where the $Re_{BP,h}$ and He_h for slot flow are defined as:

$$Re_{BP,h} = \frac{v\rho\left(D_h - D_o\right)}{\mu_p} \tag{105}$$

and

$$He_h = \frac{\tau_o \rho\left(D_h - D_o\right)^2}{\mu_p^2} \tag{106}$$

where

Re_{BP} is the Reynolds number of a Bingham Plastic fluid;

v is the fluid mean velocity, expressed in metres per second;

ρ is the density, expressed in kilograms per cubic metres;

d_a is the inner diameter of the annulus, expressed in metres;

D_a is the outer diameter of the annulus, expressed in metres.

μ_p is the plastic viscosity of a Bingham Plastic fluid, expressed in pascal seconds;

He is the Hedstrom number;

τ_o is the yield stress of a Bingham Plastic fluid, expressed in pascals.

In Equation (101), friction factor of a Bingham Plastic fluid flowing through a slot, if the Reynolds and Hedstrom numbers are expressed in terms of hydraulic diameters, then the equation can be written as:

$$f = 16\left(\frac{1{,}5}{Re_{BP,h}} + \frac{(9/8)He_h}{6Re_{BP,h}^2}\right) \tag{107}$$

which can be simplified to

$$f = 24\left(\frac{1}{Re_{BP,h}} + \frac{He_h}{8Re_{BP,h}^2}\right) \tag{108}$$

which is the same as Equation (104).

Hence Equations (100) to (103) recommended here for laminar flow of a Bingham Plastic fluid can be obtained from analytically derived exact equations.

In turbulent flow, whatever the flow geometry is, the friction factor can be calculated from the following equation:

$$f = A\left(Re_{BP}\right)^{-B} \tag{109}$$

where

f is the friction factor;

Re_{BP} is the Reynolds number of a Bingham Plastic fluid.

This is a preview. Click here to purchase the full publication.
— All rights reserved

The constants A and B are given below.

He	*A*	*B*
$\leqslant 0{,}75 \times 10^5$	0,20 656	0,3 780
$0{,}75 \times 10^5 < \text{He} \leqslant 1{,}575 \times 10^5$	0,26 365	0,38 931
$>1{,}575 \times 10^5$	0,20 521	0,35 579

In transitional flow, a log-log approximation is performed between $Re = Re_{\text{BP1}}$ and $Re = Re_{\text{BP2}}$.

13.4.2 Examples of calculations

13.4.2.1 Example 1

What is the critical flow rate for turbulent flow, in metres per second, for a Bingham Plastic fluid with a density of 1 560 kg/m^3, rotational viscometer plastic viscosity μ_p of 6×10^{-3} Pa·s and rotational viscometer yield point τ_o of 4 Pa, flowing in a pipe having inner diameter d of 0,059 m?

The rotational viscometer's PV and YP are modified as:

$$\mu_\text{p} = 1 \times 0{,}001 \times \exp\left[0{,}9\,815 \ln\left(6 \times 10^{-3} \times 1\,000\right) - 0{,}03\,832\right] = 5{,}586 \times 10^{-3}$$

$$\tau_p = 0{,}4\,788 \times (1{,}1938 \times 4 \times 2{,}0\,885 - 1{,}611) = 4{,}004$$

The Hedstrom number He is:

$$He = \frac{4{,}004 \times 1\,560 \times 0{,}059^2}{\left(5{,}5\,862 \times 10^{-3}\right)^2} = 696\,596$$

Once He is calculated, α_c and Re_{BP2} are estimated as:

$$\alpha_\text{c} = \frac{3}{4}\,\frac{\left[(2 \times 696\,596)/24\,500 + 3/4\right] - \sqrt{\left[(2 \times 696\,596)/24\,500 + 3/4\right]^2 - 4(696\,596/24\,500)^2}}{2(696\,596/24\,500)} = 0{,}638$$

$$Re_{\text{BP2}} = \frac{696\,596 \times \left[0{,}968\,774 - (1{,}362\,439 \times 0{,}638) + (0{,}160\,082\,2 \times 0{,}638^4\right]}{8 \times 0{,}638} = 17\,203$$

The critical velocity is:

$$v_c = \frac{5{,}586 \times 10^{-3} \times 17\,203}{1\,560 \times 0{,}059} = 1{,}04 \text{ m/s}$$

and the critical flowrate is:

$$q_\text{c} = \frac{\pi \times 0{,}059}{4} \times 1{,}04 = 2{,}85 \times 10^{-3} \text{ m/s}$$

© ISO 2003 — All righ
This is a preview. Click here to purchase the full publication.

13.4.2.2 Example 2

What is the friction pressure, in pascals, over 500 m for the same fluid flowing at 0,015 $m^3 \cdot s^{-1}$?

Its velocity is:

$$v = \frac{4 \times 0{,}015 \times 1}{\pi \times 0{,}059} = 5{,}50 \text{ m/s}$$

So the Bingham Reynolds number is:

$$Re_{BP} = \frac{1 \times 5{,}50 \times 1\,560 \times 0{,}059}{5{,}586\,2 \times 10^{-3}} = 90\,620$$

Since Re is greater than Re_{BP2} (17 203) the flow regime is turbulent, and since He is greater than $1{,}525 \times 10^5$ the value of the friction factor is determined from:

$$f = 0{,}206\,56 \times 90\,620^{-0{,}378\,0} = 2{,}76 \times 10^{-3}$$

So the friction pressure gradient is given by:

$$\frac{\Delta p}{L} = \frac{2 \times 1\,560 \times 5{,}5 \times \left(2{,}76 \times 10^{-3}\right) \times 1}{0{,}059} = 803 \text{ Pa/m}$$

which gives a friction pressure of:

$$\Delta p = 803 \times 500 = 401\,500 \text{ Pa}$$

13.4.2.3 Example 3

What is the critical flow rate for turbulent flow, in cubic metres per second, for a Bingham Plastic fluid with a density of 1 560 kg/m^3, a rotational viscometer plastic viscosity of 6×10^{-3} Pa·s and a rotational viscometer yield point of 4 Pa, flowing in a 0,215 9/0,177 8 m annulus?

The ratio is $d_a / D_a = 0{,}177\,8 / 0{,}215\,9 = 0{,}823\,5$

This is greater than 0,3, hence slot approximation shall be used. However, the example will be worked out for both pipe and slot models.

The critical velocity for turbulent flow is estimated as follows:

a) Hedstrom number — Annular flow — Pipe

$$He = \frac{4{,}004 \times 1560 \times (0{,}215\,9 - 0{,}177\,8)^2}{\left(5{,}586 \times 10^{-3}\right)^2} = 290\,580$$

b) Hedstrom number — Annular flow — Slot

$$He = \frac{4{,}004 \times 1\,560 \times (0{,}215\,9 - 0{,}177\,8)^2}{1{,}5^2 \times \left(5{,}586\,2 \times 10^{-3}\right)^2} = 129\,150$$

This is a preview. Click here to purchase the full publication.

— All rights reserved

c) α_c **— Annular flow — Pipe**

$$\alpha_c = \frac{3}{4}\frac{\left[(2\times 290\,580)/24\,500+3/4\right]-\sqrt{\left[(2\times 290\,580)/24\,500+3/4\right]^2-4(290\,580/24\,500)^2}}{2(290\,580/24\,500)} = 0{,}583\,6$$

d) α_c **— Annular flow — Slot**

$$\alpha_c = \frac{3}{4}\frac{\left[(2\times 129\,150)/24\,500+3/4\right]-\sqrt{\left[(2\times 129\,150)/24\,500+3/4\right]^2-4(129\,150/24\,500)^2}}{2(129\,150/24\,500)} = 0{,}515\,4$$

e) Critical Bingham Reynolds number Re_{BP2} **— Annular flow — Pipe**

$$Re_{\mathrm{BP2}} = \frac{290\,580\times\left[0{,}968\,774-1{,}362\,439\times 0{,}583\,6+0{,}160\,082\,2\times(0{,}583\,6)^4\right]}{8\times 0{,}583\,6} = 11\,964$$

f) Critical Bingham Reynolds number Re_{BP2} **— Annular flow — Slot**

$$Re_{\mathrm{BP2}} = \frac{129\,150\times\left[0{,}968\,774-1{,}362\,439\times 0{,}515\,4+0{,}160\,082\,2\times(0{,}515\,4)^4\right]}{12\times 0{,}510\,2} = 7\,040$$

g) Critical fluid mean velocity for turbulent flow — Annular flow — Pipe

$$v_{\mathrm{c}} = \frac{\left(5{,}586\times 10^{-3}\right)\times 11\,964}{1\,560\times(0{,}215\,9-0{,}177\,8)} = 1{,}12 \text{ m/s}$$

h) Critical fluid mean velocity for turbulent flow — Annular flow — Slot

$$v_{\mathrm{c}} = \frac{1{,}5\times\left(5{,}586\times 10^{-3}\right)\times 7\,040}{1\,560\times(0{,}215\,9-0{,}177\,8)} = 0{,}99 \text{ m/s}$$

i) Critical flowrate — Annular flow — Pipe

$$q_{\mathrm{c}} = \frac{\pi\times\left(0{,}215\,9^2-0{,}177\,8^2\right)\times 1{,}12}{4} = 0{,}013 \text{ m}^3/\text{s}$$

j) Critical flowrate — Annular flow — Slot

$$q_{\mathrm{c}} = \frac{\pi\times\left(0{,}215\,9^2-0{,}177\,8^2\right)\times 1{,}12}{4} = 0{,}013 \text{ m}^3/\text{s}$$

13.4.2.4 Example 4

What is the friction pressure, in pascals, over 500 m for the same fluid flowing at 0,015 m^3/s?

© ISO 2003 — All righ
This is a preview. Click here to purchase the full publication.

Its velocity is:

$$v = \frac{4 \times 0{,}15}{\pi\left(0{,}215\,9^2 - 0{,}177\,8^2\right)} = 1{,}27 \text{ m/s}$$

a) Reynolds number — Annular flow — Pipe

$$Re_{\text{BP}} = \frac{1{,}27 \times 1\,560 \times (0{,}215\,9 - 0{,}177\,8)}{5{,}586\,2 \times 10^{-3}} = 13\,520$$

b) Reynolds number — Annular flow — Slot

$$Re_{\text{BP}} = \frac{1{,}27 \times 1\,560 \times (0{,}215\,9 - 0{,}177\,8)}{1{,}5 \times 5{,}586\,2 \times 10^{-3}} = 9\,008$$

Since Re_{BP} is greater than Re_{BP2} in both pipe and slot models, the flow regime is turbulent.

c) Pipe-flow model

For the pipe-flow model, the Hedstrom number, He, is greater than $1{,}575 \times 10^5$. So the friction factor, f, is given by:

$$f = 0{,}205\,21 \times 13\,520^{-0{,}355\,79} = 6{,}96 \times 10^{-3}$$

Thus the friction pressure gradient is given by:

$$\frac{\Delta p}{L} = \frac{2 \times 1\,560 \times 1{,}27^2 \times \left(6{,}96 \times 10^{-3}\right) \times 1}{(0{,}215\,9 - 0{,}177\,8)} = 919{,}28 \text{ Pa/m}$$

which gives a friction pressure of:

$$\Delta p = 919{,}28 \times 500 = 459\,640 \text{ Pa}$$

Slot-flow model

For the slot-flow model, the Hedstrom number, He, is such that $0{,}75 \times 10^5 < He < 1{,}575 \times 10^5$. So the friction factor, f, is given by:

$$f = 0{,}263\,651 \times 9\,008^{-0{,}389\,31} = 7{,}61 \times 10^{-3}$$

So the friction pressure gradient is given by:

$$\frac{\Delta p}{L} = \frac{2 \times 1\,560 \times 1{,}27^2 \times \left(7{,}61 \times 10^{-3}\right) \times 1}{(0{,}215\,9 - 0{,}177\,8)} = 1\,005 \text{ Pa/m}$$

which gives a friction pressure of:

$$\Delta p = 1\,005 \times 500 = 502\,500 \text{ Pa}$$

This is a preview. Click here to purchase the full publication.
— All rights reserved

13.5 Conversion factors

SI unit	to be multiplied by	to get value in USC units
Pa	1×10^{-5}	bar
m^3	6,29	bbl
m^3/s	$6{,}29 \times 60$	bbl/min
Pa·s	1 000	cP
m	3,28	ft
m^3/s	$264{,}19 \times 60$	gal/min
m	39,37	in
m^3	1 000	l
m^3/s	$1\,000 \times 60$	l/min
kg/m^3	$2{,}2 \times (3{,}785\,2 \times 10^3)$	lbm/gal
kg/m^3	$2{,}2 \times 0{,}304\,8^3$	lbm/ft^3
Pa	2,09	$lbf/100\ ft^2$
$Pa{\cdot}s^n$	0,020 9	$lbf{\cdot}s^n/ft^2$
Pa	6 894,65	psi

14 Test procedure for arctic cementing slurries

14.1 General

This procedure is intended for the testing of cement slurries that are to be placed in areas known to contain permafrost. The conditioning temperature for the test equipment, materials to be tested and the test temperatures shall be controlled to ± 1 °C (± 2 °F).

14.2 Preparation of cement slurry

Test samples shall be prepared according to Clause 5, except that the cement blend and mixing equipment shall be preconditioned at –7 °C (20 °F). Mix water shall be pre-chilled to 1 °C (34 °F), and the slurry temperature shall be recorded immediately after mixing; ~ 4 °C (40 °F) is typical. Each of the above temperatures shall be measured and reported on all tests.

14.3 Fluid fraction

The fluid fraction shall be expressed as percent by mass of basic dry blend (not including any additives needed for placement).

14.4 Thickening time

A thickening-time test shall be performed in a consistometer at 4 °C (40 °F) at atmospheric pressure.

14.5 Compressive strength

Specimens shall be cured at –7 °C (20 °F) and 4 °C (40 °F) for the desired testing period, i.e. 1 d, 3 d or 7 d.

The moulds shall be preconditioned by cooling to the temperature of the curing bath, i.e. –7 °C (20 °F) or 4 °C (40 °F).

© ISO 2003 — All righ
This is a preview. Click here to purchase the full publication.

Stir the selected cementing compositions for 90 min in a consistometer at 4 °C (40 °F) before pouring into the preconditioned moulds for curing. For curing at temperatures below 0 °C (32 °F), seal the test specimens in a container of fresh water at test temperature or 2 °C (35 °F), whichever is higher. Submerge the sealed container in a mineral oil or glycol bath at test temperature in a manner consistent with avoiding contamination of the fresh water and specimens.

EXAMPLE For 24-h compressive strengths:

a) Stir cement slurry for 90 minutes at 4 °C (40 °F) and atmospheric pressure.

b) Quickly pour slurry into preconditioned moulds, seal in a suitable container filled with fresh water [for tests below 0 °C (32 °F)], and submerge in curing bath.

c) Cure slurry for 22 h at –7 °C (20 °F) or 4 °C (40 °F), and monitor temperature.

d) Remove cubes from moulds 30 min before the test and place them in 4 °C (40 °F) water. Crush the specimens at the loading rates described in 7.5.6 a).

14.6 Freeze-thaw cycling at atmospheric pressure

Prepare slurry as in 14.2 (do not precondition the slurry as in 14.5) and cure under the following sequence (it is suggested that the cycle begin on a Monday):

a) 48 h at 4 °C (40 °F) Monday

b) 24 h at –7 °C (20 °F) Wednesday

c) 24 h at 4 °C (40 °F) Thursday

d) 72 h at 38 °C (100 °F) Friday

e) 72 h at 77 °C (170 °F) Monday

f) 24 h at 38 °C (100 °F) Thursday

g) 72 h at –7 °C (20 °F) Friday

h) Raise to 4 °C (40 °F) and repeat cycle on Monday.

14.7 Compressive strength cyclic testing

Examine the cement cubes and break them after 1 and 3 cycles under these conditions (14 d and 42 d). Cure all compressive-strength test cubes under water and in moulds during cycles with top of cement column exposed to water. Break control specimens after 48 h at 4 °C (40 °F) for reference.

15 Well-simulation slurry stability tests

15.1 Introduction

The purpose of this test is to determine the static (quiescent) stability of a cement slurry. The cement slurry is conditioned to simulate dynamic placement in a wellbore. The slurry is then left static to determine if free fluid separates from the slurry or to determine if the cement slurry experiences particle sedimentation. Both the free fluid result and the sedimentation result are required in order to understand the static stability of the slurry under downhole conditions. Free fluid can be formed with minimal sedimentation, and sedimentation can take place without free fluid being formed. Therefore, both results must be evaluated to determine slurry stability. Excessive free fluid and settling are normally considered detrimental to cement sheath quality. The amount of free fluid or settling that is acceptable varies with the application.

This is a preview. Click here to purchase the full publication.
3 — All rights reserved

15.2 Slurry mixing

Prepare the cement slurry according to Clause 5. If performing the sedimentation test described in 15.6, immediately after mixing the slurry, measure the density of the slurry using a pressurized fluid density balance.

15.3 Slurry conditioning

Any consistometer referenced in Clause 9 may be used. The following procedure applies to the most commonly used equipment.

Place the slurry in the container of the pressurized consistometer and begin a thickening-time test in accordance with Clause 9. Apply pressure and heat or cool according to the thickening-time schedule which most closely simulates actual field conditions. If desired, the slurry may be held at the specified temperature and pressure for 30 min ± 30 s or other desired conditioning period before proceeding to the next step. If the conditioning temperature is greater than 88 °C (190 °F), cool the slurry to approximately 88 °C (190 °F) for safety. If the boiling point of water in your area is less than 100 °C (212 °F), adjust test temperatures accordingly.

Release the pressure slowly [about 1 380 kPa/s (200 psi/s)]. Remove the slurry container from the consistometer, keeping the container upright so oil does not mix with the slurry. Remove the top locking ring, drive bar and collar from the shaft and the diaphragm cover. Syringe and blot any oil from the top of the diaphragm. Remove the diaphragm and the support ring. Syringe and blot any remaining oil from the top of the slurry. If the contamination is severe, discard the slurry and begin the test again. Remove the paddle and stir the slurry briskly with a spatula to ensure a uniform slurry.

At this point, proceed with either 15.4 or 15.5 for a free-fluid test. For a sedimentation test, proceed to 15.6.

NOTE The 88 °C (190 °F) safety temperature assumes a boiling point for water of 100 °C (212 °F).

15.4 Free-fluid test with heated static period

15.4.1 General

Pour the slurry into a clear graduated tube. The ratio of the slurry-filled length to the inside tube diameter shall be greater than 6:1 and less than 8:1. The clear tube shall be inert to well cements and shall not deform during the test. The clear tube shall be graduated such that the slurry volume placed in the tube can be visually determined with a precision of ± 2 ml. The free-fluid test slurry volume shall be between 100 ml and 250 ml, inclusive. Document the slurry volume placed in the tube when the tube is vertical. Document the tube dimensions as well.

Preheat (or precool) a test chamber for curing the slurry during the static period to T_{BHC} or 88 °C (190 °F), whichever is cooler. To minimize the effects of condensation on the test results, a test temperature of 88 °C (190 °F) was chosen, and a boiling point for water of 100 °C (212 °F) assumed. If the boiling point of water in your area is less than 100 °C (212 °F), adjust the 88 °C (190 °F) test temperature accordingly. This chamber may be an atmospheric heating or cooling bath/oven/jacket/chamber, or a suitable pressurized heating/cooling chamber that uses hydrocarbon oil to transmit heating/cooling to the slurry.

A bath/oven/jacket/chamber or pressurized chamber is designated hereafter in this clause as a chamber. When hydrocarbon oil is used, the oil shall have a flash point that satisfactorily meets the safety requirements of the organization performing the test.

15.4.2 Free-fluid tests at temperatures less than 88 °C (190 °F)

Immediately place the graduated tube in a heating or cooling chamber that is preheated or precooled to T_{BHC}. Cover the opening of the graduated tube to prevent evaporation. The chamber must be able to heat or cool the entire slurry. The tube can be tilted to simulate hole angle, if desired. Appropriate precautions shall be taken to ensure the static curing is performed at essentially vibration free conditions.

© ISO 2003 — All righ
This is a preview. Click here to purchase the full publication.

The temperature is maintained at T_{BHC} for the remainder of the test. The test duration is 2 h, starting from the time the slurry is poured into the clear tube. After the 2 h test period, the volume of free fluid (clear or coloured fluid on top of the cement slurry inside of the clear tube) shall be measured, with a precision of ± 0,2 ml.

The volume fraction, φ, of free fluid, expressed as a percent, is then calculated.

$$\varphi = \frac{V_F\,(100)}{V_S} \tag{110}$$

where

V_F is the volume, in millilitres, of free fluid;

V_S is the volume in millilitres, of slurry.

15.4.3 Free-fluid test at temperatures greater than or equal to 88 °C (190 °F)

Place the graduated tube in a preheated 88 °C (190 °F) oil-filled heating chamber. Optionally, tilt the tube to simulate hole angle. Further heat the slurry to T_{BHC} in the time required to take the slurry from a depth with 88 °C (190 °F) circulating temperature to T_{BHC}. Some heating chambers may not be able to heat fast enough; in that case heat as fast as possible but minimize overshooting the T_{BHC}. Maintain the slurry at T_{BHC} until it is time to start cooling the chamber back down to 88 °C (190 °F). The time required to cool various pieces of equipment from elevated temperatures back to 88 °C (190 °F) will vary. Maintain the pressure on the curing chamber high enough throughout the test so the slurry cannot boil (Table 4). The pressure applied can simulate bottom-hole conditions, if desired. Avoid constant pump cycling, in order to prevent vibration. The schedules found in Clause 9 can be used to aid in selecting pressure- and temperature-change rates. Take appropriate precautions to ensure that the static curing is performed in essentially vibration-free conditions.

The 2 h test period is initiated when the conditioned slurry is poured into the graduated tube. Slurries need to be cooled to 88 °C (190 °F) before the free fluid can be measured. This cooling time is part of the 2 h test period. After the 2 h test period, the volume of free fluid (clear or coloured fluid on top of the cement slurry inside of the clear tube) shall be measured. Free fluid for slurries immersed in hydrocarbon oil collects above the cement but below the oil. Measure the volume of the free fluid with a precision of ± 0,2 ml.

The volume fraction of free fluid is then calculated, as a percent, in accordance with Equation (110) above.

15.5 Free-fluid test with ambient temperature static period

Pour 250 ml of the slurry from 15.3 into a 250 ml graduated glass cylinder. The zero-to-250 ml graduated portion of the cylinder shall be no less that 232 mm (9 in) nor more than 250 mm (9,8 in) in length, graduated in 2 ml increments or less. Stir the slurry by hand with a spatula during pouring to ensure a uniform sample of the slurry. The 2 h test period is initiated when the conditioned slurry is poured into the graduated tube. Seal the graduated cylinder with plastic film wrap or equivalent material to prevent evaporation. The graduated glass cylinder may be inclined at an angle to simulate wellbore deviation. Take appropriate precautions to ensure that static curing is performed in essentially vibration-free conditions.

After the 2-h test period, measure the volume of free fluid (clear or coloured fluid on top of the cement slurry inside the clear tube) with a precision of ± 0,2 ml.

The volume fraction of free fluid is then calculated, as a percent, in accordance with Equation (110) above.

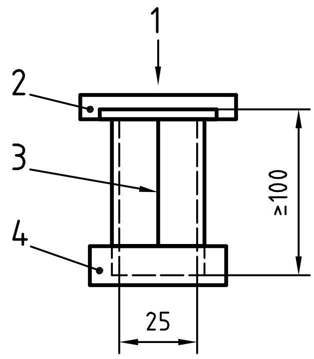
15.6 Sedimentation test

Pour slurry from 15.3 into a sedimentation tube until it is approximately 20 mm ($^3/_4$ in) from the top. The sedimentation tube shall have an inner diameter of 25 mm ± 5 mm (0,98 in ± 0,02 in). The tube length shall be a minimum of 100 mm (3,94 in). The most common tube length is approximately 200 mm (7,9 in) (see Figure 17). Lightly grease the inside of the tube, and all joints, to ensure that it is leak-tight and so that the set

This is a preview. Click here to purchase the full publication.
3 — All rights reserved

cement can be removed without damage. The tube shall be inert to well cements and shall not deform during the course of the test. Puddle the slurry in the filled tube to dislodge any air bubbles, then fill the tube completely. A top closure which allows pressure communication may be used to prevent spillage of the slurry. Place the filled tube in a water-filled preheated/precooled heating/cooling chamber in a vertical position. Preheat or precool the chamber to T_{BHC} or 88 °C (190 °F) whichever is cooler (see safety note in 15.3).

Dimensions in millimetres



Key

1 vent hole

2 lid

3 split in tube

4 base

Figure 17 — Typical sedimentation tube

Adjust the slurry temperature further to simulate temperature changes in the wellbore. Maintain sufficient pressure to prevent boiling of the slurry (see Table 4). The pressure applied may simulate bottom-hole conditions, if desired. Avoid constant-pump cycling in order to minimize vibration. The schedules in Annex E and Clause 7 can be used to aid in selecting the temperature and pressure.

Allow the slurry to cure for 24 h or until set before removing it from the heating/cooling chamber.

Cool the chamber to 88 °C (190 °F), if required (see safety note in 15.3). Release pressure from the chamber, if required. Remove the tube from the heating/cooling chamber and bring the tube to 27 °C (80 °F) ± 6 °C (10 °F) by placing it in a water bath. Once the tube has cooled, remove the cement from the tube. Keep the cement sample immersed in water, as much as possible, to prevent it from drying out. Measure the length of the set cement specimen. Mark the specimen approximately 20 mm (3/4 in) from the bottom and from the top of the sample. Then divide the middle section, between the marks, by further marks into roughly equal pieces with a minimum of two segments. Break or cut the sample at these marks, keeping the sections in order. Keep the sections immersed in water until each is weighed. A balance with a precision of 0,01 g is necessary, a precision of 0,001 g is preferred.

The preferred method for determining the density of each section is as follows. Place a beaker containing water on the balance and tare the balance to zero. Remove a section to be measured from the water bath and gently dry it with a paper towel. Place this section on the balance beside the beaker. Record the mass and remove the section from the balance. Retare the balance to zero. Next place a noose of thin line around the section. Pick up the section by the line and suspend the section in the water in the beaker such that the sample is totally surrounded by water. The sample shall not touch the bottom or sides of the beaker. Air bubbles shall not be clinging to the section. Obtain the mass with the sample suspended in water. Remove the sample from the water and retare the balance. Repeat the procedure for each set cement section.

By applying the Archimedes Principle, calculate the relative density of each cement core section.

$$d_{\mathrm{rel}} = \frac{m_{\mathrm{air}}}{m_{\mathrm{water}}} \tag{111}$$

The results are used to construct a density profile for the entire sample.

© ISO 2003 — All righ
This is a preview. Click here to purchase the full publication.