HYDRAULICALLY OPERATED STAGE CEMENTER IMPROVES CEMENTING OPERATIONS

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ABSTRACT

A recently developed hydraulically operated (HO) stage cementer has proven beneficial in cementing both vertical and horizontal wells. Although the tool was developed primarily to aid in cementing highly deviated and horizontal wells, its application in any situation calling for a stage cementer can be beneficial.

1. In operations where a free-fall opening plug (bomb shaped) is normally used, the waiting time for free fall to the plug seat is eliminated, saving rig time and allowing for continuous circulation of the hole. These cementers can be opened immediately, which is beneficial in those applications in which first stage cement is brought above the cementer.

2. If a displacement plug (pump down style) is normally used, the need is eliminated for excess cement in the casing to ensure that the first stage is not over-displaced, saving drill out time after cement is set. In this configuration, a positive check of float equipment for secure holding can be made.

The cementer is designed to monitor annulus pressure and internal pressure. When internal pressure reaches a predetermined level above annulus pressure at the tool, the cementer opens and circulation begins for the second stage. The cementer is closed by a conventional closing plug.

This paper presents discussion of HO stage cementer operation, options available with the cementers, job design, and results of actual job conduct using these methods.

INTRODUCTION

Multistage cementing consists of conventional placement of cement slurry around the lower part of a casing string, followed by placement of successive upper stages through perforations, or through ports in a cementing tool, after the lower section has been cemented.[1] Most multistage cementing is done in two stages, however additional stages are possible.[2]

Stage cementing is useful in the applications listed below.[1-6]

1. Where a long column of cement is required and one or more of the formations encountered by the column will not support the hydrostatic pressure of the column prior to set of the cement.

2. Where two or more widely separated intervals must be cemented.

3. For suspending casing below base of permafrost.

4. In deep, hot wells where different cement characteristics may be needed in separate sections of the well. For example, retarded cement designed for high temperature may not set if circulated to low temperature zones of the well.

5. Where zones contain corrosive fluids and/or sour gas that could migrate to fresh water zones, stage cementing is an economical alternative to setting short strings of casing.

6. In general, stage cementing allows strings to be cemented in shorter intervals, relieving both hydrostatic and friction pressures exerted on weak formations, minimizing cement contamination, and improving cement circulation, coverage, and bonding for upper formations. The longer the column of cement and well fluid in the annulus, the greater these pressures. Stage cementing contains these pressures by controlling the length of intervals between stage collars.

7. Cementing between a high pressure gas zone and lost circulation zone.

8. Cementing a full hole of slotted or perforated liners.

Operation of a conventional multiple stage cementing tool requires landing a plug to open the tool for the second stage of cement (Fig. 1). As reported by Smith,[6] the maximum angle of well deviation at which the plug can reasonably be expected to fall is about 30°. Deviation greater than 30° will probably cause the plug to hang up at a collar, thus requiring the plug to be pushed to the tool by a wireline sinker bar or workstring.

Many factors, including viscosity and density of the fluid in the casing, as well as hole deviation, will affect the falling rate of the opening plug.[6] A good rule of thumb is to allow 1 minute for each 200 to 400 ft of depth.[6]

Development of the hydraulically operated (HO) stage cementer was begun to deal with (1) the problem of opening the stage cementer in a deviated well, and (2) to eliminate excess time spent waiting for opening plugs to fall through viscous drilling mud even in vertical wells.

DESIGN

Design parameters given for the HO stage cementer were that it (1) could be run to any depth and hole deviation angle, and (2) could be opened by hydraulic pressure applied inside the casing after landing of the first stage shutoff plug.

The HO stage cementer is similar in many ways to a conventional stage cementer, and will perform as a conventional tool if desired, even utilizing the same opening plug. The HO tool has a differential area in the opening sleeve which monitors both internal and external pressures. Shear pins keep the opening sleeve anchored, and the number of shear pins installed determines the opening pressure.

Application of pump pressure to the casing ID opens the tool when pump pressure at the tool exceeds the opening pressure.

Other design characteristics of the HO stage cementer are listed below.

1. Closed by a standard closing (displacement-type) plug.
2. Can be opened by a free-fall plug.
3. Entire opening sleeve, releasing sleeve, and closing plug are drilled out.

OPERATIONS

A standard casing configuration for running the HO stage cementer in on a two-stage cementing job is shown in Fig. 2. On this job, floating equipment for the first stage of cement is run in with the shutoff baffle for the first stage directly on top of the floating equipment. This means that a first-stage bottom plug cannot be run. It is necessary to install the shutoff baffle directly on top of a piece of floating equipment for the baffle to have sufficient backup to be able to hold the pressure required to open the HO stage cementer. If it is not possible to pressurize the casing string on top of the first-stage shutoff plug, the HO stage cementer must be opened using a standard free-fall opening plug.

The HO stage cementer can be installed at any point in the casing string above the first-stage shutoff baffle. This is different from a standard stage cementer that requires a minimum distance from the first-stage shutoff baffle to the opening seat in the cementer. This variation is due to the requirement of a standard cementer that enough fluid is compressed between the cementer and the shutoff baffle to allow the opening sleeve with an opening plug in it to travel down far enough to expose the ports in the cementer.

The opening sleeve in the HO stage cementer has a differential area associated with it that allows pressure applied above hydrostatic to act across this area and load the shear pins holding the opening sleeve closed. The number of shear pins is preset at the factory but can be field adjusted to give the desired nominal opening pressure.

After casing is run to bottom (Fig. 3) any necessary circulation and/or application spacers or flushes can be done prior to running the first stage of cement. After the first stage of cement is mixed and pumped, the first-stage shutoff plug (top plug) is released and displaced down to the shutoff baffle. Once the plug is in the baffle, any pressure applied above the circulation pressure will begin to load the pins in the opening sleeve and try to open the cementer. This allows freedom to pump cement above the cementer on the first stage without concern that the cement will set up before a standard free-fall opening plug has time to fall down to allow for opening the cementer.

Once the plug has landed (Fig. 4) pressure can be released if desired to determine whether the float collar or shoe is holding for the first stage of cement. If so, pressure can be immediately re-applied to open the HO stage cementer and circulate out any excess cement on the first stage and wait for the first stage to set up.

Because the HO stage cementer has a differential area inside, opening pressure can be affected by two possible situations.

1. If cement is brought up over the cementer ports on the first stage and displacing fluid is lighter than cement, hydrostatic difference between cement and displacing fluid must be added to the nominal opening pressure to calculate the true opening pressure. This is because hydrostatic pressure difference acts through the cementer ports in such a way that they work to keep the tool closed. This pressure must be overcome before load will be applied to shear the opening pins.

2. If the HO stage cementer is being used in conjunction with an external casing packer to combat lost circulation, the fluid level may be low in the annulus. This can cause the cementer to open at a pressure lower than nominal because more hydrostatic pressure is available inside the tool trying to open it than there is outside the tool trying to keep it closed.

Once the HO stage cementer is opened and excess cement from the first stage circulated out (Fig. 5) the second stage of cement can be mixed and pumped. It is followed by the closing plug which is pumped down to the cementer.

After the closing plug is pumped down to the cementer, pressure is applied which will shear the pins holding the releasing sleeve in place and allow it to move out from under a set of collet fingers on the closing sleeve (Fig 6.). Once the collet fingers are retracted, the closing sleeve will travel down with continued pressure and isolate the ports in the outside case with a set of seal rings. Additional travel will cause a set of lock rings on the closing sleeve to engage and lock the cementer closed.

The amount of pressure required to completely close the HO stage cementer is dependent on the relative distance between the cementer and the shutoff baffle. If the distance is small, i.e., less than 100 ft, pressure required to completely close the HO stage cementer will be about 1000 psi higher than nominal. This is usually not a problem since operators normally land the closing plug with 1000 psi additional just to make sure the plug is seated and the cementer closed.

After the second stage of cement is set up, the HO stage cementer can be drilled out (Fig. 7). All materials within the drift diameter of the tool can be drilled with conventional bits and procedures. An advantage of the HO stage cementer in drilling out is that the standard free-fall opening plug is not in the cementer, which lessens drillout time.

CASE HISTORIES

Case 1. A major operating company had significant lost circulation to a permeable zone which had a gas cap pressure of 460 psi. An HO stage cementer run above an inflatable packer was selected to cement the well in two stages.

Well Data:

Depth	1507 ft
Surface casing	8 5/8 in. OD to 1070 ft, hole underreamed from bottom of surface casing to total depth
Casing	7 in. OD to 1502 ft
HO stage cementer	1040 ft, with inflatable packer immediately below

The special slim-hole isolation packer allowed for isolation of the gas-producing zone and lost circulation away from the portion of slurry that would be in the surface casing. Using the HO stage cementer, the first stage of cement was run up over the lost circulation zone and the gas cap. Once the first stage was in place, pressuring up on first-stage top plug allowed the packer to inflate and isolate the gas from the surface. Additional pressure opened the cementer and permitted the second stage to be completed without gas-cutting the slurry.

Calculated opening pressure for the cementer, allowing for hydrostatic difference between the displacing fluid and cement outside the casing was 2235 ft. Actual opening pressure on the job was 2200 psi. Calculated opening pressure on shear pins in the tool was 1483 psi; tool closed at 1200 psi.

Two more jobs of this nature were run for the same operator, with similar results.

Case 2. Well Data:

Production casing . . . . . 7 in. OD to 2435 ft
HO stage cementer . . . . . 2372 ft
External casing packer . . 2386 ft

In this case, a production casing string was cemented using an external casing packer to control lost circulation. The HO stage cementer was used to circulate out excess cement left from the packer inflation process. This circulation helps remove danger of cement setting up inside casing string prior to displacement of the main cement slurry.

To cement the well, casing was run to bottom and the shutoff plug, followed by cement to inflate the packer, was pumped down to the shutoff baffle. When the shutoff plug landed, pressure was immediately applied to inflate the packer. Increased pressure after the packer was inflated locked the packer closed and allowed the cementer to open to circulate out excess cement. Calculated opening pressure was 1845 psi; a pressure of 2500 psi was required to open the tool. This discrepancy was attributed to stiffening of internal lubricants of the cementer, due to cool temperatures. After cement displacement, a pressure of 2000 psi was placed on the tool to ensure that it had closed.

Case 3. Well Data:

Casing . . . . . Production casing 5 1/2 in. OD to 8536 ft

HO cementer . . 4002 ft

A major oil company was cementing a standard string of production casing and wanted to use the HO stage cementer to save drillout time. This time savings is the result of not using a free-fall opening plug (commonly called the opening bomb). Not having to drill up this piece of equipment normally has saved an average of 30 minutes to an hour of drillout time for the cementer. When the job was conducted, the calculated displacement for the shutoff plug was pumped following the first stage of cement. When the shutoff plug did not land, an additional 2.5 percent of displacement was pumped and no pressure indication was seen. Because the casing extended to surface, a standard free-fall opening plug was dropped and allowed to fall to the cementer. Pressure was applied and the tool opened with 700 psi. The second stage was pumped and the tool closed with 1200 psi. A consensus among the people on location was that an additional amount of displacement on the first stage, to allow for aerated mud, would have allowed the job to proceed as designed.

CONCLUSIONS

1. Use of a hydraulically operated stage cementer is feasible and beneficial in cementing vertical and deviated wells.

2. Cementers of this type can be applied in any condition for which a conventional stage cementer is appropriate.

3. Rig time is saved due to (a) elimination of time spent waiting for opening plug to drop, and (b) reduced drillout.

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ACKNOWLEDGEMENTS

The authors thank the management of Halliburton Services for permission to present this paper.

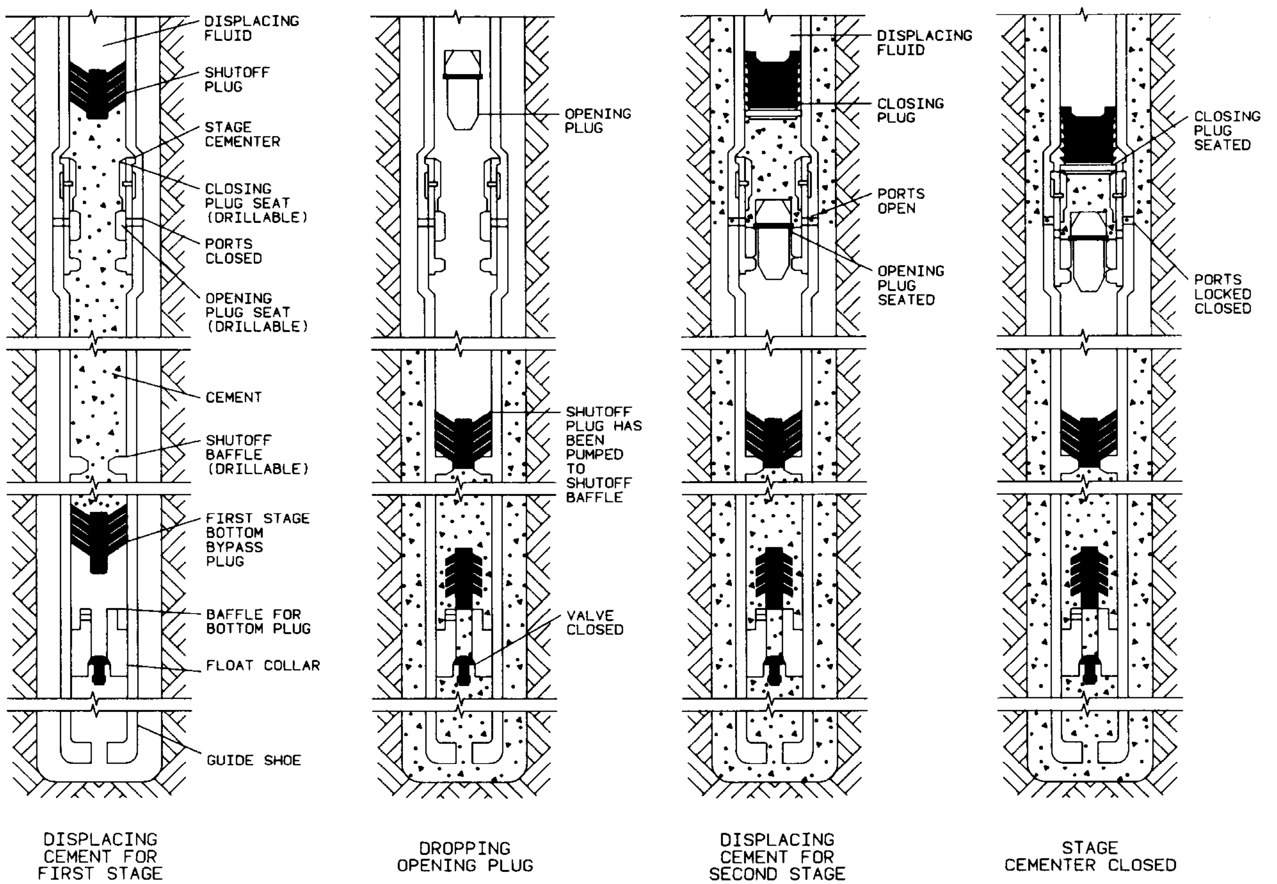

Figure 1 - Two-stage cementing with conventional stage cementer

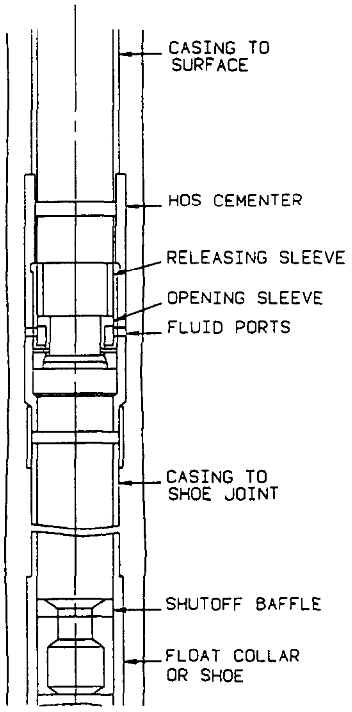

Figure 2 - Running in the hole with HO stage cementer

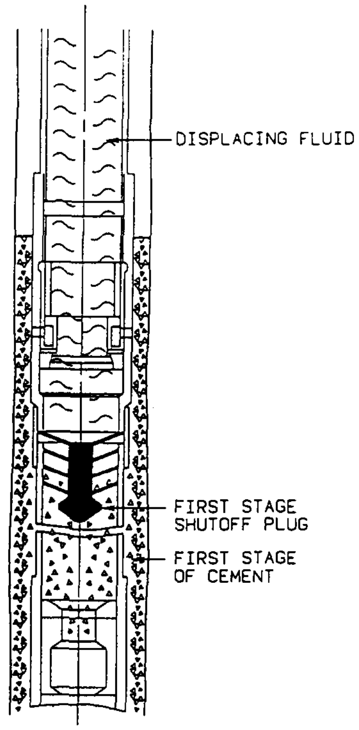

Figure 3 - Pumping first stage of cement

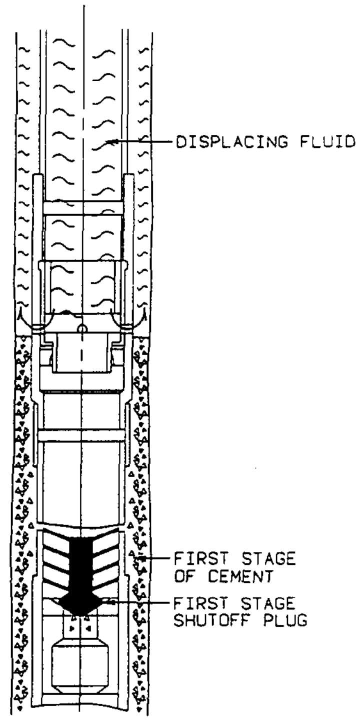

Figure 4 - Shutoff plug landed and HO stage cementer opened

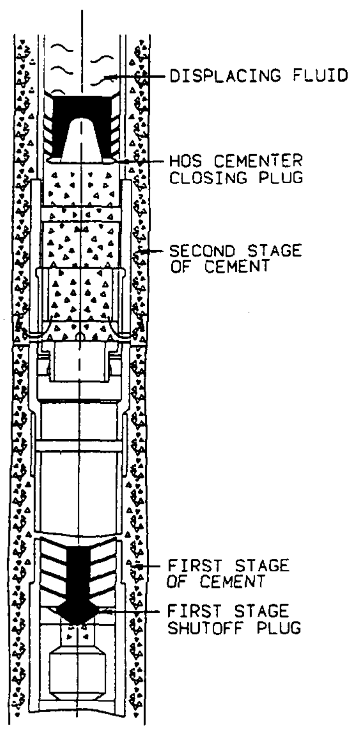

Figure 5 - Pumping second stage of cement

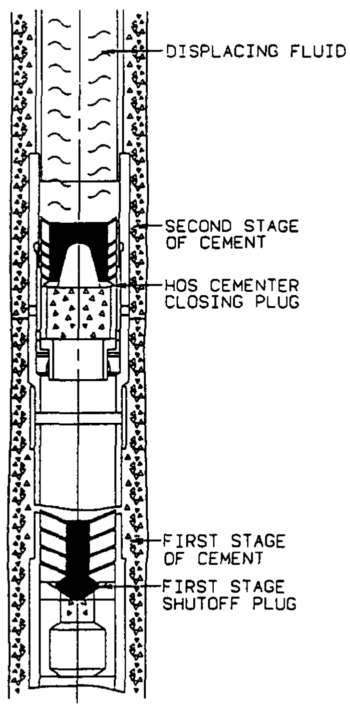

Figure 6 - Cementer closed, second stage completed

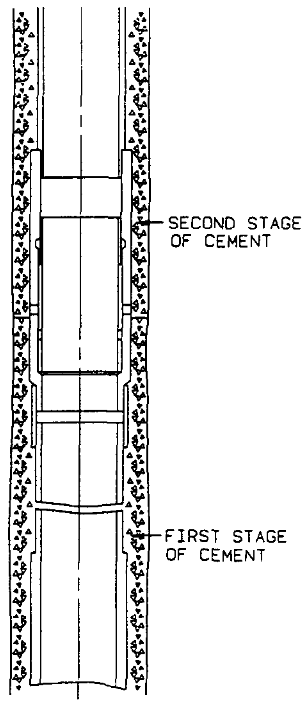

Figure 7 - Drillout complete