THESIS TITLE: IMPROVED RECOVERY TECHNIQUE FOR HIGH RATE GAS WELLS IN THE NIGER DELTA FOR PRODUCTIVITY AND RELIABILITY ENHANCEMENT

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ABSTRACT

The aim of this study is to use the field data in the Niger Delta gas reservoir to find an effective sand control method for high rate gas wells in the region.

In this research, the reservoir pressures were recorded for each well and the wells were flowed at a minimum of four different flowrates to estimate other relevant data. The bottomhole flowing pressures were taken through a computer program & correlation.

Gas well deliverability test is used as a model, which relates the Gas flowrate ratio (Y) to pseudo-pressure ratio (X) for the respective wells. For each approach a graph is plotted based on gas flowrate ratio (Y) and pseudo-pressure ratio (X) data generated.

For accuracy in the work, field data were taken for four individual days in a time span of four months. Parameters used in this research are k, $\mu_{g,}$ P_{wf}, P_r, Ƶ and S.

From my observation in the plot, ESS line tends to increase as the gas is being produced while the EGP line with time decline gradually as gas is produced, hence; ESS provides larger inflow area with less friction during gas production thereby enhancing the well productivity.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Niger delta province has one petroleum system, which is the Akata-Agbada petroleum system. The primary source of rock is the upper Akata formation and the marine shale of the lowermost Agbada formation. Oil and gas is produced from sandstone region within the Agbada formation, however, turbidities sand in the upper Akata formation is a potential target in deepwater offshore and possibly beneath currently producing interval onshore (Ekweozor, C. & Okoye,N. 1980). Controlling formation sand production is costly as it requires huge investment but when successful stabilizes the reservoir and maximizes production and increases recoverable reserves, hence prolong the life of the well. Sand production can lead to reduce recovery rates, equipment rusting and sand settling in the surface vessels. These problems can be overcome through slowing down production rate or using External gravel packing technique or Expandable Sand Screen in controlling sand production in gas wells. Sand production poses a key challenge in field development project in the Niger delta region of Nigeria. Most reservoirs in this region are characterized by high porosity and permeability friable formations. Various sand control techniques like External and Internal gravel packs, Chemical Sand Consolidation (SCON), Stand-alone screens, Pre-packed screens, and Expandable Sand Screens (ESS) has been used. ESS has been used in over 30 wells across the eastern and western Niger delta wells by SPDC and this technology has proven to be reliable and many wells have been rejuvenated. The productivity of ESS completion is superior to other sand control methods especially when used in openhole (Egyptian, A. 2015). An Expandable Sand

Screen (ESS) is a new sand control technique which combines many of the properties of gravel packs with that of stand-alone screen. It is an extension of the expandable casing technology and it is used to control the ingress of solids in oil and gas reservoirs in weak and unconsolidated formations. The screen consists of a sand exclusion screen that is capable of considering an expansion when a cone-shaped mandrel is driven through it. ESS expands against the borehole providing support and eliminates the annular space between the sand screen and wellbore thereby reducing sand movement, fines migration, and associated plugging sand impingement and erosion risks minimized, the filtration surface are maximized and future reservoir treatment and control becomes feasible. It also reduces frictional pressure losses and promotes more transient inflow profiles which boast productivity (Weatherford International 1999). External gravel packing (openhole) completions provide another opportunity for sand control. External gravel pack method should be avoided in formations that have sand and shale laminations if the shale's are prone to uncontrollable eroding and/or sloughing Appah, D. (2001). High rate gas wells are gas wells that produce mainly gas at a faster rate during production, and are becoming more popular around the world, particularly in offshore locations. The gas may contain subordinate amounts of liquid hydrocarbons and water. Operators of high-rate gas wells are faced with several challenges like hydrate formation, water production and sand production. Completing high rate gas wells in areas where sand control is required ranks among the top challenges faced in the industry. High velocity gas flowing through the downhole hardware joining forces with the abrasive nature of finer formation solids dislodged and produced can shorten the completion life of the well and also have severe financial implications for the operators (Weatherford, 1999).

1.2 OBJECTIVES OF STUDY

- The main objective of this work is to evaluate an effective sand control technique for high-rate gas wells in the Niger Delta and also to evaluation the performance of the treatment types

1.3 PROBLEM STATEMENT

A significant proportion of gas production comes from the sand-prone reservoirs. If sand enters a well after it has been completed, it can erode and damage equipment and cause loss of production. There is need for installation of effective sand control measures to prevent sand production and enhance well's productivity and reliability in these sand prone reservoirs.

1.4 JUSTIFICATION OF THE RESEARCH WORK

This research work on an effectiveness of sand control methods in high-rate gas wells cannot be over emphasized. It is no doubt that Niger delta of Nigeria is among the leading in gas production, therefore, in other to produce these fields in a safe and economic way, a real time monitoring device should be design and an adequate control measures put in place to checkmate sand influx. Hence, this work is important to:

- Increase productivity index
- Protect surface equipment from destruction
- Prevent the collapse of subsurface equipment (tubing).
- Prolonged life of the reservoir for greater production-output
- Reduced work-over and operational costs from catastrophic breakdown of well and/or reservoir.

1.5 SCOPE OF THE WORK

This research work is limited to high-rate gas wells in the Niger delta region of Nigeria. Oils wells in this region are not considered in this work. The two sand control techniques considered in this research work are the Expandable Sand Screen (ESS) and the External Gravel Pack (EGP).

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL VIEW OF SAND PRODUCTION

Since the invention of Expandable Sand Screens (ESS) in 1999, the technique has been run in about twenty-five (25) fields. In year 2000, 23000ft of ESS was used by Chevron as a sand control measure to prevent sand production from a flowing reservoir. ESS offered sand control without frac-pack and also overcome the problem associated with hole plugging and erosion (Offshore Mag. 2001).

West Delta 117 field located in USA was discovered in 1962 and has since been developed with over 100 wells drilled in the field. The pay sand is stacked deltaic deposits from 4900ft to 14,500ft. Sand control was installed in most of the wells in the field to address historical sand control problems. As at May 2010 in well G-7 S/T1, EGP fail to produce best economic solutions required then and Stand-alone Screens completion was not durable to ensure well life longevity. Due to the failure of these completion techniques to meet the test of time, ESS completion was employed in the well and economic reality was achieved through lowering the initial cost of the well and reducing the risk of early water production compromising gas production (Offshore Mag. 2001).

Bhit gas field is located at 150km North-east of Karachi and 10km South-west of Dadu in the Sindh Province. All Bhit development wells had been completed with 7" monobore style completion and some wells have production of more than 90MMSCFD. The first ever Expandable Selective Sand Screen open hole completion in Pakistan was successfully deployed with combined efforts of the Operator and Service company operation team. This installation proved the advantages of Slim-hole drilling and the economic benefit of large bores to maximize well productivity by lowering the turbulent skin effect in a high rate gas well (Montagna, Arshad & Egge 2005).

Asmari formation is an unconsolidated sandstone formation and it aid sand production since 1940. Recently, Expandable Sand Screen (ESS) was installed to forestall sand production. The well was then produced sand free for about five years. It can be said that ESS technique is a good alternative for Iranian sandstone reservoirs, based on the outcome of gas production in the Persian fields (Reza, S. & Abouzar, M. 2010).

Off-recent, Brunei Shell Petroleum (BSP) in Texas has run this technology in both casedhole and openhole completions and the productivity data of the ESS-completed zones have been up to expectation. For instance, openhole applications in BSP's S.W. Ampa field shows that the Productivity Index (PI) of ESS-completed reservoirs is better than expected, with one ESS zone having some 50% higher PI than similar OHGP zones. Also, casedhole applications in the Champion West field shows better performance of the reservoirs completed with ESS than that completed with IGP. In all cased and openhole ESS-completions, no indications of sand production, screen plugging or screen erosion has been observed (Vliet, J. & Lau, H. 2002).

A case history of a sand control campaign using ESS technology in two oil and gas production wells offshore India is presented. Major drivers for choosing ESS as an alternative for gravel pack in the wells were cost savings in terms of rigtime, less risky operations in multi-zone completions in deviated wellbores and higher expected productivity index due to larger effective wellbore radius. After the wells were brought on stream, the effectiveness of the ESS completions in controlling sand production was routinely evaluated using a digital ultrasound sand monitor. The technology proved effective (Chandra S. & Carh A. 2003).

Saudi Aramco reservoir is unconsolidated in nature and thus a sand control measure is requiring alleviating the problem of sanding. After series of market survey, Saudi Aramco opted for ESS which has collapse strength of 2500psi and the screen integrity is considered to be the strongest in the market. The ESS was run inside the well for sand control prevention purpose and the result from the field shows that the well was later put back on production and the well productivity was excellent (Vliet, J. & Lau, H. 2002).

Mansuri-34 is the first application of openhole ESS (Expandable Sand Screen) technology within Southern Iran. National Iranian Oil Company (NIOC) awarded the contract of sand control solution as a part of Mansuri oilfield development project to Weatherford Completion and Production Systems. There were some wells completed with ESS in southern Iran before now, but they all were cased hole, hence make this job the first time of its own. An openhole completion strategy was selected in order to boost well productivity, with the reservoir section lined with ESS in order to provide borehole support and optimize production rates still further and more importantly allow them to be sustained for a longer period, improving ultimate reservoir recovery factors. NIOC decided to use expandable sand screen (ESS) as the most profitable sand control method over existing sand control solutions for this well. Well fluid was displaced by gas-oil and the well was flowed into different choke sizes. The well is producing 6000 BOPD without sand production which impressed the operator (Mansuri Project Weatherford 2006).

Openhole applications in BSP's S.W. Ampa field shows that the Productivity Index (PI) of ESS-completed reservoirs is better than expected, with one ESS zone having some 50% higher PI than similar OHGP zones. Also, casedhole applications in the Champion West field shows better performance of the reservoirs completed with ESS than that completed with IGP. In all cased and openhole ESS-completions, no indications of sand production, screen plugging or screen erosion has been observed to date (Weatherford, 2015).

2.2 HISTORY OF KAMBOLA FIELD

The kambola field was discovered in 1967 and is sited North-west of Rivers State, Nigeria. The field is poorly consolidated in nature and as a result is prone to sanding. It has six hydrocarbon bearing horizons ranging between 9000 and 12,600feet. These horizons are L5000X, L6000, L7000H, G1500Y, G2000Y and G3000X. The G-Reservoirs are completely gas bearing while the L-Reservoirs are oil bearing. The reservoir contain about 1666.3Bscf of Gas Initially in Place (GIIP) and 85.4mmstb of condensate. The wells were drilled some years back with an objective of supplying gas to NLNG P4/P5. The formations were drilled without a major problem from surface -Akata formation to 13737ftah in the Agbada formation. The wells were producing from sandstone layer-3 of Agbada formation with External Gravel Packing (EGP) considered by SPDC as sand control technique. The cap-rock was determined at 13582ftah. Wells drilled in this field has been put on production for some years with External Gravel Pack (EGP) technique installed as sand control mechanism. Due to problems like partial plugging, screen erosion, sand influx and loss of productivity which are associated with the use of this technique and the difficulties involved in cleaning up the hole before and after installing completion equipment, SPDC and other partners opted for ESS technique to possibly enhance inflow performance. The problem of Stand-alone screens was found to be the incorrect fluid quality used and subsequent collapse of the screen, subsurface erosion and several improper practices engaged during the installation. The well was sidetracked and re-completed to increase production from layers 1 & 2 of the sandstone Agbada formation as well as cut the excessive sand production with the installation of ESS as sand control technique. Kambola field is the first field openhole ESS technique is applied in the Niger Delta. The openhole completion strategy was selected in order to boast well productivity, with the reservoir section lined with ESS in order to provide borehole support and give optimum reservoir recovery factor. ESS apart from being affected by fluid quality and plugging of the small screen opening offers larger inflow area with less wellbore friction when compare to other conventional techniques. ESS is cost effective; require longer delivery time (Cooper, 2005).

2.3 INFLUENCE OF ESS & EGP ON WELL PRODUCTIVITY

Expandable Sand Screens: For about two decades now, ESS technique has revolutionized sand control by enhancing well productivity at a reduced costs compared to other traditional techniques. ESS stabilizes formations, conforms to open-holes, minimizes completion skin-effect and friction-induced pressure losses and this has enhance the well productivity and reserve recovery (Weatherford 2015).

External Gravel Packs: Effective gravel packing yields long term production. Effective sand exclusion is achieved at the expense of reducing a well's production capacity and Productivity Index (PI) is used as a yardstick for evaluating the productivity of External Gravel packed completions (Oil and Gas Journal 1996).

2.4 ADVANTAGES OF EXPANDABLE SAND SCREENS (ESS) OVER EXTERNAL GRAVEL PACK (EGP)

In May 2010 at well G-7 S/T1 in USA, EGP fail to produce best economic solutions required then and Stand-alone Screens completion was not durable to ensure well life longevity. Due to the failure of these completion techniques to meet the test of time, ESS completion was employed in the well and economic reality was achieved through lowering the initial cost of the well and reducing the risk of early water production compromising gas production. Its merits include:

- Increase in hole size efficiency
- Minimizing the effect of skin in the well and enhance natural reservoir inflow capacity towards achieving optimum production rates
- Based on its ability, it is used remedial work

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 MATERIALS

The materials used for this research work were gotten from field production data in the Niger Delta region of Nigeria. Namely:

List of Parameters:

Permeability, k	Depth, H
Gas viscosity, μ_g	Well-flowing pressure, P_{wf}
Reservoir pressure, P_r	Gas deviation factor, z
Skin factor, s	Real gas pseudo-pressure, P_p
Gas flow-rate ratio, Y	Pseudo-pressure ratio, X

Table3.1: table showing list of parameters (Mishra, et.al. 1954)

List of Equipments:

Tubing hanger	Surface casing
Casing shoe	Flow coupling
Downhole Pressure gauge	Production packer
Mirrage plug	Sump packer
Wireline entry guide	Gravel
Bull nose	Screen

Table3.2: table showing list of equipments (Mishra,S. & Caudle, B. 1954)

The production data were obtained from several wells. Details description of the parameters and equipments from the wells are shown below:

Table3.3: Well test data for ESS wells

S/N	Parameters	Units	Well data
1	Depth, H	Ftah	13737
2	Reservoir pressures, P_{r1}, P_{r2}, P_{r3}, P_{r4}	Psi	5850; 4505 5230; 5962
3	Well flowing pressures, P_{wf1}; P_{wf2} P_{wf3}; P_{wf4}	Psi	5476; 4383 3460; 3050
4	Reservoir radius, r_e	Ft	1500
5	Wellbore radius, r_w	Ft	0.31
6	Gas viscosity, μ_g	Cp	0.0168
7	Gas deviation factors, Z_1; Z_2; Z_3; Z_4;	-	0.89817, 0.90079, 0.88627, 0.87122
8	Skin factor	-	0.57

Source: Obtained from ESS producing well

Table3.4: Well test data for EGP wells

S/N	Parameters	Units	Well data
1	Depth, H	Ftah	13737
2	Reservoir pressures, P_{r1}, P_{r2}, P_{r3}, P_{r4}	Psi	5850; 4505 5230; 5962
3	Well flowing pressures, P_{wf1}; P_{wf2} P_{wf3}; P_{wf4}	Psi	1350; 1550 1470; 1490
4	Reservoir radius, r_e	Ft	1500
5	Wellbore radius, r_w	Ft	0.31
6	Gas viscosity, μ_g	Cp	0.0168
7	Gas deviation factors, Z_1; Z_2; Z_3; Z_4;	-	0.89817, 0.90079, 0.88627, 0.87122
8	Skin factor	-	0.57

Source: Obtained from ESS producing well

3.2 Schematic of the wells

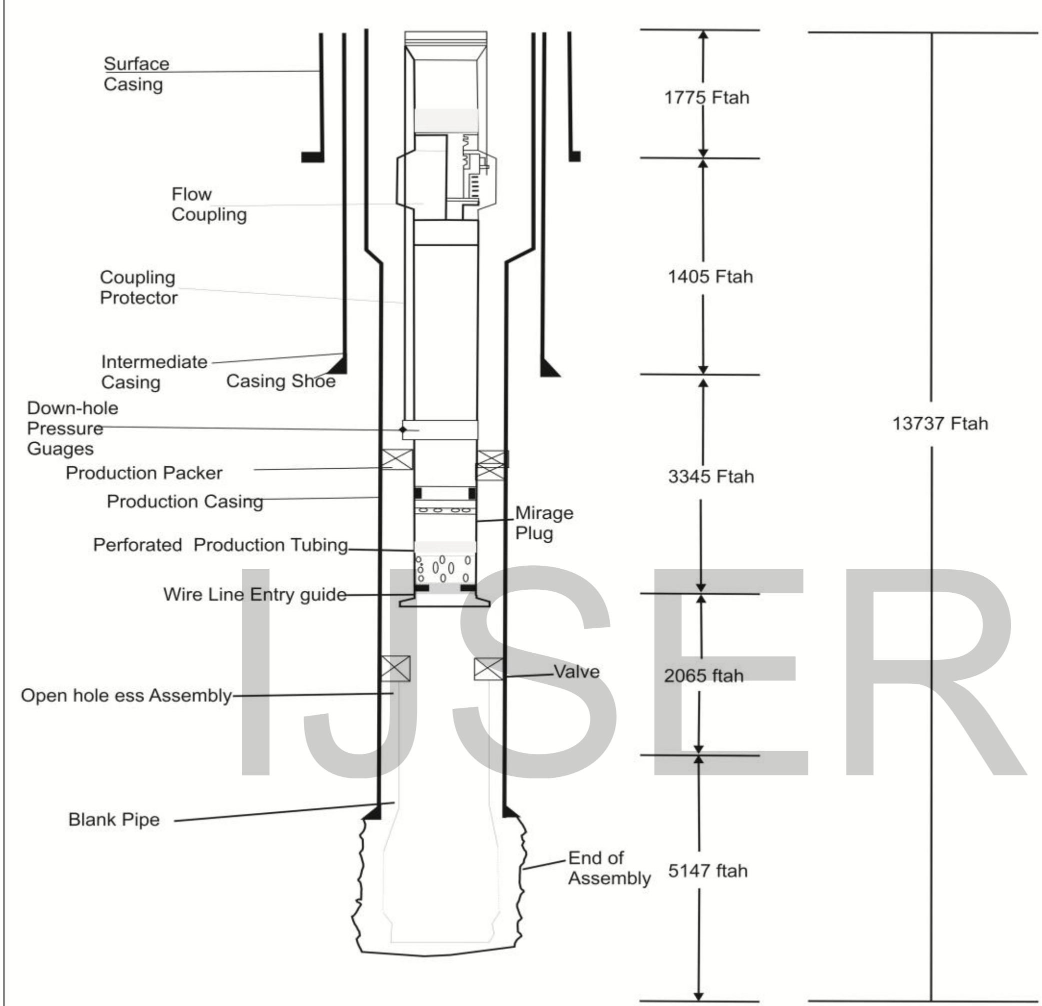

Fig3.1: Completion status of Expandable Sand Screen well (EPG-TWCC, SPDC, 2010)

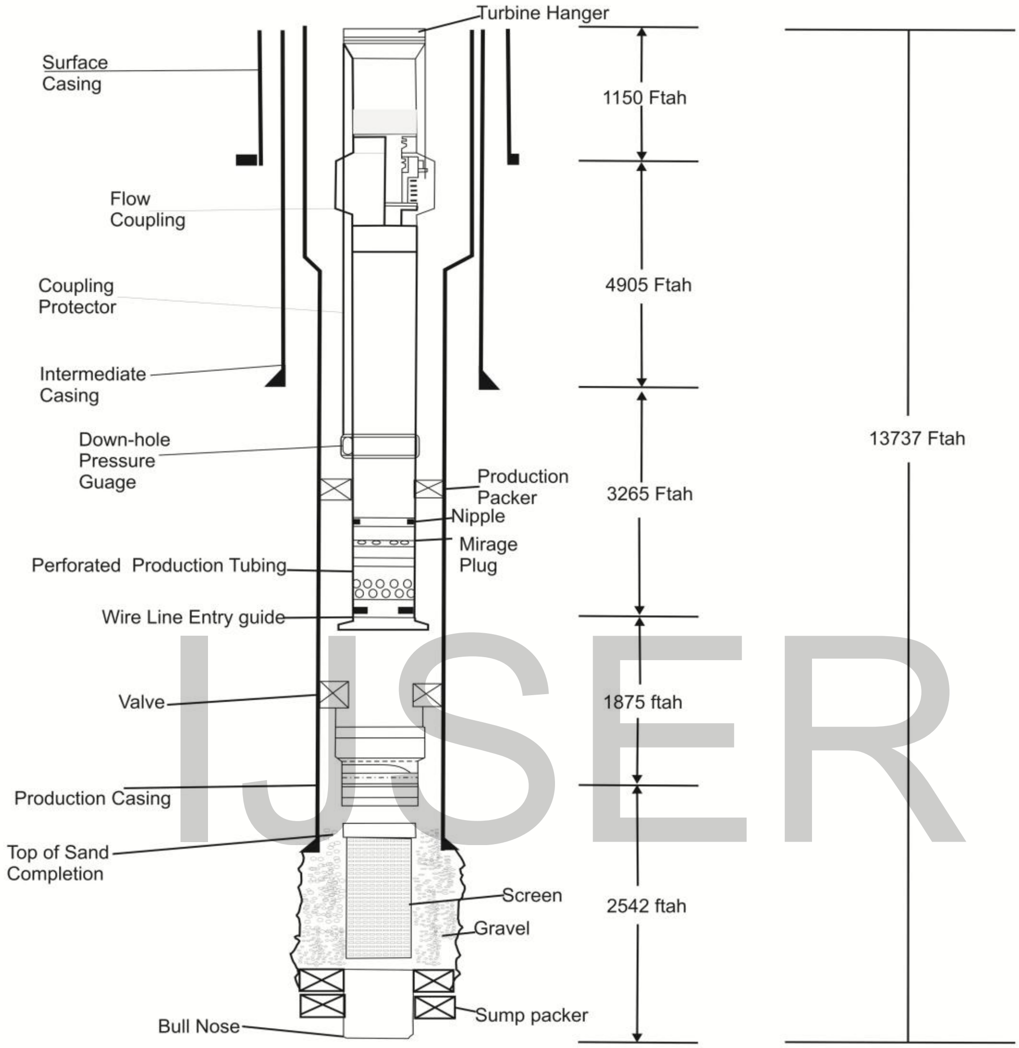

Fig3.2: Completion status of External Gravel Pack well (UI-TWCC, SPDC, 2010)

3.3 Research Methodology

Selection of Control Measure

The selection of an effective sand control technique is based on performance, durability and effectiveness of the treatment type used in a well. The treatment types evaluated in this project are Expandable Sand Screen (ESS) and External Gravel Pack (EGP). EGP has evolved more than 70 years but still involves complex fluid and gravel pumping operations. ESS were deployed to overcome the shortcomings of both existing techniques while also providing some benefits like larger inflow area, operational simplicity and multi-zone capability.

Production Data survey using ESS technique

The producing wells are gas wells in the Niger Delta field spudded on January 8, 2010 and were completed on March 2010 with an objective of supplying additional gas to NLNG P4/P5. The wells have an expected gas recovery of Ca.152.5Bscf and 8.5mmstb of associated condensate. The wells total depth are 13737ftah & 11880ftah (feet along hole) respectively and the wells were completed as a single string gas producer with 270 micro ESS installed as sand control mechanism.

Production Data survey using EGP technique

The producing wells two are gas development wells in the Niger Delta field spudded on December 27, 2009 with an objective of supplying additional gas to NLNG P4/P5. The wells have an expected gas recovery of Ca.159.5Bscf and 8.2mmstb of associated condensate. The wells total depth are 13737ftah & 11880ftah (feet along hole) respectively and the wells were completed as a single string gas producer with 250 micro EGP consisting of 20/40 mesh gravel was installed as sand control mechanism.

Basic Assumptions

a) A homogeneous, isotropic, unfractured reservoir with a closed outer boundary.
b) A single, fully penetrating well.

c) Stabilized conditions prevail, i.e. pseudo-steady state equations can be used to describe gas flow in the reservoir.

d) Turbulent flow effects are characterized by a constant turbulent factor, D and a rate dependent skin (Hazin, A. & Sulaiman, A. 2009)

Evaluation of the Performance of the Treatment Types

Gas well deliverability test is applied in this thesis to predict the performance of the treatment types. Employing the rock, fluid and system properties in Table 3.1, data points pairs of Y (q/q_{max}) and X [$P_p(P_{wf})/P_p(P_r)$] are generated. Pseudopressure ratio (X) and Gas flowrate ratio (Y) are dimensionless.

$$Y = \frac{q}{q_{max}} \quad - - - - - - - - - - \quad 1$$

$$X = \{P_p(P_{wf}) | P_p(P_r)\} \quad - - - - - - - - \quad 2$$

$$P_p(P) = 2\ln\left[{}^{P}/_{\mu z}\right] \quad - - - - - - - - - - - \quad 3$$

$$Y = -0.7193X^6 + 0.6221X^5 + 0.3037X^4 - 0.6108X^3 + 0.0756X^2 - 0.6712X + 1.0006 \quad - - - - - - - - - - - - \quad 4$$

ESS wells

Calculating $P_p(P_r)$ for the ESS wells using P_r values

$$P_p(P_r) = 2\ln\left[{}^{P_r}/_{\mu z}\right]$$

For well-1: P_r = 5850,

$$P_p(P_r) = 2\ln\left[{}^{5850}/_{0.0168 \times 0.89817}\right] \qquad = 2\ln(387693.0711)$$

$$= 2(12.86796925) \qquad = 25.7359 \text{ psi/cp}$$

Applying the same procedure for other ESS wells, we have;

for well-2: P_r = 4505psi @ Z = 0.90079; $P_p(P_r)$ = 25.2744 psi/cp

for well-3: P_r = 5230psi @ Z = 0.88627; $P_p(P_r)$ = 25.5060 psi/cp

for well-4: P_r = 5962psi @ Z = 0.87122; $P_p(P_r)$ = 25.7667 psi/cp

Calculating $P_p(P_{wf})$ for the ESS wells using P_{wf} values

$$P_p(P_{wf}) = 2\ln\left[{}^{P_{wf}}/_{\mu z}\right]$$

For well-1: P_{wf} = 5476psi

$$P_p(P_{wf}) = 2\ln\left[{}^{5476}/_{0.0168 \times 0.89817}\right] \qquad = 2\ln(362907.2235)$$

$$= 2(12.8019025) \qquad = 25.6038\ \text{psi/cp}$$

Applying the same procedure for other ESS wells, we have;

for well-2: P_{wf} = 4383psi @ Z = 0.90079; $P_p(P_{wf})$ = 25.1527 psi/cp

for well-3: P_{wf} = 3460psi @ Z = 0.88627; $P_p(P_{wf})$ = 24.4600 psi/cp

for well-4: P_{wf} = 3050psi @ Z = 0.87122; $P_p(P_{wf})$ = 24.7465 psi/cp

Calculating the pseudo-pressure ratio (X) for the respective wells

Given that; $X = \{P_p(P_{wf}) | P_p(P_r)\}$

$\mathbf{P_p(P_r)}$, psi/cp	$\mathbf{P_p(P_{wf})}$, psi/cp	$\mathbf{P_p(P_{wf})/P_p(P_r) = X}$
25.7359	25.6038	0.9949
25.2744	24.7465	0.9791
25.5060	25.1527	0.9861
25.7667	24.4600	0.9493

Table3.5: showing pseudo-pressure ratio (X) for the respective wells

<u>Calculating the gas flow-rate ratio (Y) for the respective wells</u>

Given that;

$$Y = -0.7193X^6 + 0.6221X^5 + 0.3037X^4 - 0.6108X^3 + 0.0756X^2 - 0.6712X + 1.0006$$

For well-1 @ X =0.9949

$$Y = -0.7193(0.9949)^6 + 0.6221(0.9949)^5 + 0.3037(0.9949)^4 - 0.6108(0.9949)^3 + 0.0756(0.9949)^2 - 0.6712(0.9949) + 1.0006$$

$$= 0.0125$$

Applying the same procedure for other ESS wells, we have;

$for\ well - 2\ @\ X = 0.9791; Y = 0.0478$

$for\ well - 3\ @\ X = 0.9861; Y = 0.0324$

$for\ well - 4\ @\ X = 0.9493; Y = 0.1088$

<u>Tabulating the values of Y & X for ESS wells</u>

$\boldsymbol{Y = \frac{q}{q_{max}}}$	$\boldsymbol{X = \{P_p(P_{wf}) \mid P_p(P_r)\}}$
0.0125	0.9949
0.0478	0.9791
0.0324	0.9861
0.1088	0.9493

Table3.6: showing values of X & Y for ESS wells

EGP wells

Calculating $P_p(P_{wf})$ for the EGP wells using P_{wf} values

$$P_p(P_{wf}) = 2\ln\left[{P_{wf}}/{\mu z}\right]$$

For well-1: P_{wf} = 1350psi

$$= 2\ln\left[{}^{1350}/_{0.0168 \times 0.89817}\right] \qquad = 2\ln(89467.6318)$$

$$= 2(11.40163218) \qquad = 22.8033 \text{ psi/cp}$$

Applying the same procedure for other EGP wells, we have;

for well-2: P_{wf} = 1550psi @ Z = 0.90079; $P_p(P_{wf})$ = 23.0737 psi/cp

for well-3: P_{wf} = 1470psi @ Z = 0.88627; $P_p(P_{wf})$ = 23.0345 psi/cp

for well-4: P_{wf} = 1490psi @ Z = 0.87122; $P_p(P_{wf})$ = 23.0273 psi/cp

Calculating the pseudo-pressure ratio (X) for the respective wells

Given that; $X = \{P_p(P_{wf}) | P_p(P_r)\}$

$P_p(P_r)$, psi/cp	**$P_p(P_{wf})$**, psi/cp	**$P_p(P_{wf})/P_p(P_r)$ = X**
25.7359	22.8033	0.8861
25.2744	23.0737	0.9129
25.5060	23.0345	0.9031
25.7667	23.0273	0.8934

Table3.7: showing pseudo-pressure ratio (X) for the respective wells

Calculating the gas flow-rate ratio (Y) for the respective wells

Given that;

$$Y = -0.7193X^6 + 0.6221X^5 + 0.3037X^4 - 0.6108X^3 + 0.0756X^2 - 0.6712X + 1.0006$$

For well-1 @ X =0.8861

$$Y = -0.7193(0.8861)^6 + 0.6221(0.8861)^5 + 0.3037(0.8861)^4 - 0.6108(0.8861)^3 + 0.0756(0.8861)^2 - 0.6712(0.8861) + 1.0006$$

$$= 0.2191$$

Applying the same procedure for other EGP wells, we have;

$for\ well - 2\ @\ X\ = 0.9129; Y = 0.1752$

$for\ well - 3\ @\ X\ = 0.9031; Y = 0.1917$

$for\ well - 4\ @\ X\ = 0.8934; Y = 0.2075$

Tabulating the values of Y & X for EGP wells

$\boldsymbol{Y = \frac{q}{q_{max}}}$	$\boldsymbol{X = \{P_p(P_{wf}) \vert P_p(P_r)\}}$
0.2191	0.8861
0.1752	0.9129
0.1917	0.9031
0.2075	0.8934

Table3.8: showing values of X & Y for EGP wells

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

From the data generated in the previous chapter, a plot of Y versus X is shown in fig.4.1 below:

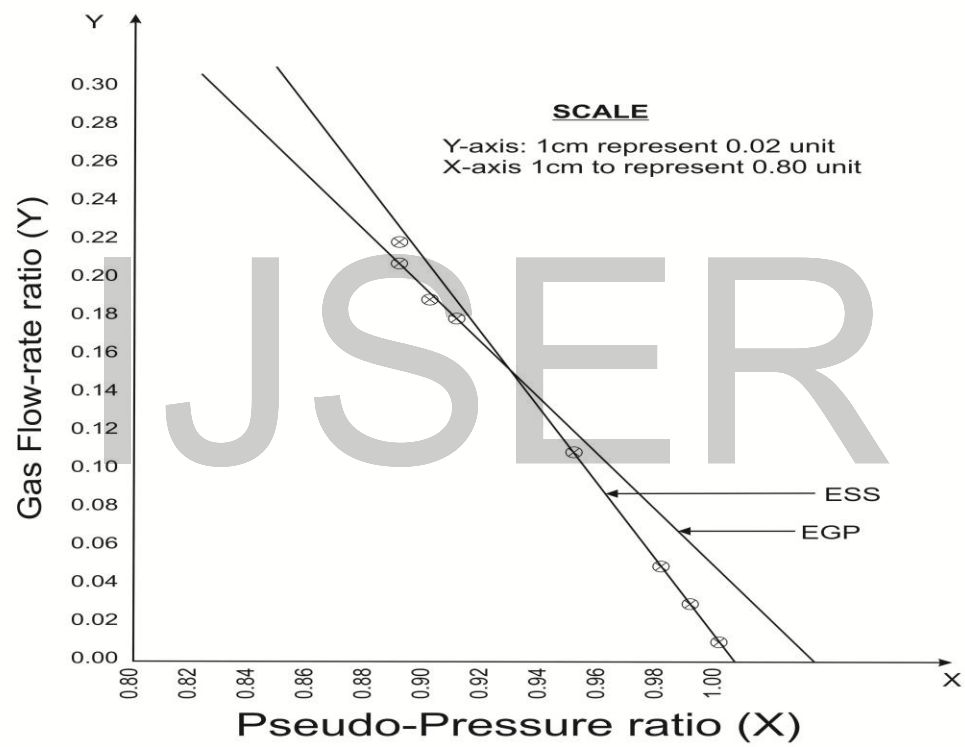

Fig. 4.1

Fig.4.1: plot of gas flow-rate ratio (Y) versus peudo-pressure ratio (X)

4.2 Discussion of Result

The well test data used in this research are limited to reservoir pressure, gas specific gravity, reservoir permeability and bottomhole flowing pressure. Additional key properties such as net formation thickness, z-factor and skin factor are included in this work to develop a more general dimensionless Inflow Performance Relationship (IPR).

Gas well deliverability test is used as a parameter to predict the performance of gas wells. Typically, the wells are produced at a minimum of four different flow-rates. The plot of Y versus X reflects the stabilized deliverability of the well, and stabilized deliverability shows the ability to produce against a given back-pressure at a given stage of reservoir depletion.

The analysis from the graph shows that:

i) The two lines intersect at point 0.154 along Y-axis.

ii) ESS line tends to increase as the gas is produced. This increase is as a result of a hitch flow experienced at the bottom of the well.

iii) EGP line tends to decrease as the gas is produced. The decrease in EGP well performance may be due to debris and loose sand from the formation during production which plugs the pore spaces in the gravel pack. It can also be caused by unclean completion fluid which causes contamination, wrong gravel size selection which can cause sand influx, wrong selection of screen slot to retain the gravel and ineffective placement technique.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The application of an integrated completion using expandable sand screens as the primary sand control completion technique has proved to enhance economic solution when compared to conventional gravel pack completion. The application of ESS as the sand control completion technique in this field enhances the productivity life of the ESS wells as compared to that of EGP wells.

ESS provides larger inflow area with less friction during production, whereas EGP due to some friction caused by the packed gravels required high drawdown pressure during production.

ESS offers several advantages over conventional gravel packs, for instance; easier logistics, simpler operations, larger-bore access to the completed zone, better support of the formation in openhole completions, and potential for remedial zonal isolation.

In terms of durability, EGP is considered as it yields long-term production with reduce well productivity. It productivity is a function of the permeability of the gravel pack sand and how it is placed.

5.2 Recommendation

The following recommendations are made:

1) The test should also be carried out in a fractured reservoir to determine its effectiveness and performance.
2) Additional field data should be employed to further determine the performance of these treatment types.
3) Calculation of future gas deliverability should be considered to ascertain the durability of the technique.

REFERENCES

Akpabio J. U. (1994) "Sand production in oil and gas producing wells as it affects production in the Niger Delta". B.Eng. Project, Department of Petroleum Engineering University of Port Harcourt.

Al-baggal Z.A., and Abbott J.W., (2006) "Abu Dhabi International Petroleum Exhibition and Conference". Abu Dhabi, United Arab Emirates.

Appah, D. (2001). "New Gravel Pack Technique Reduces Sand Production in Niger Delta Wells". Oil and Gas Journal.

Brar, G.S.and Aziz, K., (1978) "Analysis of Modified Isochronal tests to predict the stabilized deliverability potential of gas wells without using stabilized flow data".

Cameron J.A. (2005). "Weatherford Completion and Production Systems". Society of Petroleum Engineers, Dubai, United State Emirates.

Chandra S. and Ali E. (2003). "Expandable Sand Screens for Multi-zone Sand Control Completions". Carh Energy. India.

Ekweozor C.M. and Okoye N.V. (1980). "Petroleum Source Bed Evaluation of Tertiary Niger Delta".American Association of Petroleum Geologists Bulletin.

Egyptian Journal of Petroleum (EJP). (2015). Nairobi.

Hazim Al-Attar and Sulaiman Al-zuhair., (2009) "A General Approach for Deliverability Calculations for Gas wells". Dept. of Chemical & Petroleum Engineering, UAE University.

Journal of Petroleum Exploration and Production Technology. (2012) Volume 2. Germany.

Mishra, S., and Caudle, B. (1984) "A Simplified Procedure for Gas Deliverability Calculations using dimensionless IPR curves". Paper SPE 13231 presented at the SPE Annual Technical Conference and Exhibition, Houston.

Montagna J., Arshad M. & Egge G. (2005) "Slimhole Drilling with ESS for Low-cost, High Deliverability Wells". SPE Annual Technical Conference and Exhibition, Texas.

Offshore Digital Magazine (ODM). (2001) "Sand Control Solutions". United State of America.

Oil and Gas Journal (OGJ). (1998), Robert Gordon University. Aberdeen.

Reza S.M. and Abouzar M.R., (2010) "Successful Application of Expandable Sand Screen in Persian Oil and Gas Fields".SPE Production and Operations Conference and Exhibition. Tunis, Tunisia.

Ripa G., Pellicano D. and Stockmeyer C., (2005) "Expandable Completion Technology: High Rate Gas Producer/Storage Workover Application". Offshore Technology Conference. Houston, Texas.

Vliet J. and Lau H.C., (2002) "Productivity of Wells Completed with Expandable Sand Screen". Brunei, Texas.

Wali A., Uzoho F., Nwankwo C., Ekwealor J. (2015). "Evaluation of Cased-hole Expandable Sand Screen Application in Gas wells". SPE Nigeria Annual International Conference & Exhibition, Lagos, Nigeria.

Weatherford International Inc., Houston. (1999). "WFT'S Petroline Unit Installs World's First Horizontal Expandable Sand Screen". Retrieved from http://www.weatherford.com/cs/wft

Weatherford International Inc., Russia. (2005). "Weatherford Install Expandable Sand Screen Installation for BP". Retrieved from http://www.weatherford.com/bp

Weekse A., Steve G. & Urselmann R. (2002). "Expandable Sand Screen: Three New World Records in the Brigantine Field". IADC/SPE Drilling Conference, Texas.

Woodsize Energy Ltd. (2012). "Big Bore Gas Wells". Western Shelf, Australia

World Magazine (2004). "Sand Control Succeeds in High Rate Big Bore Gas Wells". Australia.

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Appendix A

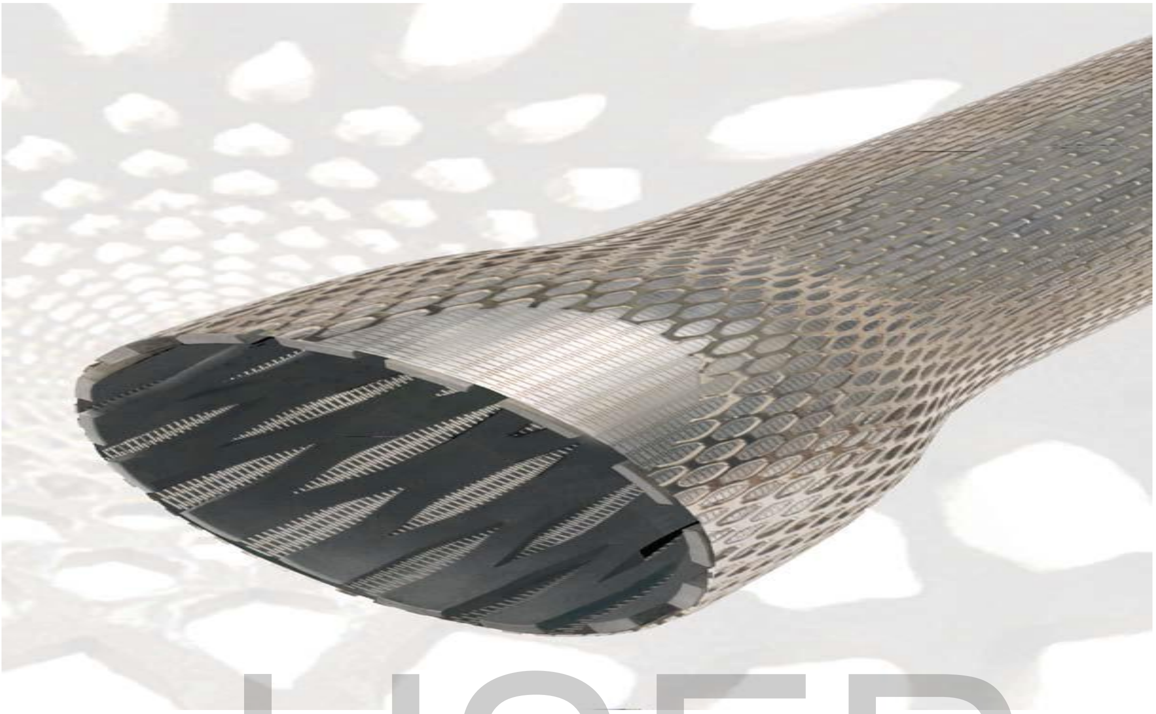

Fig1. Cross sectional picture of conical expanded ESS screen. (Offshore Digital Magazine, 2001)

Appendix B

Fig2. Picture of an Expandable Sand Screen. (Oil & Gas Journal, 1996)

Appendix C

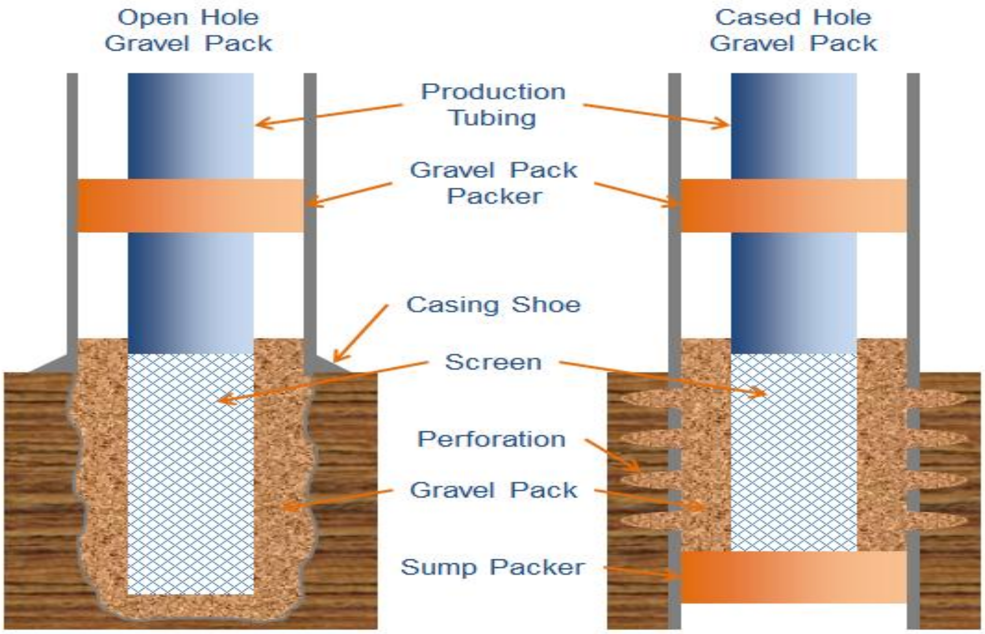

Fig3. Picture showing External & Internal gravel pack. Dunefront consulting firm, Houston, USA

Appendix D

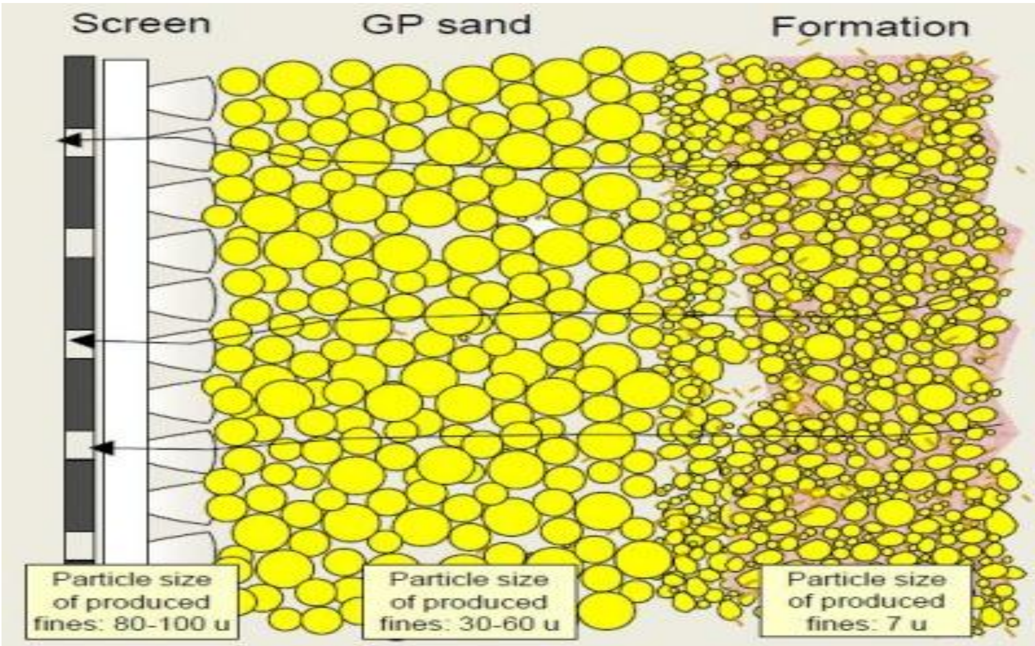

Fig4. Picture of a typical External Gravel Pack Completion setting. (Weatherford International Ltd. 2005)

Appendix E

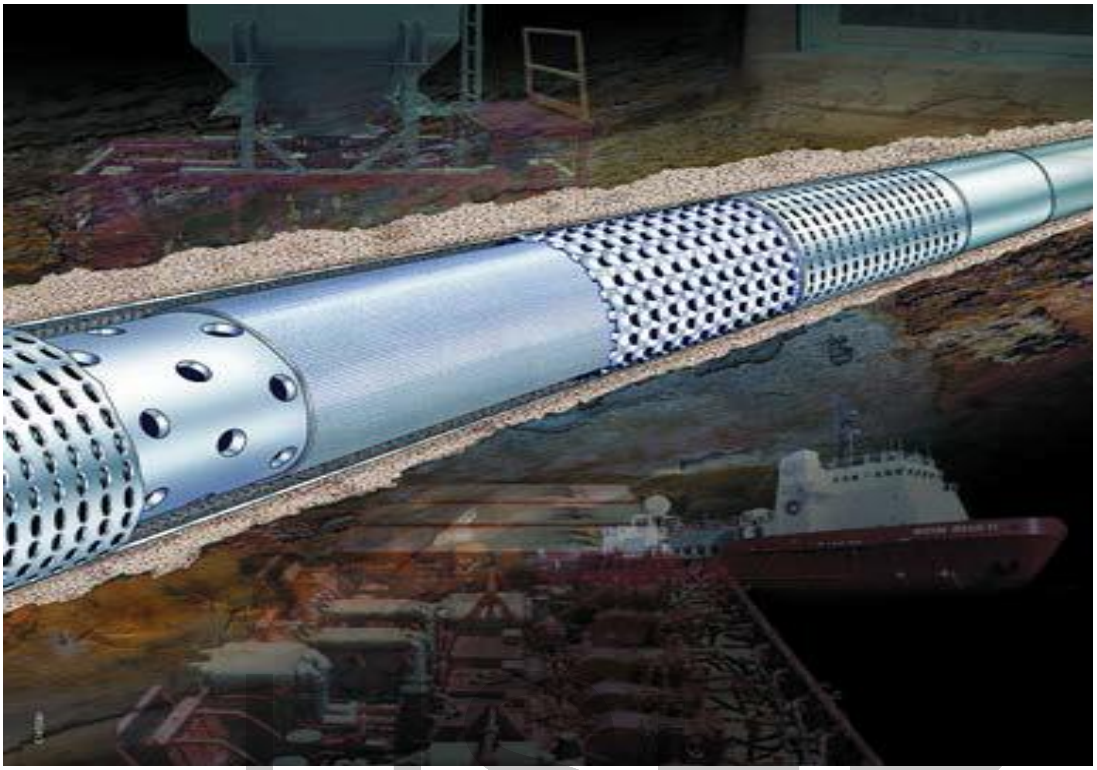

Fig2.2 A picture of Stand-alone Screen.Journal of Petroleum Exploration and Production Technology. (2012)

Appendix F

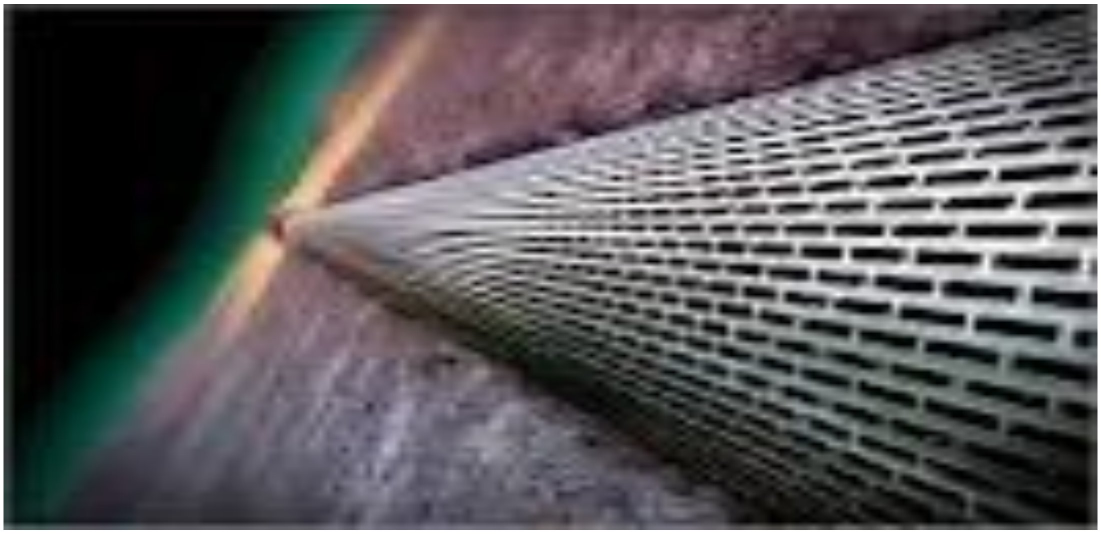

Fig2.2 A picture of ESS after conical expansion. (Oil & Gas Journal, 1996).