Sensing of Gas Leak through Piezoresistive Smart Oil Well Cement

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Abstract: In this study, smart cement sensitivity to gas leak was evaluated using the piezoresistive smart cement. The high pressure – high temperature (HPHT) chamber was used to perform the test. The gas leak in the Smart Cement slurry was investigated immediately after mixing. Results indicated that Smart Cement is sensitive to gas flow and pressure variations.

1. Introduction:

With the reported failures and growing interest in environmental and economic concerns in the oil and gas industry, integrity of the cement sheath is more crucial today than ever before. (Wilson, 2017). Hence, adequate cement jobs are critical to ensure the integrity of wells during placement operations and throughout the entire service life of oil and gas wells (Vipulanandan et. al. 2015). Unfortunately, until now there are no reliable technologies for monitoring cement operations in real time (Vipulanandan et al. 2014). There are also concerns regarding abandoned wells were failure of cement plugs may result in fluid migration through the cement plug (Bois et. al. 2019). The industry's alternatives for verifying well cement operations have plenty of disadvantages and limitations. The coverage of the logging tools available is limited and some of the available methods are intrusive and may ultimately jeopardize the cement integrity or alter its rheological properties. The interpretations of these logs are usually made with minimum or no information about what really happened during the cement job (Benge G. 2015). A Strategy or method to improve the chance of success when setting or spotting cement fluids/slurries is missing. More or so, it si random acts or attempts hoping the law of averages will provide the results (Heinold and Shine, 2017). This challenge could be addressed by introducing cements that exhibit self-sensing capabilities (Smart Cement). Thus, improving the current well cement slurry design promotes the visualization of cement operations in real time by means of measuring the change in electrical resistivity due to induced mechanical stress known as piezoresistive effect. This technology models the behavior of cement based on the nonlinear p-q model which was developed by Vipulanandan et al., 1990. By monitoring resistivity changes in cement, this technology may help in detecting gas leaks. Therefore, this study is dedicated to investigate the pathways for gas migration in well cement and test the sensitivity of piezoresistive smart cement to gas leak and pressure variations in the HPHT chamber.

2. Objective:

Overall objective was to investigate the sensitivity of smart cement slurry in detecting gas leak.

3. Materials and Method:

Class H cement (350 g) and water (140 mL) with conductive filler (0.15 g). LCR is used to measure the resistance variations and nitrogen gas to pressurize the cell containing the cement. The experimental set up is shown in **Fig. 1**.

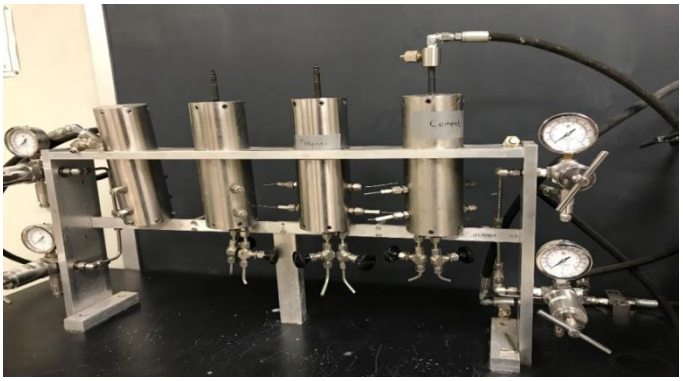

Figure 1. High Pressure and High Temperature Gas Leak Testing Apparatus

Using HPHT **Fig. 1**, the following procedure was followed for testing smart cement sensitivity:

1. Opening the pressure valve and fluid loss valve and apply 50 psi pressure.
2. Continue taking measurement every 1 minute.
3. Close the lower (fluid loss) valve and increase pressure to 100 psi.
4. Continue taking measurements every 1 minute.
5. Release the pressure from both valves.

4. Results and Discussion: Smart Cement was very sensitive to applied pressure (**Fig. 2-4, Table1**):

Table 1. Gas Leak Test Results

Total Fluid Loss (mL)	5
Initial Resistivity (Ω.m)	1
K factor (m^{-1})	22.1
Curing Time (hours)	0

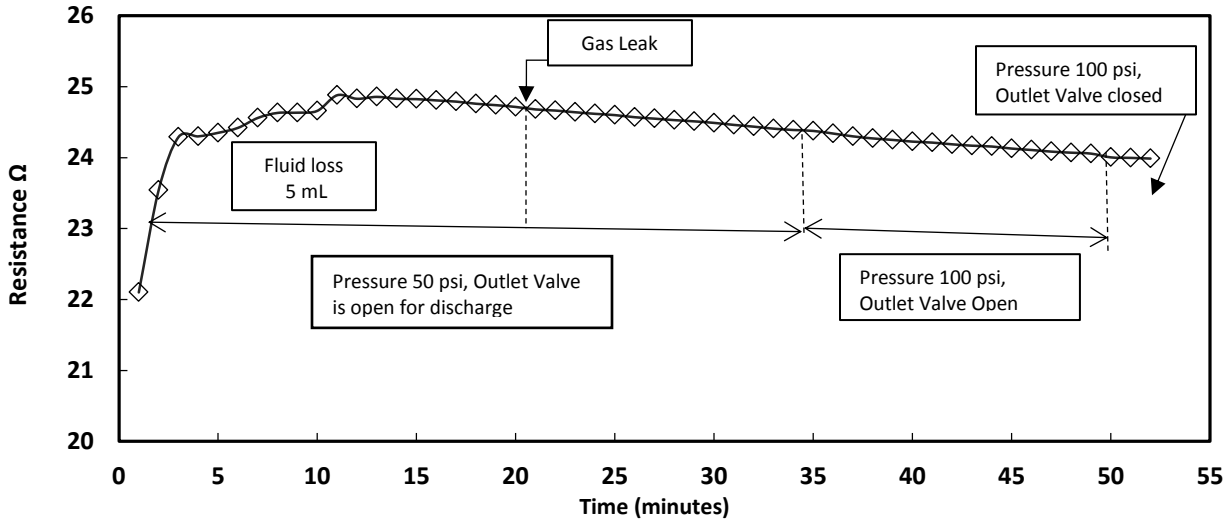

Figure 2: Resistance versus Time

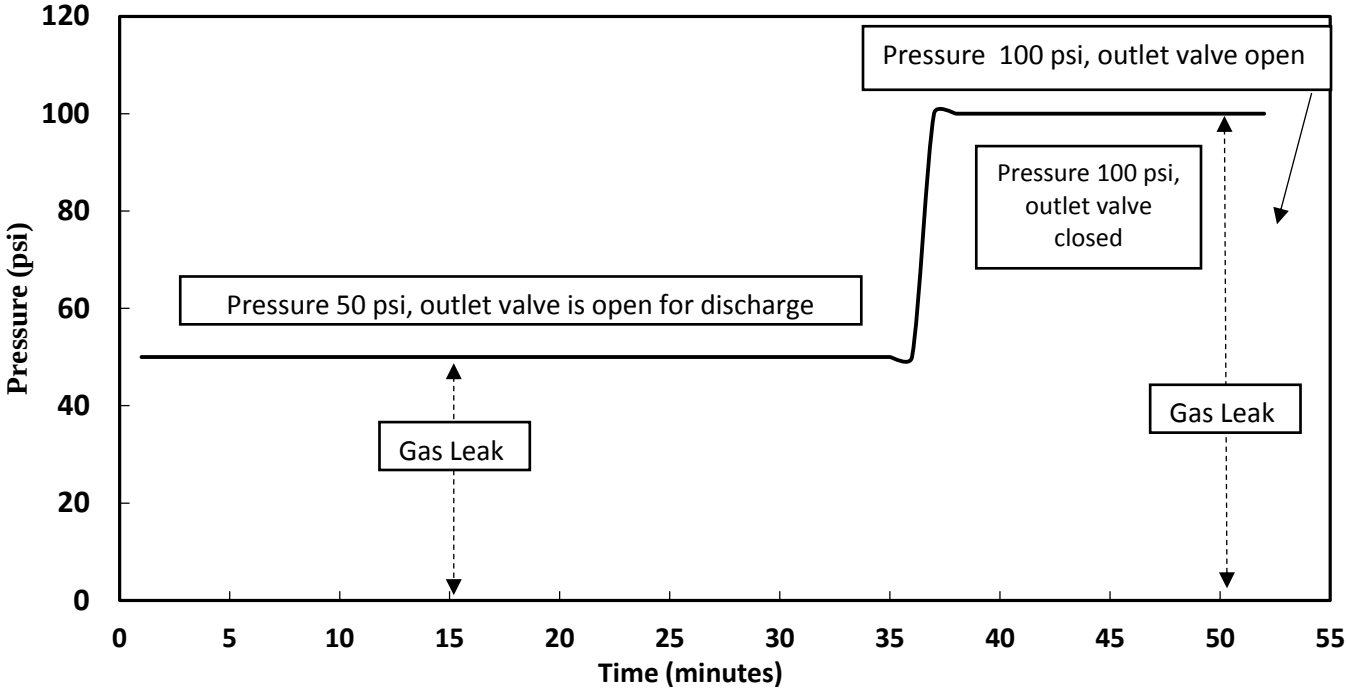

Figure 3:Pressure versus Time

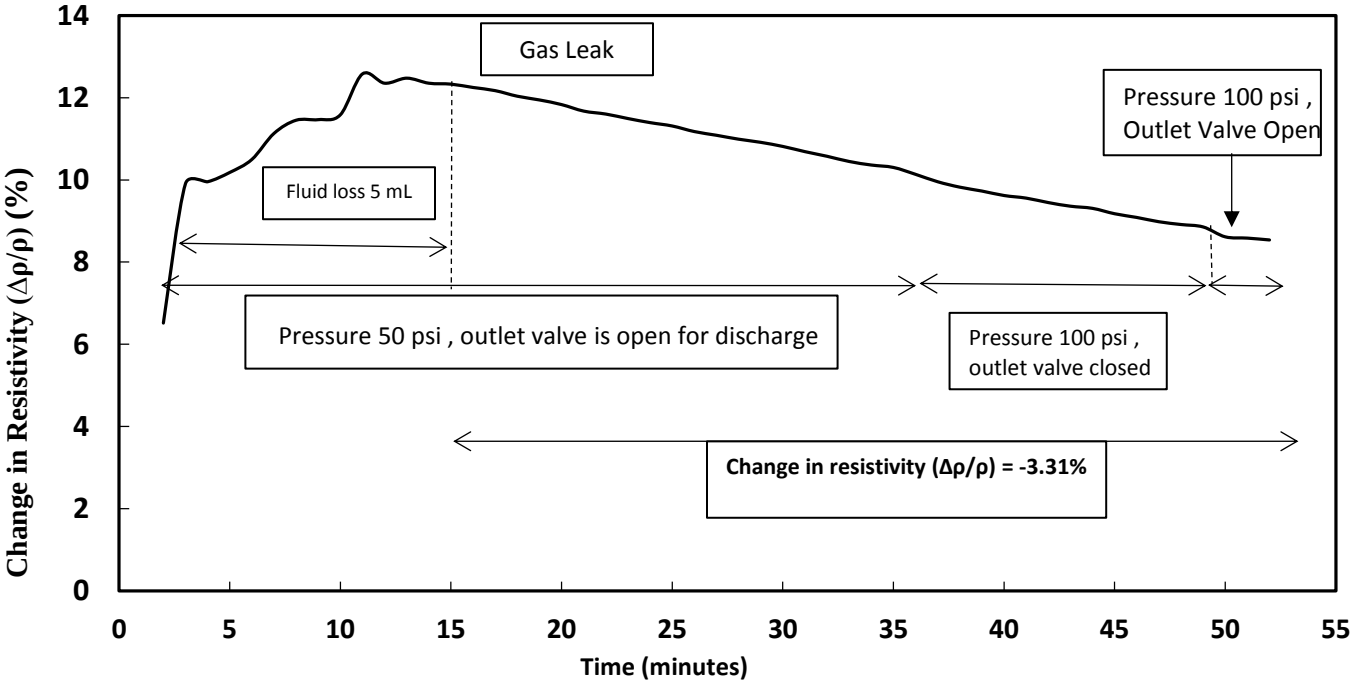

Figure 4: Change in Resistivity versus Time

5. Conclusion:

1. Smart cement was sensitive to gas leak through the cement and change in resistivity by -3.31%.
2. Smart cement was sensitive to pressure variations.
3. The sensitivity of smart cement could help in the detection of gas migration in wellbore annulus in real time.

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7.References

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