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FINAL QUALIFICATION WORK

SELECTION OF THE UNIT OF ELECTRIC CENTRIFUGAL PUMPS IN THE WELL ON THE EXAMPLE OF THE SUBANG FIELD

Job completed:

"__" _______ 2020 __________H.D.P Halim

The work is approved for protection:
Scientific adviser - Ph.D., associate professor

"__" ______ 2020 __________ G.R. Ganiev

Head of the Department of Development and
field exploitation
hard-to-recover hydrocarbons,
PhD, Associate Professor

"__" ______ 2020 __________ M.A. Varfolomeev

Comptroller - manager
basic metrology department
and flow measuring instruments
oil and gas, Ph.D., senior researcher
"__" ______ 2020 __________ I.I. Fishman

Kazan 2020

ANNOTATION

The final qualifying work on the topic "Selection of the installation of electric submersible pumps in a well on the example of the Subang field" contains 84 pages, 19 figures, 15 tables, 42 formulas.

Key words: OIL, FIELD, WELL, ELECTRIC CENTRIFUGAL PUMP, PRODUCTIVITY COEFFICIENT.

The object of study is the Subang oil field (West Java, Indonesia).

The purpose of the final qualification work is:

- Analysis of the applied ESP;
- Analysis of optimization of well operation with the use of electric submersible pumps on the example of a field.

In the course of the work, an analysis was made of the current state of well development at the Subang field, as well as selection technologies were considered and measures were taken to improve the efficiency of well operation using electric centrifugal pump units.

Recommendations are given for improving the efficiency of well operation using electric centrifugal pump units. The design, technological, technical and operational characteristics of oil production pumps with two upper and two lower sections are considered.

The economic efficiency / significance of the work lies in the development of measures to improve the efficiency of operation of electric centrifugal pump installations, which allow solving the problem: with jamming of installations, increasing the operating time of electric submersible equipment.

CONTENT

LIST OF SYMBOLS AND ABBREVIATIONS

In this paper, the following conventions and abbreviations are used:

API - (American Petroleum Institute) American Petroleum Institute

BHP - (Brake Horse Power) effective power, hp

GOR – (gas/oil ratio) gas-oil ratio, m3

HP - (horsepower) horsepower (unit of power)

ID - (Inside Diameter of Tubing) inner diameter of pipes, mm

KVA - power transformer, kVA

MD – (Measured Depth) oil and gas well length, m

MSDS - Material Safety Data Sheet

OD - (Outer Diameter) outer diameter of pipes, mm

Pb – (Bubble Point Pressure) saturation pressure

PI – (Productivity Index) productivity index (wells), (m^3⁄day)/MPa

PIP - (Pump Intake Pressure) pump inlet pressure, MPa

Rs – gas solubility in oil, m3/m3

SGf is the specific gravity of the fluid mixture, kg/m3

Sgo – specific gravity of oil, kg/m3

SGw – specific gravity of water, kg/m3

TDH - (Total Dynamic Head) full dynamic head, m

THP – (Tubing Head Pressure) pressure in the tubing head, kg/m

TVD – (True Vertical Depth) oil and gas well depth, m

WC – (Water Cut) water cut, %

WFL - (Working Fluid Level) working fluid level[a1], m

JSC - Joint Stock Company

Efficiency - efficiency factor

tubing - tubing

USHGN - installation of a sucker rod pump

ESP - installation of an electric centrifugal pump

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INTRODUCTION

"This work is based on materials collected by the author during the period of internship in Subang (West Java, Indonesia)".

Reservoir fluid can be lifted from the well to the surface in three ways: flowing, gas-lift and pumping-compressor methods.

With the flowing method of operation, we obtain a natural influx of oil. Over time, the field moves to the third stage of the development stage, the reservoir pressure drops. With a decrease in reservoir energy, the rise of liquid to the surface is not provided. At this stage, it becomes necessary to use additional energy. As an additional energy and a continuation of the fountain method is a gas lift. High pressure gas is used as additional energy in the gas lift method. The artificial lift is carried out in many ways, i.e. using a pump unit (rod pump), progressive cavity pump, hydraulic pump, gas lift and a submersible electric pump (electric submersible pump).

ESP is a centrifugal pump driven by electrical energy, which consists of several stages (levels), where each stage has a diffuser and an impeller mounted on a shaft.

On the well BBS-XY were installed with pump IND-750/54 Hz / 455stepswith a capacity of 268 barrels per day (42 m3/day). The result of the assessment is that well production can be optimized optimally with the BBS-XY well design targeting 2,000 bbl/d (317.9 m3/d).

The purpose of this work is to calculate the ESP estimate. To achieve this goal, it is necessary to solve the following tasks:

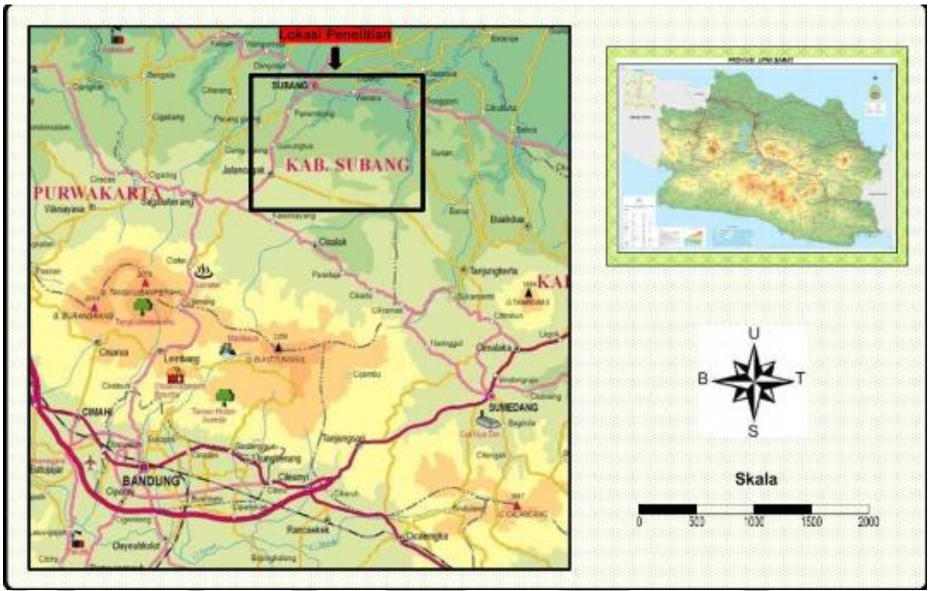
- choice of pump;
- determination of the installation depth of the pump;
- determination of the optimal number of steps;
- determination of the needs of gas pumping devices;
- choice of motor, power cable, transformer and drive speed variator.

During the calculation, a pump was selected: REDAG-2000/ 57 Hz / 115 stages, 4918 ft pump depth(1499 m) TVD/5316 ft (1620 m) MD, 125 hp (91.94 kW);volt; 52.7 amps (125.7 kW) and AWG#1 cable, which has a cable drop of 11.5 volts/1000, and a 300 kVA transformer.

1 GEOLOGICAL AND PHYSICAL CHARACTERISTICS OF THE DEPOSIT

1.1 General information about the area

Administratively, the Subang field is located in Subang Regency in West Java, Indonesia. The territorial boundaries of the Subang district, namely the West Bandung regency, the West the regency of Purwakarta and Karawang, in the east the Sumedang regency and Indramayu, while the North borders the Java Sea.



Rice. 1.1 - Location mapPlace of BirthSubang

Van Bemmelen (1949) divided the physiography of West Java into 4 parts of a large physiographic zone (Figure 1.2), namely the Bogor zone, the Bandung zone, the coastal plain of Jakarta, and the southern mountainous zone of West Java. Based on the physiographic division of zones, the study area included in the Bogor zone belongs to the northern zone of West Java, extending from Tangerang, Bogor, Purvakarta, Sumedang, Subang, Majalengka and Kuningan [1]. The Bogor zone is an anticlinorium, due to the intensity of the multiplicity of interlayers formed in the Submenian Neogene, with some intrusion of hypabyssal volcanic necks, reserves and ledges. The Bogor zone is generally Bermorphologically Perbukitanian, which extends from west to east with a maximum width of about 40 km. The rocks that make it up consist of sedimentary rocks of Tertiary and igneous types, both intrusive and extrusive. The morphology of the rocky hills is composed of igneous intrusions similar to those found in the Sanggabuana Mountain Complex, Purwakarta.

Rice. 1.2 - Division of physiography of West Java

The climate of the region is tropical with significant rainfall. The temperature averages 25.7 °C. October is the warmest month. January is the coldest month, with temperatures averaging 26.1 °C. the average rainfall per year is 2712 mm. The driest month is August and most of the precipitation here falls in January, averaging 359mm.

1.2 Tectonic and geological structure of the region

The tectonic and geological structure in the West Java region, under the influence of the tectonics of the Indonesian archipelago, is the meeting place of three plates, that is, the Eurasian plate, which is relatively more silent, the Pacific Ocean, which moves relative to the northwest direction, and the Indo-Australian plate, which moves relative to the North [2]. Based on the reconstruction of geodynamics, the subduction of the Australian Plate to the bottom of the Eurasian Plate, which is active in the Eocene, resulted in the dispersion of Tertiary volcanic rocks on the island of Java in a West–East direction. The interaction between these plates certainly gave rise to an order of geology quite complex for the Indonesian archipelago. In particular, for the island of Java, the most important aspects of tectonics are the development of the tectonics of the Sunda shelf,

Rice. 1.3 - The structure of Java and its environs

The movement of a fault across a probe pattern is usually a patterned deformation (deformation). This pattern is known to have begun to form at the age of the Pliocene (Eocene-Late Oligocene) or about 53-32 million years ago. While the Java pattern that is developing is represented by a fault-reverse fault directed from west to east. The dates of the beginning of formation are from the late Oligocene-early Miocene, or about 32 million years ago.

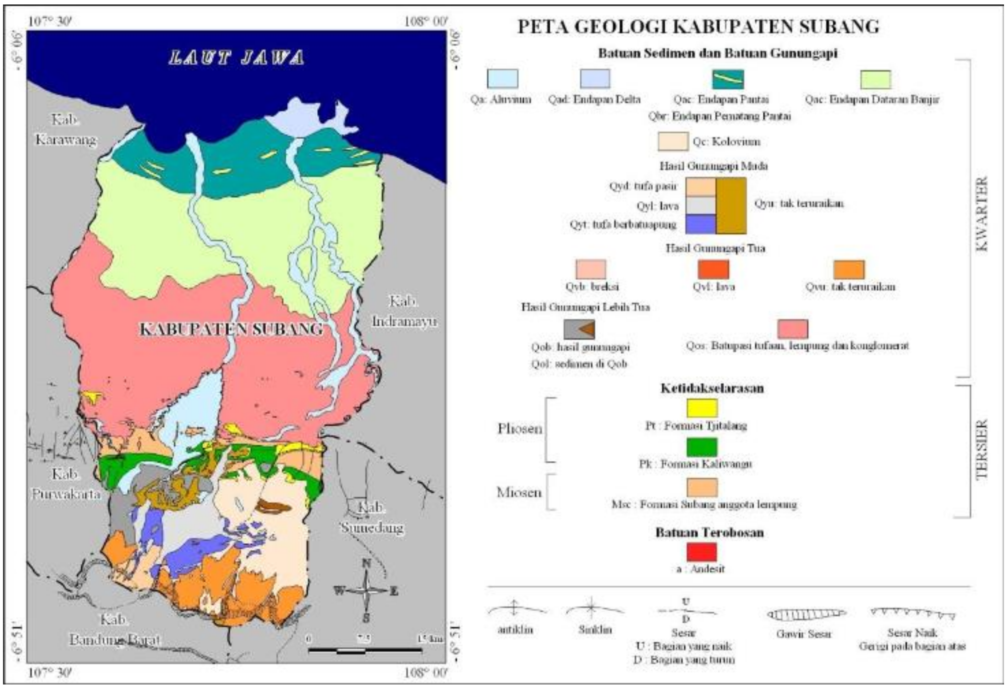
Based on the geological structure, according to Van Bemmelen (1949), West Java experienced 2 periods of tectonic plates, namely:

1. Period Tectonic Intra-Miocene.

   During this period, the formation of the geotic wedge continues in the southern part, which leads to the advance of forces to the north, which formed the structure of folds and faults of the living Miocene, and especially in the central and northern parts of the island of Java. In line with this, the breakthrough of the dacitic and andesit hornblende intrusions also occurs.

2. Period of the Tectonic PliO-Pleistocene.

   There is a multiplicity process going on in the rock that leads north due to the decline of the northern part of the Bandung zone, so the Bogor pressing zone is strong.



Rice. 1.4 - Geological map of the Subang area, West Java

The pressure increases the multiple and reverse fault structure in the northern part of the Bogor zone, which is a zone extending between Subang and Mount Chiremay, a fault zone known as the "Baribis thrust".

1.3 Stratigraphy of the region

Martojoyo (2003) in his dissertation divides the area of West Java into three depositional mandalas: the continental shelf outcrop mandalas, the Bogor Basin mandalas, and the Banten mandalas. The main division of the mandalas is generally based on the characteristics and deployment of the Tertiary deposits of the stratigraphic region in western Java. According to the tertiary beginning of the development of sedimentation, the Mandala of Bantam resembles the mandala of the Bogor basin. However, at the Tertiary end, it more closely resembles the impact mandala on the Northern Continental Shelf (Martodjojo, 1984). Based on the division of the Mandala into sedimentary deposits, the study area lies in the Mandal basin of the Bogor. The mandala of the Bogor sedimentation basin covers the zone of the physiographic Van Bemmelen (1949), namely, the Bogor zone, the Bandung zone, and the Pegununganselatan zone [3].

This Mandala is characterized by the deposition of gravity flow, which is usually found in fragments of igneous rocks and sediments such as andesite, basalt, tuff and limestone. The mandala of the Bogor basin according to Martodjojo (2003) underwent changes from time to time during the centuries of the Tertiary-Quaternary period. This Mandala consists of three cycles of sedimentation, starting with the sedimentation of marine sediments as a result of the gravity flow mechanism from south to north.

Later, at the beginning of the Miocene, a fiery mountain settles, which comes from the south of the island of Java, where basalt-andesites are located. The completed shoaling of the Bogor Basin towards the north began in the Middle Miocene as a result of the formation of Subang and the formation of Kalivangu, which shows the sedimentary environment of the exposure up to the transitional period (see Appendix A). Then, in the late Miocene, the sedimentation of the herd of facies becomes cloudy locally due to the steep slopes on the south side of the basin.

The facies are called members of the Chikandung [4], which is formed at the final stage of the process of siltation of the Bogor basin. During the Pliocene, the Bogor basin turned into soil, which then precipitated the formation of Tsitalang. Further, Martodjojo (2003) made a cross section of the stratigraphy reconstructed from north to south in West Java (see Appendix A) [3].

The study area is located in the north of the cross section of the stratigraphy, the picture above shows the Subang Formation. In the north of the basin, the oldest rocks that can be studied are the basalt-andesite rocks and the tuff-living Cretaceous down to the Eocene, which is the Jatibarang Formation. From above, this formation is deposited in the flattened Tsibulakan Formation of the middle Miocene age.

The characteristic lithology of this formation is represented by greyish-brown carbonate flakes with lapisanbatubar inserts in the lower part, off-white limestone with shale and fine sand inserts in the middle part, and sand alternating with marl and clay in the upper part. The sedimentary environment of this formation is presented in the form of shallow marines. In the Levilian area, which is west of the darisebaran of this formation, this formation has changed facies to the Bojongmanik Formation with a sedimentary environment in the form of a transition zone between the beach and the lagoon. The Bojongmanik Formation has an age range that nearly coincides with the Cibulakan Formation, i.e. Middle Miocene [3]. In the upper part of the Cibulakan Formation, a specialized block of limestones in West Java is deposited in harmony with Formasiparigi. The Subang Formation is deposited harmoniously at the top of the Parigi Formation. The characteristic lithology of the formation of the Subangiogenic loam becomes more and more layered towards the top into a hard and non-metallic brown clay. The Subang Formation is harmoniously covered by the Kaliwanguyang Formation, typically composed of sandstone and argillaceous stone [3].

1.4 General information about the company

Pertamina EP JSC is an Indonesian state-owned oil and gas company. It was established in 1968 as a result of the merger of Pertamin (founded in 1961) and Permina (founded in 1957). Pertamina EP SA is the largest producer and exporter of liquefied natural gas.

JSC "Pertamina EP" carrying out economic activities in the extractive sector of oil and gas fields, including exploration and exploitation. In addition, Pertamina EP SA also carries out business activities by supporting other persons who directly or indirectly support the core business area.

The working area of Pertamina EP SA is 113,613.90 square kilometers, which is the abundance of most of the Pertamina EP JSC energy oil and gas production region. The business management scheme of the measurement work area was carried out with the help of managed own (own operation) and cooperation in the form of partnership, namely 4 oil and gas development projects, 7 unification zones and 39 partnership agreement zones, consisting of 24 technical assistant contract contracts, 15 contract operations . When viewed from different geographical points, Pertamina EP works in almost all regions of Indonesia.

The working area of Pertamina EP is divided into five assets. The activity of the fifth asset is divided into 19 Fields. Below are the five assets, including their fields:

1. JSC "Pertamina EP" 1st asset
   - Rantau deposits, Aceh Province, North Sumatra;
   - Susu deposits, North Sumatra;
   - Deposits Lirik, Riau;
   - Jambi deposits, Kasang.
2. JSC "Pertamina EP" 2nd asset
   - Praboumulikh deposits, South Sumatra;
   - Pendopo deposits, South Sumatra;
   - Limau deposits, South Sumatra;
   - Ader deposits, South Sumatra.
3. JSC "Pertamina EP" 3rd asset
   - Subang deposits, West Java;
   - Jatibarang deposits, West Java;
   - Tambun deposits, West Java.
4. JSC "Pertamina EP" 4th asset
   - Cepu deposits, Central Java;
   - Deposits Deposit, East Java;
   - Papua deposits, West Papua;

- Dongi Matindok fields, Central Sulawesi;
- Sukovati deposits, East Java.

5. JSC "Pertamina EP"5th asset
   - Sangatta fields, East Kalimantan;
   - Bunyu deposits, East Kalimantan;
   - Tanjung fields, South Kalimantan;
   - Sangasanga fields, East Kalimantan;
   - Tarakan deposits, East Kalimantan.

Rice. 1.5 - Working area of JSC "Pertamina EP"

The internship took place in JSC "Pertamina EP" 3rd asset Subang. The Subang field is managed by Pertamina EP JSC The 3rd asset of the Subang Field includes the Purwakarta region, the city of Subang.

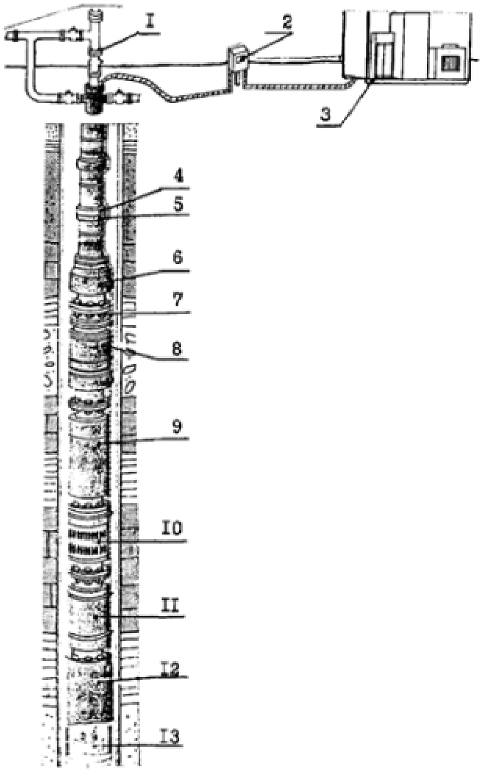
The assets managed by Pertamina EP JSC Subang Fields are 10 collection stations, 2 CO2 removal units and 3 test units.

The total number of wells owned was 142 wells, 6 injection wells, 65 producers and 71 non-producers.

2 ANALYTICAL REVIEW OF THE LITERATURE

2.1 Types of submersible deep well pumps

A submersible pump is a small-sized (in diameter) centrifugal pumps driven by an electric motor, placed together with an electric motor at the required suspension depth in the well [6].

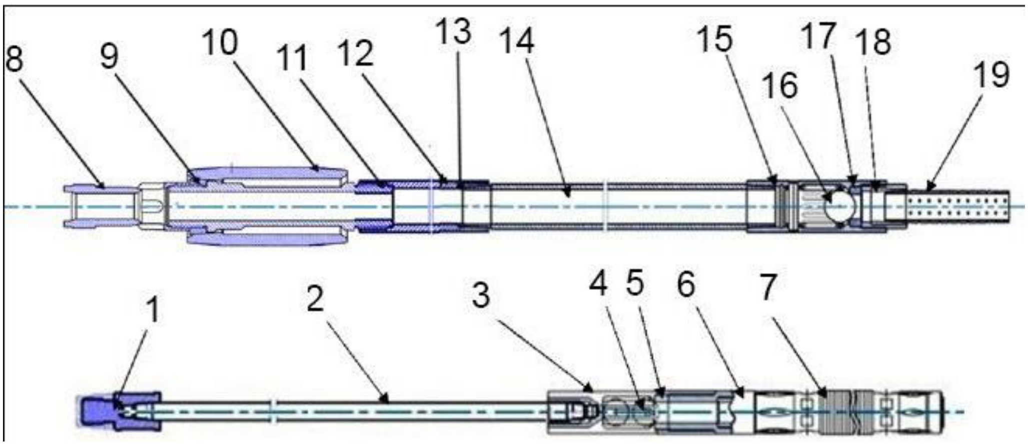


1 - wellhead equipment; 2 – remote connection point; 3 - transformer complex substation; 4 - drain valve; 5 - check valve; 6 - module, head; 7 - cable; 8 - module-section; 9 – pump gas separator module; 10 – original module; 11 - protector; 12 - electric motor; 13 - thermomanometric system.

Rice. 2.1 - Installation of a submersible centrifugal pump

Submersible pumps according to their design features are divided into two large groups:

a) Rod submersible pumps. They are driven by an independent motor. It is above the surface of the water. This process occurs due to the use of a mechanical connection - the so-called rod;



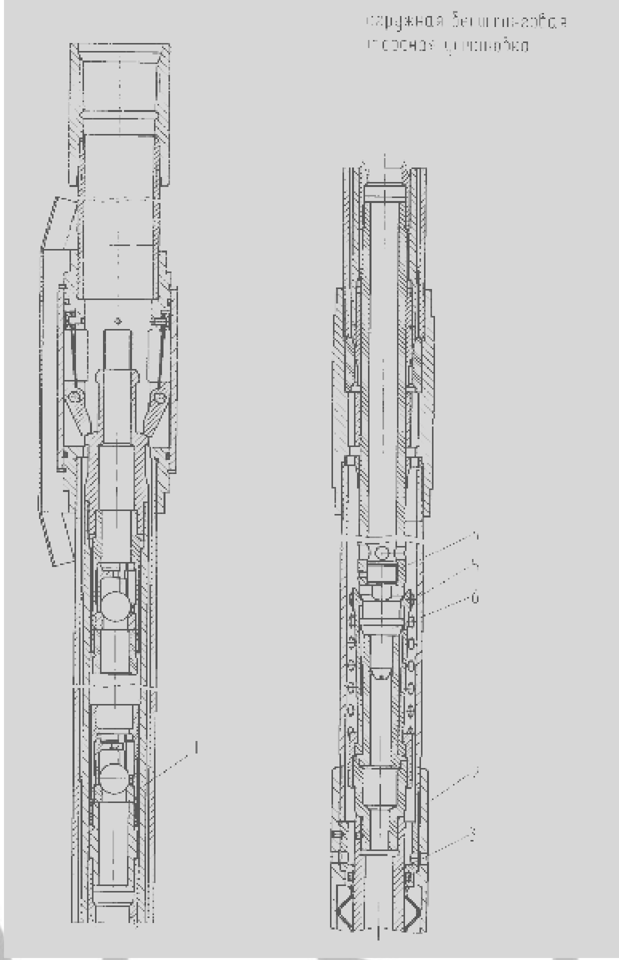
1 - stem adapter; 2 - stock; 3 - discharge valve; 4 - ball; 5 - saddle; 6 - plunger adapter; 7 - sealing part; 8 - rod guide; 9 - sealing ring; 10 - anchor spindle; 11 - spindle mount; 12 - threaded part; 13 - extension sleeve; 14 – pump cylinder; 15 – receiving valve housing; 16, 17 - valve pair ball-seat; 18 - seat holder; 19 - coarse filter

Rice. 2.2 - Components in rod submersible pumps

б) Rodless submersible pumps. They are manufactured in one unit together with the engine. It can be either electric or pneumatic. In the first case, power is supplied by a submersible electric cable.

The submersible rodless pumping unit comprises a plunger pump 1 and a submersible linear motor 2, the rod 3 of which is connected to the plunger 4 of the pump 1. The plunger pump 1 is installed in the well above the linear motor 2 and is plug-in. The rod 3 of the linear electric motor 2 is connected to the plunger 4 of the pump 1 by means of a collet 5. The position 6 indicates the hook of the plunger 4 of the pump 1.

Submersible rodless pumping units consist of are the result of a combination of the main positive design features of the USHGN (the use of a positive displacement type of pump that allows you to control the flow without changing the pressure characteristic) and installations with an electric centrifugal pump (ESP) (the use of a direct submersible electric drive for an electric centrifugal pump), as well as the same exclusion of the negative aspects of the same methods of operation, such as: the use of a metal-intensive ground drive; systems of mechanisms that convert rotational motion into reciprocating; sucker rod columns.



1 - plunger pump; 2 - submersible linear motor; 3 - stock; 4 - plunger; 5 - collets; 6 - plunger hook

Rice. 2.3 - Submersible rodless pumping unit

Depending on their principle of operation, there are 3 main types of submersible pumps, such as:

а) Screw pumps. In their design there is a spiral, which is mounted on the rotor. For its operation, a spiral located on the stator is required. As a result of the rotation of the rotor, a certain volume of water rises from the well to the top;

б) vibration pumps. They use a special vibrator. It communicates with an electromagnetic coil through which an alternating electric current passes. Thus, an electromagnetic field arises. It is she who launches the vibrator. Due to the pumping effect;

в) Centrifugal pumps. These devices are the most efficient. The principle of operation of this device is based on the fact that its engine creates a rotating effect on the shaft. It is equipped with one or more wheels that have special blades. They are the ones who bring the water up. Let's look at each pump in more detail.

screw pump

Screw pumps are designed for the production of high-viscosity and light oils with a high content of mechanical impurities and a high gas content. Downhole screw pumps are positive displacement pumps, which makes it possible to pump out well fluid with a high content of sand [7].

Compared to other artificial lift methods, PCPs typically have lower capital and operating costs due to easier installation and lower power consumption. Screw pumps are successfully used for the selection of both high-viscosity liquids and liquids with a high content of mechanical impurities.

The screw pump system consists of:

а) submersible screw pump;

б) drive - drive head (motor, gearbox) or submersible motor;

в) control stations;

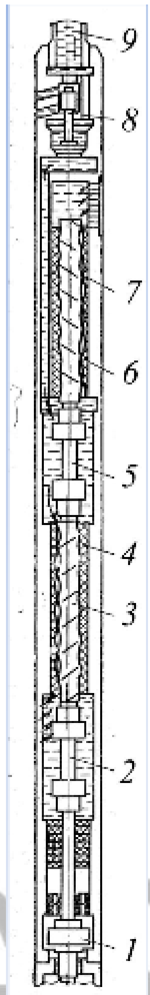
г) pumping rods, tubing;

д) rod, pipe centralizers, anchors.

The principle of operation of the pump

The pump is connected to an electrical circuit or a pneumatic line. When the pump is turned on, the motor shaft begins to rotate at a certain number of revolutions per minute. The rotation of the motor shaft through the coupling is transmitted to the gearbox shaft. The gears of the reducer, which are in sequential engagement, reduce the number of revolutions at the output of the reducer and increase the torque. Through the adapter shaft, located in the bearing assembly, the angular velocity of the gear motor is transmitted to the cardan shaft or transport auger, which in turn drives the pump rotor through the swivel joint.

Let us consider the operation of a screw pump, where the branch pipe on the side of the gerotor pair is suction, and the branch pipe on the side of the pump housing is pressure. The direction of rotation of the moving parts of the pump occurs according to this scheme (right - left or counterclockwise, if you look at the end of the rotor from the liquid suction side). The screw rotates in the stator. Since the center of rotation of the rotor is displaced relative to the central axis of the stator by the amount of eccentricity, and the elastomer layer of the stator has a helical shape, a vacuum cavity is formed on the side of the fluid inlet to the pump. Fluid is sucked into this space. The rotor makes a 90-degree turn and this cavity with the liquid in it is hermetically sealed, while the liquid itself receives movement inside the stator of the gerotor pair.



1 - starting clutch; 2, 5 - eccentric couplings; 3 - right screw; 4 - right clip; 6 - left screw; 7 - left clip; 8 - safety valve; 9 - sludge pipe

Rice. 2.4 - Components in screw submersible pumps

With each subsequent turn of the screw, a new portion of the liquid enters the gerotor pair, and the previously supplied liquid receives more and more displacement. Since the body of the rotor also has a spiral shape along its entire length, in conjunction with the stator it forms several closed volumes. It is through these volumes that the liquid moves when the rotor rotates, moving away from the suction point, and since these cavities are sealed, the pumped liquid cannot flow back to the suction side. Further, the pumped liquid under pressure enters the pump housing from the gerotor pair and exits the pump through the pressure pipe. In the event that the moving parts of the pump rotate clockwise, then the pipe of the pump housing is suction, and the pipe of the gerotor pair is discharge.

Advantages and disadvantages

The advantages of screw pumps are much greater than the disadvantages. Consider what advantages this type of pump has in comparison with others:

а) Positive displacement pump and each revolution of the rotor is equal to a certain amount of pumped medium, so there is the possibility of precise regulation of performance;

б) The pump is self-priming;

в) Since the rotating parts are directly connected to each other, and the volumetric cavities between the stator and the rotor are sealed, the pump has a high coefficient of field action;

г) The pump can be used both in horizontal and vertical position;

д) The pump can pump liquids in different directions, as it has a reverse function;

е) Capable of pumping non-viscous, viscous, highly viscous and even non-Newtonian liquids.

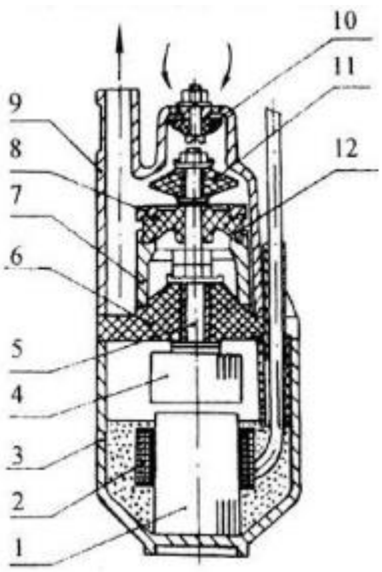
The disadvantages of screw pumps include their high cost associated with the complexity of their manufacture, as well as their mass and overall dimensions. In addition, this type of pump is not designed to work without liquid, as this will lead to failure of the pump stator.

Vibratory submersible pump

The vibratory submersible pump works on the principle of pressure difference in the discharge chamber. The suction of water into the chamber occurs due to the reciprocating movements of the piston of the rubber diaphragm.

In more detail, it looks like this. When the submersible device is connected to the mains, current flows to the coil winding and a magnetic field is created. As a result, the core coil is magnetized and attracts the vibrator. Thus, the diaphragm through the rod bends inward and is pulled to the discharge chamber, therefore, a vacuum is formed in the suction chamber, the pressure decreases. The space of the suction chamber is filled with water, which is sucked from the source through check valves.

The very task of alternating current is such that for a certain time the magnetization disappears, the rod comes back with the help of a shock absorber. The piston presses on the water that is inside the suction chamber and the pressure increases in it. Since the valves are closed by water pressure, there is nothing left but to exit into the pressure chamber. When the magnetization occurs again and the rod goes back simultaneously with the piston, the pressure in the injection chamber increases and the water goes through the channels to the water supply. At the same time, a vacuum is formed in the suction chamber and water is sucked from the source. These magnetization cycles occur more than 100 times per second. The progressive movements of the rod, by and large, are vibrations, for which this type of pump is called "vibration".



1 - core; 2 - coil; 3 - body; 4 - anchors; 5 - stock; 6 - shock absorber; 7 - clutch; 8 - emphasis; 9 - pump housing; 10 - valve; 11 - piston; 12 - diaphragm

Rice. 2.5 - Vibratory submersible pump components

The device is quite simple, so they are unpretentious and do not require special operation. Nothing needs to be lubricated here, because there are no rotating bearings and parts. The submersible mechanism almost does not heat up during operation, so all elements do not wear out so much. Vibration pumps are not afraid of mineral salts, pump alkaline water without problems and work at any temperature. Everything points to the reliability of the device, but still, let's think about this. Vibrations that cause water to be sucked from the source, and then move to the water supply, can have a destructive effect.

The principle of operation of the pump

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Advantages and disadvantages

It is worth talking about the advantages and disadvantages that a vibration pump has. Its positive qualities include a simple device, rare breakdowns, compactness and reliability. However, there are also a number of disadvantages. For example, if the well is not strengthened, over time, the constant vibration of the pump can simply destroy it. In addition, for full-fledged work, he needs a little rest, otherwise, with continuous work, he may fail. The depth of immersion, unfortunately, is also small - only 3 meters.

Centrifugal pump

Currently, submersible centrifugal pumps with a vertical shaft and a submersible electric motor are mainly used to lift water from a well. However, small radial dimensions, due to the diameter of the casing strings into which centrifugal pumps are lowered, practically unlimited axial dimensions, the need to overcome high heads and the operation of the pump in a submerged state led to the creation of centrifugal pumping units of a specific design.

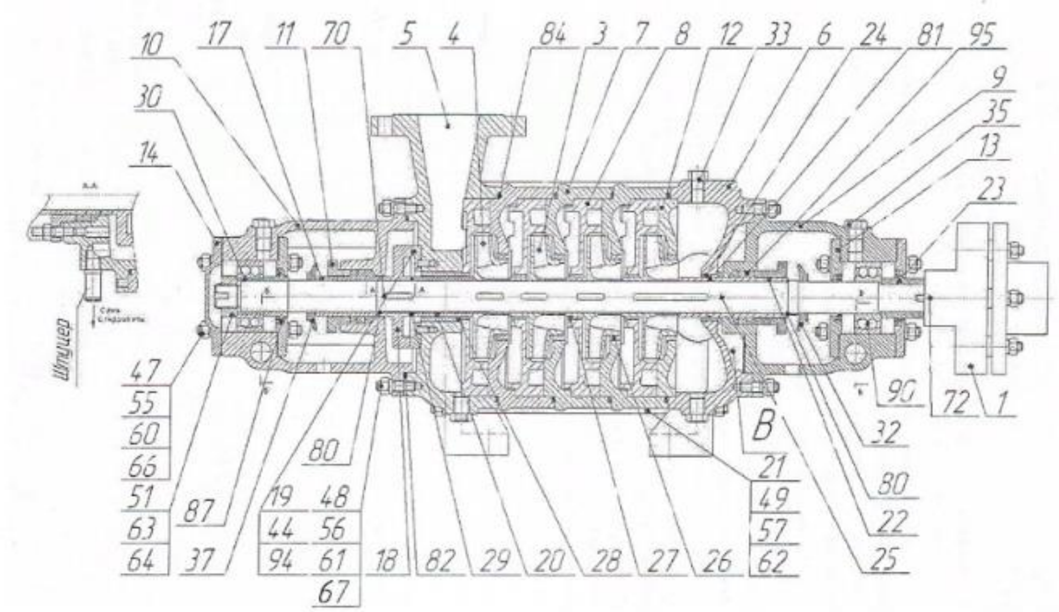
The principle of operation of the pump

When the impeller rotates, the liquid that is in the channels of the impeller between its blades will be thrown away from the center of the impeller to the periphery under the action of centrifugal force. At the same time, a vacuum will be created in the central part of the wheel, and pressure will increase on the periphery, as a result of which the liquid from the pump will begin to flow into the pressure pipeline.

This forms a vacuum, under the influence of which the liquid will simultaneously begin to flow into the pump from the suction pipe. Due to the fact that the pump housing consists of separate sections, it is possible, without changing the feed, to change the pressure by setting the required number of sections.

This changes only the length of the shaft and tie rods. During operation of the pump, due to the pressure of the liquid on the side surfaces of the impellers, which are unequal in area, a force arises that tends to shift the pump rotor towards the suction side. To balance the specified axial force in the pump, a hydraulic foot is used, consisting of a hydraulic foot disk, a hydraulic foot ring and a bushing.

During operation of the pump, the liquid passes through the annular gap formed by the opening of the discharge cover and the sleeve and presses on the disk of the hydraulic heel with a force that is equal in magnitude to the sum of the forces acting on the impeller, but directed towards the discharge. Thus, the pump rotor is balanced. Equality of effort is set automatically, thanks to the possibility of axial movement of the pump rotor. Part of the liquid from the hydraulic foot discharge chamber passes between the bushing and stuffing box packing, which ensures liquid lubrication of rubbing surfaces and their cooling.



1- coupling; 3.4 - working wheel; 5 - discharge cover; 6 - suction cover; 7 - body; 8 - guide apparatus; 9 - front bracket; 10 - rear bracket; 11 - gland bushing; 12 - guide vane ring; 13 - front cover; 14 – blind cover; 17 - shaft nut; 18 – hydraulic heel disk; 19 – hydraulic foot ring; 20 - remote bushing; 21 - tie rod; 22 - shaft shirt; 23 - spacer bushing; 24 - hydraulic seal bushing; 25 - shaft; 26.27 - sealing ring; 28 - sleeve unloading; 29 - adjusting ring; 30 - bearing sleeve; 32 - ring; 33.35 - cork; 37 – ring 44-bolt M12x25; 47 - nut M12; 48 - nut M16; 49 - nut M30; 51 - nut M42; 55 - washer 12; 56 - washer 16; 57 - washer 30; 60, 61, 62, 63, 64 - washers; 66.67 - studs; 70, 71, 72 - dowels; 80.81, 82, 83, 84 - rubber rings, 87 - cuff; 90 - bearing; 95 - through-weaving stuffing.

Rice. 2.6 - Components of a vibrating centrifugal pump

The pump consists of a housing and a rotor. Suction covers 6 and discharge covers 5, guide vane bodies 7 with guide vanes 8, front 9 and rear brackets 10 are attached to the casing. Guide vane casings and covers are pulled together with tie rods 21. from shaft 25, on which impellers 3.8 are installed, hydraulic foot disk 18, bushings 20,28,30 bearings 90 and coupling half 1. All these parts are pulled together on the shaft with a special nut 51. The places where the shaft exits the housing are sealed with stuffing box packing 95, impregnated with an anti-friction compound. The cross section of the gland is a square.

The packing rings on the shaft are installed with a relative offset of the cuts by 120 and are pressed by the stuffing box bushings 11 using nuts 47 on the studs 66. The rotor is supported by 2 radial spherical bearings 90, which are installed in brackets 9 and 10 in a sliding fit that allows the rotor to move in the axial direction by the value of the rotor stroke. The places where the shaft exits the bearings are sealed with cuffs 87. The bearing chambers are closed with covers 14 and 13, fixed with studs and nuts. To prevent water from entering the bearing chambers, bumpers 32.37 are installed. The body of the guide vane 7, the guide vane 8 and the impeller 3 together form a pump section. In total, the pump can have up to 10 sections.

Advantages and disadvantages

The advantages and disadvantages of centrifugal pumps are listed below:

Advantages:

а) uniform flow and constant pressure at a constant mode;
б) simplicity of the device and ease of maintenance;
в) speed, ease;
г) ease of regulation;
д) sufficiently high suction height;
е) the possibility of pumping contaminated liquids;
ж) wide range of feed and pressure changes.

Flaws:

а) preliminary filling of the pumped liquid is required;
б) high sealing of the suction line is required;
в) inextricable connection between flow and pressure;
г) dependence of efficiency on supply and pressure;
д) low efficiency at low flow rates and high fluid viscosity

2.2 Corrosion control methods

Corrosion is an important and costly problem in the petroleum industry requiring special attention when designing production equipment. Harsh environments involving CO2 and H2S present particular challenges. Corrosion costs the oil industry hundreds of millions of dollars annually. Water flooding, CO2 flooding, deep gas wells are great examples of cases where a lot of materials have been provided and corrosion issues are expected to continue to do so. The corrosion rate in a neutral solution with low salinity is usually very low. In contrast, the corrosion rate is very high in a low pH solution, which is formed by the presence of liquid materials or a high partial pressure of CO2. Corrosion in the gas and oil industry is mainly associated with CO2 gas, since it is a type present in the oil field. Hydration of carbonic acid CO2 causes corrosion on carbon steel. It is thanks to carbonic acid that the pH of the medium can be lowered.

The degree of corrosiveness caused by CO2 gas depends on environmental conditions such as temperature, CO2 partial pressure, corrosive film properties, and flow conditions. Due to its low cost and availability, carbon steel is used as the main building material for pipelines in the oil and gas industry and electric submersible pumps, but it is highly susceptible to corrosion in CO2 environments. Aqueous carbon dioxide (CO2) is corrosive and eats away at carbon steel pipelines and ESPs.

Corrosion processes - classification

According to the type of aggressive environments, the following types of corrosion occur:

а) Gas character;
б) Atmospheric character;
в) corrosion in electrolytes;
г) corrosion in non-electrolytes;
д) underground character;
е) biocorrosion;
ж) stray current corrosion.

According to flow conditions:

а) contact;
б) slotted;
в) corrosion at incomplete immersion;
г) corrosion at full immersion;
д) friction corrosion;
е) corrosion during variable immersion;
ж) intercrystalline corrosion;
з) stress corrosion.

In a well, the contact between fluids and equipment can be characterized by general or localized corrosion. In the first case, corrosion occurs over the entire surface of the metal or in any part of it. With local corrosion, which occurs most often, the destruction of the metal occurs pointwise. In this case, penetrating damage may be observed.

Corrosion protection methods

There are chemical, physical and technological methods of protection.

The first method consists in the use of chemical reagents that are fed into the well and the annulus in various ways. The greatest efficiency is the supply of reagents from the reservoir zone, for example, through injection wells. With such a system, anti-corrosion protection of downhole equipment is provided along the entire height. Increasingly, physical methods are used to protect downhole equipment from corrosion. It is often possible to observe anti-corrosion design features: the use of stainless steel, fiberglass or an anti-corrosion coating in the manufacture of various parts and well equipment.

One of the chemical corrosion control methods selected in the BBS-XY well is corrosion inhibitor-INR-787. Used to prevent corrosion on a pipe or riser. The principle of operation is that the corrosion inhibitor, injected simultaneously with the oil or gas, will coat the pipe walls in such a way as to prevent a reaction between the pipeline containing the iron metal and oxygen.

Physical methods of protection of downhole equipment against corrosion. The use of stainless steel, fiberglass or anti-corrosion coating in the manufacture of various parts and well equipment.

It should be said that replacing conventional pipes with “stainless steel” tubing has a positive effect, even despite a significant difference in cost. This effect is especially pronounced in wells with a problematic fluid in terms of corrosiveness. A positive effect is also obtained by coating the base metal of the ESP body with various alloying metals: chromium, nickel, silicon and others. In this case, corrosion resistance is maintained as long as the coating does not show damage, which often occurs during the lowering or lifting of the pump from the well. It is quite possible to eliminate underfilm type corrosion in ESPs due to electrochemical protection, which consists in applying an anode coating that has a more negative potential compared to the base metal of the pump and casing string.

The essence of such protection is the destruction of the protective (anodic) coating, and not the cathode, which in this case is the main material of the ESP. Protection will be effective until the tread coating is completely corroded. The same principle of tread protection can be applied without coating. In this case, a protector with a negative charge is attached to the protected equipment. At the end of the tread life, it dissolves and must be replaced. It is known that the main aggressive substance in the produced oil is hydrogen sulfide. This substance is a waste product of sulfate-reducing bacteria. The hydrogen contained in it easily penetrates into the metal, significantly reducing its strength, and iron sulfides deposited on metal surfaces form galvanic vapors, As a result, the latter gradually corrodes. The presence of aggressive microorganisms in the well is also due to the scale of the use of fresh water in the process of field development. Underestimation of the possible influence of these microorganisms in the process of biocorrosion can lead to premature breakdowns and failures. Along with water, the development of biocorrosion is promoted by substances such as nitrogen, sulfur, oxygen, which are a nutrient medium for microorganisms.

It should be noted that microorganisms affect metals in different ways. For example, zinc is not subject to destruction, and brass is able to kill aggressive organisms. That is why the selection of the main material of downhole equipment must be approached after a thorough analysis. It should also be said that the fight against manifestations of corrosive aggressiveness in oil production should be carried out in a comprehensive manner. Only in this case will it be possible to eliminate the harmful effects, save the fishing equipment and increase its service life.

2.3 Types and causes of wear

A gradual decrease in the operational properties of units, products and production mechanisms as a result of a change in their size, shape or physico-chemical characteristics is wear (aging).

Depreciation is formed during the operation of the equipment. There are a number of factors that determine the rate of equipment aging:

а) Friction;

б) Temperature conditions (extreme - in particular);

в) Periodic, impulse or static loads of mechanical action and so on.

It should be noted that almost all types of equipment wear can be slowed down:

а) Constructive decisions;

б) Compliance with the rules of operation;

в) Use of high-quality and modern lubricants;

г) Timely scheduled preventive repairs and maintenance.

All of these types of wear affect performance. It is important to add that the degree and rate of wear are determined by friction conditions, loads, and material characteristics. In addition, the design features of the equipment play an important role.

Types of wear

The decrease in reliability and decrease in the durability of equipment are due to the deterioration of its condition as a result of physical or obsolescence. Physical wear should be understood as a change in the shape, dimensions, integrity and physical and mechanical properties of parts and assemblies, which is established visually or by measurements [8].

Obsolescence of equipment is determined by the degree of lag of its technical and design purpose from the level of advanced technology (low productivity, product quality, efficiency, etc.).

a) Mechanical wear

Mechanical wear can be expressed in breakage, surface wear and a decrease in the mechanical properties of the part.

1) Breaking

Complete failure of the part or the appearance of cracks on it is the result of exceeding the permissible loads. Sometimes the cause of the breakdown lies in non-compliance with the manufacturing technology of the equipment (poor-quality casting, welding, etc.).

2) Surface wear

Under any operating and maintenance conditions, surface wear of parts in contact with other parts or media is inevitable. The nature and magnitude of wear depend on various factors: physical and mechanical properties of rubbing parts and media; specific loads; and relative speeds of movement, etc.

3) Wear due to friction forces

Wear is a gradual destruction of the surface of the material, which may be accompanied by the separation of particles from the surface, the transfer of particles of one body to the surface of the conjugated body, a change in the geometric shape of the rubbing surfaces and the properties of the surface layers of the material.

4) Abrasion

Abrasion is the relative movement of parts pressed against each other [9]. Friction surfaces with any processing have a roughness, i.e. recesses and tubercles. With mutual movement, the tubercles are smoothed out. As a result of the gradual running-in of rubbing surfaces, the work of friction will decrease and wear will stop. Therefore, it is very important to observe the established break-in regime for new equipment.

Another cause of abrasion may be the molecular contact of the surfaces in separate areas, in which they merge by welding. With the relative movement of the surfaces, the welding points are destroyed: many particles come off the friction surfaces.

During friction, the surfaces of the parts heat up. As a result of this, the amorphous layers of the run-in surfaces soften under certain conditions, are transferred to certain distances, and, having fallen into the depressions, harden.

5) Bullying

Scoring is the formation of rather deep grooves on the surface, which serves as a prerequisite for further intense abrasion. It has been established that the most frequent cases of scuffing are in rubbing pairs made of the same metal.

6) Abrasive abrasion

In addition to solid particles formed during abrasion, a lot of small particles in the form of dust, sand, scale, soot fall on the rubbing surfaces. They are brought in with the lubricant or formed under certain operating conditions. The effect of these particles is small if their dimensions are less than the thickness of the lubricant layer.

7) Collapse deformation and fatigue mowing

With a low quality of processing of rubbing surfaces, the actual contact area is much less than the theoretical one: the parts are in contact only with protruding ridges. When the limiting pressure is reached, the deformation of the crushing of the sections protruding beyond the average contact surface occurs.

A frequent change in the direction and magnitude of the load on the rubbing surfaces leads to metal fatigue, as a result of which individual particles peel off from the surfaces (fatigue mowing).

б) Erosive wear

Many media that parts come into contact with contain solid particles (salts, sand, coke in oil streams; catalyst, absorbent, etc.) that cause abrasion or wear. Similar wear is observed with strong and prolonged impacts on the surface of liquid and steam jets. The destruction of the surface of the part, which occurs under the action of friction and impact from the working environment, is called erosive wear.

в) fatigue wear

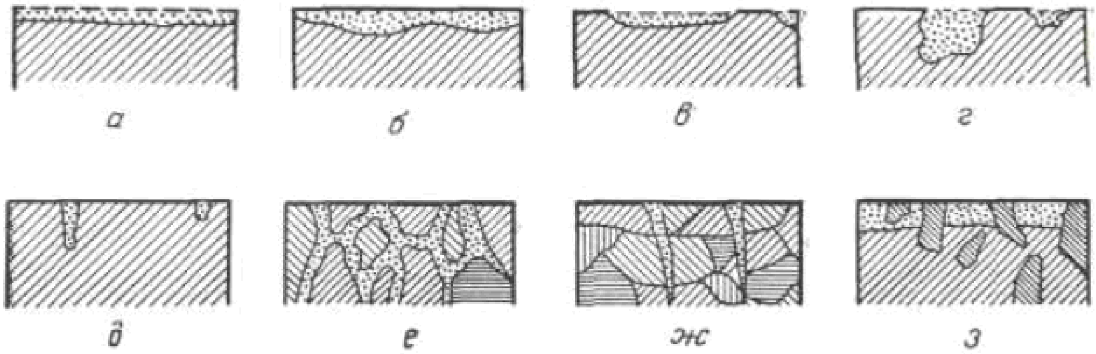
There are frequent cases when a part subjected to variable loads breaks at stresses much lower than the tensile strength of the part material. The complete or partial destruction of a part under the action of stresses, the value of which is less than the tensile strength, is called fatigue wear.

г) Corrosive wear

Corrosion is understood as the destruction of the metal surface, which is a consequence of the occurrence of chemical or electrochemical processes. Corrosion can be continuous, local, intergranular and selective.

With continuous corrosion, the surface of the part wears out relatively evenly. According to the degree of uniformity of the corrosion destruction of the surface layer, continuous uniform (see Fig. 2.7, a) and continuous uneven (see Fig. 2.7, b) are distinguished.

With local corrosion, destruction does not spread over the entire surface of contact with the medium, but covers only certain areas of the surface and is localized on them. In this case, craters and depressions are formed, the development of which can lead to the appearance of through holes. Varieties of local corrosion are: corrosion by individual spots (see Fig. 2.7, c), pitting (see Fig. 2.7, d), pitting (see Fig. 2.7, e).



a - continuous uniform; b - continuous uneven; c - local; g - ulcerative; d - point; f – intergranular; g - transcrystalline; h - structural-selective

Rice. 2.7 - The nature and forms of the spread of corrosive wear

Intergranular (or intercrystalline) corrosion - the destruction of metals along the grain boundary (Fig. 2.7, e). This type of corrosion is typical for parts made of chromium-nickel steels, copper-aluminum, magnesium-aluminum and other alloys.

According to the mechanism of action, chemical and electrochemical corrosion are distinguished.

Chemical corrosion - metal corrosion by chemically active substances (acids, alkalis, salt solutions, etc.).

Electrochemical corrosion is widespread, occurring in aqueous solutions of electrolytes, in an environment of moist gases and alkalis under the action of an electric current. In this case, metal ions pass into the electrolyte solution.

Underground (soil) corrosion is the result of the action of soil on the metal. In most cases, it occurs during aeration and is local in nature. A variety of soil corrosion is biocorrosion (microbiological corrosion) caused by microorganisms. Most often, it appears in earthen soil, in ditches, in sea or river silt.

The outer surfaces of equipment, pipelines, metal structures are subject to atmospheric corrosion, which occurs in the presence of an excess amount of oxygen under the alternating action of moisture and dry air on the metal.

In chemical equipment, so-called contact corrosion is possible. It occurs at the site of contact between two different or identical metals in different states.

д) Thermal wear

A significant part of the equipment of chemical and petrochemical plants operates at high temperatures. Under these conditions, being in a stressed state, the steel structure undergoes creep and relaxation over time.

Creep is a slow plastic deformation of a structural element under a constant load. If the stresses are small, then the growth of deformation over time may stop. At high stresses, deformations can increase until the product fails.

Relaxation is understood as a spontaneous decrease in stress in a part, with a constant value of its deformation, under the influence of high temperature. Relaxation can lead to equipment depressurization and accidents. Violation of the stability of the structure at high temperatures is due to graphitization, spheroidization and intergranular corrosion.

The process of graphitization is the destruction of carbide with the formation of free graphite, resulting in a decrease in the impact strength of the metal. Gray cast iron, carbon and molybdenum steels are susceptible to graphitization at temperatures above 500 °C. Spheroidization does not significantly affect the strength of steels. It lies in the fact that lamellar perlite takes on a round granular shape over time.

2.4 Complicating factors affecting the operation of the ESP

As an example, consider a plant operating in the Subang field. According to the data, an ESP was installed in the BBS-XY well. But after 2 weeks of production, the pump showed overload (stuck). The ESP was replaced. According to the results of ESP extraction, various deposits were found. During the operation of the field, the flow rate decreases, the number of repairs increases. The deterioration of the geological and technological conditions of their operation leads to losses in oil production due to downtime of wells in anticipation of repairs and the period of its implementation.

Under such conditions, one of the main ways to increase the efficiency of well operation is to increase their turnaround time (MTO), primarily wells equipped with ESPs, which account for the bulk of the production.

Failure of submersible electric motors (SEM) due to depressurization and overheating, wear of the pump working parts or their clogging with mechanical impurities, salt deposits. Overheating of individual units of the ESP also leads to damage to the part of the cable line passing directly through the ESP housing.

One of the problems in the operation of wells equipped with ESPs is the fall of parts or entire ESPs on the bottom. One of the generally recognized causes of these accidents is the vibration of the installation during operation. Moreover, the vibration level is determined both by the initial quality of the ESP and by the operating conditions of the ESP.

3 TECHNOLOGICAL PART

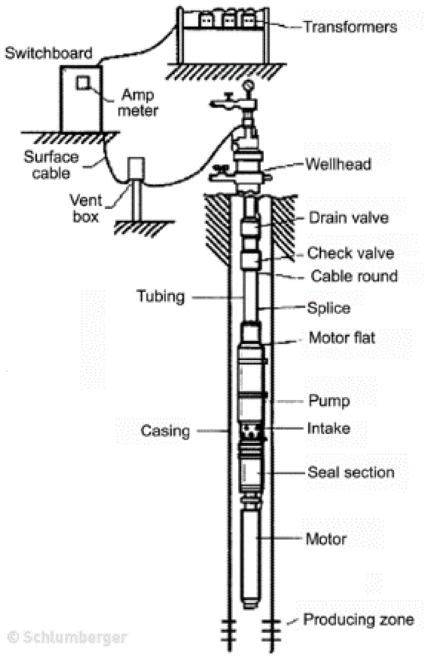
3.1 General scheme and main elements of a submersible electric centrifugal pump

In most oil fields, at the stage of operation, downhole pumps are used for pumping oil at the wellhead, which have an electric drive. The pump typically includes several centrifugal pump sections in series, which can be configured to suit specific wellbore conditions for a particular application. Electric centrifugal pumps (ESPs) are a common artificial lift technique, providing a wide range of sizes and capacities [10]. Electric centrifugal pumps are used in old fields with high water cut (high water-to-oil ratio).

The ESP uses a centrifugal pump that is connected to an electric motor and operates while submerged in the well fluid. A hermetically sealed electric motor turns a series of impellers. Any impeller in the series delivers liquid through an outlet to the inlet of the impeller located above it.

In ESP systems, the electric motor is located at the bottom of the assembly, and the pump at the top (Fig. 3.1). An electrical cable is attached to the outer surface of the tubing and the assembly is lowered into the well such that the pump and motor are below the liquid level. The mechanical seal system and the equalizing safety seal (equivalent names) are used to prevent liquid from entering the motor and eliminate the risk of short circuit. The pump is connected either to a pipe, to a flexible hose, or lowered along rails or wire in such a way that the pump sits on a flange coupling with a foot, while connecting to the compressor pipes.

When the electric motor rotates, the rotation is transmitted to the impeller in the battery in series. The more sections the pump has, the higher the liquid will rise. The electric motor is selected taking into account the needs of the pump. The pump is designed to pump a certain volume of liquid. The shaft is made of monel metal, and the sections are made of corrosion and wear resistant material. The pump has a rotary centrifugal movement. A guard is attached to the top of the pump to isolate the motor and to allow the shaft to move in the center to drive the pump.



From top to bottom - Transformers, control panel, ammeter, wellhead cable, electrical box, wellhead equipment, drain valve, check valve, round cable, tubing, splice, horizontal motor, pump, inlets, casing string, insulating section, electric motor.

Rice. 3.1 - Components of a centrifugal pump

The cable runs from the top of the motor, to the side of the pump/seal, and is attached to the outside surface of any tubing along the entire length of the production string from the motor to the wellhead and then to the electrical junction box. The cable consists of 3 strands of protected and insulated permanent wire. Due to the limited opening around the pump/seal, a flat cable is used from the motor to the tubing above the pump, which is spliced with a smaller diameter cable to improve flotation to the wellhead. The cable has a metal sheath for high protection against damage.

The design of ESP systems requires a multifaceted and thorough study in order to simultaneously solve a number of specific problems of their use. The design requires data on well inflow (flow curve) or well productivity curve, data on well fluids (oil rate, water-oil condition, gas-liquid ratio), pipe data (depths and dimensions of tubing and casing), temperatures (downhole and at the wellhead), and pressure at the wellhead. Proper design and selection of equipment also requires data on solids, solid deposits, asphaltenes, corrosive liquids, corrosive gases, etc.

The wellhead equipment requires the installation of a power transformer and a control panel, as well as an air-cooled electrical distribution box. In the event that a controlled speed drive is required, an additional step-up transformer is needed in the circuit before the cable enters the wellhead. The tubing head is designed to support the tubing string and insulate the electrical cable.

This insulator is normally capable of withstanding a pressure of at least 20864 kPa. The control panel is equipped with an ammeter, fuse, lightning protection and shutdown system. It also includes a high and low current switch and an alarm. This approach contributes to the ability to operate the well continuously, intermittently, or completely stop the operation. It provides protection against high voltages or imbalances that may occur in the power supply. Transformers, as a rule, are located on the edge of the cluster base. The incoming electrical voltage is transformed into the voltage required to run the motor at a certain load, to compensate for the loss in the cable.

Higher voltage (lower current) reduces downhole wireline loss, but other conditions must be taken into account (Field Pump Handbook, 2006). The ESP dramatically loses performance when a percentage of gas that exceeds the threshold level enters the pump. The threshold level for the first occurrence of a gas problem is usually assumed to be 10% gas by volume at the pump inlet at pump inlet pressure. Due to the fact that the pumps have a high - up to 4000 rpm (67 years) - rotation speed and a small opening, they are not resistant to the influence of the solid phase. Under the solid phase, it should be understood sand.

ESPs for oil well casings are available in diameters from 10 to 22 centimeters. Casing pumps with large diameters are used preferably in water wells [10].

For certain casing size, larger diameter equipment is suitable. Large diameter equipment is more concise, both the motor and pumps are more efficient, and the motor is easier to cool – quiet compact wellhead equipment.

Advantages

ESP provides a number of advantages:

а) Adapts to highly deviated wells; up to horizontal, but must be installed in a straight section;

б) Ability to adapt to the required deep wellheads at a distance of 1.8 m from each other for maximum surface density;

в) The possibility of using the minimum space for monitoring the subsoil and related production facilities;

г) Quiet, safe and hygienic for acceptable offshore and environmentally friendly operations

д) Provides volume increase and reduction in water consumption caused by pressure maintenance and secondary restoration work;

е) Allows you to place wells in production even when drilling and working on wells in close proximity;

ж) Can be used in various aggressive environments.

Flaws

ESP has some disadvantages that need to be taken into account.

а) Withstands only minimal percentages of solids (sand) production, although there are special pumps with hardened surfaces and bearings to minimize wear and increase service life;

б) Expensive pull operations and loss of production occur when correcting well failures, especially in the marine environment;

Long service life of ESP equipment is essential to maintain economics and production.

3.2 Calculation when selecting ESP

Evaluation of centrifugal pump performance in BBS-XY wells is made taking into account the settings and adjustments of the pump type, number of stages and pump depth to obtain the desired production rate in accordance with the reservoir productivity, so that the resulting production rate (Q) is optimal. The basis for planning the installation of an electric centrifugal pump (ESP) is divided into three methods. When planning an electric centrifugal pump (ESP) in a BBS-XY well, the pump installation depth, pump type, number of pump stages, electric motor, as well as the choice of cables and transformers in accordance with the received assignment of the optimal production rate in accordance with the reservoir productivity will be taken into account.

3.2.1 Well productivity

The productivity of a well is the ability of a well to produce the fluid it contains under a certain pressure. The ability of a well to produce fluid is highly dependent on the type of formation and driving force, as well as the conditions of the formation. Parameters that express well productivity: Productivity Index (PI) and well indicator curve (Inflow Performance Relationship (IPR)).

Productivity Index (PI)

The well productivity index is one of the important indicators for determining the well flow rate. It is one of the main indicators in the calculation of pumping and other types of well operation [11].

The simplest approach to describing production well opportunities using the concept of productivity factor has been developed with some assumptions as follows:

а) steady flow (stationary state) and the viscosity of a fluid flowing motionless.

б) flow that flows radially in the well.

в) the flow consists of an incompressible fluid of one phase.

г) permeability around the well is uniform.

д) layer saturated with fluid.

Fluid flow in porous media was proposed by Dupuy with the following equation:

$$q = 7{,}08 \times 10^{-3} \frac{kh(P_r - P_{wf})}{\mu_o \beta_o \left[\ln\left(\frac{re}{rw}\right)\right]} \quad (3.1)$$

Where,

q - production rate, barrels / day (m3 / day)

k - permeability, mD

h - reservoir thickness, feet (m)

Pr - reservoir pressure, lbf/in² (atm)

Pwf - bottomhole pressure, lbf/in² (atm)

μo – viscosity, cP

βo – volumetric coefficient, m3/m3

re - dehydration radius of the well, feet (m)

rw - hole radius, feet (m)

Basically, the Productivity Index (PI) is an indicator that shows the ability of a well to produce as much volume of liquid as expressed in barrels per day at a pressure difference between reservoir pressure () and head flow (Pwf) at the bottom of the well. The Productivity Index (PI) is expressed in barrels/day/lbf/in²/MPa) (of total production (oil and water), so the mathematical equation is as follows:$\overline{P}_r$($\frac{м^3}{сут}$

$$PI = \frac{qo+qw}{(P_r - P_{wf})} = \frac{q}{(P_r - P_{wf})} \quad (3.2)$$

Where,

PI - Productivity Index, barrels / day / lbf / in² / MPa)($\frac{м^3}{сут}$

qo - oil production rate, barrels / day (m3 / day)

qw – water production rate, barrels/day (m3/day)

q - total production rate, barrels / day (m3 / day)

Pr is reservoir pressure,lbf/in²(atm)

Pwf - bottomhole pressure, lbf/in² (atm)

Well indicator diagram (Inflow Performance Relationship (IPR)).

The Productivity Index (PI) is only a rough indication of a well's ability to produce. With respect to well planning or monitoring well performance during production, the PI price can be expressed graphically, which is called an Inflow Performance Relationship (IPR) chart.

The well indicator diagram describes the relationship between well flow rate (q) and bottomhole pressure (Pwf).

Single-phase indicator diagram of a well

Based on the definition of the productivity index (PI), the variable that forms the IPR curves is the production rate (q) and the downhole flow pressure (Pwf). The IPR curve of one phase forms a straight line due to the pressure reservoir or pressure flow the bottom of the well is still above the bubble pressure (Pb) so that no gas is released from the liquid and only the liquid phase is flowing.

The following equation can be used to calculate the IPR flow rate:

$$q = PI \times (P_r - P_{wf}) \tag{3.3}$$

Where,

q - production rate, barrels / day (m3 / day)

PI - productivity index, $\frac{м^3/сут}{МПа}$

Pr - reservoir pressure, lbf/in² (atm)

Pwf - bottomhole pressure, lbf/in² (atm)

Two-phase indicator well diagram

As it changes the pressure at the bottom of the well, when the flow pressure at the bottom of the well is below the bubble point pressure (Pb) of the oil, the gas that was originally dissolved will be released and come out of the liquid in two phases that will form bubbles.

Indicator curve, curved. This shows that PI will decrease as production speed increases, as shown in Fig. 3.2. The two-phase type IPR equation was developed by Vogel. The Vogel method can be used to create pressure conditions above and below the bubble point pressure. The IPR curve above the bubble point pressure will be formed by the gas straight, while below the bubble point pressure the IPR curve will be a curved line. In this study, Vogel IPR methods are used because this method is a two-phase type IPR method and can be used for saturated oil reservoirs and undersaturated oil reservoirs.

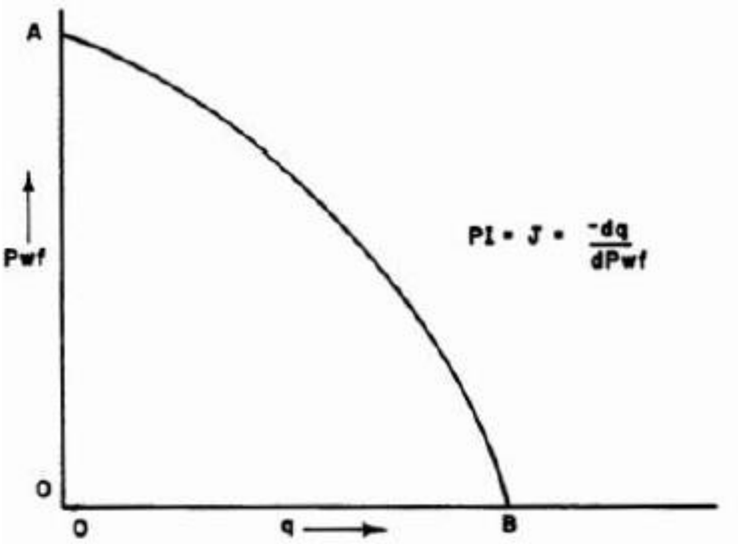


Fig 3.2 - Two-phase type IPR curve

The Vogel equation can be written as follows:

$$\frac{q}{q_{max}} = 1 - 0{,}2\left(\frac{P_{wf}}{P_r}\right) - 0{,}8\left(\frac{P_{wf}}{P_r}\right)^2 \qquad (3.4)$$

Where,

q - flow rate, barrels / day (m3 / day)

qmax - maximum flow rate, barrels / day (m3 / day)

Pr - reservoir pressure, lbf/in² (atm)

Pwf - bottomhole pressure, lbf/in² (atm)

The Vogel method can be used to generate an IPR curve for two types of reservoir conditions, namely:

a) Saturated oil reservoirs (Pr < PB)

When the reservoir pressure is equal to or lower than the bubble point pressure, then the oil reservoir is called a saturated oil reservoir. The calculation procedure for constructing an IPR curve using the Vogel method on a saturated oil reservoir can be performed as follows:

1) Determine qmax using the equation:

$$q_{max} = \frac{q}{1-0{,}2\left(\frac{P_{wf}}{P_r}\right)-0{,}8\left(\frac{P_{wf}}{P_r}\right)^2} \qquad (3.5)$$

2) Determine q to take Pwf with the equation:

$$q = q_{max}\left(1 - 0{,}2\left(\frac{P_{wf}}{P_r}\right) - 0{,}8\left(\frac{P_{wf}}{P_r}\right)^2\right) \qquad (3.6)$$

б) Undersaturated oil reservoirs (Pr > Pb)

When using the Vogel method for an undersaturated oil reservoir, two options must be considered when using it, i.e. when:

Conditions Pr > Pb and Pwf > Pb

The condition Pr > Pb and Pwf > Pb is shown in Figure 3.2. The flow pressure at the bottom of the well is greater than or equal to the bubble point pressure:

1) Calculate PI using Equation (3.2)
2) Calculate the flow rate when the bubble point pressure (qb) is reached using the equation:

$$q_b = PI(P_r - P_b) \tag{3.7}$$

3) We determine qmax using the equation:

$$q_{max} = q_b + \frac{PI \times P_b}{1,8} \tag{3.8}$$

4) Use the q value when Pwf < Pb and using the equation calculate:

$$q = q_b + \frac{PI \times P_b}{1,8}\left[1 - 0,2\left(\frac{P_{wf}}{P_r}\right) - 0,8\left(\frac{P_{wf}}{P_r}\right)^2\right] \tag{3.9}$$

5) For Pwf > Pb, the IPR curve is linear, so equation (3.3.) can be used to calculate q
6) Let's plot qo versus Pwf

Conditions Pr < Pb and Pwf < Pb

Under the condition Pr > Pb and Pwf < Pb is shown in Figure 3.2. Then the work procedure for compiling the IPR curve can be carried out as follows:

1) Determine PI with the equation as follows

$$PI = \frac{q}{(P_r - P_b) + \frac{P_b}{1,8}\left[1 - 0,2\left(\frac{P_{wf}}{P_r}\right) - 0,8\left(\frac{P_{wf}}{P_r}\right)^2\right]} \tag{3.10}$$

2) Determine equation qb using formula (3.7)
3) Determine q max using equation (3.8)
4) Determine q at various prices Pwf time Pwf > Pb using equation (3.3)
5) Determine Q at various prices pwf all times pwf all < PB using Equation (3.9)
6) Plot vs. qo Pwf

Three-phase indicator well IPR

The Wiggins method can be used to construct a three-phase type IPR. The Wiggins method includes the development of the Vogel method, which takes into account the rate of oil and water production using the following formula:

$$qo = qo_{max}\left(1 - 0,52\left(\frac{P_{wf}}{P_r}\right) - 0,48\left(\frac{P_{wf}}{P_r}\right)^2\right) \tag{3.11}$$

$$qw = qw_{max}\left(1 - 0,72\left(\frac{P_{wf}}{P_r}\right) - 0,28\left(\frac{P_{wf}}{P_r}\right)^2\right) \tag{3.12}$$

The fabrication procedure for the IPR method with the Wiggins equation is as follows:

1) Calculate using the following equation: qo_{max}

$$qo_{max} = \frac{qo}{1-0,52\left(\frac{P_{wf}}{P_r}\right)-0,48\left(\frac{P_{wf}}{P_r}\right)^2} \quad (3.13)$$

2) Calculate using the following equation: qw_{max}

$$qw_{max} = \frac{qw}{1-0,72\left(\frac{P_{wf}}{P_r}\right)-0,28\left(\frac{P_{wf}}{P_r}\right)^2} \quad (3.14)$$

3) Determine qo to accept Pwf using Equation (3.11).
4) Determine qw with the assumption Pwf using Equation (3.12).

Put the qo and qw of each Pwf on the table, and sum the qo and qw of each Pwf to get the total production rate (Q).

3.2.2 Physical properties of formation fluid

The physical properties of the fluid (gas, oil and water) must be known as they are the main variable of fluid flow in porous media and pipes. The physical properties of the fluid that will be discussed are the physical properties of the fluid influencing the design of an electric submersible pump (ESP), these are the specific gravity of the fluid mixture (SGf), °API, bubble point pressure (Pb), gas oil ratio (GOR), gas solubility in oil (Rs), volumetric coefficient, viscosity (μ).

Specific Gravity of Fluid Mixture (SGf)

The specific gravity of a fluid mixture (SGf) is the ratio between the density of a liquid and the density of a liquid standard. The specific gravity of the liquid is:

$$SG_f = \frac{\rho_f}{62,4}\frac{lb/cuft}{lb/cuft} \text{ или } SG_f = \frac{\rho_f}{62,4}\frac{gr/cc}{gr/cc} \quad (3.15)$$

The scale used to express the specific gravity (SG) of oil is °API. As for the API price, we can determine the value of the specific gravity, taking into account the ratio, as follows:

$$SGo = \frac{141,5}{(131,5+°API)} \text{ или } °API = \frac{141,5}{SGo} - 131,5 \quad (3.16)$$

The specific gravity of a fluid mixture (SGf) can be calculated if the cost of specific gravity of water (SGw), specific gravity of oil (SGo) and water cut (WC) is known, namely using the following equation:

$$SG_f mix = (1 - WC) \times SG_o + WC \times SG_w \quad (3.17)$$

Where,

SGf - specific gravity of the fluid mixture Pound-force/in² ft per ft (kg/m3)

SGo - specific gravity of oil, lbf/in² ft per ft (kg/m3)

SGw - specific gravity of water, lbf/in² ft per ft (kg/m3)

WC - water cut, %

Bubble points (Pb)

Bubble point pressure is defined as the pressure at which gas is initially formed from the oil solution, caused by the pressure drop in the reservoir.

Gas ratio (GOR)

GOR is a comparison of the total flow rate of the ratio of gas and oil flow rates, cubic feet at standard conditions per barrels of oil at standard conditions (m3 / m3)

$$GOR = \frac{q_g}{q_0} \tag{3.18}$$

Where,

GOR - GOR, standard cubic feet per barrel of oil at standard conditions (m3/m3)

q□ - gas consumption, standard cubic feet per day (m3)

qo – oil consumption, barrel of oil per day (m3)

Solubility Gas (Rs)

The solubility of gas in oil is defined as the number of government standard cubic meters of gas that dissolves in crude oil per barrel in a tank, expressed as standard cubic feet per barrel of oil at standard conditions (m3/m3). Gas solubility depends on pressure, temperature, density, specific gravity of the gas, API oil severity. We calculate the dissolved gas by pressure and specific temperature:

$$R_s = \gamma_g \times \left[\frac{P}{18 \times 10^{0.00091(T) - 0.0125x(API)}}\right]^{1,205} \tag{3.19}$$

Where,

Rs is the solubility of gas in oil, cubic feet at standard conditions per barrel of oil at standard conditions (m3/m3)

T – temperature, ℉ (℃)

P - pressure, lbf/in² (MPa)

Formation of the volume factor

Formation volume factors are defined as the ratio of the volume of liquid in the formation to the volume of liquid in the standard state. The volume of water, oil, or gas in a reservoir is highly dependent on pressure and temperature and is related to the amount of gas dissolved in the fluid.

The change in oil volume due to changes in pressure and temperature is calculated to determine the oil volume factor. The change in volume occurs due to the influx of the gas phase into the oil solution.

The volume factor of oil is defined as the ratio of the volume of liquid in reservoir conditions to the volume of liquid, reduced to atmospheric pressure and temperature of 20 ℃, m3/m3.

The gas volume factor b, m3/m3 can be calculated using the formula:

$$b = \frac{5{,}04 \times Z \times T}{P} \tag{3.20}$$

Where,

b is the gas volume ratio, barrel of oil per million standard cubic feet (m3/m3)

Z is the coefficient of deviation of real gas from ideal gas

T is temperature, ℝ (℃)

P - pressure, lbf/in² (Pa)

Oil Volume Factor (Bo)

The oil volume factor is used to calculate volume at reservoir conditions that include 1 bbl of reservoir combined with the volume of dissolved gas.

$$B_o = 0{,}972 + 14{,}7 \times 10^{-4} \left(R_s \times \sqrt{\frac{\gamma_g}{\gamma_o}} + 1{,}25 \times T \right)^{1{,}175} \tag{3.21}$$

Where,

Bo – oil volume factor, barrels at reservoir conditions per barrels of oil at standard conditions (m³)

Rs is the solubility of gas in oil, gas in cubic feet under standard conditions to a barrel of oil under standard conditions (m3/m3)

γ□ – specific gravity of gas, kg/m3

γo – specific gravity of oil, kg/m3

T – temperature, ℃

Definition of Production Capacity

Determining the production capacity is done by performing an inflow efficiency dependency analysis (IPR). IPR using the Wiggins equation.

Determination of the Specific Gravity and Gradient of a Fluid Mixture

The determination of the specific gravity of a liquid mixture is made using equation (3.17)

The magnitude of the fluid mixture gradient can be calculated using the following equation:

$$G_f mix = SG_f mix \times 0{,}433 \tag{3.22}$$

Where,

SG_f- specific gravity of the fluid mixture, lbf/in² ft per ft (kg/m3)

G_f - fluid mixture gradient, lbf/in² per ft (kg/m3)

Fluid Flow Calculation

Calculation of liquid flow and gas content of smoke can be done by calculating the pump inlet pressure first. The suction pressure of the pump depends on the installation depth of the pump and the flow pressure at the bottom of the well. The calculation of the pump inlet pressure can be done using the equation:

$$PIP = P_{wf} - \left(\left(D_{mid-perf} - PSD\right) \times G_f mix\right) \quad (2.23)$$

Where,

PIP - pump inlet pressure, lbf/in² (MPa)

Pwf - bottomhole pressure, lbf/in² (MPa)

Dmid-perf - depth of medium perforation, feet (m)

PSD - pump installation depth, feet (m)

G_f - fluid mixture gradient, lbf/in² per ft (kg/m3)

Using the previous equation, we will get Rs, Bo, and Bg, which will then be used to get the total gas volume, solving the free gas volume with the following equation:

$$T_g = \frac{q_o \times GOR}{1000} \quad (3.24)$$

$$V_{sg} = \frac{q_o \times R_s}{1000} \quad (3.25)$$

$$V_{fg} = T_g - V_{sg} \quad (3.26)$$

Where,

Tg - total volume of gas, thousand cubic feet (m3)

Vsg - solution gas volume, thousand cubic feet (m3)

Vfg - free volume of gas, thousand cubic feet (m3)

The following equation can then be used to calculate the volume of fluid entering the pump inlet:

$$V_w = q_w \times B_w \quad (3.27)$$

$$V_o = q_o \times B_o \quad (3.28)$$

$$V_g = q_g \times B_g \quad (3.29)$$

$$V_t = V_o + V_g + V_w \quad (3.30)$$

Once the total liquid volume and the volume of each liquid are known, the gas content of the smoke at the inlet of the pump can be obtained from the following equation:

$$\%FreeGas = \frac{V_g}{V_t} \quad (3.31)$$

Where,

Vo is the volume of oil at the pump inlet, barrels of oil under standard conditions (m3)

Vg - gas volume at the pump inlet, barrels of oil under standard conditions (m3)

Vw is the volume of water at the pump inlet, barrels of oil under standard conditions (m3)

Vt is the total volume of liquid at the pump inlet, barrels of oil under standard conditions (m3)

Total dynamic head (TDH) calculation

TDH is the total pressure of the positive displacement pump, which is converted to length (m) so that fluid production can be up to the surface. Total dynamic head calculations can be performed using the following steps:

а) determine the pressure by the level of the working fluid

$$WFL = D_{mid-perf} - \left(\frac{P_{wf}}{G_f mix}\right) \quad (3.32)$$

Where,

Pwf - bottomhole pressure, lbf/in² (MPa)

Gf is the fluid mixture gradient, lbf/in² per ft (kg/m3)

б) Determine the head due to loss of friction in the pipeline

Determination of friction loss (in meters) per 304 m in a pipe can be used by the equation "Hazen - Williams formula" as shown below:

$$F = 2{,}083 \times \left(\frac{100}{C}\right)^{1{,}85} \times \frac{(Q/34{,}3)^{1{,}85}}{ID^{4{,}8655}} \times SG_{fmix} \quad (3.33)$$

$$Hf = \frac{PSD \times F}{1000} \quad (3.34)$$

Where,

F - friction losses per 304 m

Hf - friction head in the pipe, ft (m)

Q – flow rate, barrels per day (m3/day)

C - 120 (for a new pipe) and 94 (for an old pipe)

ID - tube diameter, inch (mm)

Determine head head head pressure (Ht)

The tubing head pressure (THP) is the pressure required at the tubing head. The THP must be able to drain the liquid up to the separator. The tubing head pressure can be converted to long head by the equation as follows:

$$H_t = \frac{THP}{G_f mix} \quad (3.35)$$

Where,

THP - tubing head pressure, lbf/in² (kg/m)

G_f - fluid mixture gradient, lbf/in² per ft (kg/m3)

From the three equations above, it is then possible to calculate the total dynamic head (TDH):

$$TDH = WFL + Ft + Ht \quad (3.36)$$

Where,

TDH = Total Dynamic Head, ft (m)

WFL = Operating Fluid Level, ft (m)

Ft = pipeline friction loss, ft (m)

Ht = wellhead pressure loss, ft (m)

Pump Selection

The choice of the type of pump used has a very strong influence on the production volume and power consumption. So that production can be optimal and power is used efficiently, the pump installed must be in accordance with the reservoir productivity. Pump selection can be done with the following steps:

1) determine the capacity of the pump

The capacity of the pump should be dissesauaican with the production capacity of the well. The flow rate from the well must be within the operating range recommended by the manufacturer for each type of pump.

2) calculate the number of pump stages.

The calculation of the total number of pump stages required can be obtained from the equation:

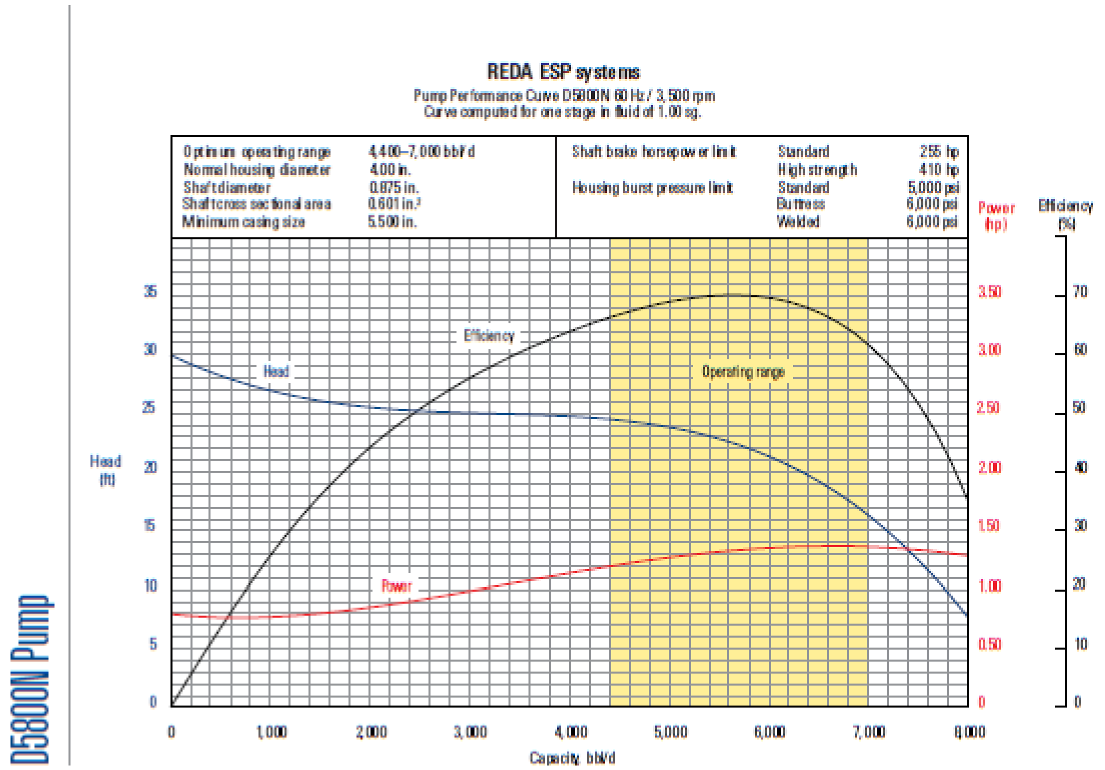
$$\text{Количество ступеней} = \frac{TDH}{head/stages} \times SG_f mix \quad (3.37)$$

When using the Pump Performance Curve, the head per stage of the selected pump is known at a given flow rate. Typically, a safety factor of 10% or more of the number of planning steps will be added.

Table 3.1 - Ratio of type, series, outer diameter and body size

Type	Series	outer diameter, mm	Minimum Case Size, mm
A	338	8585	114
D	400	10160	139
G	540	13030	168
S	538	13665	177
H	562	14300	177

J	675	17145	219
L	738	18415	244
M	862	21920	273
N	950	2413	298
N	950	25400	298
P	1125	285.75	339



Rice. 3.3 - Single Frequency Pump Performance D5800N

Motor Selection

To determine the type of motor, first determine the amount of horsepower (power) per step on the pump performance curve. The total horsepower that is needed is the product of the multiplication between the number of stages, the number of HP/stage, and the specific gravity of the fluid. So the required HP can be calculated with the following steps:

1) Define BHP motor

$$BHP_{motor} = {}^{HP}/_{\text{ступени}} \times \text{количество ступеней} \times SG_f mix \quad (3.38)$$

2) Determine the required power of the tread/seal section.
3) Determine the required capacity of the gas separator in horsepower.
4) Determine the total amount of horsepower (hp) in the system.

$$HPsystem = BHPmotor + HPprotector + HPgas\ separator \quad (3.39)$$

Knowing the amount of power in the system, one can determine the type of motor to be used.

On any engine that is used, there are restrictions on use. Limits are set on the engine power, that is, the engine load. The load on the engine is limited to a maximum of 90%, under these conditions the engine can work well. Equation for calculating engine load:.

$$MotorLoad = \frac{HP_{total}}{HP_{nameplate}} \quad (3.40)$$

Selection of cables and transformers

When selecting the type of cable to be used, consideration must be given to amperage, downhole voltage and temperature, fluid properties, and the clearance between the tubing OD and the casing ID motor. As well as the necessary additional cable for connection on the surface. While the following steps can be taken to select a transformer:

1) Calculate surface stress:

$$V_{surf} = V_{motor} + \left(\frac{V_{drop}}{1000} \times (L + 100) \times Correction\ Factor\right) \quad (3.41)$$

2) Calculate the power consumption of the transformer

$$KVA = \frac{1{,}73 \times V_{surf} \times Ampere\ Motor}{1000} \quad (3.42)$$

Where,

KVA - power transformer, kVA

Vsurf - surface voltage, volt (V)

L is the length of the loop cable, feet (m)

Vdrop - voltage drop, volt (V)

3.3 Calculations

3.3.1 IPR calculation using the Wiggins method

IPR well BBS-XY

In this discussion, the IPR is generated using the Wiggins equation.

1) We determine PI by the formula (3.2): ,

$$PI = \frac{268}{(1729-1168)} = 4{,}615 \text{ barrels/day per lbf/in}^2 (127.27) \frac{\text{м}^3/\text{сут}}{\text{МПа}}$$

2) We determine the maximum oil consumption (qo max) using equation (3.13)

$$qo_{max} = \frac{10,72}{1-0,52\left(\frac{1168}{1729}\right)-0,48\left(\frac{1168}{1729}\right)^2} = 263,38$$ barrels/day (41.87 m3⁄day)

3) Calculate the maximum water flow (qw max) using equation (2.14)

$$qw_{max} = \frac{257,28}{1-0,72\left(\frac{1168}{1729}\right)-0,28\left(\frac{1168}{1729}\right)^2} = 6318,68$$ barrels/day (1004 m3⁄day)

4) We determine the oil consumption (qo) taking into account the estimated price Pwf, using equation (3.11)

$$qo = 263,38\left(1 - 0,52\left(\frac{1168}{1729}\right) - 0,48\left(\frac{1168}{1729}\right)^2\right) = 113,1$$barrels/day (17.9 m3⁄day)

5) We determine the price of water consumption (qw) taking into account the price Pwf, using equation (3.12)

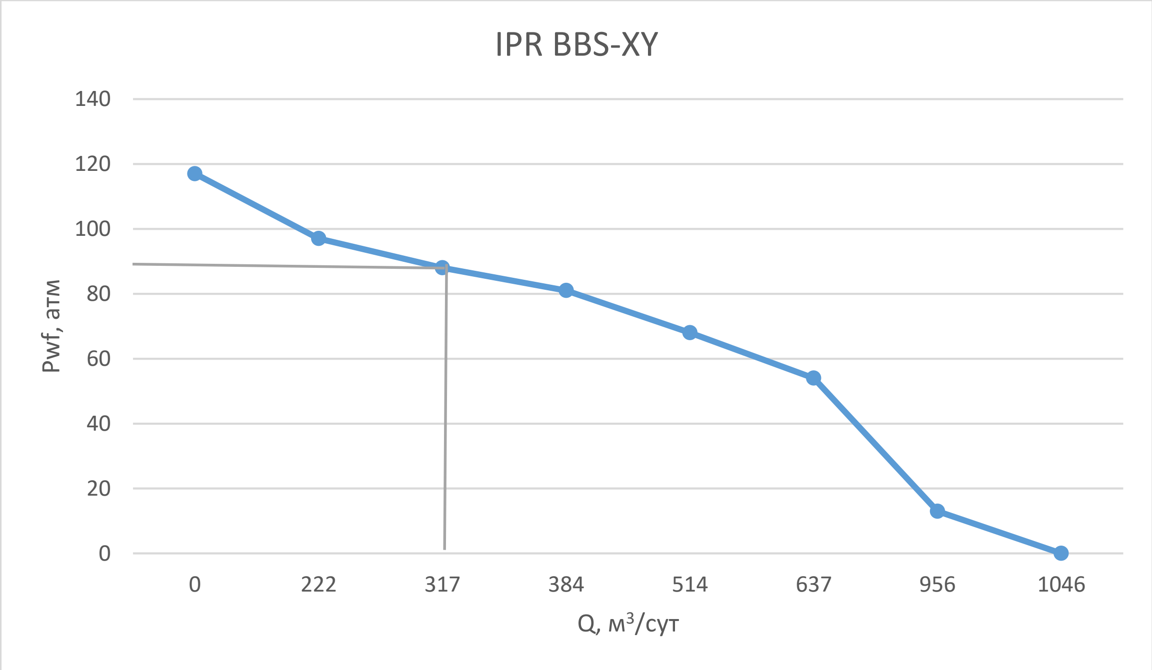
$$qw = qw_{max}\left(1 - 0,72\left(\frac{1168}{1729}\right) - 0,28\left(\frac{1168}{1729}\right)^2\right) = 2437.98$$ bbl/d (387 m3⁄d)

6) Let's fill the table with data on the functional relationship between productivity and bottomhole pressure in order to get the production rate (Q)

Table 3.2 - Data for constructing an indicator curve in BBS-XY wells

Given for plotting the IPR indicator curve				
Pwf, atm	Pwf/Ps, atm	Qo, m3/day	Qw, m3/day	Q, m3/day
117	0.068	0	0	0
97	0.056	10	212	222
88	0.051	14	303	317
81	0.046	17	367	384
68	0.039	22	492	514
54	0.031	27	609	637
13	0.008	39	917	956
0	0.00	41	1004	1046

Based on the data from the table, we build an indicator curve (IPR), which is the relationship between the head pressure flow rate at the bottom of the well (Pwf) and the fluid flow rate (Q), as shown in fig. 3.4,



Rice. 3.4 - Indicator curve (IPR) of the well BBS-XY

According to the graph results, the indicator curve (IPR) of the BBS-XY well achieved Qmax 1046 m3/day, while according to the results of production well tests, an output of 42 m3/day was obtained at a Pwf of 114 atm with a water cut of 96%. According to these parameters, and after optimization, it is planned to produce up to 317.9 m3/day at Pwf 88 atm.

3.3.2 ESP evaluation

The BBS-XY well data with an attached pump is an EJP IND 750 with 455 steps at 54 Hz. The data used for this estimate is from the 2019 data below,

Total flow (QL): 268 bbl/d (42 m3/d)

Oil consumption (Qo) : 39.05 barrels / day (6.2 m3 / day)

Gas consumption (Qg) : 12 million std. cube ft/day (33.9 m3/day)

Water cut: 96%

Static pressure (Ps): 1729 lbf/in² (11.92 MPa)

Pressure flow rate base (Pwf): 1681 lbf/in² (11.59 MPa)

Wellhead pressure (Pwh) :100 lbf/in² (0.00689 MPa)

GOR : 1119 standard cubic feet per standard oil barrels (31.68 m3)

SG oil: 0.875

SG water: 1.02

BHT, ℉: 226℉ (107.7℃)

Case size: outer diameter 177 mm / inner diameter 161.8 mm

Tube size : outer diameter 73.025 mm / inner diameter 61.98 mm

Perforation interval: 1559-1563 m TVD

medium perforation depth: 1561 m TVD

Well depth, m: 1609 m TVD 1762 m MD

a) Calculation of the total dynamic head of the well BBS-XY

On the BBS-XY well, the ESP pump is installed at a depth of 4561 TVD 4163 m/m MD. Next, we calculate the full dynamic head:

1) Calculate the specific gravity of the fluid mixture and the gradient of the fluid mixture using equations (3.17) and (3.22)

$$SG_f mix = (1 - 0{,}96) \times 0{,}875 + 0{,}96 \times 1{,}02 = 1{,}0142$$

$$G_f mix = 1{,}0142 \times 0{,}433 = 0{,}4391 \text{ lbf/in}^2\text{per feet (1012 kg/m3)}$$

2) Determine the working fluid level (WFL) using equations (3.32)

$$WFL = 5123 - \left(\frac{1681}{0{,}4391}\right) = 1295{,}17 \text{ ft (394 m)}$$

3) Calculate the friction loss using equation (3.33), total flow rate 42 m3/day and pipeline size 73.025:0,33 м/304м

$$\mathrm{F} = 2{,}083 \times \left(\frac{100}{94}\right)^{1{,}85} \times \frac{(268/34{,}3)^{1{,}85}}{2{,}441^{4{,}8655}} = \frac{1{,}1}{1000} \text{футов (0.33 m/304 m)}$$

4) Calculate the head friction at a pump installation depth of 4561 feet (1390 m) MD using Equation (3.34):

$$\mathrm{Hf} = \frac{1.1 \text{ футов}}{1000 \text{ футов}} \times 4561 = 4{,}9 \text{ футов(1.5m)}$$

5) Calculate the head pressure at the pipeline head using Equation (3.35)

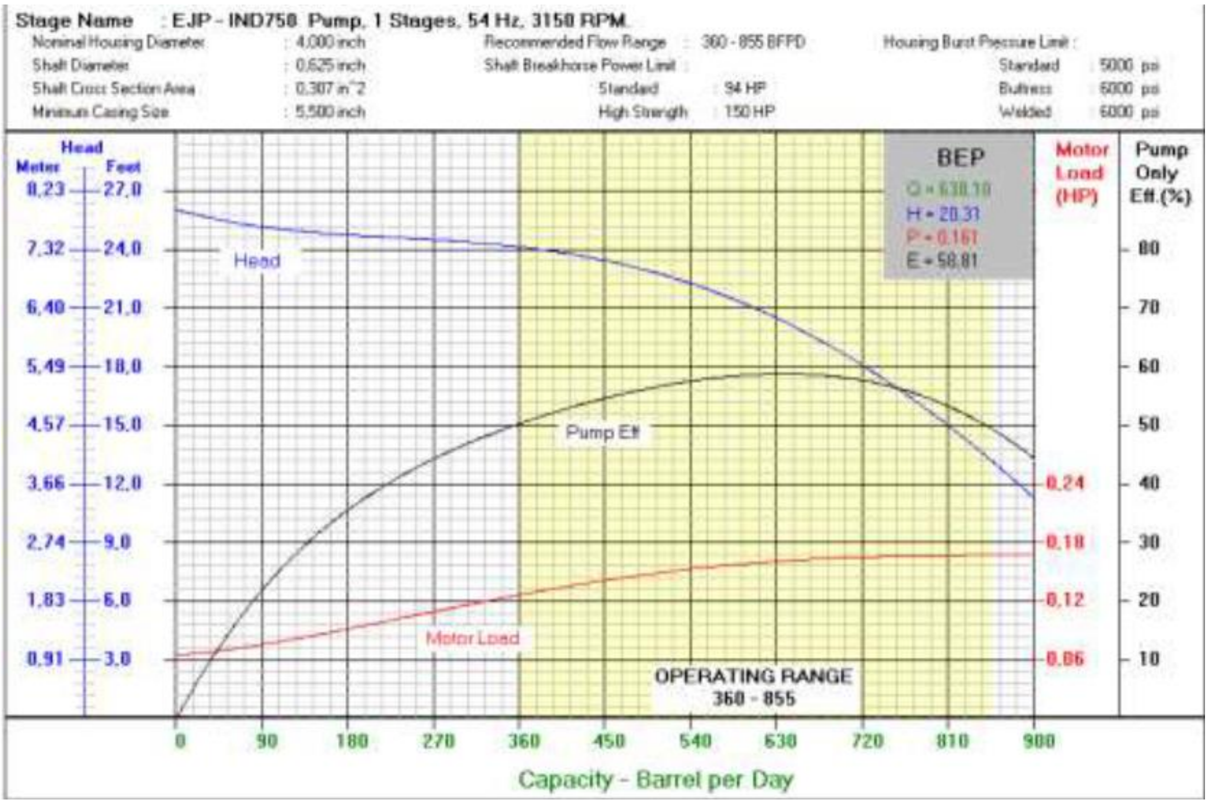
$$\mathrm{Ht} = \frac{100 \text{ фунт−сила/дюйм}^2}{0{,}4391 \text{ фунт−сила/дюйм}^2 \text{/футов}} = 227{,}7 \text{ футов(69.4m)}$$

6) Calculate the total dynamic head (TDH) using equation (3.36)

$$TDH = 1295{,}19 + 4{,}9 + 227{,}7 = 1527{,}8 \text{ футов(465.6m)}$$

б) Selection of ESP pumping wells BBS-XY

At the same time, the pump installed on the BBS-XY well is operated by an EJP IND 750 with a frequency of 455 steps 54 Hz. The data can be taken as the data required for the operation of the pump used with the higher stages.



Rice. 3.5 - Typical pump performance curves IND-750, 54 Hz, 3150 rpm

Consider the initial design of the operating pump. We also consider the characteristic curve of the performance of the pump IND-750, 54 Hz according to Fig. 3.5, we will enter the data in Table 3.3:

Table 3.3 - IND-750 pump data

Options	Reading Results
flow rate,m3/day	101
Head, feet/steps	20.31
Power, hp / steps	0.16
steps	88
Total connected steps	455
BHP pump, HP	72.8

c) Calculation of gas flow at the pump inlet

1) Calculate the pump inlet pressure (PIP) using equations 3.23:

$$\text{PIP} = 1297 - \left((5123 - 4918) \times 0{,}4391\right) = 1207 \text{ psi (8.32 MPa)}$$

2) Calculate the solubility of gas in oil (Rs) using the equation for the use of pump inlet pressure (PIP) (3.19):

$\text{Rs} = 0{,}6\left(\frac{1207}{18\times10^{0{,}00091(226)-0{,}0125(30{,}21)}}\right)^{1{,}205} = 74{,}4$ standard cubic feet per barrels of oil at standard conditions (13.17 m3/m3)

3) Calculate the formation oil volume ratio (Bo) to the pump inlet pressure (PIP) using equation (3.21)

$\text{B}_\text{o} = 0{,}972 + 1{,}47\times10^{-4}\left(74{,}4\left(\frac{0{,}6}{0{,}875}\right)^{0{,}5} + 1{,}25(226)\right) = 1{,}113$ barrels at reservoir conditions per barrels of oil at standard conditions (0.15 m³)

4) Calculate the formation gas volume (Bg) at the pump inlet (PIP) using Equation 3.20:

$\text{Bg} = \frac{5{,}04\times0{,}925\times(460+226)}{1221{,}7} = 2{,}557$ barrel of oil per million standard cubic feet (356.2 m3/m3)

5) Calculate the total volume of gas, dissolve the volume of free gas in the volume of free gas using equations (3.24), (3.25) and (3.26) :

Total Gas Inlet Pump (PIP)

$$\text{Tg} = \frac{(2000\times(1-0{,}97))\times1119}{1000} = 72{,}37 \text{ thousand cubic feet (2.03 m3)}$$

Volume of Dissolved Gas at Pump Inlet (PIP)

$$\text{V}_\text{sg} = \frac{(2000\times(1-0{,}97))\times74{,}4}{1000} = 4{,}46 \text{ thousand cubic feet (0.11 m3)}$$

Free gas volume at pump inlet (PIP)

$$V_{f\text{g}} = 72{,}37 - 4{,}46 = 67{,}91 \text{ thousand cubic feet (1.89 m3)}$$

6) Calculate the volume of fluid entering the pump inlet, taking into account equations (3.27), (3.28), (3.29) and (3.30)

Oil production volume

$V_o = \left(2000\times(1-0{,}97)\right)\times1{,}113 = 200{,}3$ barrels of oil at standard conditions (31.79 m3)

Gas volume

$V_\text{g} = 67{,}91\times2{,}557 = 173{,}62$ barrels of oil at standard conditions (27.50 m3)

Water volume

$V_\text{w} = 1940$ barrels of oil at standard conditions (308.4 m3)

Total liquid volume

$V_\text{t} = 200{,}3 + 173{,}62 + 1940 = 2313{,}9$ barrels of oil at standard conditions (367.7 m3)

7) Calculate the percentage of free gas at the pump intake using equation (3.31)

$$\%FreeGas = \frac{173,62}{2313,9} = 7,5\%$$

As a result of calculating free gas at the pump inlet, a figure of 7.5% was achieved for BBS-XY wells. If the free gas content, according to the results of the calculation, exceeds 5%, then it is necessary to install a gas scrubber or gas separator. Consider the tools needed to solve the problem of free gas entering the pump.

Table 3.4 - Gas treatment device

Pump or gas device	Percentage of free gas treated
Radial stage pump	10%
Pump with mixing stages	20%-25%
AGH (except 562 series)	45%
AGH Series 562	35%
Poseidon-axial stages	75%

From the table above, you can choose a pump, with radial stages for use on BBS-XY wells.

3.3.3 ESP planning

a) Total dynamic head (TDH) calculation for BBS-XY well

Before starting the calculation of the total dynamic head, it is necessary to determine the installation depth of the ESP pump. On the BBS-XY, the rig is at 4,918 ft (1,499 m) TVD/5,316 ft (1,620 m) MD. Calculate the total sum of the dynamic head:

1) Calculate the specific gravity of the fluid mixture and the gradient of the fluid mixture using equations (3.17) and (3.22):

$$SG_f mix = (1 - 0,96) \times 0,875 + 0,96 \times 1,02 = 1,006$$

$G_f mix = 1,0142 \times 0,433 = 0,4391$Pounds per square inch to feet (1012 kg/m3)

2) We determine the working liquid level (WFL) using equations (2.32):

$$WFL = 5123 - \left(\frac{1297}{0,4391}\right) = 2169,7 \text{ ft (661 m)}$$

3) Calculate the friction loss (F) using equation (3.33) with a design flow rate of 2000 bbl/d (317.9 m3/d) and a pipeline size of 2 7/8 in (73.025 mm):

$$F = 2,083 \times \left(\frac{100}{94}\right)^{1,85} \times \frac{(2000/34,3)^{1,85}}{2,441^{4,8655}} =$$

56,1футов/1000футов(17.09m/304.8m)

4) Calculate head friction (Hf) at PSD 5316 ft (1620 m) MD using equation (3.34):

$$Hf = \frac{56,1}{1000} \times 5316 = 298,47 \text{ ft (90.83 m)}$$

5) Calculate the head pressure at the pipeline head using Equation (3.35):

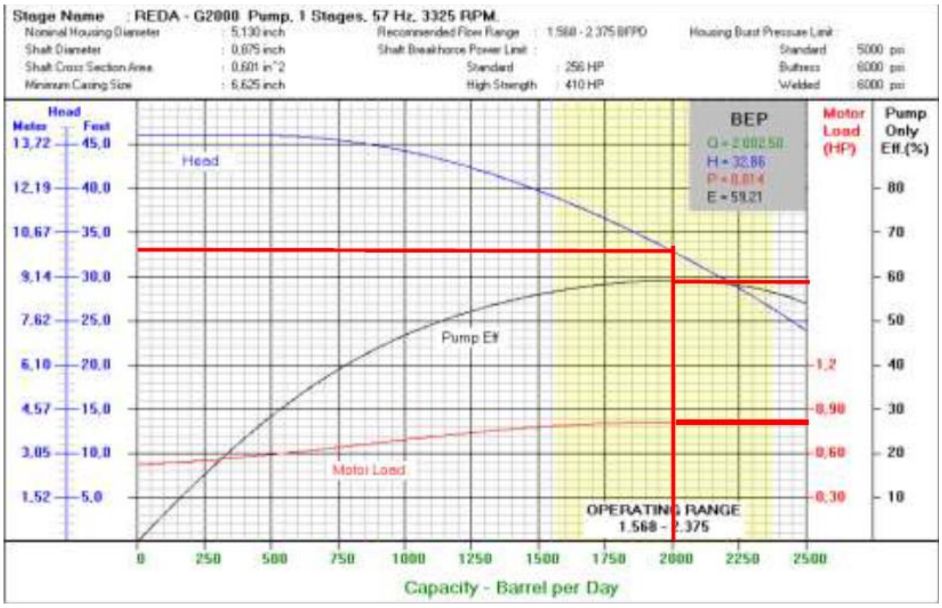
$$Ht = \frac{100}{0,4391} = 227,7\text{ft (69.4 m)}$$

6) Calculate the total dynamic head (TDH) using equation (3.36):

$$TDH = 2169,7 + 298,47 + 227,7 = 2695,86\text{ft (821.4 m)}$$

б) Selection of ESP pumping well BBS-XY

The choice of ESP pump type is adjusted depending on the size of the casing and the planned flow rate. The flow rate that is planned for BBS-XY is 2,000 bbl/d (317.9 m³/d). The type of pump that can accommodate the flow rate of the REDA G-2000 pump; 57 Hz; 3325 rpm operating range 1258-2375 bbl/d (200-377 m3/d)



Rice. 3.6 - Pump performance curve REDA G-2000, 57 Hz; 3325 rpm

Mathematically, the number of pump stages required to deal with pressure can be calculated using Equation (3.37):

$$\text{Количество ступеней} = \frac{2657,09}{33} \times 1,0142 = 81\text{steps}$$

If you add a safety factor for the pump stages by 40%, then the total number of pump stages will be used by 115 stages.

The results of reading the performance curve of the REDA G-2000 pump are as follows:

Table 3.5 - Performance of the REDA G-2000 pump

Options	Reading results
Consumption	2000

Head	33
Force	0.8
Pump efficiency	59
Total number of steps	115

б) Motor well selection BBS-XY

To select a motor, first of all, it is necessary to specify the power per stage on the pump performance curve in advance, which is then multiplied by the number of stages and the specific gravity of the liquid to get the effective power (BHP, hp). To determine the effective power (BHP) of the engine, equation (2.38) is used:

$$BHP_{motor} = 0{,}8 \times 115 \times 1{,}0142 = 93 \text{ л. с}(68.4 \text{ kW})$$

Once the power demand (BHP) is known, it can be determined and then the engine type to be used can be selected. In the work it is planned to use a reference book on the technical characteristics of the engine 125 hp (91.94 kW); 1491 volts; 52.7 amps (125.7 kW). The design load of the engine is selected in such a way as not to exceed the limit, we use the equation for calculating the engine load (3.40)

$$MotorLoad = \frac{93{,}5}{125} = 73{,}7\%$$

The catalog, which is used as a reference for motor selection, is used for planning design on the BBS-XY well. The catalog of engines is presented in the Appendix (see Appendix B).

в) Cable selection and well transformer BBS-XY

The cables used are 100 feet (30.48 m) longer than the depth of the pump for the additional surface mounted cable.

When selecting an ESP cable, it is necessary to know the maximum surface voltage in order to calculate the voltage drop across the cable. Voltage values and cable brand are selected according to the application. See Appendix B.

From the application, select an AWG#1 cable that has a cable voltage drop of 11.5 volts/1000 feet (11.5 volts/304.8 m). Next, we calculate the required voltage and transformer:

1. We calculate the surface stress according to equation (2.42)

$$V_{surf} = 1491 + \left(\frac{11{,}5}{1000} \times (5416) \times 1{,}354\right) = 157{,}33 \text{ вольт}$$

2. Calculate the power consumption of the transformer using equation (2.43)

$$KVA = \frac{1{,}73 \times 1575{,}33 \times 54}{1000} = 147{,}168 \text{ кВа}$$

The calculated transformer is suitable for the requirements of a transformer with a power of 147.168 kVA, and a size of 300 kVA.

Table 3.6 - Comparative analysis of pumps operated in the BBS-XY well

No.	Options	Installed pump	Suggested pump
1	Production speed	268 barrels/day (42 m3/day)	2000 barrels/day (317.9 m3/day)
2	water cut	96%	97%
3	Pump installation depth	4,163 ft (1,268 m) TVD/4,561 ft (1,390 m) MD	4,918 ft (1,499 m) TVD/5,316 ft (1,620 m) MD
4	Pump inlet pressure	1259.29 lbf/in² (8.68 MPa)	1206.97 lbf/in² (8.32 MPa)
5	General dynamic head	1,527.8 ft (465.6 m)	2695.86 ft (821.7 m)
6	Pump type	IND-750;54Hz	G-2000;57Hz
7	Number of steps	455 steps	115 steps
8	OD pump	4.00 in (101.6 mm)	5.13 in (130.3 mm)
9	BHP pump	73.8 hp (54.28 kW)	92.9 hp (68.33 kW)
10	HP motor	120 hp (88.26 kW)	125 hp (91.94 kW)
eleven	Voltage motor	1070 Volt	2386 Volt
12	Electricity	70 Amps (74.9 kW)	52.7 Amps (125.7 kW)
13	cable type	AWG#1; 4,721 feet (1,438 m)	AWG#1; 5,416 feet (1,650 m)
14	Transformer	300 kVA	300 kVA

Based on BBS-xy ESP planning to achieve a flow rate of 2000 bbl/d (317.9 m3/d), it is planned to operate the pump at a flow rate of 1258-2375 bbl/d (200-377 m3/d). According to the initial data, it is proposed to use a pump with a flow rate REDA G-2000; 57 Hz; 3325 rpm operating range 1258-2375 bbl/d (200-377 m3/d). Number of pump stages 115, with engine specifications 125 hp (91.94 kW); 1491 volts; 52.7 amps (125.7 kW) and AWG#1 cable, which has a cable drop of 11.5 volts/1000, and a 300 kVA transformer.

4 Economy

Pertamina EP JSC 3rd Asset in Subang Field is working with an ESP rental service provider, namely Maju Mandiri Utama JSC (MMU), in performing crude oil lifting using the electric submersible pump production method. Below are the results of calculating the economic conditions for the operation of the installed pump and the planned pump.
The cost of rent is from 489 to 756 dollars.

Table 4.1 - The cost of rent for the month of April (756 dollars)

No.	Data	Meaning
1	Net production, barrels per day	10.72
2	Monthly production, bopm barrels per month	325.89
3	Oil price (USD/bbl)	49.25
4	Gross income per month (USD)	16.050
5	ESP rental prices (USD / day)	756
6	Total lift cost (USD/day)	756
7	Net income per month (USD)	-6.932
8	Net income per day (USD)	-228
9	US dollar to Indonesian rupiah exchange rate	13.274.0
10	Net income per day (Indonesian rupiah)	-3.037.014
eleven	Net income per month (Indonesian rupiah)	-92.021.220

Exchange rate 1 US dollar = 68.58 on 06/10/2020

According to the initial data, it can be said that the cost of the rent of $756 is not economically beneficial for the organization.

Table 4.2 - The cost of rent for the month of April

No.	Data	Meaning
1	Net production, barrels per day	10.72
2	Monthly production, bopm barrels per month	325.89
3	Oil price (USD/bbl)	49.25
4	Gross income per month (USD)	16.050
5	ESP rental prices (USD / day)	489
6	Total lift cost (USD/day)	489
7	Net income per month (USD)	1.184
8	Net income per day (USD)	39
9	US dollar to Indonesian rupiah exchange rate	13.274.0
10	Net income per day (Indonesian rupiah)	517.157
eleven	Net income per month (Indonesian rupiah)	5.721.570

Exchange rate 1 US dollar = 68.58 on 06/10/2020

Based on the initial data, it can be said that the cost of the rent of $489 is cost-effective for the organization.

Table 4.3 - The cost of rent for the month of May

No.	Data	Meaning
1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00
3	Oil price (USD/bbl)	50.71
4	Gross income per month (USD)	92.495
5	ESP rental prices (USD / day)	756
6	Total lift cost (USD/day)	756
7	Net income per month (USD)	69.513
8	Net income per day (USD)	2.287
9	US dollar to Indonesian rupiah exchange rate	13.273.0
10	Net income per day (Indonesian rupiah)	30.351.967
eleven	Net income per month (Indonesian rupiah)	922.699.808

Exchange rate 1 US dollar = 68.58 on 06/10/2020

Table 4.4 - The cost of rent for the month of May

No.	Data	Meaning
1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00
3	Oil price (USD/bbl)	50.71
4	Gross income per month (USD)	92.495
5	ESP rental prices (USD / day)	489
6	Total lift cost (USD/day)	489
7	Net income per month (USD)	77.629
8	Net income per day (USD)	2.554
9	US dollar to Indonesian rupiah exchange rate	13.273.0
10	Net income per day (Indonesian rupiah)	33.896.083
eleven	Net income per month (Indonesian rupiah)	1.030.440.929

Exchange rate 1 US dollar = 68.58 on 06/10/2020

In the results of tables 4.3 and 4.4, with a rent with a lower cost, economic efficiency is greater.

Table 4.5 - The cost of rent for the month of June

No.	Data	Meaning

1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00
3	Oil price (USD/bbl)	47.28
4	Gross income per month (USD)	86.239
5	ESP rental prices (USD / day)	756
6	Total lift cost (USD/day)	756
7	Net income per month (USD)	63.256
8	Net income per day (USD)	2.081
9	US dollar to Indonesian rupiah exchange rate	13.279.6
10	Net income per day (Indonesian rupiah)	27.632.132
eleven	Net income per month (Indonesian rupiah)	840.016.820

Exchange rate 1 US dollar = 68.58 on 06/10/2020

Table 4.6 - The cost of rent for the month of June

No.	Data	Meaning
1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00
3	Oil price (USD/bbl)	47.28
4	Gross income per month (USD)	86.239
5	ESP rental prices (USD / day)	489
6	Total lift cost (USD/day)	489
7	Net income per month (USD)	71.373
8	Net income per day (USD)	2.348
9	US dollar to Indonesian rupiah exchange rate	13.279.0
10	Net income per day (Indonesian rupiah)	31.177.778
eleven	Net income per month (Indonesian rupiah)	947.804.445

Exchange rate 1 US dollar = 68.58 on 06/10/2020

Table 4.7 - The cost of rent for the month of June

No.	Data	Meaning
1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00

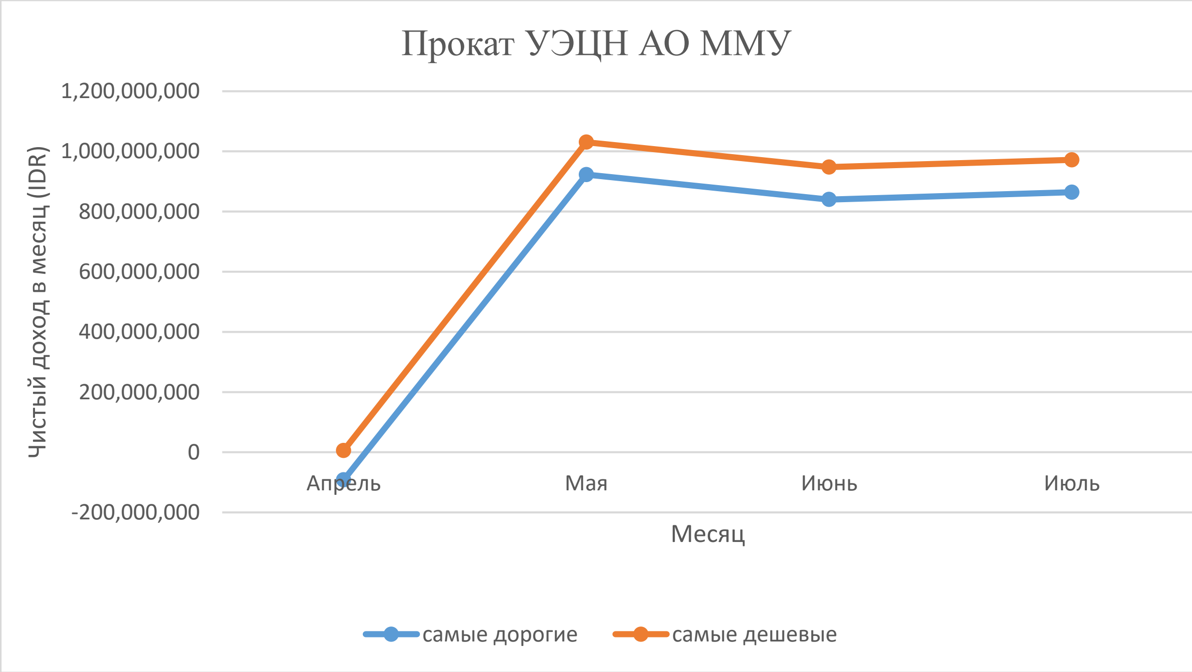
3	Oil price (USD/bbl)	48.38
4	Gross income per month (USD)	88.245
5	ESP rental prices (USD / day)	756
6	Total lift cost (USD/day)	756
7	Net income per month (USD)	65.263
8	Net income per day (USD)	2.147
9	US dollar to Indonesian rupiah exchange rate	13.239.6
10	Net income per day (Indonesian rupiah)	28.423.393
eleven	Net income per month (Indonesian rupiah)	864.071.161

Exchange rate 1 US dollar = 68.58 on 06/10/2020

Table 4.8 - The cost of rent for the month of July

No.	Data	Meaning
1	Net production, barrels per day	60.00
2	Monthly production, bopm barrels per month	1824.00
3	Oil price (USD/bbl)	48.38
4	Gross income per month (USD)	88.245
5	ESP rental prices (USD / day)	489
6	Total lift cost (USD/day)	489
7	Net income per month (USD)	73.380
8	Net income per day (USD)	2.414
9	US dollar to Indonesian rupiah exchange rate	13.239.9
10	Net income per day (Indonesian rupiah)	31.958.444
eleven	Net income per month (Indonesian rupiah)	971.536.692

Exchange rate 1 US dollar = 68.58 on 06/10/2020



Rice. 4.1 - Graphic scheme for assessing the economic situation with the hiring of ESP JSC "Maju Mandiri Utama"

Figure 4.1 presents the analysis by tables. Based on the results of the ESP evaluation, it can be recommended for engineering and economic planning on the BBS-XY well.

5 HEALTH AND SAFETY

5.1 Industrial safety

Occupational safety and accidents are safety-related work tools, materials and processing, the workplace and its environment, and the way work is done. An accident is an unforeseen and unexpected event with unforeseen circumstances and outcome [5].

Necessary conditions for fulfillment:

а) Maintaining the professional skills and improving the health of public workers in each field of activity;

б) Prevention of problems arising as a result of work, with the health of workers, caused by the state or condition of the working environment.

Ensuring normal working conditions to prevent health hazards.

Occupational health and safety cannot be separated by the production process. In accordance with this, the development of construction was carried out, then the draft law No. 12 of 2003 On employment of the population was developed [4].

Article 86 of Law No. 13 of 2003 states that every worker or worker has the right to health and safety at work, morality and decency, and to be treated with dignity and religious values. The laws and regulations in the field of occupational health and safety were also affected as a replacement for the previous regulation, namely the Veiligheids Regulation, STBl No. 406 1910, which did not adequately assess the face of progress and development [5].

The regulation is the Law No. 1 of 1970 on labor safety, covering all working environments, whether on the ground, in the soil, on the surface of the water, in the water or in the air, which is in the field of the energy law of the Republic of Indonesia. Such legislation also establishes the conditions for ensuring labor safety, starting with planning, production, transportation, distribution, trade, installation, application, use, maintenance and storage of materials, goods, products for technical and industrial purposes, containing and creating a risk of accident [5] .

Actually, as for the reasons for accidents, they occurred due to wrong actions or unsafe conditions. Negligence as the cause of an accident is the intrinsic value of safety [5]. The main causes of accidents at work include:

а) personnel factors

1) weakness of knowledge and skills;
2) Lack of Motivation;
3) Physical Problem.
4) Job Factor

– the level of work is not adequate enough;
– maintenance is not adequate;
– the use of these tools is not true;
– The test purchase is not rigid.

5) direct cause of accidents at work.

б) unsafe actions

1) control the tool instead of authority;
2) Operate the tool at high speed;
3) position of any work;
4) repair tool when the tool is working;
5) Circumstances that are not considered non-dangerous

– lack of protective equipment;
– insufficient number of signs warning of danger;
– noise / dust above the maximum allowable.

Table 5.1 - Types of physical hazards in the production process

Types of physical hazards	limit value	Control
Noise	85 dBA/8 h	regulate the technique with the manufacture of silencers; regulate the introduction with limited exposure time; management of PPE using ear protectors.
Vibration	whole body: 0.5 m2/sec arm: 2.5 m2 / sec	Engineering management: use low vibration equipment;

Continuation of Table 5.1

		Using the machine the cutters are still sharp so it is more efficient; Administrative control: interspersed with some other work to reduce the time of continuous use of the vibrating machine.
Heat Stress (Heat Cramping, Heat	In the workplace from 21° C	Maintain the temperature of the

Stroke, Heat Exhaustion, Dehydration)	to 30° C with a relative humidity of 65% to 95%.	workplace within the specified range; Make sure ventilation is adequate; Hydration of the body with sufficient drinking.
Radiation	Up to 5.0 rem/year (radiation workers)	Use of lead/tin (Pb) protector;

5.2 Analysis of harmful factors during the operation of oil wells by ESP units at the Subang field

In the oil and gas industry, with improper organization of labor and production and non-compliance with certain preventive measures, there may be a harmful effect on humans of oil vapors, gases and other substances used or accompanying the production process.

Noise and vibration - the sources of noise and vibration in the oil and gas industry are mud pumps, a rotary table, a drawworks, a vibrating screen, internal combustion engines, electric motors, gas generator compressors, elements of ventilation installations.

Strong noise, acting on the hearing organs, can lead to complete deafness or occupational hearing loss. At the same time, the normal activity of the cardiovascular and digestive systems is disrupted, and chronic diseases occur. Noise affects the state of mental balance. Under the influence of noise, depletion of brain cells, delayed psychological reactions and functional changes in the nervous system are observed.

Vibration - Vibration refers to mechanical vibrations of elastic bodies, various structures, machines and tools, leading in some cases to a violation of the mechanical strength and tightness of equipment and communications. The harmful effect of vibration on the human body is expressed in the occurrence of a vibration disease.

Vibration can arise from the imbalance of moving parts of equipment, from equipment, from pulsating flows of liquids and gases in pipelines, as well as from the operation of pneumatic and electric hand tools.

Under the action of vibrations, changes can occur in the nervous and osseous-articular systems, a drop in muscle strength and mass, an increase in blood pressure, impaired visual acuity, memory loss, spasms of the heart vessels.

Deviation of climatic parameters - climate is a complex of physical parameters of air that affect the state of body heat. This includes temperature, humidity, air speed, solar radiation intensity and barometric pressure. The maximum temperature for the Subang area is +32°C, minimum parameters +16.2°C. In summer, workers should be provided with a cap that excludes the hot head from the sun's rays.

Radiation - The sources of electromagnetic radiation are radio and electronic devices, inductors, capacitors of thermal installations, transformers, antennas, flange connections of waveguide paths, microwave generators, etc.

A person does not see and does not feel electromagnetic fields, and that is why he is not always warned against the dangerous effects of these Deposits. Electromagnetic radiation has a harmful effect on the human body. In the blood, which is an electrolyte, under the influence of electromagnetic radiation, ion currents arise, causing tissue heating. At a certain intensity of radiation, called the thermal threshold, the body may not be able to cope with the heat generated.

Heating is especially dangerous for organs with an underdeveloped vascular system with low blood circulation (eyes, brain, stomach, etc.). If the eyes are exposed to radiation for several days, the lens may become cloudy, which can cause cataracts.

In addition to thermal effects, electromagnetic radiation has an adverse effect on the nervous system, causing dysfunction of the cardiovascular system, metabolism.

Prolonged exposure to an electromagnetic field on a person causes increased fatigue, leads to a decrease in the quality of work operations, severe pain in the heart, changes in blood pressure and pulse.

The assessment of the danger of exposure to an electromagnetic field on a person is made by the magnitude of the electromagnetic energy absorbed by the human body.

It has been established that electromagnetic fields of currents of industrial frequency (characterized by an oscillation frequency from 3 to 300 Hz) also have a negative impact on the body of workers. The adverse effects of industrial frequency currents appear only at a magnetic field strength of the order of 160-200 A / m. Often, the magnetic field strength does not exceed 20-25 A / m, so it is enough to assess the danger of exposure to an electromagnetic field by the magnitude of the electric field strength.

5.3 Analysis of identification of hazardous factors during the operation of oil wells by ESP units at the field

Electric shock in the construction and oilfield sectors is all too common. They are often deadly. Electric shock in its simplest sense is the contact of a person with electricity. The greater the electrical voltage, the more likely the worker will die or suffer life-changing serious injury. oilfield sites can work with equipment where the voltage exceeds 500 volts. Exposure to 500 volts or more is often catastrophic.

Electric shock in oilfield industries can occur when a worker comes into direct contact with live power lines, electronic equipment, accidents between vehicles and power lines.

Water is not a protection against electrical contact. Offshore oil rigs often have electrical components. Oil rig failure can result in electric shock.

One of the most dangerous and often overlooked oil field impact hazards is overhead power lines. As the oil rig equipment grew tall, it could come into contact with power lines operating at high voltages. When a metal object, such as a faucet, touches or approaches a power line, electricity flows through the equipment to the ground. Crane operators, ground crews in contact with or within range of equipment can be severely impacted due to step or touch potential. Workers must be trained to recognize all kinds of impact hazards and maintain a safe approach distance.

As a general rule, the first step should be to seek immediate medical attention. The head of the company should be notified about this. The worker should receive emergency medical attention either at the scene of the accident or at the local emergency department.

Anyone providing assistance must be aware that the area where the accident occurred may not be safe. Potential exposure to electrical wires, power lines, equipment and other electrical hazards in the future. It may be dangerous to touch anything or anyone, including the victim. It is very important that the electrical power must be turned off. The work of protecting the area and providing care to the patient should be entrusted to electrical specialists, local energy companies and emergency medical specialists.

Once it is clear that the casualty can be held without further electrical stimulation, several steps must be taken, depending on the type and extent of the injuries sustained:

а) A trained professional or volunteer may need to perform rescue breathing;

б) Any wounds may be raised and pressure may be applied to stop any bleeding;

в) You may want to cover the victim with a blanket (unless they have open wounds).

Fire – One of the main hazards for workers working on oil rigs is fire. Oil is highly flammable, as are some chemicals regularly used in onshore drilling, including hydrogen sulfide. The well can also create too much pressure, which can lead to an explosion if it is not corrected in time.

Falls and falling tools

Falls and related accidents can be a concern in many types of jobs, but they are major concerns on onshore oil rigs. Even more dangerous is when workers drop tools. Workers must wear hard hats to protect themselves from this kind of accident.

mechanical equipment

Oil rigs use several types of hazardous equipment that can pose a risk to workers. These include drilling machines, spinning machines and auxiliary equipment such as cranes and forklifts. The fact that such machines are often quite noisy makes this danger all the more real, as it can be difficult for workers to communicate with each other.

5.4 Environmental safety

Pertamina EP SA ensures safety and health protection at work for employees and external guests as part of external employees.

The procedure for ensuring environmental safety of Pertamina EP SA between the following rules: safety and labor protection at the workplace is given by Pertamina EP SA between the following rules:

Ventilation / air circulation system

а) Inside the workplace, which is enclosed, should be made to ventilate the tools in order to get fresh air circulating;

б) If it is necessary to prevent health hazards from air contaminated with dust, gases or other causes, ventilation should be carried out to remove polluted air (exhaust);

в) If technically it is not possible to remove dust, harmful gas, tenga work must use personal protective equipment (respiratory protection equipment / respirator) as necessary.

Household Waste Management

а) Waste generated from offices and households is placed in the trash can;

б) Garbage should be separated between B3 (hazardous and toxic) and household (non-B3) waste;

в) Waste not classified under category B3 includes but is not limited to paper, our cardboard and glass. While B3 garbage includes, among other things: toner used catridge (copier, printer, fax), lamp used;

г) For non-B3 waste can fit in household landfills;

д) Waste shelter B3 must be well maintained and provided with a sign warning of waste shelter;

е) Shelter B3 Waste should be free from sources that could lead to pollution, explosion or fire;

ж) B3 waste is collected and then delivered to a B3 waste management site or to a third party (supplier) that has government approval.

Fire Hazard and Fire Extinguishers Fire Hazard Prevention

а) Each hot/cold worker must be provided with a work permit letter and a safe work permit, and carry out a risk assessment (labor safety analysis);

б) At the location of the workplace, it must be ensured that inspection and control / measurements are carried out free from sources of danger (flammable materials).

Fire extinguisher

а) The type and number of fixed or portable fire extinguishers should be determined according to the potential hazard and fire class level;

б) Workers should be given knowledge on how-how to use fire extinguishers;

в) Fire extinguishers must be periodically inspected by authorized personnel and properly maintained;

г) The placement of fire extinguishing equipment is adapted to the needs and regulations, as well as to a position that is easy to see and reach.

Toxic and hazardous chemicals

а) Materials - Flammable materials and the unused part must be managed properly so as not to create a potential fire hazard;

б) Every purchase of chemicals must be accompanied by an MSDS (Material Safety Data Sheet) so that it can be made aware of the potential hazard;

в) The Material Safety Data Sheet must be communicated to employees and made available in the work area, with training to understand it and know how to control risks.

5.5 Safety in emergency situations

Emergencies are events or incidents that are unplanned and undesirable to the detriment of the company or interfere with the smooth operation of both the part and the whole, which must be prevented and at the same time eliminated quickly and accurately so that their consequences can be suppressed as little as possible. . It includes emergency provisions, namely:

а) Local emergencies

Local emergencies Events on and off the ground that have the potential to impact operations on the ground;

б) State of emergency outside the battlefield

An off-field emergency is an event that occurs far from the location of the operation and does not have a direct impact on the location of the operation.

The criterion for introducing a state of emergency is:

1) Direct action and often occurs in the field of local or external impact (for example: localized fire, pipeline leaks leading to oil spills);
2) Short-to-medium impact
(for example: less than 15 barrels of non-significant production lost to pencemaranair due to an oil spill);
3) business continuity may be partially interrupted;

4) local resources are usually used to respond and control the situation, but may also require assistance from units carrying out other operations under the Pertamina EP SA program;
5) the time period for response is usually limited and the situation may worsen;
6) media/public interest during a state of emergency could potentially become a crisis if not mitigated/sufficiently addressed.

5.6 Legal and organizational security issues

Protection against labor laws is intended to guarantee the fundamental rights of workers and ensure similarity and treatment without discrimination on any grounds for the realization of the well-being of workers and their families, taking into account the development and progress of business and the interests of employers.

Laws and regulations relating to the protection of workers Act No. 13 of 2003 on labor and the application of the rule of law in the world of work.

Job issues in Indonesia are related to the hubungankerjoy, which is not balanced between the employer and employees in the preparation of the employment contract. Not only the seimbardals are making an agreement, but also the business competition climate is getting tougher, which is forcing the company to make production cost-effective. The problem of employment in Indonesia has been regulated by law.

Legislation, government regulations and ministerial decrees that apply in general to any workplace are as follows:

Employment related legislation:

Law No. 13 of 2003"employment".

Law No. 3 of 1992"social security of workers".

Law No. 11 of 1992"pension funds".

Law No. 21 of 2000"workers unions/trade unions".

Law No. 36 of 2009"income tax".

CONCLUSION

In this final qualification work, a comparative analysis of pumps and an analysis of the factors that lead to premature failure of ESPs were carried out using the example of the Subang field.

As a result of the analysis of methods, the following conclusions can be drawn:

Well BBS-XY installed an ESP (ID-750/54 Hz / 455 stages) with a capacity of 268barrels per day (42 m3/day). Well BBS-X Y targets production at a rate of 2000barrels per day (317.9 m3/day). The calculation and evaluation results show that the ESP used (IND-750/54 Hz/455) can no longer be used to achieve the target performance level, since it is out of the pump performance range.

During the work the following tasks were solved:

To reach the production target of 2,000 barrels per day(317.9 m3/day)the required pump capacity is appropriate, so the ESP pump needs to be redesigned on the BBS-XY well.

ESP redesign includes selection of pumps, determination of the pump installation depth and the optimal number of stages, determination of the needs of gas pumping devices, selection of the motor, power cable, transformer and drive speed variator.

Based on the results of the calculation, in order to increase productivity, it is necessary to redesign the ESP in the BBS-XY well to achieve the target flow rate of 2000 barrels per day(317.9 m3/day).

As a result of the analysis, the following conclusions can be drawn:

BBS-XY well with IND-750 / 54 Hz / 455 steps 4163 ft. set depth (PSD)(1268 m)TVD 4561 feet(1390m)MD) has a total dynamic head (TDH) of 1,527.8 ft (465.6 m) at a production rate of 268 bbl/d(42 m3/day)with a water cut of 96%.

BBS-XY well plans to produce 2,000 bpd(317.9 m3/day)at Pwf 1297 lbf/in² (8.94 MPa), assuming a 97% water cut. G-2000 / 57 Hz / 115 stages pump suggested, 4918 ft pump depth(1499m) TVD/5316ft (1620m) MD

Technical characteristics are also calculated: engine technical characteristics125 hp (91.94 kW);volt; 52.7 amps (125.7 kW) and AWG#1 cable, which has a cable drop of 11.5 volts/1000, and a 300 kVA transformer.

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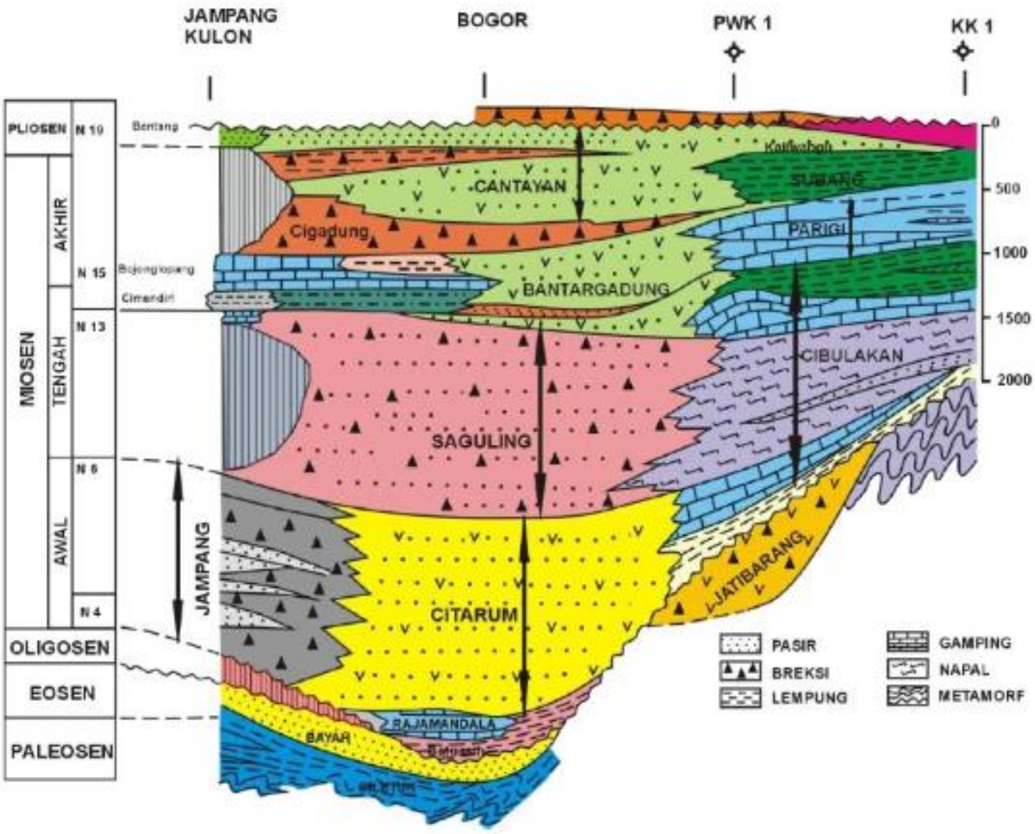
Annex A

Cross Section of the North-South Stratigraphy of West Java



Annex B

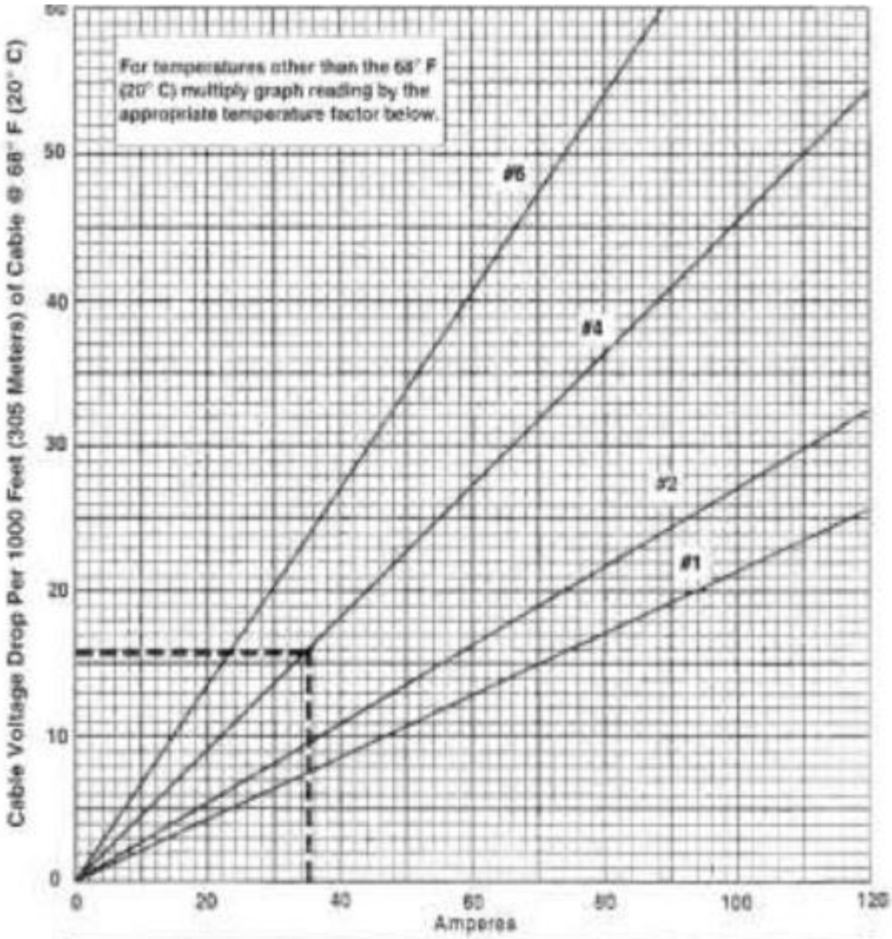
REDA Motor Catalog 540 Series

540 Series Motor—DK Type (Continued)

Power Rating at 60-Hz Frequency, hp	Voltage at 60-Hz Frequency, V	Power Rating at 50-Hz Frequency, hp	Voltage at 60-Hz Frequency, V	Current, A	Type	Length, ft [m]	Weight, lbm [kg]	Carbon Steel Part Number	Redalloy Alloy Part Number
100	844	83	703	74.5	S	13.0 [4.0]	808 [366.8]	2011949	tba
					UT	13.1 [4.0]	808 [366.8]	tba[1]	tba
	1,018		848	61.8	S	13.0 [4.0]	808 [366.8]	tba	tba
					UT	13.1 [4.0]	808 [366.8]	2011745	tba
	1,368		1,140	46.0	S	13.0 [4.0]	808 [366.8]	2011950	tba
					UT	13.1 [4.0]	808 [366.8]	tba	2011713
	2,590		2,157	24.3	S	13.0 [4.0]	808 [366.8]	2011710	2011723
					UT	13.1 [4.0]	808 [366.8]	2011746	tba
125	1,491	104	1,242	52.7	S	15.7 [4.8]	976 [443.1]	2011951	tba
					UT	15.8 [4.8]	976 [443.1]	2011934	tba
	1,710		1,424	46.0	S	15.7 [4.8]	976 [443.1]	tba	tba
					UT	15.8 [4.8]	976 [443.1]	tba	2011921
	2,583		2,152	30.4	S	15.7 [4.8]	976 [443.1]	2011711	tba
					UT	15.8 [4.8]	976 [443.1]	2011747	2011923
150	1,004	125	836	93.9	S	19.4 [5.9]	1,169 [530.7]	tba	tba
					UT	18.7 [5.7]	1,169 [530.7]	2011748	tba
					CT	18.9 [5.8]	1,169 [530.7]	tba	tba
	1,268		1,055	74.5	S	19.4 [5.9]	1,169 [530.7]	tba	tba
					UT	18.7 [5.7]	1,169 [530.7]	2011749	2011714
					CT	18.9 [5.8]	1,169 [530.7]	2011831	2011827
	2,575		2,145	36.6	S	19.4 [5.9]	1,194 [542.1]	2012047	1060409
					UT	18.7 [5.7]	1,194 [542.1]	2011751	2011916
					CT	18.9 [5.8]	1,194 [542.1]	2011887	tba
163	2,790	135	2,324	36.6	S	20.0 [6.1]	1,243 [564.3]	tba	tba
					UT	20.0 [6.1]	1,243 [564.3]	tba	2011890
175	1,171	146	975	94.0	S	22.2 [6.8]	1,336 [606.5]	tba	tba
					UT	21.2 [6.5]	1,336 [606.5]	tba	tba
					CT	21.5 [6.6]	1,336 [606.5]	2011888	tba
	1,477		1,230	74.5	S	22.2 [6.8]	1,336 [606.5]	tba	tba
					UT	21.2 [6.5]	1,336 [606.5]	2011752	2011715
					CT	21.5 [6.6]	1,336 [606.5]	2011832	2011823
	2,393		1,993	46.0	S	22.2 [6.8]	1,380 [626.5]	2012048	2012045
					UT	21.2 [6.5]	1,380 [626.5]	2011935	2011716
200	1,339	167	1,115	93.9	S	24.9 [7.6]	1,492 [677.4]	tba	tba
					UT	24.1 [7.4]	1,492 [677.4]	2011753	2011718
					CT	24.3 [7.4]	1,492 [677.4]	2011835	2011821
	2,398		1,998	52.7	S	24.9 [7.6]	1,498 [680.1]	2012049	tba
					UT	24.1 [7.4]	1,498 [680.1]	2011936	2011768

Annex B

Voltage Drop Cable Chart



Temp. °F (°C)	Multiplying Factor	Temp. °F (°C)	Multiplying Factor	Temp. °F (°C)	Multiplying Factor
100 (38)	[illegible]	[illegible]	1.223	240 (116)	1.376
110 (43)	[illegible]	180 (82)	1.245	250 (121)	1.398
[illegible]	[illegible]	[illegible]	[illegible]	260 (127)	1.420
[illegible]	[illegible]	[illegible]	1.288	270 (132)	1.441
[illegible]	[illegible]	210 (99)	1.310	280 (138)	1.463
[illegible]	[illegible]	220 (104)	1.332	290 (143)	1.485
[illegible]	[illegible]	230 (110)	1.354	300 (159)	1.507

Figure 4 - 4