Challenges, Selection and Optimization of Artificial Lift Modes for Dewatering of CBM Wells

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ABSTRACT

Artificial lift techniques are required to recover water that is produced by the coal beds before production of the coal bed methane. The most common artificial-lift types include electric submersible pumps (ESPs), progressing cavity pumps (PCPs), Sucker Rod Pump (SRPs), and gas lift. The method and criteria for selecting lift equipment is similar to other wells and is governed primarily by the expected production rate and secondary is minimize downtime.As per available infrastructure and maintenance facilities, it is often best to choose the lift system that is simple to operate and least troublesome. This paper intends to study the optimization and selection of artificial lift methods under various well conditions to draw a comprehensive comparative analysis.

ESPs are ideal for pumping volumes in excess of 150m3/d approx. from coal wells, but these pumps require reliable electricity and can be damaged by coal solids (fines), which are common in the early productive life of a well. PCPs are popular in many CBM projects because they can produce 15 to 150 m3/d, handle coal fines effectively, and require little maintenance. The SRP handles low-to-medium water volumes of 1 to 80m3/d and requires little maintenance. Gas lift is the least expensive lift system to operate. It requires no electrical power and handles wide range of dewatering rates. Gas lift, however, requires specific well pressure tolerances to work effectively.

In this study, 16 wells of CBM Asset Bokaro (ONGC, India) which includes 10 wells of Jharia field and 6 wells of Bokaro field were considered for analysis. The major pump failures observed due to high torque, low efficiency and erratic load conditions.

The cause of these pump failures were unscrewed rod, gas interference or gas lock, stator damage, tubing failure, plugged pump intake screens and insufficient motor cooling. The bottom line is that no matter which artificial-lift system is used, it is crucial to minimize downtime and keep the well pumped off.

This paper gives idea about optimization and selection of lift modes and study also includes software simulation and modelling of CBM wells.

INTRODUCTION

Most CBM reservoirs initially produce only water because the cleats are filled with water. Typically, water must be produced continuously from coal seams to reduce reservoir pressure and release the gas. Once the pressure in the cleat system is lowered by water production to the "critical desorption pressure," gas will desorb from the matrix.

As the desorption process continues, a free methane gas saturation builds up within the cleat system. Once the gas saturation exceeds the critical gas saturation, the desorbed gas will flow along with water through the cleat system to the production well.

So, for gas production pressure must be reduced, typically by "de-watering" the cleat system. De-watering simply implies the production of the water located within cleat system. As water is a highly incompressible fluid, the removal of large volumes of water from the cleat system causes a rapid drop in reservoir pressure, allowing the methane to de-sorb from the surface of the coal particles, diffuse through the matrix and ultimately find its way into the cleat system.

This phenomenon can also be seen in the flat slope of the isotherm near initial pressure, which represents significant pressure reduction without much gas production.

Production Profile of CBM Wells

Generally, early production typically consists entirely of water, driven by the fact that there is little (if any) free gas in the cleat system to produce, but by the relative permeability effect, which favours flow of the predominant phase. As gas saturation (and therefore relative permeability to gas) in the cleat system increases, the gas rate begin to reach commercial levels. Water rate will drop as the gas rate climbs. This behaviour is almost opposite to the production performance from conventional gas wells, where gas rate is highest and water production is lowest in early life (Palmer et al., 2005)

Artificial Lift Requirement

As earlier mentioned lifting water from the wellbore addresses both the need to de-water the reservoir and need to minimize back-pressure on the reservoir. Multiple factors dictate whether a well will be able to lift water to the surface without assistance. These factors include the initial reservoir pressure, permeability, the operating pressure of the surface equipment and the gas-to-water ratio of the produced fluid.

Initial reservoir pressures in CBM tend to range from slightly over-pressured to slightly under-pressured. Consequently, even in the best case, reservoir pressure will usually not lift a full column of water for prolonged periods. During the early phase of a field development, while water saturation in the cleat system is still high, there will be limited gas production lift the water from the wellbore. So, even though the reservoir pressure is highest, artificial lift is almost likely needed for initial completion of a CBM well. As field development matures, when the cleat system has been partially or fully de-watered, initial gas production can be substantial and artificial lift might not be needed at initial completion of a well. Occasionally, there can be circumstances where the cleat system contains free gas at initial conditions. This situation not only provides for immediate gas production but also lessens the likelihood that artificial lift will be needed initially. Just as the need for artificial lift at initial completion of a well may vary, the need for artificial lift later in a well's life may also vary. The declining water rate typically seen in CBM wells can often generate conditions where artificial lift is no longer needed in a particular well or, sometimes the declining reservoir pressure seen later in a well's life can necessitate artificial lift even though the water rate is extremely low. Despite these different scenarios, It may be said that CBM wells need artificial lift during early stages that may decrease as the well matures. This situation is just opposite to wells in conventional reservoirs, which usually need artificial lift later in a well's life.

Challenges for artificial lift in CBM field

For any CBM operation, production of solids along with fluids, pose a challenge immediately after the start of water unloading (Krawiec et al., 2008). There are three distinct grouping of produced solid that create different type of problem in different mode of lifts.

a) **Sand to silt sized coal solid:** these solids are primary culprits for pump failure. Coal “fine” become suspended in water with little agitation and if trace amount of hydrocarbon were present, the suspended solids create a thick, sticky 'coal foam” or “coal sludge”. This coal slug generally plug the lift equipment like pump barrel (SRP), intake (ESP) etc.
b) **Gravel to silt sized:** These pieces of coal fine most likely to pass through if the well are completed in slotted liner. Although these size of solids no longer directly cause pump failure, the accumulation of coal solids in the sump

may contribute to stuck pump and may require well workover/fishing job.

c) Gravel size large shale/ coal solid coal "chunks" sometimes fall in the sump and contribute greatly to difficulties in pump being stuck while pulling the production assembly on rig servicing job.

Selection of artificial lift for CBM field operations (Simpson et al., 1997)

a) SRP (Sucker rod pumps)

SRP is the most popular method used to remove liquid from CBM wells but it has some problem with gassy and solid laden production. CBM wells will always be "gassy" in SRP operation and is managed through either systems of natural separation, poor-boy separation, packer separation etc.

For CBM operations, SRPs need to be suitably modified for the operational requirement. Generally 75-100 ft. of submergence is required and less than NPSH there is possibility of gas locking. Typical SRPs for CBM consist of Top hold down pump, full opening cage for gas and solid, tungsten carbide seat and alloy ball, martin-ring plunger for initial solid-laden production and later a spray metal plunger with chrome plated barrel.

b) PCP (Progressive cavity pumps)

PCP is of simple design and its ability to handle solids and viscous fluid made it very popular. The pump has only one moving part down hole with no valve and will not gas lock but can overheat when handling excessive gas. In CBM production PCP's are set initially to avoid solids plugging and later taken down to lower BHP and better gas separation.

In practice it shows that 60 feet is the submergence required over the pump to keep it charged. Gas separator should be considered if the gas interference problem observed in pump.

This pump has very poor ability for cold start with solid piled above pump or wedge between rotor/ stator. It is necessary to unseat the pump and add soap lubricant to get the pump restarted.

c) Gas Lift

It is a flexible method of lift that is not troubled with gas interference or solid for most part. However it will not bring the producing pressure down as far other pump system. A large surface system constituting of complete injection line network and compressor system is one of reasons that gas lift is not generally used for dewatering CBM wells. CBM field in ONGC has used air compression in few wells, where air injection is done through 1" pipe inside the production tubing during the initial period of production.

d) Jet Pump

These pumps are rarely effective in gas wells because ports are too small for low density compressible flow. More over Jet pump needs high NPSH to avoid cavitation's which inconsistent with required bottom hole pressure in most CBM wells.

e) Electrical submersible pump (ESP)

ESP's are typically reserved for applications where the produced flow is primarily liquid at a high flow rate and free gas is low. Presence of free gas tends to dramatically reduce pump efficiency. Moreover, presence of solid and their shapes and hardness can excessive radial wear and can even cut through the impeller.

The NPSH of an ESP in all liquid is generally low up to 20-30 psi (46-70ft) which is one of the lowest. But for ESP operation in a CBM well the amount of produced liquid constantly declines and therefore if it goes below the ESPs recommended turnaround range, the pump has to be replaced with the new set of pumps suiting the required condition. Therefore, for very high angled or horizontal wells ESP's are good option compared to the surface connected lift modes e.g. SRP, PCP which may need more work over jobs.

Best Pumping Practices in CBM Wells (Himanshu Pant, 2013)

a) Tubing selection

As well as completed in different size casing depending upon volume of water expected along with depth, pressure required to hydraulically fracture the coal seams and the amount of solids that the wells will typically produce. 2 7/8 tubing and 3 1/2" tubing are used in 4 ½" and 5 ½" and 7" casing respectively. For PCP pump, 7/8" or 1" in 2 7/8" tubing and 1 1/8" rod in 3 ½" tubing are used as cross sectional area will be less to bring more solids to surface because of higher fluid velocity.

b) Pump Selection

Depending upon reservoir, well characteristics, fluid properties and production data, various capacities of PCP and ESP pump are supplied by pump manufactures.In early stages, CBM wells produce water and gas along with frac sand and coal fines. Use of PCP as its solid handling capacity is better than ESP. After well has dewatered for sufficient time and solid production has decreased, ESP can be used. Also, we need to keep monitoring the production plots to accurately fit the pump in the well and decide on when to install high capacity and low capacity pump.

c) Pump setting depth

Suppose there six seams hydraulically fractured, initially the pump should be the above the coal seams. As the fluid level gradually drops down, bring the pump below the coal seams in stages as production of solids decreases. The closures pressure of the coal seams is the critical factor while placing the pump. There should be 20 m true vertical depth difference from either side of the pump intake depth and hydraulically fractured seams to avoid turbulence in front of seams and prevent excessive sand ingress to the wellbore.

In general, coalbed methane production can be divided into three phases. The first phase is characterized by a high water rate and a very low gas rate. Gas rates can be inclining or declining, depending on relative permeability. The boundary between phases one and two is when we've reached our minimum bottom hole pressure in the well, and we have also reached our desorption pressure. At this point, water rate starts to decrease, and we really see an increase in our methane rate. At the end of phase two,water rate is pretty low. Phase three, therefore, is characterized by a decline in gas rate that looks like that for conventional gas reservoirs and very low water rates.

As the, water rate starts to decrease with increase in methane rate (transit from phase-I to Phase-II), It is crucial to land the intake of pump below the bottom most seam. This allows gas to break out of the Formation and travel up the tubing/casing annulus and not through pump/tubing. Another important thing to be kept in mind is to make sure to drill an adequate sump beneath the coal seams to create an area where sand/coal fines can settle beneath the perforations keeping the pump safe. So, true vertical depth of sump should be of at least 50m (20 m difference between pump intake and perforations to avoid turbulence + 30 m for frac sand/coal fines to settle out).

d) Operating practices

For effective dewatering in a new well, start PCP with the minimum rpm based on pump curves supplied by pump manufacturer. Record the water level upon start up and every day. Pump the well for a week at the same rpm to get stabilized rate. Increase the speed of the pump at a step of 25-50 rpm per week until the water level drops with desired rate of 5 meter per day. Dewatering above this rate can damage the coal seams and causes higher sand and coal fines production in the wellbore. The ideal pump range of CBM applications is around 250-350 rpm. If dewatering rate is less than rate of water influx from reservoir even after pump is running at maximum rpm, as increase in friction in pump can damage the rotor of the pump. When the well has dewatered for sufficient time and better understanding of the production capacity of the well is gained and solids production has decreased, run with appropriate ESP, also keep monitoring the water level to prevent any pump off condition.

e) Tail Pipe length

The tailpipes are used in both vertical and highly deviated wells below PCP. In deviated wells where dogleg severity is greater than 4 deg/100ft, it is highly risky to run the sucker rod through that high DLS. In vertical wells tailpipes minimize depth related failure of sucker rods, reduce the risk of high torque due to sand production through tubing/pump and also reduce the slug flow in tubing. Tailpipes are designed to position to position the pump intake about 20m below bottom most hydraulic fractured seam. It is found that volumetric efficiency of the pump after using the tailpipes has increased considerably.

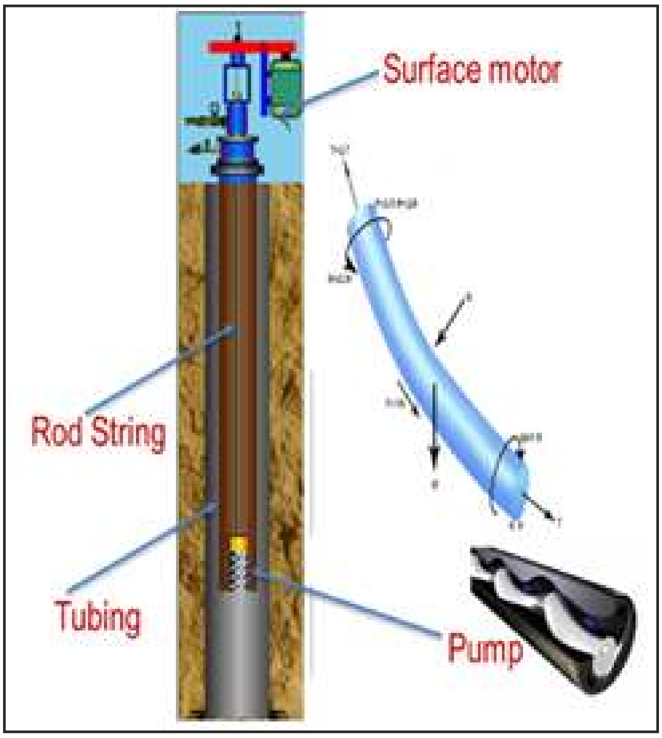

Fig. 1: Progressive Cavity Pump System

CASE STUDY

In this study, 16 wells of CBM Asset Bokaro (ONGC, India) were considered for analysis. The overall field description is given below:

No. of PCP wells	:	09
No. of SRP wells	:	07
Well Depth range	:	500 to 1100 mts
Inclination angle	:	$37^{o}$to 70^{o}
Tubing size	:	2 7/8”
Casing size	:	5 ½”, N-80
Gas Production rate	:	1000 to 2000 m^3/d
Water production rate	:	2 to 70 m^3/d
Sand size	:	20/40 mesh
Dynamic Liquid level	:	300 to 750 mts
Reservoir pressure	:	Sub-hydrostatic
Reservoir temperature	:	80^{o}C
SRP surface Unit	:	160-173-86
Plunger diameter	:	1.75 to 2.25”
SPM	:	3 to 7
Max. Stroke Length	:	86”
PCP surface unit	:	41- 1200
RPM range	:	100 to 200

PCP Wells

PCP is considered suitable in the initial phase of water unloading as it has some advantages other mode of lift. The standard softwarewas used for design and optimization of PCP wells.

a) Pump performance curves

Pump performance curve is very important parameter for optimization of fluid rate and optimal running life of PCP. Especially, slippage mainly depends upon differential pressure across pump so extra increase in differential pressure can lead to reduction in liquid rate of well. The performance curve for particular PCP well is given in fig 2 & fig 3.

b) Multiphase behaviour of PCP (Christian et al., 2005)

In multiphase flow conditions, the gases are compressed towards the discharge end. This leads to, from suction to discharge, a significant reduction in the gas volume fraction (GVF) and volumetric rate, as well as an increase in the mixture density. Specially, as the pressure increases, the gas volume

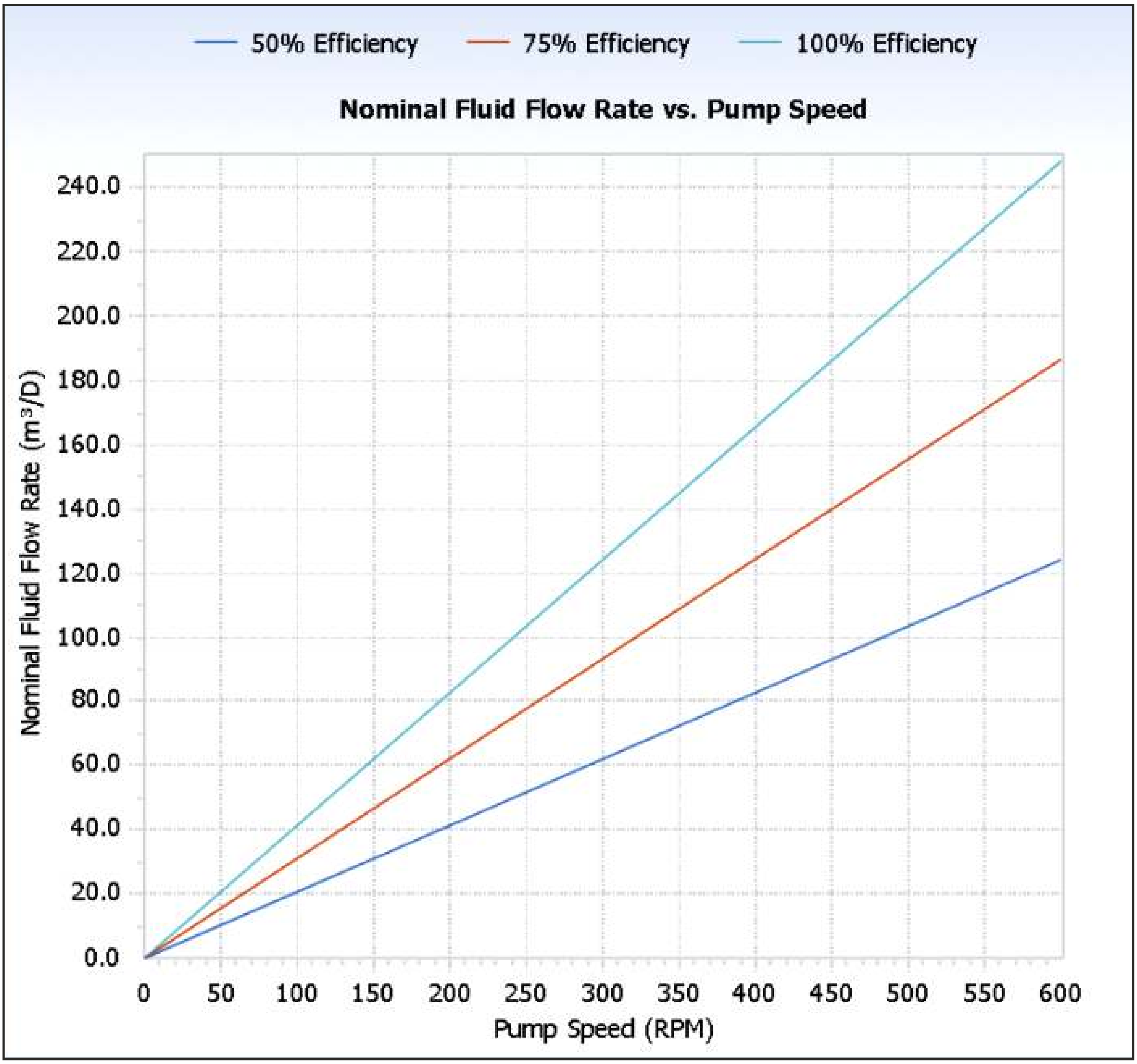

Fig. 2: Fluid rate vs.pump speed

decreases, so the frequency of gas molecule collision increases and causes a rise in temperature, i.e. the work done to compress the gas is the energy that increases the gas temperature. There may also be premature failure in the temperature sensitive components suchas the elastomer stator of the PCP.

c) Rod-Tubing contact load in inclined wells

PCPs in deviated wells experience frequent wear problems especially in wells with contact between drive string and tubing. Without effective protection, this leads to tubing piercing, crack in the tubing, production loss etc. To increase pump performance in the deviated wells, an effective protection against frictional wear is required.The dog leg severity and corresponding rod-tubing contact load is given in fig 4 & fig 5.

It is very important that the placement of the pump, as designed for PCP is done, so as to avoid premature failure of pump due to proppant and coal fine production in the initial part of water unloading. PCP can handle fair amount of coal fine but presence

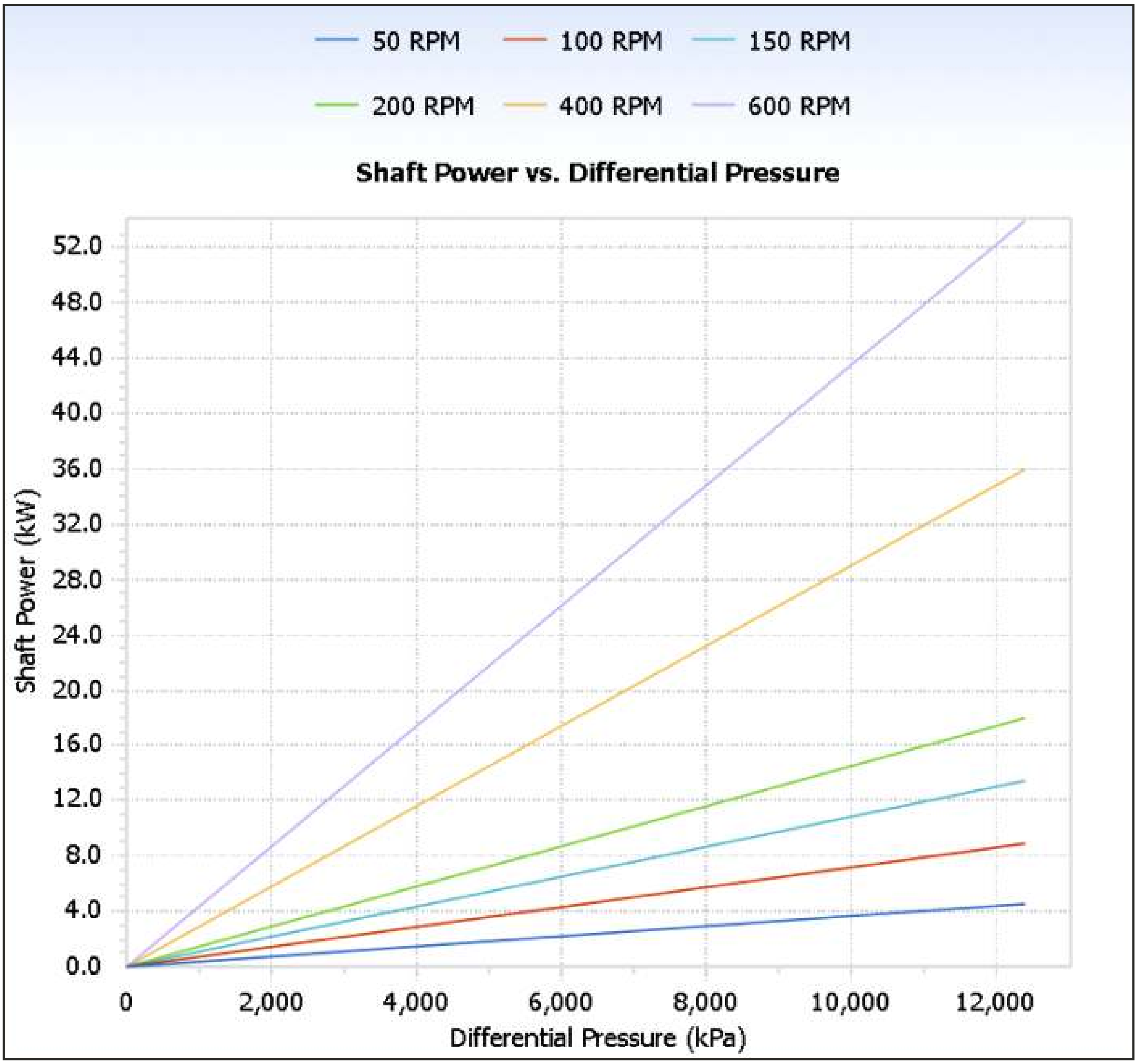

Fig. 3: Shaft power variation vs. Differential pressure

of abrasive proppant may damage elastomer (Majid S. Delpassand, 2003).

Therefore, it is proposed that the PCP may be installed about 50 mts above the upper seam in the initial production phase. The Pump RPM can gradually be increased as the production of proppant decreases.

After initial water unloading when well pressure gets lowered to the desorption pressure, the gas production gradually starts. At this stage, although lift may not be required, a small amount of liquid has to be produced continuously to maintain very low pressure against the coal seams, using the PCP. The PCP in this case may be heated up due gas in the fluid which may again damage the elastomer as the cooling rate by fluid is very low.

SRP Wells

In the later phase, the selected lift has to handle low rate of liquid production with variable amount of gas. In this phase, SRP is a suitable mode of lift. A

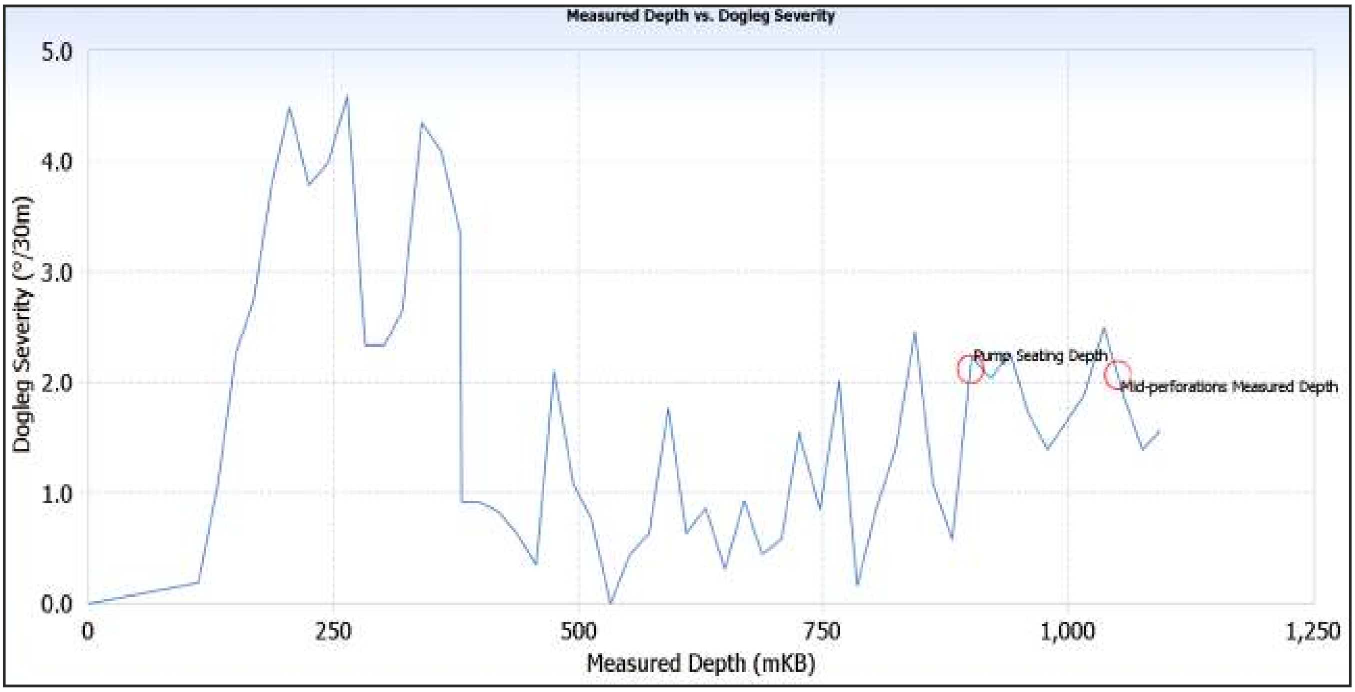

Fig. 4: Dog Leg Severity distribution

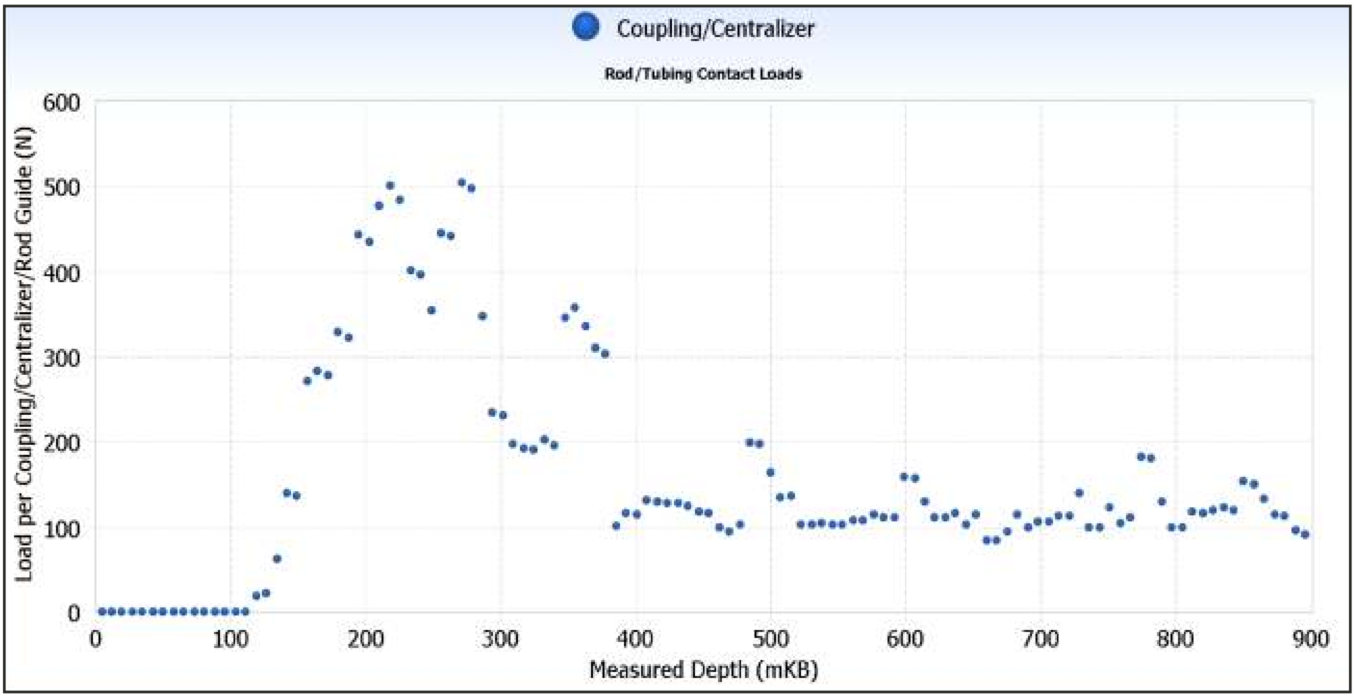

Fig. 5: Rod-tubing contact load distribution in PCP well

natural gas anchoring is best suited option to avoid gas interference in SRP operation. A higher capacity surface unit may be required to be installed to pull the rods, in case coal fines settle above the barrel. The standard softwarewas used for designing SRP considering the well profile.

a) Multiphase behaviour of SRP

Free gas entering the space between the travelling valve (TV) and the standing valve (SV) or gas interference is one of the major contributors to low pump efficiency in sucker rod pump (SRP) wells besides affecting the normal valve action. In order to

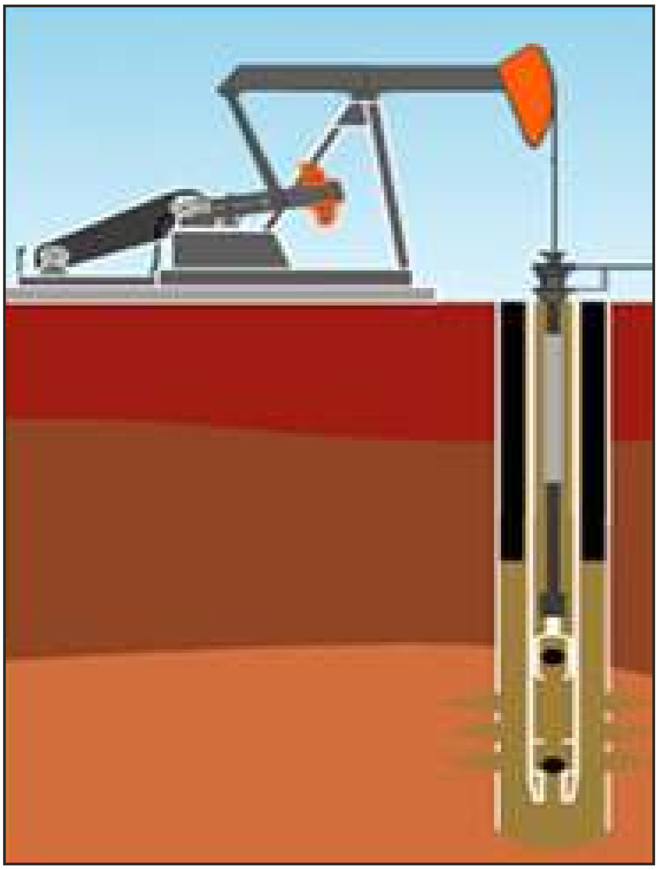

Fig. 6: SRP

understand gas interference and to combat this problem effectively, the pumping conditions that occur in a SRP well need to be analysed. A better understanding of pump volumetric efficiency, gas anchor design and pump's maximum available compression ratio vis-à-vis required compression ratio of the installation is essential. The field dynagraph and simulated dynagraph for pump performance is given in fig 7 & fig 8.

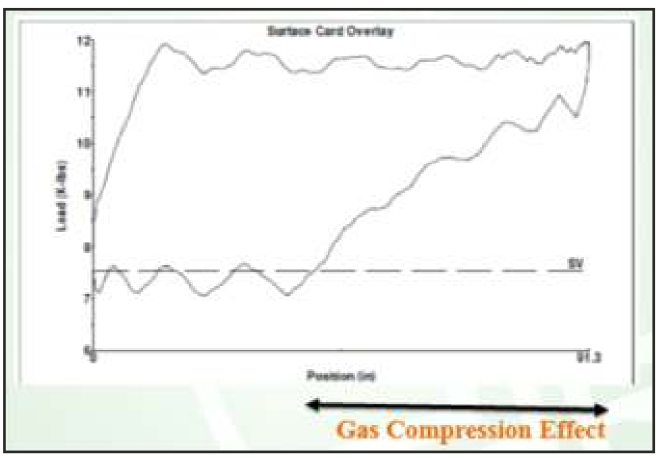

Fig. 7: Field Dynagraph

b) Gear Box Loading in SRP

Due to the inclined nature, high pump depth, low dynamic liquid level and high pump operating parameters (stroke length and stroke per minutes) can increase the gear box loading above the safe limit so design and optimization of SRP within maximum gear box loading limit is very important for CBM wells. The gear box loading graph for particular SRP well is given in fig 9.

c) Side forces in Inclined wells

Sucker rod pump is more problematic in comparison to progressing cavity pump for deviated wells because SRP is reciprocating type pump. This is because SRP wells, require proper Rod Guide optimization.The dog-leg severity, side forces and well profile are given in Fig 10, 11 & 12, respectively.

CONCLUSIONS AND RECOMMENDATIONS

- Progressing cavity pump can be most suitable lift for dewatering CBM wells in all manner, if target dewatering rate is not high (<150 m^3/d).
- 7/8" or 1" in 2 7/8" tubing and 1 1/8" rod in 3 ½" tubing can use to bring more solids to surface because of higher fluid velocity.
- It is necessary to install rod guides/centralizers in deviated wells according to side forces/rod-tubing contact load to avoid frequent failures.
- It is recommended to initially use PCP as its solid handling capacity is better than ESP.

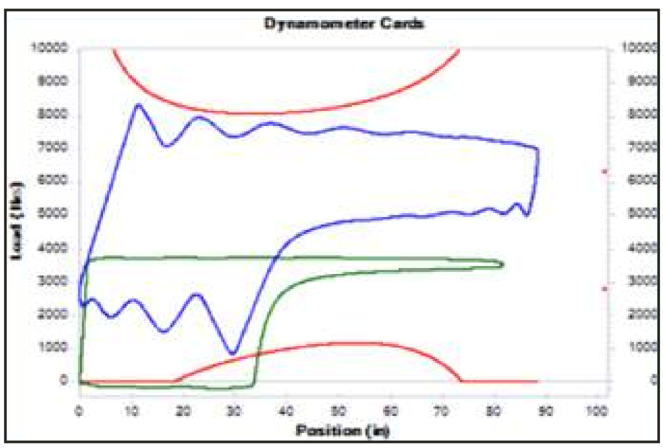

Fig. 8: Simulated dynagraph

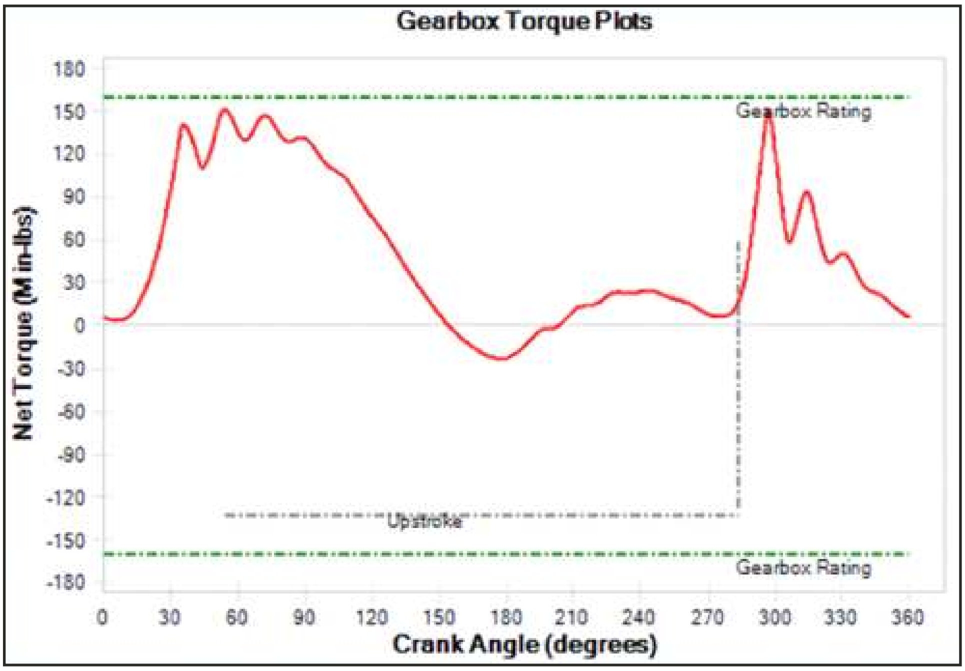

Fig. 9: Gear box loading graph

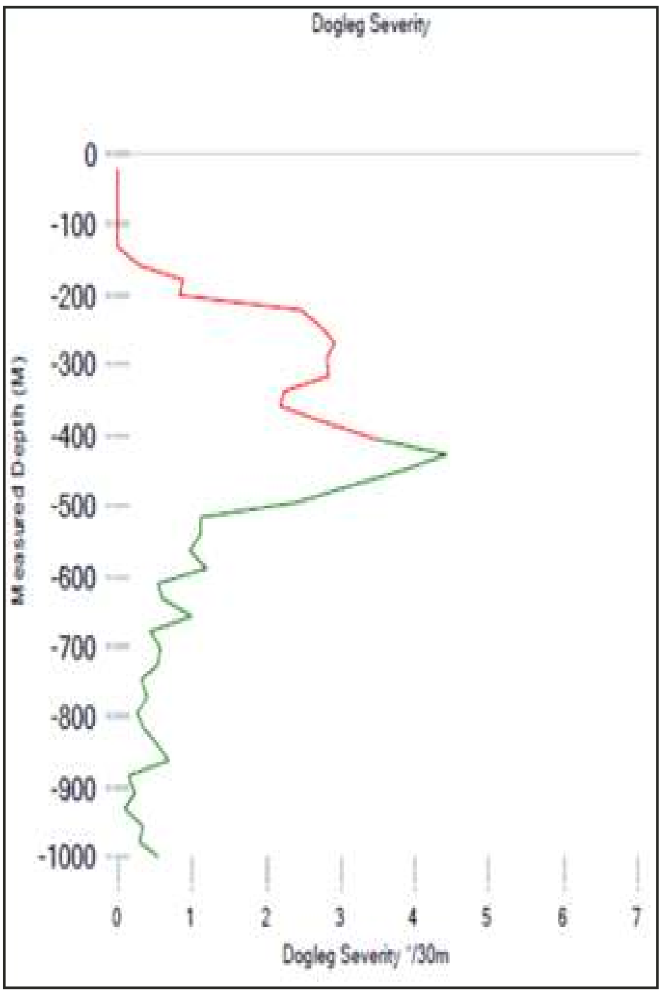

Fig. 10: Dog leg severity

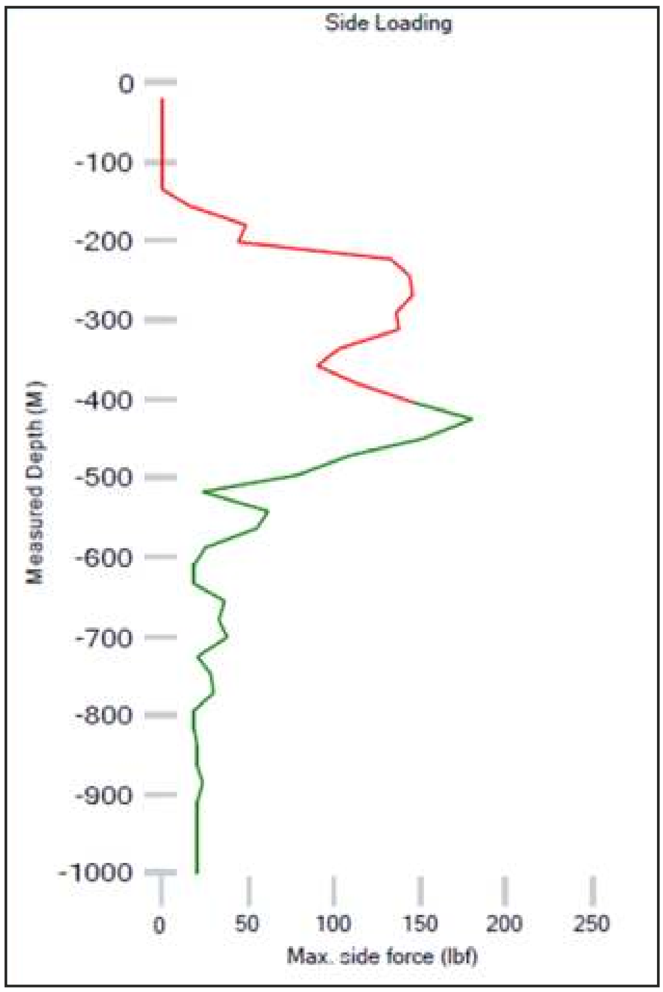

Fig. 11: Side Forces in SRP

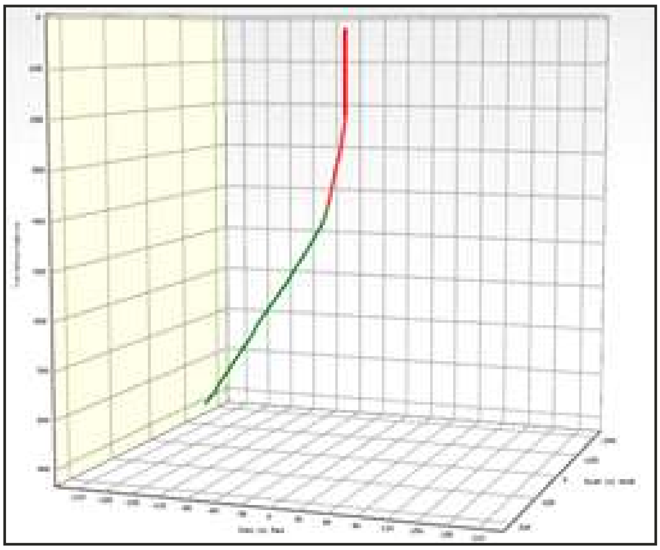

Fig. 12: Well profile

When well has dewatered for sufficient time and solid production has decreased, ESP or SRP can be used.

- Pump can be placed below lower seam to get natural gas separation. A higher capacity unit than that designed may be used to pull the coal fines laden fluid, if required.
- For PCP, It is recommended to increase the speed of the pump at a step of 25-50 rpm per week until the water level drops with desired rate of 5 meter per day. Dewatering above this rate can damage the coal seams and causes higher sand and coal fines production in the wellbore.
- Use of VFD/VSD need to be considered while procuring the PCP to fully utilize the pump during the production life of the well.
- During the actual drilling of the new deviated well, consideration must be taken to keep the dog-leg-severity less than 5 deg/ 30 m as planned to avoid premature rod failure in the SRP / PCP's.

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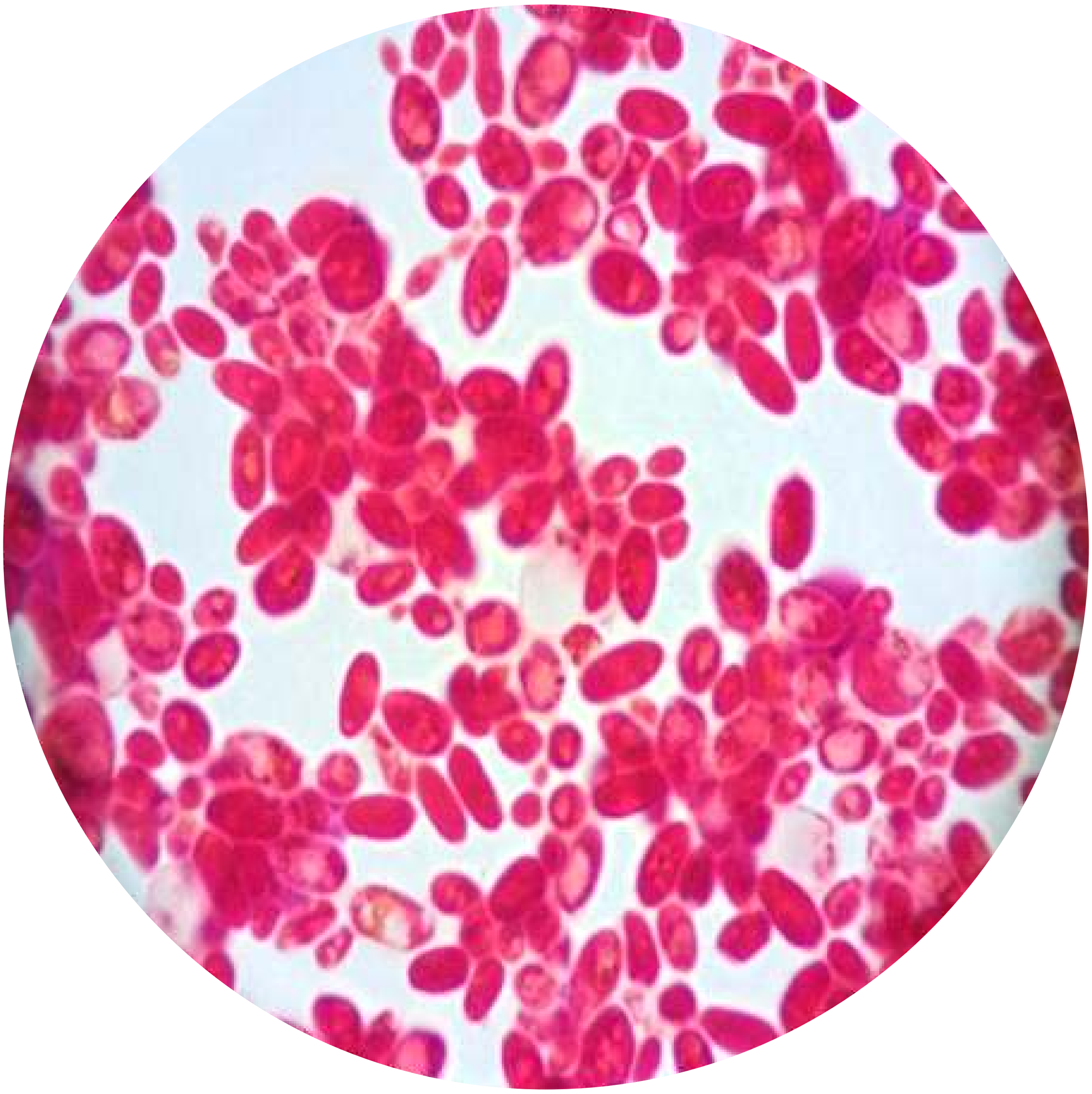
20.	Paleontographica Indica No.9, 2008	Sudhir Shukla	650.00	50.00
21.	Geological map of Kutch Basin	S K Biswas & S V Deshpande	1000.00	50.00



Yeast microbial system for biofuel.
Courtesy by: **Vishal Thakur**