Proper cementing, sealing is key to zonal isolation

DEEPWATER CEMENTING

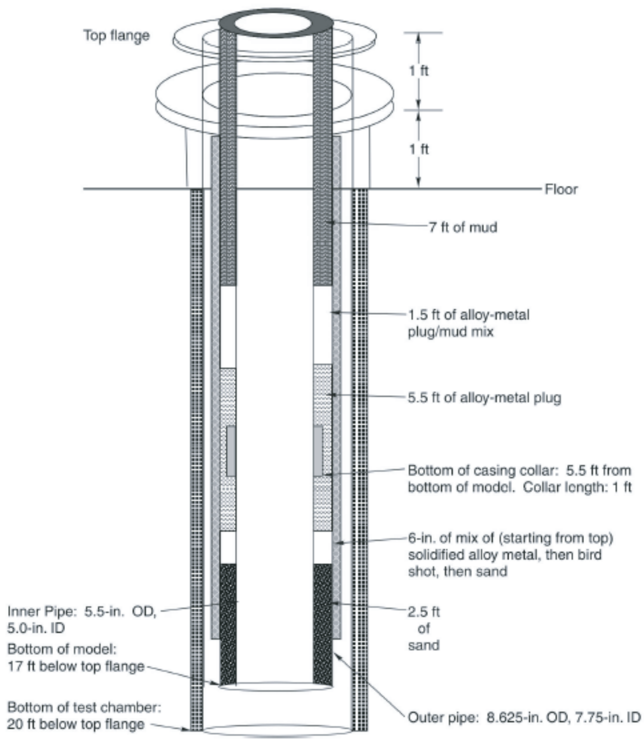
CEMENTING IN OFFSHORE deepwater wells is a complex operation compared to the traditional cementing operations on the shelf and land. Huge volume requirements, specialized equipment and high pressures complicate the cementing process. Accuracy in displacement calculations is required to ensure proper displacement of cement with drilling mud. Not being able to "bump the plug" always leaves the uncertainty if enough was pumped for proper displacement or if over-displacement has occurred resulting in a complete failure of the cementing operation.

With deepwater operations moving to deeper seas, the effect of temperature variations and high pressure induce another difficult-to-model parameter: compressibility of a synthetic mud. The authors researched several Gulf of Mexico deepwater wells.

Each well interval was analyzed to evaluate the success of cementing jobs and to understand the major contributing factors for failures. In-depth temperature, pressure and mud modeling studies were performed to understand the effect of compressibility on these cement jobs. Dynamic temperature modeling has facilitated more accurate prediction of mud temperatures inside the drill string during and after the cementing operation.

Proper temperature modeling has facilitated better 3D modeling of mud compressibility with respect to pressure and temperature. Ultimately the theoretical modeling results are compared with actual field data. The comparative matrix shows the nature of the complexity of this analysis and serves as a pioneering attempt in quantifying the effect of mud compressibility in deepwater cementing operations.

An Investigation to Determine the Effect of Synthetic Mud Compressibility in Deepwater Cementing Operations (IADC/SPE 87193) **K C Singamshetty**, **G J Authement**, **Baker Hughes INTEQ**; **J T Dieffenbaugher**, **R Dupre**, **ChevronTexaco**.



A low-melt-point alloy metal is dropped down the backside of the casing where annular pressure is observed, melting the metal with an induction heating tool and then allowing it to cool and solidify. This process forms an annular seal to stop fluid communication between the formation and wellhead. IADC/SPE 87198

FOAM CEMENT

Cementing high-pressure, high-temperature (HPHT) wells poses various challenges not seen in normal well conditions. The following objectives are critical for HPHT wells:

- Preventing losses during drilling fluid circulation and cement placement;
- Displacing the drilling fluid and placing the cement effectively;
- Preventing free-water or gas-channel development;
- Reducing slurry fluid-loss;
- Providing support for the production tools;
- Decreasing compression loads on casing connectors;
- Preventing damage to cement sheath;
- Preventing annular gas pressure over the life of the well.

The industry is recognizing the interaction between these factors to determine the optimal cement slurry design to accomplish these objectives. The authors will present and discuss the engineering analysis to determine the optimum cement sheath properties for integrity during the life of the well at HPHT conditions.

The authors will also compare foamed cement to non-foamed slurries to achieve these objectives. Other important issues that will be discussed are the performance of nitrogen at HPHT conditions and the rheological properties of the foams.

Key issues addressed will be the state and solubility of nitrogen under downhole conditions, and the integrity of the cement sheath during the life of the well. Thermodynamic solution theory and experimental studies are applied to the former and finite element analysis is applied to the latter.

Case examples will be presented for foam and hybrid-cementing operations at HTHP conditions of different Norwegian, North Sea wells.

Cement properties are contrasted for the different foam and hybrid cement slurry properties with respect to achieving the HPHT objectives such as placement efficiency and sheath properties; pre-job design to obtain the objectives; job planning and procedures; job execution; and post-job evaluation of the cement systems.

Foam Cement Engineering & Imple-

mentation for Cement Sheath Integrity at High-Temperature and High-Pressure (IADC/SPE 87194) **J E Griffith**, **K Ravi**, **G Lende**, **Halliburton**; **A Saasen**, **O H Jordal**, **N E Nodland**, **Statoil**.

EVALUATING CEMENT SYSTEMS

Loss of zonal isolation in a wellbore can be caused by the mechanical failure of the cement or by the generation of a micro-annulus. However, the behavior of the sealant is driven by the special boundary conditions.

Large-scale laboratory testing of the cement sheath in an annular geometry and in a confined situation was performed to simulate various well conditions and to evaluate the behavior of several sealants under simulated downhole conditions. The failure modes of the cement sheath were determined as a function of the cement properties and loading parameters.

The authors will outline key sealant system properties required to provide long-term zonal isolation.

A series of large-scale tests were performed on cement systems with different mechanical characteristics to evaluate the sealing performance in an annular geometry. Strain cycles were imposed on the cemented ring while simultaneous measurements of induced deformations of the annulus and observations of the failure mode (tensile cracks or microannulus) were made.

The conductivity to gas of the cement annulus was also measured as a function of time during these various cycles to estimate the quality of the isolation. Different scenarios encountered in the field such as the opening and closing of micro-annuli have been simulated. The cement properties, elasticity, strength and expansion over time, as well as the stiffness of the confining formation proved to be the key parameters in controlling zonal isolation.

Finally, the experiments have validated a numerical model that predicts the mode of failure as a function of the loading parameters, wellbore geometry and the mechanical properties of the steel, cement and rock. This allows the determination of the cement properties required and to design a cement system with these properties to provide long-term zonal isolation as a function of the expected downhole conditions.

Evaluation of Cement Systems for Oil and Gas Well Zonal Isolation in a Full-Scale Annular Geometry (IADC/SPE 87195) **L Boukhelifa**, **S G James**, **S Le Roy-Delage**, **M J Thiercelin**, **Schlumberger**; **N Moroni**, **Eni Petroleum**; **G Lemaire**, **National Institute of Applied Sciences**.

REVERSE CIRCULATION

Conventional means of primary cement placement pump the cementing fluids down the casing and well returns are taken from the annulus. This is the most common way of cement placement for the industry and has been used for more than 80 years.

Much less commonly used by the industry but recently gaining in use is the reverse circulation of cement (RCC) technique. When using the RCC technique, the cementing fluids are pumped into the annulus of the well and returns are taken through the casing.

The recent acceptance of the RCC technique is mainly driven by economics and state-of-the-art technology bringing an alternative technique. Benefits of the RCC technique can include lowering bottom hole placement pressure, reducing cement retarder concentration, lowering the time for cement placement, and increasing location safety.

The main drawback to is determining when uncontaminated cement is at and around the casing shoe.

The authors will discuss the benefits and shortcomings of the RCC technique in relation to fluid friction, cement slurry design, location safety and zonal isolation. They will illustrate through a case history how the RCC technique's strengths are obtained while shortcomings are minimized.

The authors will also present field data from a recent job using the RCC technique on a 3,100 m gas well in Alberta, Canada, as well as lessons learned.

Reverse Circulation of Primary Cementing Jobs: Evaluation and Case History (IADC/SPE 87197) **J E Griffith**, **F Tahmourpour**, **G A Schappert**, **Halliburton**; **J Davies**, **K H Parenteau**, **Anadarko Canada Corporation**.

MOLTEN METAL SEAL

The authors describe proof-of-concept developments to form a seal for the purpose of mitigating sustained casing pressure due to annular pressure buildup. Annular pressure results from formation fluid communicating through an unintended channel that forms in the cement sometime after it cures.

In most cases this is observed at the wellhead after the well is placed on production, making it difficult to isolate the pressure source. It is not feasible to physically reach any of the key points of fluid communication once the occurrence is observed.

A method has been tested in which a low-melt-point alloy metal is dropped down the backside of the casing where annular pressure was observed, melting the metal with an induction heating tool and then allowing it to cool and solidify. This process forms an annular seal to stop fluid communication between the formation and wellhead.

This method was demonstrated within a simulated, full-scale well section. An electromagnetic induction tool provided sufficient localized heating to completely melt solder-type alloy metal placed between concentric casings. Subsequent pressure testing verified that a complete melt, sufficient to provide an effective seal against fluid pressure, was achieved in both water- and synthetic-base drilling fluids.

Shear-bond test results of various alloys were equal or superior to cement, and the solid-liquid phase transitions (set points) occur at precise temperature levels. All metals tested contained bismuth because of its unique characteristic of expanding upon solidification to provide enhanced pressure-containment performance.

Full-scale testing was conducted using 17 ft long concentric annular models constructed of 8-in. and 5-in. diameter steel pipes. Subsequent field testing is being planned.

Remediating Sustained Casing Pressure by Forming a Down Hole Annular Seal from Molten Metal (IADC/SPE 87198 – Alternate) **T E Becker**, **Halliburton Energy Services**; **R B Carpenter**, **M E Gonzalez**, **V L Granberry**, **ChevronTexaco**.