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A REPLY TO DISCUSSION OF THE PAPER "THE HYDRATION OF SALINE OILWELL CEMENT" BY JOHN BENSTED

Xian Lin, Xingshang Zhou and Mingjian Huo
Research Institute of Engineering Technology of China
National Petroleum Corporation
40 Jin-Tang Road, Tanggu, Tianjin 300451, China

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We have received Dr. John Bensted's discussion of our paper. We appreciate this paper very much.

In the Zhong Yuang, Jian Hang and Xing Jian oil fields etc. of China, wells of thick salt formations have been a common occurrence. Hence, both lower saline slurry and high saline slurry are commonly employed here to successfully undertake well cementing through salt layers. As you correctly point out, the presence of a saline slurry in the wellbore reduces considerably the rate of dissolution of the salt formations. This enables the cement slurry to harden in the annulus to give a protective sheath without producing undesirable wellbore collapse, and thus to secure the well in question. In addition, we have also applied the bentonite and fly ash etc. extended well cementing slurries to successfully cement such wells, as well as other cementing slurries such as chemicals aerate cementing slurries system (s.g.1.2-1.6). But we have not carried out the theoretical study yet.

Zhou et al. (1) have pointed out, oilwell cement slurry prepared with saltwater and silica sand, cured at 160°C and 20.7MPa, the strength decreases with increasing salt content at longer curing periods above 12hr. The strength decreasing of samples cured at 160°C is caused by new phases formed at elevated temperatures (compared with the strength of slurries prepared with saltwater hydrated at 93°C and 20.7 MPa). Erik B. Nelson was of the view that C-S-H gel is an excellent binding material at well temperatures less than about 110°C. At higher temperatures, C-S-H gel is subject to metamorphosis, which usually results in decreased compressive strength and increased permeability of the set cement. C-S-H gel often converts to a phase called "alpha dicalcium silicate hydrate". Ding Shuxiu (3) (4) suggested that C-S-H gel under hydrothermal temperature range 75-95°C converts to C_2SH_2. When increasing the temperature to 120-150°C, C-S-H transforms into $C_2SH(A)$ (alpha C_2SH). If silica flour or silica sand in this latter case is employed, C-S-H will react with SiO_2, which results in the formation of CSH(B) and $C_5S_6H_4$ (tobermorite) et al. Both hydrates have lower Ca/Si mol ratio. The compressive strength of $C_2SH(A)$ is about 1.9 MPa far lower than about 32.5 MPa of CSH(B) and 16.5 MPa of $C_5S_6H_4$. Our (1) DTA and XRD analyses of samples cured at 160°C and 20.7MPa show the existence of $C_2SH(A)$, which confirms these views.

Dr. John Bensted points out, in the U.K. continental shelf area of the southern North Sea, saline slurries with 18% BWOW NaCl have regularly been employed to undertake well cementing through salt layers. The wells involved in these cementing jobs were not more than ca. 9000 ft (2745m). According to API Schedules, the bottom hole circulating temperature-BHCT is less than 70°C. Hydrothermal changes in the poorly crystalline calcium silicate hydrates formed in the annulus were not observed. Our work (1) indicated that salt content affects the interface between $Ca(OH)_2$ and C-S-H. Salt also changes the endothermic peak of $Ca(OH)_2$ in DTA analysis. The effect of salt on C-S-H is due to the absorption of NaCl microcrystallites and Na^+ on the surface of the fibrous structure. These imply that salt content affects the crystallites formation of the hydrates. High salt content results in the formation of poor crystallite calcium silicate hydrates. These conclusions are in agreement with data gathered in the southern North Sea.

We have not undertaken the theoretical study of the oilwell cement slurry extension using bentonite in saltwater. Dr. John Bensted (5) has published another paper titled, "Effects of Storage upon the Cementing Properties of Class G Oilwell Cement Plus 8% Bentonite Blends" in this journal. Among these testing phenomena, we regard that the absorption of Ca^{2+} by bentonite plays an important role in cement slurry or in cement exposed in a moist environment.

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