

Evaluation and Testing of Mechanical Cement Wiper Plugs

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Evaluation and Testing of Mechanical Cement Wiper Plugs

1 Scope

The purpose of this technical report is for recommended testing, evaluation, and performance requirements for mechanical cement wiper plugs.

2 Normative References

This document contains no normative references. For a listing of other articles associated with this publication, see the Bibliography.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1

baffle

A ring or plate made of drillable material that is mounted in the casing to provide a landing surface for a cement plug and may (or may not) also provide a sealing surface.

3.2

bump pressure

The amount of pressure applied to the casing when a cementing plug is landed (bumped) onto a baffle, float collar, or another plug.

3.3

cement (slurry)

A mixture of calcium silicates and water, possibly containing other materials, that sets to a hard, rocklike substance.

3.4

cementation/cementing

The application of pressure pumping cementing fluids (spacers and cement slurries) to various points in a wellbore.

3.5

displacement fluid

The fluid used to displace the cement slurry from the casing that is normally separated from the cement slurry by a top wiper plug and / or a spacer fluid.

3.6

drillable

Capable of being drilled up in a reasonable amount of time by a drill bit.

3.7

elastomer

An elastic, flexible rubberlike material, including natural or synthetic rubber compounds, polyurethanes, and thermoplastic elastomers.

3.8

float collar

A tool containing a one-way check valve to prevent return flow of the cementing fluids from the annulus into the casing.

NOTE It has threaded connections that attached near the bottom of a casing string and may also provide a landing and/or sealing surface for wiper plugs.

3.9

frangible

Capable of being broken; breakable.

3.10

insert (body, core, plug insert)

A structural member used to provide mechanical stiffness and strength to the cementing wiper plug.

NOTE Common materials used in the fabrication of insert or cores could include, but are not limited to wood, sand resin, aluminum, hard rubber or thermoplastic, thermoset plastic, or composite.

3.11

knit lines

Imperfections in a molded part caused by the incomplete joining of the uncured rubber during molding.

NOTE Line or lines created where the rubber flows converge can cause weakening or breaking of the component.

3.12

landing collar

A component installed near the bottom of the casing string on which a cement plug lands during the primary cementing operation.

NOTE The internal components of the landing collar are generally fabricated from plastics, cement, and other drillable materials and may or may not include a backpressure valve.

3.13

landing pressure rating

Differential pressure that can safely be applied from above to one or more cementing plugs that are resting on a landing surface (such as landing collar or float collar).

3.14

liner

A string of pipe used to case open hole below existing casing and extends into another string of casing, but not all the way to surface, usually overlapping the previous casing by a few hundred feet.

3.15

liner running tool

A tool used to run, set, and release from a liner.

3.16

multistage cementing collar (diversion valve tool, port collar, cementer)

A tool with threaded connections for use in a string of casing or tubing to allow pumping cementing fluids into the annulus at a point up-hole from the bottom, in addition to pumping fluid around the shoe (at different intervals and times; commonly called two stages).

NOTE The tool usually has ports that are opened for communication to the outside of the casing and closed at the end of the job.

3.17

plastic

Any of various organic compounds produced by polymerization, capable of being molded, extruded, and cast into various shapes and films.

NOTE Examples include phenolic, composite (composed of a plastic or glass material with reinforcing filler), and any thermoplastic or thermoset resin.

3.18**plug container/cement head**

An accessory attached to the top of the casing, tubing, or drill pipe to facilitate launching wiper plugs when cementing the casing or liner that has passages for cement slurry and chambers for cementing plugs.

3.19**rupture disk**

The part of a bottom cementing plug that blocks the flow path through the center of the plug but is later broken to allow flow through the plug.

NOTE Sometimes referred to as diaphragm.

3.20**spacer**

A fluid designed to separate cement slurries from other fluids, minimizing contamination of the cement and removing drilling fluid from the annulus during cementation.

NOTE A spacer is considered to be a cementing fluid.

3.21**wiper plug**

A device that is used to separate fluids and wipes the internal surface of the pipe as it is pumped from one location in the pipe to another.

3.22**wiping efficiency**

Wiping efficiency is the measure of mechanical wiping of the tubular inside diameter (ID) performed by the cementing plug or similar device.

3.23**wiping section**

The part of the cementing plug that is flexible and wipes the casing, tubing, liner, or drill pipe.

4 Purpose of Mechanical Cementing Wiper Plugs

4.1 General

Mechanical cementing wiper plugs are used in most application including casing, liners, drill pipe, and tubing for primary and remedial cementing operations where they serve multiple functions in well operations, such as the following:

- separation of fluids inside of pipe;
- wiping of materials from the inner surface of pipe;
- operation of a downhole tool;
- surface indication of a downhole event; and
- formation of a temporary pressure barrier.

4.2 Fluid Separation

The separation of fluids inside of casing, drill pipe, or tubing during cementing operations is necessary to prevent intermixing and contamination that can compromise the objectives of the job. Fluids for a cementing job are normally

designed with an increasing density hierarchy. Spacer fluids are designed to be denser than the drilling mud, the lead cement slurry (when used) is designed to be denser than the spacer, and the tail slurry is designed to be denser than the lead slurry or spacer (when no lead slurry is used).

This density hierarchy has been shown to improve mud removal in the annulus where buoyancy effects aid a fluid of higher density in displacing a fluid of lesser density when the fluids are moving in an upward direction. When moving in a downward direction (either free-fall and/or pressure pumping), as is the case inside of the pipe, this density hierarchy will cause the higher density fluids to fall through the lower density fluids ahead of them, resulting in fluid contamination and poor mud removal. This phenomenon is especially severe in cases of large diameter pipe or when the density differential between fluids is very high. The use of cementing wiper plugs between fluid types is the only technique that will prevent this from occurring. In the case of multiple fluids, the use of multiple bottom plugs should be considered.

During displacement, the displacement fluid is usually lower density than the tail cement, so the density differential inside of the pipe is not an issue. However, the displacement fluid is usually a drilling or completion fluid that is not fully compatible with the tail cement so use of a top cementing plug to separate the fluids is required.

4.3 Wiping the Inner Surface of the Pipe

Regardless of bulk mud removal inside of pipe, fluids may leave a thin film at the inner wall of casing, tubing, or drill pipe that cannot be removed by subsequent fluids. Depending on the fluid and the operation, this film can lead to several problems.

Inside of casing, the bottom plug(s) will serve to wipe the film of mud from the inner wall of the pipe(s) and the top plug(s) will serve to wipe the cement film from the pipe(s) (see Table 1). Without a bottom plug, the mud film may remain until it is eventually wiped by the top plug. This can result in a large volume of mud accumulating in front of the top plug that would end up in the shoe track or even in the annulus after the plug is bumped (see Table 1). This could potentially cause a failure to obtain a successful leak-off test after drilling out the shoe. Without the use of a top plug, a film of cement may remain on the inner wall of the casing. A subsequent bit and scraper run may be required to remove this film before continuing drilling or completion operations.

Table 1—Calculated Accumulated Volume of Wiped Fill Ahead of Top Cementing Plugs per 1000 ft (300 m) of Pipe Wiped

Mud Sheath Thickness in. (mm)	7 in. (177.8 mm) Casing ft (m)	9 ⁵ / ₈ in. (244.5 mm) Casing ft (m)	13 ³ / ₈ in. (339.7 mm) Casing ft (m)
1/16 (1.6)	40 (12.2)	28 (8.5)	20 (6.1)
1/32 (0.8)	20 (6.1)	12 (3.7)	10 (3.1)
1/64 (0.4)	10 (3.0)	7 (2.1)	5 (1.5)

In casing strings that are made up of more than one pipe size, it is important to use wiper plugs that are designed to wipe all internal diameters in the string. Failure to use the appropriately sized plugs may lead to a residual mud or cement film on the inside of the pipe.

An additional problem is cement accumulation in internal upsets in drill pipe or tubing if proper wiping devices are not utilized. It is important to use drill pipe wiper darts that have fins designed to wipe both the pipe body and the internal upsets. The use of foam wiper balls (fabricated from an air or frothy foam material) may also be effective, either alone or in conjunction with wiper darts to remove fluid accumulations from the upsets.

4.4 Downhole Tool Operation

4.4.1 General

In addition to serving to separate fluids inside the pipe and to wipe the interior of the pipe, wiper plugs are used to operate certain downhole tools. The following are among the operations performed by cementing wiper plugs:

- release of liner wiper plugs;
- release of subsea plug;
- shifting of stage cementing tools; and
- temporary barrier to set external casing packers with pressure.

4.4.2 Liner Wiper Plug

Full ID liner wiper plugs cannot pass through the drill pipe, and are therefore hung beneath the drill pipe when the liner is run. A dart is pumped through the drill pipe, wipes the drill pipe, and latches into the liner wiper plug. Pressure is increased to shear the pins, and the dart and liner wiper plug travel together, wiping the inside of the liner. Liner wiper plugs are available in either two plug or single plug sets.

4.4.3 Subsea Released Plugs

When a subsea wellhead is used, the configuration is much like a liner, with the casing hung beneath drill pipe. Either single or double plug sets are available.

4.4.4 Operate Stage Cementing Tool

Stage cementing tools are devices that provide ports in the casing string so that separate operations can be performed below and above the tool. These tools consist of ports, or holes, in the body of the tool with a sleeve and seals that shift to alternately open and then close the ports. Special opening and closing plugs are used to shift the position of the sleeve.

4.5 Event Indication

4.5.1 General

When plugs pass or land on a profile inside of pipe, a positive pressure indication can be detectable at surface. This pressure indication can mark a specific event in the operation, including, but not limited to, the following:

- plug landing (bumping the plug);
- landing of drill pipe wiper darts for liners or subsea released plugs;
- multiple stage cementing tool operation; and
- depth indication.

When determining an event from recorded data, the data sampling interval shall be appropriate for the expected duration of the event.

4.5.2 Plug Landing

4.5.2.1 General

A surface pressure increase can indicate when a wiper plug has reached the landing collar or other profile located inside of the pipe.

4.5.2.2 End of Displacement

A pressure increase indicates a wiper plug has landed on the landing collar during primary cementing. This pressure increase, usually referred to as bumping the plug, indicates displacement has been completed. This pressure slope is different and should not be confused from the lift pressure slope from lighter fluids displacing heavier fluids.

4.5.2.3 Remedial Cementing

In squeeze and plug operations, cement is placed in the well through drill pipe or tubing. In many cases, small volumes of cement are used and it is critical to control the exact location to ensure that the cement slurry is placed where required. The use of wiper plugs in conjunction with landing seats located near the end of the work string can provide a positive pressure indication when the wiper plug lands on the seat, indicating the cement is at the end of the work string as an example.

4.5.2.4 Displacement Volume Determination

Bottom cementing plugs can be used for obtaining accurate casing capacity. Prior to beginning the cementing operation, a bottom plug may be launched and displaced with drilling fluid to the landing collar. By measuring the volume pumped when the surface pressure indication from landing the plug occurs, the effective displacement volume can be determined. The effective displacement volume takes the following factors into account:

- actual casing capacity;
- fluid compressibility; and
- efficiency of surface pumping equipment.

Because fluids may by-pass a cementing plug during travel down a casing, using the pumped volume to land the bottom plug as the effective displacement volume of the casing should take into account the risks associated with under/over displacing the cement slurry.

4.5.3 Landing of a Drill Pipe Wiper Dart

For liners and subsea released plug systems, a pressure indication can be seen when the dart lands and the pins holding the subsurface wiper plug are sheared. This pressure indication can be used to reset the displacement volume counter, with the calculated liner or casing volume used as the displacement volume to land the plug. This helps to ensure the plug is displaced as close to the landing collar as possible and that cement is placed where desired without over displacing.

Because fluids may by-pass a drill pipe wiper dart during travel down drill pipe, using the pumped volume to land the bottom plug as the effective displacement volume of the drill pipe should take into account the risks associated with under/over displacing the cement slurry.

4.5.4 Multiple-stage Cementing Tool Operation

Wiper plugs are sometimes used to operate stage tools. An increase and/or decrease in surface pressure that indicates when each operation of the tool is completed.

4.5.5 Depth Indication

Some cementing plug designs provide event indications identifying the location of the plug during displacement. Generally, the depth indication is provided when coupled with an integral casing sub with an internal profile that engages a mating profile on the cementing plug.

4.6 Temporary Pressure Barrier

4.6.1 General

Mechanical plugs may also be required to function as a temporary pressure barrier for the following:

- pressure testing casing; and
- prevent fluid flow back with latch-down plugs.

4.6.2 Pressure Testing Casing

In order to test the casing using mechanical plugs, the plugs shall be bumped and a positive pressure seal shall be present between the plug(s) and the landing collar.

NOTE The pressure barrier provided by the plug is only in one direction; the plug does not provide a barrier to flow in the upward direction (from the annulus into the casing).

4.6.3 Latch-down Plugs

In certain cementing operations, such as cementing small diameter casing or cementing via an inner-string on large diameter casings, a latch-down type mechanical wiper plug may be utilized. A latch-down plug is designed to mechanically lock into the landing collar when the plug has been bumped and is generally used as a top plug. Once locked in, the plug cannot move back up the casing. A latch-down plug may be used to provide a temporary pressure barrier for casing pressure testing and also to prevent fluid from flowing back into the casing due to the hydrostatic differential at the shoe at the end of the job. Latch-down plugs shall be bumped into place in order to function properly.

5 Background Information

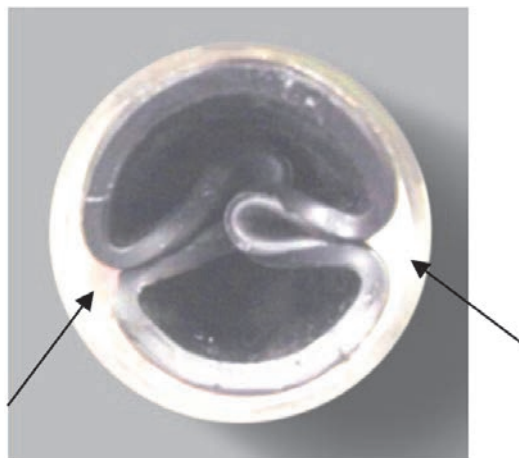
5.1 Short and Long Fin Plugs

5.1.1 Short fin cementing plugs are typically designed for use in single ID applications versus multiple ID applications (such as internal upset or tapered/combo strings) where the cementing wiper plug is used to wipe with uniform inside diameter from top to bottom. Short fins are generally considered to provide increased stiffness as compared to long fins of similar thickness.

5.1.2 Long fin cementing plugs are typically designed for use in applications where the cementing plug is used to wipe with varying inside diameters. ID variations can be caused by tapered casing strings, drill pipe tool joints, internal seats of stage cementing tools, and other restrictions. Long fins on cementing plugs are less stiff compared to short fins. Therefore, long fin cementing wiper plugs typically have an increased length than short fin cementing wiper plugs to maintain stability while inside the pipe. As the long fin cementing plugs are installed into or pumped through decreasing diameters or restrictions, the long fins will tend to wrinkle, thereby reducing wiping efficiency and allowing fluid bypassing. (See Figure 1.)

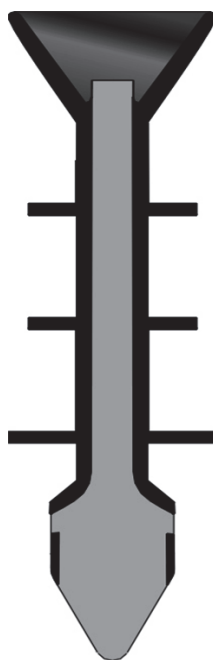
5.2 Combination or Multiple Diameter Fin Cementing Plugs

Combination cementing wiper plugs generally incorporate multiple fin diameters on a single assembly as shown in Figure 2 or Figure 3. These figures represent possible plug configurations that can be used in multi-diameter strings. Each fin diameter is designed to wipe a different range of pipe IDs. The larger, more flexible fins wipe the larger pipe.



NOTE This photo shows how wrinkling of long wiper fins can occur, potentially allowing bypassing and affecting displacement efficiency; two arrows point to sections where no wiper contact is made with the ID of the tube.

Figure 1—Photo of 5 in. (127.0 mm) Drill Pipe Dart Installed into 3 in. (76.2 mm) ID Tube



NOTE Typically used for wiping multiple diameters.

Figure 2—Typical Long Fin Cementing Plug

The smaller ID, stiffer plug will wipe the smaller diameter pipe with the larger more flexible fins buckling and bypassing fluids. Thus, when the combination cementing wiper plug assemblies are used, fluid separation and improved wiping efficiency of the different IDs is achieved.

5.3 Other Wiping Mechanisms

Several other mechanical devices are used in place of short and/or long fin cementing plugs. Such devices could include but are not limited to deformable balls, tear drop darts, or any combination of these into assemblies. These wiping devices have unique performance characteristics that enable fluid separation, wiping, and/or landing indication for specific wellbore applications.



NOTE Typically used for wiping tapered casing or tubing strings.

Figure 3—Example of Combination Cementing Wiper Plugs

5.4 Launching Methods and Apparatus

5.4.1 Cementing Heads or Plug Containers

A cementing operation is commonly performed using a cement head or plug container to attach surface circulating equipment to the pipe being cemented. One or more cementing plugs are preinstalled into the plug container prior to being attached to the pipe. Figure 4, Figure 5, and Figure 6 show typical types of plug containers used in cementing operations. When cementing operations are performed, valves and retention devices are manipulated to divert fluid flow and release the cementing plug, launching the cementing plug from the plug container and into the pipe being cemented. Plug containers may incorporate a visual means of indicating plug launch (tattletale devices). The use of multiple cementing plugs is desired to provide separation of multiple fluids. Special cementing heads or systems can be used to contain and launch more than the typical one or two cementing plugs during the execution of cementing operations. Heads are available for manual or remote control operation.

5.4.2 Top Drive Casing Cement Head

Cement plugs are loaded into a canister and protected from flow during circulation and cementing. Upon retracting the pin puller mandrel, the plug will free fall into the main section of the cement head and will be pumped into the casing. Figure 7 shows a flow-around top drive cement head.

Some models may have a ball dropper located below the bottom plug pin puller where a ball of a given size can be dropped into the casing to function a tool downhole.

5.4.3 Top Drive Cementing Head

A top drive cementing head is typically used for selectively launching darts used to release liner wiper plugs and subsurface released cementing plugs. Figure 8 shows a typical top drive cementing head with top and bottom dart releasers and a ball drop system.