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Investigation of the Effect of Water Salinity on the Thickening Time of Cement Slurry

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ABSTRACT

Cementing techniques involves the deployment of cement slurry on the oil-well annulus and casing to provide proper zonal separation. The target is to completely hinder fluids in the well from interacting from one part to another, provide anchor for casing, prevent corrosion of the casing, prevent shock loads during drilling, and avoid blowouts, plug off vugular zones and for abandonment. This experiment was done following American Petroleum Institute (API) recommended practice 13B-2, with the aim of investigating the effects of salinity level of water on the thickening time of cement slurry. The significance of the thickening time test is to determine the duration of cementing operation to ensure successful zonal isolation without cementing the drill pipes and damaging the wellbore. The thickening time test was conducted at a constant temperature of 140 °F and downhole pressure of 3000 Psi, the salinity of the water was varied from 200 ppm, 1000 ppm, 10000 ppm, 15000 ppm and 20000 ppm. The results revealed that, the different salinity levels for 100 BC are 131mins, 111mins, 92mins, 65mins and 47mins and the different salinity levels for 70 BC are 122mins, 105mins, 85mins, 61mins and 43mins respectively. The result revealed that salinity level at low temperatures and pressures has accelerating effects on the hydration of cement; that is as the salinity level increases the thickening time decreases and vice-versa. The data produced by the experimental investigations therefore will aid in the optimization of cement design and its use for numerical simulations of well cement performance.

Keywords: Water Salinity, Thickening Time, Cement Slurry, Oil Well Cementing, Rheology

INTRODUCTION

The quality of cement formulation and slurry is crucial to the integrity of oil well construction, as it ensures well safety and durability [1]. Well cementing is a multi-step process that involves the precise placement of cement slurry into the wellbore. The slurry typically consists of a blend of cement, water, and various additives that enhances its performance. Once pumped into the wellbore, the cement slurry is allowed to set and harden, transforming into a solid mass that provides structural support to the well. The supporting function of the cement is crucial for the overall stability of the well. It helps maintain the integrity of the casing, ensuring that it remains in its intended position and prevents the well from collapsing or deforming under the pressure exerted by the surrounding formations. Incomplete well zone isolation has been linked to changes in oil well operation efficiency and production capacity; inefficient cementing will inevitably result in production below optimal levels [2]. Changes in rheological properties must be taken into account during cement job design to ensure proper flowability and displacement efficiency. Additionally, salinity can affect the water-cement interaction, changing the flow characteristics of cement slurries, including their viscosity, yield stress, and fluidity. Generally speaking, higher salinity tends to increase the slurry's viscosity and yield stress, making it more difficult to pump and displace the cement [3].

In oil well cementing applications, where the slurry must be pumped into the wellbore and allowed to set to create a seal, the thickening time of the slurry is a critical property that must be controlled to ensure that it sets at the right time and does not become too thick or thin, which can lead to poor cementing quality and even failure [4]. The thickening time is a measurement of the period of time that the cement slurry remains in a fluid state and is pumpable [5]. The impact of curing temperature and water-to-cement ratio on the thickening time of oil well cement slurries was examined by [6]. They discovered that as the curing temperature rose and the water-to-cement ratio decreased, the thickening time increased. A consistometer that tracks a slurry's consistency over time under the expected temperature and pressure conditions is used to measure thickening time under simulated downhole circumstances [7].

Salinity plays a function in the thickening time and setting qualities of cement slurry. Generally, increased salinity tends to hasten the thickening time and setting process. This is due to the fact that the presence of salts alters the cement particles' hydration kinetics, causing quicker chemical reactions and an earlier gel structure formation. Increased salinity can speed up the thickening process, which may affect how well the slurry can be pumped and placed. In order to regulate the thickening time and setting properties, salinity effects must be taken into account when creating the slurry and choosing the right additives, such as accelerators or retarders [8, 9].

Poor cement slurry design can result in incomplete zonal isolation between the casing and the formation, potentially leading to fluid channeling and even wellbore collapse [10]. To ensure long-term stability and durability, the Oil Well Cementing (OWC) procedure involves preparing the cement slurry, adding water and additives, and properly placing and pumping Class-G cement slurry into the wellbore [11].

Two major factors that can affect well efficiency and potentially reduce oil production are inadequate cement slurry design and poor cementing practices. In oil and gas drilling operations, the thickening time of cement slurry is critical to the success of cementing jobs. However, high salinity in wellbore fluids can significantly influence the slurry's thickening time, leading to operational challenges and compromising well integrity. This research is necessary because the extent to which water salinity affects cement slurry thickening time has not been thoroughly established in cement slurry design.

Experimental

2.1 Materials

1. Class G cement,
2. Laboratory water
3. Salt water with different chloride concentration
4. Antifoam (ASP - 742)

The equipment and apparatus used in the conduction of the experiment are listed below:

1. Constistometer
2. Measuring cylinder
3. 50ml beaker
4. Stopwatch
5. Electronic Weighing balance
6. Stirrer
7. Warring blender
8. Slurry cup
9. Syringe

2.2. Cement Slurry Preparation

The quantities of cement, water with varying salinity levels, and defoamer used are presented in Table 1. These materials were measured and blended in accordance with the API Recommended Practice 13B-2 standard (1998), using a Waring blender (Figure 1). Liquid additives were measured by volume with syringes, while solid additives were measured by mass using an electronic balance. The Waring blender was first operated at a speed of 4000 ± 200 rpm. Water was poured into the blending cup, followed by the liquid additives, then the solid additives, and finally the cement, all within 15 seconds. The blender speed was then increased to 12,000 rpm and maintained for 35 seconds to ensure homogeneity. This procedure was repeated for different runs with varying dispersant concentrations.

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Table 1. Laboratory Quantities for the Salt Water, Class G Cement and the Antifoam.

COMPONETS	**WEIGHT (gram)**	**VOLUME (ml)**
G-CEMENT	784.4829	247.3149
FRESH WATER	351.3238	351.7107
ASP – 742	0.884001	0.974428
TOTAL	1136.691	600
Mix Fluid		352.6851

Figure 1. Warring Blender.

2.3. Thickening Time Test

The standard method for measuring thickening time is outlined in the API Recommended Practice 13B-2 (1998). Thickening time refers to the period during which the slurry remains in a fluid, pumpable state under specified temperature and pressure conditions.

For this test, the slurry was prepared as described in Section 2.1, with water salinity varied across different concentrations. The test was conducted at two consistency levels: 70 BC and 100 BC. After blending, the slurry was transferred into a slurry cup, which was then placed in a high-temperature, high-pressure (HTHP) consistometer (Figure 2). The testing conditions were maintained at 140°F and 3000 psi to simulate the downhole environment of the well formation.

The test was terminated once the cement slurry reached a consistency indicating that it was no longer pumpable and had lost its hydrostatic pressure. The time taken to reach this point is referred to as the setting time. In this study, the test was concluded when the slurry consistency reached 70 BC and 100 BC (Bearden Consistency).

Figure 2. Atmospheric Consistometer.

RESULTS AND DISCUSSION

Below in Table 2 - Table 4 are values from the experiment conducted to ascertain the effect of salinity level on thickening time of cement slurry as were recorded.

Table 2. Additives and Salinity Concentration in the formulated Slurry.

Additive					
Dyckorhoff-G					
Cement (% - BWOC)	100	100	100	100	100
Defoamer					
(Gal/Sk)	0.014	0.014	0.014	0.014	0.014
Water					
Requirement	4.96	4.96	4.96	4.96	4.96
(SK)					
Slurry					
Density (PPG)	15.8	15.8	15.8	15.8	15.8
Chloride					
Content					
(PPM)	200	1000	10000	15000	20000

Table 3. The Thickening Time Results at 70 BC with Different Chloride Content.

Salinity Level (ppm)	Thickening Time (min)
200	122
1000	105
10000	85
15000	61
20000	43

Table 4. The Thickening Time Results at 100 BC with Different Chloride Content.

Salinity Level (ppm)	Thickening Time (min)
200	131
1000	111
10000	92
15000	65
20000	47

Table 2 presents the additives and salinity concentrations used in the formulated cement slurry. A chloride kit was employed to determine the chloride ion concentration in the water. However, the chemical composition of the water was not analyzed to identify the specific chloride compounds present.

The antifoam additive in the formulation serves only to remove air bubbles from the cement slurry and prevent pump cavitation during cementing operations. For a 15.8 ppg slurry, it is typically added at a dosage of 0.014 gal/sk to ensure effective air bubble removal.

The chloride concentrations of the water used were 200 ppm, 1000 ppm, 10,000 ppm, 15,000 ppm, and 20,000 ppm. The water requirement for all five formulated slurries was 4.96 gal/sk, as shown in Table 2. This indicates that salinity concentration had no effect on the amount of water required for cement slurry preparation.

Tables 3 and 4 present the thickening time results at 70 BC and 100 BC. Thickening time is a critical parameter, as it indicates the duration available to safely mix and place the cement slurry into the well annulus before it sets or hardens.

From the tables, it can be observed that as salinity increased from 200 ppm to 20,000 ppm, the thickening time decreased. This trend is consistent with the findings of Teodoriu & Asamba [12], Yougjian et al. [13], Mbadike & Elinwa [14], and Ranjbar et al. [15].

At 100 BC, the results showed that at a salinity level of 200 ppm, the setting time was 131 minutes, whereas at 20,000 ppm it was reduced to 47 minutes—representing approximately a 64% reduction in thickening time. Similarly, at 70 BC, a salinity level of 200 ppm resulted in a thickening time of 122 minutes, while at 20,000 ppm it decreased to 43 minutes, also reflecting about a 64% reduction.

From these results, it can be deduced that increasing water salinity in slurry formulation leads to a decrease in the thickening time of cement slurry. The rheology of the cement slurry at higher salinity levels was not measured, as the focus of this study was solely on thickening time.

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CONCLUSION

The thickening time of cement slurry decreases as the chloride concentration in the mix water increases, with results indicating about a 64% reduction. This finding suggests the need to measure and account for the salt content of mix water before laboratory testing and field application, as overlooking this factor can lead to inaccurate thickening time predictions.

In practical terms, shortened thickening time poses serious risks during oil well cementing operations. If the slurry sets too quickly, it may harden inside the casing or pumping equipment, leading to non-productive time, costly remedial operations, or even permanent well integrity issues. These risks underscore the importance of carefully evaluating water chemistry prior to slurry design and incorporating appropriate additives—such as retarders—to counteract the accelerating effect of high salinity.

This research demonstrates that salt concentration plays a role comparable to accelerators in influencing thickening time. Therefore, accurate slurry formulation must account not only for conventional additives but also for the salinity of the mix water to ensure reliable placement, pumpability, and long-term zonal isolation.

Abbreviations

API	American Petroleum Institute
BC	Bearden Consistency
OWC	Oil Well Cementing

Conflicts of Interest

The authors declare no conflicts of interest.

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