

SAMPLE COPY. CLICK HERE TO PURCHASE THE FULL E-BOOK.

packer to isolate the squeeze area from the rest of the well. This method enables closer control of the entire squeeze cementing process and permits a more efficient placement of the cementing slurry into targeted zone.

- Top-down annular casing squeeze method is typically used to force cement to surface when it failed to do so during the primary cement job. These squeeze jobs are normally performed by pumping cement down the casing annulus by an outer casing valve or installing a small tubing string into the targeted annuli and pumping cement through this tubing. Monitoring the pressure of the inner casing pressure and the annular pressure in which the cement is being pumped is necessary to prevent casing damage caused by collapse (inner casing) or rupture (outer casing).

Common squeeze cementing packers:

- Squeeze-cementing casing packers (tools) are used to control the placement of job fluids and isolate wellbore pressures during cement squeeze operations. Squeeze-cement packers are classified as either drillable or retrievable. The type of packer used is dependent on the squeeze job objective(s), casing and tubing condition, and formation parameters.
- Drillable-casing packers (retainers) are designed and manufactured to be drilled out of the casing when required. Drillable casing packers can be set using conventional work strings in compression or tension, or by electric wireline operations. These tools typically incorporate a "sliding" or "poppet" valve, which closes when the work-string stinger is pulled out of the retainer following the squeeze job. The retainer contains the pressure below, which is beneficial in many cement squeeze operations.
- Retrievable-squeeze packers are designed and manufactured using high-strength steel to provide a higher pressure rating than drillable casing packers. These retrievable packers also feature a fluid bypass system, which reduces formation surge and swab pressure events during installation and removal from the well. Additionally, the packers have mechanical and hydraulic casing slips, which anchor the packer to the casing wall. And, because they have a larger internal diameter, casing perforating tools and other diagnostic tools can be used during well operations. Since these packers feature high-strength steel, fluid circulation ports and casing slips, it is very important to monitor fluid volumes, casing and work string pressures, and pipe movement during operations to prevent these packers from becoming "stuck" in the well. Removal of "stuck" retrievable squeeze packers usually requires extensive milling, which if unsuccessful may result in loss of the wellbore section or even the entire well.

Job design

To design an effective cement squeeze plan, the well operator generally works with the cementing service provider to select the casing packer type, cement placement method (hesitation, stage or continuous pumping) and the cement slurry design. To make their selections, well operators and cement service providers use several variables:

- Job objective;
- Well and operational risk and safety;
- Well operations and production history;
- Casing size, age and pressure rating;
- Drillpipe or tubing size and pressure rating;
- Formation properties;
 - Pore pressure;
 - Permeability;
 - Fracture gradient;
 - Fluids types (oil, gas, water, combination);
- Diagnostic logs (Cement bond, temperature, noise);
- Well fluids and type;
- Rig capabilities;
- Field history and previous squeeze job results.

Plug cementing

Plug cementing is another remedial cementing technique and refers to the method of placing the cement slurry into the wellbore to create a solid wellbore seal or "plug". The general plug cementing process involves selecting the location for the plug, positioning the end of the work string at the bottom of the desired plug depth, mixing and pumping a cement slurry down the work string (drillpipe or tubing) into the wellbore, removing the work string from the cement column and allowing the cement slurry to harden in the wellbore.

Applications

Well or zone abandonment:

- Seal a dry hole;
- Seal depleted zones;
- Seal non-commercial zones or wellbores;
- Temporary well or zone abandonment.

Zonal isolation or well stability:

- Isolate one pressure zone from another;
- Prevent zonal fluid communication;
- Stop lost circulation events;
- Enable drilling through fracture or weak formations.

Directional drilling (kick-off plugs):

- Support controlled changes in well trajectory (whipstock operations);
- Sidetrack operators around a "fish".

SAMPLE COPY. CLICK HERE TO PURCHASE THE FULL E-BOOK.

Formation testing:

- Creates a base for open-hole formation test tools.

Common plug techniques

Listed below are the four most frequently used cement plug placement methods:

- Balanced-plug method is the most often used method to install or set a cement plug in the wellbore. It works by means of the "balanced hydrostatic pressures" concept. "Balanced" describes a condition in which the top of cement and spacer outside the work string are at the same height as the top of cement inside the work string at the end of pumping. To help achieve this balance, it is important that the well is in a fluid static state, the wellbore and drilling mud are prepared to receive cement, the spacers/flushes volumes and densities meet design requirements and the cement slurry is designed to ensure safe cement placement and removal of the work string. Rig operations should be prepared to begin removing (pulling) the work string from the cement at the design rate as soon as the cement is in place and surface pressure has been released.
- Two-plug method uses wiper plugs or rubber balls to isolate the cement from well fluids (prevent contamination) in the drillpipe and provide positive surface pressure events, which are used as an indication of cement placement in the wellbore. Once the lead cement spacer or flush has been pumped into the work string, the bottom wiper plug or ball is released into the work string, the cement volume is mixed and pumped, the top wiper plug/rubber ball is released and drilling mud is used to displace the cement. When the bottom plug/ball lands in a receiving tool, a positive surface event occurs that indicates the position of the leading edge of the cement slurry. Additional surface pressure is applied to release the bottom wiper plug/ball, enabling the cement to be pumped into place. The top wiper plug lands in the wiper plug/ball receiving tool, indicating that cement is in place. Surface pressure is then applied, causing the top wiper plug/ball to be sheared out of the tool, which re-establishes work string circulation. The work string is then pulled from the cement column at the designed rate; rig operations should be prepared to conduct this step as soon as the cement is in place and surface pressure has been released.
- Dump bailer method incorporates the use of a cylindrical fluid container, which is run into the well with wireline. When the bottom of the dump bailer reaches the desired depth, an electrical or mechanical trigger is used to open the bottom of the cylindrical fluid container, thereby releasing the cement slurry into the well bore. Typically, this method requires multiple runs, because fluid container's limited capacity.
- Mechanically supported plug method is a variation of the

balance plug method that incorporates a mechanical tool to provide a bottom for the cement column and prevent migration of the cement column down the wellbore. This method allows for a choice of several mechanical tools: inflatable packers, cement baskets, tools that use expandable membranes, which open when positioned in the wellbore. Once the mechanical tool is in the wellbore at the designed depth, the work string is positioned above the tool and the balance plug or two-plug method is used to place the cement column in the wellbore.

Job Design

When designing a cement plug that will meet the required objectives, the well operator will work with the cementing service provider to select the appropriate plug setting technique and the cement slurry design. To formulate a design operators and cement service providers consider a number of variables:

- Job objective;
- Well and operational risk and safety;
- Well operations history;
- Casing size, age and pressure rating;
- Hole size and hole enlargement;
- Well stability;
- Drillpipe or tubing size and pressure rating;
- Cement plug setting tools;
- Well fluids and type;
- Rig capabilities;
- Field history and previous plug job results;
- Hole angle.

Lost circulation cement squeezes and plugs

In some cases, controlling lost circulation during drilling operations may call for a cement squeeze or plug job to minimize or stop drilling fluid losses and help regain full returns of the circulation fluids to surface. The formation interval into which fluids are lost is commonly called the "thief zone."

Losses may be halted and well circulation restored by spotting a cement plug across the thief zone and, after waiting on cement (WOC), drilling back through the plug. This operation can sometimes be less costly than a squeeze-cement job. Spotting plug cement in open-holes across thief zones with smaller diameter tubing has the advantage of less risk for drillpipe sticking issues and better cement placement. The tubing is often called a "stinger pipe" which can be installed below the drillpipe. However, many plug and squeeze-cement jobs are pumped "through the bit" due to the time required to trip out and back into the well with a lost-circulation treatment bottomhole assembly (BHA).

Low-pressure or depleted "thief zones" that steal well fluids drilling fluids can sometimes be sealed by a squeeze-cementing job. In severe cases, more than one job may be

SAMPLE COPY. CLICK HERE TO PURCHASE THE FULL E-BOOK.

required. A combination squeeze-and plug-cementing job may be needed when losses occur after drilling out the casting shoe. This can sometimes improve cement placement in the annulus between the open hole and the shoe track including some distance above the shoe track. For deeper thief zones, drillpipe is pulled up above the top of the cement plug and, if needed, above the open-hole; applying squeeze pressure at this stage will force some plug cement into the thief zone. By placing the end of the drillpipe inside the casting shoe, the risk of stuck drill pipe can be eliminated.

Cementing through the bit

Conducting cementing operations when a drill bit is in the well, is a very high risk operation and requires an additional level of pre-job planning including both Job Safety Analysis (JSA) and risk assessments. When precautions were taken, cement slurries have been successfully pumped through the drilling BHA, including motors, without prematurely setting. One key condition for successful jobs is making sure the hole (motor, BHA, DP, annulus, etc.) is cooled by circulating enough drilling fluid. The BHA tools temperature readings should be used for test temperatures used in cement's laboratory thickening time tests. When no temperature data is available, thermal modeling computer software can be run to determine how long it takes the circulating drilling fluid to cool the recently drilled "hot" hole section and BHA. The start of the cement squeeze or plug job can then be delayed until the hole and BHA (motor, etc.) is cool enough to prevent shorter than designed pump times. When needed, add retarder in the cement slurry based on lab testing with higher temperatures.

Other recommendations are listed below:

1. Total bit nozzle flow area and other flow restrictions in the BHA should be sufficient for the designed pump rate and is sometimes specified to be greater than 0.5 sq. in.;
2. The backside surface pressure is continuously monitored to check if cement is circulated up the annulus. This is intended for placing plug cement, but not for squeezing cement;
3. For shoe squeezes, the bit and BHA are spotted inside the last string of casing one or two pipe stands above the shoe;
4. Open hole squeezes to control lost circulation, place the bit one or two pipe stands above the lost circulation zone.
5. Run a lab-tested, compatible spacer ahead and behind the cement slurry. Spacer volumes are determined based on conditions;
6. Do not stop pumping with cement inside the drill pipe (DP). When the spacer reached the bit, close the choke manifold to begin bullheading cement into the zone of interest;
7. A DP swivel is installed above the rotary table and DP is rotated either intermittently or continuously to check for

any increase in TOB that may indicate that cement is in the annulus;

8. If TOB increases during the job, further action is taken to keep the DP free such as immediately PU one stand and check that TOB decreases before continuing the squeeze.
9. If TOB doesn't decrease and hook load increased during PU, immediately shut down the squeeze and take further action such as POOH to prevent planting DP;
10. After all cement slurry has cleared the DP, pull five stands or 500 ft of DP and continue checking TOB;
11. When the designed squeeze pressure is achieved, circulate drilling fluid to clear the annulus of any cement slurry. Continue to WOC until cement is set and rig is ready to continue drilling operations.

Preparing the well and wellsite for cementing

Pre-job meeting

The service company supervisor should hold a pre-job meeting with his crew, the rig crew and all other involved personnel in cementing the well to review responsibilities and coordinate the operations to be performed. Safety should always be the top priority.

That meeting may cover a number of topics:

- Roles and responsibilities - It is important that everyone involved understand their role during the cement job; open communication is essential. The pre-job meeting is a means to establish everyone's role and to discuss potential risks and contingency plans to deal with any issue that may develop.
- Rigging-up and pressure testing of treatment lines should be discussed.
- Job procedure - Every step of the cement job should be covered. Volume calculations of cement, mix water, displacement, expected pit gains should have been independently verified by at least two members of the team. The pressure to bump the plug calculation should also be independently verified. Depending on job specifics, there may be other pressure, volume or rate calculations that need to be performed and verified before the job. Equipment and material checks should be also be independently verified by two or more people.
- Potential events to discuss - Unplanned issues include lost circulation, excess gas, well control issues, equipment failures, abnormally high or low pump pressure limits, slow mixing rates, cement volume shortages, lack of cement density control, failure of plug to bump on time and floats to hold.
- Contingency plans - Circulating the job out and starting over criteria and switching from cement pumps to rig pumps in order to circulate out, dropping the top plug and

SAMPLE COPY. CLICK HERE TO PURCHASE THE FULL E-BOOK.

displacing without pumping the planned job volume and a complete list of standby equipment on site.

- Weather conditions - Considerations include how extreme heat, cold, or offshore sea state conditions might affect personnel, equipment and materials. Extreme temperatures may introduce conditions different from the cement job's design conditions (ambient) that could cause compromise the job. For example, in the Middle East, on several occasions cement has prematurely set inside the batch mixer as a result of prepumping and variance in ambient temperature used by the design from lab: 120-140°F. The possibility of these effects should be discussed together with measures to mitigate the adverse effects of extreme weather conditions.

Preparing the well for cementing

Hole and mud conditioning for cementing operations should begin prior to tripping the drillstring out of the hole for the purpose of running casing. While the wellbore may be clean enough to enable trouble-free tripping operations, the presence of cuttings beds, fill on bottom, or mud with undesirable properties make running and cementing casing difficult. Even though the well will need to be circulated and conditioned again after casing is run to bottom, the hole should be clean and the drilling fluid should have the desired mud properties before casing is run.

The drilling program should outline the hole-cleaning procedures to be followed for each hole section. The procedures should specify guidelines for flow rate, pipe reciprocation, pipe rotation, cuttings and gas monitoring as well as drilling fluid property specifications. Hole cleaning practices will differ between vertical or near vertical wells, and extended reach high-angle or horizontal wells. For wells with greater than 30° to 40° of inclination, torque-and-drag monitoring is recommended to help determine when the hole is clean. Torque-and-drag can be monitored by using work string pick-up and slack-off weight indicator readings and rotating torque measurements. Torque-and-drag monitoring can be used during hole cleaning and tripping operations to gauge the quality of the hole. This applies to tripping the drillstring or casing.

Hole and mud conditioning becomes imperative in the following situations:

- Liner cement jobs run with tight tubular/annular clearances, when the liner hanger is set the annular flow path becomes more restricted and prone to plugging with cuttings, debris or gelled mud;
- All wells with tight annular clearances;
- Wellbores with small mud weight margins between the minimum mud weight needed to control formation pressure and the mud weight that results in mud losses to the formation, resulting in loss of returns caused by

bridging or plugging off with cuttings in tight clearances, and high equivalent circulating density (ECD) from the frictional pressure drop while circulating;

- During casing or liner running, surge and swab pressures can result in losses or formation fluid influxes if the tripping speed is not controlled. The drilling program should specify the running speed to minimize surge effects. Computer programs are available to aid ECD management and to determine the proper tripping speed to minimize surge and swab forces. In very close-tolerance situations, "auto-fill" float equipment can be used to minimize surge pressures by allowing mud to flow up the inside of the casing while casing is run in the well. The "auto-fill" float equipment can be converted to conventional float equipment when needed. Surge pressures can also be minimized by controlling the mud properties so that they have non-progressive gel strengths and overall viscosity readings as low as practical for hole cleaning. Depending on well conditions, the well should be circulated at prescribed intervals while running in the hole to help break gel strengths and ensure the well is stable.

Hole conditioning with casing on bottom

Once casing is on bottom, the well should be circulated until well conditions are stable and the wellbore is free of excess gas. Mud properties in and out should be the same and within specifications. Between bottoms-up and the casing volume, a minimum of the larger of the two should be pumped. Pumping a minimum of one casing volume will indicate if there are any foreign objects in the casing that might plug up the float equipment. Pumping bottoms-up will reveal if there have been any influxes into the well during casing running operations. Other factors that may need to be considered for circulating with casing on bottom are the need to cool the wellbore down, cleaning the wellbore of cuttings and maintaining the optimum rheology for mud removal by cement. In general, the pump rate should be as fast as possible without inducing lost circulation.

Rig personnel support of cementing operations

Drilling rig personnel may be assigned a number of cementing operation support activities:

- Identifying the location of mix water, drilling mud or both supply lines that furnish cementing equipment (cement pump/batch mixer) with mix water and drilling mud;
- Ensuring there is sufficient cement mix water, drilling mud or both to mix and displace the cement and communicating and facilitating the method of fluid transfer (centrifugal pump, gravity feed, etc.);
- Identifying the barite supply lines that furnish cementing equipment (cement pump/batch mixer) with bulk barite - typically for spacers;
- Facilitating the movement of liquid additives (drums,

SAMPLE COPY. CLICK HERE TO PURCHASE THE FULL E-BOOK.

- totes, etc.) from the storage area to the liquid additive system and the pneumatic transfer of cement from the rig tanks to the cementing unit during cementing operations that take place offshore or at remote sites;
- Informing the cementing service providers of any restrictions on the placement of the cementing equipment on location;
 - Monitoring returns at surface for change in flow rates and presence of pumped fluids (spacer and cement slurry) and diverting contaminated fluids from the active system;
 - Many operations require the rig pump to take over displacement – in this case rig personnel should coordinate closely with cementing personnel regarding volumes, rates and returns.

Rig personnel should be cautious when working in or near the cement pumping unit, cement bulk equipment, liquid additive systems, process controls, batch mixers, flow/mass meters, densitometers, temporary bulk/liquid transfer lines, bulk manifolds and electronic cabling. Rig personnel should always be aware of the location and service state (not in service, pressure testing, in operation, etc.) of the high pressure discharge iron from the cementing unit to the rig floor as well as the status of pressurized bulk tanks, lines and hoses. During foamed cementing operations, care should be exercised around the cryogenic nitrogen storage tanks, nitrogen pumps and nitrogen discharge/vent lines.

Cement dust

Well cementing operations utilize equipment designed to prevent the escape of cement dust into the atmosphere. However, in the event that personnel are exposed to ‘cement dust, hazard mitigation procedures are used to prevent injuries or health issues. Local regulators may publish these procedures to help prevent HSE incidents and require them to be posted on bulletin boards or included in the rig’s safety manuals at the wellsite. For example, the U.S. Occupational Safety and Health Administration’s (OSHA) guidelines are shown below:

- Hazard: Exposure to cement dust can irritate eyes, nose, throat and the upper respiratory system. Skin contact may result in moderate irritation to thickening/ cracking of skin to severe skin damage from chemical burns. Silica exposure can lead to lung injuries including silicosis and lung cancer.

Solutions:^{*}

- Rinse eyes with water if they come into contact with cement dust and consult a physician;
- Use soap and water to wash off dust to avoid skin damage;

* Reference: OSHA 3221-12N 2004

- Wear a P-, N- or R-95 respirator to minimize inhalation of cement dust;
- Eat and drink only in dust-free areas to avoid ingesting cement dust.

Rig personnel may also provide support in the preparation of washes or spacers used in the cementing operation. The mixing of spacer fluids should be conducted using instructions provided by the cementing service company or, in the case of more complex spacer systems, under the direct supervision of the service company personnel. Rig personnel should always be mindful of the exposure and respiratory hazards associated with the handling and mixing of materials used to prepare washes and spacers. As such, rig personnel involved in the mixing of spacer fluids should always abide by the same personal protection equipment requirements as those used by the cementing service provider.

Mixing cement slurry during the cementing operation is the responsibility of the cementing service company. However, rig personnel may be asked to provide assistance to the cementing service supervisor or other cementing personnel on certain occasions:

- Assisting the cementing service providers with obtaining samples of cement slurry, bulk materials and liquid additives;
- Providing a tally of materials being consumed, additives, mix water, etc;
- Managing fuel and air supply for cementing equipment and ensuring that the air supply is dry;
- Helping the cementing service company manage the rig bulk material supply system;
- Measuring and recording slurry density using pressurized mud balance;
- Assisting in efforts to repair cementing equipment

Rigging up and pressure testing treatment lines

In preparing for cementing and pumping operations, service company personnel rig up and use a high-pressure treatment line often referred to as a cement service line. They may ask the rig crew to assist them in this operation. High-pressure pumping requires managing hazards and risk. In addition, all personnel must comply with local regulations. Examples can be found under OHSA rules in North America, DNV in Norway or ANP in Brazil.

Components of a high-pressure line

- Chiksan/swivel joint is a high pressure articulating hardline used to make connections adjustable by rotating and a swiveling them. A double chiksan enables an easier rig up for spacing and flexibility, regarding vibrations and pump pulsations during operations.
- Pressure relief (pop-off) valve is a safety device that protects contained systems from over pressuring. In most