

Cement Job Real Time Data Acquisition, Analysis and Visualization

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Abstract

The adaptation of fourth industrial revolution (4IR) technologies used for collecting large data sets during all aspects of their upstream operations has increased significantly in the Oil & Gas Industry. For many years cementing services companies have collected data from each cement job by means of an isolated monitoring system with parameters specific to cement placement operations, such as fluid densities, flow rates, pumping pressure and volumes pumped. Sensors connected to a data acquisition system and central computer, built into each cement pumping unit and independent from the data acquisition system on the drilling rig, provide this data, plotted in real time during each cement job and the data is stored in the same central computer memory. At the same time, the drilling rig also monitors and records essential data parameters in real time that have an impact on cement job assessment and visualization. These parameters include stand pipe pressure, rig pump flow rate, return flow rate, hook load, mud tank system, returned flow or any other parameters connected to the drilling rigs real time data monitoring system.

Often there are inconsistent correlations between the data sets caused by the different recording systems. The unification and gathering of required data from both the drilling rig and the cement unit in a single recording file system will enable relative job decision makers to read potential risks to the cement job objectives and increase confidence towards mitigating procedures.

Introduction

The objective of this paper is to describe the way in which real time data available on the cement pumping unit acquisition system during a cement job can be transmitted to the acquisition system that is utilized by the drilling rig and separate from the one utilized by the cement pumping unit. Another objective of this paper is to discuss the usefulness of combining the two data streams from the cement pumping unit and drilling rig acquisition systems for analyses and evaluation during and after cement placement.

Some important background information will be covered by a brief review of the hydraulic placement of cement during well construction, the design and evaluation process of each cement placement and how software is used to calculate both surface and down hole pressure, hook load and displacement efficiency

in the annulus. A description of the different sets of data that can be recorded by the cement pumping unit acquisition system and the corresponding sensors that are used to provide that data will be reviewed. This will be followed by outlining the process by which the data recorded during a cement job is printed and archived with the well file.

Finally, a process that was used to test and deploy the transmitting of real time cement unit data to the drilling rig acquisition system from six different service companies will be explained. The different ways that the combined data from the drilling rig and the cement unit can be used for real time monitoring and decision making, post job evaluation and top of cement interpretation will follow.

Review of The Hydraulic Placement of Cement

The placement of cement in the casing by open hole or cased hole annulus during well construction is known as 'primary cementing.' Primary cementing can be thought of as two separate studies. The first being the design and testing of the fluids that are mixed and pumped, which includes cement slurry, spacer, pre-flush and drilling fluid. The second being a hydraulic pumping process where the spacer, pre-flush and cement slurry are pumped into the casing or liner and displaced to the bottom and into the annulus. This requires special mixing and pumping equipment provided by a service company, which can be truck or trailer mounted and mobile for onshore operations or permanently installed for offshore operations.

Once the casing or liner has reached the required depth, drilling fluid is circulated and conditioned by the drilling rig pumps until homogenous. Then spacer and/or pre-flush is pumped by either the cement pumping unit or the drilling rig pumps. After releasing a wiper plug (referred to as 'bottom plug' and not always used) the cement pumping unit begins mixing and pumping the cement slurry or slurries. After releasing another wiper plug (referred to as 'top plug' and always used) either the cement pumping unit or drilling rig pumps are used to pump drilling fluid, which displaces the top plug down to the landing collar on the float equipment where a sharp increase in pressure can be seen at the surface, known as bumping the plug. See *figure 1* (Nelson and Guillot, 2006)

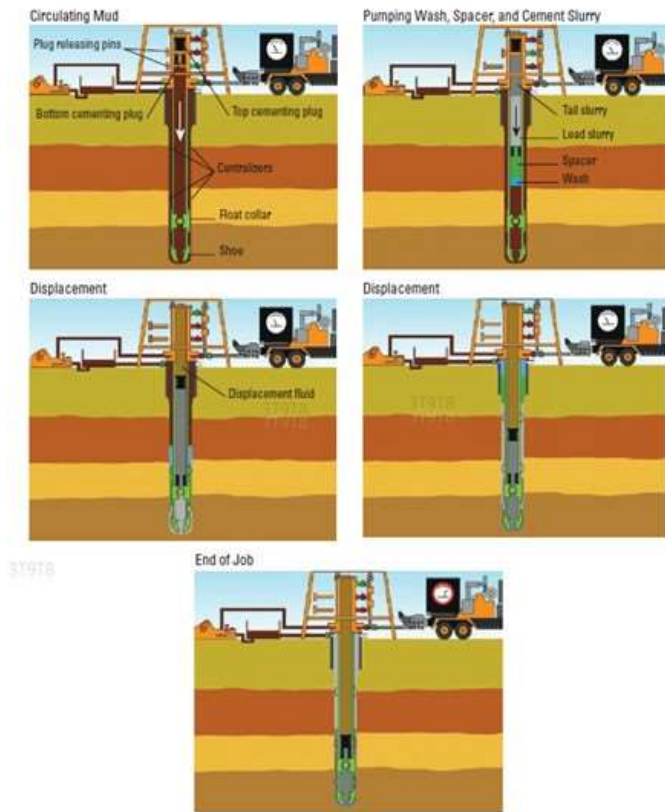


Figure 1: Typical Primary Cementing Process, Image courtesy of SLB. Used with permission.

The hydraulic pressure applied against the top plug forces the spacer, pre-flush and cement slurry or slurries down to the bottom of the casing or liner and then up into the annulus behind the pipe. Since the spacer and cement have a higher density and viscosity than the drilling fluid, the pressure at surface required to maintain a constant flow rate begins to slowly increase as more spacer and cement enter and are lifted up through the annulus. This increase in pressure can be monitored on the gauges attached to the cement pumping unit or the drilling rig pumps. Consequently, the pressure exerted on the well also increases and care must be taken not to exceed the fracture pressure of the formations to avoid loss of circulation. If the weight of the casing or liner remains hung in the elevators during the cement job the hook load will increase while pumping the spacer and cement and will then decrease when the spacer and cement are displaced into the annulus. The surface pressures, downhole pressures and hook load during a cement job can be predicted using software and hydraulic equations before the cement job in the planning and design phase.

Cementing Design and Evaluation

Many software packages and computer applications for modeling and simulating the placement of cement are available in the industry today. Some software can be purchased by the individual but most of the software are proprietary to each cementing service company. Many years of testing, vetting and optimizing the algorithms have been spent by the service

companies to develop and deploy the software to make the design and evaluation of cementing more efficient and accurate. Cementing software have many modeling capabilities and features, however, this study will focus on their ability to calculate pumping pressure and hydraulic horsepower required by surface pumping equipment, pressure applied downhole and hook load (Shan Shan Liu et al., 2022). The software is also used to display a well schematic with the depths of the fluid interfaces, the top of cement for example. Computer modeling can also be used to display an animation of the different fluid stages moving through the casing or liner and in the annulus of the well bore schematic with the corresponding charts showing the calculated values, such as surface pressure or downhole pressure. It can be said that the modern-day cement modeling software creates a rudimentary digital twin of the well bore.

In order for the computer models and applications to function the user must enter the depths and diameters of the open hole, casing, liner and drill pipe. The user must also enter the sequence of fluids to be pumped and the corresponding volumes. Alternatively, the user can input the desired top of each fluid in the annulus and casing or liner and the software will calculate the volume of each fluid to achieve that. For each fluid the user must input the density and viscosity and the flow rate at which they will be pumped. Based on these user inputs the software calculates and models the hydraulic placement of cement with simulations of surface pressure, hook load, rate in vs rate out and downhole pressure with margins against fracture pressure, casing or liner burst and collapse pressure.

See Figure 2 below, which demonstrates the ability of computer modeling to simulate the surface pump pressure vs time with corresponding user input flow rate, fluid density and volume.

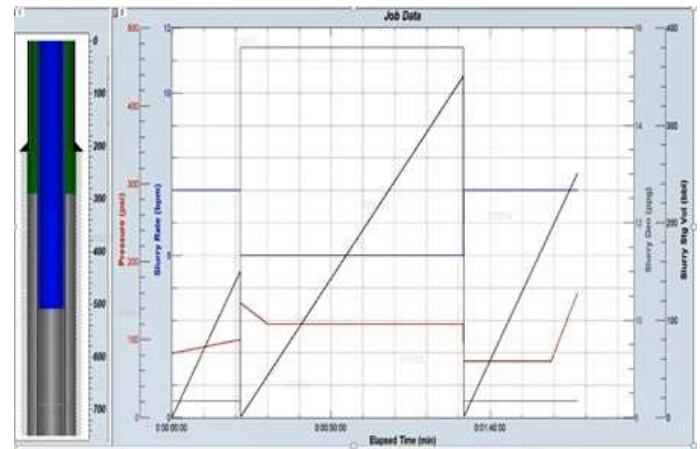


Figure 2: Simulated Surface Pressure vs Time

See Figure 3 below, which is an example of a simulated down hole pressure, expressed as equivalent circulating density, ECD, vs time with corresponding simulated surface pump pressure.

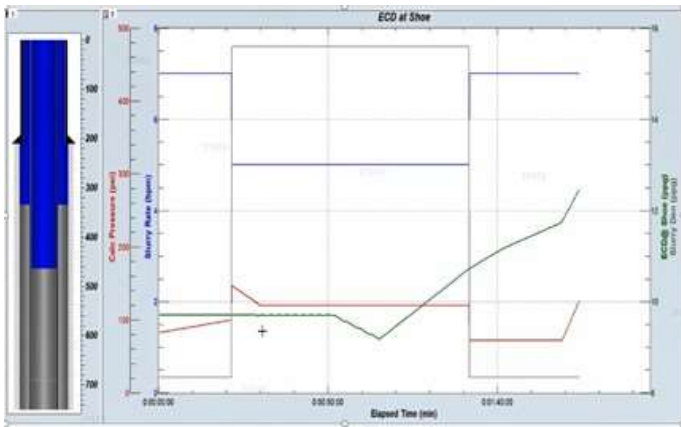


Figure 3: Simulated Downhole Pressure and Surface Pressure

See Figure 4 below, which shows how cementing software can simulate the dynamically changing hook load during the placement of cement.

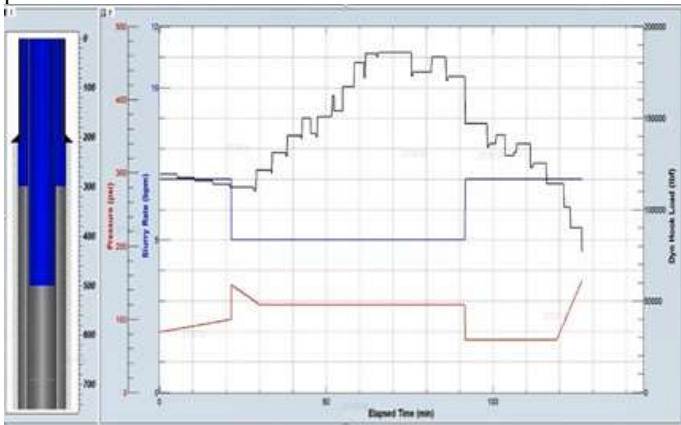


Figure 4: Simulated Hook Load and Surface Pressure

See Figure 5 below, which is an example of some of the more advanced features of computer modeling where the fluid intermixing is simulated and also the efficiency of one fluid to displace another fluid in the annulus during placement is simulated, for example spacer displacing mud and cement displacing spacer.

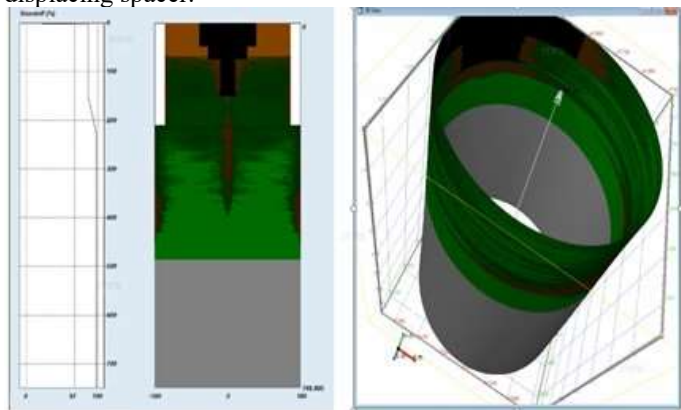


Figure 5: Simulated Standoff and Displacement Efficiency

Since the software runs very rapidly the user has the ability to run many iterations of different rates, volumes, fluid densities

and viscosities to optimize the placement while planning for a cement job.

After the cement job has been completed, it is important to evaluate how well the fluids were mixed and pumped by the equipment and crew, if the designed fluid sequence and rates resulted in pressures that were predicted by the computer modeling and if the objectives of the cement job were met. This post job evaluation can be accomplished by the same software and computer applications that were used for the initial design. As was stated earlier, the initial simulations are based on flow rates, volumes and fluid densities entered by the user. Actual rates, volumes, pressures and densities recorded digitally during the cement job by the cement pumping unit can be imported into the computer modeling software. All of the simulations used for the design phase can be repeated with the imported data, allowing the user to analyze the actual rates vs planned rates, the actual volumes vs the planned volumes, the actual fluid densities vs the planned densities and finally actual surface pressure vs predicted surface pressure. With this comparison an estimated top of cement can be calculated.

See Figure 6 below, which is an example of recorded rates, volumes and fluid densities imported into a computer model to compare the actual pressure during the cement job to the predicted pressure.

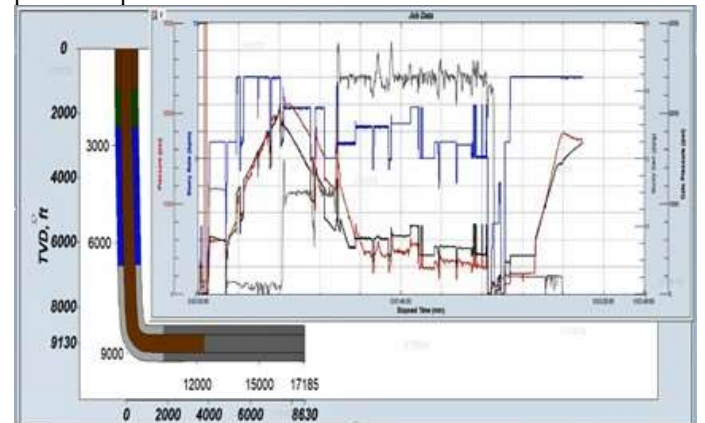


Figure 6: Simulation with Import of Recorded Pressure, Rates, Densities and Volumes

See Figure 7 below, which is an example of a good match of predicted pressure against actual pressure, indicating the cement slurry was placed properly.

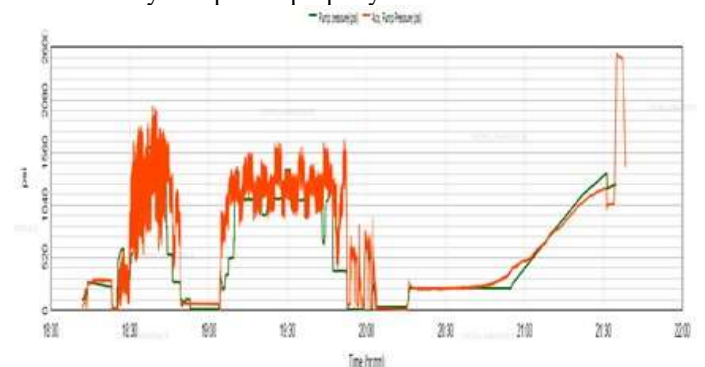


Figure 7: Example of Good Pressure Match

See Figure 8 below, which is an example of a poor match of predicted pressure against actual pressure, indicating losses may have occurred during the cement job and top of cement is not as expected.

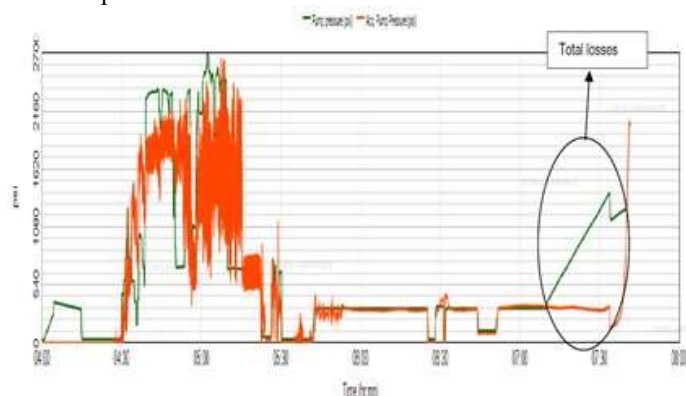


Figure 8: Example of Poor Pressure Match

The digital data recorded during a cement job is only available because each cement unit is outfitted with sensors and acquisition hardware and software.

Sensors and Real Time Data Recorded and Displayed Onboard A Cement Pumping Unit

In the past, the only technology available for recording pressure, rate, density and volume on a cement pumping unit were analogue, paper chart recorders. Today there are many digital sensors installed on each cement pumping unit designed to transmit digital data to an acquisition system used for displaying and recording the data during a cement job. See Figure 9 below, which is an example of a transducer used for transmitting pressure data. A typical cement pumping unit has one of these installed on each pump and also one installed on the discharge manifold.



Figure 9: Example of Pressure Transducers

See Figure 10 below, which is an example of a magnetic flow meter used for transmitting flow rate data. Most cement

pumping units have this type of flow meter installed in the suction manifold of each high-pressure pump.



Figure 10: Example of Magnetic Flow Meter

See Figure 11 below, which is an example of a proximity switch also used for transmitting flow rate data.



Figure 11: Example of Proximity Switch

The proximity switch counts each revolution of the drive shaft connected to the high-pressure pump, which can then be correlated to a certain volume for each revolution, similar to a stroke counter. Again, most cement pumping units have a proximity switch installed on each high-pressure pump. If the pumps lose prime or cavitate the magnetic flow meter will transmit less or even no flow rate while the proximity switch will continue to transmit the same flow rate. This difference in flow rate can be flagged and corrected during the execution of the cement job if the high-pressure pumps lose prime or are not pumping at the correct pump efficiency. See Figure 12 below, which is an example of a Coriolis densitometer used for transmitting density data.



Figure 12: Example of Coriolis Densitometers

All cement units have at least one densitometer installed in the mixing package so the operator can make the necessary adjustments to mix fluid and bulk cement delivery and ensure that the cement slurry is mixed at the designed density. Today, most cement pumping units also have a densitometer installed in the suction manifold of each high-pressure pump so that the density of all the fluids pumped can be monitored and recorded, not just the cement slurry.

Each of the sensors are connected via cabling to a central bank of programmable logic controllers, PLCs, on the cement unit where the transmitted data from each sensor can be converted from analogue data to a digital data format that is compatible with computer software designed to display the data in a user-friendly application. For example, a pressure transducer sending an analogue signal in the range of 4 to 20 milli-amps can be converted by a PLC into a range of 0 to 20,000 psi or other range based on the maximum capacity of the device. Some cement pumping units may also have a central processing unit, CPU, with a display and touch screen or keyboard that is connected to the PLCs and monitors and records the digital data and other cement pumping units may have junctions where a lap top computer can be connected to the PLCs. See Figure 13 below, which is an example of a cement unit with an onboard CPU, display and touch screen where real time data can be viewed on the cement pumping unit during a cement job.



Figure 13: Example of Real Time Data Acquisition on A Cement Pumping Unit

The display includes the pressure and flow rate from each high-pressure pump, the cement slurry mixing density and fluid density being pumped, the total flow rate of both high-pressure pumps combined, the total volume pumped and the volume of the current stage. The example display also includes a chart, which graphs the pressure, rate and density vs time. With so much valuable data now being captured during each cement job, the opportunity presents itself to utilize this data for something more than just viewing and archiving.

The Current Process of Archiving Recorded Data from The Cementing Pumping Unit

After the completion of a cement job where real time data is being recorded on the cement pumping unit, the data recording is stopped by the operator and saved to the CPU memory or saved on the lap top computer memory. From that point the data file can be copied onto a portable memory device such as a universal serial bus, USB, flash drive or onto a floppy disk on older acquisition systems that may still be in use. With the data file copied onto a personal computer or lap top the operator can prepare charts and tables and print them out for the post job paperwork, which becomes part of the well record. See figure 14 below, which is an example of a typical post job chart.

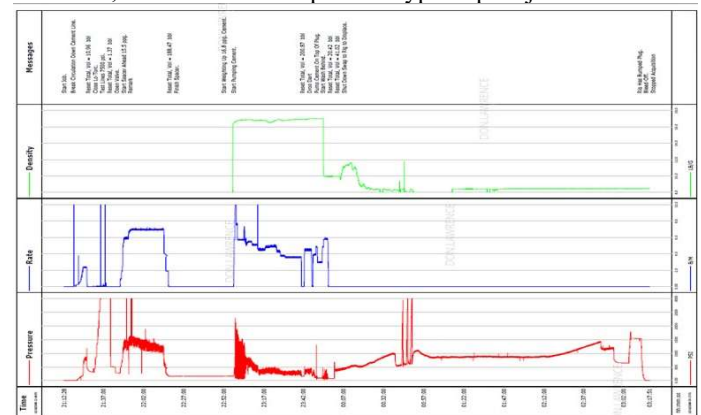


Figure 14: Example of Post Job Chart with Recorded Cement Job Data, Pressure, Rate and Density.

A post job chart can be printed out on paper as a hard copy or saved in a digital format, such as Portable Document Format,

PDF, or as a picture. The post job chart will have at least three tracks for pressure vs time, flow rate vs time, density vs time and sometimes total volume and stage volume vs time. The example in *figure 14* also has a track for comments that the operator can input during the job. Comments may include the time at which each fluid stage begins and ends, explanation of pressure spikes, switching tanks and other such events. Almost all charts and graphs of cement job recorded data are generated by software applications that are designed to present the charts and graphs in a standard and consistent format, based on the raw recorded digital data that is imported into the software applications. If a more detailed analysis of the data is needed or if a custom chart or graph is needed, the raw data can be imported into spreadsheets or other applications to make custom charts and graphs.

As was described earlier, the raw data recorded during a cement job can also be imported into the design software where the initial simulations of surface and down hole pressure, hook load and displacement efficiency can be repeated with the actual rates, volumes and densities of the fluid stages. Also, the predicted surface pressure can be compared to the actual surface pressure. This type of post job simulation on the design software with imported recorded data is referred to as a “playback.” Ideally, the best time to perform the playback is immediately after the cement job or at least within 24 hours to determine if the cement job objectives were met. Unfortunately, the playback is rarely performed immediately after the cement job and more often than not the playback is never performed at all. This lack of post job analysis can be explained. The design software that is needed to perform a playback is rarely available on the job site so the recorded data needs to be transferred to the service company office where the post job playback can be done. Transmitting the data from job site to office is not always possible due to remote locations with limited bandwidth. If the operator does not download the data file from the cement pumping unit CPU, or is not able to transmit the data file to the office, then the data file remains on the cement pumping unit or on the operator’s personal computer. As more and more jobs are recorded and stored on the cement pumping unit CPU, eventually older data will need to be deleted to free up storage memory. For onshore operations the cement pumping unit may move to another location or there may be a crew change.

Looking closely at the example post job chart of recorded data in *figure 14* there are stages during the cement job that do have a full set of data needed for complete post job analysis and playback. At the beginning of the job there is no density data of the fluid being pumped. After the cement slurry stage, again there is no density data of the fluid being pumped and also there is no flow rate data of the fluid being pumped. As was mentioned earlier, the displacement can be carried out by the drilling rig pumps or by the cement pumping unit. If the drilling rig pumps are used for the displacement, the flow rate and density of the fluids will not be recorded by the cement pumping unit acquisition system. Also, the drilling rig pumps can be used to pump the spacer and/or pre-flush ahead of the cement slurry. Again, the flow rate and density would not be

recorded on the cement pumping unit acquisition system. Anyone tasked with performing a post job playback and evaluation of the cement job would have to track down this missing data. After obtaining the missing data the user would now have to combine two data sets into one data set that is compatible with the design software needed for the playback and evaluation. If there is missing data from the cement pumping unit data acquisition and if this is because the drilling rig pumps were used for pumping the spacer and/or the displacement, the missing data is still available as it is recorded by the acquisition system used by the drilling rig.

Real Time Data Recorded and Displayed Onboard the Drilling Rig

Like the cement pumping unit, the drilling rig is also outfitted with many sensors that are sending data to a central acquisition system where the data is displayed for viewing at the job site and also transmitted in real time to the office. In comparison to the cement pumping unit, the drilling rig has much more sensors and data being displayed and recorded in real time. Also, in comparison to the cement unit, the rig is recording data 24 hours a day until the completion of the well while a cement job data recording is only a few hours at a time. See *figure 15* below, which is an example of a real time data display from the drilling rig acquisition while running drill pipe or casing into the well.

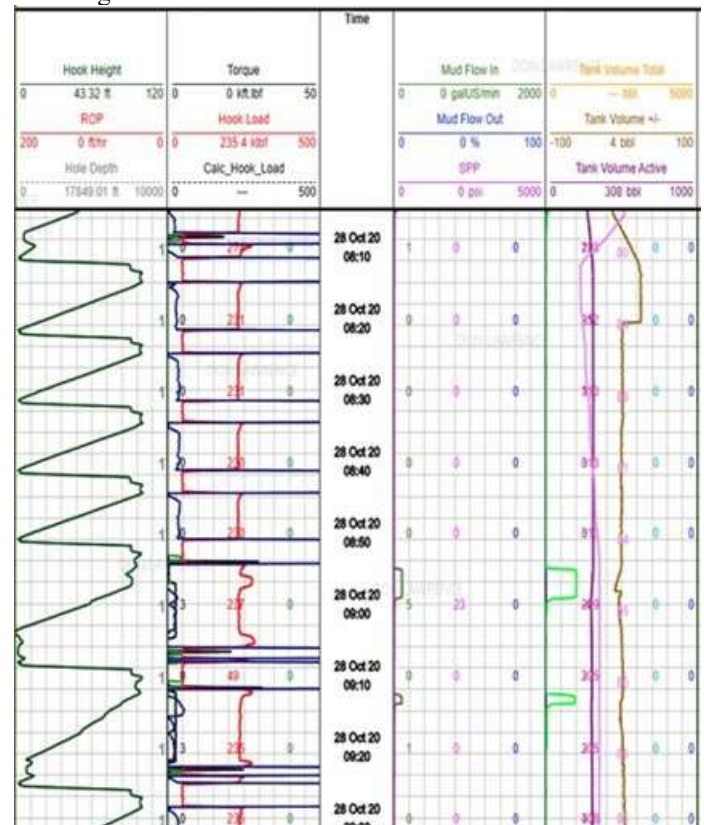


Figure 15: Example of Real Time Drilling Rig Data While Running into The Well

The drilling rig acquisition system can record and display the

block position or hook height, the rate of penetration, ROP, current depth, well depth, hook load, weight on bit, torque, rotation, pump flow rate, return rate, stand pipe pressure, active pit volume and other rig tank volumes. Examining the example in *figure 15*, it can be determined that the drilling rig is running into the well since the block position is moving up and down with no pump rate, return rate or stand pipe pressure and the current depth is increasing. See *figure 16* below, which is an example of a real time data display from the drilling rig acquisition while drilling.

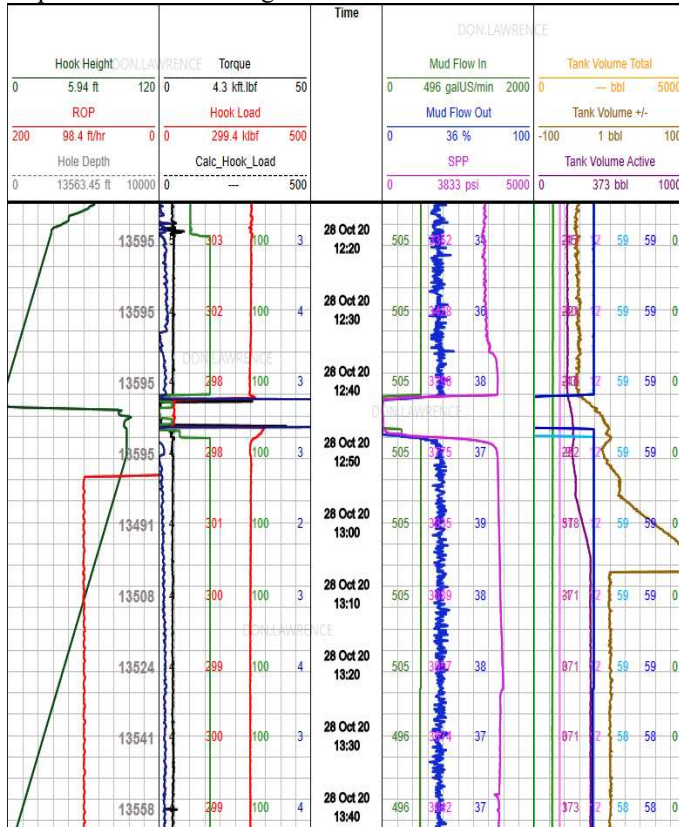


Figure 16: Example of Real Time Drilling Rig Data While Drilling

Examining the example in *figure 16*, the drilling parameters can be viewed in real time and decisions can be made to optimize the ROP. Three tracks, which are needed for post job evaluation of a cement job when the drilling rig pump is used for the displacement stage or for pumping the spacer, and that can be seen in the example from *figure 16* are Mud Flow In, Mud Flow Out and Stand Pipe Pressure, SPP. Also, anyone working on a post job playback and evaluation of a cement job would most certainly be interested in the recorded active tank volume during the displacement stage, as this would allow the user to identify any losses that may have occurred and even the severity of the losses. This can be a very useful correlation when the surface pressure recorded during a cement job does not match the actual pressure. See *figure 17* below, which is an example of a real time data display from the drilling rig acquisition during a cement job.

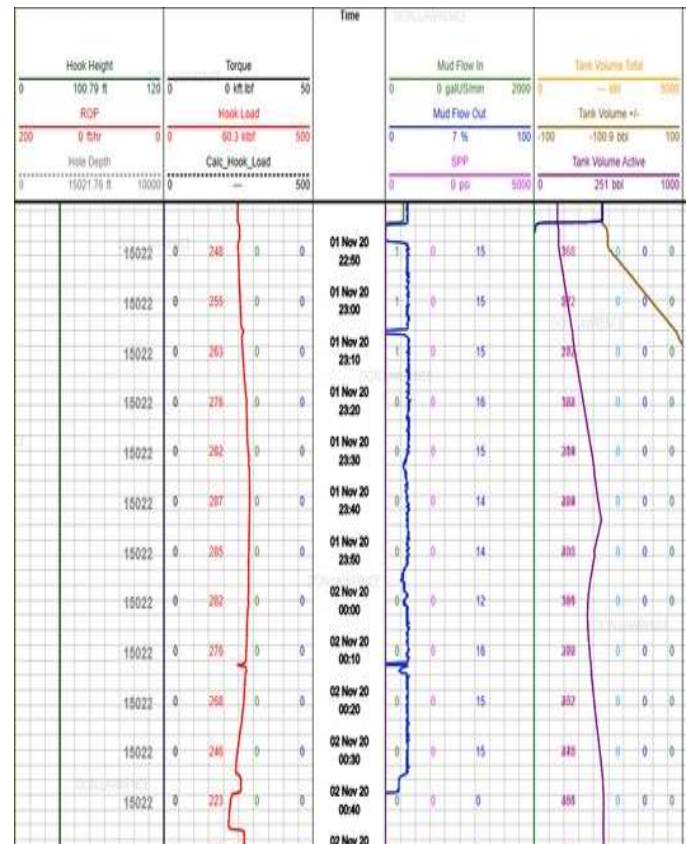


Figure 17: Example of Real Time Drilling Rig Data During A Cement Job

Just from looking at the example in *figure 17*, it would be difficult to know that a cement job is taking place, but there are a few signature patterns in the data that are common place during a cement job. Notice that the Mud Flow Out track is recording a return rate but the drilling rig pumps are not engaged. In this example the cement unit is pumping into the well with full returns. Notice also that the Active Tank Volume is increasing for a period of time, then decreasing for another period of time and then increasing again. This can be correlated to the volume of cement and spacer that were pumped, followed by the volume of mud required to overcome the u-tubing effect of the heavy spacer and cement fluids and then the volume to stabilize the rate in versus the rate out. And finally, notice how the hook load increases while spacer and cement are pumped into the casing and then the hook load starts to decrease as the spacer and cement enter and are then lifted into the annulus by the displacing fluid. A correlation could be made to estimate how much differential pressure would be required to reduce the hook load by the amount recorded and also how much hydrostatic pressure would be required to increase the hook load by the amount that was recorded. Based on this data alone, a rough estimate of the volume and density of the cement could be calculated as well as the top of the cement in the annulus. If the real time data from the cement pumping unit could be plotted and recorded by the drilling rig acquisition system, side by side with the Hook Load, Mud Flow In, Mud Flow Out, SPP and Active Tank Volume, these correlations and signature

patterns in the data would be much more apparent and algorithms could be developed to more accurately predict the top of cement in the annulus. In addition, the data recorded during the cement job could be more easily saved and archived along with the drilling rig data as part of the well record.

Transmitting Data from The Cement Pumping Unit to the Drilling Rig Data Acquisition Application

A project was undertaken to transmit the real time data from the cement pumping unit to the drilling rig acquisition system during all cement jobs. This project required collaboration between all of the cement service companies, the drilling rig data acquisition provider, information technology (IT) security, software and applications management. After determining the data format required by the drilling rig data acquisition system the next step was to meet with each service company and plan for converting their data stream into the required data format. Some of the service companies already had the data conversion feature built into their acquisition application on each cement pumping unit. Other service companies did not have this feature so data from those cement pumping units required a

separate piece of hardware to convert the data to the needed format.

The next step in the project was to create a cement dashboard in the drilling rig data acquisition application settings. There are many different dashboards built into the drilling rig data application, each specifically designed to group the most relevant tracks and read outs for different phases of the well. There is a drilling dashboard, casing running dashboard, logging while drilling, LWD, dashboard and many others. Since cementing occurs only intermittently during the well a separate dashboard was needed that would not interfere with the daily use of the other dashboards and could be specifically designed for evaluating cementing operations. It was also necessary to set up a data mapping standard for all of the cementing service companies to follow. For example, all cement unit pressure transmitted to the cementing dashboard must be labeled CMT_PRESS and the units must be in pounds per square inch, PSI. See figure 18, which is a snapshot of the cementing dashboard that was developed and is currently in use by the drilling rig data acquisition for the display of cement pumping unit real time data. The cementing dashboard

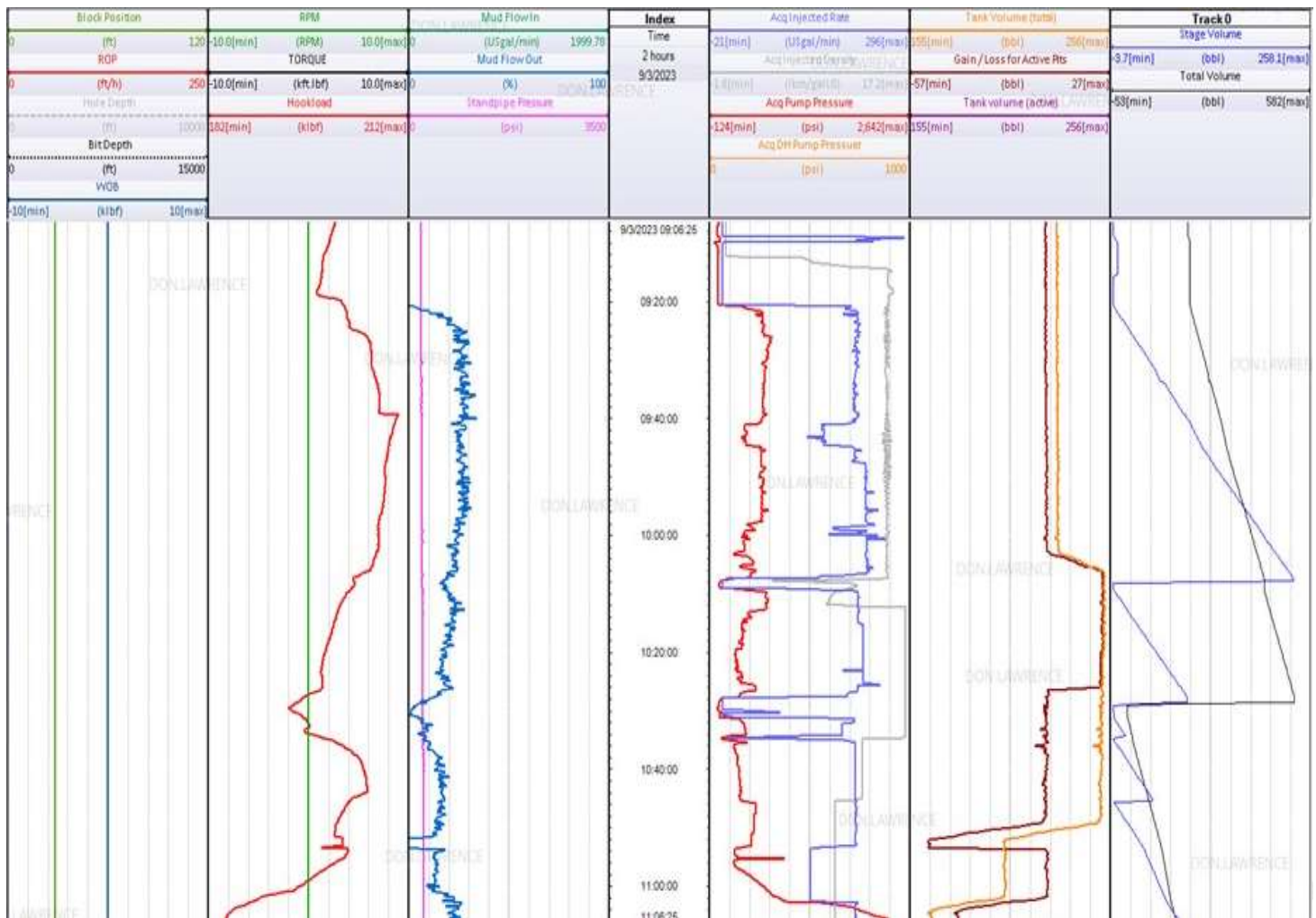


Figure 18: The Cementing Dashboard

combines the drilling rig data tracks that are needed for cement job evaluation and post job playback with the cement pumping unit data tracks all on one page, with standardized time stamp and formats. When the real time data from the cement pumping unit is being transmitted to the drilling rig data acquisition system, the pressure, rate and density tracks are already set up to be displayed in one block of tracks and the total volume and stage volume are already set up to be displayed on another block of tracks. This allows the user to see and correlate, either in real time or post job, how the drilling rig Mud Flow Out and Active Tank Volume correspond to changes in the cement pumping unit flow rate. This also allows the user to see and correlate how the hook load dynamically changes with the corresponding cement pumping unit pressure track.

The next step in the project was called the base test. The drilling rig data acquisition service provider set up a computer simulation of their acquisition system. Each service company came to the office and connected their lap top computer to the simulator. The lap top computer was loaded with the same software that their cement pumping units use to record real time data. Using playback mode, each service company transmitted previously recorded cement pumping unit data via their lap top computer to the drilling rig data acquisition simulator. While transmitting the playback data, it was possible to test the compatibility of each service company's data transmission with the drilling rig data acquisition simulator and make any needed adjustments in the settings. After several iterations all of the service companies completed the base testing phase and they were given the go ahead to test their data transmission during an actual cement job, which was called the field test phase.

The transmission of real time data from the cement pumping unit to the drilling rig data acquisition system was through an Ethernet data cable and switch. See *figure 19* below, which is a photograph of the Ethernet data cable connected to the junction acquisition box, JAB, on the cement pumping unit during the first field test.



Figure 19: Ethernet Data Cable Connected to Cement Pumping Unit Junction Acquisition Box

The Ethernet data cable was then run along the ground to an office in the living quarters on the job site where it could be

connected to a lap top computer or, if needed, to data conversion hardware. The lap top computer and/or data conversion unit were connected to an Ethernet switch and a second Ethernet cable was run to the drilling rig data acquisition office on the job site. See *figures 20* below, which are photographs of the lap top computer, Ethernet switch and Ethernet data cable that was used to send and receive data between the cement pumping unit and drilling rig data acquisition systems on the first field test.

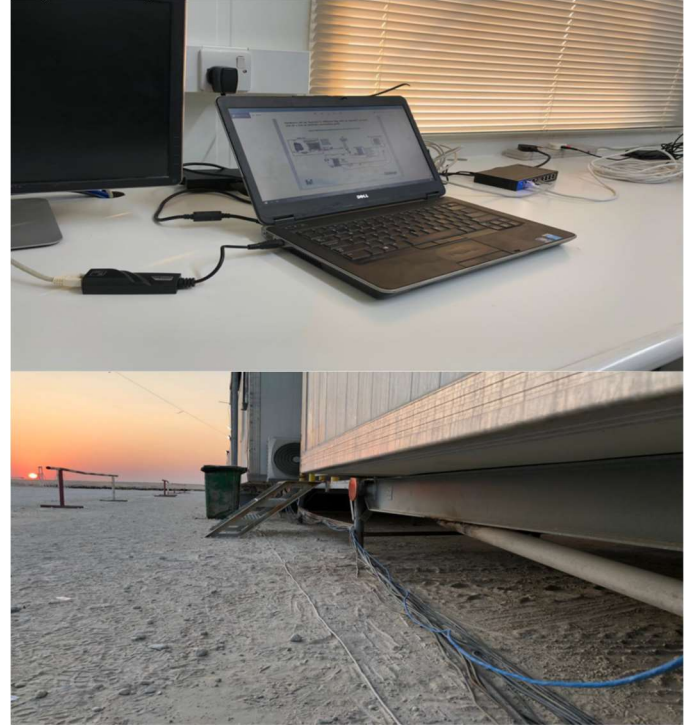


Figure 20: Lap Top, Ethernet Switch and Data Cable Connecting Drilling Rig Acquisition Office to Cementing Unit

See *figure 21* below (Torres et al., 2017) which illustrates the flow of data now available between the drilling rig data system, the cement pumping unit data system and the cement design software for real time evaluation and visualization.

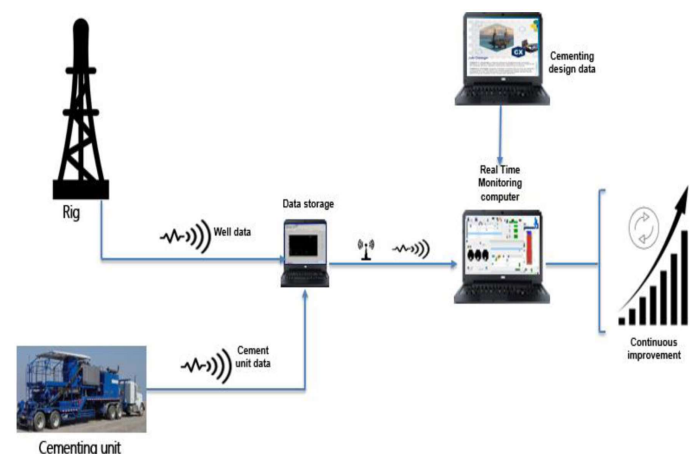


Figure 21: Well Data from Drilling Rig and Cement Data from Cement Unit Connected To Central Data Acquisition System.

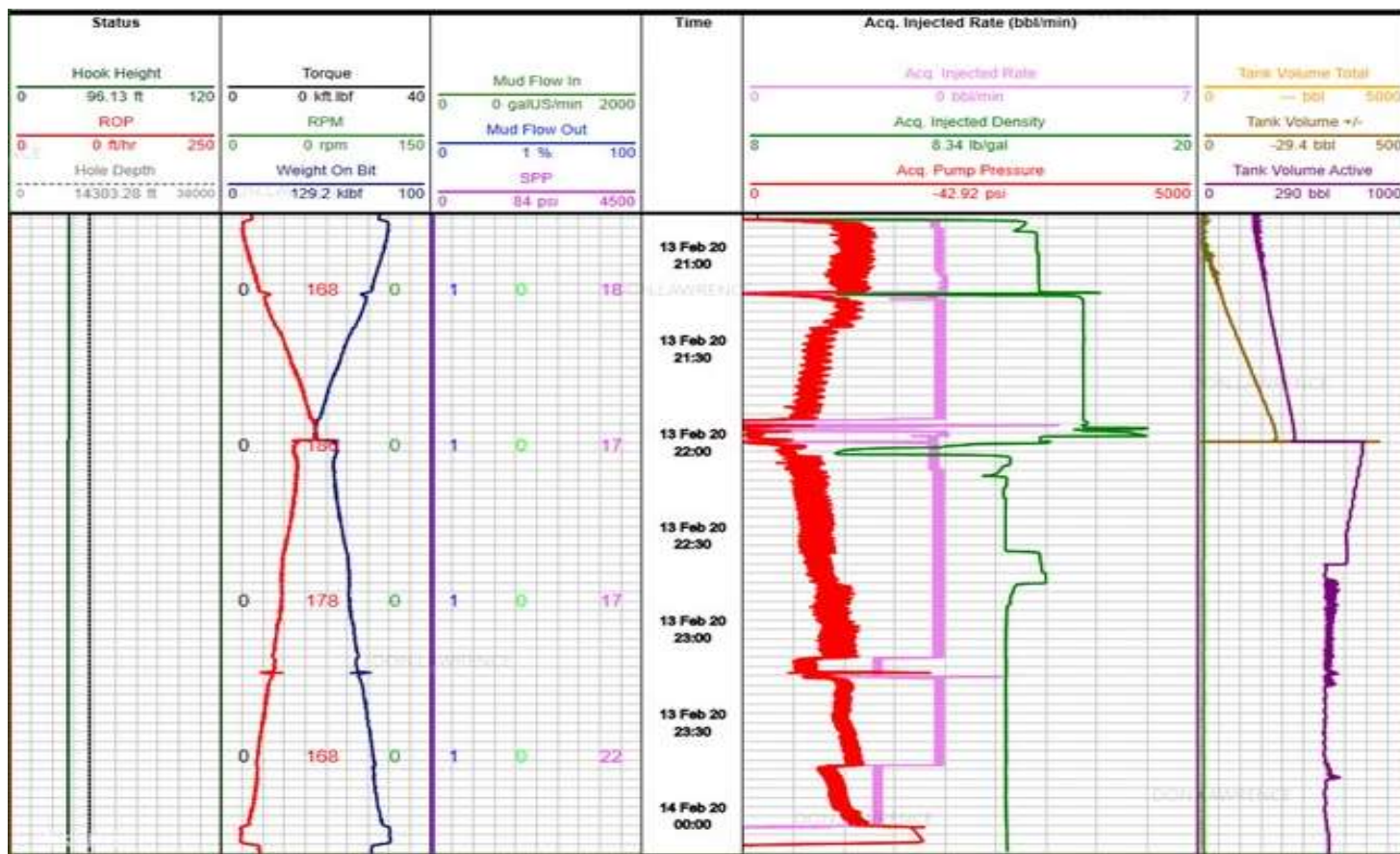


Figure 22: Cement Dashboard from The First Field Test

After the data cables are connected an Internet Protocol, IP, address is assigned by the drilling rig data acquisition engineer to the lap top computer, which can now receive data from the cement pumping unit data acquisition system and send converted data to the drilling rig data system. See *figure 22*, which is a snapshot of the real time cement data recorded from the first field test. The cement pumping unit pressure, rate and density were successfully transmitted and displayed on the cement dashboard in real time during the cementing operation. Anyone with access to the drilling rig data application could view the cement dashboard either from home, office or on the rig site. Anyone viewing the cement dashboard could see how the Active Tank Volume and Hook Load tracks are increasing while the spacer and cement are being pumped. Also, anyone viewing the cement dashboard could track the consistency of the cement slurry, if the rates were close to the designed rates and if the pressure is close to the anticipated pressure. During displacement the Active Tank Volume could be monitored for any changes that may indicate losses or gains and the Hook Load could be monitored for expected trends like decreasing during displacement, which indicates that the cement slurry and spacer are being continuously lifted in the annulus. One thing noticed very clearly after the first field test was how the Hook Load track is almost a mirror reflection of the Pump Pressure track and also the Weight On Bit track has the same trends as

the Pump Pressure Track. It would be difficult to tell the difference between the Weight On Bit track and the Pump Pressure track without labeling and units. Like the base test, all of the service companies successfully completed a field test after several iterations. With the infrastructure now in place to monitor cementing operations using the drilling rig data acquisition application, now compatible with all service companies cement unit real time data acquisition systems, the next step was to consider how and if this new data stream could be used to evaluate the quality of each cement job, and not just for monitoring and archiving the cement data.

Cement Evaluation in Real Time

The cement dashboard is now a valuable tool for viewing the real time data from the cement pumping unit and the drilling rig or for reviewing the recorded data for post job analysis. All of the data needed to run a post job playback can be readily downloaded and imported into cementing design software, applications and computer modeling for evaluation of the cement job or for investigations. (Contreras et al., 2017) Efforts are now underway to utilize the cement dashboard to create more advanced displays and dashboards in the drilling rig data acquisition system that can generate the same charts, graphs, animations and tables as the post job playback, but in real time. This would allow the user to visualize at what depth the fluids

such as spacer, pre-flush and cement slurry are located in the casing, liner or annulus at any point during the cement placement and correlate that with cement unit or drilling rig pressure, tank volumes and hook load. This would also allow the user to view a graph of calculated pressure vs actual pressure in real time during the cement job. Another feature would also be an evaluation of design rates and volumes vs actual rates and volumes in real time and finally a real time evaluation of the cement slurry planned density vs actual density. With this kind of dashboard for real time cement evaluation, much more information would be available for stakeholders to make decisions during the cement job to deal with any problems that may occur. For example, scrubbing the job, circulating out and starting over if unable to control the density of the cement slurry.

Some of the cement service companies already have such applications to evaluate a cement job in real time. However, the applications developed by the service companies require that real time data from the cement pumping unit and drilling rig be transmitted to a remote server for processing and the calculated data is transmitted back. This transferring of data to a remote server presents a problem for IT security regulations. The cement dashboard can be set up to transmit data back to the service company lab top computer on the rig site, described earlier, and the data can be processed for real time evaluation at the rig site and without the need for transmitting the data to any remote server. See *figure 23* below as an example of real time evaluation software available from one of the service companies, and which has been integrated into the cement dashboard and in use for critical cement jobs.

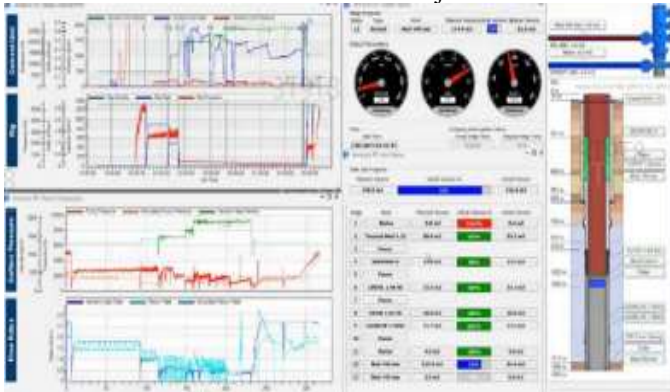


Figure 23: Service Company Real Time Cement Evaluation Display

The drilling rig data acquisition provider have also developed a real time cementing evaluation display that can be used in addition to the cementing dashboard. Before the cement job, the user enters the well geometry, the fluid sequence and anticipated pressure vs volume into the well file. Then during the cement job, the cement evaluation display imports the real time cement pumping unit and drilling rig data from the cement dashboard and displays a calculated top of cement, graphs of calculated pressure vs anticipated pressure, planned volume and rates versus actual volumes and rates. See *figure 24* below as

an example of the cement evaluation display available from the drilling rig data acquisition application.



Figure 24: Real Time Cement Evaluation Display from Drilling Rig Data Acquisition Application

Other projects are also being developed based on the availability of the cement dashboard. One such project is using artificial intelligence, AI, to analyze all of the data from all of the cement jobs and find patterns in the data that would allow the AI to make recommendations on future cement jobs and estimate the chances of successfully meeting the objectives. Another such project is developing an algorithm to generate a virtual cement unit pressure track based on the hook load and weight on bit data recorded during cement placement. And there is also a project to develop a code that would import the recorded cement pumping unit data into the cement dashboard post job. This will be useful for uploading cement data from previous years or for a cement job where it was not possible to use the cement dashboard.

Conclusions

The objective of this study was to merge real time data from a cement pumping unit with the real time data from the drilling rig data acquisition system into one application. The objective was successfully accomplished and deployed. Real time data from any cement job can be viewed on the cement dashboard, either from home, office or on the rig site. The ability to view real time cement data gives stakeholders and decision makers the tools they need to be more involved in the cementing operations and intervene when needed. (Purvis et al., 1992) Having the cement data integrated into the drilling rig data acquisition system will be very useful for archiving the cementing post job evaluation in the well records. Many things were learned by all parties involved about data acquisition and transmission. The cementing dashboard sparked many new ideas and projects that will add value to future cement job designs, planning, execution and evaluation while also bringing the cementing process into the fourth industrial revolution.

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