



HYDRO-PLUG[®] LCM Standard Field Application Procedures

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1. Overview

HYDRO-PLUG® self-expanding lost circulation material (LCM) hydrates with time and temperature. HYDRO-PLUG LCM is pumped in an un-hydrated or partially hydrated state in a fresh water base carrier fluid. The particle size distribution of the pill is designed to pass through measurement-while-drilling (MWD) and other downhole tools. The HYDRO-PLUG lost circulation treatment pills are recommended to prepare only in Fresh water. Rig pumps are normally used to place HYDRO-PLUG LCM; no special equipment is required.

HYDRO-PLUG LCM is designed with a moderately large PSD material; plus the self-expanding component precludes using it as background LCM. It can be applied conventionally as a product in a pill formulated in fresh water even when working with either WBM drilling fluid or OBM on location. It can be applied via sweep, hesitation squeeze or pump-spot-soak operations. The preferred application technique is a hesitation squeeze in a fresh water base pill.

When a lost circulation treatment does not stop the fluid loss, consideration should be given to the following:

- Was the lost circulation pill placed in the proper location?
- Did the pill have sufficient volume/concentration of material?
- Were the type and sizes of particulate material appropriate for the scenario?

When drilling in lost circulation prone areas, it is recommended to run a treating sub in the drillstring. This equipment can be opened/closed multiple times and allows the pumping of large lost circulation material without plugging bit nozzles or small clearances in the BHA. This also insures that arbitrary restrictions from the supplier on the size and amount of LCM that may be pumped through their downhole tools can be overcome.

2. Mixing Table: The SG used for HYDRO-PLUG LCM is 2.0.

Weight SG (ppg)	Water bbl (m ³)	BARAZAN ppb (Kg/m ³)	BAROID ppb (Kg/m ³)	HYDRO-PLUG LCM ppb (Kg/m ³)
9.35 (1.12)	0.883 (0.14)	0.75 (2.14)	2.3 (7.0)	80 (229)
9.5 (1.14)	0.877 (0.139)	0.75 (2.14)	11.4 (33)	80 (229)
10 (1.2)	0.858 (0.136)	0.75 (2.14)	38.9 (111)	80 (229)
10.5 (1.26)	0.84 (0.134)	0.75 (2.14)	66.4 (190)	80 (229)
11.0 (1.32)	0.821 (0.131)	0.75 (2.14)	93.9 (268)	80 (229)
11.5 (1.38)	0.802 (0.128)	0.75 (2.14)	121.4 (347)	80 (229)
12.0 (1.44)	0.804 (0.128)	0.75 (2.14)	162 (463)	60 (171)
12.5 (1.5)	0.785 (0.125)	0.75 (2.14)	189.5 (541)	60 (171)
13.0 (1.56)	0.766 (0.122)	0.75 (2.14)	217 (620)	60 (171)
13.5 (1.62)	0.748 (0.119)	0.75 (2.14)	244.5 (699)	60 (171)
14.0 (1.68)	0.729 (0.116)	0.75 (2.14)	272 (777)	60 (171)
14.5 (1.74)	0.711 (0.113)	0.75 (2.14)	299.5 (856)	60 (171)
15.0 (1.8)	0.702 (0.112)	0.75 (2.14)	333.6 (953)	50 (143)
15.5 (1.86)	0.683 (0.109)	0.75 (2.14)	361.1 (1032)	50 (143)
16.0 (1.92)	0.665 (0.106)	0.75 (2.14)	388.6 (1110)	50 (143)
16.5 (1.98)	0.646 (0.103)	0.75 (2.14)	416.1 (1189)	50 (143)
17.0 (2.04)	0.628 (0.1)	0.75 (2.14)	443.6 (1267)	50 (143)
17.5 (2.1)	0.609 (0.097)	0.75 (2.14)	471.1 (1346)	50 (143)
18.0 (2.16)	0.59 (0.094)	0.75 (2.14)	498.6 (1425)	50 (143)

HYDRO-PLUG LCM is an “Engineered, Composite Solution” (one sack). It can be used alone or as a supplement to other one sack solutions like STOPPIT® LCM and BaraBlend®-680LCM (only when DIAMOND SEAL LCM is not an option). When used alone, supplemental materials may be required to increase the PSD – STEELSEAL® 1000 and WALL-NUT® M are recommended.

3. Mixing Considerations

HYDRO-PLUG LCM should be prepared with good stirring and agitation, but without excessive shear. High shear mixing devices (e.g., cement blenders and powerful centrifugal pumps) should be avoided. Excessive shear may increase the temperature and cause the material to hydrate on the surface. If possible, slow the mixing pump down so that the fluid temperature does not exceed 125°F while circulating.

- **Un-weighted**

- **DO NOT add LIME or CAUSTIC SODA.**
- Mix 80 pounds per barrel (ppb) of HYDRO-PLUG LCM in fresh water, with 0.5 to 0.75 ppb of BARAZAN® viscosifier.
- **Pump immediately.**

- **Weighted**

- **DO NOT add LIME or CAUSTIC SODA.**
- Refer to **Mixing Table** above to prepare required weighted HYDRO-PLUG LCM pill. Mix the required amount of BARAZAN in fresh water and add BAROID® weighing agent to the desired density. Then add suggested amount of HYDRO-PLUG LCM through hopper (run a small stream of fresh water while mixing HYDRO-PLUG LCM, as BAROID weighing agent will absorb some free water).
- **Pump immediately.**

4. Pumping Procedure Summary

Pump the pill and clear the pipe. Pull up into casing or safely above the zone of loss. Apply a gentle squeeze (150-250 psi). HYDRO-PLUG LCM penetrates into fractures and expands to plug the voids. The self-expanding property of this LCM is dependent on temperature. So, consideration should be given to the temperature to which HYDRO-PLUG LCM is being subjected. The table below provides time within which HYDRO-PLUG LCM fully hydrates for specific temperature ranges.

Setting Time:

Temperature	70°F-100°F 21°C-38°C	100°F-150°F 38°C-66°C	150°F-200°F 66°C-93°C	>200°F >93°C
Time	5 – 7 hrs	4 – 6 hrs	3 – 4 hrs	2 – 3 hrs

Cement Plug/Cement Squeeze:

If lost returns occurred while drilling the interval (or during a previous cementing attempt), a HYDRO-PLUG LCM pill can be used to help prevent further losses and achieve a successful cement job.

- **Procedure:** Mix HYDRO-PLUG material as per above mixing instructions, then pump and clear pipe prior to pumping cement. As the cement is pumped, HYDRO-PLUG LCM will penetrate and seal fractures, thus allowing cement returns to surface.

5. Detail Pumping Procedure

When squeezing into a loss zone, the liquid phase (water) is filtered out of the slurry. A firm, dense plug remains within the fracture or permeable zone rather than at or near the face of the wellbore. This promotes “fracture-tip screen-out” and prevents fracture propagation. It also minimizes the possibility of the seal being removed during drilling operations and/or repeated remedial loss treatments. Fresh Water-based pills are required regardless of whether water or oil/synthetic based fluids are being used (DIAMOND SEAL LCM will not hydrate in oil, but will retain the hydration from the water carrier).

The volume of pill mixed and pumped is many times controlled by factors other than the estimated need of what is required. It is safe to say that the initial application should be as large a volume with as high a concentration of material that is practical to mix and place on the specific drilling rig. The greatest unknown in many cases is the actual location of the loss zone. Larger volume pills have a higher probability of success when this is the case.

1. The lost circulation material pill should cover the entire potential lost circulation zone, if at all practical. To insure this is done, mix twice the open hole volume or, if that is not possible, mix twice the volume of the interval to be treated. Ideally, enough slurry should be available to cover all potential loss zones, as well as enough excess volume available for squeezing operations.
2. Begin with approximately 80% of the prescribed volume of water (see Mixing Table). To the water, add BARAZAN®, or an equivalent viscosifier; if mixing a weighted pill, add BAROID® [or, preferably, SWEEP-WATE®, due to its superior particle size distribution (PSD) for lost circulation applications]; add the HYDRO-PLUG LCM and then the remainder of the water and pump immediately.

3. If spotting a weighted slurry, it should have a density near the drilling fluid in use, but does not have to be exact (+/- 0.50 ppg).
4. Placement of the bit at the proper depth is critical, but many times must be done without precise knowledge of the loss zone location. Preferably, the bit will be located inside casing above the loss zone. For a long open hole interval, this may not be practical. However, since HYDRO-PLUG LCM contains swellable polymer, run the bottom of the drill pipe or bit to +/-100 ft above the loss zone and will allow the total pill volume to be displaced into the open hole. To lower the probability of stuck pipe, you do not normally run the pipe into or below the loss zone.
5. While the pill is inside pipe, the pump pressure is not exerted on the formation, so high flow rates can be used to pump the LCM pill until it reaches the end of the pipe, bit or PBL sub. This can be on the order of 5 bpm (600 lpm). Before beginning the hesitation squeeze, check the annulus. If no fluid can be seen, use the fill-up line and fill the hole.
6. Once the LCM pill is located at the bit, open-ended pipe, or the PBL sub, close the annular BOP, and pump the slurry at 1.0-1.5 bpm (120 – 180 lpm). This will direct the slurry downhole to the point of loss. If pumping pressure allows, pump the total LCM pill volume in to the loss zone.
7. Begin the hesitation squeeze by pumping at 0.25 – 0.50 bpm (40 – 80 lpm). When a pressure of 50 psi (3 bar) is obtained, discontinue pumping for 10 – 15 minutes. Repeat this procedure until 50 psi (3 bar) can be maintained, then attempt progressively higher pressures in 40 – 50 psi (2 – 3 bar) increments. With this hesitation squeeze method, there will be a pressure bleed off each time the pump is stopped. However, with each successive squeeze, the pressure should stabilize at a progressively higher level.
8. If no pressure builds, then wait two hours – since swelling polymer is a part of the treatment and repeat step #8 (above). If no pressure is measured, the treatment has not been successful and must be repeated with the same pill or a modified treatment selection. Experience in an area will generally dictate the exact path to follow, but this should be decided during the well planning stage.
9. A 200 – 600 psi (15 – 40 bar) squeeze is generally considered to be very good but, if possible, you want to squeeze to the equivalent mud weight (ECD) required to drill ahead in this interval or run casing and cement. When maximum holding pressure is obtained, **shut down for 4 hours**.
10. Bleed the pressure from the annulus slowly, and then recirculate the remaining LCM pill out of the hole.

11. Run the drill pipe back into the hole slowly, monitoring the weight indicator and checking for bridges. Wash to bottom, drilling any LCM plug – if encountered. Any remaining LCM may be retained in the drilling fluid and removed at the shakers.

6. Additional Notes

- There are 2 key factors to obtaining a best possible chance for a successful LCM squeeze:
 1. a slurry with a high solids content and high fluid loss should be prepared
 2. the placement of the slurry at the proper location in the wellbore so that it can seal the loss zone
- Do not hurry to build squeeze pressure; patience and time are necessary to obtain a successful squeeze
- Do not mix a weighted slurry too far in advance of using it; all weighted fluids are subject to barite settling over time.
- Use a low pressure gauge to accurately measure squeeze pressure; if possible, rig-up equipment so that drill pipe and casing pressures can be monitored easily and precisely.
- If the slurry is to be placed through the bit or BHA, install a PBL sub (preferred), drill pipe screen or choke nipple. The choke nipple should be smaller than the bit nozzle size. This will prevent plugging of the bit, and foreign objects can be easily removed at surface to avoid disrupting operations.
- No special equipment is needed to pump low weight slurries (<12 ppg or <1.44 S.G.). The slurry can be mixed in a clean, uncontaminated mud pit and pumped with rig pumps. The operators may consider using a cement company blender and pump unit to place weighted slurries of over 12 ppg (>1.44 S.G.). This gives better control of squeeze pressure and avoids contamination.
- Attempt to accurately determine the location of the loss zone, to increase the chances for obtaining a successful squeeze (temperature log and/or MWD).
- Always have a sufficient quantity of material on location for additional squeeze procedures.
- If supplementing the LCM pill with synthetic fibers larger than 3mm in length, place the slurry open-ended or through the PBL sub. If you are unsure, consult the appropriate lost circulation subject matter expert.