

Drifting Cement Plugs for Geothermal Wells

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Keywords: cement plug, balanced plug, drift plug, geothermal cementing, lost circulation

ABSTRACT

Loss of circulation while drilling a Geothermal well is very common, because typically geothermal formations are highly fractured or poorly consolidated; these conditions inherently lead to lost circulation. These potential 'thief' zones may allow drilling fluid (and later, casing cement slurry) to enter the formation instead of circulating back to surface

When losses occur, lost circulation material is typically applied first, followed by cement plugs. Lost circulation cement plugs are used to isolate the well bore from highly porous or fractured zones that are under-pressured.

Cement plugs may be used to seal lost circulation zones, allowing drilling to continue through and below the loss zone with good returns to surface. Innovative drift plug technologies may be used in place of conventional balanced plug methods, achieving better results in severe loss zones.

1. INTRODUCTION

Lost circulation plugs are used to isolate the well bore from highly porous or fractured zones that are under-pressured. These potential 'thief' zones may allow drilling fluid (and later, casing cement slurry) to enter the formation instead of circulating back to surface. A lost circulation cement plug creates a seal between a specific zone and the well bore. However, setting a cement plug presents risks. Plugs are emplaced through drill pipe, and the use of improper procedures and techniques can result in drill pipe filled with set cement or, worse yet, drill pipe cemented in the well bore.

Some lost circulation zones (LCZ) are not effectively sealed with a conventional balanced plug. Instead, drift plugs are more effective, particularly when severe total loss zones are encountered. Balanced plugs are briefly discussed for background; however, drift plugs, the procedures for setting them, and their benefits are the main focus of this discussion

2. BALANCED PLUGS

Cement plugs that are emplaced using the balanced method are commonly referred to as 'balanced' plugs. The balanced plug method consists of pumping a desired quantity of cement slurry through drill pipe or tubing until the level of cement outside is equal to that inside the string (Smith, 1990; Figure 1). This process typically involves running the drill pipe past the loss zone and displacing cement as a balanced plug across, into and above the loss zone. Sometimes, a reactive flush with a small water spacer is pumped ahead of the cement (the density and volume of the flush should be accounted for while calculating the displacement of the balanced plug). Balanced plugs are effective where the loss rate is low enough that the cement stops moving into the formation long before it sets. The success or failure of a conventional balanced plug is totally dependent on the cement remaining static within the well bore. Reactive flushes are sometimes very effective in stopping the movement of the cement.

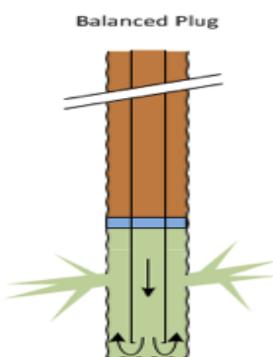


Figure 1: Cement Balanced plug

2.1 Procedure for Setting a Balanced Plug

1. Run the drill pipe past the LCZ and ensure the hole is clear.
2. Circulate at least one full drill pipe volume of mud or water to clear the drill pipe.
3. Pump sufficient volume for a 100-270 linear foot plug as indicated by the rate of loss, hole size, cement blend chosen and rig capabilities.
 - a. After mixing and pumping cement, the slurry should be displaced at maximum rate. Displacement should be calculated to leave the top of cement inside of the pipe just above the balanced point to ensure a “dry job” while pulling out of the hole.
 - b. The drill pipe should be moving at all times while pumping. By keeping the pipe moving at all times the driller can usually tell if the hole is getting ‘tight’ (a precursor to getting stuck) and may abort the job at any time to avoid cementing the drill pipe in the hole.
4. Pull drill pipe out of hole at a steady, smooth rate.

The equation for finding the height of a balanced plug with pipe in the hole is:

$$h = \frac{N}{(C+T)} \quad (1)$$

where h is height of balanced cement column (ft), N is cement slurry used (ft^3), C is volume per linear foot between tubing (or drill pipe) and casing (or hole; $\text{ft}^3/\text{linear ft}$) and T is volume per linear foot inside tubing (or drill pipe; $\text{ft}^3/\text{linear ft}$) (Halliburton Services, 2012).

3. DRIFT PLUGS

A drift plug is a cement plug that is emplaced in the borehole above a loss zone and allowed to drift down into the loss zone as a single mass of cement. Drift plugs are not suitable for partial loss zones and should only be used where total losses are encountered. Drift plugs are very effective in treating severe total lost circulation. The drift plug is displaced like a hydraulic piston; the displacement is balanced so that the plug stops moving after some of the cement has entered the loss zone. After placement of a drift plug, the slurry ‘drifts’ into the loss zone, filling channels of the zone where it will set after it stops moving.

If a plug of cement is to be left in the hole above the severe LCZ, the hydrostatic pressure of the mud-cement column must equal the original hydrostatic pressure before the cement plug was emplaced. The original hydrostatic pressure is the maximum pressure that the loss zone will support after the cement plug is placed and before the cement sets. The hydrostatic head is equal to the pressure in the loss zone. The pressure in the loss zone cannot be changed by a drilling rig. We can pump enough to change the fluid level in the well and the hydrostatic in the wellbore. However, once pumping stops, the fluid level will return to equilibrium with the pressure in the loss zone.

To design and set the drift plug, find the parameters of the process that will affect the plug. These parameters are the static fluid level in the well bore, mud density, and cement slurry density. Determine the desired vertical length of the plug. The density differences determine the displacement estimate. The static fluid level, and pipe and hole diameters, affect the volumes required for the plug.

The fluid level in the well will drop a distance equal to the increased hydrostatic head imposed by the cement on the well bore. The new fluid level in the open hole can be calculated as:

$$L_{\text{new}} = L_{\text{original}} - \left[\frac{\rho_{\text{mud}}}{\rho_{\text{cement}}} \times L_{\text{plug}} \right] \quad (2)$$

where L_{new} is the new fluid level, L_{original} is the original fluid level, ρ_{mud} is the mud density, ρ_{cement} is the cement density, and L_{plug} is the length of cement plug.

The pipe displacement volume is estimated in the field via routine volume calculation. Only the drill pipe from the top of the new fluid level must be displaced.

$$D_{\text{total}} = [(L_{\text{pipe}} - h_{\text{balancedplug}} - L_{\text{new}}) \times C_{\text{pipe}}] \quad (3)$$

where D_{total} is the total volume of displacement, L_{pipe} is the length of the pipe string, $h_{\text{balancedplug}}$ is the top of the balanced plug, L_{new} is the new fluid level after plug emplacement, and C_{pipe} is the capacity of the pipe (ft^3 per linear ft). A truly accurate calculation is not feasible because the new fluid level, L_{new} , cannot be measured while pumping the plug. This leads to some contamination of the cement plug and, therefore, significant excess is recommended.

3.1 Procedure for Drift Plug

1. The first step to properly emplace a drift plug is to determine the static fluid level using a floating ‘bob’ on wireline (Figure 2) inside of the drill pipe or a similar method or estimate the fluid level from changes in pump pressure.

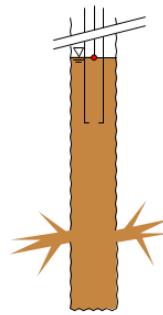


Figure 2: Static hole.

2. Run open-ended drill pipe with a saw tooth or run a bit past the loss zone to make sure it is not covered with fill. Wash through the loss zone if it is obstructed, then short trip to ensure it stays open (Figure 3)

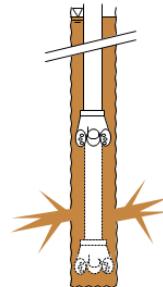


Figure 3: Cleanout past the LCZ

3. Pull out of the hole for a diffuser on open-ended drill pipe. (The diffuser is especially important in larger diameter holes. A cement diffuser is simply a cut off piece of drill pipe plugged, and bull nosed on the bottom with several holes cut around the circumference, Figure 4).

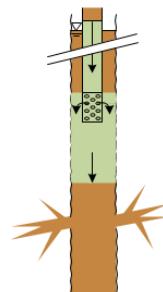


Figure 4: Pumping drift plug.

4. Run in the hole and set the diffuser at the nearest point, in even joints, above the LCZ (experience indicates that this is the most effective depth).
5. Pump the determined volume of cement and displace as calculated above. (The diffuser holes divert the cement flow in a lateral direction, instead of vertically, to form a piston-like plug in the borehole, Figure 5)

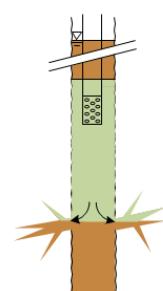


Figure 5: Displaced drift plug.

- a. After mixing and pumping cement, the slurry should be displaced at maximum rate. Displacement should be estimated to leave the hydrostatic head inside the pipe as nearly equal to the hydrostatic head outside the pipe as possible.
- b. The drill pipe should be moving at all times while pumping. By keeping the pipe moving at all times the driller can usually tell if the hole is getting 'tight' (a precursor to getting stuck) and may abort the job at any time to avoid cementing the drill pipe in the hole.
6. After displacing the slurry by the estimated amount into the well bore, pull out of the cement with the drill pipe at a steady rate, while allowing the hydrostatic head inside and outside of the pipe to equalize (Figure 6)

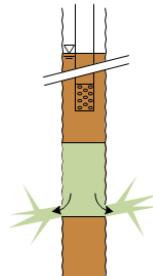


Figure 6: While pulling out of the drift plug.

7. Do not pump any additional fluid into the wellbore and allow the plug to drift.

The plug will not drift further down than the lowest point of the loss zone, subsequently the cement will set and produce a drillable interval to continue past the LCZ and proceed with the drilling program (Figure 7).

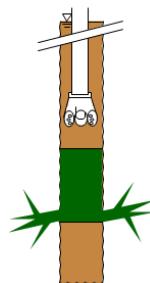


Figure 7: Set to drill out good plug.

4. CONCLUSION

Drift plugs provide better results in severe loss zones than conventional balanced plugs due to balancing the hydrostatic pressure in the well bore. Greater success may be achieved through drift plugs, minimizing the need for multiple plugs with resultant savings in cost and fewer hole-stability problems

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