

## Successful application of Thixotropic LCM Technology for zonal isolation in Magdalena Medio Basin Colombia

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### Abstract

This application was developed in a condensed gas producing well located in the Magdalena Medio Basin in Colombia. Due to the decline in the production of the well the well owner decided to perform an isolating intervention to the actual production zone and perforating a deeper zone within the same interval. Level losses and gas production in the well increased the risk associated to the pull out of the production string. The major goal of this application was to reduce the level losses by hydraulic pressure and control of gas production.

Lab tests are necessary to set the setting time and temperature to form a high-compressive strength LCM pill. Hydraulic analysis, Water characterization and displacement procedure are required to guarantee the success of this type of application.

The thixotropic pill was mixed in a conventional workover rig mud pits without any issues. The system was successfully pumped through the production string and after the recommended setting time, the plug was drilled out and the workover operations continued. A total of 102 ft of perforations were successfully isolated and the well was filled with 9.8 ppg brine without any losses, pulled out production pipe without gas influx all within 3 hours after pumped the thixotropic pill.

This technology is a magnesia-based phase transformation fluid that is easy to place downhole across a loss zone and demonstrate thixotropic behavior under downhole conditions. It was customized to set and form a high-compressive-strength plug to combat a severe loss circulation incident.

### Introduction

Controlling gas migration and loss circulation in intervals with gas-contributing formations and formations with hydrostatic pressures exceeding formation pressure is one of the biggest challenges in the industry, whether at the completion, workover, or drilling a well. Since it is necessary to have control of the well pressures if you want to carry out interventions and/or assembly changes safely. Normally, these situations increase non-productive time and cost due to the requirement of

additional equipment and products. On many occasions, it is hardly feasible to continue with the proposed operations.

Conventional technologies such as; fibrous, swelling polymer / fiber, cross-linking polymer, and high fluid loss squeeze do not present adequate adherence and consistency to perform a good seal. Additionally, they have low compressibility and require special conditions to be pumped since they can block the tools and limit circulation and functionality. On the other hand, resins and cement are technologies that help minimize circulation losses, generate high compressibility but require special equipment for mixing and pumping with the limitation of not being able to be pumped through tools or injection through the completion from the surface. This type of technologies requires more time to acquire consistency and resistance with the drawback of not being able to be removed by acid and therefore its potential use in reservoir areas is restricted.

When gas migration and lost circulation occur simultaneously in the reservoir, it is necessary that the technologies are as friendly as possible, easy to apply, with rapid sealing capacity and preferably acidifiable and/or that can be removed under conventional treatment. The materials used in the reservoir must minimize damage and must facilitate the continuity of operations and applicability.

Most conventional LCM fluids involve long mixing time, cement unit equipment requirements, and have limitation to be spotted through string tool. This is a drawback because the success of the operation will be reduced that could lead to well control event.

Novel thixotropic LCM technology has been implemented to seal losses and prevent gas migration with completions or drilling fluids system. The technology demonstrates thixotropic behavior under downhole conditions. It is customized to set and form a high-compressive-strength plug to combat severe loss circulation incident. It is an acid soluble system with the ability to pump through different tool and bit nozzles; it is easy to mix and pump.

One of the advantages of this novel technology is the short mixing time without additional mixing equipment requirement. This technology has minimal impact on personal safety and the environment. The novel thixotropic LCM pill has the ability to take high compressibility in short time for continuous operations with minimize NPT.

This document describes the technology and operational procedures for the application of this novel technology where loss incidents occur in completions operations. A successful application in a condensate gas producing well has been demonstrated.

### Thixotropic LCM Technology Description

Novel thixotropic LCM technology is high strength acid soluble lost circulation material designed to operate in conventional temperature environments while providing an alternative to conventional cement plug. The system tolerates WBM/OBM contamination to a certain level. The System components have been specifically designed to work together to provide excellent performance within the operating limits.

### System Composition

1. Solid, main component that reacts to form a plug
2. Defoamer
3. Viscoelastic surfactant to provide pseudo crosslink
4. Setting control additive used to delay the settling process.
5. Accelerant

### Features and Benefits

- Thixotropic shear thinning gels
  - a. Easy to place downhole
  - b. Prevent gas migration
  - c. Resist flow through loss zones before setting

This thixotropic behavior can help to reduce the losses into the formation while it is pumped through permeable zone. The rheology properties and the time-dependent shear thinning behavior can be customized according to operations requirements as it can be observed in figure 1.



Figure 1. Viscoelastic / Gel thixotropic behavior.

- High compressive strength
  - a. Can be used to set as an isolation plug
  - b. Strengthens loss zones enabling drilling to reach section target depth

The novel thixotropic technology has the advantage to move from thixotropic behaviors to solid hard set. When the fluid reaches the temperature that was set to work. Figure 2 and 3 show the conversion from thixotropic fluid to solid set.

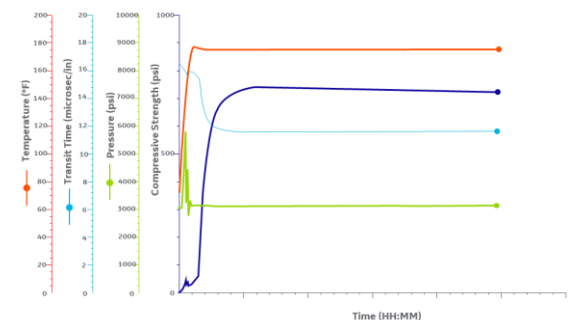


Figure 2. Compressive strength chart of 12.5 ppg Thixotropic LCM pill evaluates to 175°F



Figure 3. Viscoelastic / Gel thixotropic behavior @ 175°F

- High acid solubility, 90%+
  - a. This allows easy removal of the material and potentially have application in the reservoir.

The system it is acid solubility 93% with HCL 15% as can be observed in the Figure 4.

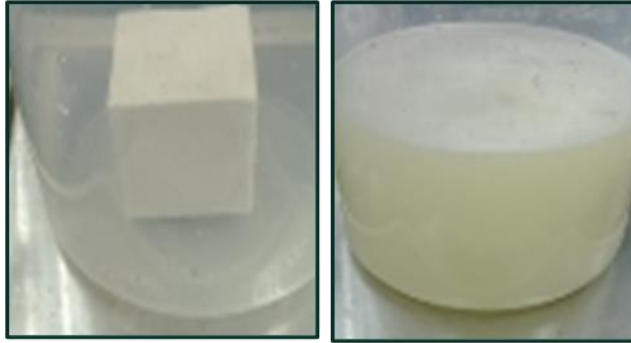


Figure 4. Thixotropic pill is acid soluble.

- Rapid deployment
  - a. Pump from slug tank
  - b. No time-consuming extra trip
  - c. Can be pumped through string tools
- Customizable setting time
  - a. Minimize volume
  - b. Minimize risk associated with flash set
  - c. Increase chances of bridging across loss zone

### Thixotropic LCM Technology Engineering

The Thixotropic LCM plug laboratory customization and field execution require analysis based on below factors to stimulate downhole conditions during planning phase to improve the success ratio with similar LCM system:

1. Estimate volume of Thixotropic LCM pill to be mixed and pumped based on loss scenario.

$$V = OHV500 + (SLR \times TT)$$

2. Estimate bottomhole static and dynamic temperature to customize LCM setting time. As Thixotropic LCM plug setting mechanism is temperature dependent, the precise estimation of bottomhole temperature (both static and dynamic temperature) is critical. A precise temperature profile facilitates optimum time to trip out to safe zone and minimize loss of Thixotropic LCM pill in formation before setting.

It is recommended to use software applications to determine the temperature the LCM pill will reach while pumping and allowing it to soak. This

estimation will allow us to customize the pill formulations for specific job application. The offset static temperature logs and dynamic temperature profile from MWD tools can be used to correlate this temperature profile. Consider laboratory mixing temperature to be the same as estimated mixing temperature in the field.

3. Evaluate formation strength based on geo-mechanical analysis to determine the fracture gradient to limit ECD exerted across the weak zone. The spacers can be used to balance the hydrostatic in case fracture gradient is lower than the resultant ECD.
4. Optimize pumping rate for spacers and Thixotropic LCM pill to avoid inducing losses further and optimize the pumping rate to spot the pill
5. Review placement procedures based on rig facility and wellbore profile. Based on operational experience, Thixotropic LCM setting time for laboratory customization as below.

For Vertical hole (up to 20 deg inclination)

$$ST = T_{\text{spacer}} + T_{\text{PILL}} + SVDT + TT$$

For angle < 45 deg

$$ST = (T_{\text{spacer}} + T_{\text{PILL}} + SVDT + TT) \times 1.15$$

For angle > 45 deg

$$ST = (T_{\text{spacer}} + T_{\text{PILL}} + SVDT + TT) \times 1.2$$

6. QA/QC of product and water analysis will assist further on pill performance.
7. Evaluate the effect of contamination with active fluid on Thixotropic LCM setting time and the compressive strength. The compressive strength required for the pill plug should be more than expected overbalance to drill across the weak zone. This will prevent breaking the bridge established across the loss zone while drilling.
8. Collect representative samples of Thixotropic mix and keep it in an oven at temperature equivalent to bottomhole temperature to determine soaking time

### Key Operational Considerations

Thixotropic LCM technology is recommended where severe lost circulation events occur and other conventional LCM materials fail.

Consider the below listed factors during planning and execution:

1. Estimate volume of thixotropic pill to be mixed and pumped based on loss scenario.
2. Estimate bottomhole static and dynamic temperature to customize LCM setting time.
3. Evaluate formation strength based on geo-mechanical analysis to determine the fracture gradient to limit ECD exerted across the weak zone.
4. Estimate equivalent ECD exerted against weak zone while pumping spacers and Thixotropic pill to avoid inducing losses further and optimize the pumping rate.
5. Review placement procedures based on rig facility and wellbore profile.
6. Evaluate QA/QC of product and water analysis to further verify pill performance.
7. Evaluate the effect of contamination on thixotropic setting time and compressive strength.

### ***Thixotropic LCM technology field trial.***

#### ***Executive Summary***

The M1 well is a condensed gas producing well located in the Magdalena Medio Basin in Colombia. Due to the decline in production of the well, operator decided to perform an intervention isolating the actual production zone and perforating a deeper zone within the same interval.

It was necessary to design a workover fluid capable of isolating the current production area without altering its petrophysical properties. Two conventional block pills were injected into the well production zone without positive results to control fluids losses and a consequent formation gas flow due to the lack of hydrostatic pressure.

The technology was recommended for:

- Help to seal temporally the perforating zone in a Porquero formation with a high compressive strength system
- Benefits to be pumped through production string.
- The plug it is impermeable and help to reduce the gas migration.
- Provide the seal and support to increase the mud density to help to control the well.

Thixotropic LCM technology System was mixed, pumped, and achieved complete isolation of the production zone. The

well was then filled with 9.8 ppg brine without losses and the production string was successfully pulled out.

The solid plug was drilled out, the deeper zone was perforated, and the well intervention was complete.

#### ***Background information.***

Customer in Colombia planned to isolate the production zone in a gas condensate well during a workover operation to pull out production string and perforate a new zone located below the original production zone (See Fig 5. Well Bore Schematic).

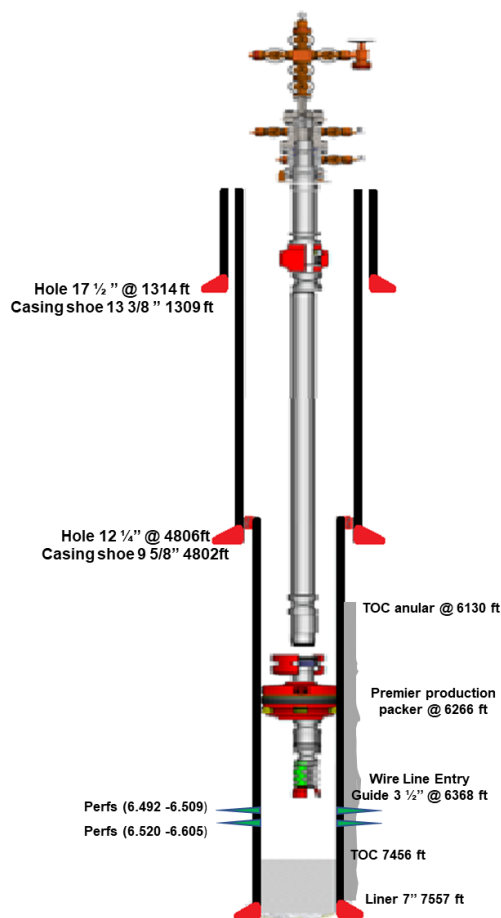


Fig 5. Well Bore Schematic.

Two conventional block pills were pumped in attempt isolate the production zone, to fill the well, and avoid fluid losses and gas influx without success the behavior of this application can be observe in the figure 6. The operator thinks in an expandable liner solution or the use of a Resin pill with a coiled unit and a batch mixer to isolate the zone. Customer Reservoir Engineer requested an option that would allow the operator to re-enter the isolated zone in the instance that the new target zone production was not viable and recover productivity.

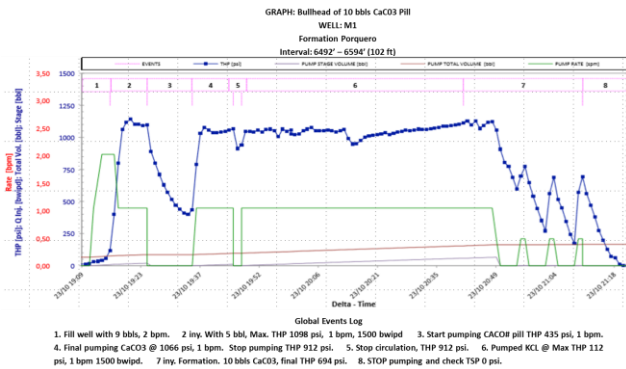


Fig. 6 Pressure while pumping conventional Block Pills (non success)

The Thixotropic LCM technology was recommended to control the losses by providing zonal isolation due to its compressive strength, easy to drill out and acid-soluble properties.

A total of 18-bbls of Thixotropic LCM technology was mixed in the rig's slug tank without issue and then 10 bbl. were squeezed through production pipe to isolate 102 ft. of perforations in the reservoir zone.

The Thixotropic fluid was injected at a rate 1 bbl per min. once the system reached the first perforation and the SPP increase from 625 psi to 816 psi indicate the pill entered the perforations. This pressure was maintained while covering the entire production zone

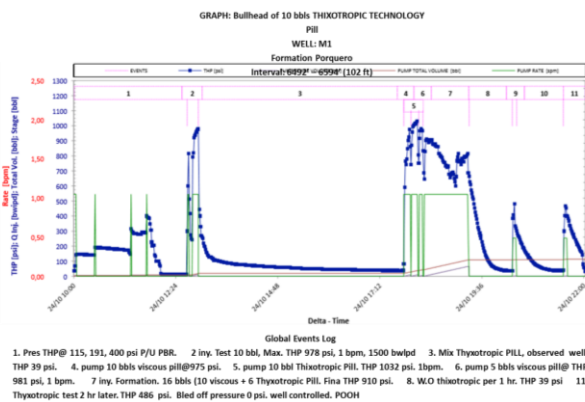


Fig. 7 Pressure while pumping thixotropic pill technology (success)

The estimated volume injected into the formation was 6 bbls.

After spotting the pill, the thixotropic LCM technology soaked for one hour as designed to solidify into a solid plug. 8.4 ppg brine was then pumped at 0.5 bpm, increasing the pump pressure to 511 psi and then stopped. After waiting, one more hour the process was repeated again reaching a SPP of 486 psi. the behavior of this application can be observed in the figure 7.

Customer decided to continue with workover operation. The production packer was first released, and a check flow was performed (No gas flow or losses). After confirming the well was static, the production string was then pulled from the well. Then the well was displaced from 8.4 ppg to 9.8 ppg brine. The successful placement of the Thixotropic LCM technology allowed the operator control fluid losses, isolate the production zone, control the well and avoid the use of Coiled tubing and batch mixer.

By selecting Thixotropic LCM technology as an alternative option to coiled tubing, the operator saved an estimate \$123K by avoiding NPT related to mobilization and rig up time. The Key performance indicator of this application can be observe in the table 1

### Key Performance Indicators

Table 1. Key performance indicator of field trial application .

Lost-time Accidents	No injuries or illness related to personnel in conformance with HSE policies of the local government or D&E	Accomplished ✓
Spill to the Environment	Accidental spills (discharge) of drilling fluids or base fluids from the drilling location should not occur	Accomplished ✓
Non-productive Time (NPT)	Zero NPT related to Thixotropic LCM technology (Plug of Surface and Downhole Equipment)	Accomplished ✓
Materials Delivery	Fluid and Product to be delivered on time	Accomplished ✓
Thixotropic Displacement	No Channeling	Accomplished ✓
	No cross contamination with other fluids 100% Cover of the target zone	Accomplished ✓

## Challenge

- Fill the well with completions fluids before the workover operation; control the well to reduce the gas production.
- Insolated the Porquero formation Pump the Thixotropic LCM through the completion string

## Operational Plan

The following procedure was performed in the workover operation:

1. HSE and Pre Job meeting
2. Flush the lines from Slug Pit all the way to Top Drive. All lines must be clear in order to avoid contamination of the Thixotropic LCM pill.
3. Pump 30 bbl of KCl Brine to 1 bpm, validate injectivity in the Upper Porquero Fm. (500 strokes)
4. Mix Thixotropic LCM Technology.
5. Pump 10 bbls Hi Vis Lead Spacer (166 strokes)
  - a. 2.0 ppb Xanplex D
  - b. 60 bbls of Fresh Water
6. Pump 10 bbls Thixotropic LCM (133 strokes)
7. Pump 5 bbls Hi Vis Lead Spacer (83 strokes)
8. Pump 57 bbls of KCl brine to displace the thixotropic in the Well (950 strokes)
9. Stop the pumps and Wait 2 hours
10. Pump 4 bbls (67 strokes) of KCl brine, Validate Injectivity test in Porquero Formation
11. Pulled out completion system
12. Pulled out drill pipe.
13. Continue with the Workover Plan

## Results.

The Thixotropic LCM technology was mixed in a conventional workover rig mud pits without any issues, saving a potential rental cost of batch mixer.

The thixotropic LCM technology System was successfully pumped through a production string.

After the recommended settling time thixotropic LCM Plug was drilled out and the workover operations continued. A total of 102 ft of perforations were successfully isolated and the well

was filled with 9.8 ppg brine without any losses (1000 psi of differential pressure - Hydrostatic pressure vs Pore pressure). Pulled out production pipe without gas influx; only 3 hours after pumped thixotropic LCM

After this successful application, the customer required the Thixotropic LCM system to be used in other workover applications.

## CONCLUSION.

The Thixotropic LCM technology can be mixed in a conventional workover rig mud pits without any issues, saving a potential rental cost of batch mixer.

The thixotropic technology can be pumped through completions tool without any issues.

The thixotropic LCM technology can be helping to seal formation with migration of gas and the same time control de fluid losses in permeability formation.

The thixotropic LCM pill is high compressible and can use higher density in the completion fluids if this it is required.

The thixotropic LCM has the ability to solidify quickly, reduce NPT required by other technologies and help to solve losses and gas migration quickly

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## Nomenclature

$Ft$  = feet

$V$  = Volume of pill

$OHV500$  = Open hole volume to cover 500 ft.

$SLR$  = Static loss rate (bbl/hr)

$TT$  = Estimated tripping time required to pull out to theoretical top of pill in hours.

$Ppg$  = pounds per gallon

$LCM$  = lost control Material

$ST$  = Estimation for setting time for Laboratory customization.

$T_{spacer}$  = Time to Pump lead spacer

$T_{PILL}$  = Time to pump pill

$SVDT$  = String displacement time

$HCL$ : Hydrochloric acid

$MWD$ : Measure while Drilling

% = Percentage

$^{\circ}F$  = Temperature Fahrenheit

$WBM$  = Water Base Mud

$OBM$  = Oil Base Mud

$ECD$  = Equivalent circulating Density

*NPT = Non Productive Time*

*Bbl = Barrel*

*Bpm = Barrels per minute*

*SPP = Stand Pipe Pressure*

## References

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<https://doi.org/10.2118/183945-MS>