Gulf of Mexico SPU

Recommended Practice for Cement Design and Operations in DW GoM

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TABLE OF CONTENTS

1 Introduction

1.1 Overview

Obtaining a competent cement job and proper tubular placement are the most important aspects of well design and construction. By using the guidelines set in the Basis of Design, Drilling Engineers, cementing service providers, and rig personnel will coordinate the detailed planning and design of cement jobs from conception to execution. Drilling engineers are responsible for reviewing the results of cement slurries and spacer tests, as well as the details of cement operations including volumes to be pumped, pumping schedules, casing jewelry, etc.

The key requirements for a successful cement job are as follows:

- Production interval
  - Achieving zonal isolation of all hydrocarbon and water zones
  - Ensuring well integrity during the life of the well
  - Compliance with all MMS regulations
- Intermediate casing and liners
  - Good shoe test (integrity) to allow drilling to the next casing point
  - Zonal isolation across any exposed hydrocarbon or water bearing formations
  - Seal at the TOL (with packer or cement)
  - Compliance with all MMS regulations

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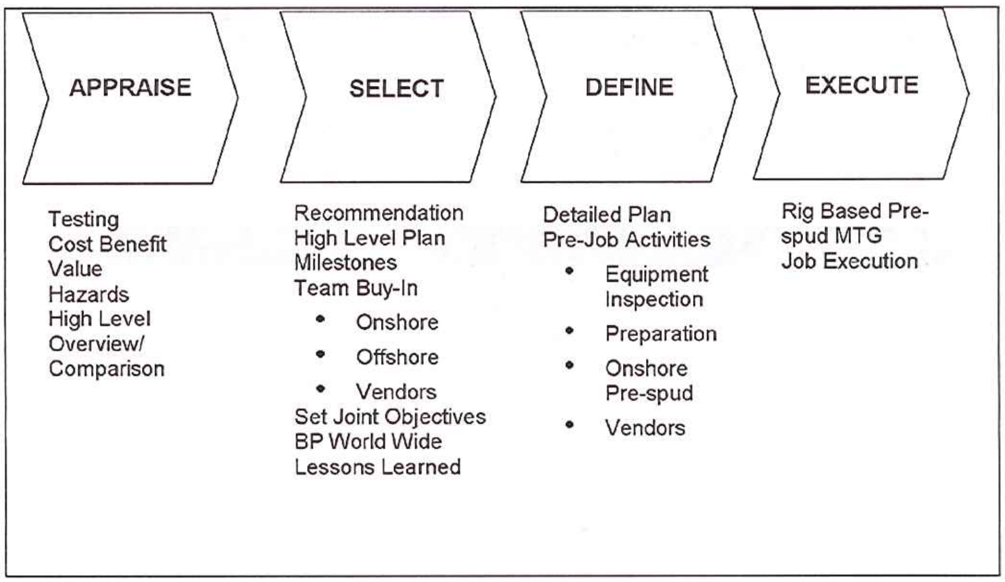
1.2 BtB Cementing Process Guide

As with all BP engineering work, engineers should follow the logic of the BtB process. Refer to BP document 2200-T2-DO-RP-0003, "Drilling Engineering BtB Stage Gate Process (Well Level)."

Figure 1: Beyond the Best Process Flowchart



2 Minimum Requirements and Standards

2.1 Purpose

The purpose of this manual is to guide Drilling personnel through the cement design process and to identify minimum requirements and standards of cement design and operations. It is imperative that all the requirements are met.

Note: **The attitude of "all we need is a shoe test" is unacceptable. In some cases, a shoe test might be the most important aspect of the cement job, but future well utility should be considered.**

In instances where adverse conditions prohibit compliance to the following standards, team leaders and drilling managers will be notified and the BP MOC process will be used to document the adverse conditions and the revised procedure.

Standards	Responsible Parties
Casing Jewelry	Drilling engineers are responsible for design and proper placement of casing jewelry.
Cement Slurries and Spacer Tests	Drilling engineers are responsible for overseeing the implementation and required specifications of all tests
Dual Plugs	Dual plugs will be run on all cement jobs that have sized equipment
ECD Modeling	Service providers and drilling engineers
Meetings	Drilling engineers are responsible for conducting the following meetings: • Project Initiation meeting with all team members • Planning meetings • Planning or Operations engineers should attend JSEA and rig floor meetings
Pumping Schedules	Drilling engineers are responsible for designing and following pump schedules that include all plug and dart bumps
Rig Duty	Planning or Operations engineers will be on the rig from tubular running through FIT, LOT, or production tubular test
Volumes to be Pumped	Drilling engineers are responsible for calculating necessary cement volumes and ensuring that adequate dry cement volumes are on the rig prior to all cement jobs

2.2 Acronyms and Definitions

Acronym	Definition
APB	Annular Pressure Buildup
API	American Petroleum Institute
AV	Annular Velocity
Bc	Bearden Units of Consistency, as measured in a cement consistometer. It is an empirical measure of the consistency of the cement slurry
BHCT	Bottom Hole Circulating Temperature
BHST	Bottom Hole Static Temperature
BOD	Basis of Design
BtB	Beyond the Best
Cementing Basis of Design (BOD)	Document outlining the general cementing requirements for the entire well including cementing job Objectives, Risks and Remediation for each casing string
DW GoM	BP Deepwater Gulf of Mexico
DWO	BP's Drilling and Wells Operations Policy
ECD	Equivalent Circulating Density
ETP	BP's Engineering Technical Practice
Excess	Extra cement added to the calculated cement volume to account for uncertainty of hole size and contamination of the slurry during placement
FIT	Formation Integrity Test
Flow Potential Factor	A dimensionless number used to gauge the potential for invasion of gas into a cement column after the cement becomes static
FMA	Fluid Migration Analyzer – laboratory equipment used to measure the capacity of cement slurries to control gas migration under simulated downhole conditions
GoM	Gulf of Mexico
HPHT	Pressure threshold: 15,000 psi
HSSE	Health, Safety, Security, Environment
HTHP	Temperature threshold: 350°F
ISO	International Standards Organization
JSEA	Job Safety and Environmental Assessment
LAS	Liquid Additive System
Lead Cement	Normally a light density formulation that may be used when top of cement is required to cover up-hole hydrocarbon or water zones
LOT	Leak Off Test
MD	Measured Depth
MEPT	Maximum Estimated Job Placement Time
MMS	Minerals Management Service
MOC	Management of Change (BP process)
MSDS	Material Safety Data Sheet
PPE	Personal Protective Equipment

Acronym	Definition
Project	Field, a well, a casing or a liner string
RP	Recommended Practice
SBM	Synthetic Base Mud
SGSA	Static Gel Strength Analyzer. An updated version of the UCA test device. This testing apparatus can, in addition to estimating the compressive strength development of cements, estimate the static gel strength development of cement slurries vs. time
Tail Cement	Higher density formulation that will be used from total depth to 1,000 ft MD or 500 ft TVD (whichever is higher) above the Intermediate casing or liner shoe
TOC	Top of Cement
TOL	Top of the Liner
TT	Thickening Time
TVD	True Vertical Depth
UCA	Ultrasonic Cement Analyzer. A lab test device which estimates compressive strength development (vs. time) of cement formulations
WOC	Waiting On Cement

3 Job Design: Cement Slurries

The drilling engineer will provide the cementing service provider all of the necessary data and information to allow for an effective cement slurry and spacer design and cement job plan. Drilling engineers will also provide the Test Matrix for BP GoM and any additional required tests to be run on cement slurries and spacers.

The data and information provided by the drilling engineer will include, but will not be limited to:

- Clearly defined, cement job objectives listed in the BOD. In some cases, the main objective will be a competent shoe, along with a cement top below the previous shoe to prevent APB. Other jobs will require cement cover exposed hydrocarbon or water zones.
- Identified potential risks to achieving the objectives.
- Formation properties and formation fluids (e.g., detailed pore pressure and fracture pressure profiles, LOT or FIT at the previous shoe, caliper if available, inclination profile, location of all hydrocarbon and water zones, and drilling fluid type and properties).
- Estimated bottom hole static temperature.
- Complete wellbore geometry: all ODs, IDs, drift, depths, etc.

3.1 Selection of Cement Systems

The selection of cement slurries for hydrocarbon and water zones will depend on well conditions. Below are several scenarios requiring different cement slurries.

3.1.1 Benign Cases

In some cases, tectonics, or large changes in reservoir pressures and/or compaction are negligible and holes are capable of supporting normal cement slurry densities with no expectation of extreme casing loading. Also, the most important aspect of the job will be a good shoe, requiring 1,000 ft MD or 500 ft TVD (whichever is higher) of cement above the shoe. In these cases, use premium cement with silica flour plus additives to control fluid loss, free fluid and thickening time at densities of ~ 16.6 ppg.

3.1.2 Low Fracture Gradients

In these situations, low density slurries will be required (for example, 13.5 ppg). Specialty solids laden systems like Schlumberger's CemCRETE or Halliburton's Tune-Light should be used.

3.1.3 Extremely Low Fracture Gradients

In cases of extremely low fracture gradients (e.g., across highly depleted zones) foam cement systems will be required (for slurry densities lower than ~ 11-12 ppg).

3.1.4 <u>Special Situations</u>

If upper zones need to be covered across a drilling liner, an adequate amount of cement may be required to bring the cement slurry above the TOL to account for cement contamination toward the top of the cement column.

3.1.5 <u>Other Extreme Situations</u>

Cases of extreme reservoir temperatures (300+°F), expected large changes in casing loads due to reservoir compaction during production, or due to tectonics, etc. are possible. Specialty cement systems will be required to ensure well longevity. In those situations, the drilling engineer, with approval from management, will coordinate with the service provider for special services needed to design the cement slurries for the life of the well (e.g., Halliburton's Life of the Well Service).

3.1.6 <u>Other General Slurry Design Considerations</u>

- Slurry density to prevent or minimize lost circulation, based on the mud density and hole conditions
- Depending on hole conditions, the slurry design should address the potential for wellbore fluid migration after the cement job
- Length of the cement column (TOC):
  - Design should cover all productive horizons.
  - WOC time considerations due to length of the cement column
  - May require a lead and a tail slurry
  - May require a 2-stage job
  - May require a low density (but competent) cement slurry for a good shoe test
  - APB considerations
- Fluid loss in production jobs should be low, particularly for tight liner configurations, to minimize flow migration after cementing and damage to the pay zones permeability from the cement filtrate (~ 50 ml API fluid loss).
- In the case of intermediate jobs with tight annular configurations, low fluid loss (~ 50 ml API) may be needed to prevent cement slurry dehydration against permeable zones. If good annular clearances are present, normally a moderate FL control is all that will be needed (~ 200 ml API).
- Zero free fluid to prevent high hole side channeling. If the hole section is vertical and there is no potential for formation fluids after cementing, free fluid of 1% may be allowed.
- No settling (static or dynamic depending on the well configuration).
- Compressive strength on production jobs sufficient for perforating (minimum 1,000 psi after 24 hours with the cement slurry contaminated with 5% of the mud).
- Compressive strength on intermediate jobs sufficient to generate a good shoe test (2,000+ psi, particularly when relatively small volumes of slurry are pumped, as is the case when all that is needed is a good shoe). High compressive strength slurries have greater resistance to contamination than lower CS slurries.
- Thickening time should be the calculated as job time + 1-1/2 to 2 hours at BHCT. The calculated job time when cementing a liner, if the cement is brought above the TOL, should include a minimum of 45 minutes to release from the hanger. If a lead and tail

slurry are to be pumped, the lead slurry will always have a longer thickening time than the tail slurry. If the excess cement slurry at the top of the liner is going to be reversed out, the cement slurry thickening time and gel strength development testing will mimic and account for the time to release the packer, circulate and reverse out.

- As required by the Cement Slurry and Spacer Testing Protocol and Test Matrix for BP – GoM., all final testing on the cement slurries will be performed using the actual mix water, cement and additives located on-site, prior to pumping the job. All tests will be completed and reported to the drilling engineer ahead of pumping the job.

3.2 Slurry Volume and Excess Factors

3.2.1 Liners

When cementing a liner, the best practice is to bring cement to 300-500 ft MD above the top of the liner with the drill pipe removed. This will minimize the potential for weak, contaminated cement in the liner overlap. This practice will be particularly applicable if hydrocarbon zones are located up-hole (close to the previous shoe). A liner top packer may be used even if cement is brought above the TOL. However, there are situations when it may not be desirable to bring cement above the TOL (for example to prevent APB). In those cases, a liner top packer will be used.

If Cement is Pumped above the Liner

In deepwater operations, often an open hole caliper is not run. If one is available, the cement volume will be: caliper-calculated open hole annular volume from the shoe plus 10% excess + shoe track volume + casing/liner lap volume + volume of casing from TOC to TOL.

If no caliper is available, the hole will be assumed to be gauge (this is normally a reasonable assumption for holes drilled with oil base type muds). In this case the cement volume will be: gauge hole-calculated open hole annular volume from the shoe plus 15% excess + shoe track volume + casing/liner lap volume + volume of casing from TOC to TOL.

If the Top of Cement is not planned to reach the Previous Casing

If a caliper is available, the cement volume will be: caliper-calculated open hole annular volume from the shoe to the desired TOC plus 10% excess + shoe track volume.

If no caliper is available, the cement volume will be: gauge hole-calculated open hole annular volume from the shoe to the desired TOC plus 15% excess + shoe track volume.

Note 1: It will be important to select a TOC that will ensure up-hole hydrocarbon zones will be covered with uncontaminated cement.

Note 2: Recalculate the TOC using the callipered or gauge hole annular volume and the calculated cement volume including the % excess, to make sure the TOC remains below the previous casing.

3.2.2 Long Strings

Single Stage Cement Job

- Single stage with a single cement slurry system. The top of cement should be a minimum of 1,000 ft MD or 500 ft TVD above the upper most zone of interest. However, consideration should be given to issues of APB. The drilling engineer will consult with the production and/or the completion engineers on issues of APB.
- Single stage with two slurry cement system. The tail slurry, at a minimum, should cover 500 ft MD above the upper most target reservoir. However, consideration should be given to issues of APB.

3.2.3 Spacers

The drilling engineer will give the service company provider, the spreadsheet (Test Matrix) containing the required tests for the spacer, and those requirements should be based on BP's GoM Testing Protocol.

A spacer volume sufficient to cover 1,000 ft of open hole or provide 10 minutes of contact time at the planned displacement rate should be pumped ahead of the cement slurry. The spacer must be compatible with both the drilling fluid and the cement slurry. The density should normally be designed midway between the mud density and cement density. The rheology of the spacer will be such that a proper pressure drop hierarchy mud-spacer-slurry will be maintained during the cement job, at the expected pump rates, to minimize channeling of the fluids. The pressure drop hierarchy will be calculated by the service provider using lab measured rheologies of the mud, spacer and cement slurry, at the job estimated pump rates and using the open hole configuration of the job at hand.

The use of a pre-flush will be optional. One of the main purposes of a pre-flush is to reduce the hydrostatic head during the cement job to help minimize losses. When used, volume of pre-flush used will consider the wellbore ECD limits (dynamic) as well as well control requirements (static and dynamic.)

3.2.4 Cementing Wiper Plugs

Cementing wiper plugs will be certified by the service provider to be applicable for the temperature and chemical environment of the well. They will be rated for all the pressures that will be applied to the plug; during the cementing operations (plug bumping) and subsequent pressure testing of the casing.

Dual plug systems will be used in all instances when equipment is available. Cement slurries can become severely contaminated with the spacer while going down the casing if a bottom plug is not used in between the spacer and the cement slurry. Therefore, the bottom plug will be dropped ahead of the cement slurry and not in front of the spacer.

In the event of adverse conditions where a single plug is used, the EXCESS volume of cement pumped should be increased to account for the contamination of the cement inside the casing and any APB issues (for example by an extra 20-25%).

4 Centralization, Hole Cleaning and Casing Attachments

4.1 Overview

The shoe track will always be centralized, minimum one centralizer/joint. In addition, all hydrocarbon and water zones will be centralized below, across and above the zone. When hole conditions allow, the zones will be centralized a minimum of 300 ft above and below the zone. The goal will be to obtain 80+% standoff.

The drilling engineer will coordinate with the service provider (equipment or cementing services) to run a centralizer placement simulator to optimize the selection and placement of centralizers for the hole section at hand. The simulations will be run using the actual hole inclination profile and if available, the caliper log or best estimate of the actual hole diameter. The type of centralizer (bow, rigid or solid) will be selected based first on torque and drag implications, and second on the ability of obtaining the desired standoff. Stop collar selection will be based on drift restrictions and the maximum obtainable holding force. The goal is to obtain a minimum of 30,000 lbs tested on the selected grade of pipe.

Use two rigid centralizers in the liner overlap when the TOC is required to be brought above the liner. This is especially important when cement is required to cover hydrocarbon or water zones.

The shoe will contain two spring loaded valves (plunger or flapper) rated (API RP 10F) for the expected circulation and cementing times, rates and temperature. The float collar should contain one valve (no valve if surge equipment will be used).

4.2 Cleaning the Hole Prior to Running Pipe

The drilling engineer will ensure that every effort is taken to properly clean the hole from cuttings, sag barite, etc. prior to running the casing or liner. This is particularly important in deviated sections of the well and extremely important when a liner will be run. The drilling engineer will coordinate with rig personnel to apply best hole cleaning practices as included in the well's mud program, in preparation for running the casing or liner.

4.2.1 <u>Running Casing or Liner</u>

The drilling engineer and service provider will determine running speeds based on surge and swab simulations to minimize losses. Information will be provided to the rig personnel with instructions to be strictly followed as per the design.

Run surge reduction equipment if losses are expected while running the pipe to bottom. Drilling engineers will obtain a dispensation to de-activate the surge equipment near the bottom of the hole. However, well control issues should be considered and accounted for when requesting this dispensation.

When running in the hole, stopping at the previous shoe to circulate the hole should be considered, particularly in cases when the hole has been static for a long time, and if losses in the open hole are a possibility. The intention is to break the mud gels in the casing-casing section of the hole to reduce surge pressures ahead of running the pipe in the hole. Also, record torque pick-up and slack-off values.

4.3 Hole Conditioning Ahead of the Cement Job

Hole conditioning will be done after the casing or liner is on bottom.

4.3.1 Cases with No Hydrocarbon Zones Up-Hole

Once the casing is on bottom or the liner is hung off, circulation of the hole should be started slowly, and the pumps staged slowly to a previously calculated safe pump rate. It is best to circulate minimum of two bottoms up before starting to pump the cement job, or a minimum of 5 hours, whichever is greater. Pressure should be modeled before the job and actuals compared to the model.

4.3.2 Cases of Zones of Interest Up-Hole

A sensitive pressure drop transducer near the top of the casing or drill pipe (may be on or near the cementing head) will be used to monitor the surface pressure while conditioning the hole and during the entire cementing operation. Best practices for hole conditioning will be followed in order to minimize the potential for losses during breaking circulation and hole conditioning.

4.4 Performing the Cement Job

The density and surface rheology of the spacer after batch-mixed and ahead of the cement job will be tested on location by the cementing service provider to confirm that they are as designed. If not, the spacer will be discarded and re-mixed.

Every effort will be made to mix and pump the cement job exactly as it was designed (optimized). The pump schedule will be followed whenever possible. The job surface pressures, densities and rates will be continuously monitored and recorded during placement and particularly during displacement, for a permanent record of the job.

4.5 Other General Guidelines

At the beginning of hole cleaning, initial circulate rates should not exceed AVs during the drilling phase to prevent pack-offs.

After the risk of pack-off has decreased, maximize circulation rates to ensure proper hole cleaning and conditioning for cementing. Maximum circulating rates should be calculated using the fracture gradient profile and a safety factor.

If hole conditions and wellhead systems allow, reciprocate the casing while conditioning and cementing. Also, use rotating liner hangers that allow rotation to 20+rpm.

Pressure test the casing or liner right after bumping the plug (prior to the cement setting) to avoid damaging the cement sheath if testing is done after the cement is set.

CAUTION:	**When installing a liner top packer while the cement is going through its gelation stage, the positive effect of the hydrostatic head above the TOC is eliminated from the cement until it sets. Because the packer acts as a shut off valve, even small fluid losses from the cement (fluid loss and hydration effects) can cause severe pressure loses inside the cement column, thus possibly motivating formation fluid invasion of the cement column.** **Because of this effect, the use of integral liner top packers is not advisable when high pressure gas zones are present in the open hole. If an integral liner top packer will be run for special reasons, special care will be taken by the service provider to design a very "tight" migration control cement slurry that will be tested in the lab considering release of the hydrostatic above the cement column once the packer is set.**

5 BP's ETP Checklists for Planning and Executing Cement Jobs

5.1 Wellsite Leader/Drilling Engineer's Cementing Responsibilities

5.1.1 General

- Supervise all companies involved in the safe execution of the cement job.
- Verify that the final slurry recommendation meets the job requirements including DWOP and ETP compliance.
- The specifications given in the drilling program should be checked against actual conditions in the well.
- Ensure that all companies are contacted and informed in time to complete these preparations for the job.
- Approve all reports, worksheets and job tickets.
- In areas where the "Working Time Directive" applies ensure there are sufficient resources to prepare and execute the cement job.
- In areas where a chemical permit is required, ensure that all chemicals including contingencies are included in the permit.

5.1.2 Slurry Design

- For an offshore location ensure all final slurry designs have been based on samples of materials taken at the rig site.
- Confirm with the cement engineer that sufficient materials and contingency materials (normally 100% extra) are available at the rig site.
- Ensure the thickening time of the slurry is greater than the planned job time, including mixing time.
  - As a general guide, the thickening time to 50Bc at the bottom hole circulating temperature should exceed the time to mix, pump and displace by more than 2 hours.
  - Review achievable mixing rate based on bulk supply and ensure this is factored into the pumping time estimate.
- Review strength development indicated by laboratory testing against timeline for subsequent operations (pressure testing, barrier removal, drill out) and discuss any WOC identified with Cement Company to assess possible mitigations.

5.1.3 Equipment

- Confirm with Cement Engineer that all cement unit maintenance is current and all pressure retaining equipment (e.g., cement heads/chiksans) have appropriate testing/certification.
- Confirm that acceptable wash up procedures and disposal plans have been made.

- Confirm float equipment was callipered, checked for debris and threads are acceptable.
- Also confirm operation of float equipment during casing running operation.
- If a stage collar is being used, confirm it has been checked for closed position, it is clear of debris and the threads are not damaged. Check plugs and baffles are correctly installed.
- For a subsea plug or liner system, confirm plugs are correctly assembled, swivel is acceptable and plugs are compatible with launch balls/darts and landing collar.
- Drift drill pipe and x-overs in landing/running string.
- Check the launch balls/darts have been correctly loaded in the dropping head.
- Ensure there are no beveled profiles inside any of the equipment that restrict the travel of a plug or dart.
- For surface cement heads, confirm O-rings, valves and manifold are acceptable and that the pipe seals and indicator system are functioning.
- Confirm the LAS calibration is correct (particularly verify accuracy of automatic LAS) and all data recording devices are functioning correctly.
- Confirm correct centralizers are available and suitable stop collars have been supplied.
- Confirm installation is according to design and review any necessary changes with the Cement Company engineer.
- Where a computer based LAS is used, the Wellsite Leader will verify that the correct information has been loaded.
- Ensure exclusion of non-essential personnel during pressure testing operations and ensure an announcement is made.
- Confirm that all temporary pipe work connections and ratings are compatible.
- Confirm that the Drilling Contractor has prepared the bulk system and pits

5.1.4 Job Planning

- Review job simulation from the Cement Company and ECD predictions at relevant depths. Review/agree proposed pumping schedule with Cement Engineer and Drilling Contractor.
- Confirm planned slurry excess with Cement Engineer and whether this is on caliper or theoretical OH diameter.
- Assess the potential for TOC to impact APB mitigations or the BOP.
- Review field spacer properties against planned design; confirm it has been amended to deal with any changes in mud properties required during the drilling phase. Ensure a biocide is added to any spacer left behind pipe.
- Ensure any departures from the plan are discussed with Cementing Company to ensure their impact is fully assessed.
- Where appropriate, the BP "Management of Change" process should be followed.
- Agree plug launching sequence and verify plug launches via indicators on cement head.
- Review casing pressure testing requirements, timing and contingencies.
- Review and communicate plans for mud and hole conditioning, equipment clean-up and disposal of contaminated returns.

5.1.5 Execution

- Coordinate the execution of the cement job. Ensure that all relevant personnel are issued with a detailed program of the cement job, highlighting individual responsibilities. The detailed program must include volumes, pressures and pump rates for the cementing and displacing operations. Contingency plans must also be drawn up. Procedures must be written to cover alternative mix water supply, rig pump failure, and what to do if predicted pressures are exceeded or return volumes are insufficient to maintain displacement with mud.

- Ensure Drilling Contractor, Cementer, Mud Engineer and Mud Logger have reviewed their responsibilities for supporting the cementing operation and confirm they have met all requirements in their appropriate checklists.
- Hold pre-job meeting with all involved in the cementing and pressure testing operations.
- Confirm PPE is available and MSDS reviewed before handling chemicals.
- Clarify with the Cement Contractor if job involves any new technology at this location.
- If new technology is involved, verify competence and experience of Cement Company personnel.
- Clarify lines of communication and use of PA or radios in noisy areas.

* Where a pill has been spotted in the rat hole to prevent cement slumping, ensure circulation has occurred at casing setting depth.
* Carry out independent calculations for the cement job and reconcile results.
* Determine the displacement volume, pump strokes and time at which the displacement rate should be reduced prior to bumping the plugs. Displace cement at maximum rate allowable by pressure limitations, unless advised otherwise.
* Confirm mud compressibility with Mud Engineer and ensure this is factored into the displacement calculation.
* Review pre-job circulation and mud conditioning requirements with Cementer and Mud Engineer and agree plan.
* Where mud properties are different from those used in simulations by Cement Company, request modeling of pressures and displacement to be updated.
* Displacement should be from a separate pit than the returns, so that displacement volumes can be accurately monitored.
* The pump stroke counters will not be relied on as the only means of calculating the volume of displacement pumped (this may not be possible with large displacement volumes).
* Agree in advance the additional displacement volume that can be pumped to bump the plug and the pressure which must be held after bump and the duration of the test.
* Unless rig pump efficiency is very well understood, use the cement unit to displace cement plugs, liner jobs and for all cementing through drill pipe.
* Volumes should be cross checked from mud pit measurements as well as the cement unit displacement tanks.
* Inform the mudloggers and Driller as to which mud pits are being used for mix water preparation.
* The volume of each type of mix water to be used for both lead and tail cement jobs.
* The expected gain, per barrel of mix water blended with cement, for both lead and tail slurries.
* The expected total volume of returns during the cement job and the expected overall increase in pit volume.
* Ensure the pressurized mud balance has been calibrated and is used to confirm slurry density during cementing operation.
* Inform the mudloggers and the Driller at the start of mixing cement.

Quickly review the experience level of Service Provider personnel on location. Previous experience and experience with cement jobs on this rig.	
With the SPL and rig personnel, walk around the cement bulk equipment and cement and water delivery systems as well as venting rig-up including lines, to gain assurance that no interruptions will take place during the job due to poor materials movement or venting of cement into for example a pressurized tank. Ask about previews delivery or venting problems if any and recent corrective actions taken.	
Quickly review the experience level of rig personnel that will be assisting during the cementing operation.	

Safety Meeting Before the Cement Job	✓
Detailed review of relevant HSE issues: lines pressure testing, areas to stay away from, PPE equipment needed for the job, emergency shut-in procedure, contingencies plan, etc.	
Review of cement job, e.g., volumes, pump schedules, maximum displacement volumes, etc. Emphasis on the job to be mixed and pumped as closely as possible to the way it was designed and simulated. Need to keep written logs of all operations including time, volumes and pressures at the time of the events.	
Pipe movement, if any. For example, liner rotation. Rate, duration? Maximum allowed torque/drag.	
Darts, plugs releasing. Expected release pressures. Expected volume, pressure when plug bumps.	
Assignment of responsibilities. For example, who will be monitoring returns? Where will the Wellsite Leader and SPL be located during the job if needed? Who will be checking the density with the pressurized mud balance? How often? Who will be watching the cement delivery? Releasing of darts, Delivering of liquid additives to the mix water? Collecting cement, additive, mix water samples, wet samples? Etc.	
Communication devises: type, availability, who will have them?	

5.2.4 Cement Job Execution

Cementing Job Execution	✓
All personnel wearing required PPE?	
SPL present when mixing spacer?	
Correct spacer volume mixed in clean pits including dead volume? __________ bbls	
Density of spacer verified with pressurized mud balance? _______ lbs/gal	
Surface rheology of spacer measured and corresponding to expected/lab values? If not, spacer disposed of and remixed?	
Lines pressure tested to desired pressure? Lines retested if needed? _________ psi	
Spacer and slurry/slurries pumped as per design: volumes, rates?	
Spacer and slurry/slurries pumped at the designed density?	
Density monitored with densiometer and periodically checked during the job with the pressurized mud balance?	
Surface job pressures periodically checked vs. simulation?	
Measured surface pressures correlating to expected/predicted pressures?	
Samples taken and sealed: mix water, dry cement, additives?	

Cementing Job Execution	✓
Wet samples taken: spacer, lead and tail slurries?	
Wet samples placed in water bath? Bath temperature: _________°F	
All job data recorded including during displacement? Rates, densities, surface pressure.	
Pumping equipment working properly?	
Delivery systems working properly?	
Good communications among all personnel involved?	
Rate of returns during the job? Full, partial losses, total losses? When?	
Corrective action taken if losses are experienced? Reduction of rate?	
Darts, plugs released and landing as expected?	
Displacement volume pumped as agreed? Total ___________ bbls	
Top plug landed?	
Extra pressure applied to plug after landing as agreed?________ psi	
Final lifting pressure? Value as expected? ___________ psi	
Floats held?	
Flowback volume after releasing the surface pressure? _________ bbls	

5.2.5 Post Cement Job

Actions after the Cement Job	✓
Document detailed description of any event not going as plan: shutdowns, leaks, problems with delivery of materials, rates, densities, pressures different from plan, etc.	
Conduct a brief materials balance: cement, mix water, additives used vs. expected quantities?	
After the job, conduct a meeting with the Wellsite Leader and Service Provider Leader. What went right? What went wrong? Lessons Learned?	

6 BP – GoM Testing Protocol

6.1 Objectives of the Protocol

This protocol clearly defines the test methods and other requirements for cement slurries and spacer systems in BP's DW GoM. Considering the extreme conditions while cementing deepwater wells, this protocol includes the most recent test procedures available. Laboratory conditions must simulate field conditions while testing cement slurries and spacer fluids. In particular, laboratory technicians should focus on temperature, pressure and pump time.

Note: BP reserves the right to modify this document and the accompanying Recommended Tests Guidelines and Test Matrix as needed.

6.2 Laboratory Equipment Calibration

All testing equipment shall be certified by the Service Company to have been properly calibrated according to API/ISO and industry (manufacturer) procedures. Any equipment not properly calibrated or not in optimum operating conditions shall not be used.

6.3 Safety Procedures

The laboratory shall have a safety protocol. BP may from time to time conduct an HSSE audit of the facilities.

6.4 Tests Required – General

6.4.1 Cement Slurry Testing

The generalized Test Matrix (Attachment 1) will be used by BP engineers to identify the specific tests to be run for each casing string for the project. BP engineers will adjust the test requirements (Test Matrix) as needed for each project, depending on the conditions at hand (for example, potential for shallow hazards). The Recommended Tests Guidelines (Attachment 2) shows the tests to be performed for different hole conditions. The Recommended Tests Guidelines will be used by BP engineers to decide which tests to request. These tests may include:

- Pressurized balance density
- Thickening time
- Compressive strength development
- WOC time
- Fluid loss
- Free fluid
- Settling behavior (stability: static and dynamic)
- Rheology
- Gel strength development

6.4.2 Spacer System Testing

The generalized Test Matrix will be used by BP engineers to identify which specific tests to run for each casing string for the project. BP engineers will adjust the test requirements (Test Matrix) as needed for each project, depending on the conditions at hand (for example, HPHT conditions). Test(s) requested by BP engineers may include:

- Pressurized balance density
- Fluid loss
- Settling behavior (stability: static and dynamic)
- Rheology
- Wetability properties
- Compatibility with the cement slurry and the mud in the hole including:
  - Rheology of mud-spacer, spacer-slurry mixtures, and mixtures of the three fluids
  - Effect of the spacer on the fluid loss of the cement slurry
  - Effect of the spacer on the thickening time of the cement slurry
  - Effect of the spacer on the compressive strength development of the cement slurry
  - Effect of the spacer on the settling properties of the cement slurry

6.4.3 Cementing Laboratory Audit

A detailed audit of the laboratory facilities (equipment, calibrations, record keeping, personnel experience, etc.) may be conduced by a qualified BP engineer or an independent contractor at any time selected by BP. If improvements are needed as per the audit's report, a detailed plan to close out audit findings will be constructed with a target date for close-out.

6.4.4 Samples of Cement, Additives and Water

Prior to initiating the final testing stage for the given project, samples of the cement, additives and mixing water to be used in the cementing job or jobs shall be collected at the rig site and sent to the lab that will be performing the tests. Sufficient time and logistics should be used to allow the slurry testing to be conducted and test results reviewed by operations team prior to carrying out job at rig site.

Note: The service provider is to maintain proper records of shelf life under offshore weather conditions of liquid additives kept offshore, and will replace unused additive batches as needed.

6.4.5 Order of Addition of Additives

Slurry response at well conditions may be affected by the order of addition of liquid additives to the mix water. Therefore, the laboratory mixing procedure shall be documented in detail and included in the slurry and spacer recommendation, and it shall be exactly followed when preparing the mix water in the field.

6.4.6 Test Procedures

Unless specifically indicated in this protocol document, test procedures will strictly adhere to those included in the latest version of API_RP-10B or its equivalent ISO document, ISO 10426-1. Laboratory technicians that will be conducting the testing for the project will be required to be proficient with test procedures included in the API or ISO document and with any other test procedures included in this protocol, before initiating testing for the project.

6.4.7 Reporting of Test Results

The results of all the testing, including the conditions of the tests (temperature, pressure, time to bottom, etc.) and test charts (thickening time, compressive strength, gel strength, etc.) shall be submitted in writing to the BP engineer that requested the testing, with sufficient time to be reviewed, ahead of the cement job.

6.4.8 BHCT and Shut-in Temperature Profiles

An un-steady state well temperature simulator shall be used to simulate the temperature profiles during circulation and during shut-in. API BHCT correlations shall not be used for deep water wells (were not developed for deep water). The input data to the simulator is to include all the required information such as detailed well geometry (including riser and estimated sea currents), fluids and formation thermal properties, job rates, etc. Across salt, the input to the program must include salt thermal properties (salt has high thermal conductivity). Predictions from the simulator will first be carefully checked vs. downhole temperature measurements (log temperatures, circulating temperature bombs, etc.) to fine-tune them as needed to try to ensure the temperature profile predictions will be reliable and useable.

The simulated circulating and shut-in temperature profiles shall be followed, as closely as practical, to conduct in the lab, the thickening time, compressive strength and other tests required by this document.

6.4.9 Pressurized Balance Density Check

The density of all cement slurries and spacer systems shall be measured in the laboratory with a properly calibrated, pressurized mud balance, to verify that the designs are producing the expected densities. Accuracy of the pressurized mud balance is considered to be ± 0.1 lb/gal.

6.4.10 Thickening Time Test

Thickening time schedules shall be strictly well tailored (API average tables shall not be used). Time to bottom shall be calculated using the well parameters: drill pipe and casing size, section depth and the average pump rate to be used during the job. Temperature profiles to be used shall be those simulated by the fine-tuned temperature simulator (see BHCT and Shut-in Temperature Profiles section). Final test pressure for the test shall be calculated using the mud density in the hole and the hole TVD (when possible, the corrected for compressibility mud density will be used).

6.4.11 Criteria for Acceptable Thickening Time

The following criteria for acceptable thickening time values shall be used to minimize WOC times and the time cement slurries remain liquid in the annulus after placement. The criteria are given below:

Minimum TT = MEPT + 1-1/2 hr (2 hr for HPHT jobs, 1 hr for plug jobs)

Where:

MEPT = Maximum Estimated Job Placement Time

TT = Thickening Time

If the cement slurry will be batch-mixed, the surface retention time (time in the batch mixer) shall be added to the calculated minimum TT. The retention time shall be simulated in the consistometer at the expected surface mixing temperature and at atmospheric pressure. Surface retention time and the thickening time at BHCT and bottom hole pressure shall be clearly reported to avoid confusion. For example: "the thickening time was measured as follows: 1-1/2 hr surface retention time at 85°F plus 4:00 hr thickening time to 70 Bc".

Maximum TT accepted shall be two hours above the Minimum TT.

Note: **Longer maximum TT's may be accepted as long as the "Drill Ahead" compressive strength of the cement slurry (normally ~ 500 psi) at the top of the cement column is developed by the proposed slurry within field acceptable WOC times.**

6.4.12 Sensitivity Thickening Time Tests for HPHT Applications

For HPHT wells, the sensitivity of cement slurries response to BHCT temperature and retarder concentration changes shall be measured.

6.4.13 Sensitivity to Retarder Concentration

The slurry thickening time shall be retested using retarder concentrations of +/- 5% the design concentration. Acceptable slurry designs shall be those that generate:

Thickening time > Maximum Estimated Job Placement Time (MEPT) with 5% less retarder.

Thickening time < 2 x base slurry thickening time with 5% more retarder.

Thickening times that decrease with less retarder and increase with more retarder.

6.4.14 Sensitivity to BHCT

To account for the uncertainty of predicting the actual BHCT of the HPHT well, once the thickening time at the BHCT has been obtained, the thickening time shall be repeated at a hotter BHCT of 15°F (8.3°C) above the predicted BHCT. If the thickening time of the slurry at the hotter BHCT is less than or equal to the MEPT, the slurry shall be redesigned (for example, by increasing the retarder loading) to generate a thickening time above the MEPT, at the hotter BHCT.

6.4.15 Compressive Strength Test

The slurry shall be brought to BHCT in the pressured consistometer using the simulated temperature and pressure profiles previously mentioned in this document, held at that temperature for 1/2 hour (cooled to 190°F if BHCT is higher than 190°F) and then placed in the curing chamber, UCA or SGSA and heated to the BHST following as closely as possibly the previously simulated heat-up temperature profile. Tests shall be run for a minimum of 24 hours. UCA or SGSA testing shall be preferentially used to be able to have a permanent record (vs. time) of the CS data and to help select a safe WOC time.

Note: For surface casing, pre-conditioning of the slurry shall be done in the atmospheric consistometer equipped with chilled water.

6.4.16 Compressive Strength Test at the TOC Column and WOC Time

The compressive strength of the cement at the top of the cement column (e.g., for liner jobs) and the WOC time shall be determined using an Ultrasonic Cement Analyzer (UCA or SGSA). The test shall be conducted at a minimum of 5,000 psi and at the predicted static temperature at the top of the cement column or at a temperature of 15°F (8.3°C) lower than the BHST whichever is cooler. The cement slurry shall be pre-conditioned in a pressurized consistometer at bottom hole conditions of temperature and pressure. The entire compressive strength UCA or SGSA chart shall be included in the report to the BP engineer.

Note: Best practices recommend not to resume operations until the cement has developed a reasonable "Drill Ahead" CS (normally 500+ psi) at the top of the column, but in offshore operations, this value has been reduced to as low as 100-200 psi for the surface casing.

6.4.17 Fluid Loss Test

For this Protocol, the preferred API/ISO test method to run this test is using a stirred fluid loss cell, if one is available in the lab. However, in its absence, a static fluid loss cell may be used, as per API/ISO RPs. The cells shall be equipped with a properly calibrated thermocouple (not a spring thermometer) on the body of the cell or even better, through the lid of the cell, such that the actual slurry or spacer temperature is measured. When using the stirred fluid loss cell, the fluid shall be heated under pressure to the BHCT using the simulated temperature profile. If a static cell is used, the slurry shall be brought to bottom hole conditions of temperature and pressure in a pressurized consistometer prior to transferring the slurry to the fluid loss cell (the fluid may need to be cooled down to ~ 185°F before removing it from the consistometer). The fluid loss data shall be collected and recorded as recommended by the RP-10B document. The condition and thickness of the filtercake shall be reported at the end of the test.

6.4.18 Free Fluid Test

For this Protocol, the preferred API/ISO test method to conduct this test is at the BHCT and under 1,000 psi pressure, using a see-through glass tube that will fit inside the stirred fluid loss cell. The tube (which will have a volume less than 250 ml) shall be sealed with a temperature resistant material at the top. This material needs to allow transmission of pressure to the fluid in the tube without rupturing. The stirred fluid loss cell with the tube inside is to be filled with water to a level that will prevent the water from contacting the top of the sealed tube. The stirred fluid loss cell is to be tilted to 45° and the test conducted for 2 hours. After the 2 hours the cell is to be cooled down and the free fluid in the tube measured. The possible existence of a channel on the high side of the tube shall be carefully examined and if present, the slurry shall be redesigned. The required free fluid of cement slurries using this testing approach shall be zero for inclined sections of hole and/or for hole sections where formation fluids migration after cementing is a concern. For vertical holes with no potential for migration after cementing, the maximum allowed free fluid shall be 1%.

In the absence of a stirred fluid loss cell, the free fluid tests may be run at atmospheric pressure, with the 250 ml test tube inside a constant temperature water bath (at BHCT or 185°F whichever is less), and at an angle of 45°. The tests conditions shall be clearly included in the report to the BP engineer.

6.5 Settling Properties Tests

6.5.1 Cement Slurries

The static and dynamic settling properties of cement slurries shall be measured. There are two static settling tests accepted by this Protocol. One is quantitative and the other qualitative. The quantitative on is the one in API RP-10B and ISO 1046-2 documents. This method requires the cement to set up before making the measurements. The qualitative, non-API/ISO static settling test uses the consistometer. It is included in the Appendix of this document. This other test procedure shall be used for screening (early design stages) of potential cement slurry formulations. It is much faster than the API/ISO test. The dynamic setting test shall be the one included in the Appendix. The dynamic settling test, a non-API/ISO test, uses a special consistometer paddle and a high pressure consistometer equipped with a variable speed motor. Criteria for acceptance of cement slurries after a static test using the consistometer and a dynamic settling test are included with the test methods in the Appendix.

6.5.2 Spacer Fluids

The static and dynamic settling properties of spacer fluids shall be measured. The static settling test shall be the non-API/ISO that uses the consistometer, included in the Appendix. The dynamic setting test shall be the one included in the Appendix. These are the only settling tests capable of determining the settling properties of fluids like spacers that do not set up.

6.5.3 Rheology Test

This test shall be conducted as per the current API RP-10B procedure. It requires a heating cup. The procedure requires that the readings be taken in ascending order and then repeated in descending order. The rheology shall be reported as the average of the two runs, at the average test temperature (BHCT or 185°F whichever is less). The ratio of the reading shall be reported as well. They may be used as an indication of slurry settling or of gelation. The slurry shall be conditioned at the BHCT and pressure in an atmospheric or pressurized consistometer prior to this test, using the simulated temperature and pressure profiles. This test may be run prior to the Fluid Loss Test (if the static cell is being used), with the same sample of slurry to save time.

6.5.4 Gel Strength Development Test

This test shall be conducted at static downhole conditions of temperature and pressure using either a vein rheometer, a MACS, a Mini-MACS Analyzer (Halliburton lab equipment) or a SGSA (Chandler engineering equipment). The slurry shall be pre-conditioned to the BHCT and pressure prior to the test, using the simulated temperature and pressure profiles.

Note: If a UGSA is being used to measure the compressive strength of the cement slurry, the gel strength of the cement will automatically be measured by this device during the gelation stage of the slurry.

Gel strength shall be measured, and the critical gel strength determined for non-foamed cement slurries designed to control shallow hazards (water and/or gas flows across conductor or surface casing intervals). Likewise, gel strength shall be measured, and the critical gel strength determined for non-foamed cement slurries designed for situations when the risk of formation fluids migration after cementing is high (when the flow potential is high and/or when the initial – right after the cement job – overbalance pressure across the potentially offending zone is < 200 psi.)

Note: For scenarios that include the potential for formation fluids migration after the cement job as described above, foam cement or other invasion/migration control type slurry shall be designed.

6.5.5 Cement Slurry Capacity to Control Formation Fluids Invasion and Migration after the Cement Job

A gas migration test may need to be conducted to verify that the proposed cement slurry formulation will indeed be capable of controlling gas migration after the cement job.

The capacity of the cement slurry to prevent formation fluids invasion and migration after the cement job shall be measured using a FMA test device for slurries to be placed across gas or water zones with flow potential factors equal or greater than 6. A definition of flow potential factor is given in this Appendix. For high flow potential factors, cement recipes require migration control additives in addition to very good fluid loss control. The FMA test schedule shall be calculated using the scale-down method as described in SPE paper 19522 by Beirute and Cheung, 1990. For the calculations required by the scale-down method, the gel strength of the cement slurry shall be measured using the procedure outlined under Gel Strength Development Test. If the test shows that the slurry will not control migration, the cement slurry shall be redesigned and the test repeated.

6.5.6 Compatibility Tests

Two fluids are considered to be compatible if no significant change in the desired properties occurs as a result of mixing the fluids (this applies to all the properties, not just to viscosity). Compatibility tests shall be performed between the spacer and the field mud, and the spacer and the cement slurry to be used in the job. Tests shall also be performed to investigate the compatibility of the three fluids together (1/3 each mixed together), because problems may develop downhole if the three fluids come in contact (channeling, bypassing).

The API RP-10B provides details on tests that can be performed to determine rheology compatibilities. Tests are also outlined to check the effect of spacers on the cement slurry thickening time, compressive strength, fluid loss and settling characteristics.

Compatibility tests shall be conducted with fresh samples of mud from the hole section to be cemented. Additives and concentrations may be changed in the mud as the well is deepened, and this may affect the compatibility response of the spacer. Likewise, the design of the cement slurries changes with well depth.

Regarding compressive strength of the cement slurry, spacers are expected to negatively affect it to some degree because of dilution and chemical effects. This is normally not considered a serious problem since the contaminated interface spacer-cement slurry will be pumped above the zone of interest. However, if severe effects on compressive strength are noticed, the spacer system shall be re-designed.

Some retardation (thickening time) of the slurry by the spacer is also acceptable based on the same argument, but the spacer must not accelerate the cement slurry for obvious reasons. In addition, the spacer must not severely affect the fluid loss control properties of the mud and the cement slurry, particularly when the hole includes high permeability zones or there is risk of formation fluids migration after cementing.

When a cement evaluation log will be run, the compressive strength of a 95/5 and 75/25 cement/spacer combination shall be run. In addition, the impedance of the uncontaminated and the contaminated cement shall be calculated from the transit time of the UCA or SGSA and reported to assist with the calibration and interpretation of the cement evaluation log.

6.5.7 Wetability Test

When displacing an oil-based drilling fluid, the pipe/formation must be changed from an oil-wet to a water-wet condition so that the cement can bond properly. With oil (or synthetic oil) based drilling fluids, a water-based spacer with water-wetting surfactants shall be used. Some oil-based spacer/flush may be used ahead of the water-based spacer (oil-based spacers are naturally compatible with oil-based drilling fluids). When a water-based drilling fluid is being used, the spacer system must be water-based.

The wetability properties of the spacer system shall be tested for all cement jobs that will have oil base mud in the hole. The tests shall be conducted with fresh samples of mud from the hole section to be cemented. Additives and concentrations may be changed in the mud as the well is deepened, and this may affect the wetability response of the spacer.

As to the writing of this document, there is no API/ISO wetability test available. The wetability tests used shall be either the "Rod" Test or the "Rotor" Test given in the Appendix. The purpose of those tests is to detect the true wetability properties of the spacer system and not the ability of the spacer to clean films of mud from the pipe surface. The tests shall be used to determine if the surfactant package selection or the concentration of the surfactants is adequate for complete water-wetting of the pipe.

6.5.8 Testing of Foam Cement Systems

Large scale tests have demonstrated that foamed cements with foam qualities ranging from 18% to 38% resist shear failure during internal casing pressurization. Therefore, foam cement systems shall be designed to be in this range of foam quality at downhole conditions.

Foam cement systems shall be mixed and tested in the laboratory according to the most recent version of ISO 10426-4. According to that document, the following tests shall be conducted on the un-foamed (base) cement slurry:

- Thickening time
- Rheology (simulators use it to predict foam rheology)
- Fluid loss
- Free fluid

The following tests shall be conducted on the foamed cement slurry:

- Compressive strength
- Foam stability

7 References

1. Refer to MMS and other relevant documents – get the references
2. Include BP Drilling and Well Operations Policy (DWOP)
3. BP's GoM Cement Testing Protocol and Test Matrix
4. Relevant API/ISO Specifications, Recommended Practices and Technical Reports:
    - API Spec 10A/ISO 10426-1 Specification for Cements and Materials for Well Cementing
    - API RP 10B-2/ISO 10426-2 Recommended Practice for Testing Well Cements
    - API RP 10B-3/ISO 10426-3 Recommended Practice on Testing of Deepwater Well Cement Formulations
    - API Spec 10D/ISO 10427-1 Specification for Bow-Spring Casing Centralizers
    - API RP 10D-2/ISO 10427-2 Recommended Practice for Centralizer Placement and Stop Collar
    - Testing
    - API RP 10F/ISO 10427-3 Recommended Practice for Performance Testing of Cementing Float
    - Equipment
    - API TR 10TR1 Cement Sheath Evaluation

- API TR 10TR4 Technical Report on Considerations Regarding Selection of
- Centralizers for Primary Cementing Operations
- API TR 10TR5 Technical Report on Methods for Testing of Solid and Rigid Centralizers

Attachment 1: Cement Slurry Generalized Test Matrix

(to come)

Attachment 2: Recommended Test Guidelines for Hole Conditions

(to come)

From: Taylor, Charles E
Sent: Wed Mar 25 16:37:18 2009
To: Emmerson, Tony C; Walz, Gregory S; Driscoll, Pete; Sanders, Robert O; Kidd, Gavin N; Sims, David C; Nohavitza, Glenn R
Cc: 'RMBCONSUL@aol.com'; Sprague, Jonathan D
Subject: Cementing Workshops
Importance: Normal

I believe most of you are aware that Robert Beirute has been reviewing our cementing practices on our current wells and is preparing a Cementing Best Practices document.
Starting the second week in April, Robert will hold a series of workshops for our engineers to educate them on cementing basics and go over the issues he believes has contributed to some of our recent cementing problems. Each workshop will be repeated twice during the week to accommodate different schedules. We can add additional workshops based on demand. Due to size of the conference rooms, the workshops will be limited to 15 participants.
The first workshop will be on April 7 from 1:00 to 3:00 in room 1094 and will cover Virtual Cementing Lab Tour and Recommended Testing Protocol for BP GOM. It will be repeated again on April 8 from 1:00 to 3:00 in room 1094.
I will send out the meeting requests to the Team Leaders for you to forward on to the engineers in your groups.

Charles Taylor
Drilling Engineering TL

EXHIBIT # 789
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- Inform the mudloggers and Driller when changing from the lead to the tail cement slurry and at the end of pumping cement.
- Maintain plot of displacement versus top of cement and also the position of the top plug, identifying any pressure events during displacement with the volume pumped.
- Compare theoretical and actual pressures.
- Periodically advise the mudloggers of total cement slurry pumped.
- Record all mixing, displacing, bumping, opening/closing of DV collars, etc. on pressure chart.
- After bumping top plug, release pressure, measure returns and check for backflow.
- If float equipment fails and/or pressure is held on the casing, a pressure gauge should be installed on the cement head so that the required pressure can be maintained and excessive pressure bled off periodically. In this case the pressure left on must not exceed the observed differential pressure between mud and cement.

5.2 QA/QC of Cementing Jobs at Wellsite

5.2.1 Overview

The following tables assume that the entire cementing operation, from lab testing of the fluids to be mixed and pumped, to the pump schedule to be used, has been carefully designed and optimized by the Service Provider and the operator engineers. Therefore, these Guidelines are to help with performing the cementing operation as closely as possible to the way the job was optimized and simulated.

5.2.2 Documents Needed

Item	✓
Lab report from the Service Provider showing the cement slurry/slurries and spacer formulations and tests results including Density, Thickening Time, Compressive Strength. Fluid Loss, Free Fluid, etc.	
Final, Optimized Job Simulation by the Service provider including volumes to be pumped, Pump (Rate) Schedule and expected surface pressures.	
Other relevant documentation for example surge/swab simulation, centralizer placement simulation, well inclination profile, latest mud log report, etc.	

5.2.3 Actions Prior to the Cement Job

Allow Plenty of Time Ahead of the Cement Job	✓
Review entire cementing job procedure from mixing to completion with the Wellsite Leader and the Service Provider Leader (SPL) on location, to collect information, and to gain complete understanding/agreement on how the job will be performed from start to finish.	
As a team, clear up any misunderstandings and address/answer all questions, for example, making sure the bottom plug will be released ahead of the cement slurry.	
Review all needed calculations. This should include review of calculated displacement volume which may consider the addition of extra volume to account for compressibility of the mud, vs. length/volume of the shoe track.	
Review the centralizer program, float equipment and cementing plugs to be used.	
Review the casing running speed. If casing is already on bottom, where losses experienced? Is there a need for the SPL to rerun the cement job simulator to adjust the pumping schedule to minimize losses during the cement job?	
Discuss hole conditioning ahead of the cement job: Rates schedule, time. Pressure transducer installed to monitor the surface pressure while circulating?	

Review Equipment with SPL	✓
With the SPL, go over all the equipment that will be used for the cementing operation: Pumping equipment, flow meters, densiometers, pressurized mud balance, liquid additives delivery system, etc.	
Pumping unit: age, recently maintained? Pressure tested? Recent problems?	
Flow meters, maintained, calibrated? Recent problems and actions taken?	
Densiometer calibration: how and when done? Correlates well with pressurized mud balance?	
Pressurized mud balance, recently calibrated with water? Functioning correctly? Piston, valve?	
Note: Verify calibration of pressurized mud balance with water. Check proper functionality of piston and valve. Proper functionality and cleanliness of this device is important to the success of the cementing job.	
Liquid additives delivery system: how does it work, recent maintenance, calibration?	
Equipment backup. What if some equipment fails? Preventive actions?	
Cement and mix water delivery systems: Rig-up to minimize interruptions? Past experiences and corrective actions taken?	
Cement venting system. Rig-up to minimize problems?	
Spacer mixing: cleaning of pits ahead and after mixing? Procedure to ensure spacer is mixed as designed?	
Cementing head working pressure rating ________psi.	
Testing of lines, to what pressure?_________ psi	
Darts loading procedure.	
Recording of the job parameters during mixing and displacement even if the displacement is done by the rig. Onsite PC working properly and ready to collect all the job data?	

With the SPL and Rig Personnel	✓