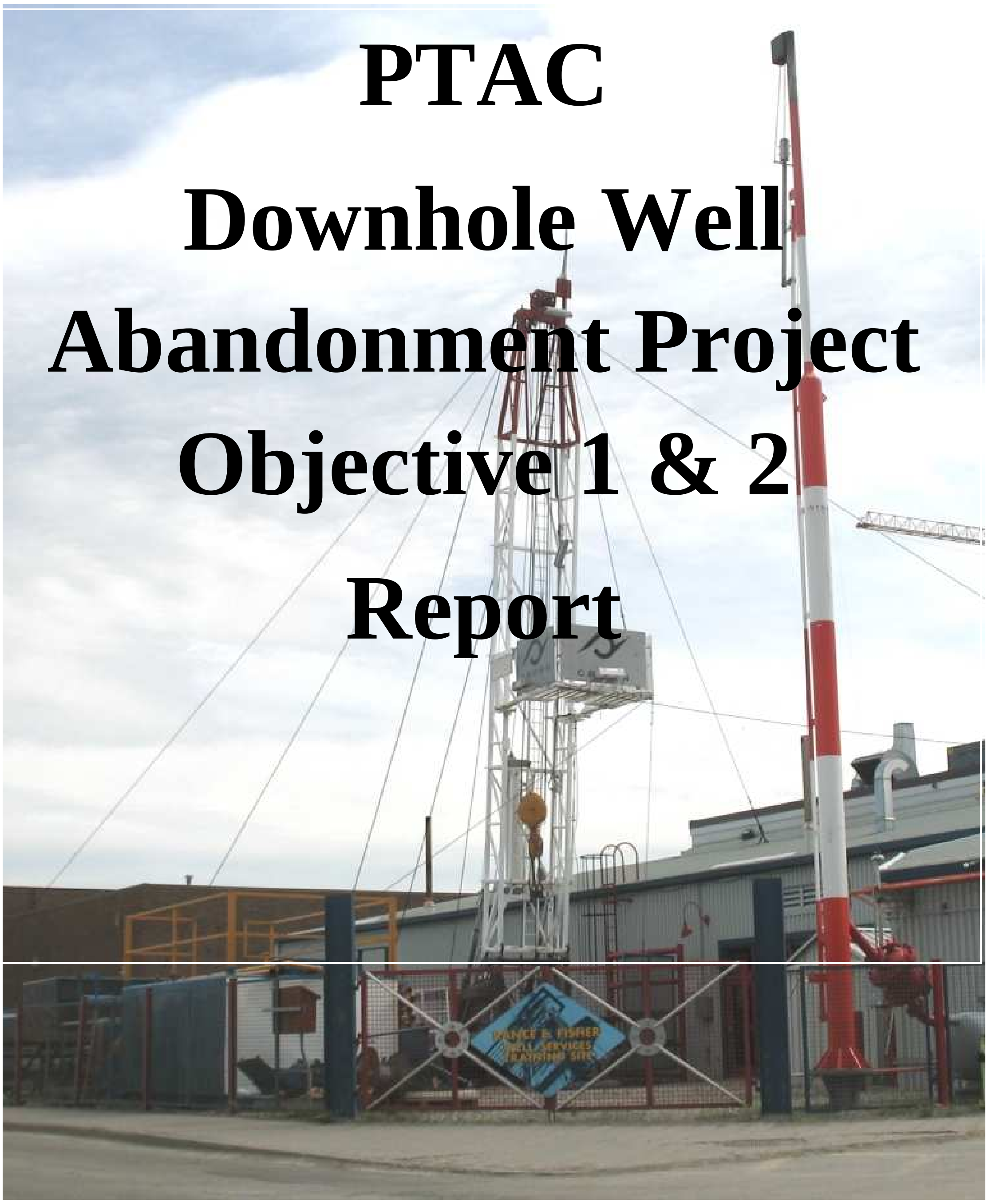
PTAC

Downhole Well Abandonment Project Objective 1 & 2 Report



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Executive Summary

The Southern Alberta Institute Of Technology (SAIT) has been contracted by the Petroleum Technology Alliance Of Canada (PTAC) to evaluate different aspects of the current well abandonment practices in Alberta. This report looks at both the minimum length of an in casing cement plug required to withstand 7000 kPa in a pressure balanced test design, and an evaluation of cement strength using neat Class G hydrated in different wellbore fluid environments.

1. PRESSURE TEST CEMENT PLUG OBJECTIVE:

Determine minimum cement plug length (+/- 0.5 meters) to hold 7 MPa in 114mm, 139mm and 177.8 mm casing for 60 minutes minimum. Samples to have radial, external pressure balanced support. A failure is determined by any leakage past the cement plug, or cement plug movement.

Leakage past cement plugs of 0.5, 1.0, and 1.5 m occurred in all the 114, 139 and 178 mm casing samples tested. A 2.0 m long plug was tested in the 178 mm casing size and this proved to be the quickest sample to leak. The leaks seemed to travel in a linear path along one side of the cement plug.

Only one plug moved and it moved 2 mm. This was a 1.5m long plug in 178 mm casing. Reasons for this movement are not known.

Based on these results, it is unclear whether longer plug lengths could contain 7000 kPa without leakage. It is believed however, that longer plug lengths would eliminate the possibility of cement plug movement.

2. TEST PLUGS IN WELLBORE FLUID ENVIRONMENTS OBJECTIVE:

Observe and measure the 10 day and 30 day compressive strength of Oilwell Class "G" neat cement, with a density of 1900 kg/m3. These cement samples are to be hydrated in typical wellbore fluid environments that could have a detrimental impact by contaminating the cement or altering its chemistry. These environments are fresh water, fresh water with corrosion inhibitor, produced water, 3% KCL water, and crude oil. Cement to be placed in these different fluid environments using through tubing and dump bailing methods.

Compressive strength of samples increased with hydration time regardless of the fluid environment.

The crude oil environment caused a small reduction in compressive strength, while the other fluids tested were about equal. The crude oil samples showed oil staining within the broken test samples broken during compression testing.

The tubing placement and dump bailing methods employed showed good displacement of the wellbore fluid environment at the bottom of the samples. Some small wellbore fluid voids were evident along the sides of some of the samples placed.

Introduction

This report covers work done in 2011 and conclusions drawn in a study to determine the minimum length of an in casing cement plug required to withstand 7000, and an evaluation of cement strength using neat Class G hydrated in different wellbore fluid environments.

The original 2011 Scope Of Work is as follows:

PRESSURE TEST PLUGS

1. Retest Sample #4 (114mm casing with 0.487m cement plug) to 3000 kPa and monitor pressure for 24 hours in a constant temperature environment.
2. Determine minimum cement plug length (+/- 0.1 meters) to hold 7 MPa in 114mm, 139mm and 177.8 mm casing for 60 minutes minimum. Samples to have radial, external pressure balanced support. A failure is determined by any leakage past the cement plug, or cement plug movement. Three samples to be tested in each size and plug length to confirm repeatability of test.

TEST PLUGS IN WELLBORE FLUID ENVIRONMENTS

1. Observe and measure the setting time of Oilwell Class "G" neat cement, with a density of 1900 kg/m3, achieving the optimal compressive strength requirement in various wellbore fluid environments that could have a detrimental impact by contaminating the cement or altering its chemistry . These environments are fresh water, fresh water with inhibitor, 7.0% brine water, brine water with inhibitor, and crude oil.

There were two series of tests conducted, with a review and modifications to plans made after the first series of tests.

Test Series #1 was conducted in March, April and May, 2011. Results are summarized in this report. The first objective of the Pressure Test Plugs was conducted during this series, however Sample #4 started to leak early in the test before significant pressure could be applied and the test was terminated.

It was following the May 3, 2011 report of these results that the scope of work was modified as follows:

PRESSURE TEST PLUGS.

1. Determine minimum cement plug length (+/- 0.5 meters) to hold 7 MPa in 114mm, 139mm and 177.8 mm casing for 60 minutes minimum. Samples to have radial, external pressure balanced support. A failure is determined by any leakage past the cement plug, or cement plug movement.
2. Test a sample similar to the externally pressure supported sample tested in 2010 to determine if this sample would contain pressure for a longer period of time without a leak.

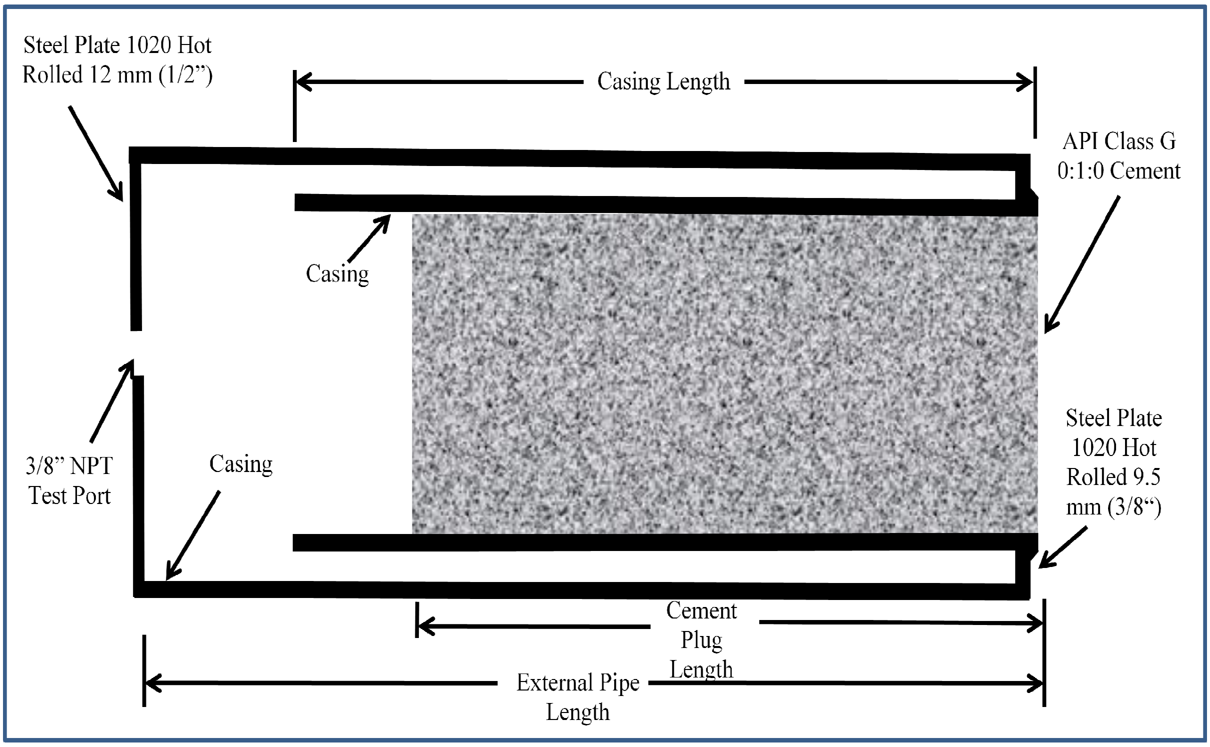
TEST PLUGS IN WELLBORE FLUID ENVIRONMENTS

1. Observe and measure the 10 day and 30 day compressive strength of Oilwell Class “G” neat cement, with a density of 1900 kg/m3. These cement samples are to be hydrated in typical wellbore fluid environments that could have a detrimental impact by contaminating the cement or altering its chemistry. These environments are fresh water, fresh water with corrosion inhibitor, produced water, 3% KCL water, and crude oil. Cement to be placed in these different fluid environments using through tubing and dump bailing methods.

Test Series #2 was then conducted in July, August and September, 2011 using the revised scope of work on samples fabricated in May, June and July of 2011.

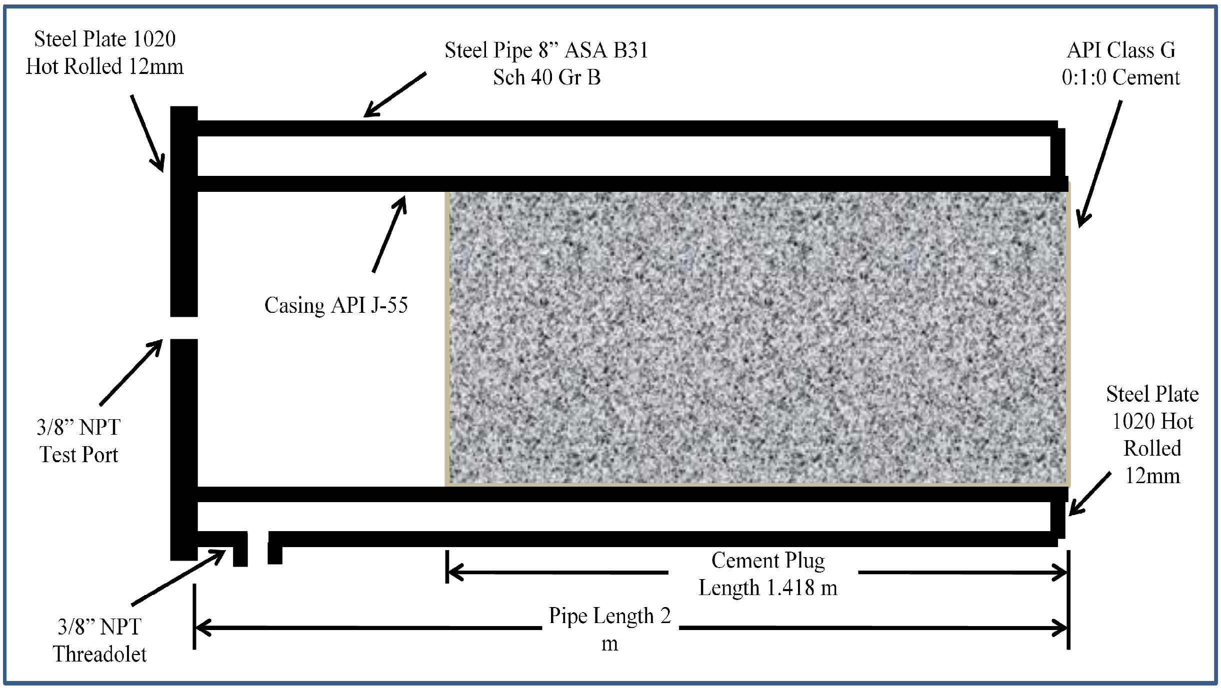
Pressure Test Plugs Series # 1 – Test Results - March - May, 2011

In March 2011 it was believed that in a pressure balanced test design, such as shown, plug leakage would be less of a concern than plug movement. In this design, hydraulic pressure on the outside of the internal casing would be equal to the pressure inside where fluid could contact. This pressure balance design was utilized to eliminate casing expansion, due to internal pressure, as a reason for a leak past the cement plug.



2011 Test Sample Pressure Balanced Design

This design was chosen based on a test conducted in 2010 where a pressure balanced sample held pressure without leakage for approximately 10 minutes. Unfortunately this test should have been run longer using a pressure data logger. That sample is illustrated in the figure below. The annulus and internal volume were connected by a common line and pressurized simultaneously.



2010 Test Sample Pressure Balanced Design

In the first series of pressure tests conducted in 2011 plug lengths of 0.1 to 0.3 m were used. These lengths were based on dry push tests done on cement plugs poured and then pressed out with a hydraulic press to determine the shear bond strength between the cement and 114, 139 and 178 mm casing. Based on these calculations, plug lengths of 0.2 m would be adequate to prevent plug movement at 7 MPa.

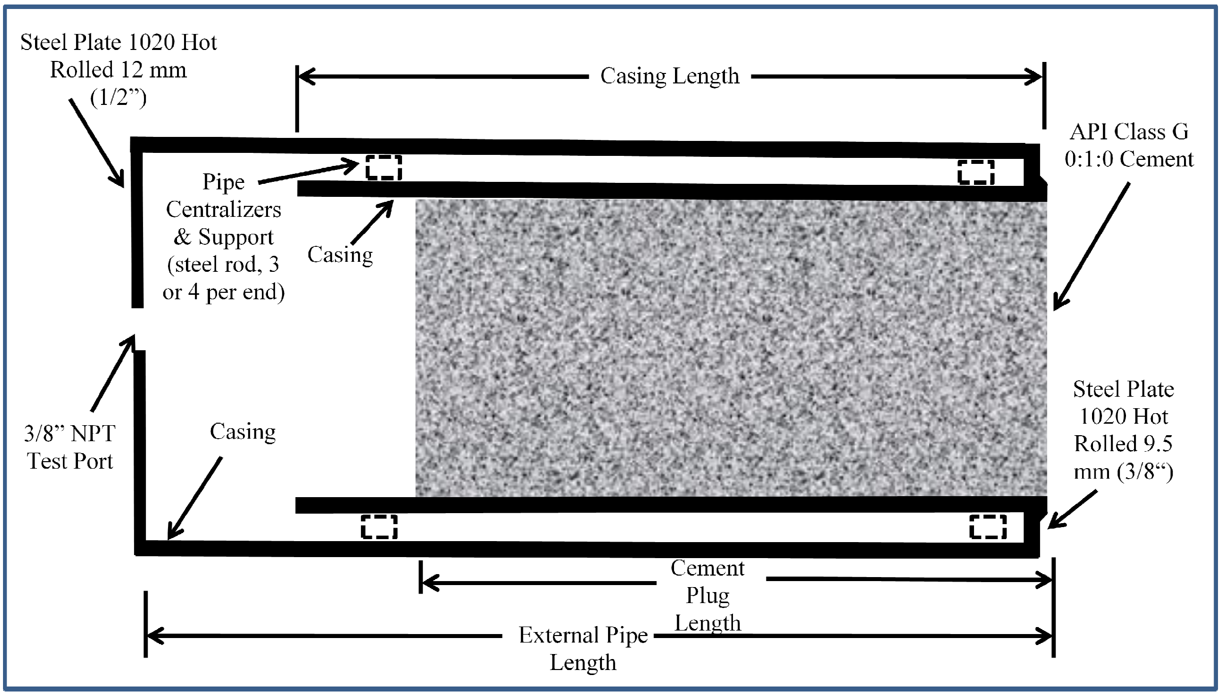
The samples tested showed plug movement in all 0.2 m long plugs tested, but not the 0.3m long plug in the 114 and 139mm casing sizes. The 0.3 m long plug did see movement in the 178 mm casing. All samples leaked fluid, despite the pressure balanced design. It was concluded that the plugs may have been lubricated by the leaking fluid which promoted plug movement.

Regardless of the plug movement, all samples leaked, necessitating a new round of tests utilizing longer cement plugs.

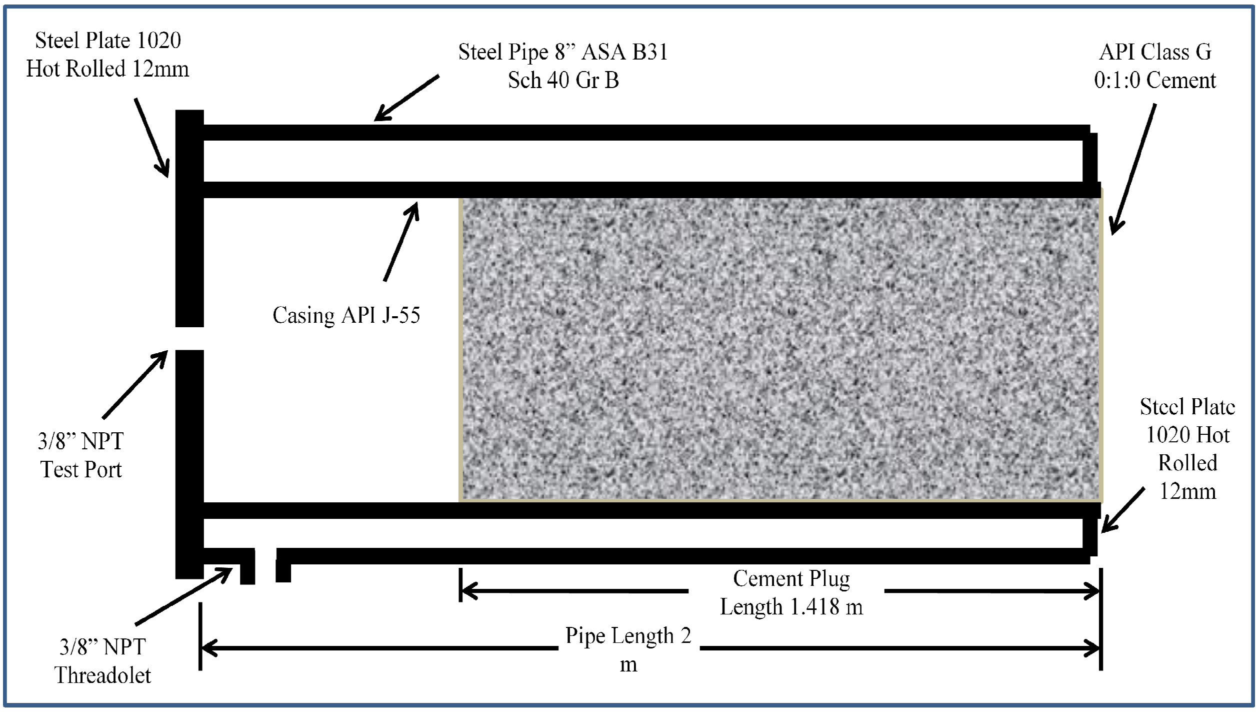
Pressure Test Plugs Series # 2 – Test Results May - Sept, 2011

Pressure Test Sample Design & Dimensions (July/Aug, 2011 Tests)

Sample Number	Quantity	Cement Plug Length (m)	Casing OD (mm)	Casing ID (mm)	Casing Weight (kg/m)	Casing Length (m)	Ext. Pipe OD (mm)	Ext. Pipe ID (mm)	Ext. Pipe Weight (kg/m)	Ext. Pipe Length (m)
4050	1	0.5	114.3	103.9	14.1	0.75	139.7	127.3	20.8	1.0
4100	1	1.0	114.3	103.9	14.1	1.25	139.7	127.3	20.8	1.5
4150	1	1.5	114.3	103.9	14.1	1.75	139.7	127.3	20.8	2.0
5050	1	0.5	139.7	127.3	20.8	0.75	177.8	164.0	29.8	1.0
5100	1	1.0	139.7	127.3	20.8	1.25	177.8	164.0	29.8	1.5
5150	1	1.5	139.7	127.3	20.8	1.75	177.8	164.0	29.8	2.0
7050	1	0.5	177.8	164.0	29.8	0.75	219.0	202.7	42.6	1.0
7100	1	1.0	177.8	164.0	29.8	1.25	219.0	202.7	42.6	1.5
7150	1	1.5	177.8	164.0	29.8	1.75	219.0	202.7	42.6	2.0
7200	1	2.0	177.8	164.0	29.8	2.25	219.0	202.7	42.6	2.5



Sample Number	Quantity	Cement Plug Length (m)	Casing OD (mm)	Casing ID (mm)	Casing Weight (kg/m)	Casing Length (m)	Ext. Pipe OD (mm)	Ext. Pipe ID (mm)	Ext. Pipe Weight (kg/m)	Ext. Pipe Length (m)
7140DD	1	1.418	177.8	164.0	29.8	2.00	219.0	202.7	42.6	2.0



Sample 7140DD illustrated above was fabricated and tested to compare to an identical 2010 sample, and to test a slightly different pressure balance design.

Pressure Test Sample Fabrication (May - July, 2011)

Test samples were fabricated using the following steps:

1. Cut all pipe and end plates to dimension.
2. Weld 3 or 4 spacer/support rods on internal pipe.
3. Weld Open End Donut to both the internal and external pipe.
4. Using a wire wheel powered by an electric drill, remove all dirt, loose scale and rust from sample internal surface prior to pouring cement.
5. Seal open end with plastic and stand vertical on smooth surface.
6. Mix 1900 kg/m3 Class G cement with fresh water and pour into internal pipe. Fill to desired plug length. Cement mixed with rotary cement mixer (not as effective as a high energy or jet mixer).
7. Allow cement to hydrate for over 10 days undisturbed in a heated shop. (Sample 7200 was too tall and had to be poured outdoors).
8. Transported pipe samples in the back of a pickup to the welding shop and place horizontally on a pallet outdoors (samples fabricated in June and July).
9. Weld end pressure plate to samples.
10. Transported in the back of a pickup to the pressure test location and stored horizontally.

Cleaning Pipe Surface Prior To Cementing

Cleaned Pipe Surface

Cement Mixer Used For Tests

Pouring Cement In Pressure Test Samples

Pressure Test Samples With Cement Poured

Checking Cement Plug Length


Fresh Cement Poured In Pressure Test Samples

Sample 7100 Pressure Plate End

Sample 7100 Cement Plug End

Sample 7140DD Pressure Plate End

Sample 7140DD Cement Plug End

Pressure Test Procedure (July/Aug, 2011 Tests)

1. Fill test samples with fresh ambient temperature water.
2. Attach test manifold (pressure transducer, ball valve and hydraulic coupler).
3. Position samples horizontally on blocks.
4. Attach hydraulic line to test manifold and hydraulic hand power pack.
5. Attach pressure data logger to pressure transducer on the test manifold.
6. Secure hydraulic line to test sample with multiple wraps of nylon rope.
7. Pressure sample to 7000 kPa with hydraulic power pack located at a safe distance. Stop pumping, monitor pressure fall off for at least 1 hour, monitor cement end for leakage.
8. If pressure falls off within the first 30 minutes, repressure to 7000 kPa and monitor.
9. Continue maintaining pressure near 7000 kPa for 30 minutes, then allow to fall off for at least 1 hour while monitoring open cement end for leakage.
10. Depressure sample. Remove pressure manifold. Drain off any hydraulic oil and water.

Pressure Test Apparatus Prior To Extending And Securing Hose

Sample 4100 Leaking During Test

Sample 7150 Leaking

Sample 7150 With 2.0 mm Plug Movement

Sample 7150 With 2.0 mm Plug Movement

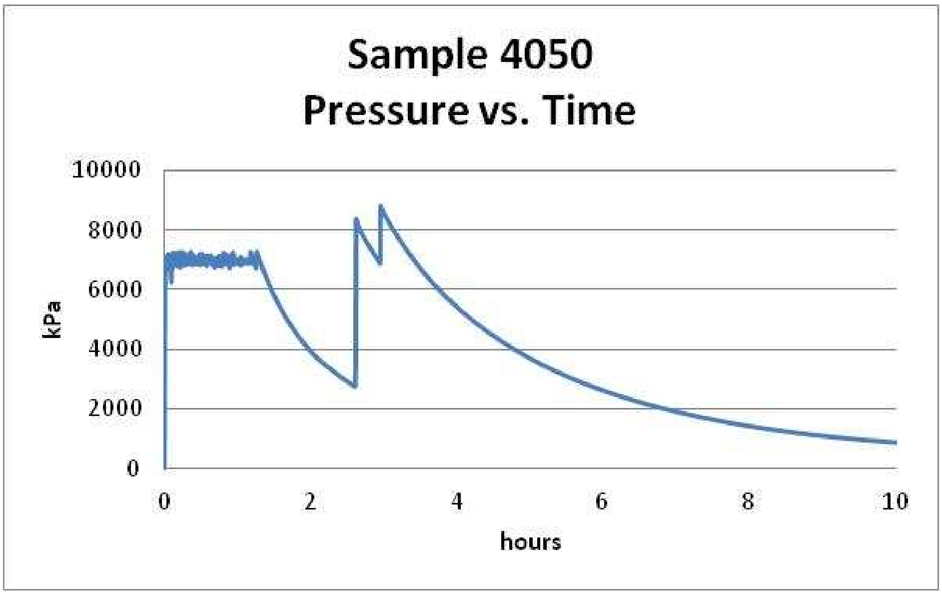
Pressure Test Data & Results (July/Aug, 2011 Tests)

Leakage occurred in all samples except sample 5100 where the test was discontinued after 1.75 hours. In this sample, the pressure had declined significantly and leakage would have occurred if the test was continued.

The longest time it took for a leak to occur was over 7 days with sample 7140DD.

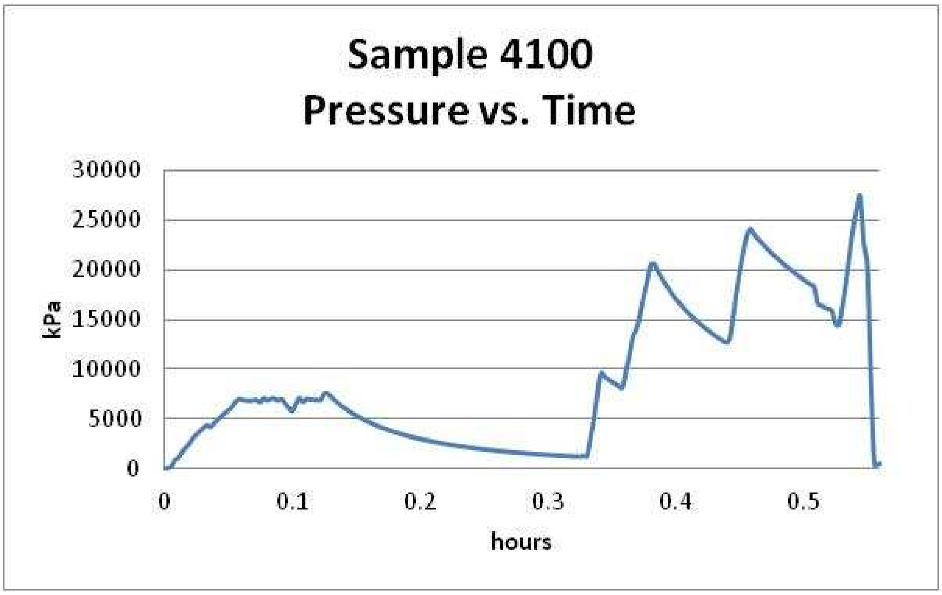
The shortest time it took for a leak to occur was 3 minutes with Sample 7200.

Sample 4050 (0.5 Meter Long Cement Plug)



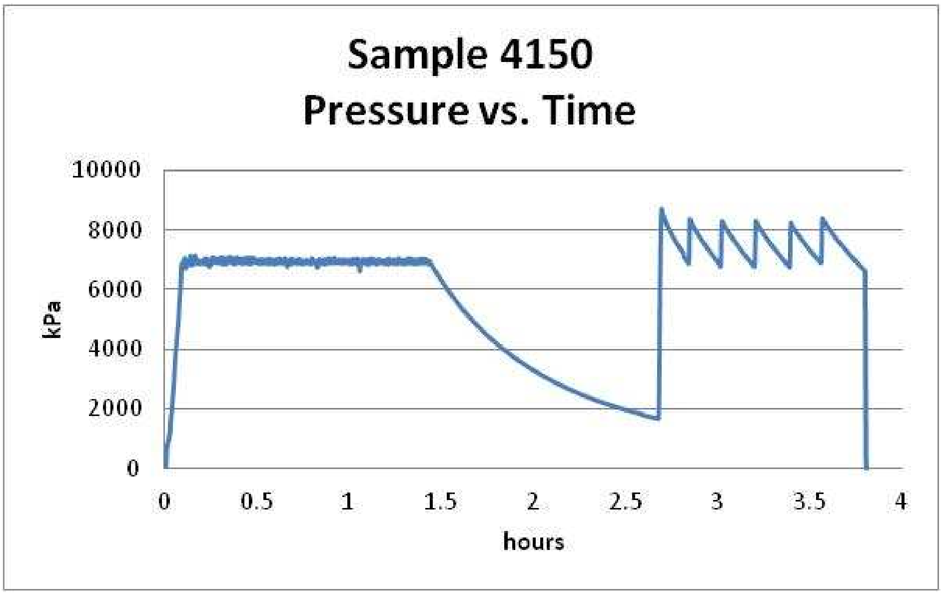
Leakage occurred, uncertain of time. No cement plug movement. Cement hydration time 21 days.

Sample 4100 (1.0 Meter Long Cement Plug)



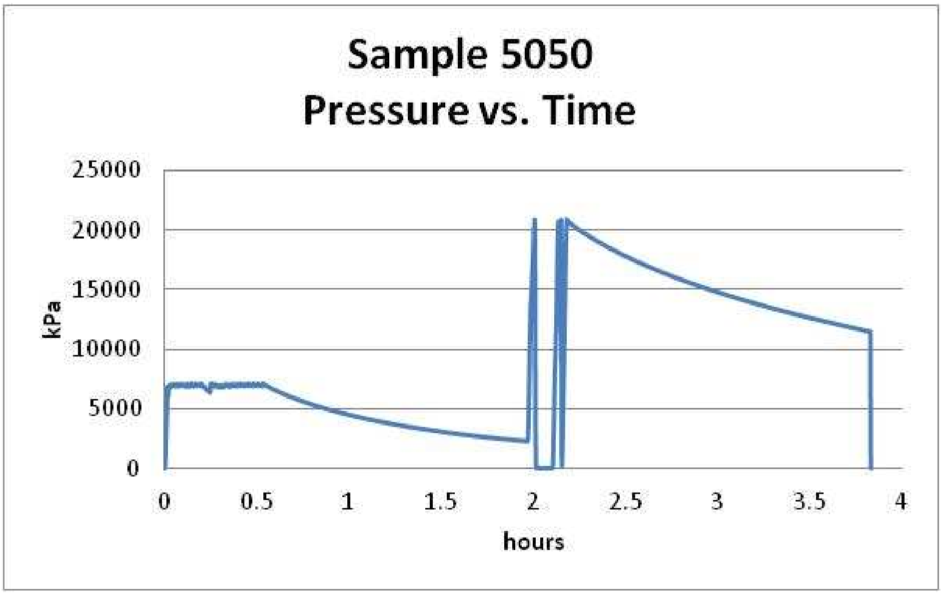
Leakage occurred within 0.25 hours. No cement plug movement despite higher a higher pressure test conducted after the 7 MPa test. Cement hydration time 21 days.

Sample 4150 (1.5 Meter Long Cement Plug)



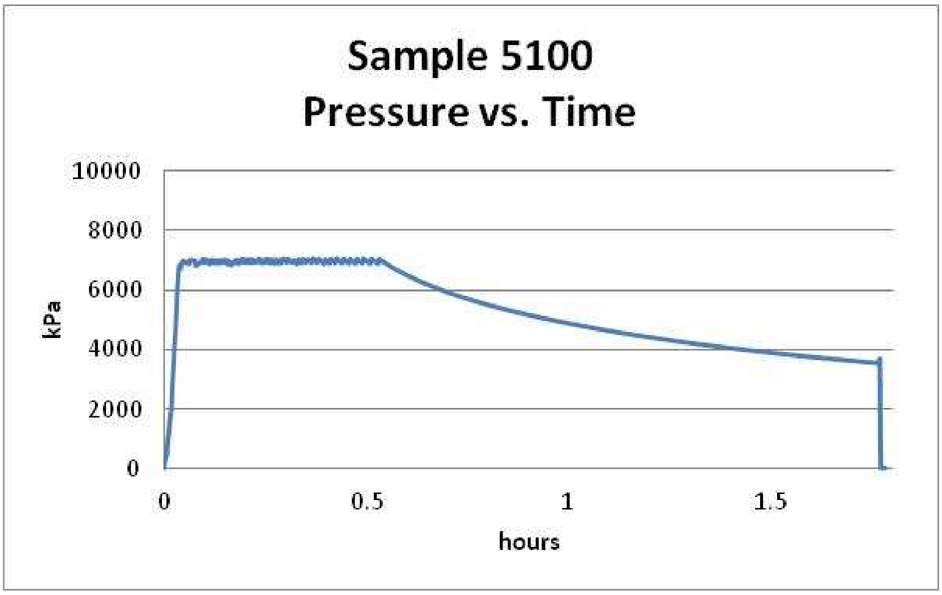
Leakage occurred after 1.25 hours. No Plug movement despite higher a higher pressure test conducted after the 7 MPa test. Cement hydration time 21 days.

Sample 5050 **(0.5 Meter Long Cement Plug)**



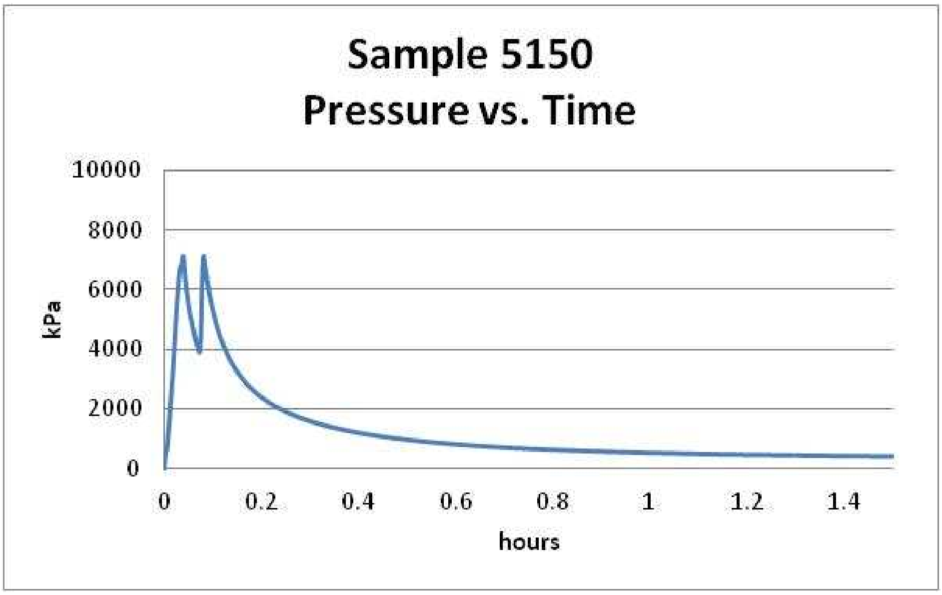
Leakage occurred 3.25 hours into the test. No plug movement despite higher a higher pressure test conducted after the 7 MPa test. Cement hydration time 22 days.

Sample 5100 **(1.0 Meter Long Cement Plug)**



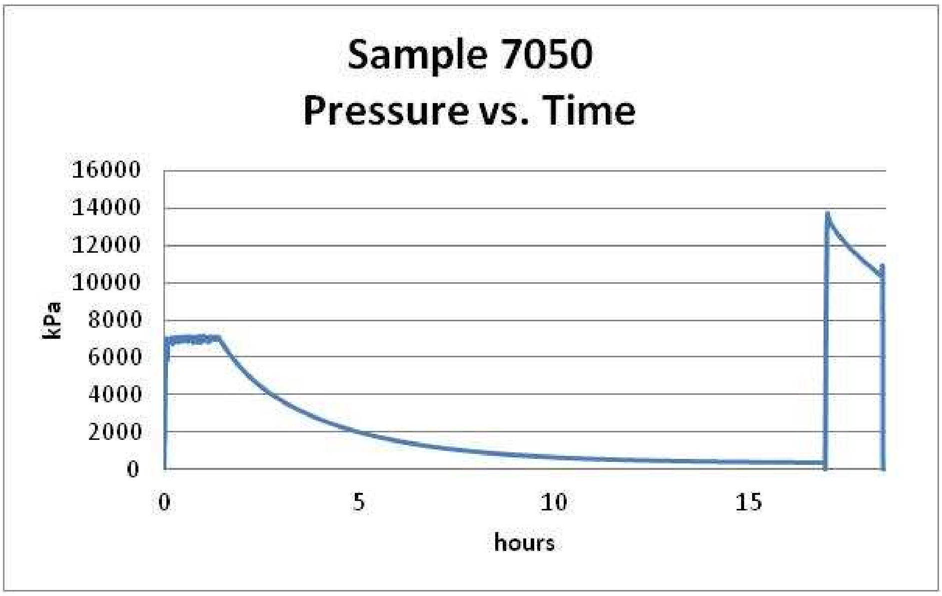
Leakage did not occur during the test period. No plug movement. Cement hydration time 22 days.

Sample 5150 (1.5 Meter Long Cement Plug)



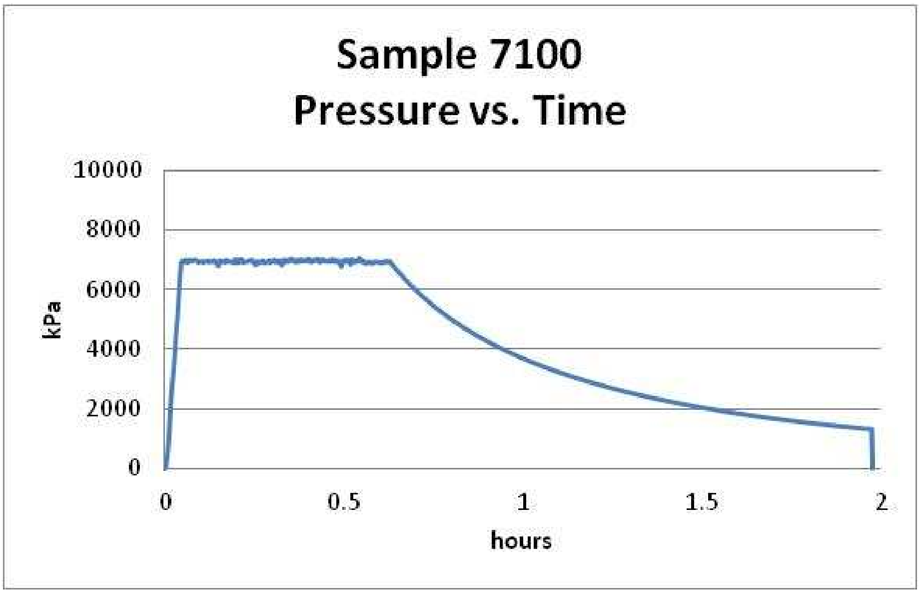
Leakage occurred almost immediately. No plug movement. Cement hydration time 22 days.

Sample 7050 (0.5 Meter Long Cement Plug)



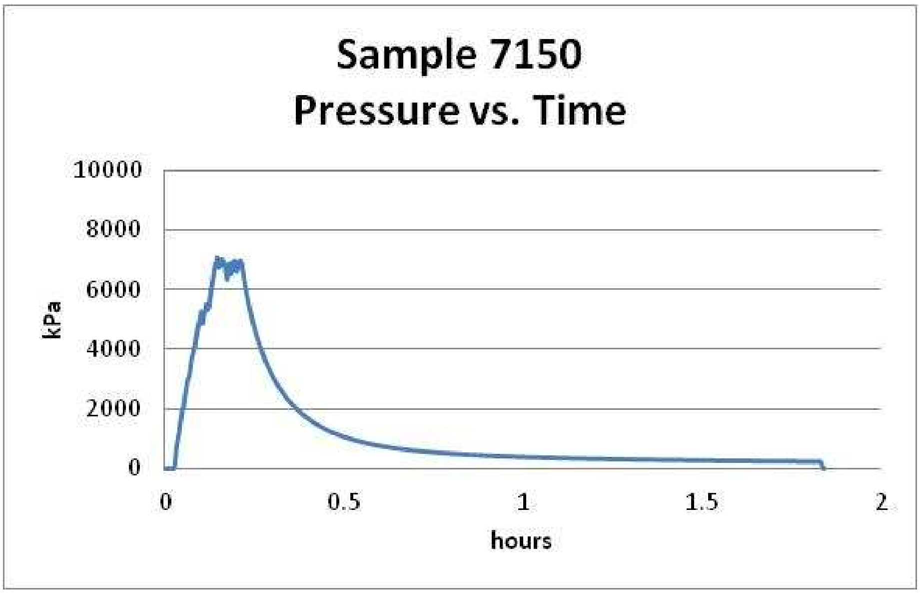
Leakage occurred 23 hours into the test. No plug movement despite higher a higher pressure test conducted after the 7 MPa test. Cement hydration time 21 days.

Sample 7100 **(1.0 Meter Long Cement Plug)**



Leakage occurred 0.5 hours into the test. No plug movement. Cement hydration time 28 days.

Sample 7150 **(1.5 Meter Long Cement Plug)**



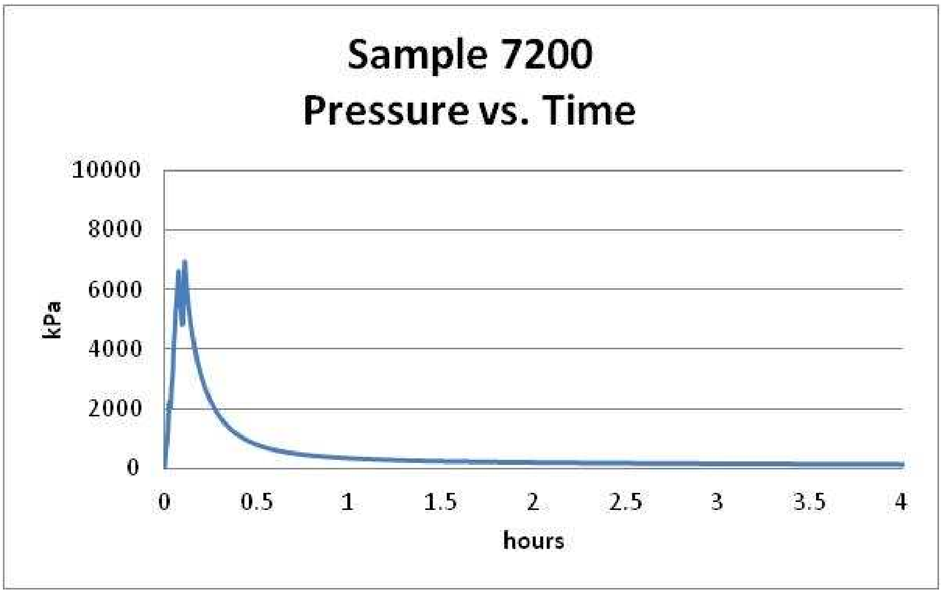
Leakage occurred 5 minutes into the test. Plug movement of 2.0 mm occurred after the leak started. Cement hydration time 28 days.

Sample 7150 Leaking

Sample 7150 With 2.0 mm Plug Movement

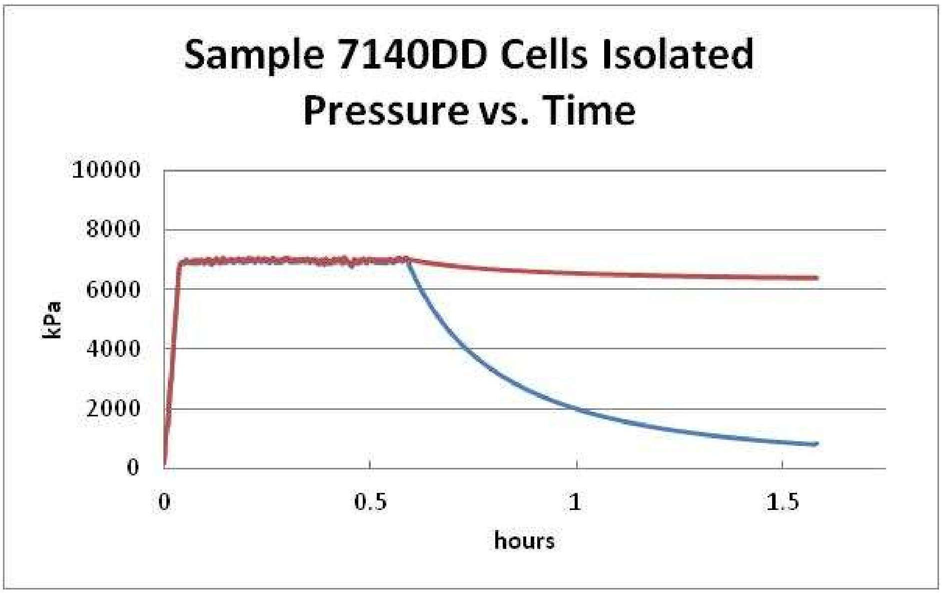
Sample 7150 With 2.0 mm Plug Movement

Sample 7200 (2.0 Meter Long Cement Plug)



Leakage occurred 3 minutes into the test. No plug movement. Cement hydration time 38 days.

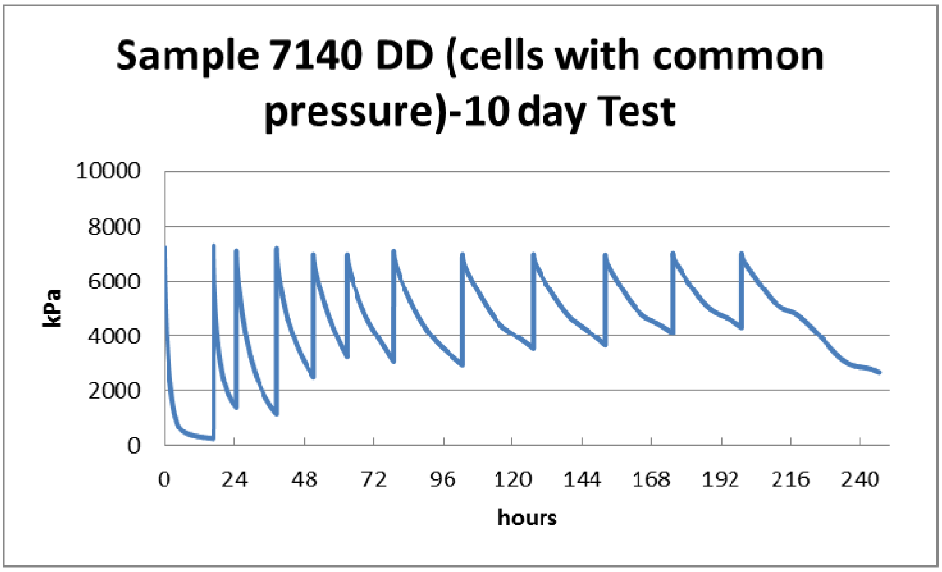
Sample 7140DD (1.42 Meter Long Cement Plug)



This sample was fabricated with an external annulus that could be pressured up separately. In the pressure test illustrated above, the annulus was isolated from the inside of the test casing after 0.6 hours.

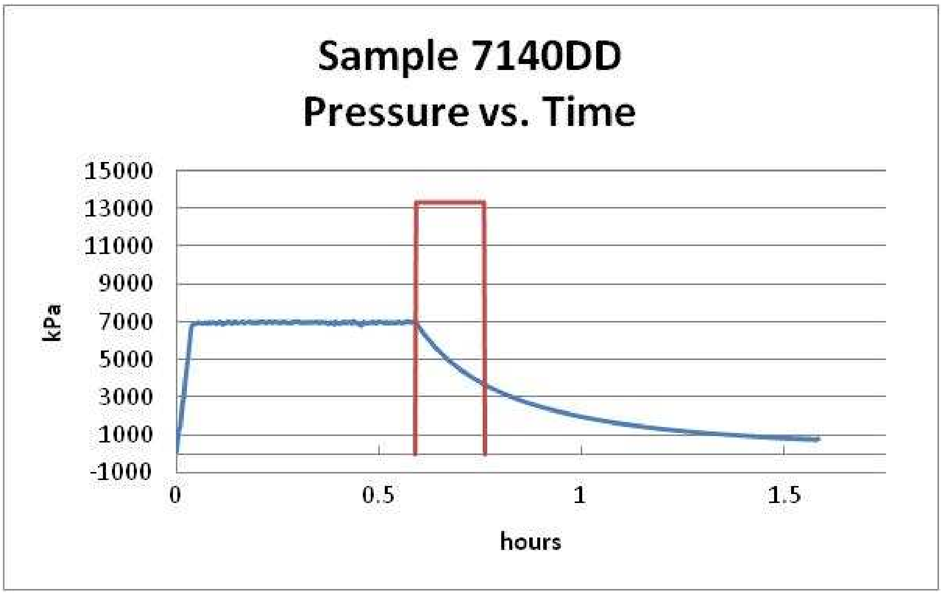
The pressure in the inside of the casing declined (as shown on the lower curve) because of fluid leaking along the cement plug, although no leakage was evident until the test was continued for 7 days.

The pressure in the annulus declined (as shown on the upper curve) due to the slight shrinkage of the test casing as its internal pressure declined.



This sample was retested after the first 1.6 hour test with the inside of the casing and the annulus hooked up to a common line. Leakage occurred 7 days into the test. No plug movement. Cement hydration time 21 days at start of test.

The following chart shows a comparison of this year's test (shown in blue) to a test conducted on an identical test sample fabricated and tested in June 2010 (shown in red). This test was redone this year using a pressure data logger to confirm the results.



The test done in 2010 showed no pressure decline in a 10 minute test measured with a pressure gauge. The reason for last year's success, in light of this year's failure could not be explained.

Pressure Test Failure Observations (July/Aug, 2011 Tests)

Pressure leaks occurred on all samples tested in June and July 2011.

Three samples were cut open to look at the leak path.

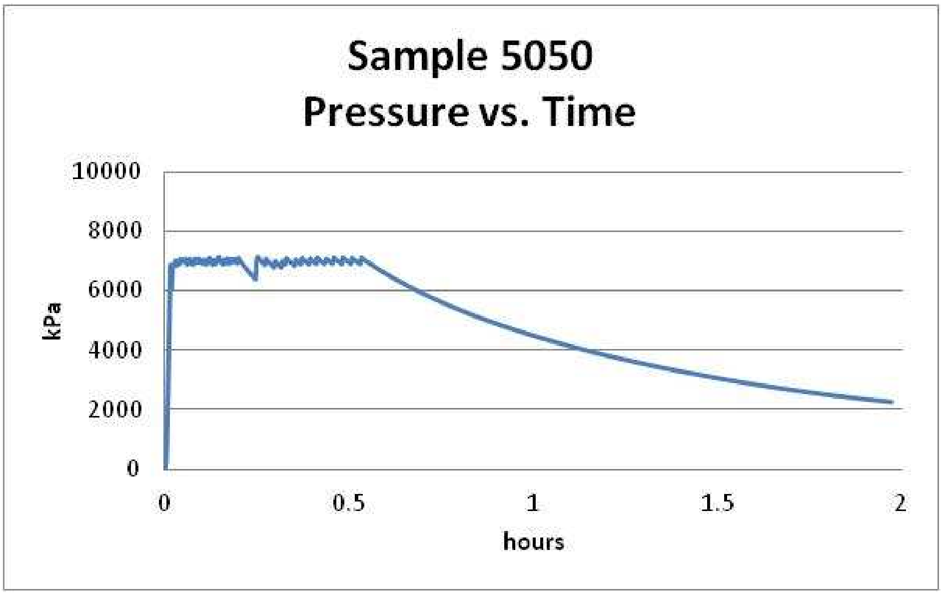
Sample 5050 was one of the slowest pressure decline rates with pressure declining from 7000 kPa to 2278 kPa in 1.5 hours shut in time. This cement plug is 0.5 m long in 139 mm casing.

Sample 5150 was one of the fastest pressure decline rates with pressure declining from 7000 kPa to 395 kPa in 1.5 hours shut in time. This cement plug is 1.5 m long in 139 mm casing.

Sample 7200 was also one of the fastest pressure decline rates with pressure declining from 7000 kPa to 210 kPa in 1.5 hours shut in time. This cement plug is 2.0 m long in 178 mm casing.

The flow path of all the leaks seemed to follow a relatively straight path along the pipe length

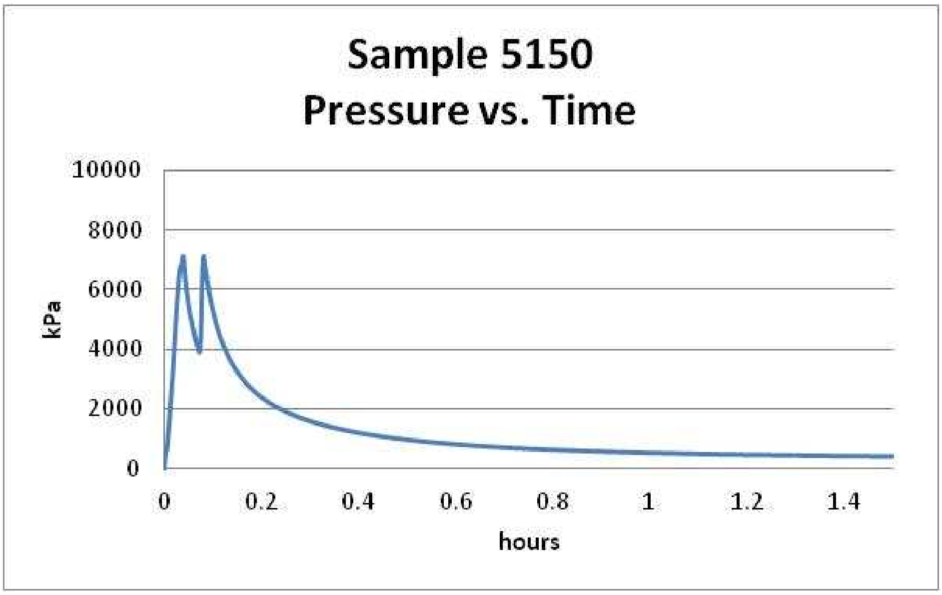
Sample 5050 (0.5 Meter Long Cement Plug)

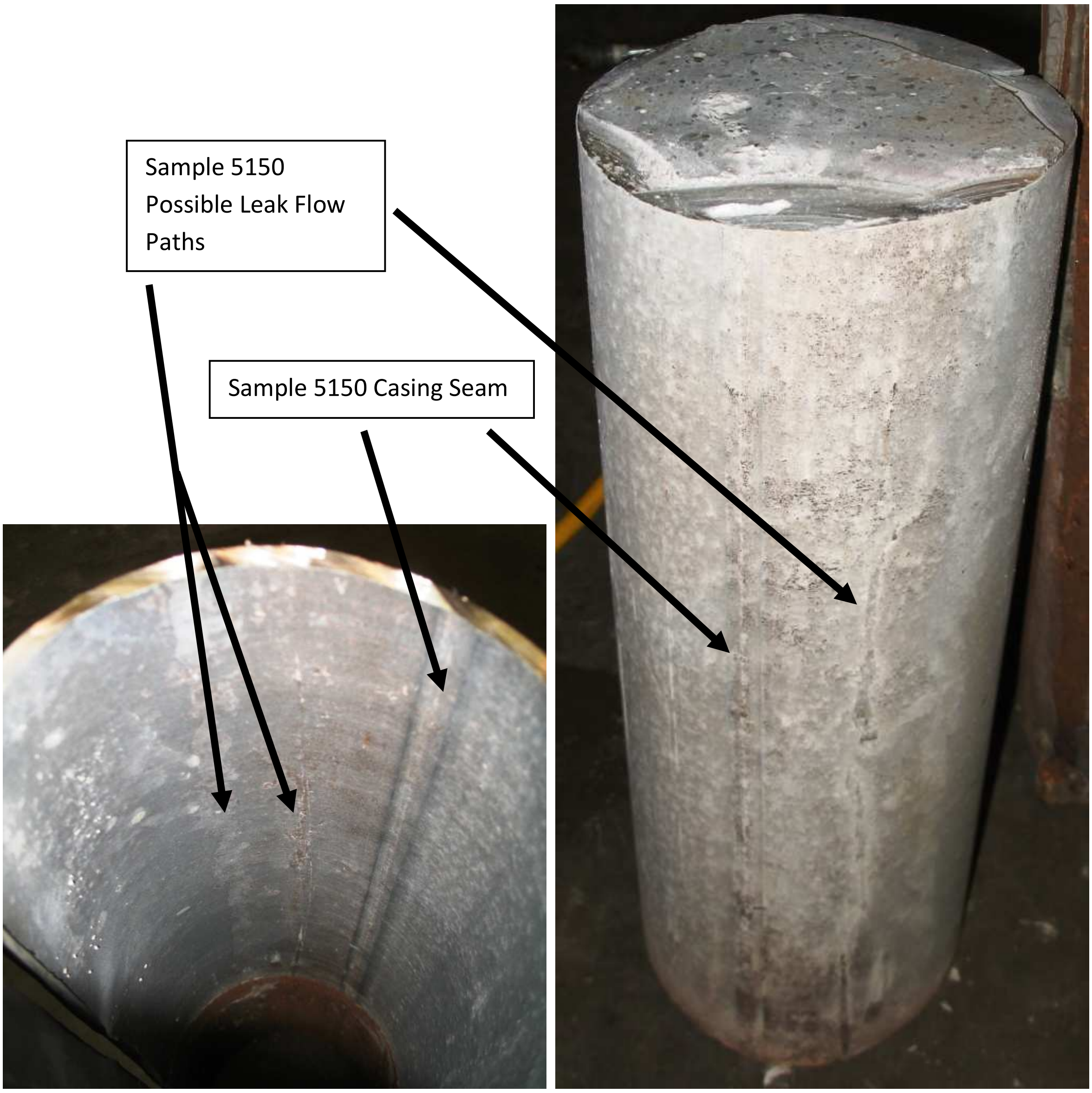


Sample 5050 Possible Leak Path

Sample 5050 Cement Plug

Sample 5150 (1.5 Meter Long Cement Plug)

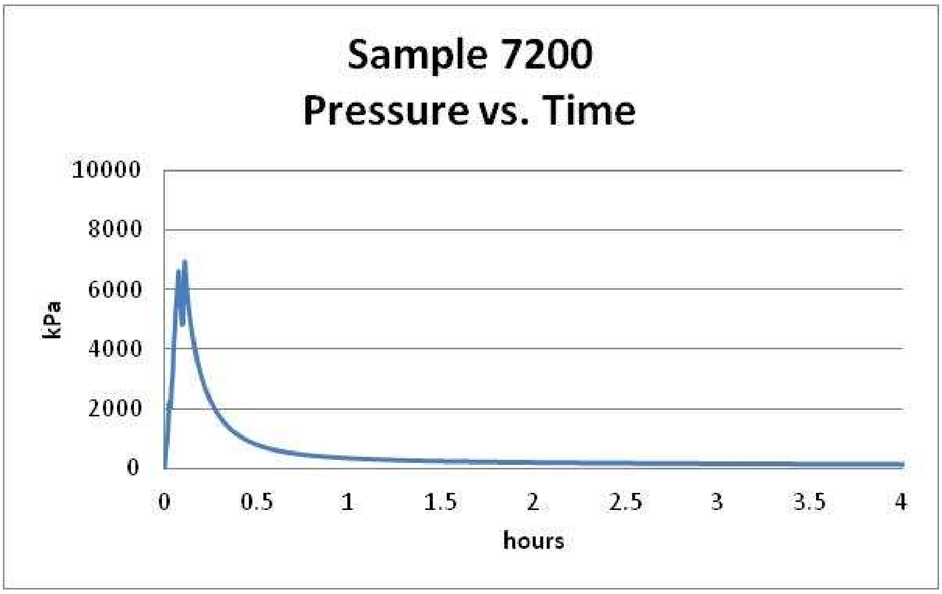




Sample 5150 Leak Path Visible Left Of Csg Seam

Cement Plug Leak Path Visible Right Of Csg Seam

Sample 7200 **(2.0 Meter Long Cement Plug)**



Sample 7200 Cut And Pulled Apart

Sample 7200 Top Of Cement Plug And Pipe

Sample 7200 Top Of Cement Plug And Pipe

Sample 7200 Top Of Cement Plug With Water Leak Erosional Flow Paths Visible

Wellbore Fluid Environments Series # 1 Test Results - March - May, 2011

On April 26, 2011, 30 compression test samples of neat Class G 1900 kg/m^3 cement were prepared, pouring 6 samples into 5 different fluid environments.

The fluids used were fresh water, corrosion inhibited water (1.5% by volume Champion Cortron R-2383C), 3% KCL water, Turner Valley 40 API sour crude oil, Turner Valley sour produced water (533 mg/l CL$^-$).

The samples were prepared as follows:

1. Mix cement in rotary mixer and check density. Ensure 1900 kg/m^3.
2. Prepare 100 mm ID PVC pipe samples 220 mm long, seal one end with plastic wrap and wet entire interior with desired test fluid. Drain excess fluid.
3. Pour cement into PVC pipe samples to a depth of 210 mm
4. Gently fill PVC pipe sample to top with desired test fluid.
5. Cover with plastic wrap and let stand for 10 days or 30 days in a heated shop.
6. After hydration period, drain off fluid, and cut PVC pipe to expose cement.
7. Polish cement sample ends square and perform compression test as per CSA A23.2-9C standard.

Compression Test Samples Poured & Then Topped With Fluid & Sealed

Compression Test Samples Corrosion Inhibited Water On Left, Crude Oil On Right

Polishing Ends On Compression Test Samples

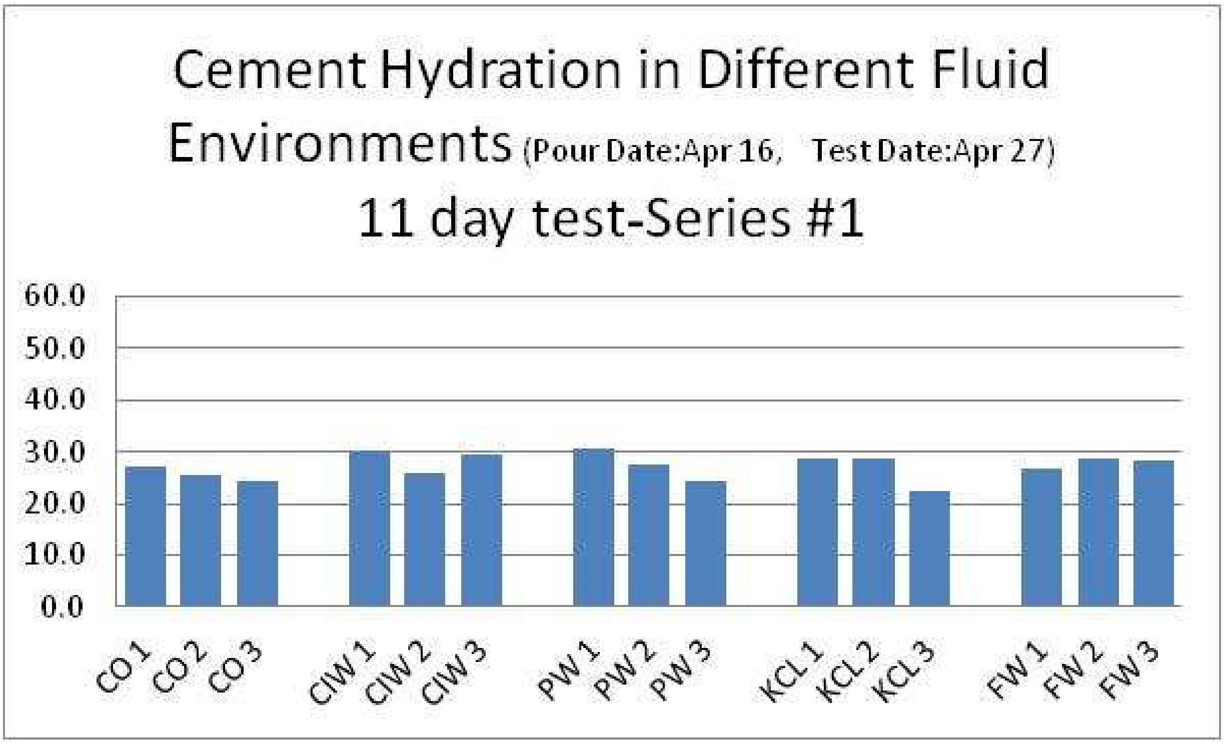
Performing Compression Test

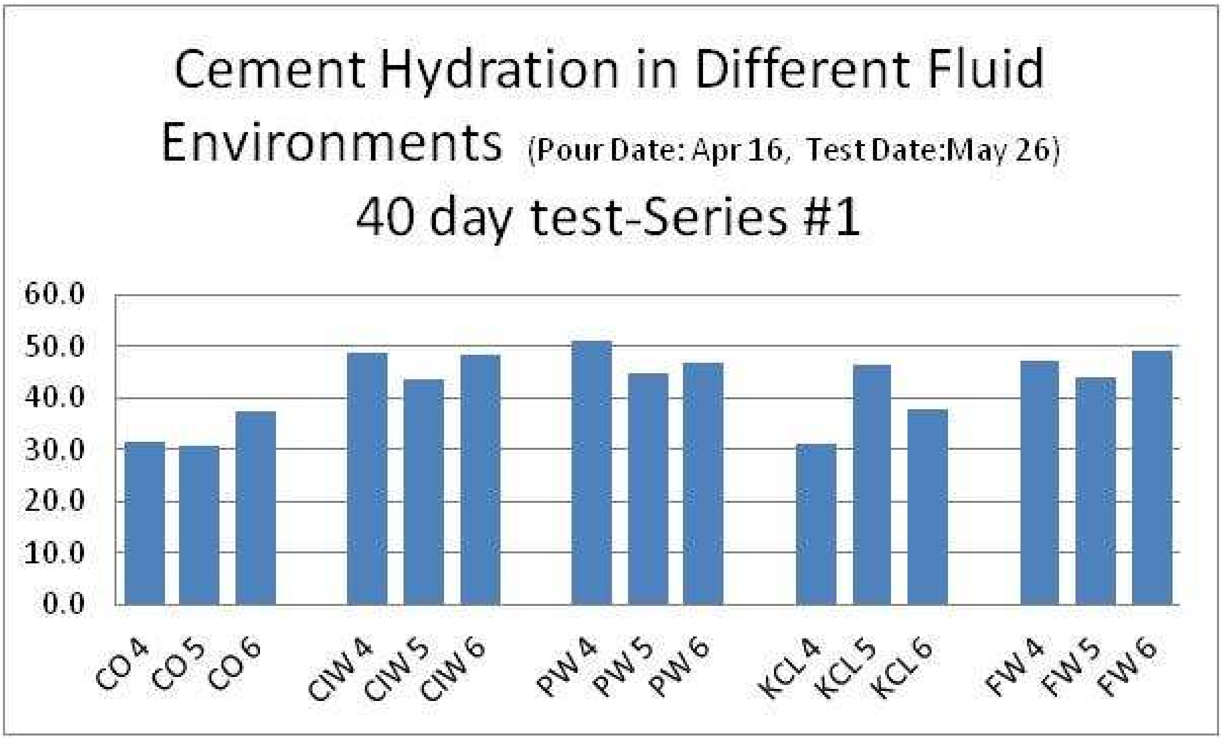
Performing Compression Test

Test results are shown on the following graphs. In both the 11 day and 40 day compression tests, a wide variation of compressive strengths was measured, with the crude oil samples being slightly lower than the others. 30 day compression tests could not be performed due to availability of lab and lab personnel.

The variation of compressive strengths, even within the same fluid environments may have been caused by mixing cement in a low energy mixer with resultant poorly mixed particles (small fish eyes). Scratch tests on these small particles proved them to truly be hydrated cement, but with a different color resulting from a higher cement/water ratio. Depending upon the quantity of these particles, the compression tests could have been affected.

The crude oil samples were darker in color inside (visible once broken), indicating possible crude oil contamination into the water based cement slurry. This may have been the reason for weaker samples in the 40 day tests. The other fluids showed some discoloration due to the fluid environment, but not as much as the crude oil.


Cement Hydration in Different Fluid Environments (Pour Date:Apr 16, Test Date:Apr 27)
11 day test-Series #1
60.0
50.0
40.0
30.0
20.0
10.0
0.0
CO1
CO2
CO3
CIW 1
CIW 2
CIW 3
PW 1
PW 2
PW 3
KCL 1
KCL 2
KCL 3
FW 1
FW 2
FW 3


Cement Hydration in Different Fluid Environments (Pour Date: Apr 16, Test Date:May 26)
40 day test-Series #1
60.0
50.0
40.0
30.0
20.0
10.0
0.0
CO4
CO5
CO6
CIW 4
CIW 5
CIW 6
PW 4
PW 5
PW 6
KCL 4
KCL 5
KCL 6
FW 4
FW 5
FW 6

Wellbore Fluid Environments Series # 2 Test Results - June - August, 2011

Fluid Environment Test (June – Aug, 2011) - Sample Fabrication & Testing Method

During the last meeting on May 3, 2011 it was discussed that placement of the cement in the fluid environments should be done through tubing and dump bailing. It was thought that this would increase the exposure of the cement slurry to contamination in the different fluid environments.

Test sample containers were constructed of 100 mm ID PVC pipe, 1.2 m long.

The samples were prepared as follows:

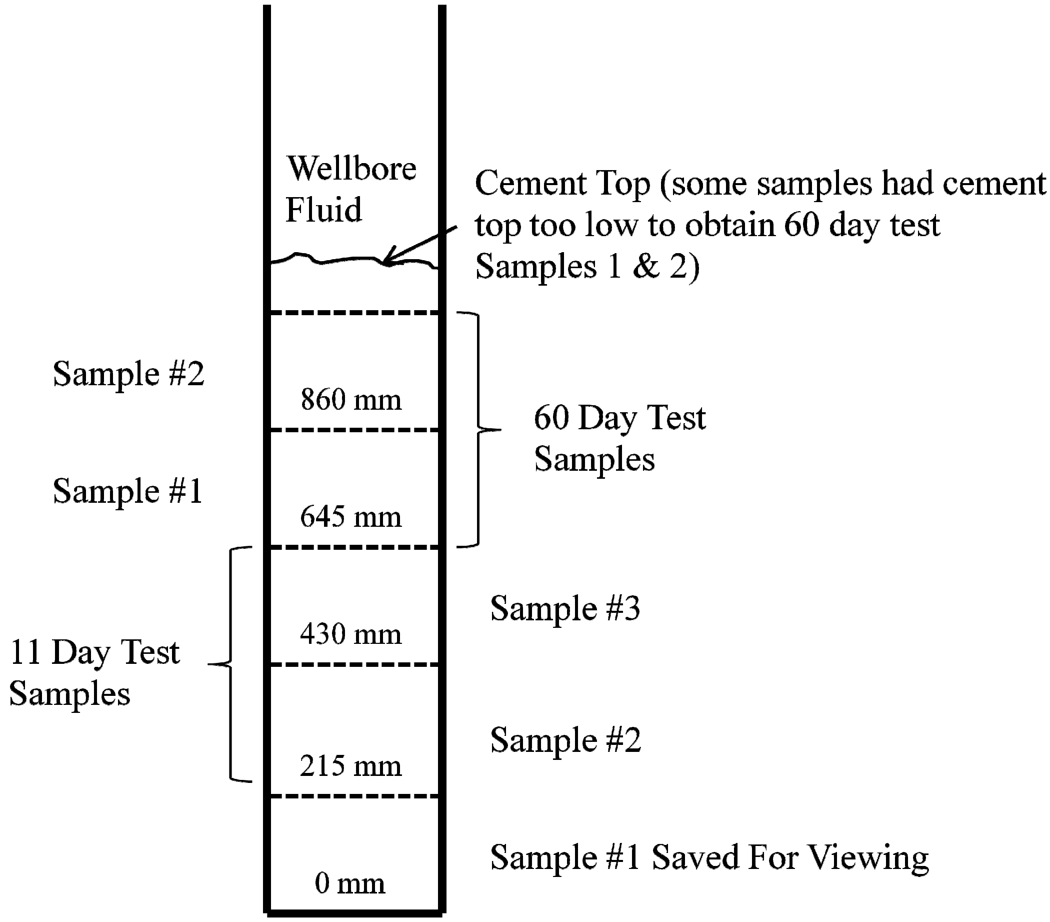
1. Mix cement in rotary mixer and check density. Ensure 1900 kg/m^3.
2. Prepare 100 mm ID PVC pipe samples 1.5 m long, seal one end with plastic wrap and duct tape and stand vertically on a smooth surface.
3. Fill samples1/ 2 full of the desired fluids
4. Place cement in 5 different fluid environment samples by pouring cement into a large funnel attached to 1.6 m of plastic hose extending to the bottom of the sample.
5. Place cement in 5 different fluid environment samples by pouring cement into a dump bailer fabricated from 60.3 mm x 0.9 m pipe with plastic wrap on the bottom and a bladed plunger to cut the plastic. Lower the dump bailer to the bottom of the PVC sample pipe, strike the bottom to cut the plastic wrap and slowly draw the bailer out.
6. Ensure good volume of fluid on top of the cement.
7. Cover with plastic wrap and let stand for 10 days or 30 days minimum. Samples poured and stored outdoors in the shade (June 25/26 to Aug 23).
8. After hydration period, drain off fluid, and cut 3 – 215 mm compression test samples from the bottom of each 1.2 m fluid environment sample using a masonary wheel on a cut off saw. Keep the bottom 215 mm section for placement method evaluation. Use the next two 215 mm samples for the early compression test. Cut PVC pipe to expose cement.
9. Seal the end of the remainder of the original 1.2 m lengths, top with fluid and reseal the top to continue the hydration test for the next compression test date.
10. On 215 mm samples intended for early compression testing, polish cement sample ends square and perform compression test as per CSA A23.2-9C standard.

Compression Test Samples – Placing Cement With Funnel And Hose (Tubing Placement)


Fluid Environment Test - Dump Bailer

Compression Test Samples – Placing Cement With Dump Bailer

Compression Test Samples – Cutting Sample With Masonary Cut Off Wheel



Compression Test Samples – Cut Pattern On 1.2 m PVC Pipe

Fluid Environment Test (June – Aug, 2011) - Placement Method Effectiveness – Tubing Placement vs Dump Bailing

In this test, we saved the bottom 210 mm of each sample to view the placement method effectiveness. All samples showed complete displacement of the fluid environment at the bottom of the PVC test samples.

Bottom View Of Tubing Placed (Labelled TBG) & Dump Bailed (Labelled DB) Samples

Bottom View Of Tubing Placed (Labelled TBG) & Dump Bailed (Labelled DB) Samples

Bottom View Of Tubing Placed (Labelled TBG) & Dump Bailed (Labelled DB) Samples

There were voids left along the side of the samples in both the tubing placement and dump bail placement methods.

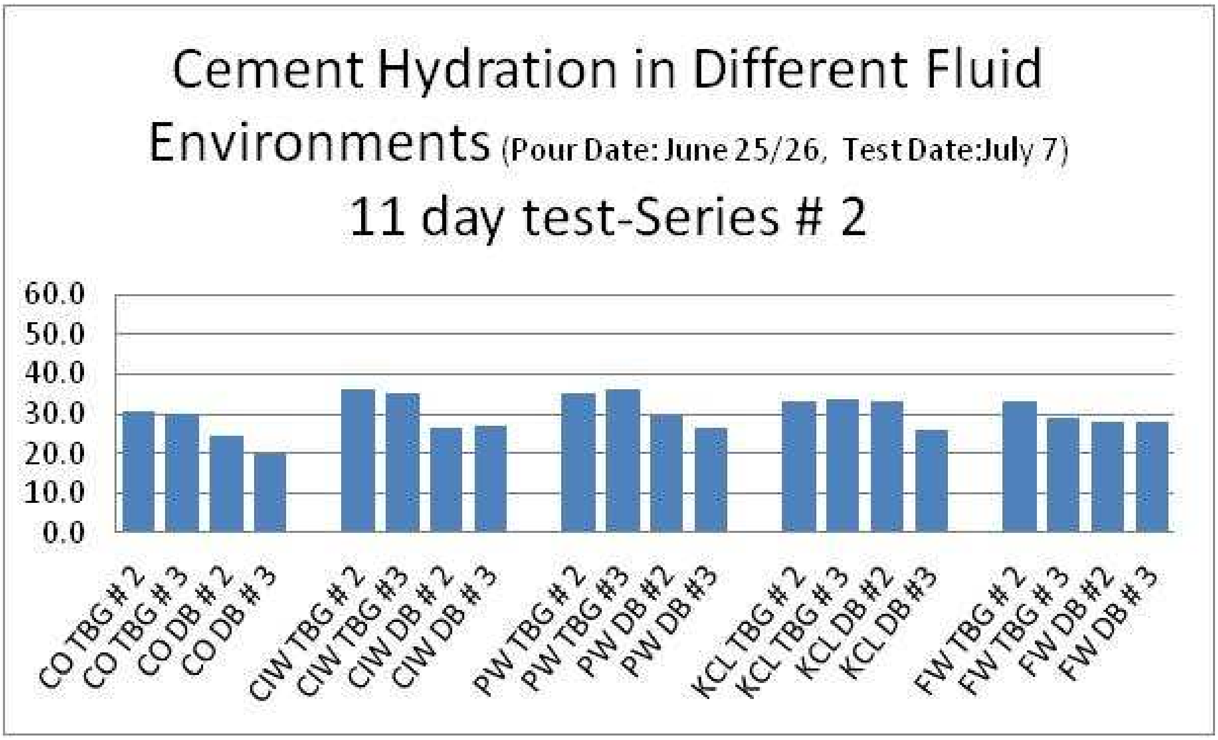
In the tubing placement method this may have been caused by the tubing laid against the side of the PVC where the fluid was not completely displaced by cement (similar to uncentralized casing in a well primary cement job.

In the dump bail placement method this may have been caused by the dump bailer dragged along the side of the PVC pipe on the way in, carrying the test fluid down with it.

Tubing Placement In Corrosion Inhibited And Produced Water Showing Voids Along Side. Cut From Samples 860 to 1075 mm From Bottom Of Test Sample (Near Top Of Sample)

Fluid Environment (June – Aug, 2011) - Compression Test Results

Test results are shown on the following graphs. In both the 11 day and 60 compression tests, a wide variation of compressive strengths was measured, with the crude oil samples being slightly lower than the others. 30 day compression tests could not be performed due to lab personnel on holidays. Not all environment samples had sufficient cement to perform the 60 day tests.



CO – Crude Oil

CIW – Corrosion Inhibited Water

PW – Produced Water

KCL – 3% KCL Fresh Water

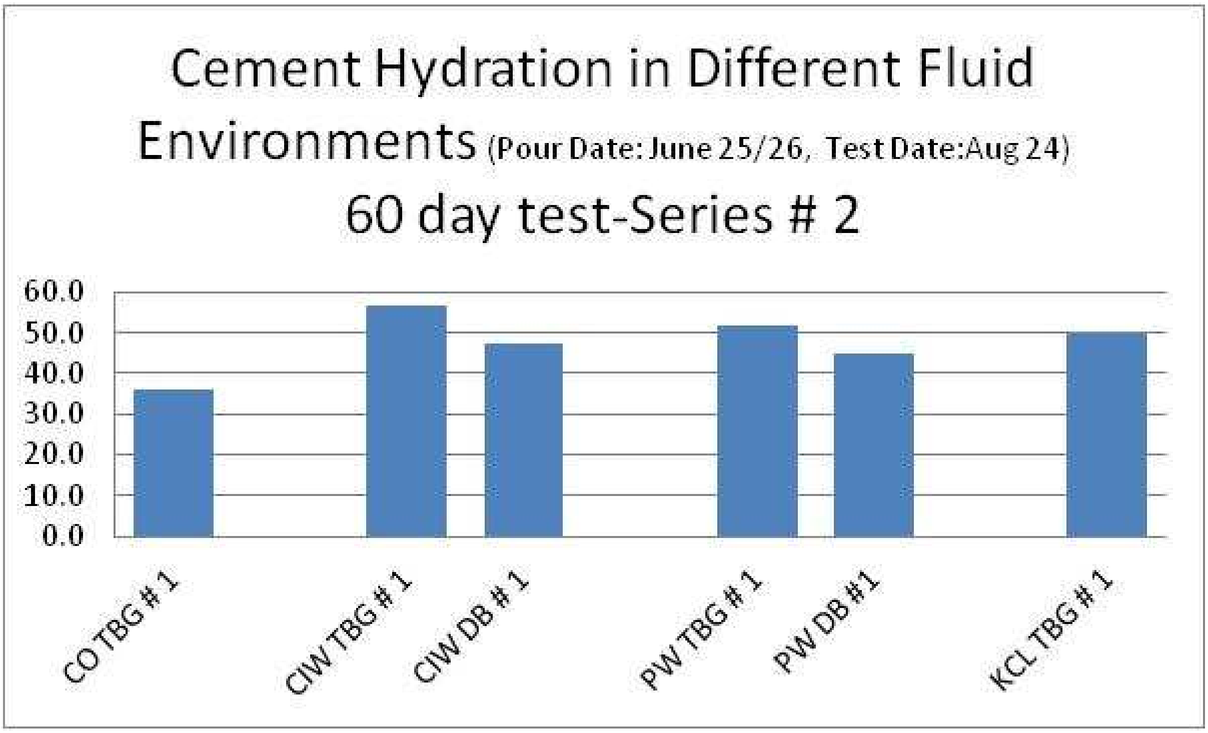
FW – Fresh Water

TBG – Tubing Placement Method

DB – Dump Bail Placement Method

#2 – Sample #2 as per page 43 of this report

#3 – Sample #3 as per page 43 of this report



The variation of compressive strengths, even within the same fluid environments may have been caused by mixing cement in a low energy mixer with resultant unmixed particles (small fish eyes). Depending upon the quantity of these particles, the compression tests could have been affected.

The crude oil samples were darker in color inside once broken, indicating possible crude oil contamination into the water based cement slurry. This may have been the reason for weaker samples in the 40 day tests. The other fluids showed some discoloration due to the fluid environment, but not as much as the crude oil.

Crude Oil (CO) and Corrosion Inhibited Water (CIW) 60 day Compression Test Samples

Note the oil staining within the Crude Oil Sample.

Note the small dark particles within the cement showing less than perfect mixing of the cement using a low energy rotary mixer.

KCL and Produced Water (PW) 60 day Compression Test Samples

Note the small dark particles within the cement showing less than perfect mixing of the cement using a low energy rotary mixer.

Observations / Conclusions

The test results and conclusions are as follows:

1. Pressure Test Cement Plug Objective:

Determine minimum cement plug length (+/- 0.5 meters) to hold 7 MPa in 114mm, 139mm and 177.8 mm casing for 60 minutes minimum. Samples to have radial, external pressure balanced support. A failure is determined by any leakage past the cement plug, or cement plug movement.

Leakage past cement plugs of 0.5, 1.0, and 1.5 m occurred in all the 114, 139 and 178 mm casing samples tested. A 2.0 m long plug was tested in the 178 mm casing size and this proved to be the quickest sample to leak. The leaks seemed to travel in a linear path along one side of the cement plug.

Length did not seem to affect the leak rate since the quickest leak occurred in a 2.0 m long plug and one of the 0.5m long plugs displayed one of the slowest leak rates.

All test samples were of a pressure balanced design with equal pressure on the inside and outside of the casing. The pressure balance design was utilized to eliminate casing expansion, due to internal pressure, as a reason for a leak past the cement plug.

Only one plug moved and it moved 2 mm. This was a 1.5m long plug in 178 mm casing. Reasons for this movement are not known.

Based on these results, it is unclear whether longer plug lengths could contain 7000 kPa without leakage. It is believed however, that longer plug lengths would eliminate the possibility of cement plug movement.

Longer samples were not tested due to fabrication, handling and environmental control issues. It was believed that longer samples would create potential flexing problems when handled, which may compromise the results.

2. TEST PLUGS IN WELLBORE FLUID ENVIRONMENTS

Observe and measure the 10 day and 30 day compressive strength of Oilwell Class "G" neat cement, with a density of 1900 kg/m3. These cement samples are to be hydrated in typical wellbore fluid environments that could have a detrimental impact by contaminating the cement or altering its chemistry. These environments are fresh water, fresh water with corrosion inhibitor, produced water, 3% KCL water, and crude oil. Cement to be placed in these different fluid environments using through tubing and dump bailing methods.

Compressive strength of samples increased with hydration time regardless of the fluid environment.

The crude oil environment caused a small reduction in compressive strength, while the other fluids tested were about equal. The crude oil samples showed oil staining within the broken test samples.

There was a significant variation in compressive strengths even using the same placement method in the same fluid. This is attributed to utilization of a low energy rotary cement mixer resulting in less than perfect mixing. Small particles were visible within the broken compression test samples. These are small particles of cement (fish eyes) that were not blended with enough water.

The tubing placement and dump bailing methods employed showed good displacement of the wellbore fluid environment at the bottom of the samples. Some wellbore fluid voids were evident along the sides of some of the samples placed by tubing and dump bailing. These were believed to be caused by the tubing lying against the pipe wall, and by the dump bailer sliding down along the tubing wall and dragging wellbore fluid into the cement.