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Multifunctional Cement Spacer Fluid Improves Cement Seal Integrity, Minimizes Formation Damage, and Controls Lost Circulation

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Abstract

The effectiveness of a multipurpose cement spacer fluid is quantified in Haynesville Shale Basin and Midland Basin. Effective fluid performance is demonstrated in laboratory and well applications. Fluid stability, compatibility, formation sealing performance, and lost circulation control function are quantified. The spacer consists of a special blend of materials that provide the critical performance properties. Additional fluid components (fibers, surfactants, weighting materials) can be added as conditions dictate to extend the fluid's utility. Laboratory performance criteria include rheology, static and dynamic settling, fluid compatibility, wettability, permeability sealing and slot sealing. Fluids for field application are designed to have density between mud and cement with PV range designed appropriately to yield maximum displacement efficiency. Surfactants are added to achieve fluid compatibility and wettability. Permeability sealing effectiveness is confirmed on a sand bed while slot sealing is tested in a pressurized slot cell. Spacer fluid laboratory performance testing confirm the spacer's excellent fluid properties over a range of application conditions. Rheological properties are ideal for optimized placement rate and drilling fluid removal. Static and dynamic settling tests substantiate fluid stability even at elevated application temperatures; a parameter crucial to optimized cement placement in long horizontal well-bores. Excellent compatibility and wettability are also noted. Sealing test results indicate the fluid minimizes both filtrate losses into water-sensitive formation and losses of whole fluid into weak zones. Results of several production casing cementing jobs using the multipurpose cement spacer are compared to previous jobs using other spacer fluids. The initial job using the multipurpose spacer was first time casing rotation was maintained throughout the entire treatment. Casing rotation "torqued out" once previous spacers entered the annulus indicating incompatibility, settling, and/or ineffective displacement. Average seal effectiveness increased appreciably compared to other spacers. Lost circulation during placement was experienced on wells cemented with other spacer fluids, but job monitoring and TOC measurement indicate none occurred when using the multipurpose spacer fluid.

The multifunctional spacer fluid is easily mixed and formulated to function over a variety of well conditions. Effectiveness of the fluid as a cement spacer, formation sealer, and lost circulation control fluid is demonstrated over a wide range of temperature and well conditions. Use of this universal fluid in the cementing fluid train results in complete and long-lasting annular seal to support stimulation and production operations.

Introduction

In order to construct a well that will last long enough to insure that it is an economic success, it is necessary to get the best zone isolation in all of the casing strings as possible. This translates to optimally displacing the drilling fluid and replacing that fluid with cement slurry that will set and develop an isolation barrier in the annulus. This set cement sheath protects the casing from corrosion and it also prevents fluids from migrating throughout the annulus. The displacement efficiency i.e., the amount of drilling fluid that is replaced with cement, is important to maximize as the cement has proven to be a good seal in the annulus between the pipe and the formation if the displacement efficiency of the drilling fluid is high enough (Griffin, et all 1995). The displacement process is critical in all wells, but it is further complicated in highly deviated and/or horizontal wells (Sabins, 1990). Horizontal well structure is the widely employed in most unconventional basins in the US and it is a very important consideration for well construction and the cementing process.

This process of drilling fluid displacement almost always requires that a spacer fluid be pumped between the drilling fluid and the cement slurry. This spacer fluid has several functions that can help the displacing process and help optimize the zone isolation that is achieved. First, the spacer fluid typically has a density between that of the drilling fluid and the cement so that the added buoyancy will assist in the push of the drilling fluid up the annulus (Moran et al 1990). At this density the rheology profile should be such that it also aids in the displacement process. In addition, the spacer fluid must be compatible with both the drilling fluid and the cement slurry. This compatibility means that the intermixing of these fluids must not create a significant increase in viscosity to compromise the pressure requirements to place the cement slurry in the annulus. The spacer must not settle in dynamic or static conditions in the well and allow the weighting material to segregate (Moran, 1990). The weighting material is necessary to keep the density at the appropriate level. This stable spacer must also help remove the settled solids on the bottom of the hole left by the drilling fluid during the drilling of the well. This issue is significant as the horizontal wells greatly contribute to solid settling in the lateral section. Typically, the spacer must be thin enough to keep the friction pressure low enough so that losses due to pressure are minimized. In addition, many times pipe movement is used in wells to help in the displacement process. Wells that have eccentric annuli, pipe movement can be very useful (Moran, SPE 109563). Excess pressure can cause differential sticking that limit pipe movement. In wells that have oil-based drilling fluid the spacer must remove the bulk drilling fluid but also help remove the oil film and "water wet" the surface of the casing. This water wet casing creates a desirable condition for the cement to bond and promote isolation. One additional function that the new spacer composition can have is "sealing ability". The sealing ability of the spacer refers to the ability of the spacer to provide a very low fluid loss requirement that seals the permeability and/or small natural fractures with a very low permeability membrane in the open hole sections. This "sealing" ability allows for lower Equivalent Circulating Densities during fluid placement and helps promote an additional resistance to loss of fluid from the cement slurry. This lower fluid loss help is very beneficial in areas where fluid migration through the cemented annulus can be a problem. This sealing ability can also help loss circulation material bridge and seal whole fluid losses.

All the above requirements for the spacer fluid can be achieved through a novel Multifunctional Cement Spacer System (MCSS). This system is specifically designed to meet the objectives needed for the spacer design. This paper will summerize the use of the MCSS in two different basins: The Haynesville Shale Basin and the Midland Basin. Each is distinctly different but both can benefit from the use of MCSS during cementing. The below table summarizes all of the requirements that the MCSS must meet and the applicable lab test that can be used to determine the useful property along with the basin of applicability. Each property and test will be described in the Laboratory Testing Section. The details of the applicability of the property in each basin will be described in the Case History section for each of the basins.

Table 1 – Summary of Property and Lab Test for MCSS Spacer

#	Property	Lab Test	Basin of Applicability
1	Viscosity/Density Design	Rotational Rheometer	Haynesville/ Midland
2	Sealing of Permeable Zones/Improve ECD	Sealing Test (Sand Bed)	Haynesville/ Midland
3	Compatible with Mud	Compatibility Test (Rotational Rheometer)	Haynesville
4	Water Wet Pipe	Rheometer Rotor Testing	Haynesville
5	Fluid Stability	On/Off Consistometer/ Density Variation	Haynesville
6	Fluid Loss Control of Cement	Sand Bed Fluid Loss (Multiple Fluids)	Haynesville/ Midland
7	Slot Sealing for Losses	Slot Tester	Midland

In this paper several things will be presented. First, the laboratory tests that demonstrate and validate several critical spacer requirements will be presented. Secondly, a summary will be presented on two basins that the MCSS was applied to help optimize the cementing treatment. The two areas are the Haynesville shale in North Louisiana and the Midland Basin is West Texas. Each of the areas have special requirements from the Multifunctional Spacer System. Each will be discussed in its own section.

Lab Testing of Multifunctional Spacer

The following section will summerize the lab testing of the MCSS spacer. Several different tests will be examined and some example data provided. As summarized in the previous section, not all the lab tests are applicable in both of the basins that we will be evaluating. The Haynesville Shale is high density, high temperature application while the Midland Basin is unweighted density at low temperature. Data will be provided to illustrate the testing that would cover both basins. All the testing will be performed at the BHCT of the wells or at 190 °F whichever is lower.

1. *Density and Viscosity Design*

In order for a spacer to be effective, it must be designed to the density and rheology that will optimize drilling fluid displacement. The density is normally designed to be between the density of the drilling fluid and the cement slurry. The rheology should be such that the friction pressure generated by the spacer is not significant, the carrying capacity of the spacer is adequate, and viscosity remains high enough to displace drilling fluid. Below is an example of the density, temperature, and the corresponding PV and YP at the temperature. This test is useful for both the applications in the Midland Basin and the Haynesville Shale.

Table 2 – Summary of Viscosity and Density of the MCSS

Test	Dry Spacer (lb/bbl)	Density (lb/gal)	Temperature (˚F)	PV/YP at Temperature
1	15	8.8	80 F	30/15
2a	15	8.8	150 F	25/20
3a	12	12.5	150 F	34/33
3b	12	12.5	190 F	26/22
4	10	14.0	190 F	56/36
5a	7	16.0	150 F	53/40
5b	7	16.0	190 F	45/37

Note: Test 1 is applicable for the Midland Basin while Test 5a and b are applicable for the Haynesville Shale

2. *Sealing Test*

A sealing test quantify the degree of sealing of the spacer system. The test is conducted in a conventional, long fluid loss cell but 100 mesh sand is used in the cell as the permeable media. Two different tests are conducted. First, a fluid loss test is conducted using 1000 psi differential pressure using the unweighted spacer mix at 150 F. In order for it to be considered Excellent + the 15-to-30-minute fluid loss rate should be less than 0.5 cc/min. The MCSS normal unweighted spacer concentration is 15 lb/bbl as shown in Test #1 in the following table. Next, the same test is conducted at 100 psi. Several different tests at various densities are provided for comparison purposes. The filtrate loss rate from 15 minutes to 30 minutes is calculated and rated as to the effectiveness of the seal.

Table 3 - Sealing Test Summary

#	Mix lb/bbl	Density lb/gal	Temp °F	Sealing 100psi cc/min	Sealing	Rheos PV/YP 190 °F
1	15	8.6	150	0.27	EX+	40/25
2	15	12.5	190	0.33	EX+	57/39
3	12	12.5	190	0.47	EX+	34.5/33.4
4	7	16.0	190	0.27	EX+	65.9/56

Note: the following is the key for category

Excellent +	<0.5 cc/min	**Good**	<1.0 cc/min
Excellent	<0.75 cc/min	**Poor**	>1.0 cc/min

3. *Compatibility Tests*

Standardized API compatibilities can be run to determine the viscosity changes when various amounts of spacer and mud mixed together. Below is an example of the compatibilities of the a 16.0 lb/gal oil-based drilling mud with a 16.2 lb./gal MCSS spacer. This is typical of the data that is developed for the MCSS spacer for use in the Hayesville Shale wells.

Table 4 – Typical Example of Compatibilities Conducted for Spacer and Drilling Fluids

Fluid	**Fluid**	**RPM**	**RPM**	**RPM**	**RPM**	**RPM**
Spacer	**Drilling Mud**	**30**	**60**	**100**	**200**	**300**
0%	100%	13	18	25	37	48
5%	95%	17	24	33	52	71
25%	75%	60	72	81	101	114
50%	50%	56	64	73	98	118
25%	75%	41	52	65	94	121
95%	5%	52	68	83	111	134
100%	0%	44	56	68	92	109

The above data is measured at 190 °F after conditioning for 30 minutes at the 190 °F. The data clearly shows that at all concentrations of spacer and drilling mud the corresponding dial readings are not appreciably high.

The compatibilities of the unweighted spacer that is used in the Midland basin is not being measured because the cut brine used the drill the wells and the unweighted MCSS spacer are very compatible by nature (both are aqueous and unweighted with extra solids).

4. *Wettability Pipe/Rotor Test*

A test that has become popular to show the ability of a spacer to produce a water wet pipe. This test is called the “Rotor Wettability Test”. This is applicable when oil-based drilling fluid is used (only in the Haynesville Shale). First, the drilling fluid and Spacer to be tested is heated to the test temperature and conditioned for 20 minutes at temperature. The rotor from the rotational viscometer is placed into a container of the oil-based drilling fluid and rotated at 100 rpm for a total of 10 minutes (see picture one below). The rotor is then placed into the spacer fluid to test and rotated for 10 minutes. After the 10 minutes the rotor is placed into a container of water and rotated at 100 rpm. The resulting cleanliness of the rotor is visually observed. If the rotor is clean and is “water wet” to the touch then the spacer has been considered properly designed and the rotor is “water wet”.

Typical Wettability Rotor Test results are shown in the follow pictures. The picture on the left shows the oil-based drilling fluid covering the sleeve after 10 minutes of exposure to the mud followed by 5 minutes in water all rotating at 100 rpm. The picture on the right is after the drilling fluid coated sleeve has been exposed to the spacer with the wetting surfactants and then place in water for 5 minutes all rotating at 100 rpm. The sleeve has been completely clean of the oil base fluid and has left the rotor water wet.

Figure 1 – Before/After Picture of Rotating Sleeve with Oil Based Mud and MCSS

5. *Stability Test*

When using weighted spacers for high temperature wells the stability of the spacer comes into question. The spacer design should not show signs of settling at the elevated temperature and pressure and insure that it will not compromise the ability of the plugs to go down the inside of the casing or segregate/settle into the casing by borehole annulus. Two types of settling tests can be conducted on the spacer. First, the spacer can be mixed and placed into a HTHP consistometer. The spacer fluid to be tested is brought to bottom hole temperature and pressure and then held there for several hours. During this hold at temperature several static times are simulated. The normal test included 3 static times for 15 minutes each followed by three dynamic times. The deflection of the consistency when the rotation is turned back on can allow an interpretation of the amount of settling that occurred during the static time. If the deflection is high, it is indicative of settling of the fluid. If the deflection is low, then the settling of the fluid is limited. Figure 2 is an example of the on/off stability test. As you see the deflection of the consistency measurement is very low on each of the three on/off sequences. This test indicated that the spacer in question was stable at BHCT of 320 °F.

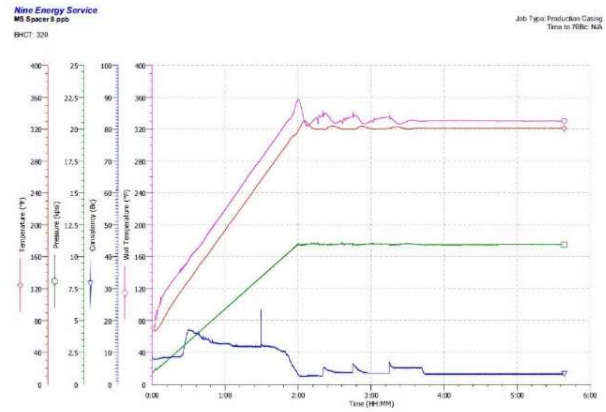

Figure 2 - On/Off Stability Test

In addition to the above stop/start test, a more quantified measure of the density separation can be determined by continually stirring the spacer in a HTHP consistometer at elevated temperature for one hour, the stirring is stopped, and the spacer allowed to cool to 190 F while being static. The density of the of the spacer is measured at top, middle and bottom. The density measurements in the middle and bottom of the spacer are shown in Table 5. The table summarizes the density measurements for a spacer at 16.0 lb/gal and at 350 F.

Table 5 - Density Measurements of Static Spacer

Section	Density (lb/gal)	% Variation
Designed Spacer	16.0	NA
Middle 1/3	14.9	7% (Low)
Bottom 1/3	17.7	11% (High)

6. *Fluid Loss/Sand Bed*

The MCSS sealing property can help lower the fluid loss from the cement slurry that follows in the well. The spacer as we have noted has a sealing ability in the permeability of the formation. This sealing ability can help lower the fluid loss of the cement. However, because the sealing effect of the spacer needs some penetration into the formation to form the inner formation membrane, a 100-mesh sand bed is used. The following table illustrates the help of the MCSS spacer can have on the cement. The sealing effect of the spacer is shown in the sand bed column. Cement Slurry #1 is a low fluid loss cement slurry similar to the cement slurry utilized in the Haynesville Shale wells. The fluid loss on the sand bed of the low fluid loss cement is roughly what was measured in the standard fluid loss test conducted on a screen, 116 cc/30 minutes and 150 cc/30 minutes on the sand bed. After placing a spacer and allowing it to seal for 10 minutes under differential pressure the cement fluid loss is lowered from 150 cc to 20 cc. Even using a high fluid loss cement that blows out in 14 secs, when the spacer is placed on the sand bed for 10 minutes lowers the Cement Slurry # 2 with no fluid loss control down to 80 cc/30 minutes. This level of fluid loss on a screen would be considered good fluid loss control in cement slurry design.

Table 6 – Fluid Loss of Cement with and without Sealing Spacer at 190 F

Fluid	Fluid Comp	API Cement Fluid Loss	Fluid Loss Sand Bed	Fluid Sealing cc/min	Spacer Cement Sand Bed
Spacer	16.0 MCSS	NA	NA	0.3	NA
Cement Slurry 1	16.5 Low Fluid Loss	116 cc	55 cc/30 min	NA	26 cc/30 min
Cement Slurry 2	16.5 No Fluid Loss	1200cc	100cc /14 sec	0.5	80cc/30 min

7. Slot Testing with LCM

The testing of the ability of fluids to seal in a loss circulation environment has been developed. This test is called the slot testing. The MCSS fluid is mixed and blended with 4 ppb LCM particulates and 2 ppb fibers for help control the loss of circulation. A pressure of 100 psi is place on the fluid and in this case a 1-millimeter slot was used to test the sealing of the slot. Below is a picture of the low temperature and pressure slot tester and the slot that was used on the left. On the right is a picture of several of the slots that can be used in the tester. The smaller one is the 1 mm with the other one is the 3 mm. For the purposes of this project only the 1 mm slot was used.

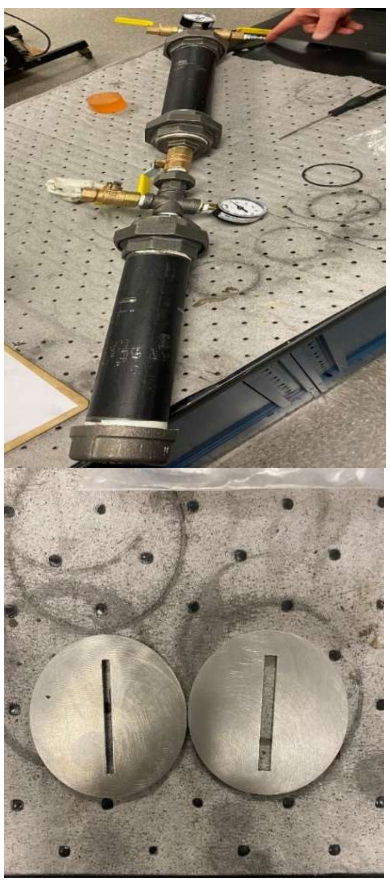

Figure 3 – Slot Tester and Slot

The following table is illustrative of the ability of the MCSS spacer to help with the loss of circulation. Slot tests were conducted at room temperature with the unweighted MCSS spacer. A conventional non-sealing spacer was also tested. All the tests were conducted at room temperature and 100 psi. The sealing spacer with the combo of LCM and Fiber sealed on the 1 mm slot with 100 psi. The conventional gel spacer with the same loading of LCM and Fiber did not seal on the 1 mm slot. The sealing spacer helped the LCM/Fiber combo control the losses.

Table 7 – Slot Testing Results

Spacer	Loading of Spacer	Loading LCM/Fiber	100 psi slot test
MCSS	Unweighted	2ppb/2ppb	Pass
Conventional	Unweighted	2ppb/2ppb	Fail

Challenges in Haynesville, Long String Cementing

Cementing in the Haynesville Shale has unique challenges. The spacer design and its utility is critical to help achieve the desired zone isolation. Eighteen wells in the Haynesville have been cemented the Multifunctional Spacer on the production strings with great success. There are several key elements of the Haynesville wells make it difficult to cement successfully. Each is summarized here:

- The wells in question are typically high temperature/high pressure wells. These elevated conditions make the fluid properties and procedures difficult. Special design criteria are necessary.
- These wells are slim hole in their design. This smaller pipe in small hole complicates the circulation of fluids and the pressure associated with the cementing treatment.
- Long horizontal sections are typical in these wells. These long sections coupled with the temperature means that the fluid used in the wells need to be stable yet low in viscosity to maintain reasonable pressures
- Due to complications of having slim hole and the increased tendency of increased circulation pressure pipe movement is desired to help with low side solids and improved displacement of the high-density drilling fluid.
- The control of the ECD's while cementing is critical to insure that the cement is circulated into place and done so is good fashion to obtain the circulation rate necessary to remove solids and whole drilling fluid.

Below is table that summarizes the basic conditions that are in the Haynesville shale.

Table 8 - Summary of Well Conditions Haynesville Shale

Item	Typical Condition
Total Measured Depth	21000’
Total Vertical Depth	13664
Horizontal Length to Cement	6000’
Casing Size	5 ½”/5”
Hole Size	6 ¾”
Top of Cement	6000’
Depth of Last Casing	12505’
Size of Last Casing	7 5/8”
Mud Density/Type	OBM/16.0 ppg
Spacer Density	16.2 ppg
Cement Density	16.4
Cement Type	Low fluid loss/gas tight
Pipe Movement	Yes
Centralization	Minimal/25%
Frac Gradient	19 to 19.5 ppg
Surfactants for Spacer	2 gal/bbl A, 2 gal/bbl B
Displacement Rate	4 to 5 bbl/min
Volume of Spacer	60 bbls
Contact Time for Spacer	15 min+
Displacing Fluid	10 ppg NaCl

Case History Summary for Haynesville Shale Wells

The following is a summary of the wells cemented in the Haynesville Shale area. There are 18 wells from a BHCT of 280 F to 370F. Two criteria are noted for success. The first criterion was that the casing was rotated throughout the entire cementing treatment. It has noted for a number of years that pipe movement and especially pipe rotation could be a significant in helping drilling fluid removal during the cementing treatment. But in horizontal wells and the slim hole design the rotation of pipe was even more significant. Prior to the use of the MCSS on these wells it was common that pipe movement could not be maintained once the spacer reached the end of the casing and was turning into the annulus. This was due to the stability of the spacer fluid at temperature i.e., the settling of the weighting material from the spacer and the higher friction pressure required to push the spacer and cement through the annular space through the horizontal space and up to the previous shoe. In fact, figure 4 and 5 shows the effect of the pipe movement on the displacement efficiency using the CemPro+ modeling software. These two figures indicated the significance of the pipe movement on the overall displacement efficiency and ultimate zone isolation. The second criterion for success shown in Table 9 is the “Pressure Match: criterion. The displacement pressure signature can be used to estimate the displacement efficiency as well as the final top of the cement slurry in question. If the pre-job pressure signature matches the actual job pressures, within reason, using the rates conducted on the job the job could be considered successful. Figure 6 is shown as example of one of the wells with the pressure match plot.

Table 9 - Summary of Case Histories: Haynesville Shale

Well #	BHCT	Success Criteria 1	Success Criteria 2
		Rotation of Casing Throughout Job	Pressure Match/Fluid Tops
1	370	YES	YES
2	355	NO (No Rotation Before Job)	YES
3	320	NO (Head Malfunction)	YES
4	320	YES	YES
5	320	YES	YES
6	365	YES	YES
7	345	YES	YES
8	345	YES	YES
9	320	YES	YES
10	320	YES	YES
11	330	YES	YES
12	310	YES	YES
13	320	YES	YES
14	330	YES	YES
15	280	YES	YES
16	280	YES	YES
17	280	YES	YES
18	280	YES	YES

In these horizontal wells in the Haynesville Shale, it is very important to use pipe movement because of the dramatic affect the pipe movement has on the displacement efficiency. Before the service company started this project a number of jobs were performed using conventional non-sealing spacers from other service providers. In all the previous jobs the pipe movement could not be maintained once the spacer entered the annulus. Once the MCSS spacer was utilized in all of the 18 jobs except for two the pipe was able to be rotated throughout the job. The two that could not be rotated did so for reasons outside of the fluids being pumped.

The following figures are showing the displacement efficiency using pipe movement versus not using pipe movement. The results are dramatic. The displacement efficiency is dramatically lower without the pipe movement (varies from 90%+ at the bottom and slowly lowers to 80% at 15,000 to about 60% at 12,500’). The pipe movement simulation shows a very different result. By using 15 rpm casing rotation the bottom was 100% to 15,000’ and stayed at 80%+ up to top of cement at 12,500’

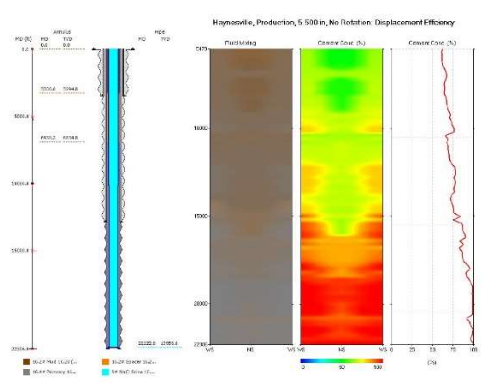

Figure 3 - Displacement of Drilling Fluid without Casing Rotation

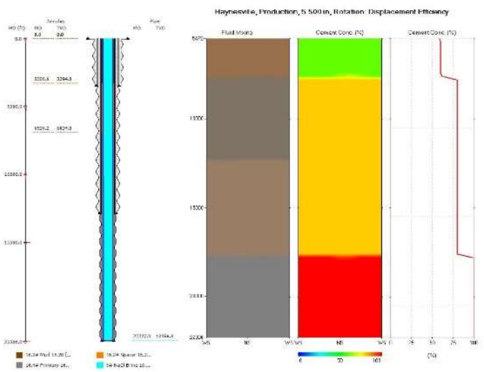

Figure 4 – Displacement with 15 RPM of Casing Rotation

The other criteria for success on these jobs was a pressure match on the pre-job simulation and the actual data from the job. Figure 6 shows a match from job #6 that had a BHCT of 365 F. The simulated pressure (dotted red line) and the actual pressure (solid red line) matched very closely for 95% of the job. There is a slight variation on the actual pressure at the end of the job for a little over 10 minutes. There may have been some slight loss of circulation.

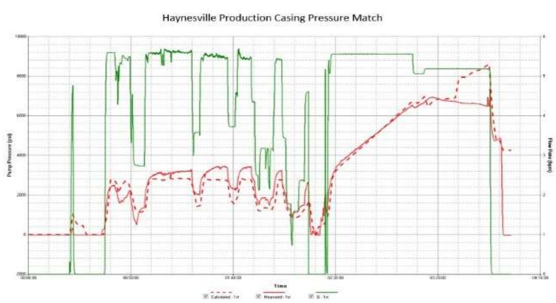

Figure 5 - The Pressure Match of Job # 6: Pressure and Job Pump Rate vs Time

Challenges in the Midland Basin, Intermediate Cementing

In order to achieve good zone isolation in the Midland Basin on the Intermediate String cementing it is critical that the spacer used will deliver the properties necessary to cement the wells in good fashion. Several critical things are desired in the Midland basin cementing. The following are the list of the critical wells paraments that greatly affect the cementing placement and overall seal of the wells.

- Low frac gradients
- Excessive washouts, poor displacement of mud
- Regulatory requirements for top of cement
- Loss of circulation
- Fall back after cementing

The service company was able to address these issues with a combination of spacer with LCM package of materials and a specially designed thixotropic cement.

Below is a summary of the typical well conditions in the Midland Basin.

Table 10 - Summary of Well Conditions Midland Basin

Item	Typical Well Conditions
Total Measured Depth	6000’
Total Vertical Depth	6000’
Casing Size	9 5/8”
Hole Size	12 ¼”
Top of Cement	Surface
Depth of Last Casing	Surface 1300’
Size of Last Casing	13 3/8”
Cement Density	11.0 ppg
Cement Slurry Type	Thixotropic/high fluid loss
LCM in Cement Slurry	1 ppb
LCM in Spacer	Combo LCM/fibers
Mud Density/Type	Cut Brine/8.5 ppg
Spacer Density/Volume BBls	9.5-10 ppg/50 bbl
Cement Density	11.0 ppg lead, 14.0 ppg tail
Pipe Movement	No
Centralization	Minimal/ vertical section
Pump Rate on Job	4 to 6 bbls/min
Criteria for Success	Cement to surface
Frac Gradient	9.0 ppg
Pre-job Circulation	2 bottoms up

Case History Summary Midland Basin

The above summary of well conditions summerize the well conditions on cementing the intermediate in the Midland Basin. To date 60 jobs have been performed using the Spacer/LCM/Thixotropic cement for one specific client in the Midland Basin.

The following is the summary of the success of this process. These wells are summarized in the Single Stage row. Prior to using the MCSS on these wells, they were cemented using a two-stage cement tool and a packer. Row 1 shows the number of wells using the Two Stage approach as a comparison:

Table 11 Summary of the Wells Cemented in Midland Basin

Type	# Jobs	Jobs with Cement to Surface	Success Rate	Total bbls of Cement to Surface	Average Cement to Surface per Job bbls
Two Stage	133	70	52%	5,147	73
Single Stage	60	53	88%*	5,195	98

Note: Even though cement was not at surface in 12% of jobs the Texas Rail Road Commission indicated that the cement tops in these jobs were indeed high enough to pass the regulations.

Several things are important from the above table. The main success criterion for single stage cementing is bringing cement back to surface. Secondly of the 60 single stage jobs pumped the average success rate was 88%.

This higher success rate actually translates into lower cement volumes needed compared to stage cementing. The average Barrels needed per job was significantly lower for each job in the single stage verses the two stage jobs. The following figure summarizes the benefit in volume and cost to client.

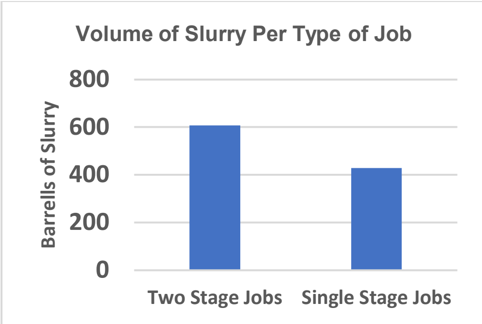

Figure 6 – Comparison Volume of Slurry for Two Types of Jobs

Figure 6 is a summary of the 60 jobs in question that used the MCSS. Several major things were accomplished. First the two-stage cementing tool was eliminated. Second of all the cement volume was able to be lowered. Finally, the Top of Cement was high enough on every well to meet the TRRC requirements. On average there was 16 cement jobs per month. Taking the average slurry cost of $75/bbl the cost savings to the Operator was $214,800 a month. This savings does not include the cost of the DV tool, the packer or the extra rig cost to do the two-stage job.

Conclusions

1. The Multifunctional Cement Spacer System has several desired properties that can help with cementing of Haynesville Shale Wells and Midland Basin Wells. They are flexible design rheology with density, sealing properties, wettability of pipe, compatibility with well fluids, lowering fluid loss of cement and loss of circulation.
2. A design of cementing treatment to cement Haynesville Shale wells should include a MCSS. This MCSS will help with rotation of pipe throughout the job, control of losses, stability at high temperatures, help lowering the fluid loss of the cement and excellent mud removal.
3. Stability of the MCSS used in the Haynesville Shale wells at elevated Temperatures can be achieved at up to 380 °F.
4. The MCSS spacer system use in Haynesville Shale can promote a water wet pipe to achieve maximum cement bonding to the pipe when using Oil Based Mud.
5. A design of cementing treatment to cement Midland Basin shale wells should include a MCSS. This MCSS will help with, control of losses, sealing of formation permeability, excellent drilling fluid removal and cement fall back.
6. The use of the MCSS along with thixotropic cement has been able to eliminate the need for two-stage cementing in the Midland Basin. This new cementing process utilizing the MCSS has saved the customer substantial costs for the wells.

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