Effect of Thermal Shock on the Performance of Smart Cement

B. Basirat and C. Vipulanandan, Ph.D., P.E.
Texas Hurricane Center for Innovative Technology (THC-IT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
E-mail: bbasirat@uh.edu, cvipulanandan@uh.edu, Phone: (713) 743-4278

Abstract
Piezoresistive smart cement sheath supporting a casing showed significant sensitivity in thermal shock situation. Depending how long the temperature gradient was applied to the material the resistivity changed up to 55% for heating and 266% in freezing conditions.

1. Introduction
The purpose of the cemented casing is to provide zonal insulation and a hydraulic seal. It prevents the fluid contamination in the borehole and blocks the escape of fluid to the surface. It also anchors and supports the casing string. The possibility of the corrosion of the steel casing decreased by cement sheath. The primary cementing is a critical procedure in the construction of the wellbore. The defected cement may lead to gas migration and might end up to blow out, which counts as one of the disaster in the oil industry.
There are four categories of likely causes of uncontrolled gas migration in a well including: tubing and casing leaks, poor mud displacement, improper cement-slurry design and damage to primary cement after setting (Nelson, 1990).
The radial crack propagation may occur in geothermal and petroleum applications. The injection of cold fluid into hot rocks causes the formation of several cracks. The thermal shock implies thermal stress on the cracks' lengths of the cemented well. The thermal gradient occurs when components are subjected to rapid changes in temperature and temperature gradient (Tarasovs and Ghassemi, 2012).
Therefore, Knowledge of in situ monitoring of the oil well is a primary goal to detect the defect or crack in the cement due to temperature gradient.

2. Objective
The objective of this study is to investigate the effect of thermal shock on smart cement based on the change in resistivity due to rapid heating and freezing.

3. Results and Discussion
If the surface temperature of a body is rapidly changed from T_0 to T_1, the generated stress in the material is described as Eq. (1)

$$\boldsymbol{\sigma} = \frac{\boldsymbol{\alpha}.\boldsymbol{E}.(\boldsymbol{T_0} - \boldsymbol{T_1})}{(\mathbf{1} - \boldsymbol{\upsilon})} \quad \textbf{(1)}$$

The basic thermal shock parameter R is the maximum temperature change which can be withstood without the stress generated exceeding the fracture stress. Where R= Hasselman Parameters, σ_f = fracture strength, E = Young's modulus, ν = Poisson's ratio, α = thermal expansion coefficient

$$\boldsymbol{R} = \frac{\boldsymbol{\sigma_f}(\mathbf{1} - \boldsymbol{\upsilon})}{\boldsymbol{\alpha}.\boldsymbol{E}} \quad \textbf{(2)}$$

Table 1 summarizes the material properties of the smart cement and the Hasselman Parameter, the temperature which can be tolerate by the material. In Fig 1 and 2 the smart cement was heated up first and freezed later. The resistivity changes were measured vertically and horizontally, respectively. The resistivity dropped between 52 to 55 % during applying the heat and increase around 260 to 266 % while freezing. The weigh changes were monitored (Fig. 3) and had similar trend compared to the electrical resistance changes.

Table 1. Coefficients for calculating Thermal Shock Parameter

σ_f (MPa)	ν	α (10^{-6}/°C)	E (GPa)	ΔT or R (°C)
4	0.3	18-20	10-30	5-16

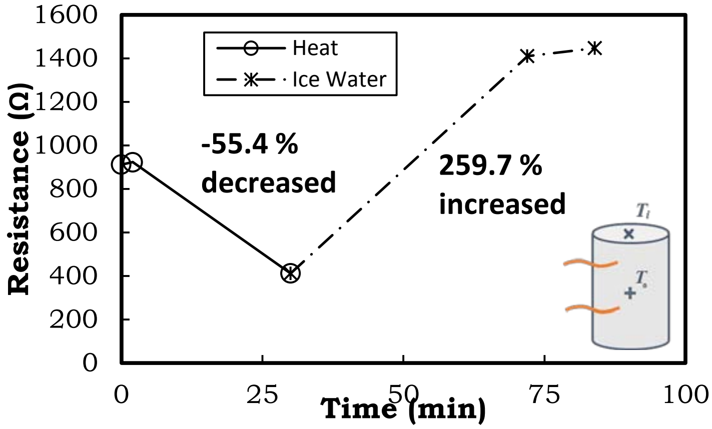

Figure 1. Vertical Resistance under the heat and cold effects

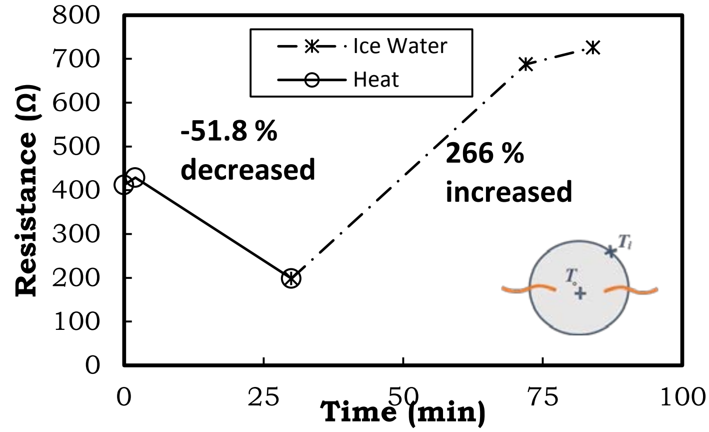

Figure 2. Horizontal Resistance under the heat and cold effects

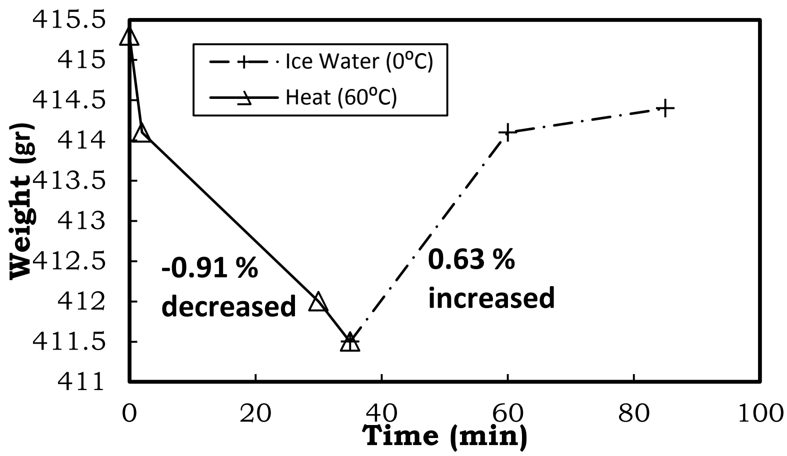

Figure 3. Change in Weight under the heat and cold effects

4. Conclusion

The smart cement is really sensitive against temperature gradients as well as thermal shock which can happen in the oil well and the smart cement gives the capability of monitoring the changes. These significant changes were about 55% in hot condition and up to 260 % in freezing condition in a similar rate (the slopes are similar).

5. Acknowledgment

This study was supported by the Texas Hurricane Center for Innovative Technology (THC -IT).

6. References

1. Nelson, E. B., (1990), "Well Cementing." Houston, Texas: *Schlumberger Educational Services*.
2. Tarasovs, S. and Ghassemi, A., (2012), "Radial cracking of a borehole by pressure and thermal shock", *American Rock Mechanic Association*, (ARMA) 12-425.
3. Cotton, JW., (1994), "Thermal Shock of Ceramic" *Technology International*, *CERAM Research Website*.