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Evaluation of the impact of Emulsion Droplets Characteristics in Oil and Gas Production Line

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Abstract: *This study evaluates the impact of Emulsion droplets characteristics in oil and gas production line. Emulsion droplets are carried from the reservoir to the wellhead to avoid forming films in the risers and accumulating the down-hole leading to liquid loading. Liquid loading is the main effect of emulsion droplet in oil and gas wells. The focus of this work is on the eradication of liquid loading in oil and gas wells and this is narrowed to the determination of the fluid properties using HYSYS, gas flow rate and the critical flow rate that can carry the emulsion droplets from the reservoir to the surface or surface and the prediction of point of liquid loading at operations. Loading will be eradicated if the producing gas flow rate is greater than the critical flow rate. The producing gas flow rates to lift the liquids from the bottom to the surface were 0.0331m^3/s, 0.0329 m^3/s, 0.0332 m^3/s, 0.0335 m^3/s, 0.0335 m^3/s, 0.0336 m^3/s, 0.0337 m^3/s and 0.0339 m^3/s respectively. The corresponding critical gas rates from the bottom to surface were 0.000327m^3/s, 0.000342 m^3/s, 0.000331 m^3/s, 0.000334 m^3/s, 0.000332 m^3/s, 0.000328 m^3/s, 0.000304 m^3/s and 0.000294m^3/s respectively. The critical velocity and rates at the wellhead were the controlling factors for liquid loading. The critical velocity a t the wellhead was recorded as 0.23m/s and the critical flow rate at the surface was 0.000294 m^3/s, respectively. Whenever the critical gas velocity is greater than the producing gas velocity, liquid fall-back occurs. In conclusion, liquid loading is eradicated as the producing gas velocities are greater than the critical velocities that can lift the liquids from the bottom to the surface. It was recommended among others that the engineering simulation software (HYSYS) should be used for controlling emulsions droplets characteristics of oil and gas wells with a view of determining stable conditions for achieving a better performance.*

Keywords*:* Emulsion droplets, production line, oil and gas

INTRODUCTION

Petroleum and natural gas often are found in the same fields and are often extracted using similar methods. When it comes to gas, a petroleum company decides whether to drill. The primary goal is not the immediate production of large quantities of gas, rather to recover the greatest total amount of gas over a long period of time. With careful management, wells may produce oil or gas for more than 30 years of operation. Gas wells always produce some amount of liquids with gas, be it water or condensate. Liquid developed in the wellbore are entirely transported to the surface by gas stream. Many wells are experiencing persistent production decline during their lifetime. The decreasing gas production is subject to the nature of reservoir depletion. However, a greater than expected production decline often follows the already justified reservoir pressure depletion, especially when multiphase mixture in the wellbore has relatively liquid to gas ratio that exceeds permissible liquid content limit in the well (Davidsson et al 2014). Due to erratic and oscillating behaviors of surface measurements of pressure and flow rate, the production of gas profile deviates from stable to unstable. The exact origin of this petroleum reservoir is not cleared but is considered to be from plants, animals and marine life through thermal and bacterial breakdown. The composition of crude oil mainly comprises of organic compounds, principally hydrocarbons with inorganic non hydrocarbon compounds (small percentages), such as carbon dioxide, sulphur, nitrogen and metal compounds. Some natural gas is released as associated petroleum gas along with the oil. A well that is designed to produce only gas may be termed a gas well. Wells are created by drilling down into an oil or gas reserve that is then mounted with an extraction device such as a pump-jack which allows extraction from the reserve. Creating the wells can be an expensive process, costing at least hundreds of thousands of dollars, and costing much more when in hard to reach areas, i.e. when creating offshore oil platforms. The process of modern drilling for wells first started in the 19th century, but was made more efficient with advances to oil drilling rigs during the 20th century (Wong et al 2015).

Emulsion droplet is the dispersion of one liquid in another immiscible liquid. Common emulsions droplets can be oil suspended in water or aqueous phase (o/w) or water suspended in oil (w/o).Crude Oil and gas are multifaceted raw materials due to their applications in more diverse range of sectors than other energy sources and they constitute the cleanest burning fossil fuel (Berdzenadze, 2015). Emulsion droplets are small drops of liquids that may be in form of water condensate or hydrocarbons condensate. It is also formed as a result of condensation of vapour and its formation occurs as the flow field causes the interface between the fluids to deform leading to the growth of interfacial instabilities (Roberts et al; 2001). The separation of oil and water phases is one of the most common and least understood processes in a production facility. As fluids flow into the bottom of the well bore, up the tubing, and through surface chokes and equipment, the oil and water are thoroughly mixed. The liquid must be eventually routed to a vessel where it is separated into a continuous oil phase containing dispersed droplets of water (sometimes referred to as an emulsion) and a continuous water phase containing dispersed droplets of oil. Emulsion Droplets are small drops of liquids that may be in form of free water condensate or hydrocarbons condensate. It is also formed as a result of condensation of vapour and its formation occurs as the flow field causes the interface between the fluids to deform leading to the growth of interfacial instabilities (Thorsen et al; 2001). This emulsion droplet will form films on the tubings or pipes and settles at the bottom of the well (reservoir) thereby imposing a back-pressure on the reservoir. When these emulsions droplets produced in the tubings are unable to reach the surface of the well, films will be formed on the tubing and accumulate at the bottom of the well; thereby causing a barrier in production. The barriers in production may be reservoir depletion, liquid loading. Other effects of emulsions droplets are erosion formation, degradation of equipment and well abandonment.

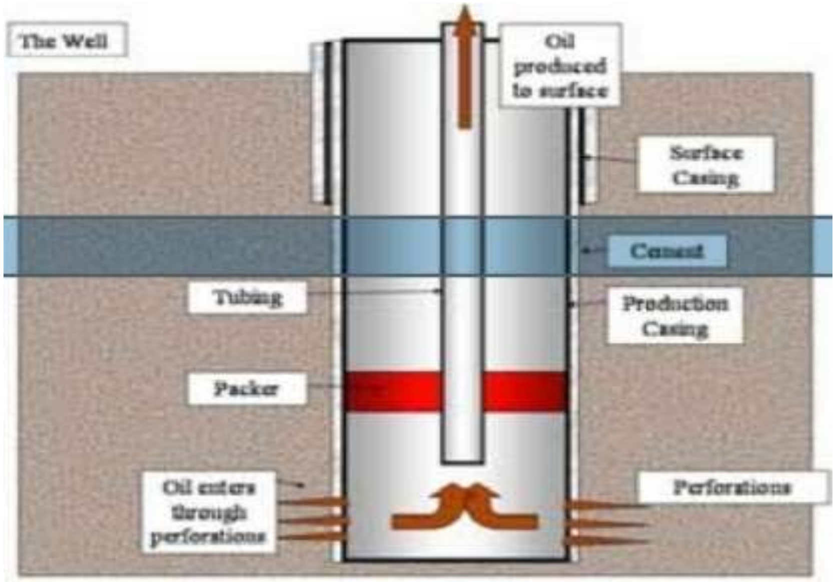

Fig 1: Gas Well with Production Tubing (Havard 2013)

Emulsion droplets formation occurs as a result of the flow field causing the interface of the fluids (usually at junction and flow focusing geometries) to deform, leading to the growth of interfacial instabilities, (Thorsen *et al*, (2001). This means that emulsion droplets occur at the risers gets in contact with the immiscible liquids inside the hole at a junction. Also, emulsion droplet is firstly distorted from spherical shape initially, into oblate spheroid as a result of the different distribution of pressure on the surface of droplet in parallel air flow; bag-type breakup (that is droplet shows the body shape of a bag), then vibration-type breakup and those emulsion droplet with small deformation would not breakup (Liu *et al* 2009) .The factors which may affect the capacity and flow properties are the porosity, permeability, capillary pressure, compressibility and fluid saturation. In the reservoir rock case, these characteristics are not standard ones determined before rock formation; but are linked closely, to the geological processes that brought the sediments together and deposited them in the sequences and under the chemical and physical changes inherent in the system (Guo, 2011).

Emulsion droplet causes most of the gas drill wells to be abandoned due to the fact that there is no critical velocity to pull it to the surface. At this point, liquid loading or Liquid fallback is experienced. Liquid loading is an accumulation of water, gas condensate or both in the tubing that can impair gas production if not diagnosed in a time, can kill the well. Liquid fallback or loading, in a nutshell can be defined as the accumulation of water in the wellbore due to insufficient gas velocity to evacuate the liquid phase which is co-produced with the gas resulting in reduction or complete cessation of gas production. These usually occur due to depletion of the reservoir pressure and at this stage the gas produced is unable to lift the liquid produced alongside it, to the surface and as such causing an accumulation of the liquid in the wellbore, and overtime as the liquid accumulates it builds up a high hydrostatic pressure in the wellbore thereby preventing further production of gas.

Liquid loading leads to the premature death of a gas well which becomes a financial loss to the operating company (Princewill et al 2018). The liquid content in the gas comes from a variety of sources either in water form or in vapour form depending on the prevailing well conditions, some sources are; free water present in the formation produced alongside the gas, water condensate and hydrocarbon condensate which enter the well as vapour but while travelling up the tubing condenses, in a case where the well completion is an open one, water or other liquid can flow from other zones into the well bore, in a case where there is an aquifer below the gas zone

The developed liquids in the wellbore are transported to the surface. Some portion of liquids starts to flow back to the well bore, and a liquid column builds up the bottom-hole. It creates hydrocarbon back pressure to the surface, reducing the gas inflow from the reservoir. This process is called Liquid loading. Liquid loading is a common problem in gas wells. Liquid loading occurs when the gas velocity is insufficient to carry the produced liquid to surface facilities. The accumulation of the liquid in the wellbore will cause a decline in the well production rate or the well might cease to flow. To avoid liquid loading in gas wells, the well should be produced at or exceed a certain minimum flow rate and velocity. This particular rate is termed as the critical gas flow rate, which is defined as minimum gas rate required to lift the produced condensate liquid or water to the surface without liquid accumulation downhole. Critical velocity is the minimum velocity that can lift the droplets to the surface. Here the well will be produced at a high Velocity so as to stay in mist flow by the use of smaller tubings or by creating a lower well head pressure (Akpan et al, 2018).

This study uses Turner et al (1969) model in analyzing and predicting the minimum gas flow rate that can still prevent liquid loading. They presented two mathematical models describing the liquid loading problem: the film movement model and the entrained droplet movement model. The most widely used and generally accepted approach for predicting the onset of liquid loading is to evaluate the so-called “critical flow rate” through some well-established correlations. The empirical expression most favoured by the petroleum industry is the Turner correlation (Turner *et al.*, 1969), which states that liquid droplet flow reversal triggers the onset of liquid loading. This critical velocity model is based on the force balance between the largest liquid droplet and the upward gas flow in the wellbore.

Liquid fall back takes place where the producing gas velocity is less than critical velocity. In predicting the point of liquid loading, the critical velocity and rates must be determined. Critical velocity is the minimum velocity required to lift the emulsion droplets from the liquid zone to the wellhead (Turner *et al*, 1969).The most accurate and popular model in predicting liquid loading in oil and gas wells is shown in equation 1.

$$u_c = 1.92\left[\frac{\sigma(\rho_L - \rho_G)}{\rho_G^2}\right]^{1/4}$$ (Turner *et al*, 1969) Equation 1

Where; u_c = critical velocity; σ = Interfacial tension, N/m; ρ_L = Density of liquid, kg/m^3 and $\rho_{G=}$Density of gas, kg/m^3

Well are drilled in order to produce either oil or gas from the reservoir to the surface. Sometimes this process is faced with challenges one of which is the formation of complex and extremely stable emulsion droplets which may serve as a barrier during the production process of crude oil or gas. The barriers caused by emulsion droplets in production may be reservoir depletion and liquid loading. Most of the gas wells in the oil and gas industries are abandoned. Government and producing companies do not care to find out the cause of these well abandonment after much money has been sunk into it. Over the years, government and oil producing companies have been abandoning wells due to one problem or the other from one location to the other even at the point of production. Less attention has been paid to what causes well abandonment.

It is basically on this ground that this research seeks to analyze oil emulsions as it contributes to liquid loading, erosion formation, equipment degradation, products contamination and oil wells abandonment. It is expected that the outcome of this work will be beneficial to the researcher and other individuals such as the government and oil producing companies. It will spur up awareness for future investigations. The problem of oil wells abandonment, equipment degradation and liquid fallback or liquid loading will be eradicated from the well bore as emulsion droplets will be carried to the surface. This study evaluates the impact of emulsion droplets and eradicates liquid loading from gas wells so as to achieve a better well performance.

Aim and Objectives of the Study

The aim of this study was to evaluate the impact of Emulsion droplets characteristics in oil and gas production line. The objectives were:

i. To determine the fluid properties using HYSYS (One Liner V15.6: 2022)
ii. To determine the gas flow rate and the critical flow rate that can carry the emulsion droplets from the reservoir to the surface or surface..
iii. To predict the point of liquid fallback at operations

MATERIALS AND METHODS

The materials involve a typical molar data of petroleum reservoir fluid (Table 1) and Operational Gas Well Data for Eket (2017-2020) as in Table 2. Another most important material in use for this work is an engineering simulation software developed by Aspen Technologies Incorporated, called HYSYS (One Liner V15.6: 2022) used for determining he fluid properties.

Table 1: Typical Molar Composition of Petroleum Reservoir Fluid (Guo*et al.*, 2007)

Component	Gas (%)	Gas Condensate (%)	Volatile Oil (%)	Black Oil (%)
N_2	0.3	0.71	1.67	0.67
CO_2	1.1	8.85	2.18	2.11
C_1	90.0	70.86	60.51	34.93
C_2	4.9	8.53	7.52	7.00
C_3	1.9	4.95	4.74	7.82
$C_{4\,(i+n)}$	1.1	2.00	4.12	5.48
$C_{5\,(i+n)}$	0.4	0.81	2.97	3.80
$C_{6\,(i+n)}$	6 + :0.3	0.46	1.99	3.04
C_7		0.61	2.45	4.39
C_8		0.71	2.41	4.71
C_9		0.39	1.69	3.21
C_{10}		0.28	1.42	1.79
C_{11}		0.20	1.02	1.72
C_{12}		0.15	12 + : 5.31	1.74
C_{13}		0.11		1.74
C_{14}		0.10		1.35
C_{15}		0.07		1.34
C_{16}		0.05		1.06
C_{17}		17 + : 0.37		1.02
C_{18}				1.00
C_{19}				0.90
C_{20}				20 +:9.2

Table 2: Operational Gas Well Data for Eket (2017-2020)

Temperature	Molar Flow Rate of gas	Molar Flow Rate of water	Pressure	Pipe Length	Pipe Diameter	True vertical depth
85^0C	15.2kg/s	0.36 kg/s	25000KN/m^2	500m	4.0"(0.1016m) External Diameter 3.52"(0.0894m) Internal Diameter	3500m

Methods

Simulation software developed by Aspen Technology incorporated called HYSYS (OneLiner V15.6: 2022) was used to determine the fluid properties. The following steps were taken to analyze the fluid data. The procedure started by clicking on the start menu and selecting HYSYS among the various programs in the computer system. Hydrocarbons were added with respect to Table 3.1 as 'new case' was opened from the file menu. The component list was specified and the fluid composition was put into the program, then normalize to give a total mole fraction of one. Peng-Robinson equation was selected from 'add command' as the fluid package was opened. Stream 1 for gas and stream 2 for water were added as "flow sheet" was selected from the simulation environment. Stream 1 contains the mole fraction of all the hydrocarbons. The fluid data (temperature, pressure, mass flow rate and so on) were added from Appendix 1 under "conditions". Lastly, a thermodynamic model called Beggs and Brill model was chosen as the multiphase flow model and the simulation was entered. Depending on the depth of the well, the properties of saturated fluid at various depths were obtained using HYSYS**.** Depending on the depth of the well, the properties of saturated fluid at different depths of the oil reservoir were obtained using HYSYS**.** The depth of the well was 3500m with seven different pipe segments of 500m each. At various depths of the well, HYSYS generated more fluid values for calculations as being summarized in Table 2 below. The temperature and other fluid properties vary depending on the depth of the well.

Prediction of Liquid Loading

Liquid loading takes place where the producing gas flow rate is less than critical gas flow rate.. In predicting the point of liquid loading, the critical gas flow rate must be determined. The critical gas rate is the flow rate that can lift the emulsion droplets from the liquid zone to the wellhead. It is given by;

$$Q_{CRI=}\ 3.060\ [\frac{\mathrm{PxAxU_C}}{ZxT}]$$ (Nosseir et al, 2000) Equation **2**

Where, $Q_{CRI=}$critical gas flow rate, (m^3/s); T = Temperature (in ^{0}c), A = Area (m^2); P = Pressure of the fluid (N/m^2); Z = Compressibility factor; and U_G =Critical velocity (m/s).
Substituting the values of P, T, Z, from table 11 and A, U_C into equation **2**;

At 3500m deep:, $Q_{CRI=}0.000327m^3/s$, At 3000m deep: $Q_{CRI=}0.000342\ m^3/s$
At 2500m deep:, $Q_{CRI=}0.000331m^3/s$, At 2000m deep: $Q_{CRI=}0.000334m^3/s$
At 1500m deep:, $Q_{CRI=}0.000332m^3/s$, At 1000m deep: $Q_{CRI=}0.000328m/s$
At 500m deep:, $Q_{CRI=}0.000304\ m^3/s$, At the surface level: $Q_{CRI=}0.000294m^3/s$.

RESULTS

Fluid properties using HYSYS

The fluid properties at various depths of the oil reservoir are given below:
The generated fluid properties by HYSYS are shown below. The fluid properties varies depending on the well formations. Tables 3 to 10 shows the generated data while Table 11 shows the summary of the fluid properties for the analysis.

Table 3: Fluid Properties at 3500m deep

Stream Name	Gas 1	Vapour Phase	Liquid Phase	Equeous Phase
Vapour/Phase Fraction	0.9995	0.9995	0.0004	0.0000
Temperature (°C)	75.05	75.05	75.05	75.05
Preasure (KPa)	2.500e+004	2.500e +004	2.500e+004	2.500e +004
Molar Flow(kgmol/hr)	630.9	630.8	0.1133	8.218e-003
Mass Flow (kg/h)	1.411e+004	1.410e+004	7.198	0.1481
Std Ideal LigVol flow(m^3/h)	37.91	37.90	1.210e-002	1.485e-004
Molar Enthalpy(kJ/kgmol)	-8.828e+004	-8.826e+004	-1.576e+005	-2.827e+005
Molar Entropy (kJ/kgmol-C)	149.3	149.3	161.9	64.07
Heat Flow (kJ/h)	-5.570e+007	-5.68e+007	-1.786e+004	-2323
Liquid Volume flow@ stdcond(m^3/h)	-	-	1.193e-002	1.460e-004
Molecular Weight	22.36	22.35	63.53	18.03
Molar Density (kgmol/m^3)	5.231	5.230	8.461	54.27
Mass Density (kg/m^3)	439.1	439.1	439.1	864.8
Act. Vol. flow (m^3/h)	121.6	120.6	1.339e-002	1.514e-004
Mass Enthalpy (kJ/kg)	-3949	-3949	-2481	-1.568e+004
Mass Entropy (kJ/kg-C)	6.679	6.682	2.547	3.554
Heat Capacity (kJ/kgmol-C)	64.57	64.57	161.5	77.82
Mass Heat Capacity (kJ/kg-C)	2.889	2.889	2.542	4.317
Lower Heating Value (kJ/kgmol)	9.965e+005	9.962e+005	2.846e+006	3.064
Mass Lower Heating Value (kJ/kg)	4.457e+004	4.457e+004	4.480e+004	0.1700
Phase Fraction (Vol Basis)	0.9997	0.9997	3.193e-004	3.916e-006
Phase Fraction (Mass Basis)	0.9995	0.9995	5.103e-004	1.050e-005
Partial Pressure of CO_2 (kPa)	486.2	-	-	-
Act. Gas Flow (Act_m^3/h)	-	119.16	-	-
AvgLiq Density (kgmol/m^3)	16.64	16.64	9.360	55.35
Specific Heat ((kJ/kgmol-C)	64.59	64.59	161.5	77.82

Std Gas Flow (STD_m^3/h)	1.492e+004	1.492e+004	2.679	0.1943
Act Liq Flow (m^3/s)	3.761e-006	-	3.719e-006	4.206e-008
Z Factor	-	0.7891	0.4790	7.424e-002
Watson K	16.87	16.87	13.31	8.475
Cp/(Cp-R)	1.148	1.148	1.054	1.120
Cp/Cv	1.616	1.616	1.279	1.162
Heat of Vapour (kJ/kgmol)	8059	-	-	-
Kinematic Viscousity (cSt)	-	0.1524	0.3091	0.4202
Liq Mass Density (stdcond) (m^3/h)	-	-	603.1	1015
Molar Vol (m^3/kgmol)	0.1912	0.1912	0.1182	0.843e-002
Mass Heat of Vap (kJ/kg)	360.5	-	-	-
Surface Tension (dyne/cm)	41.00	-	41.30	41.00
Thermal Capacity (W/m-K)	-	4.839e-002	8.426e-002	0.6608
Viscosity (cP)	-	7.781e-002	0.1772	0.3131

Table 4: Fluid Properties at 3000m Deep

Stream Name	**Gas 2**	**Vapour Phase**	**Liq Phase**	**Equeous Phase**
Vapour/Phase Fraction	0.9994	0.9994	0.0004	0.0000
Temperature (^{0}C)	70.01	70.01	70.01	70.01
Preasure (KPa)	2.000e+004	2.000e +004	2.000e+004	2.000e +004
Molar Flow(kgmol/hr)	640.6	641.0	0.1137	8.318e-003
Mass Flow (kg/h)	1.431e+004	1.420e+004	7.223	0.150
Std Ideal LigVol flow(m^3/h)	37.80	37.65	1.200e-002	1.475e-004
Molar Enthalpy(kJ/kgmol)	-8.828e+004	-8.826e+004	-1.576e+005	-2.827e+005
Molar Entropy(kJ/kgmol-C)	149.3	149.3	161.9	64.07
Heat Flow (kJ/h)	-5.570e+007	-5.68e+007	-1.786e+004	-2323
LiqVol flow@ stdcond(m^3/h)	-	-	1.193e-002	1.460e-004
Molecular Weight	22.37	22.35	64.53	18.13
Molar Density (kgmol/m^3)	5.229	5.228	8.561	54.30
Mass Density (kg/m^3)	138.2	138.2	754.4	745.5
Act. Vol flow (m^3/h)	120.8	120.3	1.329e-002	1.614e-004
Mass Enthalpy (kJ/kg)	-3949	-3949	-2481	-1.568e+004
Mass Entropy (kJ/kg-C)	6.680	6.684	2.548	3.556
Heat Capacity (kJ/kgmol-C)	64.59	64.59	161.8	77.88
Mass Heat Capacity (kJ/kg-C)	2.890	2.890	2.544	4.317
Lower Heating Val(kJ/kgmol)	9.966e+005	9.966e+005	2.866e+006	3.162
Mass Lower Heating Val(kJ/kg)	4.458e+004	4.458e+004	4.486e+004	0.171
Phase Fraction (Vol Basis)	0.9997	0.9997	3.193e-004	3.916e-006
Phase Fraction (Mass Basis)	0.9995	0.9995	5.103e-004	1.050e-005
Partial Pressure of CO_2(kPa)	279.1	-	-	-
Act. Gas Flow (Act_m^3/h)	-	118.44	-	-
AvgLiq Density (kgmol/m^3)	16.63	16.63	9.357	55.33
Specific Heat ((kJ/kgmol-C)	64.61	64.61	161.6	77.86
Std Gas Flow (STD_m^3/h)	1.495e+004	1.495e+004	2.682	0.1945
Act Liq Flow (m^3/s)	3.763e-006	-	3.718e-006	4.207e-008

Z Factor	-	0.7893	0.4520	7.64e-002
Watson K	16.90	16.90	13.33	8.477
Cp/(Cp-R)	1.1453	1.153	1.055	1.122
Cp/Cv	1.618	1.618	1.278	1.164
Heat of Vapour (kJ/kgmol)	8062	-	-	-
Kinematic Viscousity (cSt)	-	0.1524	0.3091	0.4202
Liq Mass Density (stdcond) (m^3/h)	-	-	603.1	1015
Molar Vol (m^3/kgmol)	0.1911	0.1911	0.1180	0.841e-002
Mass Heat of Vap (kJ/kg)	360.5	-	-	-
Surface Tension (dyne/cm)	7.70	-	7.70	7.71
Thermal Capacity (W/m-K)	-	4.839e-002	8.426e-002	0.6608
Viscosity (cP)	-	2.19e-002	0.1782	0.4411

Table 5: Fluid Properties at 2500m deep

Stream Name	Gas 3	Vapour Phase	Liq Phase	Equeous Phase
Vapour/Phase Fraction	0.9995	0.9995	0.0004	0.0000
Temperature (^{0}C)	68.01	68.01	68.01	68.01
Preasure (KPa)	1.918e+004	1.918e+004	1.918e+004	1.918e+004
Molar Flow (kgmol/hr)	658.2	670.11	0.1140	8.518e-003
Mass Flow (kg/h)	1.451e+004	1.480e+004	7.381	0.162
Std Ideal LigVol flow(m^3/h)	37.51	37.48	1.1980e-002	1.455e-004
Molar Enthalpy (kJ/kgmol)	-8.828e+00	-8.826e+004	-1.576e+005	-2.827e+005
Molar Entropy(kJ/kgmol-C)	149.3	149.3	161.9	64.07
Heat Flow (kJ/h)	-5.570e+007	-5.68e+007	-1.786e+004	-2323
LiqVol flow@ stdcond(m^3/h)	-	-	1.193e-002	1.460e-004
Molecular Weight	22.38	22.38	64.55	18.16
Molar Density (kgmol/m^3)	5.229	5.226	8.564	54.32
Mass Density (kg/m^3)	123.3	123.3	674.8	674.8
Act. Vol flow (m^3/h)	121.8	121.6	1.339e-002	1.514e-004
Mass Enthalpy (kJ/kg)	-3949	-3949	-2481	-1.568e+004
Mass Entropy (kJ/kg-C)	6.690	6.685	2.549	3.558
Heat Capacity (kJ/kgmol-C)	64.61	64.61	161.92	
Mass Heat Capacity (kJ/kg-C)	2.892	2.892	2.545	4.318
Lower Heating Val(kJ/kgmol)	9.975e+005	9.972e+005	2.867e+006	3.200
Mass Lower Heating Val(kJ/kg)	4.477e+004	4.477e+004	4.491e+004	0.1810
Phase Fraction (Vol Basis)	0.9997	0.9997	3.193e-004	3.916e-006
Phase Fraction (Mass Basis)	0.9995	0.9995	5.103e-004	1.050e-005
Partial Pressure of CO_2(kPa)	277.7	-	-	-
Act. Gas Flow (Act_m^3/h)	-	119.52	-	-
AvgLiq Density (kgmol/m^3)	16.62	16.61	9.355	55.32
Specific Heat ((kJ/kgmol-C)	64.63	64.63	161.8	77.88
Std Gas Flow (STD_m^3/h)	1.496e+004	1.496e+004	2.683	0.1947
StdIdlLiq Mass Density (kg/m^3) 372.1	372.1	594.7	997.8	
Act Liq Flow (m^3/s)	3.761e-006	-	3.719e-006	4.206e-008
Z Factor	-	0.7897	0.3890	7.824e-002

Watson K	16.91	16.91	13.35	8.476
Cp/(Cp-R)	1.1454	1.1454	1.059	1.123
Cp/Cv	1.619	1.619	1.280	1.166
Heat of Vapour (kJ/kgmol)	8065	-	-	-
Kinematic Viscousity (cSt)	-	0.1524	0.3091	0.4202
Liq Mass Density (stdcond) (m^3/h)	-	-	603.1	1015
Molar Vol (m^3/kgmol)	0.1910	0.1910	0.1180	0.841e-002
Mass Heat of Vap (kJ/kg)	360.7	-	-	-
Surface Tension (dyne/cm)	6.95	-	6.95	6.96
Thermal Capacity (W/m-K)	-	4.839e-002	8.426e-002	0.6608
Viscosity (cP)	-	1.95e-002	0.3662	0.5110

Table 6: Fluid Properties at 2000m deep

Stream Name	**Fluid**	**Vapour Phase**	**Equeous Phase**
Vapour/Phase Fraction	0.9493	0.9493	0.0606
Temperature (^{0}C)	65.03	65.03	65.03
Preasure (KPa)	1.901e+004	1.901e +004	1.901e +004
Molar Flow(kgmol/hr)	1344	1276	68.08
Mass Flow (kg/h)	5.630e+004	5.631e+004	1227
Std Ideal LigVol flow(m^3/h)	108.0	106.8	1.229
Molar Enthalpy(kJ/kgmol)	-1.314e+005	-1.234e+005	-2.821e+005
Molar Entropy(kJ/kgmol-C)	147.3	151.7	65.22
Heat Flow (kJ/h)	-1.766e+008	-1.574e+008	-1.919e+007
LiqVol flow@ stdcond(m^3/h)	118.4	119.8	1.208
Molecular Weight	22.38	22.50	18.03
Molar Density (kgmol/m^3)	11.01	10.56	54.26
Mass Density (kg/m^3)	121.1	121.1	674.1
Act. Vol flow (m^3/h)	122.1	120.8	1.254
Mass Enthalpy (kJ/kg)	-3136	-2858	-1.564e+004
Mass Entropy (kJ/kg-C)	3.516	3.514	3.618
Heat Capacity (kJ/kgmol-C)	115.7	117.7	77.59
Mass Heat Capacity (kJ/kg-C)	2.761	2.727	4.303
Lower Heating Value(kJ/kgmol)	1.833e+006	1.931e+006	6.322
Mass Lower Heating Val(kJ/kg)	4.37e+004	4.474e+004	0.3507
Phase Fraction (Vol Basis)	0.9886	0.9886	1.138e-002
Phase Fraction (Mass Basis)	0.9782	0.9782	2.179e-002
Partial Pressure of CO_2(kPa)	277.3	-	-
Act. Gas Flow (Act_m^3/h)	-	120.6	-
AvgLiq Density (kgmol/m^3)	12.44	11.95	55.34
Specific Heat ((kJ/kgmol-C)	115.7	117.7	77.59
Std Gas Flow (STD_m^3/h)	3.148e+004	3.017e+004	1609
StdIdlLiq Mass Density (kg/m^3)	521.1	515.6	997.7
Act Liq Flow (m^3/s)	3.483e-004	-	3.483e-004
Z Factor	-	0.7899	0.1632
Watson K	14.10	14.10	8.437
Cp/(Cp-R)	1.077	1.076	1.120

Cp/Cv	1.354	1.369	1.157
Heat of Vapour (kJ/kgmol)	1.582e+004	-	-
Kinematic Viscousity (cSt)	-	0.1770	0.3875
Liq Mass Density (stdcond) (m^3/h)	475.5	459.8	1015
Molar Vol (m^3/kgmol)	9.082e-002	9.468e-002	1.843e-002
Mass Heat of Vap (kJ/kg)	377.7	-	-
Surface Tension (dyne/cm)	6.93	-	6.94
Thermal Capacity (W/m-K)	-	8.908E-002	0.665
Viscosity (cP)	-	1.821e-002	0.4790

Table 7: Fluid Properties at 1500m deep

Stream Name	Fluid	Vapour Phase	Equeous Phase
Vapour/Phase Fraction	0.9494	0.9494	0.0506
Temperature (^{0}C)	63.12	63.12	63.12
Preasure (KPa)	1.890e+004	1.890e+004	1.890e+004
Molar Flow(kgmol/hr)	1349	1279	68.20
Mass Flow (kg/h)	5.641e+004	5.641e+004	1230
Std Ideal LigVol flow(m^3/h)	106.20	105.8	1.225
Molar Enthalpy(kJ/kgmol)	-1.324e+005	-1.244e+005	-2.831e+005
Molar Entropy(kJ/kgmol-C)	147.7	151.9	65.26
Heat Flow (kJ/h)	-1.776e+008	-1.674e+008	-1.929e+007
LiqVol flow@ stdcond(m^3/h)	118.2	119.4	1.206
Molecular Weight	22.41	22.44	18.00
Molar Density (kgmol/m^3)	11.00	10.50	54.24
Mass Density (kg/m^3)	120.9	120.9	673.5
Act. Vol flow (m^3/h)	122.2	122.1	1.254
Mass Enthalpy (kJ/kg)	-3138	-2856	-1.574e+004
Mass Entropy (kJ/kg-C)	3.517	3.516	3.619
Heat Capacity (kJ/kgmol-C)	115.9	118.00	77.62
Mass Heat Capacity (kJ/kg-C)	2.771	2.757	4.333
Lower Heating Value(kJ/kgmol)	1.934e+006	1.944e+006	6.411
Mass Lower Heating Val(kJ/kg)	4.39e+004	4.482e+004	0.360
Phase Fraction (Vol Basis)	0.9887	0.9886	1.138e-002
Phase Fraction (Mass Basis)	0.9786	0.9782	2.179e-002
Partial Pressure of CO_2(kPa)	276.5	-	-
Act. Gas Flow (Act_m^3/h)	-	120.6	-
AvgLiq Density (kgmol/m^3)	12.45	11.94	55.35
Specific Heat ((kJ/kgmol-C)	115.72	117.76	77.61
Std Gas Flow (STD_m^3/h)	3.248e+004	3.317e+004	1612
StdIdlLiq Mass Density (kg/m^3)	521.8	515.9	997.9
Act Liq Flow (m^3/s)	3.493e-004	-	3.493e-004
Z Factor	-	0.7908	0.1732
Watson K	14.11	14.11	8.436
Cp/(Cp-R)	1.079	1.078	1.122
Cp/Cv	1.355	1.368	1.159
Heat of Vapour (kJ/kgmol)	1.586e+004	-	-
Kinematic Viscousity (cSt)	-	0.1770	0.3875

Liq Mass Density (stdcond) (m^3/h)	475.5	459.8	1015
Molar Vol (m^3/kgmol)	9.082e-002	9.468e-002	1.843e-002
Mass Heat of Vap (kJ/kg)	387.7	-	-
Surface Tension (dyne/cm)	6.834	-	6.835
Thermal Capacity (W/m-K)	-	8.908E-002	0.665
Viscosity (cP)	-	1.803e-002	0.5790

Table 8: Fluid Properties at 1000m deep

Stream Name	**Gas 6**	**Vapour Phase**	**Liq Phase**	**Equeous Phase**
Vapour/Phase Fraction	0.9996	0.9996	0.0004	0.0000
Temperature (^{0}C)	60.11	60.11	60.11	60.11
Preasure (KPa)	1.851e+004	1.851e +004	1.851e+004	1.851e +004
Molar Flow(kgmol/hr)	1200.09	1281.1	0.1146	8.818e-003
Mass Flow (kg/h)	1.511e+004	1.520e+004	7.212	0.1770
Std Ideal LigVol flow(m^3/h)	37.44	37.32	1.1720e-002	1.488e-004
Molar Enthalpy(kJ/kgmol)	-8.848e+004	-8.846e+004	-1.579e+005	-2.847e+005
Molar Entropy(kJ/kgmol-C)	149.9	149.9	163.9	64.17
Heat Flow (kJ/h)	-5.780e+007	-5.78e+007	-1.794e+004	-2326
LiqVol flow@ stdcond(m^3/h)	-	-	1.197e-002	1.470e-004
Molecular Weight	22.37	22.35	63.55	18.11
Molar Density (kgmol/m^3)	5.231	5.230	8.461	54.27
Mass Density (kg/m^3)	120.5	120.5	672.1	672.1
Act. Vol flow (m^3/h)	122.3	122.2	1.439e-002	1.614e-004
Mass Enthalpy (kJ/kg)	-3949	-3949	-2481	1.568e+004
Mass Entropy (kJ/kg-C)	6.679	6.682	2.547	3.554
Heat Capacity (kJ/kgmol-C)	64.57	64.57	161.5	77.82
Mass Heat Capacity (kJ/kg-C)	2.889	2.889	2.542	4.317
Lower Heating Val(kJ/kgmol)	9.9821e+005	9.982e+005	2.881e+006	3.411
Mass Lower Heating Val(kJ/kg)	4.623e+004	4.622e+004	4.411e+004	0.1834
Phase Fraction (Vol Basis)	0.9987	0.9697	3.194e-004	3.926e-006
Phase Fraction (Mass Basis)	0.9999	0.9999	5.123e-004	1.150e-005
Partial Pressure of CO_2(kPa)	279.1	-	-	-
Act. Gas Flow (Act_m^3/h)	-	120.96	-	-
AvgLiq Density (kgmol/m^3) 16.64	16.62	9.363	55.45	
Specific Heat ((kJ/kgmol-C)	64.69	64.69	171.5	78.82
Std Gas Flow (STD_m^3/h)	1.496e+004	2.689	0.1973	
StdIdlLiq Mass Density (kg/m^3)372 .1	372.77	594.82	997.98	-
Act Liq Flow (m^3/s)	3.773e-006	-	3.779e-006	4.236e-008
Z Factor	-	0.7910	0.2890	7.924e-002
Watson K	17.88	17.88	13.33	8.477
Cp/(Cp-R)	1.150	1.150	1.058	1.127
Cp/Cv	1.621	1.621	1.281	1.164
Heat of Vapour (kJ/kgmol)	8071	-	-	-
Kinematic Viscousity (cSt)	-	0.1544	0.3291	0.4212
Liq Mass Density (stdcond) (m^3/h)	-	-	603.5	1025
Molar Vol (m^3/kgmol)	0.2011	0.2011	0.1192	0.853e-002

Mass Heat of Vap (kJ/kg)	360.73	-	-	-
Surface Tension (dyne/cm)	6.81	-	6.81	6.81
Thermal Capacity (W/m-K)	-	4.839e-002	8.426e-002	0.6608
Viscosity (cP)	-	1.771e-002	0.1662	0.4112

Table 9: Fluid Properties at 500m deep

Stream Name	**Gas 7**	**Vapour Phase**	**Liq Phase**	**Equeous Phase**
Vapour/Phase Fraction	0.9996	0.9996	0.0004	0.0000
Temperature (^{0}C)	59.04	59.04	59.04	59.04
Preasure (KPa)	1.801e+004	1.801e+004	1.801e+00	1.801e+004
Molar Flow(kgmol/hr)	1300.90	1295.1	0.1149	9.005e-003
Mass Flow (kg/h)	1.611e+004	1.610e+004	7.813	0.1801
Std Ideal LigVol flow(m^3/h)	37.43	37.30	1.190e-002	1.435e-004
Molar Enthalpy(kJ/kgmol)	-8.858e+004	-8.825e+004	-1.670e+005	-2.627e+005
Molar Entropy(kJ/kgmol-C)	150.0	150.0	163.9	64.27
Heat Flow (kJ/h)	-5.970e+007	-5.69e+007	-1.744e+004	-2423
LiqVol flow@ stdcond(m^3/h)	-	-	1.163e-002	1.469e-004
Molecular Weight	24.22	24.22	64.53	18.07
Molar Density (kgmol/m^3)	5.432	5.431	8.468	54.37
Mass Density (kg/m^3)	120	120	563.7	563.7
Act. Vol flow (m^3/h)	122.5	122.4	1.539e-002	1.814e-004
Mass Enthalpy (kJ/kg)	-3947	-3947	-2483	-1.768e+004
Mass Entropy (kJ/kg-C)	6.879	6.782	2.557	3.654
Heat Capacity (kJ/kgmol-C)	65.57	65.57	162.5	78.80
Mass Heat Capacity (kJ/kg-C)	2.981	2.981	2.544	4.330
Lower Heating Value(kJ/kgmol)	9.940e+005	9.941e+005	2.883e+006	3.070
Mass Lower Heating Val(kJ/kg)	4.461e+004	4.462e+004	4.470e+004	0.1751
Phase Fraction (Vol Basis)	0.9993	0.9993	3.197e-004	3.920e-006
Phase Fraction (Mass Basis)	0.9997	0.9996	5.108e-004	1.055e-005
Partial Pressure of CO_2(kPa)	275.60	-	-	-
Act. Gas Flow (Act_m^3/h)	-	121.32	-	-
AvgLiq Density (kgmol/m^3	16.61	16.61	9.362	55.44
Specific Heat ((kJ/kgmol-C)	64.64	64.64	162.00	77.84
Std Gas Flow (STD_m^3/h)	1.494e+004	1.494e+004	2.680	0.1950
StdIdlLiq Mass Density (kg/m^3)	371.11	371.11	594.75	997.82
Act Liq Flow (m^3/s)	3.760e-006	-	3.709e-006	4.226e-008
Z Factor	-	0.7913	0.2710	7.914e-002
Watson K	17.90	17.90	13.41	8.481
Cp/(Cp-R)	1.151	1.152	1.061	1.129
Cp/Cv	1.624	1.624	1.283	1.166
Heat of Vapour (kJ/kgmol)	8059	-	-	-
Kinematic Viscousity (cSt)	-	0.1526	0.3093	0.4206

Liq Mass Density (stdcond) (m^3/h)	-	-	606.2	1018
Molar Vol (m^3/kgmol)	0.1915	0.1915	0.1184	0.848e-002
Mass Heat of Vap (kJ/kg)	365.70	-	-	-
Surface Tension (dyne/cm)	6.78	-	6.781	6.782
Thermal Capacity (W/m-K)	-	4.835e-002	8.428e-002	0.6610
Viscosity (cP)	-	1.75e-002	0.1662	0.4111

Table 10: Fluid Properties at surface

Stream Name	**Gas 8**	**Vapour Phase**	**Liq Phase**	**Equeous Phase**
Vapour/Phase Fraction	0.9998	0.9998	0.0002	0.0000
Temperature (^{0}C)	59.01	59.01	59.01	59.01
Pressure (KPa)	1.751e+004	1.751e+004	1.751e+004	1.751e+004
Molar Flow(kgmol/hr)	1350	1300	0.2260	1.637e-002
Mass Flow (kg/h)	1.622e+004	1.561e+004	14.36	0.2951
Std Ideal LigVol flow(m^3/h)	37.30	37.18	2.415e-002	2.958e-004
Molar Enthalpy(kJ/kgmol)	-8.832e+004	-8.827e+004	-1.578e+005	-2.828e+005
Molar Entropy(kJ/kgmol-C)	149.76	149.46	161.88	64.04
Heat Flow (kJ/h)	-5.574e+007	-5.567e+007	-3.567e+004	-4629
LiqVol flow@ stdcond(m^3/h)	-	-	2.381e-002	2.908e-004
Molecular Weight	22.37	22.34	63.55	18.03
Molar Density (kgmol/m^3)	5.205	5.204	8.462	54.28
Mass Density (kg/m^3)	119	119	542.2	542.2
Act. Vol flow (m^3/h)	122.5	121.2	1.671e-002	3.016e-004
Mass Enthalpy (kJ/kg)	-3947	-3950	-2482	-1.571e+004
Mass Entropy (kJ/kg-C)	6.681	6.685	2.543	3.552
Heat Capacity (kJ/kgmol-C)	64.52	64.49	161.58	77.80
Mass Heat Capacity (kJ/kg-C)	2.888	2.888	2.542	4.318
Lower Heating Value(kJ/kgmol)	9.967e+005	9.959e+005	2.847e+006	3.029
Mass Lower Heating Val(kJ/kg)	4.459e+004	4.459e+004	4.482e+004	0.1680
Phase Fraction (Vol Basis)	0.9994	0.9994	6.370e-004	7.802e-006
Phase Fraction (Mass Basis)	0.9990	0.9990	1.018e-003	2.092e-005
Partial Pressure of CO_2(kPa)	275.6	-	-	-
Act. Gas Flow (Act_m^3/h)	-	122.04	-	-
AvgLiq Density (kgmol/m^3)	16.67	16.65	9.358	55.55
Specific Heat ((kJ/kgmol-C)	64.52	64.49	162.5	77.86
Std Gas Flow (STD_m^3/h)	1.493e+004	1.491e+004	5.344	0.3871
StdIdlLiq Mass Density (kg/m^3)	372.18	372.9	595.71	998.0
Act Liq Flow (m^3/s)	7.503e-006	-	7.419e-0068.	379e-008
Z Factor	-	0.7917	0.3867	7.587e-002
Watson K	17.90	17.90	13.41	8.474
Cp/(Cp-R)	1.152	1.152	1.061	1.129

Cp/Cv	1.615	1.615	1.280	1.166
Heat of Vapour (kJ/kgmol)	8196	-	-	-
Kinematic Viscousity (cSt)	-	0.1528	0.3091	0.4211
Liq Mass Density (stdcond) (m^3/h)	-	-	607.82	1020
Molar Vol (m^3/kgmol)	0.1928	0.1928	0.1185	1.842e-002
Mass Heat of Vap (kJ/kg)	366.6	-	-	-
Surface Tension (dyne/cm)	6.72	-	6.72	6.73
Thermal Capacity (W/m-K)	-	4.828e-002	8.429e-002	0.6606
Viscosity (cP)	-	1.684e-002	0.2062	0.6120

Table 11: Summary of some Fluid Properties at various depths of the oil reservoir

Parameters	3500m deep	3000m deep	2500m deep	2000m deep
z	0.7891	0.7893	0.7897	0.7899
μ_G	7.781x10^{-5} Ns/m^2	2.17x 10^{-5} Ns/m^2	1.95x 10^{-5} Ns/m^2	1.82 x10^{-5} Ns/m^2
σ	0.041N/m	0.0077N/m	0.00695N/m	0.00693N/m
ρ_L	864.8kg/m^3	745.5kg/m^3	674.8kg/m^3	674.1kg/m^3
ρ_G	439.1kg/m^3	138.2kg/m^3	123.3kg/m^3	121.1kg/m^3
P	25000kPa	20000kPa	19180kPa	19010kPa
T	75.05˚C	70.01˚C	68.01˚C	65.03˚C
D	0.0894m	0.0894m	0.0894m	0.0894m
q_G	0.0331 m^3/s	0.0329 m^3/s	0.0332m^3/s	0.0335 m^3/s
Parameters	1500m deep	1000m deep	500m deep	Surface level
Z	0.7908	0.7910	0.7913	0.717
μ_G	1.801x 10^{-5}Ns/m^2	1.771x10^{-5} Ns/m^2	1.75x10^{-5} Ns/m^2	1.684x10-^{5} Ns/m^2
σ	0.006834N/m	0.00681N/m	0.00678N/m	0.00672N/m
ρ_L	673.5kg/m^3	672.1kg/m^3	563.7kg/m^3	542.2kg/m^3
ρ_G	120.9kg/m^3	120.5kg/m^3	120kg/m^3	119kg/m^3
P	18900kPa	18510kPa	18010kPa	17510kPa
T	63.12˚C	60.11˚C	59.04˚C	59.01˚C
D	0.0894m	0.0894m	0.0894m	0.0894m
q_G	0.0335m^3/s	0.0336m^3/s	0.0337m^3/s	0.0339m^3/s

Gas flow rate and the critical flow rate that can carry the emulsion droplets from the reservoir to the surface or surface.

Substituting the values of P, T, Z, from table 11 and A, U$_C$ into equation **2**;
At 3500m deep:, $Q_{CRI=}0.000327m^3/s$, At 3000m deep: $Q_{CRI=}0.000342\ m^3/s$
At 2500m deep:, $Q_{CRI=}0.000331m^3/s$, At 2000m deep: $Q_{CRI=}0.000334m^3/s$
At 1500m deep:, $Q_{CRI=}0.000332m^3/s$, At 1000m deep: $Q_{CRI=}0.000328m/s$
At 500m deep:, $Q_{CRI=}0.000304\ m^3/s$, At the surface level: $Q_{CRI=}0.000294m^3/s$.

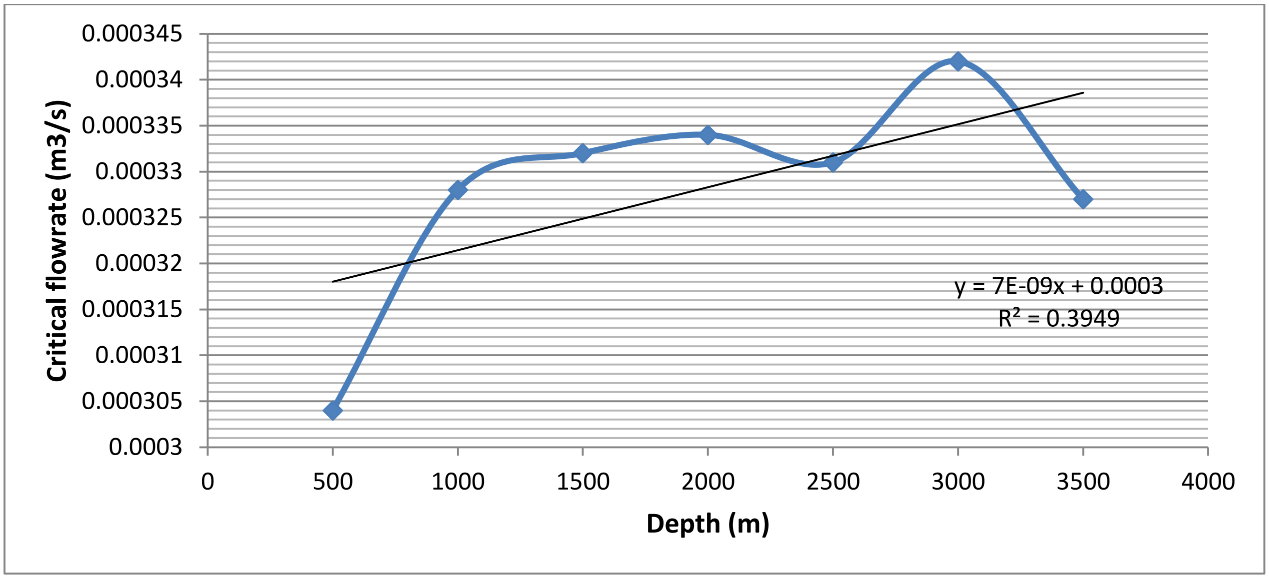

Fig 1: Graph of critical rate (m^3/s) against the well depth (m)

Fig. 1 shows that the critical flow rate increases from the bottom depending on the depth of the well**.** The graph shows that the critical rate at the bottom of the hole was smaller than that at the wellhead. The critical rates at the bottom and wellhead were obtained as 0.000327 m^3/s and 0.000294 m^3/s respectively. The maximum critical rate was obtained at the depth of 3000m as 0.000342 m^3/s.

Also, the values of the producing gas flow rate were gotten directly from HYSYS as below,
At 3500m deep, $q_G = 0.0331m^3/s$, At , 3000m deep, $q_G = 0.0329m^3/s$
At 2500m deep, $q_G = 0.0332m^3/s$, At 2000m deep, $q_G = 0.0335m^3/s$
At 1500m deep, $q_G = 0.0335m^3/s$, At 1000m deep, $q_G = 0.0336m^3/s$
At 500m deep, $q_G = 0.0337m^3/s$, At the surface level, $q_G = 0.0339/s$

The point of liquid fallback at operations

(Turner *et al*, 1969) recommended that for liquid loading to be predicted, the critical velocity must be determined at the wellhead as the controlling factor. From equation 1 above, substituting the values of σ, ρ_G and ρ_L from table 11,
At 3500m deep: U_C=0.19m/s, At 3000m deep: U_C= 0.24m/s
At 2500m deep: U_C=0.24m/s, At 2000m deep: U_C= 0.23m/s
At 1500m deep: U_C=0.27m/s, At 1000m deep: U_C = 0.25m/s
At 500m deep: U_C=0.23m/s, At the surface level: U_C= 0.23m/s

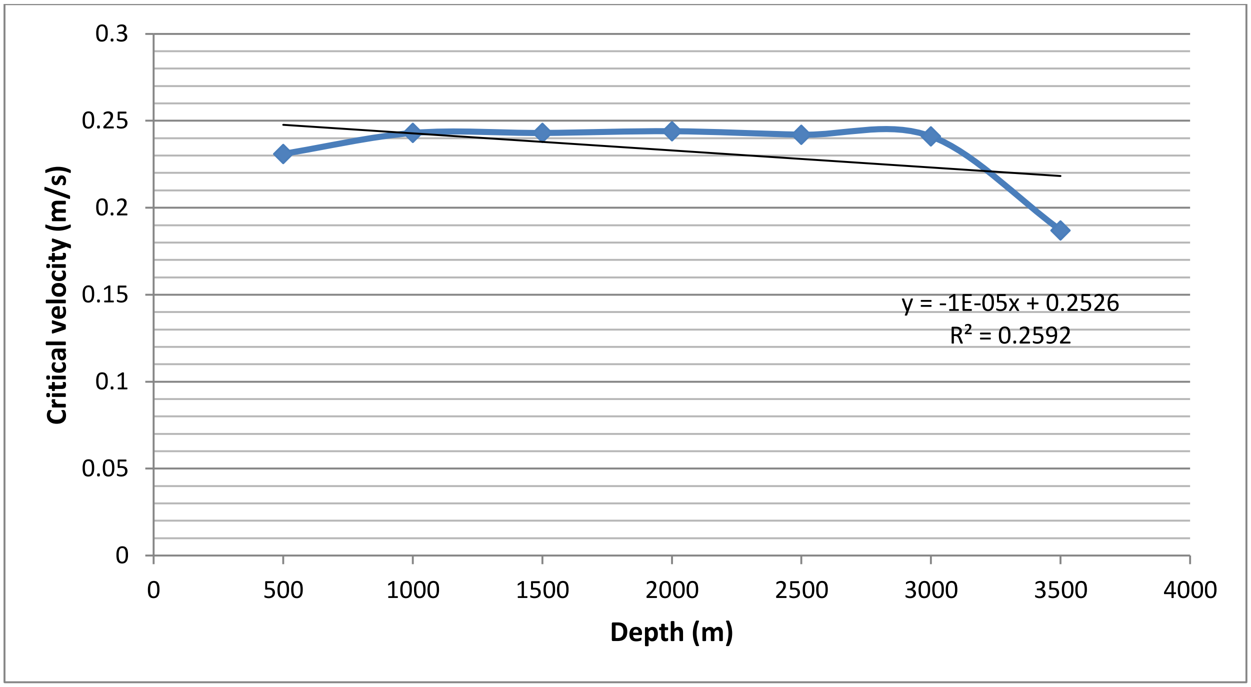

Fig 2: Graph of Critical velocity (m/s) against depth (m)

Figure 2 shows that the velocity varies depending on the depth and well formations. The critical velocity at the wellhead was 0.230m/s and the minimum critical velocity was recorded at the bottom as 0.19m/s respectively.

DISCUSSION

The results of the analysis showed that the fluid properties varied showing its full nature of compressibility in terms of fluid flow. Turner et al (1969) model which is best recommended for oil and gas production wells was used due to its accuracy, simplicity and precision. The producing gas flow rates to lift the liquids from the bottom to the surface were 0.0331m^3/s, 0.0329 m^3/s, 0.0332 m^3/s, 0.0335 m^3/s, 0.0335 m^3/s, 0.0336 m^3/s, 0.0337 m^3/s and 0.0339 m^3/s respectively. The corresponding critical gas rates from the bottom to surface were 0.000327m^3/s, 0.000342 m^3/s, 0.000331 m^3/s, 0.000334 m^3/s, 0.000332 m^3/s, 0.000328 m^3/s, 0.000304 m^3/s and 0.000294m^3/s respectively. Turner et al (1969) recommends the critical velocity at the well head to be the controlling factor for liquid loading, which was 0.23m/s. Whenever the critical gas velocity is greater than the producing gas velocity, liquid loading occurs. Liquid loading will be eradicated whenever the producing gas flow rate is greater than the critical flow rate. These findings agree with that of Princewill et al (2018) as they reported that loading occur due to depletion of the reservoir pressure and at this stage the gas produced is unable to lift the liquid produced alongside it, to the surface and as such causing an accumulation of the liquid in the wellbore, and overtime as the liquid accumulates it builds up a high hydrostatic pressure in the wellbore thereby preventing further production of gas.

Moreover, these findings are also in line with that of Davidsson et al (2014) because they found that gas producing wells are experiencing persistent production decline during their lifetime and production decline often follows the already justified reservoir pressure depletion, especially when multiphase mixture in the wellbore has relatively high liquid to gas ratio that exceeds permissible water content limit in the well.

The study is also in line with that of Wong et al (2015) who found out that Gas production profile deviates from stable to unstable indicated by erratic and oscillating behaviors of surface measurements of pressure and flow rate. Emulsion droplet is induced by dynamic interaction between multiphase flow in the reservoir and multiphase flow in the wellbore. The production impairment situation is also not sustainable and may ultimately lead to the end life of the well if appropriate prevention or remediation actions are not delivered in timely manner.

Similarly, the findings collaborates with that of Akpan et al (2018) who found out that the developed liquids in the wellbore are transported to the surface. Some portion of liquids starts to flow back to the well bore, and a liquid column builds up the bottom-hole. It creates hydrocarbon back pressure to the surface, reducing the gas inflow from the reservoir. This process is called Liquid loading. Liquid loading is a common problem in gas wells. Liquid loading occurs when the gas velocity is insufficient to carry the produced liquid to surface facilities. The accumulation of the liquid in the wellbore will cause a decline in the well production rate or the well might cease to flow. To avoid liquid loading in gas wells, the well should be produced at or exceed a certain minimum flow rate and velocity. This particular rate is termed as the critical gas flow rate, which is defined as minimum gas rate required to lift the produced condensate liquid or water to the surface without liquid accumulation downhole. Critical velocity is the minimum velocity that can lift the droplets to the surface. Here the well will be produced at a high Velocity so as to stay in mist flow by the use of smaller tubings or by creating a lower well head pressure. The inability for the emulsion droplets to be lifted to the wellhead may be due to insufficient pressure, minimum gas velocity, critical velocity and rates to lift the liquids to the surface and so on. Liquid loading was eradicated as the producing gas velocities were greater than the critical velocities at various depths of the well and a better well performance was achieved.

CONCLUSION

Whenever the producing gas flow rate is greater than the critical flow rate, Liquid loading is eradicated. Emulsion droplets can also occur when the tubings gets in contact with the liquids in the reservoir. To lift all liquids from the well, the gas flow rate and velocity must be high enough for lifting the emulsion droplets with the largest diameter. The generated fluid data from HYSYS can be used to flow other wells. The critical velocity and rate must be determined for accurate prediction of point of liquid loading.

Recommendations

This study evaluates the impact of emulsion droplets characteristics in oil and gas production line with a view of determining stable conditions for achieving a better performance. It is recommended from this analysis that;

1. The critical velocity and flow rate determined at the wellhead should be the controlling factor for predicting liquid loading
2. The use of models by the Nigerian producing companies that will lead to decline in production rate and whose predictions are less than the actual emulsion droplets flow rate of oil and gas flow should not be encouraged
3. The engineering simulation software (HYSYS) should be used for controlling liquid emulsion droplets in oil and gas well because of its high rate of liquid accumulation prediction, accuracy and reliability which ensures safety and brings about eradication of liquid fall-back.
4. It is also recommended that the oil and gas regulatory body that is in charge of inspection should regularly ensure compliance with the use of high precision models and software for analyzing the critical velocity and rates so as to eradicate liquid loading for better well performance.

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