PUMPING UNIT OPTIMIZATION

Author: Dave von Hollen Co-author: Steve Newton
BeauTech Inc.

ABSTRACT

In order to produce available fluids, pump jacks used at surface have been engineered to stroke as slow as 6 (six) strokes per minute (SPM) and as fast as 14 (fourteen) SPM. Depending on available production, pump length (stroke) and pump size were the only two other variables taken into consideration. This approach works well until a time is reached when production has declined to a point where production inflow no longer matches pump capacity. As production declined, the typical method of compensation was to shorten the stroke, downsize the pump and remain at a constant SPM somewhere around 10 (ten) SPM.

As production declines this approach eventually results in partial pump fill even with small bore pumps, short stoke and slowing the unit as much as possible with current sheave limitation.

At this point it is physically impossible to fit a large enough sheave on the gear box or small enough sheave on the electric motor to reduce the speed below approximately 6 (six) SPM.

BENEFITS

There are many benefits to be gained from further SPM reduction while maintaining long pump stroke and larger pump sizes and maintaining 24 (twenty four) hour continuous production.

1. When the well is kept in a pumped-off condition 24 (twenty four) hours per day, formation surging caused by intermittent operation is reduced or eliminated. In some cases production increases have been experienced by slowing down and maintaining constant operation.
2. Pump run time can be substantially increased and sucker rod, tubing failures decreased as fluid pound, gas lock, and cavitation are reduced or eliminated
   - Fluid pound occurs if a pump is operated in a cavitated state where there is little or no compressible substance above solid fluid. On the downstroke of the pump there is no differential pressure increase across the traveling valve ball until solid fluid is encountered. When this contact is experienced halfway through the stroke, at the pumps highest velocity, the traveling ball is instantly jammed into the top of the cage thus reducing pump life. Hydrostatic pressure build-up in the pump is immediate and may be severe enough to crack barrels, standing valve seats and cages, loosen threads, etc. which further reduces pump run time. At this point of impact, the rod string may go into compression in the first joints above the pump causing premature failure of the sucker rods and damage to the inside of the tubing. (ref. 1 and 2, illustrated on attachment 1 and 2)

   - Gas Lock occurs for one of two reasons:
     A. Gas in solution is allowed to enter the pump.
     B. Fluids with a low flash point are introduced into a cavitated pump.

   Either situation caused the same end result. The traveling ball will not open because hydrostatic pressure above the traveling ball exceeds the internal pressure which can be developed inside the pump on the downstroke. Both situations can be reduced or eliminated by slowing down and allowing sufficient fluid level over the pump for proper fill, while maintaining fluid level below the perforations in a completion with sufficient rat hole. If there is a packer in the hole all gas must be produced through the pump. To eliminate the possibility of gas lock occurring a special device may be installed on the bottom hole pump. (illustrated on attachment 3)

3. Surface equipment has less severe forces applied to it and lubrication of the gear box is continuous with no dry start-ups. As a result equipment life is increased.
4. Spikes in power demand and dry gear box start-ups are eliminated by continuos operation.
5. Belt life is increased when frequent intermittent startups are eliminated .
6. Prime mover horsepower requirements can be reduced if mechanical speed reduction is used.
7. In some instances, electrical power savings can be experienced as a result of prime mover resizing.
8. Cyclic loading is reduced.
9. Bottom hole stroke length becomes more synchronized with surface stroke length. The plunger and rods are allowed time to fall.
10. Wear points of the rods and tubing are passed less frequently.
11. Savings in pulling costs and surface equipment repairs are the prime factors to consider for SPM reduction.

APPLICATION: How to achieve optimum results.

1. Install Dynamometer load cell. Check the pump for excess leakage through either the valves or past the plunger as pump slippage requires extra strokes per minute to meet production demands. (ref. 3) Make sure the bottom hole pump is not respaced by the installation of the load cell.
2. Check fluid levels using quality instruments. Be sure to allow sufficient time for the well to normalize after shutdown for instrument installation.

There are 4 (four) basic combinations of fluid level/Downhole Dynamometer card which will be found. Two of these combinations require slow down.(illustrated on attachment 4)

1. Fluid level is at the pump, and the downhole card is full or slightly (5%) pumped off.
2. Fluid level is at the pump, but the downhole card shows excessive pump-off. (35%+_)
3. Fluid level is over the pump, but will not compress as would foamy fluid with additional casing pressure and has a full downhole card.
4. Fluid level is 1500-2000 ft. over the pump but will compress with casing pressure and the downhole card shows excessive pump off. (35%+_)

Finding #1 This is the optimum speed which is matched to the inflow of the formation.

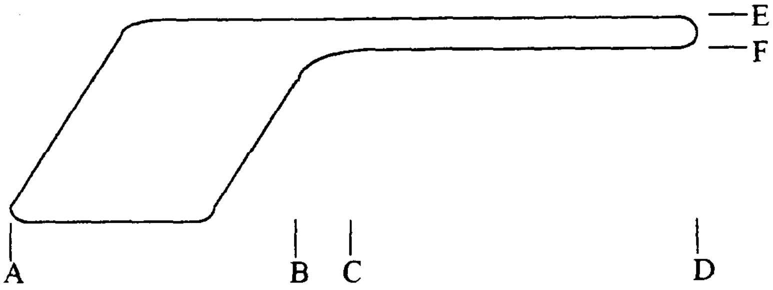
Finding #2 Provided there is little or no gas interference, this case is a simple slow down. Use of the downhole card will give accurate predictions for slowdown as discussed later.

Finding #3 This case indicates pumping problems or a unit which is under-designed

Finding #4 When additional casing pressure is temporarily applied to this unit the fluid level rapidly lowers to the pump. This can take 24 to 48 hours to accomplish on some locations, if insufficient casing gas is present. This unit also requires slowdown, but a special modification to the downhole pump is necessary.(illustrated on attachment 5)

The downhole dynamometer card is the most reliable tool to make accurate slowdown predictions.

Case #2 and # 4 should be slowed down as follows.



A - B.... amount of stroke utilized for fluid production.
B - C.... gas compression
C - D.... cavitation
E......When Peak Polish Rod load, line E,
F......and rod weight plus fluid weight minus frictional loss of tubing, line F, run parallel there is no useful work being done. The plunger is descending on a void until point C is reached. At this point compression begins.

Points A, B, & C are necessary to produce the fluid and gas being produced by this pump.

SOLUTION: If point A to D is the bottom hole stroke length and A to C is half the length of A to D, then the unit can be slowed approximately 45%.

If point A to C is only one quarter of A to D the unit can be slowed approximately 70%.

Stay overstroked by about 5% to accommodate variations in well bore inflow.

Note: At 3 to 3.5 SPM, the bottom hole card and surface card are almost identical. At this point the surface card can be used for further fine tuning.

CONCLUSION:

After a major change in pumping characteristics like this have been implemented, these are some points to remember:

1. On a newly repaired pump when the annulus has been allowed to fill, more time is needed for the fluid level to be drawn to the pump. A variable speed drive system may be used if fluid level draw down time is critical.
2. As the surface card is much more indicative of the lifting forces applied at the surface, peak polish rod load becomes a good indicator of fluid level. A load cell may also be used to measure polish rod load. (illustrated on attachment 5)
3. Power savings or cost alone are not good criteria to determine whether or not investment in this system is worth while. Longevity of the bottom hole pump, the rod string, tubing and surface equipment as well as an optimized pump are very important factors to be considered.

REFERENCES:

1. Sandia National Laboratories, RMOTC downhole dynamometer results.

2. Flex Bar, "Euler" test results.

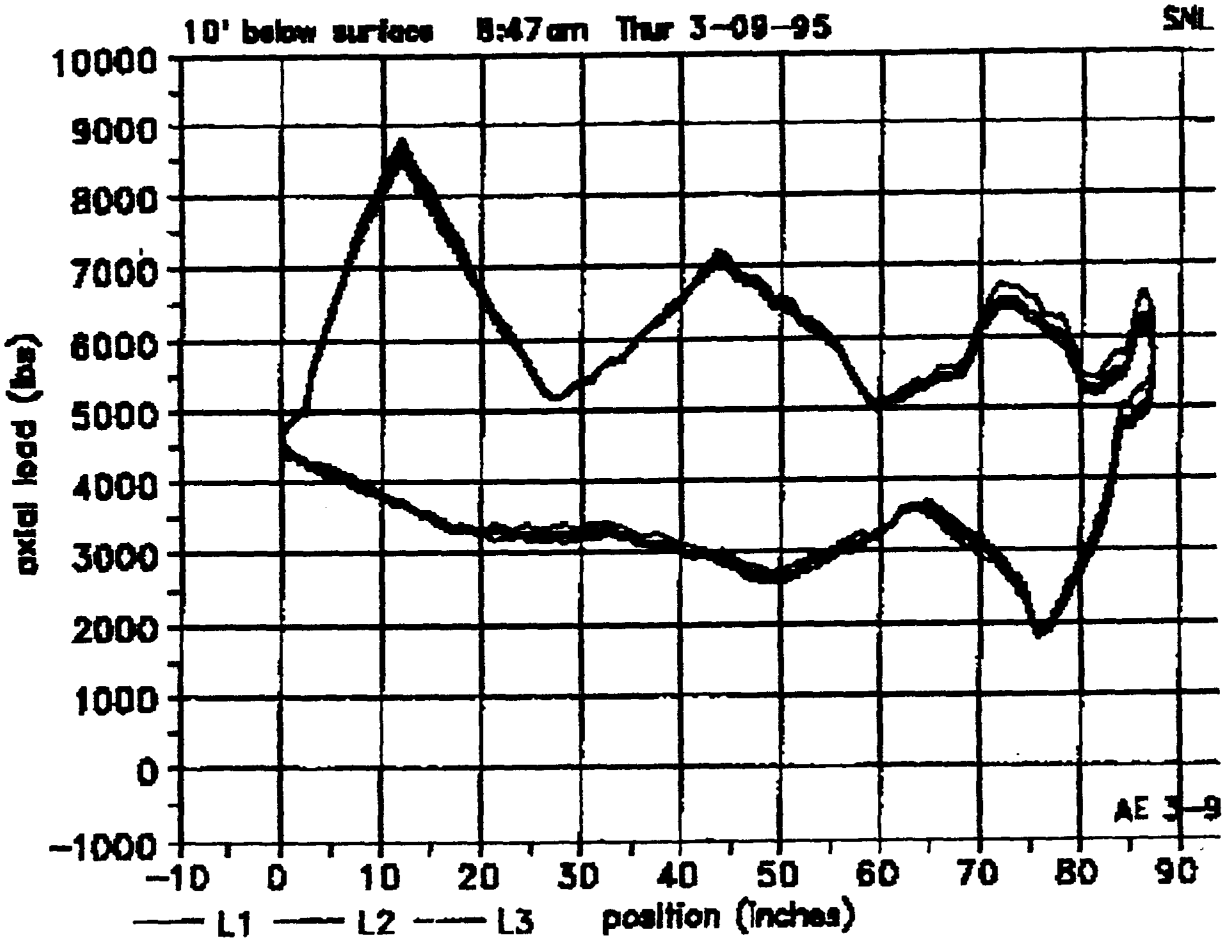
3. Nolen, K.B. , Gibbs, S.G.: "Quantitative Determination of Rod Pump Leakage using Dynamometer Techniques". SPE paper 18185, presented at the 63rd Annual Technical Conference and Exhibition, Houston, TX. Oct. 2-5, 1988.

4. Findlay II, C.P., Herring, R.B., Pike, J.S.: "Automation in Cyclical Rate Primary Reservoir Significantly Reduces Beam Pump Failures". SPE paper 30636, presented at the Annual Technical Conference and Exhibition, Dallas, TX. Oct 22-25, 1995.

Attachment 1

SANDIA LAB REPORT

Pump API designation: 25/150/Rwa/109/4/2
SPM: 11
Pump S/N set at: 2710 ft.
Stroke length: 86"
Pump size: 1-1/2"
Production: 160 water 3 oil



Attachment 2

TABLE 1.0 (Flex Bar)
Euler Loads to Buckle Various Diameters

Rod and Sinkerbar Diameters	Calculated Euler Loads Fixed	Hinged
½"	41 lbs.	10 lbs.
5/8"	100 lbs.	25 lbs.
¾"	208 bls.	52 lbs.
7/8"	385 lbs.	96 lbs.
1"	657 lbs.	164 lbs.
1-3/8	2348 lbs.	587 lbs.
1-1/2	3325 lbs.	831lbs.
1-5/8	4579 lbs.	1114 lbs.
1-3/4	6160 lbs.	1540 lbs.

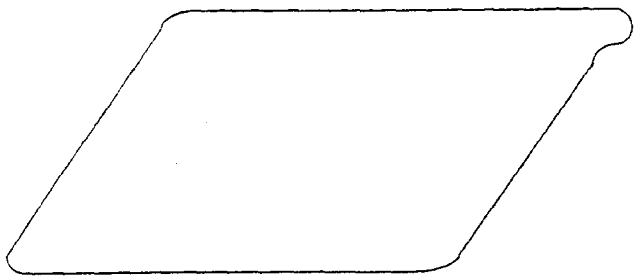
(All data based on 25-foot long sucker rods or sinkerbars with the total weight of sucker rods or sinkerbars in air, (lbs.) removed from calculation of measured loads to be consistent with the calculation of Euler Loads that does not consider the weight of the column.)

Attachment 3

Device used to eliminate gas lock and help to find bottom at slow speed without tagging the pump is shown in black.

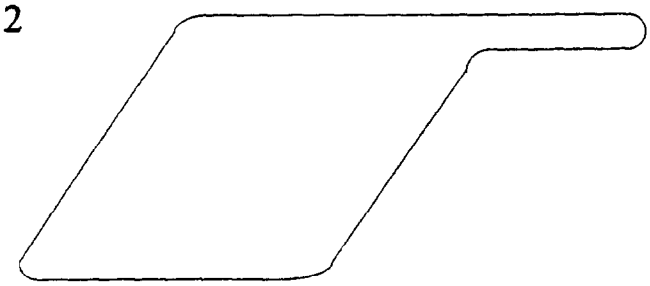
Attachment 4

1



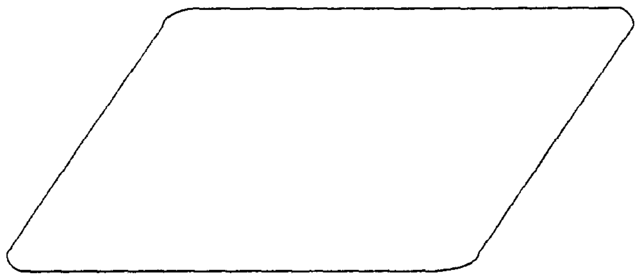
This is the ideal downhole card if the fluid level is at the pump or slightly over the pump.

2



Pumps which have lost 35%+_ of their efficiency because they are overstroked can benefit from slowdown.

3



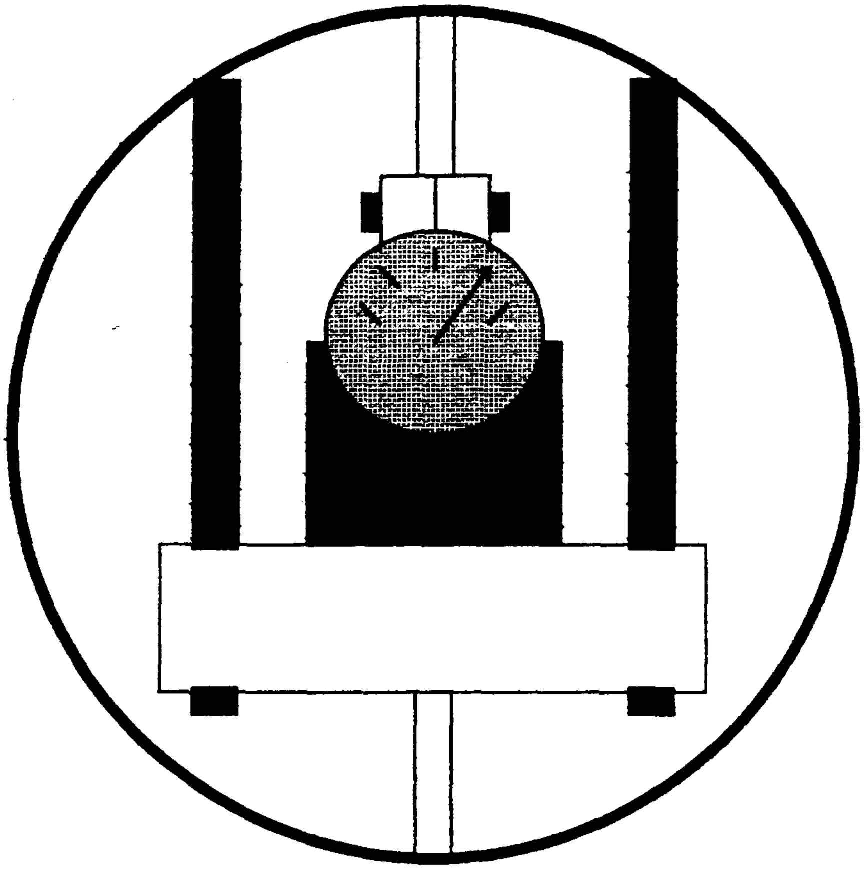
If the bottom hole card shows full with a solid fluid level hundred of feet over the pump there is either mechanical or design problems.

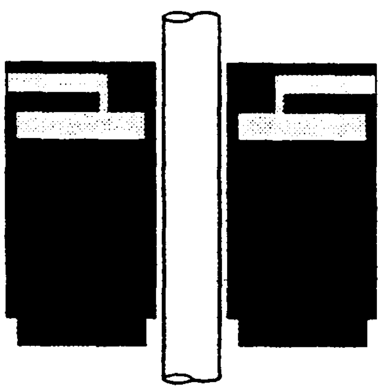
4

Even a location with gas interference can benefit from slow down .

Attachment 5

WEIGHT INDICATOR





A pump indicator is a hollow bore hydraulic cylinder located between the carrier bar and the rod clamp. It indicates the amount of load carried by the Carrier bar.

As SPM is lowered below 4 SPM the surface card and downhole card are very similar. This tool gives a good indication of downhole problems such as fluid level, paraffin build up, parted rods and cavitation.

Attachment 6