From: Richard Vargo
Sent: Wed Jul 14 08:25:29 2010
To: Timothy Quirk; Richard Dubois
Subject: FW: Data Request from D&C management
Importance: Normal
Attachments: SRP 4.1-0003 SRP Cement Lab Testing.ZIP

Tim/Richard,

I need you guys to review this document and let me know if we are meeting these expectations or have any deficiencies. Please advise as soon as you can. I know Tim is out so Richard I may need you to run this one on your own. Let me know.
Thanks.

Richard F. Vargo Jr.
Halliburton
GOM Region Manager - Cementing
100 Capital Dr.
Lafayette La. 70508
Office: 337-266-8249
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Fax: 832-553-7811
E-Mail: Richard.Vargo@Halliburton.com

From: Nicky Pellerin
Sent: Tuesday, July 13, 2010 1:07 PM
To: Durel Bernard; Ronnie Faul; Richard Vargo; Shade LeBlanc; Rick Goosen; Chris Daigle; Ricky Ramroop
Subject: FW: Data Request from D&C management

Info for meeting

From: Huseynov, Asif [mailto:Asif.Huseynov@bp.com]
Sent: Tuesday, July 13, 2010 11:28 AM
To: Nicky Pellerin
Subject: RE: Data Request from D&C management

Nicky,

Here is the requested information. Could you please let us know how the progress been on this late tomorrow?

- Confirm with your cementing supplier that:
    - They comply with their internal policies and procedures that assure cement recommendations are reviewed and approved internally prior to submission to BP
    - Slurry testing is performed per the contract, including testing specified in Segment Recommended Practice SRP 4.1-0003.
    - Any additional testing you require is understood

<<SRP 4.1-0003 SRP Cement Lab Testing.ZIP>>

Thanks and appreciated.

Asif Huseynov,

3113
Exhibit No. ______
Worldwide Court Reporters, Inc.

Drilling Engineer
GOM D&C,
BP, America
Work: 281-366-5087
Mobile: 832-331-4981
E-mail: asif.huseynov@bp.com

From: Huseynov, Asif
Sent: Tuesday, July 13, 2010 8:37 AM
To: 'MRice@exchange.slb.com'; 'YAkinpelu@exchange.slb.com'; Pellerin, Nicky M (HALLIBURTON); 'Chris.daigle@halliburton.com'; 'Shade.LeBlanc@Halliburton.com'; 'ricky.ramroop@halliburton.com'; 'Jasen.bradley@halliburton.com'; Galiunas, Michael D
Cc: 'Nicky Pellerin'; 'Mitch Rice'; 'Rick Goosen'
Subject: RE: Data Request from D&C management

Meeting room # 1072.

Thanks,

Asif Huseynov,
Drilling Engineer
GOM D&C,
BP, America
Work: 281-366-5087
Mobile: 832-331-4981

E-mail: asif.huseynov@bp.com

-----Original Appointment-----
From: Huseynov, Asif
Sent: Monday, July 12, 2010 4:41 PM
To: Huseynov, Asif; MRice@exchange.slb.com; YAkinpelu@exchange.slb.com; Pellerin, Nicky M (HALLIBURTON); Chris.daigle@halliburton.com; Shade.LeBlanc@Halliburton.com; ricky.ramroop@halliburton.com; Jasen.bradley@halliburton.com; Galiunas, Michael D
Cc: Nicky Pellerin; Mitch Rice; Rick Goosen
Subject: Data Request from D&C management
When: Tuesday, July 13, 2010 10:30 AM-11:30 AM (GMT-06:00) Central Time (US & Canada).
Where:

All,

I have been requested to gather some information together about cementing slurry designs and slurry testing. Could you please join us to this meeting tomorrow to discuss the details? Please let me know if you would like to shift the time around a little. IMT still is the first priority but we need to get this together by the end of this week for BP D&C management.

Thanks and your support is appreciated,

Asif Huseynov,
Drilling Engineer
GOM D&C,
BP, America

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Mobile: 832-331-4981
E-mail: asif.huseynov@bp.com

E&P Segment
Recommended Practice

Drilling and Completions Cementing Manual

Cement Laboratory Testing Section

SRP 4.1-0003

This practice will be subject to periodic review.

Issue Date	November 2009
Revision Date	November 2009
Next Review Date	November 2011
Technical Authority	Daryl Kellingray, Drilling Specialist Cementing and Drilling Fluids
Content Approval	Scott Sigurdson, VP Drilling and Completion Engineering
Authorization for Issue	Barbara Yilmaz, Technology Vice President, Drilling and Completions
Document Administrator	Drilling and Completions

Table of Contents

Symbols and Abbreviations

Symbol / Abbreviation	***Definition***	***Symbol / Abbreviation***	***Definition***
API	America Petroleum Institute	**psi**	Pounds per square inch
bbl	Barrel	**QA/QC**	Quality Assurance / Quality Control
Bc	Bearden Unit	**RP**	Recommended Practice
BHCT	Bottom hole circulating temperature	**rpm**	Revolutions per minute
BHP	Bottom Hole Pressure	**SG**	Specific Gravity
bpm	Barrel per minute	**SGS**	Static Gel Strength
ECD	Equivalent Circulating Density	**SGSA**	Static Gel Strength Analyser
FG	Fracture Gradient	**SME**	Subject Matter Expert
FIT	Formation integrity Test	**SPE**	Society of Petroleum Engineers
HPHT	High pressure high temperature	**SPU**	Strategic Performance Unit
ISO	International Standards Organisation	**TVD**	True Vertical Depth
min	Minute	**TT**	Transition Time
OH	Open Hole	**UCS**	Unconfined Compressive Strength
OBM	Oil Based Mud	**UCA**	Ultrasonic Cement Analyser
ppb	Pounds per barrel	**WBM**	Water Based Mud
ppf	Pounds per foot	**WOC**	Wait on Cement
PT	Pump Time	**YP**	Yield point
ppg	Pounds per gallon	**ZGT**	Zero Gel Time

1 Introduction

Laboratory testing is a critical element in successful well cementing. Cement, chemical additives and well conditions are never entirely consistent or predictable; therefore, the testing of field representative samples is critical to ensure the slurry has the properties to meet the cementing objectives. Proper simulation of the pressures and temperatures the cement will experience during the actual cement placement will ensure robust slurry designs.

2 Fundamentals

- In every country where BP operates, the laboratory should have the following cement testing capability:

  - Thickening/Pumping Time in an HPHT Consistometer
  - Rheological Properties using a Fann 35
  - Compressive Strength (UCA & destructive testing of cement cubes)
  - Density
  - Fluid Loss using an API test cell (1000 psi across 325 mesh screen)
  - Slurry Stability using a BP Settlement Test Cell
  - Free Water & Operating Free Water
  - Spacer Compatibility & Wettability
  - Material QA/QC
  - Transition times (static gel strength measurements)
  - QA/QC of dry blends and additives (e.g. Pycnometer for dry blend density)

- In remote locations, where field laboratories are only able to conduct final slurry design checks, capability to run the following tests (as a minimum) is recommended:

  - Thickening/Pumping Time in an HPHT Consistometer
  - Rheological Properties using a Fann 35
  - Compressive Strength (Ultrasonic Analyser)
  - Density
  - Fluid Loss using an API test cell (1000 psi across 325mesh screen)
  - Operating Free Water
  - Spacer Compatibility

- Regional laboratories should have a range of equipment to run nonstandard testing covering:

  - HPHT fluid loss and rheology
  - Shrinkage and expansion
  - Young's modulus / Poisson Ratio
  - Dynamic settlement
  - Chemical analysis of materials
  - Particle size analysis of materials

- Technicians / laboratory staff should be able to demonstrate appropriate training on the equipment they are operating. Laboratory equipment should have auditable maintenance and calibration records. Laboratory equipment should be calibrated by a 3rd party calibration service provider on an annual basis.

- Laboratories used for testing slurries for BP should have been audited in the last 2 years, either by the Service Provider (as part of a global quality management plan) or by BP. Review a copy of the most recent audit and assess closure of actions identified in the audit.

3 Risks

Proper laboratory testing is critical in order to provide assurance of cement slurry and set cement performance. The table below outlines the potential risks associated with cement laboratory testing and measures that can be taken to mitigate those risks.

Risks	Mitigation
Unreliable test results resulting in job failure due to poor maintenance and calibration of laboratory equipment.	Documented procedures and records for maintenance and calibration should be in place, and personnel trained on methods and procedures. Correct calibration equipment and spare-parts inventory.
Laboratory personnel who are poorly trained/ supervised or lack experience can make errors in calculation, measurement, procedure, equipment operation and interpretation of results.	Laboratory supervisor should have at least 3 years of cement laboratory experience. New technicians not left alone and formal training programme in place to ensure adequate training and competence levels. Technician competency on individual test procedures should be validated by the laboratory supervisor (or 3rd qualified party), documented and maintained on file.
Not using representative field samples and relying on historic/database results has resulted in job failures.	Always test using representative samples. Laboratory with proper sample receipt and labelling system to prevent incorrect sample use.
Bulk blend samples can be unrepresentative due to poor blending or single point sampling, resulting in incorrect results and job failure.	Correct sampling technique ("Y-bend" or automatic sampler) combining multiple samples. Compare test results with results from blend formulated in laboratory from field samples of actual constituents. Blend QA/QC via density checks. Pycnometer or sieves to confirm dry blend quality. Thickening times determined for field blends to be within 45 minutes of pilot blends for Pumping Time, <5 hours and 60 minutes when Pumping Time > 5 hours.
Testing at the wrong temperature (and/or pressure) has resulted in pipe being cemented in, or cement left in pipe and failed primary and remedial cementing operations.	Communication between BP engineer, cementing engineer, laboratory and WSL. Using latest field data available. Allowing for changes in well conditions, circulation, etc. Not relying on API schedules for temperature selection for deviated wells, HPHT and Deep Water wells. Do not rely on API ramping schedules and use a ramping schedule simulating the expected field cementing operations.
Slurry sensitivity due to change of temperature, additive concentration, cement or water. Unexpectedly short or long Pumping Times can have disastrous consequences.	Review results with recent database of test results using the same additives and cement. Slurry has a predictable linear response to temperature and retarder concentration. Perform sensitivity testing at; say +/- 15F BHCT and +/- 10% retarder when results depart from the above.
Poor connectivity and communication between engineers, laboratory and field cementers have resulted in slurries and spacers that cannot be mixed in the field (excessive viscosity, foaming, etc).	Procedures and documentation followed. Appropriate laboratory tests performed and results interpreted. Cementing engineer and laboratory located together. Detailed rig cement programs for each job. Define and discuss surface rheology limits for slurries with respect to field mixing
Test procedures and conditions do not model actual field practice and conditions.	Communications between WSL, BP engineer, cement company engineer and laboratory. Documenting procedure and conditions on the laboratory test request sheet, the laboratory report, and the rig cement program.
Reliance on Operational Free Water test alone has resulted in poor isolation in high angle wells due to cement settlement under downhole conditions.	Perform BP Settlement Test. Perform Free Water Test at an angle of 45 degrees.
Untidy, non-segregated sample storage and poor labelling results in the wrong samples being used, and job failure.	Incoming sample record book, rigorous labelling, basic QC testing, rig-segregated storage and ordered system.
Errors have been found in Laboratory spreadsheets used for calculation of chemical quantities to mix test slurries, resulting in laboratory test formulations not matching field formulations.	Audit and check laboratory calculation tools, and all chemical factors (e.g. actual material densities or book values). Laboratory to keep a written record of the exact laboratory mix formulation used (in grams and ml) for each test. Confirm that the laboratory has participated in a co-operative testing program (identical samples) with other cement laboratories, verify consistency of results.

To verify that the Cement Laboratory meets BP and industry standards, an audit by a BP Specialist and/or Contractor Specialist (working on BP's behalf) every three years and at contract award (minimum requirements).

4 Test Procedures & Conditions

4.1 Laboratory Testing Requirements for BP Cementing Operations

A range of International standards have been agreed to cover the testing of oil well cement slurries, these are outlined in Appendix 1; any laboratory working for BP is expected to be aware of and follow the most recent copies of these standards.

4.1.1 Cement Slurries

The minimum recommended slurry test requirements are detailed below. For special slurries or conditions, test requirements will require revision.

- ***All slurries incorporating a Fluids Loss aid must have API fluid loss determined.***
- ***Slurries placed for control of Shallow Flows (conductor or surface pipe) or where gas migration risk is high (predicted flow potential is high and/or static cement overbalance < 200 psi against a permeable gas bearing formations) must have static gel strength transition time and zero gel time determined.***

Job Type	Slurry	Pump Time	Compressive Strength	Operating Free Water	API Fluid Loss	Rheology	BP Settlement Test
Conductor	Neat	Note 1	No	Yes	No	Yes	No
	Extended	Yes	Yes	Yes	No	Yes	No
Surface	Lead	Yes	Note 2	Yes	No	Yes	No
	Tail	Yes	Yes	Yes	No	Yes	No
Intermediate	Lead	Yes	No	Yes	No	Yes	No
	Tail	Yes	Yes	Yes	No	Yes	No
Production Casing and Drilling liners	Lead and Tail	Yes	Yes	Yes	No	Yes	Note 3
Production Liner		Yes	Yes	Yes	Yes	Yes	Yes
Plugs		Yes	Yes	Yes	No	Yes	Note 3

Note 1 Extended testing regime applies if temperature > 40°C or slurry not Class G/H + accelerator

Note 2 Where structural support or zonal isolation is required, compressive strength must be determined. When the cement slurry is only a filler, slurry compressive strengths are unnecessary.

Note 3 When the hole angle exceeds 70°, or temperature exceeds 121° C (250° F), or weighting additives or low density particles are used, a BP settlement test is required.

For liner jobs and where cement can have contact with the drilling fluid, a contaminated PT test is required using a 95/5 cement to mud contaminant.

4.1.2 Cement Spacers

General Testing Considerations for all spacers.

Perform API mud/spacer compatibility test on intervals isolating hydrocarbon bearing formations and permeable overpressured brine or water bearing formations (each mud spacer combination only needs to be tested once per well). In addition to the mixtures defined in the API procedure, it is recommended that a 95/5 blend is prepared since field experience has show incompatibles at low levels of contamination.

ISO 10426-2 includes procedures for testing stability and gel strength of spacers using a HPHT consistometer. Additional tests may be devised to further check static and dynamic stability at surface or downhole conditions (e.g., ranging from simple observation, up to HPHT rheometer testing).

The above tests provide qualitative visual comparisons, which are difficult to document scientifically, and which may not optimize the spacer and surfactant design.

WBM

For some basic WBMs, that do not contain high levels of chlorides and do not gel on contact with cement, a spacer is not necessary and some excess cement (base design or adapted as a "scavenger") will be acceptable.

OBM

Spacer compatibility testing and water-wetting testing (for OBMs) are required initially for all spacer/mud/cement formulations; and subsequently, when the formulation and/or density of the mud, cement or spacer change significantly, or the temperature changes significantly.

Another OBM spacer testing approach uses electrical conductivity testing equipment, referred to as emulsion stability testing, reverse emulsion testing or apparent wettability testing.
The principal of operation is that OBMs are inverse emulsions of water in oil, and so have no electrical conductivity. When a water-based spacer (containing surfactants) is added, the emulsion eventually reverts, and the mixture becomes conductive – and water-wetting. The equipment measures the fluid conductivity and so deduces the best spacer/surfactant formulation.

Once for each well, confirm water wetting characteristics of the spacer on a metal coupon test with a sample of field mud. There are various test procedures that involve visual observation of the effect of spacer-surfactant fluids on OBM mud films deposited on ceramic tiles, glass or steel rods or coupons. Water droplets "beading" indicates the surface is still oil-wet.

The type and concentration of surfactant(s) in the spacer is then adjusted to optimize the water-wetting characteristics. Sometimes these tests are combined with qualitative mud cleaning tests, observing the effect of the spacer/surfactant on mud film and filter cake on a porous tile or other porous material; this type of testing is not an industry standard practice, but has proved useful in confirming the suitability of a selected surfactant package when a new mud system or surfactants is being introduced.

4.2 Selecting the test temperature to be used for laboratory testing

All cement slurry properties are temperature dependent. It is critical that the temperature chosen for the test simulates the actual well bore conditions. A slurry tested at a higher temperature than the actual wellbore may fail to set for many days and is a cause of many cement plug failures.

Cement slurries are tested at the predicted BHCT which is determined from the BHST. To predict the appropriate BHCT, determine BHST at each casing setting point from existing SPU data or a linear gradient from surface/seabed to the available temperature datum (usually reservoir).

Note: Wells penetrating large salt bodies will not exhibit a liner gradient above salt; in salt and below salt gradients can vary significantly.

For Deep Water, HPHT, Artic wells and where measured depth > twice the true vertical depth determine the BHCT by a temperature simulation using a BP approved model (e.g. WellCat / Cemcade / Welltemp). Use test pressures reflecting bottom-hole pressures at depth of interest and not those in API/ISO Schedules.

Note: For other wells, API BHCT equations are acceptable.

Compressive strengths are not normally determined at BHCT; API/ISO Schedules 1sg to 12sg heat slurry from ambient to BHST in 4 hours. This is not appropriate and will result in inaccurate predictions of strength development. Where 24 hour compressive strengths are required, the following test temperatures are recommended.

a) Tail/Plug/Squeeze Slurry - ramp to BHCT in 1 hour, then from BHCT to 0.95xBHST over 12 hours.

b) Casing Lead Slurry - ramp to BHCT in 1 hour, and then hold at BHCT.

c) For liner tops, ramp to BHCT in 1 hour, and then use either BHCT or liner-top BHSTx0.95 over 8 hours, whichever is lower.

For low temperature applications (e.g. Deep Water) maintaining the laboratory test temperature at <12C (54°F) is unnecessary due to heat of hydration as cement sets. Exceptions to this are high water ratio low density slurries, or special low heat of hydration cements; in these cases, temperatures are based on thermal simulations as these evolve less heat while setting.

In Deep Water and HPHT wells where knowledge of strength development is critical, consider use of WellCat to predict the rate at which the wellbore reheats, mapping this to heat up rates during testing.

4.3 Slurry Preparation

In laboratory testing, the cement slurry is prepared in a Waring Blendor. The dry cement or dry blend material is added to the mix fluid while under shear at 4000 rpm in not more than 15 seconds if possible. Designs that cannot achieve this and take longer than 15 seconds to disperse into the mix fluid can be considered as potentially problematic in field mixing operations. After the dry material is dispersed in the mix fluid, the cement slurry is mixed at 12000 rpm for 35 seconds. This is an attempt to simulate the short high energy mixing that the cement receives in the field.

However, where batch mixing of the slurry is planned or the slurry incorporates lightweight particles, alternative mixing procedures are required. Prepare the slurry using the API procedure (or agreed alternative) and then condition in the consistometer at surface temperature for the expected duration of the batch mixing operation. Some service companies attempt to simulate the repeated shear of the cement during mixing by modifying the API procedure with intermittent high and low shear mixing.

For slurries containing fragile lightweight particles, do not use the standard API mixing procedure (involving shearing the slurry at 12000 rpm). If the service company does not have an alternative procedure, it is recommended to continue mixing the slurry at 4000 rpm for 2 min.

4.4 Thickening Time / Pump Time

The Thickening Time Test is a dynamic (stirring) test of the slurry performance in a consistometer tested at downhole temperature and pressure. The test determines how long the slurry will remain pumpable at BHP and BHCT (the Pumping Time).

Use a High Pressure High Temperature Consistometer for all Pump Time (PT) testing; a simple non-pressurized consistometer may be used for checking very shallow (<500ft) non-critical surface casing strings on land or in very shallow water.

The "viscosity" is measured in Bc and by convention in BP a slurry is pumpable until its reaches 50 Bc.

4.5 Rheology

Rheology measurements are required at surface temperature (after mixing) and cementing BHCT. Commonly field laboratories are equipped with only a 6 or 12 speed Fann 35 rotational viscometer (or equivalent) which is limited to 88°C (190°F) at atmospheric pressure.

If the BHCT is > 88°C (190°F), condition cement at BHCT and cool back to 88°C (190°F) and determine rheological properties at 88°C. Many cementing chemicals break down or perform differently at high temperature. There are few high temperature high pressure viscometers suitable for cement; for critical wells, request rheological testing at HPHT conditions which can be performed at regional support laboratories.

Where BHCT is above 88°C (190°F), test cement spacers in Fann 50/Fann 70/75 which are readily available in mud laboratories at field locations (equipment is not generally available through the cement company).

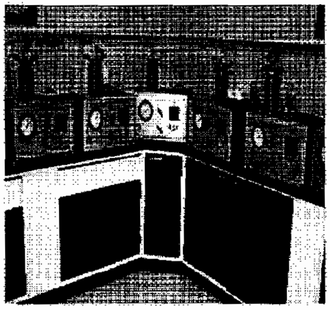
Rheological parameters are required for:

- accurate prediction of the equivalent circulating density (ECD) during cementing
- displacement modelling
- assessing mixability /pumpability of the cement
- determining gel strength development
- assessing temperature thinning as a preliminary assessment of slurry stability
- slurry QA/QC at the well site

The gel strength of the cement is also determined using the Fann 35, reporting the 10 second 10 minute gel strengths; the 10 sec gel strength is an indicator of slurry stability and the 10 minute gel strength at BHCT is required to assess the slurries thixotropic behavior.

4.6 Compressive Strength

Physical crushing of cement cubes is rarely performed and the use of the Ultrasonic Cement Analyzer (UCA) is now almost universal.



The UCA measures changes in transit time/pulse velocity as the cement develops compressive strength. Since the test is nondestructive, a continuous measurement from fluid state to solid is obtained. The UCA signal is calibrated according to algorithms built into the apparatus to relate the transit time to the equivalent cube crush strength. The laboratory personnel must select the most appropriate algorithm for the slurry type (related to density of the slurry).

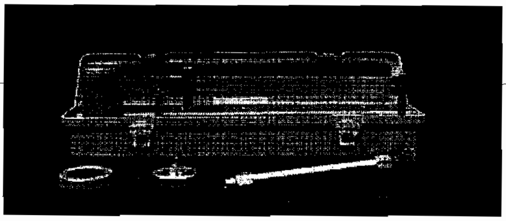
Development of some new systems that contain high loading of low density or flexible materials do not correlate well with algorithms used to correlate sonic transit time to unconfined compressive strength. If systems such as these are employed in BP wells, destructive testing should be performed. For these systems the UCA will provide the time to the point of strength development and the destructive measurement will provide a better estimate of actual UCS.

Where destructive testing is performed, it is critical that the laboratory has equipment to apply a fixed load rate to the cube to get an accurate measurement.

When determining compressive strength at BHP, pressure has been shown to impact cement hydration (setting). This is particularly important in deep water and HPHT wells to get an accurate prediction of WOC time. In these cases the UCA testing should be conducted at the appropriate BHP or as close to this pressure at the equipment allows.

4.7 Density

The laboratory is required to have a calibrated pressurized fluid balance.



Checking density of the slurry prepared confirms laboratory calculations and that the slurry has been tested at the correct density. It is also critical when slurries containing lightweight particles are used to confirm that particle attrition during mixing or at BHP does not result in densifying the slurry.

4.8 Static Gel Strength

The measurement of the gel strength development can be performed using:

- Fann 35
- Vane Rheometer
- MACS or Mini-MACS analyzer (Halliburton)
- UCA Static Gel Strength Analyser (SGSA) (Chandler)

The gel strength determined using a Fann 35 is used for displacement analysis, but is not appropriate in the assessment of gas migration or shallow water flow risk and prevention. Only the last two methods can be conducted at simulated BHP and BHCT. All 4 techniques will give different numbers for SGS.

The MACS analyzer measures the shear resistance of the (essentially static) slurry by moving a paddle through it at slow speed (rotating at 0.5 deg per min).

The most common technique used for determining the Static Gel Strength (SGS) used for assessing gas migration, is the Static Gel Strength Analyzer (SGSA). In this analyses, the pulse velocity changes before the cement has reached initial set and translates these readings into a gel strength (lb/100sqft) using internal algorithms.

Static gel strength is unrelated to thickening time measurements; its critical parameter is Transition Time (TT). This is purely related to changes occurring under static conditions and is not to be confused with concept of right angled setting behavior reported on Pump Time (PT) tests.

The two key measurements reported for gel strength are Zero Gel Time (ZGT) and TT. The ZGT is when the cement slurry loses the ability to transmit full hydrostatic pressure, normally taken as time to reach 100 lbf/100 sq ft. Transition Time is the time from the ZGT until the slurry has developed sufficient gel strength to prevent the migration of gas (normally taken as 500 lbf/100 sq ft).

These tests only indicate trends since in practice fluid loss and temperatures have a large impact on gel strength development. Completing the gel strength measurement at the temperature at the depth of interest is critical (and this is seldom at the bottom of the well).

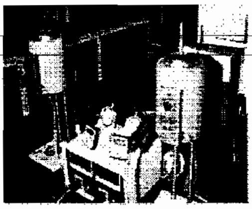
When using a SGSA the slurry has to be conditioned in a Consistometer before placement into the cell.

These tests are critical in assessing if the slurry is fit for purpose for controlling gas/fluid migration and should be completed where the slurry is required for this service.

Static gel strength measurements are important where thixotropic slurries are being used and when cement is left static above the liner running tool or around an expandable liner and hangers.

4.9 Fluid Loss

Cement fluid loss tests are performed with a 1000 psi differential pressure across a 325 mesh screen.



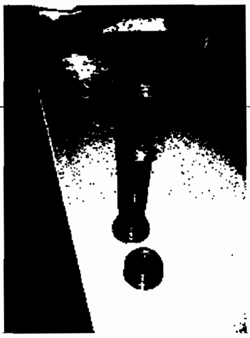
When BHCT exceeds 88°C (190°F) it is necessary to use a high pressure stirring fluid loss cell (recommended); alternatively a cell with a pressurized back-pressure chamber and condenser can be used.

The test only gives a ranking of slurries and is not truly representative of fluid loss under down hole conditions; the overbalance is not normally 1000 psi and filtration will occur through formations which have previously been exposed to drilling fluid which impacts their near wellbore permeability. There is no comparison of HPHT mud fluid loss with the values from the above test on cement and cement fluid loss is significantly higher than an OBM.

For water shut off squeezes across producing perforations, filter cake height should be assessed to determine suitability for plugging perforations.

4.10 Sedimentation Test Tube (BP Settlement Test)

The BP Settlement test assess the stability of the cement while it sets under downhole pressure and temperatures, The cement slurry is cured in a small tube (203 mm (8") x 25 mm (1") diameter), at temperature and pressure representative of well conditions.



Once set, the sample can be removed from the tube and measurements made to determine free fluid, settling and segregation. The key measurements are:

- Depth to set cement from top of cell (i.e. settlement)
- Density variation along the column

It is critical that the test is conducted according to the BP Settlement Procedure; do not use the API procedure. Appendix 2 provides detail on the cell and the test procedure to adopt.

Where lightweight and heavyweight particles are added to a slurry design, consider a dynamic settlement test. This test determines if under low shear the light or heavy particles separate from the bulk slurry due to gels being broken. The dynamic settlement test is normally conducted in a consistometer with a modified cell and lower speeds than normally pump time tests.

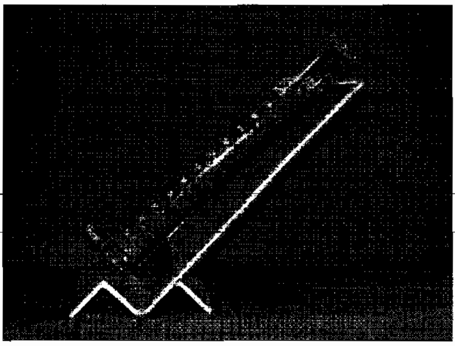
4.11 Free Fluid Test (Free Water)

Free water is a basic QC test for a slurry design; unfortunately there are many laboratory procedures for free fluid determination, all of which may give different results.

The slurry is pre-conditioned at wellbore temperature and pressure in a consistometer for at least 30 minutes. However, the time that the slurry is stirred at temperature & pressure is not dictated (by API/ISO) and the duration of preconditioning affects free water results. After this pre-conditioning, the slurry is poured into a sample tube which is then left for a 2 hour test period in a vibration free area, under one or more of the following possible test conditions:

- Vertical or inclined at an angle
- Ambient temperature and pressure
- In a heating or cooling chamber/bath, at ambient pressure
- In an HPHT chamber

Deviated free water test



Most field laboratories do not have suitable pressurized chambers, so the most common procedure is to pre-condition the slurry for 30 minutes in the consistometer, and then perform an ambient temperature/pressure test. If the well is deviated, or stricter control of free fluid is desired, the test cylinder is inclined at 45 degrees during the 2hr test period. This test procedure is not representative of downhole conditions; however, it does provide basic QC and comparative results. For critical jobs (liners / hole angle> 30° / slurries using lightweight or heavy weight particles / HPHT conditions) and where temperature exceeds 250°F perform a BP Settlement Test.

5.0 Other tests

5.1 Gas Migration

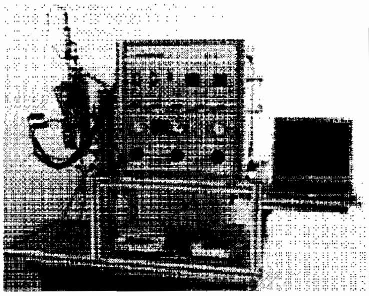
Prior to entering into this type of work, consult an EPT Subject Matter Expert (SME) to establish acceptable procedures required to determine realistic properties

Gas migration testing is complex and difficult to interpret; there is not an industry agreed testing procedure, and each company / service company region has preferred test procedures. Most tests work on the principle of assessing transmission of a gas pressure across the cement as it sets; however, there are many variables that can impact success and failure not related to slurries ability to prevent gas migration.

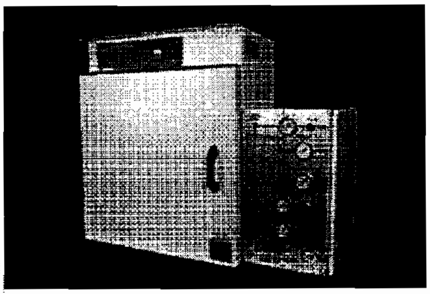
In addition to gas migration tests, Static Gel Strength, Fluid Loss & Free Fluid/Settlement testing must be performed as well to understand the broader performance of the slurry.

The most commonly used Service Company laboratory equipment is shown below. Since data is qualitative and only demonstrates merits of different slurries tested on the same equipment, care should be taken in the interpretation of the results.

Foam slurries cannot be tested in this equipment, but they may be a very good solution to a gas migration problem.



Chandler Fluids Migration Analyser (FMA)



Chandler Cement Hydration Analyser (CHA)

5.2 Mechanical Properties

Prior to entering into this type of work consult an EPT Subject Matter Expert (SME) to establish acceptable models and the procedures required to determine realistic properties

With increased concerns with regards to cement integrity, mathematical models have been introduced to predict the risk of cement failure under pressure and temperature changes that occur during drilling / completion and well operations. This has required determination of the relevant mechanical properties, the critical ones being measured are:

- Shrinkage / Expansion
- Young's Modulus
- Poisson Ratio
- Friction Angle
- Tensile Strength

Very few Service Company laboratories are set up to determine any of these properties at downhole temperatures and pressures. The repeatability of the results determined under realistic conditions can be poor.

6.0 Interpretation of laboratory results

6.1 Spacer Compatibility

Guidance for accessing spacer compatibility from mixtures of spacer and mud.

IDEAL **Compatible**	**ACCEPTABLE** **Slight Incompatibility**	**NOT RECOMMENDED** **Limited Compatibility**	**UNACCEPTABLE** **Incompatible**
No Fann reading is > the higher of the two components at the same rotational speed.	Any Fann reading is more than 25% > the higher of the two components at the same rotational speed	Any Fann reading approaching 50% > the higher of the two components at the same rotational speed.	Any Fann reading is more than 50% > the highest of the two components at the same rotational speed.
Often such ideal compatibility is not achievable.	Sometimes analysis is limited to the 100 rpm reading, this being felt representative of typical annular shear rate.	May be acceptable if only one or two mix ratios approach 50%, and it is not possible to re-design the spacer due to lack of time, laboratory facilities or alternative chemicals.	Phase separation, settling or obvious formation of gel or paste also indicates incompatibility.

Water wetting tests are normally visual, but it is recommended that digital photographs are provided to confirm acceptability of the surfactant package.

A spacer which is unstable after mixing will cause problems in surface equipment and may result in a compromised cement job; instability at temperature and pressure will also cause problems during placement and recovery of liner running strings. Spacers with negative yield points or insufficient gel structure to support barite need additional viscosities.

6.2 Thickening time tests

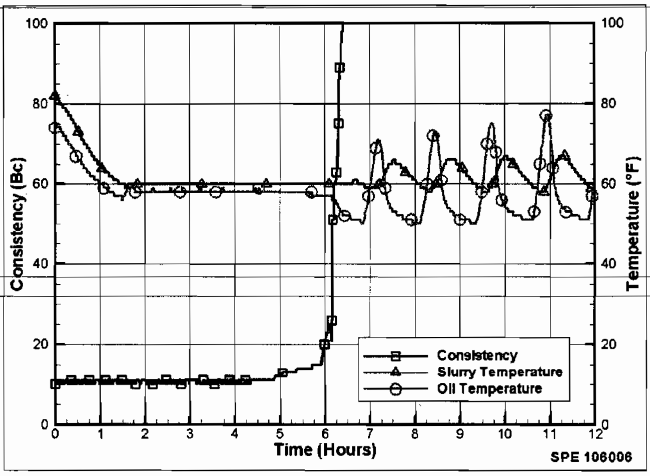
The key elements to consider when reviewing thickening time results are:

- Adequate pump time as defined by time to 50 Bc.
- Shape of the thickening time curve to assess whether setting is occurring correctly.

Request Service Company to provide the entire thickening time curve; as a minimum, review the times to 30/50/70/100 Bc.

An example of good setting behavior is shown below. In this case the time from 30-100 Bc is less than 15 minutes indicating effective, controlled retardation and rapid setting.

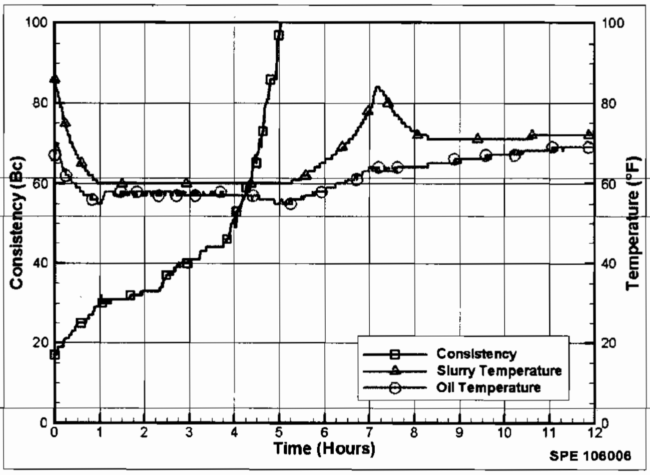
Slurry Showing Right Angle Set



- Initial Consistency is low
- Consistency doesn't change for majority of the test
- Consistency curve turns sharply (right angle) to indicate thickening time
- 70 BC is followed by heat of hydration indicating thickening time is caused by cement hydration

An example of a slurry showing unacceptable gel setting behavior is shown below; in this case the time from 30 – 100 Bc is very extended (in some cases it may not reach 100 Bc during the test). This indicates a slurry which may develop compressive strength very slowly or if the pumps are shut down during displacement it might be difficult to initiate flow again. If the time from 30Bc to 70 Bc is greater than 1 hour, it's possible the slurry is not suitable as anything other than a filler slurry (and still may carry placement risks).

Gel Setting behavior



- High initial Consistency
- Consistency continuously increases over time
- 70 BC reached with no indication of heat of hydration
- Temperature variations are caused by differences in heating a gelled plug versus liquid cement

It is also important to look at the initial "viscosity" of the slurry at the start of the test and values above 30 Bc may indicate there would be problems mixing the system and/or high pump pressures.

If the full laboratory test data is supplied, review the output to confirm that pressure and temperature did not fluctuate during the test after reaching simulated BHP and BHCT until the pump time was reached.

6.3 Rheological Properties

The Fann 600 rpm is not used for characterization of cement slurry rheology, studies have found that shear rates above 511 sec^{-1} can result in inconsistent readings and poor repeatability; higher shear rates are not representative of the shear rates. Generally plastic viscosity and yield point (according to the Bingham model) are reported. The data from ECD simulations is often curve fitted and this can cause problems when data is fitted to Power Law during one simulation and Herschel Buckley in another. Reject slurries which have very low (or even theoretical negative) yield points; it is unlikely they will be stable or fit the frictional hierarchy normally required for spacer and mud displacement.

When measuring and designing fluid rheologies for mud displacement, it is essential that all fluids (e.g. mud, spacer and cement slurries) are tested and compared at the same temperature. Typically the mud company will use only the 600 and 300 rpm readings to determine PV and YP, which normally results in a much higher YP as compared to that calculated using the 100 to 300 rpm readings.

Whilst not recommended by API/ISO document, a two point estimation of PV and YP of cement can be made using the following:

PV = 1.5 (300 rdg - 100 rdg)

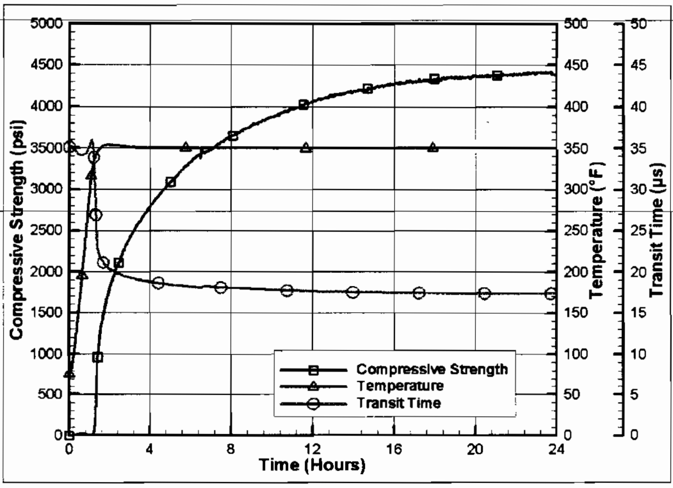
YP = 300 rdg – PV

Often the data is curve fitted to a Power Law model, but generally cement is best described by the Herschel Buckley rheological model to give the most accurate predictions of ECD and surface pressures.

6.4 Compressive Strength

The following is an example of a UCA output that provides estimates of initial set (50 psi), time to develop strength for drill out (500 psi) and adequate strength for sidetrack (>2500 psi).

Detailed UCA Chart for a Kick-Off Plug Design



- UCA = Ultrasonic Compressive Strength Analyzer
- 50 psi indicates initial set
- High 12 and 24 hour compressive strengths
- Cement hard enough such that drilling is much more likely in the surrounding formation

The results determined in a UCA are from correlation curves of pulse velocity vs. compressive strength and the results are less reliable for lightweight blended cements and cements containing weighting materials.

Because of this, UCA do not give absolute values (determined from destructive testing) and whilst the correlation is very good for 15.8 ppg (1.9 SG) slurries, the values are less accurate for lightweight and high density slurries. Ensure the correct algorithm has been used particularly when using hollow sphere lightweight particles or high density material.

Where a cement evaluation log is to be run, determine compressive strength development (change in acoustic impedance) for a 95/5 cement/spacer combination to get a more realistic value to interpretation of ultrasonic evaluation logs.

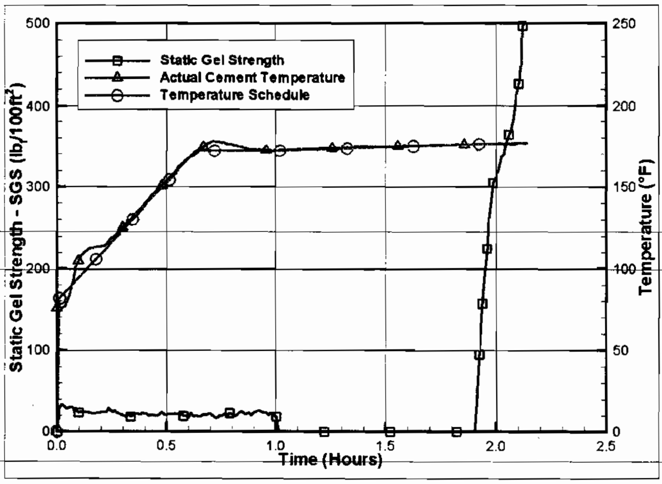
6.5 Density

If the slurry design includes lightweight particles, then request the density to be measured after the slurry has been exposed to simulated BHP and BHCT in a consistometer. If the density after exposure to pressure has increased more than 0.5 ppg (0.06 SG), the planned lightweight particles are not appropriate and should be changed out for a stronger lightweight particle (or a slurry not relying on lightweight particles should be considered)

6.6 Static Gel Strength

A typical output from the SGSA is shown below. Where the slurry has been designed to prevent shallow flow, use a slurry with Zero Gel Time (ZGT) > 30 minutes and a transition time less than 45 minutes.

Ideal Static Gel Strength (SGS) Development



- Test equipment emulates cement placement
- Static test that measures the gel of a fluid over time
- Zero Gel Time
  - Time to 100 lb/100ft^2
  - Loss of hydrostatic pressure
- 500 lb/100ft^2
  - Gel Strength Strong enough to prohibit wellbore fluid influx
- Transition Time
  - Time from 100 to 500 lb/100ft^2
  - Wellbore fluids can percolate through the column of cement

Although the guidance on ZGT and transition time limits applies to all procedures used to determine static gel strength, data from different procedures cannot be compared. SGSA tests can produce incorrect results for several reasons particularly when conducted in remote locations where the test is not routine. It is recommended that at least 2 tests are conducted to confirm behavior of the slurry where shallow flow risks are high.

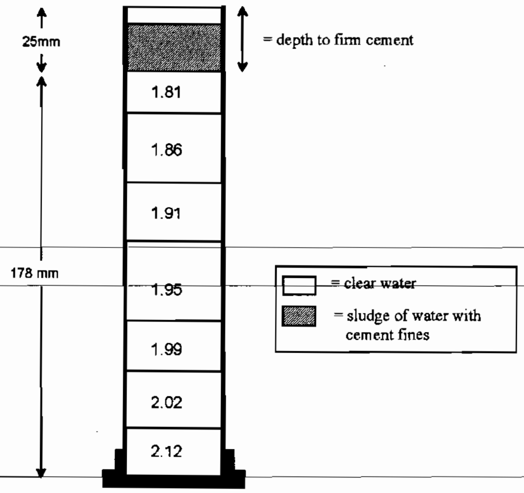
6.7 Fluid Loss

A simple 1.9 SG slurry without any fluids loss additive will have an API fluid loss of +/- 800 mls. The following table gives a guideline on the fluid loss control required for various scenarios, but does not supersede local experience.

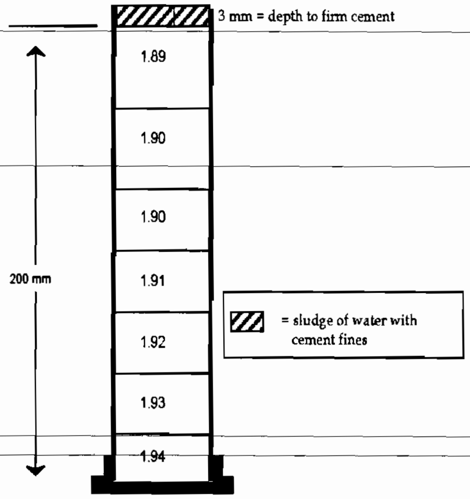
Annular Clearance (hole ID – casing OD) (inches)	**Predominant Formation**	**Discrete Permeable Zone to Isolate (Y/N)**	**Fluid Loss Guide (mls)**
> 2	Sand Shale	N N	No control No control
1.5 - 2	Sand Shale	N N	< 250 No control
1 - 1.5	Sand Shale	N N	< 150 No control
< 1	Sand Shale	N N	< 100 < 150
> 2	Sand	Y	< 150
1.5 - 2	Sand	Y	< 100
1 - 1.5	Sand	Y	< 75
< 1	Sand	Y	< 50

6.8 Settlement

The following diagram shows an expected reporting format demonstrating a slurry with *unacceptable* properties.



The following diagram shows an expected reporting format demonstrating a slurry with *acceptable* properties



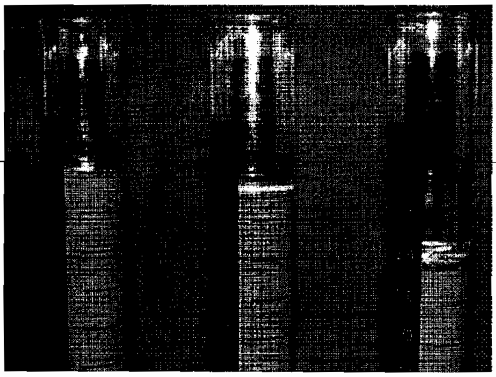
The following table provides guidance on acceptable settlement.

Hole angle (deg)	Depth to firm cement (mm)
< 45	< 5
> 45	<3

Where lightweight or high density particles are being added to the slurry, a density difference of less than 10% from top to bottom is recommended.

6.9 Free Water

The figure below shows typical results from a free water test, one slurry shows trace (essentially zero) free water, the centre result would be unacceptable for a tail slurry, but would be typical for a lead slurry. The final test shows very high unacceptable free water.



The following guidelines are for tests performed at ambient temperature and pressure, following pre-conditioning in an HPHT consistometer.

Surface pipe and non-critical string

- <1.5% (<3.75 cc)

Gas control, production strings and highly deviated wellbores (Settlement Test also required)

- Trace (< 0.5% / <1.25 cc)

7.0 Other tests

7.1 Gas Migration

Consult an EPT Subject Matter Expert (SME) for support and guidance in interpreting results of these tests.

Gas Migration control is not required just because a formation contains gas, in many cases effective cement placement and fluid loss control is all that is required to mitigate gas migration.

Where a gas migration risk assessment identifies a high level of risk of gas migration (or over pressured shallow water flow), these tests should be completed as a final assurance after slurries have been tested and optimised for all the properties required in the Basis of Design (Pump Time ,Transition Time, Fluid Loss, Settlement, etc).

The lack of reliability and inability to relate Gas Migration testing to field performance means these tests are not primary design tests, but used to confirm a slurry meeting other gas migration criteria does prevent flow while cement sets.

There is little or no comparison between results from one laboratory to another or between the various testing procedures, so only relate results performed on the same equipment at the same laboratory.

7.2 Mechanical Properties

Consult an EPT Subject Matter Expert (SME) for support and guidance in interpreting results of these tests.

7.2.1 Shrinkage/Expansion

If cement is allowed to dry it will shrink. Most measurements of shrinkage over predict cement shrinkage due to the internal development of porosity during the cement hydration reaction. Review and consult on any result reported suggesting shrinkage of over 2% since it is unlikely this is the true bulk volume shrinkage and may lead to prediction of tensile failure and use of over complicated expensive slurry designs.

7.2.2 Young's Modulus

Most of the computer models used to predict the mechanical performance of the cement when subjected to wellbore stresses, i.e. Schlumberger (CemStress), Halliburton (WellLife) and BJ

(IsoVision), are highly dependent on Young's Modulus. The Young's Modulus of the cement has been shown to reduce with increasing confining forces which means in deeper sections cement is more ductile and less likely to fail. It is recommended to use values in modelling determined under triaxial testing to obtain accurate predictions of performance of the set cement. If the initial assessment using default values indicates a cement with a lower Young's Modulus is required, a lower density conventional extended slurry will result in a significantly lower Young's Modulus. This simple low cost approach is the first approach to adopt before using more expensive slurries with flexible particles or gas added.

A lower Young's Modulus is often accompanied by reduced compressive strength and this needs to be carefully considered in respect to risk of compressive failure of the cement or extended WOC.

For oil well cements, slurry values will be between 0.5 x 10^6 psi – 1.5 x 10^6 psi; a 1.9 SG (16 ppg) cement will be about 1 x 10^6 psi. For comparison "plastics" are typically +/- 0.25 x 10^6 psi.

7.2.3 Poisson ratio

Poisson ratio also shows dependency on confining pressure; typical values are 0.12 -0.2 with lower values associated with material containing "flexible" particles. A 1.9 SG (16 ppg) cement will have a 0.15 -0.16 Poisson ratio.

7.2.4 Tensile Strength

Tensile strength for most cement is related to compressive strength; with some special additives the relation to some level can be decoupled. Typically a simple extended lead slurry will have tensile strength of 100 -200 psi and a 1.9 SG (16 ppg) cement 250 – 350 psi. These numbers can be increased to above 500 psi with more complex slurry design approaches.

The most common failure mode predicted in mechanical modelling of cement during life of well is tensile failure. The optimal value of tensile strength on the cement system is one that will prevent tensile failure of the cement sheath through out the life of the well. These target values should be determined by modelling the events that are expected to occur with the use of cement sheath modelling programs.

7.2.5 Friction Angle

This is a critical parameter in Halliburton's WellLife analysis; data shows this to have significant variability. The value cannot be zero and one should treat any value approaching zero with suspicion. Values between 5 -15° are expected. Because of data variability request test results from at least 3 separate tests at the same curing time to assess reliability of any subsequent modelling.

APPENDIX 1

Standards

Generally testing of cement slurries and spacers will be performed according to the most recent version of API (Spec 10) or ISO (10426) Standards & Specifications. Currently these are:

ISO 10426-1:2005
Petroleum and natural gas industries – Cements and materials for well cementing -- Part 1: Specification

ISO 10426-2:2003
Petroleum and natural gas industries -- Cements and materials for well cementing – Part 2: Testing of well cements

ISO 10426-2:2003/Amd 1:2005
Water-wetting capability testing

ISO 10426-3:2003
Petroleum and natural gas industries -- Cements and materials for well cementing – Part 3: Testing of deepwater well cement formulations

ISO 10426-4:2004
Petroleum and natural gas industries -- Cements and materials for well cementing – Part 4: Preparation and testing of foamed cement slurries at atmospheric pressure

ISO 10426-5:2004
Petroleum and natural gas industries -- Cements and materials for well cementing – Part 5: Determination of shrinkage and expansion of well cement formulations at atmospheric pressure

ISO 10426-6:2008
Petroleum and natural gas industries – Cements and materials for well cementing -- Part 6: Methods for determining the static gel strength of cement formulations

Cementing contractor engineers and laboratory personnel should have copies of the most recent editions and be familiar with the contents (confirm this by audit).

Note: While the above standards define the standard test procedures, local procedures can be modified and adapted to better model actual wellbore conditions and job procedures, provided this is clear to, and understood by all concerned.

APPENDIX 2

BP Cement Settling Test

INSTRUCTIONS FOR PERFORMING A SETTLING TEST

Description of Settling Tube
A complete engineering diagram of the tube is available from BP Research at Sunbury: drawing No. BPE/MF/1154.

The (reusable) tube is a cylinder with the axis vertical. Internal height is 203mm (8.00") and the internal diameter is 25mm. The tube is designed to be opened along its length to facilitate removal of the hardened core of cement. A lid should be provided to cover the mould and yet permit transmission of pressure between pressurizing medium (water) and the slurry. A height of 203mm was chosen as the maximum height which would fit conveniently in HT/HP curing cells. If it is preferred to use a long fluid loss cell to cure the sample then the tube height should be 190.5mm (7.50"). In any case, the dimensions of the tube should be clearly stated on any reports.

Method
The inside of the tube and all joints should be lightly greased. After assembly it should be tested to ensure that it is leak-tight by filling it with water. It should then be emptied and dried without disturbing the joints, either by wiping the inside gently with paper tissue or by blowing with air. A suitable antifoam / defoamer must be added to the slurry. The slurry should be prepared according to API Specification 10, Section 5. The slurry should be conditioned either 1) on a pressurised consistometer to the appropriate BHCT and pressure as for the thickening time test (do not exceed 85C if the BHCT is greater than this temperature) or 2) on an atmospheric consistometer to the appropriate BHCT at the appropriate heat-up rate. Meanwhile, the settling tube should be heated to BHCT in the curing chamber or the long fluid loss cell (do not exceed 85C if BHCT is greater than this temperature)

Once at BHCT, remove the slurry cup and the settling tube from the respective machines. Check that the inside of the settling tube is dry before proceeding. Open the slurry cup and discard any oil that may have got inside the cup. Pour the slurry into the tube until it is approximately 20mm from the top. Tap the tube to dislodge any air bubbles. Fill the tube completely and tap the tube again to remove air. Check the tube is completely filled and put the (lightly greased) lid in place. Wipe off surplus cement from the outside of the tube. Place the tube in a curing chamber (or long fluid loss cell) heated to BHCT (or to 85C if BHCT greater than this), CAREFULLY. Avoid spilling any cement. Apply 3000psi (or 1000 psi if using the long fluid loss cell). If the BHCT is greater than 85C then heat the curing cell to BHCT at 2C per minute until at BHCT. Maintain BHCT until the end of the test. Duration is normally overnight, approximately 16 hours. Cool the cell to below 90C and release the pressure slowly. Place the tube in water at room temperature for approximately 15 minutes. Do not remove the tube from water until the tube is at ambient temperature.

Measuring Settlement (refer to section 4)
Remove the lid and measure the depth from the top of the tube to the top of HARD CEMENT. Do this with a metal rod of similar dimensions to a consistometer thermocouple. Record this figure (in mm) as the "settlement". Record the nature of

the "free fluid" which is the fluid on top of the hard cement in the tube. This free fluid could be clear free water, soft sludge of cement fines etc.

Measuring density of the column

THIS TEST SHOULD PROCEED WITHOUT HESITATION SO THAT IT IS COMPLETED BEFORE THE CEMENT DRIES OUT SIGNIFICANTLY.

Remove the tube from the water, split the tube, remove the hardened cement core and wipe off any excess grease. Make marks along the core at approx. 30mm intervals. Break the core at these marks. This may be done by holding it against a rigid metal edge and striking the core opposite this contact point with a hammer. Keep the sections in order - number them if necessary. Using a top-pan balance capable of measuring to an accuracy of 0.01 gram and record the weight of each section quickly (W1).

Take a 250-400ml beaker, 2/3 full of distilled water at ambient temperature, and tare it on the balance. Suspend each section of core, in turn, from a noose of thin monofilament wire (nylon or steel) and lower it into the beaker so that the core section is completely immersed in the water. Take care the keep the suspended section away from the sides of the beaker and ensure that no air bubbles are trapped. Record the weight on the balance (W2, weight of the section in water), quickly.

$$\text{Density of core section, SG,} = \frac{\text{weight of section in air}}{\text{weight of section in water}} = \frac{(W1)}{(W2)}$$

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