THE 40-FOOT STROKE, WINCH TYPE PUMPING UNIT

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The use of a long slow stroke in rod-pumped oil wells has been the goal of prudent operators for many years. They have recognized that a major cost of operation was the repair and replacement of sucker rods, tubing, and bottom-hole pumps. Since most of these failures were the result of fatigue, corrosion fatigue, or wear, a reduction in the number and magnitude of fatigue-producing strokes would dramatically reduce their operating costs.

For example, one stroke per minute is 525,600 strokes per year. Three strokes per minute is 1,576,800 strokes per year. Twelve strokes per minute is 6,307,200 strokes per year. If the fatigue life of an average rod string or bottom hole pump is 20,000,000 strokes, under field operating conditions they would last only 3.17 years at twelve strokes per minute but they would last 12.68 years at three strokes per minute.

Since reduced pumping speeds also dramatically reduce dynamic loads, the peak load and the range of load would also be dramatically reduced. For example, with 18,000 pounds of rod load and 7,000 pounds of fluid load the following predicted loads would result.

	PPRL	MPRL
3-480	26,098 lb	16,903 lb
12-120SPM	28,410 lb	13,590 lb

RANGE	PERCENT RANGE	1-INCH ROD PEAK STRESS
9,916 lb	35%	33,228 psi
15,820 lb	54%	37,445 psi

Peak rod stress and the range of stress are *the* determinant factors in expected rod fatigue life. The meaningful reductions illustrated above would result in significant improvements in rod life if they were the *only* factors considered.

The total impact of reducing the strokes per year from 6.3 million to 1.6 million together with meaningful reductions in peak stress and range of stress is considerable. The improvement in bottom-hole pump-wear life from 3.14 years to 12.68 years is an additional benefit. It becomes very easy to visualize a pumping oilfield without a servicing unit in sight.

With these obvious advantages, the use of longer strokes at slower speeds has gained wide acceptance. Unfortunately, these long strokes with conventional walking beam pumping units greatly magnify the torque requirement. For example (Fig. 1): Using 20,000 lb PPRL and 10,000 lb MPRL and 15,000 lb CBE, S/2 = Torque Arm.

With walking-beam pumping units, any increase in stroke length results in torque magnification proportional to the amount of increase. In addition, the walking beam and supporting structure becomes massive and quite tall to accommodate this longer stroke. The size limitations of this configuration limit the maximum practical stroke length.

In the search to obtain the long stroke without the limitations of walking beam units, a return was made to the age old principle of the winch. The principle of continuous mechanical advantage over long distances was already in wide usage in all other segments of industry.

To illustrate the advantages of the winch, the following example is presented using the loads from the previous example (Fig. 2): PPRL = 20,000 lb MPRL = 10,000 lb CBE = 15,000 lb.

This drastic reduction in peak torque and in the size of the structure required becomes greater and greater when longer stroke lengths are considered. It

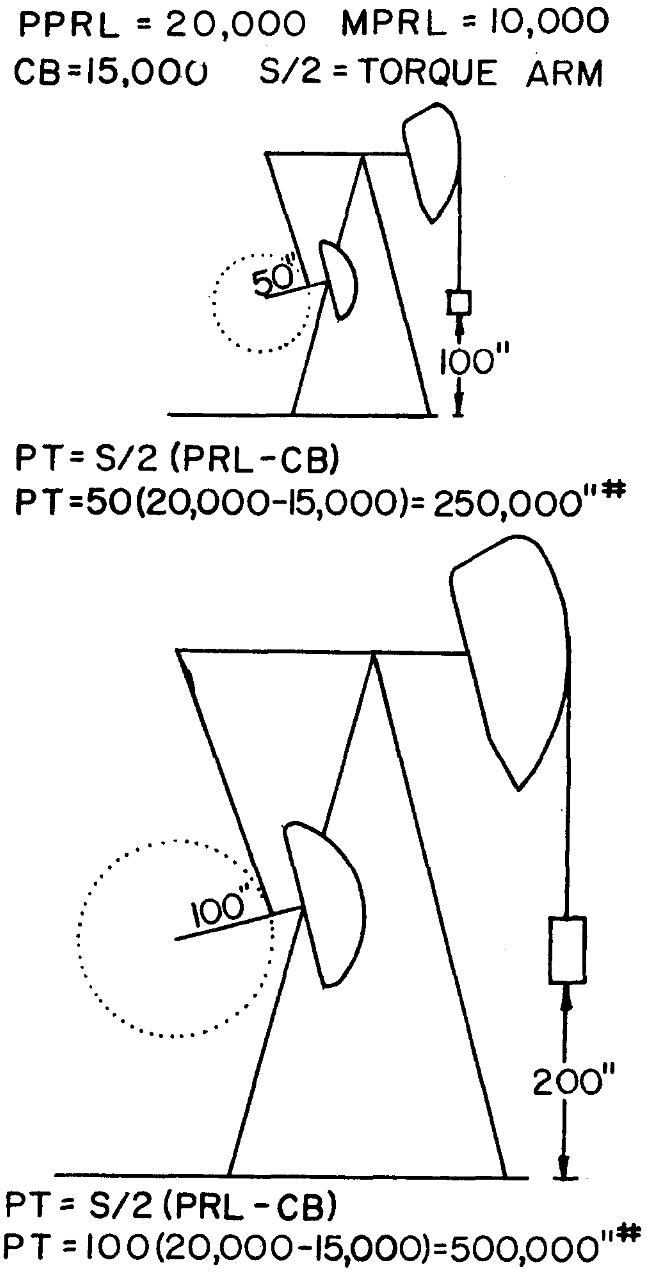

FIGURE 1

should be obvious that each rotation of the winch drum produces 100-inches more stroke with no increase in torque or in the physical size of the structure.

One problem remains: stopping the machine at the end of the stroke, turning it around, and driving it in the opposite direction.

If the motor was just turned off the machine would come to a stop because of the unbalanced loads being lifted in both directions of motion. On the upstroke the weight of rods and fluid are greater than the counterbalance. On the downstroke the

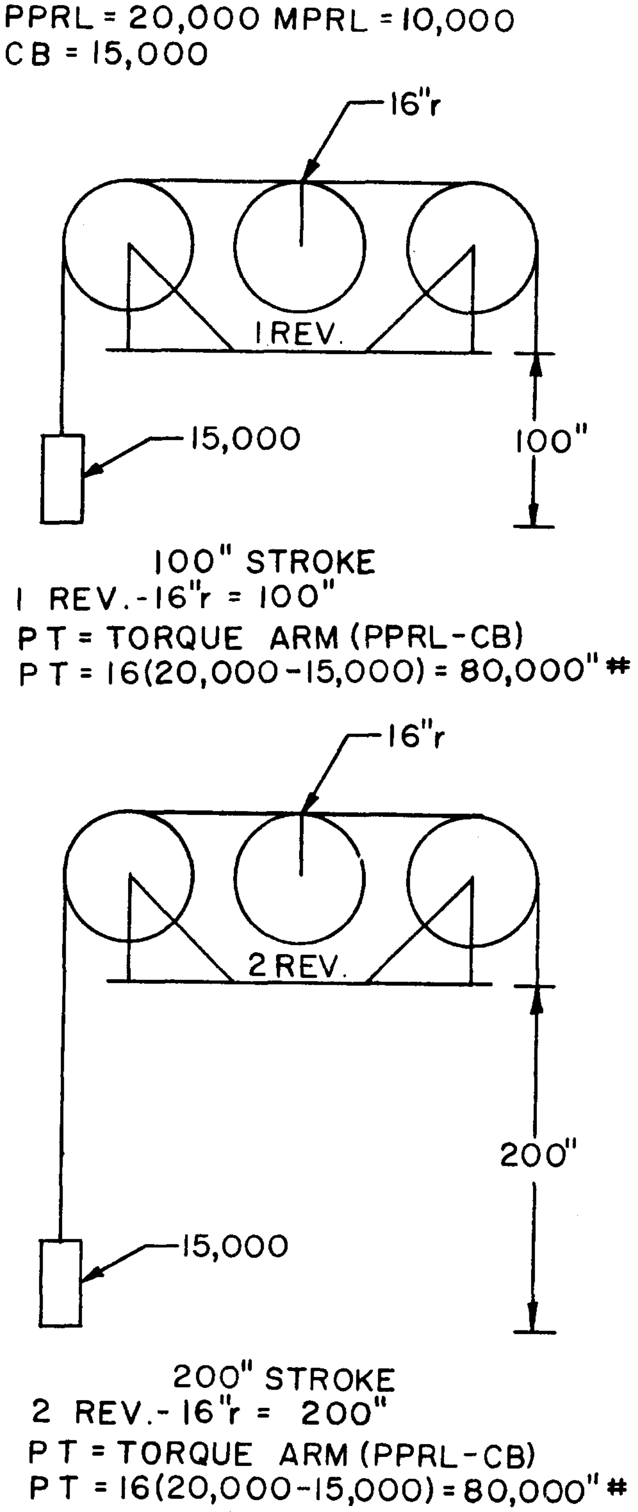

FIGURE 2

counterbalance weight is greater than the weight of rods only. These unbalanced loads would serve to brake the machine to a stop. However, the turnaround points would be very imprecise, especially as fluid levels changed during operation of the well.

Again a return was made to the age-old principle of the cam. When the motor is turned off, the rotational inertial energy of the machine can be stored. This energy can be used to stop the machine and start it in the opposite direction. So the use of cams permits the storing of inertial energy and the use of this energy to start the machine in the opposite direction.

The working leverage is effectively changed by the cams. For example, as the upstroke is completed the motor is turned off. The inertia of the machine continues rotation and the wellside cable is raised by the up-cam and the counterbalance cable is lowered by the down-cam. This conversion of inertial energy to potential energy causes the unit to stop at a rather precise point. These cams change the mechanical advantage of the mechanism and create a torque in the downstroke direction (Fig. 3).

The inertial energy of the machine has been stored by the cams and creates a large opposing force to start the machine in the opposite direction. Since this force is stored by the cams external to the gear box, and with the motor off the gears do not carry this torque. As the machine starts in the opposite direction, the potential energy stored in the cams is converted to inertial energy, driving the machine to about 2/3 to 3/4 of maximum speed. At this point the motor is turned on running in the proper direction. Since the motor has already been driven to a significant speed and the machine is already in motion in the proper direction, motor-starting currents are greatly reduced.

The contour of the cams was developed with computer assistance to provide optimum polished-rod motion at the points of turn-around. Since turn-around occurs after the motor is turned off, the rate and motion of the turn-around is controlled by polished-rod forces. This produces vastly improved

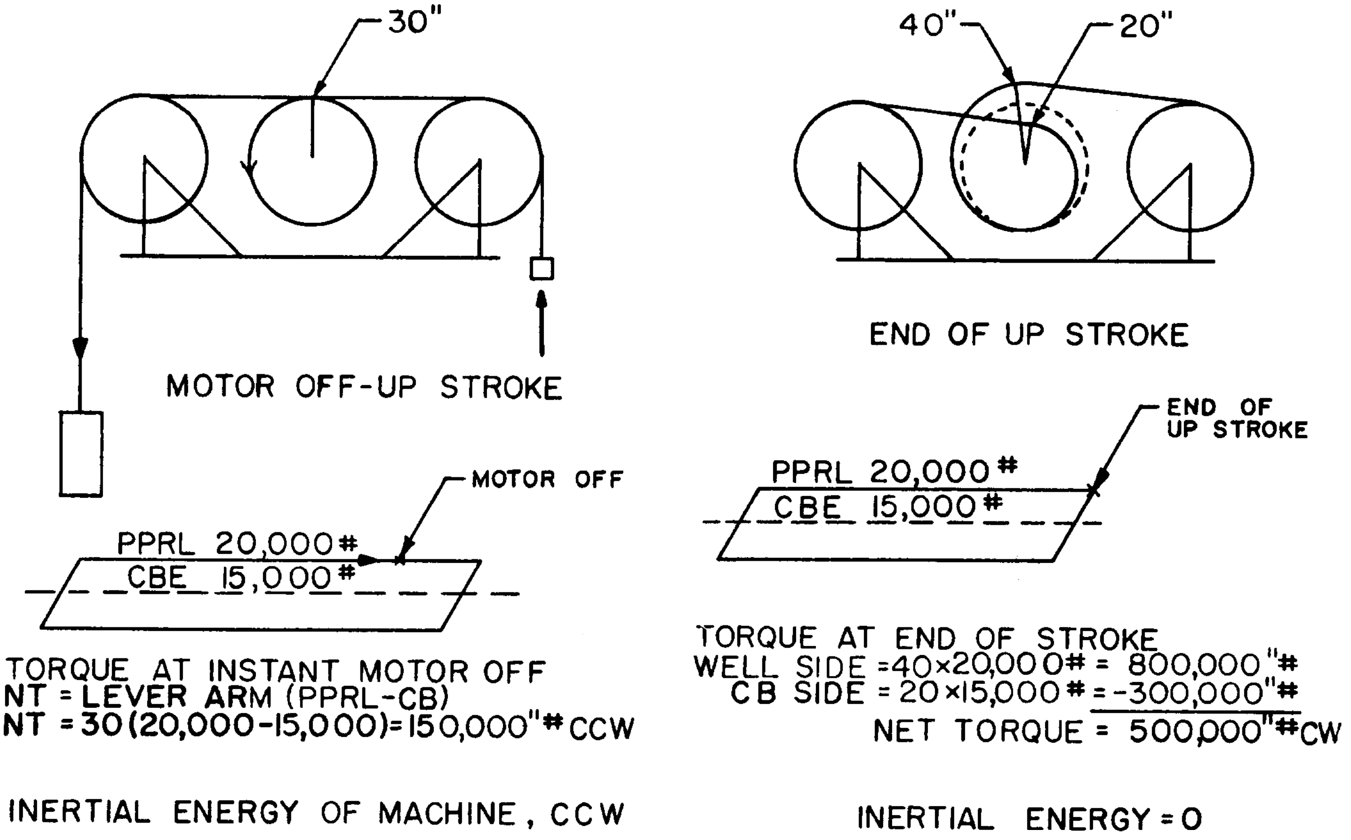

FIGURE 3

motion when compared to the turn-arounds of walking beam units where stroke reversals are imposed by the motion of a driven machine. The significance of this becomes apparent when stroke times are considered. At 15 strokes per minute, one complete stroke takes only 4 seconds. This 4 seconds includes an upstroke, a downstroke, and two stroke reversals. At three strokes per minute, one complete stroke takes 20 seconds. Stroke time is divided as follows: 7 seconds for the upstroke (motor on), 3 seconds for stroke reversal (motor off), 7 seconds for the downstroke (motor on), and 3 seconds for stroke reversal (motor off). A 3-second period (with the motor off) just to reverse the stroke, contrasts very favorable with 4 seconds for a complete upstroke, a downstroke, and two stroke reversals, in terms of rod dynamics and fatigue.

The use of these cams to store rotational energy and to provide power-off turn-arounds is responsible for a large portion of the energy saving. In the example above the motor is completely off for 6 seconds of the 20 seconds required per stroke. The motor drives only 14 seconds of the total of 20 seconds. During the period of driving, the counterbalance effect is always at its maximum, and the upstroke and downstroke loads remain almost constant. The horsepower required is only the difference between a steady wellside load and a steady counterbalance load times the torque arm of the power drum. Under these conditions of load the motor is able to operate at a steady load with high efficiency. When the motor is turned off, no power is used. So the motor operates only 14 seconds out of 20 seconds or 70 percent of the time. When it is on, it is operating under steady and efficient conditions.

Contrast this with the motor load of a conventional unit. The torque curve, and therefore the motor load curve, goes through two large peaks. If the motor is properly sized it will be loaded to more than 100 percent of its rating during these peaks. On both sides of these peaks the motor load drops to a zero and oftentimes negative load. The no-load current of the average oilfield motor is about 40 per cent of its full load current. So when the motor load drops to zero and no work is being done, 40 percent of more of the full load current is still being used. When the load becomes negative, the motor serves as a generator which puts current back in the power line. This generated work is done at very low efficiency since a squirrel cage motor is not a good generator. In addition, this work must be restored to the system at another point in the stroke, so even greater inefficiencies result.

Dependable motor control is essential for optimum efficiency of the winch type machine. Control of the "motor off" position is variable within limits. This permits small stroke length changes with a twist of a knob. For a longer stroke length, the motor is left on for a short time after the cam is reached. For a shorter stroke length the motor is turned off just prior to or at the cam. Total change in stroke length by this method is from 38-feet to 44-feet or about 15 percent off the total stroke.

It is also very important to start the motor at a specific point. Our computer studies have shown that dynamometer card shape can be controlled, to a pronounced degree, by selecting the proper instant for motor start.

It was found that rod harmonics could be largely dampened out if the motor is started at the proper instant. This instant occurs just after the load has peaked at its maximum or minimum after turn-around. The rod string, which is actually a long spring, has been disturbed by the turn-around and the pick up or release of load. When the load reaches it maximum value, the spring is extended to its maximum length. This disturbance causes the spring to start vibrating at its natural frequency. (This natural frequency is a function of the speed of energy transmission in the rod string and the length of the rod string.) This vibration at natural frequency is the factor that determines the shape of dynamometer cards. Walking beam pumping units *impose* a stroke frequency and polished-rod motion on the rod string. This produces certain forces and dynamics in the basic polished-rod load. It also produces rod vibrations. Some pumping speeds amplify natural vibrations and some dampen out natural vibrations. Since the starting point of the winch unit can be selected, and no arbitrary motion is imposed, it is possible to choose a start point which dampens out these natural vibrations.

A patented control was developed which utilizes a strain transducer to monitor well loads. When the load has reached maximum or minimum value, control logic determines the exact instant for motor start that will dampen out rod vibrations (harmonics). This reduces or eliminates the fatigue-producing load variations generated by harmonics.

It makes it possible to produce a dynamometer card which is essentially a parallelogram. This ideal dynamometer card gives minimum fatigue and minimum torque per unit of work.

Since the control monitors the well load continuously, this output is used for detection of downhole well problems when downhole well problems occur, the control shuts the unit down, sets the brake and lights a digital display which advises the operator of the downhole problem to look for.

Since stroke position and load are both used in the control of the unit, it is only necessary to plug in an X-Y plotter to obtain instantaneous dynamometer cards. It is also possible to transmit this information to a remote monitoring point or computer. The dynamometer card could be displayed at this point.

In summary, the use of the winch principle in a rod pumping system has many advantages. This machine, together with its advanced control, brings new answers to old oilfield problems.