UNDERGROUND MINING ENGINEERING 27 (2015) 65-74 UDK 62
UNIVERSITY OF BELGRADE - FACULTY OF MINING AND GEOLOGY YU ISSN 03542904

Review paper

CASING CEMENTING IN DIFFICULT GEOLOGICAL CONDITIONS

CEMENTACIJA ZAŠTITNIH CEVI U OTEŽANIM GEOLOŠKIM USLOVIMA

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Received: October 30, 2015 **Accepted:** November 23, 2015

Abstract: In extreme environments and remote areas, exploration puts increasing demands on the technology required for developing new reserves. As drilling operations for oil and gas penetrate deeper horizons, wellbore construction faces new challenges. Deeper and larger hole sections, higher formation pressures and higher temperatures, result in wells that cannot be properly or safely completed with conventional cementing techniques.

The integrity of cement sheat is commonly measured by its ability to provide long term zonal isolation in the well. It also has to physically support the casing, withstand pressure and temperature changes, and protect the casing from corrosive fluids. The cement bond failure can cause well control situation, losses of reservoir fluid, migration of fluid from one zone to another, and poor stimulations operations.

This paper presents some aspects of new technology tailored to these demands from Schlumberger. Advanced Cement Technology provides a range of cement alternatives, tailored to the well, with properties superior to those of conventional cements to achieve zonal isolation in oil field operations for the life of the well.

Key words: casing, cementing, aditives, slurry

Apstrakt: U ekstremnim uslovima i udaljenim oblastima istraživanje postavlja veće zahteve pred tehnologiju koja je potrebna za pripremu i puštanje otkrivenog naftnog ili gasnog ležišta u proizvodnju. Kako se pri bušenje nafte i gasa prodire u dublje formacije, konstrukcija kanala bušotine suočava se sa novim izazovima. Dublje, odnosno sekcije većih prečnika, viši slojni pritisci i temperature, rezultuju bušotinama koje se ne mogu odgovarajuće ili bezbedno opremiti sa konvencionalnim tehnikama cementiranja.

Integritet cementne obloge se obično meri njenom sposobnošću da obezbedi dugotrajnu izolaciju slojeva u bušotini. Ona takođe mora da fizički podrži zaštitne cevi, izdrži promene pritiska i temperature, i štiti kolonu od agresivnih tečnosti. Oštećenje cementne veze može da izazove uslove za dotok ili erupciju, gubitke slojnih fluida, migracije fluida iz jedne zone u drugu, i neuspešne stimulacije.

Ovaj rad predstavlja neke aspekte nove tehnologije iz kompanije Schlumberger prilagođene ovim zahtevima. Napredna tehnologija pruža niz alternativa cementu,

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za različite uslove u bušotinama, sa osobinama koje su bolje od konvencionalnog cementa za postizanje izolacije slojeva tokom životnog veka bušotine.

Ključne reči: zaštitne cevi, cementacija, aditivi, mešavina

1. INTRODUCTION

Cementing job is the process of placing cement slurry to the desired location in the annular between casing and well bore with general function to bond the casing and formation, to protect producing formations, to prevent migration of formation fluids between zones and to control lost circulation.

The slurry properties which are generally considered to be important include:

- Density – this may need to be high to control the well or low to prevent fracturing weak formations;
- Fluidity to enable pumping and placement;
- Setting time, or pumping time, so that the slurry sets soon after the job is complete and the subsequent operations can begin;
- Strength – this may or may not be important. A kick-off plug may need a high strength;
- Stable suspension of particles – non-sedimenting. Free Fluid or free water;
- Ability to resist dehydration against permeability – Fluid Loss;
- Permeability;
- Shrinkage;
- Durability. The cement must last a long time – longer than the well – and prevent fluids moving between the subsurface and surface.

The optimum water to cement ratio for a cement slurry is the result of a balance between opposing trends. On the one hand, low water to cement ratios generate dense, high strength set cements. Test have suggested that the maximum cement strength is obtained at a water-cement ratio of about 0.25 litres of water per kilogram of cement. This is the minimum amount of water necessary to fully chemically react and hydrate the cement particles.

The well design will normally fix a range for the slurry density. This will be influenced by the height to which the cement is to be lifted, e.g. 150 m inside the previous shoe, and the available pore/fracture pressure window. The slurry density will normally be higher than the mud density.

Portland cements that conform to American Petroleum Institute (API) Specification (ISO 10426-1:2000) are supplied where available or by request. These cements are supplied as Ordinary grade (Classes A and C), Moderate Sulfate Resistant grade (Classes B, C, G and H), or High Sulfate Resistant grade (Classes B, C, G and H). Sulfate resistance is necessary to protect against attack of the hydrated (set) cement by soluble sulfates (API, 2010).

Formation brines containing sulfates are among the most destructive downhole agents to Portland cements. The deterioration is usually characterized by expansion, strength loss, cracking, and finally complete failure of the cement structure.

When this occurs in a producing well, where sulphate-containing formation water is in contact with the cement at the outside of casing, integrity may be corrupted and productivity and zonal isolation adversely affected. This is clearly an undesirable effect and therefore the possibility of sulphate-induced cement disintegration should be avoided by using a sulphate resistant cement.

Oil-well cements containing less than 3% of tri-Calcium Aluminate (Ca_3A) are resistant against sulphate attack after setting, and should be used whenever downhole brines may exist which contain magnesium and sodium sulfates. Sulfate attack can also be substantially reduced by the addition of pozzolanic materials, such as fly ash, to the cement system. Cement failures due to sulfate attack are more common in shallow wells where temperatures are lower than 90°C (Shell Internationale, 1994).

Each API Class of cement has a "normal" water ratio for a neat (no additives) slurry. The water-cement ratio for each API class is given as percent water (litre of water per kilogram of cement).

The slurry density and yield are also given in the Table 1 (BP & Chevron Texaco, 2002).

Table 1 - API Normal cement slurry densities

API Cement Class	**Water [%]**	**Weight [kg/m^3]**	**Volume [l/kg]**
A	46	1870	10.4
B	46	1870	10.4
C	56	1775	9.8
G	44	1895	10.5
H	38	1965	10.9
D, E, F	38	1965	10.9

There are basically just two ways to adjust cement slurry density:

- Modify the water content;
- Add particles.

In practice, it is often a combination of both approaches that is used.

Particles have either low or high specific gravity depending on whether the intention is to reduce or increase the slurry density. Often these density controlling additives require additional water to be included in the formulation to maintain the desired consistency, or the use of some concentration of dispersant.

The simplest way to modify the slurry density is by changing the water to cement ratio. For example, densified slurries can be designed by reducing the water concentration. On the other hand, light density slurries can be designed by increasing the water concentration from the normal values. When designing light weight slurries by adding extra water, additives need to be included to "tie up" the water and prevent slurry instability.

Advanced Cement Technology from Schlumberger, incorporating years of research and developmen, provides a range of cement alternatives such as CemCRETE systems and CemSTONE systems for cementing operations that help provide effective zonal isolation and well integrity.

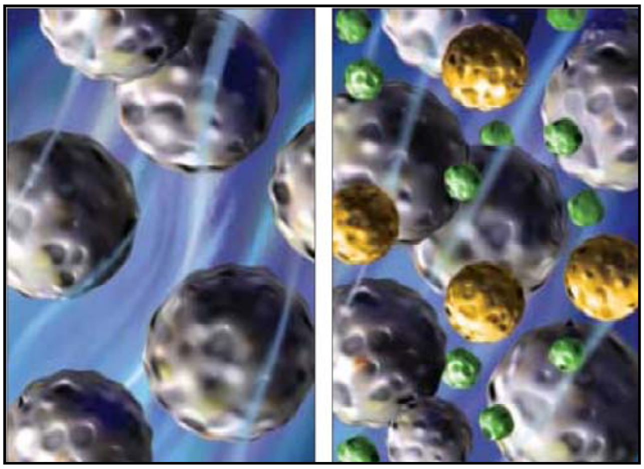

Figure 1 - Standard cement slurries require water to fill the void between particles. CemCRETE slurries fill the interparticle void with more solids, giving superior cement properties (http://www.slb.com)

2. CEMCRETE CONCRETE-BASED OILWELL CEMENTING TECHNOLOGY

CemCRETE slurries are systems that allow deeper casing points, better high-pressure, high-temperature (HPHT) wells and different formulations for various applications.

LiteCRETE slurry systems provide the high strength and low permeability, even at densities as low as 900 kg/m^3, necessary to cement across weak formations.

DensCRETE technology gives very high-density cements (to 2 880 kg/m^3), for well control with low viscosity.

CemCRETE Advanced Cement Technology is a high-performance alternative to conventional oilwell cement slurries that changes the fundamental rules for cementing. Casing strings can be set deeper without worrying about lost returns. Cements in HPHT wells can be placed at lower circulating pressures and higher rates.

Unfortunately, in conventional cementing slurries, the amount of water needed for mixing and pumping is much more than is optimum for set cement. CemCRETE technology disconnects these two phases of cement performance to give both optimum slurry properties and excellent set-cement performance.

CemCRETE technology increases the solids content of the slurry by using engineered particle size distribution. Smaller particles fill the void space between larger ones, resulting in a slurry requiring less water, yet retaining good fluid properties. More solids in cement provides greater compressive strength, reduces cement permeability and increases resistance to corrosive fluids (Figure 2). Choosing solids with different properties allows slurry designs to meet the requirements of the application.

CemCRETE designs mean cements for production casing can be lower density while maintaining optimum properties for isolation. The set cement performs better than standard cement for the life of the well. In remedial operations, increasing solids content improves the penetrating ability of the slurry and decreases placement pressures.

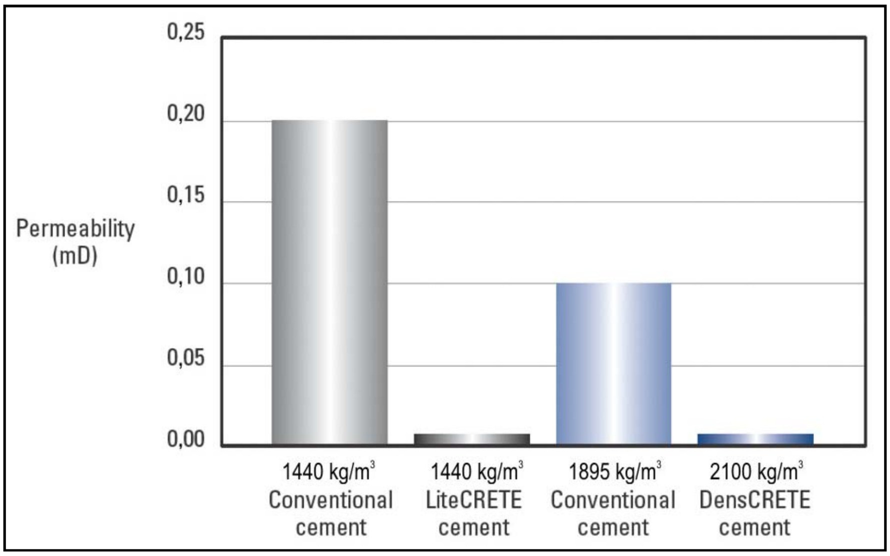

Figure 2 - Properties of CemCRETE cements are superior to those of cement made using conventional technology

2.1. LiteCRETE low-density slurry system

Lightweight cements are used to control losses to weak or high-permeability formations. In most cases, cement extended by the addition of water and additives to prevent water separation are adequate to control the losses. These cements generally have low strength and high permeability. However, when low density with either high strength or low permeability is required, special formulations are necessary to meet those requirements.

Applications for lightweight cements include very weak, fractured, and highly permeable or vuggy formations. Such cements can be used in primary, squeeze or plug cementing.

When cementing across weak formations, it can be difficult to place sufficient cement behind the casing without using extended, low-density cement slurries or multiple-stage cementing operations. A simple, low-density slurry that performs like conventional-density cements can eliminate these restrictions and allow to set casing deeper.

The LiteCRETE high-performance system enables to redesign casing program and provides cement properties at extended-slurry densities. LiteCRETE slurries can be mixed from 900 kg/m^3 to 1 560 kg/m^3 for effective placement across weak formations. Once set, these cements provide compressive strength and permeability that are superior to properties of other lightweight systems and even comparable to those of 1 900 kg/m³ cement (Figure 3 and 4).

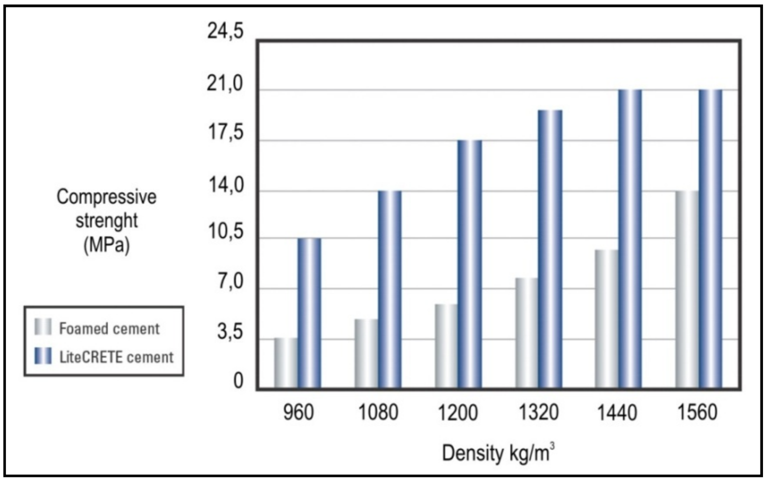

Figure 3 - Strength of LiteCRETE slurries are superior to properties produced by foamed cement

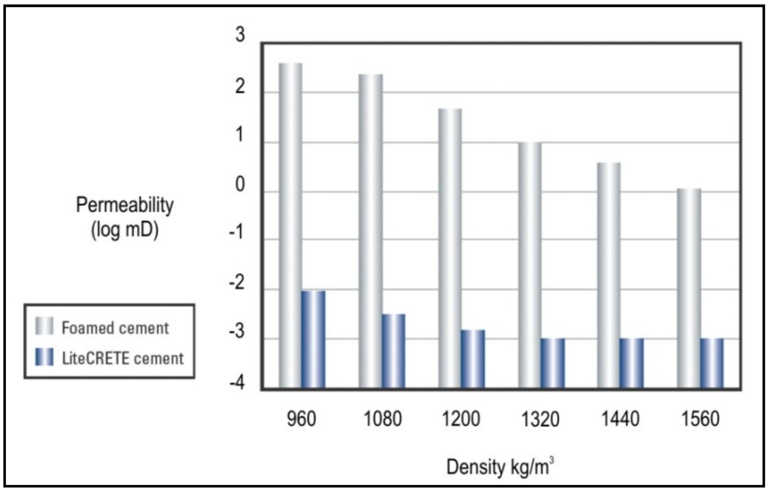

Figure 4 - Permeability of LiteCRETE slurries is superior to properties produced by foamed cement

Low-density LiteCRETE slurry frequently eliminates stage cementing in long intervals. With performance similar to higher-density slurries, it can give exceptional perforation quality without reducing cement integrity. LiteCRETE systems are even strong enough for hydraulic fracturing treatments or setting kickoff plugs.

2.2. DensCRETE Advanced Cement Technology

When working on HPHT wells, the fewer unplanned concerns there are, the smoother the operation runs. An ideal cement system offers a simple design, lower viscosity and the versatility of slurry density that can be easily increased on location.

Using unique engineered-particle-size technology, DensCRETE systems give very high density cements, up to 2 880 kg/m^3, with low viscosity. Because of higher compressive strength and lower permeability, DensCRETE slurries outperform conventional high-density slurries to provide high-pressure zonal isolation.

The primary applications for DensCRETE technology include high-pressure primary cementing, well control plugging, whipstock or kickoff plugging, and grouting operations.

Drilling through high-pressure zone can require sudden changes in mud weight. With DensCRETE technology, it is possible quickly increase the slurry density by 120 kg/m^3 on location. With reduced risks, shorter placement times and lower costs, DensCRETE systems offer the high-density cementing alternative with higher performance.

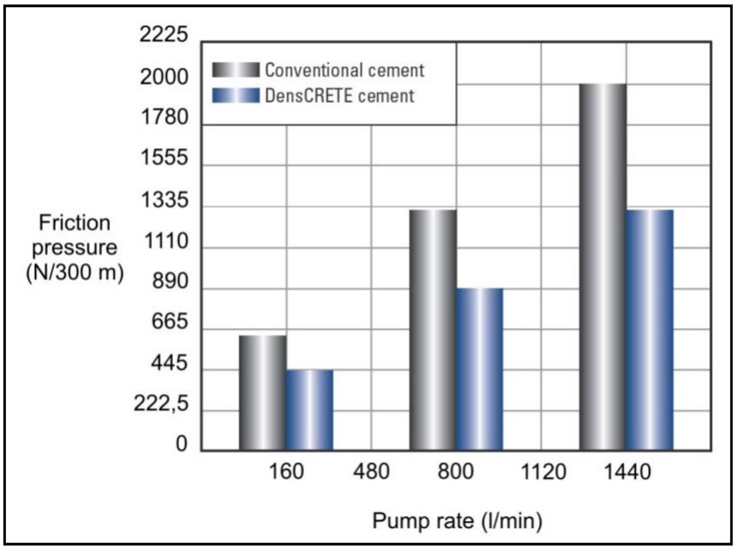

Figure 5 - CemCRETE technology results in slurry formulations that have excellent flow properties. Friction pressures are much reduced, so slurries can be placed at greater flow rates to reduce placement time and enable better mud removal

3. CEMSTONE ADVANCED CEMENT TECHNOLOGY

CemSTONE systems provide reliable, long-term zonal isolation despite changing downhole conditions. These systems control set-cement properties, such as flexibility, expansion and impact resistance, so the cement can withstand stresses that destroy conventional oilwell cements. The following systems are included in the CemSTONE family.

FlexSTONE systems provide mechanical properties that can be adjusted to match the wellbore stresses and provide permanent zonal isolation to seal wellbore fluids behind casing. DuraSTONE Advanced Cement Technology systems are tougher and have better impact resistance than conventional cements, so they are more durable and provide better isolation under rugged drilling and completion conditions.

3.1. FlexSTONE Advanced Cement Technology

For years cements were designed based on the optimal properties necessary for slurry placement. The set-cement properties (high compressive strength and low permeability) were assumed to be sufficient for all well conditions. Today, the importance of an isolation material that will last under complicated well stresses is better understood.

The set cement must withstand stresses caused by changes in temperature and pressure in the wellbore throughout the well's life. This reliability is especially relevant considering the expense and difficulty of repairing wells.

Changes in pressure caused by production, injection or high-pressure treatments can impose stresses on the cement through the casing. Isolation is always needed across the productive intervals, but it is also needed in other intervals that may protect valuable surface waters or prevent movement of corrosive or hazardous liquid or gas behind the casing. Changes in temperatures resulting from production of high-temperature fluids or injection of hot fluids, such as steam, can expand the casing and create great stresses in the cement sheath. These changes can cause tensile stresses that crack the cement (Nelson, 1990).

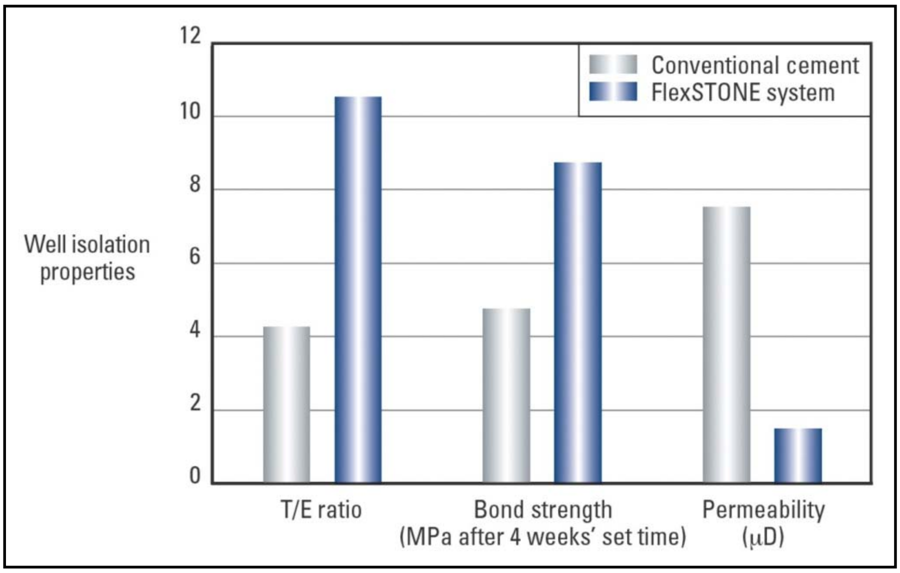

Figure 6 - Properties of conventional cements are not adequate for difficult well isolation. FlexSTONE systems have higher ratios of strength to Young's modulus (T/E) and higher bond strength while maintaining low permeability

FlexSTONE Advanced Cement Technology systems offer mechanical properties that can be engineered to meet the changing stresses in the wellbore: lower permeability than conventional cements, good compressive strength, better flexibility and better chemical resistance. With these properties customized to the well, the system will resist stresses and maintain isolation.

FlexSTONE systems also expand to seal any microannulus. Because FlexSTONE cements are engineered to be more flexible than the formation they seal, this expansion of the cement sheath is two to three times greater than possible with conventional cement systems, thus assuring complete hydraulic isolation.

3.2. DuraSTONE Advanced Cement Technology

Previously, oilwell cements were designed to be pumped, to develop strength and then to remain relatively undisturbed behind casing, thereby providing isolation and pipe support throughout the production cycle of the well. Mechanical shocks during further drilling or other well operations that can destroy the integrity of the cement sheath were not considered, although they could impair zonal isolation.

Modern reservoirs require more complicated technology. Complex drilling programs call for bicentered bits, multilaterals or milled windows, and difficult sidetracks. Completions use larger perforations or higher perforation densities in ever thinner producing intervals. Isolation in these situations is critical; it requires a tougher material with better tolerance to vibration and impact.

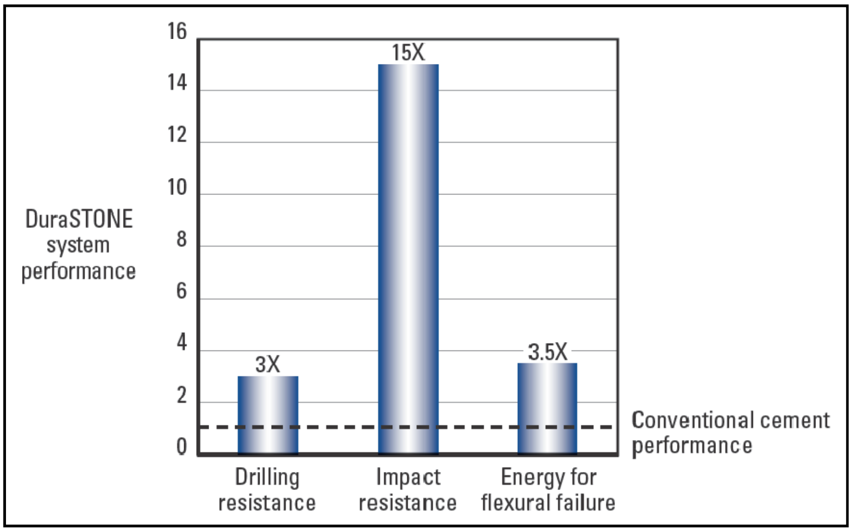

Figure 7 - DuraSTONE systems are tougher than conventional cement. They have better drilling and impact resistance, and significantly more energy is required to cause flexural failure

DuraSTONE Advanced Cement Technology systems are more durable or tougher than conventional systems with broad density range (1 200 kg/m^3 to

3 360 kg/m^3). Drilling tests have shown DuraSTONE systems to be two to three times tougher than conventional cements; this allows faster kickoff in less distance, even in hard formations (Figure 7).

4. CONCLUSION

Weak formations, gas migration and other extreme geological conditions occur with unpredictable frequency in many parts of the world. The oil and gas industry have interest in focusing on materials and procedures to overcome and solve the potential problems which cause the failure of cement zonal isolation.

The newest generation of Schlumberger Advanced Cement Technology, offer set-cement properties that can be adjusted to meet the requirements of the well. With these systems, properties such as permeability and strength are superior to those of conventional cements. Slurries can be lighter (or heavier) than ever, without compromising properties of the set cement.

They are purpose-built to withstand mechanical stresses and changes in temperature and pressure that damage conventional cements. These new systems offer control over properties never possible with conventional oilwell cement, such as flexibility, expansion and impact resistance.

Schlumberger products presented in this article demonstrate that integration of services and technologies coupled with advances in simulation, modeling and product technologies have moved the industry forward in well cementing and potentially, producing well longevity.

ACKNOWLEDGEMENT

This paper was realized as a part of the project (No. 33001) financed by the Ministry of Education, Science and Techonological Development of the Republic of Serbia within the framework of Programme of research in the field of technological development for the period 2011-2015.

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