A New Method Of Artificial Lift

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ABSTRACT

Lifting problems in producing wells can drastically cut the oil operator's profit on initial investment. Well conditions that cause severe lifting problems are:

1. High sand content in the producing fluid which will often damage or freeze the bottom hole pump.
2. Paraffin or gyp accumulation on the tubing I. D. and sucker rods, resulting in eventual plugging.
3. The oil produced is of low gravity and cannot be efficiently pumped in cold weather.

Wells with the above conditions are presently being pumped with optimum efficiency through use of a new method of artificial lift. The method applies the principle of sonic energy to oil well production.

The equipment used will vibrate the tubing string in such a manner that valves in the tubing collars will lift the fluid to the surface.

INTRODUCTION

The sonic oil well pump differs from conventional oil well pumps in that it has no plunger, working barrel, sucker rods, or walking beam. It does make use of the tubing string with a one-way check valve in each tubing connection.

The sonic pump was developed by Mr. A. G. Bodine, Jr., the president of The Soundrive Co. of Los Angeles, Calif. Mr. Bodine, who also developed the sonic drill, is perhaps the world's foremost authority on the practical application of infrasonic energy.

A sonic pump in operation is shown in Fig. 1. The pump is lifting fluid with a high sand content from a well 900 ft. deep. Notice the pile of sand pumped from the well. This pump, which had been in operation for approximately eight months at the time this picture was taken, is located on the American Republic Lease of C. D. Fisher, an independent operator of Houston, Texas. The pump is pumping at the rate of 250 barrels of fluid per day, containing three per cent 14 degree gravity oil and large amounts of sand.

Fig. 1

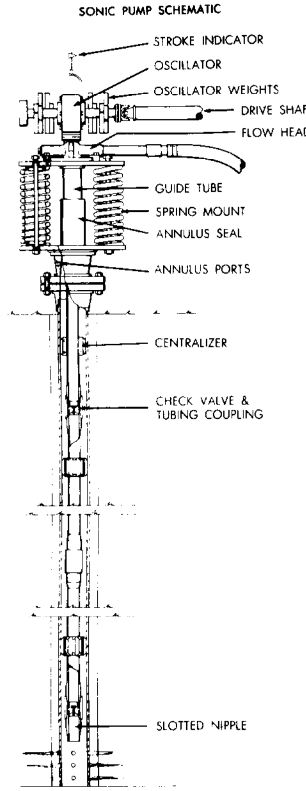


Fig. 2

DESCRIPTION OF EQUIPMENT

Shown in Fig. 2 is a diagram of a majority of the component assemblies of the sonic pump. Descriptions of these assemblies follow.

Spring Mount Assembly

The spring mount assembly consists of two steel plates, 22 in. in diameter and 3/4 in. thick, which are separated by balanced sets of springs. The bottom plate is flanged to the casing, while the top plate is connected to the tubing and the oscillator assembly. Thus, the upper end of the tubing has freedom for vertical movement.

Just below the bottom plate of the spring mount assembly is located a fluid return port. The port may be used as a means of returning fluid down the annulus for the purpose of lubricating tubing centralizers. The spring mount assembly contains the annulus seal, which serves as a pressure seal between the tubing and the casing. It also maintains a sealed bearing surface through which the tubing passes while vibrating.

Oscillator Assembly

The oscillator assembly, which is mounted on the top plate of the spring mount assembly, consists of a gear box with two parallel shafts extending out each side. Two eccentric weights are located on each end of the two shafts so that any horizontal forces cancel each other. When placed in any degree of unbalance, the weights combine

Fig. 3

their vertical forces to impart the tubing vibration in a vertical direction. The degree of unbalance of the weights determines the amplitude of the vibrations. Best results are obtained when the weights are adjusted to cause a total stroke of from 0.2 in. to 0.5 in.

Drive Shaft

A standard automotive type drive shaft transmits the power to the oscillator. The end of the drive shaft opposite the oscillator is connected to a jack shaft attached with pillow block bearings on an "A" frame motor mount. Any conventional type prime mover may be used.

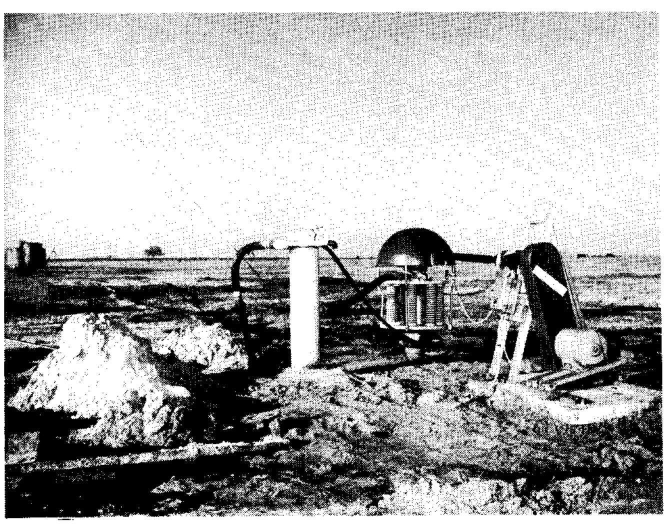


Fig. 4

Check Valves

Check valves are installed at each end of the tubing string and in each tubing connection. Vibration of the tubing will cause the valves to open and close rapidly with each stroke. On the downstroke of the vibration, the valves open to allow fluid from below to pass through.

On the upstroke, the valves close and through the action of the tubing, the fluid is impelled upward at a high rate. The check valve giving best performance has a valve body of heat treated nylon with a Hycar rubber poppet (Fig. 3).

Tubing-Casing Centralizers

Tubing-casing centralizers (Fig. 3) are installed at the ends and center of each tubing joint, or approximately ten feet apart. Purpose of the centralizers is to minimize or eliminate lateral vibrations in the tubing and to prevent the tubing from wearing against the casing. Constructed of wear-resistant plastic with low friction characteristics, the two-piece centralizers are bolted to the tubing.

Sand Trap

A cylindrical sand trap may be installed on wells in which the fluid produced is high in sand content (Fig. 4). The flexible hose from the pump connects to the sand trap at a point lower than the rigid flow line leaving the trap. The sand settles to the bottom of the trap and is blown out through a valve.

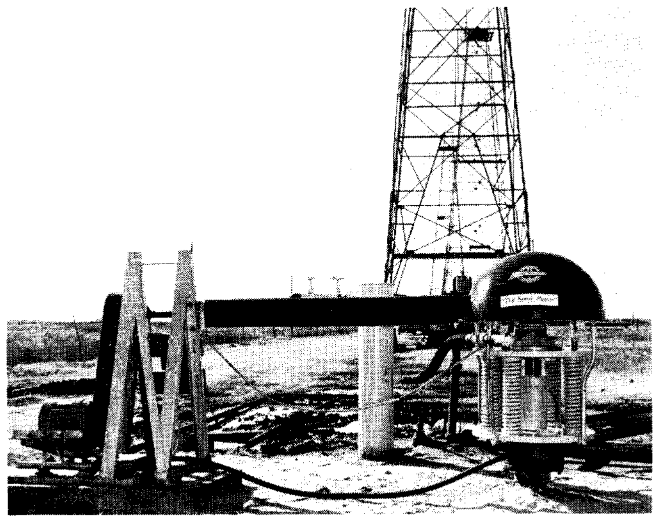


Fig. 5

Limit Switch

A limit switch (Fig. 5) will automatically shut down the pump should the amplitude become excessive. The increase in total stroke will cause the top plate of the spring mount to hit the extended arm of the switch and thus stop the motor driving the pump.

EASE OF INSTALLATION

Installation of the sonic pump requires a minimum of labor and equipment. As shown in Fig. 6, the spring mount of the pump uses the production casing for a foundation, thus eliminating the need of a concrete foundation. Also, as the prime mover is connected to the oscillator through a universal, only a simple, inexpensive motor base is required.

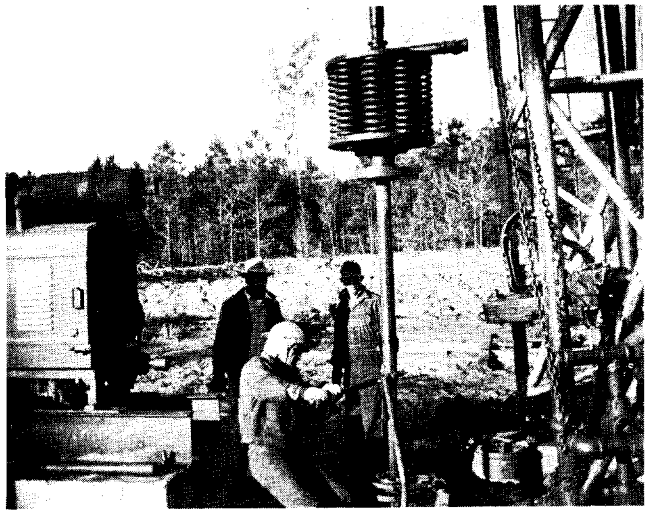


Fig. 6

The pump is held in place by the pulling rig, while the tubing is coupled on the pump guide tube (Fig. 6). After this connection has been made, the pump and tubing string are lowered until the pump flange rests on the casing flange. The two flanges are then bolted together.

The positive connection which the sonic pump has between the tubing and flow line eliminates the need of a stuffing box. Pump vibrations are absorbed by the section of flexible hose between the pump and flow line.

THEORY OF OPERATION

The theory of operation of the sonic pump is based on the elastic characteristics of a metal rod or tube, free at both ends, which will vibrate according to the principle of simple harmonic motion in an elastic body. When a steel tube, in this case the tubing string, is vibrated at one end at a rate corresponding to its fundamental frequency, the vibrations are transmitted over the entire length of the tube and form a standing wave on the tube. The tube is then said to be in resonance.

The fundamental frequency, which is a function of the velocity of the vibration and the tubing length, can be obtained by use of the formula in Fig. 7. The velocity of sound in steel, 990,000 ft. per minute, is constant and does not vary with the frequency. Thus, the formula for the fundamental frequency is equal to 990,000 divided by twice the length of the tubing plus 75 ft. The 75 ft. is added to the tubing length to compensate for the mass of the spring mount and oscillator.

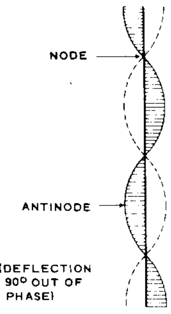
Fig. 7 contains the calculation for the fundamental frequency of a well with 1425 ft. of tubing. The fundamental frequency would be the result of dividing 990,000 by 3,000 or 330 vibrations per minute.

Best results are obtained in the oscillator range of 600 to 1200 r. p. m. Various harmonics may be obtained by increasing the fundamental frequency in whole number multiples. Thus, in the third harmonic, the oscillator will be operating at 990 vibrations per minute. This is within the recommended range of operation.

At the fundamental frequency, the two ends of the tubing string move in opposite directions through the cycle while the middle of the string remains relatively motionless. As the frequency is increased by whole number multiples of the fundamental frequency (two, three, etc.), the number of sections of tubing which are in motion are increased by one greater than the whole number multiple. Thus, when operating in the third harmonic, four sections of the tubing are moving.

The schematic in Fig. 7 shows the third harmonic wave pattern. As can be seen, when operating at a resonant condition, the two ends of the tubing are vibrating at the maximum amplitude, termed an antinode in the wave pattern, while at three other points in the tubing there will be virtually no wave motion and the tubing will be at rest. These points are termed nodes.

FREQUENCY ANALYSIS



$f_n = \frac{V}{\lambda}$ V = VELOCITY, λ = WAVE LENGTH

$V = \sqrt{\frac{e}{d}}$ e = MODULUS OF ELAST., d = DENSITY

V = 990,000 fpm FOR STEEL

$f_n = \frac{990{,}000}{2(L+75)}$ L = LENGTH OF TUBING

75 FT. IS ADDED TO THE TUBING LENGTH TO COMPENSATE FOR THE MASS OF THE SPRING MOUNT AND OSCILLATOR.

EXAMPLE

FOR TUBING LENGTH OF 1425 FT.

$f_n = \frac{990{,}000}{2(1425+75)} = 330$ VIBRATIONS / MIN.

OSCILATOR RANGE 600 TO 1200 R.P.M.

3RD HARMONIC = $3(f_n)$

OR 3(330) = 990 VIBRATIONS / MIN.

Fig. 7

The nodes are the points where the downward vibration is cancelled by the upward vibration. Thus, the tubing string as a whole does not move up and down, but sections of the tubing move in opposite directions from adjacent sections. By this means, the fluid is raised from valve to valve through the tubing to the surface.

After the correct frequency has been obtained, the correct size of the required sheaves for the v-belt drive of the electric motor may be calculated as follows:

(Oscillator RPM) (Oscillator sheave diameter) =
(Motor RPM) (Motor sheave diameter)

As the motor speed and required oscillator speed are known, the sheave sizes can be readily obtained.

ADVANTAGES OF NEW LIFT METHOD

The sonic method of oil well pumping offers the oil operator the following advantages:

1. Fluids with high sand content, and nonlubricating fluids such as water-laden oil can be pumped without wear or plugging.
2. Gyp or mud are easily pumped.
3. Low gravity crudes have been pumped with excellent results. Ten to twelve degree gravity crude has been pumped with ease.
4. Gas as well as liquid can be pumped. Sonic pump will not gas lock.

CONCLUSION

After a review of field operations to date, the following conclusions may be drawn on the sonic method of oil well pumping:

1. Where there is corrosion, there is a possibility of parting tubing. This is also a hazard in conventional pumping, although sucker rod parts are more common. Future development in operation techniques using various corrosion inhibitors should keep tubing parts at a minimum.
2. The oil operator is provided with a simple, durable, and inexpensive means of pumping shallow to medium depth wells.
3. The necessity of continuous repairs has caused extremely high lifting costs in such problem wells as those with high contents of sand, gyp, paraffin, etc. The sonic pump will economically produce these wells.