

# Advances Since “A Study of Low Temperature Cementing”

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I am honoured to follow an article written 50 years ago by W.M. Thorvadson. Studying the installation of cement systems at low temperatures was important for achieving wellbore integrity in 1962, and the performance of cement systems at low temperature continues to be critical for wellbore integrity today. There have been many changes in the last 50 years, and yet some of the basics are still the same. Computer simulations have significantly increased our ability to predict the exposure conditions and evaluate cement performance. The oil industry still uses Portland cement-based systems for cementing, and calcium chloride is still used as an accelerator. New additives and materials have been introduced as the industry drills more challenging wells and requires performance in extreme conditions.

We are still drilling wells through permafrost in the Arctic, but we are also drilling wells in the cold-temperature, high-pressure regimes of deepwater. We are cementing heavy oil wells in cold environments, and then subjecting the wells to large temperature and pressure increases as we inject steam to recover the heavy oil. We investigate not just thickening time and wait on cement (WOC) time, but we also investigate mechanical properties of the set cement system to understand if it can maintain well integrity for the full life cycle. Cement is a critical piece of well integrity throughout the life of the well (**Fig. 1**).

Computer simulations have allowed the industry to more accurately predict exposure conditions for cement. Mr. Thorvaldson had the benefit of making measurements of temperature in the wellbore before and after cementing operations. Today, we can use temperature simulators to predict cement temperatures during cementing operations and during WOC. The computer also allows us to investigate several other critical parameters such as efficiency of mud removal, the risk of gas migration, simulated pressures, and simulated temperatures. Additionally, we can use computer simulations to understand the cement sheath stress condition during wellbore operations that take place after the cement is set.

For wells drilled in the Arctic through the permafrost, cement is required to set and gain compressive strength in sub-freezing conditions. Fast-setting cement systems for use through permafrost have been developed to set before the system freezes. Lower-density systems are desired to achieve a cement sheath from the bottom to the top of the well. Lightweight materials were added together with optimized particle size distribution so that high-solids volume fraction slurries with excellent properties can be achieved (**Fig. 2**). Cement systems are routinely used at densities of 1300 kg/m<sup>3</sup>; in fact, cement systems exist today with densities as low as 700 kg/m<sup>3</sup>.

The oil industry has also moved to the extreme conditions of deepwater offshore. Seafloor temperatures near freezing are common in the deepwater operations on the east coast of Canada. In addition to the cold temperatures, the cement slurries must also achieve early compressive strength in the high-pressure environment. As wells are drilled in water depths greater than 2300 m, the cement slurries must perform in pressures greater than 23 MPa at the seafloor. Cement systems with short transition times and early compressive strength development are necessary to provide structural support for the well. These cement systems must also be formulated to transition quickly from a gel state to a set state so that there is minimal risk of annular flow.



Fig. 1—Cement for well integrity.

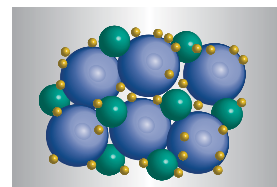


Fig. 2—Optimized particle distribution.

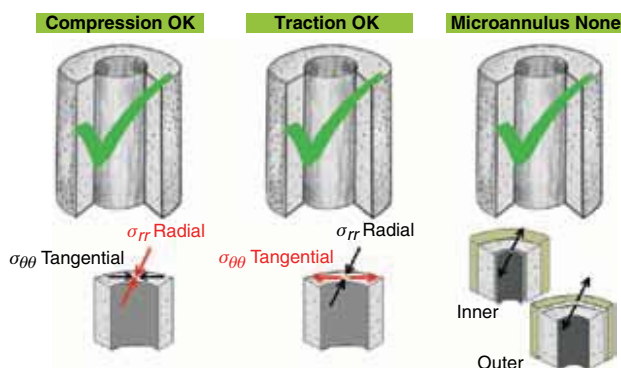


Fig. 3—Computer simulation.

Cement system performance is also critical in extreme environments such as heavy oil wells. Cement slurries are placed in reservoirs with very low temperatures (often ranging from 5–13°C). The cement must set and provide support for the well. Then steam is applied to produce the resource. The cement sheath is exposed to large temperature changes, as well as significant stress due to the expansion of the casing. Specialized cement systems may be used in these situations. Cement properties such as Young's modulus, Poisson's ratio, tensile strength, and compressive strength may also be of importance. Software programs can be used to evaluate the cement system to determine that it can withstand the stresses that are anticipated in the wellbore.

The cement sheath is not only a passive seal in the annulus. Novel materials and the concept of self-healing cement have been recently introduced to the industry. The cement sheath provides isolation for flow in the annulus. If the traditional cement system cracks, it is not obvious that it can maintain the seal. With the availability of self-healing cements, cement can heal or close the crack if it occurs and maintain the integrity of the cement sheath for the entire life of the well.

Cement is a critical component of today's wells, providing wellbore integrity throughout the life of the well. The industry continues to successfully use cement in low-temperature and more extreme environments as we drill more challenging wells. Computer simulations help us to predict the exposure conditions so fit-for-purpose cement systems can be installed, providing zonal isolation and well integrity for the life of the well (**Fig. 3**). As we consider the strides that have been made since 1962, we look forward to the implementation of significant technology during the next generation.