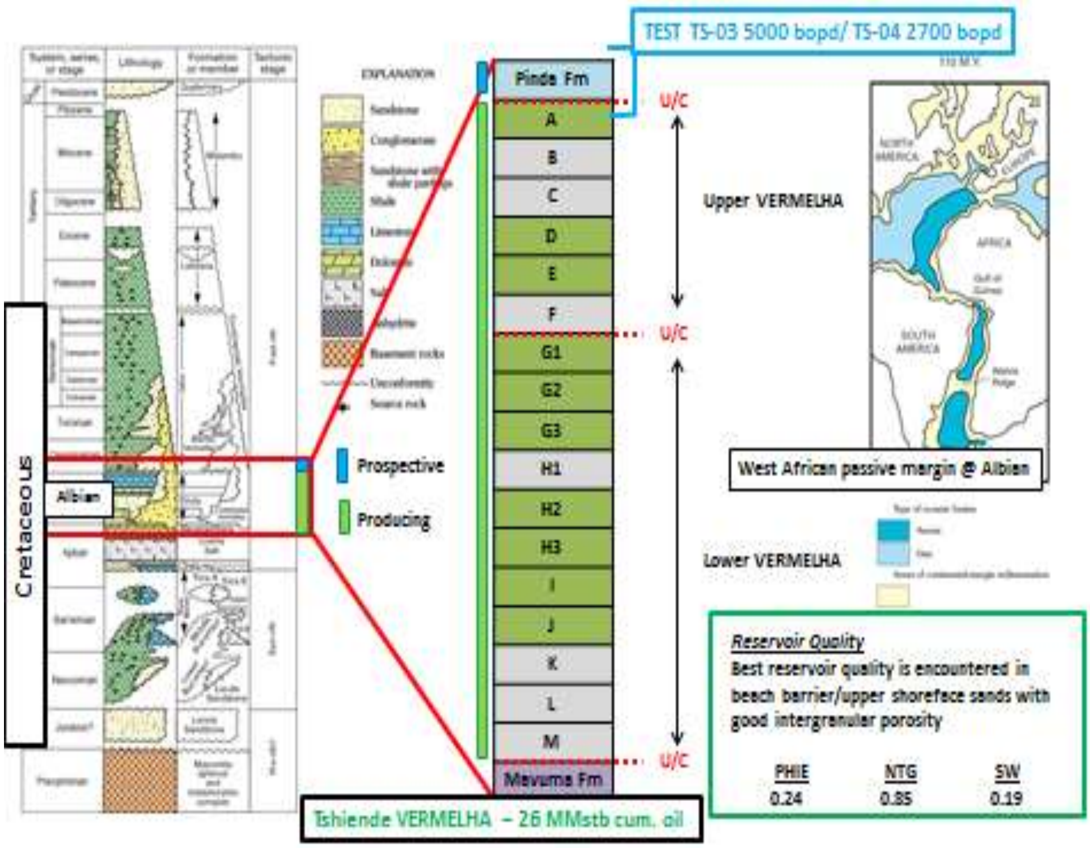

Figure 5. Tshiende Vermelha stratigraphy [4].

The petrophysical properties encountered in the Vermelha reservoir are shown in Table 1 below:

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Table1. Permeabilities and Porosities of Vermelha Lithofacies [4]

Roches	Φ Min	Φ average	ΦMax	K(mD)Minimum	K(mD)average	K(mD)maximum
Dolomite	2.5	13	18	0.10	5	40
Siltstone	6	14	21	0.20	10	40
Sandstone	5	12	23	0.30	100	600
Sand	16	22	27	0.30	700	1000

3.5. Notions On The Efficiency Of The Flow Of Hydrocarbons In An Oil Well

One of the most important components in the total system of a well is the reservoir, which is a porous and permeable subsurface formation containing a natural, individual and separate accumulation of hydrocarbons (oil and/or gas), limited by an impermeable rock barrier and often by an aquifer barrier, and which is characterized by a unique pressure system. One of the fixed pressures at any time in the life of the tank is the average tank pressure PR. [8, 2, 9, 10,11] . The flow of hydrocarbons to the well depends on the drawdown or pressure drop in the reservoir (PR – Pwf).
The relationship between flow and pressure drop in the porous medium can be very complex and depends on parameters, such as rock properties and fluid properties, flow regime, fluid saturation, fluid compressibility, damaged or stimulated formation [12, 13, 14]. The flow of fluid from the reservoir to the well is called "Inflow Performance" and the graphical representation of flow as a function of dynamic (or well) downhole pressure is called "Inflow Performance Relationship" (IPR).[7,]

3.5.1. Concept Productivity Index

When the fluid pressure at the bottom of the well is above the bubble point, the productivity index will be constant.
As the pressure falls below the bubble point, the IP productivity index will decrease as the gas exits the solution. Gilbert (1954), the father of modern production engineering, was the first to understand the full significance of this decline in the productivity index [9,13,]. He drew the curve that represents the flow pressure at the bottom of the $\bar{\bar{P}}$wf well as a function of the flow rate Q, this is the IPR

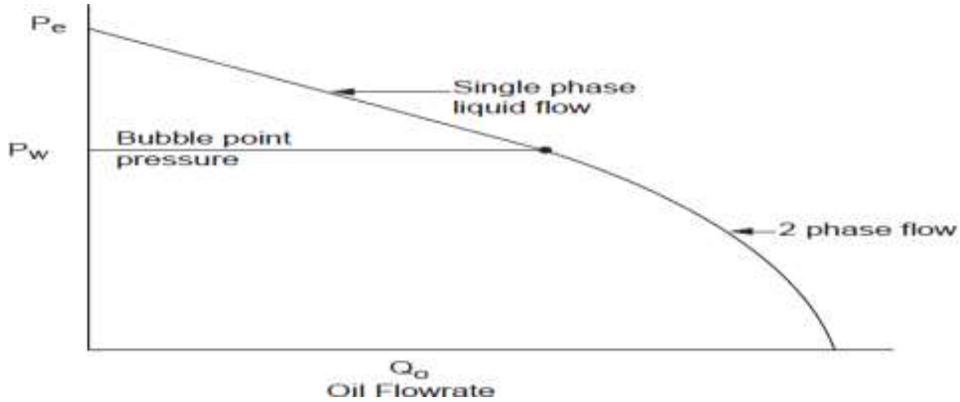

Figure 6. IPR Curve [2]

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The ends of the IPR curves are the average reservoir pressure $\bar{\bar{P}}r$ at a flow rate between zero, and the maximum flow Qmax flowing to the bottom of the well at a pressure of zero, in practice it is not possible to reach this value, because the flow pressure at the bottom of the well must always have a certain finite value. [8, 2,9,15,16]

3.5.2. Determination Of The Efficiency Of The Flow Of Hydrocarbons In The Tshiende 07 well

One of the most important components in the total system of a well is the reservoir, which is a porous and permeable subsurface formation containing a natural, individual and separate accumulation of hydrocarbons (oil and/or gas), limited by an impermeable rock barrier and often by an aquifer barrier, and which is characterized by a unique pressure system. One of the fixed pressures at any time in the life of the tank is the average tank pressure PR. [8, 12,13].
The flow of hydrocarbons to the well depends on the drawdown or pressure drop in the reservoir (PR – Pwf).The relationship between flow and pressure drop in the porous medium can be very complex and depends on parameters, such as rock properties and fluid properties, flow regime, fluid saturation, fluid compressibility, damaged or stimulated formation. [12, 2,17 ,18.19]. The efficiency of the flow of hydrocarbons in a producing well depends on several parameters, which we will mention in the following lines. For this chapter we will use some of the techniques seen in chapter two of our work, but this time we will do it in the Tshiende 07 well which is one of the producing wells in the field of the same name in the coastal basin of the Democratic Republic of Congo.So as it has been said, to know the efficiency of the flow of hydrocarbons in a well, you need to have the following information:
• The pressure at the wellhead; • The size of the tubing (the diameter and depth);
• The physico-chemical properties of the fluid;• The PVT parameters of the tank;
• Type and/or regime of fluid flow;• The roughness of the tubing wall;• GOR, WOR, GLR etc...
• The size of the tubing (the diameter and depth);• The physico-chemical properties of the fluid;
• The PVT parameters of the tank;• Type and/or regime of fluid flow; • The roughness of the tubing wall;
• GOR, WOR, GLR etc... [9 ,19,20 ,21 ,22 ,23]

3.5.3. Presentation of the completion diagram of the Tshiende 07 Shaft

The TS 07 well was drilled in 1995, its accumulations were encountered in the Vermelha reservoir of the Tshiende field.Was put into production in June of the same year. This well has been converted into pumped activation mode precisely in Electric Submersible Pump (ESP) to date, the 3D seismic work carried out in 1995 has made it possible to locate the TS 07 Well in the ABCD zones of the Vermelha reservoir. The TS 07 well is a sub-vertical profile in three phases, up to a final depth of 2365m KB (TD), it produces from the post salt reservoir known as "Vermelha" of Albian age, from the Lower Cretaceous period and from the secondary era.This shaft is equipped with two production casings, including the 13 3/8" surface casing laid at 414m KB and the 9 5/8" technical casing laid at 1728.3m KB as well as a lost column placed at 2190m KB whose suspension head (liner changer) is anchored at 1574.6 or 153.7m KB above the 9 5/8" casing shoe sabot.
Just after drilling, the Well was completed in bottom-surface connection by a conventional completion equipped with 3 1/2" diameter tubing which, after a period of eruptive production, it was converted into a hydraulic pumping system with the activation of a jet pump (power system).In 2006, the TS 07 well was converted to an activation by an Electrical Submersible Pump, equipped with a conventional single string completion, equipped at the bottom (BHA) with an activation system by submerged electric pumping[24].

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N°	Bottom hole equipment	ID	OD	Depth	Length
	TR Navifor 2			13,28	13,28
1	Olive Breda 11" x 3"1/2 NV bot x 3"1/2 EU top x 3" BPV	75.94	277	13,44	0,16
	1 Pup joint 3"1/2 Nvam L80 9.2#			14,14	0,70
	14 Tubings 3"1/2 Nvam L80 9.2 #	73.50	88.90	147,09	132,95
	Pup joint 3" 1/2 Nvam L80 9.2#			149,07	1,98
2	Landing nipple 2.81" B 3"1/2 Nvam	71.37	110.00	149,62	0,55
	Pup joint 3" 1/2 Nvam L80 9.2#			150,61	0,99
	14 Tubings 3"1/2 Nvam L80 9.2#	72.80		283,55	132,94
	Pup joint 3" 1/2 Nvam L80 9.2#			286,59	3,04
3	Mandrin gaz lift KBMG avec filetage 3"1/2 Nvam	73.50	130.00	288,57	1,98
	Pup joint 3" 1/2 Nvam L80 9.2#			290,06	1,49
	43 Tubings 3"1/2 Nvam L80 9.2#	72.80		694,36	404,30
	Pup joint 3" 1/2 Nvam L80 9.2#			696,35	1,99
4	Mandrin gaz lift KBMG avec filetage 3"1/2 Nvam	73.50	130.00	698,33	1,98
	Pup joint 3" 1/2 Nvam L80 9.2#			699,31	0,98
	Pup joint 3" 1/2 Nvam L80 9.2#			701,29	1,98
5	Injection sub avec clapet taré à 41 bar	73.50	142.00	701,86	0,57
	Pup joint 3" 1/2 Nvam L80 9.2#			702,84	0,98
	Pup joint 3" 1/2 Nvam L80 9.2# + XO			705,08	2,24
6	Packer Weatherford HYDRO 1 3"1/2 NVam	73.50	152.4	707,48	2,40
	Pup joint 3" 1/2 Nvam L80 9.20# + XO			709,19	1,71
	1 Tubings 3"1/2 Nvam L80 9.2#			718,62	9,43
	Pup joint 3" 1/2 Nvam L80 9.20#			721,60	2,98
7	Landing nipple 2.75 F 3"1/2 Nvam L80 9.20#	69.85	97.00	722,04	0,44
	Pup joint 3" 1/2 Nvam L80 9.20#			723,02	0,98
	1 Tubings 3"1/2 Nvam L80 9.2#			732,53	9,51
	Pup joint 3"1/2 Nvam L80 9.20#			733,51	0,98
8	Wire line entry guide 3"12 NVam	73.50	110	734,58	1,07
	Bridge plu Halliburton EZ drill 7"			883,80	
	Top divider			885,20	
	Divider EB2 Baker + centreur + anchor			889,05	3,85
	Packer 7" RR2 Baker			889,30	0,25
	Flow coupling + tubing 5" Vam			894,64	5,34
	Indicator collet + tubing 5" Vam + XO 5" Vam x 4" Vam			896,73	2,09
	Joint de sécurité + XO 4" Vam x 3"1/2 Vam + tubing			935,64	38,91
	Xo 3"1/2 Vam x NU + tubing 3"1/2 NU			937,12	1,48
	Crépines slot 10 + blank + crépine			970,35	33,23
	Tubing 3"1/2 NU			971,58	1,23
	O'ring seal sub			971,83	0,25
	Tell tale			973,83	2,00
	Bull plug			973,98	0,15

Miscellaneous (Casing, Plug, Fish...)	ID	Lbs.ft	Bot depth	Top depth
Casing 7" VAM L80	161.7mm	23 #	930,00	

Perforation intervals				
	Depth		Type	Status
1	871,50	879,00	TCP	open

Comments

Complétion descendue le 15-04-03
TCP 4"1/2 6 coups/ft HSD
Poids MD table mobile : 4000 lbs
Protecteur ligne d'injection 3/8" type NCCL 1706

Max inclination	62°40 à 843m
Packer fluid Type	
SG	1,02
Completion type	
Weight ↗	20 Klb
↘	15 Klb
Weight/Height on PKR	2.5 T / 0.10m
Rig	Athéna / SN 23
Reference depth	TR NAVIFOR II 13.28m
Final depth	1002m/RKB
Type of SCSSV	
Type of Packer	
Bottom gauge	○ Yes ◉ No
Tubing OD	3" 1/2
Production casing OD	7 "
Activation type	

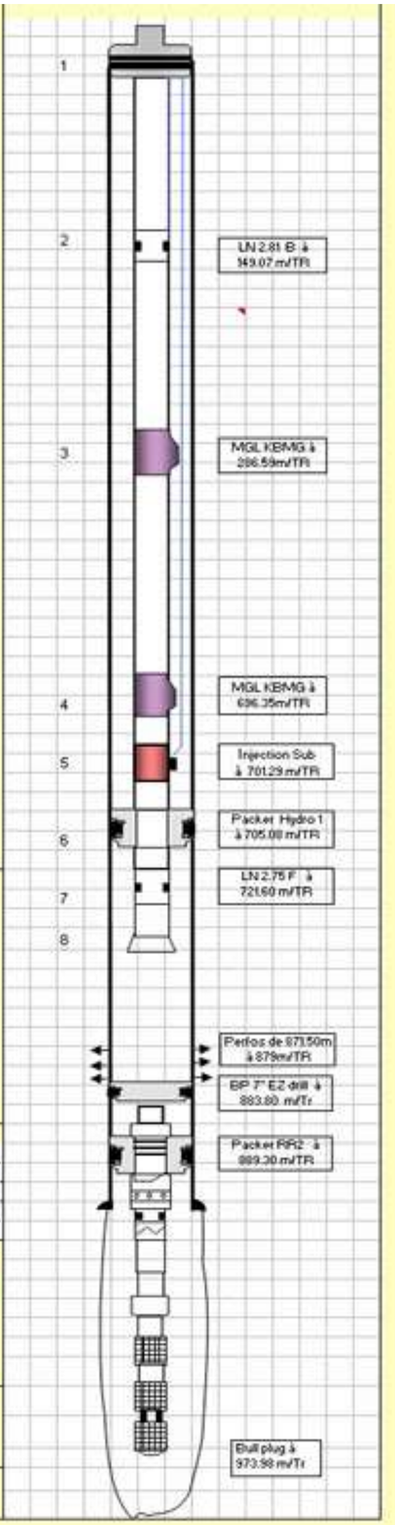

Figure 7. Completion diagram of the Tshiende 07 well [24]

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3.5.4. Production from the Tshiende 07 well

Graphically on Figure 6 We can see that the TS 07 well produces much more water than oil (Petroleum) with a rate of more than 70% on the total production of fluid, which is not at all good.

Table 2. TS 07 Well Production History [25]

DATES	QO (BOPD)	QW (BWPD)	BSW (%)	QL (BFPD)	WOR
01/01/2017	400	1000	20	1400	2,5
01/03/2017	399	1000	41	1399	2,50
01/05/2017	300	1000	41	1300	3,33
01/07/2017	300	1000	41	1300	3,33
01/10/2017	299	1000	41	1299	3,34
01/10/2017	250	1000	22	1250	3,34
01/12/2017	200	1000,500	40	1200,500	5,0025
01/02/2018	199	550	45	749	2,76
01/04/2018	210	1000	60	1210	4,76
01/06/2018	200	595	65	795	2,975
01/08/2019	399	1500	80	1899	3,75
01/10/2019	300	1500,750	86	1800,750	5,0025
01/12/2019	350	1500,850	86,5	1850,85	4,28
01/04/2020	200	2000	90	2200	10
01/06/2020	200,50	2000	90,5	2200,50	9,97
01/08/2020	150	2500	100	2650	16,66
TOTAL	4356,5	20147,1		24503,6	

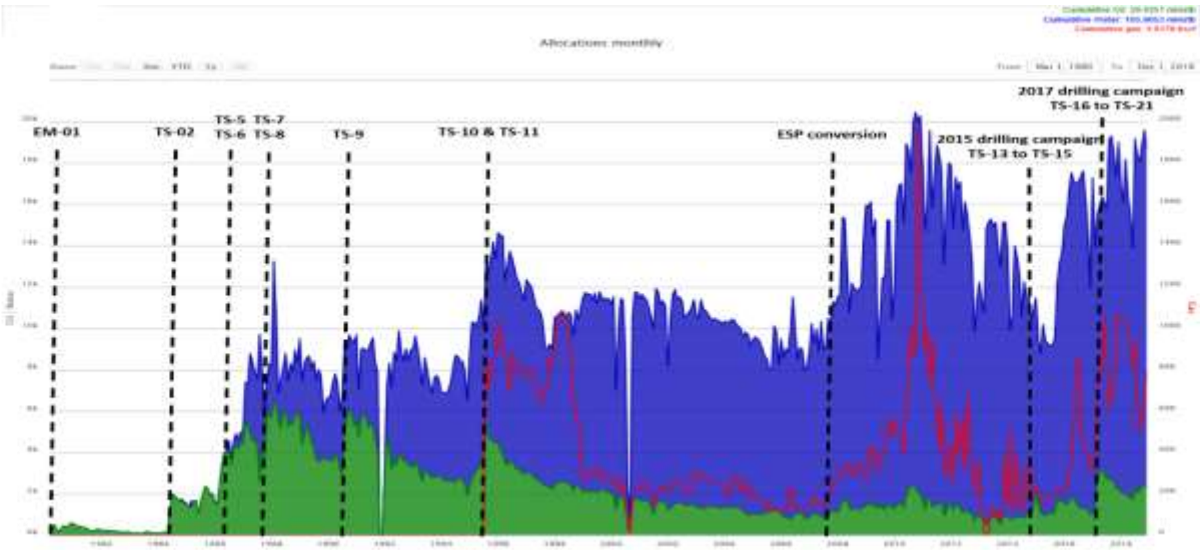

Figure 9. Historical diagram of the annual production of the Tshiende field (Pérenco-Rep,[26]

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3.5.5. Study Of The Performance Of Tshiende 07 Wells

Determining the performance of a well requires knowledge of several parameters, among others: the PVT of the fluid and/or wells, the nature of the fluid, the architecture of the well, etc.Table 03 presents a summary of some of the parameters used to determine the performance of the TS 07 well.

Table 3. PVT parameters and fluid nature of the TS07 well

Parameters	Values
Reservoir Pressure Pr (psi)	2731
Pressure at bubble point Pb (psi)	927
Downhole Pressure Pwf (psi)	285
Wellhead pressure Phf (psi)	170
Tank Temperature Tr (°F)	178
Wellhead Temperature Th (°F)	93
Q Liquid Flow Rate (stb/d)	1440
Tubing Diameter (inch)	3,5
Well Depth (ft)	7759
Volumetric factor of formation	1,11
Fluid viscosity μo (cp)	2,79
Oil density do (API)	33,1
Gas density	0,788
Gas Oil ratio GOR	213
Thicknesses H (m)	131,7
K-permeability (mD)	4,7
Water salinity (g/l)	300

3.5.6. Calculation Of The Productivity Index Of The TS 07 Well

The production of liquid alone and as the reservoir pressure is much higher than the pressure at the bubble point according to Table 3 in the TS 07 well, confirms the presence of a monophasic flow within the Vermelha reservoir.To determine the productivity index in the TS 07 well of the Tshiende field, we will use relation (3.1) because we are dealing with an undersaturated reservoir, i.e. the reservoir pressure is greater than the pressure at the bubble point (PR ≥ Pb):

$$J = \frac{q_o}{P_R - P_b + \frac{P_b}{1.8}\left[1 - 0{,}2\cdot\left(\frac{P_{wf}}{P_b}\right) - 0{,}8\left(\frac{P_{wf}}{P_b}\right)^2\right]} \quad (1)$$

$$IP = \text{J} = \frac{1440}{2731 - 927 + \frac{927}{1.8}\left[1 - 0{,}2\cdot\left(\frac{285}{927}\right) - 0{,}8\left(\frac{285}{927}\right)^2\right]} = 0{,}64046\ stb/d - psi \quad (2)$$

After the calculation, we found a productivity index (PI) equal to 0.64046 stb/day-psi.This clearly shows that the TS 07 well has a very high productivity index as it is above 0.5 stb/day-psi.

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3.5.7.Calculation Of Maximum Flow in The TS 07 Well

Since the reservoir pressure is higher than the bubble point pressure (P_R≥ P_b) and the downhole pressure is lower than the bubble point pressure (Pwf ≤Pb), a generalized IPR model can be formulated.This can be done by combining IPR's linear model for single-phase flow with Vogel's model for two-phase flow [11,2].According to the linear IPR model, the flow rate at bubble point pressure is:

$Q_b = J \cdot (Pr - Pb)$ (3)
$Q_b = 0{,}64046 \,.\, (2731 - 927)$= 1155, 38 Stb/d (4)

Based on Vogel's linear IPR model, the additional flow rate caused by pressure below the bubble pressure is expressed as:

$$\Delta Q = Q_V[1 - 0{,}2(\frac{P_{wf}}{P_b}) - 0{,}8\left(\frac{P_{wf}}{P_b}\right)^2] \quad (5)$$

Thus, the flow rate at a downhole pressure lower than the pressure at the bubble point is expressed in:

$$Q = Q_b + Q_V\left[1 - 0{,}2\left(\frac{P_{wf}}{P_b}\right) - 0{,}8\left(\frac{P_{wf}}{P_b}\right)^2\right] \quad (6)$$

And like: $Q_V = \frac{J \times P_b}{1{,}8}$ (7)

$$Q_V = (\frac{0.64046 \cdot 927}{1.8}) = 329.837 \text{ stb/d}. \quad (8)$$

The liquid flow rate at the two-phase flow portion is 329.837 stb/d. Hence equation (8) becomes:

$$Q = J \cdot (P_r - P_b) + \frac{J \times P_b}{1.8}[1 - 0{,}2(\frac{P_{wf}}{P_b}) - 0{,}8\left(\frac{P_{wf}}{P_b}\right)^2] \quad (9)$$

And when we bring the downhole pressure back to zero psi, that is, we apply the term Absolute Open Flow (AOF) and we will have the maximum flow rate in the TS 07 well.

$$Q_{max} = 0{,}64046 \cdot (2731 - 927) + \frac{0{,}64046.927}{1.8}[1 - 0{,}2\left(\frac{0}{927}\right) - 0{,}8\left(\frac{0}{927}\right)^2] \quad (10)$$
$$Qmax = 1485\ stb/d$$

3.5.8. Inflow Performance Relationship (IPR) Curve Plotting

To obtain the Inflow Performance Relationship (IPR) curve, it is simply necessary to vary the flow rate of the well's production in the relationship (11) shown below, to obtain the different pairs of pressures at the bottom of the wells and their corresponding flow rates.

$$P_{wf} = 0.125\overline{(P_r)}\left[\sqrt{81 - 80\left(\frac{Q}{Q_{max}}\right)} - 1\right] \quad (11)$$

Hence for the case of our Tshiende 07 well, after calculation, we present the different pressure pairs at the bottom of the wells and their corresponding liquid flows in Table 3 below.

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Table 4. Flow and Pressure Values at the Bottom of the Tshiende 07 Well

Q (stb/d)	Pwf (psi)
0	2731
200	2519
400	2291
600	2040
800	1760
1000	1437
1200	1039
1400	465
1485	0

The different values of each pair (downhole pressures and their corresponding flow rates) presented in Table 3 allow us to draw the Inflow Performance Relationship (IPR) curve which is presented in Figure 8 below.

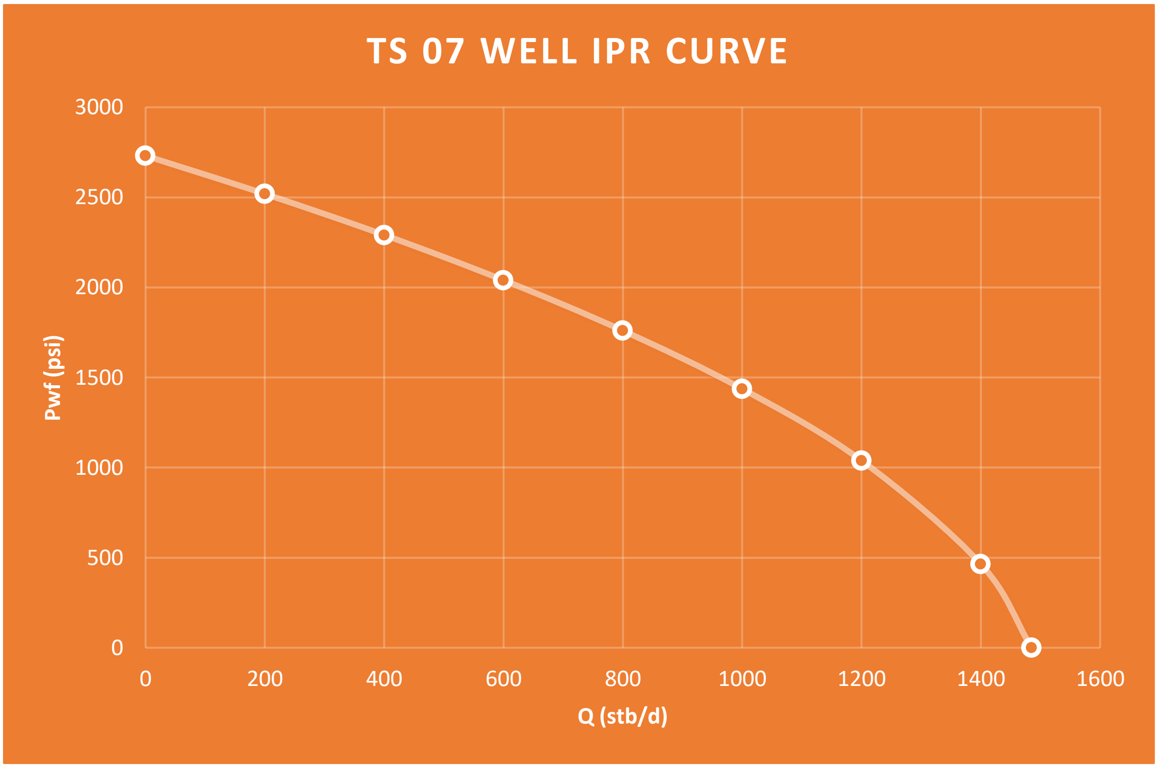

Figure 10. Inflow Performance Relationship (IPR) curve of the TS 07 well

First, the Inflow Performance Relationship (IPR) curve clearly shows us the evolution of the production that the well can have over time.
So this curve also explains, when we want to produce a flow rate of 1485 stb/d at the surface, we would have to have the pressure at the bottom of the well of 0 psi; but it is impossible to have a pressure at the bottom of

a value of zero. So if we wanted to produce a flow rate of 1000 stb/d at the surface, we would have to have the downhole pressure of 1437 psi.
Second, the curve shows us the type of fluid flow in the well that is partial two-phase, because the curve starts with a straight line that means the flow is monophasic, and its course ends with a curve that means two-phase.

3.6. Determination of the Efficiency of Hydrocarbon Flow in Tshiende 07 Well Tubing

As noted in the introduction, with respect to the different mathematical approaches to determining either tubing performance or hydrocarbon flow efficiency, then as the calculations are tedious, we used the software to determine the latter in the Tshiende 07 well.

3.7. Determination of the hydraulic parameters of the flow of hydrocarbons in a well

The determination of the hydraulic parameters of the hydrocarbon flow using the Poettmann–Carpenter mathematical approach requires knowledge of several parameters. On this note, given the calculations in hand by cutting the production tubing by segment are tedious, we used the Poettman - Carpenter BHP xls software in order to know the pressure at the bottom of the well and so much other information present in Table 4 below for the Tshiende 07 well.

3.8. Tubing Performance Relationship (TPR) curve plotting

After the calculations of the different values of the parameters characterizing the efficiency of the hydrocarbon flow and or the tubing performance of the Tshiende 07 well, we have the necessary information for the plotting of the TPR curves. These curves are plotted according to the pressure couples at the bottom of the well and the corresponding flow rates (Pwf and Q). Calculate in iteration from one segment to another of the tubing to determine different pressures by the Poettmann and Carpenter model, repeat for different flow rates until enough torques of the points (Pwf and Q) are found to draw the tubing performance curve (TPR).

The table below shows the downhole pressure pairs and their corresponding flow rates for the Tshiende 07 well for the current diameter of 3.5 inch.

Table 5.Downhole pressure couples and their corresponding flow rates allowing the drawing of the TPR curve of the Tshiende 07 well

Q (stb/d)	Pwf (psi)
0	
166	931
331	1 030
497	1 102
662	1 162
828	1 213
994	1 259
1 159	1 300
1 325	1 339
1 490	1 375

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Table 6. Values of the hydraulic parameters characterizing the efficiency of the flow of hydrocarbons in the Tshiende 07 well

Poettman-CarpenterBHP.xls				
Description: This spreadsheet calculates the flowing bottom hole pressure based on tubing head pressure and tubing flow performance using Poettmann-Carpenter Method.				
Instruction: 1) Select a unit system; 2) Update parameter values in the Input Data section; 3) Click "Solution" button; and 4) View result in the Solution section.				
Input Data:	US Field Units		SI Units	
Tubing ID:	3,5	in	0,05	M
Wellhead pressure:	170	psia	3,5	MPa
Liquid production rate:	1440	stb/d	65	m3/d
Producing gas-liquid ratio (GLR):	275	scf/stb	200	sm3/m3
Water cut (WC):	70	%	25	%
Oil gravity:	33,1	oAPI	0,9	1 for fresh water
Water specific gravity:	1,05	1 for fresh water	1,07	1 for fresh water
Gas specific gravity:	0,788	1 for air	0,65	1 for air
N2 content in gas:	0	mole fraction	0	mole fraction
CO2 content in gas:	0	mole fraction	0	mole fraction
H2S content in gas:	0	mole fraction	0	mole fraction
Formation volume factor for water:	1,2	rb/stb	1	rm3/sm3
Wellhead temperature:	93	oF	35	oC
Tubing shoe depth:	7759	ft	1500	M
Bottom hole temperature:	178	oF	60	oC
Solution				
Oil specific gravity =	0,86	1 for fresh water	0,86	1 for fresh water
Mass associated with 1 stb of oil =	1214,20	lb	550,03	Kg

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Solution gas ratio at wellhead =	29,37	scf/stb	5,23	sm3/m3
Oil formation volume factor at wellhead =	1,02	rb/stb	1,02	rm3/m3
Volume associated with 1 stb of oil at wellhead =	100,37	cf	2,84	m3
Fluid density at wellhead =	12,10	lb/cf	193,38	kg/m3
Solution gas-oil ratio at bottom hole =	412,57	scf/stb	73,48	sm3/m3
Oil formation volume factor at bottom hole =	1,25	rb/stb	1,25	rm3/m3
Volume associated with 1 stb of oil at bottom hole =	26,73	cf	0,76	m3
Fluid density at bottom hole =	45,42	lb/cf	726,07	kg/m3
The average fluid density =	28,76	lb/cf	459,73	kg/m3
Inertial force (D□v) =	26,50	lb/day-ft	39,38	kg/day-m
Friction factor =	0,0307		0,03	
Friction term =	54,06	(lb/cf)2	13815	(kg/cm)2
Error in depth =	0,00	ft	0,00	M
Bottom hole pressure =	1821	psia	12,39	MPa

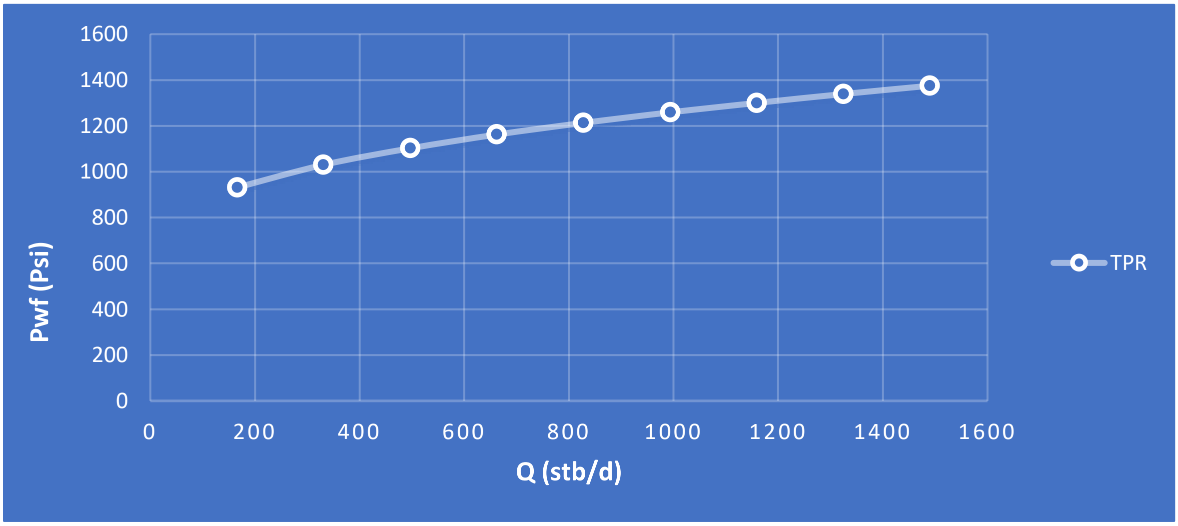

Figure 11: Tubing Performance Relationship (TPR) curve of Tshiende 07 well with the diameter of 3.5 inch.

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Figure 11 of the Tubing Performance Relationship (TPR) curve in acronym above, shows us the tubing behaviors in the face of fluid, reservoir and even well characteristics. So this explains the fluid flows that the tubing can bring back to the surface installations with its corresponding pressures.

3.9. Application of nodal analysis in the Tshiende 07 well

Nodal analysis is based on the principle of pressure continuity, which suggests that the pressure at a node is unique, regardless of whether the pressure was set from the upstream or downstream equipment. The performance curve (pressure – flow) of upstream equipment is called the "inflow performance curve" while that of downstream equipment is called the "outflow performance curve." The intersection of two performance curves gives the operating point, which is the pressure and the operating flow rate at the node considered. Nodal analysis usually uses the wellhead or bottom of the well as the solution node [2].Concerning the Tshiende 07 study well, we will use the bottom of the well as the solution node with the idea of really knowing the tubing performance and the efficiency of the hydrocarbon flow. It should be noted that we consider the inflow performance curve as IPR and Outflow performance curve as our TPR, and since the calculations are tedious, we used the Bottom Hole Noda lOil-HB.xls software to determine the operating point between the two curves. Table 6 below shows the expected result.

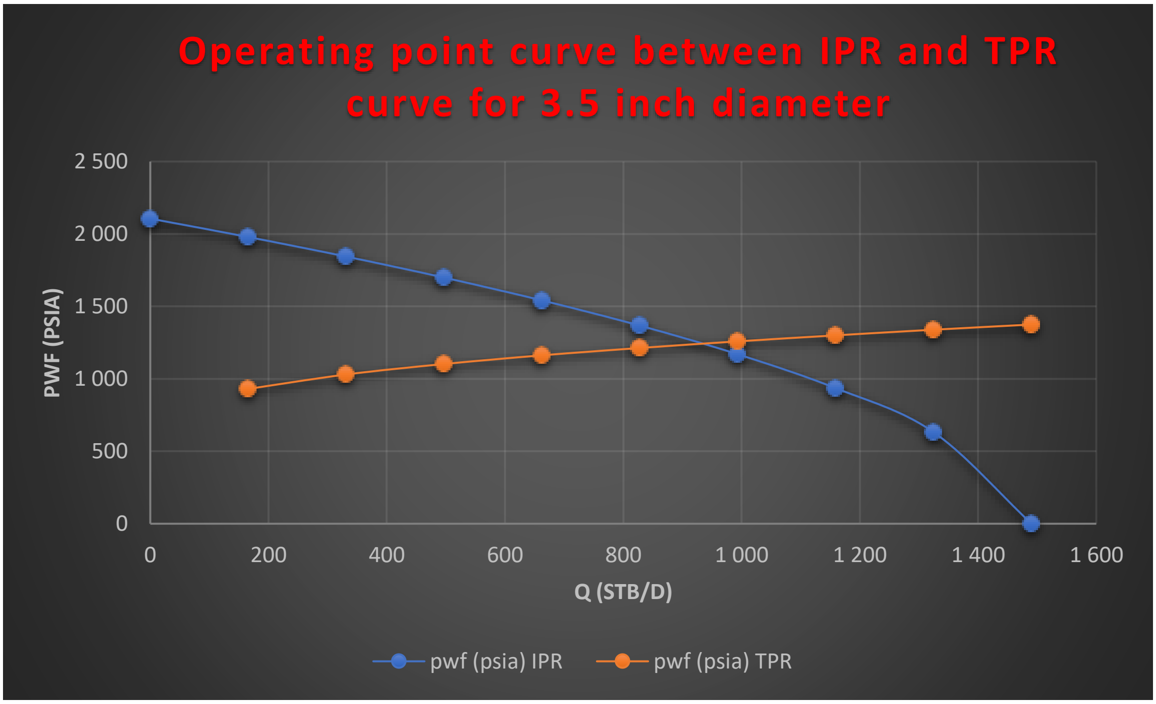

Figure 12. Operating points between the IPR and TPR curves of Tshiende 07 well with the diameter of 3.5 inch.

Figure 10 reveals the operating point between the Inflow Performance Relationship (IPR) curve and the Tubing Performance Relationship (TPR) curve of the Tshiende 07 well with a diameter of 3.5 inch which gives the downhole pressure torque and the flow rate in the tubing of a value of 950 stb/d; 1250 psi for 3.5 inch diameter tubing.

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Table 7. The input and output data for the determination of the operating point between the IPR and TPR curve for the 3.5 inch tubing diameter

BottomHoleNodalOil-HB.xls					
Description: This spreadsheet calculates operating point using Hagedorn-Brown Correlation.					
Instruction: 1) Select a unit system; 2) Update parameter values in the Input Data section; 3) Click "Solution" button; and 4) View result in the Result section and charts.					
Input Data		US Field Units		SI Units	
	Depth (D):	7 759	Ft	3 000	M
	Tubing inner diameter (dti):	3,5	in.	0,0500	M
	Oil gravity (API):	33,1	oAPI	0,80	S.G.
	Oil viscosity (cp):	2,79	cp	0,0020	Pa-s
	Production GLR (GLR):	275	scf/bbl	90	sm3/m3
	Gas specific gravity (□g):	0,788	air =1	0,709	air =1
	Flowing tubing head pressure (phf):	215	psia	3,00	MPa
	Flowing tubing head temperature (thf):	93	oF	40,00	oC
	Flowing temperature at tubing shoe (twf):	178	oF	85,00	oC
	Water cut (WC):	50	%	0	%
	Reservoir pressure (pe):	2745,65	psia	35	MPa
	Bubble point pressure (pb):	941,65	psia	28	MPa
	Productivity above bubble point (J*):	0,64046	stb/d-psi	6	m3/d-Mpa
Solution	US Field Units :	qb =	1 155	stb/d	
		qmax =	1 485	stb/d	
		q	pwf (psia)		
		(stb/d)	IPR	TPR	
		0	2 106		
		166	1 979	931	
		331	1 844	1 030	
		497	1 699	1 102	
		662	1 542	1 162	
		828	1 367	1 213	
		994	1 170	1 259	
		1 159	936	1 300	
		1 325	632	1 339	
	s	1 490	0	1 375	

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4.CONCLUSIONS

The article focused on the determination of the efficiency of hydrocarbon flow in the Tshiende-07 well in Onshore of the Coastal Basin of the Democratic Republic of Congo.To achieve the general objective assigned to this work, we collected and processed the oil data from the Tshiende-07 well using computer tools: Microsoft Excel, L'arc-Gis, BottomHoleNodaleOil-HB.xls and used the Vogel and Poettmann and - Carpenter equations.

The main results obtained can be summarized as follows:

- ✓ Reservoir: the Ts-07 well crossed the Vermelha reservoir of Albian age and composed of: clay, sand and dolomite. The Vermelha is overrun by the Pinda Formation and rests on the Mavuma Formation.
- ✓ Production: For the period from 2017-2020, the Ts-07 well produced 4356.5 quantities of oil (Qo), 20147.1 quantities of water (Qw) and 24503.6 quantities of total liquid (QL)
- ✓ Productivity index: The productivity index gave a value of 0.64046 stb/day-psi which actually shows that the well has a high productivity index.

By applying Vogel's method, it allowed us to know the maximum flow rate for the same well with a value of 1485 stb/d.The shape of IPR curves: starts with a straight line that means that the flow is monophasic and its course ends with a curve that means two-phase.The shape of the TPR curves: this one shows us the behaviour of the tubing in relation to the characteristics of the fluid, the reservoir and even the well. This explains the flow of fluid that the tubing can bring back to the surface installations with its corresponding pressures.The intersection between the IPR and TPR curves gave the operating point characterized by the tubing diameter which is 3.5 inch for a pressure - flow torque of 950stb/d1250psi.

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