

Ultra-Lightweight Cement

Quarterly Report

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1.0 Abstract

The objective of this project is to develop an improved ultra-lightweight cement using ultralight hollow glass spheres (ULHS). Work reported herein addresses Task 1: Assess Ultra-Lightweight Cementing Problems and Task 3: Test Ultra-Lightweight Cements. Results reported this quarter include a review and summary of Halliburton Energy Services (HES) and BJ Services historical performance data for lightweight cement applications. These data are analyzed and compared to ULHS cement and foamed cement performances. Similar data is expected from Schlumberger, and an analysis of this data will be completed in the following phases of the project. Quality control testing of materials used to formulate ULHS cements in the laboratory was completed to establish baseline material performance standards. A testing protocol was developed employing standard procedures as well as procedures tailored to evaluate ULHS and foamed cement. This protocol is presented and discussed. Results of further testing of ULHS cements are presented along with an analysis to establish cement performance design criteria to be used during the remainder of the project. Finally, a list of relevant literature on lightweight cement performance is compiled for review during the next quarter.

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4.0 Introduction

Oilwell cementing involves placing a pumpable slurry of Portland cement, additives, and water into a well bore. The slurry is pumped into the annular space between the borehole and a steel pipe, called a casing, intended to produce a conduit from the reservoir to the surface. The cement sets in place to support the casing in the hole, to isolate various formations from one another, and to control fluid movement within the well.

Typical cement fluid density ranges from 14 to 17 lb/gal. Certain conditions can be encountered during the well construction process that necessitate application of cements with much lower density. Lower density is required to limit hydrostatic pressure exerted on formations through which the wellbore passes in order to prevent the formation from fracturing and imbibing the well fluid. This phenomenon, called lost circulation, increases the time to drill and complete the well and increases construction cost due to expensive remedial treatments. Most common sections of a well in which lost circulation occurs are the upper sections: surface casings and intermediate casings. Since formations covered by these casings are relatively close to the Earth's surface, application temperatures for these low-density cements are relatively low.

The minimum practical density achievable with conventional cements and additives is roughly 11 lb/gal. At this density, the stability of the slurry and strength of the set cement are only marginally acceptable. The primary density-reducing material in these conventional cements is water. Additional water dilutes the cement, causing low strength. Lower temperature further delays strength development. Achieving density requirements lower than this threshold or strength requirements greater than minimum necessitate use of ultra-lightweight materials mixed into the slurry.

Ultra-lightweight hollow spheres (ULHS) are excellent as candidate material for producing ultra-lightweight cements. These small, hollow glass beads effectively encapsulate air in the slurry, thereby lowering the slurry density significantly compared to the addition of water to the slurry.

This project is designed to develop cementing systems using ULHS. The development will be achieved through a carefully designed program of modeling, design, laboratory testing, and field testing.

The phase of the project documented in this report involves further evaluation of ULHS cement, initial evaluation of foamed cement, and comparison of historical lightweight cement performance data from HES and BJ Services with the ULHS and foamed cement data. The compressive strength characteristics of these ULHS cements were also analyzed.

5.0 Executive Summary

The second quarter of this investigation focused on the completion of the evaluation of ULHS materials. The basic performance criteria were established to underpin the design of field-applicable cements for evaluation in the remainder of the project. Performance testing for foamed cement was initiated. In addition, a full suite of testing methods for ULHS and foamed cement were identified, and a routine quality control (QC) procedure was completed and implemented. Finally, historical data on lightweight cements were analyzed and a comprehensive literature search on lightweight cement data was initiated.

6.0 Experimental

Experimental methods employed in this investigation are based on generally-accepted laboratory test procedures for oilwell cements. Where applicable, standard methods presented in the API RP 10B¹ are followed. These tests include: thickening time, compressive strength, rheology, and free fluid.

Non-standard test procedures were necessary because of the unique nature of the ULHS. The spheres are brittle and can break when mixed in a slurry and subjected to differential pressure or shear. Additionally, the sphere's specific gravity is less than water, so the spheres can float, resulting in solids segregation. These non-standard laboratory methods include slurry mixing, density vs. pressure, and slurry stability.

Non-standard testing procedures for ULHS cements are outlined in detail in Appendix A. Procedures that are under development for consideration by ISO for laboratory mixing of foamed cements are also presented in this appendix. The results of testing presented in this report and Quarterly Report 1 indicate that these test procedures produced meaningful, representative data for lightweight cement. These test procedures will be adopted for the remainder of this work.

7.0 Results and Discussion

Laboratory data presented in the body of this report only contains sufficient information to denote trends or emphasize conclusions. Complete composition and data are presented in Appendix B.

7.1 BJ Services and HES Historical Data Analysis

Project members, Halliburton Energy Services (HES), and BJ Services, provided the data used in this study of lightweight cements (Appendix C). Data was compiled from field laboratory tests of active cement applications. These data represent a significant population of actual lightweight cement applications. Exact compositions were not specified because of the proprietary nature of these formulations. However, density, 24-hr. compressive strength, and BHCT information were complete. Similar data is expected from Schlumberger, and an extended analysis of all data will be completed in the following phases of the project. A summary of the data received to date is contained in Tables 7.1 through 7.3 (Page 8).

Table 7.1—Summary of Testing Data Sets from HES and BJ Services

Type of Cement	No. of Tests in Data Set	Type of Applications and Compositions							
		Offshore	Land-Based	With Bentonite	With Sodium Silicate	With Calcium Sulfate	With Microspheres	With HEC	With Blastfurnace Slag
HES Unfoamed	3778	most	small %	1097 (29%)	1077 (29%)	787 (21%)	137 (4%)	286 (8%)	20 (0.5%)
HES Foamed	294	all*	n/a	unspecified	unspecified	unspecified	unspecified	unspecified	unspecified
BJ Unfoamed	178	50	127	28 (16%)	55 (31%)	unspecified	48 (27%)	unspecified	unspecified

*Water depth ranged from 113 ft to 7,600 ft, with a large majority between 2,000 and 5,000 ft.

Table 7.2—Summary of Density Data

Type of Cement	Percentage of Tests within a Density Range (%)		
	9.0 to 10.9 lb/gal	11.0 to 11.9 lb/gal	12.0 to 13.0 lb/gal
HES Unfoamed	0.7	26.6	72.7
HES Foamed	11.0	22.0	67.0
BJ Unfoamed	16.0	32.0	55.0

Table 7.3—Types of Cement Used in Historical Test Data

Type of Cement	Base Cement Components (%)									
	Class A	Class C	Class G	Class H	TLW/TXI	Microfine	Fly Ash/Class A	Fly Ash/Class H	Slag	Others
HES Unfoamed	19.0	—	—	35.0	20.0	7.0	6.0	11.0	2.0	—
HES Foamed*	47.0	—	—	9.4	—	43.0*	—	< 1.0	< 1.0	—
BJ Unfoamed	12.0	33.0	12.0	42.0	—	—	—	—	—	= 1.0

*All tests between 10.0 and 11.9 lb/gal were run using an unknown percentage of Microfine cement. Only 33 (19%) of the 12.0 to 12.9 lb/gal were run using Microfine cement. All remaining tests were either Class A (a large majority) or Class H.

This study investigates compressive strength information for lightweight cement systems. The compressive strength data is organized into three practical categories:

- 500 psi and above
- 200 to 499 psi
- Below 200 psi

This data analysis focuses on the 24-hour compressive strength of the two general categories of lightweight cements: foamed and unfoamed. Compressive strength is not necessarily the only deciding variable for cement evaluation, but it was chosen because it is readily available from the data. Because of insufficient information regarding composition, further analysis by composition is impractical.

Figure 1 on Page 9 depicts the data distribution for the two different categories of lightweight cements (foamed and unfoamed). The data for the unfoamed cements combines approximately 3,780 data sets from HES and approximately 170 data sets from BJ. HES also provides approximately 310 data sets for foamed slurries. No foamed cement data was provided by BJ at the time of this report.

The data is based on a variety of traditional lightweight cement systems including bentonite slurries, microfine cements, sodium silicate slurries, slurries with fumed silica, and hollow-sphere slurries (different from those studied in this project). Because more historical data is expected, only general relationships have been analyzed among the existing data. A detailed evaluation will be completed when the new data is received.

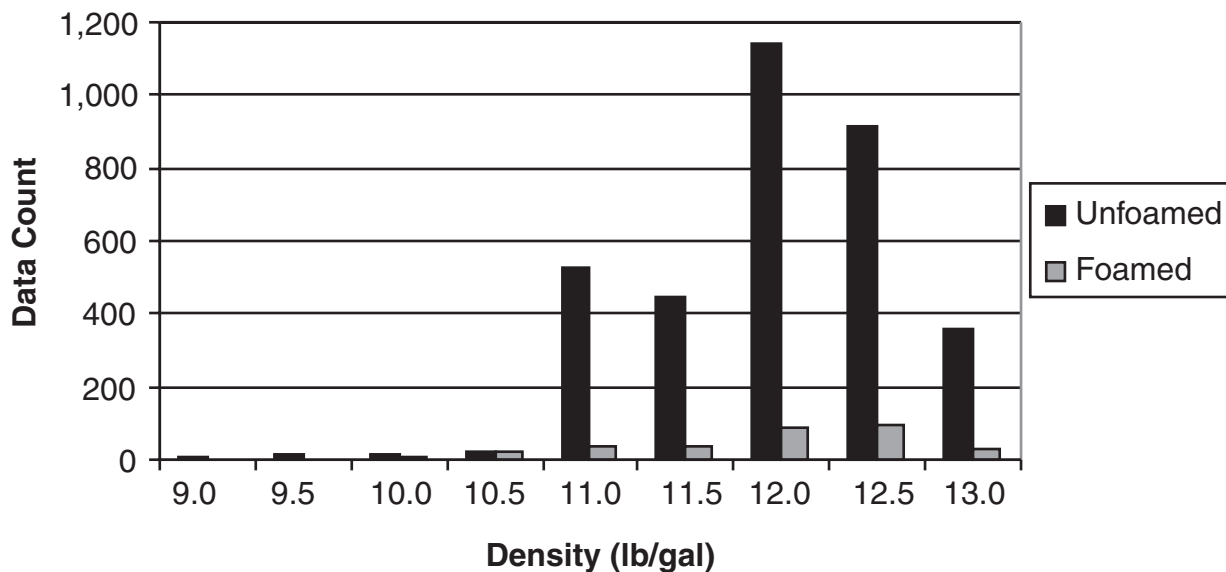


Fig. 1—Data distribution for foamed and unfoamed cements

The database contains limited temperature data for a large percentage of the unfoamed slurries. BHCT is chosen as one way to differentiate the data because it is the temperature parameter common to most of the data sets. Most (97%) of the foamed cement data collected was for BHCT of 100°F or below. Forty-eight percent (48%) of the unfoamed cement data is for BHCT of 100°F or below. The data analysis is divided into three broad temperature categories: 1) all temperatures, 2) BHCT of 100°F and below, and 3) BHCT of 101°F and above. The temperature categories will be divided into smaller segments (20°F) for analysis once the historical data set is complete.

This study examines lightweight cement systems with a density of 13.0 lb/gal or less. To better trace the trends of slurry density versus compressive strength, the density values are divided into ranges with 0.5 lb/gal increments. For example, the density range of 11.0 lb/gal covers all densities from 11.0 to 11.4 lb/gal, and the 11.5 lb/gal density range covers all densities from 11.5 to 11.9 lb/gal.

Most of the slurry densities are 11.0 lb/gal or greater (see Figure 1). Ninety-nine percent (99%) of the unfoamed cements and 90% of the foamed cements have densities of 11.0 lb/gal or greater.

Figures 2 through 4 (Pages 10 and 11) present data for conventional unfoamed cements. Figure 2 shows the percentage of all cements that fall into the three compressive-strength categories. Figures 3 and 4 display the data for temperatures below 100°F (Figure 3) and above 101°F (Figure 4). These charts show percentage plots of each cement density division with compressive strength within each temperature category. Note the trend of low strength at low density.

Figure 3 depicts the data count associated with each of the different densities. The small number of data points below 11.0 lb/gal came mostly from BJ slurries that contained hollow ceramic or glass spheres. The small amount of data from these specialized slurries tends to contradict the general trend of an increase in compressive strength with an increase in density. This same anomaly can also be seen in Figure 4. The fact that these data points are for cements with ULHS strengthens the stipulation that ULHS can extend the practical lower density limit of cement.

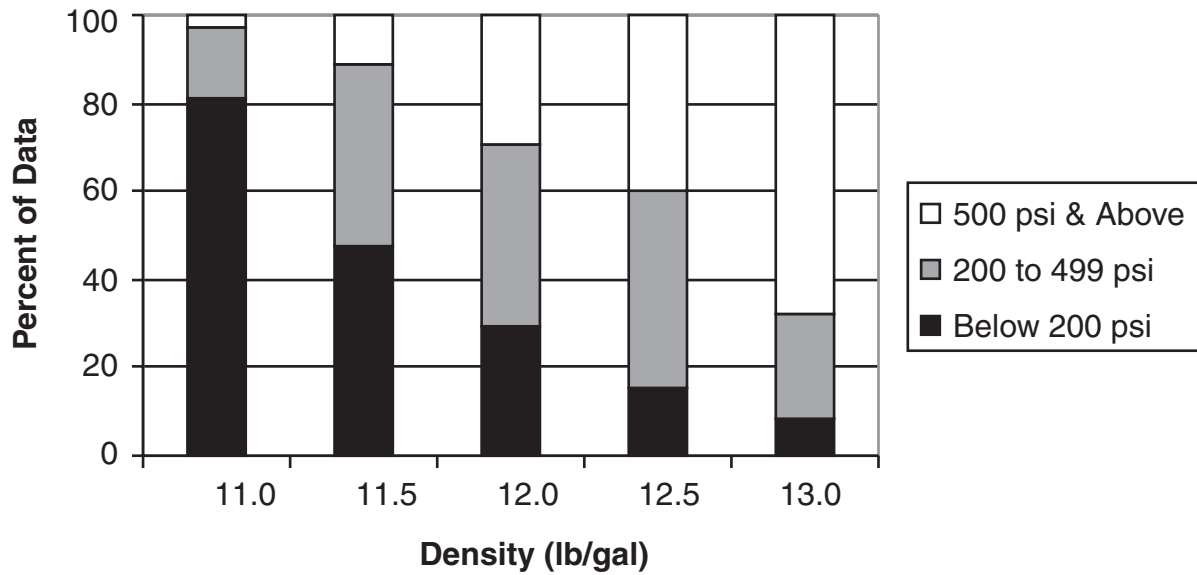


Fig. 2—24-hr compressive strength for all temperature categories of unfoamed cement

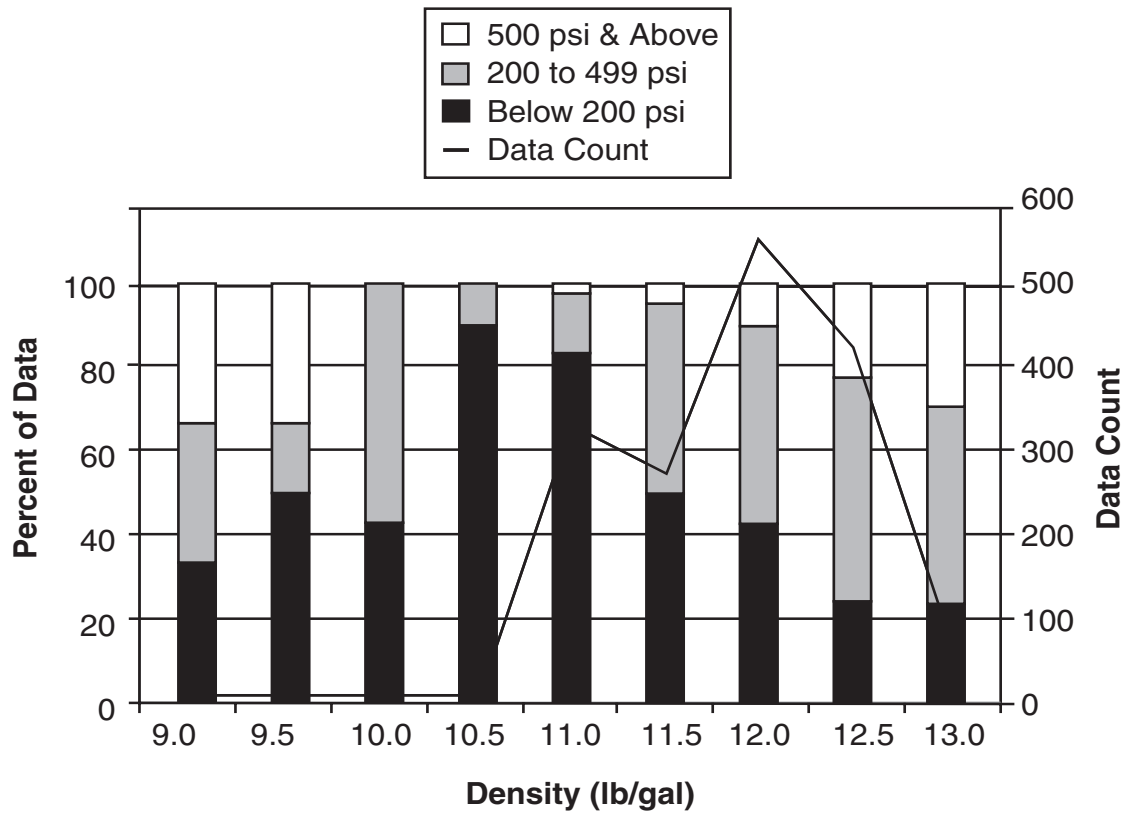


Fig. 3—24-hr compressive strength for unfoamed cement at 100°F and below

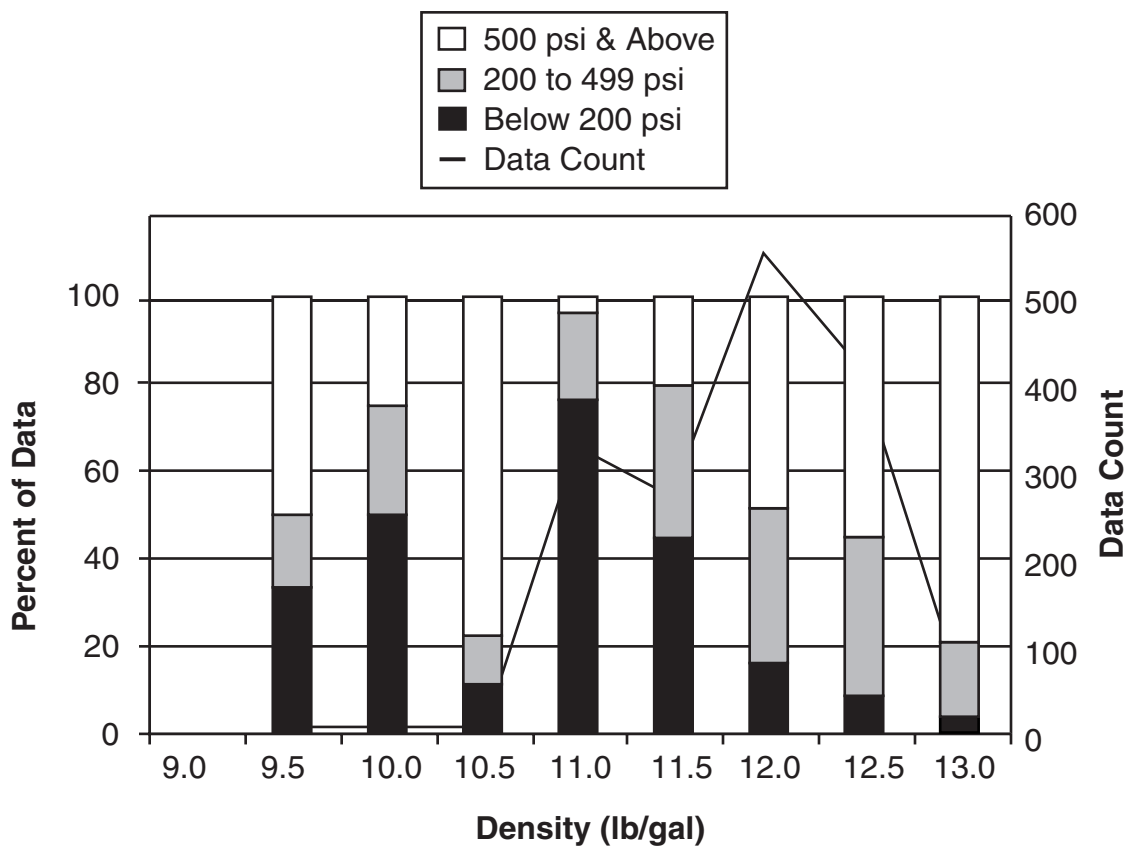


Fig. 4—24-hr compressive strength for unfoamed cement at 101°F and above

Figures 5 and 6 (Page 12) present foamed cement data from the HES data. Note that the trend identified for unfoamed cements also applies to the foamed cements. The majority of the foamed slurries in the historical data set have a BHCT between 60 and 65°F, which could account for the lower compressive strength.

The service company data reviewed to date indicate that the compressive strengths of cements at densities below 12.5 lb/gal are lower than those of cements at higher densities. Competent and strong lightweight cements are particularly scarce for low-temperature applications.

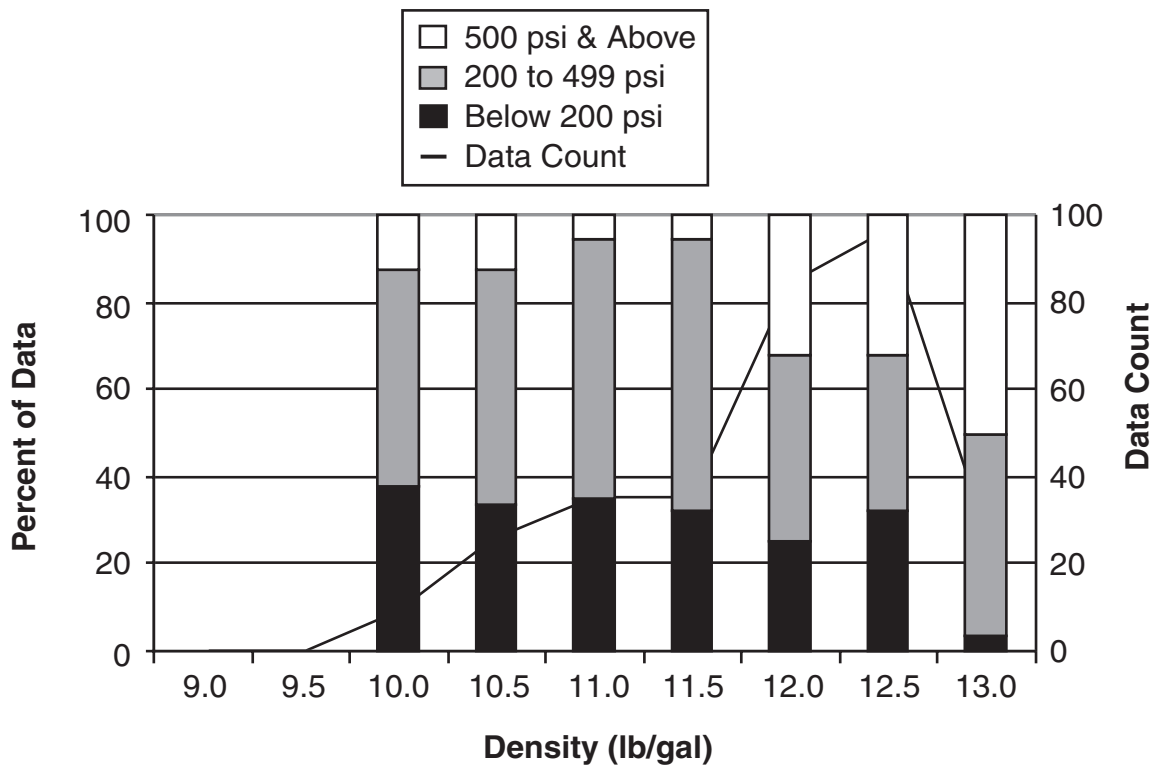


Fig. 5—24-hr compressive strength for all temperatures of foamed cement

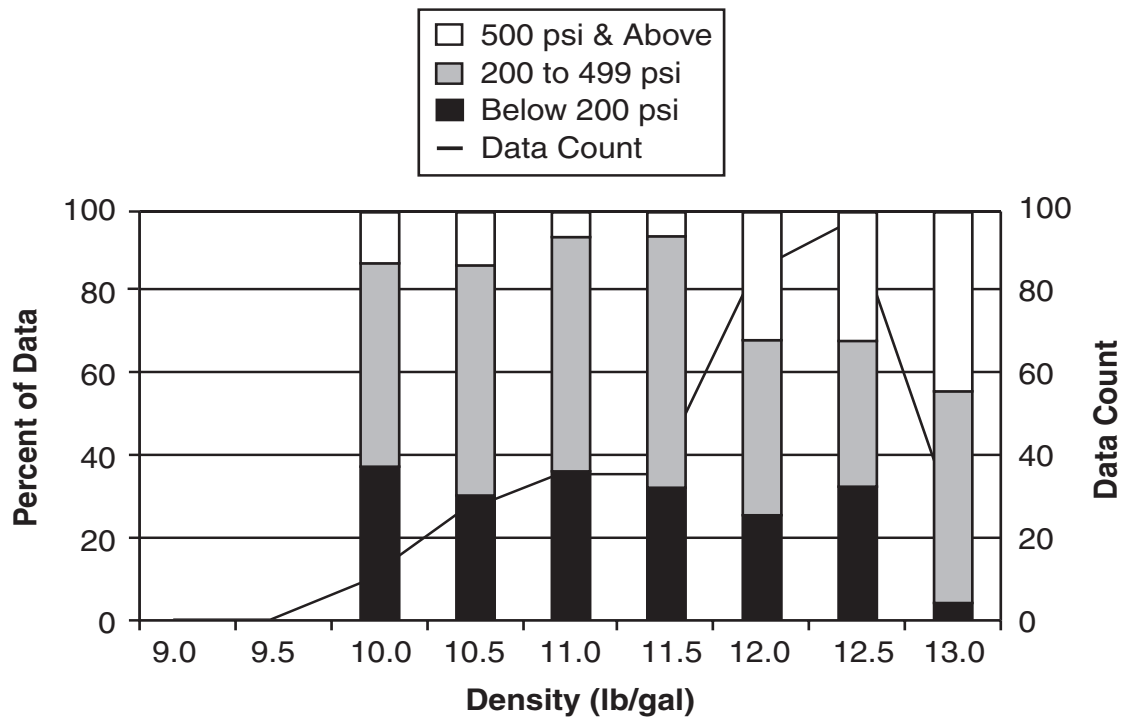


Fig. 6—24-hr compressive strength for foamed cement at 100°F and below

7.1.1 High-Strength Microsphere Performance

Figure 7 compares the 24-hour compressive strengths of unfoamed cement alternatives with a BHCT of 100°F or below. This figure shows the 90th percentile of compressive strengths for the unfoamed, historical data that was collected in the comprehensive study. The 90th percentile was chosen for comparison because it is a favorable representation of the data, with 90% of the data distribution being at or below the specified compressive strength. Compressive strength data was also collected and presented for slurries containing high-strength ULHS. The curing temperature for the ULHS slurries was 80°F.

Cement slurries containing ULHS and their associated test data are further discussed in Section 7.3. Figure 7 shows that at densities less than 12.0 lb/gal, ULHS slurries have higher compressive strength than the 90th percentile of unfoamed, historical cements, even considering all temperatures.

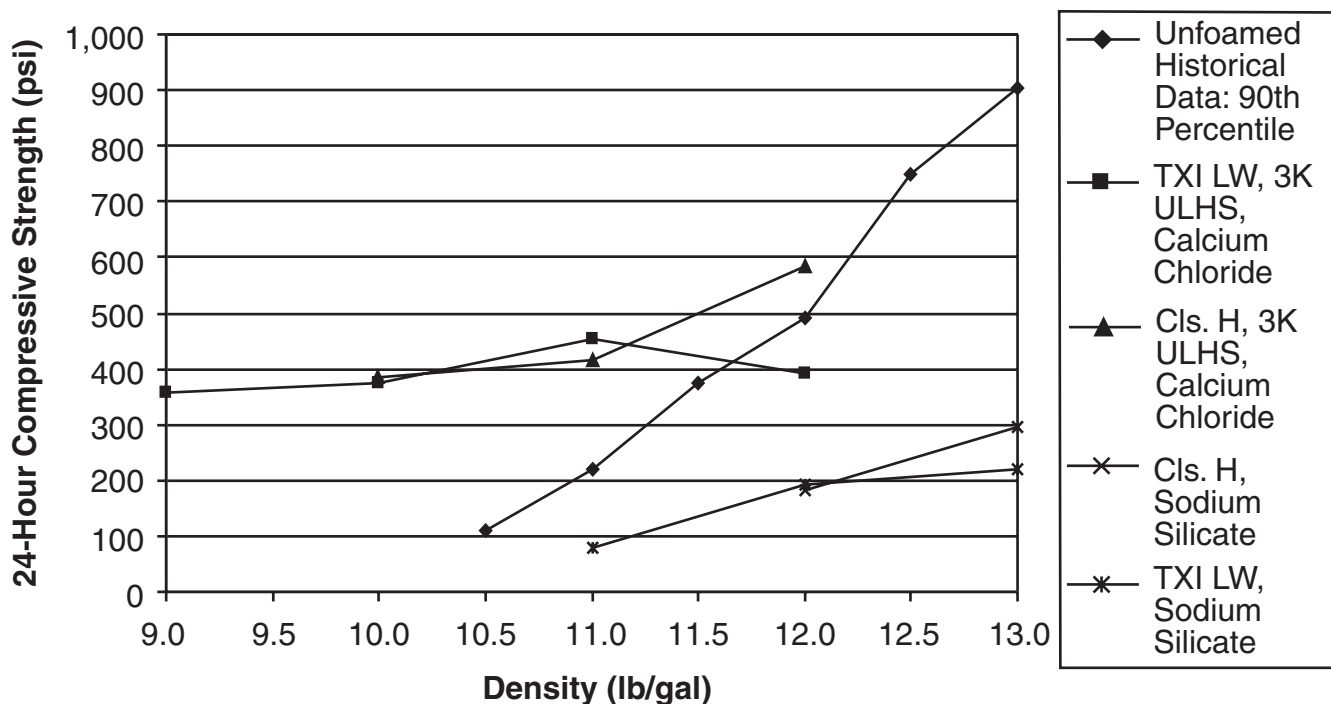


Fig. 7—Compressive strengths of unfoamed cements

7.1.2 Alternative Foamed Slurry

Figure 8 compares the 24-hour compressive strengths of foamed cement alternatives with BHCT of 100°F or below. This figure contains the 90th percentile of the foamed cements that were collected in the comprehensive study of lightweight slurries. Compressive-strength data is discussed in Section 7.1 of this report. Figure 8 shows that the alternative foamed slurry that was specifically designed for this project significantly outperformed the 90th percentile of historical data. The majority of the foamed slurries in the historical data set have a BHCT between 60 and 65°F, which could account for the lower compressive strength.

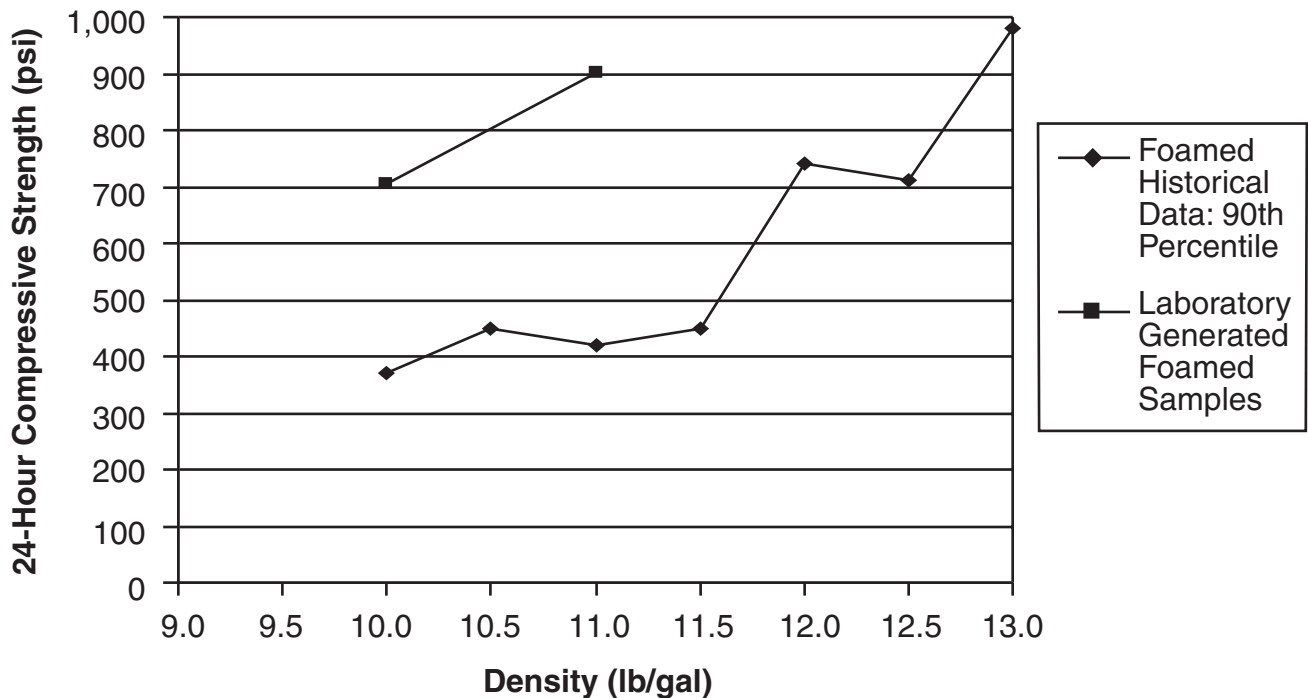


Fig. 8—Compressive strengths of foamed cements

7.2 Cement Quality Control Program

An extensive quality-control program was initiated because of the large quantity of cement used over the course of this project. Each bucket of cement is labeled with a materials log number and date upon receipt. When a bucket is first opened for use, the date of opening is also recorded into the materials log. This log number will be referenced on the lab sheets for each test performed. Where applicable, tests according to the API Specification 10A are conducted. Additionally, several other tests tailored specifically for the test conditions and materials (rheology and low-temperature compressive strength development) are included in this QC Program.

The Class A and Class H cement performance requirements are presented in API Specification 10A. Because the Lightweight Oilwell cement is not an API cement, it is tested according to QC procedures developed by the manufacturer.

This quality-control program is necessary because of the large volume of cement used during this DOE project. Initially, the testing lab received five 5-gallon buckets of API Class A cement (analogous to ASTM Type I cement), ten 5-gallon buckets of API Class H cement, and nineteen 3-gallon buckets of Lightweight Oilwell cement from TXI. Both API Specification tests and tests recommended by Advisory Board Members are being performed for the cement quality control program. The physical requirements used for testing each of the cements are listed in Table 7.4. To accelerate the rate of compressive-strength development at low temperatures, calcium chloride (CaCl_2) is being used with both classes of cement according to Table 7.5. Calcium chloride was selected because it is one of the most effective and commonly used cement accelerators.

All of these tests have been run to provide a baseline for each type of cement. This data will provide a comparison when examining other data for this project. The complete set of tests will be conducted periodically throughout the DOE Project. Table 7.6 (Page 16) shows the first set of data conducted by the testing lab on the three cements received.

Quality control tests initiated in the first quarter of work were completed during this quarter. A complete summary of this data is presented in Appendix D. These data track well with performance data that was provided by the vendors and presented in the previous report. The test results exceeded the required specifications, and this process will be repeated when new cement supplies are received. Data will be presented in the appendices of future reports.

Table 7.4—Cement Slurry Compositions for Quality-Control Testing Program

Cement	Mix Water (%)	Density (lb/gal)	Cement (g)	Water (mL)	Test
Class A	46	15.6	772	355	API
TXI LW	75	13.2	541	406	TT and CS
TXI LW	105	12.1	426	447	FW
Class H	38	16.4	860	327	API

Table 7.5—Percent CaCl_2 for Low-Temperature Compressive Strengths

Temperature (°F)	CaCl_2 (%)
80	0.0
60	1.0
45	2.0

**Table 7.6—Quality Control Testing of
Cement Compositions Specified in Table 7.4**

	Lightweight	Class A	Class H
Free Water (% by vol.)	0.8	0	1.2
Initial Viscosity (Bc)	6	8	13
Spec 5 Thickening Time (hr:min to 100 Bc)	2:20	2:21	1:54
Compressive Strength (psi)			
45°F (2% CaCl₂)	166	737	
60°F (1% CaCl₂)	254	1194	
80°F (24 hr)	523	1689	
100°F (8 hr)		754	1202
100°F (24 hr)		2607	
120°F (24 hr)	1579		
140°F (8 hr)			1964
Viscometer Readings^a (rpm)			
300	57	80	85
200	50	65	70
100	42	49	53
60	38	40	45
30	33	34	38
6	22	17	14
3	12	10	8

^aAfter 20 minutes conditioning on atmospheric consistometer at 80°F

7.3 Design of Cement Slurries Containing ULHS

7.3.1 Comparison of UCA vs. Crush Strength

A series of compressive-strength comparison tests were prepared with ULHS cements to determine the accuracy of measuring compressive strength with a UCA. The UCA tests were run using the lightweight correlation that is programmed in as one of the three density options. The trapped air in the ULHS can alter the ultrasonic signal, creating inaccurate measurements. Results of these tests are presented in Figures 9 through 14 (Pages 17 through 22). The results indicate that UCA vs. crush strength agreement is fairly good for Class A cements. However, agreement is not acceptable for TXILW cements containing ULHS.

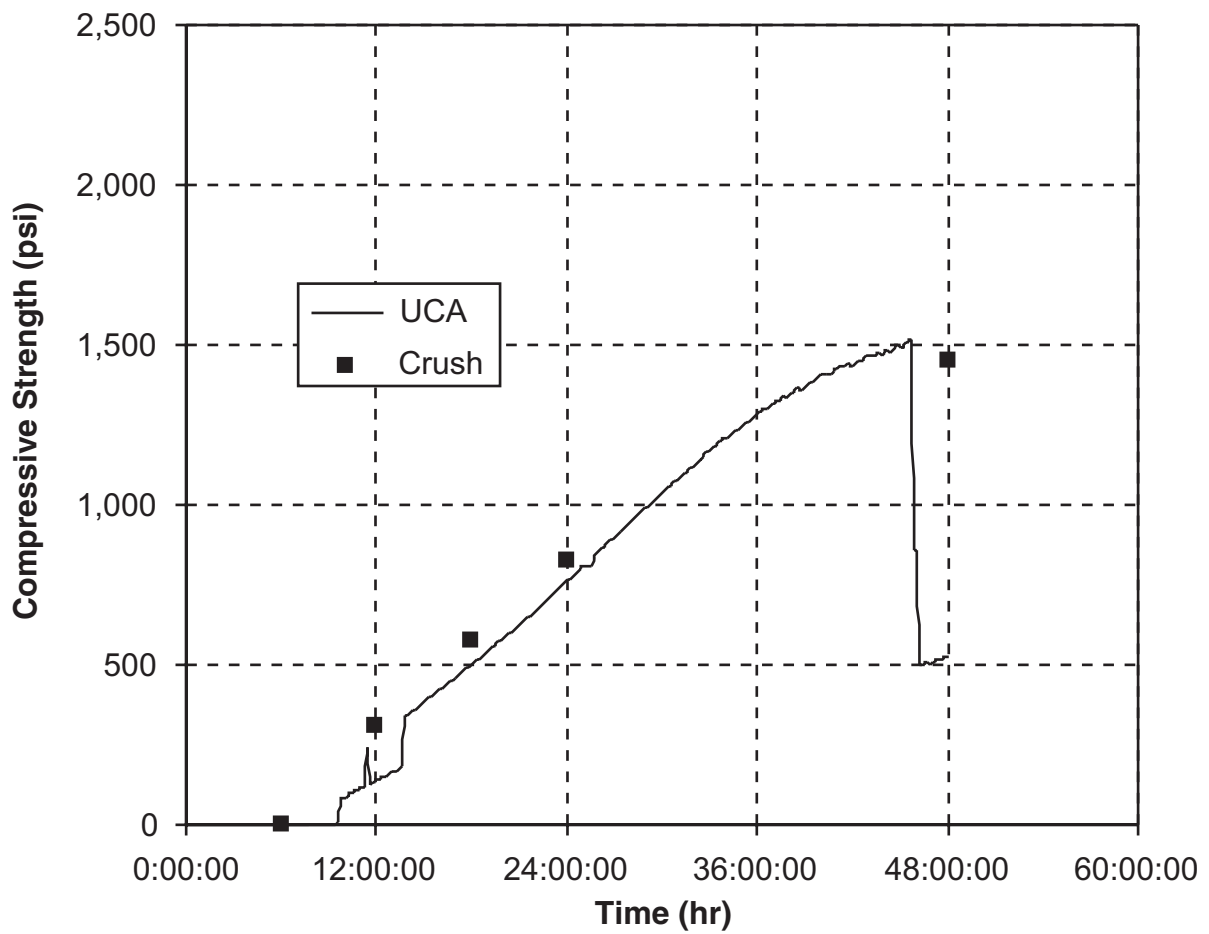


Fig. 9—Comparison of UCA (lightweight correlation) vs. crush strength for Class A cement + 15% 3K ULHS mixed at 10.95 lb/gal

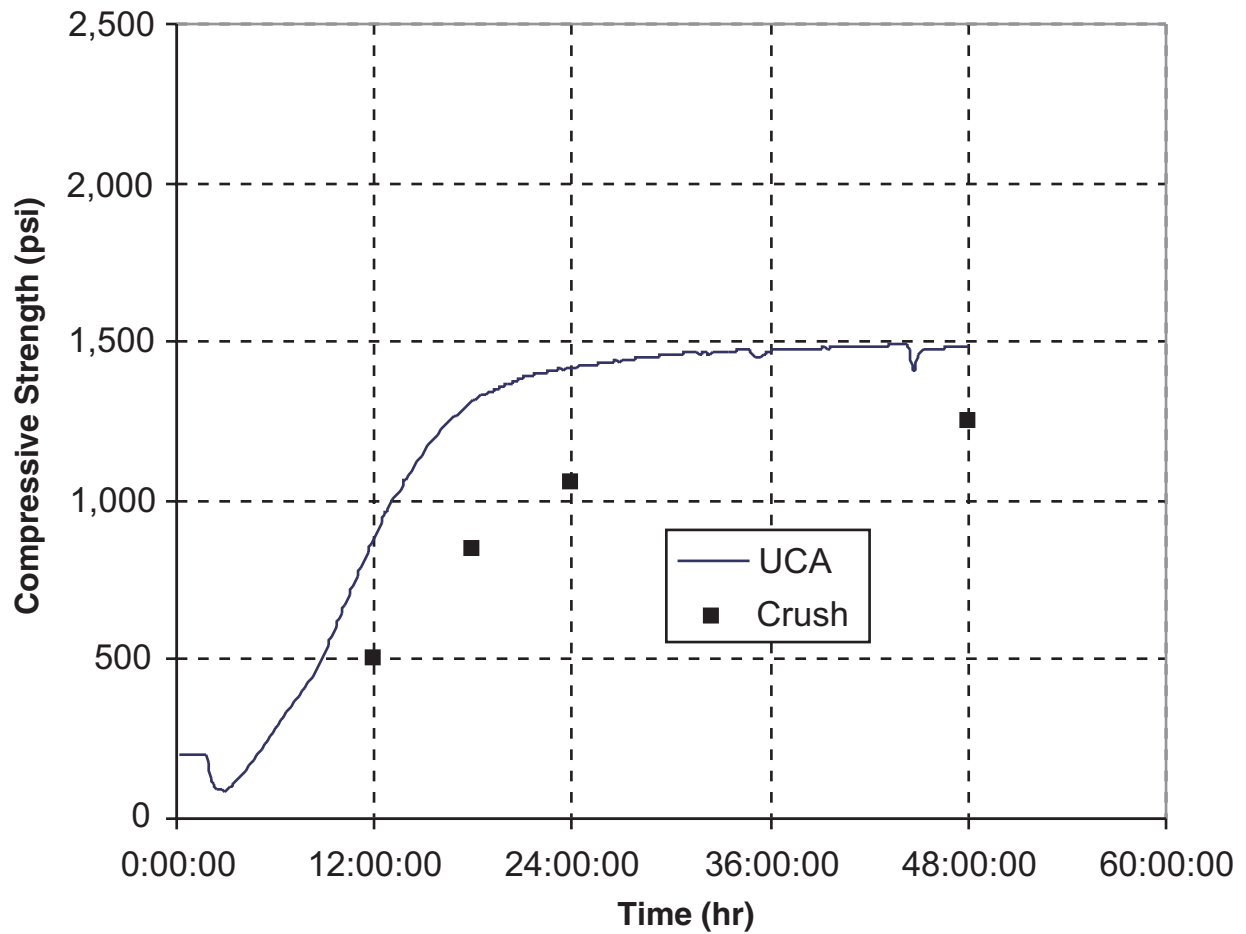


Fig. 10—Comparison of UCA (lightweight correlation) vs. crush strength for TXILW + 27.56% 3K ULHS mixed at 9.0 lb/gal

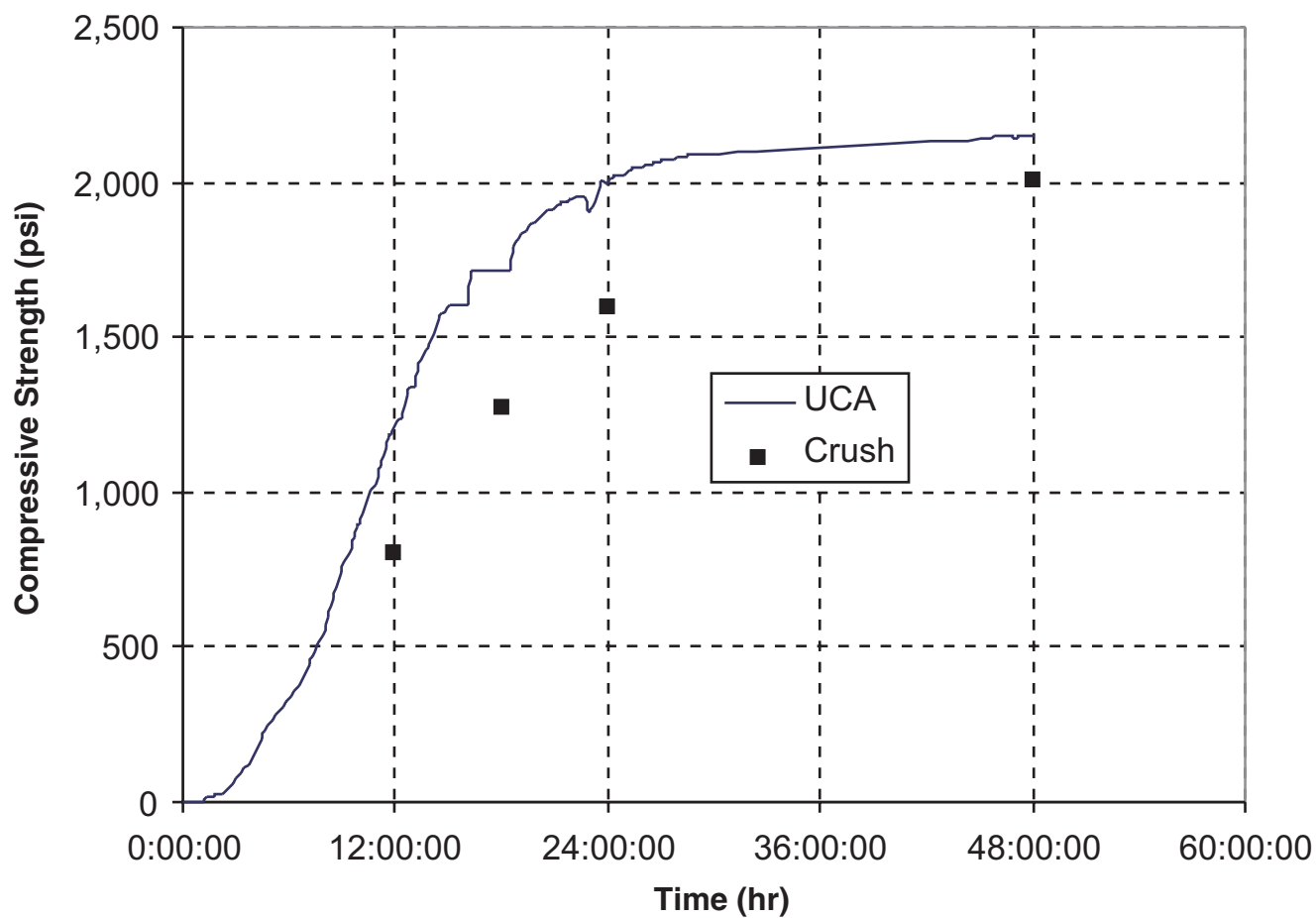


Fig. 11—Comparison of UCA (lightweight correlation) vs. crush strength for TXILW + 6.12% 3K ULHS mixed at 11.5 lb/gal

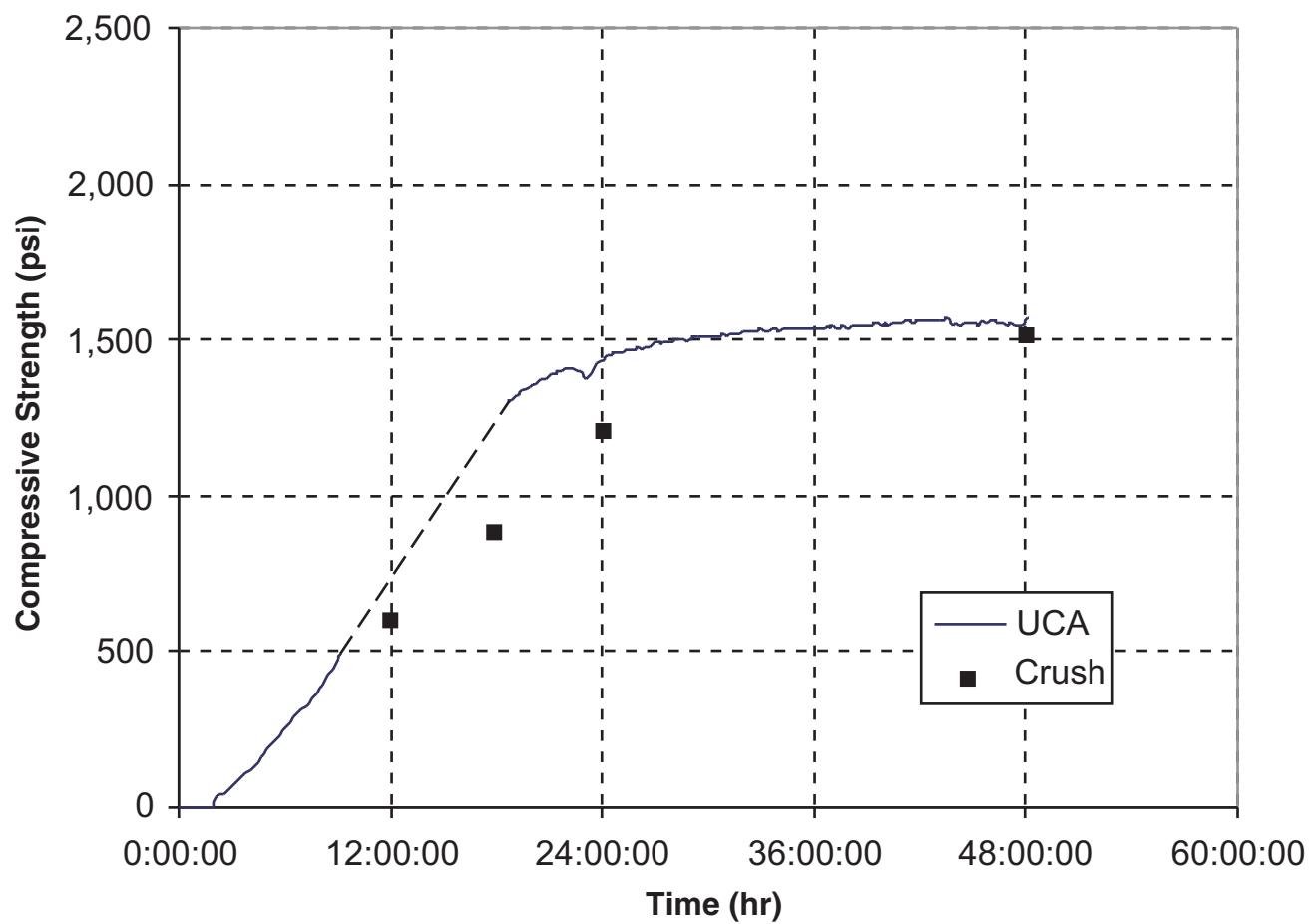


Fig. 12—Comparison of UCA (lightweight correlation) vs. crush strength for TXILW +16.49% 3K ULHS mixed at 10.0 lb/gal

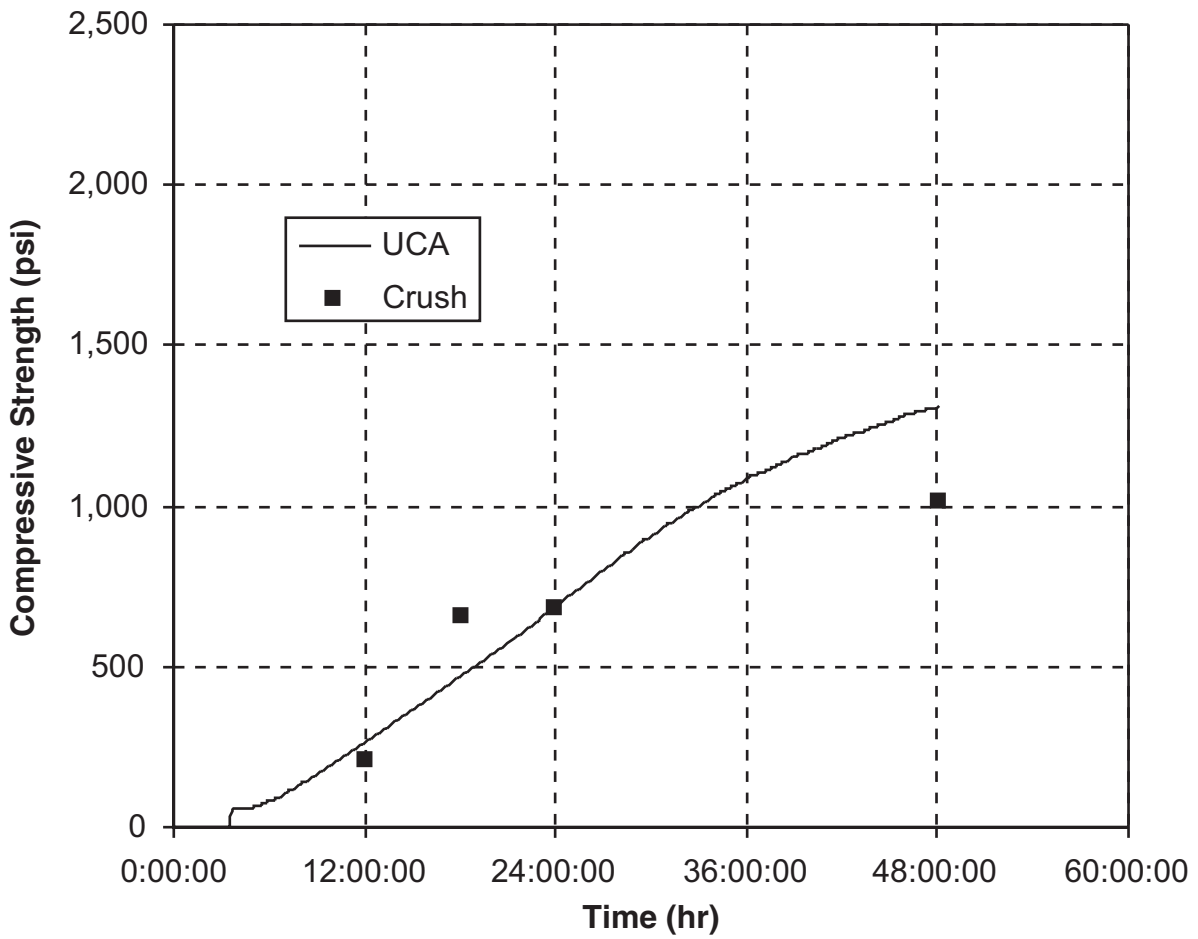


Fig. 13—Comparison of UCA (lightweight correlation) vs. crush strength for Class A cement + 20% 3K ULHS mixed at 10.15 lb/gal

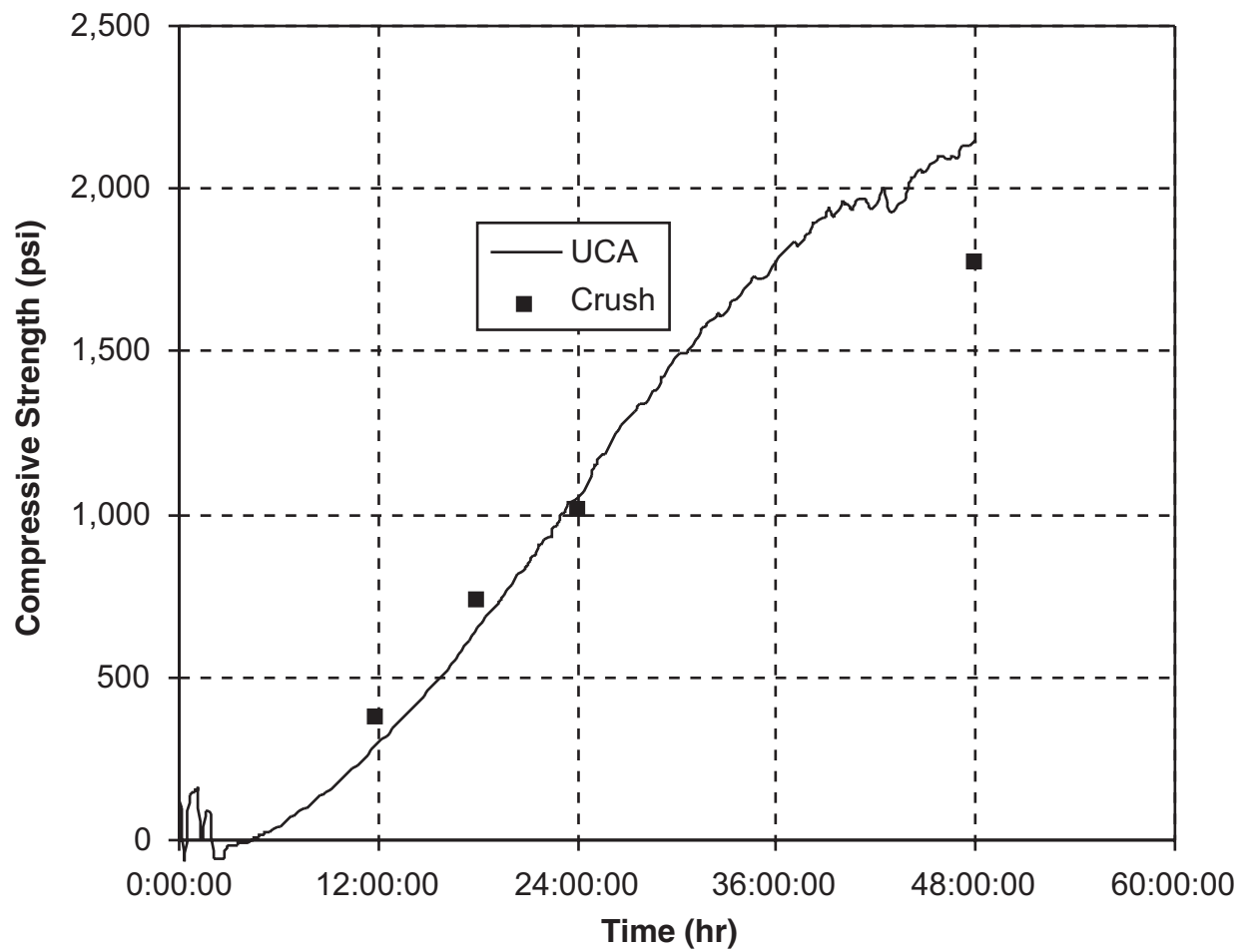


Fig. 14—Comparison of UCA (lightweight correlation) vs. crush strength for Class A cement + 10% 3K ULHS mixed at 12.0 lb/gal

7.3.2 Glass Bead Specific Gravity vs. Applied Pressure

In Report 1, data for three different kinds of ULHS were presented. Work during the second quarter has completed analysis of specific gravity vs. applied pressure performance for all ULHS materials in cement. The data are presented in Figure 15. From this figure it appears that the 5K beads are more sensitive to pressure than the 4K beads. These findings will be investigated in future studies of the project.

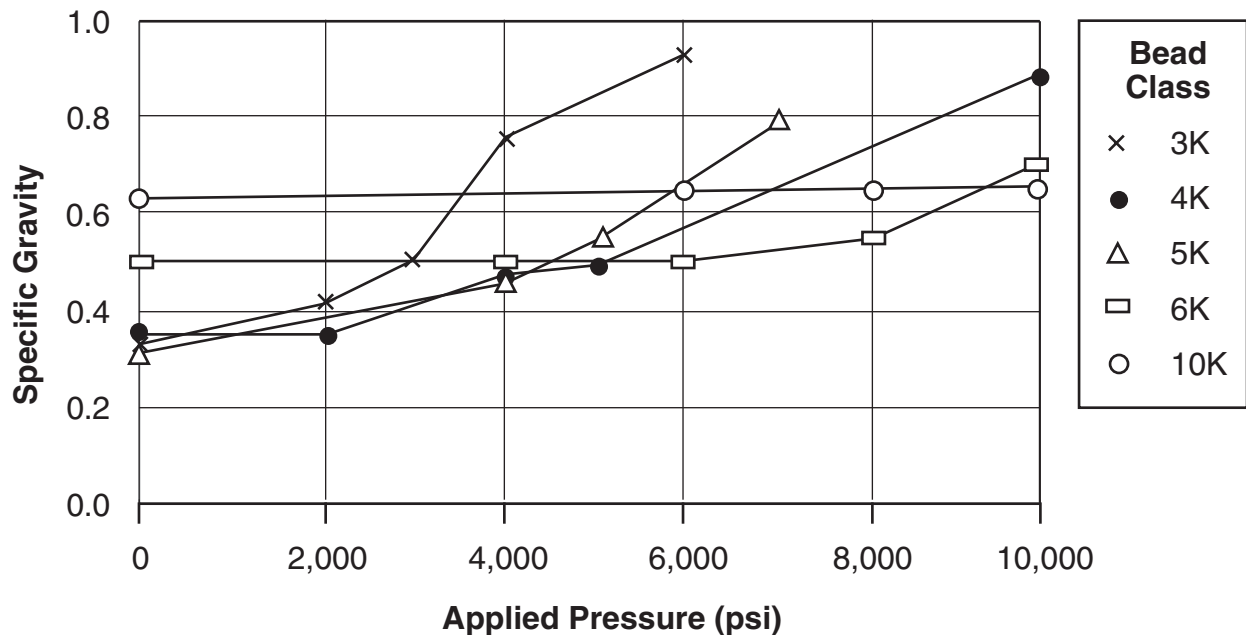


Fig. 15—Specific gravity vs. applied pressure for ULHS cements

7.3.3 Rheology: Ascending/Descending Speed

The rheology effects of running a rotational viscometer in descending and ascending order were measured for ULHS cements in the first phase. However, the testing was repeated, following API procedures. The results of repeat testing with six different ULHS cements and mix water concentrations are shown in Figures 16 through 21 (Pages 24 through 26). This testing evaluated the centrifugal effects of the rotational viscometer on the stability of the slurries. Figures 16 through 21 show the results of this testing. The data indicate that little separation is indicated by running the tests in ascending and then descending order.

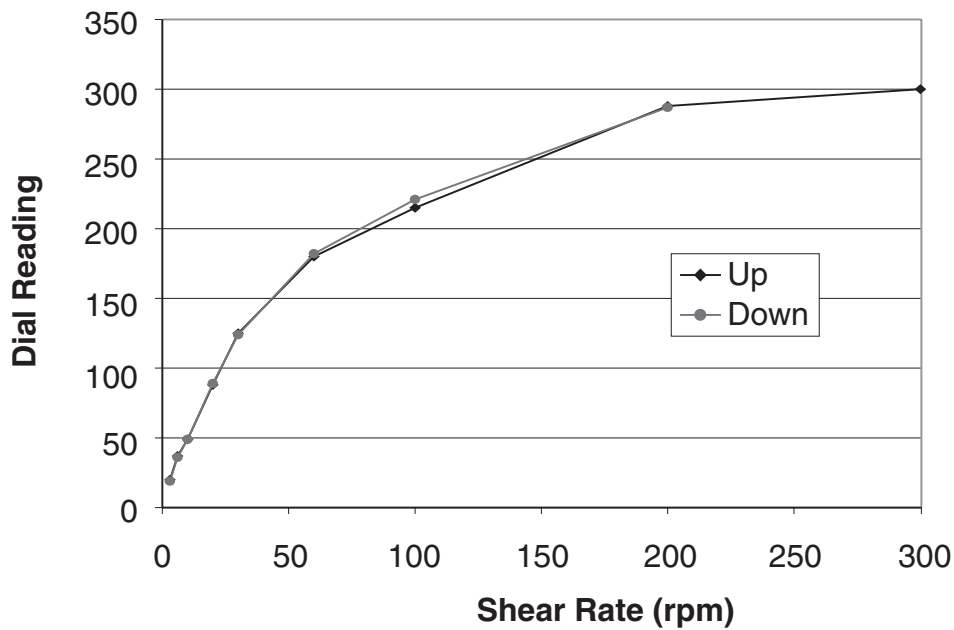


Fig. 16—Rheology of an 11.5-lb/gal slurry of TXILW + 9.98% 3K ULHS mixed with 5.5 gal/sk of fresh water

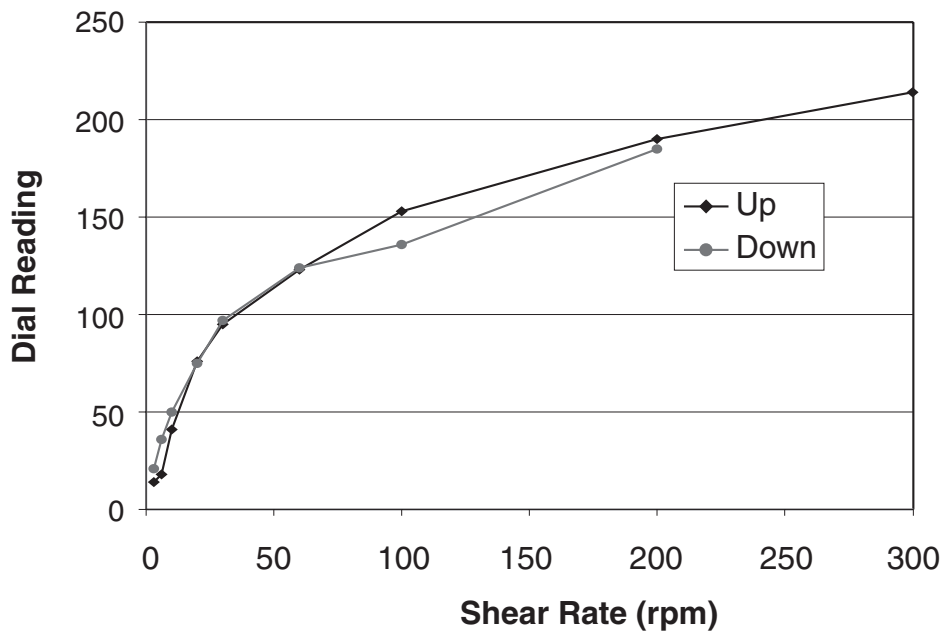


Fig. 17—Rheology of an 11.5-lb/gal slurry of TXILW + 9.21% 3K ULHS mixed with 6.0 gal/sk of fresh water

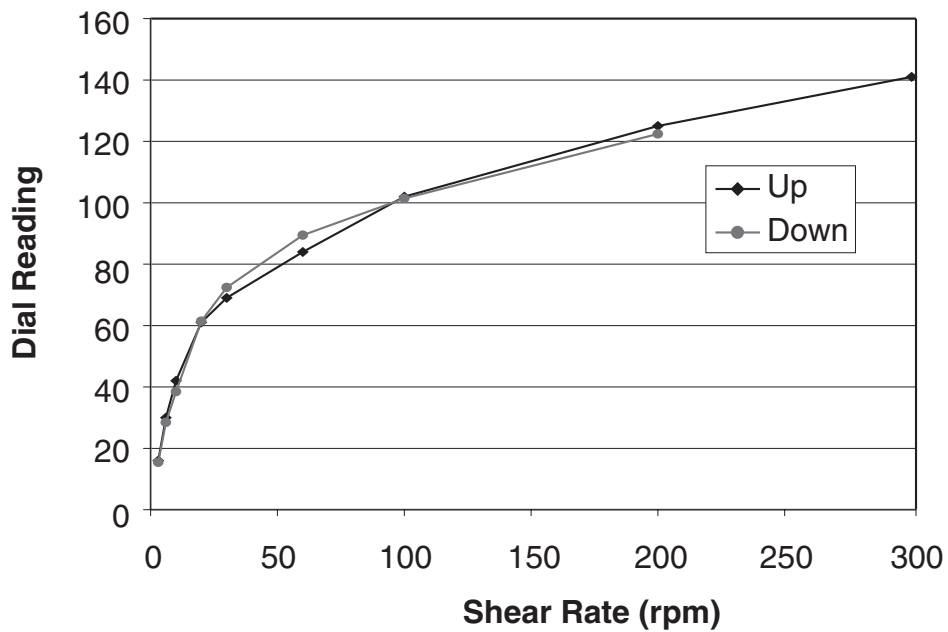


Fig 18—Rheology of an 11.5-lb/gal slurry of TXILW + 8.44% 3K ULHS mixed with 6.5 gal/sk of fresh water

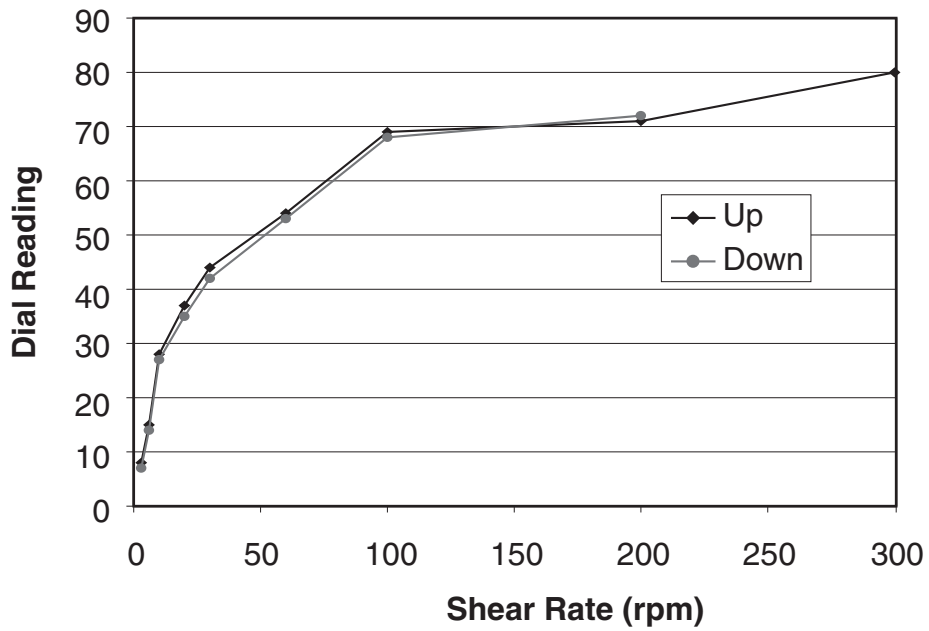


Fig. 19—Rheology of an 11.5-lb/gal slurry of TXILW + 7.67% 3K ULHS mixed with 7.0 gal/sk of fresh water

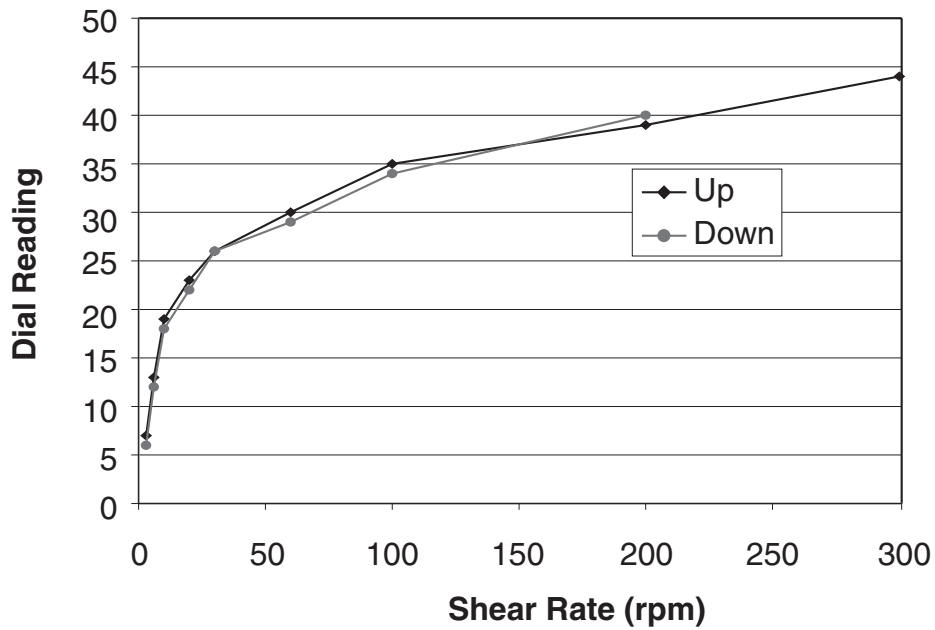


Fig. 20—Rheology of an 11.5-lb/gal slurry of TXILW + 6.12% 3K ULHS mixed with 8.0 gal/sk of fresh water

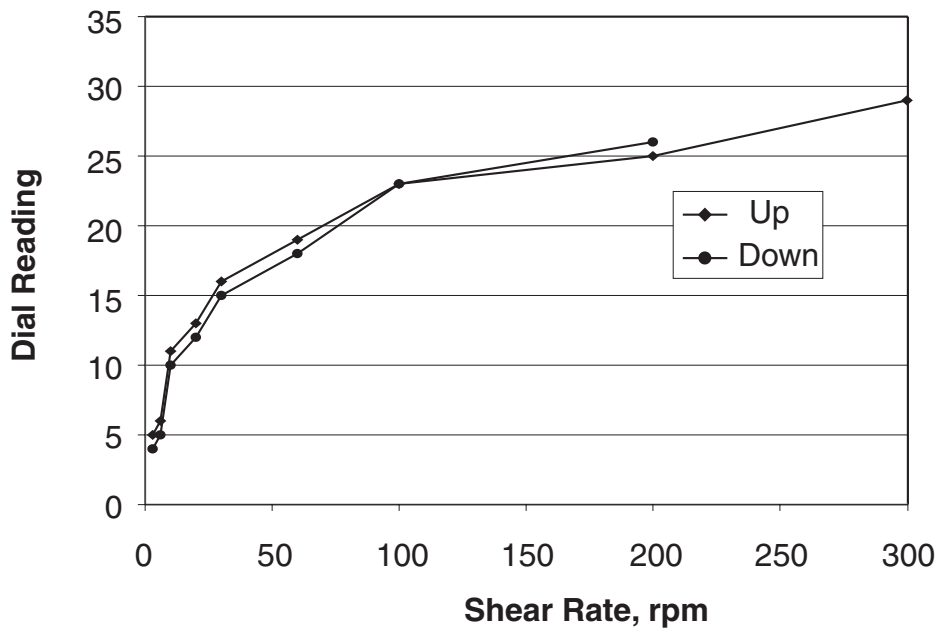


Fig. 21—Rheology of an 11.5-lb/gal slurry of TXILW + 4.58% 3K ULHS mixed with 9.0 gal/sk of fresh water

7.3.4 Shear Effect on Slurry Density

Mixing of ULHS with a Waring blender causes breakage of some spheres due to shearing by the blender blade. This breakage alters the slurry density and yield. Investigation of the effects of high shear on the ULHS breakage was initiated in the first phase of this project. However, results from the initial testing indicated that a procedure change was needed because random density variations in the atmospheric density measurements were introduced by air entrainment. Experiments were repeated using defoamer and a pressurized mud balance to determine density variations. The data presented in Table 7.7 indicates that the higher strength ULHS are essentially unaffected by the level of shear imparted by a Waring blender. The data indicate that all ULHS suffered some breakage, but the degree of breakage, as manifested by an increase in slurry density, was considered negligible. Therefore, cements containing ULHS will be mixed according to standard laboratory procedures. It should be noted that actual field mixing is not as likely to have the same harsh shearing effect as what is seen in these laboratory tests. However, field mixing effects must be measured from full-scale tests.

**Table 7.7—Waring Blender
Shear Energy Effect on Class A Slurries**

ULHS	Water (gps)	Density at Shear Time		
		0 sec	35 sec	50 sec
13.0 lb/gal Slurries				
6.64% 3K	6.00	12.9	13.1	13.2
6.40% 4K	6.15	13.0	13.1	13.2
6.40% 5K	6.15	13.1	13.3	13.3
6.40% 6K	7.07	13.0	13.1	13.1
10.0 lb/gal Slurries				
18.0% 3K	12.00	9.9	10.1	10.2
18.74% 4K	12.00	10.0	10.0	10.1
18.74% 5K	12.00	10.0	10.0	10.1
25.14% 6K	12.00	10.0	10.0	10.1

7.4 Comparison of ULHS and Foamed Cements

A series of lightweight cements was created using ULHS or foamed cement to establish realistic performance for these materials. Initial testing focused on compressive-strength development.

The results shown in Tables 7.8 through 7.10 (Page 28) indicate that the range of application for foamed cements is extended compared to historical data or to cements with traditional lightweight additives.

**Table 7.8—TXI Lightweight Cements 24-hr
Compressive Strength With and Without 3K ULHS**

Density (lb/gal)	Additives	Temp. (°F)	Compressive Strength (psi)
9.0	ULHS, 2% CaCl ₂	65	300
9.0	ULHS, 2% CaCl ₂	80	410
10.0	ULHS, 2% CaCl ₂	65	310
10.0	ULHS, 2% CaCl ₂	80	440
11.0	ULHS, 2% CaCl ₂	65	395
11.0	2% Na ₂ SiO ₂	65	60
11.0	ULHS, 2% CaCl ₂	80	510
11.0	2% Na ₂ SiO ₂	80	95
12.0	ULHS, 2% CaCl ₂	65	390
12.0	1% Na ₂ SiO ₂	65	200
12.0	ULHS, 2% CaCl ₂	80	395
12.0	1% Na ₂ SiO ₂	80	180
13.0	0.5% Na ₂ SiO ₂	65	150
13.0	0.5% Na ₂ SiO ₂	80	290

**Table 7.9—Class H Cement 24-hr Compressive
Strength With and Without 3K ULHS**

Density (lb/gal)	Additives	Temp. (°F)	Compressive Strength (psi)
10.0	ULHS, 2% CaCl ₂	65	320
10.0	ULHS, 2% CaCl ₂	80	450
11.0	ULHS, 2% CaCl ₂	65	365
11.0	ULHS, 2% CaCl ₂	80	470
12.0	ULHS, 2% CaCl ₂	65	519
12.0	3% Na ₂ SiO ₂	65	115
12.0	ULHS, 2% CaCl ₂	80	650
12.0	3% Na ₂ SiO ₂	80	241
13.0	2% Na ₂ SiO ₂	65	205
13.0	2% Na ₂ SiO ₂	80	380

**Table 7.10—Foamed Cement 24-hr
Compressive Strength Development**

Density (lb/gal)	Temp. (°F)	Compressive Strength (psi)
10.0	80	705
11.0	80	900

7.5 U.S. Literature Review

A literature search on lightweight cements and alkali-aggregate reactions was conducted during this quarter. Preliminary results are presented in Appendix E. Many of these papers are summarized. No time has been devoted to preparing a complete summary of the reference literature. This will be done during the next quarter.

8.0 Conclusions

Based on initial results presented herein, the following conclusions can be drawn:

- Historical lightweight cement performance data analysis has given a reference point to establish further testing. The data set will be more completely analyzed as more data are added. ULHS cements could possibly extend this lower limit to below 10.0 lb/gal.
- Waring blender shear during mixing results in negligible breakage of the specific ULHS materials being studied in this project. The ULHS manufacturer does not recommend the use of a high-speed blender for mixing. Further mixing studies will be investigated in the next project quarter.
- For this project, UCA is acceptable for showing general trends of strength development, but actual compressive strength measurements should be gathered from crush tests.
- Rotational viscometer operation in ascending or descending order has no effect on rheology measurement of the specific ULHS slurries designed for this project.
- Laboratory designed test procedures for ULHS and foamed cements are established.
- Ongoing quality control procedures are established, and the results will be reported in appropriate appendices.

9.0 References

1. API Recommended Practice 10 B, 22nd Edition, December 1997: "Recommended Practice for Testing Well Cements," American Petroleum Institute.
2. API Specification 10A, 22nd Edition, January 1, 1995: "Specification for Cements and Materials for Well Cementing," American Petroleum Institute.
3. ISO 10426-2: Petroleum and Natural Gas Industries - Cements and Materials for Well Cementing, Part 2: Recommended Practice for Testing of Well Cements, 1998.

10.0 List of Acronyms and Abbreviations

lb/gal—pound(s) per gallon
lb/ft—pound(s) per foot
rpm—revolutions per minute
gal/sk—gallon(s) per sack
gps—gallon(s) per second
g/cc—grams per cubic centimeter
g—gram
cc—cubic centimeter
psi—pound(s) per square inch
ULHS—ultralight hollow glass spheres
API—American Petroleum Institute
avg.—average
BHCT—bottomhole circulating temperature
BHST—bottomhole static temperature
TXI—Texas Industries, a cement supplier
TXILW—a lightweight cement available from TXI
CSI—Cementing Solutions, Inc.
QC—quality control
Bc—Bearden units of consistency
AT—atmospheric
3M—Minnesota Mining and Manufacturing
3K—3,000-psi designation
4K—4,000-psi designation
5K—5,000-psi designation
6K—6,000-psi designation
10K—10,000-psi designation
TT—thickening time test
CS—compressive strength test
FW—free water test

Appendix A—Non-Standard Test Procedures Developed for ULHS Cements

A.1 Procedure 1—Mixing Beads without High Shear

Note: Mixing glass beads into a cement slurry using a Waring blender can break beads, thereby altering the slurry density.

1. Weigh out the appropriate amounts of the cement sample and additives, water, and glass beads into separate containers.
2. Mix the cement slurry according to Section 5.3.5 of API RP 10B.
3. Pour the slurry into a metal mixing bowl and slowly add the glass beads while continuously mixing by hand with a spatula.

A.2 Procedure 2—Mixing Beads with High Shear

Mix the slurry, including the beads, according to API RP 10B. Measure the density with a pressurized mud balance to assess the degree of density change due to breakage.

A.3 Procedures for Performing Stability Test

1. Prepare the cement and bead slurry as described in the *Mixing Beads with High Shear* instructions above.
2. Pour 250 mL of the thoroughly mixed slurry into a 250-mL graduated cylinder and seal to prevent evaporation.
3. Stand the graduated cylinder upright in an 80°F water bath with water level equal to the height of cement in the graduated cylinder, and leave the cylinder in the bath for 1 hour.
4. Mark the 250-mL graduated cylinder into three sections (Top, Middle, Bottom).

Top 1/3 Section: 170 to 250 mL

Middle 1/3 Section: 80 to 170 mL

Bottom 1/3 Section: 0 to 80 mL

5. Fill a (30-mL) syringe with 1 to 5 mL of the cement and bead mixture to remove any air trapped in the tip of the syringe; then eject the slurry into the waste bin, leaving the tip filled. Wipe any residue from the outside of the syringe.
6. Tare the syringe from Step 5 on a balance.
7. Refill the syringe with a least 10 mL of the cement and bead mixture from the top 1/3 section of the graduated cylinder. Wipe any residue from the outside of the syringe.
8. Weigh and record the weight and volume of the syringe containing the mixture.

9. Calculate the specific gravity of the mixture by dividing the recorded weight of the cement and bead mixture by the volume of the mixture measured into the syringe. Compute the density by multiplying by the density of water (8.33 lb/gal).

Example: Syringe plus Cement and ULHS = 38.14 g
 Volume of Cement and ULHS = 30 mL

$$38.14 \text{ g} \div 30 \text{ mL} = 1.271 \text{ g/mL}$$
$$1.271 \text{ g/mL} \times 8.33 = 10.59 \text{ lb/gal}$$

10. Eject the slurry into a waste bin, and repeat Steps 6 through 9 with the other two (middle and bottom) 1/3 sections of the graduated cylinder. Use a length of tubing attached to the syringe tip to access the lower portions of the cylinder.

A.4 Calculations for Determining Density Difference Due to Separation

1. Using the data obtained in Section A.3, subtract the top density from the bottom density.
2. Divide this value by the bottom density and multiply by 100.
3. The resulting value is the percent of density difference caused by glass bubble separation.

Example: Top Density = 15.0 lb/gal
 Bottom Density = 15.5 lb/gal

$$15.5 - 15.0 = 0.5$$
$$(0.5 \div 15.5) \times 100 = 3.23\% \text{ density difference}$$

4. Repeat Steps 1 through 3 for the middle data.

A.5 Laboratory Mixing, Testing Procedures, and Testing Scope for Foamed Cement

This part of ISO 10426 defines the recommended practices for the atmospheric generation and testing of foamed cement slurries and their corresponding unfoamed base slurries.

A.6 Preparing Unfoamed Base Slurry

A.6.1 Calculation of Base Cement With and Without Surfactants

Because the final slurry for foamed cement contains surfactant(s), these materials cannot be added to the base slurry for initial mixing. This will require that the density of the base slurry be adjusted to compensate for the later addition of the surfactant(s) prior to foaming.

Example: Slurry Design: Class G Cement + 0.2 gal/sk Surfactant
 Base slurry density = 14.5 lb/gal
 Surfactant weight = 10 lb/gal

Base Slurry Calculations:	<u>Weight</u>	<u>Volume</u>
Cement	94 lb	3.59 gal
Surfactant	2 lb (0.2 gal * 10 lb/gal)	0.2 gal
Water	55.39 lb	6.65 gal
Total	151.39 lb	10.44 gal

Calculation of:	<u>Weight %</u>	<u>Contributions</u>
Cement	62.09 %	(94/151.39)
Surfactant	1.32 %	(2/151.39)
Water	36.59 %	(5.39/151.39)

Slurry without Surfactants:	<u>Weight</u>	<u>Volume</u>
Cement	94 lb	3.59 gal
Water	55.39 lb	6.65 gal
Total	149.39 lb	10.24 gal

Slurry Density without Surfactants: $149.39/10.24 = 14.59 \text{ lb/gal}$

A.7 Equipment

A.7.1 Blender Container

A special blending container is required for preparing foamed cement at ambient pressure in the laboratory. (A typical blending container is shown in Figure A.1, Page 34.) The blending container is similar to the one used for standard slurry preparation except that it has a threaded cap with an O-ring seal. The cap has a small hole (approx. 3/4-in. diameter) in the center fitted with a removable plug that has an O-ring seal.

A.7.2 Mixing Blade Assembly

The mixing blade assembly can be either a single mixing blade as supplied by the manufacturer or a multiple, stacked-blade assembly. Testing-to-date has not identified a significant difference in the two blade assemblies.

A.7.3 Single Blade Assembly

The single blade assembly should conform to ISO/DIS 10426-2, clause 5.

A.7.4 Multi-Blade Assembly

The multi-blade or stacked-blade assembly is constructed of a series of assemblies, each blade corresponding to the requirements of ISO/DIS 10426-2, clause 5. The assembly consists of five (5) standard blades attached to a central shaft, and spaced equally throughout the mixing container. A typical assembly is shown in Figure A.1.

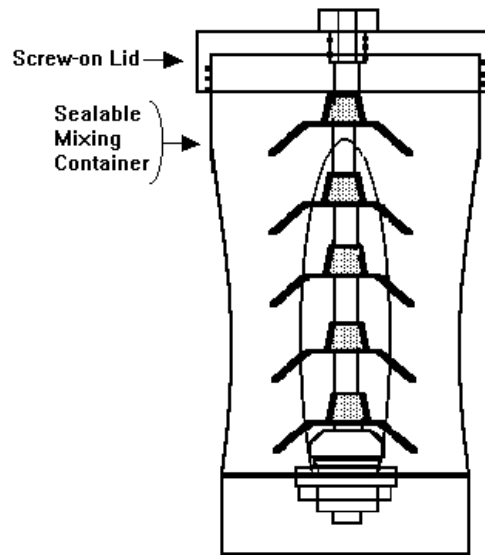


Fig. A.1—Example of a typical blending container

A.8 Container Volume

Accurate determination of the volume of the blending container is critical to this procedure. The calculations for slurry volume and foamed cement density are based on this volume determination. Weigh the clean, dry, blending container (including mixing assembly, screw-on lid and screw-in plug for the lid). Remove the screw-on lid from the mixing container and then remove the screw-in plug from the lid. Fill the mixing container with water and then screw the lid on tightly. Pour additional water into the hole in the lid for the plug until the container is completely filled, and then screw the plug tightly into the lid. Wipe the excess water that exits from the plug's vent hole, and then weigh the container again. The weight of the water inside the container is then divided by the density of the water to determine an accurate volume for the mixing container.

A.9 Preparing Base Cement Slurry

This method assumes that the base slurry as described in Section A.6.1 is being prepared in a separate mixing container, and this slurry is then to be weighed into the mixing container described in Section A.7.1. To prepare sufficient volume may require multiple mixes with the standard mixing procedure.

Test samples, without the addition of foaming surfactants, should be prepared according to ISO/DIS 10426-2, clause 5. When possible, the temperature of the cement sample, additives, and mix water should be within $\pm 2^{\circ}\text{C}$ (3°F) of the respective temperatures recorded from the well site. The temperature of the mixing container should approximate that of the mix water being used in the slurry design. The mixing device should be calibrated annually to a tolerance of $\pm 3,3$ rev/s (200 rpm) at 66,7 rev/s (4,000 rpm) and $\pm 8,3$ rev/s (500 rpm) at 200 rev/s (12,000 rpm). As required, the density of the unfoamed cement slurry can be determined by methods found in ISO/DIS 10426-2, clause 6.

A.10 Determining Slurry Volumes and Weights

A.10.1 Slurry Volume

Determine the volume of unfoamed cement slurry to be mixed. The total volume of unfoamed cement slurry should include the volume of the surfactant(s) to be added to the slurry. The surfactant(s) is to be added after the initial mixing of the base slurry. The volume of unfoamed slurry to be placed in the container may be determined by the following procedure.

When it is desired to foam a slurry with a specific amount of gas per unit volume of slurry (foam quality), the resultant density of the foamed slurry must be determined. This can be calculated by Equation 1.

$$FD = (100 - \%G) \div 100 \times UFDS \quad (1)$$

Where:

FD	=	Foamed density of the slurry
%G	=	Percentage of gas in final foamed slurry
UFDS	=	Unfoamed slurry density with surfactant(s)

When a desired foamed slurry density is known or after calculating it with Equation 1, determine the grams of cement slurry including surfactant(s) that is to be placed into the foam blender to prepare the foamed slurry. This can be calculated by Equation 2.

$$GUFS = CV \times SGUFS \quad (2)$$

Where:

GUFS	=	Grams of unfoamed slurry including surfactant(s) to be placed into the foam mixer
CV	=	Container volume of foam mixer (mL)
SGUFS	=	Specific gravity of the foamed slurry

Example:

Container volume	=	1170 mL
Base slurry density	=	14.5 lb/gal (1.74 g/mL)
Foamed cement density	=	10.0 lb/gal (1.2 g/mL)
Volume percent air	=	$(14.5 - 10) \div 14.5 \times 100 = 31.03\%$
Unfoamed slurry volume	=	$1170 - (1170 \times 31.03\%) = 806.95 \text{ mL}$
Unfoamed slurry weight	=	$806.95 \times 1.74 = 1404.1 \text{ g}$

A.10.2 Surfactant(s) and Slurry Weight

The surfactant(s) weight is determined by taking the unfoamed slurry weight and multiplying by the percent by weight of surfactant(s). The slurry weight is determined by taking the unfoamed slurry weight and subtracting the surfactant(s) weight. This can be calculated by Equation 3.

$$GS = TGUFS \div TGS \times GUFS \quad (3)$$

Where: GS = Grams of surfactants (total) to place into the foam mixer with the unfoamed slurry without surfactant(s)
TGUFS = Total grams unfoamed slurry prepared in A.6
TGS = Total grams surfactant that would be used in TGUFS

$$GUSM = GUFS - GS \quad (4)$$

Where: GUSM = Grams of unfoamed slurry without surfactant(s) to be placed into the mixer.

Example: Unfoamed slurry weight = 1404.1 g
Percent by weight of surfactant = 1.32 %

Surfactant weight = $1404.1 \times 0.0132 = 18.5$ g
Slurry weight = $1404.1 - 18.5 = 1385.6$ g

A.11 Preparing the Atmospheric Foamed Slurry

Based on the volume calculated in Section A.10.1, weigh the appropriate amount of the prepared slurry into the special mixing container. Add the calculated amount of surfactant(s). The final weight of the cement slurry and added surfactant(s) should be checked against the final desired base slurry density. Before foaming, verify that the total weight of the slurry and added surfactant(s) corresponds to the weight calculated in Section A.10.2.

A.11.1 Generating a Foamed Cement

Make sure the mixing container is sealed. Using the blade assembly described in Section A.7.3 or A.7.4, the slurry should be mixed at the 12,000 rpm setting for 15 seconds. Because of the increase in slurry volume and viscosity, the maximum rpm of the blender could be less than 12,000 rpm. The maximum attainable rpm will depend on the power of the blender, slurry density, and foam quality. Record and report the final rpm of the mixer.

During the mixing, there will be a noticeable change in the sound (pitch) from the blender. After mixing, there may be some slight pressure in the mixing container because of temperature increases and energy imparted to the foam during the foaming process. Be careful when removing the top of the mixing container. After mixing, open the sampling port, and verify that the slurry completely fills the slurry mixing container. If the slurry does not fill the mixing container at the end of the 15 second mixing, it is doubtful the slurry will foam properly under field conditions. The slurry should be redesigned.

A.11.2 Determining Foamed Slurry Density

The density of the foamed slurry should be determined by pouring it into a container with a large open top that has a known volume when completely filled. Weight the container, pour the foamed slurry into the container, and level the top with a straight blade. Wipe the outside of the container clean, and weigh the container with the foamed slurry.

A pressurized slurry density balance should never be used to determine the density of a foamed cement prepared at atmospheric pressure since this can compress the gas bubbles, and the slurry density indication will be high. The non-pressurized slurry density balance is also not recommended because the small hole in the center of the lid can cause a restriction that may partially pressurize the slurry and cause errors in the density determination.

A.12 Atmospheric Testing of Foamed Cement Slurries

Because of the high air entrainment in a foamed cement slurry, it is necessary to modify some of the standard testing procedures to prevent obtaining erroneous test results.

A.12.1 Determining Slurry Stability

Evaluate the foam stability by pouring a sample of the foamed cement slurry into a container or graduated cylinder for 2 hours of continued evaluation. Cover or seal the top of the container to prevent drying or dehydration of the sample. Since the main purpose of this test is to check for settling and stability in the foamed slurry, the visual appearance of the foamed slurry (such as free fluid, settling, or bubbles concentrated in a specific area) must be noted. If desired, density measurements may be made of the foam at multiple locations in the cylinder after the 2-hour period. To determine the density of the slurry at various locations in the cylinder, a large syringe with a Tygon tube on it can be used to remove small portions from the top, middle, and bottom. The removed slurry can then be transferred to a smaller graduated cylinder to determine the weight of a known volume of the slurry. From there, the specific gravity and density can be determined.

Preferred Method—Pour the foamed slurry into a standard 250-mL graduated cylinder that is used for free-fluid testing. Cover the top of the cylinder to prevent dehydration, place it onto the counter-top, and visually examine it during the 2-hour period. The cylinder can not be cured at temperatures above the ambient temperature at which the foamed slurry was prepared because an increase in temperature will increase the bubble size and may have an effect on the slurry stability.

Optional Method 1—Perform the above test in a smaller graduated cylinder, such as a standard 50-mL TC (to contain), standard 100-mL TC, or a wide-mouth 100-mL TC cylinder.

Optional Method 2—Perform the above test in an open-top sample container or in a plastic container with a lid. For containers that are not transparent, there will only be a visual inspection of the top surface at the conclusion of the 2 hours.

Check foam stability by curing samples until they are set for density gradient measurement throughout the sample. These may be cured in non-greased, covered 508-mm (2-in.) diameter, 1016-mm (4-in.) tall cylinders or any appropriate covered container. Cut or break the samples into sections, mark them from the top to the bottom, and measure the specific gravity of each section. The specimen should not be cut with a saw that uses water. The use of water may cause the specimen to absorb water and change the density of the specimen. Large variations in density from sample top to bottom are an indication of instability. When determining the specific gravity by Archimedes principal, it is recommended that a beaker of fresh water be placed on a scale and tared. The specimen is placed into a loop of fine string (or thread) and suspended in the water for the first measurement for determining the volume of the specimen (V). The volume of the specimen (mL) will be equal to the weight of the water displaced by the specimen when suspended in the water. The weight of the specimen being suspended in the water must be determined quickly to prevent the specimen from absorbing water and giving erroneous results. The specimen is then lowered to rest on the bottom of the beaker of water to obtain the actual weight of the specimen (W). The specific gravity (SG) is then determined ($W \div V = SG$). The slurry density can also be determined ($SG \times 8.33 = \text{lb/gal}$).

Evaluate foam stability at an elevated temperature <190°F.

The PVC curing mold (Figure A.2, Page 39) is prepared by applying primer/cleaner and glue to the PVC parts and assembling them. Allow sufficient time for the glue to harden. Apply Teflon® tape to the brass fittings.

The atmospheric prepared foamed slurry is poured into the PVC mold and the large brass fitting screwed into the top. Slurry must exit the center hole of the large brass fitting. The small brass plug is then screwed into the large brass fitting and both tightened. Cure at the desired temperature until set. The specimen may be cured in a vertical position or at a specific angle if requested. After curing, cool to room temperature, remove the brass fitting and plug from the top, and examine the top of the foam. Note any obvious problems in the top of the foamed slurry. Cut the PVC into multiple pieces (at least three), marking each piece to reference the top to bottom sections. The specimen should not be cut with a saw that uses water. The use of water may cause the specimen to absorb water and change the density of the specimen. Carefully cut the PVC longitudinally along each segment until the PVC can be removed. Examine the set foamed sections for signs of instability. These specimens can then be tested for density using the Archimedes principal described above. Compressive strengths can also be determined on each section providing the sample is a uniform cylinder.

The following materials are for the PVC curing mold:

- 1/4-in. brass plug
- 1-in × 1/4-in. brass reducer
- 1-in. PVC collar
- 1-in. PVC Schedule 40
- Tubing (6 to 8 in. long)
- 1-in. PVC cap

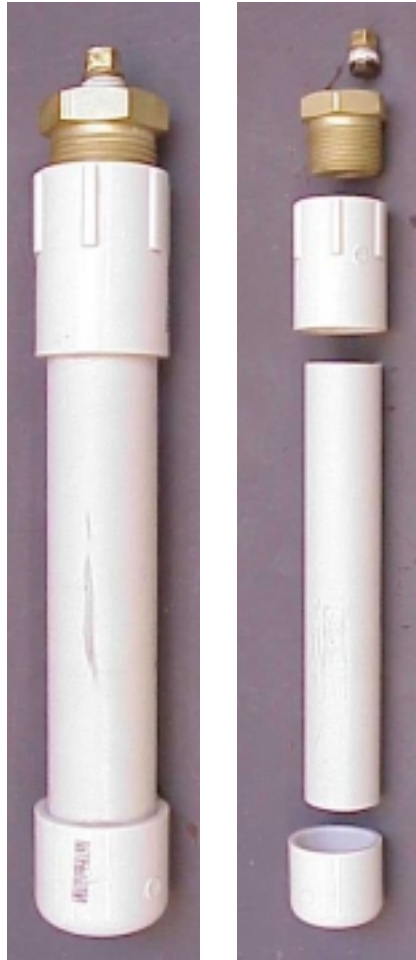


Fig. A.2—PVC curing mold

Signs of foam instability include the following:

- More than a trace of free fluid
- Bubble breakout noted by bubbles appearing on the surface of the sample. In severe cases, bubble coalescing (breaking, enlargement, merging, etc.) may be seen on the surface.
- Excessive column height reduction. If the foamed sample temperature is greater than room temperature when poured, a small amount of shrinkage in volume will occur as the sample cools. Minor meniscus effects are normal.
- Signs of density segregation as indicated by streaking or light to dark coloring change from top to bottom.
- Large variations in density from sample top to bottom.

A.12.2 Determining Compressive Strength

Atmospheric prepared foamed cement is poured into a curing mold that can be sealed. The sealing lid prevents the foamed slurry from expanding out of the curing mold as it is heated, which will result in an undesired density decrease. The mold can be a standard 508-mm (2-in.) cube mold with a cover clamped to the top. Plastic cylinder molds (508-mm [2-in.] diameter by 1016-mm [4-in.] height) with a sealable top have also been used and placed into a clamp device.

The sealed mold containing the foamed cement slurry is then placed into an atmospheric water bath, cured, and the strength is determined as specified by API. The temperature is normally limited to approximately 65°C (149°F), but can sometimes be increased to 90°C (194°F) if there is a good seal to keep the slurry from expanding out of the curing mold.

A.12.3 Determining Permeability

For determination of the permeability of atmospheric-prepared foamed cement, the preferred procedure is to pour the foamed cement slurry into permeability test molds. These test specimens are then cured and tested for permeability while still in the permeability mold. If the foamed cement slurry is poured into a mold in which the specimen must be removed, cored, cut, or sealed in the permeability testing apparatus; the specimen may not be strong enough to perform these operations without damaging it. The curing of atmospheric-prepared foamed cement slurries should be conducted under atmospheric pressure as for the compressive strengths in Section A.12.2.

The permeability testing of the cured specimens will be performed using the procedures in ISO/DIS 10426-2, clause 11.

A.12.4 Determining Other Tests on Base Unfoamed Slurry

A slurry that is foamed at atmospheric pressure should not be tested under pressure. Testing an atmospheric pressure prepared slurry under pressure will compress the foamed slurry and allow contamination when tested in a HPHT consistometer for thickening time. A compressed foamed slurry will also result in testing a heavier slurry if compressive strength specimens are cured under pressure.

For the following tests, the base unfoamed slurry without the surfactant(s) is prepared according to ISO/DIS 10426-2, clause 5. After the slurry is prepared, the mixer is stopped and the surfactant(s) added and stirred gently with a spatula to distribute it uniformly in the slurry. It is recommended the slurry be transferred gently from the mixing container to a beaker and back three times to ensure a uniform distribution. The use of a small amount of material for preventing/breaking air entrainment in slurries that are not foamed is permitted for these tests. Materials to prevent/break air entrainment should not be used in any foamed slurries.

A.12.5 Determining Thickening Time

Since the surfactant(s) will affect the thickening time, and the foam itself does not affect the thickening time of a cement slurry, the thickening time test is normally performed using a standard HPHT consistometer on the base unfoamed cement slurry containing the surfactant(s).

The thickening time test of the unfoamed slurry containing the surfactant(s) will be performed using the procedures in ISO/DIS 10426-2, clause 9.

A.12.6 Determining Fluid Loss

Fluid-loss tests performed with an atmospheric-prepared foamed cement are not likely to yield reliable results. Fluid-loss testing of a cement slurry that has been foamed requires special modifications to the fluid-loss cell and the foamed cement slurry must be prepared and transferred into the fluid-loss cell under pressure. The fluid-loss values obtained from a foamed cement slurry will be slightly less than that of the base unfoamed cement slurry. The fluid loss of the base unfoamed cement is normally used as an indication of the fluid loss of the foamed cement slurry. The static fluid-loss test of the unfoamed slurry containing the surfactant(s) will be performed using the procedures in ISO/DIS 10426-2, clause 10.

TXI Lightweight Slurries**Initial Slurry Designs Used To Determine the Mixability of ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
10.00	1.92	6.5	18.96	Unspecified
10.00	1.97	7.0	18.46	Unspecified
10.00	2.02	7.5	17.97	Unspecified
10.00	2.07	8.0	17.48	Unspecified
10.00	2.27	10.0	15.50	Unspecified
10.00	2.37	11.0	14.52	Unspecified
10.00	1.87	6.0	19.01	1% Melcret K3F
10.00	1.92	6.5	18.51	1% Melcret K3F
10.00	1.97	7.0	18.02	1% Melcret K3F
10.00	2.02	7.5	17.53	1% Melcret K3F
11.50	1.49	5.5	9.98	Unspecified
11.50	1.53	6.0	9.21	Unspecified
11.50	1.58	6.5	8.44	Unspecified
11.50	1.62	7.0	7.67	Unspecified
11.50	1.70	8.0	6.12	Unspecified
11.50	1.78	9.0	4.58	Unspecified

**Crush Test Slurry Designs Used for Comparing
Conventional, Foam, and ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
Conventional				
11.00	2.45	14.96	None	2% Sodium Silicate
12.00	1.77	9.92	None	1% Sodium Silicate
12.00	2.38	14.05	None	3% Sodium Silicate
13.00	1.42	7.16	None	2% Sodium Silicate
13.00	1.86	10.20	None	5% Sodium Silicate
ULHS				
9.00	2.45	8.01	28.71	2% CaCl ₂
10.04	2.40	7.53	22.00	2% CaCl ₂
11.00	1.81	7.79	9.98	2% CaCl ₂
Foam				
9.00	1.38	7.00	None	.02% Witcolate, .01% Aromox C12, 2% CaCl ₂
10.00	1.38	7.00	None	.02% Witcolate, .01% Aromox C12, 2% CaCl ₂
11.00	1.38	7.00	None	.02% Witcolate, .01% Aromox C12, 2% CaCl ₂

Class A Slurries**Initial Slurry Designs Used To Determine the Mixability of ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
10.00	2.33	7.20	21.91	Unspecified
10.00	2.38	7.60	21.60	Unspecified
10.00	2.42	8.00	21.27	Unspecified
10.00	2.44	8.20	21.12	Unspecified
10.00	2.52	9.00	20.94	Unspecified
10.00	2.57	9.50	20.10	Unspecified
10.00	2.62	10.00	19.70	Unspecified
10.00	2.67	10.50	19.31	Unspecified
10.00	2.72	11.00	18.92	Unspecified
10.00	2.22	6.00	22.41	1% Melcret K3F
10.00	2.28	6.50	22.49	1% Melcret K3F
10.00	2.35	7.20	21.94	1% Melcret K3F
10.00	2.37	7.50	21.23	1% Melcret K3F
10.00	2.30	6.50	22.55	3% Melcret K3F
10.00	2.37	7.20	22.00	3% Melcret K3F
13.00	1.46	4.80	8.26	Unspecified
13.00	1.49	5.20	7.65	Unspecified
13.00	1.50	5.40	7.34	Unspecified
13.00	1.53	5.80	6.72	Unspecified
13.00	1.54	6.00	6.42	Unspecified
13.00	1.61	7.00	4.87	Unspecified
13.00	1.41	4.00	9.00	1% Melcret K3F
13.00	1.43	4.40	8.39	1% Melcret K3F
13.00	1.46	4.80	7.77	1% Melcret K3F

Class A Slurries**Crush Test Slurry Designs Used for Comparing
Conventional, Foam, and ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
Conventional				
11.50	2.76	16.87	None	3% Sodium Silicate
12.00	2.38	14.05	None	3% Sodium Silicate
13.00	1.86	10.20	None	2% Sodium Silicate
ULHS				
9.05	3.26	11.50	31.00	2% CaCl ₂
10.09	2.46	8.37	21.33	2% CaCl ₂
11.07	2.15	8.37	13.63	2% CaCl ₂
12.05	1.92	8.37	7.65	2% CaCl ₂
Foam				
9.00	1.31	6.03	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂
10.00	1.31	6.02	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂
11.00	1.31	6.02	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂

Class H Slurries**Initial Slurry Designs Used To Determine the Mixability of ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
13.00	1.46	4.80	8.27	Unspecified
13.00	1.49	5.20	7.65	Unspecified
13.00	1.53	5.80	6.72	Unspecified

**Crush Test Slurry Designs Used for Comparing
Conventional, Foam, and ULHS Slurries**

Density (lb/gal)	Yield (ft³/sk)	Water Requirement (gal/sk)	ULHS (%bwoc)	Additives (%bwoc)
Conventional				
12.00	2.38	14.05	None	3% Sodium Silicate
13.00	1.86	10.20	None	2% Sodium Silicate
ULHS				
9.00	3.09	10.00	31.00	2% CaCl ₂
10.00	2.48	8.37	21.33	2% CaCl ₂
10.00	2.40	7.53	22.00	2% CaCl ₂
11.00	2.17	8.37	13.63	2% CaCl ₂
11.00	1.98	6.22	16.00	2% CaCl ₂
12.00	1.92	8.37	7.65	2% CaCl ₂
Foam				
9.00	1.30	6.02	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂
10.00	1.30	6.02	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂
11.00	1.30	6.02	None	.03% Witcolate, .01% Aromox C12, 2% CaCl ₂

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-1	y		3907	9.2		95	9800	5:49	676	1800	Slag
HES-11	y		120	9.2	82	80	165	8:00+	80	80	TLW
HES-11	y		1100	9.8		85	3361	5:00+			TLW
HES-3		n		10.0		60	7600	4:45			A
HES-4	y		210	10.0		91	2100		183	271	A
HES-11	y		210	10.0		91	2100		155	244	TLW
HES-4	y		210	10.0		91	2100		126	185	Micro-fine
HES-11		n		10.0		119	6100	4:16			TLW
HES-11		n		10.0		119	6100	5:18		176	TLW
HES-11	y		2945	10.0		47	6200	5:00+		0	TLW
HES-5	y		142	10.0	120	103	2500	5:00+	85	156	H
HES-6		n		10.1	130	111	2752	4:38	4900		
HES-3	y		1605	10.5		75	2600	7:31	83	226	A
HES-2				10.5	181	145	7200	2:30	423	982	H
HES-11	y		250	10.5	92	80	1000	7:00+	FIRM	72	TLW
HES-11	y		250	10.5	92	80	1000	7:00+	50	70	TLW
HES-11	y		722	10.5	0	85	1305	6:00+	0	0	TLW
HES-11	y		220	10.5	97	83	1308	5:00+	FIRM	50	TLW
HES-4	y		2945	10.6		47	6200	5:00+		64	A
HES-3	y		1605	10.8		75	2600	2:21			A
HES-3	y		1605	10.8		75	2600	3:15			A
HES-3	y		2100	10.8		60	3650		0	54	A
HES-3	y		2100	10.8		60	3650		57	64	A
A	y		148	10.8	94	82	1200	4:00+	SET	110	H
HES-3	y		167	10.9		87	1732	2:57			A
HES-11	y		100	11.0	130	103	4500		184		TLW
HES-3	y		1711	11.0		80	2600	3:42			A
HES-4	y		210	11.0		91	2100		436	863	A
A	y		210	11.0		91	2100		89	128	Micro-fine
F		n		11.0	220	182	12055	4:20	238	286	Micro-fine
HES-2		n		11.0	181	145	7200	2:17	526	581	H
HES-3	y		1490	11.0		80	2505	2:29	377	487	A
A	y		1000	11.0		60	14085	7:00+		102	H
HES-11	y		31	11.0	86	80	555	6:00+	0	0	TLW
HES-11	y		31	11.0	86	80	555	6:00+	31	113	TLW
HES-3		n		11.0		60	7600	5:18			A
A	y		150	11.0	92	80	1000	4:00+	112	274	A
HES-3	y		100	11.0	130	103	4500	4:35	247	642	A
HES-4	y		100	11.0	130	100	4500	4:27	404	564	A
HES-11	y		100	11.0	130	103	4500	4:02	0	95	TLW
HES-11	y		100	11.0	130	103	4500	6:00+	75	129	TLW
A	y		50	11.0	136	104	4799	6:00+	111	188	H
HES-11	y		100	11.0	130	103	4500		107	159	TLW
HES-11	y		100	11.0	130	103	4500	6:00+	53	95	TLW
HES-11	y		100	11.0	130	103	4500	6:00+	87	92	TLW
HES-3	y		1736	11.0		60	2450	4:19	105	175	A
A	y		480	11.0	97	84	1400	6:00+	126	345	A
A	y		174	11.0	95	80	1000	6:00+	115	205	A
HES-2	y		110	11.0	94	83	1300	5:00+	80	490	A
HES-11	y		80	11.0	160	116	6425	4:43			TLW
HES-11	y		1120	11.0	140	112	7990	2:53	30	90	TLW
HES-11	y		253	11.0	122	97	3862	7:00+	40	150	TLW
A	y		238	11.0	102	86	1894	6:00+	40	70	H
A	y		153	11.0	90	80	800	5:00+	FIRM	30	H
A	y		180	11.0	146	111	5555	7:00+	170	220	A
A	y		37	11.0	139	105	4500	6:00+	175	185	A
F	y		210	11.0		135	1868	2:00	172	180	Micro-fine
A	y		50	11.0	133	103	4400	2:04	270	280	A
HES-7	y		2841	11.0	0	72	5600	7:00+	0	0	A
A	y		193	11.0	96	83	1300	5:00+	120	190	A
A	y		300	11.0	125	98	3897	4:00+	130	200	H
HES-1	y		3214	11.0		80	6350	6:00+	115	160	Slag
F		n		11.0		228	12402	7:50	250	300	Micro-fine
HES-11		n		11.0	240	192	13000	5:55			TLW
HES-11		n		11.0	240	192	13000	6:00	90	324	TLW
A	y		180	11.0	128	102	4200	6:30+	76	103	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
F		n		11.0	213	172	9713	5:00+	307	334	Micro-fine
A	y		385	11.0	118	102	4500	6:00+			A
A	y		50	11.0	133	103	4400	2:55	150	160	A
HES-3	y		1470	11.1		70	2600	5:03			A
A	y		50	11.1	161	122	7000	7:00+	37	50	H
HES-11	y		100	11.2	96	83	1300	6:00+	0	89	TLW
HES-11	y		380	11.2		95	6000	5:30+	32	86	TLW
HES-11	y		380	11.2		95	6000	4:30+	75	139	TLW
HES-11	y		380	11.2	154	115	6000	6:53	225	436	TLW
HES-11	y		380	11.2		70	1450	6:00+	38	67	TLW
HES-11	y		100	11.2	96	83	1300	7:00+	0	0	TLW
A	y		148	11.2	128	101	4863	5:00+	0	150	H
HES-7	y		100	11.2	96	83	1300	7:00+	0	74	H
HES-11	y		76	11.2	145	110	8174	4:00+	374	531	TLW
HES-11	y		100	11.2	171	125	7000	5:50	184	305	TLW
HES-11	y		76	11.2	211	163	12182	3:45	460	500	TLW
HES-7	y		2100	11.2		65	2500	6:00+	0	0	A
HES-11	y		76	11.2	211	163	12182	3:40	450	570	TLW
HES-11	y		380	11.2	154	115	6000	6:47	191	614	TLW
B	y		200	11.3	120	98	4000	4:30	86	128	H
F		n		11.3	194	156	8625	2:08	285	341	Micro-fine
A	y		123	11.3	113	94	3200	5:00+	130	200	H
A	y		280	11.4	102	89	3223	5:00+	75	127	H
A	y		110	11.4	95	80	1000	4:30+	95	120	H
A	y		420	11.4	115	99	4334	6:00+	138	201	A
A	y		420	11.4		102	4500	6:00+	187	257	A
A	y		420	11.4		102	4500		56	99	H
A	y		385	11.4		98	4094	5:00+	69	175	A
A	y		113	11.4	90	80	753	4:00+	50	100	H
A	y		164	11.4	93	81	1100	4:30+	101	163	A
A	y		113	11.4	95	84	2000	4:00+	60	110	H
A	y		113	11.4	101	89	6460		80	160	H
A	y		113	11.4	101	89	6460	4:00+	70	130	H
A	y		222	11.4	125	100	3850	5:00+	50	110	H
A	y		164	11.4	93	81	1100	4:00+			A
A	y		260	11.4	120	96	4820	5:00+	60	120	H
A	y		164	11.4	125	100	4084	4:00+	178	193	A
A	y		127	11.4	136	105	4700	7:00+	120	210	A
A	y		45	11.4	128	101	4000	5:00+	88	170	H
A	y		225	11.4	139	106	4853	5:00+	130	180	H
A	y		324	11.4	92	80	900	5:30+	70	121	H
A	y		80	11.4		84	2295	6:00+			H
A	y		108	11.4	91	80	1000	4:00+	50	110	H
A	y		108	11.4	108	92	2500	4:00+	60	120	H
A	y		90	11.4	92	80	1000	4:00+	52	140	A
A	y		228	11.4	92	80	1000	4:00+	60	152	A
A	y		181	11.4	92	80	1000	4:00+	130	150	H
A	y		181	11.4	110	93	3768	4:00+	140	155	H
A	y		236	11.4	118	97	4112	5:00+	78	130	H
A	y		47	11.4	119	96	3000	5:00+	90	173	A
A	y		245	11.4	126	100	4398	4:30	129	212	A
A	y		148	11.4	128	101	4000	4:00+	120	135	H
A	y		68	11.4	89	80	820	4:20	250	320	A
A	y		68	11.4	136	105	4700	2:20	230	390	A
A		n		11.4		80	50			70	A
A		n		11.4	80	80	270	4:00+		86	A
HES-11	y		20	11.4	97	84	1450	4:00+	87	113	TLW
HES-11	y		20	11.4	150	116	6400	3:45	255	419	TLW
A	y		43	11.4	152	115	6000	6:30+	142	155	H
A	y		236	11.4	95	83	1300	6:00+	83	107	A
A	y		420	11.4		100	3538	6:00+	98	147	A
A	y		427	11.4	100	89	2000	5:30+	75	140	H
A	y		165	11.4	118	96	3120	7:00+	140	220	A
A	y		236	11.4	118	97	4112	5:00+	70	130	H
A	y		427	11.4	117	99	4200	5:00+	85	158	H
A	y		420	11.4		84	1502	6:30+	90	171	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		372	11.4		82	1200	8:20	111	193	A
A	y		372	11.4		82	1200	8:20	111	193	A
A	y		260	11.4	95	83	1300	5:00+			H
A	y		260	11.4	95	83	1340	5:00+			H
A	y		420	11.4		85	1600	7:16	103	206	A
A	y		420	11.4		83	1200	5:30+	98		A
A	y		199	11.4	92	80	1050	5:00+	110	140	H
A	y		372	11.4	116	97	3500	6:03	274	348	A
A	y		260	11.4	125	99	3600	5:00+	50	110	H
A	y		236	11.4	95	83	1300	6:00+	89	112	A
HES-11	y		38	11.4	95	80	1000		36	229	TLW
A	y		120	11.4	197	147	9000		0	SET	H
A	y		25	11.4	88	80	700	2:00+	90	140	A
A	y		80	11.4	100	87	1700	5:00+	99	145	H
A	y		43	11.4	120	98	3500	3:30+	60	110	H
A	y		25	11.4	116	96	3000	3:00+	79	125	A
A	y		890	11.4	121	103	4500	6:00+	57	113	H
A	y		800	11.4	146	114	6000	6:30+	0	115	H
A	y		150	11.4	90	80	800	7:00+	0	51	H
A	y		30	11.4	92	80	1000	6:00+	0	60	H
HES-11	y		385	11.4		74	1450	4:00+	70	137	TLW
A		n		11.4	92	80	1000		60	120	H
HES-11	y		160	11.4		80	1000	6:00+	79	106	TLW
A	y		100	11.4	120	96	3100	5:00+	170	290	A
A	y		160	11.4	96	83	1300	6:00+			H
A	y		118	11.4	148	106	4500	5:00+	66	147	H
HES-11	y		57	11.4	92	80	1000	4:00+	92	109	TLW
A	y		150	11.4	115	94	2700	7:00+	0	52	H
A	y		8	11.4	108	92	2500	5:00+	65	116	H
A	y		8	11.4	108	92	2500	5:00+	58	81	H
HES-11	y		220	11.4	104	90	2180	4:00+	133	388	TLW
A	y		220	11.4	115	96	3525	3:00+	199	251	A
HES-11	y		78	11.4	116	96	3710	4:48	310	600	TLW
HES-11	y		160	11.4	119	98	3902	6:44	122	583	TLW
HES-11	y		40	11.4	119	98	3500	4:00+	168	601	TLW
HES-11	y		10	11.4	125	100	3800	5:00+	350	558	TLW
A	y		180	11.4	124	100	4000	4:00+	105	153	A
HES-11	y		25	11.4	124	100	4000	3:28	325	384	TLW
HES-11		n		11.4		80	1000	4:00+	79	110	TLW
B	y		100	11.4	92	80	1000	4:00+	300	310	A
A	y		52	11.4	117	96	3892	4:30+	50	130	H
A	y		238	11.4	126	100	4173	4:30+	70	120	H
A	y		90	11.4	125	98	3500	4:00+	85	125	A
A	y		90	11.4	120	98	3500	5:00+	145	216	A
A	y		210	11.4	114	98	3800	4:13	144	216	A
A	y		228	11.4	120	98	4275	5:00+	120	195	A
A	y		12	11.4	128	101	4000	4:30+	90	135	A
A	y		107	11.4	138	106	4800	4:30+			H
A	y		226	11.4	125	100	4000	4:30+	109	122	H
A	y		238	11.4	128	101	4600	4:36	160	206	A
A	y		245	11.4	143	109	5200	4:30+	78	116	A
A	y		90	11.4	140	107	5000	5:00+			H
A	y		9	11.4	140	108	5200	4:30			A
A	y		12	11.4	156	118	6350	7:00+	130	160	H
A	y		9	11.4	140	108	5200	7:30+	105	115	H
A		n		11.4	96	83	1300	5:00+	120	170	A
A	y		645	11.4		80	2500	4:00+	50	110	A
A	y		25	11.4	128	101	4000	5:00+	116	143	H
A	y		50	11.4	128	101	4000	4:00+	170	290	A
A	y		180	11.4	136	105	4700	6:00+	125	141	H
A	y		100	11.4	140	107	5000	5:00+	130	240	A
A		n		11.4	142	108	5200	6:30+	0	60	H
A	y		170	11.4	95	84	1400	4:00+	74	117	H
B	y		50	11.4	115	96	3000	4:00+	95	110	H
A	y		38	11.4	133	103	4937	8:00+	99	120	H
A	y		61	11.4	125	102	4300	4:00+	78	134	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		220	11.4	139	105	4677	7:00+	190	230	H
A	y		181	11.4	121	98	3500	4:00+	70	110	H
A	y		80	11.4	140	107	5000	7:00+	130	155	H
A	y		250	11.4		80	1000	6:30+	123	132	A
A	y		90	11.4	140	108	5350	4:00+	170	250	H
A	y		55	11.4	152	115	6345	4:00+	130	150	H
A	y		200	11.4		80	900	5:00+	0	102	H
A	y		35	11.4	95	81	1150	4:00+	50	121	H
A	y		358	11.4	102	89	2000	4:30+	69	157	A
A	y		365	11.4	122	98	3450	6:05	140	190	A
A	y		261	11.4	130	103	4500	5:00+	107	122	H
A	y		261	11.4	130	103	4500	4:30+	164	167	A
HES-3	y		6224	11.4		79	10000	6:49	0	160	A
A	y		155	11.4	90	80	900	5:00+	87	106	H
A	y		151	11.4	90	80	1000	4:00+	69	197	A
A	y		35	11.4	94	81	1100	6:00+	83	124	H
A	y		218	11.4	115	96	3150	4:00+	160	179	A
A	y		50	11.4	91	81	1100	5:00+	78	121	H
A	y		160	11.4	150	114	7150	5:00+	140	160	H
A	y		54	11.4	91	80	1050	4:30+	191	240	A
HES-11	y		80	11.4	103	88	1800	4:00+	88	108	TLW
A	y		45	11.4	98	84	1400	5:30+			H
A	y		151	11.4	90	80	1000	4:00+	119	205	A
A	y		151	11.4	93	81	1147	5:00+	130	150	H
A	y		35	11.4	113	93	2500	5:00+	94	197	H
A	y		35	11.4	117	95	3175	5:00+	87	116	H
A	y		126	11.4	103	89	2000	5:30+	83	131	H
A	y		126	11.4	103	89	2000	5:30+	93	119	H
A	y		20	11.4	118	93	2500	4:00+	184	243	A
A	y		151	11.4	120	98	3500	4:30+	86	99	H
A	y		107	11.4	95	82	1200	9:35	118	159	A
A	y		151	11.4	90	80	1000	4:00+	60	155	A
A	y		185	11.4	128	101	4000	4:00+	90	160	A
A	y		206	11.4	92	80	1000	4:00+	70	105	H
A	y		280	11.4	105	90	2000	6:30+	79	139	H
A	y		40	11.4	110	93	2500	4:00+	90	130	H
A	y		390	11.4	108	92	2630	6:00+	75	219	A
A	y		1430	11.4		75	2600	5:00+	50	110	A
A	y		38	11.4	118	97	3500	4:00+	88	164	H
A	y		293	11.4	109	96	3500	5:00+	95	165	H
A	y		340	11.4	115	97	3800	7:00+	58	79	H
A	y		206	11.4	124	99	4211	4:00+	75	115	H
HES-11	y		2000	11.4		90	4505	7:00+	55	215	TLW
A	y		35	11.4	135	105	4800	4:00+	102	133	H
A	y		35	11.4	135	105	4800	4:00+	111	192	A
A	y		110	11.4	140	107	5000	4:00+	103	110	H
A	y		130	11.4	128	101	4000	7:00+	60	120	H
A	y		90	11.4	142	108	5372	4:00+	130	160	H
A	y		200	11.4	128	101	5986	6:00+	28	79	H
A	y		60	11.4	130	103	4500	5:00+	90	129	H
HES-11	y		50	11.4	130	103	4500		0	111	TLW
HES-11	y		50	11.4	130	103	4500	5:23	97	173	TLW
A	y		162	11.4	138	104	4500	4:00+	120	150	H
A	y		68	11.4	135	104	4854	4:00+	140	280	H
A	y		21	11.4	124	100	4000	4:00+	125	155	H
HES-11	y		2000	11.4		92	4500	6:00	42	179	TLW
A	y		60	11.4	128	101	4000	4:00+	127	139	A
A	y		150	11.4	142	107	5080	6:00+	89	142	H
A	y		150	11.4	153	113	5600	7:30+	90	121	H
A	y		9	11.4	143	109	5200	6:00+	120	148	H
A	y		52	11.4	119	97	3400	7:00+	80	176	H
A	y		110	11.4	135	105	4600	4:00+	102	134	H
A	y		42	11.4	140	108	8020	6:00+	0	157	H
A	y		53	11.4	99	86	1921	4:00+	195	208	A
A	y		85	11.4	92	80	1000	4:00+	110	140	A
A	y		108	11.4	94	82	1200	4:00+	25	140	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		42	11.4	106	92	2794	6:00+	101	155	H
A	y		85	11.4	110	93	2500	4:00+	120	180	A
A	y		194	11.4	138	104	5525	5:00+	102	133	H
HES-11	y		2000	11.4	90	80	5000	6:00+	0	80	TLW
HES-11	y		722	11.4	130	103	4500	5:00+	217	497	TLW
A	y		157	11.4	143	105	4500	4:00+	130	160	H
A	y		90	11.4	146	110	5250	5:30+	0	172	H
A	y		160	11.4	140	108	5200	6:00+	78	135	H
A	y		42	11.4	140	108	6883	6:00+	122	130	H
A	y		168	11.4	115	97	3500	4:00+	162	185	A
A	y		42	11.4	140	108	7132	6:00+	80	120	H
A	y		87	11.4	145	114	6000	5:00+	136	164	H
A	y		42	11.4	140	108	7487	6:00+	0	125	H
A	y		42	11.4	140	108	8423	6:00+	0	110	H
A	y		60	11.4	145	108	6350	5:00+	125	132	H
A	y		154	11.4	155	112	5400	2:14	206	397	A
A	y		154	11.4	158	112	5200	6:30+	110	160	H
A	y		68	11.4	92	80	1000	3:00+			A
A	y		167	11.4	94	82	1200	4:00+	110	140	H
A	y		68	11.4	91	80	1000	3:00+	109	171	A
A	y		50	11.4	105	91	2200	5:00+	106	130	H
A	y		68	11.4	105	90	2100	3:00+			A
A	y		68	11.4	105	90	2100	3:00+	115	175	A
A	y		160	11.4	135	104	4500	6:00+			H
A	y		180	11.4	155	110	5000	5:00+	61	158	H
A	y		45	11.4	152	112	5500	5:30+	101	118	H
A	y		151	11.4	115	97	3500	5:00+	83	158	H
A	y		151	11.4	115	97	3500	5:00+	75	165	H
A	y		155	11.4	120	98	3635	5:00+	92	125	H
A	y		54	11.4	118	97	3500	4:00+	100	149	H
A	y		150	11.4	115	96	3000	5:00+	105	178	H
A	y		151	11.4	115	97	3500	4:00+	95	125	H
A	y		58	11.4	139	105	4500	5:00+	116	131	H
A	y		35	11.4	136	103	4300	5:00+	105	150	H
A	y		100	11.4	128	102	4400	5:00+	120	128	H
A	y		250	11.4	134	104	4550	9:30+	68	120	H
A	y		54	11.4	124	100	4000	4:00+	115	146	H
A	y		50	11.4	130	101	4000	5:30+			H
A	y		194	11.4	92	80	1000	5:00+	88	155	H
A	y		65	11.4	141	108	5100	5:00+			H
A	y		154	11.4	92	80	800	4:00+	100	130	H
A	y		95	11.4	90	80	998	3:00+	110	140	H
A	y		164	11.4	90	80	1000	3:00+	SET	130	H
A		n		11.4	90	80	1000	3:00+	55	125	A
A	y		300	11.4	98	86	1630	5:00+	70	140	A
A	y		500	11.4		80	1600	5:00+	108	376	A
A	y		294	11.4	93	82	1175	5:30+			H
A	y		95	11.4	94	83	1856	3:00+	100	145	H
A	y		121	11.4	125	100	3800	4:00+	65	140	H
A	y		294	11.4	120	97	3200	5:00+	98	168	H
A	y		70	11.4	135	106	5000	5:30+			A
A	y		70	11.4	135	106	5000	4:30+	60	110	H
A	y		110	11.4	138	107	5000	5:00+	95	121	H
A	y		148	11.4	90	80	800	4:00+	83	143	H
A	y		65	11.4	141	108	5100	5:00+	93	128	H
A	y		41	11.4	128	99	3670	5:00+	100	120	H
A	y		100	11.4	132	104	5100	6:00+	80	100	H
A	y		100	11.4	126	101	4200	7:00+	60	100	H
A	y		220	11.4	120	98	4636	6:30+	60	75	H
A	y		100	11.4	150	109	6488	5:30+	100	110	H
A	y		100	11.4	150	109	5078	8:00+	110	170	H
A	y		220	11.4	134	104	4500	7:00+	80	100	A
A	y		204	11.4	92	80	1000	5:00+	40	77	H
A	y		204	11.4	120	97	3300	5:00+	45	100	H
A	y		45	11.4	138	104	4948	6:00+	80	120	H
A	y		22	11.4	152	115	6000	7:00+	50	72	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		42	11.4	136	104	4500	6:00+	40	100	H
A	y		55	11.4	130	104	4630	5:00+	50	100	H
A	y		220	11.4	91	80	1000	4:00+	FIRM	70	H
A	y		35	11.4	126	99	4378	7:00+	80	110	H
A	y		14	11.4	132	104	4500	5:30+	40	110	H
A	y		60	11.4	92	82	1000	5:39	160	200	A
A	y		61	11.4	130	100	4000	2:40			A
A	y		90	11.4	0	91	1000	4:30+	40	60	H
A	y		90	11.4	132	104	4500	5:00+	90	130	H
A	y		23	11.4	134	104	4500	7:00+	60	120	A
A	y		300	11.4	98	84	1400	5:00+	20	80	A
A	y		16	11.4	110	92	2500	7:00+	20	80	A
A	y		41	11.4	95	80	1000	3:00+	50	80	H
A	y		48	11.4	90	80	800	3:00+	FIRM	80	H
A	y		36	11.4	92	80	1000	5:00+	50	100	H
A	y		36	11.4	128	100	4000	5:30+	90	120	H
A	y		73	11.4	125	96	3000	4:27	80	100	A
A	y		55	11.4	90	80	800	4:00+	50	70	H
A	y		90	11.4	134	104	4500	9:00+	50	160	H
A	y		25	11.4	124	100	4000	4:00+	88	165	H
A	y		750	11.4		80	1825		15	40	H
B	y		65	11.4	145	107	5016	7:30+	40	60	H
A	y		68	11.4	132	103	6022	4:30+	225	250	H
A	y		1550	11.4		80	5000	6:00+	20	65	H
A	y		87	11.4	93	80	800	5:00+	40	80	A
A	y		87	11.4	138	106	4800	5:00+	40	60	A
A	y		110	11.4	140	107	5000	5:00+	110	130	A
A	y		80	11.4	133	99	3771	5:00+	50	60	H
A	y		1061	11.4		70	2800	10:00+	0	FIRM	H
A	y		100	11.4	146	117	6500	5:00+	40	60	H
A	y		227	11.4	104	90	2000	5:00+	50	110	A
A	y		1050	11.4		77	2800		0	65	H
A	y		245	11.4	94	82	1200	4:00+	FIRM	100	H
A	y		200	11.4	134	104	4585	5:30+	50	170	H
A	y		45	11.4	140	107	5000	7:00+	40	60	H
A	y		131	11.4	145	106	4500	6:00+	60	170	H
A	y		131	11.4	95	80	1000	5:00+	30	60	H
A	y		46	11.4		75	1000	5:00+	35	80	H
A	y		143	11.4	115	99	4790	6:00+	60	80	A
A	y		55	11.4	140	107	5000	6:00+	70	90	H
A	y		256	11.4	90	80	1000	4:30+	30	60	H
A	y		82	11.4	140	107	5000	5:00+	30	80	H
A	y		82	11.4	140	107	5000	5:00+	60	100	H
A	y		650	11.4		120	5155	1:15			A
A	y		650	11.4	122	106	5155	2:34	170	280	A
HES-9	y		98	11.4		130	4500	4:03	60	280	77.5/22.5 TLW/MM
A	y		120	11.4	92	80	1000	5:00+	30	70	H
A	y		245	11.4	124	101	4205	5:00+	60	90	H
A	y		191	11.4	114	94	3030	5:00+	FIRM	40	H
A	y		296	11.4	125	102	4500	5:00+	0	70	H
A	y		80	11.4	160	116	6425	8:00+			H
A	y		50	11.4	104	86	1600	6:00+	30	80	H
A	y		258	11.4	95	82	1200	5:00+	40	70	H
A	y		258	11.4	131	102	4329	5:00+	60	100	H
A	y		50	11.4	162	114	5500	8:00+	60	100	H
A	y		50	11.4	162	114	5500	5:00+			H
A	y		50	11.4	112	93	2500	5:00+	40	70	H
A	y		221	11.4	132	101	4000	6:45+	70	110	H
A	y		100	11.4	140	106	4700	5:00+	35	55	H
A	y		50	11.4	90	80	800	5:00+	0	50	H
A	y		100	11.4	94	80	1000	5:00+	30	50	H
A	y		61	11.4	135	104	4500	5:00+	60	100	H
A	y		191	11.4	92	80	1000	4:00+	0	50	H
A	y		58	11.4	105	92	2617	6:00+	80	140	H
A	y		191	11.4	132	103	4772	6:00+	90	130	H
A	y		180	11.4	90	80	800	5:00+	40	80	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		100	11.4	116	97	3500	7:00+	110	160	H
A		n		11.4	134	104	4550	5:00+	100	110	H
A	y		180	11.4	124	100	4540	6:00+	50	90	H
HES-7	y		2841	11.4	0	75	5600	5:00+	0	0	A
A	y		6500	11.4	0	68	11000	6:00+	0	0	H
A	y		180	11.4	111	93	2710	5:00+	FIRM	40	H
A	y		227	11.4	91	80	1000	5:00+	70	120	H
A	y		120	11.4	92	80	1000	4:00+	FIRM	20	H
A	y		120	11.4	116	95	3000	5:00+	70	110	H
A	y		120	11.4	122	97	3500	5:00+	40	60	H
A	y		191	11.4	92	80	1000	5:00+	80	120	H
A	y		300	11.4	98	84	1500	4:00+	150	180	A
A	y		34	11.4	122	97	3500	4:00+	70	110	H
A	y		120	11.4	138	108	5000	7:30+	100	140	H
A	y		30	11.4	130	104	4500	8:00+	70	110	H
A	y		84	11.4	122	97	3300	6:00+	70	80	H
B	y		372	11.4	95	84	1500	4:00+	0	100	H
A	y		50	11.4	160	120	6500	5:00+	190	210	H
A	y		100	11.4	90	80	800	4:00+	FIRM	70	H
A	y		202	11.4	95	80	800	5:00+	70	90	H
A	y		25	11.4	100	91	2500	8:00+	70	130	H
A	y		60	11.4	120	96	3500	4:00+	60	100	H
A	y		180	11.4	92	80	1000	3:00+	70	110	A
A	y		180	11.4	141	108	5100	4:00+	90	140	A
A	y		210	11.4	122	99	4000	6:00+	55	110	H
A	y		55	11.4	0	105	4600	6:00+	110	160	H
A	y		163	11.4	120	102	4500	5:00+	60	105	H
A	y		314	11.4	128	100	4000	6:00+	80	130	H
A	y		155	11.4	98	84	1500	6:00+	90	130	H
A	y		155	11.4	148	113	5747	6:00+	110	140	H
A	y		241	11.4	115	96	5047	9:00+	60	90	H
A	y		100	11.4	143	108	4900	7:00+	30	60	H
A	y		50	11.4	92	80	950	4:00+	80	140	A
A	y		50	11.4	125	98	3500	2:43	271	410	A
A	y		100	11.4	117	96	3180	6:00+	FIRM	110	H
A	y		100	11.4	134	104	4500	7:00+	60	110	H
A	y		40	11.4	128	100	4063	6:00+	60	170	H
A	y		50	11.4	92	80	1000	3:00+	0	50	H
A	y		58	11.4	90	80	700	5:00+	FIRM	50	H
A	y		73	11.4	95	80	1000	4:30+	40	70	A
A	y		77	11.4	98	82	1200	6:00+	90	140	H
A	y		300	11.4	115	95	2900	4:00+	110	180	A
A	y		199	11.4	96	83	1300	5:00+	120	210	A
A	y		517	11.4	103	90	2100	7:00+	82	127	A
A	y		184	11.4	97	80	1000	4:00+	50	110	H
A	y		184	11.4	122	98	3758	4:00+	80	130	H
A	y		100	11.4	88	80	750	3:00+	0	50	H
A	y		100	11.4	115	97	3500	4:00+	0	50	H
A	y		104	11.4	118	97	3500	4:30+	120	140	H
A	y		45	11.4	93	80	1000	4:00+	0	60	H
A	y		45	11.4	138	104	4500	7:30+	192	386	H
A	y		82	11.4	92	80	1000	4:00+	80	130	H
A	y		95	11.4	109	93	2786	4:00+	175	290	H
A	y		38	11.4	122	98	3500	4:00+	130	160	H
A	y		175	11.4	122	98	3500	7:00+	110	130	H
A	y		134	11.4	98	85	1500	5:00+	100	150	H
A	y		126	11.4	98	85	1659	5:00+	100	140	H
A	y		79	11.4		95	4927	6:00+	120	290	H
A	y		79	11.4		95	4927	4:00+	100	180	H
A	y		79	11.4	134	106	4927	5:00+	130	160	H
A		n		11.4	171	128	7600	4:48	170	270	H
A	y		48	11.4	130	102	4200	5:00+	50	190	A
A	y		370	11.4		95	4904	5:00+	115	135	H
A	y		78	11.4	90	80	800	5:00+	110	210	A
A	y		78	11.4	110	93	2500	5:00+	120	190	A
A	y		250	11.4	127	100	3915	4:00+	130	200	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		40	11.4	94	82	1200	3:00+	50	95	H
A	y		40	11.4	94	82	1200	4:00+	0	120	H
A	y		202	11.4	90	80	800	6:00+	40	55	H
A	y		82	11.4	128	101	4043	4:00+	110	180	H
A	y		183	11.4	92	80	1000	5:00+	120	240	A
A	y		227	11.4	135	104	4516	5:00+	50	70	A
HES-11	y		38	11.4	134	104	4500	6:00+	244	1247	TLW
HES-11	y		385	11.4	130	106	5000	5:30+	164	433	TLW
A	y		180	11.4	92	80	1000	6:00+	95	130	A
A	y		30	11.4	114	93	2500	5:00+	280	289	A
A	y		124	11.4	129	99	3500	7:00+	110	160	H
A	y		18	11.4	135	102	4000	4:30+	85	109	H
A	y		85	11.4	134	104	4528	7:00+	60	120	H
A	y		55	11.4	140	105	4635	7:00+	130	160	H
A	y		102	11.4	143	108	5000	7:00+	138	175	H
A	y		142	11.4	158	110	5175	5:00+	122	132	H
A	y		150	11.4	155	110	5000	5:00+	107	137	H
A	y		25	11.4	116	96	3000	3:53	276	391	A
A	y		22	11.4	95	82	1200	4:30+	0	125	H
A	y		50	11.4	93	80	1000	4:00+	105	120	H
A	y		340	11.4	100	89	2000	5:00+	140	150	A
A	y		22	11.4	135	105	4660	6:00+	90	160	H
A	y		152	11.4	140	107	5000	6:00+			A
A	y		120	11.4	143	109	5300	4:00+	124	163	H
A	y		176	11.4	140	107	5000	7:00+	190	270	A
A	y		175	11.4	90	80	800	6:00+	87	112	H
A	y		175	11.4	114	95	2943	5:30+	0	155	H
A	y		120	11.4	110	93	2500	6:17	262	376	A
A	y		175	11.4	111	93	2500	5:00+			H
A	y		175	11.4	90	80	900	6:30+	70	120	H
A	y		689	11.4		87	2000	4:00+	50	120	A
A	y		689	11.4	138	108	5300	5:00+	90	159	A
A	y		40	11.4	134	104	4500	5:00+	50	100	H
A	y		100	11.4	115	100	2500		98	151	H
A	y		65	11.4	126	100	4000	4:00+	40	110	H
A	y		303	11.4	126	103	4889	5:30+	130	180	A
A	y		124	11.4	124	98	4044	4:00+	50	85	H
A	y		80	11.4	92	80	1000	4:00+	90	140	H
A	y		45	11.4	95	80	900	6:53	110	150	A
A	y		107	11.4	125	96	3000	3:53	150	200	A
A	y		45	11.4	116	96	3000	3:39	130	160	A
A	y		222	11.4	110	93	2905	6:00+	140	170	H
A	y		240	11.4	115	97	3500		0	50	H
A	y		240	11.4	115	97	3500	13:26	0	100	A
A	y		44	11.4	127	100	3900	4:00+	130	180	H
A	y		334	11.4	103	89	2000	5:00+	160	180	A
A	y		232	11.4	110	93	2500	4:43	120	145	A
A	y		152	11.4	112	93	2600	4:00+	120	160	H
A	y		65	11.4	110	93	2500	4:00+	30	70	H
A	y		200	11.4	92	80	1000	4:00+	SET	140	H
A	y		106	11.4	95	80	1000	5:00+	30	42	H
A	y		72	11.4	117	96	3316	5:00+	40	110	H
A	y		25	11.4	108	92	2500	5:00+	30	60	A
A	y		1163	11.4		70	3100	4:00+	FIRM	60	H
A	y		87	11.4	140	107	5190	4:00+	40	80	H
A	y		58	11.4	132	103	4300	5:00+	80	100	A
A	y		233	11.4	120	100	4000	6:00+	50	65	A
A	y		75	11.4	128	101	4000	5:30+	130	180	H
A	y		160	11.4	120	100	4000	4:00+	35	60	H
A	y		100	11.4	129	99	3500	6:00+	50	65	H
A	y		80	11.4	140	106	4700	6:00+	60	140	H
B	y		67	11.4	91	80	1000	5:00+	30	70	H
A	y		334	11.4	138	107	5186	5:00+			A
A	y		58	11.4	122	98	3850	4:30+	130	180	H
A	y		222	11.4	98	85	1881	5:00+	125	195	A
A	y		200	11.4	108	90	2000	5:00+	120	130	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		225	11.4	116	96	3089	4:00	110	180	A
A	y		220	11.4	125	100	4000	4:00+	160	180	A
A	y		220	11.4	125	100	4000	4:00+	120	140	H
A	y		89	11.4	140	107	5143	4:00+	110	160	H
A	y		30	11.4	140	105	4500	6:00+	50	101	H
A	y		212	11.4	138	106	4839	4:00+	170	180	A
A	y		79	11.4		80	3000		0	130	H
A	y		517	11.4	123	101	4643	4:00+	0	90	A
A	y		50	11.4	133	103	4400	5:00+	120	170	H
A	y		40	11.4	92	80	1000	4:04	250	310	A
A	y		340	11.4	104	90	2129	5:00	110	150	A
A	y		48	11.4	124	98	3500	4:00+	150	200	H
A	y		38	11.4	105	90	2000	4:00+	170	220	A
A	y		63	11.4	124	98	3500	7:00+	130	190	H
A	y		63	11.4	130	101	4000	4:00+	150	190	H
A	y		40	11.4	140	107	5133	4:00+	140	210	A
A	y		220	11.4	96	83	1500	5:00+	0	60	H
A	y		220	11.4	102	88	3189	5:00+	0	60	H
A	y		9	11.4	126	100	3800	5:30+	170	215	A
A	y		72	11.4	122	98	4082	4:00+	110	150	H
A	y		40	11.4	115	96	3000	4:00+	120	190	H
A	y		80	11.4	140	106	4800	4:00+	150	190	H
A	y		80	11.4	138	105	4700	4:00+			H
A	y		37	11.4	143	105	4500	6:30+	165	195	H
A	y		38	11.4	88	80	800	4:00+	180	210	A
A	y		58	11.4	126	103	4500	4:00+	277	347	TLW
A	y		114	11.4	152	115	6000	8:09	150	170	H
A		n		11.5	128	101	4000		142	229	Micro-fine
HES-11	y		3200	11.5		73	7000	7:00+	0	0	TLW
HES-3	y		6220	11.5		79	10000	4:20			A
F		n		11.5	192	157	9394	3:40	46	255	Micro-fine
HES-11	y		17	11.5	150	116	6400	2:50			TLW
HES-11	y		3000	11.5		65	4500	8:00+			TLW
A	y		80	11.5	116	96	3000	4:00	142	233	H
HES-11	y		50	11.5	114	95	2850	6:30	0	122	TLW
HES-11	y		50	11.5	98	85	1500	7:00+	73	175	TLW
HES-11	y		107	11.5	210	163	12227	4:06	460	890	TLW
A	y		241	11.5	135	107	5075	5:00+	158	288	H
HES-11	y			11.5	142	109	6708	7:12	40	150	TLW
HES-11	y			11.5	142	109	6708		75	230	TLW
HES-11	y			11.5	142	109	6708	6:48	200	530	TLW
HES-11	y			11.5	142	109	6708		75	230	TLW
HES-11	y			11.5	142	109	6708		170	450	TLW
HES-11	y			11.5	145	111	7040	5:30	53	94	TLW
F	y			11.5		90	1600	3:37	94	230	Micro-fine
HES-11	y			11.5		90	1600	6:00+	62	157	TLW
B	y			11.5	99	90	2300	4:38	54	114	A
HES-3	y			11.5		60	4085	4:00+		296	A
HES-3	y			11.5		60	4085			89	A
A	y			11.5	120	96	3080	5:00+	94	134	H
B	y			11.5		91	2400			122	A
HES-7	y			11.5		91	2400			82	A
HES-11	y			11.5		86	1900	5:00+	107	132	TLW
HES-3	y			11.5		100	4600	6:24			FLOSTOP-I
HES-3	y			11.5		75	2600	6:00+			A
HES-3		n		11.5		80	4085	5:30+			A
A	y			11.5		60	4085	5:00+		40	A
A	y			11.5	91	80	900	4:00+	110	140	H
HES-11	y			11.5	122	97	3200	5:00+	133	414	TLW
A	y			11.5	96	84	1500	4:00+	140	175	H
A	y			11.5	96	84	1500	4:00+	135	210	H
B	y			11.5	105	90	2100		36	44	50/50 H/POZ
HES-11		n		11.5		80	80	5:00+	132	341	TLW
B	y			11.5	210	159	11295	6:30+	120	180	65/35 H/POZ
B	y			11.5	210	159	11295	6:30+	120	130	65/35 H/POZ
HES-3	y			11.5		70	3950	4:00+	96	347	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-7	y			11.5	0	65	4550	4:30+	0	0	A
HES-7	y			11.5	0	63	7000	5:30+			A
HES-7	y			11.5	200	151	9800	9:00+			50/50 H/POZ
HES-7	y			11.5	200	151	9800	9:00+			50/50 H/POZ
HES-11	y			11.5	96	83	1300	6:00+	102	222	TLW
A	y			11.5	130	103	4500	7:00+	120	150	H
A	y			11.5	134	106	5010	6:00+	95	107	H
F	y			11.5	122	104	3800	3:05	333	494	Micro-fine
F	y			11.5	170	138	7400	3:51	439	519	Micro-fine
F	y			11.5	230	194	13900	4:00+	346	379	Micro-fine
F		n		11.5	195	159	9522	0:43			Micro-fine
F		n		11.5	164	134	7000	3:27	381	477	Micro-fine
A	y			11.5	128	101	4000	4:30+	99	118	H
HES-11	y			11.5	94	83	1300	4:00+	87	184	TLW
HES-11	y			11.5	117	98	4000	5:00+	194	386	TLW
HES-11	y			11.5	106	93	2600	5:00+			TLW
HES-11	y			11.5	94	84	1420	5:00+			TLW
B	y			11.5	257	198	11800	8:30+	180	340	65/35 H/POZ
A	y			11.5	185	136	8100	6:00+	54	71	H
HES-7	y			11.5	0	70	7200	5:00+	0	0	A
HES-11	y			11.5	135	106	5000	4:00+	144	409	TLW
F	y			11.5		92	2900	3:45+	323	347	Micro-fine
B	y			11.5	90	80	1050	6:00+	FIRM	20	50/50 H/POZ
F	y			11.5	225	186	11795	5:00+	625	705	Micro-fine
A	y			11.5	100	83	1300	6:00+		147	A
B		n		11.5		83	1500	6:30+	39	150	A
A	y		320	11.6	102	89	3223	5:00+	99	137	H
A	y		57	11.6	128	101	4000	5:00+			H
HES-3	y		2920	11.6		75	6500	5:20	115	334	A
A		n		11.6		80	50		0	0	A
A		n		11.6	90	80	1000		170	346	A
A	y		126	11.6	140	105	4500	3:00			A
A	y		110	11.6	90	80	760	5:00+	117	143	H
A	y		80	11.6	126	96	4000	4:47	289	416	A
A	y		250	11.6	90	80	880	6:00+	68	131	H
A	y		110	11.6	127	101	4071	5:00+	125	155	H
A	y		320	11.6	102	89	2690	4:00+		142	H
A	y		250	11.6	120	100	3952	6:00+	81	101	H
A	y		250	11.6	120	98	3429	6:00+	75	140	H
A	y		250	11.6	110	95	3100	6:00+	98	126	H
A	y		250	11.6	111	95	3100	6:00+	785	1424	H
A	y		182	11.6	128	103	4500	7:00+	102	152	H
A	y		250	11.6	96	80	800	6:00+	94	121	H
HES-3	y		1450	11.7		100	4600	4:47	191	340	FLOSTOP-I
A	y		320	11.7	164	117	6000	6:55	120	140	H
HES-3	y		6220	11.7		70	8016	6:00+			FLOSTOP-I
HES-3	y		6220	11.7		60	8016		104	327	FLOSTOP-I
B	y		200	11.7	172	132	11000	3:54	66	211	H
HES-11	y		100	11.7	98	85	1500	6:00+	96	273	TLW
A	y		3822	11.7		106	7450	2:30			A
A	y		1420	11.7		95	6600	6:30+	173	315	A
HES-11	y		20	11.7	134	102	4200	5:00+	210	760	TLW
F		n		11.7	166	136	7550	3:55	557	698	Micro-fine
A	y		358	11.7	120	98	3700	4:33	131	181	A
HES-3	y		2649	11.7		80	7234	6:07	141	313	A
A	y		363	11.7	120	98	3657	7:12	110	200	H
A		n		11.8		110	4000	8:00+			H
A		n		11.8		60	100		50	110	A
A		n		11.8		93	2500		0	57	
A		n		11.8		110	4000	9:00+			H
A		n		11.8		110	4000	9:00+			H
A		n		11.8		110	4000	9:58			H
A		n		11.8		80	1000		110	250	A
A		n		11.8		110	4000	8:00+			H
HES-11		n		11.8	80	80	1000	5:58	157	200	TXI
A		n		11.8		96	3000	5:25	232	325	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
F		n		11.8	140	140	6278	4:40	140	580	Micro-matrix
A	y		10	11.8	114	95	3015	4:17	211	273	A
HES-11		n		11.8	118	93	2500	4:45		166	TXI
HES-11		n		11.8	103	86	1630	4:07		280	TXI
B		n		11.8	95	80	1000	4:00+	160	200	H
A	y		50	11.8	120	96	3100	5:00+	40	80	H
B	y		75	11.8	145	107	4700	4:52	100	130	H
A	y		60	11.8	130	101	4000	4:00+	110	160	H
B	y		75	11.8	145	108	5131	4:02	70	100	H
B	y		75	11.8	116	94	2831	5:00+	160	200	H
A	y		122	11.8	128	101	4000	5:30+	140	240	H
A	y		122	11.8	95	82	1250	5:00+	130	220	H
A	y		75	11.8	91	80	750	5:00+	56	97	H
A	y		20	11.8	93	82	1200	6:00+	65	115	H
A	y		20	11.8	102	82	1200	5:00+	142	206	H
A	y		20	11.8	93	82	1200	4:00+	100	130	H
A	y		120	11.8	130	102	6226	4:00+	50	139	H
A		n		11.8	98	82	1250	5:00+	170	220	A
A		n		11.8	132	102	4200	5:00+	40	90	A
HES-11	y		1500	11.8		70	5200	7:00+	32	50	TLW
A	y		35	11.8	134	104	4500	5:30+	227	328	H
A	y		80	11.8	114	95	3100	5:00+	155	190	H
A	y		80	11.8	126	96	4000	5:00+	299	426	A
A	y		80	11.8	124	95	4000	4:00+	167	325	A
A	y		85	11.8	126	96	4000	10:00+	211	296	A
A	y		100	11.8	95	80	1000	8:00+	30	80	H
A	y		100	11.8	144	108	5386	8:00+	80	115	H
A	y		100	11.8	115	95	3000	6:00+	40	90	H
A	y		100	11.8	90	80	800	6:00+	0	56	H
A	y		100	11.8	116	96	3500	6:00+	50	100	H
A	y		30	11.8	141	108	5100	5:00+	142	163	H
B	y		180	11.8	134	104	4535	4:17	122	178	H
B	y		180	11.8	130	102	4216	4:21	168	205	H
A	y		200	11.8	145	109	5200	7:30+	0	63	H
A	y		220	11.8	125	99	3950	6:30+	145	175	H
A	y		250	11.8	132	101	5400	7:00+	135	155	H
HES-11	y		300	11.8	112	99	3800	6:30+	81	193	TLW
HES-11	y		300	11.8		80	1000	6:00+	47	55	TLW
A	y		365	11.8	112	92	2414	4:00+	159	228	A
A	y		45	11.8	128	104	4985	6:00+	94	106	H
A	y		360	11.8	92	80	1000	4:00+	120	200	H
A	y		30	11.8	129	103	4500	5:00+	143	169	H
B	y		35	11.8	112	95	3000	5:00+	40	100	H
B	y		35	11.8	112	95	3000	5:00+	40	100	H
B	y		35	11.8	92	80	1000	5:00+	0	FIRM	H
B	y		35	11.8	92	80	1000	5:00+	0	60	H
B	y		35	11.8	140	108	5000	6:00	50	90	H
B	y		35	11.8	140	108	5000	5:00	50	130	H
B	y		75	11.8	89	80	750	5:00+	70	80	H
B	y		75	11.8	90	80	800	3:30+	30	110	H
B	y		75	11.8	126	100	4000	4:00+	60	140	H
A	y		90	11.8	130	102	4200	6:00+	50	130	H
A	y		10	11.8	140	107	5000	5:30+	128	194	H
B	y		110	11.8	135	105	4800	5:41	120	140	H
A	y		100	11.8	134	104	4693	4:30+	180	230	H
A	y		100	11.8	121	98	3600	5:00+	115	190	H
A	y		100	11.8	115	93	2500	5:00+	155	210	H
A	y		120	11.8	140	116	5200	5:00+	164	188	H
A	y		145	11.8	128	101	4000	4:00+	98	138	H
A	y		145	11.8	92	80	1000		0	169	H
A	y		140	11.8	132	101	4323	10:00+	80	100	H
A	y		15	11.8	140	107	5000	6:30+	105	140	H
A	y		265	11.8	109	93	4431	5:00+	110	255	H
A	y		350	11.8	115	97	3500	3:37	258	372	A
A	y		333	11.8	120	97	5000	5:00+	95	280	A
A	y		25	11.8	130	104	4700	6:30+	215	250	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		22	11.8	125	100	4000	5:00+	130	200	H
A	y		20	11.8	135	106	5000	5:00+	162	222	H
B		n		11.8	122	98	3500	5:00+	50	103	65/35 A/POZ
B		n		11.8	115	93	2550	5:00+	130	160	65/35 A/POZ
A		n		11.8	147	110	5250	5:00+	90	100	H
A	y		800	11.8	130	102	4200	4:32		262	A
HES-11	y		800	11.8	125	103	4500	6:00+	235	365	TLW
HES-11	y		800	11.8	103	91	2300	6:00+	149	374	TLW
A		n		11.8	85	80	300		108	140	A
A		n		11.8	85	80	300		190	205	A
A	y		100	11.8	92	80	1000	5:00+	130	300	A
B	y		218	11.8	134	104	4500	4:00+	70	150	H
HES-11	y		50	11.8	139	106	4900	3:00+	820	1680	TLW
HES-11	y		850	11.8	105	91	2575	4:06	70	160	TLW
A	y		75	11.8	127	99	4200	8:00+	163	260	H
A	y		50	11.8	122	99	3540	2:39	150	355	A
B	y		75	11.8	120	98	3500	5:05	90	170	H
B	y		75	11.8	90	80	750	5:00+	43	80	H
B	y		75	11.8	140	106	5016	3:30	150	250	H
B	y		65	11.8	116	96	3000	4:00+	125	190	H
B	y		65	11.8	90	80	750	4:00+	50	150	H
B	y		95	11.8	90	80	753	4:19	150	170	A
B	y		95	11.8	125	100	3751	4:00+	0	140	H
B	y		97	11.8	135	102	4600	3:15	160	220	H
B	y		97	11.8	125	100	4080	4:22	140	180	H
B	y		97	11.8	90	80	750	4:00+	110	150	H
HES-11	y		925	11.8	121	103	4610	4:33			TLW
HES-3	y		925	11.8		80	2050	5:00+			A
A	y		625	11.8	100	87	1707	4:00+	125	175	H
A	y		1420	11.8		98	6000	5:00+	120	160	A
A	y		700	11.8	130	101	4000	7:00+	75	127	H
HES-7	y		3778	11.8		70	6100	4:00+	0	120	H
E	y		3778	11.8		70	6100	5:30+	140	210	H
A	y		4000	11.8	0	90	6000	4:00+	90	220	A
A	y		520	11.8	125	101	4148	4:00+	220	235	A
A	y		520	11.8	0	80	2085	4:00+	80	210	H
B		n		11.8	156	114	5800	5:30+			65/35 A/POZ
HES-11		n		11.8	140	102	4500	3:55	0	187	TXI
A	y		1120	11.8		110	4950	8:00+	50	138	H
A	y		1120	11.8		85	1850	6:00+			H
A	y		1120	11.8		99	5149	4:00+	160	350	A
A	y		1120	11.8		79	2018	3:30+	139	305	A
HES-3	y		1560	11.8		65	4100	7:00+	89	124	FLOSTOP-I
HES-3	y		2760	11.8		93	6300	4:13	111	426	A
HES-3	y		4243	11.8		80	6321	6:00			A
HES-3	y		4243	11.8		90	8321	3:00			A
HES-3	y		4243	11.8		90	8321	5:31	140	261	A
HES-11	y		340	11.8	125	101	4342	8:14	26	325	TLW
A	y		350	11.8	103	90	2100	6:20	239	292	A
A	y		350	11.8	103	90	2100	4:38	140	290	A
A	y		50	11.8		80	3000			320	A
A	y		50	11.8		80	3000			250	A
HES-7	y		40	11.8	100	85	1500	5:30+	85	100	H
A	y		160	11.8	114	94	3314	6:00+	80	110	H
A	y		200	11.8	122	97	5518	8:00+	110	160	H
A	y		200	11.8	95	80	1012	8:00+	60	148	H
HES-11	y		340	11.8	125	101	4342	8:28	26	365	TLW
B	y		280	11.8	180	132	8929	4:58	140	360	65/35 H/POZ
F	y		340	11.8	182	150	9231	2:38			FLOSTOP-I
F	y		340	11.8	182	150	9231	4:45	690	704	FLOSTOP-I
A	y		160	11.8	145	108	5387	5:00+	230	270	H
A	y		160	11.8	109	92	2683	5:00+	75	100	H
A	y		160	11.8	90	80	825	5:00+	80	100	H
A	y		210	11.8	112	93	5284	7:00+	80	200	H
A	y		350	11.8	135	106	5000	6:00+	126	194	H
A	y		220	11.8	97	85	2797	4:00+	190	210	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		280	11.8		90	1500	6:00+	27	66	TLW
B		n		11.8		99	3500	3:01			A
B		n		11.8	287	243	15500	3:40	294	560	65/35 H/POZ
A	y		160	11.8	92	80	1000	4:00+	122	218	A
A	y		160	11.8	120	98	3500	4:30+	75	221	H
A	y		160	11.8	92	80	1000	4:00+	100	157	H
A	y		260	11.8	133	104	4500	4:30+	211	308	A
A	y		225	11.8	118	98	6800	6:00+	0	FIRM	H
A	y		225	11.8	146	107	9310	6:00+			H
A	y		225	11.8	114	95	4480	6:00+	80	110	H
A	y		225	11.8	146	110	9777	6:00+	0	0	H
A	y		225	11.8	146	110	9777	5:27	150	188	H
HES-11	y		40	11.8	115	95	2950	5:12	0	280	TLW
A	y		50	11.8	102	89	2000	5:30+	120	189	H
A	y		50	11.8	89	80	800	5:00+	88	124	H
B	y		150	11.8	112	94	3000	8:45	190	230	H
A		n		11.8	140	105	4600	8:15	100	140	A
HES-11	y		2266	11.8		95	5100	4:15	107	276	TLW
HES-3	y		6417	11.8		75	8100	4:20	SET	151	A
HES-3	y		6417	11.8		75	8900	4:20	466	1109	A
A	y		2100	11.8		65	2500	6:00+		57	A
HES-11	y		1970	11.8		80	3500	4:00+	0	83	TLW
HES-11	y		63	11.8	97	82	1200	4:30+		193	TLW
A	y		50	11.8		115	6000	10:00+	90	100	H
HES-7	y		50	11.8	152	115	6000	9:30+	60	100	H
HES-11	y		50	11.8		115	6000	7:03	190	270	TLW
A	y		50	11.8		115	6000	10:00+	104	127	H
HES-7	y		65	11.8	171	125	7000	7:00+	151	189	H
HES-11	y		65	11.8	171	125	7000	5:12	230	682	TLW
A	y		45	11.8	94	81	1100	4:00+	100	170	A
HES-11	y		65	11.8	170	128	7500	8:05	160	260	TLW
HES-11	y		65	11.8	170	127	7400	5:10	480	600	TLW
HES-11	y		65	11.8	170	127	7400	7:03	0	490	TLW
HES-11	y		65	11.8	170	128	7500	7:56	140	300	TLW
HES-11	y		70	11.8	146	114	6000	7:00+	333	572	TLW
HES-11	y		70	11.8	133	112	6000		336	550	TLW
A	y		50	11.8	96	84	1702	6:00+			A
A	y		50	11.8	95	84	1698	6:00+	231	273	A
A	y		50	11.8	95	84	1698	4:00+	231	273	A
A		n		11.8	119	96	3000	2:43			A
A	y		50	11.8		80	1000			229	A
A	y		50	11.8	118	97	3200	5:00+	90	155	H
B	y		202	11.8	150	107	4500	8:00+	60	110	H
B	y		202	11.8	90	80	800	4:45+	30	50	H
A		n		11.8	127	101	3920	5:00+	60	125	A
HES-11		n		11.8	150	109	5000	2:19			TXI
HES-11		n		11.8	150	109	5000	3:38	299	391	TXI
B		n		11.8	134	105	4700	6:00+	60	111	65/35 A/POZ
A		n		11.8	250	205	12200	1:12			H
A		n		11.8	250	205	12200	1:40			H
A		n		11.8	132	104	4500	5:00+	55	125	A
B		n		11.8	116	96	3000	5:00+			65/35 A/POZ
A	y		246	11.8	95	82	1200	4:30+	112	371	A
A	y		246	11.8	132	104	4500	6:00+	130	185	H
A	y		10	11.8	128	101	4000	4:00+	140	260	A
A	y		10	11.8	128	101	4000	4:00+	120	170	H
A	y		10	11.8	92	80	1000	4:00+	155	225	A
HES-11	y		10	11.8	92	80	1000	6:30+	210	360	TLW
A	y		95	11.8		90	2000	5:00+	120	150	A
A	y		200	11.8	97	85	1500	7:00+	155	240	H
HES-11	y		182	11.8	96	83	1300	4:00+	120	240	TLW
A		n		11.8	145	108	4900	2:26			A
HES-7		n		11.8	196	149	13661	5:00+	150	180	H
HES-11	y		25	11.8	105	91	2200	5:30+	94	249	TLW
HES-7	y		25	11.8	114	95	3011	4:00+	SET	150	H
B	y		25	11.8	94	82	1160	4:00+	110	170	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-7	y		25	11.8	116	96	4370	4:00+	75	230	H
HES-11	y		40	11.8	108	92	2300	5:00+	355	421	TLW
HES-11	y		40	11.8	108	92	2300	5:00+	121	346	TLW
HES-11	y		40	11.8	108	92	2300	5:00+	90	189	TLW
HES-11	y		30	11.8	124	98	5500	4:00	240	650	TLW
HES-11	y		30	11.8	92	80	1000	5:00+	160	230	TLW
B	y		75	11.8	191	144	10415	3:36	390	470	H
B	y		75	11.8	99	89	1950	7:00+	140	240	H
B	y		75	11.8	102	89	1950	4:00+	150	165	H
HES-11	y		50	11.8	109	93	2673	5:00+	140	520	TLW
HES-7	y		186	11.8	160	122	9263	4:00+	90	140	H
HES-7	y		186	11.8	160	122	9400	4:00+	130	1520	H
HES-7	y		186	11.8	200	152	13912	5:30+	165	199	H
HES-7	y		186	11.8	173	130	11700	4:30+	125	230	H
A	y		200	11.8	105	91	2900	5:00+	140	184	H
B	y		200	11.8	175	140	13500	3:15	74	165	H
A	y		200	11.8	119	98	4077	5:30+	130	220	H
A	y		200	11.8	105	92	2500	6:00+		180	H
A	y		200	11.8	153	117	6508	4:30	140	290	H
A	y		200	11.8	112	95	4000	5:00+	190	375	H
A	y		200	11.8	134	104	5978	5:00+		80	H
HES-7	y		200	11.8	199	151	13800	5:43	67	96	H
HES-7	y		200	11.8	199	151	13800	5:43	67	96	H
A	y		200	11.8	105	91	2500	5:00+		175	H
B	y		200	11.8	135	104	5000	5:00+	78	178	H
A	y		200	11.8	134	105	7427	5:00+	100	115	H
A	y		200	11.8	0	103	6000	7:00+	80	110	H
HES-7	y		200	11.8	175	134	14075	6:00+	130	180	H
HES-7	y		200	11.8	175	134	14075	5:00+	120	220	H
A	y		200	11.8	100	89	2000	5:00+	61	92	H
A	y		200	11.8	119	98	4224	4:00+	108	132	H
HES-7	y		250	11.8	188	142	13652	5:30+	230	450	H
HES-7	y		250	11.8	188	142	13652	5:00+	210	415	H
A	y		200	11.8	140	107	5369	6:00+	350	730	H
HES-11	y		300	11.8	75	75	647	5:00+	32	70	TLW
A	y		200	11.8	132	106	5500	6:00+	70	120	H
HES-11	y		35	11.8		85	1500	6:30			TLW
A	y		60	11.8	140	105	4500	4:30+	151	210	H
A	y		60	11.8	128	103	4500	6:00+		120	H
A	y		60	11.8	92	80	800	4:00+	190	210	H
A	y		60	11.8	92	80	800	3:30+	128	200	H
A	y		35	11.8	135	105	4800	4:00+	144	183	H
A	y		175	11.8	92	80	1000	5:00+	35	134	H
A	y		175	11.8	134	104	4500	5:00+	60	115	H
B	y		50	11.8	90	80	750	4:00+	130	175	A
A	y		20	11.8	134	104	4500	7:00+	110	140	H
A	y		65	11.8	131	103	4660	7:00+	310	690	H
A	y		90	11.8	140	106	4860	6:00+	135	165	H
HES-11	y		180	11.8		91	2300	6:00+	50	64	TLW
HES-7	y		20	11.8	151	114	5900	8:30+	109	152	H
A	y		20	11.8	124	100	4000	5:30+	98	130	H
A	y		20	11.8	90	80	800	5:00+	76	103	H
A	y		20	11.8	90	80	800	6:00+	78	106	H
A	y		326	11.8	95	85	2060	6:00+	75	137	H
A	y		326	11.8	122	99	3995	6:00+	99		H
A	y		326	11.8	92	81	1100	6:00+	72		H
A	y		385	11.8	95	84	1500	6:00+	91	176	H
A	y		450	11.8	115	97	3500	4:30	117		A
A	y		20	11.8	124	100	4000	5:30+	57	95	H
B	y		25	11.8	127	101	4200	5:56	220	250	H
HES-11	y		35	11.8		85	1500	6:15	56	177	TLW
HES-11	y		35	11.8		80	1200	8:00	50	625	TLW
A	y		12	11.8	93	81	1509	4:00+	180	230	A
HES-11	y		60	11.8	242	195	14978	7:34	770	800	TLW
HES-11	y		60	11.8	212	167	12680	7:40	0	860	TLW
HES-11	y		60	11.8	128	101	4000			280	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		160	11.8	126	100	3800	4:56	165	221	A
HES-11		n		11.8		93	2500	3:36	151	268	TXI
F		n		11.8	216	174	9685	3:47	669	728	F
F		n		11.8	216	174	9685	5:00+			F
B		n		11.8	119	96	3000	8:49	120	150	65/35 A/POZ
F		n		11.8	179	145	8002	3:13	324	526	F
B		n		11.8	123	94	2530	5:26	130	295	A
B		n		11.8	150	104	4200	4:52			A
A	y		55	11.8	142	107	5000	7:00+	170	220	A
A	y		60	11.8	92	80	1000	6:00+	80	210	H
A	y		60	11.8	92	80	1000	4:00+	80	210	H
A	y		10	11.8	113	95	3000	3:00+	120	175	H
A	y		190	11.8	87	80	750		188	382	A
B	y		190	11.8	88	80	800	5:00+	20	80	H
A	y		260	11.8	135	105	4750	6:00+	253	407	A
A	y		260	11.8		93	1100	4:00+	162	324	A
A	y		365	11.8	112	91	3243	4:00+	149	174	A
A	y		365	11.8	90	82	1200	5:30+			A
HES-11	y		365	11.8	112	96	3476	7:00+	246	429	TLW
B	y		30	11.8	116	95	2800	5:50	100	200	H
B	y		25	11.8	90	80	750	6:00+	120	210	H
A		n		11.8	120	96	3000	4:15	290	330	A
A		n		11.8	120	96	3000	4:12	280	320	A
A		n		11.8	110	95	3000	6:00+	190	300	A
A	y		1100	11.8		90	6000	3:50	172	285	A
HES-11	y		1932	11.8		80	3400	5:00+	102	173	TLW
HES-11	y		1932	11.8		90	4500	4:30+	183	647	TLW
HES-3	y		2649	11.8		80	7234	3:23			A
HES-3	y		2920	11.8		70	5000	6:00+			A
HES-3	y		2920	11.8		75	6500	2:54			A
HES-11	y		75	11.8		80	1000	7:30	29	63	TLW
HES-11	y		75	11.8		104	4500	6:02	209	318	TLW
A	y		40	11.8	94	82	1200	5:00+	140	200	H
HES-11	y		70	11.8	117	96	3000	7:00+	150	447	TLW
A	y		90	11.8	128	101	4200	6:00+	57	102	H
A	y		160	11.8	132	100	3943	5:00+	110	180	H
A	y		160	11.8	92	80	1000	4:00+	30	140	H
A	y		150	11.8	160	121	9900	6:00+	40	80	H
A	y		150	11.8	160	119	8681	5:00+	70	150	H
A	y		150	11.8	165	122	8750	5:00+	190	210	H
A	y		175	11.8	96	86	3190	5:00+	130	190	A
A	y		290	11.8		108	5000	5:30+	72	155	H
HES-11	y		290	11.8		108	5000	5:53	119	485	TLW
B	y		180	11.8	116	96	3000	4:00+	160	220	H
B	y		180	11.8	116	96	3000	5:00+	180	220	H
B	y		180	11.8	92	80	850	4:00+	50	150	H
A	y		354	11.8	102	87	1967	5:00+			H
F	y		30	11.8		213	11410	2:30	341	478	F
HES-11	y		30	11.8		83	1000	6:30	0	103	TLW
A	y		220	11.8	135	106	5000	5:00+	128	475	H
HES-11	y		220	11.8	230	183	14043	3:00			TLW
A	y		250	11.8	135	106	5000	5:00+	143	674	H
A	y		40	11.8	118	97	3500	4:00+	85	130	A
A	y		200	11.8	140	107	5000	5:30+	125	170	H
A		n		11.8	100	85	1500	6:00+	164	330	A
HES-11		n		11.9	135	105	4700	5:54	361		TLW
F		n		11.9	255	215	14600	3:36	870	1040	Micro-fine
HES-11		n		11.9	203	156	11060	2:40	1030	1380	TLW
HES-11		n		11.9	203	156	11060	2:44	1190	1230	TLW
HES-11	y		110	11.9	90	80	1000	6:30+	109	240	TLW
HES-11	y		110	11.9	125	100	4000	7:00+	360	763	TLW
HES-11	y		110	11.9	132	101	4700	5:57			TLW
HES-11	y		110	11.9	143	107	4800	4:28			TLW
F	y		85	11.9		223	12905	4:18	250	430	Micro-fine
HES-11	y		90	11.9	144	109	5300	6:28	127	280	TLW
F	y		140	11.9	300	252	15278	3:08	440	460	Micro-fine

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		260	11.9	95	82	1250	6:30+	28	65	TLW
HES-11	y		265	11.9	106	91	6350	6:00+	66	179	TLW
HES-11	y		265	11.9		86	3050	6:00+	50	138	TLW
HES-11	y		265	11.9	105	93	2900	7:00+	50	178	TLW
HES-11	y		265	11.9	92	80	1000	6:00+	200	250	TLW
HES-11	y		252	11.9	118	98	3708	6:00+	195	753	TLW
HES-11	y		252	11.9	118	98	3600	6:00+	139	841	TLW
HES-11	y		252	11.9	118	97	3542	4:27	222	414	TLW
HES-11	y		25	11.9	116	96	3300	6:30+	158	565	TLW
HES-11	y		25	11.9	92	80	1000	5:00+	114	214	TLW
HES-11		n		11.9		129	6200	5:26	62	415	TLW
A	y		1419	11.9		95	6600	3:34			A
HES-3	y		2761	11.9		93	6300	3:24			A
F	y		40	11.9	242	208	12091	3:00	510	830	Micro-fine
B	y		200	11.9	130	102	4200	6:00+	121	227	65/35 A/POZ
HES-11	y		75	11.9	164	123	7000	5:46	123	841	TLW
HES-11	y		75	11.9	164	123	7000	9:14	520	999	TLW
F	y		200	11.9		255	12170	4:06	390	620	Micro-fine
HES-11	y		220	11.9	120	97	3789	5:00+	46	220	TLW
HES-11	y		95	11.9	115	96	3200	7:16	79	354	TLW
A	y		220	11.9		129	9485	5:00+	135	160	H
F	y		380	11.9	235	205	15531	3:41	450	610	Micro-fine
F	y		35	11.9		238	13482	5:28	430	630	Micro-fine
HES-11	y		220	11.9	106	92	3235	7:18	81	217	TLW
HES-11	y		220	11.9	111	95	3300	5:00+	250	818	TLW
HES-11	y		125	11.9	91	81	1100		81	166	TLW
HES-11	y		125	11.9	92	81	1100		107	217	TLW
HES-11	y		115	11.9	93	80	1050	6:00+	88	460	TLW
HES-11	y		115	11.9	130	101	4050	5:00+	150	233	TLW
F	y		55	11.9	227	190	12824	3:10	360	690	Micro-fine
F	y		55	11.9	247	204	12824	3:36	770	820	Micro-fine
HES-11	y		1750	11.9		71	2825		89	301	TLW
HES-11	y		40	11.9	90	80	1000	4:00+	116	340	TLW
HES-11	y		40	11.9	120	98	3500	5:00+	240	450	TLW
B	y		135	11.9	92	80	1000	6:00+	60	140	H
HES-11	y		225	11.9	120	98	3400	6:02	171	291	TLW
HES-11	y		40	11.9		77	650	5:00+	28	56	TLW
HES-11	y		155	11.9	92	80	1000	3:30+	147	219	TLW
HES-11	y		150	11.9	110	91	2200	5:30+	79	263	TLW
HES-11	y		220	11.9		93	3373	6:00+	379	950	TLW
A		n		12.0	128	101	4000	4:07	228	415	Micro-fine
A		n		12.0	0	110	3000	6:44			H
A		n		12.0		110	4000	6:00+			H
B		n		12.0		93	2500	4:05	281	350	C
HES-11		n		12.0	80	80	1000	4:16	186	358	TXI
A		n		12.0	90	80	1000		161	308	A
F	y		230	12.0	168	138	8024	4:45	612	921	Micro-fine
B		n		12.0		160	10000	6:00+	562	783	75/25 A/POZ
B		n		12.0		160	10000	6:00+	672	1192	65/35 A/POZ
B		n		12.0		101	4000	4:58			50/50 H/POZ
B		n		12.0		85	4000			50	75/25 A/POZ
HES-11		n		12.0	80	93	2500	4:48	425	693	TXI
A		n		12.0	128	101	4000	4:07	228	415	Micro-fine
B		n		12.0	120	96	3000		116		65/35 A/POZ
		n		12.0	120	96	3000		74		A
B		n		12.0	90	80	1000		58	86	65/35 A/POZ
B		n		12.0		93	2500		0	50	HPLC
A		n		12.0	93	87	1000		269	454	A
A		n		12.0	95	80	1000			234	H
F		n		12.0	237	202	14500	4:03	842	992	Micro-fine
HES-11		n		12.0	142	108	5200	5:18			TLW
		n		12.0	94	83	1300	8:00+	85	110	A
HES-11		n		12.0	150	113	5800	5:00+			TLW
B		n		12.0	125	96	3000	2:30	200	240	85/15 H/POZ
B		n		12.0	130	101	4000	3:57			65/35 A/POZ
HES-3		n		12.0		65	5479	3:36	0	80	FLOSTOP I

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A		n		12.0		65	5479	5:00+	0	FIRM	A
		n		12.0	138	106	4800	7:00+	FIRM	130	A
A	y		6200	12.0		105	14000	5:55	310	330	H
A	y		6200	12.0		79	10000	6:19	105	248	A
		n		12.0	128	101	4000	7:00+	70	180	A
F		n		12.0	128	108	4015	3:00	510	515	Micro-fine
F		n		12.0	128	108	4015	4:18	250	400	Micro-fine
HES-11		n		12.0	104	90	2000	4:52	285	651	TLW
F	y		30	12.0	0	173	7750	4:00	145	750	Micro-fine
F	y		30	12.0	186	186	8881	3:26	590	1460	Micro-fine
HES-11	y		30	12.0	128	101	4000	4:30+	93	289	TLW
B	y		30	12.0	145	111	5684	3:58	260	280	H
B	y		30	12.0	102	89	1950	4:00+	90	230	H
A	y		25	12.0	104	90	2000	5:50	165	500	A
F		n		12.0	230	189	11800	3:51	225	380	Micro-fine
B		n		12.0	125	100	4000	7:00+	80	200	65/35 H/POZ
HES-11		n		12.0	206	158	10500	3:45	821	932	TLW
HES-11		n		12.0	255	207	14180	3:52	703	808	TLW
B		n		12.0	132	101	4000	4:03	115	198	65/35 A/POZ
HES-11		n		12.0	105	90	2150	6:05	240	430	TLW
B		n		12.0	120	99	4000	5:00+	90	120	65/35 A/POZ
		n		12.0	127	101	4100	5:00+	FIRM	200	A
B		n		12.0	224	176	12040	4:32	188	463	65/35 H/POZ
B		n		12.0	205	156	11800	3:36	310	830	65/35 H/POZ
F		n		12.0	238	199	13158	4:00	410	590	Micro-fine
		n		12.0	134	104	4684	5:00+	105	180	A
		n		12.0	134	105	4500	7:00+	130	220	A
		n		12.0	116	96	3000	5:00+		220	A
B		n		12.0	190	146	9825	5:30+	310	490	65/35 H/POZ
F		n		12.0	163	133	6884	4:33	530	1000	Micro-fine
B		n		12.0	128	101	4000			119	65/35 H/POZ
		n		12.0	122	98	3500	7:00+	75	190	A
B	y		102	12.0	126	99	4032	5:00+	220	270	H
B	y		70	12.0	90	80	750	5:00+	110	135	H
B	y		120	12.0	120	96	3000	6:00+	60	110	H
B	y		120	12.0	90	80	750	6:00+	37	60	H
B	y		122	12.0	130	101	4000	5:41	80	120	H
B	y		122	12.0	95	82	1200	5:00+	0	70	H
A	y		140	12.0	120	93	3000	5:00+	170	325	H
F	y		50	12.0	202	162	8750	3:25	1055	1577	Micro-fine
B	y		102	12.0	126	99	4032	5:00	130	150	H
HES-11	y		188	12.0	126	100	3800	4:40	322	1087	TLW
B	y		20	12.0	128	101	4000	12:38	115	154	65/35 H/POZ
B	y		20	12.0	128	101	4000	9:34		90	65/35 H/POZ
F	y		15	12.0		145	5852	4:00+	58	321	Micro-fine
A	y		15	12.0	141	108	7040	5:00+	104	150	H
HES-11	y		25	12.0	150	121	7400	4:04			TLW
HES-11	y		15	12.0	140	113	6000	4:30			TLW
HES-11	y		15	12.0	94	82	1250	6:00+		250	TLW
		n		12.0	134	104	4500	6:00+	46	130	A
B		n		12.0	118	97	3150	4:47			65/35 A/POZ
B		n		12.0	113	94	2650	4:17			65/35 A/POZ
		n		12.0	155	130	8600	5:00+	245	536	A
F		n		12.0	96	89	1295	2:30			Micro-fine
A		n		12.0	117	96	3100	6:00+	110	150	A
B		n		12.0	226	184	15070	2:42			65/35 H/POZ
B		n		12.0	196	149	9685	5:12	510	1090	50/50 H/POZ
B		n		12.0	122	98	3500	7:30+	106	236	65/35 H/POZ
B		n		12.0	140	107	5000	5:00+			65/35 H/POZ
B		n		12.0	160	119	6400	4:30+			65/35 H/POZ
B		n		12.0	185	151	8802	4:00+	159	352	65/35 H/POZ
		n		12.0	115	96	3000	5:00+	FIRM	150	A
F		n		12.0		97	3600		436	445	Micro-fine
		n		12.0	130	103	4500	6:00+	110	120	A
B		n		12.0	130	101	4000	6:00+			65/35 H/POZ
B		n		12.0	130	101	4000	3:40			65/35 A/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
		n		12.0	134	103	4300	5:00+	130	250	A
		n		12.0	134	104	4500	6:00+	40	170	A
B		n		12.0	122	98	3500	3:53			65/35 A/POZ
B		n		12.0	105	91	2300	5:00+	65	115	65/35 A/POZ
B		n		12.0	105	91	2300	5:00+	65	115	65/35 A/POZ
B		n		12.0		97	3500	4:10	97	117	A
B		n		12.0	207	159	10700	3:45			65/35 H/POZ
HES-11		n		12.0	196	149	9958	4:32	869	889	TLW
B		n		12.0	105	91	2200	4:00+	40	100	65/35 A/POZ
		n		12.0	110	93	2600	6:00+	111	210	A
HES-3	y		6679	12.0		65	7800	5:00+	50	135	FLOSTOP I
HES-11		n		12.0	107	90	2000	4:00+	140	250	TLW
A		n		12.0	125	100	3800	5:00+	180	270	A
B		n		12.0	120	98	3500	3:44			65/35 A/POZ
		n		12.0	116	96	3000	5:00+	110	130	A
A	y		550	12.0	103	90	2182	6:00+	125	370	A
F	y		750	12.0	195	168	11261	3:21	780	1290	Micro-fine
F	y		750	12.0	200	164	10025	3:03	780	1290	Micro-fine
A	y		3822	12.0		58	5373	5:30+			A
A	y		72	12.0	135	104	4500	6:00+	120	180	A
B	y		81	12.0	140	105	4904	7:15	150	325	H
B	y		81	12.0	96	80	1000	4:00+	160	234	H
A	y		70	12.0	133	99	4000	5:43	222	262	A
A	y		70	12.0	126	96	4000	3:32			A
F	y		100	12.0	180	153	8130	3:27	670	740	Micro-fine
B	y		108	12.0	90	80	800	4:00+			H
HES-11	y		112	12.0	125	101	4100	6:30+	429	802	TLW
HES-11	y		140	12.0	171	128	8500	4:08	721	979	TLW
HES-11	y		142	12.0	134	104	4500	6:11	270	410	TLW
B	y		170	12.0	140	106	4800	9:00+	53	131	H
F	y		170	12.0	0	160	8260	8:00	0	70	Micro-fine
F	y		170	12.0	160	160	8260	4:20	90	670	Micro-fine
HES-11	y		250	12.0	90	80	817		65	230	TLW
HES-11	y		250	12.0	122	98	3500	7:29	230	470	TLW
HES-11	y		250	12.0	95	82	2198	5:00+	40	180	TLW
HES-11	y		250	12.0	90	80	821	5:00+	120	200	TLW
HES-11	y		250	12.0	94	82	2198	4:30+	100	180	TLW
F	y		250	12.0	220	182	11652	3:29	860	1190	Micro-fine
HES-11	y		245	12.0	131	104	4700	6:00	440	815	TLW
F	y		280	12.0	155	155	7616	4:54	180	990	Micro-fine
F	y		280	12.0	175	142	7900	3:37	780		Micro-fine
B	y		306	12.0	126	100	3800	4:00+	105	300	H
B	y		306	12.0	92	80	950	3:00+	0	110	H
HES-11	y		365	12.0	106	93	2963	5:38	111	471	TLW
HES-11	y		365	12.0	120	98	4003	7:00+	142	402	TLW
B	y		50	12.0	93	80	900	4:00+	231	270	H
B	y		50	12.0	144	112	6448	3:47	110	161	H
B	y		50	12.0	144	112	6448	5:23	50	204	H
B	y		50	12.0	90	80	900	5:00+	0	245	H
F	y		80	12.0	227	187	11782	4:34	750	1200	Micro-fine
B	y		50	12.0	144	112	6448	5:19	103	178	H
A	y		250	12.0	90	80	800	5:00+	SET	120	H
A	y		300	12.0	126	107	5100	5:00+	119	298	H
A	y		25	12.0	125	99	3700	5:10	193	308	A
A	y		25	12.0	91	80	900	5:00+	256	337	A
F	y		25	12.0	181	147	8400	4:10	290	500	Micro-fine
B	y		35	12.0	128	101	4000	5:00+	220	240	H
B	y		35	12.0	90	80	790	5:00+	50	200	H
HES-11	y		50	12.0	228	181	12700	4:00	797	1120	TLW
HES-11	y		50	12.0	130	106	5000	4:46	309	667	TLW
A	y		50	12.0	110	90	2000	5:00+	147	177	H
HES-11	y		50	12.0	130	106	5000	7:22			TLW
A	y		50	12.0		80	1000		0	89	A
HES-11	y		50	12.0	130	106	5000	4:33	346	691	TLW
A	y		50	12.0	125	99	4250	6:00+	259	333	A
B	y		61	12.0	146	111	5500	5:20	200	220	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		68	12.0	120	102	4500	5:00+	100	240	H
A	y		50	12.0	140	107	5000	5:00+	70	160	A
A	y		72	12.0	134	104	4500	4:00+	220	250	A
F	y		82	12.0	148	121	6000	4:54	237	832	Micro-fine
F	y		80	12.0	211	174	11199	4:23	620	880	Micro-fine
F	y		80	12.0	221	183	12088	2:41			Micro-fine
B	y		80	12.0	230	181	13410	4:15	30	120	65/35 H/POZ
B	y		80	12.0	216	167	11614	4:10	96	200	65/35 H/POZ
B	y		80	12.0	216	167	11614	3:41	70	120	65/35 H/POZ
F	y		85	12.0		184	9428	4:06	510	870	Micro-fine
A	y		10	12.0	140	108	5200	3:56			A
A	y		10	12.0	142	109	5250	5:00+	210	320	H
A	y		75	12.0	130	107	5200	2:57	145	280	A
HES-11	y		107	12.0	210	163	11983	3:58	1090	1710	TLW
HES-11	y		120	12.0	82	80	165	3:20	301	500	TLW
E	y		120	12.0	82	80	165	5:00+			H
F	y		123	12.0	130	109	4500	4:20	192	666	Micro-fine
B	y		111	12.0		156	11000	6:24			H
B	y		130	12.0	132	103	4469	7:54	185	240	H
B	y		130	12.0	92	80	1000	5:00+	120	220	H
HES-7	y		137	12.0	163	125	7947	6:00+	219	273	H
HES-7	y		137	12.0	163	125	7947	6:00+	311	632	H
HES-7	y		137	12.0	133	110	5707	5:00+	108	189	H
B	y		130	12.0	91	80	1000	5:00+	108	269	H
B	y		130	12.0	132	105	5150	4:00+	186	1228	H
A	y		140	12.0		80	1230	5:00+	150	309	A
HES-11	y		145	12.0	140	107	5000	5:02	250	450	TLW
B	y		250	12.0	126	100	3800	5:00+	90	180	H
B	y		250	12.0	135	105	4600	6:22	190	305	H
A	y		160	12.0	134	104	4500	4:00+	306	418	A
F	y		138	12.0		158	7067	5:00+	330	1029	Micro-fine
HES-11	y		209	12.0	136	105	4650	6:00+	0	146	TLW
HES-11	y		209	12.0	92	80	975	6:00+	0	50	TLW
HES-11	y		241	12.0	125	101	4150	5:02	140	418	TLW
A	y		254	12.0	93	81	1100	5:00+	70	160	H
F	y		280	12.0	148	148	5574	3:28	260	820	Micro-fine
F	y		280	12.0	148	121	5574	3:45	260	820	Micro-fine
F	y		280	12.0		160	8100	4:45	616	739	Micro-fine
F	y		267	12.0	92	82	1400	4:00+	130	150	Micro-fine
B	y		272	12.0	92	80	1000	5:30+	106	162	H
HES-7	y		272	12.0	131	102	5920	10:00+	448	920	H
B	y		272	12.0	131	102	5920	5:00+			H
B	y		25	12.0	130	104	4700	4:15			H
F	y		600	12.0	150	128	6100	3:00	120	560	Micro-fine
B	y		25	12.0	113	98	3900	5:00+	80	220	H
B	y		25	12.0	134	104	4500	6:22	110	180	H
HES-11	y		25	12.0	234	185	13333	5:33	315	1014	TLW
A	y		20	12.0	92	80	1000	4:00+	200	330	A
A	y		21	12.0	92	80	1000	4:00+	90	130	50/50 H/POZ
A	y		21	12.0	129	101	4060	4:00+	260	300	A
HES-2	y		600	12.0		80	975	6:00+	141	352	A
F	y		71	12.0		188	12152	4:10	973	956	Micro-fine
HES-11		n		12.0	115	100	3015	4:30+			TLW
HES-11		n		12.0	115	100	3015	4:57	254	490	TLW
B		n		12.0	119	96	3000	4:07			65/35 A/POZ
F		n		12.0	130	109	3850	4:30	114	450	Micro-fine
HES-11	y		650	12.0		103	4630	5:30+	220	520	TLW
HES-11	y		980	12.0	0	87	4100	6:00+	160	430	TLW
B		n		12.0	116	96	3000	4:23			65/35 A/POZ
A	y		3822	12.0		106	7450	2:45			A
A	y		3822	12.0		79	7450	5:30+		124	A
A		n		12.0	135	102	4175	8:00+	90	95	A
B		n		12.0	105	91	2250	5:00+	100	130	65/35 A/POZ
		n		12.0	125	99	3700			120	A
F		n		12.0	152	152	6000	5:38	102	572	Micro-fine
A	y		300	12.0		81	1303	6:00+	170	289	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		1250	12.0	102	88	1800	6:45		363	A
HES-11	y		1491	12.0	0	84	4000	4:00+	160	260	TLW
HES-11	y		1491	12.0	0	84	4000	4:00+	80	200	TLW
HES-3	y		1491	12.0		80	2900	6:00+	364	784	A
F	y		250	12.0	185	157	10103	4:18	780	820	Micro-fine
B	y		633	12.0	106	92	2644	3:31	150	180	A
B	y		633	12.0	106	92	2644	6:00+	120	150	H
HES-11	y		850	12.0	0	80	1950	6:00+	100	220	TLW
HES-3	y		981	12.0		80	2600	3:58	483	727	A
HES-3	y		1195	12.0		80	2770	3:50	420	601	FLOSTOP I
A	y		1195	12.0		80	2770	5:00+		50	A
A	y		1250	12.0	100	87	1800	4:45	344	461	A
A	y		1250	12.0	130	102	4250	4:47	365	618	A
F	y		1250	12.0	160	131	7250	5:13	420	1031	Micro-fine
A	y		1250	12.0	100	87	1700	7:04		198	A
A	y		1250	12.0	130	102	4250	2:45			A
F	y		1250	12.0		60	600	2:30+	0	0	Micro-fine
F	y		760	12.0		242	13500	3:22	560		Micro-fine
HES-11	y		760	12.0		83	2612	5:00+		170	TLW
F	y		760	12.0	242	202	13500	3:00	1895		Micro-fine
F	y		760	12.0	214	176	11200	3:34	750		Micro-fine
F	y		760	12.0	170	143	10000	2:45	400	1410	Micro-fine
A	y		855	12.0	120	105	4900	6:00+	50	80	H
HES-7		n		12.0		123	6200	7:00+		0	A
HES-7		n		12.0		122	5500	7:00+	28	153	A
HES-7		n		12.0		122	5200	6:32	0	218	A
HES-7		n		12.0		122	5500	5:23			A
A		n		12.0	100	84	1450	5:30+	225	385	A
HES-11		n		12.0	105	94	1700	4:12	214	360	TLW
A		n		12.0	85	80	300		30	255	A
A		n		12.0	85	80	300		FIRM	70	A
A		n		12.0	85	80	300				A
A		n		12.0	85	80	300		0	160	A
A		n		12.0	85	80	300		0	80	A
A		n		12.0	85	80	300		140	270	A
		n		12.0	134	104	4500	5:00+	FIRM	50	A
B		n		12.0	206	158	10500	3:08			65/35 H/POZ
		n		12.0	128	101	4000	8:00+			A
		n		12.0	128	101	4000	8:00+	105	140	A
		n		12.0	125	100	4000	6:00+		73	A
F		n		12.0	180	153	8660	3:16	460	530	Micro-fine
B		n		12.0	122	100	4000	4:58	131	217	65/35 A/POZ
A	y		255	12.0	115	101	4350	3:24	439	603	A
HES-11	y		100	12.0		93	2636	6:26	130	287	TLW
HES-7	y		106	12.0	220	173	14010	4:23	153	285	H
HES-11	y		106	12.0	116	96	3000	4:00+	322	1085	TLW
B	y		50	12.0	226	176	13193	4:00	400	530	65/35 H/POZ
HES-7	y		100	12.0	218	170	12500	6:00+	180	208	H
F	y		100	12.0	220	184	12820	3:08	1450	1545	Micro-fine
B	y		150	12.0	218	168	13053	4:13	150	320	65/35 H/POZ
HES-7	y		220	12.0	161	122	8288	6:00+	197	340	H
F	y		221	12.0	174	149	12390	4:25	530	1410	Micro-fine
HES-7	y		206	12.0	158	131	7866	4:00+	180	520	H
B	y		96	12.0	207	159	11120	6:30+	421	1238	50/50 H/POZ
HES-11	y		920	12.0	121	103	4610	5:00	168	408	TLW
A	y		693	12.0	0	90	3400	4:00+	100	210	A
HES-11	y		1711	12.0		90	4200	6:24	106	328	TLW
A	y		1086	12.0		81	5000	7:00+	130	250	H
HES-7	y		100	12.0	185	143	9953	6:00+	295	1215	H
HES-7	y		138	12.0	230	181	16160	5:00+	FIRM	40	H
F	y		240	12.0	153	129	7500	3:19	80	740	Micro-fine
A	y		218	12.0	134	104	4500	4:00+	55	100	H
F	y		206	12.0	165	140	8490	2:43	480	730	Micro-fine
F	y		95	12.0	180	147	8768	2:55	1260	1870	Micro-fine
A	y		30	12.0	122	98	3500	2:20	260	420	A
A	y		58	12.0	88	80	750	6:00+	115	180	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		58	12.0	117	96	3120	6:00+	190	230	H
HES-11	y		60	12.0	145	109	5000	4:20	130	385	TLW
F	y		65	12.0	205	165	9152	3:24	1170	1210	Micro-fine
F	y		356	12.0	210	176	12490	4:10	680	880	Micro-fine
F	y		356	12.0	227	189	12600	3:15	760	1710	Micro-fine
F	y		356	12.0	180	146	8200	5:14	370	890	Micro-fine
B	y		190	12.0	92	80	1000	5:30+	0	60	H
B	y		50	12.0	119	96	3000	3:00+			H
F	y		926	12.0	183	153	10462	5:16	0	540	Micro-fine
HES-11	y		926	12.0	121	103	4610	4:30			TLW
HES-3	y		926	12.0		80	2050	5:00+	414	665	A
F	y		633	12.0	168	146	13174	3:44	490	715	Micro-fine
A	y		720	12.0	117	99	3834	3:43	281	436	A
F	y		720	12.0	124	100	5623	2:21	350	441	Micro-fine
HES-11	y		720	12.0	118	99	3834	5:50	233	286	TLW
F	y		720	12.0	132	112	6400	4:40	158	258	Micro-fine
A	y		720	12.0	117	99	3788	4:28	259	582	A
B	y		720	12.0	99	90	2300	6:00+	0	60	A
HES-11	y		720	12.0	117	99	3834	5:30	106	284	TLW
B	y		720	12.0	99	90	2300	4:30	68	110	A
A	y		720	12.0	117	99	3834	6:27	183	292	A
HES-7	y		700	12.0	117	97	4066	6:00+	70	90	H
B	y		700	12.0	95	88	1850	5:00+	FIRM	100	H
A	y		1605	12.0		100	4600	6:00+	180	320	TLW
A	y		1605	12.0		100	4600	5:30+	110	205	H
A	y		1605	12.0		90	4200	6:13	100	260	TLW
A	y		1419	12.0		95	6600	3:56			A
HES-11	y		1711	12.0		90	4200	5:25			TLW
HES-11	y		1646	12.0		80	4200	8:46	66	169	TLW
F	y		1646	12.0		168	16700	5:30	232	623	Micro-fine
HES-11	y		2200	12.0		70	3550	6:00+		120	TLW
F	y		1500	12.0	0	132	10700	3:35	150	290	Micro-fine
F	y		2663	12.0	0	120	13450	2:55	95	120	Micro-fine
HES-11	y		2081	12.0		70	3700	4:00+	0	120	TLW
HES-11	y		2081	12.0		75	3700	4:00+		0	TLW
HES-11	y		2120	12.0		75	3800	6:00+		0	TLW
		n		12.0	130	101	4000	6:30+	0	66	A
		n		12.0	124	100	4000	7:00+	130	260	A
B		n		12.0	135	109	5500	4:00+	105	310	H
B		n		12.0	114	97	3500	3:00+	220	320	H
F		n		12.0	166	136	7550	4:38	52	1072	Micro-fine
B		n		12.0	132	101	4000	6:30+			65/35 H/POZ
	y		200	12.0	115	96	3000	5:00+	110	200	A
F	y		200	12.0	165	137	8572	3:51	700	1270	Micro-fine
A	y		100	12.0	93	82	1200	6:30+		309	A
B		n		12.0	99	85	1500	5:30+	0	54	65/35 A/POZ
C	y		883	12.0		100	4000	3:38	95	188	A
HES-11	y		518	12.0	0	90	2000	4:30+	78	163	TLW
HES-7	y		2046	12.0		72	5934	5:45	40	60	H
HES-7	y		2046	12.0		72	5934	5:00+	20	170	H
A	y		2100	12.0	0	92	5600	6:17	0	100	A
A	y		2100	12.0	0	65	3600	10:00+	0	0	A
HES-7	y		2841	12.0	0	80	7000	5:15+	30	110	A
HES-11	y		517	12.0		99	4150	4:45	160	240	TLW
HES-11	y		517	12.0		72	1700	4:00+	110	170	TLW
HES-11	y		760	12.0	110	93	2550	7:30	64	147	TLW
HES-11	y		760	12.0	103	92	2550	8:45	58	152	TLW
A	y		1306	12.0		80	2490	5:00+	110	250	A
A	y		1306	12.0		88	4190	5:00+	110	250	A
HES-11	y		3227	12.0		70	4875		60	117	TLW
HES-11	y		3227	12.0		70	4875	5:00+	0	50	TLW
A	y		3227	12.0		70	4875	4:00+	0	50	A
HES-11	y		3227	12.0		70	4875	4:00+	0	0	TLW
F	y		3227	12.0	0	128	14735	3:30	95	640	Micro-fine
HES-11	y		3227	12.0		70	4875	4:00+	0	100	TLW
HES-11	y		3325	12.0		70	5200	5:00+	0	0	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		3467	12.0		65	5200	5:30+	FIRM	30	TLW
A	y		525	12.0		80	2300	4:00+		0	A
E	y		525	12.0		80	2300	4:30+	0	0	TLW
HES-2	y		525	12.0		80	2300	4:00+	0	50	A
E	y		525	12.0		80	2300	4:30+	0	0	TLW
HES-11	y		525	12.0		80	2300	4:00+	90	152	TLW
A	y		4100	12.0		75	8500	5:10		373	A
A	y		4100	12.0		72	7250	5:00+		191	A
HES-3	y		4243	12.0		80	6321	3:23			A
HES-11	y		856	12.0	127	99	3950	6:26	26	405	TLW
HES-11	y		856	12.0	103	90	2200	5:00+	140	318	TLW
HES-11	y		856	12.0	103	90	2100	7:30+	79	177	TLW
F	y		900	12.0		175	15200	4:45	818	1590	Micro-fine
A	y		6500	12.0	0	65	5119	10:16	0	40	TLW
HES-11	y		750	12.0	118	101	5400	5:00+	1660	2275	TLW
HES-11		n		12.0	250	201	13050	4:07	600	707	TLW
HES-11		n		12.0	250	201	13050	5:30+	530	588	TLW
HES-11		n		12.0	250	201	13050	3:51	232	239	TLW
HES-11		n		12.0	250	201	13050	5:30+	436	1036	TLW
B		n		12.0	125	98	3500	5:30+			65/35 A/POZ
B		n		12.0	210	161	10700	5:28	114	456	65/35 H/POZ
HES-11		n		12.0	150	122	5528	3:30	130	390	TLW
		n		12.0	116	96	3000	6:00+	FIRM	160	A
B	y		40	12.0	170	127	7500	8:30+	60	70	65/35 H/POZ
B	y		40	12.0	120	98	3500	5:00+	104	258	65/35 A/POZ
B	y		40	12.0	209	158	10100	5:58	310	460	65/35 H/POZ
A	y		50	12.0	133	103	4400	2:26	280	500	A
A	y		51	12.0	116	96	3005	2:50	170	380	A
A	y		51	12.0	92	80	1000	4:00+	75	220	A
B	y		50	12.0	120	96	3000	5:39	100	150	H
B	y		50	12.0	90	80	750	5:00+	60	100	H
A	y		51	12.0	114	95	2800	4:10	220	380	A
A	y		51	12.0	88	80	700	4:00+	121	261	A
B	y		52	12.0	134	104	4400	4:00+	170	225	H
B	y		55	12.0	122	98	3912	4:55	115	160	65/35 A/POZ
A	y		55	12.0	90	80	800	4:39	232	440	A
F	y		100	12.0	170	143	10226	4:40	386	933	Micro-fine
F	y		170	12.0	186	150	8244	3:49	1091	1564	Micro-fine
A	y		360	12.0		55	670	3:00+	54		A
A	y		380	12.0	92	82	1200	4:00+	130	160	H
A	y		380	12.0	118	96	3999	6:00+	220	350	H
HES-11	y		342	12.0		100	4729	7:44	162	413	TLW
HES-11	y		342	12.0		100	4729	6:46	187	404	TLW
HES-11	y		342	12.0		89	2000	6:15	54	105	TLW
HES-11	y		342	12.0		102	4676	6:35	128	225	TLW
HES-11	y		300	12.0	119	96	3000	6:00+	233	322	TLW
F	y		300	12.0	198	162	9900	3:28	990	1340	Micro-fine
HES-11	y		252	12.0	96	80	1000	4:30+	50	285	TLW
HES-11	y		252	12.0	116	96	3000	4:48	190	430	TLW
A	y		275	12.0	130	105	4900	5:30	240	290	H
HES-11	y		250	12.0	121	98	4836	5:00+	498	967	TLW
HES-11	y		250	12.0	110	93	3905	4:30+	150	180	TLW
F	y		283	12.0	270	232	12676	4:12	690	850	Micro-fine
F	y		283	12.0	191	159	7398	3:47	470	600	Micro-fine
F	y		285	12.0		242	11972	3:41	1044	1374	Micro-fine
F	y		285	12.0		205	11600	3:04	1112	1222	Micro-fine
HES-11	y		478	12.0		85	1500	8:00	105	204	TLW
A	y		350	12.0	105	92	2500			69	H
HES-11	y		80	12.0	100	85	1500	7:00+	130	330	TLW
A	y		100	12.0	105	92	2500			53	H
A	y		100	12.0	105	92	2500			72	H
HES-11	y		292	12.0	128	101	4000	4:35	280	640	TLW
HES-11	y		292	12.0	128	101	4000	3:26			TLW
A	y		360	12.0	118	97	5000	4:00+	190	300	H
F	y		250	12.0	105	94	2100	4:00+	55	120	Micro-fine
HES-11	y		288	12.0		119	6641	8:02	0	371	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		329	12.0		91	4250	7:37	53	132	TLW
HES-11	y		390	12.0		89	2000	6:15	31	42	TLW
A	y		22	12.0	134	104	4500	6:00+	270	295	A
B	y		50	12.0	158	116	8222	5:00+	100	130	65/35 H/POZ
A	y		285	12.0	122	98	3450	4:00+	100	170	H
A	y		324	12.0	92	82	1200	6:00+	150	220	H
A	y		324	12.0	120	97	3400	5:00+	110	228	H
HES-11	y		324	12.0	120	97	3225	4:00+	550	940	TLW
HES-11	y		347	12.0		102	4270	7:25	34	197	TLW
B	y		219	12.0	126	100	4000	6:24	50	130	H
B	y		219	12.0	90	80	1000	7:00+		90	H
F	y		220	12.0	126	126	3575	3:32	70	250	Micro-fine
A	y		220	12.0		83	1543	4:30+	28	164	H
HES-11	y		220	12.0	120	96	3217	5:00+	370	740	TLW
HES-11	y		265	12.0	116	96	3000	5:30+	171	346	TLW
HES-11	y		265	12.0	116	96	3000	3:35			TLW
F	y		280	12.0	172	147	8400	2:39	470	1230	Micro-fine
F	y		280	12.0	172	147	8400	5:02	720	1170	Micro-fine
HES-11	y		300	12.0	108	92	3134	6:00+	193	314	TLW
HES-11	y		300	12.0	112	94	4903	5:30+	204	331	TLW
A	y		61	12.0	90	80	900	4:00+	120	240	A
B	y		61	12.0	170	113	5200	8:00+	66	227	65/35 H/POZ
A	y		220	12.0		100	4117	6:00+	87	173	H
A	y		324	12.0	92	82	1200	4:00+	140	170	H
HES-11	y		324	12.0	118	96	3400	4:00+	220	485	TLW
HES-11	y		342	12.0	127	102	4800	7:56	71	244	TLW
A	y		200	12.0	130	102	4200	3:07			A
A	y		235	12.0	114	95	3000	5:00+	100	110	H
HES-11	y		342	12.0	127	97	3220	7:06	347	600	TLW
F	y		342	12.0	131	111	6200	3:33	161	379	Micro-fine
HES-11	y		342	12.0	104	92	6116	4:00+		235	TLW
B		n		12.0	100	85	1500	5:00+	61	111	65/35 H/POZ
B		n		12.0	152	115	6000	5:00+	90	185	65/35 H/POZ
B		n		12.0	122	98	3500	4:30+	0	89	65/35 H/POZ
F	y		208	12.0	100	88	1700	5:00+	80	100	Micro-fine
A	y		218	12.0	103	89	2379	5:00+		109	H
		n		12.0	100	85	1500	5:00+			A
F		n		12.0	220	181	11117	10:31+	636	1546	Micro-fine
		n		12.0	140	107	5000	7:00+	220	370	A
		n		12.0	125	101	4200	4:00+	90	160	A
B		n		12.0	170	127	7700	4:30+	266	510	65/35 H/POZ
B		n		12.0	170	128	7500	5:48	120	170	65/35 H/POZ
B		n		12.0	212	162	10600	6:56	90	120	65/35 H/POZ
		n		12.0	122	98	3500	5:00+			A
HES-11		n		12.0	181	145	7200	2:20	1152	1425	TLW
B		n		12.0	116	96	3000	6:04	83	151	65/35 A/POZ
B		n		12.0	270	224	14625	6:00+			65/35 H/POZ
B		n		12.0	130	101	4000	6:00			65/35 H/POZ
		n		12.0	115	99	4000		80	105	A
		n		12.0	130	101	4000	7:00+	135	225	A
B		n		12.0	120	100	4000		66	264	65/35 H/POZ
B		n		12.0	155	114	5800	6:00+			65/35 H/POZ
B		n		12.0	120	100	4000		87	300	65/35 A/POZ
		n		12.0	115	95	2910	5:00+	110	200	A
B		n		12.0	120	100	4000	4:39			65/35 A/POZ
B		n		12.0	122	98	3500	5:00+			65/35 A/POZ
		n		12.0	155	117	6200	7:00+	SET	120	A
F		n		12.0	188	150	7727	4:01	990	1310	Micro-fine
HES-11		n		12.0	119	98	3500	5:00+	234	656	TLW
		n		12.0	120	96	3200	7:00+			A
F		n		12.0		280	12862	2:41	535	588	Micro-fine
A		n		12.0	110	96	3500	7:03	110	170	A
		n		12.0	122	98	3500		70	180	A
F		n		12.0	221	191	12650	3:05	505	560	Micro-fine
F		n		12.0		210	10393	5:20	1265	1355	Micro-fine
		n		12.0	129	102	4100	6:00+	100	240	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		12.0	107	92	2450	7:00+	170	295	65/35 A/POZ
B		n		12.0	110	93	2600	5:00+	120	160	65/35 A/POZ
		n		12.0	117	97	3300	5:00+	20	70	A
		n		12.0	116	96	3000	5:00+	128	137	A
B		n		12.0	108	92	2400		0	116	65/35 H/POZ
B		n		12.0		85	1000	6:00+			65/35 A/POZ
		n		12.0	130	102	4200	7:00+	110	1200	A
B		n		12.0	130	101	4000	6:00+	0	176	65/35 H/POZ
F		n		12.0	190	153	8451	3:10	1090	1360	Micro-fine
F		n		12.0	160	130	6500	3:00	770	1090	Micro-fine
		n		12.0	110	95	3000	5:00+	105	120	A
		n		12.0	126	100	3800	7:00+	75	195	A
B		n		12.0	128	101	4000	6:00+	80	200	65/35 A/POZ
B		n		12.0	265	213	15100	5:19	430	550	65/35 H/POZ
B		n		12.0	156	118	6350	5:30+		255	65/35 H/POZ
F		n		12.0	140	117	6004	4:45	255	673	Micro-fine
B		n		12.0	164	123	7000	6:00+		493	65/35 H/POZ
B		n		12.0	160	117	6100	6:00	65	125	65/35 H/POZ
F	y		1025	12.0	159	135	10076	3:35	708	825	Micro-fine
F		n		12.0	138	117	4860	4:30+	130	420	Micro-fine
F	y		40	12.0	140	116	5085	1:07			Micro-fine
F	y		40	12.0	140	116	5085	0:37			Micro-fine
F	y		158	12.0	164	164	7173	4:32	230	620	Micro-fine
F	y		200	12.0	165	136	7428	3:02	540	1010	Micro-fine
HES-11	y		120	12.0	122	98	3500	5:00+	0	265	TLW
A	y		120	12.0	91	80	920	4:00+	164	260	A
F	y		138	12.0	119	103	3272	4:00+	95	110	Micro-fine
A	y		145	12.0	116	96	3000	5:00+	400	450	A
HES-11	y		167	12.0	120	98	3500	4:47	375	944	TLW
A	y		253	12.0	115	97	3500	6:01	380	450	A
A	y		253	12.0	119	98	3500	4:00+	110	240	A
A	y		253	12.0	115	97	3500	4:14	363	490	A
A	y		184	12.0	90	80	900	4:00+	160	305	A
F	y		195	12.0	126	108	3804	4:30+	90	200	Micro-fine
HES-11	y		222	12.0	115	95	5724	5:30+	SET	350	TLW
HES-11	y		222	12.0	125	99	8539	5:30+	195	360	TLW
HES-11	y		227	12.0	116	96	6200	4:00+	25	630	TLW
HES-11	y		227	12.0	105	90	6323	5:30	90	360	TLW
F	y		230	12.0	147	122	6514	2:24	404	686	Micro-fine
B	y		303	12.0	126	106	5000	5:00	110	150	H
HES-7	y		295	12.0	119	96	3750	4:00+	100	160	H
B	y		200	12.0	110	91	2305		76	155	65/35 H/POZ
F	y		200	12.0	128	108	3671	6:30+	333	1147	Micro-fine
HES-11	y		215	12.0	134	104	4500	5:48	580	969	TLW
B	y		210	12.0	112	89	1975	6:00+	60	130	50/50 A/POZ
F	y		210	12.0	102	84	1859	4:25	305	346	Micro-fine
B	y		210	12.0	88	80	856	10:00+	50	118	50/50 A/POZ
HES-11	y		210	12.0		84	1859	5:30+	76	130	TLW
HES-11	y		210	12.0	88	80	856	10:09	97	142	TLW
HES-11	y		210	12.0	97	84	2100	9:48	88	131	TLW
HES-11	y		210	12.0	110	97	2600	4:11	313	465	TLW
HES-11	y		210	12.0	102	84	1859	7:00+	103	189	TLW
B	y		210	12.0	94	80	905	6:00+	50	64	50/50 A/POZ
A	y		210	12.0		91	2100	4:08	109	320	Micro-fine
HES-2	y		210	12.0		91	2100		595	1914	A
A	y		210	12.0	110	97	2600	3:35	243	329	A
HES-11	y		210	12.0	110	97	2600	6:00+	69	121	TLW
F	y		50	12.0	174	174	7825	3:54	426	895	Micro-fine
HES-7	y		240	12.0	128	100	4000	4:30+	80	110	H
B	y		38	12.0	113	95	3000	4:30+	50	105	H
A	y		20	12.0	107	92	2500	5:44	232	318	A
B	y		20	12.0	108	92	2500	6:00+	FIRM	50	65/35 H/POZ
A	y		120	12.0	123	103	4500	5:00+	0	170	H
A	y		120	12.0	118	99	4034	3:00+	100	120	H
A	y		120	12.0	128	103	4630		141	229	H
A	y		120	12.0	120	100	4000	4:00+	110	130	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
F	y		42	12.0		130	4851	2:41	113	362	Micro-fine
B	y		65	12.0	143	105	4500	5:30+	150	215	H
B	y		65	12.0	94	80	1000	4:00+	160	230	A
HES-11		n		12.0	206	156	10000	3:58	500	873	TLW
A	y		77	12.0	90	80	700	5:00+	130	150	H
F	y		80	12.0	180	146	8000	3:09	690	1030	Micro-fine
A	y		80	12.0	95	82	1250	5:53	105	210	A
HES-11	y		100	12.0	94	80	1000	5:30+	100	510	TLW
HES-11		n		12.0		210	4060	3:10	956	1029	TLW
B		n		12.0	116	96	3000	6:00+	100	113	65/35 A/POZ
F		n		12.0	202	166	10129	3:46	400	780	Micro-fine
F		n		12.0	203	166	10134	3:29	400	780	Micro-fine
A	y		3797	12.0		82	9500	4:56	120	170	A
HES-7	y		1200	12.0		72	5934	7:00+	40	140	H
A	y		1025	12.0	102	89	2053	5:00+	90	180	A
F	y		1025	12.0	128	110	4150	4:30+	100	190	Micro-fine
A	y		1025	12.0	104	90	2287	5:00+	0	0	A
A	y		1025	12.0	125	102	4400	7:00+	160	270	A
F	y		1025	12.0	126	108	3849	3:30	90	200	Micro-fine
A	y		3030	12.0		120	12000	7:58	166	217	H
A	y		3633	12.0		96	9896	6:00+	100	150	H
HES-11	y		2095	12.0		90	4673	7:00+	104	289	TLW
HES-11	y		6627	12.0		125	14820	4:25	233	578	TLW
HES-11	y		6627	12.0		125	14820	3:08			TLW
F	y		6627	12.0		105	12700	2:03	70	90	Micro-fine
HES-11	y		6627	12.0		125	15000	3:25	122	309	TLW
A	y		6739	12.0	120	96	4136	6:00+	140	250	H
HES-11	y		6739	12.0		125	15500	3:40	176	396	TLW
HES-11	y		6588	12.0		120	14550	3:41	205	530	TLW
A	y		1300	12.0	110	94	4000	5:00+	221	304	A
A	y		1300	12.0	122	100	6000	5:00+	211	298	A
HES-11	y		1334	12.0		75	4500	7:00+	56	230	TLW
HES-11	y		1334	12.0		63	2750	5:00+	0	115	TLW
HES-11	y		1400	12.0		80	1780	4:00+	120	220	TLW
HES-7	y		3200	12.0		145	13685	3:53	300	380	H
HES-11	y		6037	12.0	0	90	12000	5:55	FIRM	430	TLW
A	y		2707	12.0		105	6500	5+00+	120	250	A
A	y		2707	12.0		90	5000	4:00+	185	290	A
A	y		2707	12.0		101	6250	6:00+	230	310	A
HES-2	y		2945	12.0			5100			159	A
HES-2	y		2945	12.0	72	72	5100	2:56			A
A	y		2945	12.0	72	72	5100	5:00+		32	A
HES-2	y		3000	12.0			5500		0	54	A
F	y		3000	12.0	0	159	19597	3:49	740	770	Micro-fine
A	y		3800	12.0		82	9500	4:56	120	170	A
HES-3	y		3944	12.0		70	3950	4:00+	92	324	A
HES-3	y		5378	12.0		80	9050	4:03	67	204	A
HES-3	y		5378	12.0		80	9050	6:05			A
HES-7	y		3855	12.0	0	72	5450	4:30+	0		A
HES-7	y		3845	12.0	0	63	7000	6:00+	74	149	A
B	y		14	12.0	300	270	18261	4:24	211	244	H
B	y		48	12.0	106	90	2000	4:00+	160	250	H
HES-7	y		54	12.0	105	90	2000	4:00+	128	308	H
HES-11	y		52	12.0	150	115	6000	5:00+	122	208	TLW
HES-11	y		52	12.0	0	255	17000	7:10	0	0	TLW
HES-11	y		52	12.0	318	276	17000	7:57	0	0	TLW
F	y		49	12.0		62	400	2:00+	0	120	Micro-fine
B	y		60	12.0	100	82	1200	5:00+	115	184	H
B	y		60	12.0	100	87	1700	5:00+	60	195	H
B	y		60	12.0	100	87	1700	4:00+	106	206	H
B	y		60	12.0	130	103	4500	4:00+	144	254	H
B	y		46	12.0	302	261	16867	3:10	360	550	H
HES-7	y		45	12.0	105	89	2000	5:30+	0	114	H
HES-11	y		60	12.0	230	178	11500	7:50		633	TLW
HES-11	y		50	12.0		83	1000	6:00+	0	0	TLW
A	y		240	12.0	126	102	4553	8:30+	141	270	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		200	12.0	155	110	5000	5:29	411	412	TLW
A	y		174	12.0	155	110	5000	4:10	155	205	H
F	y		172	12.0	280	242	13259	3:38	430	960	Micro-fine
F	y		170	12.0	259	206	10336	3:44	730	880	Micro-fine
B		n		12.0	120	99	4000	7:00+	40	120	65/35 A/POZ
B		n		12.0	128	101	4000	6:00+			65/35 H/POZ
B		n		12.0	135	102	4200	3:08	94	188	65/35 A/POZ
F	y		150	12.0	0	224	10929	3:35	534	860	Micro-fine
A	y		160	12.0	175	121	7500	5:45	120	230	H
B		n		12.0	131	102	4230	3:38			65/35 A/POZ
A		n		12.0	104	88	1800	4:01	50	200	A
HES-7		n		12.0		50	50			51	A
		n		12.0	124	100	4000	7:00+	60	100	A
		n		12.0	122	97	3500	5:00+	80	125	A
		n		12.0	135	104	4450	5:00+	140	195	A
B		n		12.0	128	100	4000	5:00+	100	125	65/35 A/POZ
		n		12.0	110	94	3000		95	120	A
HES-11		n		12.0	93	84	1500		94	248	TLW
B		n		12.0	256	211	12600	3:08	750	760	65/35 H/POZ
F		n		12.0	225	184	11070	3:20	820	1600	Micro-fine
		n		12.0	125	98	3500	5:00+	40	150	A
HES-11		n		12.0		178	13500	6:12		792	TLW
HES-11		n		12.0		178	13500	8:56			TLW
A		n		12.0	113	95	3000	8:00+	240	340	A
B		n		12.0		96	3000	5:30+	89	152	65/35 A/POZ
		n		12.0	122	98	3500	6:30+			A
B		n		12.0	128	101	4000	4:05			65/35 A/POZ
F		n		12.0	104	94	2000	3:00	230	270	Micro-fine
F		n		12.0	250	202	11154	3:29	820	980	Micro-fine
HES-11		n		12.0	165	126	9485	2:50	720	840	TLW
		n		12.0	133	103	4400	6:00+	120	310	A
B		n		12.0	122	98	3500	5:00	120	175	65/35 A/POZ
		n		12.0	150	112	5620	8:00+			A
B		n		12.0	95	80	1000	6:00+	30	140	H
B		n		12.0	118	96	3000	3:38			65/35 A/POZ
B	y		67	12.0	142	111	6316	4:00+	100	120	H
A	y		191	12.0	134	104	5598	5:30+	220	280	H
A	y		200	12.0	134	104	5512	5:30	160	223	H
B	y		200	12.0	171	128	10105	5:00+	240	480	65/35 H/POZ
A	y		191	12.0	134	104	5030	5:00+	240	250	H
F	y		212	12.0		173	9038	4:50	FIRM	670	Micro-fine
HES-11	y		220	12.0	115	96	5000	6:00+	90	380	TLW
F	y		332	12.0		176	13365	3:03	700	1710	Micro-fine
F	y		174	12.0	164	136	8303	3:06	420	780	Micro-fine
B	y		75	12.0	143	109	5250	5:34	60	170	H
A	y		525	12.0		89	2370	6:00+	55	210	A
A	y		525	12.0		89	2370	7:18	130	370	A
HES-11	y		525	12.0	134	106	4940	6:10	270	676	TLW
HES-2	y		525	12.0	110	97	3700	6:11	50	80	A
F	y		525	12.0		140	5580	5:43	210	946	Micro-fine
HES-2	y		525	12.0	100	91	2370	5:00+	112	140	A
HES-11	y		525	12.0	140	110	5595	5:29	276	643	TLW
F	y		90	12.0	265	224	15054	9:00+	1580	1940	Micro-fine
HES-11	y		94	12.0	140	109	5400	5:15	224	649	TLW
B	y		60	12.0	135	105	4800	6:56	70	150	H
B	y		60	12.0	135	105	4800	7:02	100	190	H
B	y		95	12.0	130	102	4100	4:55	110	150	H
A	y		130	12.0	142	108	5200	6:00+	82	116	H
B	y		128	12.0	140	107	5000	5:00+	144	176	65/35 A/POZ
B	y		128	12.0	92	80	1000	4:00+		100	65/35 A/POZ
B	y		122	12.0	134	104	4727	6:04	210	290	H
B	y		122	12.0	134	104	4644	5:36	160	210	H
B	y		122	12.0	116	96	3831	5:58	196	253	H
B	y		124	12.0	132	103	4400	6:15	170	240	H
B	y		124	12.0	134	104	4644	6:20	190	300	H
F	y		137	12.0	253	214	14600	3:06	510	955	Micro-fine

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		150	12.0	135	106	5000	4:47	165	263	H
A	y		182	12.0	96	83	1300	4:00+	160	200	H
HES-11	y		182	12.0	142	108	5200	7:29	55	195	TLW
B	y		150	12.0	128	101	4000	5:00+	429	487	65/35 H/POZ
B	y		150	12.0	128	101	4000	5:06	819	890	65/35 A/POZ
B		n		12.0	180	143	10764	6:11	180	370	65/35 H/POZ
B		n		12.0	120	96	3000	5:40	330	520	85/15 H/POZ
B		n		12.0	180	180	10764	4:16	410	550	65/35 H/POZ
B	y		380	12.0	104	89	2000	5:00+	40	160	H
B	y		380	12.0	150	114	5800	5:05	70	120	H
A	y		51	12.0	122	98	3500	6:00+	159	215	A
F	y		51	12.0	110	97	2500	2:39	294	332	Micro-fine
F	y		51	12.0	175	144	8841	3:04	350	798	Micro-fine
F	y		108	12.0	170	138	7500	3:56	540	1000	Micro-fine
F	y		108	12.0	182	148	8500	3:35	1000	1050	Micro-fine
F	y		108	12.0	210	172	10500	4:28	1150	1320	Micro-fine
HES-11	y		108	12.0	118	97	3200	5:30+	250	550	TLW
F	y		108	12.0	194	159	9500	4:44	990	1650	Micro-fine
A	y		530	12.0	98	87	1800	6:00+	140	340	H
F	y		209	12.0		140	13270	2:53	1092	1216	Micro-fine
A	y		325	12.0	104	90	2425	3:00+	110	228	A
A	y		325	12.0	105	90	2100	4:00+	124	244	A
F	y		325	12.0	104	94	2000	4:30+	171	296	Micro-fine
B	y		328	12.0	135	104	4500	5:15	128	230	65/35 A/POZ
A	y		328	12.0	98	85	1500	4:00+	325	360	A
B	y		328	12.0	142	108	5100	4:28	120	185	65/35 A/POZ
F	y		200	12.0	166	166	8050	5:17	270	1090	Micro-fine
B	y		190	12.0	98	85	1500	4:00+	40	120	H
B	y		200	12.0	97	85	1500	6:00+	30	75	H
HES-11	y		385	12.0	189	151	11390	6:07		567	TLW
B	y		380	12.0	120	99	4393	5:30	140	250	H
HES-11	y		380	12.0	141	113	6000	5:39	285	776	TLW
A	y		380	12.0	140	112	5800	6:24	130	200	H
B	y		380	12.0	100	83	1300	7:00+	120	240	H
HES-11	y		420	12.0	201	167	14300	4:43	237	1560	TLW
B		n		12.0	120	97	3300	5:00+	25	25	65/35 H/POZ
F		n		12.0	92	80	800	6:00+	182	324	A
B	y		37	12.0	126	104	4600	4:57	90	190	H
HES-11	y		37	12.0	115	96	3000	5:00+	121	487	TLW
A	y		35	12.0	126	103	4500	6:30+	211	244	H
A	y		29	12.0	125	101	4100	5:00+	230	405	A
A	y		65	12.0	140	108	5150	6:00+	170	220	A
A	y		65	12.0	140	107	5000	4:00+	230	380	A
A	y		30	12.0		114	6000	7:00+	185	250	H
B	y		48	12.0	116	96	3000	5:37	160	200	H
F	y		50	12.0	144	119	5800	2:34	270	580	Micro-fine
F	y		55	12.0	140	116	5852	3:20	260	610	Micro-fine
F	y		60	12.0	165	138	9065	5:00+			Micro-fine
B	y		60	12.0	129	102	4100	6:01	80	240	H
HES-7	y		60	12.0		145	9265	7:00+			H
HES-7	y		60	12.0	88	80	800	5:00+	40	50	H
HES-7	y		60	12.0	120	98	3700	5:00+	45	60	H
B	y		55	12.0	92	80	1000	4:00+	25	130	H
HES-7	y		55	12.0	120	98	3700				H
F	y		60	12.0	165	138	9065	6:30+	260	930	Micro-fine
HES-7	y		60	12.0	90	80	1000	6:00+		0	H
F	y		60	12.0	165	138	9065	0:59			Micro-fine
HES-7	y		60	12.0	167	145	9265				H
HES-7	y		60	12.0	167	145	9265	7:00+	186	265	H
HES-11	y		96	12.0	94	83	1856	4:30+			TLW
B	y		90	12.0	202	154	11210	5:30+	189	330	65/35 H/POZ
F	y		90	12.0	188	188	9200	6:25	195	1690	Micro-fine
F	y		90	12.0	0	190	10000	3:15	520	870	Micro-fine
B	y		90	12.0	180	144	11950	4:42	268	1051	65/35 H/POZ
B	y		90	12.0	180	144	11950	4:57	0	955	65/35 H/POZ
F	y		90	12.0	192	159	10135	4:23	1054	1077	Micro-fine

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		60	12.0	93	81	1110	6:00+	160	240	H
B	y		60	12.0	93	81	1110	6:00+	120	230	H
B	y		60	12.0	138	106	4820	6:57	140	180	H
B	y		110	12.0	131	102	4230	4:53	170	210	H
B	y		60	12.0	120	98	3320	7:30+	90	150	H
B	y		60	12.0	120	98	3320	5:55	200	280	H
B	y		105	12.0	115	96	3000	4:30+	58	192	H
HES-11	y		75	12.0	129	102	4300	6:58	464	1260	TLW
F	y		105	12.0		210	11576	4:52	340	550	Micro-fine
F	y		110	12.0		160	7120	4:44	370	980	Micro-fine
F	y		113	12.0		148	8300	4:15	390	1000	Micro-fine
F	y		130	12.0	215	177	11300	4:18	890	990	Micro-fine
HES-11	y		184	12.0	135	104	4500	6:00+	93	230	TLW
HES-11	y		184	12.0	88	80	900		116	326	TLW
HES-11	y		184	12.0	135	104	4500	3:00			TLW
HES-11	y		184	12.0	117	96	3000	4:00+	221	867	TLW
A	y		200	12.0	118	97	3670	4:00+	150	190	A
A	y		235	12.0	133	103	5400	3:30+	372	328	A
A	y		235	12.0	98	85	1500	3:00+	126	238	A
A	y		235	12.0	132	103	4570	4:00+	228	318	A
A	y		235	12.0	98	85	1500	3:00+	130	252	A
F	y		235	12.0	85	84	500	4:00+	189	303	Micro-fine
HES-11	y		280	12.0	133	104	4800	5:26	316	889	TLW
HES-11	y		370	12.0	125	90	4500	6:56	104	363	TLW
F	y		350	12.0	90	86	797	4:00+	150	190	Micro-fine
B	y		372	12.0	112	95	4280	6:45	110	170	H
F	y		372	12.0		205	16000	5:13	610	1280	Micro-fine
B	y		372	12.0	95	84	1500	5:00+	FIRM	90	H
B	y		372	12.0	95	84	1500	5:00+	20	110	H
A	y		25	12.0	128	101	4000	5:00+	280	340	A
A	y		25	12.0	125	100	4000	7:00+	260	330	A
B	y		30	12.0	139	108	5150	5:12	135	210	H
F	y		30	12.0	224	183	11130	3:21	760	1080	Micro-fine
B	y		181	12.0	174	134	10893	4:35	80	183	65/35 H/POZ
HES-11	y		181	12.0	96	86	1650	7:33	166	260	TLW
B	y		181	12.0	146	114	7250	5:30+	106	177	65/35 H/POZ
B	y		181	12.0	111	98	2591	7:00+	60	130	H
B	y		181	12.0	146	114	7250				65/35 H/POZ
HES-7	y		110	12.0	137	107	5000	5:30+	80	100	H
B	y		110	12.0	94	83	1300	5:00+	70	200	H
B	y		110	12.0	94	83	1300	5:00+	90	240	H
B	y		110	12.0	93	82	1200	4:00+	150	270	A
B	y		110	12.0	94	83	1300				H
B	y		110	12.0	125	102	4500	6:28	130	260	H
B	y		100	12.0	158	120	6685	2:56	120	190	H
B	y		100	12.0	88	80	800	6:00+	25	130	H
F	y		100	12.0	170	145	11000	3:47	650	1520	Micro-fine
B	y		100	12.0	96	84	1450	5:00+	30	90	H
HES-11	y		100	12.0	91	80	1000	5:30+	81	155	TLW
B	y		100	12.0	93	81	1100	5:00+	50	90	H
F	y		100	12.0	228	190	11882	3:10	910	655	Micro-fine
B	y		100	12.0	96	84	1450	8:00+	FIRM	90	A
B	y		100	12.0	93	81	1100	5:00+	170	260	H
HES-11	y		100	12.0	134	104	4500	4:33	445	975	TLW
B	y		100	12.0	152	115	6000	7:04	60	250	H
B	y		100	12.0	113	95	3000	6:36	60	120	H
HES-11	y		100	12.0		104	4600	6:30+	257	703	TLW
F	y		140	12.0	166	135	7200	3:38	621	981	Micro-fine
F	y		60	12.0	195	160	9672	3:45	650	1670	Micro-fine
F	y		164	12.0	0	182	8500	3:45	100	540	Micro-fine
F	y		164	12.0	182	182	8500	2:17	680	720	Micro-fine
F	y		40	12.0		199	9900	4:38	440	1030	Micro-fine
F	y		40	12.0		199	9900	5:26	430	1020	Micro-fine
F	y		230	12.0	200	200	10086	4:06	450	1300	Micro-fine
HES-11	y		211	12.0	125	103	4500	6:20	116	310	TLW
HES-11	y		180	12.0	125	103	4500	4:50			TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		303	12.0	126	103	4889	5:08	330	720	TLW
HES-11	y		380	12.0	95	84	1400	5:00+	129	367	TLW
HES-11	y		380	12.0	95	84	1400	3:30	145	367	TLW
F	y		280	12.0	0	80	585	5:27	FIRM	90	Micro-fine
A	y		288	12.0	139	105	5550	5:00+	138	242	A
A	y		288	12.0		78	1300	5:00+		313	A
HES-11	y		288	12.0	139	105	5550	4:12	70	330	TLW
A	y		288	12.0		90	4600	6:00+		265	A
A	y		288	12.0	140	107	5000	5:00+	90	190	A
A	y		288	12.0	95	83	1300	6:00+	279	380	A
HES-11	y		288	12.0	139	105	5550	4:12	70	330	TLW
B	y		62	12.0	92	80	1000	6:00+	60	120	H
B	y		62	12.0	134	104	4500	6:00+		140	H
B	y		62	12.0	134	104	4500	5:04	270	340	H
B	y		62	12.0	124	98	4200	6:00+	90	150	H
B	y		62	12.0	92	80	1000	6:00+		140	H
B	y		62	12.0	128	100	4000	5:03	130	220	H
B	y		62	12.0	92	80	1000	6:00+		100	H
B	y		62	12.0	134	104	4500	4:01	250	315	H
B	y		62	12.0	124	100	4000	5:30	190	260	H
HES-7	y		62	12.0	187	161	11745	6:30+	228	310	H
B	y		62	12.0	134	104	4500	7:15	190	240	H
B	y		62	12.0	92	80	1000	6:00+	60	90	H
B	y		62	12.0	124	100	4000	5:00	70	160	H
B	y		62	12.0	124	98	4200	6:00+	120	140	H
B	y		55	12.0	90	80	800	4:00+	30	90	H
B	y		63	12.0	114	94	3000	6:15+	70	135	H
F	y		62	12.0	215	177	11050	3:43	900	1220	Micro-fine
B	y		62	12.0	135	105	4600	5:00	160	215	H
B	y		62	12.0	135	105	4600	4:30+	185	235	H
B	y		62	12.0	92	80	1000	4:00+	100	170	H
HES-11	y		62	12.0	112	94	2650	4:00	293	527	TLW
F	y		62	12.0	224	193	12077	2:36	650	990	Micro-fine
B	y		62	12.0	132	104	4500	6:37	90	200	H
F	y		80	12.0	130	130	5820	6:08	100	310	Micro-fine
		n		12.0	124	100	4000	6:00+	110	180	A
F		n		12.0	225	184	11200	3:10	1050	1260	Micro-fine
B		n		12.0	110	95	3000	5:00+	145	240	65/35 A/POZ
B		n		12.0	115	96	3000	8:00+			65/35 A/POZ
F	y		50	12.0	181	147	8500	4:27	470	920	Micro-fine
F	y		50	12.0	235	196	13061	6:20	790	950	Micro-fine
B		n		12.0	125	97	3100	10:12	120	390	85/15 H/POZ
B		n		12.0	125	97	3100	2:46	200	235	85/15 H/POZ
F		n		12.0	205	174	9582	3:47	830	1150	Micro-fine
B		n		12.0	136	104	4500	3:08			65/35 A/POZ
B		n		12.0	97	84	1400	5:00+			65/35 A/POZ
		n		12.0	129	101	4280	5:00+	60	120	A
F		n		12.0	180	142	6200	5:30+			Micro-fine
F		n		12.0	160	129	6300	3:02	990	1000	Micro-fine
F		n		12.0	115	100	2700			1100	Micro-fine
F		n		12.0	115	100	2700	3:00+	345		Micro-fine
A	y		50	12.0	124	100	4000	6:00+	300	370	A
F		n		12.0	140	115	4300	4:00	240	610	Micro-fine
B		n		12.0	122	98	3500	6:00+			65/35 A/POZ
		n		12.0	122	98	3500	5:00+	124	245	A
B		n		12.0	114	95	3100	5:00+	90	110	65/35 A/POZ
B		n		12.0	124	100	4000	5:07	150	196	65/35 A/POZ
B		n		12.0	179	131	7630	6:00+			65/35 H/POZ
F		n		12.0	215	185	11000	4:10	750	1020	Micro-fine
		n		12.0	105	90	2000	5:00+	95	125	A
		n		12.0	122	97	3300	5:00+	SET	100	A
HES-10		n		12.0		80	1000			60	A
		n		12.0	135	105	4600	7:00+			A
B		n		12.0	126	100	3800	6:00+	1049	1510	65/35 H/POZ
B		n		12.0	105	91	2250	5:00+	40	100	65/35 A/POZ
		n		12.0	150	104	4200	9:22	60	140	85/15 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
		n		12.0	150	104	4200	2:45	239	300	85/15 H/POZ
HES-7	y		127	12.0	95	80	1000	6:00+	FIRM	550	H
A	y		75	12.0	134	103	4340	5:00+	150	180	A
A	y		103	12.0	134	104	4500	4:30+	306	318	A
A	y		100	12.0	92	80	1000	4:00+	47	289	A
A	y		90	12.0	125	98	3500	4:00+	194	253	A
A	y		90	12.0	90	80	800	4:00+	133	258	A
A	y		103	12.0	116	96	3800	3:00+	142	254	A
B	y		103	12.0	140	109	5500	6:32	114	348	65/35 A/POZ
B	y		103	12.0	94	83	1300	6:00+	84	170	65/35 A/POZ
A	y		110	12.0	92	80	1020	3:00+	97	206	A
A	y		110	12.0	89	80	800	4:00+	47	290	A
A	y		110	12.0	122	98	3500	4:00+	160	320	A
A	y		110	12.0	116	96	3000	4:00+	198	363	A
F	y		111	12.0	0	190	9716	3:59	400	1230	Micro-fine
A	y		111	12.0	138	106	5146	6:03	173	350	A
A	y		110	12.0	92	80	1000	4:00+	97	206	A
A	y		110	12.0	127	100	4610	4:00+	255	304	A
A	y		110	12.0	132	103	4330	4:00+	363	394	A
A	y		110	12.0	92	80	1000	4:30+	152	188	A
A	y		110	12.0	134	104	4500	4:00+	236	322	A
F	y		90	12.0	192	165	10722	3:05	870	1170	Micro-fine
A	y		110	12.0	125	103	4500	4:50	267	372	A
HES-7	y		127	12.0	135	107	5000	6:00+	FIRM	155	H
HES-7	y		127	12.0	103	88	1900	6:00+	30	105	H
HES-7	y		127	12.0	143	108	4973	6:00+	100	173	H
A	y		120	12.0	92	80	1000	4:00+	150	175	A
A	y		120	12.0	134	104	4500	4:00+	210	265	A
A	y		111	12.0	92	80	1000	4:00+	130	240	A
A	y		111	12.0	125	100	3800	4:00+	159	200	A
B	y		143	12.0	128	101	4597	5:00+	180	220	H
B	y		143	12.0	128	101	4597	5:31	200	230	H
B	y		143	12.0	93	81	1100	4:00+	135	210	H
A	y		181	12.0	92	80	1000	6:00+	124	221	H
A	y		181	12.0	128	101	4000	6:00+	150	250	H
B	y		186	12.0	166	128	10618	5:00+	260	480	65/35 H/POZ
B	y		186	12.0	148	112	9221	5:30+	220	250	65/35 H/POZ
F	y		202	12.0	130	110	5286	4:02	218	240	Micro-fine
F	y		210	12.0	150	150	5711	2:59	324	805	Micro-fine
A	y		215	12.0	132	103	4300	6:00+	170	225	H
A	y		220	12.0	125	99	3700	8:00+	210	250	H
A	y		220	12.0	128	101	4000	7:30+	121	237	H
A	y		220	12.0	128	101	4000	6:00+	187	200	H
B	y		290	12.0	145	110	5400	5:27	140	160	65/35 A/POZ
B	y		60	12.0	128	101	4000	4:42	99	285	H
B	y		60	12.0	89	80	750	4:00+	50	157	H
B		n		12.0	110	92	2500	5:00+	30	80	65/35 A/POZ
		n		12.0	122	94	2500	6:00+	140	210	A
B	y		122	12.0	174	130	7950	4:06	95	282	H
B	y		122	12.0	96	83	1350		160	380	H
B	y		122	12.0	96	83	1350	4:00+	120	195	H
B	y		120	12.0	185	136	8100	4:15	257	284	H
HES-7	y		108	12.0	93	80	1028	6:00+	FIRM	40	H
HES-7	y		320	12.0	120	105	5000	6:30+	SET	90	H
HES-7	y		722	12.0	150	117	8355	6:00+	70	100	H
B	y		1514	12.0		95	6000	4:00+	240	550	65/35 A/POZ
B	y		1514	12.0		95	6000	4:00+	130	200	65/35 A/POZ
HES-3	y		2649	12.0		75	3784	2:45			A
HES-3	y		2920	12.0		70	5000	5:30+	119	419	A
HES-3	y		3270	12.0		70	5200	3:23			FLOSTOP I
HES-3	y		3270	12.0		70	5200	4:34	140	340	FLOSTOP I
HES-3	y		3270	12.0		70	5200	3:42			FLOSTOP I
A	y		1051	12.0		76	2800	4:00+	128	300	A
A	y		1051	12.0		97	4882	6:00+	140	310	A
		n		12.0	128	103	4500	6:00+	60	130	A
F	y		40	12.0		140	4903	6:38	1041	1755	Micro-fine

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
F	y		40	12.0	275	275	11464	6:09	880	955	Micro-fine
HES-11	y		47	12.0		131	8200	4:25			TLW
B	y		45	12.0	88	80	700	4:00+	100	170	H
A	y		40	12.0	134	104	4500	5:00+	90	200	A
A	y		40	12.0	92	80	1000	4:00+	60	210	A
A	y		40	12.0	94	80	1000	6:30	220	465	A
A	y		35	12.0	134	104	4500	4:22	220	300	A
A	y		35	12.0	92	80	1000	4:00+	130	280	A
HES-7	y		44	12.0	134	104	4500	6:00+	90	160	H
HES-7	y		44	12.0	134	104	4500	8:00+	80	140	H
HES-7	y		20	12.0	139	106	4600	5:00+	150	180	H
HES-7	y		20	12.0	140	106	4700	5:00+	50	110	H
HES-7	y		20	12.0	139	105	4500	5:00+	80	150	H
HES-7	y		20	12.0	148	107	4700	8:00+	110	190	H
HES-7	y		20	12.0	148	107	4700	8:00+	160	220	H
B	y		53	12.0	113	95	3000	6:00+	95	150	H
B	y		53	12.0	93	80	1000	4:00+	130	195	H
B	y		53	12.0	150	111	6010	7:54	50	230	H
B	y		52	12.0	94	80	1050	4:00+	120	240	H
B	y		52	12.0	152	112	5500	7:30	0	160	H
HES-11	y		57	12.0	141	105	4500	4:19	766	1040	TLW
HES-11	y		57	12.0	141	105	4500	6:00+	561	662	TLW
HES-11	y		57	12.0	134	104	4900	5:00+	480	1093	TLW
A	y		62	12.0	89	80	800	6:00+	160	200	A
A	y		62	12.0	119	98	3500	5:00+	290	440	A
A	y		70	12.0	128	101	4000	4:00+	130	465	A
HES-11	y		38	12.0	134	104	4500	6:30+	500	891	TLW
F	y		66	12.0	167	136	7220	3:40	730		Micro-fine
B	y		22	12.0	172	125	7000	7:30+	186	470	65/35 H/POZ
B	y		145	12.0	123	98	5054	6:00+	60	100	H
HES-11	y		160	12.0	150	114	7150	2:20	640	840	TLW
HES-11	y		160	12.0	125	100	4400	4:30	430	625	TLW
HES-11	y		160	12.0	125	100	4400	5:16			TLW
HES-7	y		160	12.0	160	128	9451	5:00+	130	200	H
F	y		153	12.0	158	135	7800	3:41	196	940	Micro-fine
HES-11	y		175	12.0	97	84	1950	5:30+	108	247	TLW
F	y		184	12.0	150	123	6000	3:32	260	820	Micro-fine
F	y		184	12.0	85	84	500	4:00+	220	247	Micro-fine
F	y		291	12.0		240	1074	3:00	1240	1590	Micro-fine
A	y		256	12.0	83	82	586	4:00+	0	98	H
A	y		300	12.0	138	105	4500	5:00+	120	140	H
F	y		300	12.0	0	117	3918	3:48	160	480	Micro-fine
F	y		300	12.0	0	103	2298	4:15+	150	450	Micro-fine
A	y		40	12.0	95	82	1175	5:00+	91	228	H
A	y		40	12.0	144	109	5300	8:00+	243	345	H
A	y		296	12.0	118	96	3000	5:00+	330	420	A
A	y		296	12.0	116	96	3000	5:00+	170	240	A
F	y		325	12.0	120	120	3054	5:00	155	190	Micro-fine
HES-11	y		354	12.0	135	98	3129	5:30	440	975	TLW
HES-11	y		35	12.0		102	4500	6:15	61	125	TLW
HES-11	y		35	12.0		102	4500	6:48	52	234	TLW
B	y		36	12.0	170	128	7595	6:42	170	260	65/35 H/POZ
B	y		40	12.0	129	99	3500	6:30	220	260	H
B	y		40	12.0	89	80	750	5:30+	130	210	H
HES-11	y		85	12.0	92	80	1000	6:00+	50	125	TLW
HES-11	y		240	12.0	207	166	13380	6:17	75	815	TLW
A	y		245	12.0	110	93	2500	4:00+	160	310	A
HES-11	y		225	12.0	188	150	11370	4:52	497	1194	TLW
HES-11	y		225	12.0	210	169	14000	7:33	0	1322	TLW
HES-11	y		225	12.0	210	169	14000	5:22	95	954	TLW
B	y		210	12.0	120	98	3600	4:00+	150	260	H
B	y		240	12.0	120	98	3600	6:20	115	188	H
B	y		210	12.0	181	136	8593	3:53	540	550	H
HES-11	y		210	12.0	120	98	3600	6:00+	110	250	TLW
F	y		40	12.0	233	196	13640	3:21	605	1340	Micro-fine
A	y		54	12.0	90	80	850	5:00+		81	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		54	12.0		92	4500	4:14			A
A	y		54	12.0	145	114	6025	5:00+			H
A	y		35	12.0	115	97	3500	5:23	157	332	A
B	y		68	12.0	93	82	1200	4:00+	105	170	H
B	y		68	12.0	130	103	4500	4:30+	110	310	H
B	y		105	12.0	138	106	4900	5:00+	60	160	H
HES-11	y		100	12.0		109	5150	4:50	368	730	TLW
F	y		126	12.0	87	85	558	5:00+	130	175	Micro-fine
HES-11	y		126	12.0	123	99	5965	4:00+	300	700	TLW
HES-11	y		126	12.0	108	92	4300	4:00+	100	340	TLW
F	y		126	12.0	123	106	5940	4:50	100	230	Micro-fine
HES-7	y		126	12.0	190	145	9792	4:05	158	167	H
HES-11	y		151	12.0	106	91	4533	5:00+	155	260	TLW
HES-11	y		151	12.0	132	103	7660	4:00+	270	530	TLW
HES-11	y		151	12.0	124	100	6029	5:00+	230	520	TLW
HES-7	y		152	12.0	229	183	13866	6:00+	91	135	H
HES-7	y		155	12.0	208	161	12288	4:50	573	800	H
HES-7	y		155	12.0	222	174	14554	5:30+	186	224	H
F		n		12.0		92	1000	5:50			Micro-fine
F		n		12.0		92	1000	5:00+		203	Micro-fine
B	y		28	12.0	136	103	4300	4:20	181	236	H
B	y		28	12.0	136	103	4300	4:36			H
B	y		28	12.0	136	103	4300	6:18	103	108	H
B	y		28	12.0	136	103	4300	3:03		196	H
B	y		28	12.0	136	103	4300	5:29			H
A	y		36	12.0	146	111	5425	5:30+		180	H
B		n		12.0	106	90	2000	4:41		659	65/35 A/POZ
F		n		12.0	116	101	3000	5:12	95	220	Micro-fine
		n		12.0	120	96	3000	7:00+	50	200	A
F		n		12.0	205	165	8896	3:07			Micro-fine
B		n		12.0	123	99	3600	5:00+	0	96	65/35 A/POZ
B		n		12.1		230	14000			1030	75/25 POZ/A
B		n		12.1	215	165	11433	2:26			65/35 H/POZ
B	y		47	12.1		80	1000			96	65/35 A/POZ
HES-3	y		2761	12.1		80	4900	4:02	172	573	A
HES-3	y		2000	12.1		80	3500	4:02	183	580	A
HES-3	y		2841	12.1		80	4925	3:34		154	A
HES-3	y		2920	12.1		70	5000	3:51			A
HES-11	y		47	12.1	153	113	8100	5:15+	70	160	TLW
B	y		200	12.1	172	132	11000	3:47	166	233	H
B		n		12.1	170	127	7500	5:06	330	415	65/35 H/POZ
B		n		12.1	225	176	12100	6:03	890	940	65/35 H/POZ
HES-3	y		3270	12.1		65	5200	6:00+			FLOSTOP I
HES-3	y		3270	12.1		65	5200	7:10	57	345	FLOSTOP I
B	y		280	12.1	93	82	1200	4:30	131	176	H
HES-3	y		6224	12.2		70	7700	3:45	0	331	A
B		n		12.2	245	199	14900	7:34	970	990	65/35 H/POZ
HES-11		n		12.2	207	159	10600	4:30	522	1511	TLW
B		n		12.2	124	97	3200	3:10	250	290	85/15 A/POZ
B		n		12.2	190	145	9400	8:50	0	252	65/35 H/POZ
HES-11	y		20	12.2	159	120	6600	4:20	313	876	TLW
HES-11		n		12.2	173	132	8400	3:39	450	800	TLW
B	y		10	12.2	212	164	11000	6:30+	510	600	50/50 H/POZ
B	y		83	12.2	185	139	8800	3:20	140	310	65/35 H/POZ
B	y		83	12.2	197	150	9807	6:00+	210	370	65/35 H/POZ
B	y		83	12.2	191	145	9400	5:00+	85	235	65/35 H/POZ
B	y		83	12.2	185	139	8800	4:19	135	230	65/35 H/POZ
B	y		83	12.2	210	163	11600	6:00+	250	420	65/35 H/POZ
B	y		83	12.2	200	152	10320	3:31	120	170	65/35 H/POZ
HES-11	y		107	12.2	210	163	12227	4:08	0	1190	TLW
HES-11	y		167	12.2		90	1950	4:30+	189	557	TLW
B	y		20	12.2	116	96	3000	5:49			65/35 A/POZ
HES-3	y		1756	12.2		80	3500	4:03			FLOSTOP I
A		n		12.2	85	80	300		160	306	A
HES-3	y		1646	12.2		90	4200	4:46	475	580	FLOSTOP I
A	y		250	12.2	130	103	4835	4:00+	305	450	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		890	12.2	121	104	4500	5:30+	152	253	H
HES-3	y		1419	12.2		80	3500	7:20	253	450	A
HES-11		n		12.2	193	146	9450	3:54	505	824	TLW
B		n		12.2	224	171	10800	3:14			65/35 H/POZ
F	y		2521	12.2	0	107	7200	3:42	760	850	FLOSTOP I
F	y		2521	12.2	0	107	7200	3:38			FLOSTOP I
HES-3	y		2841	12.2		80	4925	2:46			A
HES-3	y		2588	12.2		70	3590	4:46			A
HES-3	y		4243	12.2		70	6321	4:30	0	324	A
B	y		50	12.2	230	181	13410	3:59			65/35 H/POZ
HES-11	y		350	12.2		110	5925	5:06	50	500	TLW
B	y		210	12.2	186	137	12735	6:30+	130	260	65/35 H/POZ
A		n		12.2		80	50			56	A
B		n		12.2	105	90	2100		51	91	65/35 A/POZ
HES-7	y		1000	12.2	100	90	2200	6:00+		48	H
HES-3	y		2100	12.2		70	3000	3:25	180	419	A
HES-3	y		2707	12.2		70	4105	4:00+	0	154	FLOSTOP I
HES-3	y		2707	12.2		70	4105	3:52	190	280	FLOSTOP I
HES-11	y		63	12.2	114	94	2800	5:00+	445	780	TLW
A	y		63	12.2	114	94	2800	5:00+	230	260	H
A		n		12.2	104	88	1800		170	255	A
B		n		12.2	215	167	11800	3:40	521		65/35 H/POZ
B		n		12.2	119	96	3000	3:02	380	520	85/15 A/POZ
B		n		12.2	220	172	11700	4:32			65/35 H/POZ
B	y		130	12.2	216	167	11624	5:30+	780	940	50/50 H/POZ
HES-8	y		50	12.2	92	80	800	6:00+	85	215	A
F	y		372	12.2	145	121	6800	3:40	275	1100	Micro-fine
HES-11	y		180	12.2	95	82	1250	6:00+	150	170	TLW
HES-11	y		380	12.2	130	103	4500	6:32	200	480	TLW
HES-3	y		50	12.2		80	960	3:30	965	1522	A
HES-11		n		12.2	200	148	9000	3:25			TLW
B		n		12.2		143	10150	4:00			50/50 H/POZ
	y		122	12.2	92	80	1000	4:00+	109	189	H
A	y		1136	12.2		90	5882	3:11	63	423	A
HES-3	y		3236	12.2		60	5200	4:37	0	190	FLOSTOP I
HES-11	y		167	12.2	130	101	4000	4:08	550	1240	TLW
HES-11	y		167	12.2	130	101	4000	4:51	700	850	TLW
HES-11	y		1490	12.3	121	103	4962	5:00	378	937	TLW
HES-11		n		12.3		96	2900	2:28	277	575	TXI
HES-11	y		126	12.3	184	139	10599	3:50	817	1330	TLW
HES-3	y		2672	12.3		70	3950	5:32			FLOSTOP I
HES-3	y		2672	12.3		80	3875	3:55	456	537	FLOSTOP I
HES-3	y		3907	12.3		70	3950	4:27			A
HES-11		n		12.3	96	82	1200	3:41	431	649	TXI
A	y		1419	12.3		95	6600	3:39			A
HES-3	y		1900	12.3		80	3800	3:43	76	242	A
HES-3	y		1419	12.3		80	3500	5:20	0	182	A
B		n		12.3	115	96	3000	8:00+	78	105	65/35 A/POZ
B		n		12.3	115	93	2500		290	367	50/50 TXI/POZ
B	y		46	12.3	200	151	9800	8:30	85	217	65/35 H/POZ
HES-11		n		12.3		96	2900	3:02	360	437	TXI
HES-3	y		5372	12.3		85	2000	4:45	656	1027	A
HES-3	y		1000	12.3	97	89	2000	3:07			A
A	y		60	12.3	142	107	4800	7:17	199	262	H
B		n		12.3	132	103	4400		576	720	Micro-fine
HES-11		n		12.3	132	103	4400	3:22	332	403	TXI
B	y		120	12.3	91	80	1000	4:00+	180	220	A
B	y		120	12.3	165	127	7800	4:48	380	640	H
HES-7	y		200	12.3	220	172	13450	5:55	555	1300	H
HES-3	y		2100	12.3		70	3000	2:38	111	436	A
B	y		85	12.3	93	80	1000	5:00+	120	230	H
HES-11	y		1564	12.3		93	7400	3:50	160	669	TLW
HES-3	y		3343	12.3		65	5200	3:30+			FLOSTOP I
B	y		35	12.3	90	80	900	7:00+	180	230	65/35 A/POZ
HES-7	y		3845	12.3	0	63	7000	6:00+	78	148	A
B		n		12.3	125	97	3200	4:55	170	320	85/15 A/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		35	12.3	120	98	3600	3:22	170	370	65/35 A/POZ
B	y		110	12.3		245	15500	3:43	164	197	HTLD
B	y		52	12.3	318	276	17000	9:10			65/35 H/POZ
B	y		52	12.3	318	276	17000	9:00+			65/35 H/POZ
B		n		12.3	120	97	3263		640	670	85/15 A/POZ
HES-3	y		1334	12.3		70	2750	5:04	270	850	FLOSTOP I
HES-3	y		1753	12.3		70	4500	2:41	FIRM	170	FLOSTOP I
HES-11	y		3236	12.3		110	10208	3:55	280	504	TLW
HES-3	y		1756	12.3		80	3400	6:58	150	250	FLOSTOP I
B		n		12.3	170	118	6000	3:18	280	560	65/35 H/POZ
HES-3	y		1756	12.3		80	3500	3:45	360	560	FLOSTOP I
HES-3	y		1753	12.3		70	4500	2:41	FIRM	170	FLOSTOP I
HES-7	y		1025	12.3		115	12000	5:30+	162	210	H
HES-3	y		3105	12.3		57	5020	5:00+	FIRM	160	FLOSTOP I
HES-3	y		3105	12.3		78	7170	5:00+	FIRM	160	FLOSTOP I
HES-3	y		6588	12.3		65	7425	4:40	FIRM	190	FLOSTOP I
HES-3	y		1074	12.3		71	2408	2:56	FIRM	380	FLOSTOP I
B	y		70	12.3	256	207	13500	9:00+	0	90	65/35 H/POZ
B	y		35	12.3	125	97	3100	4:03	345	390	65/35 A/POZ
HES-3	y		3500	12.3		65	5475	5:40			FLOSTOP I
HES-11	y		35	12.4	140	107	5000	4:47	274	671	TLW
HES-11	y		18	12.4	160	123	7270	3:32	539	1041	TLW
HES-11	y		16	12.4		113	6200	4:19			TLW
HES-11	y		13	12.4	140	113	6000	4:48		1250	TLW
HES-11	y		35	12.4	154	116	6200	3:28	777	1447	TLW
HES-11	y		13	12.4	146	114	6000	3:52	470	1338	TLW
HES-11	y		13	12.4	146	114	6000	3:42	541	1185	TLW
B		n		12.4		80	50			180	H
HES-11	y		20	12.4	148	115	6200	3:40	500	1260	TLW
F	y		100	12.4	200	200	10500	2:45	542	1920	Micro-fine
HES-11	y		16	12.4	138	109	5320	3:30+	0	1027	TLW
HES-11	y		16	12.4	140	109	5420	4:25	397	895	TLW
HES-11	y		16	12.4	92	82	1200	7:00+		157	TLW
HES-11	y		13	12.4	92	82	1200	7:00+		138	TLW
HES-11	y		18	12.4	93	82	1200	7:42		417	TLW
F	y		220	12.4	148	121	5645	1:38			Micro-fine
HES-11	y		13	12.4	140	113	6000	3:52			TLW
B		n		12.4	177	133	8100	3:56	320	620	65/35 H/POZ
B	y		40	12.4	120	98	3500	6:00+	164	262	65/35 A/POZ
HES-11		n		12.4	186	139	8500	4:55			TLW
F	y		950	12.4		60	600	4:00+	0	99	Micro-fine
B	y		90	12.4	238	181	13110	7:00+			65/35 H/POZ
B	y		90	12.4	203	152	10650	6:22			65/35 H/POZ
B	y		90	12.4	203	152	10650	2:07	173	546	65/35 H/POZ
B		n		12.4	236	188	13000	4:13	357	647	65/35 H/POZ
B		n		12.4	100	91	1485	4:04	169	331	65/35 A/POZ
F	y		100	12.4	200	200	10500	1:25			Micro-fine
HES-11	y		365	12.4		106	5000	7:00+	753	951	TLW
B	y		37	12.4	135	105	4600	6:00+	110	251	65/35 H/POZ
B	y		35	12.4	135	106	4900	6:00+	164	373	65/35 H/POZ
HES-11	y		365	12.4		86	1955	4:26	113	421	TLW
B	y		120	12.4	158	120	6800	5:30+	167	322	65/35 H/POZ
B	y		100	12.4		95	4140	4:30+	55	136	65/35 H/POZ
B		n		12.4		80	50			108	A
B		n		12.4	116	96	3000	5:00+	50	131	65/35 H/POZ
B		n		12.4	230	182	12800	3:20	672	1009	65/35 H/POZ
B		n		12.4	245	196	12800	5:50			65/35 H/POZ
B		n		12.4	220	172	11700	4:57	537	904	65/35 H/POZ
B		n		12.4	218	169	11670	2:25	50	852	65/35 H/POZ
B	y		56	12.4	200	151	9647	5:30+	0	344	65/35 H/POZ
HES-11		n		12.4	138	105	4600	4:10			TLW
B	y		60	12.4	172	128	7600	5:00+	286	822	65/35 H/POZ
HES-3	y		2588	12.4		70	3590	3:37	104	681	A
B		n		12.4	150	109	5000	4:28	185	326	65/35 A/POZ
B		n		12.4	130	101	4000	6:00+	139	237	65/35 H/POZ
B	y		40	12.4	138	104	4500	7:13	144	260	65/35 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		12.4	136	104	4500	4:03	96	170	65/35 A/POZ
B		n		12.4	116	96	3200	6:30+		198	65/35 A/POZ
B	y		40	12.4	120	98	3500	3:00			65/35 A/POZ
B	y		53	12.4	193	139	8880	5:30+	0	115	65/35 H/POZ
F		n		12.4	133	111	4412	1:52	576	1056	Micro-fine
B		n		12.4		80	50			89	A
B		n		12.4		90	0	3:36	98	168	A
HES-11	y		145	12.4	140	107	5008	5:44	289	353	TLW
HES-11	y		170	12.4	130	102	4683	5:35	415	707	TLW
B	y		40	12.4	135	135	4513	3:26			65/35 H/POZ
HES-11	y		326	12.4	102	90	2167	6:50			TLW
F	y		200	12.4		170	9910	3:39	1148	1200	Micro-fine
HES-11	y		326	12.4	91	81	1100	9:21		256	TLW
F	y		200	12.4		170	9910	7:00+			Micro-fine
HES-3	y		2588	12.4	62	60	3590	3:15(5:5			A
B	y		30	12.4		94	2800	4:14			H
B	y		30	12.4		94	2800	7:55			H
HES-11	y		95	12.4	148	109	5000	4:59	855	1140	TLW
B	y		80	12.4	134	104	4500	6:00+			65/35 A/POZ
B		n		12.4	134	104	4500	8:00+			65/35 A/POZ
F		n		12.4	250	210	14200	4:30+	811	1689	Micro-fine
HES-11	y		326	12.4	102	90	2167	6:50			TLW
E		n		12.4	175	127	7200	3:30	110	150	H
A	y		93	12.4	104	90	2000	10:00+(*	90	290	A
B	y		93	12.4	104	90	2000	6:30	140	160	H
B	y		80	12.4	230	181	13366	5:08	90	130	65/35 H/POZ
A	y		140	12.4	132	101	4323	5:00+	240	260	H
B		n		12.4	93	80	1000			230	65/35 A/POZ
B	y		83	12.4	204	156	11006	4:00+			65/35 H/POZ
HES-7	y		160	12.4	175	129	8972	6:00+	161	233	H
HES-7	y		160	12.4	175	129	8340	5:30+	210	320	H
HES-7	y		210	12.4		94	3200		0	167	H
HES-7	y		210	12.4		94	3200		0	86	H
B	y		20	12.4	118	97	3200	5:30+	80	180	65/35 A/POZ
B	y		20	12.4	90	80	800	5:00+	75	110	65/35 A/POZ
HES-11	y		80	12.4	225	176	13090	4:31	1318	1580	TLW
HES-7	y		160	12.4	180	134	9105	5:40	200	290	H
B		n		12.4	212	165	11800	4:31	390	1010	65/35 H/POZ
B	y		120	12.4	189	143	9100	5:00+	210	280	65/35 H/POZ
B	y		55	12.4	218	170	12100	5:24	180	395	65/35 H/POZ
B	y		55	12.4	218	169	12100	3:32	800	1400	65/35 H/POZ
B	y		55	12.4	200	154	11000	3:05	225	400	65/35 H/POZ
B	y		55	12.4	213	166	11700	4:21	140	380	65/35 H/POZ
B		n		12.4	115	93	2500	5:00+	200	340	65/35 A/POZ
B	y		80	12.4	254	205	15774	8:04	0	60	65/35 H/POZ
B		n		12.4	217	168	11400	4:02	600	650	65/35 H/POZ
B	y		70	12.4	248	201	14000	3:50	40	140	65/35 H/POZ
B		n		12.4	295	248	15470	5:02	825	1070	65/35 H/POZ
B		n		12.4	250	202	14675	4:20	740	860	65/35 H/POZ
HES-7	y		160	12.4	170	126	8432	6:00+	231	310	H
HES-7	y		158	12.4	144	107	5467	7:00+	165	630	H
B		n		12.4	266	219	14300	8:00+	590	660	65/35 H/POZ
B		n		12.4	162	122	6900	5:06	110	240	65/35 H/POZ
B	y		83	12.4	204	156	11006	3:15	210	340	65/35 H/POZ
B	y		83	12.4	193	146	9800	3:51	120	240	65/35 H/POZ
HES-11	y		219	12.4	116	96	3000	5:24	154	506	TLW
HES-11	y		415	12.4	158	119	12200	3:54	817	1100	TLW
HES-11	y		650	12.4	138	108	5300	4:50	629	1160	TLW
HES-11	y		170	12.4	122	101	4260	5:00+	190	388	TLW
HES-11	y		170	12.4	122	101	4260	5:00+	218	404	TLW
HES-11	y		57	12.4	141	105	4500	5:17	486	684	TLW
HES-11	y		219	12.4	137	104	4350	4:15			TLW
B	y		20	12.4	90	80	800	5:00+	75	110	65/35 A/POZ
HES-11	y		219	12.4	116	96	3000	5:40	283	1010	TLW
B	y		90	12.4	180	144	11950	4:07	359	742	65/35 H/POZ
HES-11	y		15	12.4	122	98	3500	5:03	380	710	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		15	12.4	122	98	3500	6:00+	309	775	TLW
F	y		140	12.4		80	240	2:05	325	500	Micro-fine
B		n		12.4	203	153	9817	3:45			65/35 H/POZ
B		n		12.4	135	104	4400	6:00+			65/35 A/POZ
F		n		12.4	250	210	14200	2:52	850	1139	Micro-fine
HES-11	y		168	12.4	126	99	3500	3:55	0	0	TLW
B		n		12.4		80	1000		182	285	85/15 A/POZ
B		n		12.4	210	160	10400	5:35	600	660	65/35 H/POZ
B	y		49	12.4		98	4385	4:18	245	465	H
B	y		83	12.4	204	156	10725	3:06	105	298	65/35 H/POZ
B		n		12.4	210	160	10400	3:35	640	1160	65/35 H/POZ
B	y		83	12.4	204	156	10970	4:03	103	250	65/35 H/POZ
B		n		12.4	224	162	9650	3:36	490	1040	65/35 H/POZ
B	y		83	12.4	215	159	9807	3:48	90	710	65/35 H/POZ
B		n		12.4	145	108	4900	6:40	220	340	65/35 A/POZ
B	y		83	12.4	206	158	10582	5:12	550	900	65/35 H/POZ
HES-3	y		2081	12.4		70	3700	4:38	200	350	FLOSTOP I
F	y		52	12.4	120	103	3300	5:08	587	875	Micro-fine
B	y		250	12.4	245	200	15050	4:07	106	240	65/35 H/POZ
B	y		250	12.4	245	199	17842	5:36		215	65/35 H/POZ
B		n		12.4	150	115	6000	5:00+			65/35 H/POZ
B	y		83	12.4	210	163	11900	6:20	486	714	65/35 H/POZ
B	y		122	12.4	178	134	8250	6:22	140	440	65/35 H/POZ
B		n		12.4	238	190	13281	6:03			65/35 H/POZ
A	y		255	12.5		73	1340	5:30+		368	A
A	y		130	12.5	95	83	1470	4:49	524	856	A
HES-11	y		265	12.5	90	82	1200	6:05	143	370	TLW
A	y		70	12.5	92	82	1000	3:00+	369	513	A
A	y		84	12.5	92	82	1000	3:30+	211	408	A
A	y		130	12.5	94	82	1300	4:00+	258	469	A
HES-11	y		75	12.5	106	93	2963	6:00+			TLW
HES-3	y		5372	12.5		85	2000	4:56	298	932	A
A	y		130	12.5	107	93	3402	4:00+	225	425	A
HES-11	y		155	12.5	122	98	3500	5:58	396	1291	TLW
HES-11	y		127	12.5	118	97	3748	5:45+	139	205	TLW
HES-11	y		116	12.5	118	97	3748	4:35	0	646	TLW
HES-11	y		127	12.5	118	97	3748	4:45	173	418	TLW
A	y		53	12.5	125	97	3200	2:39			A
A	y		70	12.5	133	99	4000	3:15			A
A	y		23	12.5	126	100	6000	4:30+	289	316	H
HES-11	y		127	12.5	122	98	3798	6:22	216	671	TLW
HES-11	y		116	12.5	122	98	3798	5:18	440	1251	TLW
HES-11	y		127	12.5	125	99	3865	5:56	319	1054	TLW
A	y		255	12.5	115	101	4350	2:22			A
F	y		1736	12.5		80	4200	2:23			TLW/Micro-fine
F	y		1736	12.5		80	4200	2:48			TLW/Micro-fine
F	y		1736	12.5		80	4200	3:00			TLW/Micro-fine
HES-11	y		116	12.5	125	101	4816	4:23	421	711	TLW
A	y		1736	12.5		80	4200	3:28			TLW
A	y		1736	12.5		80	4200	6:00	94	279	TLW
A	y		255	12.5	122	101	4200	3:25	445	678	A
A	y		170	12.5	136	105	4700	6:00+		263	H
HES-11	y		90	12.5	134	102	4200	4:58	201	338	TLW
A	y		76	12.5	130	102	4300	4:00+	320	455	H
HES-11	y		100	12.5	131	104	4600	6:30+	333	442	TLW
B		n		12.5	138	104	4500	6:00+	110	418	65/35 A/POZ
HES-3	y		500	12.5		59	5100	5:00	121	503	A
A	y		90	12.5	146	111	7160	3:14	192	331	H
HES-11	y		90	12.5	144	109	5300	5:15	565	1800	TLW
HES-3	y		3270	12.5		74	6700	5:24	54	140	A
B	y		2161	12.5		93	7400		189	377	65/35 A/POZ
HES-3	y		5370	12.5		60	7600	4:30+	50	108	A
HES-11	y		100	12.5	186	137	8876	3:15	671	1471	TLW
B	y		80	12.5	170	136	9000	5:15		200	65/35 H/POZ
HES-3	y		6500	12.5		65	9150	3:50	185	800	A
HES-11	y		127	12.5	195	147	9945	3:20	1012	1182	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		116	12.5	194	145	10332	3:08	834	873	TLW
HES-11	y		98	12.5	189	144	9540	4:45	0	223	TLW
HES-11	y		98	12.5	205	158	13450		229	400	TLW
HES-11	y		127	12.5	208	158	12466	3:14	658	950	TLW
HES-3	y		5370	12.5		92	10750	3:59			A
HES-3	y		6500	12.5		85	11200	2:30	267	610	A
HES-11	y		127	12.5	219	169	12222	4:10	928	1115	TLW
B		n		12.5	230	180	11900	4:30	275	1200	75/25 POZ/H
B		n		12.5	230	180	11900		270	1065	75/25 POZ/H
HES-11	y		90	12.5	221	176	13829	4:42	1139	1436	TLW
B	y		30	12.5	230	182	13500	6:30	1044	1254	50/50 H/POZ
HES-11	y		90	12.5	225	179	13900	3:45			TLW
F	y		300	12.5	105	95	2700	2:30	624	1285	Micro-fine
HES-11	y		1736	12.5		95	6600	2:53			TLW
HES-11	y		1736	12.5		95	6600	3:23	121	595	TLW
F		n		12.5	204	169	11272	3:11	1334	1368	Micro-fine
F	y		106	12.5		228	13082	3:51	1250	2244	Micro-fine
F	y		106	12.5		228	13082	4:10	550	1730	Micro-fine
A	y		10	12.5	92	80	1000	4:00+	250	510	A
HES-11	y		10	12.5	92	80	1000	4:00+	280	520	TLW
A	y		10	12.5	92	80	1000	4:00+	100	380	A
A	y		10	12.5	92	80	1000	4:00+	278	607	A
HES-11	y		10	12.5	92	80	1000	4:00+	247	645	TLW
A		n		12.5	118	96	3000	2:39			A
A	y		2500	12.5		60	7000			436	A
A	y		2500	12.5		85	10000			512	A
HES-11	y		45	12.5	91	80	900	5:00+	193	230	TLW
A	y		184	12.5	90	80	900	5:00+	172	377	A
A	y		184	12.5	90	80	900	3:00+	150	330	A
HES-11	y		184	12.5	92	80	1000	5:00	221	521	TLW
HES-11	y		45	12.5	122	97	3500	3:38	528	771	TLW
HES-11	y		184	12.5	135	104	4500	1:50			TLW
HES-11	y		184	12.5	135	104	4500	4:30+	293	500	TLW
HES-11	y		209	12.5	139	109	7474	5:01	575	979	TLW
A	y		2588	12.5		73	6650	6:50			A
B	y		153	12.5	170	127	9550	4:09	199	528	65/35 H/POZ
HES-7	y		66	12.5	170	127	8688	4:30+	233	317	H
HES-7	y		155	12.5	169	128	8918	5:30+	0	50	H
HES-7	y		50	12.5	202	151	10750	4:30+	91	192	H
B		n		12.5	200	152	10760	4:07	847	934	65/35 H/POZ
HES-11	y		100	12.5		157	11130	3:04	798	949	TLW
B	y		100	12.5	207	159	11120	6:30+	540	865	50/50 H/POZ
HES-7	y		35	12.5	223	172	11000	6:00+	172	324	H
HES-7	y		85	12.5	214	167	12817	5:02	1600	2500	H
HES-7	y		85	12.5	214	167	12617	4:32	302	407	H
HES-11	y		32	12.5		225	15600	6:23			TLW
HES-11	y		32	12.5		254	15600	5:00			TLW
HES-11	y		60	12.5		283	19000	9:36			TLW
HES-11	y		167	12.5		87	1732	4:30	155	342	TLW
HES-7	y		124	12.5		152	9969	10:26	260	400	H
B	y		130	12.5		143	10800	5:45			H
HES-7	y		66	12.5		169	11562	11:00	370		H
B	y		63	12.5		237	15883	10:30+			HTLD
B	y		63	12.5		258	17400	11:38			HTLD
B	y		60	12.5		283	19000	7:16			HTLD
B	y		60	12.5		283	19000	7:10			HTLD
B	y		60	12.5		283	19000	8:38			HTLD
B	y		63	12.5		283	19000	5:30			HTLD
B	y		63	12.5		283	19000	5:34			HTLD
B	y		50	12.5		283	19000	12:38			HTLD
B	y		63	12.5		283	19000	8:32			HTLD
F		n		12.5	168	136	6976	3:05	1168	1297	Micro-fine
HES-11	y		100	12.5	193	161	11052	5:00+	357	946	TLW
A	y		79	12.5	92	80	1000	4:00+	110	270	H
HES-11	y		1450	12.5	121	103	4962	3:34			TLW
HES-11	y		1450	12.5	121	103	4962	4:10			TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		1491	12.5	121	103	4500	3:42	197	516	TLW
B		n		12.5		95	700	5:00+	105	227	65/35 A/POZ
B	y		150	12.5	92	80	1000		70	185	65/35 A/POZ
B	y		150	12.5	92	80	1000		102	224	65/35 H/POZ
A	y		158	12.5	93	80	1000		430	1376	A
A	y		98	12.5	109	92	4980	5:02	395	613	A
A		n		12.5	112	94	2700	5:44	80	333	A
HES-11	y		722	12.5		50	2500	6:00+	30	115	TLW
HES-11	y		722	12.5		78	2020	7:04	127	162	TLW
HES-11	y		722	12.5		78	2020		76	134	TLW
HES-11	y		2000	12.5		60	2600	6:00+	83	162	TLW
HES-11	y		12	12.5	110	93	2500	5:00+	448	920	TLW
A	y		424	12.5	100	89	2000	4:31	261	654	A
B	y		305	12.5	135	106	4700	5:51		379	65/35 H/POZ
B	y		150	12.5	129	102	4500	8:02	127	241	65/35 H/POZ
B		n		12.5	130	101	4000	7:00+			65/35 A/POZ
HES-11	y		2192	12.5		82	4507	4:00+	110	140	TLW
HES-11	y		3227	12.5		97	6430	5:00	102	115	TLW
B	y		3227	12.5		105	9260	4:38	180	270	65/35 A/POZ
B		n		12.5		240	15400	7:00+			H
HES-7	y		23	12.5	95	82	1200	4:00+	85	173	H
HES-7	y		23	12.5	190	143	9511	5:30+	510	1086	H
B	y		144	12.5	206	156	10300	4:02	262	607	65/35 H/POZ
B		n		12.5	97	84	1400	5:00+		138	65/35 A/POZ
A		n		12.5	97	84	1400	4:45		239	A
B		n		12.5	97	84	1400	4:39		244	A
B		n		12.5		144	8450	5:00+	223	1485	65/35 H/POZ
A		n		12.5		80	50			50	A
HES-11		n		12.5		175	11200	3:07	1174	1550	TLW
HES-11		n		12.5	226	175	11200	3:50			TLW
B		n		12.5	190	155	9174	3:55	480	820	H
B	y		50	12.5	167	125	7250	6:12			65/35 H/POZ
HES-11	y		18	12.5	144	109	5773	3:45	721	970	TLW
HES-11	y		18	12.5	151	115	6508	3:32	597	989	TLW
HES-11	y		18	12.5	151	114	6258	3:32	597	989	TLW
HES-11	y		13	12.5	151	113	6200	3:30	826	1060	TLW
F	y		47	12.5	105	94	2100	2:28	770	950	Micro-fine
B		n		12.5		80	1000		85	156	50/50 A/POZ
B		n		12.5	115	93	2500	4:01	361	512	50/50 TXI/POZ
A	y		385	12.5	130	103	4540	5:00+	275	404	H
B		n		12.5	183	138	8600	5:30+	317	627	65/35 H/POZ
B		n		12.5	212	165	11820	4:02	829	1364	65/35 H/POZ
B		n		12.5	250	202	15135	4:23	1097	1201	65/35 H/POZ
B		n		12.5	85	83	600	3:00+	121	182	65/35 A/POZ
B	y		210	12.5	88	80	856	6:00+	0	62	50/50 H/POZ
HES-11	y		385	12.5	95	83	1300	7:39	0	175	TLW
HES-11	y		385	12.5	95	83	1300	7:13	221	487	TLW
A	y		515	12.5		85	1750	5:00+			A
HES-11	y		222	12.5		80	1000	6:00+	150	349	TLW
HES-11	y		220	12.5		80	1000	6:00+	244	453	TLW
HES-11	y		750	12.5		86	1900	6:00+	159	429	TLW
HES-11	y		220	12.5		80	1000	6:00+	143	563	TLW
HES-11	y		210	12.5		84	1859	6:42	50	375	TLW
A	y		750	12.5		80	1750	5:50	162	379	A
HES-11	y		210	12.5		84	1859	6:00+	113	743	TLW
A	y		400	12.5		82	1200	5:00+	147	445	A
A	y		400	12.5		82	1200	5:00+	85	125	H
HES-11	y		550	12.5	105	94	2996	4:00+	191	502	TLW
A	y		340	12.5	103	91	2901	5:20	248	469	A
HES-11	y		385	12.5	110	93	2600	5:30	217	482	TLW
HES-11	y		385	12.5	110	93	2600	4:18	400	835	TLW
A	y		1072	12.5	90	80	2350	6:13	196	725	A
HES-11	y		50	12.5		90	2110	5:51	151	512	TLW
HES-11	y		45	12.5		93	2600	5:34	316	754	TLW
HES-11	y		50	12.5		93	2600	3:54	38	957	TLW
HES-11	y		280	12.5	110	95	6000	5:00+	126	527	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		342	12.5		90	3716	4:45	100	250	TLW
HES-11	y		342	12.5	111	96	3861	4:57		205	TLW
A	y		2672	12.5		80	3875	5:00+		99	A
A	y		280	12.5	116	97	4500	3:15	404	494	A
B		n		12.5	119	96	3000	3:59	115	202	65/35 A/POZ
A	y		1419	12.5		80	3500	5:00+	159	270	A
A	y		515	12.5		82	3000	5:00+	265	439	A
HES-11	y		290	12.5		95	3050	5:30+		945	TLW
HES-11	y		750	12.5		98	3800	4:00	308	974	TLW
HES-11	y		220	12.5		99	3575	6:00+	150	403	TLW
A	y		400	12.5	116	98	3600	4:48	304	620	A
A	y		300	12.5	116	98	3600	5:00+	116	265	H
HES-11	y		32	12.5		104	4500	5:35	288	1025	TLW
HES-11	y		340	12.5		102	4676	6:37	52	305	TLW
A		n		12.5		92	4700	6:30+	1588	2342	A
HES-11	y		300	12.5		105	5000	7:20	0	162	TLW
HES-11	y		2000	12.5		65	4500	3:48	0	60	TLW
HES-11	y		220	12.5		92	4450	6:00+	367	752	TLW
HES-11	y		280	12.5	128	102	4700	3:11		579	TLW
B	y		525	12.5	127	110	5896	6:37			65/35 H/POZ
HES-11	y		350	12.5		110	5925	3:30			TLW
HES-11	y		220	12.5	142	108	5200	3:33	147	882	TLW
HES-11	y		3200	12.5		70	5200	5:00+			TLW
HES-11	y		350	12.5		111	6030	7:43	0	1254	TLW
B	y		525	12.5	127	110	5896	4:00+	140	240	65/35 H/POZ
HES-11	y		33	12.5		119	6800	8:06	0	377	TLW
A	y		1419	12.5		95	6600	8:00+		265	H
A	y		1419	12.5		95	6600	3:41			A
HES-11	y		290	12.5		124	6500	6:30+	266	580	TLW
HES-11	y		290	12.5		124	6500	4:20	243	551	TLW
HES-7	y		1900	12.5		97	6100	6:00+		106	A
HES-7	y		1900	12.5		90	6100	6:00+	123	196	A
B		n		12.5	165	124	7100	3:45+	209	464	65/35 H/POZ
HES-7	y		1419	12.5		115	7700	5:30+	305	354	A
HES-7	y		1419	12.5		128	8900	7:00+			A
HES-11	y		32	12.5	174	132	8250	4:12	221	1129	TLW
HES-7	y		420	12.5		135	8160	6:00+	95	198	H
HES-11	y		120	12.5	181	138	9400	4:00	0	1609	TLW
HES-11	y		120	12.5	182	139	9060	3:26	489	1355	TLW
HES-11	y		170	12.5	210	156	9650	4:00	102	1556	TLW
HES-11	y		35	12.5	185	142	10700	3:37	262	1530	TLW
HES-7	y		420	12.5		145	10112	5:44			H
HES-11	y		40	12.5	215	161	10100	7:49		0	TLW
B	y		40	12.5	215	161	10100	10:30+	497	738	HTLD
HES-11	y		45	12.5		161	10000	9:48			TLW
HES-11	y		45	12.5		161	10000	10:45	0	0	TLW
HES-11	y		2000	12.5		95	11351	4:18	229	409	TLW
B	y		35	12.5	193	152	11140	4:14	198	1087	65/35 H/POZ
HES-11		n		12.5		161	10100	9:04	0	25	TLW
HES-11	y		385	12.5	206	160	11945	6:15		0	TLW
HES-11	y		420	12.5		164	12300	6:50	0	1205	TLW
HES-11	y		420	12.5		164	13371	5:25	0	1344	TLW
B	y		35	12.5	219	174	12900	3:43	699	1605	65/35 H/POZ
B	y		35	12.5	219	174	12900	4:12	142	1643	65/35 H/POZ
HES-11	y		420	12.5		180	14913	5:24	0	1222	TLW
HES-11	y		420	12.5		197	15165	4:00	1153	1402	TLW
B	y		63	12.5	349	317	19500	8:09	216	486	HTLD
B	y		63	12.5		260	19000	7:59	50	165	HTLD
HES-11	y		150	12.5	95	82	1200	5:30+	101	131	TLW
HES-11		n		12.5	320	271	16050	3:30	343	533	TLW
F		n		12.5	152	124	6000	0:24			Micro-fine
F		n		12.5	152	124	6000	2:50	1089	1653	Micro-fine
HES-11	y		120	12.5	182	148	8700	2:45	1290	1676	TLW
B	y		20	12.5	116	101	3050	3:53	134	249	65/35 A/POZ
HES-11	y		50	12.5		204	9560	3:02	717	1000	TLW
HES-11	y		55	12.5		156	9500	5:57	462	1142	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
A	y		844	12.5	108	95	3300	4:16	245	518	A
HES-11	y		360	12.5	136	105	5169	4:26	165	520	TLW
HES-11	y		360	12.5	136	105	5169	8:11	120	424	TLW
B	y		225	12.5	160	120	8100	5:00+	220	448	65/35 H/POZ
B		n		12.5	160	137	9700	3:10			65/35 H/POZ
HES-7	y		117	12.5		180	11970	8:00+	228	268	H
HES-7	y		45	12.5	196	159	14852	3:56	310	385	H
B		n		12.5	250	202	14000	4:11			65/35 H/POZ
HES-3	y		1010	12.5		60	3650		70	191	A
HES-3	y		1010	12.5		60	3650	6:00+	146	229	A
HES-11		n		12.5	228	179	12300	3:13	65	1123	TLW
F	y		800	12.5		60	600	4:00+	73	395	Micro-fine
A	y		450	12.5		60	1452	4:00+	100	160	H
A	y		450	12.5		60	1452	4:00+	68	266	H
A	y		295	12.5	120	100	3950	6:00+	169	340	H
A	y		295	12.5	120	100	3950	6:00+	149	324	H
A	y		372	12.5		95	4950	5:00+	130	190	H
A	y		450	12.5		95	4952	7:00+	178	220	H
A	y		450	12.5		95	4952	7:00+	155	321	H
A	y		295	12.5	130	105	4875	6:00+	163	257	H
B		n		12.5	230	180	11900	4:20	0	105	65/35 H/POZ
HES-11	y		10	12.5	229	181	12425	4:20	1122	1255	TLW
B		n		12.5	282	240	15764		92	265	H
B	y		237	12.5	120	99	3800	4:30+	142	235	65/35 H/POZ
A	y		645	12.5		83	4500	4:00+	153	300	A
HES-11	y		380	12.5	130	103	4500	5:27			TLW
A	y		645	12.5		90	4000	4:29	270	350	A
B		n		12.5	185	139	8750	5:30	0	770	65/35 H/POZ
B		n		12.5	190	140	8300	3:56			65/35 H/POZ
B		n		12.5	212	163	10700	4:33			65/35 H/POZ
B		n		12.5	240	175	10300	5:18	1000	1730	65/35 H/POZ
B		n		12.5	240	174	10100	5:16	158	480	65/35 H/POZ
F	y		2940	12.5		40	3210	4:00+			Micro-fine
F	y		2940	12.5		40	3210	6:00+		165	Micro-fine
A	y		3300	12.5		47	4140		0	92	A
B	y		220	12.5	130	102	4200	3:45	218	349	65/35 A/POZ
HES-3		n		12.5		60	4085			146	A
HES-3	y		3300	12.5		58	5340	5:00+	0	197	A
B		n		12.5	160	117	6300	4:00			65/35 H/POZ
B	y		122	12.5	165	127	7800	5:35	800	940	H
B	y		122	12.5	174	130	7950	4:44	182	527	H
B	y		122	12.5	185	136	8100	4:15	288	1121	H
B		n		12.5	188	142	9000	3:02	135	383	65/35 H/POZ
B		n		12.5	228	161	9000	3:32	880	960	65/35 H/POZ
B		n		12.5	224	174	11500	3:16	113	626	65/35 H/POZ
B		n		12.5	232	184	12756	6:22	702	1440	65/35 H/POZ
HES-3	y		3907	12.5		70	3950	2:59	121	669	A
B	y		325	12.5	144	122	7763	3:02	336	508	65/35 A/POZ
B	y		325	12.5	144	122	7763	3:10	224	562	65/35 A/POZ
A	y		45	12.5	120	103	3000	3:00+			H
A	y		45	12.5	120	103	3000	3:00+			H
HES-10	y		3855	12.5		50	5200	4:00+			TLW
HES-10	y		3855	12.5		50	5200	4:00+			TLW
HES-11	y		1754	12.5	111	94	2825		175	230	TLW
HES-11	y		1754	12.5		71	2825	4:44	170	235	TLW
HES-3	y		2700	12.5		55	2950	3:55	64	216	A
A	y		720	12.5	124	100	3800	6:00+	194	400	H
A	y		720	12.5	124	100	5623	3:31	255	500	A
B	y		50	12.5	122	98	3500	3:15	190	390	65/35 A/POZ
A	y		1754	12.5		70	3016	5:00+	0	120	TLW
HES-11	y		252	12.5	137	105	7000	5:00+	474	1494	TLW
HES-3	y		2700	12.5		70	4200	3:41	0	436	A
HES-3	y		2700	12.5		80	5300	3:00	0	563	A
HES-3	y		2700	12.5		90	5700	2:33	250	378	A
HES-11	y		1754	12.5		94	5560	5:00+	330	500	TLW
HES-11	y		1754	12.5	135	114	6325	3:26		310	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-3	y		4243	12.5		65	6321	4:05	121	787	A
HES-11	y		67	12.5	166	126	7500	4:20	215	1200	TLW
B	y		60	12.5	198	152	10300	5:03	182	921	H
B	y		4243	12.5		105	10900	4:49	0	180	65/35 H/POZ
HES-11	y		981	12.5	115	99	4000	4:16	185	427	TLW
HES-11	y		70	12.5	146	114	6000	4:02	610	717	TLW
HES-11	y		50	12.5	160	122	8300	3:45	1068	1250	TLW
HES-11	y		10	12.5	172	133	9000	2:42			TLW
HES-11	y		10	12.5	172	133	9000	5:08	159	1989	TLW
HES-11	y		138	12.5	182	137	9120	4:26	771	1509	TLW
HES-11	y		10	12.5	190	151	11138	4:05	0	1079	TLW
HES-11		n		12.5	223	173	12100	4:30			TLW
B	y		70	12.5	290	249	17500	6:55	252	309	HTLD
HES-11	y		70	12.5	322	281	17500	6:00+			TLW
B	y		70	12.5	322	281	17500	7:32	139	1362	HTLD
HES-7	y		41	12.5	100	85	1500	5:00+	110	180	H
HES-7	y		167	12.5	111	93	3925	4:00+	150	230	H
HES-7	y		167	12.5	129	102	8549	5:00+	150	220	H
HES-7	y		176	12.5	150	112	6100	5:00+			H
HES-7	y		41	12.5	166	125	7300	5:35	90	230	H
HES-7	y		41	12.5	166	125	7300	7:00+	320	330	H
B	y		150	12.5	188	136	10250	4:15	120	400	65/35 H/POZ
B	y		160	12.5	180	133	10000	5:40	101	372	65/35 H/POZ
B		n		12.5	168	126	7300	4:20	178	259	65/35 H/POZ
F		n		12.5	130	109	4215	1:50		586	Micro-fine
F		n		12.5	138	115	5132	1:30			Micro-fine
HES-3	y		2707	12.5		70	4105	4:00	124	497	FLOSTOP I
HES-3	y		3227	12.5		70	4875	3:47	114	468	FLOSTOP I
B	y		2096	12.5		100	6395	5:23	150	230	65/35 A/POZ
F	y		110	12.5	180	148	8900	3:35	1120	1410	Micro-fine
HES-3		n		12.5		70	3950	4:06	50	280	FLOSTOP I
HES-3		n		12.5		70	4150	3:33	830	880	FLOSTOP I
F	y		29	12.5	270	232	16316	5:48	1430	1480	Micro-fine
HES-3	y		1754	12.5		75	2825	3:24	125	500	FLOSTOP I
F		n		12.5	225	184	11200	3:26	1040	1280	Micro-fine
HES-11	y		3325	12.5		95	7100	5:11			TLW
A		n		12.5	85	80	300			460	A
B		n		12.5	230	181	12770	5:30+	760	1080	75/25 POZ/A
B		n		12.5	200	152	10000	7:00+	580	750	75/25 POZ/A
B	y		40	12.5	188	130	9021	3:33	485	1060	H
B		n		12.5	190	144	9100	5:00+	570	760	75/25 POZ/A
B		n		12.5	194	147	9800	5:00+	580	780	75/25 POZ/A
HES-11		n		12.5	176	132	8000	2:43			TLW
HES-11		n		12.5	196	139	8000	3:53	SET	1160	TLW
B	y		525	12.5	125	102	4384	5:47	190	270	65/35 H/POZ
B	y		525	12.5	126	109	5700	4:00+	140	290	65/35 H/POZ
A	y		450	12.5		95	4952	9:30	265	405	H
HES-11	y		182	12.5	125	107	5150	5:48	200	705	TLW
A	y		633	12.5	120	105	5303	4:00+	150	290	A
B	y		60	12.5	290	249	17500	4:45	200	310	HTLD
B	y		60	12.5	290	249	17500	6:25		220	HTLD
HES-2	y		1086	12.5		70	2400	6:00+	160	450	A
HES-2	y		1086	12.5		70	2400	6:00+	110	350	A
B	y		85	12.5	142	107	4800	4:18	240	340	H
HES-11	y		2081	12.5		85	5100	4:00+	95	130	TLW
HES-11	y		51	12.5	197	149	10503	5:00	0	260	TLW
A	y		1195	12.5		90	4900	5:00+		0	H
B	y		120	12.5	188	145	10043	3:33	210	300	65/35 H/POZ
F	y		550	12.5		155	6800	3:46	1230	1390	Micro-fine
A	y		3153	12.5		70	8800	4:00+	1250	1360	A
B		n		12.5	206	158	10500	6:00+	620	670	75/25 POZ/A
HES-11	y		310	12.5	92	84	1500	5:00+	100	260	TLW
HES-11	y		310	12.5	115	98	3600	6:06	420	940	TLW
A	y		40	12.5	140	107	5602	4:31	185	220	H
B	y		41	12.5	134	104	4500	4:47	105	230	85/15 H/POZ
HES-11	y		222	12.5	118	96	6200	4:00+	70	485	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-3	y		6738	12.5		65	7800	3:39	120	360	FLOSTOP I
A	y		40	12.5	92	80	1000	4:00+	190	330	A
B	y		144	12.5		157	10150	11:20	SET	410	H
A	y		1195	12.5		90	4900	5:00+		72	H
A	y		1195	12.5		90	4900	5:00+	0	58	H
B		n		12.5	211	163	12000	4:03	570	1210	65/35 H/POZ
A	y		224	12.5	128	101	4692	3:51	200	340	H
B		n		12.5	220	172	11700	4:49	790	860	75/25 POZ/A
A	y		40	12.5	140	107	5602	5:42	140	230	H
HES-7	y		143	12.5		160	10750	10:41	0	440	H
A	y		3752	12.5		70	5650	5:00+	130	200	H
A	y		3752	12.5		70	5650	6:00+	150	265	H
A	y		3752	12.5		94	7500	5:00+	185	340	H
A		n		12.5	85	80	300		0	99	A
A		n		12.5	85	80	300		90	410	A
A		n		12.5	85	80	300		0	190	A
A		n		12.5	85	80	300		FIRM	175	A
A	y		663	12.5	115	97	3500	4:00+	110	250	A
B		n		12.5	190	144	9240	4:00	200	840	65/35 H/POZ
B	y		525	12.5	127	109	6600	5:06	150	270	65/35 H/POZ
B	y		525	12.5	127	109	6600	7:03	88	185	65/35 H/POZ
B	y		200	12.5	110	93	2700	4:30+	170	270	50/50 H/POZ
B	y		41	12.5	134	104	4500	4:06	120	200	85/15 H/POZ
HES-11	y		42	12.5	145	110	5300	4:54	850	1175	TLW
A	y		1736	12.5		95	5800	7:22	135	140	H
A	y		1736	12.5		95	5800		70	185	H
B	y		1736	12.5		80	3304	2:00+	160		A
A	y		1136	12.5		80	6150	4:00+	120	180	H
B	y		25	12.5	215	167	11860	0:52			50/50 H/POZ
A	y		663	12.5	115	97	3500	7:00+	100	180	H
A	y		663	12.5	115	97	3500	6:00+	290	390	H
A	y		663	12.5	115	97	3500	6:00+	290	390	H
HES-7	y		587	12.5		88	4500	5:00+	0	140	H
HES-7	y		1753	12.5		70	4500	4:00+		0	H
HES-7	y		420	12.5	190	154	11900	6:30+	440	655	H
A	y		209	12.5	153	117	6508	5:00+	251	469	H
B	y		80	12.5	176	132	8350	5:18	80	195	65/35 H/POZ
A	y		209	12.5	188	141	10678	2:24			H
HES-7	y		209	12.5	188	141	10678	6:30+	230	250	H
A	y		1736	12.5		95	5800	4:30+	137	279	H
HES-3	y		6385	12.5		65	7500	3:44	FIRM	220	FLOSTOP I
E	y		255	12.5	94	87	1240	2:30	65	140	A
HES-7	y		688	12.5	116	97	4066	7:00+	82	250	H
B		n		12.5	95	86	1700	4:14	129	190	85/15 A/POZ
B		n		12.5	115	98	3550	5:00+	80	290	85/15 H/POZ
HES-11	y		100	12.5	129	99	3500	6:15			TLW
HES-11	y		2192	12.5		65	4417	7:00+	0	50	TLW
HES-11	y		2192	12.5		65	4417	6:00+	FIRM	100	TLW
B	y		34	12.5	223	175	12728	3:54	992	1270	50/50 H/POZ
A	y		633	12.5	105	90	3100	5:00+	60	200	H
HES-3	y		2134	12.5		65	3630	6:22	0	190	FLOSTOP I
B	y		525	12.5	137	111	5700	7:39	90	250	65/35 H/POZ
B	y		525	12.5	137	111	6100	5:44	80	280	65/35 H/POZ
A	y		240	12.5	145	108	5077	5:30	160	250	H
HES-11	y		288	12.5		80	1619	5:45+	359	653	TLW
HES-11	y		288	12.5	139	105	5550	5:00	0	0	TLW
HES-11	y		288	12.5	139	105	5550		500	1380	TLW
HES-1		n		12.5		100	6400	7:16			SLAG
HES-1		n		12.5		100	6400	5:40			SLAG
HES-7	y		650	12.5	118	100	4350	6:00+	148	301	H
B	y		277	12.5	172	132	8352	4:22	140	200	65/35 H/POZ
HES-7	y		650	12.5	181	149	12000	5:34	126	190	H
	y		80	12.5	230	181	13410	5:30+			65/35 H/POZ
B		n		12.5	175	127	7200	4:26	250	365	65/35 H/POZ
B	y		277	12.5	207	159	14156	3:35	30	60	65/35 H/POZ
HES-1	y		2940	12.5		81	6400	5:11	255	605	SLAG

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-1	y		2940	12.5		81	7100	5:11	255	605	SLAG
HES-11	y		34	12.5	230	189	11510	3:07	1200	1710	TLW
A	y		1061	12.5		70	2800	10:00+	50	150	H
A	y		2978	12.5		90	8000	5:00+	60	120	H
A	y		2978	12.5		86	7000	5:00+	70	200	H
HES-7	y		478	12.5		94	4650	5:30+	0	80	H
HES-7	y		478	12.5		128	4090	5:30+	194	305	H
A	y		227	12.5	100	80	1000	5:00+	110	380	A
B		n		12.5	228	179	12800	5:26	260	750	65/35 H/POZ
B	y		100	12.5	170	134	11000	4:12	160	207	65/35 H/POZ
A	y		650	12.5	126	101	4485	5:06	140	210	A
HES-7	y		650	12.5	126	101	4486	6:00+	144	298	A
B	y		86	12.5	237	189	13500	3:53	310	340	65/35 H/POZ
B	y		100	12.5	145	113	6021	7:09	80	180	65/35 H/POZ
B		n		12.5	219	166	10700	3:50	510	680	65/35 H/POZ
B	y		650	12.5		63	1874	5:30+	40	100	A
HES-3	y		3400	12.5		65	5200	3:38			FLOSTOP I
A		n		12.5		110	4000	10:00+	250		H
HES-7	y		130	12.5	134	109	5500	8:00+	140	260	H
A	y		372	12.5	140	107	5000	5:57	230	280	H
HES-11	y		722	12.5		65	2620	5:00+	0	FIRM	TLW
A	y		236	12.5	135	105	4700	5:00+	190	290	A
HES-7	y		1200	12.5		70	4500	6:00+	50	150	A
HES-7	y		1200	12.5		70	4500	6:30+	60	110	A
HES-7	y		3244	12.5		73	6800	5:00+	0	75	H
F	y		145	12.5		80	250	3:27	145	210	Micro-fine
HES-7	y		3200	12.5		109	10765	5:30+	30	120	H
HES-7	y		3200	12.5		109	10765	6:00+	30	120	H
HES-11	y		320	12.5	120	96	3000	4:13	310	1180	TLW
HES-7	y		110	12.5	180	135	8300	6:00+	297	396	H
HES-7	y		55	12.5		153	10400	7:00			H
HES-3		n		12.5		53	4358	3:06	90	250	FLOSTOP I
B		n		12.5	120	97	3263	5:00+	160	230	65/35 H/POZ
B		n		12.5	120	97	3263		320	360	65/35 A/POZ
A	y		1072	12.5		92	4200	5:00+	128	200	H
HES-1	y		3800	12.5		82	9500	4:00	543	576	SLAG
A	y		3800	12.5		82	9500	2:15			A
HES-7	y		2320	12.5		80	5000	4:30+	60	100	H
A		n		12.5	110	90	2000	5:30+	130	200	A
A	y		650	12.5	125	101	5831	4:47	160	350	A
B	y		305	12.5	193	147	10300	4:21	540	1000	65/35 H/POZ
HES-7	y		209	12.5	194	147	11858	7:00+	280	390	H
HES-7	y		209	12.5	194	147	11858	6:00+	220	260	H
B	y		83	12.5	209	161	11500	4:13	80	180	65/35 H/POZ
B	y		83	12.5	209	161	11500	4:39	90	190	65/35 H/POZ
B	y		90	12.5	225	176	13986	4:27	225	360	65/35 H/POZ
B	y		80	12.5	235	187	13390	6:54	130	180	65/35 H/POZ
HES-8	y		3210	12.5		70	5450	6:00+	32	92	FLOSTOP III
HES-8	y		3210	12.5		70	5450	6:37	110	455	FLOSTOP III
HES-7	y		360	12.5	182	136	9957	6:00+	370	490	H
HES-1	y		3800	12.5		82	9500	4:50	626	670	SLAG
A	y		1072	12.5	118	100	4200	5:00+	130	180	H
HES-1	y		2945	12.5		81	7110	3:45		0	SLAG
HES-1	y		2940	12.5		82	7110	4:59	0	102	SLAG
B	y		66	12.5	261	209	15100	6:10	220	240	HTLD
HES-11	y		2407	12.5		58	3849	6:00+	123	205	TLW
HES-1	y		2945	12.5		81	7110	4:56	336	580	SLAG
A	y		1070	12.5		80	2200	5:00+	FIRM	230	H
HES-11	y		42	12.5	94	80	1000	5:00+		240	TLW
B	y		36	12.5	180	136	10940	6:25	390	660	65/35 H/POZ
B	y		83	12.5	198	150	10500	6:18	300	1120	65/35 H/POZ
HES-7	y		3940	12.5		109	9725	6:00+	250	280	H
HES-11	y		42	12.5	94	80	1000			180	TLW
HES-11	y		42	12.5	134	101	4650	4:00+		630	TLW
B	y		36	12.5	204	159	14500	8:02	70	200	65/35 H/POZ
B	y		36	12.5	235	180	14500	7:16	125	256	65/35 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		185	12.5	126	98	4527	6:30+	640	1429	TLW
HES-7	y		68	12.5	245	198	15800	9:30+	0	102	H
B	y		372	12.5	120	99	4350	6:00+	80	120	H
B	y		372	12.5	120	99	4350	7:56	100	260	H
A	y		220	12.5	0	75	1600	4:00+	140	420	A
A	y		220	12.5	95	85	1600	6:00+	80	210	H
A	y		220	12.5	150	109	5000	2:30	470	500	A
A	y		220	12.5	150	109	5000	5:00+	170	245	H
A	y		2517	12.5	0	70	5400	5:20	150	410	A
HES-1	y		3800	12.5	0	81	9500	4:18	800	880	SLAG
HES-8	y		3940	12.5	0	109	9725	3:35	610	810	FLOSTOP III
B	y		83	12.5	198	150	10100	3:58	260	610	65/35 H/POZ
B	y		83	12.5	198	150	10250	4:35	370	850	65/35 H/POZ
HES-7	y		209	12.5	202	154	14802	5:30+	350	480	H
HES-7	y		377	12.5	130	100	3906	8:00+	60	160	H
A	y		163	12.5	102	85	1500	5:00+	60	220	H
A	y		1309	12.5	0	65	2300	4:30+	0	160	H
A	y		1309	12.5	0	65	2300	4:30+	0	120	A
A	y		1309	12.5	0	65	2300	5:00+	65	269	A
B	y		280	12.5	218	168	11500	4:55	560	580	65/35 H/POZ
B	y		280	12.5	218	168	11500	6:54	365	630	65/35 H/POZ
A	y		530	12.5	98	86	1707	5:00+	70	390	A
A	y		530	12.5	121	97	5294	6:00+	180	390	A
B	y		90	12.5	160	120	6800	6:17	160	290	65/35 H/POZ
HES-7	y		186	12.5	173	130	11700	5:00+	185	325	H
B	y		83	12.5	198	151	10250	5:36	161	709	65/35 H/POZ
F	y		90	12.5	122	104	3500	3:16	90	180	Micro-fine
A	y		6037	12.5	0	65	9000	5:30+	0	FIRM	A
HES-7	y		55	12.5	204	157	12550	4:25	210	314	H
B		n		12.5	215	168	13400	5:00	330	765	65/35 H/POZ
HES-7	y		110	12.5	0	207	15785	6:00	450	710	H
HES-7	y		110	12.5	0	207	15785	7:18	350	570	H
HES-7	y		377	12.5	150	114	5806	7:00+	70	150	H
HES-11		n		12.5	124	98	3500	4:57	440	1076	TLW
A	y		650	12.5	116	96	5801	6:30+	180	260	A
A	y		650	12.5	125	101	9302	4:50	260	270	A
	y		83	12.5	188	142	9873	5:30+	290	336	H
HES-7	y		5467	12.5	0	75	8400	7:00+	110	256	A
B	y		36	12.5	219	170	11847	4:47	305	1040	65/35 H/POZ
HES-7	y		6037	12.5	0	95	11850		85	164	H
HES-7	y		35	12.5	215	166	11565	3:43	410	478	H
B	y		150	12.5	183	135	8100	5:08	270	430	H
HES-7	y		35	12.5	237	181	11565	5:40	320	430	H
A	y		530	12.5	121	97	5294	4:38	220	420	H
A	y		530	12.5	98	86	1707	5:00+	114	320	H
HES-7	y		209	12.5	196	149	13661	5:13	140	220	H
A	y		650	12.5	0	101	9302	3:20	200	230	A
B	y		55	12.5	307	253	17900	7:47	55	94	HTLD
HES-7	y		650	12.5	164	124	10676	4:30+	230	360	H
F	y		210	12.5	101	88	2300	2:58	220	325	Micro-fine
B	y		110	12.5	162	137	9900	5:28	125	227	H
HES-7	y		110	12.5	162	137	9900	6:00+	270	500	H
HES-7	y		52	12.5	0	145	9600	6:21	213	330	H
B		n		12.5	200	152	9900	3:27	310	600	65/35 H/POZ
A	y		2800	12.5	0	65	3600	5:00+	0	60	A
HES-3	y		2800	12.5	0	60	3960	5:38	1020	1230	FLOSTOP I
HES-7	y		1753	12.5	0	70	5000	6:00+	80	120	A
A	y		650	12.5	113	95	6012	5:40	160	290	H
B		n		12.5	200	152	9900	7:48	260	1000	65/35 H/POZ
HES-7	y		105	12.5	122	97	3500	6:00+	750	830	H
A	y		650	12.5	113	95	6012	4:39	80	340	A
HES-7	y		45	12.5	213	179	13200	4:30+	158	410	H
A	y		176	12.5	127	101	4500	4:30+	300	350	H
B	y		52	12.5	92	80	1000	5:00+	163	200	H
HES-7	y		36	12.5	218	168	11500	4:00+	228	392	H
B	y		36	12.5	219	170	14008	5:33	84	330	65/35 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		60	12.5	95	83	1300	5:00+	175	220	H
B	y		52	12.5	128	100	4000	5:10	180	290	H
B	y		77	12.5	220	172	13719	3:55	550	800	65/35 H/POZ
B	y		52	12.5	128	100	4000	5:00+	230	340	H
B	y		52	12.5	92	80	1000	5:00+	110	240	H
HES-7	y		52	12.5	0	152	11208	4:33	210	290	H
B	y		36	12.5	219	170	14053	5:30	172	455	65/35 H/POZ
B	y		52	12.5	129	100	4000	6:00+	215	260	H
HES-11	y		950	12.5	136	108	5342	4:18	200	660	TLW
A	y		1611	12.5	139	110	5424	5:13	130	140	H
HES-11	y		3400	12.5	0	70	5200	7:32	70	250	TLW
HES-11	y		3400	12.5	0	70	5200	7:35	50	430	TLW
B	y		110	12.5	92	80	1000	4:00+	200	270	H
B	y		110	12.5	116	95	3000	5:41	200	440	H
B	y		63	12.5	132	104	4500	6:34	170	360	H
B	y		150	12.5	192	142	8600	5:15	160	830	65/35 H/POZ
HES-11	y		340	12.5	169	127	7400	3:52	770	990	TLW
HES-11	y		340	12.5	187	141	12260	3:03	452	935	TLW
HES-11	y		340	12.5	187	141	12260	2:08			TLW
HES-11	y		340	12.5	187	141	12260	4:18	710	1644	TLW
A	y		3600	12.5	0	65	5200	5:00+	0	0	A
A	y		3600	12.5	0	75	6700	4:19	105	603	A
B		n		12.5	142	108	5000	4:17	122	209	65/35 A/POZ
A	y		220	12.5	95	81	1200	4:00+	180	380	A
HES-11	y		6200	12.5	0	68	5305		57	157	TLW
HES-11	y		6200	12.5	0	68	5305	3:51	105	380	TLW
HES-1	y		3800	12.5	0	79	9500	3:59	329	365	SLAG
HES-7	y		3778	12.5	0	120	13275	9:45	0	80	H
HES-7	y		186	12.5	164	124	9170	5:00+	210	2450	H
HES-7	y		290	12.5	182	137	12718	5:38	138	212	H
HES-7	y		40	12.5	245	192	14000	5:30+	290	340	H
HES-7	y		40	12.5	260	202	14000		340	380	H
HES-11	y		950	12.5	105	91	2890	2:33	220	590	TLW
HES-11	y		950	12.5	141	111	7198	3:44	270	970	TLW
HES-11	y		3400	12.5	0	70	5200	6:45	140	272	TLW
B	y		110	12.5	127	100	4050	3:30+	170	320	H
B	y		110	12.5	127	100	4050	3:38	190	310	H
HES-7	y		110	12.5	127	100	4050	6:00+	130	290	H
B	y		110	12.5	137	107	5000		200	350	H
HES-7	y		85	12.5	140	108	5000	6:00+	79	340	H
HES-7	y		127	12.5	200	152	10752	8:00+	160	190	H
A	y		50	12.5	133	103	4400	6:00+	150	260	H
A	y		3550	12.5	0	85	9858		90	360	H
A	y		3550	12.5	0	83	8378	2:33	275	710	A
A	y		3550	12.5	0	83	8378	3:41	290	440	A
A	y		3550	12.5	0	80	9200	5:00+	0	94	H
HES-7		n		12.5	0	70	12500	7:00+	0	95	A
A	y		420	12.5	102	89	2045	6:00+	180	370	A
A	y		420	12.5	122	99	3957	6:57	230	340	A
B	y		90	12.5	220	177	15500	6:38	540	780	HTLD
HES-7	y		190	12.5	134	102	5621	6:00+	400	543	H
HES-1	y		3800	12.5	0	64	7340	5:00+	410	891	SLAG
B	y		40	12.5	90	80	900	4:00+	242	480	65/35 A/POZ
HES-7	y		209	12.5	135	105	5069	4:00+	70	90	H
HES-7	y		209	12.5	202	153	14000	6:00+	352	419	H
A	y		5200	12.5	0	75	10353	5:00+	50	100	H
A	y		5200	12.5	0	115	10300	8:00+	30	60	H
B	y		300	12.6		110	4235	6:00+	61	116	65/35 H/POZ
B		n		12.6	200	150	10000	4:14	366		65/35 H/POZ
HES-11	y		415	12.6	124	100	5068	3:00			TLW
HES-11	y		1754	12.6	192	159	12875	3:11	530	1340	2/1 TLW/H
HES-11	y		1754	12.6	178	149	11391	3:00	438	1250	2/1 TLW/H
HES-11	y		1754	12.6	174	146	10870	5:01	402	670	2/1 TLW/H
F	y		71	12.6	135	112	4500	3:30	1790	1917	Micro-fine
F	y		71	12.6	135	112	4500	4:17	605	671	Micro-fine
F	y		71	12.6	135	112	4500	4:44	428	494	Micro-fine

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
F	y		71	12.6	125	106	3200	3:30	625	692	Micro-fine
B	y		20	12.6	98	86	1700	4:49	190	270	H
B	y		300	12.6		111	5820	5:00+	60	255	65/35 H/POZ
B	y		150	12.6	215	160	10000	3:54	586	816	65/35 H/POZ
B	y		300	12.6		92	2200	4:30+	109	265	65/35 H/POZ
B	y		300	12.6	110	91	2200	4:30+	79	212	65/35 H/POZ
B	y		300	12.6		82	1100	4:30+	150	188	65/35 H/POZ
HES-11		n		12.6	282	240	15764	6:28	711	711	2/1 TLW/H
B		n		12.6	120	96	3000	4:06	136	280	65/35 A/POZ
B	y		45	12.6		93	6206	5:00+	155	220	65/35 H/POZ
B	y		90	12.6	184	147	12438	6:35	0	236	65/35 H/POZ
HES-11	y		760	12.6	117	99	4303	4:30	128	276	TLW
HES-11	y		50	12.6	95	82	1200	6:00+	79	102	1/1 TLW/H
B	y		240	12.6		139	5600	6:24			65/35 H/POZ
B	y		200	12.6	119	96	4800	4:00+	310	370	H
B	y		2161	12.6		93	7400		189	248	65/35 A/POZ
B		n		12.6	256	207	14700	4:45	1260	1310	65/35 H/POZ
B		n		12.6	256	207	14700	7:55	458	925	65/35 H/POZ
HES-3	y		2920	12.6		65	5200	5:00			FLOSTOP I
B	y		200	12.6	119	96	4800	4:00+	210	440	H
HES-11	y		101	12.6	210	163	12227	4:00	190	1760	TLW
B	y		41	12.6	192	145	10423	5:49	0	1130	65/35 H/POZ
B	y		182	12.6	190	144	9300	4:29	140	440	65/35 H/POZ
B	y		182	12.6	190	144	9300	3:33			50/50 H/POZ
B	y		150	12.6	195	143	8500	3:08			65/35 H/POZ
B	y		110	12.6	146	114	6000	5:36	290	640	H
B	y		41	12.6	205	154	10050	4:48	280	1155	65/35 H/POZ
B	y		40	12.6	106	91	2710	4:00+	270	480	H
HES-11	y		1754	12.6	188	152	14050	3:44	340	1350	2/1 TLW/H
HES-11	y		1754	12.6	218	169	16740	5:50	640	945	2/1 TLW/H
HES-11	y		1754	12.6		94	5500	5:00+	220	590	2/1 TLW/H
HES-11	y		1754	12.6		94	5560	5:00+	100	240	2/1 TLW/H
B		n		12.6	85	80	300			290	85/15 A/POZ
B	y		52	12.6	128	101	4000	5:00	480	555	A
B	y		52	12.6	92	80	1000	4:00+	190	300	A
HES-3	y		6201	12.6		65	7300	3:34	140	280	FLOSTOP I
HES-11	y		760	12.6	138	114	7220	7:18	198	1147	TLW
B		n		12.6	200	155	11000	3:43	359	1130	65/35 H/POZ
B	y		76	12.6		92	2300	4:35	116	214	A
B	y		200	12.6		98	4000	5:36			H
B	y		200	12.6		98	4000	4:37			H
B	y		52	12.6	134	104	4500	5:20	240	410	A
B	y		76	12.6	130	103	4500	4:35	251	551	H
B	y		76	12.6	130	103	4500	4:27	387	721	H
B	y		200	12.6	140	107	5369	5:00	110	160	H
B	y		40	12.6	138	106	5010	8:30			H
B	y		40	12.6	138	106	5010	4:19			H
B	y		553	12.6		120	5500	9:24			H
HES-11	y		1050	12.6		70	2400			287	TLW
B	y		553	12.6		108	6800	7:59		330	H
B	y		76	12.6	114	99	3300	4:15	310	360	A
B	y		35	12.6	107	92	2380	5:20	195		H
B	y		35	12.6	106	91	2300	5:03			H
B	y		35	12.6	106	91	2300	3:30+	256	437	H
B	y		40	12.6	93	80	1000	6:30+		79	H
B	y		40	12.6	100	84	1450	6:30	155	289	H
B	y		76	12.6	91	80	1000	4:00+	170	330	A
B	y		52	12.6	92	80	1000	4:00+	120	390	A
B	y		76	12.6		80	750	4:38	121	239	A
B	y		52	12.6	128	101	4000	5:38	200	530	A
HES-11		n		12.6	100	91	1500	4:18	212	417	2/1 TLW/H
B	y		20	12.6	98	86	1700	5:00+	190	350	H
B		n		12.6	211	163	10900	6:30	280	831	65/35 H/POZ
A		n		12.6		80	270	4:00+	111	231	A
B		n		12.6		93	2500		0	50	HPLC
B		n		12.6		160	12000	5:42	272	529	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		12.6		160	12000	5:36	88	489	H
A		n		12.6	110	90	2000	6:23	366	470	A
B		n		12.6	200	152	10000	4:03	0	1194	65/35 H/POZ
B	y		80	12.6	140	113	5963	4:25	324	829	H
HES-11	y		332	12.6	120	100	4126	4:55	82	663	TLW
HES-11	y		760	12.6	138	114	7220	6:12	556	1482	TLW
B	y		26	12.6		165	10500	8:58			H
B	y		26	12.6		165	10500	5:21			H
B	y		200	12.6		140	9100	5:05			H
B	y		35	12.6		134	8210	14:45			H
HES-7	y		120	12.6		115	6000	14:53			H
B	y		35	12.6		87	1750	5:40			H
B	y		165	12.6		87	1732	3:47	200	341	A
B	y		35	12.6		118	8445	8:00	0	630	H
HES-11	y		1485	12.6	143	119	7252	5:45	122	441	TLW
B	y		35	12.6	157	119	8100	6:47	60	390	H
B		n		12.6	219	167	10750	5:05	700	980	65/35 H/POZ
B		n		12.6	280	214	11671	3:30	390	630	HTLD
B	y		35	12.6		141	8950	4:47	0	395	H
HES-7	y		210	12.6		136	9820	6:45	290	380	H
B	y		110	12.6	140	107	5000		160	250	H
B	y		110	12.6	140	107	5000	4:53	95	230	H
B	y		38	12.6		126	7222	5:36	260	530	H
B	y		52	12.6		184	12930	4:58			H
B	y		110	12.6	140	107	5000	6:44	120	230	H
B		n		12.6	256	207	14700	7:10	680	1260	65/35 H/POZ
B	y		80	12.6	188	142	9483	4:10		75	65/35 H/POZ
B	y		50	12.6	122	97	3500	6:22	170	200	H
B		n		12.6		80	1100	5:00+			50/50 H/POZ
B		n		12.6		190	10000	8:00+			H
B		n		12.6		112	4000	4:16			H
B	y		52	12.6		187	14555	10:07			H
B	y		52	12.6	137	104	4500	4:25	250	290	H
B	y		52	12.6	0	143	10600	5:32	SET	570	H
HES-11	y		2800	12.6	0	82	12424	9:29			TLW
HES-11	y		2588	12.6	0	82	12424	7:02	160	380	TLW
B	y		2800	12.6	0	82	12424	10:16	90	211	H
B	y		2800	12.6	0	73	6820	10:32	130	200	H
B	y		2800	12.6	0	79	9938	6:19	25	120	H
B		n		12.6	280	214	11671	2:28			HTLD
B	y		52	12.6	0	143	10600	7:50	FIRM	440	H
B	y		2000	12.6	0	75	6400	7:29	100	220	H
B	y		52	12.6	0	152	11208	4:01	280	620	H
B	y		3000	12.6	0	73	6600	8:29	140	230	H
B	y		52	12.6	0	145	9600	4:30	80	350	H
B	y		55	12.6	92	80	900	5:00+	90	300	H
B	y		55	12.6	131	103	4400	6:43	270	420	H
B	y		2800	12.6	0	80	8720	6:50	70	140	H
B	y		2800	12.6	0	73	6894	7:28	90	180	H
B	y		2000	12.6	0	87	9200	4:20	150	410	H
B	y		50	12.6	122	97	3500	4:04	135	220	H
HES-7	y		200	12.6	145	108	9531	6:00+	254	400	H
B	y		110	12.6	182	137	8930	4:27	230	490	H
B	y		181	12.6		123	7683	6:14	170	620	H
B	y		35	12.6		126	7289	4:37	480	670	H
HES-7	y		190	12.6		148	10200	6:03		220	H
HES-7	y		190	12.6		148	10200	8:55	170	600	H
B	y		2588	12.6		77	8100	5:40			H
B	y		2588	12.6		73	6700	5:53	60	150	H
B	y		2588	12.6		73	6700	6:00+	30	40	H
B	y		50	12.6	120	98	3817	7:33	99	280	H
B		n		12.6	265	218	14700	8:22	644	1290	65/35 H/POZ
B		n		12.6	250	202	14000	6:31	450	680	65/35 H/POZ
B	y		41	12.6	106	91	2800	4:41	100	190	H
B	y		35	12.6		142	9000	7:45			H
B	y		52	12.6	117	96	3100	4:34	130	270	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		144	12.6		129	8792	3:48			H
B	y		190	12.6	134	105	5300	6:00	128	800	H
B	y		38	12.6	126	98	4114	5:47			H
B	y		38	12.6	91	81	1100	6:23	50	100	H
B		n		12.6	250	202	14000	5:32	300	565	65/35 H/POZ
B		n		12.6	225	175	11600	4:32	280	750	65/35 H/POZ
B	y		35	12.6		118	8673	4:49	280	370	H
B	y		69	12.6		174	12833	7:10	128	720	H
B	y		144	12.6	172	129	7900	3:39	400	450	H
B	y		35	12.6	115	96	3800	3:36	250	420	H
B	y		52	12.6		150	10443	8:40	0	950	H
B	y		190	12.6	148	148	10200	9:03	0	510	H
B	y		2800	12.6	0	75	7090	7:41	105	280	H
HES-7	y		200	12.6	145	108	9531	4:00+			H
B	y		52	12.6	134	104	4500	4:19	150	350	H
B	y		35	12.6	119	97	3300	3:50	180	340	H
B	y		76	12.6		137	8510	5:53	FIRM	380	H
HES-7	y		99	12.6	215	164	13487	3:46	243	377	H
HES-7	y		200	12.6	129	103	4555	6:00+	220	315	H
B		n		12.6	272	228	16621	6:12	450	490	65/35 H/POZ
HES-7	y		200	12.6	129	103	4555	6:00+	120	1710	H
B		n		12.6	260	211	14900	4:18	320	1000	65/35 H/POZ
B	y		200	12.6	129	103	4555	3:52	160	200	H
B		n		12.6	140	116	5000	4:07	130	290	65/35 A/POZ
HES-7	y		52	12.6	162	141	8900	5:58	387	510	H
HES-7	y		52	12.6		141	8900	5:37	242	1350	H
B	y		35	12.6		119	6430	5:29			H
B	y		52	12.6		120	6650	5:34			H
B	y		52	12.6		120	6650	4:43	208	430	H
B	y		181	12.6		107	6038	6:29	140	300	H
B	y		35	12.6		94	2857	4:51	100	250	H
HES-7	y		35	12.6	244	192	13700	6:31	200	340	H
B	y		52	12.6	128	101	4000	6:02	150	154	H
B	y		35	12.6	123	99	3657	3:44	196	350	H
B	y		35	12.6		131	7900	5:49	0	330	H
B		n		12.7	215	166	11030	5:20	291	990	65/35 H/POZ
B	y		139	12.7	165	126	7500	5:10	272	519	65/35 H/POZ
B		n		12.7	235	187	12900	5:13			65/35 H/POZ
HES-11	y		261	12.7	112	94	2600	5:30+	342	567	TLW
HES-11	y		261	12.7		94	2650	5:30+	26	851	TLW
HES-11	y		261	12.7	113	95	2930	5:30+	376	874	TLW
B		n		12.7	110	93	2500			385	65/35 A/POZ
HES-11	y		261	12.7	118	97	3180	5:36	405	1227	TLW
HES-11	y		261	12.7		101	4200	5:35	656	662	TLW
HES-11	y		261	12.7		105	4750	4:35	777	928	TLW
HES-11	y		80	12.7	124	100	4030	5:05		1446	TLW
HES-11	y		105	12.7	189	144	9400	4:25		1205	TLW
B		n		12.7	190	143	9000	4:33	360	1200	65/35 H/POZ
HES-11	y		130	12.7		171	12632	6:20	116	1695	TLW
B		n		12.7	225	175	11600	2:19			65/35 H/POZ
HES-8	y		800	12.7		65	1625	5:44	248	391	A
HES-11	y		225	12.7	120	98	3400	5:07	175	753	TLW
B	y		529	12.7	127	110	5896	4:57			65/35 H/POZ
HES-11	y		354	12.7		93	3500	4:20	326	594	TLW
HES-11	y		354	12.7		93	3500	4:10	567	1028	TLW
HES-11	y		130	12.7		171	12850	6:10	323	1593	TLW
HES-8	y		1500	12.7		65	2800	5:36	83	90	A
HES-11	y		130	12.7	218	171	12632	6:00	581	1529	TLW
HES-11	y		800	12.7		65	1625		115	200	TLW
HES-8	y		800	12.7		70	1625	6:00+	0	0	A
HES-11	y		800	12.7		70	1625	6:30+	40	57	TLW
B		n		12.7	177	133	8100	5:27		667	65/35 H/POZ
B	y		40	12.7	163	122	6900	4:54	243	765	65/35 H/POZ
B		n		12.7	220	167	11050	3:03	233	1163	65/35 H/POZ
HES-8	y		1500	12.7		74	3870	3:52	226	250	A
HES-11	y		200	12.7	165	124	7281	3:52	594	1405	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		82	12.7	170	136	9000	4:58		309	65/35 H/POZ
A	y		82	12.7		80	100			544	A
B		n		12.7	126	100	3850	3:31			65/35 A/POZ
B		n		12.7		153	10496	7:12			25/75 H/POZ
B	y		122	12.7	91	80	924	4:00+	0	390	H
B	y		120	12.7	95	83	1300	6:00	220	421	H
HES-11	y		1100	12.7		70	2400	6:30+	119	202	TLW
A	y		250	12.7	115	97	3500	2:40	320	380	A
B	y		137	12.7	124	100	4044	5:50	172	427	H
B	y		137	12.7	119	98	3500	5:28			H
HES-11	y		107	12.7	128	101	4000	6:00+	844	1653	TLW
HES-11	y		1100	12.7		85	4700	4:40	346	694	TLW
HES-11	y		1100	12.7	116	100	4700	4:59	298	594	TLW
B		n		12.7	223	173	11250	3:58			65/35 H/POZ
B	y		122	12.7		115	6007	6:41	190	683	H
B		n		12.7	215	165	10800	3:19			65/35 H/POZ
B		n		12.7	224	175	12000	4:58	0	831	65/35 H/POZ
B		n		12.7	228	178	11800	2:42			65/35 H/POZ
B		n		12.7	188	142	9000	6:10	0	138	65/35 H/POZ
B		n		12.7	170	123	6810	3:14	231	686	65/35 H/POZ
A	y		210	12.7	140	104	4410	5:15	245	380	H
B	y		290	12.7	125	107	4906	2:28	200	379	65/35 A/POZ
HES-11	y		80	12.7	160	123	7600	4:17	293	1462	TLW
B	y		111	12.7		99	3730	7:07			H
B	y		1470	12.7		70	2600	6:46			A
B	y		250	12.7		80	1000	6:47			H
HES-7	y		45	12.7	202	154	11157	4:58			H
HES-11	y		80	12.7	175	134	8800	4:54	0	1447	TLW
B	y		34	12.7	194	148	12600	6:01	64	290	65/35 H/POZ
B		n		12.7	197	152	10650	4:01			65/35 H/POZ
B		n		12.7	230	182	12750	5:58	80	720	65/35 H/POZ
HES-11	y		354	12.7	130	106	5000	3:57			TLW
B		n		12.7	134	104	4500		177	330	65/35 A/POZ
B		n		12.7	150	113	5800	6:15	320	571	65/35 H/POZ
B	y		122	12.7	91	80	920	6:39	150	340	H
A	y		7612	12.7		82	14000	4:00+	80	210	H
HES-3	y		2920	12.7		65	5200	4:30	140	610	FLOSTOP I
A	y		3214	12.7		95	9400	5:00+	194	330	H
HES-11		n		12.7	203	156	11060	3:29	890	1160	TLW
HES-11		n		12.7	203	156	11060	2:45	1342	1414	TLW
A	y		210	12.7	132	103	4500	7:00+	400	450	H
B		n		12.7	214	158	9600	6:22	40	775	65/35 H/POZ
B		n		12.7	196	142	8350	4:20	440	1110	65/35 H/POZ
A	y		3125	12.7		70	7500	7:00+	70	220	H
B		n		12.7	270	224	14700	6:00+			65/35 H/POZ
B		n		12.7	284	234	14600	8:00+	660	800	65/35 H/POZ
HES-11	y		260	12.7	182	134	9620	2:38	1045	1147	TLW
B		n		12.7	220	170	11220	3:51	410	840	65/35 H/POZ
B		n		12.7	260	212	13750	7:50	0	620	65/35 H/POZ
F		n		12.7	230	192	12838	4:07	570	880	Micro-fine
B		n		12.7	212	157	9600	6:22	40	630	65/35 H/POZ
HES-3	y		3500	12.7		65	5475	3:15	FIRM	160	FLOSTOP I
B		n		12.7	293	245	15280	8:00+			65/35 H/POZ
A	y		3125	12.7		80	8400	5:00+	110	150	H
B		n		12.7	280	229	14360	5:26	815	1200	65/35 H/POZ
B		n		12.7	287	238	14800	6:30	679	790	65/35 H/POZ
B		n		12.7	273	221	13850	6:12	430	650	65/35 H/POZ
B		n		12.7	263	209	13089	6:22	590	810	65/35 H/POZ
B		n		12.7	238	190	13150	5:44	710	850	65/35 H/POZ
HES-11	y		40	12.7	207	159	11644	3:45	877	1584	TLW
B		n		12.7	305	260	16100	6:22	660	790	65/35 H/POZ
B		n		12.7	152	115	6000	4:39			65/35 H/POZ
B	y		34	12.7	194	148	12600	4:07	228	553	65/35 H/POZ
B		n		12.7	187	131	7168	2:12			HLC
HES-11	y		800	12.7		60	850	6:37	67	191	TLW
HES-11	y		120	12.7	160	120	6700	3:50	1000	1700	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		688	12.7	138	115	7100	4:10	121	224	65/35 H/POZ
B		n		12.7	220	170	11200	4:41			65/35 H/POZ
A	y		57	12.7	97	85	1500	3:00+	250	400	A
B		n		12.7	105	90	2100	6:00+	53	97	65/35 A/POZ
B		n		12.7		101	4300	2:37			65/35 A/POZ
B		n		12.7	122	99	3527	6:11	230	270	65/35 A/POZ
B		n		12.7	122	99	3527	5:21	265	330	65/35 A/POZ
B		n		12.7	186	140	8800	4:02			65/35 H/POZ
B		n		12.7	204	154	9750	5:40			65/35 H/POZ
B	y		35	12.7	206	158	10500	4:01	159	662	65/35 H/POZ
B		n		12.7	190	144	9200	4:40	0	1725	65/35 H/POZ
B		n		12.7		170	10000	6:19	0	982	65/35 H/POZ
HES-11	y		40	12.7	207	159	10800	3:52	0	1346	TLW
HES-11	y		170	12.7	145	106	4500	5:00+	875	950	TLW
HES-11	y		170	12.7	127	100	4900	5:21	394	825	TLW
B		n		12.7	200	152	10000	3:45	685		65/35 H/POZ
B		n		12.7	198	149	9450	5:00+			65/35 H/POZ
B		n		12.7	191	145	9300	6:00	0	100	65/35 H/POZ
B		n		12.7	221	172	11750	4:43			65/35 H/POZ
B		n		12.7	205	154	9600	2:45			65/35 H/POZ
B		n		12.7	130	101	4000	3:49	170	231	65/35 A/POZ
B	y		23	12.7		125	8865	7:00+		977	25/75 H/POZ
B		n		12.7	178	130	7500	4:12	370	790	65/35 H/POZ
B	y		10	12.7		119	5200	5:18	250	442	65/35 H/POZ
HES-11	y		260	12.7	182	134	9620	3:32	1617	1953	TLW
B		n		12.7	208	160	10700	6:31	0	1381	65/35 H/POZ
B	y		18	12.8	92	80	1000	5:17	170	345	65/35 A/POZ
B	y		22	12.8	113	95	3000	3:00+	247	688	65/35 A/POZ
HES-7	y		134	12.8	190	145	11139	4:09	312	521	H
B	y		134	12.8	190	145	11139	4:37	105	280	65/35 H/POZ
HES-11	y		295	12.8	121	98	3471	5:33	525	1040	TLW
HES-11	y		295	12.8	133	104	4450	4:54	840	1920	TLW
B		n		12.8	191	143	8900	3:03	600	1712	50/50 H/POZ
B		n		12.8	299	236	12900	3:45			65/35 H/POZ
HES-8	y		3944	12.8		70	3950	2:44	787	1682	A
B	y		16	12.8	90	80	800	3:00+	210		65/35 A/POZ
HES-11	y		760	12.8	138	113	6200	5:30	249	2055	TLW
B	y		18	12.8	92	80	1000	6:45	197	268	65/35 A/POZ
HES-11	y		760	12.8	138	114	7172	6:00	247	1345	TLW
B		n		12.8		80	2500	5:00+	139	290	65/35 A/POZ
B		n		12.8	110	93	2500	4:40	255	329	65/35 A/POZ
B		n		12.8	101	91	2500	5:14	128	282	65/35 A/POZ
B		n		12.8	111	93	2500	4:20			65/35 A/POZ
B	y		430	12.8	122	98	3500	6:00+			65/35 A/POZ
B		n		12.8		90	3000	6:00+	320	1818	65/35 A/POZ
B	y		18	12.8	116	96	3000	3:04	402	530	65/35 A/POZ
B		n		12.8	115	97	3500	3:30			65/35 A/POZ
B		n		12.8	115	97	3500	4:07			65/35 A/POZ
B		n		12.8	113	95	3000	3:18	237	412	65/35 A/POZ
B	y		40	12.8	206	158	10550	5:00+	259	1115	65/35 H/POZ
B	y		18	12.8	89	80	850	4:00+	230	290	65/35 A/POZ
B		n		12.8	205	157	10350	3:25			65/35 H/POZ
HES-11	y		120	12.8	190	153	12375	4:40	1079	1651	TLW
HES-3	y		6500	12.8		55	7950	4:42	0	150	A
HES-11	y		80	12.8	160	131	6200	2:40			TLW
B		n		12.8	100	87	1700	6:18			65/35 A/POZ
B		n		12.8	109	91	2250	5:05	201	389	65/35 A/POZ
B		n		12.8	215	164	10400	5:00			65/35 H/POZ
B	y		52	12.8	213	166	13035	2:15			H
B	y		52	12.8	213	166	13035	3:24	185	268	H
B	y		1470	12.8		80	5600	5:55			H
B	y		1470	12.8		80	5600	5:28			H
F		n		12.8	262	216	13000	3:30	1784	2023	Micro-fine
HES-11	y		760	12.8	138	114	7310	5:15	263	1229	TLW
HES-11		n		12.8	122	98	3500	3:31	753	1464	TLW
B		n		12.8	120	98	3500	3:57		250	65/35 A/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		12.8	206	159	10845	4:03	80	1657	65/35 H/POZ
B		n		12.8	134	104	4500	5:12	148	325	65/35 H/POZ
B	y		100	12.8	164	122	8200	4:10	257	669	65/35 H/POZ
B	y		100	12.8	172	130	9900	4:39	300	710	65/35 H/POZ
B		n		12.8	220	172	11800	4:30	0	1078	65/35 H/POZ
B		n		12.8	236	188	12995	7:20			65/35 H/POZ
B		n		12.8	223	173	11500	7:45			65/35 H/POZ
HES-11		n		12.8	145	119	5200	3:24	878	1279	TLW
B	y		200	12.8	129	103	5000	5:05			65/35 H/POZ
HES-11	y		470	12.8		105	4600	4:32	550	800	TLW
HES-11	y		1050	12.8		65	4500	7:00+	0	0	TLW
B		n		12.8	95	80	1000			226	65/35 H/POZ
A		n		12.8	0	75	6000	5:57	45	142	A
B	y		18	12.8	118	97	3200	4:30+	277	580	65/35 A/POZ
HES-7		n		12.8	218	170	11875	4:23	2020	3280	H
B	y		22	12.8	90	80	900	5:00+	190	250	65/35 A/POZ
B	y		18	12.8	92	80	1000	4:00+	180	250	65/35 A/POZ
B	y		22	12.8	116	96	3000	2:30	245	380	65/35 A/POZ
HES-11		n		12.8	155	126	6350	3:06	1170	1260	TLW
B	y		22	12.8	118	97	3200	3:30+	240	415	65/35 A/POZ
HES-7	y		189	12.8	132	103	4300	7:00+	126	260	H
B	y		62	12.8	214	187	13200	10:00+		0	H
B	y		432	12.8	165	124	9550	3:56	110	270	65/35 H/POZ
HES-11	y		68	12.8	245	198	15800	6:34	1022	1663	TLW
B		n		12.8	218	170	11875	5:30	450	580	65/35 H/POZ
B	y		1047	12.8	180	135	9100	4:05	440	530	H
HES-11	y		760	12.8		104	6750	4:00			TLW
A		n		12.8	0	75	6000	6:00+	0	68	A
A		n		12.8	0	65	8000	6:42	0	190	A
HES-7	y		470	12.8	145	114	6000	5:27	395	1211	TLW
HES-7	y		68	12.8	245	198	15800	7:25	325	434	H
HES-11	y		760	12.8	128	111	6090	2:48			TLW
B	y		365	12.8	139	107	8800	5:34	177	287	65/35 H/POZ
B	y		365	12.8	142	107	8800	6:00+	133	157	65/35 H/POZ
B		n		12.8	140	109	5400	5:38	207	362	65/35 H/POZ
B		n		12.8	169	128	7700	5:30+	144	167	65/35 H/POZ
B		n		12.8	180	136	8366	3:38	410	723	H
B		n		12.8	180	138	10300	5:23	90	336	65/35 H/POZ
HES-11		n		12.8	105	95	3100	4:28	381	880	TLW
HES-11		n		12.8	213	166	12100	7:15	0	1647	TLW
HES-11		n		12.8	213	166	12100		1432	1894	TLW
HES-11		n		12.8	145	119	5000	2:40	885	1695	TLW
HES-11	y		760	12.8	128	111	6090	4:45	170	390	TLW
B	y		113	12.8	185	139	9615	3:30	220	390	65/35 H/POZ
HES-7	y		1120	12.8	0	123	11393	4:00+	130	270	H
B	y		134	12.8	185	142	9779	3:46	140	340	65/35 H/POZ
B	y		134	12.8	185	142	9779	4:25	110	196	65/35 H/POZ
B	y		134	12.8	190	146	11410	3:32	110	190	65/35 H/POZ
B	y		182	12.8	190	156	9700	3:17	510	660	H
B	y		60	12.8	290	249	17500	7:10	605		HTLD
B	y		60	12.8	290	249	17500	7:20	240	400	HTLD
HES-7	y		152	12.8	165	115	8700	4:00+			H
HES-7	y		225	12.8	161	121	7233	5:11	270	460	H
HES-11	y		107	12.8	210	163	12227	4:31	1150	1640	TLW
HES-11	y		48	12.8	139	106	5200	4:30+	750	1570	TLW
B	y		50	12.9	310	255	16000	8:00+			HTLD
B	y		200	12.9		140	9100	6:28			H
B	y		1100	12.9	135	104	4500	4:36	208	464	65/35 H/POZ
B	y		350	12.9	255	206	14600	5:28	487	731	HTLD
B		n		12.9	210	163	11750	6:26	0	248	H
B		n		12.9	315	265	15815	4:24			HTLD
B		n		12.9	275	226	14500	5:43	765	1950	HTLD
B		n		12.9	290	237	14500	5:00+			HTLD
B	y		35	12.9		175	13010	3:44	52	296	H
B		n		12.9	270	223	14500	5:20	680	1220	HTLD
B		n		12.9	275	226	14400	4:33	530	600	HTLD

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		12.9	275	226	14400	1:55			HTLD
B		n		12.9	260	210	13520	4:22	620	880	HTLD
B		n		12.9	275	226	14430	4:46	650	760	HTLD
B		n		12.9	145	106	4500	5:00+	115	270	60/40 A/POZ
HES-1	y		3214	12.9		95	9037	6:36	390	455	SLAG
B	y		50	12.9	240	196	16000	7:00+	490	790	HTLD
B		n		12.9	223	183	11300	3:37	348	553	H
B		n		13.0		96	3500		86	168	65/35 A/POZ
B		n		13.0		96	3500		71	81	25/75 A/POZ
B		n		13.0	225	176	12000	4:40	780	1225	25/75 H/POZ
HES-11		n		13.0	111	98	2500	2:29	523	848	TLW
B		n		13.0	230	167	10000	4:23	400	940	65/35 H/POZ
B		n		13.0	230	166	9855	4:20			65/35 H/POZ
HES-11		n		13.0	172	125	6942	5:45	1865	2362	TLW
A		n		13.0	115	100	3000		260	442	A
B	y		40	13.0	175	133	8560	5:22	0	418	H
HES-11	y		40	13.0	210	176	12300	3:15	1724	1796	TLW
HES-11		n		13.0	100	91	1500	2:56	397	850	TLW
HES-11		n		13.0	206	158	10500	4:18	611	694	TLW
B		n		13.0	235	187	12850	5:40	1156	1670	65/35 H/POZ
HES-11		n		13.0	95	80	1000	4:00+	131	301	TLW
B		n		13.0	204	156	10321	5:53	310	975	65/35 H/POZ
B		n		13.0	224	175	12019	4:19	980	1080	65/35 H/POZ
HES-11		n		13.0	222	173	11800	3:54			2/1 TLW/H
HES-11		n		13.0	100	91	1700	4:00+	595	858	TLW
HES-11		n		13.0		170	12423	6:18	1408	1954	2/1 TLW/H
HES-11		n		13.0	135	112	4600	2:37	1240	2034	TLW
B	y		102	13.0	187	133	10095	3:14	430	720	H
B	y		77	13.0	160	115	5800	3:33	188	838	65/35 H/POZ
HES-11	y		15	13.0	165	134	7100	4:03	0	1249	TLW
HES-11	y		15	13.0	128	102	4200	3:00+	203	634	TLW
HES-11		n		13.0	230	182	12900	6:00+			2/1 TLW/H
HES-11		n		13.0	215	168	12720	5:50	840	1125	2/1 TLW/H
HES-11		n		13.0	222	175	12913	5:40	1020	3483	2/1 TLW/H
HES-11		n		13.0	178	140	9400	6:30	707	1691	2/1 TLW/H
HES-11		n		13.0	230	185	13945	4:07	1342	2526	2/1 TLW/H
B		n		13.0	215	168	12720	5:25	385	816	65/35 H/POZ
B		n		13.0	185	142	9500	5:42	0	641	65/35 H/POZ
B		n		13.0	250	186	11300	3:39	690	870	65/35 H/POZ
B		n		13.0	134	103	4350	4:45	440	510	A
B		n		13.0	142	108	5000	2:24			65/35 A/POZ
HES-3		n		13.0		50	6600	8:20			A
B		n		13.0	215	166	11150	5:26	1686	1730	50/50 H/POZ
B		n		13.0	329	292	18300	8:00			HTLD
B		n		13.0	345	314	19500	7:02	---	113	HTLD
B		n		13.0	345	314	19500	6:52	315	1563	HTLD
B		n		13.0		207	13000	15:00+	350	390	HTLD
B		n		13.0		207	13000	14:00+	0	220	HTLD
HES-11		n		13.0	215	167	11780	4:51	747	1068	2/1 TLW/H
HES-7	y		3800	13.0		120	9660	6:30+	0	375	H
B	y		84	13.0	300	244	16316	5:44			65/35 H/POZ
B	y		84	13.0	300	244	16316	3:52	600	776	65/35 H/POZ
HES-11	y		240	13.0	141	116	4700	2:58	1096	1737	TLW
B	y		43	13.0	219	170	13067	4:05	1710	1980	50/50 H/POZ
HES-7	y		27	13.0	216	169	12800	6:02	543	676	H
HES-11	y		55	13.0	98	85	1500			711	TLW
HES-11	y		55	13.0	98	85	1500	2:02	393	825	TLW
HES-11	y		60	13.0	183	138	8600	4:03	420	1550	TLW
B	y		85	13.0	207	159	10660	6:30+	370	870	65/35 H/POZ
B	y		85	13.0	207	159	10660	3:19	120	310	65/35 H/POZ
B	y		80	13.0	200	152	10204	5:56	0	571	65/35 H/POZ
	y		10	13.0	215	167	11200		467	553	H
B	y		10	13.0	215	167	11200	7:08	0	1173	65/35 H/POZ
B	y		110	13.0	206	158	10500	3:04	767	1011	50/50 H/POZ
HES-11	y		120	13.0	190	157	13048	5:26	0	1814	TLW
HES-11	y		120	13.0	211	167	13048	5:20	0	855	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11	y		120	13.0	165	137	10600	5:13	26	2211	TLW
HES-11	y		120	13.0		240	17500	9:47			TLW
HES-11	y		120	13.0		240	17500	8:15	80	100	TLW
HES-7	y		130	13.0	204	156	13038	5:04	450		H
HES-7	y		130	13.0		147	9549	6:00			H
HES-7	y		137	13.0		132	9814	5:43	920		H
HES-7	y		137	13.0		132	8000	6:27	260	420	H
HES-11	y		147	13.0	92	80	1000	6:00+	219	632	TLW
B	y		170	13.0	160	127	9917	5:09	89	628	65/35 H/POZ
B	y		170	13.0	160	130	8641	4:29	66	358	65/35 H/POZ
HES-7	y		180	13.0	193	146	9925	3:44	316	340	H
B	y		180	13.0	193	146	9925	3:04	305	535	50/50 H/POZ
HES-11	y		180	13.0	143	115	7200	3:26	1313	2440	TLW
HES-11	y		180	13.0	143	115	7200	3:29	1050	1730	TLW
B	y		210	13.0	148	112	5650	4:44	178	263	65/35 H/POZ
F	y		200	13.0	160	160	8100	0:18			Micro-fine
HES-11	y		250	13.0	133	104	6872	7:20	673	1549	TLW
HES-11	y		250	13.0	134	104	5664	4:27	725	1199	TLW
HES-11	y		250	13.0	136	105	6085	4:18	342	654	TLW
HES-11	y		250	13.0	134	105	6485	4:45	474	1191	TLW
HES-11	y		250	13.0	140	109	7700	5:45	539	1250	TLW
HES-11	y		250	13.0	148	112	7475	3:38	309	1324	TLW
HES-11	y		250	13.0	134	105	6485	4:30	746	1235	TLW
HES-11	y		1491	13.0	143	119	7252	4:57	361	1465	TLW
MICROFINE	y		1800	13.0		74	3870	3:21			A
HES-11	y		220	13.0	120	105	5300	7:14	430	1170	TLW
HES-11	y		200	13.0	0	80	50		150	270	TLW
B	y		645	13.0		111	6500	6:30+	60	135	50/50 H/POZ
HES-11	y		700	13.0	142	107	4800	4:30	466	1200	TLW
B	y		630	13.0	141	109	5144	4:20	222	290	H
A	y		557	13.0	141	109	5144	6:19	140	180	H
B	y		557	13.0	141	109	5148	4:40	200	410	H
HES-3	y		1195	13.0		80	2770	2:49			FLOSTOP I
HES-7	y		1756	13.0		120	12183	4:54	430	616	H
HES-11	y		760	13.0		104	6750	6:20		300	TLW
B	y		2046	13.0		80	8537			187	65/35 A/POZ
A	y		340	13.0	130	106	5000	6:00+	310	1250	H
B	y		220	13.0	178	134	14596	4:00	404	551	65/35 H/POZ
HES-7	y		600	13.0	156	118	7400	6:00+	315	407	H
HES-7	y		600	13.0	156	118	7400	6:30+	862	1246	H
HES-7	y		2000	13.0	0	82	12429	10:00+	0	188	H
B	y		220	13.0	159	120	10907	3:14			65/35 H/POZ
A	y		300	13.0	114	97	3525	5:00+	170	350	H
HES-3	y		1611	13.0		80	3700	2:50			A
HES-3	y		1611	13.0		80	3700	3:55	588		A
HES-3	y		1611	13.0		80	3700	1:36			A
HES-3	y		1611	13.0		80	3700	2:22	1244	1671	A
HES-3	y		1611	13.0		80	3700	2:35			A
B	y		688	13.0	138	117	6950	2:45	208	851	65/35 H/POZ
HES-7	y		1419	13.0		95	6600	6:47	268	537	A
HES-7	y		1419	13.0		140	9744	6:40	309	554	A
HES-7	y		1419	13.0		128	8900	6:15	224	530	A
HES-11	y		2200	13.0		82	4500	5:10	130	180	TLW
HES-7	y		3393	13.0	0	75	8000	5:00+	0	74	A
HES-7	y		5100	13.0	0	90	13000	5:57	174	240	H
B		n		13.0	285	236	14830	7:00+	0	95	HFC-12.5
HES-11		n		13.0	190	152	7820	2:19	2084	2338	TLW
B		n		13.0	200	150	9400	5:42	425	667	65/35 H/POZ
B	y		3000	13.0	0	80	8720	3:49	0	172	H
A	y		1785	13.0		45	2975	4:00+	0	108	A
HES-7	y		1968	13.0		101	9600	5:13	230	351	H
HES-3	y		517	13.0		70	1109	2:28	520	920	FLOSTOP I
HES-3	y		517	13.0		86	1695	1:31	1590	2790	FLOSTOP I
HES-3	y		517	13.0		80	1109	2:35	700	1410	FLOSTOP I
HES-7	y		2840	13.0	0	80	8720	12:00+	102	386	H
HES-11	y		2161	13.0		93	7400	3:38	499	1371	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-1	y		833	13.0		80	2400	4:45	1052	1226	SLAG
HES-7	y		1965	13.0		71	5100	8:00+	FIRM	120	H
B	y		2025	13.0	0	75	6400	5:33	100	310	H
HES-7	y		2025	13.0	0	75	6400	5:30+	60	120	H
HES-7	y		2025	13.0		79	5700	10:00+	32	120	H
HES-7	y		3329	13.0		80	8000	4:00+	230	260	H
HES-7	y		3329	13.0		80	9020	6:00+	60	230	H
A	y		3329	13.0		80	9000	4:00+	70	200	A
B	y		3325	13.0		104	9100	3:28	210	340	65/35 A/POZ
HES-11	y		4243	13.0		150	16000	2:30			2/1 TLW/H
HES-11	y		4243	13.0		150	16000	4:12	518	1418	2/1 TLW/H
HES-7	y		5467	13.0	0	86	10000	5:30+	170	250	H
HES-7	y		5467	13.0	0	75	8400	7:00+	150	290	A
FOAMED	y		5467	13.0	0	75	8400	6:30+			A
B		n		13.0	250	201	13050	3:34	286	712	25/75 H/POZ
B		n		13.0	250	201	13050	5:45	395	510	25/75 H/POZ
HES-7	y		45	13.0	198	148	9600	5:07	260	360	H
B	y		50	13.0	220	164	10100	6:36	272	1318	65/35 H/POZ
HES-7	y		50	13.0	166	121	7291	5:00+	351	503	H
B	y		51	13.0	159	133	8500	2:37	370	490	H
B	y		55	13.0		150	11913	4:00+	310	460	50/50 H/POZ
B	y		40	13.0	146	111	5500	5:44	110	120	85/15 H/POZ
B	y		40	13.0	189	143	9100	4:00+		260	65/35 H/POZ
B	y		280	13.0	0	132	8929	2:08			65/35 H/POZ
HES-7	y		34	13.0	176	132	8000	4:00+	140	290	H
HES-7	y		60	13.0	176	132	8539	4:00+	289	760	H
HES-7	y		293	13.0	131	100	4200	5:00+	185	290	H
HES-11		n		13.0		155	12131	4:04	1227	1696	2/1 TLW/H
B		n		13.0	230	181	12500	6:34	0	51	65/35 H/POZ
B		n		13.0	131	102	4100	4:47	110	220	A
HES-11		n		13.0	130	109	4100	3:15	660	1010	TLW
HES-11		n		13.0	230	178	11500	6:00	624	967	2/1 TLW/H
B		n		13.0	197	147	9000	4:35	0	560	65/35 H/POZ
B		n		13.0	230	180	12000	4:49			65/35 H/POZ
B		n		13.0	205	160	10000	4:52	0	886	25/75 A/POZ
B		n		13.0	205	160	10000	5:09	0	979	25/75 A/POZ
B		n		13.0	205	160	10000	4:38	49	1146	25/75 H/POZ
POZMIX		n		13.0	205	160	10000	5:09	645	719	Pozmix 140
B		n		13.0	205	160	10000	4:06	40	1360	25/75 H/POZ
HES-11		n		13.0	178	145	8910	5:39	1153	1516	2/1 TLW/H
B		n		13.0	95	83	1275	7:00+	0	138	65/35 H/POZ
HES-11		n		13.0	228	177	11400	6:38	387	1655	2/1 TLW/H
B		n		13.0	210	162	10900	4:27			50/50 H/POZ
B		n		13.0	261	213	14600	5:13	780	920	65/35 H/POZ
B		n		13.0	220	176	13550	5:15	1340	1700	50/50 H/POZ
HES-11		n		13.0		215	15100	5:50	784	1214	2/1 TLW/H
HES-11		n		13.0		150	9650	5:15	1037	1764	2/1 TLW/H
HES-11		n		13.0		145	10235	5:34			2/1 TLW/H
HES-11		n		13.0		155	10800	5:30+	380	1273	3/2 TLW/H
HES-11		n		13.0	200	153	10500	5:30+	736	1946	2/1 TLW/H
B		n		13.0		136	8350	2:58	454	674	H
B	y		36	13.0		145	10374	7:00	112	970	H
A	y		210	13.0	102	88	2112	7:23	300	570	A
B	y		210	13.0	101	87	1750	5:30+	40	240	50/50 H/POZ
B	y		210	13.0	101	87	1750	5:00+	50	160	50/50 H/POZ
B	y		300	13.0	169	127	7400	4:30+	390	780	50/50 H/POZ
HES-7	y		250	13.0	0	141	9733	5:47	425	575	H
HES-7	y		40	13.0		141	8950	5:20	366	485	H
HES-7	y		40	13.0		112	5545	8:20	395	520	H
B	y		40	13.0	115	96	3240	5:21	220	280	H
B	y		20	13.0	166	141	10200	3:32	104	641	65/35 H/POZ
HES-11	y		40	13.0	180	136	8500	4:20	545	1090	TLW
HES-11	y		82	13.0		115	3500	2:52	300	564	TLW
B	y		58	13.0	194	147	9500	7:55	105	768	65/35 H/POZ
HES-7	y		250	13.0	0	141	9733	5:23			H
A	y		154	13.0	155	112	5400	3:54	253	370	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B		n		13.0	241	201	13428	4:15	297	536	H
B		n		13.0	238	199	13210	3:40	625	855	H
B		n		13.0	215	166	11000	2:58			65/35 H/POZ
B		n		13.0	140	115	4490	3:42	460	630	H
HES-1	y		2940	13.0		94	11770	4:06	290	338	SLAG
HES-1	y		2940	13.0		94	11770	4:30	672	726	SLAG
HES-7	y		6000	13.0	0	84	14000	7:00+	84	213	H
HES-7	y		2500	13.0	0	113	10200	3:21	244	346	H
HES-7	y		3500	13.0	0	120	11650	3:30+	162	270	H
HES-7	y		3500	13.0	0	135	14650	4:00+	210	592	H
HES-7	y		3500	13.0	0	135	14650	2:30	0	94	H
HES-7	y		3600	13.0	0	125	12500	4:38	280	290	H
HES-7	y		3600	13.0	0	125	12500	5:56			H
HES-7	y		3600	13.0	0	140	14600	6:30+			H
HES-7	y		5000	13.0	0	85	9500	5:00+	204	312	H
HES-7	y		5000	13.0	0	105	11557	4:32	161	329	H
HES-7	y		2407	13.0	0	94	8500	6:00+	90	290	H
HES-7	y		2320	13.0		82	6500	6:15+	118	259	H
HES-11	y		1334	13.0		75	4500	5:00+	225	410	TLW
HES-7	y		2559	13.0	77	70	5200	7:00+	0	131	H
HES-7	y		2559	13.0	77	70	5200	9:23		125	A
HES-7	y		3210	13.0		73	6300	15:57	0	160	H
HES-7	y		3257	13.0		77	7500	10:00+	45	140	H
HES-1	y		3000	13.0		100	11875	4:55	0	410	SLAG
HES-3	y		3944	13.0		70	5650	1:47	800	1720	A
HES-7	y		3875	13.0	0	73	6435	6:00+	30	60	A
HES-7	y		3875	13.0	0	75	9100	5:00+	90	235	H
HES-7	y		3845	13.0	0	87	10383	5:30+	267	380	H
HES-7	y		4000	13.0	0	75	9000	6:30+	85	220	A
HES-7	y		4000	13.0	0	82	9000	6:30+	156	271	A
HES-7	y		3982	13.0	0	75	8200	5:00+	120	210	H
HES-7	y		3982	13.0	0	70	7020	6:00+	FIRM	870	H
HES-7	y		84	13.0	0	135	8000	5:47	382	509	H
HES-11	y		50	13.0	230	178	11500	9:00		1197	TLW
HES-11	y		60	13.0	106	90	2000	5:00+	250	500	TLW
HES-11	y		52	13.0	0	255	17000	7:00	943	1347	TLW
B	y		55	13.0		203	13400	10:00+			HTLD
B	y		85	13.0		135	8000	5:13	0	860	H
HES-7	y		85	13.0	145	109	5000	8:00+	510	967	H
A	y		158	13.0	93	80	1000		728	1412	A
B	y		150	13.0	233	167	9500	4:47	62	236	65/35 H/POZ
B		n		13.0	172	127	7300	5:00	226	827	65/35 H/POZ
HES-11		n		13.0	150	113	5800	5:00+	932	2318	2/1 TLW/H
HES-11		n		13.0	150	113	5800	5:00+	389	793	2/1 TLW/H
B		n		13.0		80	50			88	50/50 A/POZ
B		n		13.0		80	50			105	50/50 A/POZ
B		n		13.0	221	159	9400	8:00+	290	730	65/35 H/POZ
B		n		13.0	206	146	8700	4:25	470	710	65/35 H/POZ
HES-7		n		13.0		135	8300	7:07	400	525	H
B		n		13.0	300	253	15800	5:17	0	1465	HTLD
B		n		13.0	116	96	3000	6:00+		340	65/35 A/POZ
HES-11		n		13.0	225	180	11600	4:06	1077	2535	2/1 TLW/H
B		n		13.0	118	96	3000	3:58	267	515	A
B		n		13.0	124	98	3500	4:35	262	461	A
HES-11		n		13.0	186	140	8810	3:00	1226	1682	TLW
B		n		13.0	200	150	9500	3:36			65/35 H/POZ
B	y		350	13.0	135	103	5250	3:00+	209	761	65/35 A/POZ
B	y		240	13.0	174	130	9600	5:30+	0	0	50/50 H/POZ
B	y		240	13.0	177	133	9585	6:30+		0	50/50 H/POZ
HES-11	y		21	13.0	198	149	10298	2:30	1012	1460	2/1 TLW/H
HES-11	y		21	13.0	198	149	10298	3:10	802	1609	2/1 TLW/H
HES-11	y		16	13.0	205	157	10400	3:05	1240	1420	2/1 TLW/H
HES-11	y		18	13.0	210	163	11820	3:40	779	1890	2/1 TLW/H
HES-11	y		18	13.0	201	154	11028	3:17	1090	2060	2/1 TLW/H
B	y		63	13.0	252	205	15100	4:58	260	1110	65/35 H/POZ
B	y		95	13.0	194	147	9514	4:47	242	1250	65/35 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		95	13.0	185	139	8550	4:45	0	1230	65/35 H/POZ
B	y		102	13.0	242	194	13400	4:40	768	935	HLC
B	y		102	13.0	242	194	13400	8:11	870	1120	65/35 H/POZ
HES-7	y		124	13.0		146	9450	4:00	230	340	H
HES-7	y		50	13.0		153	10400		310	360	H
HES-7	y		51	13.0	165	123	8360	5:00+	1060	1330	H
HES-7	y		51	13.0	145	111	5500	5:00+	443	1000	H
HES-7	y		51	13.0	145	110	5500	5:00+	483	1620	H
HES-7	y		51	13.0	190	143	9511	5:00+	1339	3577	H
HES-7	y		51	13.0	155	126	6246	3:00+	310	520	H
HES-7	y		70	13.0	164	123	7000	5:00+	275	710	H
HES-7	y		70	13.0	196	149	10200	3:48	431	508	H
HES-7	y		70	13.0	196	149	10200	3:33	494	520	H
HES-7	y		70	13.0	195	148	10160	3:50	349	1100	H
HES-7	y		70	13.0	145	111	6100	5:00+	609	833	H
A	y		186	13.0	113	96	3809	5:00+	230	403	H
DIACEL-M	y		325	13.0	191	158	10060	4:00	415	640	H
B	y		200	13.0	113	95	4700	4:00+	250	460	H
HES-11	y		200	13.0		107	4950	7:15			TLW
HES-7	y		20	13.0	208	162	12764		330	380	H
HES-7	y		20	13.0	208	162	12764	4:58	260	320	H
B	y		21	13.0	212	164	11000	3:46	60	460	50/50 H/POZ
B	y		21	13.0	220	172	12250	3:25	240	1290	50/50 H/POZ
B	y		34	13.0	208	163	12400	3:46	1380	1800	50/50 H/POZ
B	y		48	13.0	220	163	10042	4:08	817	1944	65/35 H/POZ
HES-7	y		65	13.0		159	10700	10:00+			H
HES-7	y		65	13.0		169	11562	7:37	475	552	H
HES-7	y		60	13.0		174	11980	5:16			H
HES-11	y		184	13.0	110	93	2750	5:25	453	905	2/1 TLW/H
HES-11	y		235	13.0	118	97	3180	5:30+		1235	TLW
HES-11	y		235	13.0	118	97	3180	6:08		904	TLW
B	y		235	13.0	190	152	11025	4:38	65	645	65/35 H/POZ
HES-11	y		280	13.0	140	107	5000	5:44	545	1312	TLW
B	y		26	13.0	236	188	14358	4:55	512	2110	50/50 H/POZ
B	y		26	13.0	128	101	4000	5:00+	335	700	50/50 A/POZ
B	y		26	13.0	220	172	11700	2:32	600	706	50/50 H/POZ
B	y		26	13.0	220	172	11700	3:02	920	1420	50/50 H/POZ
B	y		26	13.0	220	172	11700	4:20	1080	1550	50/50 H/POZ
HES-7	y		160	13.0	0	218	16309	6:10	420	600	H
B	y		181	13.0	122	100	4000	3:17	320	415	H
B	y		181	13.0	96	86	1650	6:10	220	355	H
HES-11	y		70	13.0		85	525	2:16	320	470	TLW
B	y		70	13.0	268	215	17000	6:54	372	411	HTLD
HES-7	y		70	13.0		209	15110	8:29	295	435	H
B	y		60	13.0		106	4850	7:04			H
B	y		280	13.0	194	147	9500	3:42	188	420	65/35 H/POZ
A	y		150	13.0	134	104	4500	5:18	232	562	H
HES-11	y		280	13.0	139	105	5550	4:30	915	1710	TLW
HES-11	y		280	13.0		80	1619	6:00+	430	705	TLW
HES-11	y		280	13.0	139	105	5550	4:30	915	1710	TLW
HES-7	y		447	13.0		136	3500	4:55	267	470	H
HES-11	y		64	13.0	242	195	14978	5:45			TLW
HES-11	y		64	13.0	242	195	14978	6:10			TLW
HES-11	y		64	13.0	128	101	4000			550	TLW
HES-7	y		64	13.0		161	11745	5:48	470	540	H
B	y		64	13.0		174	12309	8:12	677	1040	H
HES-11	y		64	13.0	242	195	14978	5:55	990	1050	TLW
HES-11	y		64	13.0	212	167	12680	8:06	0	1385	TLW
B	y		64	13.0	0	143	12180	3:43	160	450	H
HES-11	y		64	13.0	242	195	14978		1153	2170	TLW
B	y		64	13.0	0	176	13145	4:02	233	780	H
B	y		63	13.0	157	120	7716	3:54	647	820	H
B	y		60	13.0		80	1000	5:36			H
B		n		13.0	205	156	10200	4:09	58	652	65/35 H/POZ
B		n		13.0	217	180	11760	3:03	0	380	H
B		n		13.0	219	168	10890	4:52	1359	1990	50/50 H/POZ

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
HES-11		n		13.0		150	10000	5:49	1296	1464	2/1 TLW/H
B		n		13.0	230	167	10000	6:30+	740	1320	65/35 H/POZ
HES-7	y		25	13.0	152	115	6080	5:00+	236	522	H
HES-7	y		25	13.0	150	114	6050	5:00+	467	1774	H
B		n		13.0	122	98	3500	2:00			A
HES-11	y		60	13.0	193	145	8790	5:30+			2/1 TLW/H
B	y		60	13.0	171	128	7689	3:10			65/35 H/POZ
B	y		60	13.0		132	8000	4:26	400	1191	65/35 H/POZ
HES-11	y		60	13.0		132	8000	3:53	583	1636	2/1 TLW/H
B	y		60	13.0	215	157	9650	4:34	170	580	65/35 H/POZ
B		n		13.0	165	125	7300	3:12			65/35 H/POZ
B		n		13.0	207	159	10550	2:58	130	570	65/35 H/POZ
B		n		13.0	188	142	9000	3:28	139	1064	65/35 H/POZ
B		n		13.0	219	171	11600	3:47			65/35 H/POZ
HES-7	y		127	13.0	0	155	10300	4:23	243	322	H
B	y		90	13.0	184	147	12438	5:58	0	297	65/35 H/POZ
HES-7	y		127	13.0	0	155	11594	4:30	0	700	H
HES-7	y		127	13.0	0	175	13355	5:33	160	430	H
B	y		190	13.0	166	128	10618	5:08	185	900	65/35 H/POZ
B	y		350	13.0	140	119	8625	5:48	455	556	65/35 H/POZ
B	y		42	13.0		150	9700	5:41	131	847	65/35 H/POZ
B	y		360	13.0	160	119	9350	6:01	290	1000	65/35 H/POZ
HES-11	y		360	13.0	169	131	8300	3:39			2/1 TLW/H
HES-11		n		13.0	190	143	8950	5:28	835	3471	2/1 TLW/H
HES-11		n		13.0	190	145	9050	5:59	1070	1811	2/1 TLW/H
HES-11		n		13.0	190	143	8975	4:00	1531	1778	2/1 TLW/H
B	y		120	13.0		132	7800	5:05			H
B	y		300	13.0		135	8100	7:51			H
B	y		300	13.0	174	134	10800	5:30+	400	2800	50/50 H/POZ
HES-7	y		2526	13.0	0	85	9200	5:25+	100	240	H
HES-1	y		3214	13.0		95	9400	4:42	440	560	SLAG
HES-3	y		3200	13.0		70	5200	2:32			FLOSTOP I
HES-11	y		3236	13.0		110	9908	2:40	540	870	TLW
B	y		40	13.0	206	151	9120	4:00+	1190	2800	50/50 H/POZ
B	y		40	13.0	206	151	9120	2:34	1090	1245	50/50 H/POZ
B	y		40	13.0	206	151	9120	3:51	1025	1225	50/50 H/POZ
HES-7	y		28	13.0		177	11500	11:03			H
B	y		60	13.0	224	162	11108	3:30	745	820	50/50 H/POZ
B	y		60	13.0	190	145	11108	4:13	600	900	50/50 H/POZ
B	y		59	13.0	205	155	10000	4:20	190	261	H
B	y		79	13.0	91	80	1000	4:00+	90	270	50/50 H/POZ
B	y		50	13.0	200	153	10350	8:30+			65/35 H/POZ
HES-7	y		153	13.0	170	125	8890	3:00+	392	670	H
HES-11	y		176	13.0	202	154	11035	3:40	1140	2520	TLW
A	y		174	13.0	117	99	6600	4:00+	300	380	H
A	y		174	13.0	96	87	3000	3:00+	188	375	H
HES-11	y		185	13.0	155	115	12345		920	1180	TLW
HES-11	y		185	13.0	155	115	12345	4:40	1070	1515	TLW
HES-11	y		167	13.0	245	198	14600	5:20	570	729	1/1 TLW/H
B	y		260	13.0	162	122	7950	3:17			H
HES-11		n		13.0	249	201	13350	5:16	1197	1800	2/1 TLW/H
HES-11		n		13.0	200	153	10150	6:30+			2/1 TLW/H
HES-11		n		13.0	208	160	10730	5:18	774	1602	2/1 TLW/H
HES-11		n		13.0	200	153	10150		234	1196	2/1 TLW/H
HES-11	y		225	13.0	192	154	11700	4:36	681	1312	TLW
HES-11	y		225	13.0	207	166	13380	6:08	820	1645	TLW
B	y		245	13.0	212	176	12000	2:55	790	840	H
HES-11	y		225	13.0	210	169	14000	5:20	990	1782	TLW
HES-7	y		225	13.0	160	136	9975	5:08		400	H
HES-11	y		225	13.0	149	123	6716	5:26	1204	1448	TLW
HES-11	y		258	13.0		172	11400	4:27	0	2368	TLW
HES-11	y		258	13.0	233	184	12615	4:42	1161	1455	TLW
HES-11	y		258	13.0		144	11520	4:31	400	2182	TLW
HES-11	y		258	13.0		143	10976	5:39	0	1361	TLW
HES-11	y		258	13.0		185	14550	4:38	547	1316	TLW
HES-11	y		258	13.0	244	196	13473	5:52	1395	1506	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
	Yes	No							12 hr	24 hr	
B	y		210	13.0		182	12750	8:00+			H
B	y		210	13.0		182	12750	7:03			H
B	y		210	13.0		182	12750	1:07			H
B	y		210	13.0		181	12602	6:11			H
B	y		410	13.0	280	236	16000	6:40	366	481	HTLD
B	y		50	13.0		158	12422	6:16	0	909	H
HES-7	y		250	13.0		181	12700	9:51	380	550	H
B		n		13.0	225	186	11900	4:56	330	818	H
B		n		13.0	170	127	7496	5:43	280	667	50/50 H/POZ
A	y		150	13.0		80	1050	4:00+	124	328	H
HES-11	y		150	13.0		80	1050	4:00+	215	314	TLW
B		n		13.0	230	178	12000	4:42	970	1240	65/35 H/POZ
B		n		13.0	165	125	7100	5:23	430	950	65/35 H/POZ
HES-11		n		13.0		350	1400	2:04	135	220	TLW
B		n		13.0	223	174	12000	4:05	747	1545	50/50 H/POZ
HES-11		n		13.0		380	1130	2:08	160	200	TLW

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Foamed Slurries

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	Base Slurry Density	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Temp for Comp Str (°F)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
Yes	No										12 hr	24 hr	
Foamed HES-8	y		113	7.0	15.2	180	148	8900	180		SET	85	A
Foamed HES-8	y		3800	10.0	15.1		65	5300	54		40	200	A
Foamed HES-8	y		3800	10.0	15.1		75	5450	95		630	730	A
Foamed HES-8	y		3800	10.0	15.5		68	6030	75		50	290	A
Foamed HES-8	y		3800	10.0	15.5		68	6030	61		32	110	A
Foamed HES-8	y		3800	10.0	15.5		65	5450	73		140	370	A
Foamed HES-8	y		3800	10.0	15.5		65	5450	54		FIRM	160	A
Foamed HES-8	y		1646	10.5	15.0		80	3330	60		0	76	A
Foamed HES-8	y		3778	10.5	15.2		70	6100	70		150	440	A
Foamed HES-8	y		6600	10.5	15.1		65	7200	55		70	230	A
Foamed HES-8	y		3800	10.5	15.1		70	7000	70		380	520	A
Foamed HES-8	y		3800	10.5	15.1		65	5300	54		50	220	A
Foamed HES-8	y		3800	10.5	15.1		90	7000	100		450	670	A
Foamed HES-8	y			10.5	15.2		75	6000	65		200	312	A
Foamed HES-8	y			10.5	15.2		75	6000	65		FIRM	FIRM	A
Foamed HES-8	y		3800	10.5	15.1		73	7200	76		FIRM	390	A
Foamed HES-8	y		3800	10.5	16.2		90	7000	100		50	270	A
Foamed HES-8	y		3800	10.5	15.1		90	7000	100		480	660	A
Foamed HES-8	y		1420	10.5	15.4		65	2500	57		30	110	A
Foamed HES-1	y		1420	10.5	15.4		65	3000	60		40	125	A
Foamed HES-8	y		3800	10.5	15.5		73	7200	69		136	350	A
Foamed HES-8	y		3800	10.5	15.5		73	7000	73		70	160	A
Foamed HES-8	y		3800	10.5	15.5		90	7000	100		430	450	A
Foamed HES-8	y		3800	10.5	15.5	0	73	7200	69		110	270	A
Foamed HES-8	y		3800	10.5	15.0	0	64	7337	54		0	90	A
Foamed HES-8	y			10.5	15.4		75	6000	65		110	170	A
Foamed HES-8	y		3800	10.5	15.0	0	64	7281	72		140	360	A
Foamed HES-8	y		3800	10.5	15.5	0	73	7325	64		105	360	A
Foamed HES-8	y		2049	10.8	15.6		65	3900	65		30	280	A
Foamed HES-8	y		2100	10.8	15.6		65	3900	65		40	250	A
Foamed HES-8	y		3480	10.8	17.3	0	121	12638	150		90	135	H
Foamed HES-8	y		3153	11.0	15.2		70	5000	50		0	140	A
Foamed HES-8	y		1968	11.0	15.1		65	3150	50		0	120	A
Foamed HES-8	y			11.0	14.5		70	6880	70		190	310	SLAG
Foamed HES-8	y			11.0	15.2		55	5000	55		180	180	A
Foamed HES-8	y		3150	11.0	15.2	0	65	4330	50		180	650	A
Foamed HES-8	y		3150	11.0	15.1	0	65	4330	50		280	340	A
Foamed HES-8	y		3778	11.0	15.2		70	6100	70		130	430	A
Foamed HES-8	y		3778	11.0	15.2		70	6100	70		180	500	A
Foamed HES-8	y		2841	11.0	15.1		65	3850	47		80	240	A
Foamed HES-8	y		3800	11.0	15.1		65	5300	54		60	230	A
Foamed HES-8	y		3900	11.0	15.2		70	5820	50		0	200	A
Foamed HES-8	y		3153	11.0	15.6		70	6500	68		0	350	A
Foamed HES-8	y		3153	11.0	15.6		70	8800	68		0	350	A
Foamed HES-8	y		2841	11.0	15.1		65	3850	47		15	22	A
Foamed HES-8	y		3944	11.0	15.6		78	6880	57		0	110	A
Foamed HES-8	y		7600	11.0	15.5	0	58	8800	56		90	270	A
Foamed HES-8	y		3500	11.0	15.5	0	58	7300	48		20	80	A
Foamed HES-8	y		1420	11.0	15.4	0	54	2800	55		50	120	A
Foamed HES-8	y		285	11.0	16.3	97	85	1500	85		70	318	H
Foamed HES-8	y		285	11.0	16.4		85	50	85		180	330	H
Foamed HES-8	y		285	11.0	16.4		85	1500	85		180	330	H
Foamed HES-8	y		3944	11.0	15.6		78	6880	70		190	340	A
Foamed HES-8	y		3944	11.0	15.6		78	6880	70		220	430	A
Foamed HES-8	y		3944	11.0	15.4		65	5350	56		FIRM	115	A
Foamed HES-8	y		3944	11.0	15.6		80	6880	57		90	200	A
Foamed HES-8	y		3907	11.0	15.6		80	6880	57		60	260	A
Foamed HES-8	y		1510	11.0	15.4		65	3700	50		360	420	A
Foamed HES-8	y		3393	11.0	15.5	0	60	4500	55		0	250	A
Foamed HES-8	y		3855	11.0	15.4	0	65	4500	50		60	180	A
Foamed HES-8	y		52	11.0	15.0	318	276	17000	150		SET	330	50/50 H/POZ
Foamed HES-8	y		1965	11.1	15.1		70	3750	50		FIRM	50	A
Foamed HES-8	y		2588	11.2	14.1		70	4800	50		0	140	A
Foamed HES-8	y		3500	11.2	15.5	0	67	8000	57		38	70	A
Foamed HES-8	y		3210	11.2	15.6		64	4900	60		143	220	A
Foamed HES-8	y		1700	11.5	15.1		65	3200	65		60	250	A
Foamed HES-8	y		3940	11.5	15.1		60	4975	60		280	370	A
Foamed HES-8	y		3800	11.5	15.1		65	4910	49		40	370	A
Foamed HES-8	y		1500	11.5	15.5		65	4200	50		0	65	A
Foamed HES-8	y			11.5	16.3		65	4200	54		FIRM	260	H

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Foamed Slurries

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	Base Slurry Density	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Temp for Comp Str (°F)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
Yes	No										12 hr	24 hr	
Foamed HES-8	y			11.5	15.5		65	4200	54		0	120	A
Foamed HES-8	y		4000	11.5	15.0	0	55	5000	50		40	120	A
Foamed HES-8	y		4000	11.5	15.0	0	65	7100	70		223	480	A
Foamed HES-8	y		4000	11.5	15.0	0	65	7100	70		310	480	A
Foamed HES-8	y		3982	11.5	15.4	0	65	4980	52		0	90	A
Foamed HES-8	y		6700	11.5	15.5	0	58	9419	72		160	375	A
Foamed HES-8	y		3800	11.5	15.5		60	4920	49		FIRM	140	A
Foamed HES-8	y		3855	11.5	15.4	0	65	4550	52		40	150	A
Foamed HES-8	y		3855	11.5	15.4	0	73	6435	65		FIRM	170	A
Foamed HES-8	y		3845	11.5	15.5	0	63	7000	70		200	360	A
Foamed HES-8	y		4000	11.5	15.4		65	5000	52		40	140	A
Foamed HES-8	y		3900	11.5	15.0	0	65	7700	73		190	270	A
Foamed HES-8	y		3900	11.5	15.0	0	55	5842	50		110	520	A
Foamed HES-8	y		1753	11.5	15.5	0	62	3162	49		260	500	A
Foamed HES-8	y		2841	11.5	15.5	0	70	3850	48		70	210	A
Foamed HES-8	y		2841	11.5	15.5	0	70	4400	52		70	220	A
Foamed HES-8	y		2841	11.5	15.5	0	70	4400	52		70	220	A
Foamed HES-8	y		2841	11.5	15.5	0	75	5600	60		100	310	A
Foamed HES-8	y		3982	11.5	15.4	0	65	4980	52		0	80	A
Foamed HES-8	y		3982	11.5	16.3	0	70	7020	67		87	290	H
Foamed HES-8	y		3480	11.5	16.2	0	70	7200	72		190	240	H
Foamed HES-8	y		1646	11.6	15.0		80	3330	80		100	450	A
Foamed HES-8	y		2588	11.6	14.6		70	4800	50		0	240	A
Foamed HES-8	y		1736	11.6	15.0		80	3330	80		0	330	A
Foamed HES-8	y		2594	11.6	15.5	70	65	3400	65		250	360	A
Foamed HES-8	y		5400	11.8	15.0	0	60	5600	50		FIRM	170	A
Foamed HES-8	y		5400	11.8	15.0	0	65	7100	50		FIRM	160	A
Foamed HES-8	y		2100	11.8	15.1		65	2700	54		100	210	A
Foamed HES-8	y		2446	11.8	16.3		65	3800	74		299	410	H
Foamed HES-8	y		3944	12.0	15.1		65	5048	50		50	370	A
Foamed HES-8	y		3944	12.0	15.1		65	5048	50		30	340	A
Foamed HES-8	y		3557	12.0	15.1		65	5823	50		0	50	A
Foamed HES-8	y		1074	12.0	15.1		71	2408	71		800	880	A
Foamed HES-8	y		2588	12.0	15.0		70	4800	50		0	320	A
Foamed HES-8	y		1451	12.0	15.1		100	4600	90	3:49	250	590	A
Foamed HES-8	y		1451	12.0	15.1		100	4600	90		240	990	A
Foamed HES-8	y		3150	12.0	15.2	0	65	4330	50		250	410	A
Foamed HES-8	y		3150	12.0	15.1	0	65	4330	50		310	470	A
Foamed HES-8	y		4000	12.0	15.1	0	65	4700	50		FIRM	200	A
Foamed HES-8	y		4000	12.0	15.1	0	90	6000	100		730	1170	A
Foamed Class A	y		2521	12.0	15.2		70	3600	53		150	340	A
Foamed HES-8	y		2521	12.0	15.2		70	4820	65		235	530	A
Foamed Class A	y		2841	12.0	15.1		65	3850	52		75	270	A
Foamed Class A	y		3500	12.0	15.1		70	4800	54		0	230	A
Foamed HES-8	y		3633	12.0	15.1		65	6019	65		50	460	A
Foamed HES-8	y		3907	12.0	15.1		65	5048	50		85	460	A
Foamed Class A	y		3907	12.0	15.1		65	5048	50		102	290	A
Foamed Class A	y		3030	12.0	15.1		65	5662	72		410	610	A
Foamed Class A	y		3272	12.0	15.1		57	4573	50		FIRM	300	A
Foamed HES-8	y		3900	12.0	15.2		70	5000	40		0	120	A
Foamed HES-8	y		3900	12.0	15.1		65	5048	50		60	250	A
Foamed HES-8	y		3900	12.0	15.2		70	5000	40		0	120	A
Foamed Class A	y		3900	12.0	15.1		70	5000	40		0	140	A
Foamed HES-8	y		4100	12.0	15.1	0	65	7773	50		0	650	A
Foamed HES-8	y		4000	12.0	15.1		65	5800	60		290	520	A
Foamed HES-8	y			12.0	15.1		65	4000	RM		280	740	A
Foamed HES-8	y		7300	12.0	15.5	0	66	10100	72		180	420	A
Foamed HES-8	y		4500	12.0	15.1		70	8392	50		0	0	A
Foamed HES-8	y			12.0	15.2	0	65	8000	55		80	100	A
Foamed Class A	y		2841	12.0	15.1		65	4400	52		40	60	A
Foamed Class A	y		6700	12.0	15.5	0	58	9419	72		130	315	A
Foamed HES-8	y		3944	12.0	15.2		70	5048	50		0	170	A
Foamed HES-8	y			12.0	15.1		65	4000	RM		250	800	A
Foamed Class A	y			12.0	15.1	0	65	4000	75		380	710	A
Foamed HES-8	y			12.0	15.1	0	65	4000	55		FIRM	500	A
Foamed Class A	y		7600	12.0	15.5	0	66	10100	72		230	440	A
Foamed HES-8	y		3125	12.0	16.4		70	5400	58		121	320	H
Foamed HES-8	y		3125	12.0	16.4		70	5400	58		50	380	H
Foamed Class A	y		3557	12.0	15.5		65	5023	50		FIRM	50	A
Foamed HES-8	y		3557	12.0	15.5		65	5823	50		FIRM	80	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Foamed Slurries

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	Base Slurry Density	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Temp for Comp Str (°F)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
Yes	No										12 hr	24 hr	
Foamed Class A	y			12.0	16.0	0	90	8000	70		160	570	H
Foamed Class A	y		719	12.0	15.5		63	1874	63		130	314	A
Foamed HES-8	y		719	12.0	15.5		63	1874	63		73	260	A
Foamed HES-8	y		3000	12.0	15.5	0	62	4400	50		90	220	A
Foamed Class A	y		2521	12.0	15.5	0	70	4850	60		150	690	A
Foamed HES-8	y		2521	12.0	15.6		70	5800	76		290	370	A
Foamed HES-8	y		2521	12.0	15.5	0	65	3750	50		40	290	A
Foamed Class A	y		4000	12.0	15.0	0	76	9100	90		503	860	A
Foamed Class A	y			12.0	15.6		65	6800	65		70	330	A
Foamed Class A	y		285	12.0	16.3	135	105	4600	105		500	760	H
Foamed Class A	y		285	12.0	16.3		85	1500	90		360	420	H
Foamed Class A	y		285	12.0	16.3		85	1500	135		480	611	H
Foamed Class A	y		1300	12.0	15.5	0	62	5000	72		310	520	A
Foamed Class A	y		1300	12.0	15.5	0	62	5000	72		370	680	A
Foamed Class A	y		3100	12.0	15.0	0	58	9400	62		30	120	A
Foamed Class A	y		4200	12.0	16.4	0	65	7773	55		FIRM	330	A
Foamed Class A	y		4200	12.0	15.0	0	65	7773	55		0	90	A
Foamed Class A	y		4200	12.0	16.7	0	65	7773	55		0	180	H
Foamed Class A	y		3855	12.0	15.4	0	72	5450	55		150	570	A
Foamed Class A	y		3845	12.0	15.5	0	75	7000	55		180	500	A
Foamed Class A	y		4000	12.0	15.4		65	5800	52		70	220	A
Foamed Class A	y		3480	12.0	15.4	0	65	5564	68		560	1090	A
Foamed Class A	y			12.0	16.9	0	65	4000	45		SET	120	H
Foamed Class A	y			12.0	16.9	0	65	4000	45		SET	110	H
Foamed Class A	y		3393	12.0	15.5	0	70	7500	67		220	360	A
Foamed Class A	y		3900	12.0	15.5	0	65	4700	50		0	FIRM	A
Foamed Class A	y		3900	12.0	15.5	0	90	6000	100		640	950	A
Foamed Class A	y		3325	12.0	15.0	0	65	5037	50		60	240	A
Foamed Class A	y		5467	12.0	15.4	0	68	7000	70		270	410	A
Foamed Class A	y		1400	12.0	15.5	0	62	5000	72		350	740	A
Foamed Class A	y		4000	12.0	16.4	0	65	7773	55		FIRM	260	A
Foamed Class A	y		4000	12.0	16.7	0	65	7773	55		50	340	H
Foamed Class A	y		3982	12.0	15.4	0	65	5650	54		95	300	A
Foamed Class A	y		3200	12.0	15.5	0	75	2265	50		235	570	A
Foamed Class A	y		3200	12.0	15.5	0	65	2265	50		230	585	A
Foamed Class A	y		6800	12.0	17.5	0	80	9300	70			110	H
Foamed Class A	y		3907	12.1	15.4		66	5800	55		FIRM	240	A
Foamed Class A	y		3907	12.1	15.4		66	5800	55		FIRM	130	A
Foamed Class A	y		3800	12.2	15.1		65	5220	70		580	970	A
Foamed Class A	y		3800	12.2	15.1		65	5220	52		FIRM	140	A
Foamed Class A	y		2841	12.2	15.1		47	3800	63		360	720	A
Foamed Class A	y		3800	12.2	15.1		65	5220	53		90	450	A
Foamed Class A	y		2588	12.4	15.1		70	3400	50		0	130	A
Foamed Class A	y		2588	12.4	15.1		70	3400	50		0	140	A
Foamed Class A	y		4600	12.5	15.0	0	60	8085	50		50	124	A
Foamed Class A	y			12.5	15.1		65	5559	57		160	640	A
Foamed Class A	y		6679	12.5	14.8		65	9000	50		0	70	A
Foamed Class A	y		1965	12.5	15.1		70	3400	60		30	260	A
Foamed Class A	y		2025	12.5	15.1		70	3400	50		40	370	A
Foamed Class A	y		3210	12.5	15.1		70	5450	60		120	910	A
Foamed Class A	y		4100	12.5	15.1	0	90	9273	100		700	895	A
Foamed Class A	y			12.5	15.0		65	4850	54		120	350	A
Foamed Class H	y		7612	12.5	15.2		70	10800	67		210	450	A
Foamed Class H	y		7612	12.5	15.2		70	9300	40		0	130	A
Foamed Class H	y			12.5	15.2		55	5000	55		250	350	A
Foamed Class H	y			12.5	15.1		65	5559	57		160	670	A
Foamed Class H	y		6679	12.5	14.8		65	9000	50		0	110	A
Foamed Class H	y		6679	12.5	15.0		65	9000	50		0	115	A
Foamed Class A	y		3100	12.5	15.0	0	60	5200	50		50	220	A
Foamed Class A	y		3100	12.5	15.2	0	65	5100	50		210	315	A
Foamed Class A	y		3100	12.5	15.1	0	65	5100	50		390	500	A
Foamed Class A	y		3778	12.5	15.0		70	5700	45		0	55	A
Foamed Class A	y		3778	12.5	15.2		70	4600	45	3:22	0	50	A
Foamed Class H	y		2663	12.5	15.1	0	65	3978	55		FIRM	190	A
Foamed Class H	y		3150	12.5	15.2	0	65	4330	50		280	450	A
Foamed Class A	y		3150	12.5	15.1	0	65	4330	50		330	500	A
Foamed Class A	y		1968	12.5	15.1		65	5000	52		30	410	A
Foamed Class A	y		5250	12.5	15.0	0	65	7000	50		105	270	A
Foamed Class A	y		5800	12.5	15.1	0	65	7046	50		FIRM	150	A
Foamed Class A	y		2559	12.5	15.0		65	3377	60		150	350	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Foamed Slurries

*Slurry Type	Offshore Yes No	Water Depth (ft)	Slurry Density £13.0 lb/gal	Base Slurry Density	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Temp for Comp Str (°F)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
Foamed Class A	y	5200	12.5	15.1	0	65	8053	50			110	A
Foamed Class H	y	5200	12.5	15.1	0	65	7393	55		340	520	A
Foamed Class A	y	2559	12.5	15.0		65	3377	60		180	190	A
Foamed Class A	y	3210	12.5	15.1		65	5450	70		310	700	A
Foamed Class A	y	3272	12.5	15.1		85	6537	50		0	FIRM	A
Foamed Class A	y	3900	12.5	15.1		70	5700	40		0	115	A
Foamed Class A	y		12.5	15.2		75	6000	65		FIRM	FIRM	A
Foamed Class A	y	1400	12.5	15.1	0	65	6113	65		270	540	A
Foamed Class A	y	6679	12.5	15.0		65	9000	50		SET	160	A
Foamed Class A	y	2000	12.5	15.5		70	3400	50		0	80	A
Foamed Class H	y	5600	12.5	15.1	0	60	8290	55		110	580	A
Foamed Class A	y		12.5	15.1	0	65	8900	40				A
Foamed Class A	y	3257	12.5	15.1	0	70	5450	50		0	0	A
Foamed Class A	y	3800	12.5	15.5		82	9500	90		370	750	A
Foamed Class A	y	4100	12.5	15.0	0	105	10000	120		100	230	A
Foamed Class A	y	4100	12.5	15.0	0	90	8632	105		230	590	A
Foamed Class A	y		12.5	15.4		75	6000	65		170	425	A
Foamed Class A	y		12.5	15.0	0	65	10500	50		0	40	A
Foamed Class A	y	3557	12.5	15.0	0	60	8085	50		45	230	A
Foamed Class A	y	1485	12.5	15.6	0	70	3000	55		235	650	A
Foamed Class H	y	3000	12.5	15.5	0	65	5200	60		130	270	A
Foamed Class A	y	4000	12.5	15.0	0	65	4650	54		70	240	A
Foamed Class A	y	4000	12.5	15.0	0	65	4650	54		45	100	A
Foamed Class A	y	4600	12.5	16.0	0	68	5305	55		140	270	H
Foamed Class A	y		12.5	15.5		65	5000	57		0	90	A
Foamed Class A	y		12.5	16.3		65	5000	57		FIRM	FIRM	H
Foamed Class A	y	3100	12.5	15.5	0	74	2762	68		230	540	A
Foamed Class A	y	4000	12.5	16.0	0	65	6100	50		0	160	A
Foamed Class A	y	5000	12.5	16.4	0	65	7878	55		180	570	A
Foamed Class A	y	3600	12.5	15.0	0	65	9025	50		0	150	A
Foamed Class A	y	3750	12.5	15.0	0	65	5500	55		120	350	A
Foamed Class A	y	3750	12.5	15.0	0	65	6625	50		0	130	A
Foamed Class A	y	3750	12.5	15.5	0	60	6625	55		190	260	A
Foamed Class A	y	6700	12.5	15.5	0	67	11300	99		380	520	A
Foamed Class A	y	3800	12.5	16.3		82	9500	90		160	385	H
Foamed Class A	y	4200	12.5	16.0	0	90	9273	80		0	90	A
Foamed Class A	y	3900	12.5	15.0	0	62	5600	48		SET	60	A
Foamed Class A	y	3900	12.5	15.0	0	73	9400	88		290	500	A
Foamed Class H	y		12.5	15.4		75	6000	65		180	240	A
Foamed Class H	y		12.5	15.6		70	5200	70		220	380	A
Foamed Class A	y	3393	12.5	15.5	0	65	5500	67		222	430	A
Foamed Class A	y	3393	12.5	15.5	0	60	4500	55		190	500	A
Foamed Class A	y	3393	12.5	15.5	0	75	8000	67		490	840	A
Foamed Class A	y	3393	12.5	15.5	0	75	8000	67		530	810	A
Foamed Class A	y	5000	12.5	15.5	0	68	7000	70		290	560	A
Foamed Class A	y	5000	12.5	15.5	0	70	5700	50		203	710	A
Foamed Class A	y	1965	12.5	15.1		70	3750	5		FIRM	130	A
Foamed Class A	y	2700	12.5	16.4	0	60	4340	60		90	320	H
Foamed Class A	y	3500	12.5	15.2		70	6500	70		70	280	A
Foamed Class A	y	6201	12.5	15.5	0	70	8200	79		490	1075	A
Foamed Class A	y	4000	12.5	16.0	0	90	9273	80		210	570	A
Foamed Class H	y	4000	12.5	16.0	0	90	9273	80		20	1310	H
Foamed Class H	y	3855	12.5	15.4	0	65	4500	50		80	200	A
Foamed Class H	y	52	12.5	16.4	150	115	6000	110		40	820	H
Foamed Class H	y	3329	12.5	15.0		65	4850	54		60	300	A
Foamed Class A	y	3329	12.5	15.0		65	4850	54		25	225	A
Foamed Class A	y	3200	12.5	15.1	70	70	5100	60		65	395	A
Foamed Class H	y	3900	12.5	15.2		65	5000	50		FIRM	124	H
Foamed Class A	y	2588	12.6	14.8		70	4800	50		0	420	A
Foamed Class A	y	1965	12.6	15.6	0	65	3700	65		220	510	A
Foamed Class A	y	4700	12.6	16.0	0	65	7238	65		0	450	H
Foamed Class A	y	4700	12.6	16.0	0	65	7238	50		FIRM	560	H
Foamed Class A	y	3500	12.7	15.1		70	5900	63		180	455	A
Foamed Class A	y	4600	12.8	15.0	0	65	8800	50		40	290	A
Foamed HES-8	y	4200	12.8	15.0		70	2540	60		110	290	A
Foamed HES-8	y	3500	12.8	15.1		70	4850	57		FIRM	200	A
Foamed Class A	y	3500	12.8	15.1		70	4850	57		FIRM	150	A
Foamed Class A	y	3940	12.8	15.1		65	6175	65		350	740	A
Foamed Class H	y	3940	12.8	15.1		65	6175	70		360	694	A
Foamed Class H	y	2663	12.8	15.1	0	90	5820	100		650	890	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Foamed Slurries

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	Base Slurry Density	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Temp for Comp Str (°F)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type
Yes	No										12 hr	24 hr	
Foamed Class A	y		3329	12.8	15.1		70	4850	57		0	120	A
Foamed Class A	y		3329	12.8	15.1		70	4850	57		FIRM	130	A
Foamed Class A	y		7612	13.0	15.2		70	8380	40		0	150	A
Foamed Class A	y			13.0	15.1	0	65	8000	55		90	440	A
Foamed Class A	y			13.0	15.1	0	65	8000	55		FIRM	260	A
Foamed Class A	y		2559	13.0	15.0		65	4200	65		200	360	A
Foamed Class A	y		2559	13.0	15.0		65	4200	65		260	410	A
Foamed Class A	y			13.0	15.2	0	65	8000	55		FIRM	270	A
Foamed Class A	y		1210	13.0	15.4	0	75	3800	75		260	490	A
Foamed Class A	y		3000	13.0	15.5	0	75	8200	85		363	1020	A
Foamed Class A	y		2900	13.0	15.5	0	60	3930	50		60	220	A
Foamed Class A	y		2900	13.0	15.0	0	60	3930	50		60	220	A
Foamed Class A	y		2000	13.0	15.5	0	70	4400	60		210	1210	A
Foamed Class A	y		4200	13.0	15.5	0	65	7000	60		232	370	A
Foamed Class A	y		1025	13.0	16.4	170	138	9850	160		300	660	H
Foamed Class H	y		1025	13.0	16.3	170	138	9850	160		290	645	H
Foamed Class H	y		3100	13.0	15.0	0	74	11200	80		120	670	A
Foamed Class A	y		1200	13.0	15.5	0	68	3800	85		490	750	A
Foamed Class A	y		1200	13.0	15.6	0	68	3800	85		450	980	A
Foamed Class A	y		3393	13.0	15.5	0	60	4500	55		210	550	A
Foamed Class H	y		4700	13.0	16.0	0	65	7238	65		0	460	H
Foamed Class A	y		5000	13.0	15.5	0	75	9200	100		120	350	H
Foamed Class H	y		5000	13.0	15.5	0	75	9200	100		380	1130	A
Foamed Class H	y		2000	13.0	15.5	0	70	4400	60		180	500	A
Foamed Class H	y		2000	13.0	15.5	0	70	4000	65		160	580	A
Foamed Class A	y		2700	13.0	16.4	0	60	5440	60		50	290	H
Foamed Class A	y		5467	13.0	15.4	0	75	8400	84		410	710	A
Foamed Class A	y		4000	13.0	16.0	0	65	6691	50		90	430	A
Foamed Class A	y		2025	13.0	15.5	0	70	4400	60		190	510	A
Foamed Class A	y		1500	13.0	17.3	0	113	10200	130		640	670	H
Foamed HES-8	y		3800	10.0	15.5		65	5800	58		50	240	A
Foamed Class H	y		3800	10.0	15.5		65	5450	55		50	130	A
Foamed Class H	y		2056	12.0	15.1		65	4000	50		22	240	A
Foamed Class H	y		2056	12.0	15.1		80	6050	50		0	20	A

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
HES Special Slurry Description

Product Number: HES-1

Service Company: Halliburton

Company Designation: NewCem

General Description: Shell "Slag"

Product Number: HES-2

Service Company: Halliburton

Company Designation: Spherelite

General Description: Pozzalonic Microspheres

Product Number: HES-3

Service Company: Halliburton

Company Designation: Spherelite w/ Microfine Cement

General Description: Pozzalonic Microspheres w/ Microfine Cement

Product Number: HES-4

Service Company: Halliburton

Company Designation: Spherelite w/ Econolite

General Description: Pozzalonic Microspheres w/ Sodium Silicate

Product Number: HES-5

Service Company: Halliburton

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)

HES Special Slurry Description

Company Designation: Diacel-M

General Description: Diacel-M

Product Number: HES-6

Service Company: Halliburton

Company Designation: EPSEAL

General Description: EPSEAL

Product Number: HES-7

Service Company: Halliburton

Company Designation: WG-17, WG-17LXP, FWCA

General Description: Freewater Control

Product Number: HES-8

Service Company: Halliburton

Company Designation: Micro-Matrix

General Description: Microfine Cement

Product Number: HES-9

Service Company: Halliburton

Company Designation: Microbond

General Description: Expansive Additives

Product Number: HES-10

Service Company: Halliburton

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)

HES Special Slurry Description

Company Designation: CalSeal

General Description: Calcium Sulfate

Product Number: HES-11

Service Company: Halliburton

Company Designation: TLW / TXI

General Description: TLW / TXI

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
BJ Services Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type	MIX H ₂ O Fresh
	Yes	No							12 hr	24 hr		
BJ-1 + 2% CaCl ₂		x		9.5	90	80	1500	3:50	500		H	Fresh
BJ-1		x		9.5	180	144	10000	4:35		480	H	Fresh
BJ-1		x		9.5	180	144	10000	4:06		510	H	Fresh
BJ-1		x		11.5	180	144	10000	4:10	1638	2482	H	Fresh
BJ-1		x		8.5	180	144	10000		223	753	H	Fresh
BJ-2 + 40% Silica		x		10.8	400	200	3500	4:25		2940	G	Fresh
BJ-2 + 40% Silica		x		12.2	325	225	8000	4:15		2780	G	Fresh
BJ-2		x		11.6	140	116	5000		300	460	G	Fresh
BJ-2 + 5% Lime		x		11.6	140	116	5000		300	360	G	Fresh
BJ-2 + 40% Silica		x		10.8	400	200	3500			2771	G	Fresh
BJ-2 + 40% Silica + 5% Lime		x		10.8	400	200	3500			1287	G	Fresh
BJ-2		x		10.2	400	200	3500			276	G	Fresh
BJ-2 + 35% Silica		x		10.4	300	250	5000	4:51	1253	2343	G	Fresh
BJ-2 + 35% Silica + 5% Lime		x		14.0	600	110	4500			1963	Type 1	Fresh
BJ-2 + 35% Silica + 5% Lime		x		12.0	600	110	4500			700	Type 1	Fresh
BJ-3 + 35% Silica		x		14.0	600	110	4500			1213	Type 1	Fresh
BJ-1		x		9.3	95	80	1500	8:00+	75	154	H	Fresh
BJ-1 + 2% CaCl ₂		x		9.3	95	80	1500	8:00+	140	213	H	Fresh
BJ-1		x		10.3	95	80	1500	8:00+	220	403	H	Fresh
BJ-1 + 2% CaCl ₂		x		10.3	95	80	1500	6:20	300	496	H	Fresh
BJ-1		x		11.3	95	80	1500	8:00+	384	778	H	Fresh
BJ-1 + 2% CaCl ₂		x		11.3	95	80	1500	3:02	504	1027	H	Fresh
BJ-1		x		12.3	95	80	1500	8:00	556	1053	H	Fresh
BJ-1 + 2% CaCl ₂		x		12.3	95	80	1500	2:09	820	1238	H	Fresh
BJ-1 + 6% CaCl ₂		x		9.6	89	80	1000	8:40		450	G	Fresh
BJ-1 + 1.5% CaCl ₂		x		9.5	90	85	1000	5:27	263	513	G	Fresh
BJ-1 + 1.5% CaCl ₂		x		9.5	90	85	1000		513	563	A	Fresh
BJ-1 + 2% CaCl ₂		x		9.5	90	80	1500	3:30	500		A	Fresh
BJ-1 + 2% CaCl ₂		X		9.5	40		1000			50	A	Fresh
BJ-1 + 2% CaCl ₂		x		9.5	55		1000			160	A	Fresh
BJ-1 + 2% CaCl ₂		x		9.5	95		1000		300	670	A	Fresh
BJ-1 + 2% CaCl ₂		x		9.5	300		1000			1000	A	Fresh
BJ-1 + 2% CaCl ₂		x		11.5	40		1000			183	A	Fresh
BJ-1 + 2% CaCl ₂		x		11.5	55		1000			570	A	Fresh
BJ-1 + 2% CaCl ₂		x		11.5	95		1000		630	1280	A	Fresh
BJ-3		x		8.5	180	144	10000	4:43	223	753	H	Fresh
BJ-1 + 3% CaCl ₂ + 35% Silica		x		9.0	144	100	3000	2:57	510	813	G	Fresh
BJ-1, 5% CaCl ₂ , 10% "B"		x		9.0	144	100	3000	5:00	165	225	G	Fresh
BJ-2 + 40% Silica		x		10.8	400	200	3500	4:25		2940	G	Fresh
BJ-2 + 40% Silica		x		12.2	325	225	8000	4:15		2780	G	Fresh
BJ-2 + 40% Silica		x		10.8	400		6000			1914	G	Fresh
BJ-2 + 40% Silica + 5% Lime		x		10.8	400		6000			1114	G	Fresh
BJ-2		x		10.2	400		6000			394	G	Fresh
BJ-2 + 35% Silica + 5% Lime		x		10.4	300	250	5000	4:51	1253	2343	G	Fresh
3% "A"		x		11.8	95	85	1000	4:43		450	A	Fresh
1.5% "A"		x		12.8	80	80	1000	6:00		745	C	Fresh
10% "B"		x		12.5	120	103	7250	2:47		304	C	Fresh
10% "B", 0.2% "A",		x		12.5	120	103	7050	2:58		280	C	Fresh
15% "B"		x		11.7	124	105	5500	5:07	77	129	C	Fresh
16% "B", + dispersant		x		12.1	127	110	8200	2:37		518	C	Fresh
16% "B", + 12 LB Gilsonite		x		11.9	110	100	4570	3:41		265	C	Fresh
16% "B" + 3% Salt + Dis		x		12.1	127	110	8200	1:48		523	C	Fresh
16% "B" + 3% Salt + Dis		x		12.1	105	90	4900	2:54		433	C	Fresh
16% "B" + 3% Salt + Gil		x		12.5	130	110	6800	1:23		375	C	Fresh
3% "A" + 2% CaCl ₂		x		11.6	80	80	1000	7:20		196	C	Fresh
2% "A"		x		12.4	90	80	1950	6:25		450	C	Fresh
3% "A"		x		11.4	120	105	6000	5:18		255	C	Fresh
3% "A"		x		11.4	110	95	5200	6:50		248	C	Fresh
3% "A"		x		11.9	120	100	5600	5:49		358	C	Fresh
3% "A" + .25% CaCl ₂		x		11.9	109	102	5800	5:20		394	C	Fresh
3% "A" + 2.0% CaCl ₂		x		11.6	90	80	1110	6:24		208	C	Fresh
3% "A" + 2% CaCl ₂		x		11.9	90	80	1135	5:33		338	C	Fresh

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
BJ Services Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type	MIX H ₂ O Fresh
	Yes	No							12 hr	24 hr		
3%A" + 2% CaCl ₂ + Salt		x		11.5	86	80	750	5:55		116	C	Fresh
3% "A" + Gilsomite		x		11.4	160	133	10100	2:43		168	C	Fresh
3%A" + 5 Lb/sk Salt		x		11.4	120	103	5250	7:06		325	C	Fresh
3% "A" + 5 Lb/sk Salt		x		11.4	96	90	2800	8:38		300	C	Fresh
3% "A" + 5 Lb/sk Salt		x		11.9	96	90	2800	8:06		325	C	Fresh
3% "A" + 5 Lb/sk Salt		x		11.4	116	103	5250	6:52		373	C	Fresh
BJ-6 + "B" + "A"		x		11.8	126	116	7050	3:29	233	296	C	Fresh
BJ-7+12% Salt+ 2% CC		x		12.6	120	105	7500	2:58		343	C	Fresh
6% "B"		x		12.7	98	88	3500	5:21		400	C	Fresh
6% "B" + 3% Salt		x		12.7	120	100	7023	4:23		655	C	Fresh
6%"B"+3% Salt + Gilsomite		x		12.7	108	96	3950	2:43		1008	C	Fresh
8% "B" + 3% Salt		x		12.9	115	97	5795	3:40		750	C	Fresh
16% "B"		x		11.8	144	127	8500	3:54	93	177	H	Fresh
16% "B" + 2% Salt		x		11.7	145	135	10000	2:54		233	H	Fresh
2% "A"		x		12.6	144	121	9200	2:33		823	H	Fresh
2% "A"		x		12.4	135	115	8700	3:13		450	H	Fresh
20% "B"		x		10.5	160	133	10100	3:45	42	56	H	Fresh
BJ-8		x		12.2	80	80	500	5:53		358	A	Fresh
BJ-8		x		12.6	80	80	900	4:37		356	C	Fresh
BJ-9		x		11.0	160	133	10100	2:36	351	483	C	Fresh
BJ-9 + 8% Attapulgit		x		10.5	160	133	10100	3:48	222	306	C	Fresh
BJ-8		x		11.5	120	105	6000	4:00		55	C	Fresh
BJ-8		x		12.4	120	105	6000	3:54		335	C	Fresh
BJ-8		x		13.0	144	119	8000	3:15		711	C	Fresh
BJ-8		x		12.5	80	80	1150	3:45		475	C	Fresh
BJ-8 + 10% Salt		x		12.8	104	91	3000	5:07		400	C	Fresh
BJ-8 + 2% CaCl ₂		x		12.7	85	80	1000	5:17	188			Fresh
BJ-8 + 2% CaCl ₂ + 5lb Gil		x		12.5	110	87	2000	5:30		288	C	Fresh
BJ-8 + 2% CaCl ₂ + 5lb Kol		x		12.6	90	81	1500	5:16		458	C	Fresh
BJ-8 + 3% Salt		x		12.5	100	90	4800	5:14		275	C	Fresh
BJ-8 + 5 lb Gilsomite		x		12.7	90	83	500	6:42		288	C	Fresh
BJ-8 + 5 lb Gilsomite		x		12.3	156	123	9000	4:05		495	C	Fresh
BJ-8 + 5 lb Gilson + 3% Salt		x		12.5	128	108	6000	3:46		432	C	Fresh
BJ-8 + 5 lb Gilson + 2% KCl		x		12.6	85	80	900	5:23		280	C	Fresh
BJ-8 + 5 lb salt		x		12.6	128	108	6000	1:48		270	C	Fresh
BJ-8 + 5 lb salt		x		12.6	114	99	4000	2:46		375	C	Fresh
BJ-8 + 5% Salt		x		12.4	99	88	1900	4:45	307	623	C	Fresh
BJ-8 + 9% Salt		x		12.5	104	97	3750	3:35		375	C	Fresh
BJ-8		x		12.6	120	100	6100	4:13		375	H	Fresh
BJ-8		x		12.6	123	111	6100	3:30		410	H	Fresh
BJ-8		x		12.5	132	123	8050	2:59		520	H	Fresh
BJ-8		x		12.4	140	118	9000	3:45		595	H	Fresh
BJ-8 + 8 lb Gilson + 3% Salt		x		12.4	127	108	6000	4:07	244	406	H	Fresh
BJ-8 + 8 lb Gilson		x		12.4	152	128	9000	4:48	125	360	H	Fresh
BJ-8		x		12.4	183	145	10300	4:35		850	H	Fresh
BJ-8		x		12.7	148	124	9000	3:32		600	H	Fresh
BJ-8		x		12.4	176	145	12000	3:48		730	H	Fresh
BJ-8		x		12.7	149	131	9000	4:36		500	H	Fresh
BJ-8 + 10% Salt		x		12.4	115	108	5800	3:25		587	H	Fresh
BJ-8 + 10% Salt + 2 lb Gil		x		12.8	96	86	2000	5:05		516	H	Fresh
BJ-9 + 2% CaCl ₂		x		12.4	110	90	5000	7:07		310	C	Fresh
BJ-9 + 8 lb Gilsomite		x		13.0	165	137	11300	4:06		1892	C	Fresh
BJ-9		x		13.0	157	127	11830	4:14		2150	C	Fresh
BJ-9		x		13.0	144	119	8000	3:12		1490	C	Fresh
BJ-9 + 1 lb salt		x		13.0	155	129	9800	4:09		1583	C	Fresh
BJ-9 + 8 lb salt		x		13.0	130	110	5500	3:44		1334	C	Fresh
BJ-9 + 5 lb Gilsomite		x		13.0	175	141	12900	3:35		2163	C	Fresh
BJ-9 + 1 lb KCl + 5 lb Gilson		x		13.0	148	124	8200	3:38		1700	C	Fresh
BJ-9 + 2% KCl + 8 lb Gilson		x		13.0	170	136	11900	2:30		2680	C	Fresh
BJ-9 + 2% Salt + 0.2% "A"		x		13.0	152	127	8000	2:46		1875	C	Fresh
BJ-9 +1 lb Salt + 5 lb Gilson		x		13.0	165	137	10700	3:41		2650	H	Fresh
BJ-9 + 5 lb Salt		x		11.5	119	96	3200	7:55		375	C	Fresh

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
BJ Services Ultralight Report

*Slurry Type	Offshore		Water Depth (ft)	Slurry Density £13.0 lb/gal	BHST (°F)	BHCT (°F)	Casing Depth (ft)	Thickening Time (hr:min)	Compressive Strength (psi)		Base Cement Type	MIX H ₂ O Fresh
	Yes	No							12 hr	24 hr		
BJ-10		x		12.3	168	139	11572	3:58		1512	TXI LW	Fresh
A	x			11.8	107	90	3000		70	150	H	FRESH
A	x			12.0	182	119	9450		400	850	H	FRESH
A	x			12.4	98	80	2300		130	400	H	FRESH
B	x			12.0	142	101	5100		160	485	H	FRESH
A	x			12.4	120	91	3860		125	300	H	FRESH
A	x			11.4	120	105	3900		50	150	H	SEA
A	x			12.0	94	81	2150		90	170	H	SEA
A	x			12.4	130	95	4750		150	285	H	FRESH
A	x			11.4	128	101	4500		100	220	H	SEA
B	x			11.4	93	81	2000		90	170	H	SEA
A	x			12.5	310	252	16450		410	845	H	FRESH
A	x			11.4	128	101	4500		100	220	H	SEA
A	x			11.8	107	90	3000		70	150	H	FRESH
BJ-8 + 3% SALT	x			12.0	110	93	3345		145	290	A	FRESH
BJ-8	x			12.5	93	80	2000		95	240	A	FRESH
TXI LW + "A"	x			12.8	95	80	2160		95	240	H	FRESH
A	x			11.5	113	94	3100		50	210	H	FRESH
A	x			12.4	107	87	2890		140	380	H	FRESH
A	x			12.5	120	105	3900		160	340	H	FRESH
A	x			11.5	100	85	2420		55	104	H	FRESH
A	x			12.0	124	92	3900		120	300	H	FRESH
TXI LW + "B"	x			12.0	101	88	2500		125	295	TXI LW	SEA
BJ-8	x			12.4	116	92	3220		150	285	H	FRESH
BJ-8	x			12.4	185	130	9550		255	967	H	FRESH
BJ-8	x			12.5	110	92	3000		104	425	TYPE 1	FRESH
A	x			11.4	128	101	4500		100	220	H	SEA
A	x			11.4	102	88	2700		50	160	H	SEA
A	x			11.4	122	100	3860		50	135	H	SEA
A	x			11.4	125	100	3950		50	135	H	SEA
B	x			12.6	254	205	15800		SET	400	H	FRESH
A	x			11.4	94	80	2000		50	150	H	SEA
A	x			11.7	224	173	14100		50	200	H	SEA
A	x			11.4	94	80	2000		50	150	H	SEA
A	x			12.5	70	75	800		50	140	H	SEA
A	x			11.4	119	96	3440		50	150	H	SEA
B	x			12.0	94	80	2000		60	175	H	FRESH
A	x			11.4	93	80	2000		60	150	H	SEA
A	x			12.0	94	80	2000		65	170	H	SEA
A	x			12.0	116	93	3300		65	170	H	SEA
BJ-8	x			12.4	92	80	1966		170	356	A	SEA
BJ-8	x			12.4	145	104	5655		65	350	A	SEA
BJ-10	x			12.5	174	128	12100		1050	1460	TXI LW	FRESH
BJ-8	x			11.4	93	80	2000		60	150	H	SEA
A	x			11.4	109	91	3050		50	160	H	SEA
A	x			11.4	93	81	2000		50	150	H	SEA
A	x			11.4	132	104	4920		50	150	H	SEA
A	x			11.4	132	104	4920		50	150	H	SEA
BJ-10 + 4% Gel	x			11.5	90	80	1800		60	530	TXI LW	FRESH
BJ-8	x			12.0	114	93	3110		100	280	H	SEA
BJ-8	x			12.0	114	93	3110		50	170	H	FRESH
BJ-8	x			11.2	124	98	4600		155	250	TYPE 1	FRESH
A	x			11.4	94	80	2000		50	150	H	SEA

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
BJ Services Special Slurry Description

Product Number: BJ-1

Service Company: BJ Services Company

Company Designation: LW-7 2000

General Description: Glass Bubbles, Low Strength

Product Number: BJ-2

Service Company: BJ Services Company

Company Designation: LW-6

General Description: Ceramic Bubbles

Product Number: BJ-3

Service Company: BJ Services Company

Company Designation: Perlite

General Description: Expanded Volcanic aggregate

Product Number: BJ-4

Service Company: BJ Services Company

Company Designation: LW-7 10000

General Description: Glass Bubbles, High Strength

Product Number: BJ-5

Service Company: BJ Services Company

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)
BJ Services Special Slurry Description

Company Designation: None

General Description: Blend LW-6 and High Early strength additive

Product Number: BJ-6

Service Company: BJ Services Company

Company Designation: None

General Description: Blend Anhydrous Sodium Metasilicate and High Strength Additive

Product Number: BJ-7

Service Company: BJ Services Company

Company Designation: Attaclay

General Description: Attapulgate Clay

Product Number: BJ-8

Service Company: BJ Services Company

Company Designation: None

General Description: Poz, Cement, Bentonite Blend

Product Number: BJ-9

Service Company: BJ Services Company

Company Designation: None

General Description: Poz, Cement, Microsilica Blend

Product Number: BJ-10

Appendix C—Performance Data for Lightweight Cements (HES and BJ Services)

BJ Services Special Slurry Description

Service Company: BJ Services Company

Company Designation: TXI Lightweight

General Description: TXI Commercial Lightweight Cement

Product Number: BJ-11

Service Company: BJ Services Company

Company Designation: Prehydrated Gel

General Description: Prehydrated Bentonite Gel

Product Number:

Service Company:

Company Designation:

General Description:

Appendix D—Specification Testing

TXI Provided Information			CSI Information				CSI Free Water				CSI Rheologies										
Cmt	Mill Production	Grind	Date	CSI	Bucket	Test	at	% by	H2O	Temp	300	200	100	60	30	6	3	PV	YP	10 sec	10 min
Class	Run Date		Received	Log #	Opened	Date	%	volume	%	°F	rpm	rpm	rpm	rpm	rpm	rpm	rpm			G.S.	G.S.
LW	9/15 to 9/18/00	62	11/06/00	C-108 B-1	11/07/00	11.15.00	105	2	0.8	75	57	50	42	38	33	22	12	22.5	34.5	13	120
LW	9/15 to 9/18/00	62	11/06/00	C-108 B-2	12/05/00	1.04.01	105	2	0.8	75	58	52	45	38	32	21	13	19.5	38.5	13	125

TXI Provided Information				CSI Information				CSI Thickening Time					
Cmt	Mill Production	Run Date	Grind	Date	Received	Log #	Bucket	Test	%	Sch	Int	70	100
Class							Opened	Date	H ₂ O	#	Bc	Bc	Bc
LW	9/15 to 9/18/00	62		11/06/00	11/06/00	C-108 B-1	11/07/00	11.15.00	75.0	5	6	2:02	2:20
LW	9/15 to 9/18/01	62		11/06/00	1.5.01	C-108 B-2	12/05/00	1.5.01	75.0	5	5	2:00	2:17

TXI Provided Information				CSI Information			CSI 45°F Strengths						CSI 60°F Strengths						CSI 80°F Strengths						CSI 120°F Strengths					
Cmt	Mill Production	Grind		Date	Received	CSI Log #	Bucket Opened	Test Date	% H2O	Time Hr	Temp °F	% CaCl2	Old	Str psi	Time Hr	Temp °F	% CaCl2	Old	Str psi	Time Hr	Temp °F	Old	Str psi	Time Hr	Temp °F	Old	Str psi			
Class	Run Date																													
LW	9/15 to 9/18/00	62		11/06/00		C-108 B-1	11/07/00	11.15.00	75.0	24	45	2.0	106	166	24	60	1.0	162	254	24	80	334	523	24	120	1009	1579			
LW	9/15 to 9/18/00	62		11/06/00		C-108 B-2	12/05/00	01.04.01	75.0	24	45	2.0	103	161	24	60	1.0	141	221	24	80	282	441	24	120	783	1225			

Appendix D—Specification Testing

TXI Information			CSI Information				CSI Free Water			CSI Rheology										
Cmt Class	Prod. Date	Date Received	CSI Log #	Date Bucket Opened	Test Date	mL	% by volume	Pass/Fail	Temp °F	300 rpm	200 rpm	100 rpm	60 rpm	30 rpm	6 rpm	3 rpm	PV	YP	10 sec G.S.	10 min G.S.
H	9/27/00	11/06/00	C-108 A-1	11/06/00	11/07/00	1.9	0.8	Pass	69	89	72	53	45	37	16	10	54	35	out of	sx
H	9/27/00	11/06/00	C-108 A-1	11/06/00	11/21/00	3	1.2	Pass	80	85	70	53	45	38	14	8	48	37	9	19
H	9/28/00	11/07/00	C-108 A-2	11/06/00	01/11/01	3	1.2	Pass	80	95	80	60	51	42	20	12	52.5	42.5	15	26
H	9/27/00	11/06/00	C-108 A-2	11/06/00			0.0										0	0		
H	9/27/00	11/06/00	C-108 A-1	11/06/00			0.0										0	0		
H	9/27/00	11/06/00	C-108 A-3	02/22/01			0.0										0	0		
H	9/27/00	11/06/00	C-108 A-1	11/06/00			0.0										0	0		
H	9/27/00	11/06/00	C-108 A-3	02/22/01			0.0										0	0		

TXI Information			CSI Information				CSI Thickening Time						CSI 8hr Strengths						CSI 8hr Strengths					
Cmt	Prod.	Date	Date Received	CSI Log #	Date Bucket Opened	Test Date	% H ₂ O	Sch #	Int Bc	15'-30' Bc	100 Bc	Pass/Fail	Time Hrs	Temp °F	Str psi	Pass/Fail	Time Hrs	Temp °F	Old	Str psi	Pass/Fail			
H	9/27/00		11/06/00	C-108 A-1	11/06/00	11/07/00	38.0	5	ran	out	of	sx	8	100	335	524	Pass	8	140	1334	2087.71	Pass		
H	9/27/00		11/06/00	C-108 A-1	11/06/00	11/29/00	38.0	5	12	13	2:03	Fail	8	100	307	480	Pass	8	140	1437	2248.905	Pass		
H	9/27/00		11/06/00	C-108 A-2	11/06/00	01/11/01	38.0	5	7	13	1:54	Pass	8	100	768	1201.92	Pass	8	140	1255	1964.075	Pass		
H	9/27/00		11/06/00	C-108 A-2	11/06/00	01/12/01	38.0	5					8	100	664	1039.16	Pass	8	140	1122	1755.93	Pass		
H	9/27/00		11/06/00	C-108 A-2	11/06/00	02/12/01							8	100	271	424	Pass	8	140	1097	1716.805	Pass		
H	9/27/00		11/06/00	C-108 A-1	11/06/00	02/22/01												8	140		1617	Pass		
H	9/27/00		11/06/00	C-108 A-3	02/22/01	02/22/01												8	140		1567	Pass		
H	9/27/00		11/06/00	C-108 A-1	11/06/00	02/22/01												8	140		1550	Pass		
H	9/27/00		11/06/00	C-108 A-3	02/22/01	02/22/01												8	140		1580	Pass		

Appendix D—Specification Testing

TXI Information			CSI Information			CSI 8hr Strengths					CSI 24hr Strengths					CSI 45°F Strengths						
Cmt Class	Mill Production Run Date	Date Received	CSI Log #	Bucket Opened	Test Date	Time Hr	Temp °F	Old	Str psi	Pass/Fail	Time Hr	Temp °F	Old	Str psi	Pass/Fail	Time Hr	Temp °F	% CaCl2	Old	Str psi	Pass/Fail	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-1	11/09/00	11.17.00	8.0	100	ran out	of	sx	24	100	ran out		of sx	24	45	2.0	ran out		of	sx
Class A	9/25 to 9/27/00	11/06/00	C-113 A-2	11/20/00	11.27.00	8.0	100	482	754.33	Pass	24	100	1666	2607.29	Pass	24	45	2.0	471	737		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-3	12/04/00	12.05.00	8.0	100	ran out	of	sx	24	100	ran out		of sx	24	45	2.0	ran out	#VALUE!	sx	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-4	01/09/01	1.17.01	8.0	100		0		24	100	1652	2585.38	Pass	24	45	2.0		0		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-2	11/20/00	2.12.01	8.0	100	466	729.29	Pass	24	100	1615	2527.475	Pass	24	45	2.0	666	1042		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.15.01	8.0	100	595	931.175	Pass	24	100	1641	2568.165	Pass			2.0		0		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.22.01	8.0					24	100		2334	Pass			2.0				
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.22.01						24	100		2590	Pass			2.0				
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.22.01						24	100		2250	Pass							

TXI Information			CSI Information				CSI 60°F Strengths					CSI 80°F Strengths				
Cmt Class	Mill Production Run Date	Date Received	CSI Log #	Bucket Opened	Test Date	Time Hr	Temp °F	% CaCl2	Old	Str psi	Pass/Fail	Time Hrs	Temp °F	Old	Str psi	Pass/Fail
Class A	9/25 to 9/27/00	01/00/00	C-113 A-1	11/09/00	11.17.00	24	60	1.0	ran out	of	sx	24	80	1052	1646	1.57
Class A	9/25 to 9/27/00	11/06/00	C-113 A-2	11/20/00	11.27.00	24	60	1.0	763	1194		24	80	1079	1689	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-3	12/04/00	12.05.00	24	60	1.0	ran out	#VALUE!	sx	24	80	1292	2022	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-4	01/09/01	1.17.01	24	60	1.0		0		24	80		0	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-2	11/20/00	2.12.01		60	1.0		0					0	
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.15.01					0					0	
Class A	9/25 to 9/27/00	01/00/00	C-113 A-5	11/09/00	2.22.01											
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.22.01											
Class A	9/25 to 9/27/00	11/06/00	C-113 A-5	11/09/00	2.22.01											

Appendix D—Specification Testing

TXI Information			CSI Information					CSI Rheology									
Cmt Class	Mill Production Run Date	Date Received	CSI Log #	Bucket Opened	Test Date	Temp °F	300 rpm	200 rpm	100 rpm	60 rpm	30 rpm	6 rpm	3 rpm	PV	YP	10 sec G.S.	10 min G.S.
Class A	9/25 to 9/27/00	11/06/00	C-113 A-1	11/09/00	11.17.00	80	75	62	48	40	33	17	10	40.5	34.5	10	19
Class A	9/25 to 9/27/01	11/06/00	C-113 A-2	11/20/00	11.20.00	80	80	65	49	40	34	17	10	46.5	33.5	10	19
Class A	9/25 to 9/27/02	11/06/00	C-113 A-3	12/04/00	12.5.00	80	78	64	50	40	32	16	10	42	36	10	19
Class A	9/25 to 9/27/03	11/06/00	C-113 A-4	01/09/01	1.09.01	80	80	65	52	40	33	17	11	42	38	10	20
Class A	9/25 to 9/27/04	11/06/00	0	01/00/00										0	0		
Class A	9/25 to 9/27/05	11/10/00	0	01/00/00										0	0		
Class A	9/25 to 9/27/00	11/06/00	0	01/00/00										0	0		
Class A	0	3/19/01	C-189 A-1	3/20/01										0	0		

TXI Provided Information			CSI Information				CSI Thickening Time						
Cmt Class	Mill Production Run Date	Date Received	CSI Log #	Bucket Opened	Test Date	% H ₂ O	Sch #	Int Bc	15 to 30 ft Bc	100 Bc	Pass/Fail		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-1	11/09/00	11.15.00	46.0	4	9	10	2:17	Pass		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-2	11/20/00	1.5.01	46.0	4	8	11	2:21	Pass		
Class A	9/25 to 9/27/00	11/06/00	C-113 A-3	12/04/00	1.09.01	46.0	4	4	ran	out of sx			
Class A	9/25 to 9/27/00	11/06/00	C-113 A-4	01/09/01	1.17.01	46.0	4	4	6	2:09	Pass		
Class A	9/25 to 9/27/00	11/06/00											
Class A	9/25 to 9/27/00	11/06/00											
Class A	9/25 to 9/27/00	11/06/00											

Appendix E— Technical Literature Review of Lightweight Cement Performance

1. Light Weight Cement Systems, What They Are - How They Are Used. L. H. Eilers, Dowell Div., Dow Chem, Proc. Annu. Southwest. Pet. Short Course (1980), 27th

A review, with 10 references, on lightweight cement systems and the role of water and extenders.

2. Low-Density Foamed Portland Cements Fill Variety of Needs R. Montman, D. L. Sutton, W. M. Harms, B. G. Mody Halliburton Serv. Oil Gas J. (1982), 80(30), 209-16

A review, with 9 references, on the properties and uses of foamed cement in oil fields.

3. Cement Encapsulated Lightweight Fine Aggregate T. Yamamoto. Tohoku Denryoku K. K., Japan. Gypsum Lime (1989), 222, 304-10

A review, with 7 references, of the use of coal ash for granulation with cement-encapsulated sand and the manufacturing, physical properties, and uses of the cured material.

4. Lightweight Cement Additives W. Manns, W. Zem. Taschenbuch (1974), Meeting Date 1974-1975, 155-71. Bauverlag GmbH: Wiesbaden, Ger.

A review, with 22 references, is given on lightweight cement additives (bulk d. <1.5 kg/dm³).

5. Real-Time Quality Control of Foamed Cement Fobs: A Case Study. R.D. Thayer, D.G. Ford, S. Holekamp, D.J. Pferdehirt Proceedings of the SPE Annual Technical Conference and Exhibition. Part 3 (of 5). 03 Oct 1993-06 Oct 1993

Foamed cement is a low density cement system prepared by mixing nitrogen gas and surfactants with API portland cement. The lower density limit for conventionally extended slurries is between 11.0 and 12.0 lb/gal. Foaming permits cement slurry densities lower than water (8.33 lb/gal) while maintaining relatively high compressive strengths. These advantages and others have been well documented. Actual field mixing procedures and additive rates are critical and must be monitored to assure a competent foamed cement. Slight variations in base slurry density, base slurry rate, foamer and stabilizer rate, or nitrogen rate can significantly alter the final foam density. Formerly, foam density was measured by a radioactive densometer. This allowed for significant error when densities were less than 8.33 lb/gal. There was no physical means to collect and weigh an actual foamed cement sample.

This paper explains methods to improve the accuracy of the additive rates. It also defines a method for real-time measurement of foamed cement density. The paper describes the use of a high-pressure device downstream of the nitrogen addition that can weigh a pressurized foamed cement sample during the job. It discusses the use of concrete technology to improve the performance of lightweight cements.

6. E. Moulin (Schlumberger Dowell), P. Revil, B. Jain. Proceedings of the 1997 SPE/IADC Middle East Drilling

To successfully cement across and isolate formations with low fracture gradients requires the use of lightweight cement slurries. Conventional lightweight slurries usually have a high water-to-solid ratio, which results in long waiting-on-cement times, limited compressive strength development, and a relatively permeable cement sheath subject to acid and brine attack. A new approach to designing cement slurries effectively decouples the physical properties of set cement from the

slurry properties and density, resulting in high performance lightweight cement slurries that reduce rig time and the logistics and costs associated with using conventional slurry designs. This has been clearly demonstrated in the cases of completing in reservoirs with a low fracture gradient (eliminating the risk of block squeeze), replacement of two-stage cement jobs by a single stage, and the use of a single slurry to replace lead/tail cement and side-track plugs. Results are described from various field applications where the technology has been used.

7. Sodium Metasilicate-Modified Lightweight High Alumina Cements For Use as Geothermal Well-Cementing Materials. T. Sugama, N. Carciello. Advanced Cement Based Materials v 3 n 2 Mar 1996.p 45-53

In studying the use of sodium metasilicate- (SMS) modified high alumina cements containing mullite-shelled microspheres as light-weight geothermal cementitious materials, we found that the following were the most advantageous characteristics of the slurries and of the 200 and 300°C autoclaved cements: (1) the slurries have a low density of less than 1.25 glcc, (2) the incorporation of SMS retarded the setting of the cements, (3) sodium calcium silicate hydrate and boehmite were formed in the matrix phase by hydrothermal reactions between the cement and SMS, and (4) there was a favorable reaction between the mullite shell layer in the hollow microspheres and the SMS to form analcime and boehmite phases. For characteristics (3) and (4), the pronounced development of these phases at 300°C generated a dense microstructure in the cements and was reflected by a reduced water permeability and a low rate of porosity.

8. Use of 1.6/1.7 kg/l Slurry For Cementing Production Casings. P. Macculi (AGIP). Proceedings of the 1997 SPE/IADC Middle East Drilling Technology Conference.

A major concern in drilling operations is the problem of carrying out cementing jobs for production casings where no fracture margin during the slurry displacement exists. In general, a double stage cement job, the use of a liner with a subsequent tie-back or one more casing string is required to resolve this problem.

9. In the Adriatic Offshore we have experimented with the use of lightweight high mechanical resistance slurry (SG equals 1.6/1.7 kg/l) in 7-in. production casing cement jobs in order to complete the operation in a single stage. These cement jobs have been carried out, with positive results, in six of the fourteen Angela platform wells, in three of the four Antonella platform wells, in one Anemone cluster well (double-stage cementing to avoid one more casing string), in the Antares 1 s.t. and the Agostino 11 s.t. wells.

The wells, where the 1.6/1.7 Kg/l lightweight slurry has been used, have an average total depth of 3600 m VD, their intermediate casing shoes are set at an average depth of 1800 m VD. The use of lightweight slurry, composed of 10/30% microsilica by cement, has led to a reduction in the hydrostatic load, an optimization of rheology and filtration control (maximum differential pressure of 400 atm exist at the end of displacement) while guaranteeing the necessary high mechanical resistance. According to field data, we can conclude that the use of lightweight slurry has the following advantages: a single stage cement job can be used instead of the more complex double stage one with the consequent improvement in well and rig safety; in particular cases, a lightweight slurry can avoid setting one more casing string; improved quality of the cement job in comparison with the not always reliable results of a double-stage cementing; operational time and cost reduction.

10. Increasing Well Life by Eliminating the Multistage Cementer and Utilizing a Light Weight High Performance Slurry. T. Mukhalalaty, A. Al Suwaidi, M. Shaheen. Schlumberger Dowell. SPE 11th Middle East Oil Conference (Bahrain 2/20-23/99) Proceedings 425-37 (1999) (SPE Paper #53283)

Increasing well life by eliminating the multistage cementer and utilizing a lightweight high performance slurry. A discussion covers the annulus pressure problem; losses during cementation; poor set cement mechanical properties; different casing schemes; lightweight cement slurries, including those with ceramic hollow spheres; a reduced water slurry system; set cement properties, including compressive strength and permeability; and four case histories. Tables, diagrams, graphs, and references.

11. Application of Foam Cements in Alberta. Olanson, M. T. J Can Pet Technol v 24 n 5 Sep-Oct 1985 p 49-57.

The demand for lightweight cement in areas of low-strength formation has led to the increased use of foamed cement in PanCanadian's wells. Foamed cementing involves mixing surfactant upstream of the cement pumper and injecting nitrogen into the pumper discharge line, with a foam generator installed downstream. The 'constant foam density method' was used. Recent field tests by PanCanadian confirmed that foamed cementing is only slightly more expensive than conventional cement jobs but less costly and involving less mechanical risk than multi-stage jobs. At the same time, it can be considerably less expensive than glass or ceramic microspheres cementing.

12. Foamed Cement a Second Generation N. R. Loeffler, Dow Chem. U.S.A., Dowell Div. Spe (Soc. Pet. Eng. Aime) Permian Basin Oil Gas Recovery Conf. (Midland, Tex. 3/8-9/84) Proc. N.12592, 153-59 (Mar. 1984)

A survey of new applications for foamed cement shows that lightweight nitrified cement systems placed across weak and washed-out zones have been successfully perforated and fractured. For example, an 8.0- to 8.5-lb/gal nitrified cement replaced costly and time-inefficient cement staging in air-drilled holes with fracture gradients in the 0.4- to 0.6-psi/ft range; cost savings for one such treated well was more than \$12,000 compared with cementing by staging methods. To meet the special needs of steam flood wells, low-density (> 12 lb/gal) extended cement systems such as bentonite/sodium silicate, perlite, fly ash, hollow glass spheres, etc., are suggested.

Performance data for a 9-lb/gal cement containing glass spheres vs. a 9-lb/gal high-temperature foamed system show major losses of compressive strength; although the foamed system maintains an adequate level of strength (700 psi), the cement containing the microspheres undergoes an immediate severe loss (to < 200 psi). The three general criteria for successful oilfield foamed cement performance are also discussed.

13. ACI Manual of Concrete Practice 1999: Volume 1 Materials and General Properties of Concrete

Part 1 of the American Concrete Institute (ACI) Manual of Concrete Practice contains current committee reports and standards concerned with materials and general properties of concrete. The contents include information on the following topics: concrete notation; cement and concrete terminology; concrete construction and materials tolerances; recommended format for concrete identification in a materials property database; concrete condition survey; concrete durability; mass concrete; cracking of mass concrete; roller compacted mass concrete; prediction of creep,

shrinkage and temperature effects in concrete structures; concrete erosion and repair in hydraulic structures; selecting proportions for normal, heavyweight, and mass concrete, structural lightweight concrete, no-slump concrete, and high strength concrete; concrete admixtures; superplasticizers; lightweight aggregate concrete; design of concrete structures subjected to fatigue loading; fire endurance of concrete; use of normal and heavyweight aggregates in concrete; alkali-aggregate reactivity; corrosion of metals in concrete; shrinkage-compensating concrete; selection and use of hydraulic cements; controlled low strength materials; soil cement; pozzolans, fly ash, blast-furnace slag, and silica fume in concrete; high-strength concrete; and high-strength concrete columns.

14. Improved Performance of Lightweight Cement Slurries. JPT, Journal of Petroleum Technology v 49 n 8 Aug 1997.p 852-853

Lightweight slurries are used for cementing across formations with low fracture gradients. Conventional lightweight slurries have a high water-to-cement ratio that results in long waiting periods during cementing, slow development strength, and a relatively permeable cement sheath that is subject to acid and brine attack. However, a new engineering approach has eliminated these characteristics. The resulting high-performance lightweight slurries reduce the rig time, logistics, and costs associated with conventional designs. The new approach considers the quality of the granular mixture in terms of its water demand and optimizes particle size distributions.

15. Fundamental Study on the Properties of High Strength Lightweight Concrete (Part 5).

Tsuiba Hiroyuki; Honda Satoru; Araki Aya, Fukuoka Univ. (Fukuoka University Review Of Technological Sciences), (1993) No. 50, Pp. 137-147. Journal Code: S0905A (Fig. 11, Tbl. 6, Ref. 9) ISSN: 0285-2799

PUB. COUNTRY: Japan

DOCUMENT TYPE: Journal; Article

LANGUAGE: Japanese

AB Super high-rise reinforced apartment buildings with frame-type, ranging 30 to 40 stories, have become popular in Japan among leading construction companies. Therefore, this paper presents to a comprehensive review of high strength concrete with kinds of test specimens (model test specimen, molded cylinder test specimen), coarse aggregates (crushed stone for concrete, artificial light-weight aggregate), water cement ratios (30, 35, 40, 45, 50%) and curings (standard curings, water curings, sealed curings, air-dry curings). The cement was used a normal Portland cement and the water cement per cubic was 170 kg. The concrete was 21cm slump were prepared by using superplasticizer and high-range water reducing agent. Effect of compressive strength, Young's modulus, tensile strength, pulse velocity, rebound number by core test specimen (model test specimen) and cylinder test specimen were chiefly studied. (author abst.)

16. Using Concrete Technology to Improve the Performance of Lightweight Cements. Eric Moulin (Schlumberger Dowell); Philippe Revil, Bipin Jain. Proceedings of the 1997 SPE/IADC Middle East Drilling Technology Conference. Proceedings of the IADC/SPE Asia Pacific Drilling Technology Conference, APDT 1997. Soc Pet Eng (SPE), Richardson, TX, USA.p 243-248 SPE/IADC 39276

To successfully cement across and isolate formations with low fracture gradients requires the use of lightweight cement slurries. Conventional lightweight slurries usually have a high water-to-solid ratio, which results in long waiting-on-cement times, limited compressive strength develop-

ment, and a relatively permeable cement sheath subject to acid and brine attack. A new approach to designing cement slurries effectively decouples the physical properties of set cement from the slurry properties and density, resulting in high performance lightweight cement slurries that reduce rig time and the logistics and costs associated with using conventional slurry designs. This has been clearly demonstrated in the cases of completing in reservoirs with a low fracture gradient (eliminating the risk of block squeeze), replacement of two-stage cement jobs by a single stage, and the use of a single slurry to replace lead/tail cement and sidetrack plugs. Results are described from various field applications where the technology has been used. (Author abstract) 8 References.

17. Basic Cementing-2. Specialty Cements Can Solve Special Problems. Pat N Parker, Oil Gas J v 75 n 9 Feb 28 1977 p 128-131

Part 2 of this article reviews a number of specialty cements formulated by service companies and cement manufacturers to solve special problems encountered in oil wells. These cements, which are essentially modified Portland cements or cements manufactured from limestone, can handle both pressure and temperature extremes. Among the specialty cements discussed are pozzolan slurries, lightweight cements, thixotropic cement, and quick-setting cements.

18. Next-Generation Cementing Systems to Control Shallow Water Flow. Ronnie Faul, B. R. Reddy, James Griffith, Rocky Fitzgerald, Bryan Waugh. 32nd Annual Offshore Technology Conference - OTC 2000; Proceedings of the Annual Offshore 19. Technology Conference v 1 2000. Offshore Technol Conf, USA.p 117-122

As documented in industry literature, shallow hazards, especially shallow water flows (SWF's), pose a challenge in deepwater Gulf of Mexico operations. Cement systems that successfully solved SWF's were first used in 1992. The first of these special systems was a lightweight nonfoamed system. In 1994, special foamed lightweight systems were implemented and were proven superior both in large-scale laboratory models and in field use. Several special foamed-cement blends have been used to cement over 300 conductor casings where SWF's were a threat. These formulations consisted of highly activated cements that required special blending at the shore base before being transported to the offshore rig. Because dry additives were used, the cement slurry could not be redesigned or modified, so any unused blend had to be discarded. To address these challenges, the industry developed a lightweight foamed-cement (LFC) slurry system. This system uses only liquid additives in conjunction with the dry Portland cement on board the rig. The LFC system provides a low-density slurry with short transition times to help prevent SWF's while maintaining zonal isolation, adequate placement time, and shorter waiting-on-cement (WOC) time.

20. Foamed Cement for Squeeze Cementing Low-Pressure Highly Permeable Reservoirs. Design and Evaluation. W. Chmilowski, L.B. Kondratoff. Drilling Proceedings - SPE Annual Technical Conference and Exhibition v Delta. Publ by Soc of Petroleum Engineers of AIME, Richardson, TX, USA.p 231-245

Squeeze cementing is a highly used remedial technique that relies on controlled slurry placement as the key to success. Typically, competent low-permeability reservoirs with normal bottomhole pressures are routinely cement squeezed with little difficulty, as long as the established techniques for conventional cement squeezing are properly followed. Formations with low reservoir pore pressure and high permeability can create severe challenges for proper placement, especially if the high permeability is due to naturally occurring formation vugs and fractures. Recently, a

new technique using low-density foamed cement proved to be successful in providing a squeeze cementing method offering a much higher probability of success. In this paper, a number of key aspects that are critical to the success of squeeze treatments in these difficult reservoirs are discussed. Candidate selection, slurry design, treatment design, operational considerations, and an evaluation of squeeze treatment results are included. The evaluation focuses primarily on foamed and conventional cement squeeze treatments on wells producing from the Keg River formation in the Rainbow Lake area of northwestern Alberta, Canada. Ninety-six individual well case histories involving 151 remedial cementing operations were evaluated to determine their success. (Author abstract) 16 References

21. New Generation Foam Cement - A Universal System for Cementing A. Ruch. Oil Gas European Magazine 26/3 16,17-22 (September 2000) ISSN: 0342-5622

A discussion on nitrogen foamed cement slurries, known as foamed cement, which have been used for cementing operations in the petroleum industry for more than a decade, covers the single components of the system. Foam-Cement; various applications for foamed cement, including lightweight cement slurries, avoidance of fluid-migration, optimization of cement sheath properties; steam-injection and geothermal projects, and squeeze-applications; prerequisites and selection process for the foamed cement system; preparation, planning, and simulation for a cement job; foamed cementing equipment and job site layout; foamed cement job execution; case histories of recent foamed cement jobs, including 9.625-in. gas storage production casing across formations with different pore pressure; and limitations on economics. 3 photomicrographs, 10 graphs, flow diagram, and 7 references.

22. Bond Of Lightweight Aggregate Concrete Incorporating Condensed Silica Fume P.J Robins. Fly Ash, Silica Fume, Slag And Natural Pozzolans In Concrete. Proceedings Second International Conference, Madrid, Spain, Volume 2, Aci Special Publication, 1986., No. Sp91. P. 941-58. 27 Refs., American Concrete Institute

Condensed silica fume, at up to 30% by weight, was used as a partial cement replacement in lightweight aggregate concrete. The results of round and deformed bar cube pullout tests, with and without applied lateral stress, show that condensed silica fume increases ultimate bond strength and affects the mechanism of failure. The influence of condensed silica fume on bond stress of round bars was similar at all lateral stresses, producing a 50% increase at 20% by Weight replacement of cement. For deformed bars the increase in bond strength was more pronounced at higher levels of lateral stress, Producing increases approaching 70% at 20% silica fume content. The improvements in ultimate bond strength with condensed silica fume are shown to only partly result from the associated increases in compressive strength, the greater part resulting from the modified properties of the concrete matrix.

23. A Novel Lightweight Cement Slurry And Placement Technique For Covering Weak Shale In Appalachian Basin S V Kulkarni; D S Hina, Spe East Reg Mtg (Charleston, Wv, 10/20-22/1999) Proc 1999 (Spe-57449)

24. Successful Primary Cementing Can Be A Reality R C Smith, Amoco Prod. Co, J. Pet.

Technol. V36 N.12 1851-58 (Nov. 1984) Successful Primary Cementing Can Be a Reality.

A review of primary cementing includes planning and slurry design; blending of additives and cement, and mixing of the slurry; slurry displacement; the adequate strength of ultralight-weight cements containing new additives such as hollow glass (borosilicate or sodium silicate) or ceramic microspheres, in well-completion situations requiring cement densities lower than those attainable with conventional lightweight cement containing additives such as bentonite, diatomaceous earth, or sodium silicate; spacers and preflushes; and free fall of cements.

25. Preventing Shallow Gas Migration In Offshore Wells: The Performance Of Lead Cements. O. D Coker, K.L Harris, T.A. Williams; Proc Eur Pet Conf. Publ By Society Of Petroleum Engineers (SPE), P.O.Box 833836, Richardson, TX, USA, 24978. P 159-169

Offshore drilling operations that encounter shallow gas formations must consider the potential annular gas flow that may occur following primary cementing. Many specialized cements and procedures have been developed to combat gas migration, but the complexities of gas migration control still challenge operators worldwide. In offshore shallow environments, additional complications can arise with the presence of weak formations and cold temperatures. In such conditions, lightweight lead cements are employed to avoid fracturing the wellbore. Although lead cements are often viewed simply as 'filler' materials, shallow gas control slurries must far exceed that role as they become the mechanism to help isolate the movement of gas up the annulus. Presented in this paper is a review of the properties of gas control cementing systems specifically related to lightweight lead slurries. The importance of fluid loss control, rapid gelation, and compressive strength at the time of drillout is stressed. Silica fume cement and newer cementing additives such as colloidal silica and small particle cement are highlighted as means of helping prevent shallow gas migration. Several offshore cementing operations are documented which confirm the success of applying the prescribed designs and methods. (Author abstract) 8 References

26. Pulverised-Fuel Ash J.B. Cripwell, (Natl Power Plc, Uk) The Use Of Pfa In Construction. Proceedings Of The National Seminar, Held At University Of Dundee On 25-27 February 1992 (1992) p.

This paper is intended to provide a brief introduction to pulverised fuel ash (PFA). It describes its production and properties, comments on handling and uses, makes references to health and safety requirements, and concludes with a review of research and development. PFA consists predominantly of finely divided spherical particles mainly in the size range of 1 to 150 microns. Chemically, it is an alumino-silicate glass containing some iron, calcium, magnesium and alkali metals together with carbonaceous particles resulting from incomplete combustion. Uses for PFA include: load bearing fill, aerated concrete blocks, lightweight aggregate, cement manufacture, grouting, fillers and stabilization in road bases and sub-bases.

27. Preventing Shallow Gas Migration In Offshore Wells: The Performance Of Lead [(Primary)] Cements. O. D. Coker, K.L Harris, T.A. Williams; SPE European Petroleum Conference (Cannes, France 11/16-18/92) Proceedings V1 159-69 (1992)

Preventing shallow gas migration in offshore wells: The performance of lead [(primary)] cements. A discussion covers the need for a primary cement which can prevent gas migration in shallow wells, especially in the North Sea; the importance of complete removal of drilling fluid prior to cementing; density requirements for such cements; the other required properties of such cements, including low fluid loss, rapid gelation, zero free water, low permeability, high early compressive strength, and adequate waiting-on-cement time; the additives which provide these

properties, i.e., Portland cement, silica flour, an acrylamide copolymer to minimize fluid loss, a polymeric sulfonate dispersant, and a lignosulfonate retarder; and a case history of using lightweight cement in a well drilled in 236 ft of water in the North Sea to a depth of 2109 ft. Tables, diagram, well logs, and 18 references.

28. New Generation Foam-Cement - System For A Wide Range Of Cementing Operations. A Ruch., Erdoel Erdgas Kohle/EKEP V 116 N 5 2000.P 267-272

LANGUAGE: German

In recent years the use of Foam-Cement for cementing casing or liner during drilling operations has undergone a major development. Used successful as lightweight cement in the last decades Foam-Cement is seen today more as a system for a wide range of cementing operations than a cement slurry alone. This is mainly due to the fact that optimized computer simulation programs and automated cementing equipment is available for accurate job planning and execution. This article explains the single components of the system Foam-Cement and lists reasons for its use to cement a casing or liner, especially in critical well situations or in wells demanding technically high standards.(Author abstract) 7 References

29. Cementing The Conductor Casing Annulus In An Overpressured Water Formation. James Griffith, Proceedings Of The 1997 29th Annual Offshore Technology Conference, OTC.Part 1 (Of 4).

The technique for cementing a 20- or 24-in. outside diameter conductor pipe offshore, in deep water, in the presence of pressurized water flow, which constantly threatens to wash cement away from the wellbore are described. The conductor pipe is cemented with a lightweight, foamed slurry with good compressive strength that helps control the water flow. Three key fluids are used such as foamed drilling fluid sweeps, settable spotting fluids and foamed cement slurries. The foamed sweeps are used to bring cuttings out of the wellbore. The settable fluids have low gel strength and are composed to provide fluid-loss control. The combination of settable spotting fluid and cement slurry provides good zonal isolation of the water-flow interval.5 References

30. Mud Management, Special Slurries Improve Deepwater Cementing Operations. James Griffith, (Oil And Gas Journal V 95 N 42) Oct 20 1997. P 49-51

Deepwater cementing requires improved mud-management techniques. In the Gulf of Mexico (GOM), new mud-management techniques and specially designed cement mixtures are being used to effectively set conductor casing in deepwater conditions and to improve the success rate in cementing deepwater wells. Recent case histories in the GOM describe these new techniques and the advantages of using a specially formulated, lightweight, foamed cement slurry to avoid cement-sheath damage caused shallow-water flow. 4 References

31. Alkali-Aggregate Reactivity In Canada C. A. Rogers, Cem. Concr. Compos. (1993), 15(1-2), 13-9

A review and discussion with 23 references. In Canada, three types of alkali-aggregate reaction in Portland cement concrete are recognized. Each type is evaluated using different tests. Corrective measures such as the use of low-alkali cement, lower cement contents, or pozzolans are seldom used with reactive aggregates. Beneficiation or selective extn. is used with some reactive aggregates. Work is being conducted on multiple. study of existing tests and new, rapid tests.

32. Experimental Methods For Determining The Residual Alkali Silica Reactivity Potential In Concrete Structures Sharma, V.M.; Suri, S.B.; Chandrasekaran, N. Proc. - Int. Symp. Innovative World Concr. (1993), Volume 1, 2/193-2/203. Oxford & IBH: New Delhi, India.

A review with no references. It is essential to identify alkali reactive aggregates and their potential for deleterious expansion before their use in concrete. However, in the absence of the above evaluation, if the alkali silica reaction gets triggered in a concrete structure, determination of the residual alkali silica reactivity potential in the structure becomes inevitable for assessing its safety and durability. Laboratory testing can often be difficult, complex, time consuming and even inconclusive. Still, it is the best method to assess and evaluate the potential reactivity of aggregates prior to their use in concrete construction. While there are several established standard test methods available for determining the potential reactivity of cement-aggregate combinations and new and rapid test methods have been proposed, there are no standard test methods available for assessing the magnitude of the residual alkali-silica reactivity potential existing in a structure, for establishing its future damage potential.

33. Does Silica Fume Merely Postpone Expansion Due To Alkali-Aggregate Reactivity Berube, M. A.; Duchesne, J., Int. Conf. Alkali-Aggregate React. Concr., 9th (1992), Volume 1 71-80. Concr. Soc.: Slough, UK.

A review and discussion with 25 references. Condensed silica fume (CSF) is considered effective in suppressing concrete expansion due to alkali-silica reaction (ASR), provided it is used in sufficient amts. Various mechanisms can be proposed to explain this: higher strength, lower permeability, alkali diln., portlandite consumption in the cement paste and alkali depletion in the pore soln. due to pozzolanic reaction. The most crit. mechanism appears to be alkali depletion in the pore soln. and consequent pH decrease. However, the long-term effectiveness of CSF against ASR is presently questioned by a no. of workers. The proposed explanation is the recycling of alkalis which were entrapped early in low Ca/Si and high-alkali pozzolanic CSH. This hypothesis is based on expansion tests on concrete contg. CSF and reactive aggregates, and on chem. of pore soln. extd. at different time intervals from equiv. cement-admixt. pastes.

34. Pore Solution Chemistry And Alkali Aggregate Reaction Christopher Page And Philip Norman, Am. Concr. Inst., SP (1987), SP-100(Concr. Durability, Vol2, 1833-62

A review, with 39 references, of the progress in explaining the phenomena associated with alkali-aggregate reactions in terms of pore solution comparison. In particular, consideration is given to the effects of alkali level and water content of the concrete on the severity of reaction, the role of alkalis in pulverized fuel ashes, granulated blast-furnace slags, and other cement replacement materials in determining their effectiveness in preventing damage, and the contribution to pore solution alky. made by salt contamination of aggregates and deicing salts.

35. Some Opportunities To Offset Poor Quality Characteristics Of High-Alkali Cement Louis U. Spellman, Cem., Concr. Aggregates (1983), 5(1), 73-6

A review, with 18 references, concluding that inclusion of a substantial percentage of ground blast-furnace slag in cement manuf. minimizes the alkali-aggregate reactivity and the decreased rates of strength gain at later ages.

36. Reducing Expansion Due To Alkali- Silica Reactivity Fournier, B.; Malhotra, V. M. Concr. Int. (1996), 18(3), 55-9

A review with no references, including general objectives and scope of the research program, petrog. of the aggregates, portland cement and supplementary cementing materials, mixture, proportioning, lab. and field testing of specimens, and general observations on test results.

Review Of Alkali-Silica Reaction And Expansion Mechanisms. Alkalies In Cements And In Concrete Pore Solutions Diamond, Sidney Cem. Concr. Res. (1975), 5(4), 329-45 A review with 35 references.

37. Alkali-Aggregate Reactions And The Middle East. French, W. J.; Poole, A. B. Concrete (London) (1976), 10(1), 18-20

A review with 16 references is given on the chem. and phys. mechanisms associated with reactions between alkalis derived from cement pastes and aggregates of SiO₂ minerals or carbonate rocks to explain the causes for the rapid deterioration of some concrete structures.

38. Durable Concrete Containing Three Or Four Cementitious Materials Butler, W. Barry, Am. Concr. Inst., SP (1997), SP-170(Vol. 1, Durability Of Concrete), 309-330

A review with 25 references In most concrete markets these days, there are several varieties of pozzolans and ground slag available for use in regular and high-performance concretes. Each one has its strong points when blended with portland cement in concrete and, properly used, will provide concrete of enhanced durability. Recently, concrete contg. more than one such material has become common, even to the point of being available as ternary or quaternary blend. This paper reviews the data available on durability of concrete produced from multiple blends and discusses some of the potential benefits to specifiers and users. The blending materials covered include silica fume, fly ash, metakaolin, and ground granulated slag.

39. High-Alkali Cements For 21st Century Concretes, Davidovits, J., Am. Concr. Inst., SP (1994), SP-144(Concrete Technology), 383-97

A review with 27 references Recent literature suggests that there is considerable potential for redn. in the emission of CO₂ to the environment through the manuf. of new types of cement which do not rely on the calcination of limestone (and accompanying release of CO₂). The 1988 one billion metric tons world-wide production of cement accounted for one billion metric tons of CO₂ release, i.e. 5% of the 1988 world CO₂ emission (human activity only). This is equiv. to the CO₂ emission by the entire Japanese activity. The use of lesser amounts of calcium-based cements could be achieved through their partial replacement by alkali-activated aluminosilicate materials, which do not release large quantities of CO₂ in their manuf. The fostering of low-CO₂ high-alkali-based cements will mean a dramatic change in the research and development presently carried out in USA and other countries. Alkalis are generally thought of as the cause of deleterious alkali-aggregate-reaction. As a consequence, the tendency has been to avoid any addn. of alkali portland cement products, and often require the cement manufacturers to supply low-alkali cements. The use of MASNMR spectrog. for the detns. of compounds of alkali-activated cements, in combination with std. ASTM C 227 bar expansion, allows us to predict the potential for alkali-aggregate reaction. Our preliminary study involving ²⁷Al and ²⁹Si MASNMR spectroscopy revealed that the alkali-activated aluminosilicate cements are the synthetic analogs of natural pozzolans that are known to effectively suppress the alkali-aggregate

reaction. These cements, even with alkali contents as high as 9.2% do not generate any deleterious alkali-aggregate reaction, according to ASTM C 227 bar expansion test. Industrial experience based on the use of alkali-activated slags in Eastern Europe since 1964, associated with the com. produced alkali-activated cements in the US since 1988, suggest that high-alkali cements will ultimately improve the concrete used in buildings and highways, and also serve our global need by a) reducing the emission of CO₂ b) reducing the energy consumption during cement manufacturing in terms of a 5% growth scenario, the predicted Business as Usual (BaU) world cement production for the year 2015 equals 3500 million metric tons. Based on an amt. of blended Portland cement production in the order of 1850 million metric tons (1000 Mt. Portland + 560 Mt. slag + 290 Mt. fly ash), in the 21st century, the need for novel alkali-activated cementitious materials could be in the range of 1650 million metric tons.

40. The Alkali-Silica Reaction In Concrete. Chapter 1 - Introduction To Alkali-Aggregate Reaction In Concrete Swamy, R.N. [Editor] (Sheffield Univ, Uk); Poole, A.B. (London Univ, Queen Mary And Westfield College, Uk) 1992. P. 1-29. 43 Refs., Blackie And Sons Ltd

This chapter introduces and defines the nature of alkali-aggregate reactions in concretes. Alkali-silica reactivity in concrete is a particular variety of chemical reaction within the fabric of a concrete involving alkali hydroxides, usually derived from the alkalis present in the cement used, and reactive forms of silica present within aggregate particles. This chemical reaction also requires water for it to produce the alkali-silica gel reaction product which swells with the absorption of moisture. The amount of gel and the swelling pressures exerted are very variable depending on reaction temperature, type and proportions of reacting materials, gel composition, and other factors, but they are often sufficiently high to induce the development and propagation of microfractures in the concrete which, in turn, lead to expansion and disruption of the affected concrete structure or element. Typical deleterious features of alkali-silica reaction in concrete structures include cracking, expansion and consequent misalignment of structural elements, spalling of fragments of surface concrete as 'pop-outs', and the presence of gel in fractures or associated with aggregate particles within the concrete. The reaction typically takes between 5 and 12 years to develop, though there are many exceptions, and it is most severe where alkali concentrations in the concrete pore fluids are high. A very wide variety of aggregate rock types in structures from many parts of the world have been reported as being alkali-silica reactive. This is consequent on the reactive forms of silica often only forming a minor mineral component of the aggregate such as the cement between mineral grains. This silicious material must be amorphous or cryptocrystalline with a large surface area if it is to react sufficiently to produce deleterious effects in the concrete. (A) For the covering abstract of the BOOK see IRRD 844648.

41. Concrete Durability And Alkali Reactions. Figg, John Concrete (London) (1981), 15(8), 18-22

A review, with 14 references, discussing equiv. alkalinities of alkali metals, adverse effects of alky., cement compounds and hydration, concrete performance, alkali-aggregate reactivities, the reaction mechanism and symptoms, parameters affecting the reaction, and preventive and remedial measures.

42. Proceedings Of The 1996 10th International Conference On Alkali-Aggregate Reaction, AAR. Cement & Concrete Composites V 19 N 5-6 Oct 1997. Elsevier Sci Ltd, Exeter, Engl. P 391-480

The proceedings contains 6 papers on cement and concrete composites. Topics discussed include: cements; concrete aggregates; alkali-silica reaction; alkali-aggregates reactivity; ultra-accelerated tests; fracture mechanics; crack initiation; crack propagation; nondestructive techniques; mortar bar tests; and petrographic evaluation.

43. Possibility Of Enhanced Silica Dissolution In Concrete As In Diagenetically Altered Sandstone. Broekmans, Maarten A. T. M.; Jansen, J. Ben. H. Bull. - Nor. Geol. Unders. (1997), 433, 42-43

A review and discussion, with 13 references, of the alkali-silica reaction in concrete and the need for tests predicting the reactivity of aggregates. Sandstone as an aggregate is theoretically less prone to silica dissoln. compared with chert. Study of thirty-year-old concrete showed that fine-grained sandstone with detrital mica and diagenetic clay minerals is extremely alkali-reactive, whereas chert in the same samples reacts only slightly. Recent studies have demonstrated the catalytic interaction of phyllosilicates like mica and clay minerals in silica dissoln. and diagenetic sandstone compaction and cementation.

44. ASR Testing Remains In Technology Spotlight. (Test Methods For Alkali-Silica Reactivity). Kuennen, Tom Concrete Products, (May 1999) Vol. 102, No. 5, Pp. 6(4).

Editor's note: Test methods for alkali-silica reactivity (ASR) were among concrete program highlights at the Transportation Research Board's (TRB) 78th annual meeting in Washington, D.C. ASR testing shared the stage with new research on admixtures and fibers, freeze-thaw durability, and D-cracking prediction. Separately, an eight-member panel discussed High-Performance Concrete (HPC) pavements (note Concrete Products' March 1999 report, "FHWA to Inject \$30 Million into HPC Pavement Studies."). THIS IS THE FULL TEXT: COPYRIGHT 1999 Intertec Publishing Corporation, a PRIMEDIA Company. All rights reserved.

45. Durability of cement pastes, mortars, and concretes Struble, Leslie, Cem. Res. Prog. (1989), Volume Date 1987 157-238

A review, with 638 references, including discussions of general durability (effects of concrete parameters, quant. studies), permeability, aggressive environments (sulfates, chlorides, seawater, CO₂, other), alkali-aggregate reactions (mechanisms, reactivity tests, constituent effects, practical aspects), freeze-thaw (mechanisms, test methods, constituent effects, air entrainment), reinforcement corrosion (glass, steel, other), drying shrinkage, thermal degrdn., efflorescence, and abrasion.

46. A Critical Review Of The Recent Danish Literature On Alkali-Silica Reaction. Chatterji, S. (Teknol Inst, Taastrup, Denmark) Proceedings Of The 8th (July 17-20, 1989) International Conference On Alkali-Aggregate Reaction, Held Kyoto, Japan, 1989. P. 37-42. 14 Refs.

In Denmark researches on alkali-silica reaction have been carried out in two distinct phases. In the first phase the problem was identified as a national one. Opaline limestone, and flint of varying degree of crystallinities and porosities were identified as the main reactive aggregates. At this stage the use of a low alkali Portland cement was suggested as the effective preventive measure against alkali-silica reaction. The second phase of research started with an investigation

of the breakdown of concrete roads, which indicated that NaCl, a de-icing agent, accelerates alkali-silica reaction and that the presence of free Ca(OH)_2 is a pre-requisite for expansive alkali-silica reaction. At the same time the electron-probe micro-analytical technique was adapted for the analysis of the reaction products still within expanding structures. In subsequent investigations the above observations and the analytical technique were utilized to explore the reaction mechanisms, in the development of an accelerated mortar bar method for alkali-silica reactivity with its acceptance criterion, in the development of a simple chemical method for the identification of reactive aggregates. Independently of the above researches a method has been proposed to monitor continuously the dissolution of reactive silica in 10N NaOH solution as a means of evaluating alkali-silica reactivity. In this report the literature of this second phase of research has been critically evaluated. (A) For the covering abstract of the conference see IRRD 857024.

47. Alkali-Silica Reactions And Silica Fume: 20 Years Of Experience In Iceland. Gudmundsson, Gisli (Icelandic Building Research Inst, Reykjavik, UK); Olafsson, Hakon Cement and Concrete Research v 29 n 8 1999.p 1289-1297

In Iceland, silica fume has been blended with all Icelandic cement since 1979. Icelandic cement is unique in many ways. Common raw material for cement production is not found; therefore, less appropriate material is utilized for production. As a result, the alkali content of the cement clinker is relatively high. Because alkali-silica reactive aggregates are relatively common and favorable environmental conditions for alkali-silica reaction (ASR) prevail, ASR became a serious problem in Iceland during the 1970s. At that time research began in Iceland to look for pozzolanic material to counteract ASR reactions in Icelandic concrete. Since the opening of a ferrosilicium plant in Iceland in 1979, silica fume has been utilized as pozzolanic material in all concrete. After 20 years of service there are no signs of ASR in this concrete in Iceland. These findings are supported by scientific research, standardized alkali-silica test methods, and field observations. (Author abstract) 22 References

48. State-Of-The-Art Report On The Mechanism Of Alkali-Aggregate Reaction In Concrete Containing Fly Ash. Interim Report Schumann, D.C.; Carrasquillo, R.L.; Farbiarz, J. Published By: Texas State Department Of Highways & Public Transp (01 Feb 1988), No. 884502. P. 108. 115 Refs. Published by: Federal Highway Administration

Although aggregates were once thought to be inert, it is now known that all aggregates are chemically reactive. The chemical reactions between the aggregates and the cement paste are responsible for beneficial effects such as enhanced bond, but also for other effects that can be deleterious to the durability of the concrete. Alkali-aggregate reaction is one of such chemical reactions. Its chemistry and mechanism are not yet very well known but several hypotheses have been presented over the years and are reported herein. The prevention of expansion in concrete due to alkali-aggregate reaction has been widely investigated by many researchers around the world. It is now known that the proper use of mineral admixtures in concrete can reduce the cost of concrete, improve many material properties, and inhibit alkali-silica reaction. The effect of fly ash and silica fume and a summary of the probable mechanisms in which pozzolans affect the expansion caused by alkali-aggregate reaction in concrete is also reviewed, as well as the different methods of predicting the reactivity of aggregates and a discussion of their relative accuracy and validity. Research study title: alkali-aggregate reaction in concrete containing fly ash.

49. Use Of Cement Kiln Dust In Blended Cements - Alkali-Aggregate Reaction Expansion. Bhatti, Muhammad S.Y. (Pca, Skokie, Il, Usa) World Cem V 16 N 10 Dec 1985 P 386, 388-390, 392

Blended cements made from Portland cement, cement kiln dust and fly ash (ASTM Class F) or granulated blast furnace slag were studied for alkali-aggregate reactivity using the mortar bar expansion test. Beltane opal was used as a reactive aggregate in mortar bars. Blended cements made from cement and kiln dust showed higher expansions at 6 months than cement alone. Expansion increased even more as the level of kiln dust in blends was increased. Cement-kiln dust-fly ash blends produced lower expansion than corresponding cement-kiln dust blends with the same amount of kiln dust, and an increase in fly ash in blends further reduced expansion. Fly ash was a much better expansion inhibitor than slag in comparable blends. (Edited author abstract) 3 references

50. Alkali-Silica Reaction In Australian Concrete Structures Carse, A. (Main Roads Dept, Brisbane, Australia); Dux, (Queensland Univ, Australia) Proceedings Of The 8th (July 17-20, 1989) International Conference On Alkali-Aggregate Reaction, Held Kyoto, Japan, 1989. P. 25-30. 4 Refs., Document Type Book

This research investigation has placed significant emphasis on collecting field information of alkali-silica distressed structures and using this data to calibrate laboratory tests for predicting safe cement/aggregate combinations. It was determined that alkali-silica reaction has occurred in concrete bridges, a wharf structure and an off shore bulk loading facility. The age of the structures investigated ranges from 8 to 29 years with a corresponding period of construction from 1959 to 1980. Documentation is provided showing that the occurrence of alkali-silica reaction may not always cause destructive expansion in the associated concrete matrix. Two structures were analyzed and shown to exhibit alkali-silica reaction without any associated destructive cracking of the concrete structures. Four additional structures were shown to display similar alkali-silica reaction, however, in these cases associated destructive cracking of the concrete matrix had occurred. The reactive aggregates in the structures examined were identified as an extrusive volcanic source and a river gravel. It has been concluded from this project that the degree of alkali-silica reaction within a structure is dependent on environmental factors and can be magnified by an inadequate design concept. Details of an accelerated test for alkali-silica reaction on concrete samples are provided for use in determining safe cement/aggregate combinations.

51. Chemistry And Structure Of Hydration Products Christensen, Bruce J.; Garci, Maria C.; Olson, Rudy A.; Jennings, Hamlin M. Cem. Res. Prog. (1996), Volume Date 1994 25-50

A review, with 133 references, including discussions of pure compounds, cement hydration, effects of admixtures, creep and shrinkage thermodyn., nanostructure, and reaction kinetics, alkali-aggregate reactions, composites, hydration processes of portland and high-alumina cements, hydration of other cement types, stabilization/solidification and utilization of waste materials, effects of minerals on the hydration process, and decomposition, and carbonation.

52. Effect And Mechanism Of Natural Zeolite On Suppressing Alkali-Silica Reaction (Asr) In Concrete. Feng, N.; Jia, H.; Hao, T.; Malhotra, V.M. [Editor] Fly Ash, Silica Fume, Slag And Natural Pozzolans In Concrete. Location: Bangkok, Thailand. Held: 31 May - 5th June 1998, 1998., Vol. 2 P. 797-820. - Refs., American Concrete Institute

Effect and mechanism of natural zeolite (NZ) on preventing expansion due to alkali-silica reaction (ASR) are studied in this paper. The reduction of deleterious expansion by NZ is compared with that of three other cementitious materials: silica fume (SF), fly ash (FA), and blast-furnace slag (BFS). The order of effectiveness is SF>NZ>FA>BFS. When 30% zeolite blended cement with an alkali content of 1.82% Na₂O equivalent is used in concrete, there will be no damage from ASR even if all the aggregates are reactive. The suppression of ASR by NZ is related to its fineness. The required dosage of NZ is about 20% at a surface area of 7000 cm squared/g with the same effect. Pre-heating of NZ at 500 degrees C increases the preventive effectiveness. The suppressing mechanism of NZ on ASR is decreasing the alkali ion concentration in the pore solution in concrete through ion exchange, adsorption, and pozzolanic reaction of NZ. So the formation of alkali silicate is prevented and the interface is improved.

54. Before Using Fly Ash. Barringer, William L. (New Mexico State Highway & Transportation Dep, NM, USA) Concrete International V 19 N 4 Apr 1997.P 39-40

Provided it is properly used, fly ash can be an excellent material for use in concrete. Aside from its price and its availability, the strength-gaining ability of the fly ash should be considered in proportioning. The spherical geometry of fly ash particles can aid in placing concrete; however, good quality mixes require consistent fly ash fineness. Moreover, the proportions of fly ash to be used depends on the concrete quality desired. Fly ash may lower the heat of hydration and mitigate the resultant thermal strain, provide strength gains that are not delayed, or lessen the effect of alkali-silica reactions or alkali-aggregate reactions depending on its proportion. Tests are suggested to determine the reaction of brands of fly ash with cement type. 2 References

55. The Alkali-Silica Reaction In Concrete (This Looks Like A Good Book To Order). Swamy, R.N. [Editor] (Sheffield Univ, Uk) 1992. P. Xv+333. + Refs., Blackie And Sons Ltd. Isbn: 0-216-92691-2 Publisher Blackie And Sons Ltd, Bishopbriggs, G64 2nz, Glasgow, United Kingdom, Country United Kingdom, Language English

The first four chapters of this BOOK are devoted to the basics of the alkali silica reaction (ASR) while the remaining chapters describe the experience gained globally in tackling the problem. Chapter 1 traces the history of ASR and describes in detail the nature of alkali aggregate reactions in concrete, the basic requirements for the reaction to initiate and propagate, the factors controlling the reaction and the observed effects of the reaction. Chapter 2 presents an analysis of the chemistry of the alkali-aggregate reactions and relates this to the chemistry of cements, mineral admixtures, and the mineralogy of aggregates. A critical review of the various test methods used to detect ASR is provided in Chapter 3. Experiences of ASR in the United Kingdom, Denmark, Iceland, Canada, New Zealand, Japan and India are then presented. For abstracts of some of the individual papers see IRRD 844649-844658.

56. Use Of Dynamic Nondestructive Test Methods To Monitor Concrete Deterioration Due To Alkali-Silica Reaction. Narayan Swamy, R.; Wan, Wmr. Cement, Concrete And Aggregates (1993), Vol. 15, No. 1. P. 32-49. - Refs.,

Dynamic nondestructive tests such as pulse velocity and dynamic modulus to monitor the initiation and progress of concrete deterioration due to alkali silica reactions (ASR) are reviewed. The

study found that both pulse velocity and dynamic modulus are sensitive to material and structural changes arising from ASR and that they can respond reliably to changes prior to first crack, at first crack, and the progress of deterioration with time in concrete both with and without cementitious materials other than portland cement. It is noted, that with good engineering judgments, pulse velocity measurements can be used to assess structural deterioration due to ASR.

57. Expansive Reactions In Concrete Odler, Ivan; Jawed, Inam Mater. Sci. Concr. (1991), Volume 2, 221-47. Editor(S): Skalny, Jan P.; Mindess, Sidney. Am. Ceram. Soc.: Westerville, Ohio.

A review, with 60 references, of chem. reactions (other than alkali-aggregate reactions) that cause expansion in concrete and may lead to its deterioration. The most notable of these reactions are those involving sulfates of Ca, Mg, and alkali metals that form expansive products, essentially ettringite, in the concrete matrix. These sulfates may already be present in cement or may come from outside sources (sulfate attack). Various hypotheses on the mechanism of these reactions and the associated. vol. expansions are critically examined. The vol. expansion is harmful when allowed to proceed uncontrolled. However, if carefully controlled, it may, in fact, prove to be beneficial. This is the case with expansive cements that are used to produce pre-stressed concrete or to prevent cracking due to drying shrinkage.

58. Alkali-Silica Reaction In Concrete Hobbs, D.W. (British Concrete Association) 1988. P. 183. + Refs., Thomas Telford Books Isbn: 0 7277 1317 5 Publisher Thomas Telford Books, Thomas Telford House, 1 Heron; Quay, E14 9xf, London, United Kingdom; Document Type Book, United Kingdom, Language English

This book will give users and producers of cement, aggregate and concrete a better understanding of the alkali silica reaction (asr) and its effects upon concrete performance, and how the risks of damage occurring from the reaction can be minimized. Topics covered in the book include the reaction, alkalis in portland cement, alkalis from other sources, reactive silica, cracking and expansion, the diagnosis of the alkali silica reaction, its effects upon the properties of concrete and its structural performance, and remedial actions to counteract the damage caused. The effectiveness of various cement replacement materials in reducing the risk of asr is examined, and methods of testing aggregates and aggregate combinations with cement for their reactivity are explained. Finally, the procedures that are being adapted to minimize the risks of cracking in new construction are given.

59. The Inhibiting Effect Of Lithium Compounds On Alkali-Silica Reaction Sakaguchi, Y. (Nissan Chem Ind Ltd, Japan); Takakura, M. (Nissan Chem Ind Ltd, Japan); Kitagawa, A. (Nissan Chem Ind Ltd, Japan); Hori, T. (Nissan Chem Ind Ltd, Japan); Tomosawa, F. (Tokyo Univ, Japan); Abe, M. (Min Of Construction, Japan); Proceedings Of The 8th (July 17-20, 1989) International Conference On Alkali-Aggregate Reaction, Held Kyoto, Japan, 1989. P. 229-34. 4 Refs.; Document Type Book, Japan, Language English

Expansion of mortar bars, which contained Pyrex glass, due to alkali-silica reaction (ASR) was inhibited by addition of lithium compounds (lithium carbonate, lithium nitrite and lithium hydroxide). Lithium hydroxide was found also effective in inhibiting the expansion of mortar bars containing reactive aggregates. The inhibiting effect increased in proportion to the amount of its addition. Expansion was inhibited by impregnating the solution of lithium nitrite to both mortar bars and concrete prisms that had been subjected to accelerated expansion. The effects of lithium compounds were examined by observing the boundary face between Pyrex glass and hardened cement paste by means of energy dispersive X-ray spectrometer and by analyzing the extracted

pore solution from the mortars. It was confirmed that the alkali-silica gel, the reaction product of Pyrex glass and hardened cement paste, was not observed at the boundary face, and that the concentration of lithium ion in pore solution decreased and that of sodium and potassium ion in it was nearly constant with the passage of time. In conclusion, these results suggest that the inhibiting effect of lithium compounds is attributed to the production of a kind of lithium silicate, which hardly swells and dissolves, at the surface of the aggregate. (A) For the covering abstract of the conference see IRRD.

60. Canmet Investigations Of Supplementary Cementing Materials For Reducing Alkali-Aggregate Reactions; Part 1 Granulated/Pelletized Blast Furnace Slags Soles, J.A. (Canmet, Ottawa, Canada); Malhotra, V.M. (Canmet, Ottawa, Canada); Chen, H. (La Farge Canada Inc); Fly Ash, Silica Fume, Slag And Natural Pozzolans In Concrete. Proceedings Of The Third International Conference, Trondheim, Norway, 1989. Volume 2 (Aci Sp-114), 1989. P. 1637-56. 15 Refs., American Concrete Institute; Document Type Book, United States, Language English

The use of supplementary cementing materials for reducing harmful alkali-aggregate reactions (AAR) in concrete is being studied at the Canada Centre for Mineral and Energy Technology (CANMET). One investigation involves the use of three types of reactive aggregate and supplementary cementing materials that include fly ash, slag, silica fume and natural pozzolans. This report covers the part in which ground, granulated blast-furnace slags from one US and two Canadian sources were used to partially replace cement in concrete containing the three reactive aggregates. Test data include characterization of the materials used, their proportions in mixtures, concrete strengths, and 2-year expansion measurements of mortar bars and concrete prisms containing them. The test results indicate the effectiveness of the slags in reducing deleterious AAR, and their optimum replacement levels. These slags are all effective in controlling such reactions, particularly with the highly reactive Kingston dolostone. (A) For the covering abstract of the conference see IRRD 829586.

61. Comparison Of The Effectiveness Of Four Mineral Admixtures To Counteract Alkali-Aggregate Reaction. Durand, B. (Ecole Polytechnique, Montreal Canada); Berard, J. (Ecole Polytechnique, Montreal Canada); Soles, J.A. (Canmet, Ottawa, Canada) Proceedings Of The 7th International Conference On Concrete Alkali-Aggregate Reactions, Ottawa, Canada, 1986, 1987. P. 30-5. 7 Refs., Noyes Publications Isbn: 0-8155-1142-6; Document Type Book, United States, Language English

Two fly ashes, one silica fume and one granulated slag were used as admixtures to test the effectiveness of these pozzolans in reducing expansion of concrete due to alkali-aggregate reaction. Standard mortar bar (astm c-227) and concrete prism (csa.a23.2-14a) expansion tests were used to show the effects. Three types of aggregate were used, to represent the best known alkali - aggregate reactions: (1) trois-rivieres siliceous limestone—alkali-silica reactive; (2) kingston dolomitic limestone—alkali-carbonate reactive; (3) lady evelyn lake argillite—alkali-silica/silicate reactive. Other experimental work included the measurement of $\text{Ca}(\text{OH})_2$ content in the cement pastes, and microstructural examination of the pastes by scanning electron microscopy. The effectiveness of the mineral admixtures in reducing expansion was different for each of the three aggregates. $\text{Ca}(\text{OH})_2$ measurements and scanning electron microscopy revealed important differences related to the type of mineral admixture used and its replacement levels. (a) for the covering abstract of the conference see IRRD 811982.

62. Alkali-Silica-Reaction - A Risk For The Long-Term Stability?. Wieker, Wolfgang (Universitaet Berlin, Berlin, Ger); Betonwerk Und Fertigteil-Technik V 60 N 11 Nov 1994.P; LANGUAGE: English; German

The alkali-silica-reaction (ASR) is a concrete-damaging reaction that is brought about by a high alkali presence in the concrete, which can come from cement, additions or aggregates. These reactions lead to the formation of alkali silicates that, under moist conditions, lead to crack formation as a result of expansion phenomena. For the purpose of clarification of the reaction mechanism and finding ways of avoiding these concrete-damaging reactions, pore solutions from appropriate test specimens were pressed out and their composition analyzed. It was established that it is possible to suppress an ASR when the alkali concentration in the pore solutions is reduced by finely divided alkali binding additions (such as filter fly ashes, silica fume, etc.). 4 References

63. Mechanisms Affecting The Development Of Alkali-Silica Reaction In Hardened Concretes Exposed To Saline Environments. Sibbick, R.G. (Aston Univ, Birmingham, UK); Page, C.L.; Magazine Of Concrete Research V 50 N 2 Jun 1998.P 147-159

In circumstances where concretes containing UK aggregates with reactive siliceous components are exposed to high concentrations of NaCl there is conflicting evidence as to whether salt ingress enhances susceptibility to alkali-silica reaction (ASR). There is also uncertainty over the mechanisms involved. The research undertaken was intended to elucidate these issues. Expansion tests with concrete prisms and cores immersed in 2 and 7 M NaCl solutions at 20 and 38°C showed that significant ASR expansion and cracking could be induced in specimens containing the more highly reactive UK aggregates at alkali levels well below 3 kg/m³ Na₂O_{eq}, which is the present recommended UK limit for minimizing the risk of ASR. Even concretes containing aggregates of lower reactivity (chert-bearing gravels, etc.) were found to exhibit significant ASR expansion when exposed to NaCl solution in specimens of 3 to 4 kg/m³ Na₂O_{eq}. The role of NaCl ingress in exacerbating the development of ASR in concretes of varied composition was studied by thermoanalytical techniques and petrography combined with electron probe microanalysis. The mechanisms were found to depend on several features of the environment (NaCl concentration, temperature, etc.) and the composition of the concrete (type of reactive aggregate, alkali content, cement mineralogy, etc.). A simplified reaction scheme was proposed to account for the results obtained. (Author abstract) 18 References

64. Manufacture Of Supplementary Cementitious Materials From Cement Kiln Dust. Mishulovich, Alex (Construction Technology Lab, IL, USA); Hansen, Eric R. World Cement v 27 n 3 Mar 1996.p 116-120

The formulation and production of supplementary cementitious materials (SCM) based on cement kiln dust (CKD) was studied with the dual objective of waste reduction and inhibition of alkali-silica reactivity (ASR) in concrete. The SCM's were produced by melting and vitrification of mixes containing CKD with additives, such as clay, shale, and some industrial wastes, including power plant and incinerator ashes. The product chemical composition was close to low-melting eutectics in the ternary system CaO-SiO₂-Al₂O₃ prime and most melts were produced at temperatures below 1200°C. Vitrification provided the necessary hydraulic reactivity of the product and prevented leaching of the trace elements present in source materials. Blended cements incorporating SCMs proved to be competitive with ordinary Portland cement in strength. Adding SCM to cement reduced the ASR-related expansion by 85 to 90% in the standard test with highly reactive aggregates. (Author abstract) 10 References

65. Effectiveness Of Silica Fume In Reducing Damage Due To Alkali-Silica Reaction Kojima, T. (Ritsumeikan Univ, Kyoto, Japan); Amamsuki, S. (Ritsumeikan Univ, Kyoto, Japan); Takagi, N. (Ritsumeikan Univ, Kyoto, Japan) Proceedings Of 66. The 8th (July 17-20, 1989) International Conference On Alkali-Aggregate Reaction, Held Kyoto, Japan, 1989. P. 265-70. 3 Refs.; Document Type Book, Japan, Language English

In the early 1980s, many cases of concrete structures deteriorated as a result of alkali-silica reaction (ASR) have been reported in Japan, including T-shaped piers of the Hanshin Expressway. It has been suggested that a suitable method of reducing the risk of cracking due to ASR is to replace a part of Portland cement by pozzolanic materials such as pulverized fuel ash (FA), ground granulated blast-furnace slag (BFS) or condensed silica fume (SF). A recent report by Hobbs, DW (see IRRD 814132) states that use of pozzolanic materials is not necessarily a good method to prevent the damage due to ASR. It is necessary to ascertain that the adequate usage of pozzolanic materials can prevent the damage due to ASR. In this study, firstly in order to compare the effectiveness of three kinds of pozzolanic materials used in Japan in reducing the deterioration due to ASR, mortar bars in which a part of cement was replaced by pulverized fuel ash, ground granulated blast-furnace slag and condensed silica fume were made by using the same aggregate as that in the deteriorated structure of the Hanshin Expressway, and expansive strain was measured. Secondly in order to investigate the availability of SF, which was considered most effective in reducing the deterioration due to ASR, non-destructive tests such as ultrasonic pulse velocity, dynamic modulus of elasticity and the spectral analysis of ultrasonic pulse, were carried out on SF mortar and concrete specimens. For the covering abstract of the conference see IRRD 857024.

67. Alkali-Silica Reactivity Mechanisms and Management. Leming, M.L. (North Carolina State Univ., Raleigh, NC, USA) Mining Engineering (Littleton, Colorado) Vol 48N, 12 December 1996. P 61-64

In the decades since silica gel was first identified in material exuding from cracked concrete, a great deal of research has been conducted regarding the chemical reactions between the alkalis found in portland cement and silica found in aggregates. This paper reviews the research findings attempts to provide a simplified review of the mechanisms of the alkali-silica reaction (ASR), so that one can better understand the implications of the specifications, test results and effects on structures. In addition, the contractual relationships between the aggregate supplier and one of their major clients, the concrete supplier, examined with regard to the ASR.

68. Alkali-Aggregate Reaction In Concrete: A Review Of Basic Concepts And Engineering Implications. Fournier B (Reprint); Berube M A CANADIAN JOURNAL OF CIVIL ENGINEERING, (APR 2000) Vol. 27, No. 2, Pp. 167-191.

This paper presents theoretical and applied state-of-the-art information in the field of alkali-aggregate reactivity (AAR) in concrete. The aspects discussed include basic concepts of the reaction and expansion mechanisms, conditions conducive to the development and the sustainability of AAR in concrete, field and laboratory investigation programs for evaluating the potential alkali-reactivity of concrete aggregates, selection of preventive measures against AAR, and the management of structures affected by AAR. The management section includes the diagnosis of AAR in existing concrete structures, evaluation of the potential for future distress due to AAR, and mitigation and repair approaches used on such structures. This is an introductory paper and sets the stage for a special review of the current AAR situation in the various regions of Canada that is presented in seven papers as part of this issue.

69. Deleterious Expansion Of Concrete Due To Alkali-Silica Reaction: Influence Of Pfa And Slag. Hobbs, D.W. (Cement & Concrete Assoc, Slough, Engl) Mag Concr Res V 38 N 137 Dec 1986 P 191-205

The literature dealing with the effectiveness of partial replacement of a high-alkali cement by pulverized-fuel ash (pfa) and ground granulated blast furnace slag (slag) in preventing deleterious expansion due to the alkali-silica reaction (ASR) when a reactive aggregate is used is reviewed, and results are reported of recent tests carried out on concrete at C&CA. It is shown that the effectiveness of pfa's and slags in preventing deleterious expansion due to ASR varies widely and that the use of some pfa's and slags may not reduce the risk of deleterious expansion. (Author abstract) 48 references

70. Effectiveness Of Mineral Admixtures In Controlling Asr Expansion Swamy, R.N. (Sheffield Univ, Uk); Al-Asali, M.M. (Canmet, Ottawa, Canada) Proceedings Of The 8th (July 17-20, 1989) International Conference On Alkali-Aggregate Reaction, Held Kyoto, Japan, 1989. P. 205-10. 3 Refs; Document Type Book, Japan, Language English

Alkali silica reaction (ASR) is now known to be capable of causing considerable damage to concrete structures, which might sometimes even lead to their failure. Although the occurrence of such reaction is limited when one considers the large number of concrete structures built, the reaction can cause serious problems of serviceability when it does occur. It is therefore important to consider at the design stage the possible damages arising from ASR, and to minimize the risk of its occurrence by choice of suitable materials, and appropriate design. The most practical and beneficial means of controlling ASR expansion is probably through part replacement of cement by mineral admixtures such as fly ash, ground granulated blast furnace slag and silica fume. A number of studies on the use of these and other natural and artificial pozzolans to control ASR expansion have been reported in literature. In spite of much detailed research, there are several aspects of the role of mineral admixtures in ASR that are not yet fully understood. For example, there appears to be no single explanation on the mechanism of pozzolanic reactions and control of ASR expansion. Further, the effect of pozzolanic additions on ASR is highly variable, and the effectiveness very much depends on the type of reactive aggregate, the type of mineral admixture, the method of replacement, etc. Whilst there is a lot of evidence on mortar bar tests to show that pozzolans can reduce or even eliminate ASR expansion, there is also test data to show that materials judged as effective pozzolans by ASTM tests, sometimes even increase ASR expansion. In this paper, some test data are presented to evaluate the effectiveness of fly ash, slag and silica fume in controlling and/or reducing ASR expansion in concrete. (A) For the covering abstract of the conference see IRRD 857024.

71. Alkali-Silica Reactivity In Concrete - Importance Of Cement Content And Alkali Equivalent Johnston, C.D. (Univ Calgary, Canada) Proceedings Of The 7th International Conference On Concrete Alkali-Aggregate Reactions, Ottawa, Canada, 1986, 1987. P. 477-82. 2 Refs., Noyes Publications; Document Type Book

The effect of cement content and alkali equivalent on alkali-silica reactivity is evaluated in terms of expansion up to age 5 years for concrete prisms made with crushed glass as the coarse aggregate. What happens with each cement-aggregate combination depends strongly on the amount of alkali in the concrete available to fuel the reaction, which in turn is related to the product of cement content and alkali equivalent. three categories of reactivity can be identified: apparently innocuous for alkali contents in concrete less than about 0.05%, rapid and highly deleterious for

alkali contents more than 0.10%, and slowly expansive, potentially dangerous, and classifiable as deleterious only after 1 year or more of testing for alkali contents of 0.05-0.10%.(a) for the covering abstract of the conference see irrd 811982.

72. A Discussion Of The Paper "The Alkali-Silica Reaction. The Surface Charge Density Of Silica And Its Effect On Expansive Pressure" By F.A. Rodrigues, P.J.M. Monteiro, G. Sposito Chatterji S (Reprint) Cement And Concrete Research, (Mar 2000) Vol. 30, No. 3, Pp. 501-502.

73. Effects Of Silica Fume And Steel Fibers On Some Mechanical Properties Of High-Strength Fiber-Reinforced Concrete Eren O (Reprint); Marar K; Celik T Journal Of Testing And Evaluation, (Nov 1999) Vol. 27, No. 6, Pp. 380-387.

There are many test methods to measure the impact resistance of fiber-reinforced concrete that are complicated, time consuming, and expensive. A practical test method has been developed to measure the impact resistance of high-strength fiber-reinforced concrete (HSFRC). The equipment developed can also be used for testing aggregate impact values by simply changing the base plate of the machine. A machine was developed to measure the surface abrasion resistance of HSFRC. Testing fiber-reinforced concrete for surface abrasion resistance was found to be extremely difficult if realistic and practical results were desired. In this study the influence of silica fume on the properties of HSFRC was investigated by using silica fume at two different percentages and with three different hooked-end fibers, namely, 30/0.50, 60/0.80, and 50/0.60 length/diameter (mm/mm). Fibers were added to concrete in three different percentages of 0.5, 1.0, and 2.0% by volume of concrete. The results show that including fibers in high-strength concrete improves impact resistance, surface abrasion, and splitting tensile strength.

74. A Critical Review Of Ultra-Accelerated Tests For Alkali-Silica Reactivity Grattanbellew P E Cement & Concrete Composites, (Oct 1997) Vol. 19, No. 5-6, Pp. 403-414.

A large number of ultra-accelerated test procedures, for determining the potential alkali reactivity of aggregates, have been developed, particularly in the past 15 years. An ultra-accelerated test method is defined as one which yields results within a few days or, at most, a few weeks. A number of ultra-accelerated test methods have been adopted as 'standard tests', but few have been adequately evaluated. The rapid globalization of the construction industry will require the harmonization of National Standard Test Methods. The major requirement of ultra-accelerated test methods is that they should correctly predict the potential reactivity of aggregates in greater than 95% of the cases. Due to the complexity and variability in the composition and grain size of aggregates, it is improbable that a single test method will be developed which would be appropriate for evaluating all types of aggregates. Another major requirement for ultra-accelerated test methods is that the inter-laboratory coefficient of variation should be low, preferably less than 12%. At present, only the NBRI accelerated mortar bar method has been subject to adequate inter-laboratory evaluation. However, a more limited inter-laboratory investigation showed that the autoclave mortar bar test also shows considerable potential, as a satisfactory ultra-accelerated test method. Further refinement of the NBRI and autoclave methods is required to improve their performance with a wide variety of aggregates.

75. Effect Of Silica Fume And Steel Fibers On Some Properties Of High-Strength Concrete Eren O (Reprint); Celik T Construction And Building Materials, (Oct-Dec 1997) Vol. 11, No. 7-8, Pp. 373-382.

The main disadvantage of high-strength concrete is its highly brittle behavior and this can be overcome by adding fibers to the concrete. This would also improve some other mechanical properties of high-strength concrete such as tensile strength and compressive strength. These properties are not very well established for high-strength steel-fiber reinforced concrete (HSFRC) yet. In this study the influence of silica fume on the properties of HSFRC were investigated by using silica fume of two different percentages and three different hooked-end fibers namely, 30/0.50, 60/0.80 and 50/0.60 length/diameter (mm/mm). Fibers were added to concrete in three different volume percentages of 0.5, 1.0 and 2.0 by volume of concrete. The results indicated that there is a linear function between splitting tensile strength (F-splt) and volume percentage of fibers (V-f) [i.e. $F\text{-splt} = A(V\text{-f}) + B$, where A and B are correlation coefficients] as well as between splitting tensile strength (F) and compressive strength (F-c) of plain series A concrete [i.e. $F\text{-splt} = C(\sqrt{F\text{-c}}) + D$, where C and D are correlation coefficients]. These relations can describe the development of splitting tensile strength of HSFRC containing no silica fume, 5% silica fume and 10% silica fume by weight of cement. On the other hand, although silica fume has an effect on compressive strength, volume percentage and aspect ratio of steel fibers has little effect.

76. The Effect of Grinding On the Physical Properties Of Fly Ashes and a Portland Cement Clinker Bouzoubaa N; Zhang M H (Reprint); Bilodeau A; Malhotra V M Cement And Concrete Research, (Dec 1997) Vol. 27, No. 12, Pp. 1861-1874.

The effect of the grinding on the physical properties of three ASTM Class F fly ashes and a Portland cement clinker were investigated. The specific gravity and the fineness of the Ay ashes increased with an increase in the grinding time. However, this increase was less significant beyond 2 hours. The morphology of the fly ashes was changed by grinding. Most of the plerospheres and large, irregular-shaped particles were crushed after 2 hours of grinding. However, the number of the spherical particles reduced with increased grinding. There appears to be an optimum grinding time of approximately 4 hours for the Ay ashes beyond which the water requirement increased and the strength activity indices either decreased or did not increase significantly. (C) 1997 Elsevier Science Ltd.

77. L34 Answer 46 Of 60 Scisearch Copyright 2000 Isi (R) Performance Of Concrete Under Differnt Curing Conditions Tan K F (Reprint); Gjorv O E Cement And Concrete Research, (Mar 1996) Vol. 26, No. 3, Pp. 355-361.

The effect of curing conditions on strength and permeability of concrete was studied. Test results showed that after 3 and 7 days moist curing only the concretes with w/c ratios equal to or less than 0.4 were accepted, while after 28 days of moist curing however, even the concrete with w/c of 0.6 could be accepted. Silica fume has a significant effect on the resistance to water penetration. For the concretes both with and without silica fume and with w/c + s of 0.5, the 28-day compressive strengths of 3 and 7 days moist curing were higher than those of 28 days moist curing, and the silica fume concrete seemed to be less sensitive to early drying. The curing temperatures did not affect the water penetration of concrete, but affected the chloride penetration and compressive strength of concrete significantly.

78. Effectiveness Of Fly-Ash In Preventing Deleterious Expansion Due To Alkali-Aggregate Reaction In Normal And Steam-Cured Concrete Shayan A (Reprint); Diggins R; Ivanusec I Cement And Concrete Research, (Jan 1996) Vol. 26, No. 1, Pp. 153-164.

A non-reactive and several reactive aggregates were used in concrete specimens with and without two fly ashes (varying in total alkali content) at binder (cement + fly ash) alkali levels ranging from 0.46 to 2.5% and a binder content of 500 kg/m³ and fly ash/binder ratio of 0.25. The specimens were stored either at 23 degrees C (fog room) or 40 degrees C, 100% RH. Some specimens were steam cured at 75 degrees C for eight hours, and then transferred to 40 degrees C, 100% RH. The expansion behavior of the specimens was monitored over nearly six years, and showed that the effectiveness of the fly ash in preventing deleterious AAR expansion depended on the alkali content of the concrete. At the highest alkali content of 12.5 kg Na₂O equiv./m³, the fly ashes only had a delaying effect (one to several years), whereas at 6.9 kg Na₂O equiv./m³ they eliminated deleterious AAR expansions. Generally, for more highly reactive aggregates, and at the 2.5% alkali level, fly ash was less effective at 40°C than 23°C because the rate of AAR expansion was much higher at 40°C. At lower alkali levels and for less reactive aggregates, the temperature was not important. Fly ashes were also effective under steam-curing conditions. A measurable amount of chemical shrinkage occurred in the first few months in concretes containing fly ash and with high alkali contents, although some of these concretes later expanded and cracked as a result of aggregate reactivity. Fly ash was used in mortar specimens prepared for the expression and analysis of the pore solution and was found to be very effective in reducing the alkalinity of the pore solution, a factor contributing to its preventive effects on AAR. It is concluded (based on six-year results and the shapes of expansion curves) that the two fly ashes can be used to prevent deleterious AAR expansions in practical situations.

79. Effectiveness Of Supplementary Cementing Materials In Suppressing Expansion Due To Asr .1. Concrete Expansion And Portlandite Depletion – Discussion Chatterji S (Reprint) Cement And Concrete Research, (1994) Vol. 24, No. 8, Pp. 1572-1573.

80. Comparative-Study Of Various Silica Fumes As Additives In High-Performance Cementitious Materials. Delarrard F (Reprint); Gorse J F; Puch C Materials And Structures, (Jun 1992) Vol. 25, No. 149, Pp. 265-272.

This article concerns marginal variations in the functional properties of very-high-strength mortars and concretes resulting from the type of silica fume used. Twenty silica fumes were tested, in the presence of two cement-superplasticizer pairs. All of the results are analyzed into main components and regressions. The action of carbon on the workability of the mixtures has been verified. Finally, within the limits of the scattering of the results, it has been possible to establish an empirical law, fitted to previous results, showing the influence of the alkali content of the silica fume on its pozzolanic activity.

81. Mechanism Of Alkali-Silica Reaction And The Significance Of Calcium Hydroxide - Reply. Wang H (Reprint); Gillott J E Cement And Concrete Research, (Jan 1992) Vol. 22, No. 1, Pp. 193-194.

On The Long-Term Strength Losses Of Silica-Fume High-Strength Concretes. Delarrard F (Reprint); Bostvironnois J L Magazine Of Concrete Research, (1991) Vol. 43, No. 155, Pp. 109-119.

This Paper presents studies and tests performed at the Laboratoire Central des Ponts et Chaussées with a view to a better understanding of the long-term mechanical properties of silica-fume high-strength concretes (HSC) and very-high-strength (VHSC) concretes. After noting the discrepancies among the various references in the literature, we propose to explain the drop in strength observed by some authors after three months by the hypothesis of drying-related effects. To check the soundness of this hypothesis, mechanical tests were carried out on three different concretes, their drying was investigated by gammadensimetry, and accelerated tests were performed on mortars. The homogeneous drying to which the specimens are subjected has no negative effect on their mechanical strengths. The losses of strength observed on some concretes are therefore probably not caused by a local effect of the drying. Examination of the water content fields of VHSC specimens four years old shows that the drying occurs with a high gradient and affects only a small thickness. Mechanical tests in this case show a non-negligible drop in compressive strength. Calculation of the self-stress field due to drying shrinkage indicates that the compression at the core of the specimen is of the same order as the drop in strength observed. To conclude, it is shown that, given some hypotheses concerning the water content field, the drop in strength linked to the structural effects of drying can be not more than twice the tensile strength.

82. A New Test Method For Fiber-Reinforced Concrete Zollo R F (Reprint); Hays C D; Zellers R Cement Concrete And Aggregates, (Dec 1999) Vol. 21, No. 2, Pp. 111-116.

It has long been recognized that the principal benefit gained by using fiber reinforcement in portland cement concrete is a conversion of the material from brittle to relatively ductile behavior. The apparent ductility, or toughness, is primarily related to the improved tensile strength of fiber-reinforced concrete (FRC) especially and even after significant matrix cracking has occurred. However, the methods used to measure tensile strength and toughness of FRC have been, at best, elaborate and controversial. A practical and much needed testing methodology for fiber-reinforced concrete has been developed and adopted as an ASTM standard. It was conceived from the need to have a test that is relatively simple and inexpensive to conduct and is yet capable of assessing the tensile strength of cracked FRC. The test method, ASTM C 1399, and an interlaboratory testing program conducted to help formulate a precision statement for the new methodology is discussed.

83. Surface Modified Polypropylene Fibers For Use In Concrete Tu L (Reprint); Kruger D; Wagener J B; Carstens P A B Magazine Of Concrete Research, (Sep 1998) Vol. 50, No. 3, Pp. 209-217.

The research project reported on is concerned with the effect of modification of the surface of polypropylene fiber by a new chemical treatment process, oxyfluorination, on the properties of polypropylene fiber reinforced concrete. As a world first, the interfacial bond of polypropylene fibers with the cementitious matrix is improved by increasing the surface free energy of the fiber surface. The reasons for the poor bonding between untreated polypropylene fiber and cementitious matrix are discussed, using the fiber surface free energy and Lewis acid-base interaction concept. The contact angle of water on the polypropylene fiber surface as well as fiber surface free energy components were measured. This showed reduced contact angles, as well as increased acid-base components of the surface free energy because of oxyfluorination. Mechanical properties such as compressive strength, flexural properties and impact resistance of the fibrous concrete, reinforced with different types of oxyfluorinated polypropylene fibers, were determined and compared with those of untreated polypropylene fiber reinforced concrete. The results confirmed that the surface modification largely improves the mechanical performance of the fibrous concretes. Restrained plastic and drying shrinkage cracking tests, using restrained slab specimens and steel ring restrained specimens, indicated that the surface oxyfluorinated fibers possess a higher shrinkage cracking resistance than do unmodified fibers. The effect of surface oxyfluorination on the concrete/concrete matrix interfacial bondings was investigated using a fiber pull-out test. A mechanism for this interfacial bonding improvement is proposed. Oxyfluorinated polypropylene fiber surfaces and their interfaces with concrete matrix compared with that of unmodified fiber, were observed using scanning electronic microscopy. Some field application tests were conducted and the good results that were achieved are presented.