

# Preventing Annular Flow After Cementing in the Shallow Gulf of Mexico

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*Cement pulsation can effectively prevent gas flow in the annulus after cementing. This case study focuses on its use in a well in the shallow Gulf of Mexico.*

The morning starts with a full cup of steaming coffee in preparation for a quick review of the day's offshore Gulf of Mexico (GOM) morning drilling report. It's important to ensure everything went as planned on the surface casing cement job performed late last night and get back to making hole. Scanning the report, blood pressure rises when the reader sees the words "slight gas flow noted in the conductor/surface pipe annulus within 3 hours following cementing." The reader's eyes rapidly move forward and spot the words "diverter closed" and "platform evacuated" further down the page.

According to the U.S. Minerals Management Service, this type of situation continues to be one of the major causes of well control loss during GOM drilling operations.

In the best case, annular flow after cementing likely will make it necessary to perform a remedial cementing operation at additional cost. On the other end of the spectrum, these incidents can lead to broaching, cratering and fire – situations with which no exploration and production professional wants to be involved.

So what caused this problem? The cement program was designed and executed to perfection. Good cementing practices, including proper mud conditioning casing centralization and movement, were applied. All indicators observed in the field during the cementing operation pointed toward proper mud displacement and expectations of a good cement job.

The root cause of this problem may not be associated with shortcomings in the design or execution in any of the above activities. Annular flow shortly after cementing in the

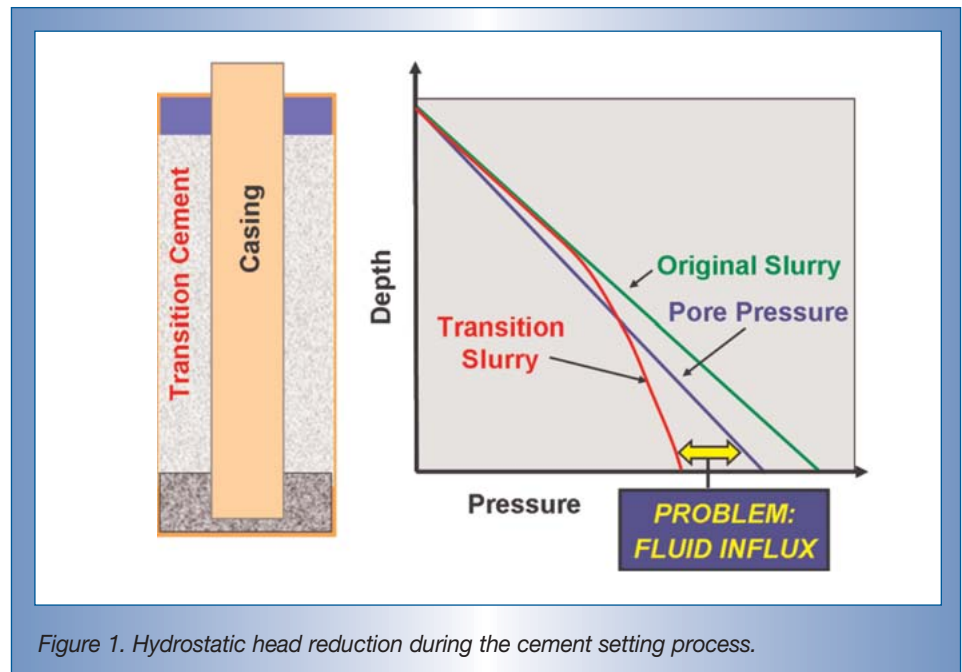


Figure 1. Hydrostatic head reduction during the cement setting process.

GOM can be significantly impacted by normal gel strength development in the cement slurry and associated loss of hydrostatic pressure on the cement column.

This process starts shortly after the cement is put in place. The cement, through its bond to the casing and formation, begins to develop initial strength to support its weight. Since the result of this action is cumulative over the length of the cement column, a significant reduction in hydrostatic pressure may be experienced in deeper sections of the cement column as it moves through the transition phase.

If certain field conditions are encountered, this loss of hydrostatic head can allow gas migration into the unset cement column. The end result may include creation of a channel to

the surface and flow or pressure on the annulus (Figure 1).

## Cement pulsation

This relatively simple and inexpensive technique recently was applied successfully in an offshore GOM well (Figure 2) to prevent this loss of hydrostatic pressure and the occurrence of flow/annular casing pressure after cementing. Commercial cement pulsation services, until recently, specifically have been targeted toward land applications. This was done to develop operational history and know-how in preparation for entry into the high-cost operating environment of the offshore market. Cement pulsation has been applied to more than 500 land wells in the United States and Canada. The success rate (defined as no annu-

lar pressure after cementing) has been about 95% on wells deviated less than 30°. It successfully has been applied in well depths from 1,900ft to more than 12,000ft. In addition, cement pulsation has helped obtain high-quality cement jobs on wells with lengthy cement columns, some more than 12,000ft in length.

The cement pulsation process encompasses the application of low-intensity pressure pulses to the annulus immediately following the primary cementing operation. As the cement column sets from the bottom to the top, the pressure pulses act to break the gel strength in the unset portion of the column, so hydrostatic pressure is maintained along the length of the unset column and fluid influx is prevented. The compressible volume (CV) of the cement column – the volume of water required to pressurize the annulus as the cement pulse is applied – is monitored during the cement setting process. The cement pulsation operation is deemed complete when the CV stabilizes. A typical pulsation time of 4 hours to 6 hours is sufficient for most slurry designs. No changes to the original cement design are required for application of the cement pulsation technique.

The key elements of the cement pulsation equipment are an air tank, water tank, valve controller and data recorder. The pulsation unit utilizes an air-over-water approach to apply the pulses on the annulus. A large steel-reinforced hose is connected between the cement pulsation unit and the annulus, and the wellbore is initially filled with fluid to the surface (cement, mud or water). Next, the air tank is controlled to apply a pre-set pulse pressure to the water tank for a given period of time. This action applies a water pulse on the annulus. Following the pulse-pressure hold period, the air pressure on the water tank is exhausted to the atmosphere, and the annulus is allowed to relax for a pre-set amount of time before the cycle is repeated.

### Offshore GOM field operations

W&T Offshore has an active drilling pro-



Figure 2. The cement pulsation unit (center) consists of the black, skid-mounted equipment.

gram in the Outer Continental Shelf/South Timbalier **Block 229**. This block is about 40 miles off the Louisiana coast in about 238ft of water. Offset wells in the area had experienced annular casing pressure in less than 18 hours following cementing of the conductor and/or surface pipe. This situation developed in spite of using an appropriate cement job design and while applying good cementing practices in the field, such as pipe movement. The pressure on these offset wells ultimately was eliminated by a remedial cement job.

W&T began to work with their cementing company, BJ Services, to identify a cost-effective solution to this problem. The additional cost of a remedial annular squeeze job could potentially add \$150,000 to the final well cost, including rig time and associated costs. Following a review of potential solutions to the annular casing pressure problem, cement pulsation was selected for application on the **ST 229 A5** well.

The construction of this well started with drive pipe set to 750ft. It was then drilled to 1,550ft with a 17½-in. bit, and finally under-reamed to 24-in. The well plan called for 18⅝-in. conductor pipe to be set to

1,550ft with a cement top at 368ft. The conductor pipe cement design called for placement of the following materials during the cementing operation:

Material	Bottom Depth (ft)	Top Depth (ft)	Density (ppg)
Sea Water	31	0	8.4
Spacer	368	31	9.8
Lead Slurry	1,250	368	12.0
Tail Slurry	1,550	1,250	16.4

The lead and tail slurry had a laboratory-tested pump time of 6:00+ hours and 2 hours and 42 min., respectively. It should also be noted the lead slurry had a fluid loss of 26 cc/30 min., and zero free water at a 45° angle.

The lead slurry was designed to control flow after cementing per accepted industry standards of less than 50 cc/30 min. fluid loss and zero free water at a 45° angle. The cement design challenge on the shelf, with respect to shallow gas flow, centers on the control of gas influx as the cement goes through transition.

The transition time refers to the time period when the cement column stops transmitting the full amount of hydrostatic pressure. This occurs when the cement starts to gel and can result in an underbalanced pressure situation.

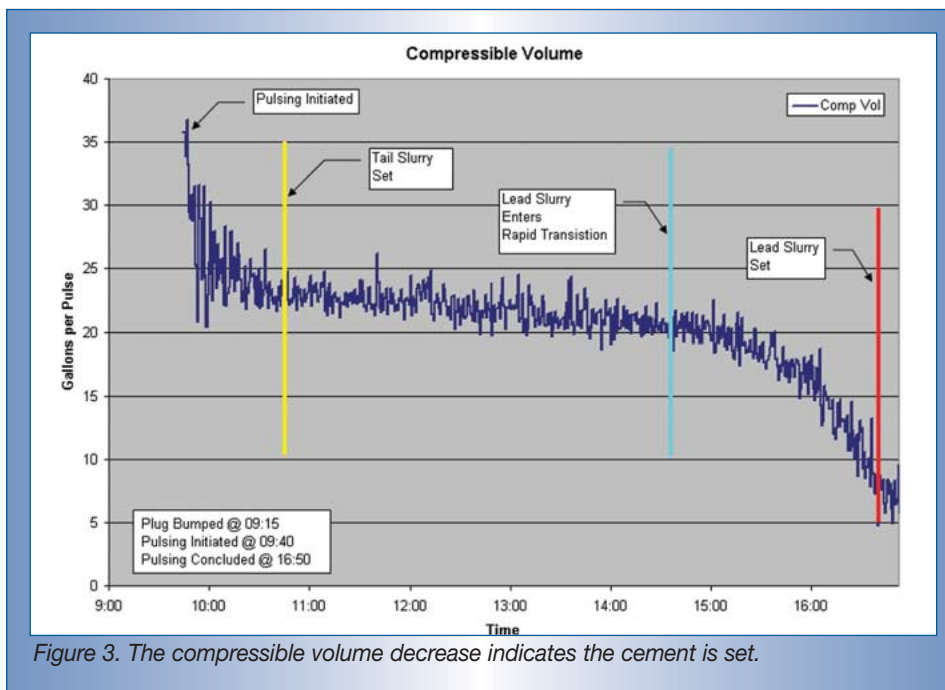


Figure 3. The compressible volume decrease indicates the cement is set.

The mathematical value is 100 lb/100 sq ft to 500 lb/100 sq ft. In other words, cement is no longer liquid at a gel strength value of 100 lb/100sq ft.

Conversely, cement is a solid when it reaches a gel strength value of 500 lb/100 sq ft. At some point between these two gel strength numbers, the hydrostatic pressure of the cement column drops below the pore pressure of the formation. This value is known as the critical gel strength value. The point between the critical gel strength value and 500 lb/100 sq ft is the point where gas or liquids may enter and contaminate the slurry.

In addition to the cement properties that control the influx of gas, application of cement pulsation may shorten this time between the critical gel strength value and the point at which the cement becomes a solid by keeping it in the liquid state longer. It is being considered that each pressure pulse may act upon the setting cement as a mini “hesitation squeeze.”

In addition to cement pulsation and slurries designed to control flow after cementing, it is important to note all industry-accepted cementing best practices must still be implemented. In the case of shallow gas, these best practices help ensure successful cement place-

ment in the wellbore. Best practices include but are not limited to:

- proper hole cleaning before pulling out of the hole to run casing;
- proper mud conditioning before the cement job;
- proper spacer type and amount;
- proper centralization;
- pipe movement during the pre-job circulation and cement job; and
- cement and spacer must be displaced into the wellbore at the proper rates.

The use of good primary job cement simulation software, such as BJ Services CmFacts™ program, is critical when modeling any cement-job design. This software will determine at what rates the drilling mud can be displaced most efficiently from the wellbore without exceeding the wellbore’s fracture gradient. This software also provides a recommendation for proper centralizer placement. Properly centralized pipe normally has a minimum standoff value of 67%.

This software must be viewed as another component of cementing best practices and is routinely used to help obtain successful cement jobs. The recommended outputs from CmFacts were incorporated into this job

design and used to attain optimum mud removal and proper cement placement, allowing cement pulsation to commence on an uncontaminated cement column.

### Cement pulsation job design challenge

The cement pulsation job design for this well had to overcome an additional obstacle. This shallow openhole section has a very narrow operating window between the fracture pressure and pore pressure. For normal openhole treating depths greater than about 2,000ft, the low-pressure pulses applied during cement pulsation typically are negligible in relation to the overall pressures experienced at deeper depths in the wellbore.

However, if a 100-psi pulse for example were imparted on shallow sand at a depth of 800ft, that would add an equivalent in excess of 2 ppg to the hydrostatic pressure profile. In light of this constraint, proprietary cement pulsation design software was used to model the minimum surface pulse pressure required to break the gel strength at the total depth of the tail slurry. The modeling indicated a surface pulse pressure of 50psi would be more than sufficient for the job, while staying below the fracture pressure of the shallow gas sand in the openhole portion of the well.

### Cementing and pulsation operations

BJ Services commenced the cementing operations at 6:30 a.m., and the cement plug was bumped at 9:15 a.m. Cement returns were observed at the surface during the cementing operation, and the rig crew washed cement from the stack from 9:15 to 9:40 a.m. The annular blowout preventer was subsequently closed to seal the annulus and cement pulsation was initiated.

The well was pulsed with 58psi surface pulses for a little more than 7 hours. The pulse was applied and held on the annulus for 15 seconds, with a 15-second pulse relaxation period following pressure exhaust. Pulse fre-

quency was constant at about 39 seconds during the course of the operation.

The two primary measurements recorded during the pulsation operation included tank water-level (CV) in the pulsation unit tank and total amount of water loss (volume) displaced to the wellbore during the pulsation operation.

The tank water-level measurement is made with a floating ball inside the cement pulsation unit tank. The water loss to the wellbore is measured with a flow meter. A total of a little more than 21 bbl (about 890 gal) of water was lost to the wellbore during this pulsation operation.

## Cement setting indicated by cement pulsation data

Following initiation of the cement pulsation operation, the initial CV (water displacement per pulse) was slightly more than 30 gal. The largest magnitude of CV typically occurs at the onset of the cement pulsation operation, as the gel strength along the length of the entire cement column is being sheared. Compressible volume will decrease over time, as the cement column develops sufficient strength to preclude the cement pulsation shearing action at the cement-to-formation/casing interfaces.

### About the Technology

The cement pulsation technology was developed with support from Gas Research Institute and was subsequently licensed to two service companies. Commercial cement pulsation services are provided by CTES LP in the United States and Trican Well Services in Canada. Cement pulsation has been applied to more than 500 wells in the United States and Canada. The success rate (defined as no annular pressure after cementing) on wells deviated less than 30° has been about 95%. It has been successfully applied in well depths ranging from 1,900ft to more than 12,000ft. In addition, cement pulsation has helped obtain high-quality cement jobs on wells with lengthy cement columns, some more than 12,000ft in length.

Compressible volume decreased rather rapidly from the start of pulsing until about 10:45 a.m., indicating the tail slurry had developed sufficient strength such that the pulses were unable to continue shearing it (Figure 3). About 420 gal of water were lost to the well during the initial 65 min of pulsing, yielding an average water loss of nearly 6.5 gal/min.

Pulsing continued until 2:40 p.m., with only a slight decline in CV, from about 23 gal/pulse to just above 20 gal/pulse. However, average water loss slowed appreciably during this time. About 390 gal of water were lost to the well during this 235-min period, with an average loss of about 1.7 gal/min during the same period. At this juncture, a cumulative water loss of about 810 gal had been recorded.

At about 2:40 p.m., the CV decreased from just more than 20 gal/pulse to about 5 gal/pulse to 6 gal/pulse by 4:40 p.m., indicating the lead slurry was setting. In addition, the rate of water loss to the wellbore decreased significantly during this time, with a loss of less than 80 gal during this 120-min period (average water loss less than 0.7 gal/min).

The CV stopped decreasing at about 4:40 p.m., indicating the lead slurry was set. Compressible volume had declined to less than 6 gal/pulse by this time, and the cement pulsation operation was deemed complete and was terminated just before 5 p.m.

### Success—no annular pressure

The combination of cement pulsation with a sound cement program design and application of proper field cementing practices all worked together to deliver the desired results – a high-quality cement job with no annular pressure or annular flow after cementing. An annular squeeze job and/or loss-of-well control incident was potentially avoided. Finally, data recorded during the pulsation operation indicated setting of the tail and lead slurries.

It is not often that a technical and economic success is obtained on the initial application of a technology in a radically different setting, such as offshore, soft rock. This positive result can in large part be attributed to close coordination among the operator, cementing company and pulsation service company before the operation.

There is still much to learn regarding application of cement pulsation in the shallow GOM environment. That being said, the following important conclusions can be inferred from this case history:

- cement pulsation is another cost-effective tool that can be applied to potentially avoid flow/annular pressure following cementing in the GOM;
- extremely low-pressure pulses can be transmitted to total depth of a cement column;
- cement pulsation data can provide real-time monitoring of the tail and lead slurry setting process; and
- field equipment design is robust and suitable for offshore applications.

Looking to the future, additional offshore candidate wells in the GOM will be sought for application of the cement pulsation technique, so a statistically valid sample of results can be accumulated. There is additional development work to be performed on the cement pulsation job-design software, and there likely is more information to be gleaned from the measurements made during the cement setting process. This information will be incorporated into future cementing programs to provide better job results and reduced well costs.

For more information about this technology, contact in the United States: CTES LP, Ed Smalley, phone: (936) 521-2222, e-mail: [ed.smalley@ctes.com](mailto:ed.smalley@ctes.com); or in Canada: Trican Well Services, Dale Dusterhofs, phone: (403) 266-0203, e-mail: [dale.dusterhofs@trican.ca](mailto:dale.dusterhofs@trican.ca) ♦

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