LINER CEMENTING EQUIPMENT AND TECHNIQUES

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INTRODUCTION

A liner is any string of casing with its top below the surface of the well. Previous papers have been written on the subject of liner cementing, but most of these papers on liners have emphasized their use in deep wells. Simpler uses of liner cementing equipment should also be discussed, since greater numbers of liners have been run in shallow-to-moderate depth wells than in deeper wells.

A discussion on conventional and special liner cementing jobs with illustrations of the equipment for these jobs is included in this paper. Problems concerned with liner movement during cementing are discussed.

SHORTER LINERS SET ON BOTTOM

Probably the simplest and least-expensive way to run a short liner is to set it on bottom (Figure 1). If the hole is not washed out badly, the liner cannot bow or buckle enough to do harm. Generally, a liner hanger is useful in preventing bow or buckle by keeping the liner straight and preventing weight loading on the bottom section of the liner. When the weight of a liner is not too much, a liner hanger is not necessary.

The amount of bow which may be tolerated can be calculated by the following equation by Lubinski *et al.*[1]

$$P = \pi \sqrt{\frac{8EI}{F}}$$

where:

P = pitch of the helix in inches

$I = \frac{\pi}{64}(\text{O.D.}^4 - \text{I.D.}^4)$

F = Weight, or force, in pounds

$E = 30 \times 10^6$ (for steel)

The amount of weight which may be tolerated may be calculated by another equation used by Lubinski *et al.* This equation calculates the stress present at the outer wall of the pipe, where excessive bending causes yielding before internal or external pressure is added.

$$S_o = \frac{F}{A_s} + \frac{DrF}{4I}$$

S_o = stress at the outer wall in psi

A_s = cross-sectional area of the pipe, in^2.

r = radial distance between the pipe and hole in inches

D = outside diameter of the pipe in inches.

The stress at the outer wall of the pipe, S_o, must be less than the minimum yield stress of the pipe, S, in psi.

When, according to these calculations, helical bow is expected, a liner hanger should be used.

The angle between the axis of a helically buckled liner and the axis of the open hole, α, can be calculated from the following formula.

$$\tan \alpha = \frac{2\pi r}{P}$$

Although there is apparently no standard of reference for the maximum-acceptable value of the angle, bow angles in excess of 2 degrees have been found to cause trouble.

The liner-setting tool (Fig. 2) has a connection below for the packoff seals on the tailpipe extending to the bottom of the liner close to the float shoe. The float shoe is usually side-ported in case of fill on the bottom, and it has cross webs or fins to make it hold or bite the bottom of the hole, facilitating easy release of the liner-setting tool. A rubber pump-down plug is released after the cement is mixed. This plug follows the cement slurry all the way to a shear-open sleeve on the bottom of the tailpipe, so the running-in string can be pulled dry. In some very low BHP wells, the rubber pump-down plug can be stopped at the bottom of the tailpipe on a seating nipple, which does not open; the running-in string is then pulled wet to prevent the dumping of displacement fluid in the hole.

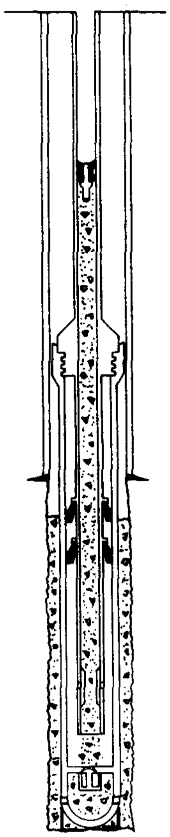

FIG. 1—CEMENTING LINER WITH LINER SET ON BOTTOM

LINER PUDDLING JOBS

The same setting equipment shown in Figure 1 may be used to run liner puddling jobs. The puddling job is one in which long-life cement, usually 24-to-36 hours setting time, is first spotted in the hole through the drill string; the drill string is then removed, and the liner is run through the wet cement, reciprocated a few times, and landed. The excess cement may be reversed out as desired. The slurry used in long-life puddling jobs should be a densified very low water-loss cement. Puddling is a good method for cementing liners in older existing open-hole completed wells with big washed-out sections or in wells which are difficult to cement in a conventional manner.

LINER HANGERS

Liner hangers are either mechanical-set(Fig. 3) or hydraulic-set (Fig. 4). A liner hanger may have more than one set of cones and slips (Fig. 5). The main benefit cited for using more than one set of slips on a hanger is greater slip-holding capacity for longer, heavier liners. A greater advantage may be the increased by-pass area around the slips during cementing, which can be beneficial in eliminating bridging as well as in reducing pressure loss.

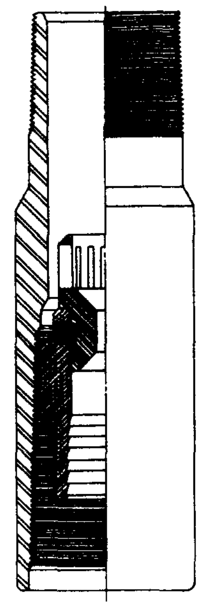

FIG. 2—LINER SETTING TOOL

The mechanical-set liner hanger is set by turning the drill pipe or running-in string to disengage a jay-slot setting mechanism, permitting the slips to wedge out from the cone to the casing. The hydraulic-set liner hanger (Fig. 4) is set by creating enough hydraulic pressure inside the hanger mechanism to move the slips up against the cone to the casing. Most of the time, this pressure is created by dropping a brass ball to land in a shear-out sub at the

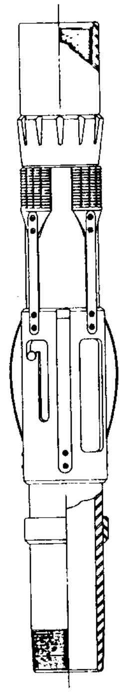

FIG. 3— MECHANICAL-SET LINER HANGER SINGLE CONE

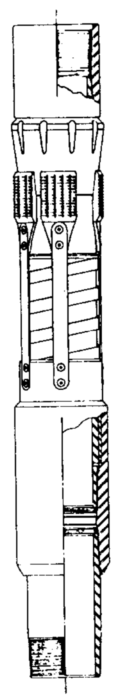

FIG. 4—HYDRAULIC-SET LINER HANGER SINGLE CONE

bottom of the liner, just above the float equipment (Fig. 6). There are several factors to be considered in selecting the method of setting the liner hanger. A mechanical-set hanger costs less than a hydraulic-set hanger. The mechanical hanger may be constructed

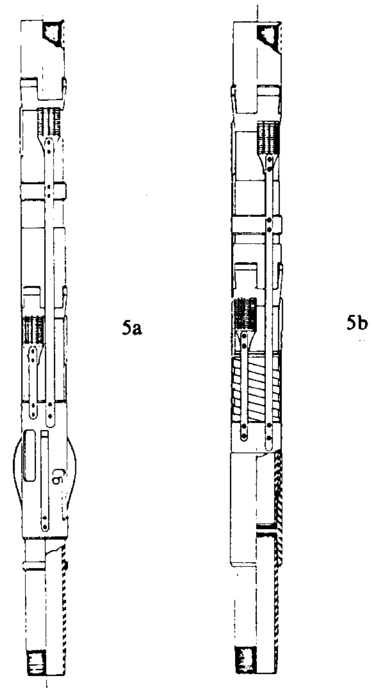

FIG. 5a—TANDEM CONE MECHANICAL-SET LINER HANGER
FIG. 5b—TANDEM CONE HYDRAULIC-SET LINER HANGER

with an integral one-piece barrel capable of holding higher pressures than a hydraulic-set liner hanger, which must depend on some type of elastomer seal to hold high pressures applied during cementing or stimulation. The mechanical-set hanger can be fluted more easily than a hydraulic-set hanger. The hydraulic-set hanger has a cylinder which cannot be fluted.

The primary advantage of a hydraulic-set hanger is ease of setting. It can be set in deviated or crooked holes much more easily than the mechanical-set hangers. The hydraulic-set hanger does not have friction or wiper springs to break off during entry of liners previously in the well. Often liners become difficult to move after they reach bottom, because of hole-friction drag; hydraulic hangers may still be set, even though the liner is stuck on the bottom. The hydraulic-set hanger is desirable when a stub liner is hung because the tie-back seal nipple must be landed before the hanger is set and not moved after placement in the receptacle.

SLIP LOADING

An important consideration in the selection of a hanger is slip area. The slip-loading against the

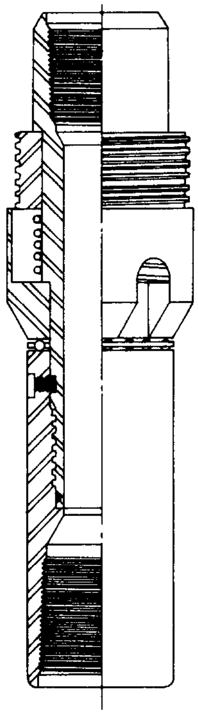

FIG. 6—LANDING COLLAR WITH BALL & SEAT SHEAR ASSEMBLY

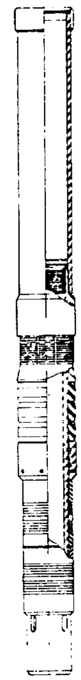

FIG. 7—LINER TOP PACKER

casing must not be excessive. The hanging of a liner is a wedging action, and the hanger slips are forced straight out against the supporting casing string. This force exerted upon the supporting casing can be excessive and cause the pipe to yield. The liner should be hung in a section of casing which is not likely to be worn by drilling, usually about 300 feet up in the supporting string. A casing caliper is sometimes used to aid in this judgment.

A simple formula for the calculation of the horizontal component or force against the supporting casing is as follows.

$$F_h = \frac{W}{2 \tan (\theta + \phi)}$$

where:

F_h is the horizontal component in pounds.

W is the weight of the liner in pounds.

θ is the angle of the cone.

ϕ is the angle whose tan is equal to the coefficient of friction between the slips and the cone in a particular well fluid.

In water muds $\phi \approx .2$

The F_h is divided by the supported slip area to determine whether loading is excessive.

LINER PACKERS

Packers often are run above the liner hanger to seal off the annulus between the liner and the supporting casing string. Liner packers originally were made of canvas and intended for low-pressure applications. For example, after the slurry is placed and the plugs bumped, the packer can be set, and excess cement reversed out of the hole. The packer has to hold only the circulating pressure while reversing out. This liner-packer application is still very popular. Modern liner packers have better sealing elements, such as nitrile rubber and lead, and are used for some higher pressure applications such as liner-squeeze jobs. Liner-squeeze cementing jobs are sometimes helpful in shutting off the gas cap in a high gas-to-oil ratio well, or in isolating a water flow—jobs difficult to accomplish in conventional liner cementing jobs.

In a liner-squeeze job, the cement slurry is displaced only part of the way down. Usually 5-20 bbl. are left in the pipe, the packer is set, and the remaining cement is block-squeezed into the open hole below the packer. This type of squeeze usually is performed at relatively low pressures, 2000-3500 psi, but the packer must have hold-down slips to prevent the liner from pumping up the hole.

Recently, liner packers have been used in a few instances to hold migration of high-pressure gas in deep wells. After the slurry is placed opposite a high pressure gas zone, the gas sometimes migrates through unset cement, "honeycombing" the cement column, causing leakage of gas into the annulus above the liner. A liner packer can be used in some cases to hold this type of migration. Extreme caution should be used in these applications. The liner-packer sealing elements can be damaged by well fluids, and cement slurry circulated during the job, possibly causing a packer failure.

A new way of handling potential and existing liner top-leaks is the use of special liner-top packers (Fig. 7), which can be inserted into a honed-out liner receptacle on top of the liner, sealing the annulus. The liner top-packer is more reliable than liner packers which are run with the liner and which may be damaged during cementation.

LINER CEMENTING

Most liner jobs are cemented by use of the two-plug system. The liner wiper plug is shear-pinned to the bottom of the liner setting tool (Fig. 2), and the slurry is followed by a smaller pump-down plug contained in the liner-cementing mainfold. When the cement is mixed and pumped into the drill pipe or tubing, the top plug is released and follows the cement, wiping the carrying string, until it latches into the liner wiper plug; an increase in pump pressure shears the pins, releasing the wiper plug; both plugs then perform as one plug, wiping behind the cement until they latch into the landing collar (Fig. 8).

The setting tool is then removed from the liner, and the running-in or carrying string is removed from the well. If the cement column has not filled up enough of the liner-hole annulus, the liner top is then squeezed. A retainer is set 75-to-100 feet above the liner, and the area behind the liner is squeezed. Ideally, but rarely ever, the two cement columns are joined.

LINER CEMENTING PROBLEMS

The nature of most liner jobs dictates running as large a liner as possible. The clearance between the liner and open-hole is sometimes very close, such as a 7-3/4-inch OD liner in an 8-1/2-inch open hole, and displacement of all of the mud from behind the liner becomes very difficult because the pipe cannot be centralized. This closeness inhibits rotation or movement of the liner. Experience has shown that these close-tolerance liner jobs cause more cementing "fill" problems, such as channeling and gas migration, than do jobs with normal clearances where centralization is used.

LINER RECIPROCATION

Pipe movement is widely recognized as a definite aid in obtaining efficient mud displacement in any cementing job. Liners are much more difficult to reciprocate or rotate during cementation because of the risk of premature release of the setting tool and because of slim crooked holes present in many wells drilled in "hard-rock country." Occasionally, an operator is willing to take this risk, usually because he has "tried about everything else" and still has trouble getting a good cement job. In a problem cementing area where reciprocation is desired, the liner hanger is often constructed with an extra long barrel so that the slips can be set first and the liner moved up and down 5-to-15 feet without accompanying movement of the slip cage in the pipe. The setting tool must be released from the liner after completion of the cement job. This release is accomplished without difficulty almost always but it certainly jangles the nerves when wet cement is up around the drill pipe.

LINER ROTATION

The equipment used in liner rotation (Fig. 9) is usually much more sophisticated than that used in liner reciprocation. A power swivel with plug-release features is used on Gulf Coast jobs where the liners are short (up to 2000 ft) and the liner-hole clearance is a good (1-1/2 inches or better). Many successful liner-rotation cementing jobs have been performed in the Gulf Coast oil producing areas.

In the Mid-Continent and Rocky Mountain "hard rock country" areas, liner rotation has not been popular, possibly because (1) the liner-hole clearance is usually less than an inch, (2) the holes are more crooked, and (3) long shale sections are common in most liner jobs in deep wells.

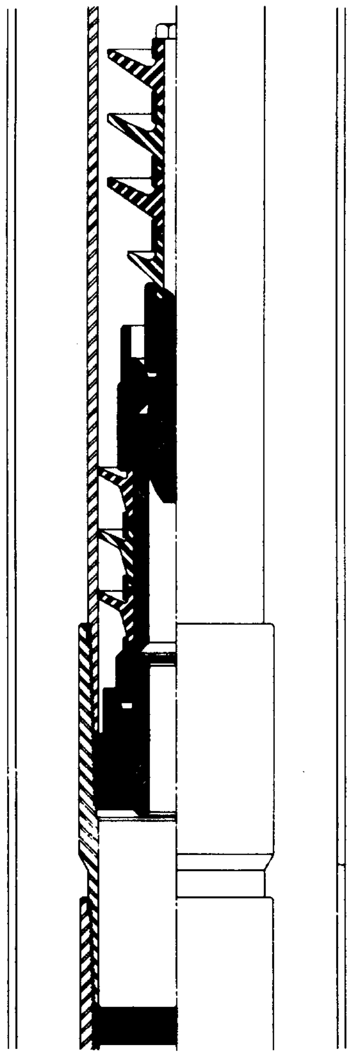

FIG. 8—LINER WIPER PLUG AND PUMP DOWN PLUG LATCHED IN LANDING COLLAR

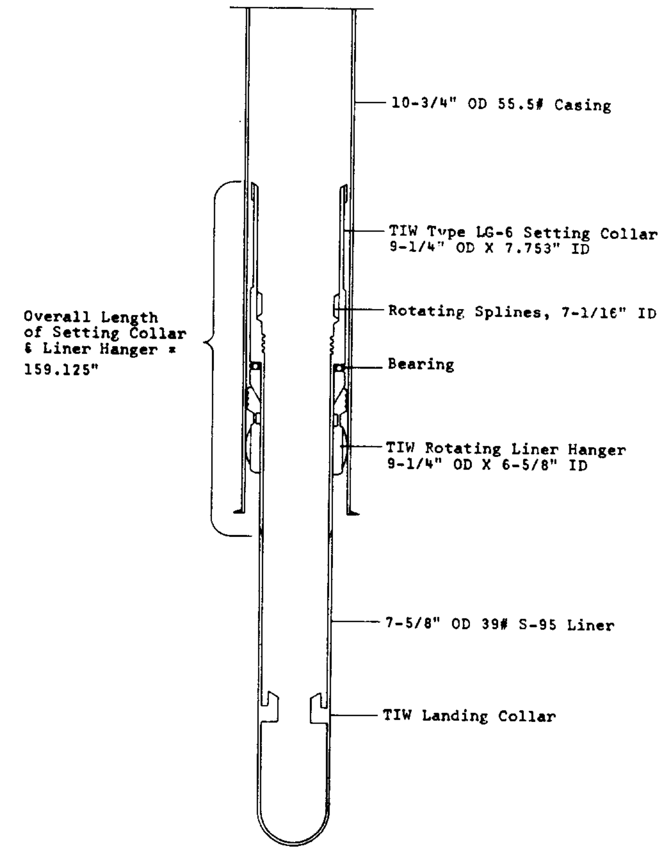

FIG. 9—LINER HANGER, ROTATING TYPE SCHEMATIC ASSEMBLY

CONCLUSION

Some authorities believe that liner movement during cementation is becoming more popular. Perhaps this is so in some areas, such as South Louisiana; however, it is not used in more than 1 out of 30 liner jobs performed in "hard-rock country." The operator should not be afraid to use this procedure when conventional liner cementing techniques have not had a high ratio of success. For example, sometimes a three-arm caliper survey indicates that an elliptical hole has been drilled, and, if the liner is lying on the low side (as it is 98 percent of the time), there is no way total mud displacement and cement implacement can be accomplished without moving the pipe. One can only hope to have enough good bonding at critical spots, which usually is sufficient. In slim hole-clearance liner jobs, some case can be made for the use of oil-base mud, which is reported to be a great aid in drilling a true round full-gauge hole.

The key to any successful casing cementing job is hole stability. In most liner-cementing jobs, hole stability is difficult to obtain, because of the clearance around the liner and the lack of proper cementing aids. A vigorous control of pumping rates is important in liner cementing if hole washing, bridging, cement fluid loss, early plug arrival, and lost circulation are to be prevented. It is no mere cliche that good planning minimizes problems in liner cementing.

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