Perigon

Guide:

HOW TO SELECT THE RIGHT TECHNOLOGY FOR SETTING BALANCED CEMENT PLUGS

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Content

Introduction and Executive Summary

Balanced cement plugs which are set off-bottom have been used for decades in the oil and gas industry for pressure isolation purposes and as mechanical platforms: Plug & abandonment plugs, kick off plugs for sidetracking, zonal isolation plugs and fluid loss plugs.

To place a proper balanced cement plug in a well has been a severe problem to the drilling industry for decades. The cement plug is rarely found at the desired depth.

The challenge

The operation of balancing the heavy cement on top of lighter fluids have proved to be very challenging. One of the major challenges is to avoid contamination of the cement slurry during the operation, especially when pulling the work string out of hole.

This often results in setting several cement plugs to achieve the objective of the plug.

The success rates for setting cement plugs can be as low as 20 percent and up to 100 percent. In the North Sea, experience has shown cement plugs fail in > 25 % of the cases.

If it becomes necessary to set several plugs before the objective is achieved, the entire process of setting one successful balanced cement plug can even take weeks.

Several techniques have been developed to keep the cement in place, but most of them are either very time consuming or have low success rate.

This guide will go into details on which factors should be considered before selecting the correct base for cement plugs:

- ❑ Technically: Is a base necessary? What are the pros and cons for each option?
- ❑ Economically: Understand the total cost picture for setting a successful cement plug

The purpose of this guide is to educate our audience to select the best possible choice of technology, for every cement plug job.

Our core message: Every driller and cementing specialist should base their decisions upon a wide range of technical and cost-related parameters, which goes beyond just the technical properties and the cost of the base technology itself.

Therefore, this guide will discuss the pros and cons for the different bases to enhance success.

Different solutions: Pros and Cons

In this guide, we discuss six different and commonly applied base technologies in the oil and gas industry, both offshore and onshore.

These solutions may be divided into two main groups:

- ❑ Different types of fluids
- ❑ Mechanical bases for the cement

As you soon will discover, the rig time cost for setting one successful cement plug may vary from approximately USD 35.000 to 92.000 for onshore locations and from USD 230.000 to 525.000 for offshore locations, depending on selected base technology.

Happy reading!

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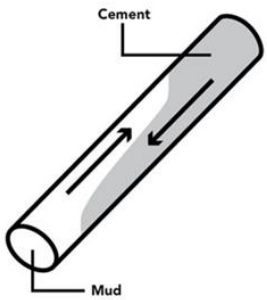
1. Most common challenges when setting off-bottom cement plugs

There are several challenges when setting balanced off-bottom cement plugs. Most of the failures relate to contaminated cement slurry.

According to our experience, these are among the most important root causes:

Cement slurry density

The density of the cement slurry is often higher than the fluid below. The difference will force the cement to move downhole and swap place with the fluid below.



In sc ure at all. In other cases, the cement becomes contaminated. When the cement does not cure or becomes contaminated, the integrity of the cement plug will not be sufficient to hold required differential pressure, or the cement plug will become too soft and not able to kick off from.

Cement slurry design and quality

There are several different additives in the cement slurry that creates different slurry properties.

It is important to have all the relevant well parameters to be able to design the correct slurry for the cement plug, such as: Temperature, pressure, type of drilling fluid and pumping time.

Accelerators, for example, speed up the thickening time for the cement slurry and can limit the available time for the cement slurry to become contaminated, but it will also limit the time the slurry can be pumped.

Cement slurry placement

As mentioned in the introduction, it is important to balance the cement slurry during displacement.

Improper planning and execution of the cement slurry placement can often lead to contamination.

When pulling the work string out of the cement plug, the initially balanced system quickly becomes unbalanced, and the cement contaminated.

Spacer

Spacers are pumped in front of and behind the cement slurry to separate the cement slurry from the well fluid.

A spacer is important to avoid slurry contamination.

The key challenge is to keep the cement separated from the well fluid until it has hardened and formed a solid cement plug.

Conclusion

Depending on choice of solution, placement time for one plug may vary from a few hours and up to several days.

The success rates for setting cement plugs can be as low as 20 percent and up to 100 percent. If it is necessary to set several plugs before the objective is achieved, it can even take weeks.

Taken rig rates into account, you can do the math: The right choice of technology is crucial.

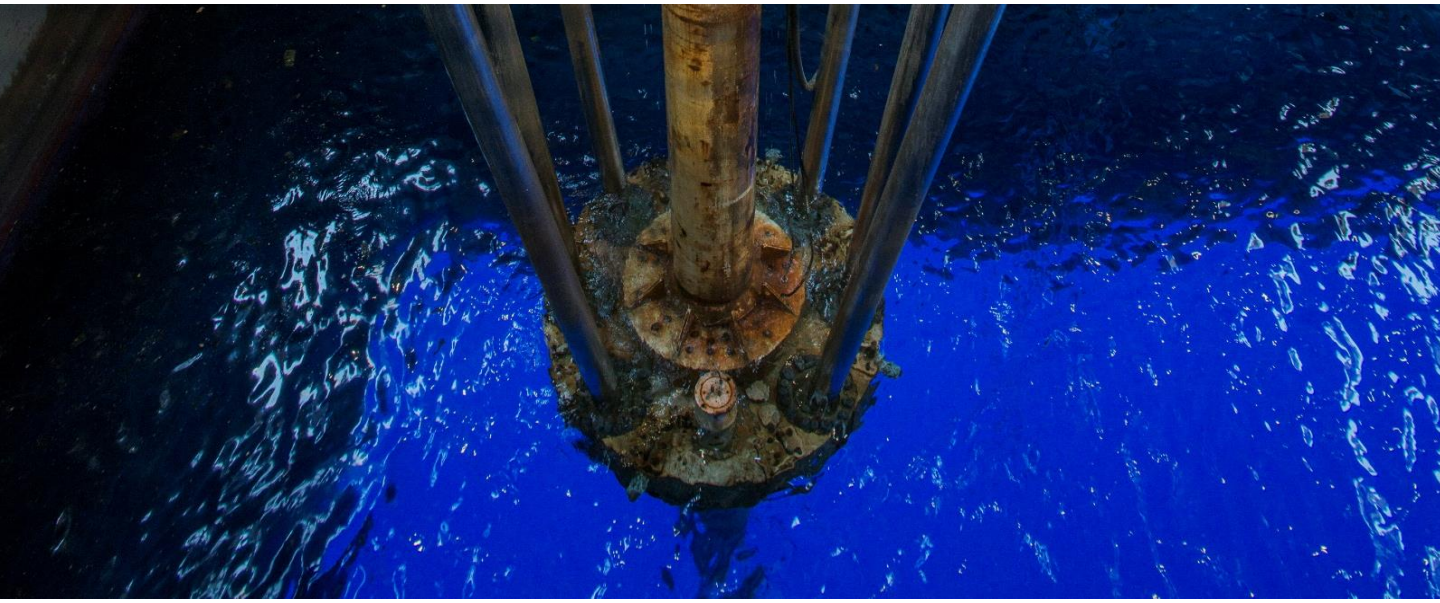
In this guide, we discuss the pros and cons for six fundamentally different and commonly applied base technologies in the oil and gas industry, both offshore and onshore.

In our opinion, every driller and cementing specialist should base their decisions upon a wide range of technical and cost-related parameters, which goes beyond just the technical properties and the cost of the base technology itself.

We suggest that 12 important parameters should apply when deciding what base technology to use:

1. Surface tank capacity issues
2. Potential mixing problems
3. Challenging to run in hole to set
4. Placement time
5. Potential fluid incapability
6. Pressure test time
7. Pull out of hole with running tool
8. Suitability for cased hole
9. Suitability for open hole
10. Need for rental equipment
11. Need for specialized personnel
12. Industry average success rate

These parameters may be used as a checklist and evaluation tool.



2. Evaluation of different solutions – Pros & Cons

You may divide the bases into two main groups, based on their basic commonality:

- Three of the bases are different types of fluids
- Three of them are mechanical bases for the cement

There are substantial technical differences between these six types of bases, which we describe below.

1. High viscous pill

As mentioned above, drilling professionals know that it is very difficult, nearly impossible, to successfully set a cement plug in a wellbore on top of a lighter fluid.

A common solution to the challenge is to place a viscous (thicker) fluid right below the planned bottom of the cement plug.
A high viscous pill is basically a mix of water and a substance (e.g. bentonite), were the substance thickens the water.

The high viscous pills are mixed on the rig, thus requiring substantial surface tank capacity (remember, the hole is often 8-10” or even larger) and mixing capabilities must be on the rig. Consequently, there is also potential fluid incapability issues related to this solution.

Increasing the viscosity of the fluid increases the fluid's ability to support solids in the cement.

However, the thicker fluid - the more difficult it is to handle, and it creates challenges during the mixing process on the rig, for the pump workload and for the pumping process thousands of meters downhole.

One of the benefits of high viscous pills is that it requires no setting time when run in hole. There is also no need to allocate time to perform pressure test, nor need to pull out of hole with running tool.

A high viscous pill may be used for cement plug setting both in cased hole and open hole. There should be no need for renting special equipment for performing these types of operation.

However, to mix and pump high viscous pills requires specialized personnel, including lab testing before pumping.

The industry average success rate for high viscous pills are approximately 75 percent, which we regard as mediocre.

The placement time of setting one high viscous pill is 3-4 hours, and the cost of the product itself is in the 'lower end', compared to other alternatives.

We estimate the time to set one cement plug using high viscous pill to 28 hours. The onshore rig time cost to set one cement plug with high viscous pill below cement is calculated at 35.000 USD.

In our calculations, we add 14 hours due to the success rate (± 75 % percent).

The approximate rig time cost for one cement plug using high viscous pill arrives at USD 52.500.

For an offshore location, the rig time cost would be around USD 346.500.

Summary: High Viscous Pill	
Surface tank capacity issues:	YES
Potential mixing problems:	YES
Challenging to run in hole to set :	N/A
Placement time:	3-4 hours
Potential fluid incapability:	YES
Pressure test time:	N/A
Pull out of hole with running tool:	N/A
Suitability for cased hole:	YES
Suitability for open hole:	YES
Need for rental equipment:	NO
Need for specialized personnel:	YES
Industry average success rate:	± 75 %

The basic idea behind a chemical reactive pill is to create a chemical reaction between the substance in the pill and the cement. The reaction forms a gel that prevents contact between the cement and the wellbore fluids below the pill.

A chemical reactive pill is somewhat like high viscous pills, but the key difference is that the chemical pill reacts with the cement due to the high pH in the cement and correspondingly low pH in the pill.

The chemical reactive pill also requires mixing possibilities and substantial surface tank capacity on the rig. There are also potential risks of fluid incapability.

However, there are normally no issues related to mixing problems or run in hole as the chemical reactive pill is pumped through the work string.

There is also no need to allocate time to perform pressure test, nor need to pull out of hole a running tool.

A chemical reactive pill may be used to set cement plugs both in cased hole and open hole. There is no need to rent special equipment for these types of operation.
However, mixing and pumping pills requires specialized personnel.

The success rate for chemical reactive pills is approximately 50 percent, which we regard as the lowest among the available base technologies for off-bottom cement plugs.

The placement time for setting a chemical reactive pill is 2-3 hours, and the cost of the product itself is in the 'lower end', compared to the other alternatives.

We estimate the time to set one cement plug using chemical reactive pill to 27 hours. The onshore rig time cost to set one cement plug using chemical reactive pill is calculated to 33.750 USD.

In our calculations, we add 27 hours due to the success rate (± 50 % percent).

The approximate rig time cost for one cement plug using chemical reactive pill arrives at USD 67.500.

For an offshore location, the rig time cost would be around USD 445.500.

Summary: Chemical Reactive Pill	
Surface tank capacity issues:	YES
Potential mixing problems:	NO
Challenging to run in hole to set :	N/A
Placement time:	2-3 hours
Potential fluid incapability:	YES
Pressure test time:	N/A
Pull out of hole with running tool:	N/A
Suitability for cased hole:	YES
Suitability for open hole:	YES
Need for rental equipment:	NO
Need for specialized personnel:	YES
Industry average success rate:	± 50 %

3. Heavy fluid below cement

When setting balanced off-bottom cement plugs they are naturally not set on the bottom of the well.

However, you can take advantage of the bottom and pump heavy fluid from the bottom of the well and up to the point where you want to set the cement plug.

To increase the density of the mud, it is very common to use barite. This solution is rather expensive and time consuming, but the success rate is usually high.

The heavy fluid also requires mixing possibilities and substantial surface tank capacity on the rig.

There are potential risks of fluid incapability, and potential issues when running in hole to set as you have to run in hole to the bottom of the well.

On the other hand, you don't need to allocate time to perform pressure test, nor need to pull a running tool out of hole.

Heavy fluid may be used for setting cement plugs both in cased hole and open hole.
There is no need to rent special equipment or use specialized personnel for performing these types of operation.

The industry average success rate for heavy fluid below cement is somewhere above 90 percent, which is one of the best among the available technologies for setting off-bottom cement plugs.

On the negative side, the placement time for heavy fluid is 6-10 hours, and the cost of the product itself is 'mediocre', compared to the other technologies.

We estimate time to set one cement plug using heavy fluid below it to 34 hours, which is 6-7 hours more than high viscous pills and chemical reactive pills.

The onshore rig time cost to set one cement plug with heavy fluid below it is calculated to 42.500 USD.

In our calculations, we add 7 hours due to the success rate (± 90 % percent).

The approximate total cost for one cement plug using heavy fluid below it arrives at USD 51.250.

For an offshore location, the rig time cost would be around USD 338.250.

Summary: Heavy Fluid Below Cement	
Surface tank capacity issues:	YES
Potential mixing problems:	YES
Challenging to run in hole to set :	YES
Placement time:	6-10 hours
Potential fluid incapability:	YES
Pressure test time:	N/A
Pull out of hole with running tool:	N/A
Suitability for cased hole:	YES
Suitability for open hole:	YES
Need for rental equipment:	NO
Need for specialized personnel:	NO
Industry average success rate:	> 90 %

4. Bridge plug

A bridge plug is a mechanical plug which anchors in the casing and holds differential pressure. Bridge plugs may be used for temporary or permanent plugging.

When a bridge plug is used as base for cement plugs, the plug itself is normally made of drillable materials such as composite and aluminum, in case the operator wants to remove the cement plug later.

The installation normally requires an extra run since it is often not desired to have the bridge plug setting tool in the well when performing the cement operation.

Bridge plugs have a high success rate but is rather expensive and time consuming to set.

Being a physical plug, it does not require mixing nor any tank capacity.

There are potential issues when running in hole to set. The placement time is usually 5-8 hours and it requires another 5-8 hours to pull out of hole with the running tool.

Finally, a bridge plug also requires approximately 1 hour for pressure test.

Bridge plugs are often used when setting balanced off-bottom cement plugs in cased holes. A bridge plug can normally not be used in open hole applications.

In addition, to set a bridge plug requires specialized personnel and rental equipment.

The industry average success rate for bridge plugs is 100 percent when the plug is successfully set, which makes bridge plugs the top performer among the available technologies for setting off-bottom cement plugs.

The cost for the product itself is estimated to ‘high end’, but this varies a lot depending on location.

We estimate the time to set one cement plug with bridge plug to 41 hours, which is 13-14 hours more than high viscous pills and chemical reactive pills.

The rig time cost to set one cement plug with bridge plug is calculated at 51.250 USD.

Based on 100 percent success rate, the approximate total cost for one cement plug using bridge plug arrives at USD 65.250, provided the bridge plug is successfully set on first attempt.

The same calculation, also provided the bridge plug is successfully set on first attempt, for an offshore location would sum up to USD 352.250.

Summary: Bridge Plug	
Surface tank capacity issues:	N/A
Potential mixing problems:	N/A
Challenging to run in hole to set :	YES
Placement time:	5-8 hours
Potential fluid incapability:	NO
Pressure test time:	1 hour
Pull out of hole with running tool:	5-8 hours
Suitability for cased hole:	YES
Suitability for open hole:	NO
Need for rental equipment:	YES
Need for specialized personnel:	YES
Industry average success rate:	100 %

5. Expandable packer

The principles of using expandable packers are in some ways the same as using a bridge plug, but they are different in design and they can also be used in open hole applications.

The plug itself is a long steel tube with a rubber gasket on the outside, which is inflated via ports, just like a balloon.

Unlike bridge plugs, expandable packers do not have slips that anchor or pure rubber elements for pressure integrity.

They are installed on the outside of a pipe and to expand them, you simply apply pressure to the inside of the packer. The expandable steel and elastomers conform to the wellbore shape and anchors to a certain degree when inflated.

Packers do obviously not require mixing nor any tank capacity. There are potential issues when running in hole to set.

The placement time is usually 5-8 hours and it requires another 5-8 hours to pull out of hole with the running tool. A packer may also require 1 hour for pressure test.

If you set an expandable packer inside the casing, the success rate is very high.

If you set an expandable packer in an open hole, the success rate is significantly lower. The gasket (balloon) can in many cases be damaged due to the internal profile of the open hole and due to limitations with the setting mechanism.

In addition, to set a packer requires specialized personnel and rental equipment.

The success rate for expandable packers is approximately 75 percent, which is a mediocre level.

The cost of the product itself is in the ‘expensive end’, but this also varies depending on location.

We estimate the time to set one cement plug using expandable packer to 41 hours, which is 13-14 hours more than high viscous pills and chemical reactive pills.

Based on an hourly onshore rig rate at 1.250 USD, the rig time cost per cement plug using expandable packer is approximately 51.250 USD.

In our calculations, we add 21 hours due to the success rate (± 75 % percent).

The approximate onshore total cost for one cement plug using expandable packer arrives at USD 91.500.

The same calculation for an offshore location would sum up to USD 525.500.

Summary: Expandable Packer	
Surface tank capacity issues:	N/A
Potential mixing problems:	N/A
Challenging to run in hole to set :	YES
Placement time:	5-8 hours
Potential fluid incapability:	NO
Pressure test time:	1 hour
Pull out of hole with running tool:	5-8 hours
Suitability for cased hole:	YES
Suitability for open hole:	YES
Need for rental equipment:	YES
Need for specialized personnel:	YES
Industry average success rate:	± 75 %

6. Cement Support Tool

Cement Support Tools are used as mechanical bases for balanced off-bottom cement plugs and is designed to create a physical barrier between a cement plug and the fluid below the plug.

The purpose of this barrier is to prevent the heavier cement swap place with the fluid below the CST and become contaminated.

The CST is inserted into the work string at surface and pumped downhole. When the tool exits the work string, it unfolds just like an umbrella and fills the open or cased hole.

When the cement plug is pumped in the next stage of the operation, the tool will be a physical barrier between the cement above the tool and the well fluid below the tool.

Consequently, it is possible to decide to use the Cement Support Tool when the work string is already in hole. It also means that it is possible to set multiple cement plugs in the same run at different depths.

CSTs do obviously not require mixing nor any tank capacity, and there are normally no issues when run in hole to set them.

The placement time is approximately 1 hour and does not require running tool. Finally, there is no need for pressure testing when using a CST.

If the correct CST size is used (there are five versions) considering the inner diameter of the string and hole, the success rate is at the same level whether the CST is used in a cased hole or in an open hole.

In addition, setting a CST does not require specialized personnel or rental equipment. The success rate for CSTs is above 95 percent, which is the second best among the six technologies.

The cost of the product itself is ‘mediocre’ compared to other technologies, but varies depending on location.

We estimate the rig time to set one cement plug using CST to 25 hours (2-3 hours less than high viscous pills and chemical reactive pills). The onshore rig time cost to set one cement plug with CST is calculated to 31.250 USD.

In our calculations, we add 3 hours due to the success rate (± 95 % percent).

The approximate total cost for one cement plug using CST arrives at USD 35.000 – which is the lowest cost compared to other solutions.

For an offshore location, the rig time cost would be around USD 231.000, which still is by far the lowest cost compared to the other technologies.

If you consider the total cement plug cost for offshore locations, the range would be from approximately 231.000 USD and all the way up to USD 525.000.

Summary: Cement Support Tool	
Surface tank capacity issues:	N/A
Potential mixing problems:	N/A
Challenging to run in hole to set :	N/A
Placement time:	1 hour
Potential fluid incapability:	N/A
Pressure test time:	N/A
Pull out of hole with running tool:	N/A
Suitability for cased hole:	YES
Suitability for open hole:	YES
Need for rental equipment:	NO
Need for specialized personnel:	NO
Industry average success rate:	> 95 %

The cost of additional rig time will quickly surpass the full cost of both the cement and the setting technology.

Therefore, you need to add “additional cost for low success rate” into the calculation for the cement plug.

research on the various cost components.

6. Conclusion

To achieve a successful balanced cement plug it is, in most cases, necessary to have a base for the cement.

The six types of bases discussed in this guide are traditionally used and it is important to decide which of these are most suitable for your application.

In addition to the cost components like placement time, testing time, need for rental equipment and specialized personnel, one must also consider the potential additional rig time if not successful on first attempt.

If you consider the total cement plug cost for onshore locations, the range would be from approximately 35.000 USD and up to USD 91.500.

4. Comparison table (onshore location)

Operational cost for cement plug base technologies - onshore	
Hourly rig rate [USD], incl all additional cost	1250
Rental days	7

Technical subjects	High viscous pill	Chemical reactive pill	Heavy fluid below cement	Bridge plug	Expandable packer	Cement Support Tool
Surface tank capacity issues?	Yes	Yes	Yes	N/A	N/A	N/A
Potential mixing problems	Yes	No	Yes	N/A	N/A	N/A
Challenging to run in hole to set	N/A	NA	Yes	Yes	Yes	N/A
Placement time [hours]	4	3	8	6	6	1
Potential fluid incapability	Yes	Yes	Yes	No	No	No
Pressure test time [hours]	N/A	N/A	N/A	1	1	N/A
Pull out of hole with running tool [hours]	N/A	N/A	N/A	5	5	N/A
Suitability for cased hole	Yes	Yes	Yes	Yes	Yes	Yes
Suitability for open hole	Yes	Yes	Yes	No	Yes	Yes
Rental equipment requirement	No	No	No	Yes	Yes	N/A
Specialized personnel requirement	Yes	Yes	No	Yes	Yes	N/A
Industry average success rate [percent]	± 70	± 50	± 90	100	± 75	± 95
Cost level for technology itself	Low	Low	Low	High	High	Medium
Cost of rental equipment & specialized personnel [USD/day]	0	0	0	2000	2000	0
Cost of rental equipment & specialized personnel [USD/job]	**0**	**0**	**0**	**14000**	**14000**	**0**
Rig time to set one cement plug [hours]	28	27	32	36	36	25
Rig time cost to set one plug [USD]	**35 000**	**33 750**	**40 000**	**45 000**	**45 000**	**31 250**
Additional rig time for low success rate* [hours]	11	27	4	0	14	1,3
Cost for low success rate [USD]	**13 750**	**33 750**	**5 000**	**0**	**17 500**	**1 625**
Approximate total cost for one cement plu	**48 750**	**67 500**	**45 000**	**59 000**	**76 500**	**32 875**

* Additional rig time for low success rate varies depending on the specific application

5. Comparison table (offshore location)

Operational cost for cement plug base technologies - offshore	
Hourly rig rate [USD], incl all additional cost	8250
Rental days	7

Technical subjects	High viscous pill	Chemical reactive pill	Heavy fluid below cement	Bridge plug	Expandable packer	Cement Support Tool
Surface tank capacity issues?	Yes	Yes	Yes	N/A	N/A	N/A
Potential mixing problems	Yes	No	Yes	N/A	N/A	N/A
Challenging to run in hole to set	N/A	NA	Yes	Yes	Yes	N/A
Placement time [hours]	4	3	8	6	6	1
Potential fluid incapability	Yes	Yes	Yes	No	No	No
Pressure test time [hours]	N/A	N/A	N/A	1	1	N/A
Pull out of hole with running tool [hours]	N/A	N/A	N/A	5	5	N/A
Suitability for cased hole	Yes	Yes	Yes	Yes	Yes	Yes
Suitability for open hole	Yes	Yes	Yes	No	Yes	Yes
Rental equipment requirement	No	No	No	Yes	Yes	N/A
Specialized personnel requirement	Yes	Yes	No	Yes	Yes	N/A
Industry average success rate [percent]	± 70	± 50	± 90	100	± 75	± 95
Cost level for technology itself	Low	Low	Low	High	High	Medium
Cost of rental equipment & specialized personnel [USD/day]	0	0	0	2000	2000	0
Cost of rental equipment & specialized personnel [USD/job]	**0**	**0**	**0**	**14000**	**14000**	**0**
Rig time to set one cement plug [hours]	28	27	34	41	41	25
Rig time cost to set one plug [USD]	**231 000**	**222 750**	**280 500**	**338 250**	**338 250**	**206 250**
Additional rig time for low success rate* [hours]	11	27	4	0	14	1,3
Cost for low success rate [USD]	**90 750**	**222 750**	**33 000**	**0**	**115 500**	**10 725**
Approximate total cost for one cement plu	**321 750**	**445 500**	**313 500**	**352 250**	**467 750**	**216 975**

* Additional rig time for low success rate varies depending on the specific application

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