Section
2

Standard Testing

This section contains instructions for performing some of the most common tests for cement slurries and includes:

- thickening time testing
- compressive strength testing
- fluid-loss testing
- rheological testing
- stability testing

Thickening Time

Procedure No.: WM-GL-HES-QM-420.010

Description

The thickening time test determines the length of time a slurry will remain pumpable under simulated well conditions. The thickening time test can simulate temperature, pressure and time. Other factors that can affect the slurry's pumpability during a job cannot be simulated exactly during a laboratory thickening time test (fluid contamination, fluid loss to formation, unforeseen temperature variations, unplanned shutdowns in pumping, etc.). Because these factors cannot be simulated, simulating known well conditions as precisely as possible is very important when determining the thickening time of the slurry to be pumped into the well.

The standard HPHT consistometer rotates the slurry cup around a paddle that is held stationary. This consistometer can be used to determine the thickening time of all slurries (cement specification testing according to *API Spec 10A/ISO 10426-1* or well simulation testing according to *API RP 10B-2/ISO 10426-2*). An alternate HPHT consistometer that is approved to determine the thickening time of well simulation testing according to *API RP 10B-2/ISO 10426-2* is one that rotates the paddle and the slurry cup is held stationary.
The Mini-MACS™ Analyzer is one of the alternate HPHT consistometers that is approved by API/ISO. The paddle stirring consistometer (alternate consistometer) is not acceptable for determining the thickening time of a cement that is being tested to see if it meets *API Spec 10A/ ISO 10426-1* specifications.

Equipment (for controlling slurry temperature)

Manual Temperature Control

If you use a manual temperature controller to perform a thickening test, help ensure that the controller can measure the slurry's temperature or a separate temperature indicator is available to measure the slurry temperature.

Note—Do not perform the thickening test according to the oil (chamber) temperature. The temperatures indicated by the slurry thermocouple and the oil (chamber) thermocouple are usually different.

Older model high-pressure, high-temperature (HPHT) consistometers have a Barber-Coleman Capacitrol (center, bottom of the instrument panel) that indicates the oil (chamber) temperature. These consistometers, for use in the thickening test, must also have a second instrument (a second Barber-Coleman, West Instrument Wheelco, or other instrument) that is not attached to the consistometer to indicate the slurry temperature.

Later model manual temperature control units that are equipped with the Honeywell Dialatrol use the Dialatrol to indicate and control the oil temperature and to indicate the temperature of the slurry. To check the slurry temperature, push the Slurry/Oil switch upward occasionally. For more information on operating the Honeywell temperature controller, refer to the instructions in consistometer manual 800.61518.

Automatic Temperature Control

New consistometers have automatic temperature control systems and many have automatic controls for pressure and other test requirements. The automatic temperature controllers should control the temperature from the slurry temperature thermocouple's indication instead of the oil thermocouple's temperature indication.

Procedure

Perform thickening time tests according to the procedures in the latest version of *API RP 10B-2/ISO 10426-2 Recommended Practice for Testing Well Cements* or specific customer requests. Use information from the well to prepare a test schedule that simulates the well conditions as precisely as possible.

API RP 10B-2/ISO 10426-2 no longer contains standard schedules of time, temperature and pressure for wells. API/ISO now provides information on calculating the test schedule and if BHCT is known it should be used. Instead of the schedule tables, currently all that is contained are tables for depth vs. BHCT for various temperature gradients. The time to temperature and pressure must be calculated from well conditions (depth, expected pump rates, casing size and densities of well-bore fluids).

When testing the thickening time of a cement to certify that it meets API/ISO qualifications, follow the procedures and conditions stated in the current API Specification 10A/ISO 10426-1 for the specific class of cement.

- For the specification test, terminate the thickening time at 100 Bearden units (B_c).
- For thickening time tests performed for a well, terminate the thickening time at 70 B_c unless otherwise specified by the customer.

Designing the Test Schedule

The *API RP 10B-2/ISO 10426-2* contains equations to calculate temperature, pressure, time to final condition, etc. to design the test schedule.

Casing and liner schedules for the same depth will have the same BHCT. However, the liner schedule will reach bottom-hole conditions in a shorter time than a corresponding casing schedule.

Squeeze and plug-back schedules for the same depth will have the same BHCT. The hesitation squeeze schedule increases to BHST at 0.2°F/min after BHCT and final squeeze pressure are reached. During this increase in temperature to BHST, the motor is cycled off for 10 minutes and on for 5 minutes for the duration of the test.

Temperature Correlation for Horizontal Wells

Although no API temperature correlation for horizontal wells exists currently, Halliburton has used the following equation since 1991:

$$T_h = T_c + [(T_f - T_c) \times (L \div 6000)]$$

Where:

T_h = bottomhole temperature at the end of the horizontal section.

T_c = calculated or measured BHCT at the vertical depth (not including the horizontal section).

T_f = BHST of the formation at the horizontal depth (final measured depth).

L = length of the horizontal section in ft (for horizontal sections less than 6,000 ft).

Note—If the length (L) is greater than or equal to 6,000 ft, assume that $T_h = T_f$.

An EXCEL software file (APIBHCT.xls), which is available by contacting the Duncan Technology Center, Zonal Isolation Products and Services, uses equations from the 1997 *API RP 10B* and the horizontal correlation contained here to calculate the BHCT for the well. Table 2.1, Page 2-8, shows an example of a calculation made with this file. Actual forms are available for downloading on HalWorld.

Table 2.1—API Bottomhole Circulating Temperature—1997 RP10B

Surface temperature	80°F
Bottomhole static temperature (BST)	°F
Temperature gradient	1.5°F/100 ft
True vertical depth (TVD) Length of horizontal section	16,000 ft 0 ft
TVD Measured depth BST Static temperature gradient	16,000 ft 16,000 ft 320°F 1.50°F/100 ft
Bottomhole circulating temperature (BCT) for:	
Casing or liner jobs	258°F (at measured depth) 258°F (at TVD)
Squeeze or plugback jobs	281°F (at measured depth) 281°F (at TVD)

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Heating Rates for Wells with a Horizontal Section

The time to temperature and pressure in a well having a horizontal section requires two different heating ramps.

When a well has a vertical portion followed by a horizontal portion, the first portion of the schedule will simulate the time required to reach the circulating temperature and pressure at the end of the vertical portion. The second portion of the schedule will then go to the final temperature and pressure at the end of the horizontal section and hold to completion. The following equation uses a known pumping rate and casing sizes to obtain the heating rate in the horizontal section:

$$T_r = (T_h - T_c) \times 1029 \times Q \div (L \times ID^2)$$

Where:

T_r = temperature ramp in °F/min in the horizontal section

T_h = bottom hole temperature at the end of the horizontal section

T_c = calculated or measured BHCT at the vertical depth (not including the horizontal section)

1029 = conversion factor

Q = flow rate in bbl/min

L = length of the horizontal section in ft (for horizontal sections less than 6,000 ft)

D = inside diameter (in.) of the casing

Note—The test pressure at the end of the horizontal section is the same as the pressure at the equivalent vertical depth.

Data Interpretation

Testing results will vary. For example, thickening time tests performed during 13 cooperative test series in the past on either a Class G or Class H cement with only cement and water under the best of conditions in multiple laboratories resulted in an average thickening time of 1 hour and 42 minutes, a standard deviation of 8.34 minutes and 2Vc (variability coefficient) of 16.17%. These 13 test series varied from average thickening times of 1 hour and 19 minutes to 1 hour and 51 minutes, standard deviations from 5.25 minutes to 13.82 minutes and $2V_c$ from 10.88% to 20.16%.

For longer pumping times, the variations normally increase, even under the best testing conditions.

Examples of multiple testing of a slurry containing only cement, SSA-1™ additive, and retarder with an average thickening time of 4 hours, have a standard deviation of 35 minutes and 2Vc of 6.31%.

Variations in the procedures, the involvement of numerous people and laboratories, and the complexity of the slurry compositions can considerably increase standard deviations and 2Vc values. When one person performs all the tests in a single laboratory on a single consistometer, variations are normally reduced.

To keep testing variations to a minimum, do the following:

- Keep the testing equipment in good condition and accurately calibrated.
- Perform tests according to exacting procedures.
- Keep the test conditions within acceptable limits (API/ISO or customer-specified tolerances).
- Minimize air entrainment in the slurry poured into the slurry cup to minimize oil contamination.
- Keep clean oil in consistometer.
- Use same materials for all tests and especially when comparing tests between labs.
- Weigh materials within accuracy specified by API/ISO or better.
- When using liquid additives, weigh them as described in the Slurry Preparation section of GLBP (Procedure 413.020) and the current *API RP 10B-2/ISO 10426-2*. Do not measure amounts by volumes.

Special Notes

1. It is recommended all HPHT consistometers contain two (2) thermocouples. One should measure the temperature of the slurry and the other should measure the temperature of the heat medium surrounding the slurry cup. For the MACS™ and Mini-MACS™ Analyzers, the second thermocouple should measure the temperature of the test chamber. If a consistometer is to be purchased that does not have the second thermocouple, the manufacturer should be requested to supply the second thermocouple and both temperatures should be monitored and recorded by the data acquisition system on the consistometer.

   a. In many cases, valuable information can be indicated by the two thermocouples that will not be noticed if the system only contains and records the slurry temperature. When the cement hydrates, heat will be generated by the heat of hydration of the slurry. If the temperature controller is working properly and the heat generated is slight, the slurry temperature may not change since the temperature control system will decrease the power to the heating element to lower the temperature of the heating medium. If a thermocouple is in the heating medium, the heat of hydration can normally be seen by a decrease in the temperature of the heating medium.

2. For the HPHT consistometer, the thermocouple that measures the temperature of the oil surrounding the slurry cup; it should protrude into the chamber enough the tip is very close to the outside of the slurry cup's sleeve. Many of these thermocouples will be too long to leave it straight and will need to be bent so the tip should be very close to the outside of the slurry cup's sleeve; but does not touch the side of the slurry cup's sleeve, the heating element or the inside wall of the test chamber.

   a. Long thermocouples that have the tip close to the slurry cup's sleeve will indicate a temperature very close to the slurry temperature after the final conditions are reached. It is normally within about 5°F of the slurry temperature indication and possibly slightly higher than the slurry temperature indication.

   b. A thermocouple that is too short will indicate a temperature lower than the slurry temperature and during the first portion of the schedule and heating ramp; it is not unusual for the chamber thermocouple to indicate as much as 50°F less than the slurry temperature. As the test runs for longer times, the chamber thermocouple indication will become closer to that of the slurry thermocouple, but normally will not get closer than 15°F less than the slurry temperature indication.

3. All standard thickening time tests should be performed by controlling the temperature from the slurry thermocouple. However when performing tests where the motor is turned off and on, this can result in poor temperature control with severe slurry temperature oscillations during the motor off cycle.

   a. For tests that require the motor to be turned off for a period of time or cycled off and on, the temperature control is often changed from the slurry thermocouple to the chamber thermocouple. This will provide much better temperature control for the test.

   i. To control from the chamber thermocouple, it is necessary that the chamber temperature track close to the slurry temperature during the test (long chamber thermocouple necessary as stated earlier).

ii. If test data is obtained when the temperature control is from the chamber thermocouple, it should be specified on the report and information given to the customer.

iii. It may be necessary to adjust the scheduled temperature to ensure the slurry temperature is at the test temperature when control is from the chamber thermocouple. When controlling from the chamber thermocouple, the slurry temperature will be indicated as the chamber temperature since the data acquisition system can not tell which thermocouple is being used for control.

iv. When a heat of hydration is noticed for a test controlled from the chamber thermocouple, the chamber temperature indications (actually slurry temperature with control switched) will show an increase in temperature and the slurry temperature indication (actually chamber temperature) will be constant and unchanged.

Compressive Strength Testing

Procedure No.: WM-GL-HES-QM-420.020

Description

The compressive strength test determines the strength of a cement composition under temperature conditions simulating well conditions. The maximum pressure used for curing is normally 3,000 psi (API/ISO), unless otherwise requested by a customer. In early API cooperative testing, it was found that 3,000 psi curing pressure was an optimum pressure and strength increased above this curing pressure was minimal. Recently, in some more complicated slurries, curing at a pressure above 3,000 psi (simulating down-hole conditions) has shown a considerable affect on the strength development. In some of these cases, there was no strength development for either a crush or UCA strength at 3,000 psi, but when the curing pressure was increased to the actual down-hole well pressure there was good strength development for the same curing time. If no strength development is seen in a reasonable time, it may be advantageous to retest at a curing pressure that simulates the actual well pressure if high pressure curing vessels are available. Testing pressure must not exceed the rating of the curing vessel. The curing pressure should be noted in the reported data.

Procedure

Preparing a Test Schedule

Perform compressive strength tests according to procedures in the latest version of *API Recommended Practice for Testing Well Cements (RP10B-2/ISO 10426-2), Section 7,* or specific customer requests. A two-ramp schedule should always be used for testing compressive strength specimens with crush or UCA testing.

Use information from the well to prepare a test schedule that simulates the well conditions as precisely as possible. You can perform compressive strength tests using conditions from various locations in the well. Normally, the strength at the bottom of the cement column is all that is required, but occasionally, the strength at the top of the cement column or at some other location in the well is needed.

If you cannot obtain all the required information from the well, use the standard API schedule that simulates the anticipated well conditions most accurately. Specify any procedures that deviate from the recommended API procedures when reporting the data.

If there is no API schedule that accurately simulates the well being tested, prepare a test schedule as follows:

1. Increase the temperature to the BHCT at the time used to reach the BHCT for the thickening time test.
2. Increase the temperature to the BHST at the end of four hours after the test was started.

Figure 2.16, on Page 2-25 shows an example of how the temperature should be increased for curing strength specimens when the thickening time schedule reaches 135°F BHCT in 30 min and the BHST for the well is 195°F.

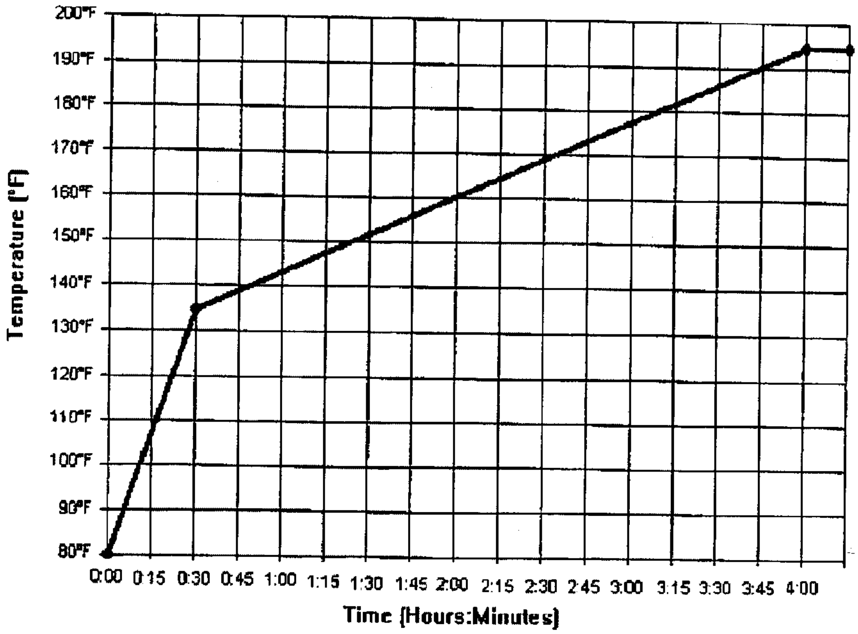

Figure 2.16—Compressive strength temperature schedule example

Performing a Compressive Strength Test

When testing the compressive strength of a cement to certify that it meets API specification, use the procedures and conditions stated in the current *API Specification 10A* for the specific class of cement.

Compressive strength (psi) can be determined by crushing a slurry sample that has been cured in a mold ("Crush Strength Testing," Procedure No. 420.030, Page 2-27) or by analyzing a slurry that has been cured in a UCA mold ("Sonic Strength Testing," Procedure No. 420.040, Page 2-33).

Note—API recommends the use of three cubes for compressive-strength tests; however, if you do not have the necessary molds or equipment to prepare three cubes, two cubes are sufficient for evaluation.

Data Interpretation

Testing results will vary. For example, from 13 cooperative test series performed on either Class G or Class H cement and cured for 8 hour compressive strength crush tests at 100°F for cement and water only, the average strength was approximately 700 psi, standard deviation 183 psi, and 2Vc (variability coefficient) 52%.

In one of these test series, as the strength increased (8 hours at 140°F or 24 hours at 100°F), the 2Vc decreased.

Testing Areas	8 hour at 100°F	24 hour at 100°F	8 hour at 140°F
Average Strength, psi	941	2451	1848
Standard Deviation, psi	332	607	454
2Vc, %	70.54	50.24	49.12

In previous cooperative test series when the UCA analyzer is used, the standard deviation and 2Vc was considerably greater when the strength is approximately 1,000 psi and slightly less when the strength is approximately 3,000 psi than for the crush strength testing.

In a special test series comparing 3,000 psi curing pressure with 15,000 psi curing pressure, crush strength tests were performed at 12, 24, and 72 hours. The average compressive strengths increased as the curing time increased while the 2Vc decreased for both curing pressures. Also, the 2Vc was less for the 15,000 psi curing pressure than for the 3,000 psi curing pressure. The strengths ranged from about 3,600 psi to 7,700 psi and the 2Vc from 25.6% to 17.4% respectively. Participation in this test series was from three to eight labs because of limited equipment available for the high pressure testing and volunteering labs.

Variations in the procedures, the involvement of numerous people and laboratories, and the presence of many additives in the slurry can increase variations in test results considerably. When one person performs all the tests in a single laboratory and with a single curing chamber or bath, the variations are usually reduced.To keep testing variations to a minimum, do the following:

- Keep the testing equipment in good condition and accurately calibrated.
- Perform tests according to exacting procedures.
- Keep the test conditions within acceptable limits (API/ISO or customer specified tolerances).
- Release pressure slowly to minimize damage from sudden decompression of the specimen, this is especially important for pressure cured foam slurries and slurries containing Super CBL.
- When the slurry is preconditioned in a HPHT consistometer, use procedures in the current *API RP 10B-2/ISO 10426-2* to minimize contamination of the slurry with pressurization oil from the consistometer.

Sonic Strength Testing

Procedure No.: WM-GL-HES-QM-420.040

Description

The sonic strength (UCA analyzer) test is a nondestructive test performed on a slurry to estimate its strength. Correlations have been developed to approximate the compressive strength of a cementing composition based on the time required for the ultrasonic signal to pass through the cement as it sets. Sonic strength and crush strength indications can vary considerably, depending on the temperature of the test, slurry composition, etc., and in most cases, the sonic strength indication will be lower than the crush strength. In some cases, the sonic strength may be as little as 50% of the crush strength.

The sonic strength test is performed according to the procedures outlined in the *API RP 10B-2/ISO10426-2*. The temperature and pressure schedule and the preconditioning options are the same as for the crush strength test. A two-ramp schedule should always be used for testing compressive strength specimens with crush or UCA testing. For a temperature schedule example, see Figure 2.16, Page 2-25.

Procedure

Perform a sonic strength (UCA analyzer) test as follows:

1. Place a slurry level gauge on top of the open UCA analyzer cell.
2. Pour slurry into the cell between the "wet" and "dry" levels marked on the gauge.
3. Pour water over the top of the slurry until the volume reaches the "Fill water to this level" marker.
4. Screw the lid into the cell. Some water should be expelled through the water connection.
5. Clean the transducer at the bottom of the chamber.
6. Grease the top of the transducer.
7. Place the cell into the chamber.
8. Connect the pressure line.
9. Connect the thermocouple.
10. Connect the transducer cable.

Preparing the Temperature/Pressure Controller

The temperature and pressure schedule used for UCA testing will be the same as would be used for crush strength curing.

For good transmission of the ultrasonic signal through the cement slurry, most UCA units require a minimum pressure of approximately 500 psi.

In many cases, the normal curing pressure is 3,000 psi. This optimum pressure recommendation came from early API cooperative testing as discussed in 420.020 (Compressive Strength

Testing). However, there may be instances where curing at higher pressures can enhance the strength development of the cement slurry.

It has also been observed in many instances where curing slurries containing Super CBL that the ultrasonic signal has problems passing through the slurry after the Super CBL reacts and generates gas inside the slurry. By increasing the pressure to 8,000 psi or greater (at least a minimum pressure of 8,000 psi or the actual bottom hole pressure for the well if it is less than 8,000 psi) has provided good ultrasonic signals and better indications of strength than when cured at 3,000 psi. It is also recommended the fiberglass sleeve be used in the UCA cell when a slurry containing Super CBL is being tested. The use of the fiberglass sleeve provides space around the outside of the sleeve for the slurry to expand into when the Super CBL reacts. The fiberglass sleeve allows the set cement to be pushed from the sleeve after a test and the ends surfaced so a crush strength can be determined on the specimen.

It is important that the slurry being tested in a UCA be a stable slurry with minimal free fluid and settling. Free fluid and/or settling may allow the top surface of the cement to not make contact with the bottom of the top cover. Without a good contact, the signal can be affected and cause problems obtaining a good signal for the strength correlation.

For strength testing with the UCA, there are 3 strength correlations for differences in slurry composition. The proper strength correlation should be selected for the slurry being tested. The correlations are; 1) for all slurries with a slurry density less than 14.0 lb/gal, 2) all slurries that are 14.0 lb/gal or heavier except for those containing metallic weighting materials, and 3) all slurries (regardless of density) if they contain metallic weighting materials.

Shutdown Procedures

Shutting Down the Temperature Controller

To shutdown the temperature controller, perform the following:

1. Stop the temperature control program.
2. Turn the HEAT switch off (if equipped with a switch).
3. Inspect the area for leaks and proper working conditions, and report any maintenance needed.
4. Check the temperature of the unit, and perform one of the following:

- If the temperature is greater than 120°F, open the cooling valve and allow the unit to cool. Ensure that the pressure drops, also. Close the valve before moving on to the next step.
- If the temperature is less than 120°F, proceed to the next step.

5. Turn the POWER switch off.
6. Close the chamber pressure supply valve.
7. Open the chamber vent valve, and perform one of the following:

- If the pressure drops, the high-pressure lines are not plugged. Keep the valve open briefly to flush the line from the supply through the vent valve to the drain; then close the valve.
- If the pressure does not drop (vent to drain), the high-pressure line is probably plugged. Schedule the unit for repairs.

8. Wrap a cloth around the high-pressure line connected to the top of the UCA analyzer autoclave cell and disconnect the high pressure line from the pressure vessel.
9. Wipe up spills or drips and clean the connector ends.
10. Close the chamber vent valve.
11. Place a metal or plastic cup under the disconnected high-pressure line, or place a cloth around its open end to collect the flush water.
12. Open the chamber pressure supply valve briefly to flush water through the disconnected high-pressure line to remove any residue in the line.
13. Close the chamber pressure supply valve.
14. Ensure the following settings on the autoclave unit:

- The power is *Off*.
- The chamber vent valve is closed.
- The chamber pressure supply valve is closed.
- The cooling valve is closed.

15. Clean and wipe all surfaces.

Rheological Testing with Bob and Sleeve

Procedure No.: WM-GL-HES-QM-420.060

Description

The rheology test determines the apparent flow properties (plastic viscosity, yield point, frictional properties, gel strength, etc.) of a cement slurry, using a rotational viscometer such as the FANN (6- or 12-speed), Chandler 12-speed or OFI 10-speed instruments.

Equipment

Item	Quantity
Rotational viscometer	1
Heated sample cup	1
Thermometer	2
Stop watch/timer	1

Procedure

Use the rotational viscometer to determine the viscosity indications and the gel strengths (10 sec and 10 min) according to the procedures specified in the latest version of *API RP 10B-2/ ISO 10426-2*, Recommended Practice for Testing Well Cements, unless the customer requests other procedures.

The API/ISO procedures are to precondition the slurry in an atmospheric or pressure consistometer by bringing the temperature from ambient to BHCT using the appropriate thickening time schedule. To evaluate if the slurry is sensitive to thermal shock, the preconditioning may be performed by preheating an atmospheric consistometer to the BHCT (not to exceed 190°F). When the temperature is above ambient temperature, use the heated sample cup to determine the viscosity indications on the viscometer (as specified by API/ISO).

Report any procedures used that deviate from the recommended API procedures.

Warning—Do not take a viscosity measurement at 600 rpm. With some slurries, taking a 600 rpm reading can have a centrifuging effect on the slurry, causing it to separate and settle. Take the 600 rpm reading only if requested by the customer, or after taking the viscosity readings at the other stirring speeds.

Data Interpretation

Testing results will vary. For example, rheological viscosities on a cement slurry with no additives (cement and water only) tested at an average of approximately 120 cp at 300 rpm has a standard deviation of approximately 20 cp and a $2V_c$ (variability coefficient) of approximately 30%. For the same slurry tested at average of approximately 80 cp at 100 rpm, the standard deviation is approximately 17 cp and the $2V_c$ is approximately 41%.

Variations in the procedures, the involvement of numerous people and laboratories, and the presence of many additives in the slurry can increase variations in test results by a considerable margin. When one person performs the test on one instrument, the variation usually decreases.

To help keep testing variations to a minimum, do the following:

- Keep the testing equipment in good condition and accurately calibrated.
- Perform tests according to exacting procedures.
- Keep the test conditions within acceptable limits (API or customer-specified tolerances).
- Minimize the oil contamination in slurries preconditioned in a HPHT consistometer.

Static Gel Strength Testing

Procedure No.: WM-GL-HES-QM-434.100

Description

The static gel strength (SGS) test determines the gel strength development characteristics of a static fluid under temperature and pressure conditions.

A static fluid with an SGS value less than 100 lb/100 ft^2 is considered to be in a relatively fluid state and will transfer hydrostatic pressure.

"Zero Gel" Time

The length of time from the point at which the fluid goes static until the SGS reaches 100 lb/ 100 ft^2 is referred to as the "zero gel" time. When the SGS value reaches 500 lb/100 ft^2, the fluid no longer transfers hydrostatic pressure from the fluid (or the fluid above it).

Important—When lead and tail slurries are to be used for the job, the lead slurry must have a longer Zero Gel Time than the tail slurry. A lead slurry with a longer Zero Gel Time than the tail slurry will provide hydrostatic pressure from the lead slurry and any fluids above to the tail slurry to the tail slurry until the tail slurry goes through its Transition Time. If the lead slurry has a shorter Zero Gel Time, hydrostatic pressure from fluids above the tail slurry can be decreased and allow gas to migrate through it.

"Transition" Time

The time required for the fluid's SGS value to increase from 100 lb/100 ft^2 to 500 lb/100 ft^2 is referred to as the "transition" time.

To control gas migration, the "zero gel" time can be long, but the "transition" time must be as short as possible (preferably, less than 20 to 30 minutes).

Procedure

The current *API RP 10B-6/ISO 10426-6* contains testing procedures for determining the SGS of cement slurries with three (3) instruments; 1) the stirring type apparatus (includes Mini-MACS™, MACS™ analyzer and Thixotropic Retrofit for the HPHT consistometer), the ultrasonic apparatus (Chandler SGSA) and the intermittent stirring apparatus (Vane rheometer).

See the link below for additional Mini-MACS analyzer information.

http://halworld.corp.halliburton.com/internal/PS/cem/contents/Technical_Documents_and_Materials/TECH/MM/MiniMACS_script.pdf

See Procedure 434.102 Chandler SGS Analyzer for additional information on how to conduct static get strength tests on the Chandler SG-SA.

Chandler SGS Analyzer

Procedure No.: WM-GL-HES-QM-434.102

Description

The Chandler SGSA (Static Gel Strength Analyzer) is an ultrasonic analyzer that provides dual functionality in that it displays both static gel strength and strength analysis from a single sample.

Static gel strength (SGS) is one of the critical measurements required to evaluate the potential for fluid inflow migration problems of cement slurry. The Chandler SGSA is designed to construct the algorithms required to transform the acoustic waveform transmitted through the cement into a quantification of static gel strength. These algorithms are applicable to a wide range of cement slurry densities and compositions including light weight, heavy weight and even latex slurries. Currently there is no correlation between the SGS obtained from the SGSA and the Mini-MACS analyzer; and, caution should be taken when using this unit for gas migration prevention purposes. At this time, there is not a specific recommended transition time for SGSA test results, but it is suggested the same guidelines are used as for the Mini-MACS analyzer. When reporting the zero gel time (ZGT) and transition time (TT) obtained with the SGSA, be sure to report that the data was obtained using the SGSA.

The sonic strength (UCA) test is performed on a slurry to estimate its strength. Correlations have been developed to approximate the compressive strength of a cementing composition based on the time required for the ultrasonic signal to pass through the cement as it sets. Sonic strength and crush strength indications can vary considerably depending on the temperature of the test, slurry composition, etc., and in most cases, the sonic strength indication will be lower than the crush strength. In some cases, the sonic strength may be as little as 50% of the crush strength. Strengths obtained from this unit should be reported as "sonic strength".

Equipment

- HPHT consistometer
- Atmospheric consistometer
- Chandler SGSA analyzer

Preheating the Cell

1. Before testing, preheat the temperature level by placing an SGSA cell that is filled with water into the chamber and connect the thermocouple cable.

Note—Be careful not to crimp the bottom transducer cable when removing the cell from the chamber or placing the cell into the machine. The cell can not be set down on a flat surface because of potential damage to the transducer.

2. Adjust the Eurotherm temperature controller using the following directions. [The PAGE button is on the lower left, the SCROLL button is second from the left, and the?and ? buttons are on the lower right.]

   a. Press PAGE until you get to the to the "ProG List" screen.

b. Press the SCROLL button to display SeG.n then press SCROLL one more time until you get to "type step."

c. Press SCROLL to display "tGt" and adjust it ?or ?to the starting temperature.

d. Press ?until "End" displays in the middle of the display.

3. Start controller by pressing and holding the "RUN" button until RUN lights up.
4. Turn the heater switch to the ON position.

Testing Procedure

1. Prepare the cement slurry according to standard API/ISO procedures found in the current *Recommended Practice for Testing Well Cements (API RP 10B-2/ISO 10426-2).*
2. Precondition the slurry according to the appropriate method described in the current *API RP 10B-2/ISO 10426-2* when SGS information is not required, or precondition the slurry according to the current *API RP 10B-6/ISO 10426-6 (Method for determining the static gel strength of cement formulations)* when the test is mainly for SGS determination.
3. Pour out the water from the SGSA cell, and lightly dry the inside of the cell prior to filling it with slurry.

Note—Be careful not to crimp the bottom transducer cable when removing the cell from the chamber or placing the cell into the machine. The cell can not set on a flat surface due to potential damage to the transducer.

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4. Prepare and lightly grease the cement contact areas of the SGSA cell to make removal of cement less difficult after test is complete.
5. Place the cell in a vise to hold it while pouring the cement slurry into it. This will minimize crimping damage to the transducer.
6. Place a slurry level gauge on top of the open SGSA cell.
7. Pour pre-conditioned slurry into the cell so it is up to the "Dry" level marking on the gauge.
8. Pour water over the top of the slurry until the volume reaches the "Fill water to this level" marker.
9. Screw the lid on to the cell. Some water should be expelled through the water connection.
10. Place the cell into the chamber. Be careful to guide the transducer into the channel facing the front of the machine.
11. Connect the transducer cable to the machine.
12. Connect the pressure line.
13. Connect the thermocouple.

Preparing the Controller

1. Turn on pump water switch
2. Turn on pump switch.

3. Adjust the pump pressure valve (Black) to start the pressurizing the cell.
4. Adjust the relief valve (Blue) to maintain the desired pressure for the cell.

NOTE—Pump pressure valve (Black) and relief valve (Blue) will need to be adjusted during the test to fine tune the desired pressure on the cell.

5. Use the Eurotherm temperature controller to program the test schedule by first pressing PAGE until you get to the to the "ProG List" screen.

Notes—
When the ultrasonic cement analyzer runs a test, it progresses through a sequence of user-specified pressures and temperatures that are planned to occur at specific times during the test. This sequence of parameters makes up the schedule of the test. The points at which one or more of the parameters change are called setpoints.

The temperature schedule used for strength testing is slightly different than for SGS testing. Although the SGSA provides dual functionality, the schedule information for the test should depend on whether you are testing the strength or SGS.

The strength test normally goes to BHCT and then BHST, while the SGS test goes to the circulating temperature at the zone of interest (BHCT or possibly less) and then to the static temperature at the zone of interest (BHST or possibly less).

When the primary testing purpose is strength, use a schedule following *API RP 10B-2/ISO 10426-2*. When the main intent is SGS determination, use a schedule following *API RP 10B-6/ISO 10426-6.*

6. Next, press the SCROLL button to display "SeG.n" and adjust to "SeG.n" of "1".
7. Then press SCROLL one more time until you get to "type ."
8. Press SCROLL to display "tGt" and adjust it to the starting temperature using the ?or ? buttons.
9. Press SCROLL to display "SeGn" and adjust to "SeG.n" "2" using ?or ?.
10. Press SCROLL to "Type rmp.t."
11. Press SCROLL to "tGt" and adjust it to the testing temperature using ?or ?
12. Press SCROLL to display "dur" and enter time to temperature, using ?or ?
13. If you are using only one ramp, press ?until "End" displays in the middle of the display. When using multiple ramps, press ?until "dwell" displays in the middle of the screen. Then repeat sSeps 8-12.
14. Start controller by pressing and holding the "RUN" button until RUN lights up.
15. Turn the heater switch to the ON position.

Preparing the Computer to Record the Test

1. Select SGSA analyzer from the screen (if there is more than one SGSA, select the one your test is on).

2. Look to see all sensors have green lights.
3. Press Start Test.
4. Enter file name for test and save.
5. Fill in any information and select ok.

SGS Testing

1. Record the elapsed time from the first application of pressure to the time the circulating temperature at the zone of interest is reached.
2. Record the SGS value when circulating temperature at the zone of interest is reached.
3. Record the time to 100 lb/100 ft^2, 200 lb/100 ft^2, 300 lb/100 ft^2, 400 lb/100 ft^2, and 500 lb/100 ft^2.
4. The ZGT will be the time to 100 lb/100 ft^2 and the TT will be the time from when 100 lb/100 ft^2 is reached until 500 lb/100 ft^2 is reached.

Shutdown

When the test is complete, the job must be ended, either manually or automatically.

On the Computer

1. Select "Test" from top tool bar.
2. Select "stop test" and a window will appear that says "Are you sure you want to stop this test?"
3. Make sure that you are stopping the correct test and select "yes."

On the Eurotherm Controller

1. Stop the controller by pressing and holding the run button on the face of the controller until the Run light is no longer on.
2. Flip the heater control switch to the off position.
3. Turn on the cooling water.
4. After the test cell has cooled to a safe temperature for removal, switch off "pump water" and flip the "water" switch to the off position.
5. Slowly open the pressure relief valve.

NOTE— If possible, make sure that the cement is set hard before opening this valve to prevent slurry from entering the high pressure lines of the SGSA.

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6. Readjust the (black) pump pressure valve and (blue) pressure relief valve to zero or counter clockwise to their starting points.
7. Disconnect the thermocouple, transducer and high pressure cable line from the cell.
8. Remove the cell from SGSA housing and clean the cell.

Cleanup

Post-test cleanup is an important part of completing a successful test and will extend the life of the UCA System. Use the following procedure to clean the analyzer:

1. Place the test cell in a vise, bottom down, with only the flattened sides of the test cell in contact with the jaws of the vise.
2. Using the handles, unscrew and remove the lid of the test cell.
3. Release the vice and lift the cell to pour the water out.
4. Return the cell to the vise, and clamp it inverted so that the bottom of the cell can be removed from the cell.
5. Push the hardened cement sample out of the cell.
6. Rinse all pieces with water and wipe clean.
7. Check the O-rings and verify that they are in good condition; if they are not, replace them.
8. Apply a film of high-temperature grease to the inside of the lid and the base up to the O-rings, and to the O-ring surface.
9. Place the test-cell body in a vise with the bottom of the cell up.

Note—Ensure that the test cell is inverted. The inside of the test-cell body is tapered from the bottom to the top, so that the bottom has a greater inner diameter than the top. The top of the test-cell body is labeled "top;" if this marking is obscured, compare the inner diameters of the ends of the cell to determine which is which.

Important—Be certain to orient the test-cell body so that only the flattened sides of the body are in contact with the vise. This placement will help prevent damage to the test-cell body.

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10. Screw on the bottom cover of the test cell.
11. Turn the cell topside up and place it into the vise. Again, orient the test cell so that only the flattened sides of the body come into contact with the vise. (This will prevent the transducer from being crimped.)
12. Screw the lid onto the cell but do not tighten the lid. This will allow the cell to be lifted by using the handles without making it difficult to open for the next person to perform a test with this instrument.