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October 26, 2010

**NATIONAL COMMISSION ON THE
BP DEEPWATER HORIZON OIL SPILL AND OFFSHORE DRILLING
CEMENT TESTING RESULTS**

MR. SAMBHAV N. "SAM" SANKAR

This report summarizes the results of the testing conducted in the cementing laboratory at Chevron's Briarpark facility at the request of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling.

We conducted these tests using samples of cement and additives supplied by Halliburton and sent to the Chevron laboratory at the request of the Commission. To our knowledge, these materials were supplied by Halliburton as representative of materials used on the Deepwater Horizon but are neither bulk plant samples nor rig samples from the actual job.

The mud sample used in the contamination testing described in this report was supplied by MI Swaco at the Commission's request. It is a sample of drilling fluid from an actual drilling operation (i.e. not laboratory-prepared nor taken from a freshly-built mud in a liquid mud plant). MI Swaco supplied an analysis (mud check) with the sample, and a similar suite of tests were run in the Chevron drilling fluids laboratory to confirm the fluid characteristics. Both the MI Swaco results and the Chevron results compare reasonably well with the field mud check #79 dated April 19, 2010. Copies of the mud reports are contained in the Appendix.

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The testing was based on the Halliburton laboratory report dated April 12, 2010 and contained in Appendix J of the BP report *Deepwater Horizon Accident Investigation Report, September 8, 2010*, Appendix J. Most of the tests were conducted using multiple protocols. API and ISO cementing standards are, for the most part, technically identical standards which allow latitude in test procedures. The Halliburton report does not contain sufficient information to determine the exact test protocol used in the Halliburton lab in all cases. Halliburton elected not to provide additional information clarifying its testing protocols that was requested through the Commission. Therefore, a range of test procedures was selected to encompass a variety of test conditions.

Many of the test results were in reasonable agreement with those reported by Halliburton. However, we were unable to generate stable foam with any of the tests described in Section 9 of this report.



Craig Gardner

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Section 1: Thickening Time

Two test schedules were used:

- (1) 135°F reached in 83 minutes with 14,458 psig
- (2) 135°F reached in 230 minutes with 14,458 psig

Schedule (1) is taken from the Halliburton report. In schedule (2), the time-to-temperature is lengthened to correspond to the time-to-bottom from the Opticem simulation dated April 18, 2010.

Table 1: Thickening Time Test Results

| Test Schedule | Laboratory | Test Identifier | 30 B _c (hh:mm) | 40 B _c (hh:mm) | 50 B _c (hh:mm) | 70 B _c (hh:mm) |
|---------------|-------------|-----------------|------------------------------|------------------------------|------------------------------|------------------------------|
| 1 | Halliburton | 73909/2 | 07:25 | 07:34 | 07:36 | 07:37 |
| 1 | Chevron | 100432-6 | 08:11 | 08:14 | 08:16 | 08:18 |
| 2 | Chevron | 100431-5 | 08:14 | 08:17 | 08:18 | 08:20 |

Section 2: Mud Balance

Density of the base slurry was confirmed with a pressurized fluid density balance using the method described in Clause 6 of API RP10B-2/ISO10426-2.

Table 2: Pressurized Mud Balance Results

| Laboratory | Test Identifier | Slurry Density (lbm/gallon) |
|-------------|--------------------------------|-----------------------------|
| Halliburton | 811529 | 16.7 |
| Chevron | 100431-5 foamed weigh up sheet | 16.7 |

Section 3: Mixability

The slurry was prepared according to Clause 5 of API RP10B-2/ISO10426-2.

Halliburton's report rated the slurry mixability as a "4" on a scale of 1 to 5, with zero being assigned to a slurry which is deemed unmixable.

Chevron rated the slurry as mixable using a combination of factors:

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The dry powder was incorporated into the mix fluid easily in 12-18 seconds depending on the particular test.

The blender consistently achieved 12,000 rpm and good slurry vortices were observed.

However, sedimentation was noted in the blender bowl.

The initial consistency of the slurry was 13 - 18 B_c depending on the particular test. For context, Chevron uses an initial consistency value of 35 B_c (maximum) as a mixability "flag".

Section 4: Fluid Loss and Free Fluid Testing

Halliburton did not report these tests. They were included in the present testing program because un-foamed cap and shoe track slurries were pumped on the job.

The slurries were conditioned in a high-temperature, high-pressure consistometer according to the same test schedules used for the thickening time testing.

The fluid loss tests were conducted according to API RP10B-2/ISO 10426-2 Clause 10, using a "short cell" fluid loss apparatus.

The free-fluid tests were conducted according to API RP10B-2/ISO 10426-2 Clause 15.5, using the ambient temperature static period. The free-fluid tests were conducted with the 250-mL graduated cylinder inclined at 45 degrees and 90 degrees (vertical). The results are found in Table 3.

Table 3: Fluid Loss and Free Water Results

| Test Schedule | Conditioning | Test Identifier | Fluid Loss (mL/30 min) | Free Fluid (90° vertical) | Free Fluid (45° angle) |
|---------------|--------------|-----------------|------------------------|---------------------------|------------------------|
| 1 | HTHP | 100432-6 | 578 | 1.6 percent | 2 percent |
| 2 | HTHP | 100431-5 | 456 | zero | Channel present |
| 1 | Atmospheric | 100432-6 | Not Run | Settling ¹ | 8.8 percent |

¹Slurry sampled from the top of the graduate weighed 15.96 lbm/gal. Slurry sampled from the bottom of the graduate weighed 17.4 lbm/gal

Section 5: UCA Compressive Strength

The sonic compressive strength of the base slurry was measured according to Clause 8 of API RP10B-2/ISO10426-2, using an ultrasonic cement analyzer. Three testing schedules were used:

- 1) Heat to 135°F in 83 minutes with 14,458 psig (thickening time schedule), condition for a total elapsed time of 3 hours from initial application of temperature and pressure, remove from the consistometer and place in a pre-heated 135°F UCA and

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heat from 135°F to 210°F in 4 hours with a confining pressure of 14,458 psig. Data are presented using both algorithm B and the foamed-cementing algorithm.

- 2) Heat to 135°F in 83 minutes with 14,458 psig (thickening time schedule), condition for a total elapsed time of 3 hours from initial application of temperature and pressure, remove from the consistometer and place in a pre-heated 135°F UCA and heat from 135°F to 180°F in 4 hours with a confining pressure of 14,458 psig (this procedure was intended to allow a comparison with the crushed foamed cube data). Data are presented using both algorithm B and the foamed-cementing algorithm.
- 3) The slurry was conditioned for 3 hours in an atmospheric consistometer at 135°F. Starting with a cold cup, place in the atmospheric consistometer and ramp temperature to 135°F as quickly as possible. Remove from the consistometer and place in a pre-heated 135°F UCA and heat 135°F to 210°F in 4 hours with a confining pressure of 14,458 psig. Data are presented using both algorithm B and the foamed-cementing algorithm.

The results are summarized in the Table 4. Copies of the test charts are found in the Appendix. The effect of drilling fluid contamination on sonic strength development is described in Section 11.

Table 4: UCA Compressive Strength Development

| Laboratory | Schedule | Pressure | 50 psi (hr:min) | 500 psi (hr:min) | 12 hour (psi) | 24 hour (psi) | 48 hour (psi) | Final (psi) |
|-------------|---|----------|--------------------|---------------------|---------------------|---------------------|---------------------|-------------------|
| Halliburton | Circulate 3 hours before pouring | 14,458 | 08:12 | 08:40 | 2301 | 2966 | 3099 | --- |
| Chevron | Protocol 1 (B algorithm) | 14,458 | 05:57 | 06:24 | 2945 | 3550 | 3831 | 3918@108 hrs |
| Chevron | Protocol 1 (foam algorithm) | 14,458 | 06:01 | 06:40 | 1040 | 1155 | 1206 | 1221@108 hrs |
| Chevron | Protocol 2 (B algorithm) | 14,458 | 09:58 | 10:47 | 1302 | 3001 | 3541 | 3760@108 hrs |
| Chevron | Protocol 2 (foam algorithm) | 14,458 | 10:03 | 11:25 | 643 | 1050 | 1153 | 1193 @ 108 hrs |
| Chevron | Protocol 3 (B algorithm) | 14,458 | 06:31 | 06:59 | 3152 | 3976 | 4481 | 4575 @ 73 hrs |
| Chevron | Protocol 3 (foam algorithm) | 14,458 | 06:35 | 07:15 | 1078 | 1232 | --- | 1232 @ 24 hrs |

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Section 6: Crush Compressive Strength

The plan was to replicate the crushed cube compressive strength values reported in the Halliburton report with the test ID 806069.

A Humboldt Manufacturing Company Model 2820 3-gang, 2-inch brass mold was prepared according to API RP10B-4/ISO 10426-4. The molds were sealed with gasket material to allow curing in an atmospheric pressure water bath at 180°F.

After 48 hours curing, the samples were removed from the molds and were observed to have lost approximately one-half inch of their original two-inch height (photographs in Appendix). Therefore, no further tests were conducted.

Section 7: FYSA Viscosity Profile and Gel Strength

The Fann Yield Stress Adapter is a proprietary Halliburton test device that replaces the bob and sleeve in a Fann 35-type rotational viscometer. The device and test method are described in SPE 133050, *Techniques for the Study of Foamed Cement Rheology*, Olowolagba and Brenneis, 2010.

This test was not performed during the present study because a stable foam could not be obtained as described in the Section 9 on foamed stability testing. Table 5 contains only Halliburton-reported results.

Table 5: FYSA Viscosity Profile

| Laboratory | Temperature | 600 rpm | 300 rpm | 200 rpm | 100 rpm | 60 rpm | 30 rpm | 6 rpm | 3 rpm |
|---------------------------------|-------------|---------|---------|---------|---------|--------|--------|-------|-------|
| Halliburton (Test ID 806074) | 80°F | 14 | 7 | 5 | 3 | 1 | 1 | 1 | 1 |

6D=1, 3D=1

The FYSA viscosity profile is measured using a different instrument and procedure than the rotor-and-bob configuration described in API RP10B-2/ISO 10426-2, Clause 12. The FYSA viscosity profile cannot be compared with the rheological results that follow in Section 8, Table 6 because of the differences in test methodology and instruments.

Section 8: Rheological Profile Measurements

The rheological values reported in Table 6 were measured using a direct-reading rotational viscometer as described in API RP10B-2/ISO 10426-2, Clause 12. A variety of conditioning methods and measurement sequences were used.

Table 6: Rheological Profile Measurements

| Laboratory | Test Conditions | 600 rpm | 300 rpm | 200 rpm | 100 rpm | 60 rpm | 30 rpm | 20 rpm | 10 rpm | 6 rpm | 3 rpm |
|-------------------------|-----------------|---------|---------|---------|---------|--------|--------|--------|--------|-------|-------|
| Halliburton (ID 806075) | Note 1 | 180 | 84 | 56 | 28 | 26 | 8 | 6 | 4 | 2 | 2 |
| Chevron | Note 2 | 164 | 78 | 52 | 26 | 16 | 8 | 6 | 4 | 2 | 2 |
| Chevron | Note 2 (rerun) | 180 | 80 | 58 | 26 | 16 | 8 | 6 | 4 | 2 | 2 |
| Chevron | Note 3 | 136 | 69 | 45 | 25 | 16 | 10 | 8 | 6 | 6 | 4 |
| Halliburton (ID 806075) | Note 4 | 130 | 56 | 40 | 20 | 12 | 8 | 6 | 4 | 4 | 2 |
| Chevron | Note 5 | 124 | 57 | 38 | 23 | 16 | 11 | 9 | 8 | 6 | 4 |
| Chevron | Note 6 | 176 | 92 | 64 | 36 | 24 | 14 | 12 | 8 | 6 | 4 |
| Chevron | Note 7 | 120 | 76 | 56 | 32 | 22 | 14 | 12 | 10 | 8 | 6 |

¹80°F – Slurry Conditioning Unknown

²80°F – Slurry as mixed – no conditioning, measure and record 300 rpm to 3 rpm readings, then measure and record 600 rpm reading

³80°F – Slurry as mixed – no conditioning, measure and record 3 rpm to 300 rpm to 3 rpm readings, then measure and record 600 rpm reading. Report the average values for the 3 rpm to 300 rpm readings. (RP10B-2/ISO 10426-2 Clause 12)

⁴135°F – Slurry Conditioning Unknown

⁵135°F Condition for 30 minutes in atmospheric consistometer. Take measurements from 3 rpm to 300 rpm to 3 rpm and average. Take 600 rpm reading last

⁶135°F Condition in an HTHP consistometer for 83-minute heat-up plus 30 minutes additional conditioning. Take measurements from 600 rpm to 3 rpm

⁷135°F Condition in HTHP consistometer for 230-minute heat-up. Take measurements from 600 to 3 rpm

Section 9: Foam Mixing and Stability

A series of nine tests were conducted under varying conditions as described below. Each test consisted of multiple measurements. API RP10B-4 and ISO 10426-4 are silent on the matter of slurry conditioning so several conditioning methods were used. None of the tests produced a stable foam. Foamed stability was assessed using several methods:

- a) Visual inspection of the fluids: base slurry and foamed slurry
- b) Density measurements of slurry sampled from the blender
- c) Density measurement of slurry sampled from graduated cylinder after a 2-hour quiescent period according to API RP10B-4/ISO 10426-4 Clause 9.3.1.
- d) Density measurement by Archimedes' Principle of samples cured in PVC molds at 180°F according to API RP10B-4/ISO 10426-4 Clause 9.3.3.

The tests are described briefly below and the density measurements summarized in Table 7.

Test 1. Target design foamed density: 14.5 lbm/gal. The slurry was foamed immediately after mixing (no conditioning). The slurry was foamed with a multi-blade assembly (API RP10B-4/ISO 10426-4 Clause 5) for 15 seconds @ 12,000 rpm. A density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be below the designed density. Settling was noted in both the base slurry and the foam so the stability tests in the graduated cylinder and the PVC tubes were not performed. Density measurements were recorded from slurry sampled from the top, bottom and middle of the mixing blender. The results are reported in Table 7.

Test 2. Target design foamed density: 14.5 lbm/gal. Because of the instability noted in the base slurry and foamed slurry in Test 1, the test procedure was modified. Slurry quantities were adjusted to allow mixing and foaming in the same blender. This eliminated the need to transfer slurry from the mixing blender to the foaming blender thereby avoiding the effects of sedimentation in the base slurry. The slurry was foamed for 15 seconds @ 12,000 rpm using the single blade assembly (API RP10B-4/ISO 10426-4 Clause 5). A density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be below the designed density. Settling was again noted in both the base slurry and the foam, so the stability tests in the graduated cylinder and the PVC tubes were not performed. Density measurements were recorded from slurry sampled from the top, bottom and middle of the mixing blender. The results are reported in Table 7.

Test 3. This was a repeat of Test 1 except that the graduated-cylinder and PVC-mold stability tests were performed. Target design foamed density: 14.5 lbm/gal. The slurry was foamed with a multi-blade assembly (API RP10B-4/ISO 10426-4 Clause 5) for 15 seconds @ 12,000 rpm. A density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be below the designed density. The stability tests in the graduated cylinder and PVC molds were conducted. The results are shown in Table 7.

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Test 4. This was the first test to include slurry conditioning. The target design density was 14.5 lbm/gal. The slurry was conditioned on an atmospheric consistometer for 20 minutes at 110°F (one of the schedules reported by Cementing Solution Inc. for their tests – Appendix K of the BP report). The slurry was foamed with a multi-blade assembly for 15 seconds @ 12,000 rpm. The density was found to be low. Settling was observed in the base and foamed slurry. The stability tests in the graduated cylinder and PVC molds were conducted. The results are reported in Table 7.

Because the measured foam density continued to be low, the laboratory calculations and the density of the base slurry were verified. API RP10B-4/ISO 10426-4 Clause 7.2 describes a method for determining an “offset factor” if the foam density is less than the design density. In this case, the offset factor was 0.4 lbm/gal. In an attempt to attain a foam density of 14.5 lbm/gal, the target foam density was 14.9 lbm/gal in subsequent tests.

Test 5. This test was performed using the offset factor calculated during Test 4. In an attempt to attain a foam density of 14.5 lbm/gal, the target foam density was 14.9 lbm/gal. The slurry was foamed immediately after mixing without conditioning. A density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be 14.9 lbm/gal.

The density attained matched the calculated value (14.9 lbm/gal) but failed to exhibit the expected drop from the offset factor (14.5 lbm/gal was expected). API RP10B-4/ISO 10426-4 Clause 7.2 (j) recommends redesigning the base slurry if the offset factor does not give the desired result. It was decided to continue with the 14.9 lbm/gal foam density for future tests as this was the value reported in the Halliburton report (specific gravity = 1.8).

The stability tests in the graduated cylinder and PVC molds were conducted. The results are reported in Table 7.

Test 6. This test began with conditioning the slurry on an atmospheric consistometer for three (3) hours at 135°F. The conditioning period matched the time reported in the Halliburton report. The offset factor density of 14.9 lbm/gal was used. The slurry was foamed with a multi-blade assembly for 15 seconds @ 12,000 rpm. Slight settling of the base slurry was noted. The density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be 14.7 lbm/gal. Stability tests in the graduated cylinder and PVC molds were conducted. The results are reported in Table 7. The density measurements from the graduated-cylinder samples were unusually high so it was decided to re-run Test 6.

Test 7. This was a repeat of Test 6. The test began with conditioning the slurry on an atmospheric consistometer for three (3) hours at 135°F. The conditioning period matched the time reported in the Halliburton report. The offset factor density of 14.9 lbm/gal was used. The slurry was foamed with a multi-blade assembly for 15 seconds @ 12,000 rpm. Slight settling of the base slurry was noted. The density check of a sample of the foamed cement in a plastic cube of known volume again showed the density to be 14.7 lbm/gal. Stability tests in the graduated

cylinder and PVC molds were conducted. The results are reported in Table 7. The results of Test 7 are in reasonable agreement with those of Test 6.

Density measurements from the graduated-cylinder samples were again high but a careful examination of the volume in the graduated cylinder indicated an approximate 10 mL reduction at the end of the 2 hour quiescent period. This reduction alone would account for a density increase from the initial 14.7 lbm/gal to 15.3 lbm/gal.

Test 8. This was a repeat of Test 7 using a mill sample of Lafarge Class H cement obtained from the manufacturer rather than the cement sample from Halliburton. The additives supplied by Halliburton for the Commission testing were used so the only change was the cement sample.

The test began with conditioning the slurry on an atmospheric consistometer for three (3) hours at 135°F. The conditioning period matched the time reported in the Halliburton report. The offset factor density of 14.9 lbm/gal was used. The slurry was foamed with a multi-blade assembly for 15 seconds @ 12,000 rpm. The density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be 14.0 lbm/gal. Stability tests in the graduated cylinder and PVC molds were conducted. The results are reported in Table 7. The performance was not improved by the change in cement sample.

Test 9. Test 9 was a repeat of Test 6 and Test 7 and achieved similar results. The test began with conditioning the slurry on an atmospheric consistometer for three (3) hours at 135°F. The conditioning period matched the time reported in the Halliburton report. The offset factor density of 14.9 lbm/gal was used. The slurry was foamed with a multi-blade assembly for 15 seconds @ 12,000 rpm. Slight settling of the base slurry was noted. The density check of a sample of the foamed cement in a plastic cube of known volume showed the density to be 14.64 lbm/gal. Stability tests in the graduated cylinder and PVC molds were conducted. The results are reported in Table 7. Tests 6, 7, and 9 are in reasonable agreement.

Table 7: Foamed Cement Stability Testing

| Test Number | Density from Blender lbm/gal | | | Density from Graduated Cylinder lbm/gal | | | Density from PVC Molds lbm/gal | | | |
|-------------|---------------------------------|--------|--------|---|--------|--------|-----------------------------------|--------|--------|--------------------------|
| | Top | Middle | Bottom | Top | Middle | Bottom | Top | Middle | Bottom | Very Bottom ¹ |
| 1 | 12.77 | 13.38 | 14.06 | NR | NR | NR | NR | NR | NR | NR |
| 2 | 13.89 | 12.95 | 14.16 | NR | NR | NR | NR | NR | NR | NR |
| 3 | NR ² | NR | NR | 10.23 | 12.21 | 13.34 | 11.7 | 13.30 | 14.10 | NR |
| 4 | 13.82 | NR | 14.13 | 13.67 | 14.14 | 14.41 | 11.96 | 11.84 | 11.80 | 12.13 |
| 5 | 14.95 | NR | NR | 13.70 | 14.22 | 14.98 | 13.97 | 13.82 | 13.96 | 14.73 |
| 6 | 14.66 | NR | NR | 15.85 | 16.09 | 16.30 | 12.80 | 12.86 | 13.07 | 12.51 |
| 7 | 14.71 | NR | NR | 14.99 | 16.11 | 16.43 | 12.16 | 13.15 | 13.79 | 13.70 |
| 8 | 14.04 | NR | NR | 9.80 | 15.84 | 16.83 | 14.05 | 18.27 | 19.14 | 19.87 |
| 9 | 14.64 | NR | NR | 15.75 | 16.25 | 16.51 | 12.91 | 13.39 | 14.17 | 14.63 |

¹The notation "very bottom" refers to the portion of cement contained predominately in the end cap of the PVC fixture.

²NR = Not Run

Section 10: Effect of Mud Contamination on Un-foamed Slurry Sonic Strength Development

The effect of drilling-fluid contamination on unfoamed slurry sonic strength development was measured according to API RB10B-2/ISO 10426-2 Clause 16.5, using an ultrasonic cement analyzer (UCA) at 210°F and 14,458 psig. Drilling-fluid concentrations of 0%, 5%, 10%, 15%, 20%, 25%, and 30% by volume were used. Note that the dilutions are noted "by volume" but were prepared in the laboratory by mass for greater accuracy (rather than mixing by volume using beakers or similar containers). The final sonic strength decreased as drilling fluid contamination increased, but the time required to achieve 100 psig sonic strength was not greatly affected.

Table 8: Drilling Fluid Contamination of Base Slurry

| Contamination % | 50 psi (hr:min) | 100 psi (hr:min) | 500 psi (hr:min) | 12 hour (psi) | 24 hour (psi) | 48 hour (psi) | Final (psi) |
|-----------------|-----------------|------------------|------------------|---------------|---------------|---------------|-------------|
| 0 | 2:49 | 8:43 | 9:21 | 2584 | 3718 | 4414 | 4210 |
| 5 | 4:02 | 7:28 | 8:04 | 2170 | 2792 | 3090 | 3160 |
| 10 | 5:07 | 7:42 | 8:24 | 2089 | 2612 | 2763 | 2763 |
| 15 | 8:36 | 8:45 | 9:26 | 1203 | 1541 | 1649 | 1717 |
| 20 | 8:09 | 8:16 | 9:12 | 890 | 1071 | 1126 | 1117 |
| 25 | 8:04 | 8:12 | --- | 271 | 322 | 343 | 345 |
| 30 ¹ | 3:55 | 7:25 | 8:37 | 717 | 814 | 837 | 828 |

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¹The 30 percent contamination test was repeated 3 times because it was difficult to maintain a homogenous mixture of drilling fluid and cement slurry at this contamination level. The strength results did not follow the final strength trend.

²500 psi sonic strength was not obtained at this contamination level.

Section 11: Stability of Foamed Cement with Mud or Spacer Contamination

The original plan included evaluating the effect of drilling fluid or spacer contamination on foamed cement stability by two methods:

- 1) Stirring 5, 10, and 15 percent volume of drilling fluid or spacer into the foamed cement slurry in a manner similar to the CSI testing contained in the BP report.
- 2) Coating the interior of the 250-mL graduated cylinder used for the foam stability test with mud or spacer, then adding the foamed cement and evaluating the effect.

Neither test series was conducted due to the inability to generate stable foams.

Section 12: Static Gel Strength Development

The static gel strength of the base slurry was tested using two methods:

Static Gel Strength Analyzer (ultrasonic method). The slurry was conditioned in an HTHP consistometer. The slurry was heated to 135°F in 83 minutes with 14,458 psig as described in ISO 10426-6. Test conditions were maintained at 135°F and 14,458 psig for 162 minutes, for a total of 245 minutes (Job Placement Time). The slurry was then removed and placed in a 135°F pre-heated SGSA with 14,458 psig.

Multiple Analysis Cement Slurry (MACS II). The slurry was conditioned in the MACS II. The slurry was heated to 135°F in 83 minutes with 14,458 psig as described in API RP10B-6/ISO 10426-6. Test conditions were maintained at 135°F and 14,458 psig for 162 minutes, for a total of 245 minutes (Job Placement Time) before beginning the static gel strength development period.

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Table 9: Static Gel Strength Development

| Instrument | Time to 100 lbf/100 ft ² gel strength | Time to 500 lbf/100 ft ² gel strength | Transition Time |
|-------------------|---|---|-----------------|
| SGSA | 2:17:30 | 3:44:00 | 1:26 |
| MACS ¹ | 4:04:00 | 4:41:00 | 0:37 |

¹The MACS data may not be correct due to the sedimentation exhibited by the base slurry.

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Appendix

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| Drilling Fluid – Cement Contamination UCA Charts | Figures 20 - 26 |

| MI SWACO | | SYNTHETIC-BASED MUD REPORT No. 79 | | | |
|--|--|--|--|---------------------------------|--|
| Operator : BP Exploration | | Field/Area : MC 252 #1 | | Depth/TVD : 18360 ft / 18349 ft | |
| Report For : B. Kalhuzo Vidrine | | Description : OCS-G 32306 | | Date : 4/19/2010 | |
| Well Name : MACONDO | | Location : MC 252 #1 | | Spud Date : | |
| Contractor : Transocean | | Water Depth : 4992 ft | | Mud Type : Rheasant | |
| Report For : J. Harrel | | Rig Name : Horizon | | Activity : Displace Cement | |
| DRILLING ASSEMBLY | | CASING (TVD) | | MUD VOLUME (bbl) | |
| 5056 ft 5.525-in DP | | 22-in Ø 8001 ft (8061 TVD) | | Hole : 2536 | |
| ft-in | | 10-in Ø 8969 ft (8969 TVD) | | Active Pits : 1959 | |
| ft-in | | 16-in Ø 11585 ft (11585 TVD) | | Total Circulating Volume : 3547 | |
| ft-in | | 13.825-in L Ø 13145 ft (13134 TVD) | | Depth Drilled Last 24hr : 8 | |
| ft-in | | 11.875-in L Ø 16113 ft (16103 TVD) | | Volume Drilled Last 24hr : 801 | |
| ft-in | | 9.875-in L Ø 17173 ft (17162 TVD) | | | |
| ft-in | | 7-in L Ø 18112 ft (18301 TVD) | | | |
| Notes: 1464 3/32" Ø 8.5-in Hughes HC-DBXC | | | | | |
| | | MUD PROPERTIES | | CIRCULATION DATA | |
| Sample From : Active 21.00 | | Active 5.00 | | Pump Rate : 600 GPM | |
| Flow Line Temp : °F | | NA | | Pump Pressure : 650 | |
| Depth/TVD : ft | | 18360/18349 | | Pump Liner : 8x15 in | |
| Mud Weight : lb/gal | | 14.5/14.5 | | Pump Capacity : gal/min | |
| Fennel Viscosity : cP | | 94 | | Flow Rate : gal/min | |
| Rheology Temp : °F | | 150 | | Pump Status : ON | |
| RSGR-300 : 1/32 | | 104.3 | | Pump Pressure : psi | |
| RSGR-100 : 32/32 | | 32/31 | | Total Circulation : 3547 | |
| RSGR : 10/9 | | 10/9 | | | |
| PV : cP | | 29 | | | |
| YP : lb/100ft² | | 15 | | | |
| 100/100m Gel : lb/100ft² | | 14.2/14.2 | | | |
| API Fluid Loss : cc/30min | | - | | | |
| HTHP Fluid Loss : cc/30min | | 2.4/2.5 | | | |
| Cake API : 1/32 | | 27 | | | |
| Unc. Ret Solids : %Vol | | 27 | | | |
| Correct Solids : %Vol | | 25.15 | | | |
| Synthetic : %Vol | | 52.5 | | | |
| Uncont. Water : %Vol | | 20.5 | | | |
| Synthetic/Water Ratio : 72/28 | | 72/28 | | | |
| Akal Mud (Spm) : 0.0 | | 0.0 | | | |
| Dr. Whole Mud : mg/L | | 27000 | | | |
| SST : mN | | 17.09 | | | |
| Line : lb/bbl | | 1.17 | | | |
| Emul Stability : 248 | | 205 | | | |
| Current Angle : degrees | | - | | | |
| MWD Tool Temp : deg F | | - | | | |
| PWD ECD : ppb | | - | | | |
| Riser Boost : gpm | | - | | | |
| LOGSD Lepo : Y/N | | No/No | | | |
| Cable Scales : Y/N | | Yes | | | |
| SST : ppb | | 21 | | | |
| PPT : spurt/m | | 6/5.4 | | | |
| Reserve Volume : bbl | | 2011 | | | |
| REMARKS AND TREATMENT | | REMARKS | | | |
| Mudwaco Man Hours: 60 Cumulative Man Hours: 4500 Start Cards: 1 Cumulative Start Cards: 99 Max bbls discharged per hour: 0 bbls No losses while running casing. No losses while landing casing. No losses while circulating. No losses while cementing. No losses while displacing cement. 1833 bbls left behind pipe. | | Run casing with no losses and got on landing casing. RHA, RFI to 18312' with no losses. Problems with converting floats. Pressure up to 1150 psi and convert rods. Circulate with no losses. Flush chime and all lines. PU and perform cement job with no losses. Displace cement with 28M with no losses. | | | |
| TIME DISTRIBUTION Last 24 hrs | | MUD VOL ACC TO (bbl) | | SOLIDS ANALYSIS | |
| Rig Maintenance | | Synthetic Added | | SST Wt% | |
| Rolling | | Water Added | | SST Conc | |
| Tripping | | Mud Reserved | | Adjusted Solids | |
| Non-productive Yr | | Mud Retrieved | | Synthetic/Water Ratio | |
| Running Casing | | Shakers | | Average S/S Solids | |
| Condition Hols | | Gravel Type | | Low Gravity Wt | |
| Cementing | | Gravel Size | | High Gravity Wt | |
| | | Adjustment | | High Gravity Wt | |
| | | Solids Retention | | ECD at Shoe | |
| | | Displacement | | ECD at TD | |
| | | Subsidence | | | |
| | | Cementing | | | |
| | | Last Spurt Flow | | | |
| | | 10000 | | | |
| | | 800 Tank Bottom | | | |
| N-1 ENOR PHONE | | REQ PHONE | | WAREHOUSE PHONE | |
| L. Lindner/B. Manjari 0 | | (281) 256-7749 | | 800-391-2147 | |
| B. Harpoy/G. Jones/J. Guitteaux | | | | | |
| | | | | DAILY COST | |
| | | | | CUMULATIVE COST | |

Figure 1: Rig Drilling Fluid Report

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October 19, 2010

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| | | | |
|--|----------------|---|------------------|
| MI SWACO <small>A Schlumberger Company</small> | | Technical Services Laboratory – Houston, Texas | |
| | | Synthetic-Base Mud Report | |
| | | ID Code No. | 101011F.008 |
| | | Lab Master No. | 20103419 |
| Operator: | M-I SWACO | Report Date: | October 11, 2010 |
| Well Name: | N/A | Depth: | N/A |
| Location: | Pelican Island | Mud Type: | RHELIANT |
| <u>Mud Properties</u> | | <u>Initial</u> | |
| Mud Weight, ppb | 14.19 | | |
| Rheo Temp, °F | 40 | 100 | 150 |
| 600 rpm | 228 | 96 | 74 |
| 300 rpm | 122 | 56 | 46 |
| 200 rpm | 85 | 42 | 35 |
| 100 rpm | 47 | 26 | 24 |
| 6 rpm | 10 | 8 | 10 |
| 3 rpm | 8 | 7 | 9 |
| PV, cps | 116 | 40 | 28 |
| YP, lbs/100 ft² | 16 | 16 | 18 |
| 10 Second Gel | 12 | 13 | 15 |
| 10 Minute Gel | 25 | 28 | 25 |
| HTHP @ 250°F, ml | 2.4 | | |
| E.S., Vts @ 120°F | 88 | | |
| Excess Lime, ppb | 2.98 | | |
| Solids, % by Vol | 28.5 | | |
| Oil, % by Vol | 50.5 | | |
| Water, % by Vol | 21.0 | | |
| Syn/Water Ratio | 70.6/29.4 | | |
| Corrected Solids, % | 27.6 | | |
| LGS, % | 6.21 | | |
| LGS, ppb | 56.47 | | |
| HGS, % | 21.4 | | |
| HGS, ppb | 314.52 | | |
| SG Wt Material | 4.2 | | |
| CaCl₂, % by wt | 10.0 | | |
| NaCl, % by wt | 6.0 | | |
| Cl, Whole Mud | 25000 | | |
| Report by: Robert Christian | | | |
| Reviewed by: Randy Ray | | | |
| Copies to: Daryl Cullum, Ole Jacob Prebensen, Mike Freeman | | | |

Figure 2: Drilling Fluid Report Supplied by MI Swaco with Commission Mud Sample

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HAL_0502222

| NAF Mud Check | | | |
|-------------------------------------|-----------------------------|-----------------------------------|------------|
| Project #: | S10140 | Date: | 10/13/2010 |
| Rig: | Pelican Island Plant Sample | Rec'd Date: | 10/13/2010 |
| Prospect: | Tank #7 | Sample date: | 10/11/2010 |
| Well: | | Depth: | |
| Lease: | | NAF g/ml = | 0.790 |
| Properties | 80°F | 120°F | 150°F |
| Density, g/ml | 1.698 | | |
| Density, lb/gal | 14.15 | | |
| Fann dial readings: | | | |
| 500 RPM | 123 | 102 | 75 |
| 300 RPM | 70 | 60 | 45 |
| 200 RPM | 51 | 44 | 35 |
| 100 RPM | 30 | 28 | 23 |
| 6 RPM | 8 | 9 | 9 |
| 3 RPM | 7 | 8 | 8 |
| Plastic viscosity, cps | 53 | 42 | 29 |
| Yield point, lb/100 ft² | 17 | 18 | 17 |
| Gel strengths, lb/100 ft² | | | |
| 10 second | 14 | 16 | 16 |
| 10 minute | 31 | 31 | 27 |
| HTHP filtrate: 500 psig, cm³/30 min | 4.0 | @ 250°F | |
| Water, cm³ (HPHT) | 0.00 | | |
| HTHP filter cake thickness, 32nd in | 3 | | |
| Retort analysis: | | | |
| Solids, vol% | 31 | | |
| NAF, vol% | 49 | | |
| Water, vol% | 20 | | |
| NAF/water ratio | 71 / 29 | | |
| NAF mud alkalinity (PCMI) | 2.49 | | |
| Whole mud chlorides, mg/l | 23,460 | | |
| Whole mud calcium, mg/l (Filtered) | 11,086 | | |
| Electrical stability (VB) @ 120°F | 89 | | |
| Lime content, lb/bbl | 3.2 | | |
| Sand Content % | | | |
| | | Electrical stability (VB) @ 150°F | 85 |
| | | Permeability Plugging Test: | |
| | | Disc Grade, micron | 35 |
| | | Test Temp, deg F | 250°F |
| | | Diff. Pressure, psi | 2,500 |
| | | Spurt Volume, ml | 0.40 |
| | | PPT Value, ml | 7.40 |
| | | PPT Cake, 32nd | 3 |
| | | Solids Analysis | |
| Retort QA (100 +/- 3 %) | 99.24% | lb/bbl | Volume % |
| Corrected solids | | | 29.54 |
| Average specific gravity of solids | 3.62 | | |
| Low gravity solids | 98.0 | | 10.77 |
| High gravity solids | 275.8 | | 18.76 |
| Chloride content, lb/bbl | | | |
| Calcium chloride | 10.78 | | |
| Total sodium chloride | 2.22 | | |
| Soluble sodium chloride | 2.22 | | |
| Water phase salinity, ppm | 156,638 | | |
| | | Solids Analysis Constants | |
| | | barite g/ml | 4.20 |
| | | low grav g/ml | 2.66 |
| | | NAF g/ml | 0.790 |

Figure 3: Chevron Analysis of MI Swaco Commission Sample

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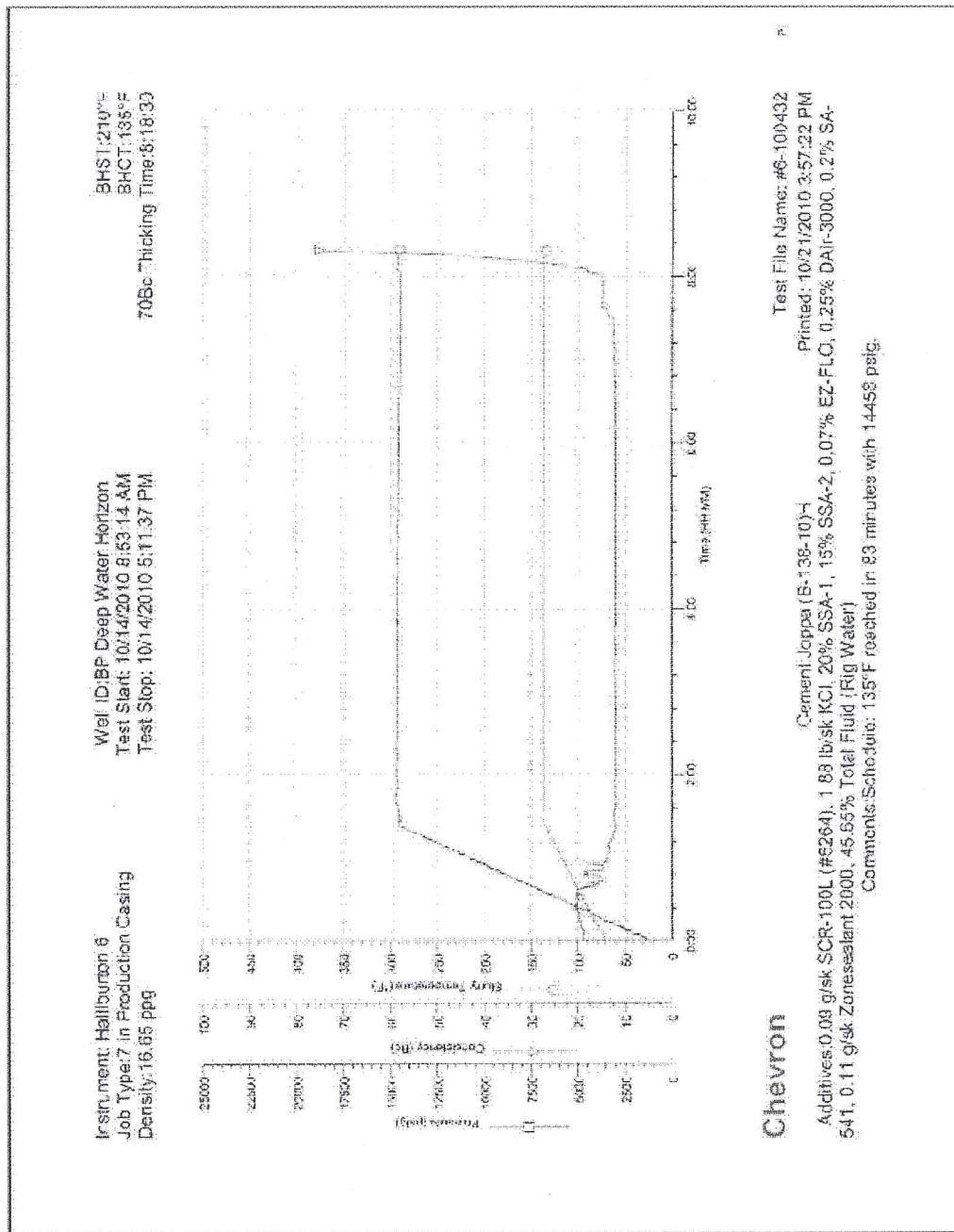


Figure 4: Thickening Time 100432-6 (82 minute heat-up)

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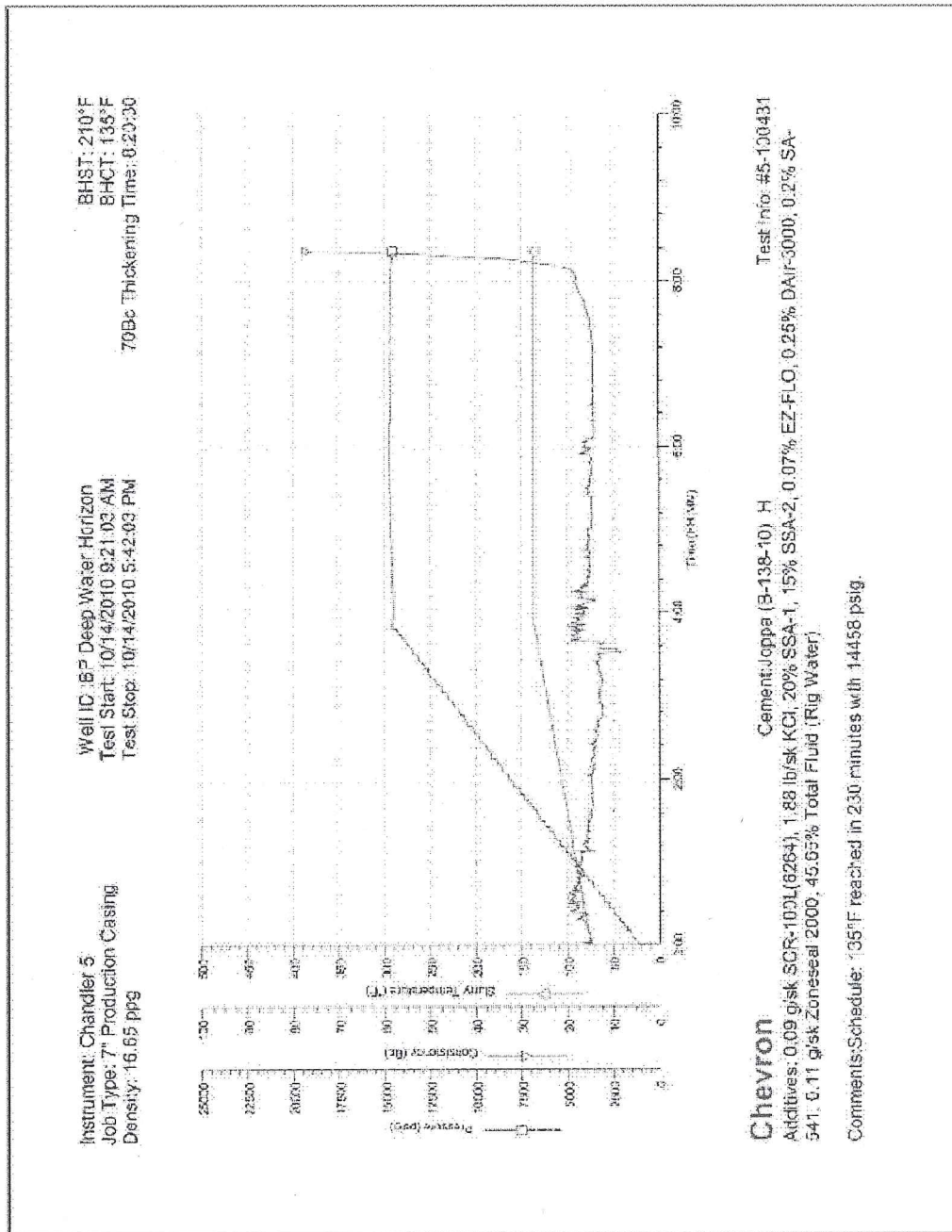


Figure 5: Thickening Time (230 minute heat-up)

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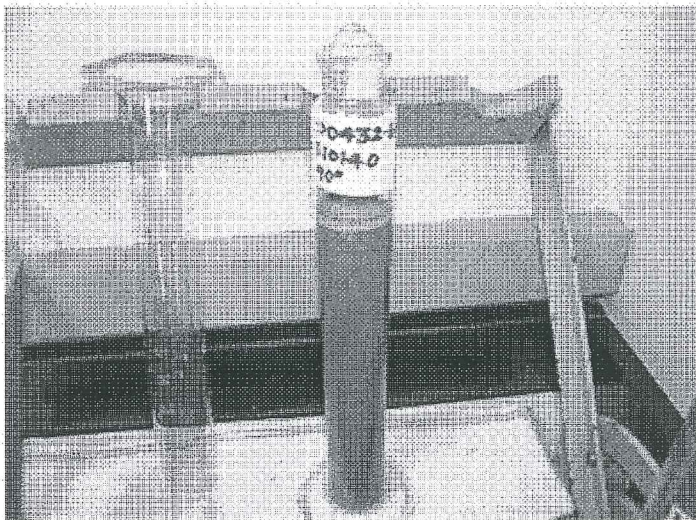


Figure 6: Free Fluid - Protocol 1 HTHP - 90 degree



Figure 7: Free Fluid - Protocol 1 HTHP - 45 degree

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Figure 8: Free Fluid - Protocol 2 HTHP - 90 degree

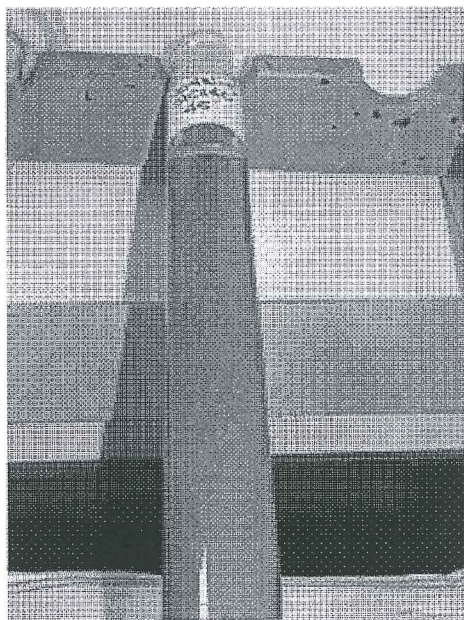


Figure 9: Free Fluid - Protocol 2 HTHP - 45 degree

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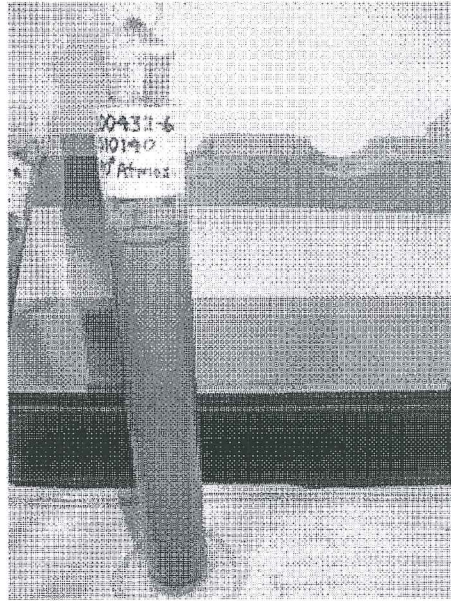


Figure 10: Free Fluid - Protocol 1 Atmospheric - 90 degree

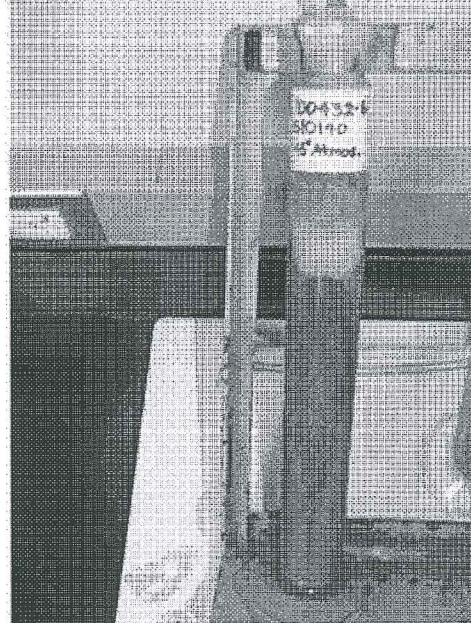


Figure 11: Free Fluid - Protocol 1 Atmospheric - 45 degree

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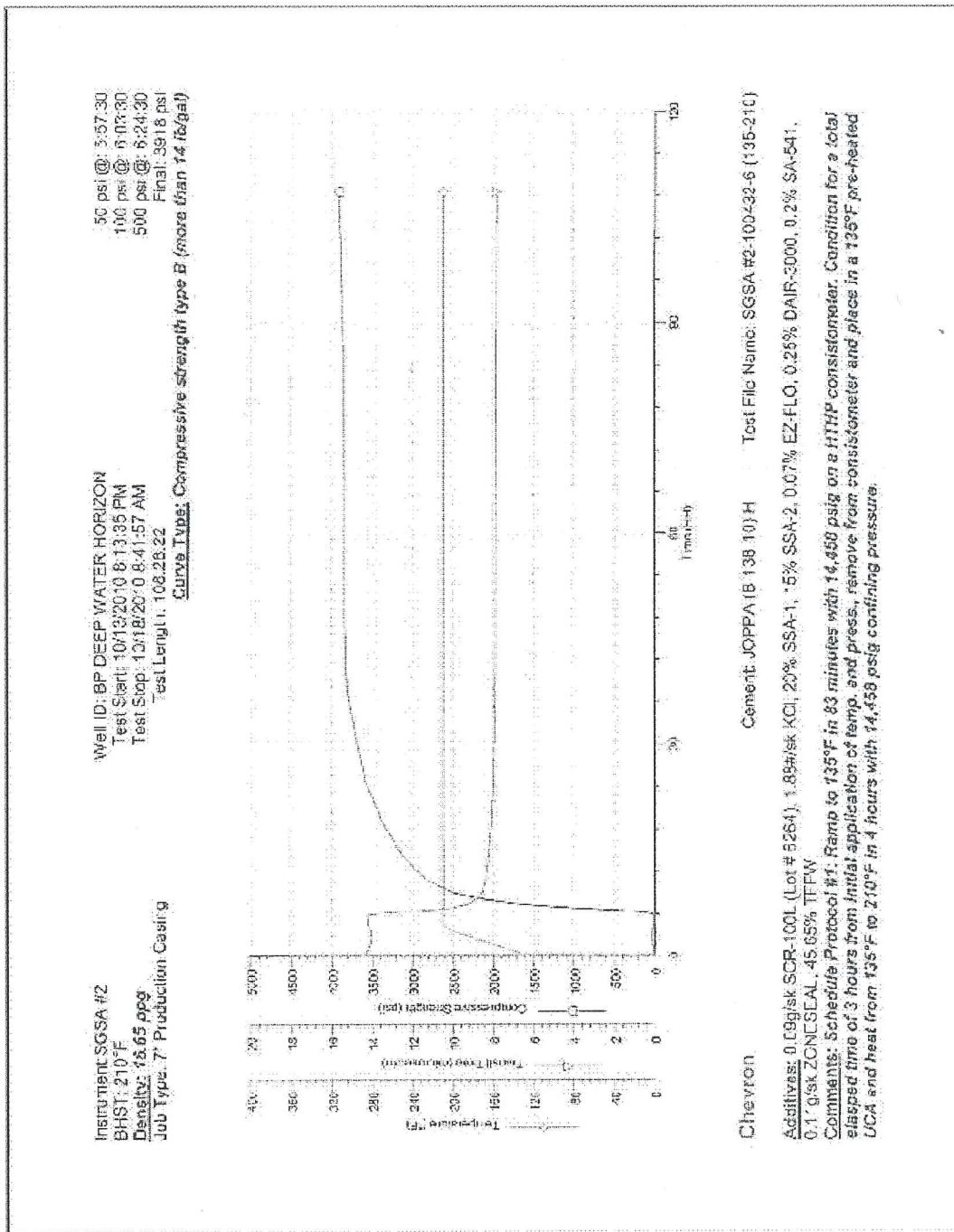


Figure 12: UCA Testing - Protocol 1 - Algorithm B (un-foamed)

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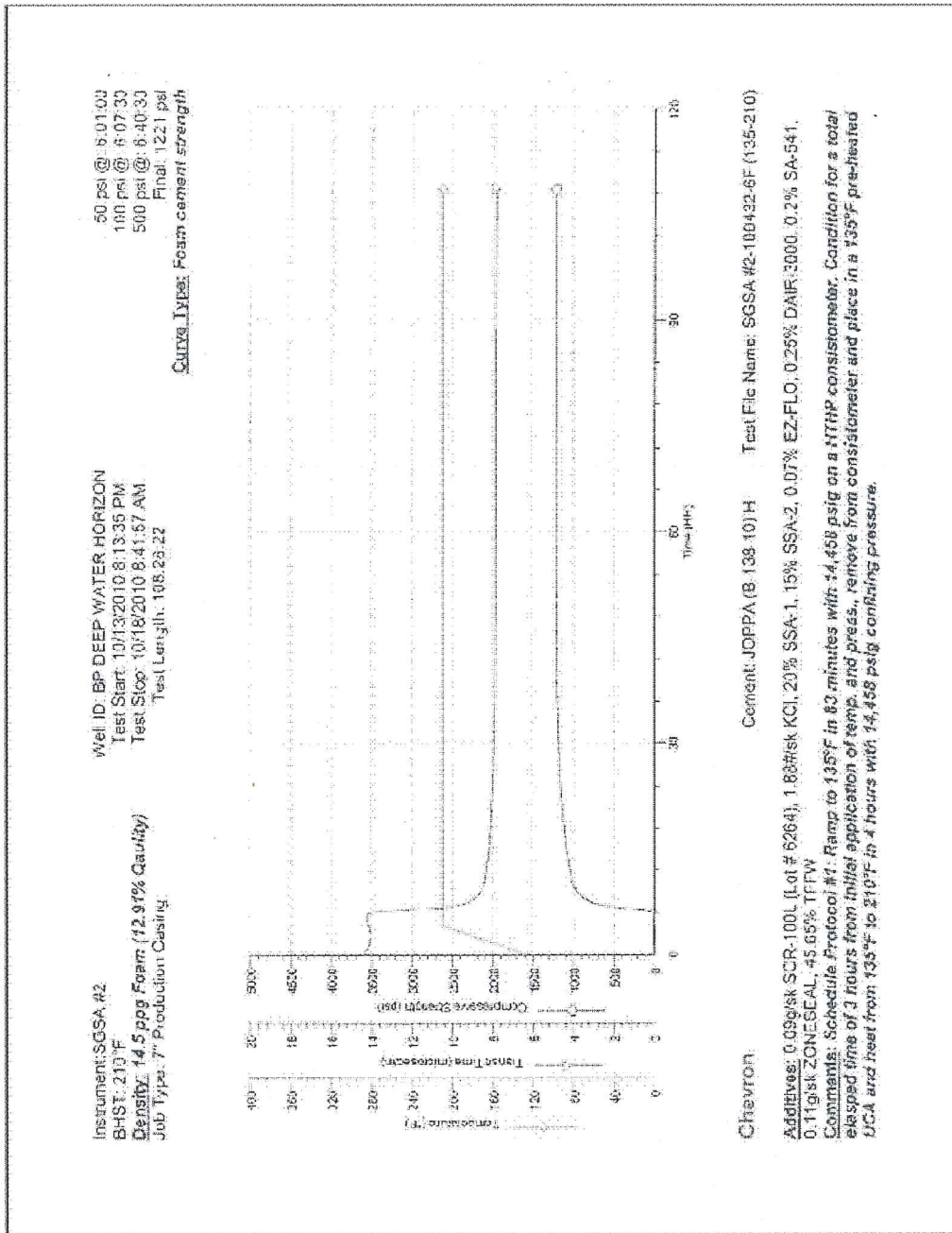


Figure 13: UCA Testing - Protocol 1 - Foamed Cement Algorithm

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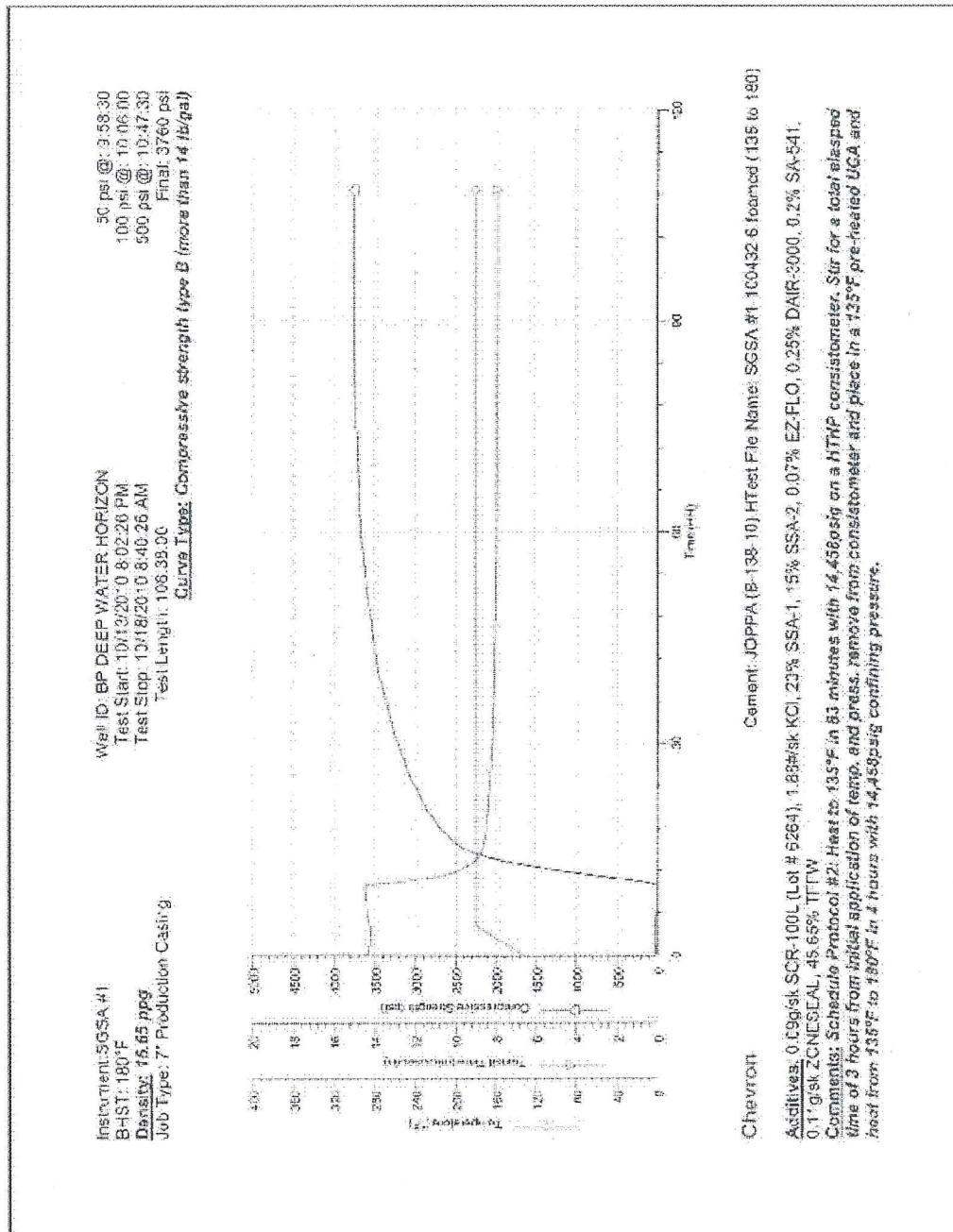


Figure 14: UCA Testing - Protocol 2 - Algorithm B (un-foamed)

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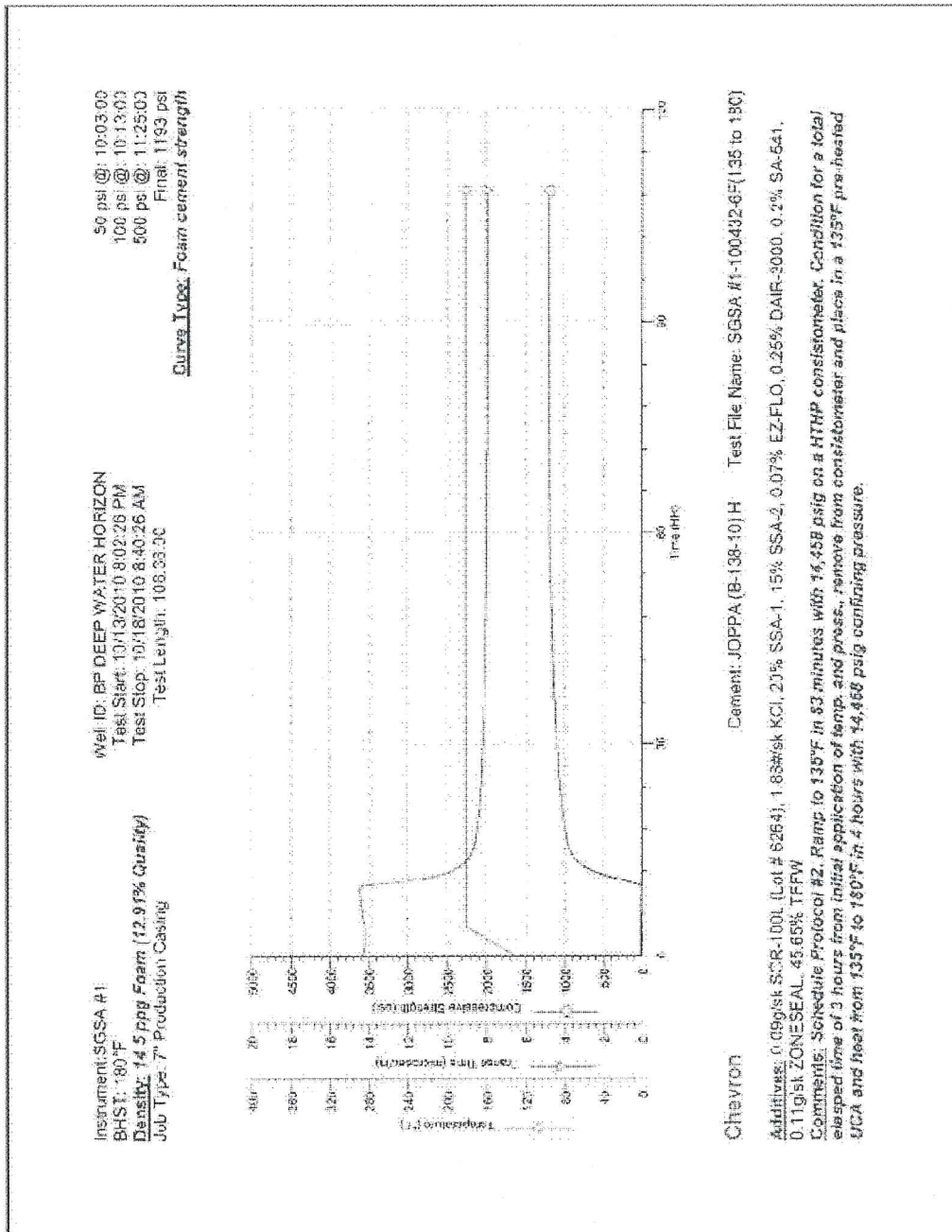


Figure 15: UCA Testing - Protocol 2 - Foamed Cement Algorithm

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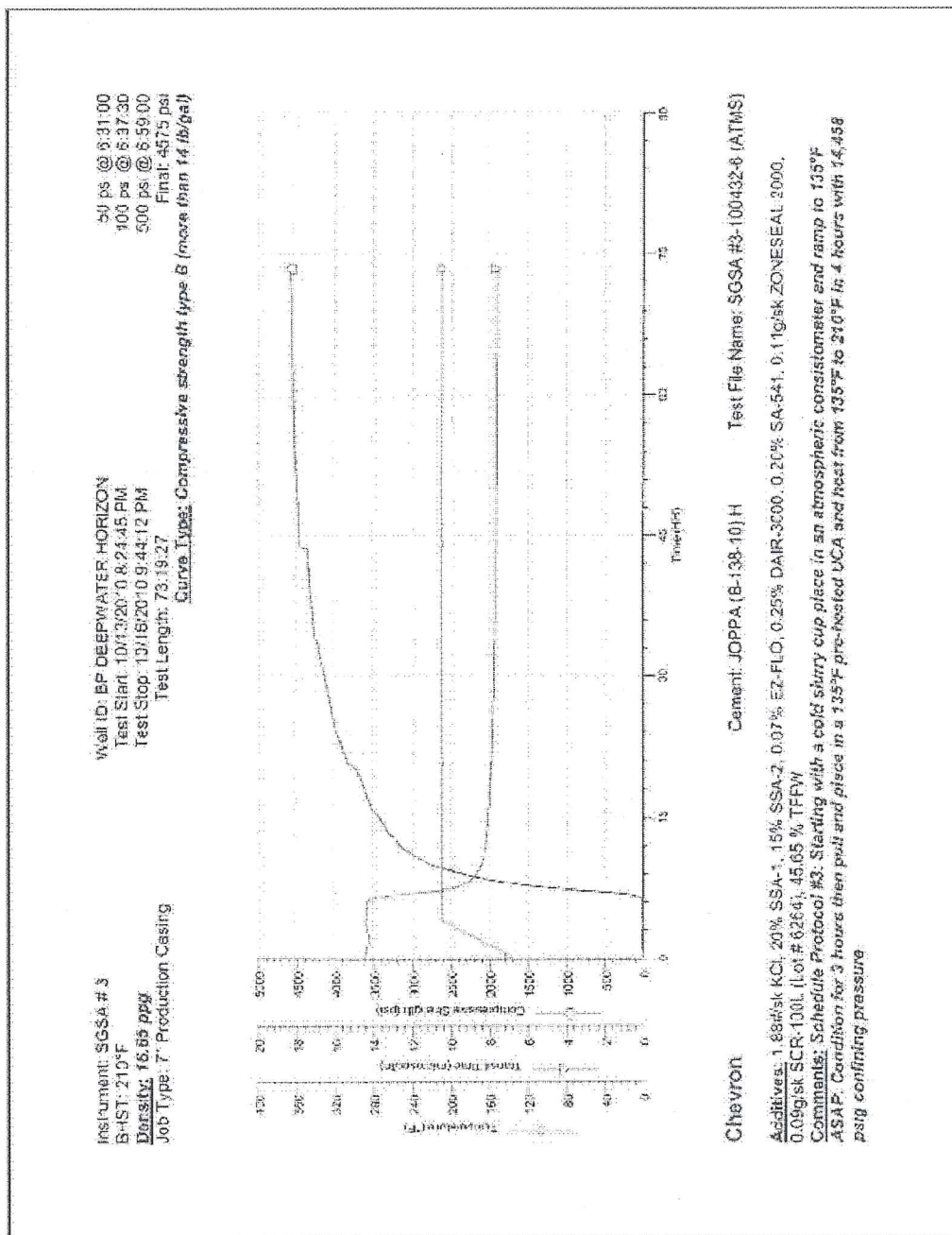


Figure 16: UCA Testing - Protocol 3 - Algorithm B (un-foamed)

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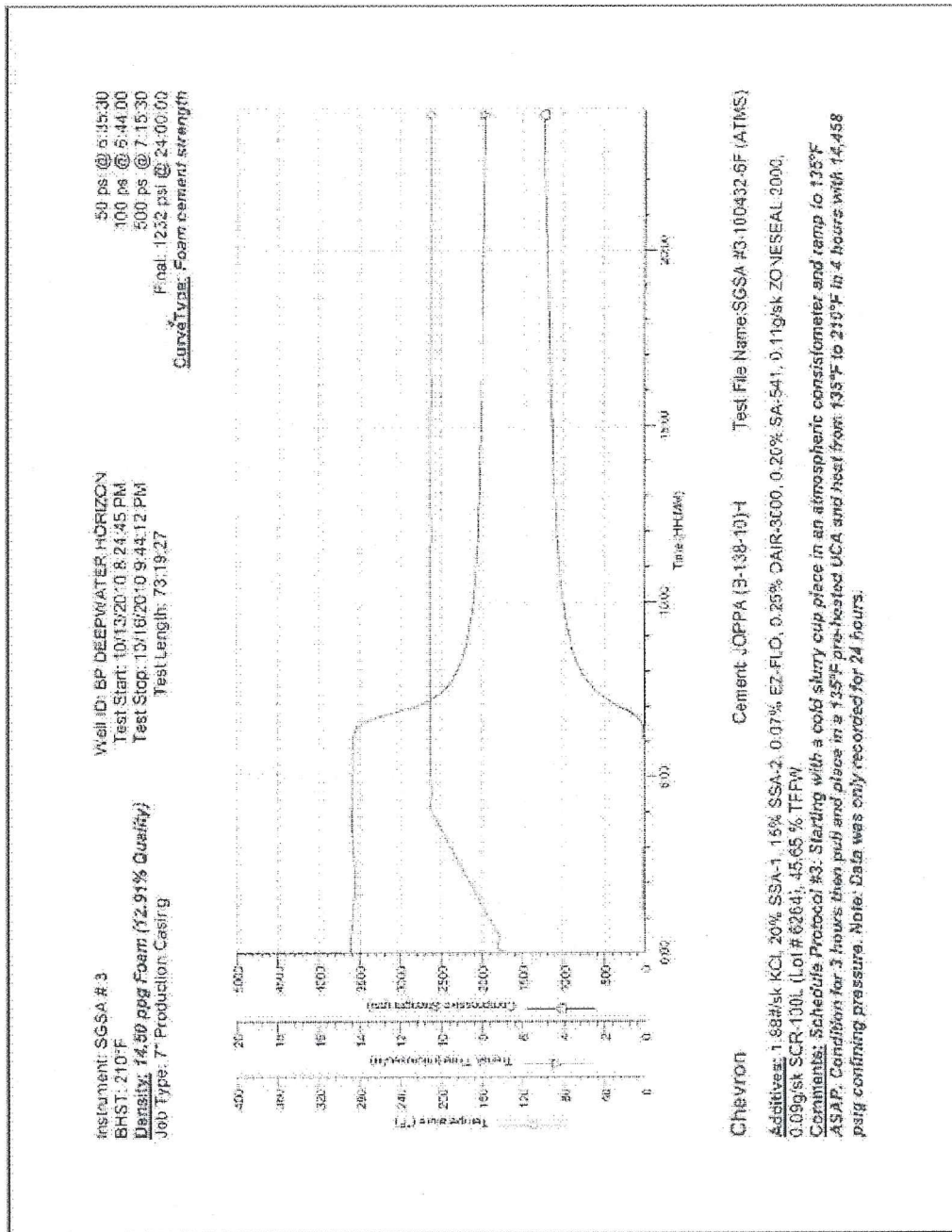


Figure 17: UCA Testing - Protocol 3 - Foamed Cement Algorithm

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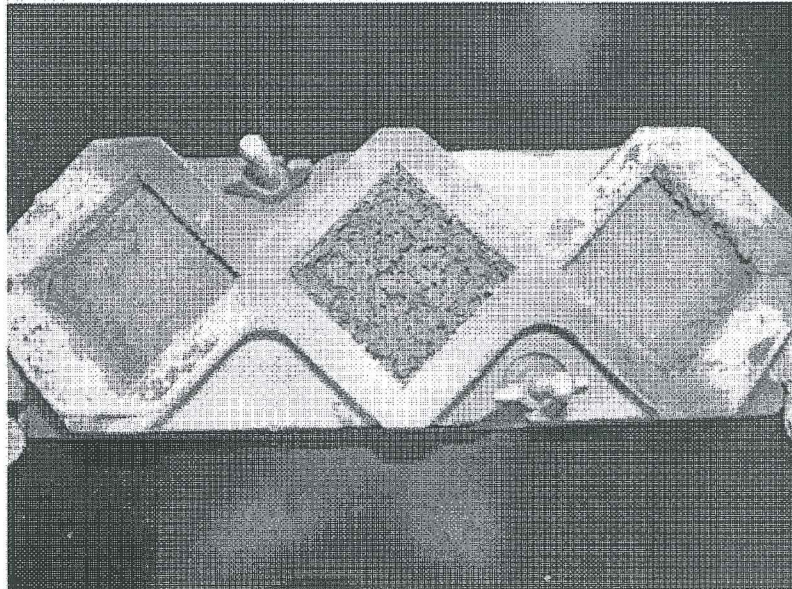


Figure 18: 48 hour Cubes in Mold

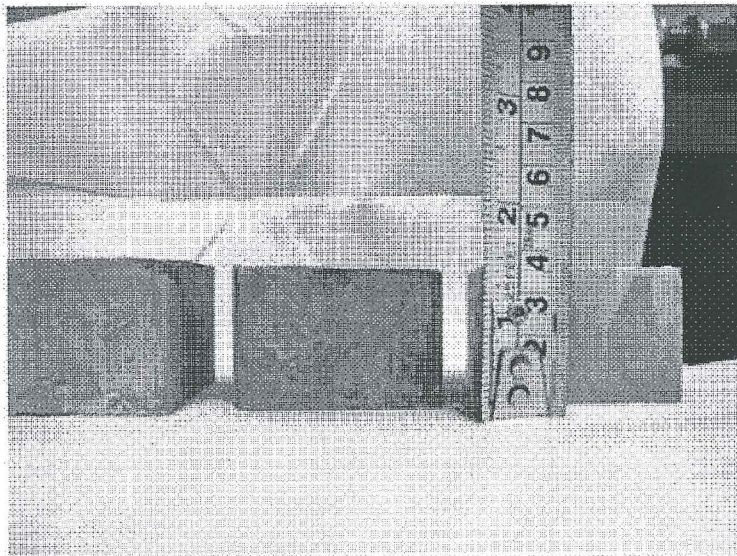


Figure 19: 48 hour Cubes Removed from Mold

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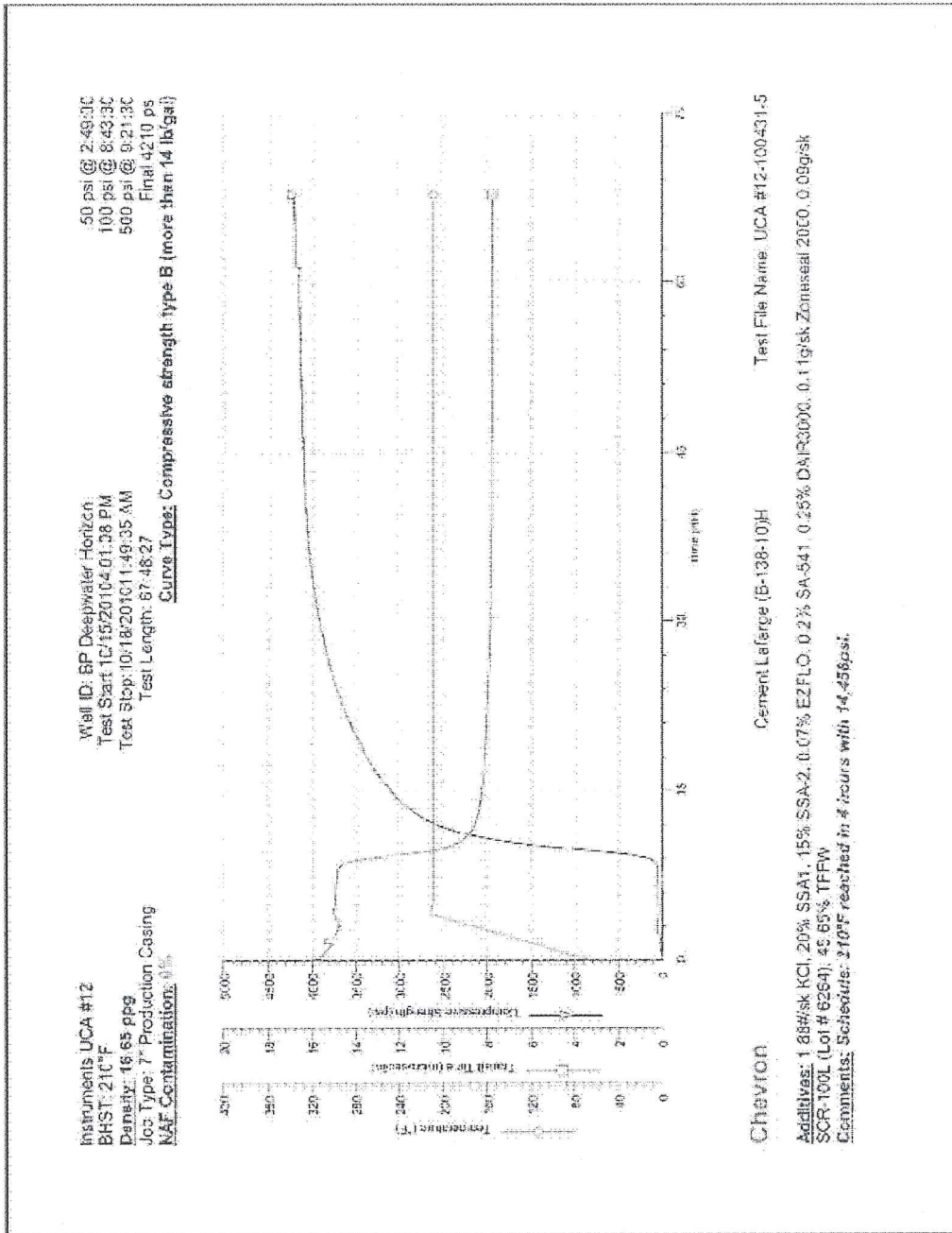


Figure 20: Zero Percent NAF Contamination

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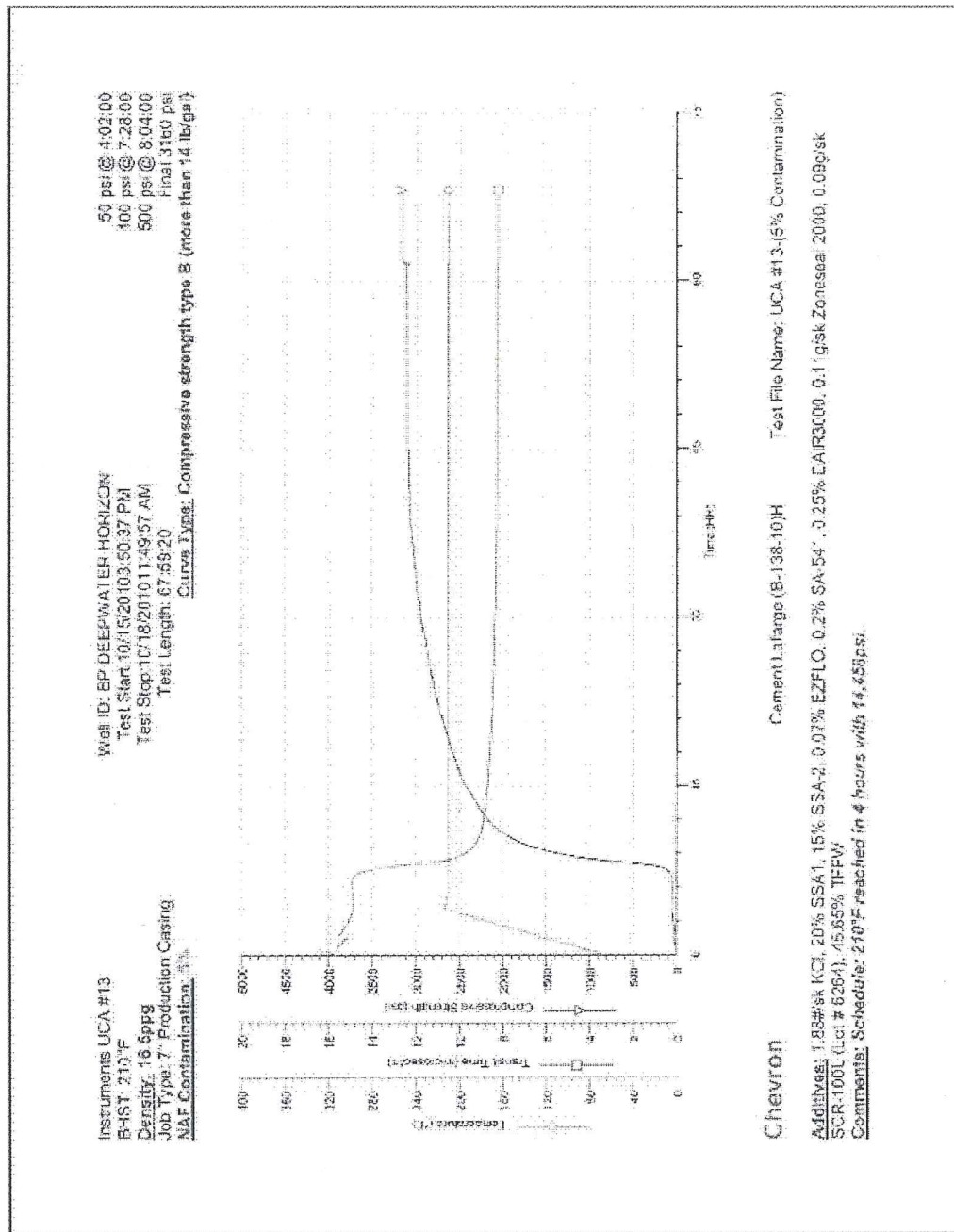


Figure 21: 5 Percent NAF Contamination

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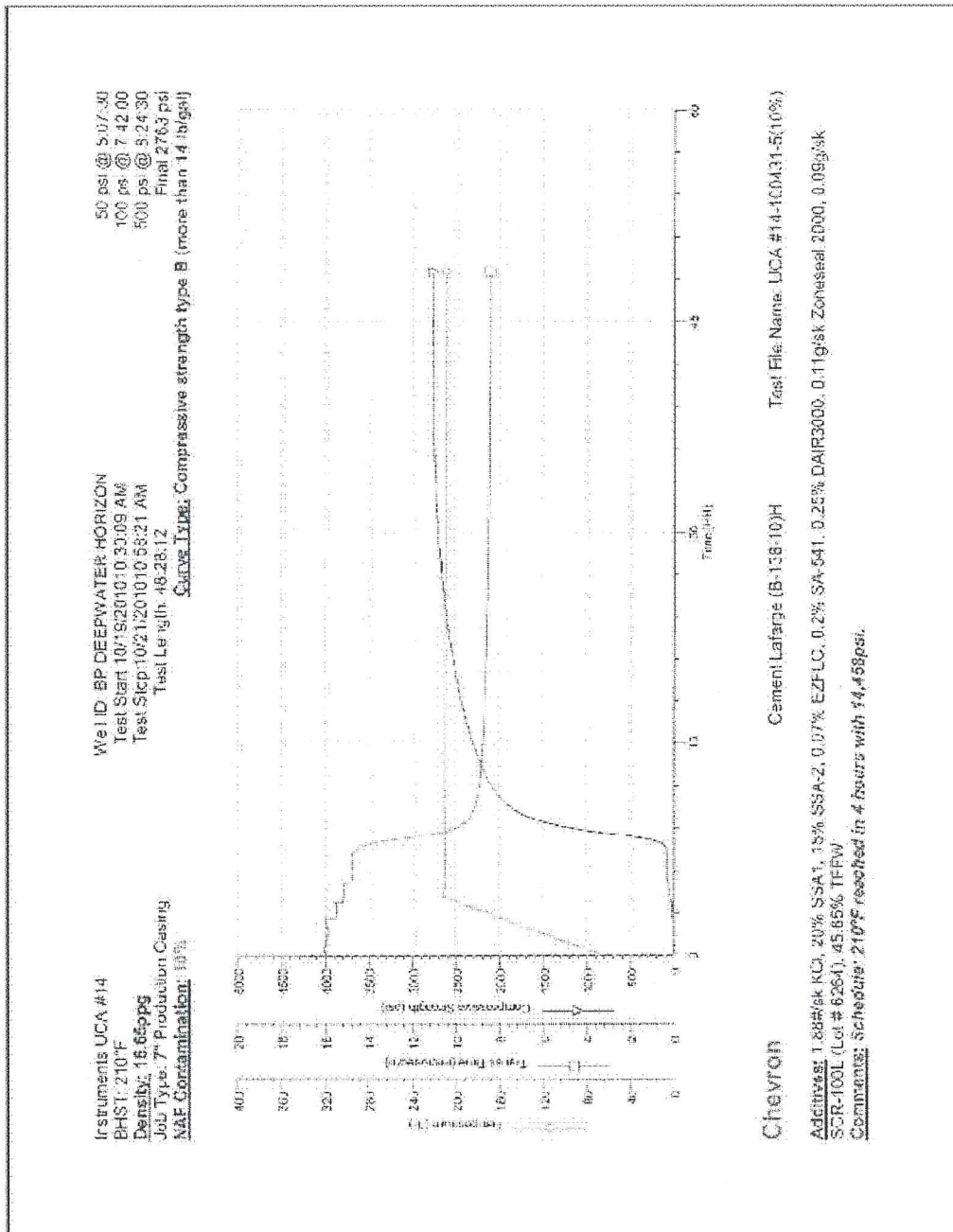


Figure 22: 10 percent NAF Contamination

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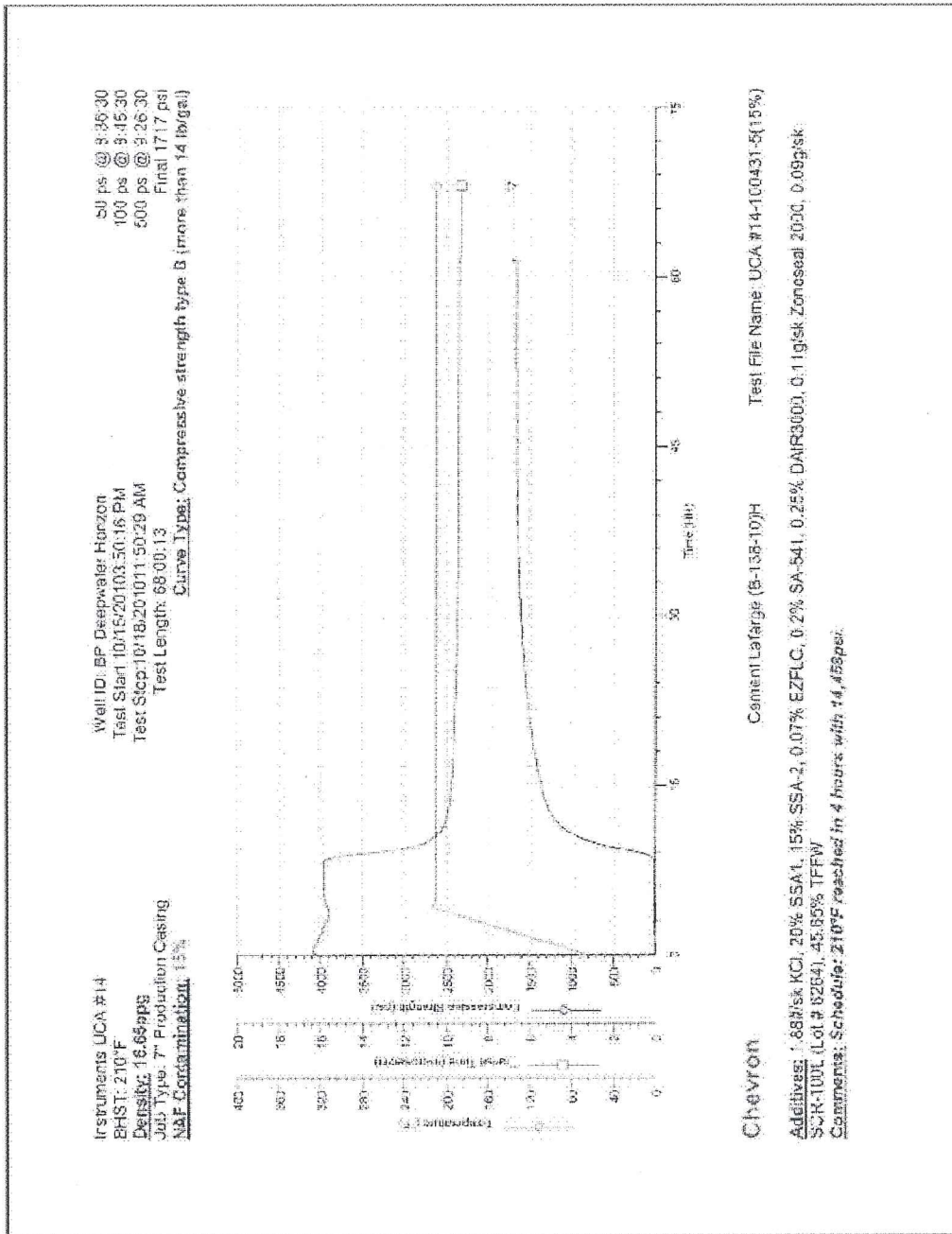


Figure 23: 15 Percent NAF Contamination

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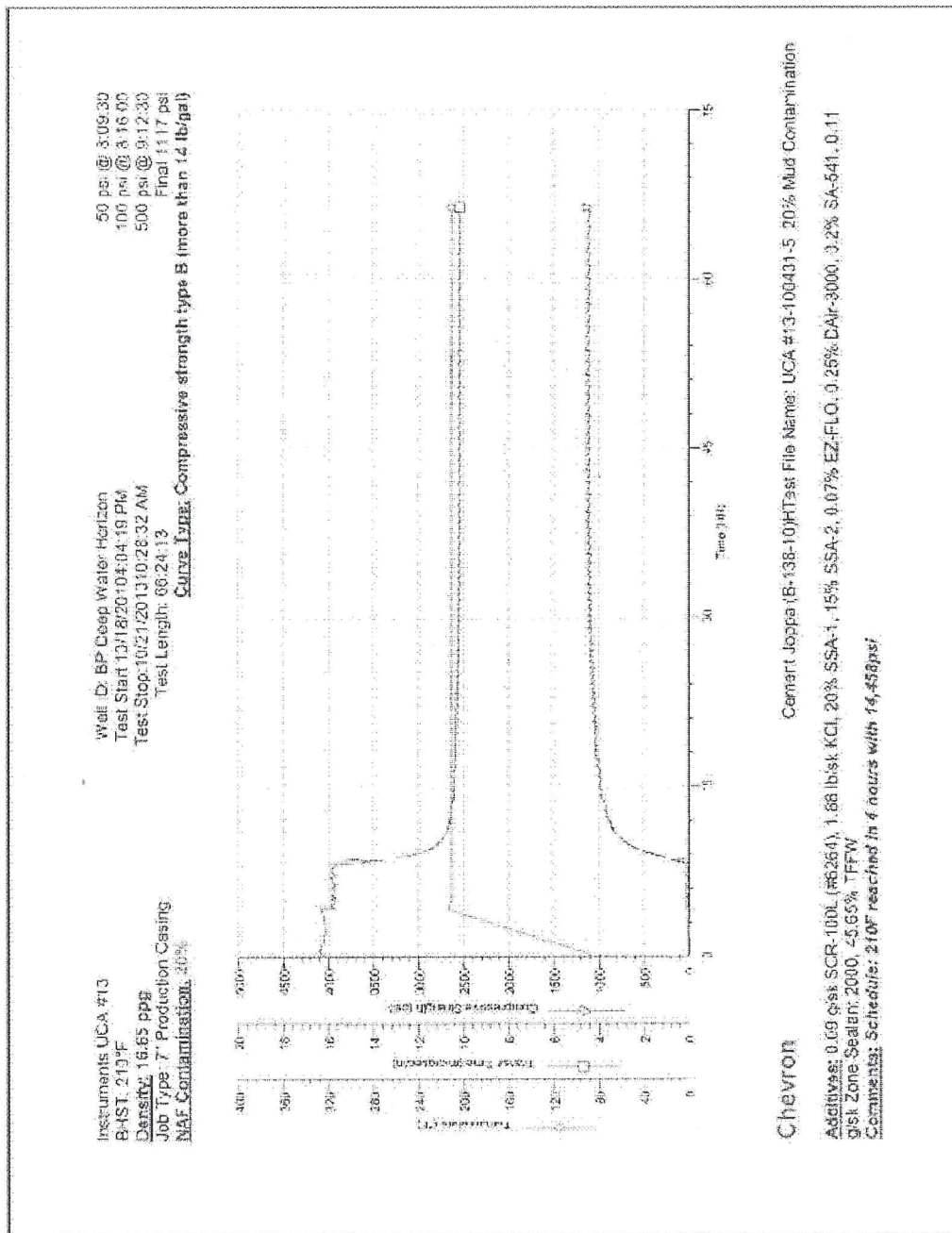


Figure 24: 20 Percent NAF Contamination

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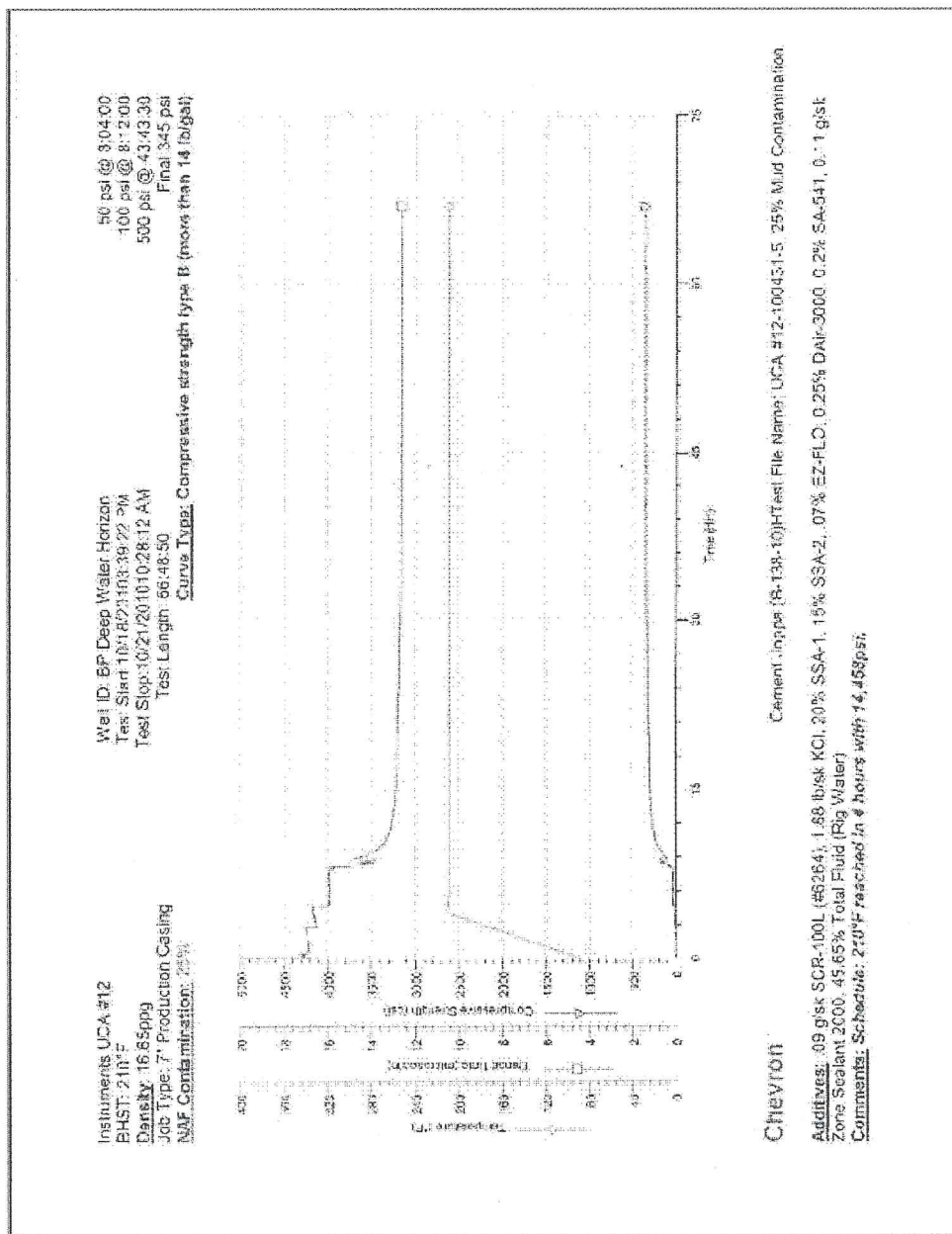


Figure 25: 25 percent NAF Contamination

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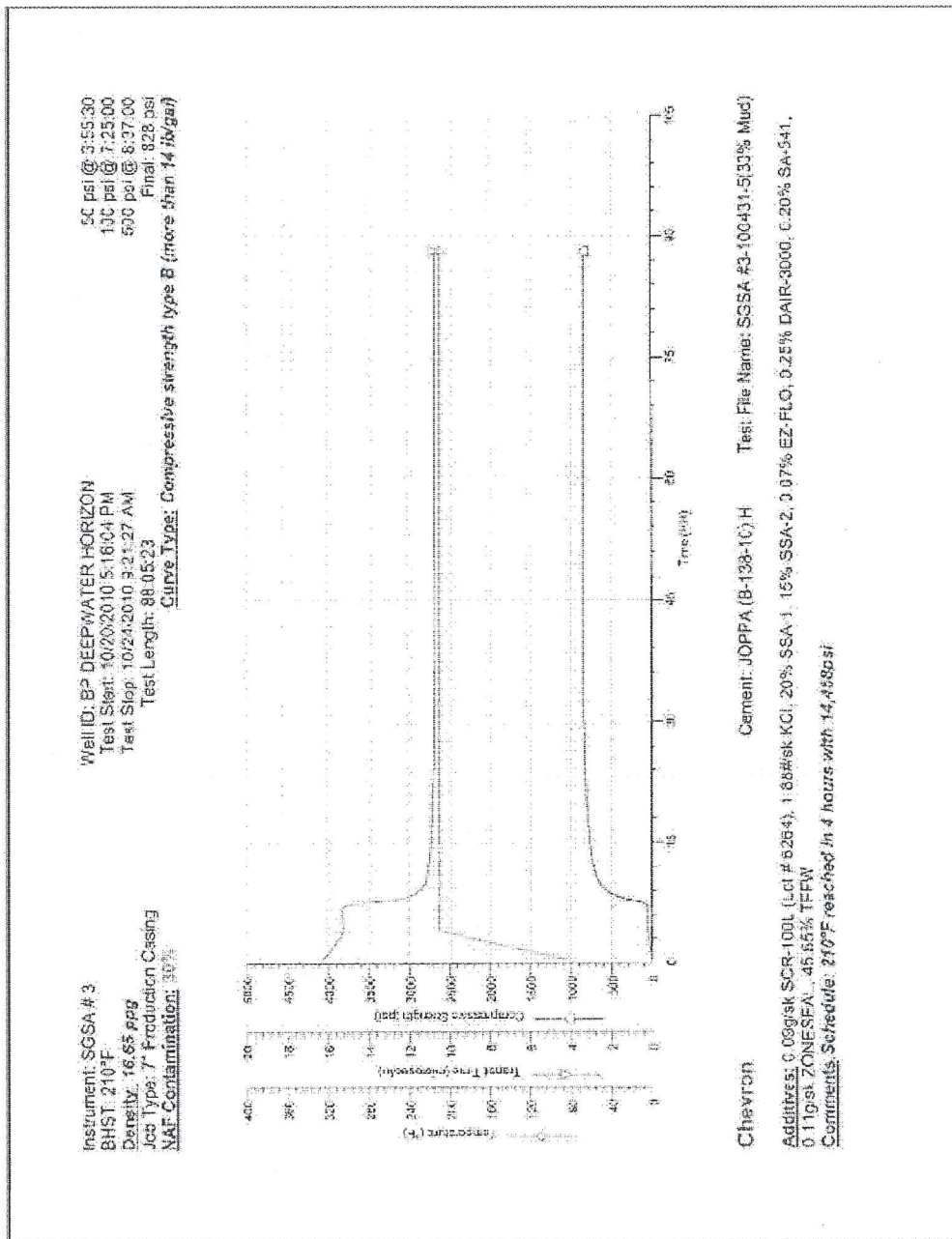


Figure 26: 30 Percent NAF Contamination

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