



**Sudan University of Science and Technology**  
**Collage of Petroleum Engineering & Technology**



**Department of Petroleum Engineering**

**Be- Tech – Five Level**

**The Efficiency of Progressive Cavity Pump  
(PCP) for Oil Sandy Field (Block-06- Sudan)**  
**(Case Study)**

A Project Submitted in Partial Fulfillment for the Requirements of the  
Degree of Be. Tech (Honor) in Petroleum Engineering

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# الاستهلال

قال تعالى:

(فَفَهَّمْنَاهَا سُلَيْمَانَ ۗ وَكُلًّا آتَيْنَا حُكْمًا وَعِلْمًا ۗ وَسَخَّرْنَا مَعَ دَاوُدَ  
الْجِبَالَ يُسَبِّحْنَ وَالطَّيْرَ ۗ وَكُنَّا فَاعِلِينَ).

صدق الله العظيم

سورة الانبياء الآية (79)

## *Dedication*

This study is dedicated to all our Fathers, Mothers, Brothers, Sisters, Friends, Teachers and Every person that support us during our long journey in this research.

May Allah (Subhanhu WaTa'ala) bless you and give you what you want.

## *Acknowledgments*

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## *Abstract*

Progressive cavity pumps (PCP) have been extensively used as artificial lift equipment in various oil field assemblies. These pumps are capable and have ability to work in oil sandy wells with high efficiency. Recently, many Sudanese oil fields suffer from the massive amount of sand production affected on (PCP); the most production problem of sand in Sudan was observed in Baleela oilfield which is located in (west kordofan state-Sudan block-6).this work aimed to (Estimate PC pump efficiency with gravel pack or without gravel pack) using data of four wells (FN-06,134,136&148) and PIPESIM software was used for designing the model. The results presented that PCP efficiency increased when permeability increased and the flow rate will increased too, that is mean the efficiency of PC Pump will be high.

## المستخلص

تستخدم مضخات التجويف التدريجي (PCP) على نطاق واسع كمعدات انتاج صناعية في مختلف مجال حقول النفط. هذه المضخات لديها القدرة على العمل في آبار النفط الرملية بكفاءة عالية. في الآونة الأخيرة، تعاني العديد من حقول النفط السودانية من الكميات الهائلة من إنتاج الرمال التي تؤثر على (PCP)؛ وقد لوحظت مشكلة الإنتاج الأكبر للرمال في السودان في حقل بليلة النفطي الموجود في (ولاية غرب كردفان-مربع 6). يهدف هذا العمل إلى (تقدير كفاءة مضخة PC مع استخدام الحصى او بدون استخدام الحصى) عن طريق بيانات من أربعة آبار (148&06,134,136) وذلك باستخدام برنامج PIPESIM. حيث أظهرت النتائج أن كفاءة مضخة PCP زادت عندما زادت النفاذية وكذلك تزداد معدلات الانتاج، وعليه تزيد كفاءة المضخة.

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# Chapter 1

## Introduction

### 1.1. Introduction:

Progressive cavity pumps (PCPs) are a special type of rotary positive displacement pumps, and were first introduced in petroleum engineering as an artificial lift method in 1970's. In a PCP, the flow through the pump is almost axial, while in all other rotary pumps, pumping fluid is forced to travel circumferentially. This gives PCP unique axial flow pattern and low internal velocity, which reduces fluid agitation and churning and therefore reduces fluids emulsion and solids erosion.

PCP has advantages of lower investment, broader applications to fluid mixtures, less maintenance, and higher efficiency to other artificial lift methods. It is becoming a popular lift tool and, for some wells, the best choice in artificial lift methods.

In petroleum industry, the most commonly used progressive cavity pump is a single lobe pump that consists of a single external helical rotor turning eccentrically inside a double internal helical stator. The rotor and the stator have the same minor diameter and are made of metal (steel). The fits between the rotor and the stator may be metal to metal, or metal to elastomeric which is set inside the stator. Compression fits are usually used for metal to elastomeric contacts, while very small clearance is left for metal to metal fits. There are chambers between the rotor and the stator, which are separated by the fits as cavities in 180° apart. The fits work as seals to prevent fluid communication between adjacent cavities. As the rotor rotates, the seal lines change positions and form fully enclosed cavities moving continuously from pump inlet to outlet.

These cavities trap fluid at the inlet and carry it along to the outlet, thus providing a non-pulsation smooth flow. Unlike centrifugal pump, fluid viscosity will not degrade pump head of a PCP, but increase pumping volumetric efficiency. Since PCP is a positive displacement pump, it doesn't have gas lock problem theoretically, but due to temperature increase from gas compression, PCP can only handle high gas slug in a short time. Due to the feature of moving seal lines, scale does not normally deposit in a PCP. PCPs have relatively low inertia of their rotating parts, and have a reliable working life.(One Petro, SPE).

## **1.2. Problem statement:**

Block6 oil field is used progressive cavity pump (PC Pump) to produce hydrocarbons storage, which consist of high amount of sand. the produced sand causes problems and failures to PC Pump , Lead to change and replace the Pc pump with new one many times through a year this study is carried out to reduce the amount of sand that enter into (PC Pump ) in order to make the production more economic .

## **1.3. Objectives:**

1. To compare the efficiency of PC Pump with Gravel packs and without Gravel pack.
2. To Estimate PC pump efficiency.

## **1.4. Background about Block 6 Field:**

Bock6 oil field is Located in west kordofan state Sudan, it has unconsolidated formation .the field uses progressive cavity pumps (PC pump) to produce hydrocarbons storage, which consist high amount of sand and crude oil with high viscosity. The produced sand along with oil causes problems and failure to PC pump. Fulla north (FN-06, FN-136, FN-134, and FN-148) wells are development wells. The field has been

developed in 2003 by petroenergy-ep Company. The development wells were put into production in 2005 starting with 5000STB/D.

The wells produced more sand, and then the wells shut down due to PC pump problems many times. the above mentioned wells are selected for case study due to pc pump problems to study the pc pump efficiency with gravel pack and without gravel pack and to avoid PC pump premature failure .By using PIPESIM software design .

## Chapter 2

### Literature Review & Theoretical Background

#### 2.1. Progressive Cavity pump Studies over the World:

Currently available Publications on this topic are rare and textbooks are scarce. Most previous studies focus on PCP (performance, Design and optimization). The studies have shown below:

Rene Moineau (1930); Afrench mathematician he was invented the principle of PCP his work was based on the geometric fact that the hypocycloid created when a rolling circle rotates within a fixed circle twice its size is a straight line path and not a curved one utilizing this concept he designed a pump that did not require a complex valve arrangement.

May and Appleby (1931):In their studies stated that the hydraulic loading caused by the differential pressure across the pump , is the principle cause of both the axial and radial loading on the rotor and stator and is the major contributory load to the wear within pumping element .

Wirth and Bourkes (1932):In their studies observed that the temporary embedding of particles in a resilient stator material protected the stator surface from wear .the resultant grooves created in the rotor surface were then found to cause counter damage to the stator by cutting into soft rubber walls.

Caberly (1941): Noted that expenditures of this magnitude obviously have a significant impact on profits. In spite of these costs effective sand control practice have yielded oil and gas from wells that otherwise , wise would have been shut in .

Hall and Harrisberger (1970): Presented data from arching experiments with unconsolidated sand in Gulf of Mexico laying the

ground work for condition of sand arch formation stabilization and failure. it was found that sand arches consisting of disaggregated failed rock under formation stress formed a region that was in plastic state , which with its unique arch shape was able to bear external loading .

Saucier 1974: Stated that the a gravel pack is adown hole filter designed and used to prevent or block the production of unwanted formation sand and solid. Saucier added the formation sand is normally being held properly in place by gravel pack sand which is held in place with a sized screen.

Adams (1986):He said to effectively control the invention of sand, we need to have technology to estimate accurately the initiation conditions, predict the sand influx rate and volume of sand production to prevent its effect on surface and subsurface production facilities which directly impact on the oil well production.

Morita (1989):In Gulf of Mexico a knowledge that shear and tensile failure contribute to the instability of the perforation tunnel and tip. Found that from an operational perspective cyclic loading (shutting), transient flow and multi phase flow are considered to be the major cause of sanding.

Veeken (1991):Answer perspective on sand production was introduced that any decision on sand control methods must be based on a good understanding of sand production.

Penberthyet 1992: He found through experiment the procedure provides measuring the pack permeability with each change in gravel size and comparing it to the formation initial permeability.in this if the final permeability is equal to the initial permeability we could say that effective sand control achieved.

Weingarten and Perkins (1995): Conducted a research on prediction of sand production in gas wells. The method proposed was

applied to 13 fields in the Gulf coast area. The rock strength was determined by core testing and log correlation and the results compared. The prediction method differs from commonly used log based sand prediction model. Their model however predicts the onset of sand production and is not designed to apply to situations where some level of sand production is allowable.

Tronvoll (1997): Asked the question whether sand production was a result of mechanical failure or hydrodynamic erosion. Experiments revealed that material went through post failure weakening. A major source of substantial sand production was attributed to the hydrodynamic forces due to fluid flow in spite of its relatively small magnitude compared to the strength of the rock; therefore, weakening of the material was identified as prerequisite for sand production.

Van den Hoek et al (2000): In Gulf manilao introduced a new study on failure modes of cavities .using the normalized drawdown pressure gradient and shear failure stress. The conclusion was that medium to large holes such as wellbore always failed in compression the material failure point was dependent only on the threshold value of effective stress. Found that perforation could fail in tension due to extreme pore pressure and smaller cavities have high resistance towards shear failure.

Mcphee et al (2000): Study carried out in bongkot field in gulf of Thailand between 1993-1994 since the sand production is an issue it has led to significant incremental costs and increased the risk of potential key flow line failures of control equipment . Found 300 tones of sand were removed from separators and water

.Erikson, et al (2001): This study is carried out in varg field in Norwegian sector of North sea , stated that sand production was experienced during the drill stem testing performed in some of the



appraised wells , found in this field , sanding issues were addressed at an early stage which gave the opportunity to review different options of sand management and selection of cost effective means of sand control .

Yearlong and Carl (2001): Wrote a paper on enhanced oil production due to sand flow , in Northwestern Canada ( heavy oil reservoir ) field data for solid and enhanced oil production , collected and used to validate the model for the cumulative sand and oil production the results indicate that sand production could reach up to 40% of total fluid production at the early production period and drop down to minimum level after the peak .

Lindbergh and Forglake (2001): In Lloydminster fields, indicate that primary recovery is dependent mainly on the process of sand production and foamy oil flow optimization of oil production, keeping sand production under control is the challenge being faced in these fields, However reduced oil flow or zero production often results with sand control especially in the heavy oil reservoir.

Gamboa et al .(2002): Presented an extensive experimental study in PCP for single and two phase flow conditions characteristics curves and transient pressure profiles within cavities in metallic stator pumps , however , no flow model was developed .

Wilson(2002) in Gulf Mexico : Non dimensional zed formation stresses with material strength based on a thick walled cylinder test and petro physical parameters to portray the sanding potential .an additional called the sand production boost factor was introduced to account for massive during water production the model showed an empirical relationship between non dimensional zed parameters and it was able to predict sanding to a reasonable degree in the field.

Jose Gamboa et,al. in 2003 Research and Development Institute of Petroleos de Venezuela S.A , presented study under title (Understanding

the Performance of Progressive Cavity pump with a metallic Stator) focused on Analytical and Experimental studies carried on progressive cavity pump fitted with a metallic stator with affixed positive clearance around the helical rotor.

Wuandtan (2005):Stated that on most occasions in the field the initiation of sand production has been observed to coincide with water breakthrough . thus it is generally believed that water production increase the risk of sand production in the field . the effect of water cut on sand production is of major importance to petroleum industry .

Cesar Ivan Medina-Chavez et, al. 2005 The University of Texas presented study under title (Design Standards, Special Specifications, and Monitoring Plan for PCP in Texas) focused on the effective application of the required procedures for the final design and construction of the new PCP and also on the development evaluation and monitoring plans for both short-term and long term performance of the PC pump.

Veeramani et al (2007):Extend the application of fictitious domain method for direct numerical simulation to fluid motion in a single lobe pcp .and have extended the same idea to simulation of rotor moving inside the stator .

Mohammed Bashir et, al.in 2009 Sudan university of science and technology presented study under title (Optimization of progressive cavity pump), this study discussed optimization of PCP focused on selection of the optimum parts of the pump which achieve the optimum performance and productivity according to the various condition of the producing wells.

Wirth and Vetter (2009):Found that the process of wear in PC pump was influenced by the fulling effect that the stator encounters due to the interference fit which leads to localize elastic deformation of the rubber.

Reza et al (2010):Carried out studies in the Persian oil field in Iran. is based on successful application of expandable sand screen , found that 80% of Iran oil reservoir are carbonate and about 20% sandstone .

Asmari formation is where the main sandstone reservoir layers are, there have been reports of sand production problems since 1940, the unconsolidated sandstone layers are main reason of sand production. Expandable sand screen was recently installed as a sand control method the out come was successful, and expandable sand screen technique is a good alternative for Iranian sand stone reservoir.

Paladino (2011):Developed a mesh generation algorithm , including the mesh motion defined by the pump kinematics which is fully integrated through for tran routines with the AMSYS –CFX @ COMMERCIAL CFC package.

Abubaker Mohamed 2012: He did the comparative study of sand control methods in Niger Delta the result show that sand control using chemicals (s con) wells have better performance than internal gravel pack (Igp) wells with well inflow quality in Vicent et al (2012)).

Did carry out some analysis in the Niger Delta region of Nigeria , it was discovered at the end of the analysis that 64% of wells analyzed were sand producers and that coastal swamp the most drilled region in the Niger Delta ,which the greater ughelli stands out as the most prolific sand producing region in the Niger Delta with over 90% of its reservoirs producing sand . Irrespective of sand control and formation depth

## **2.2. Progressive Cavity Pump (PCP) Components:**

Progressing cavity pump systems drive their name from the unique, positive displacement that evolved from the helical gear pump concept. also called screw pump, the PC pump initially were used extensively as fluid transfer pumps in wide range of industrial and manufacturing

applications, with some attempt made to use them for the surface transfer of oil fields.( by Rene Moineau in the late of 1920s)..The progressive cavity pump consist of two major equipment : (see figure 2.1)

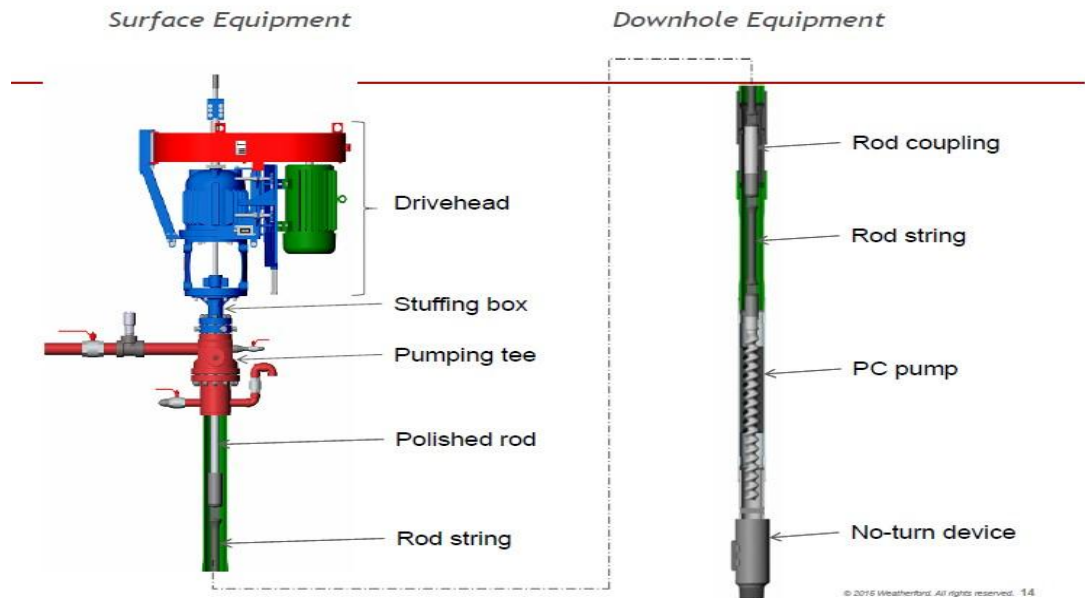


Figure (2.1) Surface and down hole assemblies of PC pump (weatherford oil field product).Lonnie Dunn, (2015)

### 2.2.1. Surface equipment:

#### i. Wellhead Drive Units:

The wellhead drive unit consists of a wellhead frame, thrust bearing, a polished-rod braking system (in most cases), and sometimes a fixed gear or belt and sheave system. In many cases, the wellhead frame threads directly onto the tubing head (see figure 2.2).

However, there is a growing trend toward the use of flanged connections, especially for applications involving drive systems that are 60HP or larger (Larry, 2006).

It has the following functions:

1. Suspend the rod string and carry the axial loads
2. Deliver the torque required at the polished rod

3. Safely rotate the polished rod at the required speed
4. Provide for safe release of the stored energy during shutdowns
5. Prevent produced fluid from escaping the system.(Larry , 2006)



Figure (2.2) Basic surface equipment for PC pumping systems (Larry, 2006)

ii. **Prime movers:**

The prime mover provides the energy to drive the surface equipment and ultimately the rod string and downhole pump. The amount of power that the prime mover must deliver depends on the power demand at the polished rod and the efficiency of the power transmission system. Typical prime-mover power ratings range from 4 to 75 kW [5 to 100 hp], although higher capacity wellhead units designed to accommodate twin electric motors providing power up to 225 kW [300 hp] have recently been introduced by several vendors in conjunction with new large displacement PC pumps. (lange et al 2006).

### **2.2.2. Down hole equipment:**

The down hole equipment consist of following assemblies:

1. Polished Rod
2. Sucker rods
3. Sucker Rod Centralizers
4. Rotor & Stator
5. Pup joint<sup>2</sup>
6. Stop bushing
- 7- Torque Anchor (One Petro, SPE).

### **2.2.3. Downhole equipment in details:**

#### **i. Sucker rods:**

Sucker rods function is to transmit the rotation from Top Drive to the rotor. The max stress is at the top of the rod string. (Sucker rod length 25 or 30 ft, Pony rods 1- 2- 4- 6- 8- 10- 12 ft) (See figure 2.3).Several different ros wd-string configurations are commonly used in PCP applications. These include continuous rods, standard rods with couplings (including hollow rods), standard rods with centralizers, and standard rods with bonded/molded rod guides. (API .1990)



Figure (2.3) Sucker Rod of PC pump

**ii. Rotor:**

Rotor is a single piece; total length of the rotor exceeds that of the stator by 0.45 to 0.50 m (see figure 2.4). There are different temperature codes and different outside diameters for each type of rotor, the higher the code the smaller outside diameter. To select the temperature code, we have to choose 2 scales over the actual down hole temperature. If down hole temperature is 90 C (code 10), we need to go to code 12 (temp. 125 C). Most pc pump manufacturers have stator products available with several different elastomer types. Because the formulation of this elastomer is considering proprietary, there is no standard naming convention. Certain generic names are common to the different manufacture but elastomer properties may very significant, the common types of elastomer are:

- Nitrile (NBR)
- Hydrogenated NBR (HNBR)
- Fluoro elastomer (FKMs) (Clegg et al 1993)



Figure (2.4) Rotor of PC pump

**iii. Stator:**

Stator is made from elastomer. The elastomer properties affected by the gas/liquid ratio and the temperature at the pump setting depth (see figure 2.5)..The common changes in elastomer mechanical properties are:

-Swelling which leads to excessive interference between rotor and stator (Stuck rotor).-Hardening, due do H<sub>2</sub>S which leads to loss the elastomer resilience or flexibility, shrink and crack (makes annulus between rotor and stator, oil drop down or slippage.) or vice verse rotor stuck.

-softening leads to weakness and seal deterioration due to co<sub>2</sub> presence.

(Clegg, J.D., Bucaram, S.M., and Hein, N.W.J. 1993).





Figure (2.5) Stator of PC pump

**iv. Stop Bushing:**

Stop bushing connected to the bottom of the stator, it provides length of 0.30 m for possible elongation of the rod and serves as landing spot during spacing out. (See figure 2.6):

(Centre for Engineering Research Inc, “PC-Pump User Guide”;  
Version 2.1; 1997).



Figure (2.6) Stop Bushing of PC pump

**v. Tubing Anchor:**

Most PCP systems operate in the clockwise direction, so the resistive (i.e., friction) torque in the system tends to unthread the production tubing connections. As a result, tubing anchors are often run below or above the PC pump so that the resistive torque loading is transferred directly to the casing. They also alleviate the need to over-torque the tubing connections during makeup, which can substantially increase the number of makeups possible before thread damage occurs. Tubing anchors should be run with large-volume pumps and in high-speed applications in which the high resistive torques and system vibrations increase the potential for tubing back off problems. Although several vendors supply conventional tubing anchors that can be used in this application, several manufacturers sell products specifically designed for PC pumping systems that differ from conventional anchors in that they resist torque while providing minimal axial load resistance. This facilitates removal of the tubing string from a well that has sanded in. (see figure 2.7): (API, 1990)



Figure (2.7) Torque Anchored of PC pump

**vi. Pup Joint:**

The pup joint function is to allow for the movement of the rotor head and it is coupling, because the inside diameter of the tubing is small. The common length of this joint is 4 ft and the outside diameter is 4 inch. . (see figure 2.8) : (API, 1990)



Figure (2.8) Pup Join of PC pump

**vii. Polished rod string:**

Standard assembly from Top as following:

2ft Pony for lifting

Full Size Coupling

Note: Coupling must be bigger than Hex Shaft

Hexagonal Shaft – Pin on top

Hex clamp on the Hex shaft @ 15 cm from top

Note: The bolts must be cross tightened.

Polished Rod PR

Note: Must be tightened on the Hex Shaft with a pipe wrench and measure the torque.

Bullet on the bottom of PR–Thread protection. ( API.1990)

### **2.3. PC Pump Installation:**

Conventional PCPs are installed by running the stator assembly on the bottom of the tubing string and the rotor on the bottom of the rod string. In contrast, with an I-PCP, the entire pump assembly is installed by the rod string and landed inside the tubing string. This allows the pump to be pulled and rerun by the rod string. The primary advantage of this system is the elimination of costly and time-consuming tubing pulls to change worn or damaged pumps or to switch to different pump sizes and configurations as downhole pumping requirements change. (SPE 2017)

### **2.4. Setting the torque anchor:**

In artificial-lift applications, a new anchoring device for insertable progressing-cavity pumps (I-PCPs) extends I-PCP applications to a larger set of candidate wells. The I-PCP anchor allows an I-PCP to be run, landed, operated, and removed from a tubing string in the absence of a previously installed pump-seating nipple (PSN) typically required for installation.

Before setting the tubing hangar it is important to set the Torque Anchor.

At approximately 50 – 60 cm before the hangar is set, turn the tubing with a pipe wrench clockwise.

Hold that position until the Tubing Hangar is firmly set. (SPE, 2014).

### **2.5. Rod String Standard –Configuration:**

Rotor + Rotor Coupling

Pony rod – 10ft or 12ft / Coupling

Centralizer / Coupling

Sucker Rod + Coupling

Centralizer + Coupling

Sucker Rod + Coupling

Centralizer + Coupling

Rod String to surface + Coupling (API, 1990)

## **2.6. Running Rotor in the Hole:**

Make sure that the Rotor is clean and free from any foreign elements / damages.

Make sure that the bottom of the Rotor is protected at all times.

For new Stator's it is advisable to lubricate the Rotor with grease to avoid any dry contact between the Elastomer of the Stator & the Rotor.

Do not drag the Rotor on the Catwalk or the Rig Floor. (API, 1990)

## **2.7. Space out –The Rod String:**

Spacing out done by the following steps:

Once the Rig Weight Indicator r shows ZERO, it would suggest that the Rotor is sitting on the Stop Bushing.

At the Well Head- Use a Paint Marker and tag the Sucker Rod.

This tag will be the “Zero String Weight Tag”.

Continue to run in & out of the stator a few times – To be sure that the Zero String Weight Tag is always in line with the well head.

After marking the Ze0ro String Weight Tag, pick up the Rod String very slowly until the Total String Weight is observed again.

At this point, the Rotor is still inside the Stop Bushing but not sitting in it.

Tag the Sucker Rod – This tag will be the “Total String Weight Tag”.

Pick up the Rod String another 30 cm more and tag it.

This tag will be the “Stop Bushing Tag”.

This indicates that the Rotor is out of the Stop Bushing.

The last tag of the space out will be the value calculated by PCM's Win Petro (API, 1990)

## **2.8. Progressive Cavity Pump (PCP) working mechanism:**

A progressive cavity pump is a rotary positive displacement pump defined as a machine in which liquid is trapped in confined volumes and transported from an inlet to an outlet port by a rotational movement of pumping element.

The downstream process or piping system produces the resistance to the flow and thus generates a pressure in the piping system and discharge portion of pump.

The main component of the pump (rotor and stator) which together constitute the pumping element. The rotor is a single start helical screw, rotates eccentrically within a static two start helical sleeve, the stator. The meshing of two parts opens and closes a cavity which from one end of the pumping element to the other transporting a volume of liquid. The entrapment and movement of an initial volume of liquid create a vacuum on the suction side which induces the flow of liquid into the pump. As the rotor revolves, the circular cross section of the rotor reciprocates within the stator slot. This reciprocating motion is a result of the straight line hypocycloid created by the rolling circle of the rotor and the fixed circle in the stator. For one revolution of the rotor the circular rotor section completes one full section of reciprocating motion. (Centre For Engineering Research, 1997)

## **2.9. PC Pump Advantages:**

- 1- High overall system energy efficiency, typically in the 55 to 75% range.
- 2- Ability to produce high concentrations of sand or other produced solids.
- 3- Ability to tolerate high percentages of free gas.
- 4- No valves or reciprocating parts to clog, gas lock, or wear.
- 5- Good resistance to abrasion.
- 6- Low internal shear rates (limits fluid emulsification through agitation).
- 7- Relatively low power costs and continuous power demand (prime mover capacity fully utilized).
- 8- Relatively simple installation and operation.
- 9- Generally low maintenance.
- 10- Low profile surface equipment. (Cholet, 1997)

## **2.10. PC Pump Disadvantages:**

- 1- Limited production rates (maximum of 800 m<sup>3</sup>/d [5,040 B/D] in large-diameter pumps, much lower in small-diameter pumps).
- 2- Limited lift capacity (maximum of 3000 m [9,840 ft]). Note that the lift capacity of larger displacement PC pumps is typically much lower.
- 3- Limited temperature capability (routine use to 100°C [212°F], potential use to 180°C [350°F] with special elastomers).
- 4- Sensitivity to fluid environment (stator elastomer may swell or deteriorate on exposure to certain fluids, including well treatment fluids).
- 5- Subject to low volumetric efficiency in wells producing substantial quantities of gas.

- 6- Sucker rod strings may be susceptible to fatigue failures.
- 7- Pump stator may sustain permanent damage if pumped dry for even short periods.
- 8- Rod-string and tubing wear can be problematic in directional and horizontal wells.
- 9- Most systems require the tubing to be pulled to replace the pump.
- 10- Vibration problems may occur in high-speed applications (mitigation may require the use of tubing anchors and stabilization of the rod string).
- 11- Paraffin control can be an issue in waxy crude applications (rotation as opposed to reciprocation of the rod string precludes use of scrapers for effective wax removal).
- 12- Lack of experience with system design, installation, and operation, especially in some areas. (Cholet, 1997)

### **2.11. The function of gravel pack:**

Gravel pack is one of popular sand-control technique used in oil, water and gas wells. It stabilizes the borehole and filters the sand from the flow, only allowing very fine particles in. Pre packed wire wrapped sand screen brings it into full play in maximizing production as well as controlling the sand. (Cocales, 1992)



# **Chapter 3**

## **Methodology**

### **3.1. PIPESIM:**

PIPESIM is a steady-state; multiphase flow simulator used for the design and analysis of oil and gas production systems. With its accurate simulation algorithms, PIPESIM helps you optimize your production and injection operations.

In this case study PIPESIM is used to conduct (pressure/temperature) profile ,Nodal analysis profile and construct model for PC pump efficiency with gravel pack and without gravel pack mechanism (PIPESIM USER GUIDE, Schulumberger,2017).

### **3.2. Model Design by PIPESIM Procedures:**

In this case study the system was designed by the following procedures:

#### **3.2.1. Collection of inserted Data:**

The first step in the design process is to gather information for the application of interest; fluid properties, reservoir parameters and production data.

**Table (3.1) wells Data**

<b>Parameters</b>	<b>FN-134</b>	<b>FN-136</b>	<b>FN-148</b>	<b>FN-06</b>
Casing Depth	1435m	1448m	1450m	1490m
Casing ID/OD	6.184"/7"	6.184"/7"	6.184"/7"	6.184"/7"
Tubing depth	1053m	998m	1010m	1000m
Tubing ID/OD	2.992"/3.5"	3.958"/4.5"	3.958"/4.5"	2.992"/3.5"
Reservoir pressure	1087psia	1109psia	1088psia	1400psia
Reservoir Temperature	61.2c	60c	61.2c	60c
Reservoir Permeability	453md	500md	520md	390md
Reservoir Thickness	14m	14m	14m	14m
Perforation Interval	1192m	1187m	1190m	1198m
Perforation Density	16API	16API	16API	16API
Perforation Diameter	2"	2"	2"	2"
Perforation Length	10"	10"	10"	10"
Drainage Radius	1500m	1500m	1500m	1500m
Borehole Diameter	8.5"	8.5"	8.5"	8.5"
Soil Temperature	35c	35c	35c	25c
Outlet Pressure	127psia	129psia	125psia	124psia
Pump Type	400-60E1800	400-60E1800	400-60E1800	400-60E1800
Pump depth	1053m	998m	1010m	1000m
Pump speed	100/150	150/200	150/200	100/150
Gravel permeability	120000md	120000md	120000md	120000md
Screen Diameter	3.5"	3.5"	3.5"	3.5"
Tunnel Length	10"	10"	10"	10"
Casing ID	6.184"	6.184"	6.184"	6.184"
Oil gravity	17.65API	19.25API	17.25API	18.25API
Water Cut	10%	10%	10%	10%
GOR	0	0	0	0

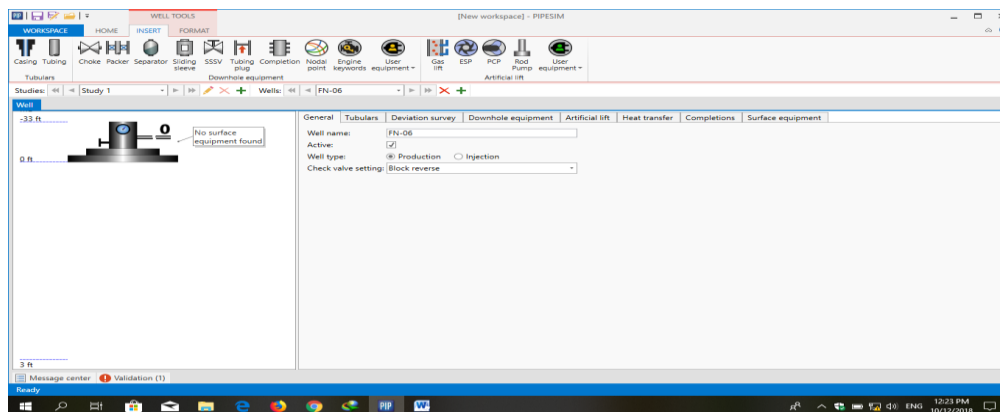
### 3.2.2. Define the physical component of the model by the following process:

#### 1-First process (PC Pump without gravel pack):

Complete the down steps without Gravel pack Data and show the Efficiency of PC Pump:

#### Step.1. General Data:

From the workspace screen of PIPESIM select the option, create new network and select well type (production well) and well name.



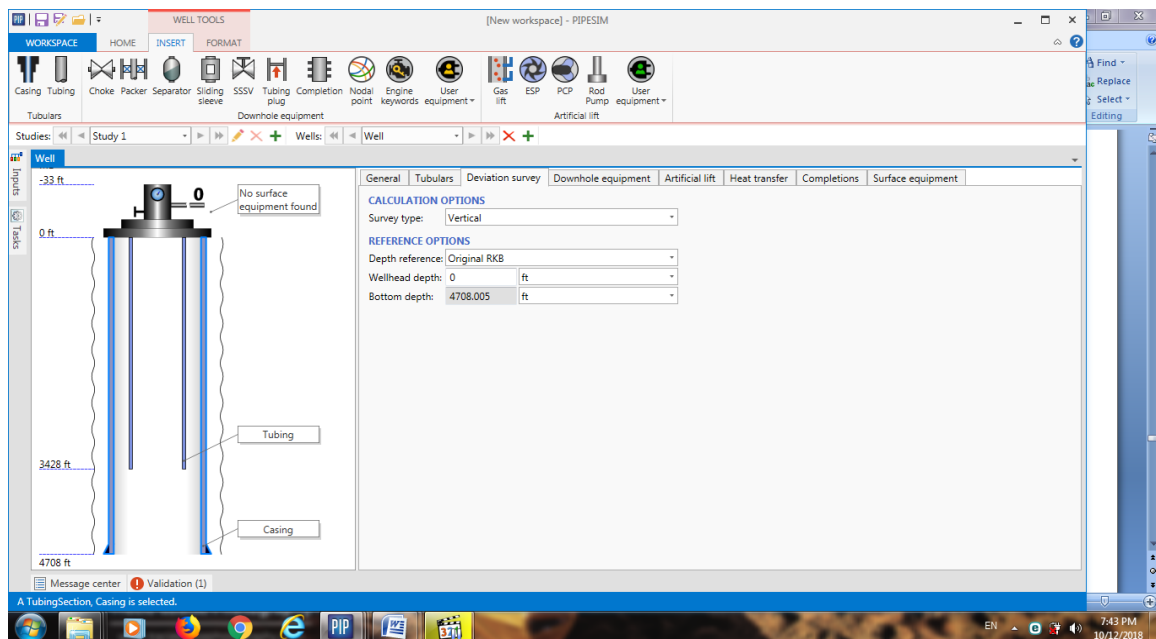
## Step.2. Tubular data:

Choose the well description mode (simple), insert the measured depth and inside diameter of (casing and tubing).



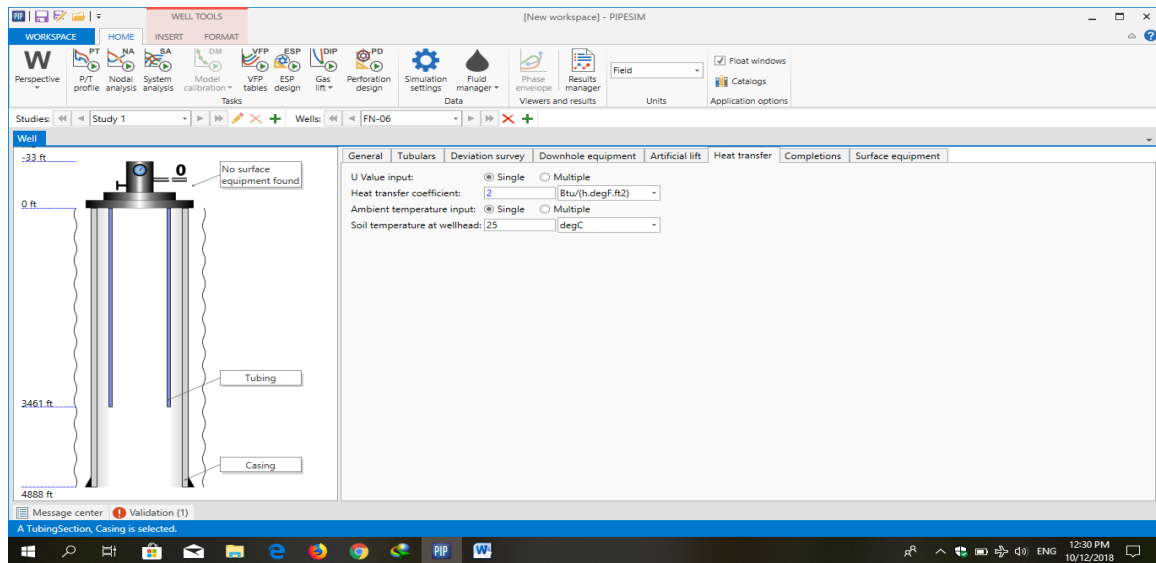
## Step.3. Deviation survey:

Select the survey type (vertical well) and enter the bottom hole depth.



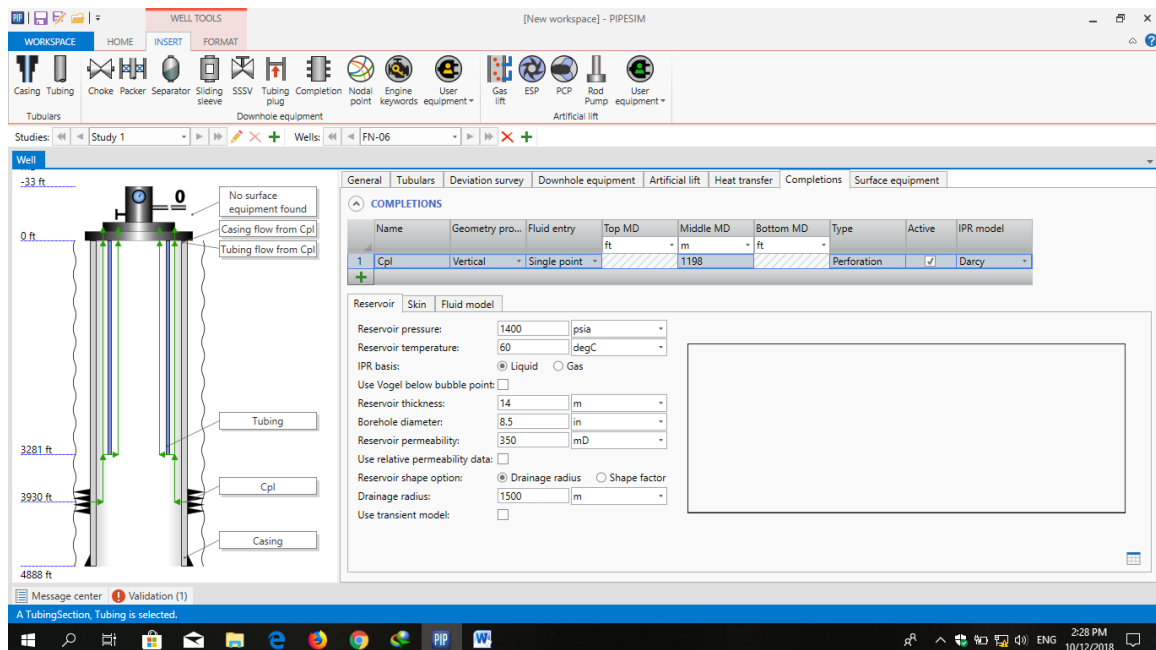
## Step.4.Heat transfer data:

From this window insert the soil temperature.



## Step.5.1. Completion data:

Insert the perforation depth, choose the inflow performance relationship model (Darcy) and insert its data (reservoir pressure, temperature and IPR basis).



## Step.5.2. Insert water cut, gas oil ratio and (API) values .

The screenshot shows the PIPESIM software interface. The 'Edit BOFluid' dialog box is open, displaying the following data:

STOCK TANK PROPERTIES		CONTAMINANT MOLE FRACTIONS	
Watercut	110 %	CO2 fraction:	0
GOR	0 SCF/STB	H2S fraction:	0
Gas specific gravity	0.64	H2 fraction:	0
Water specific gravity	1.02	CO fraction:	0
API	18.25 dAPI		

## Step.6. Select Artificial lifts Pump type (PCM 400-60E1800), insert pump setting depth and operating speed:

The screenshot shows the PIPESIM software interface with the 'Artificial lift' configuration. The 'Equipment' table is as follows:

Equipment	Name	Active	MD (ft)
1	PCM	<input checked="" type="checkbox"/>	3280.84

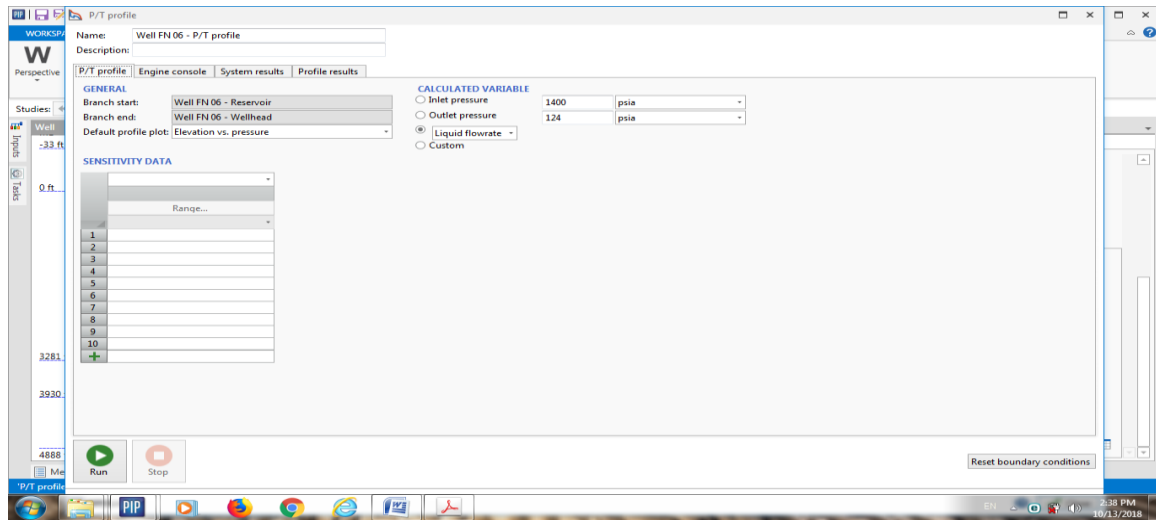
The 'PERFORMANCE DATA' section includes the following values:

- Manufacturer: PCM
- Model: 400-60E1800
- Diameter: 4.29 in
- Nominal rate: 362.664 bbl/d
- Base speed: 100 rpm
- Operating speed: 150 rpm
- Slip factor: 1
- Head factor: 1
- Flowrate factor: 1
- Power factor: 1

The performance curve graph shows Flowrate (bbl/d) on the x-axis (0 to 6500) and Torque (ft-lb) on the y-axis (0 to 1100). The graph displays a blue curve for flowrate and a green curve for torque, both showing a downward trend as flowrate increases.

## Step.7. Pressure and temperature (P/T) profile:

Insert the inlet pressure and out let pressure.



**Step .7.1:** click run and show the pressure and temperature profile as result.

**Step .7.2:** click to engine console to show the PC Pump efficiency.

## Step.8. Nodal Analysis process:

Theory:

1. Selection a node in the well (bottom hole).
2. Dividing the system at this point in to two sections.
3. Determine the drop as function of flow rate for this point.
4. Calculate the node pressure from the two direction of the flow starting with the fixed pressure (H.Dale, 1991)

The inflow to the node:-

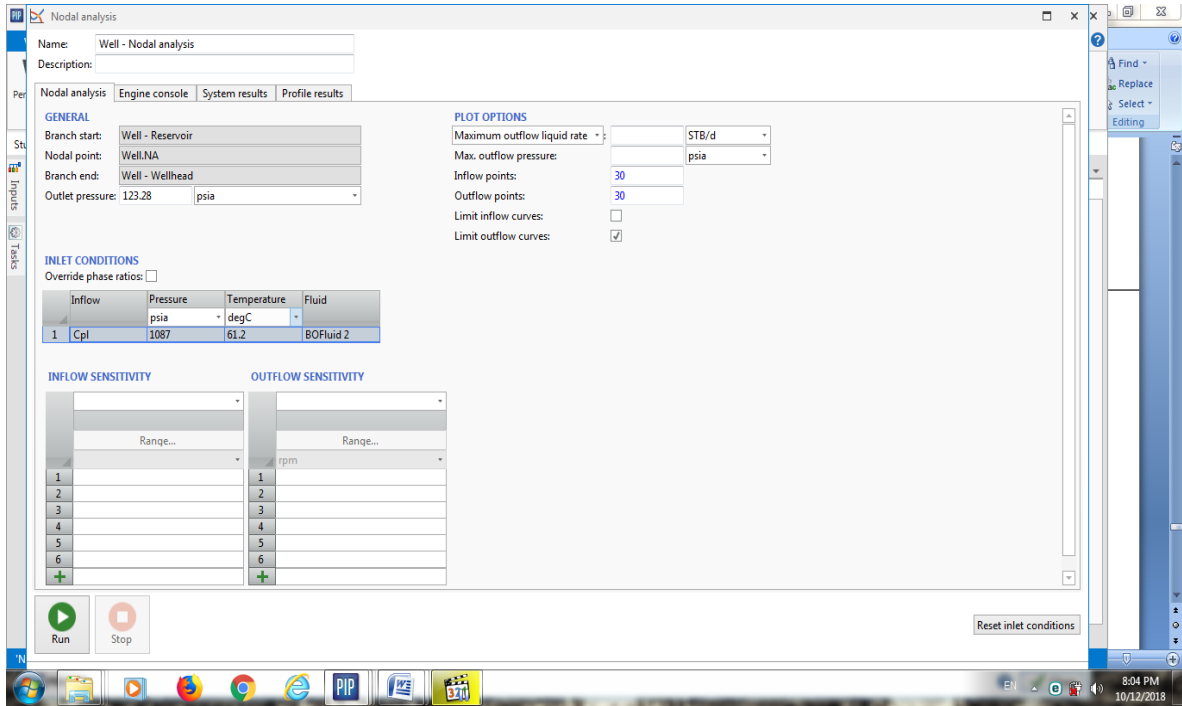
$$Pr - \Delta (\text{resistance}) = Pwf$$

The out flow from the node:-

$$Pwh + \Delta (\text{tubing}) = Pwf$$

Procedures:

Click nodal analysis potton , insert out let pressure .

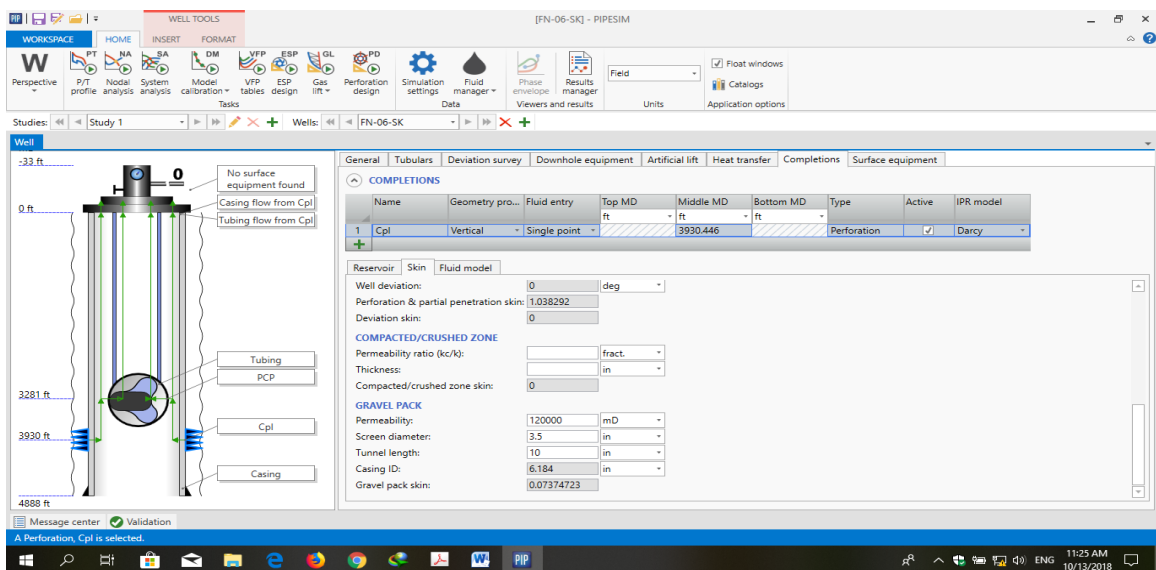


**Step .8.1:** click run and show the nodal analysis profile as result.

**Step .8.1:** click to engine consul to show the PC Pump efficiency.

## 2-Second process (PC Pump with gravel pack):

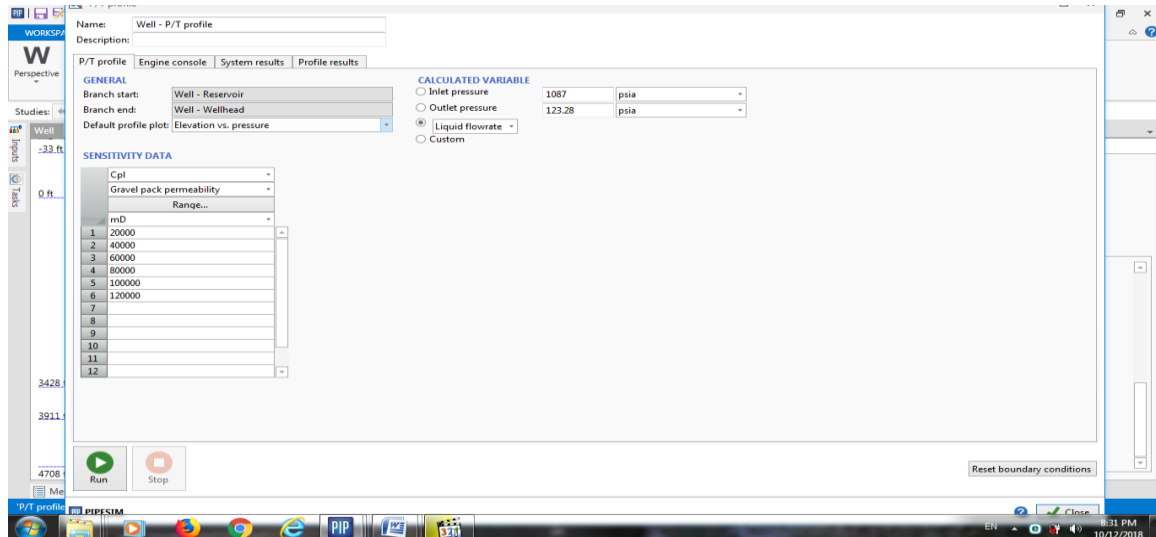
**Step.1.** Insert Gravel packs data in first process (step-5, completion –skin data):





**Step.2.** Pressure and temperature profile with sensitive data (Gravel pack permeability):

Insert the gravel pack permeability as sensitive data.



**Step.2.1.** click run and show the pressure and temperature profile as result.

**Step.2.2:** click to engine consul to show the PC Pump efficiency.

**Step.3.** Nodal analysis Pump operating speed (sensitive Data):

Theory:-

Theoretical displacement = cross section area \* stator pitch length

$$V = a * p = 4 * e * d * p$$

$e \equiv$  eccentricity

$d \equiv$  rotor diameter

Theoretical flow rate = theoretical displacement \* pump speed

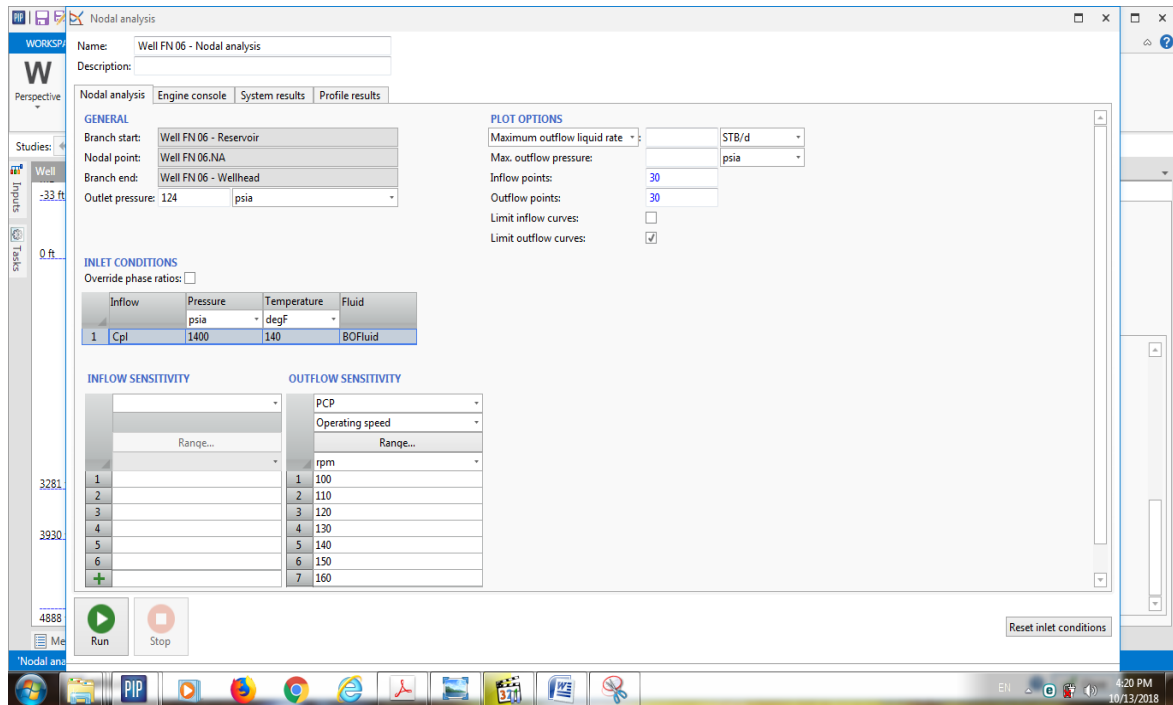
Actual flow rate = theoretical flow rate – slippage

Volumetric efficiency = [actual flow rate / theoretical flow rate]

(Weatherford 2015).

## Procedures:

Insert different pump speeds (100 – 160).



**Step.3.1.** click run and show nodal analysis profile as result.

**Step.3.2.**click run and shows the PC Pump efficiency as result.

# Chapter 4

## Results and Discussion

### 4.1. Pressure and temperature without gravel pack results:

Table (4.1) Pressure and temperature (P/T) without gravel pack results

Well name	Oil flow rate (bbl./d)	PC pump Efficiency %
FN-06	407.47	57.84
FN-136	248.00	52.99
FN-134	263.00	55.63
FN-148	253.00	54.21

The above results are shown in figures below:

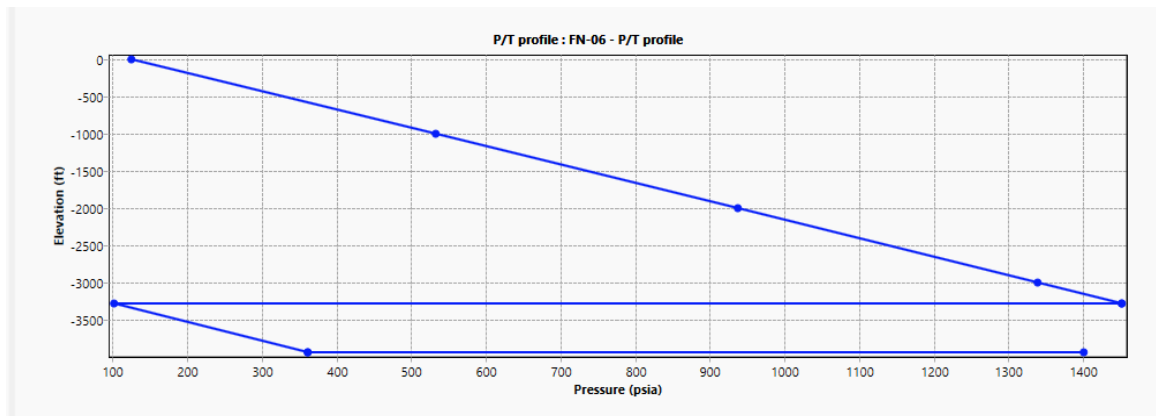


Figure (4.1) (FN-06) P/T Profile

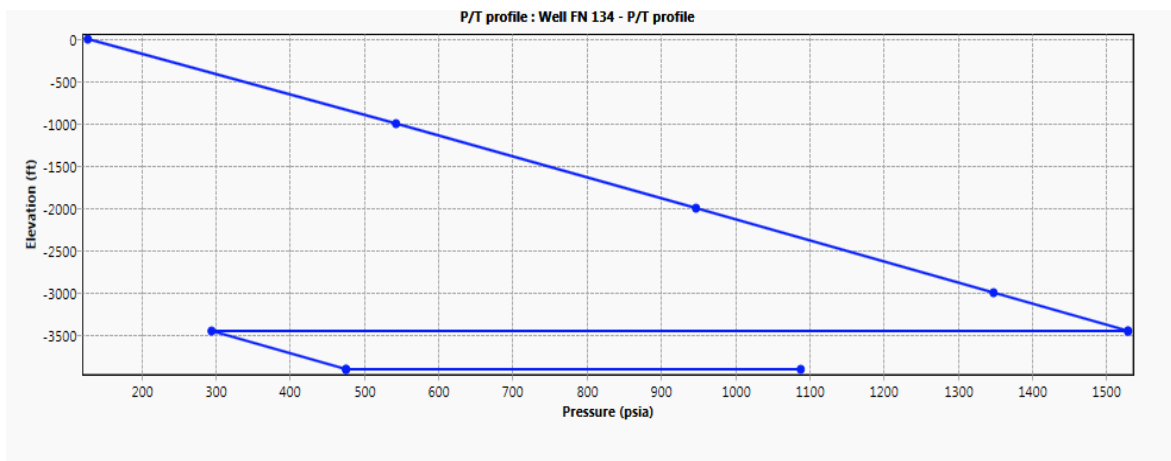


Figure (4.2) (FN-134) P/T Profile

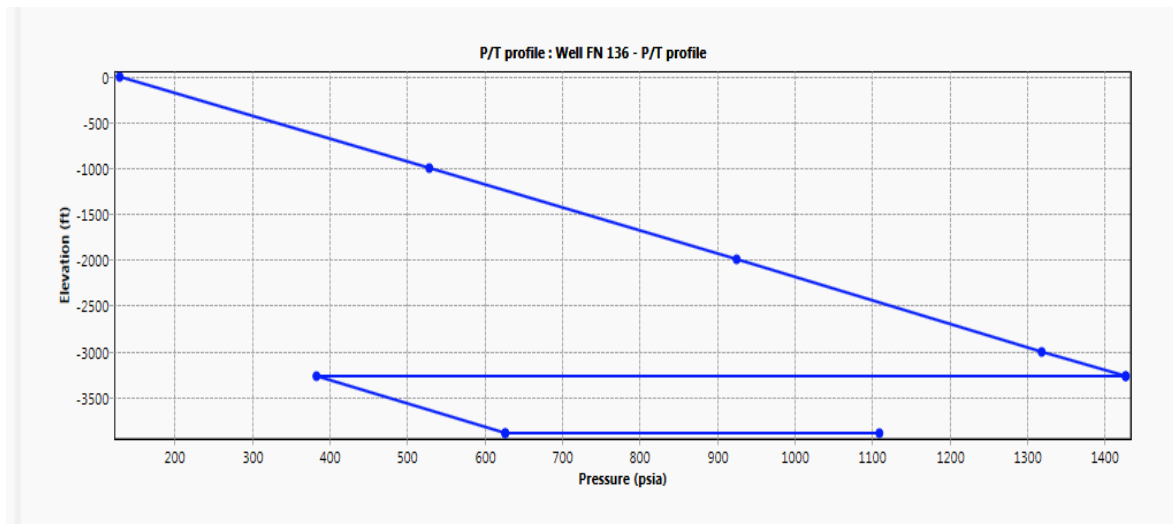


Figure (4.3) (FN -136) P/T Profile

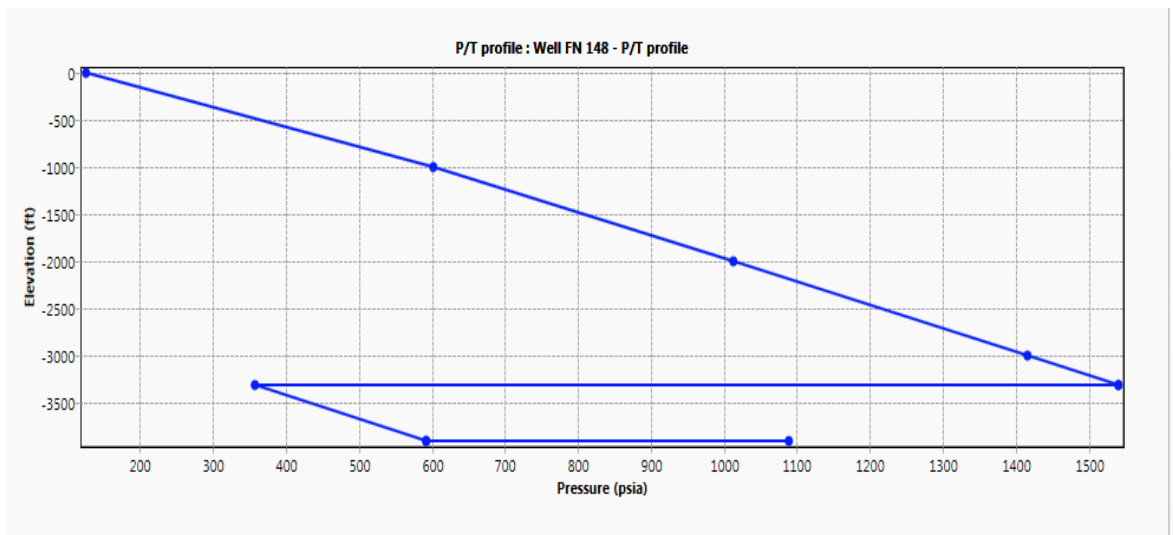


Figure (4.4) (FN -148) P/T Profile

When increasing the inlet reservoir pressure in above figures the flow rate will increase.

The pressure (p) is directly proportional to the absolute temperature, ( $p/t = \text{constant}$ ).

The elevation directly proportional to the pressure and temperature, when increasing in the temperature can effect in Elastomer, stator and decrease PC Pump efficiency.

## 4.2. Nodal analyses without gravel pack results:

Table (4.2) nodal analysis without gravel pack results

Well name	Oil flow rate (bbl./d)	Pc pump efficiency %
FN-06	416.43	56.35
FN-136	248.00	51.52
FN-134	263.00	51.32
FN-148	253.00	52.70

The above results are shown in figures below:

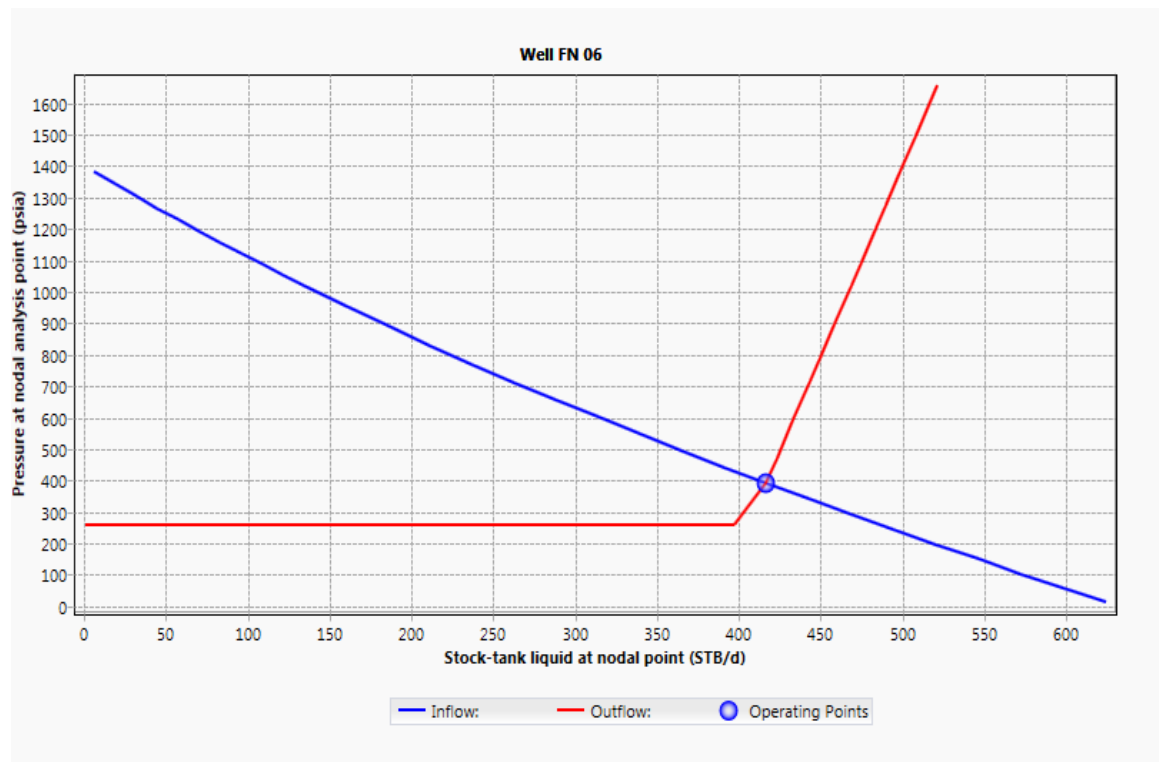


Figure (4.5) (FN- 06) Nodal analysis profile

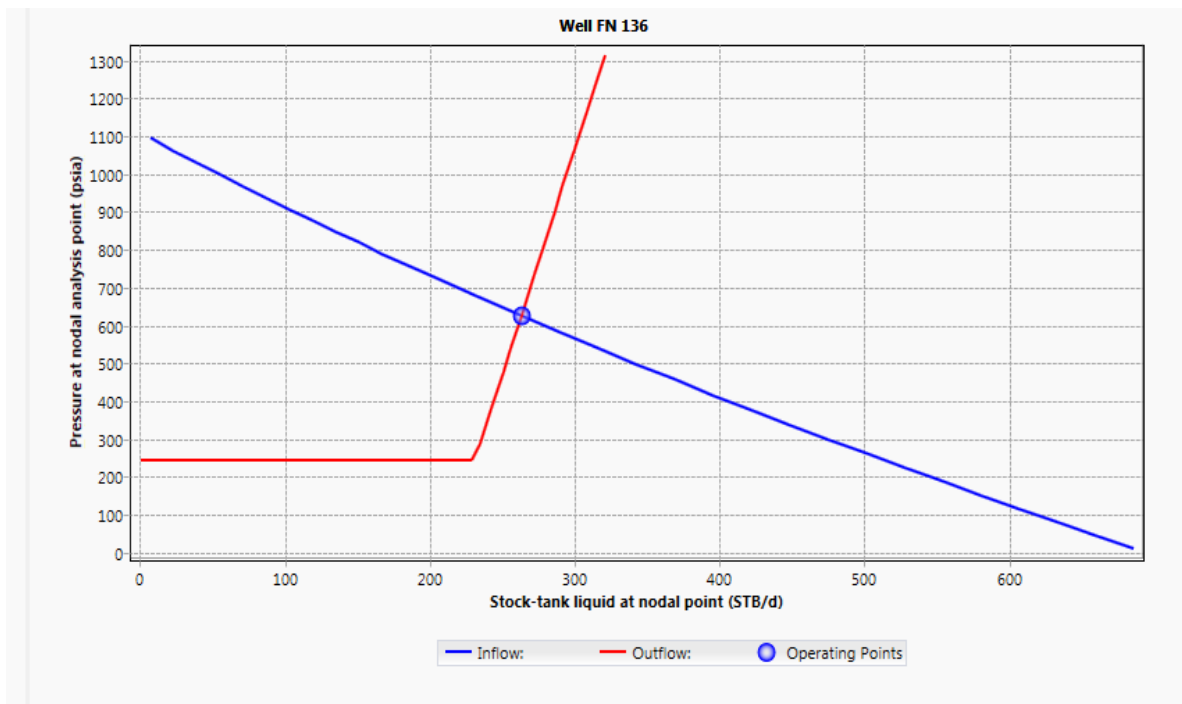


Figure (4.6) (FN-136) Nodal analysis profile

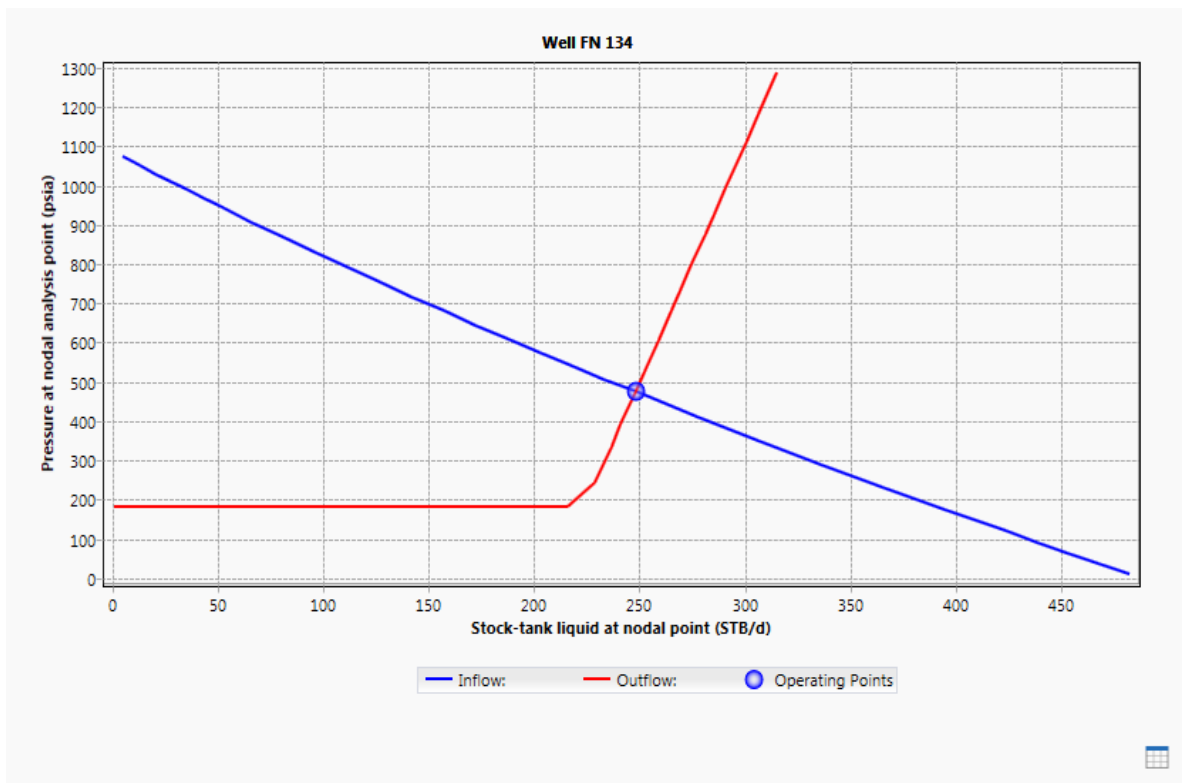


Figure (4.7) (FN-134) Nodal analysis profile

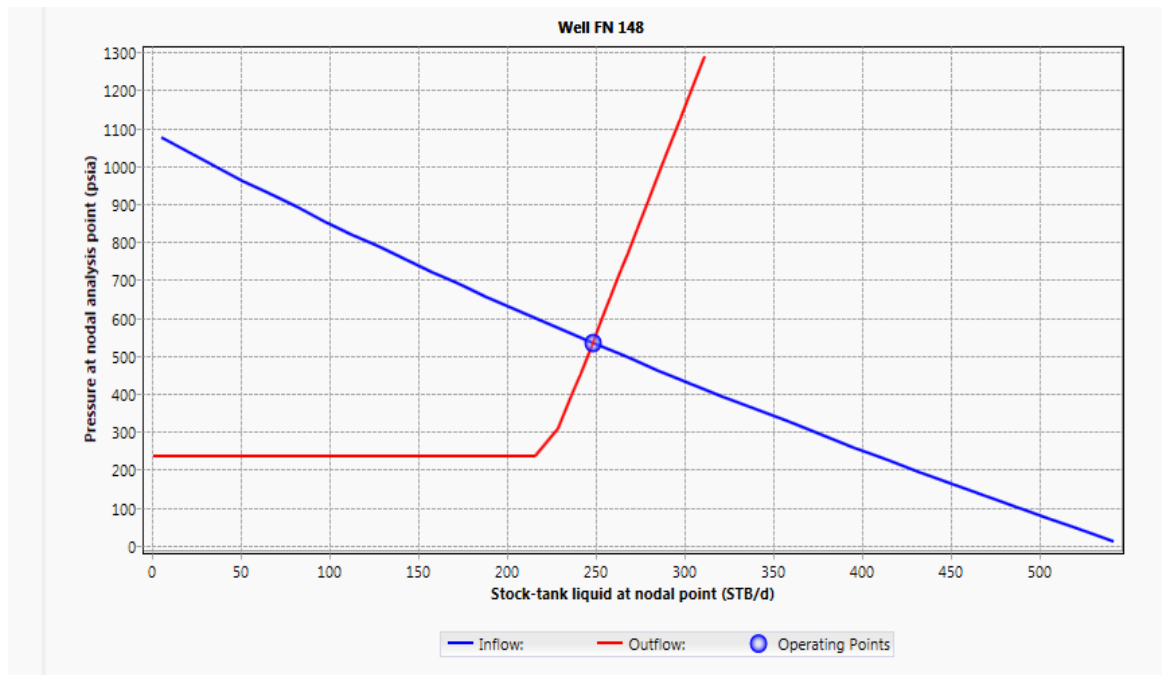


Figure (4.8) (FN-148) Nodal analysis profile

The pressure drop in any component varies with flow rate, for that reason , a plot of anode pressure versus flow rate will produce two curves the intersection will give the conditions that satisfying requirements (flow into the node equals flow out of the node ,and only one pressure can exist at anode ).

The above figures we choose the node in bottom hole to evaluate pressure in this case, when the pressure in bottom hole is low the efficiency of PC Pump will increase.

### 4.3. Pressure and temperature with gravel pack results (Permeability sensitive):

Table (4.3) pressure and temperature (P/T) with gravel pack results depending on different permeability's

Well name	Oil flow rate( bbl./d)&PCP efficiency(%) at K=20000	Oil flow rate( bbl./d)&PCP efficiency(%) at K=40000	Oil flow rate( bbl./d)&PCP efficiency(%) at K=60000	Oil flow rate( bbl./d)&PCP efficiency(%) at K=800000	Oil flow rate( bbl./d)&PCP efficiency(%) at K=100000	Oil flow rate( bbl./d)&PCP efficiency(%) at K=120000
FN-06	403.70 51.60	406.01 57.53	406.70 57.74	407.10 57.79	407.20 57.80	407.40 57.84
FN-134	241.60 51.60	242.60 51.80	242.90 51.90	243.10 51.94	243.19 51.91	243.20 51.80
FN-136	257.40 54.41	258.40 54.61	258.70 54.68	258.90 54.72	259.00 54.74	259.07 54.75
FN-148	246.3 52.7	247.40 53.00	247.8 53.1	248.10 53.15	248.20 53.18	248.30 53.19



The above results are shown in figures below:

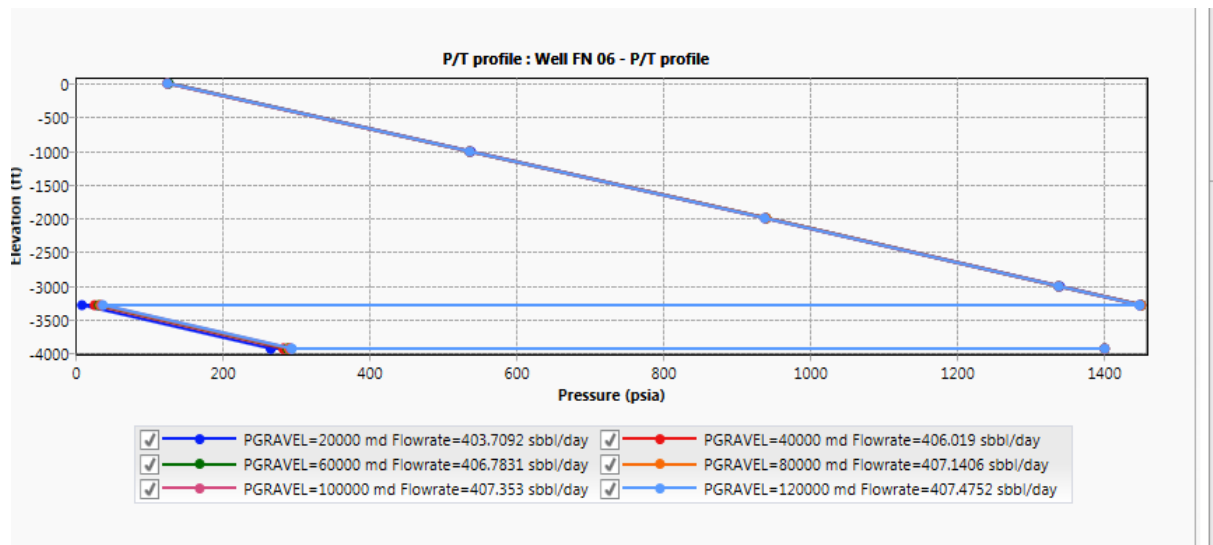


Figure (4.9): FN-06 gravel pack permeability profile result.

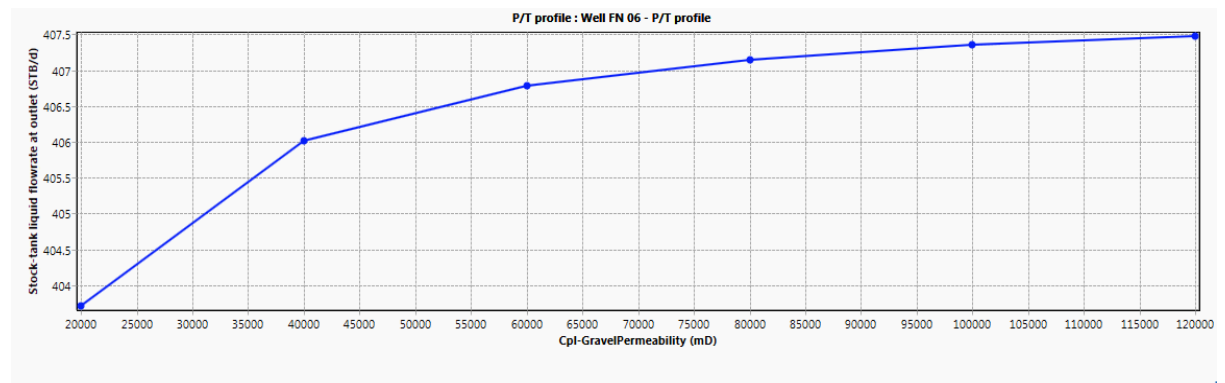


Figure (4.10): FN-06 gravel pack permeability system result.

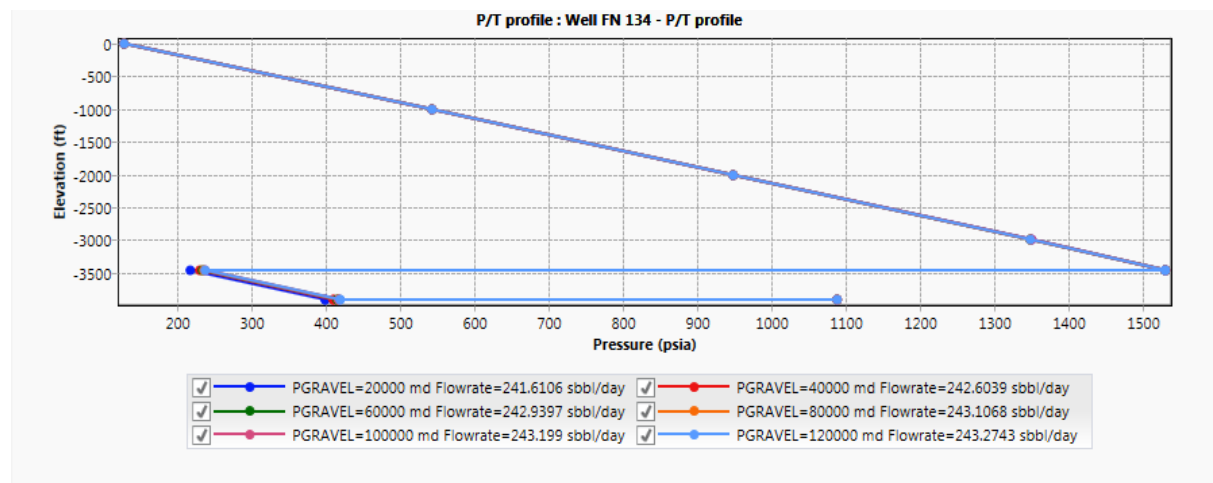


Figure (4.11): FN-134 gravel pack permeability profile result.

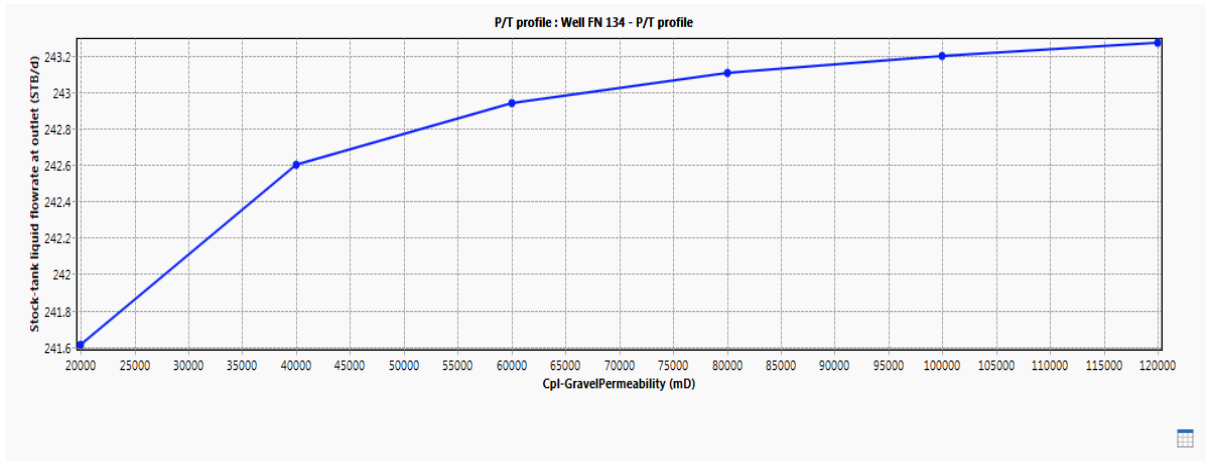


Figure (4.12): FN-134 gravel pack permeability system result.

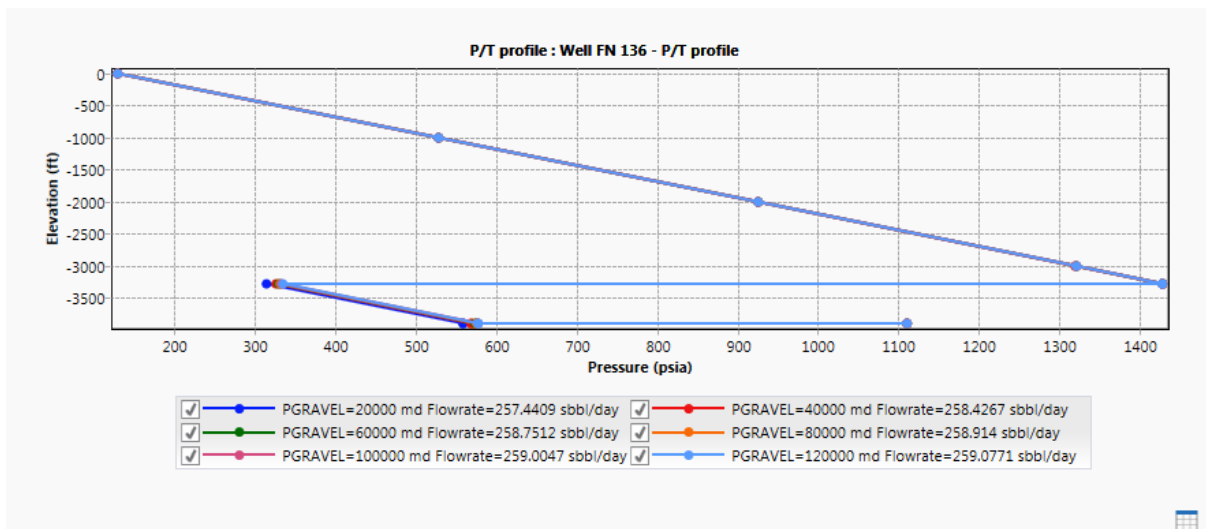


Figure (4.13): FN-136 gravel pack permeability profile result.

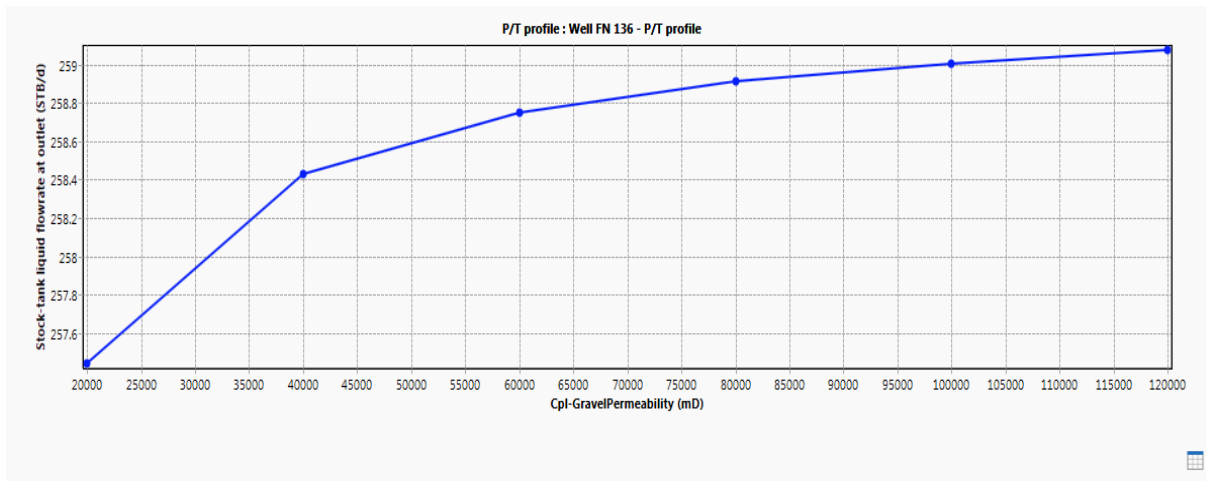


Figure (4.14): FN-136 gravel pack permeability system result.

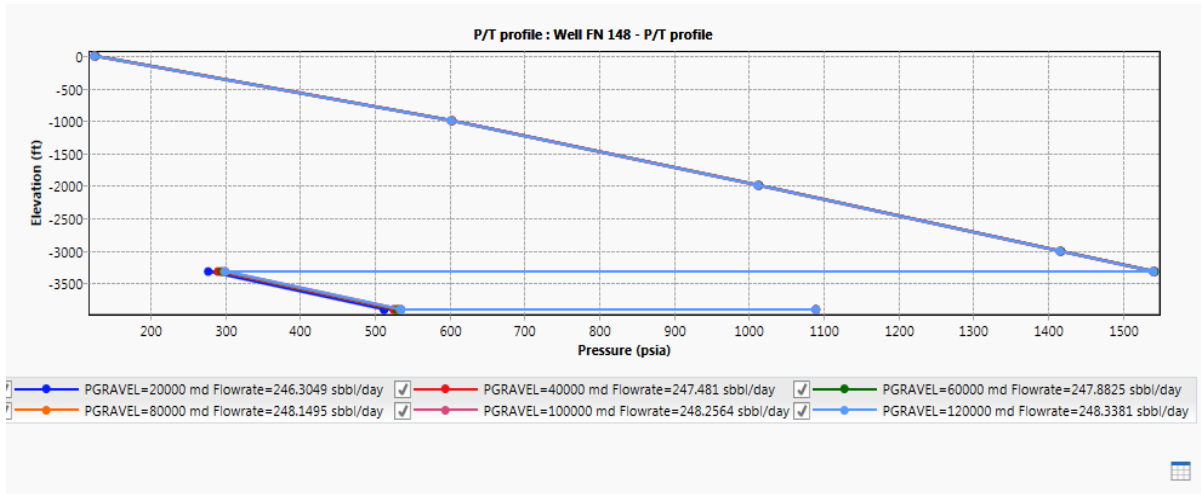


Figure (4.15): FN-148 gravel pack permeability profile result.

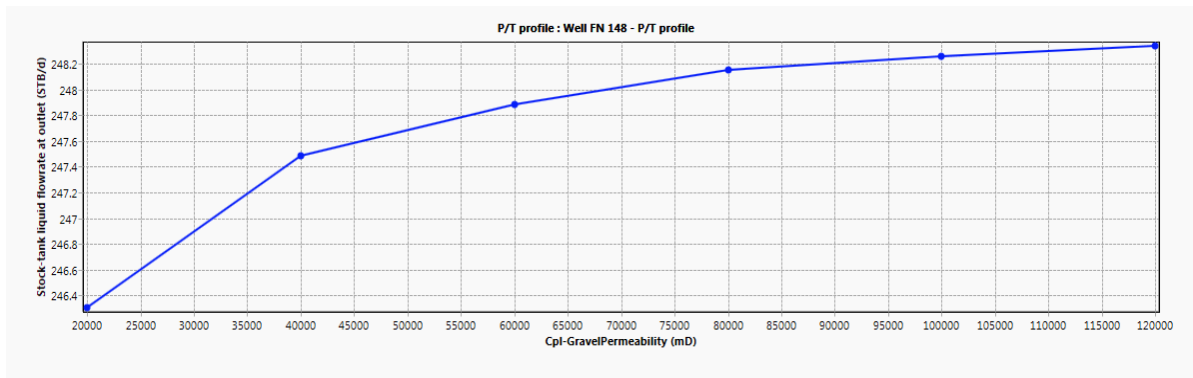


Figure (4.16): FN-148 gravel pack permeability system result.

The above figures means flow rate will directly proportional to the gravel packing permeability.

When the permeability increase the flow rate will increase, that is mean the efficiency of PC Pump will be high.

#### 4.4. Nodal analysis with gravel pack results (operating speed sensitive):

Table (4.4) nodal analysis with gravel pack results depending on different operating speed.

Well name	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :100	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :110	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :120	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :130	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :140	Oil flowrate( bbl./d) & pc p efficiency(%) at rpm :150	Oil flow rate( bbl./d) & pc p efficiency(%) at rpm :160
FN-06	261.00 55.00	290.00 56.00	219.00 56.68	348.00 57.12	378.00 57.53	407.00 57.83	ILL-COND ILL-COND
FN-134	243.00 51.98	272.00 52.95	301.00 53.76	330.00 54.39	ILL – COND 52.88	ILL-COND 49.32	ILL-COND 46.24
FN-136	259.00 54.17	289.00 55.60	319.00 56.30	250.00 56.90	381.00 57.50	411.00 58.00	441.00 58.30
FN-148	248.00 53.19	268.00 54.30	309.00 55.20	240.00 56.10	370.00 56.80	406.00 57.20	408.00 54.60

The above results are shown in figures below:

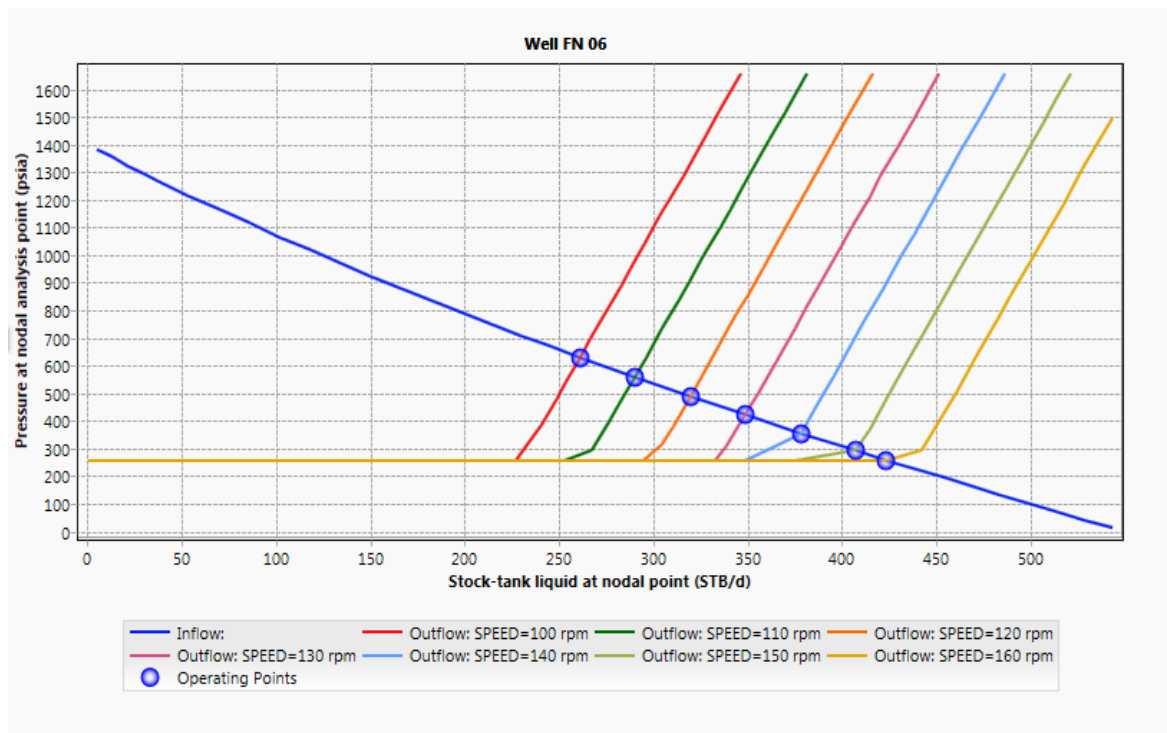


Figure (4.17): FN-06 Nodal analysis operating speed profile.

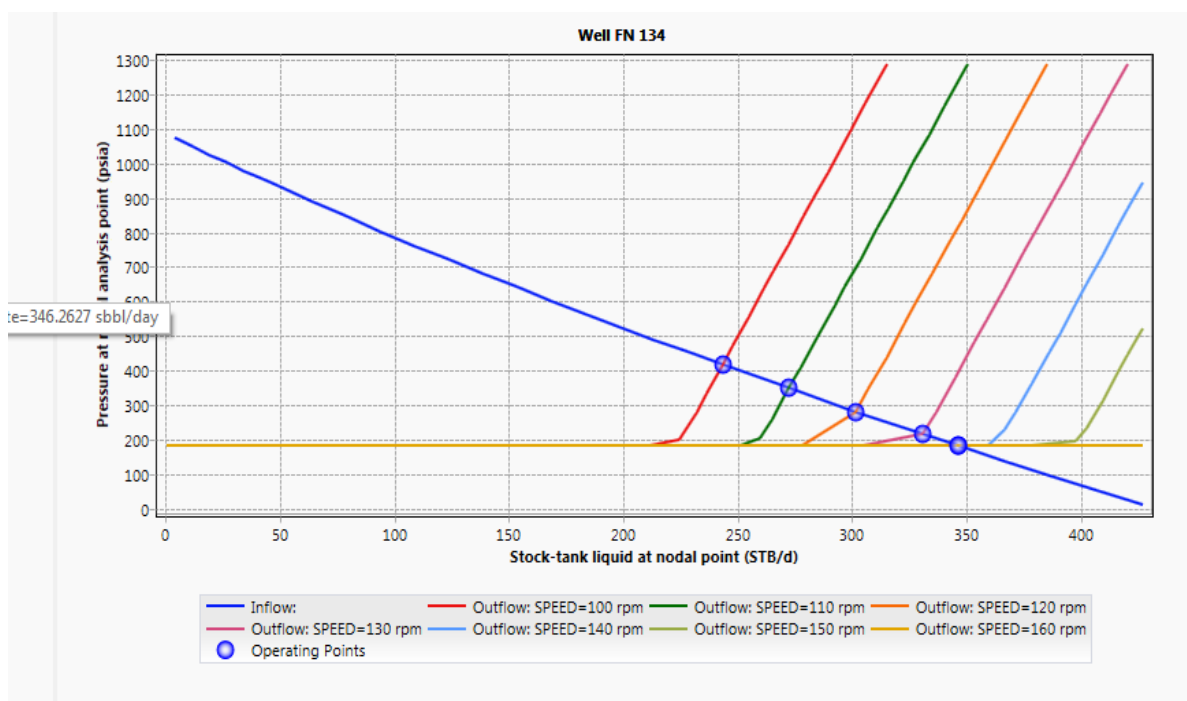


Figure (4.18): FN-134 Nodal analysis operating speed profile.

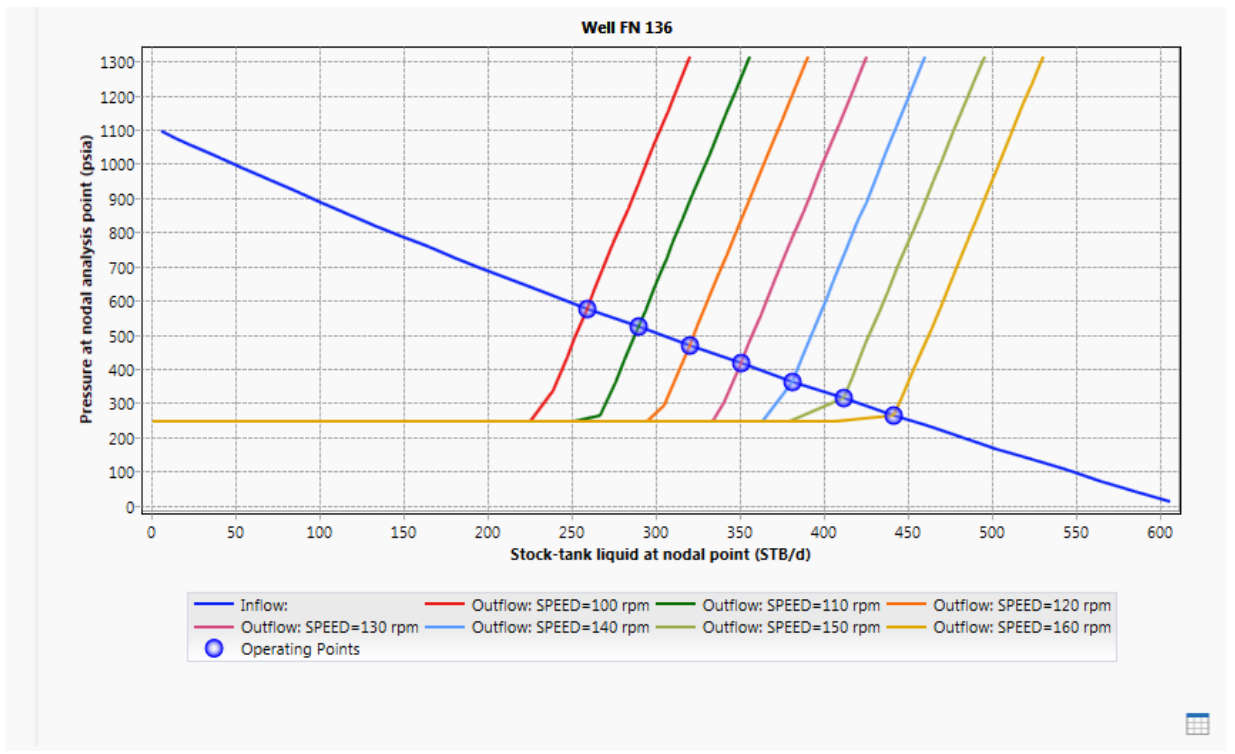


Figure (4.19): FN-136 Nodal analysis operating speed profile.

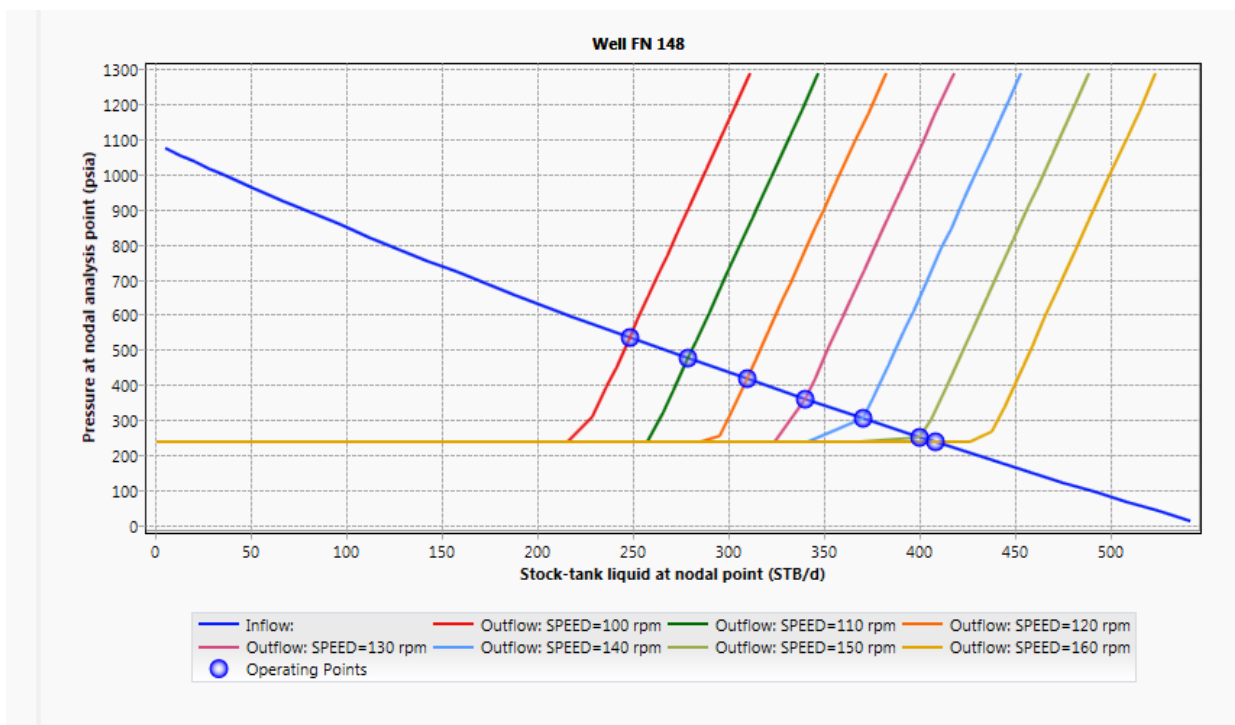


Figure (4.20): FN-148 Nodal analysis operating speed profile.

The above figures using Nodal analysis to evaluate the PC Pump operating speed at different values .The flow rate will increase when pump operating speed increased.

The estimation results from PIPESIM design without gravel pack in table (4.1) and table (4.2) and comparing results with gravel pack in table (4.3) and table (4.4) shows very little difference in PC pump efficiencies just increase in efficiency when increasing gravel pack permeability and pump speed up to moderate. when using gravel pack with permeability as sensitive data the flow rate and efficiency increase with increase in gravel pack permeability.

# Chapter 5

## Conclusion & Recommendations

### 5.1. Conclusion:

The purpose of this study in Fulla North is to compare pc pump efficiency without gravel pack and with gravel pack by using PIPESIM software, in order to estimate the performance of pc pump, protect the pump from sand effect and premature failure.

The advantages of gravel pack in this study to protect pc pump from premature failure and to keep pc pump efficiency

According to the results in case of wells without gravel pack in table (4-2) and table (4-3) and wells with gravel pack little change in flow rates and efficiencies.

When using gravel pack with pump speed as sensitive data, the flow rate and efficiency increase (100 – 150 rpm) above this speed it has ill condition.

At pump speed above 150 (ill condition) the flow rate and PC pump efficiency reduces.

### 5.2. Recommendations:

- i. The study recommends using gravel pack when using PC Pump as artificial lift method at Baleela field.
- ii. For accurate design, the study recommends more studies on different sensitive parameters.
- iii. The study recommends research on the ill condition reasons.



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