SURFACE CASING CEMENTING WITH ENERGIZED SLURRIES

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ABSTRACT

Surface casing cementing is necessary to provide a seal between the producing fluids and shallow formations that have the potential to produce fresh water. An operator in SE New Mexico experienced difficulty circulating cement on surface casings due to the fractured and vugular nature of the shallow formations. To satisfy the New Mexico Regulatory Agencies, several top out jobs had to be pumped down the annulus on each well. The cementing service provider and the operator approached the New Mexico Oil and Gas Commission, (NMOCD) with a 30-year-old technology to circulate cement in a single stage, to produce a better cement job, and significantly reduce cost. An unorthodox method of cementing surface strings to achieve a properly cemented annulus without the need for annular top out jobs was desired. This technology utilizes conventional cement foamed with nitrogen to produce low density slurry that expands and yields more volume. The following paper details how this process was introduced to solve the problem.

INTRODUCTION

The operator was experiencing excessive cost and uncertainty about the quality of the annular casing seal needed for protecting the fresh water-producing formations. Conventional methods were not applicable for this situation. Stage cementing tools and external casing packers could leave voids from the leakage into the vugs and fractures encountered while drilling. The top out stages after the initial primary cement job required waiting for the cement to set before identifying the need for the next job. Many hours of stand by time for the rig and cementing equipment were adding considerable costs to the operations. In addition, there was no way of knowing if the cement being pumped down the annulus in the 1" tubing spots was actually bridging and leaving a void or filling the voids completely. Vugs and fractures encountered were too significant for lost-circulation material to stop the losses. A new concept was needed to address the lost circulation that historically occurs between 150 and 800 feet. (Figure 1)

The service company presented a preliminary design to the operator utilizing foamed cement. This procedure consisted of creating foamed cement slurry pumped ahead of conventional unfoamed tail cement slurry on a first stage, followed by a cement plug and displaced down the casing with fresh water. Once the plug was displaced to the bottom of the casing string, fast-setting conventional slurry would be injected and placed down the casing annulus to cap the foamed cement. This proposal would be a new solution on shallow surface casings utilizing old technology. Though foamed cementing has been around for many years, it is not fully understood by much of the industry.

This unique solution presented some new problems with regulatory bodies of the State of New Mexico. Foamed cementing surface casing had been considered previously, but as far as the authors of this paper know, it had never been used in this manner. The NMOCD and the U. S. Bureau of Land Management (BLM) would need to be convinced that this process would provide a competent seal across the shallow fresh-water producing intervals that would be equal to or better than what was currently being done. It would also be necessary to provide an evaluation tool for the NMOCD and the BLM to make a final decision to accept or reject the operator's proposal. This paper will follow the process of identifying a unique solution using established technology and the hurdles involved in providing the operator and the regulatory agencies all that was necessary to make the solution happen.

UNIT PROBLEM HISTORY

To develop a solution capable of addressing problems, conditions, and limitations on well construction, gathering and assimilating the physical properties and geological features that exist is necessary to define any solution. An overview of the problems occurring during surface casing jobs in the construction area include:

- Typically, wells are drilled with a 12 ¼" hole anywhere from a depth of 1,200' up to 1,800'. Operators typically choose to run in and cement a 9 5/8" surface casing.
- Severe loss circulation usually occurs 90-95% of the time and the holes are then "dry drilled" to a total depth (TD).
- Loss of drilling mud circulation can occur anywhere from 150' to 800' in the planned development field unit.

- Drilling the surface holes for these wells progressed as follows:
  - 1995 – 1997 Air drilled or mist-drilled using a turnkey contractor
  - 1998 – 2000 The operator went back to fluid-drilling due to economics
  - 2000 – Present Air drilling with air contractor
- The cementing programs normally consisted of: mixing and pumping 200 sacks "thixotropic cement" (14 PPG, 1.52 CF/sack), 155 sacks service company's light slurry (12.4 PPG, 2.02 CF/sack), and 200 sacks class C cement as a tail-in slurry (14.8 PPG, 1.34 CF/sack). Float equipment normally consisted of a "Texas pattern" guide shoe, insert float, and six centralizers.
- Generally; wells would not circulate cement and needed to be topped out using 1" tubing.
- One-inch spotting jobs, ranging anywhere from 3-16 stages to top out, were required.
- Operator found that small stages (25 sacks) worked as well or better than larger stages. Number of attempts to fill the annulus seemed to vary randomly from well to well.
- Estimated additional costs included an extra $10-15 thousand to cement surface casings on wells that required top-outs compared to wells where cement circulated (cement, rig time, water, rentals, etc) were noted.

CONVENTIONAL SOLUTIONS THAT HAVE BEEN TRIED

1" Top-Outs – Post-Primary Cement Operations

The technique of running in a well's annulus with a slim 1" tubing and performing cement fill-up steps in a spotting method is performed in cases where cement cannot be circulated to surface. Most regulations require cement to be circulated to ensure fresh ground water protection. Each step in spotting cement down the 1" tubing must wait on the previously spotted cement to gain strength prior to attempting. A concern was that previously spotted cement had not bridged off in the annulus or had been lost entirely to the formations. Ideally, each spotted plug of cement may be tied back to the next on each successive step. Conditions needed for this technique should ideally be without losses occurring on each attempt. Often the method is undertaken with estimated depth to place the next spotted slurry.

Loss Circulation Materials (LCM)

The use of LCM during the drilling process to gain control over losses showed very little success on prior attempts and was mostly discontinued as a practice.

A technique of preceding the primary cement job with modified slurry containing super absorbents was performed on a trial basis. This technology showed promise in stopping losses to the weak fractured zones. This technique worked in some instances with the super absorbents created a swelling body capable of plugging off the losses and redirecting the following slurry up to the surface. On other instances, it did not work at all. The operator was not satisfied with the inconsistency of this technique.

DEVELOPING NEW IDEAS - PROJECT TEAM FOR CAPTURING BEST PRACTICES AND OPERATIONAL PROCEDURES

The operator requested their service provider work with them on a project team to gather historical data, investigate possible solutions, and develop procedures needed to address the surface casing requirements.

Involvement from the operator and the service providers included:

- Operator: Drilling engineer and production engineering
- Service company: Mud engineers, cementing engineers, and field service specialists

HISTORICAL INFORMATION GATHERED

To have details of all parameters of the rock architecture and geological aspects while drilling and during casing cementing operations, a list of questions were developed. Often, occurrences are not communicated to all those involved in well development projects, and situations and features witnessed by well servicing and onsite personnel need to be gathered. Some of the questions brought forth were:

- Do bit drops occur? Were they drilling into caverns?
  Historically bit drops do occur, but only for short depths.
- What has been tried to fight loss circulation? Were they running LCM when they used fluid drilling practices prior to 1995?
  Multiple types of LCM were tried with very limited success.

IDEAS CONSIDERED

The project team discussed several ideas for improving success of the surface casing cement jobs. Some of the ideas with possible methods and concerns include:

1. After pumping a conventional primary cement job, pump a foamed cement squeeze down the annulus instead of doing 1" top-outs.
   Operations required setting a 60 foot deep 14" conductor casing and prior to running the surface casing, rig up with a blow out preventer (BOP) stack or packoffs.
   Pump a non-radioactive tracer element in primary cement to mark the top of cement (TOC) for logging purposes.
   Pump a foamed cement volume down the annulus and follow with a cap using 25-50 sacks of unfoamed rapid-setting cement.
   Highly viscous properties of foamed cement slurry would displace water from the annulus with this cement.
   Present scientific data and tested performance of foamed cement properties and attributes to the NMOCD.
   Documented research and field developments for sharing information and educating decision makers on policies are required to get approval from regulatory agencies.
   Job steps utilized – operations could start pumping annular squeeze as soon as displacement plug was bumped.
   Operations would need to install flange/bell nipple/head on 14" conductor casing to control pressure/flow at surface.
   Additional materials and work probably would add $3,500-$4,000 to service company's invoice.
   Would annular squeezed cement get down to the top of the primary cement job? Technique would require annular logging information to determine job performance.

2. Pump foamed cement as lead on the primary job, and then pump a foam squeeze down the annulus instead of performing 1" top-outs.
   This process would necessitate operations setting a 60 foot deep 14" conductor casing and prior to running the 9 5/8" surface casing, rig up with a BOP stack.
   Consider pumping a barium scale additive in the leading portion of the primary cement to mark its TOC.
   Primary idea is to pump foamed lead cement, pump tail cement, displace the plug, and then pump 25-50 sacks of neat cement cap down backside annulus if the leading foamed cement circulates to the surface.
   Present scientific data and tested performance of foamed cement properties and attributes to the NMOCD.
   Documented research and field developments for sharing information and educating decision makers on policies are required to get approval from regulatory agencies.
   Operations would need to install flange/bell nipple/head on 14" conductor casing to control pressure/flow at surface.
   Additional materials and work probably would add $3,500-$4,000 to a service company's invoice.
   May need to pump 25-50 sacks down the backside (annulus) to cap foam on the backside.
   Need to be sure the well has adequate cement strength at surface to support the 9 5/8" casing.

3. Perform a top-out using 1" plastic PVC and run hotter faster-setting cements.
   If pipe gets stuck, snap it off.
   Would possibly be able to reduce weight on cement (WOC) between top-outs.
   Would possibly be able to place cement closer to bottom and eliminate voids intermittently in the annulus.

4. Perform a top-out using two 1" Plastic PVC lines and pumping cement down one while pumping sodium silicate down the other.
   If pipe gets stuck, just snap it off.
   Would be able to reduce WOC between top-outs.
   Would be able to place cement closer to bottom and help eliminate voids intermittently in the annulus.
   The cement following the sodium silicate solution would "flash-set," reducing the number of top-outs required.
   Sodium silicate usually is fairly expensive and may not be cost-effective on this project. The regulatory commissions were hesitant to give a blanket approval to place sodium silicate across fresh water.

5. Pro-actively heal loss circulation while drilling the wells.
   Reviewed past trials in 1994-95 that had no success.
   Research older well files for attempts and results.
   Investigate what types of LCM the BLM/OCD would allow to be pumped into fresh water (FW) zones?

6. Install an inflatable bladder around the casing to prevent loss of cement to formation.
Would act as a 1,200' long external casing packer (ECP).
Cost issues? Very high cost probable.
How to install this equipment? What about damage to sheath while running?
Would it give adequate zonal isolation or would there be a micro-annulus outside the sheath?

7. Squeeze conventional cement down the annulus after pumping the primary cement.
Will squeezed cement get all the way down to the primary cement job's TOC?
No flange/head required on 14" conductor casing necessary for squeeze operation and well control due to low pore pressure of loss intervals.
Would the squeeze displace all the water from the annulus?
Cement's higher density would allow it to fall to a balance state (equalize) to the formation pore pressure.
Method would probably need at least one top-out 1" job.
Method allows pumping down the annulus immediately after bumping the displacement plug on the primary job.

8. Drill to approximately 500'; run a large-diameter PVC, cement, and drill-out.
Essentially a cheap surface casing job.
Regulatory approval?
Cost effective?

Having considered the various ideas and possible techniques that could gain a better cementing of the surface casing; the decision was made to develop a foamed cement procedure. Designs were considered for circulating to surface in one stage if possible, and have a contingency plan to perform an annular squeeze process to tie back into the top of the first stage if needed. Surface control would be maintained by a wellhead system on top of a 14" conduit casing set at 60 feet. This selection was the second listed idea under consideration.

DESIGN CRITERIA AND CONSIDERATIONS FOR PRIMARY CEMENTING ON SURFACE CASINGS

A process was developed to help ensure the success of the operation. Needed information was gathered describing wellbore conditions, tubulars, and drilled hole sizes. Reservoir properties, pore pressure data for the various intervals, and fracturing pressure data for the encountered intervals were gathered. Fluids including drilling muds, spacers, and cement recipes were evaluated and rheological properties determined. Laboratory analyses on the rheology of the various fluids that would either be within the wellbore or pumped during the operation were included in the design program. Laboratory analysis was also performed to determine the pump time, fluid loss, free water, and cement slurry strength developments for quality assurance. The data was input into an engineering simulation program that addresses aspects of performing primary cementing jobs and gaining determinants and results for analysis.[5] Repeated scenarios were performed based on design evaluations and tailored to each variable considered. The most important quality assurances considered were the ability to evaluate such conditions as placement through the job, aspects of remaining above pore pressure but below fracturing pressure at any depth of the well from start to finish on the job steps, and performing this in simulation prior to performing the actual job. (Figure 2)

The computer analysis of the energized cement's coverage densities and viscosities during the treatment would allow evaluations to be considered. The primary operation's ever-changing placement processes could be analyzed and the capabilities to design a desired slurry density profile in the annulus following the cap annular squeeze are determined. These design analyses accounted for the desired foamed constituent makeup for its final placement in the wellbore with the effect of compressional conditions during the final cap squeeze if foamed cement was circulated during the first attempt (Figure 3), or if an additional stage of foamed cement was needed to achieve the desired results. (Figure 4)

During pumping operations, energized foamed cement can develop high dynamic-flow shear stress, giving it increased mud-displacement and annular filling capabilities. The internal gas (nitrogen) used to foam the system allows the slurry to maintain hydrostatic pressure over the well during the system's transition period (liquid state to solid state). Consequently, the energized slurries can effectively control gas migration and formation fluid influx, which can help limit migration channels in set cement sheaths.[10, 13] Energized foamed cement is more resistant to both temperature and pressure-induced sheath stresses, giving it ductility. Its internal microscopic bubbles allow crystalline bonds to flex without breaking. This feature was an important design consideration for integrity of the slurry.[1-4, 6-8]

Once computer design evaluations were made, the operation procedure and logistical steps were reviewed and used to maintain quality assurances. Job volumes, slurry designs, laboratory analyses, and setting up the jobs were built into a process. The jobs could be monitored in real time with a data collection system and evaluated for design match.

Laboratory analyses resulted in comprehensive materials testing and evaluations to help ensure use of the right mix for the jobs. The operator and service company agreed that the design had matured to the point it could be presented to the regulatory agencies.

INITIAL REGULATION CONCERNS

In discussions with the NMOCD, it was obvious that the NMOCD, while intrigued by the foamed cement plan and the advantages foreseen, had reservations about the plan to bullhead cement down the backside (annulus) in the event that the well still did not circulate cement on the first stage. The NMOCD asked that if the well did not circulate cement, operations pump foamed cement through the typical 1" tubing placed at the loss-circulation interval. This placement was desired to ensure the placement of cement all the way to a TOC located at ±600 ft. Initially, concerns were that friction pressures through the 1" tubing with foamed cement would be excessive. The operator's task was to research and determine the aspects requested by the NMOCD and work with the service company to qualify these requests.

After additional discussions with the NMOCD, the operator's service provider confirmed that friction pressures would be excessive if they tried to pump the foamed slurry through the 1" tubing (service provider estimated possibly over 5,000 psi in friction to spot at the required rate). The operator also explained that they would not be able to close the annular BOP to confine the foamed cement at surface with the 1" tubing in the annulus.

Another NMOCD concern was the operator's design in which the step of pumping cap cement was incorporated. Their concern was cement strength. The operator/service project team explained that the cap slurry served two purposes: (1) to confine the foamed cement so that operations could proceed with cutting off casing and nippling up the BOP, and (2) to rapidly set the cap cement to provide the additional strength needed to support the BOP stack and stabilize the surface casing. The team emphasized that the foamed cement in the job design would have far superior strength than the lightweight high-gel cements in the 11–12 lb/gal range that the industry currently uses.

Concern over the ability to pump the cement by "bullhead" placement down to the primary job's TOC was expressed. The project team explained that the high viscosity (375 to 1,500 cp in the project samples) of the foamed slurry had shown (from testing) its ability to displace and divert the cement so that the entire annulus would be covered. Its ability to expand into voids would also help. If a well's performance indicated bullheading the cement down the annulus was the only alternative of placing the top out job, the plan was to use enough excess cement to reach any potential loss zone that existed in the drilled hole.

The NMOCD was concerned about what could be done if the operator did not circulate foamed cement to surface and did not get an indication that the bullheaded second stage was performing the necessary coverage. The planned contingency was to overdisplace the second stage and proceed with running 1" tubing top-outs using the conventional method.

NMOCD admitted they did not have much experience with energized foamed cementing and would have to rely on the operator and service provider for expertise. The OCD saw the advantages of foamed slurry and satisfactorily had their questions and concerns answered. The OCD was ready to "give it a try" to "see if it works."

CONTINGENCIES FOR REGULATORY CONCERNS

The meetings and discussions detailing and describing the process gained approval from the NMOCD to try the foamed cement program on the operator's first well of their drilling program. The operator offered to run an impedance mapping tool on the first well to prove the integrity of the cement. The NMOCD was not interested in a bond-log on a well that went as planned, but reserved the logging request for a well that did not circulate cement to the surface on the primary job. One well was logged with ultra sonic cement evaluation technology and it showed a good bond from top to bottom. This was enough to convince the NMOCD that the process was successful and proved the integrity of the placement technique.

FOAMED-CEMENT OPERATIONS

During actual jobs, the cement unit used an automatic density control system to produce consistent slurry at the desired density, along with automatically controlling both the foamer/stabilizer injection unit's rate and nitrogen unit's rate according to the slurry pump rate. The equipment on surface was arranged to pump not only the primary cement job but also the follow-up cap annular stages. (Figure 5)

A "Data Acquisition Mobile Unit" was used during the cementing jobs. The unit was provided with simulation software—the same used during the design process—capable of reproducing the actual job in a "real time mode" and which allows operations to compare it with the designed job. (Figures 6-8)

CEMENT ANALYSIS AND EVALUATION OPTIONS

A follow-up logging evaluation could be performed and reviewed as required. Using these options, an evaluation could be made for possible job modifications or design changes if they were needed to improve wellbore integrity.

Because of the poor acoustic properties of foamed cement, a cement bond log (CBL) only indicates marginal zonal isolation when 100% mud displacement may be achieved. This logged response is not unusual, and an alternative method of evaluating energized foamed cement with ultrasonic logging tools has been developed. [9, 11, 12] This method evaluates the impedance variation exhibited by the foamed cement instead of the measured value of the cement's impedance. The sonic and ultrasonic logs may be used to demonstrate cement-integrity data and potential filling capabilities within wells' annuluses.

The ultrasonic scanning or imaging acoustic tool uses a single rotating ultrasonic transducer to produce high-resolution circumferential data. Data for both cement evaluation and casing evaluation are obtained in the same run or pass. The rotating transducer can provide 36 to 200 measurements per depth sample, depending on the service company provider. Depth-sample rates range from 2 to 12 samples per foot, again depending on the service company.

TYPICAL FOAMED-CEMENT JOB ON PROJECT

Once the drilling was completed, the casing floating equipment was attached and the casing was run to TD. Following circulating (pumping) two estimated hole volumes, the cementing and foaming equipment was rigged up on the casing and the foamed cement operation performed as shown:

1. Pump first stage primary job with adequate volume to circulate the cement.
2. If the cement circulates, pump a class C cement cap down the backside (annulus). No bond log is necessary.
3. If the cement did not circulate, pump foamed cement down the backside with enough volume to reach the deepest suspected loss zone.
4. If surface indications are that an operation is placing cement down the annular backside, they should tail-in and cap-out with rapid-setting class C cement. Requirements are to run a bond log on the first job like this.
5. If surface indications are that an operation is not placing cement properly down the annulus, operations should overdisplace the foamed cement and proceed with topping-out with a 1" tubing technique. (The NMOCD asked that the operator run a bond log on situations like this to show the quality of the foam cement vs. 1" top-outs.)

RESULTS OF WELL PERFORMANCES

Included is a listing of some of the wells cemented during 2003. Shown are the volumes used, if or not the wells circulated on the primary cementing operation, and the cap squeeze data. (Table 1)

RESULTS

To evaluate the performance of the foamed cement, a follow-up ultrasonic cement evaluation log (note required restrictions) was used on the fourth well cemented and indicated a good bond from surface through the loss-circulation interval down to the TD. The performance and integrity being achieved was a deterministic proof of ability to thoroughly fill the well annulus and provide a zonal isolation and shallow fresh-water protection.

As with any undertaking, the results of achieving an indicated annular isolation were determined to be a result of the process and its contingency plans. The operator viewed this effort and its impact on future endeavors in this unit as a great example of what they were looking for in terms of pro-activity and continuous improvement. Consensus was that everyone's effort in trying something new with an older proven technology to lower operating costs and in fact attain a better overall wellbore was commendable.

ECONOMIC BENEFITS

In review of the average cost of cementing the previous surface casings, it was determined that approximately $27,500 was saved per well by using the foamed-cement option with the placement techniques developed.

CONCLUSIONS

To control detrimental conditions that can impact performance in primary cementing operations on problem surface casing strings, conditions should be identified and addressed during the well construction phase. Understanding the types and effects of conditions often present when addressing loss-circulation intervals helps with the selection process for techniques needed to gain better zonal isolation methods on all casing operations. Understanding and utilizing the properties available for addressing the needs required for a solution is vital. Energized cement systems can bring better results if used in a best practices process. Utilization of computer design simulation analysis can tailor primary cementing jobs and help investigators account for complex conditions that occur during placement from start to finish on a job. The best available systems (chemical and mechanical) for generating and stabilizing energized foamed cement can produce the best performance in zonal isolation. Laboratory analysis should be conducted. Training operators and supervisors in this process can help ensure the best onsite performance. Integrity analysis may be determined from ultrasonic logging analysis to help ensure that wells are bonded. Well integrity and zonal protection are the final evaluation of success. Problems are best mitigated using an operator and service company team approach.

REFERENCES

1. Harms, W.M. and Febus, J.: "Cementing of Fragile Formations Wells with Foamed Cement Slurries," paper SPE 12755 presented at the 1984 Annual California Regional Meeting, Long Beach, 11-13 April.

2. Montman, R. and Harms, W.M.: "Oil Field Application of Low Density Foamed Portland Cements," Southwestern Petroleum Short Course, Lubbock, 22-23 April.

3. "Low Density Foamed Cements Solve Many Oilfield Problems," *World Oil* (1982) 171.

4. Aldrich, C.H. and Mitchell, B.J.: "Strength, Permeabilities, and Porosities of Oilwell Foamed Cement," 1975 ASME, Tulsa, 21-25 September..

5. Creel, P.G. and Kulakofsky, D.S.: "Computer Simulation Program for Cement Squeeze Applications," paper presented at the 1987 Southwestern Petroleum Short Course, Texas Tech University, Lubbock, 22-23 April.

6. Goodwin, K.J. and Crook, R.J.: "Cement Sheath Stress Failure," paper SPE 20453 presented at the 1990 SPE Annual Technical Conference and Exhibition, New Orleans, 23-26 September.

7. Deeg, W.F., Griffith, J.E., Crook, R.J., and Benge, G.: "How Foamed Cement Advantages Extend to Hydraulic Fracturing Operations," *World Oil* (Nov. 1999) 51-53.

8. Smith, T.R. and Ravi, K.M., "Investigation of Drilling Fluid Properties to Maximize Cement Displacement Efficiency," paper SPE 22775 presented at the 1991 SPE Annual Technical Conference and Exhibition.

9. Harness, P.E., Sabins, F.L., and Griffith, J.E.: "New Technique Provides Better Low-Density Cement Evaluation," paper SPE 24050 presented at the 1992 Western Regional Meeting, Bakersfield, 30 March – 1 April.

10. Griffith, James E.: "Method for Cementing in a Formation Subject to Water Influx," U.S. Patent No. 5,484,019 (1996).

11. Frisch, Gary J.,. Graham, William L, and Griffith, James, "Assessment of Foamed - Cement Slurries Using Conventional Cement Evaluation Logs and Improved Interpretation Methods", paper SPE 55649 presented at the 1999 SPE Rocky Mountain Regional Meeting, Gillette, Wyoming, 15–18 May.

12. Frisch, G., Graham, L., and Wyatt, D.: "Economic Evaluation of the Use of Well Logs for Diagnosing Conformance Problems," paper SPE 40036 presented at the 1998 SPE Gas Technology Symposium held in Calgary, Alberta, Canada, 15–18 March

13: Tullos, G., Minnery, G., Creel, P.G., Haest, J., and Snelson, J., "Foamed Cement Utilization on an Infill Drilling Project – Water Flood – Grayburg Formation – Southeast New Mexico – Need for Zonal Isolation—Case History," Paper presented at the 50th Southwestern Petroleum Short Course, Lubbock, Tx. April 16-17, 2003.

ACKNOWLEDGEMENTS
The authors extend sincere thanks to those whose cooperation facilitated compilation of the case histories presented in this paper. Thanks are also given to Halliburton for allowing the publication of this paper.

Table 1
A List Of Wells Cemented Utilizing The Foamed Cement Process

Well	Date	Depth Range (Ft.)	Lead Cement (Sks)	Tail Cement (Sks)	Circulated to Surface (Sks)	Foam Down Annulus (Sks)	Cap
10	3-Nov-03	1,000 – 1,800	800	150	No	275	75
9	13-Oct-03	1,000 – 1,800	520	150	No	50	75
8	25-Sep-03	1,000 – 1,800	700	150	258	No	75
7	2-Sep-03	1,000 – 1,800	520	150	65	No	75
6	15-Aug-03	1,000 – 1,800	650	150	400	No	75
5	17-May-03	1,000 – 1,800	900	150	No	275	75
4	28-Apr-03	1,000 – 1,800	700	150	No	400	75
3	9-Apr-03	1,000 – 1,800	900	150	150	No	75
2	1-Mar-03	1,000 – 1,800	500	150	No	200	75
1	27-Jan-03	1,000 – 1,800	700	150	100	No	75

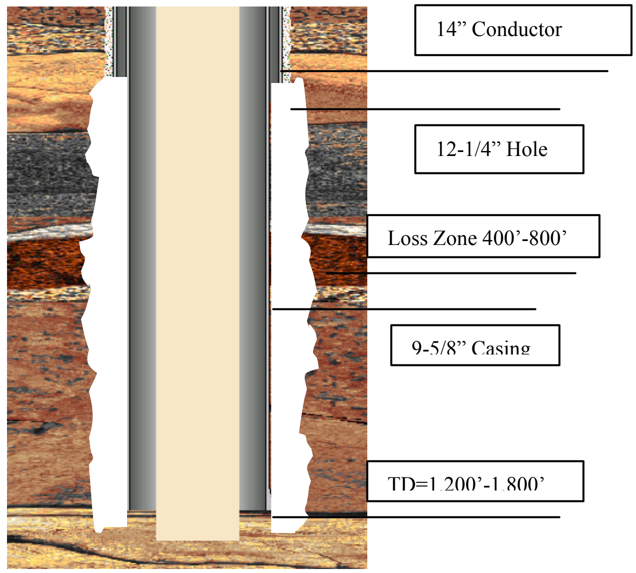


Figure 1 - Wellbore Configuration

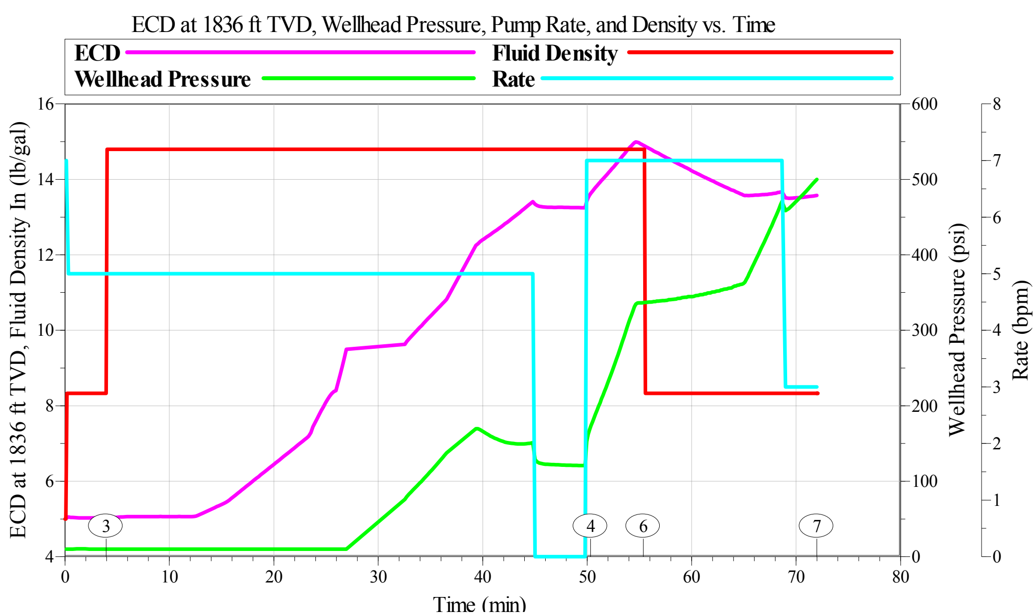


Figure 2 - The Simulation Software Evaluates the Conditions Prior to Performing the Actual Job.

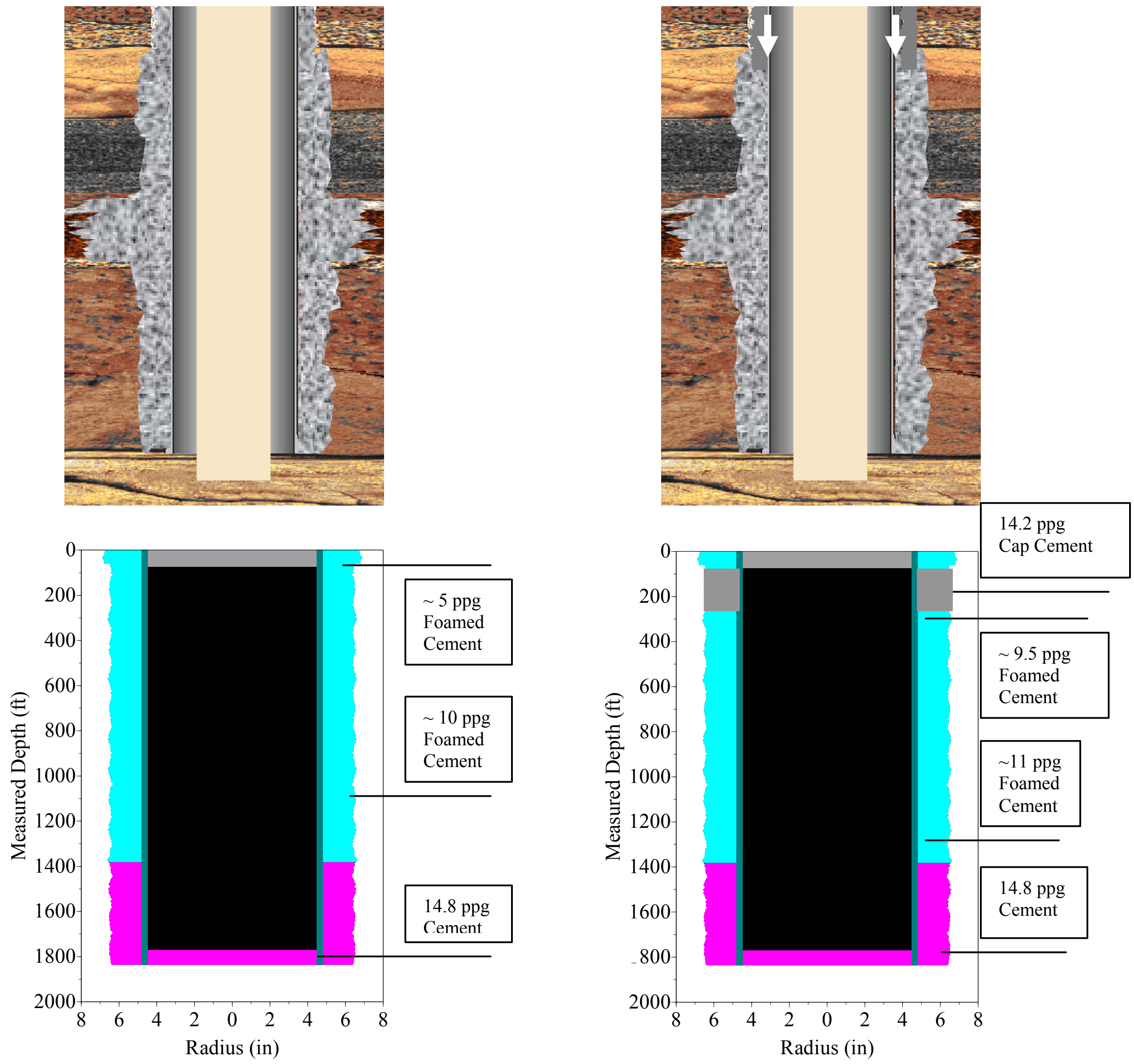


Figure 3 - Foamed cement is circulated to surface during the primary job (left). Then a cap of non-foam cement is placed down the annulus (right) to achieve the desired density profile.

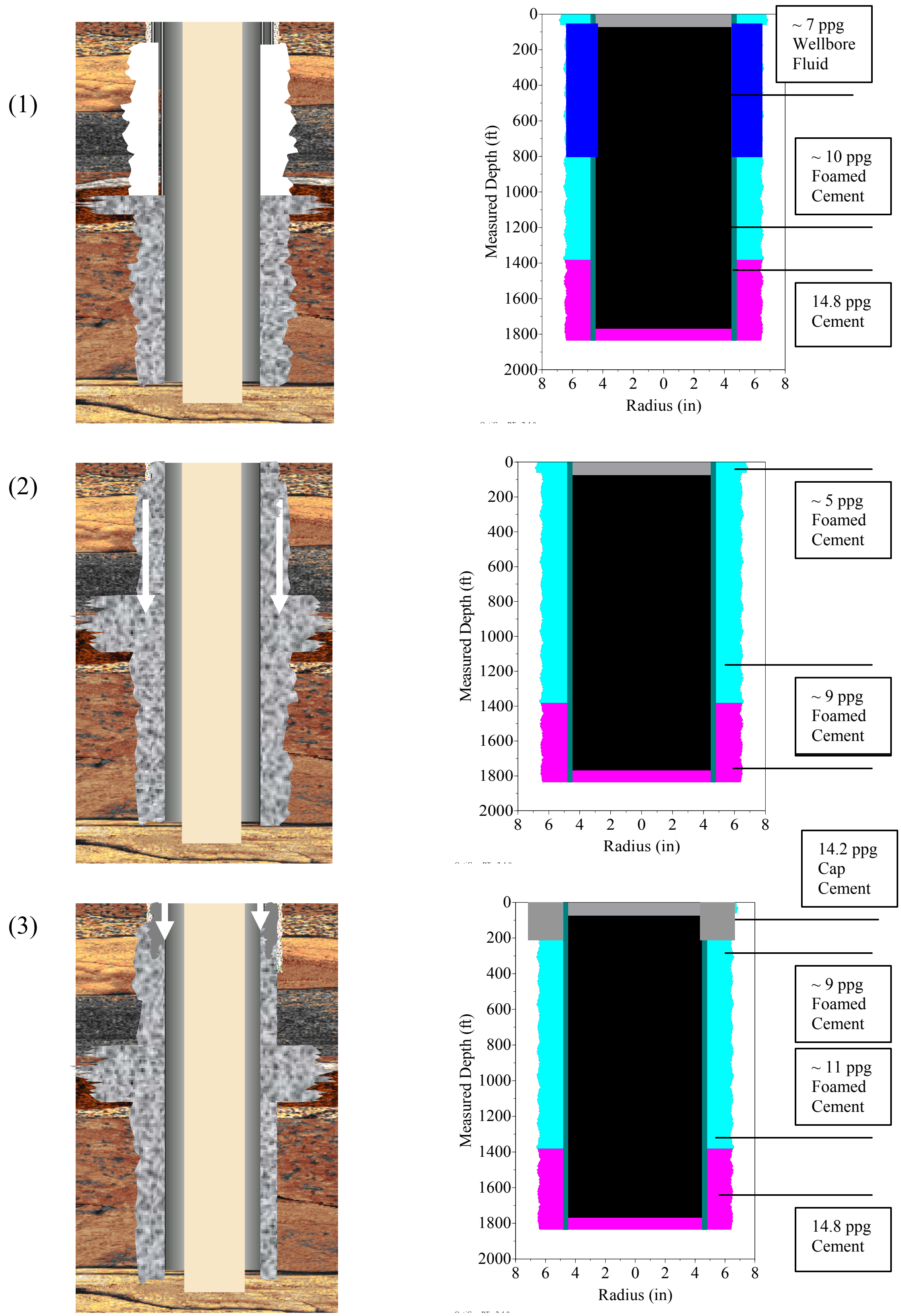


Figure 4 - During the primary job, if a foamed cement is NOT circulated to surface (1). a foamed stage is pumped down the annulus (2), followed by an non foamed cap #(3).

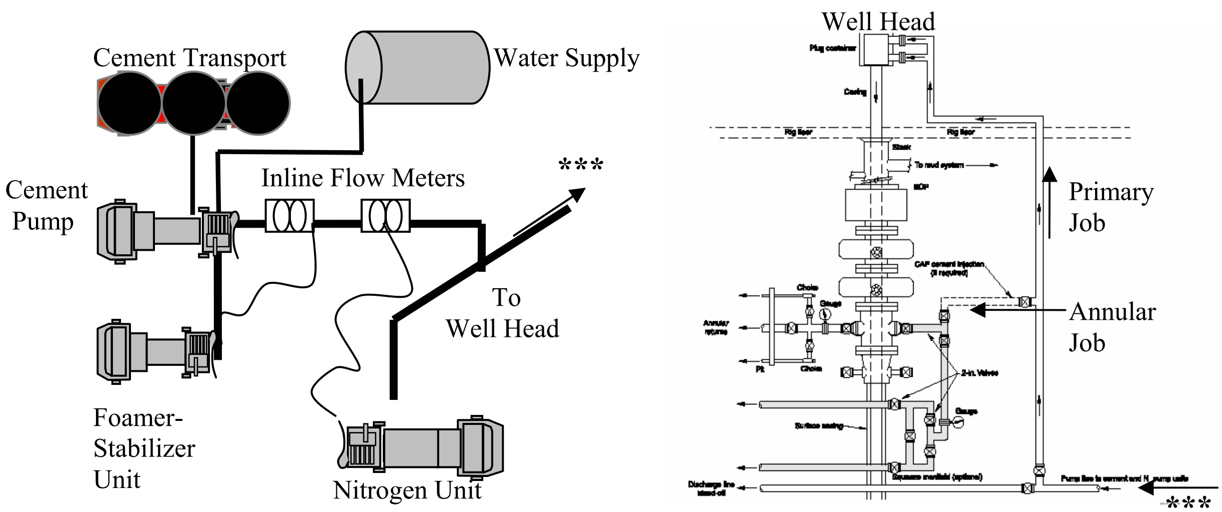
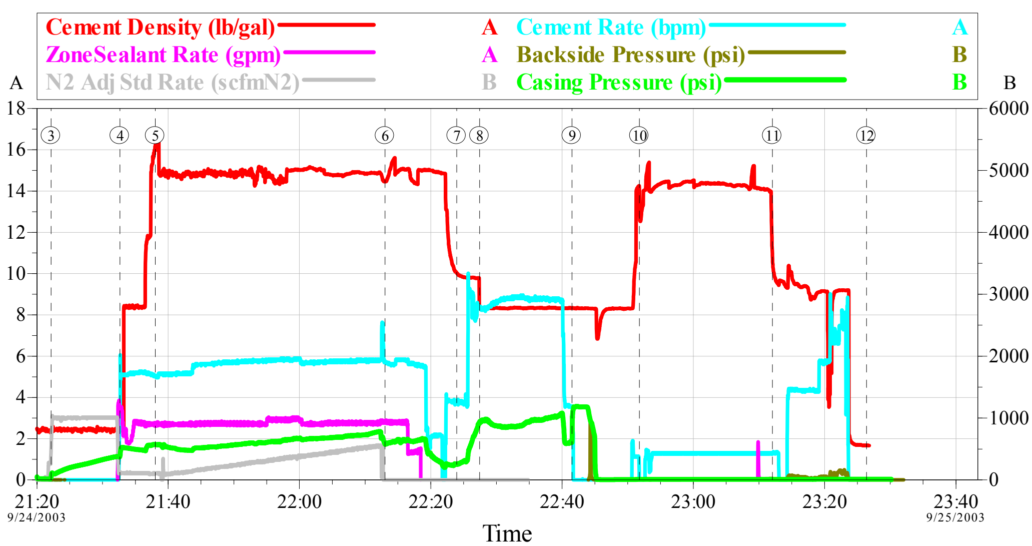


Figure 5 - The nitrogen and foamer/stabilizer units are automatically controlled by the rate read from the flow meters installed in line. Two lines are rigged up on surface casing, one for running the primary job (top) and the other for pumping the foam job down the annulus (if necessary) and the non- foamed cap.



Stages

①	Start Job	21:10:40	②	Test Lines	21:17:15	③	Pump 10,000 scf of Nitrogen	21:22:10
④	Pump 20 bbl of Water	21:32:39	⑤	Pump Lead 700 sks Foamed Cement	21:38:03	⑥	Pump Tail 150 sks Unfoamed Cement	22:13:03
⑦	Drop Plug & Start Displacement	22:23:58	⑧	Pump 138 bbl of Fresh Water	22:27:27	⑨	Bump Plug	22:41:31
⑩	Pump 75 sks of Cap Cement	22:51:47	⑪	Pump 2 bbl Water	23:12:03	⑫	End Job	23:26:23

Figure 6 - Treatment Data

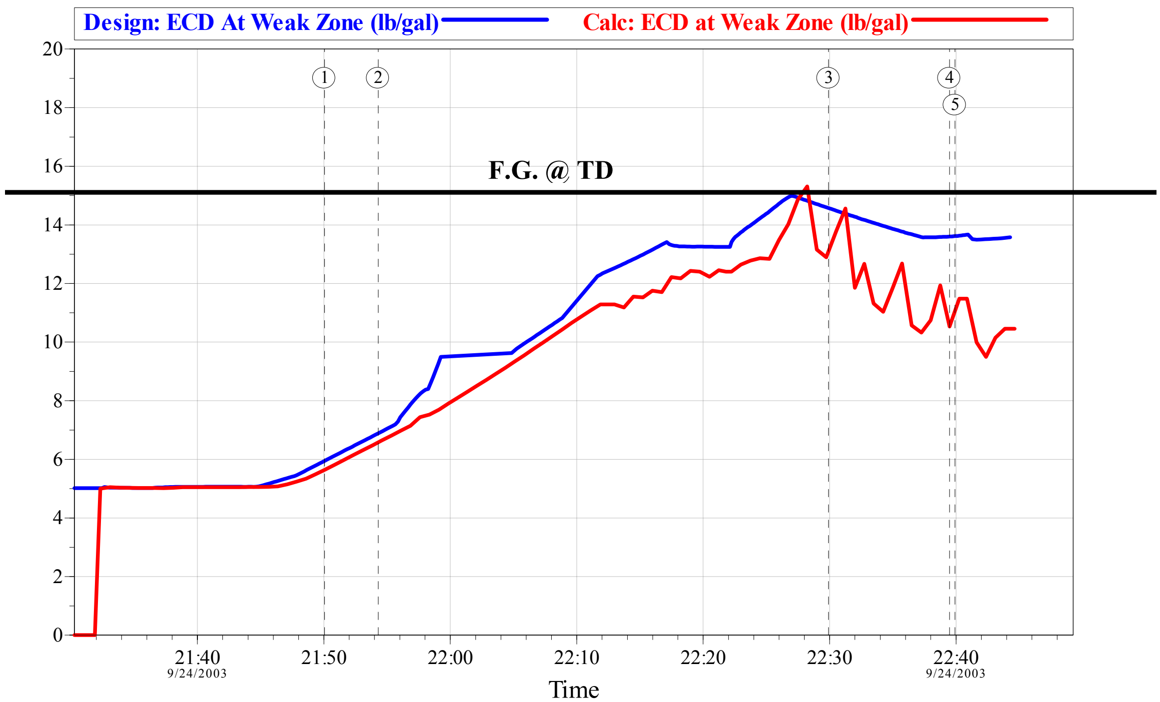


Figure 7 - Comparison Between Design and Actual Equivalent Circulating Density at TD

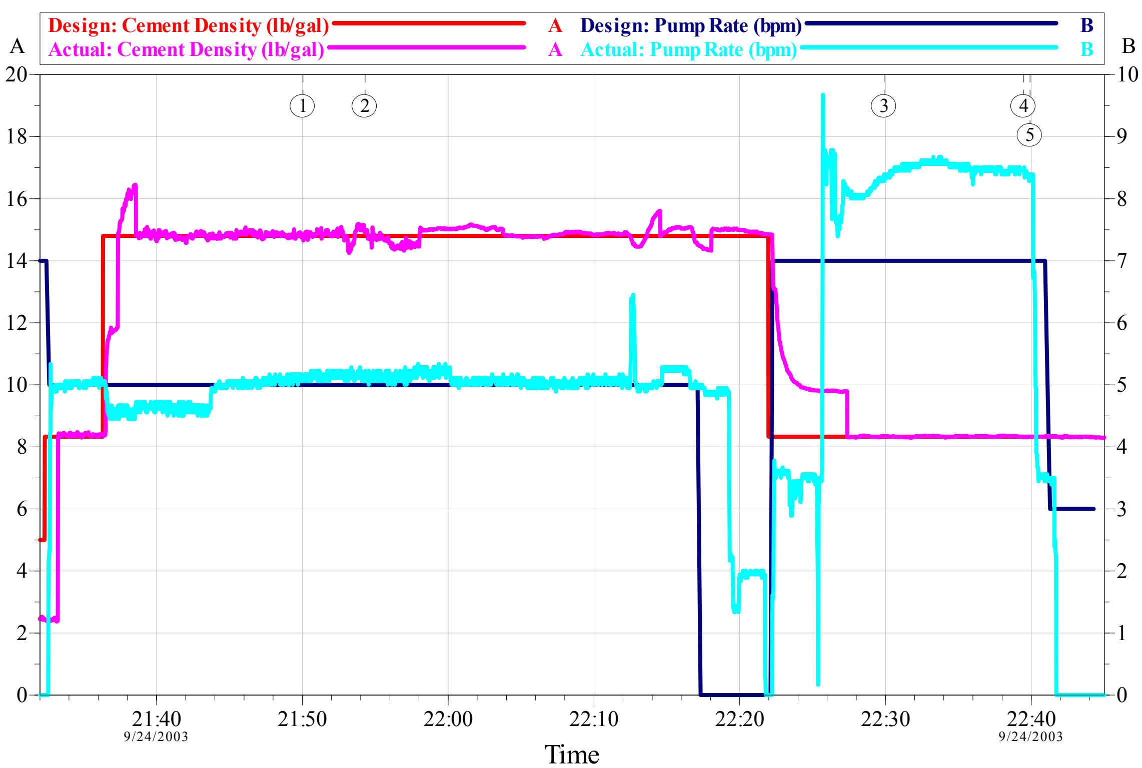


Figure 8 - Real time acquisition data helps ensures that the job is performed as designed.