Mechanical Long-Stroke Pumping Unit

E. W. METTERS
OILWELL Division, United States Steel Corp.

The purpose of this paper is to explain the principle and function of a newly introduced machine which develops a long (34-ft) stroke to produce an oil well. The machine is mechanical, operates on electrical power and is equipped with pneumatic safety controls.

At this point it might be well to describe the unit (shown in Fig. 1). It is a four-leg structural steel tower. On top of the structure are the prime mover, gear reduction box and a contoured wire line drum. These items make up the equipment which generates the stroke and the means for reversing the stroke direction. Located in the structure or derrick are adjustable reversing electrical switches which signal to the control panel located on the ground in which direction the unit is operating.

All important to the operation of the unit is the contoured wire line drum. Refer to Figs. 2-A, 2-B and 2-C to see the position of the drum in relation to three different positions of the stroke.

Figure 2-A shows the unit at midstroke. Note that the wire lines wrapped around the drum are situated on the outer periphery of the drum and at this point neither has a mechanical advantage.

In Fig. 2-B the downstroke has been completed. In this phase, the contour of the drum has been utilized to allow the well-side set of wire lines to come in toward the center line of the shaft while the counterweight lines are still on the outer periphery of the drum. At this point there is a mechanical advantage in favor of the counterweight of 30 in. to practically zero on the well side since the drum is 60 in. in diameter.

Figure 2-C depicts the same thing only this time the unit is at the top of the stroke. The wire line sets on the counterweight side have come in toward the center line of the shaft while the well-side lines stay on the outer rim of the drum. The mechanical advantage is now in favor of the well side.

In utilizing the contoured drum it is possible to extract some of the energy put into the system during the constant portion of the stroke. Contrary to a conventional beam-type pumping unit, this unit does not power the reversal portions of the stroke but coasts through them.

An analogy might help in understanding the principle involved. Figure 3 shows a weight hanging on a trolley line at Point "A". Energy is applied to the weight causing the weight to travel to the right. The energy or force will be constant until the weight reaches Point "B"; at this point the energy is turned off. The weight will continue to travel to the right but the trolley wheel is restrained at Point "C" so part of the energy previously applied to the weight has become potential energy. As this potential energy is depleted, the weight comes to a halt, reverses its direction and now has kinetic energy. As the weight swings back and again reaches Point "B" energy is again applied, but in the opposite direction and is continuously applied to Points "D" and "E" where the reversal will again take place.

Equating this analogy with the contoured wire line drum is not difficult. As the lines on the unit commence their trip on the contoured portion of the drum, the electric power is turned off as in Point "B" of Fig. 3. The drum will continue to rotate in this direction until the unbalance overcomes the motion. At this time the drum will start to rotate in the opposite direction and at a given point the electrical power is again turned on.

The control of the electric power to the prime mover is achieved by adjustable microswitches placed in the derrick and actuated by ramps on the counterweight tank.

In operation, the point at which the power is turned on and off is very important. This is generally referred to as tuning the unit. The optimum point for turning on the electric motor on the return stroke would be at the point the system has accelerated to its greatest velocity achieved by the unbalance. It will generally be turned off near the start of the contour on the drum.

The prime mover is belt-connected to the input shaft of the gear box so the direction of the motor is established by the rotation of the drum and the polarity of the motor is handled by a logic circuit in the master control panel. This circuit is actuated by the sensing or reversing switches located in the derrick.

Field operation has shown that this method of generating a long stroke has distinct advantages in producing an oil well. There has been a substantial increase in the sucker rod life. This, no doubt, is due mostly to the decrease in cycles to produce a given amount of fluid.

It was originally expected there would be a substantial increase in the life of the subsurface equipment but the actual results have been much better than had been originally expected. Certainly fewer cycles should increase the life expectancy. Barrel wear would be expected to be longer since the wear is distributed over a greater area. Valve life would be increased due to fewer cycles to pass the same amount of fluid but performance has increased even beyond the expected.

Some of this improvement can no doubt be attributed to the overall decrease in operating velocity of the system. In conventional pumping systems using beam-type pumping units, the system is operated as would be charted on a sine wave. At no time during a beam unit's operation is the reciprocating portion of the system operating at a constant velocity but is, instead, either accelerating or decelerating. This means that at two points in the cycle the reciprocating portion reaches a peak velocity. When a drum-type system is used as in the long-stroke design, 75-80 per cent of the reciprocating motion is at a constant velocity.

The contoured drum-type unit has a normal stroke length of 408 in. and a conventional air counterbalance unit has a stroke length of 300 in. to achieve the same amount of net plunger travel; the long-stroke unit would operate at 5 SPM and the conventional unit at 7 SPM, assuming the stretch were equal in both cases.

The maximum velocity achieved by the drum unit would be 465 ft/min while the velocity of the air balanced unit would be about 543 ft/min or an increase of 16 per cent.

Another comparison would be a unit with unequal geometry which achieves counterbalance by the use of counterweights on the cranks; as before, the drum unit would be operated at the same strokes per minute but the crankbalanced unit would be operating at about twelve 192-in. SPM. In this case, the maximum velocities would be 465 ft/min in both directions for the drum unit; the unit with the modified geometry would have an upstroke peak velocity of 472 ft/min and a downstroke peak velocity of about 690 ft/min or approximately a 49 per cent increase on the downstroke.

The speed at which a sucker rod system can be operated is predicated on the ability of the sucker rod to fall in the fluid and any reduction in the downstroke velocities will tend to be beneficial.

One very unique application of this unit was in a well in which 10,600 ft of 2⅞ in. tubing was cemented through a producing zone. This tubing was perforated at 10,500 ft and the well was produced through 1.9 in. OD tubing. A 46-ft, 1½ in. ID tubing pump barrel was run in the hole on the tubing at 7050 ft and the plunger was run on the end of a continuous sucker rod string. To date this has been a trouble-free installation. Just a couple of years ago it would not have been possible to produce this type of installation.

Another installation of a more conventional nature revealed some rather interesting figures. A technical service company weighed and analyzed the well after 472 days of operation. At this time the unit was operating at 4.8 SPM.

The survey showed an excessive load range in all sizes of the string; however, the ¾-in. rods had by far the widest load range. They had a maximum stress of 38,000 psi and a minimum of 6500 psi. Normally, breakage would be expected under these operating conditions but none had occurred.

The survey also showed the well fluid to be at the pump but there were no indications of a fluid pound. The unit was slowed down to 4.33 SPM which made a tremendous improvement on the load range of the rods, primarily in the ¾-in. and ⅞-in. portions. However, they still were considered to be overloaded by about 13 per cent.

At the time the survey was taken there had been no rod parts. As of December, 1969 there had still been no rod breaks for the total period and only one pump repair.

A unit of the design under discussion must by necessity have safety features which would not normally be required on beam-type units. A rather sophisticated safety system has been designed into the unit.

The elimination of the sine wave power demands makes it possible to operate the unit with a smaller motor than would be required to produce the same amount of fluid from a given depth by a beam-type pumping unit. To protect this smaller motor, solid state devices were located in the motor windings to protect it against overheating. If overheating occurs, a resistance change in the sensors activates a solid state relay which opens the motor control circuit to stop the unit. The unit will restart when the motor cools. These heat sensors also protect the motor against single phasing which occurs quite frequently in some areas.

Due to the long-stroke design of this unit, overspeeding can occur if there is a failure high in the sucker rod string or even the polished rod. This is protected against by a motor speed sensing device set to trip if overspeeding occurs. In this event, the motor is turned off and the brake is set to catch the counterbalance. The brake is mounted on the input shaft of the gear reduction box and is an air-actuated internal expanding shoe-type brake assembly.

Tied into this same air and electrical circuit are two overtravel switches. If an extreme unbalanced condition occurs, an air valve is tripped either by the counterbalance tank or the polished rod carrier bar. These valves activate the same air and electrical circuits as the overspeed device and turn off the electrical power and set the brake.

The operating controls are quite simple, consisting of an electrical on and off switch and a control air brake valve. The air and electrical systems are interlocked. If the electrical switch is moved to the "on" position and the brake has not been released, the power will not come on. Or, if during the operation of the unit the brake is set, the power to the motor will be turned off.

The safety air pressure operating range is 80 - 100 psi; if at any time the air pressure drops below a predetermined level, the unit will not function.

Since the electrical circuit is rather involved, there is built into the electric controller a series of indicator lights for visual trouble-shooting. Also there is available a plug-in test unit by which a complete run-through of all the sequencing circuits as well as all safety circuits can be made without having to operate the unit.

Being a rather sophisticated piece of machinery, certain portions of the unit must be classified as expendable. Wire lines for example are designed to have life expectancy of about five million cycles with the unit operating at maximum strokes per minute (5) and maximum polished rod load (35,000 lbs). To achieve this life it was necessary to take into account bending stress, atmospheric corrosion, internal abrasion and scuffing of the lines on the drum. The bending stress was overcome by the use of multistrands of wire line of ⅝-in. diameter operating on a 60-in. diameter drum. Special lubrication was used to overcome corrosion and internal wear. Scuffing of the wire in the drum caused by the creep of the line under load was solved by the use of a polyuereathane belt applied to the face of the contoured drum. This belt also serves another purpose. It will actually indent and distribute the load over a much greater area of the line which is in contact with the drum.

At the present time starter contact life appears to be averaging about eight months; however, several units have far exceeded this time.

Well servicing is accomplished by skidding the unit away from the well; this can be accomplished either by using the servicing unit or a winch truck. The base beams are designed to accommodate sheaves and snatch blocks to facilitate the skidding operations on and off the well.

In summary, examine the advantage which would be expected with the use of a free reversing drum-type unit as compared to a beam-type unit.

More fluid would be lifted per stroke with the peak load being about the same; the net results being fewer stress reversals required to produce a given amount of fluid or more fluid produced during the life cycles of the sucker rods.

The reduction of the velocities in the system allows the sucker rods to fall more freely in the fluid and allows the subsurface pump to function more efficiently.

In utilizing a pendulum action during the reversal phases of the stroke, torque requirements and dynamic stresses are greatly reduced and the prime mover horsepower requirement is less.

Finally, when designing a pumping installation, consideration should be given not only to the surface equipment but to the whole system and the component's function as a whole.

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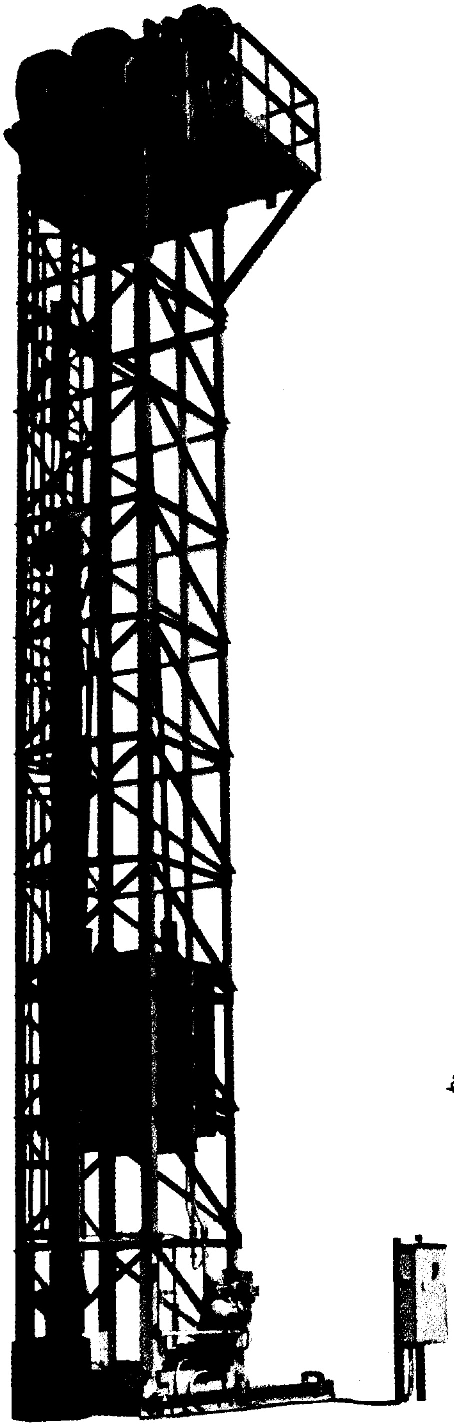

FIGURE 1

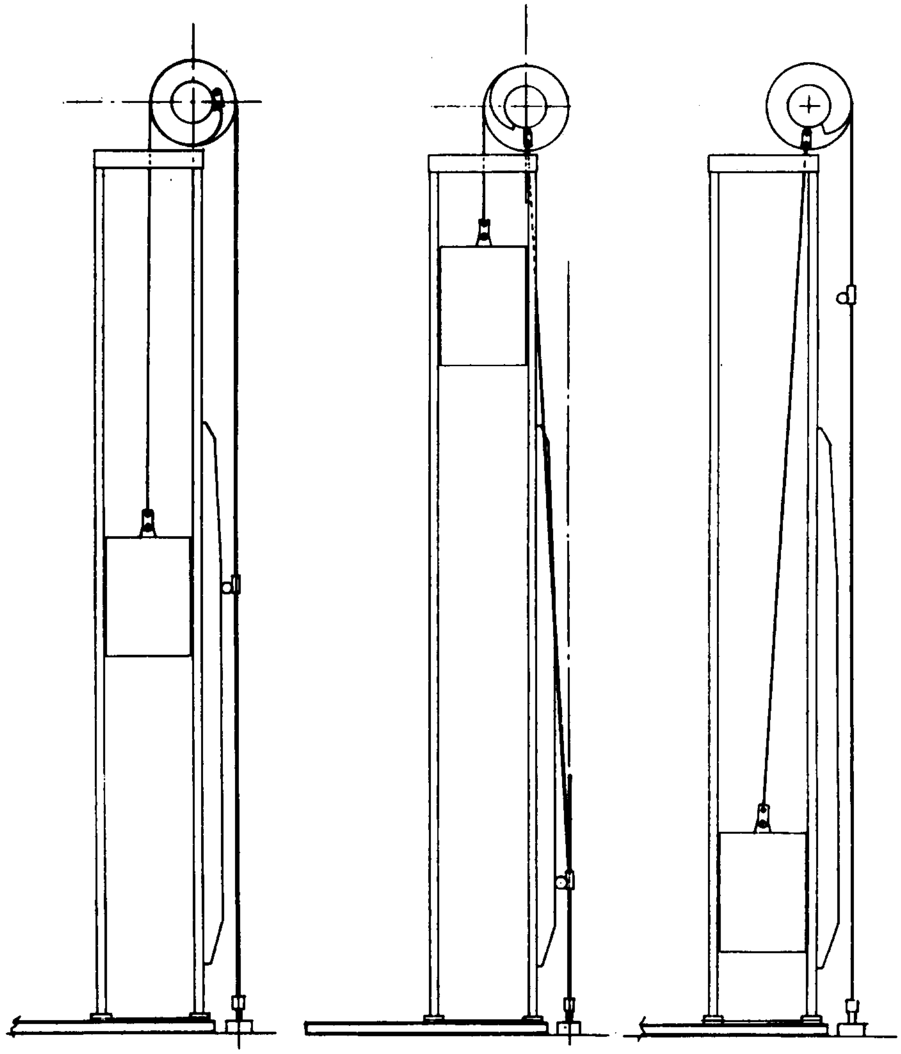

FIGURE 2A

FIGURE 2B

FIGURE 2C

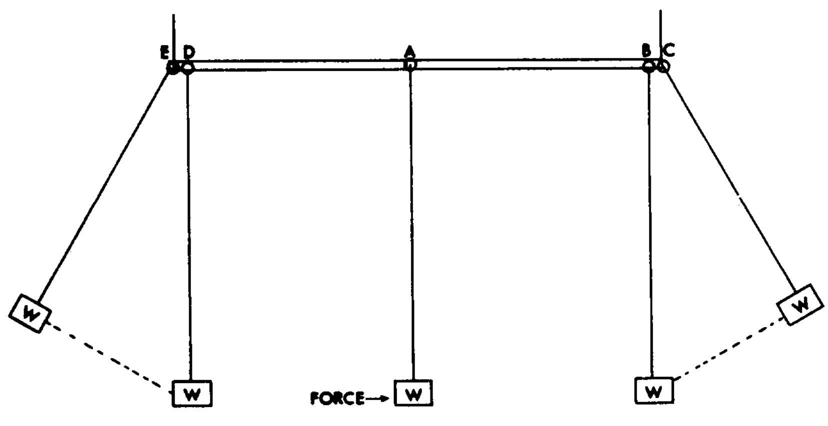

FIGURE 3