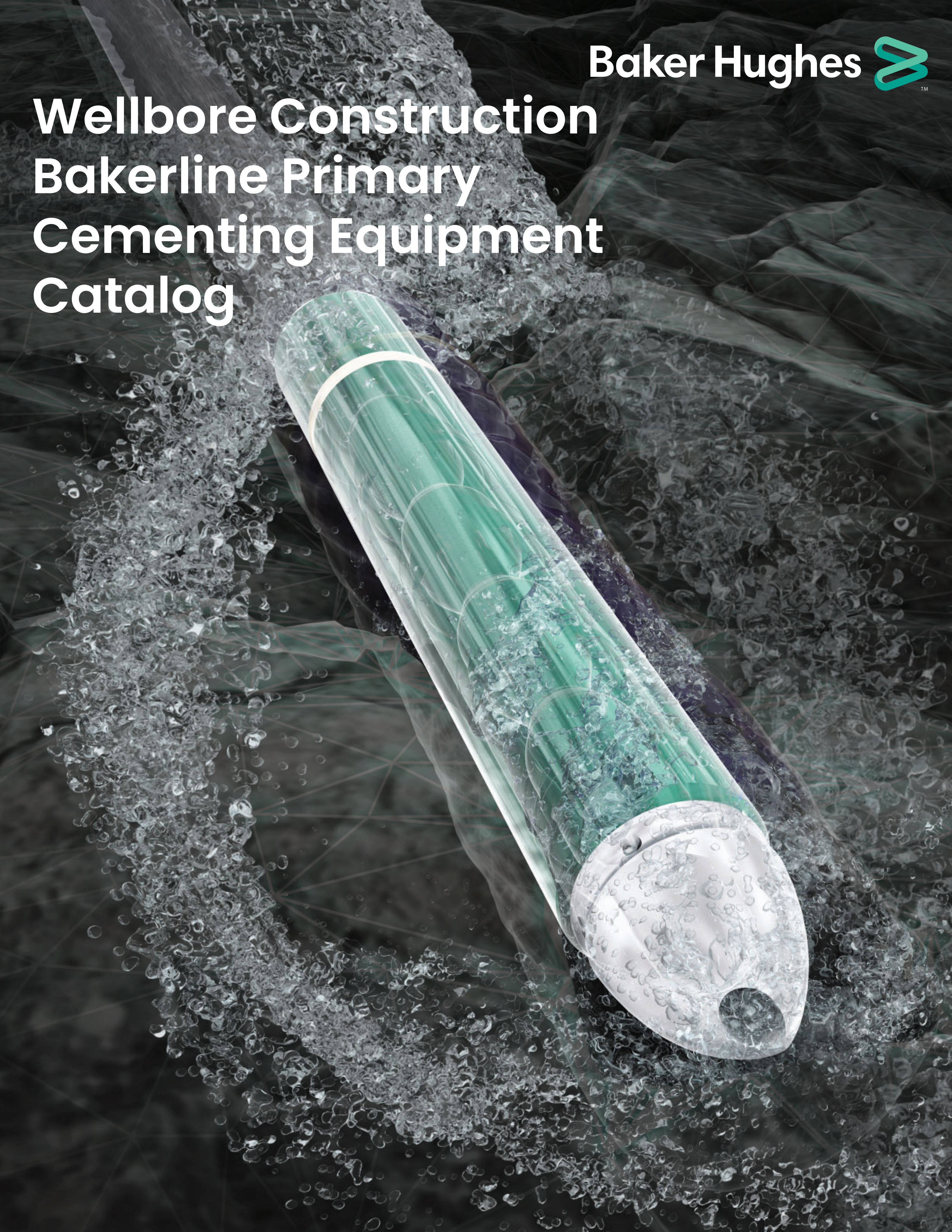
Baker Hughes

Wellbore Construction Bakerline Primary Cementing Equipment Catalog



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Introduction to Primary Cementing Equipment

Baker Hughes Primary cementing equipment consists of float equipment, guide shoes, reamer shoes, centralizers, and cementing wiper plugs. Float equipment is placed at the bottom of a casing string and guides it to total depth while preventing fluid from entering the string. A guide shoe is a piece of equipment placed on the bottom of a casing that guides it to total depth. Unlike a float shoe and float collar, a guide shoe does not have any one-way check valves. A reamer shoe is an improved version of a float shoe or guide shoe that overcomes wellbore obstructions to guide casing or liners to total depth. A reamer shoe may or may not have any one-way check valves. A centralizer is an accessory that is secured around the casing at different strategic locations to provide proper centralization and standoff between the casing and the previous casing string or the open hole to improve the quality of the cement job. Stop collars are used to restrict the lengthwise movement of centralizers on the casing in applications where this is desired. A cementing wiper plug is an accessory that separates the fluids during the cementing operation and wipe the inside of the casing clean between fluids.

Product Families	
Product Family	Product Family Description
H10072	Guide Shoes
H10050	Reamer Shoes
H10049	Float Shoes - Single Valve
H10047	Float Shoes - Double Valve
H10048	Float Collar - Single Valve
H10043	Float Collar - Double Valve
H10059	Centralizers
H10065	Stop Collars
H10069	Monobore (longstring) wiper plugs

Bakerline™ Float Equipment

Bakerline™ Float Equipment consists of fit-for-purpose float shoes, float collars and reamers shoes trusted to perform in a variety of challenging environments. Float shoes and float collars have long been considered standard equipment when installing and cementing casing strings. They perform the critical function of controlling the fluid flow into and out of the casing via one-way check valves.

The one-way check valves in this equipment self-energize to the closed position when the pressure from below exceeds the pressure from above, thus they allow flow from above to flow through while preventing flow from below. The float shoe is installed on the bottom of the casing string and the float collar is typically installed one or two joints above the float shoe. The float collar allows contaminated cement slurry to be captured in the shoe track instead of being pumped into the annulus, thereby improving the quality of the cement in the annulus around the shoe. The float shoe guides the casing through the open hole during installation down to the final setting depth. The float collar acts as a backup in case the one-way check valves in the float shoe fails.

In cemented applications the float collar acts as the landing point for wiper plugs, unless a separate landing collar is used above the float collar, and the volume between the float shoe and float collar is filled with cement to create a competent barrier against formation pressure. The float equipment prevents backflow of fluid from the annulus into the casing during casing installation if the hydrostatic pressure in the annulus exceeds the hydrostatic pressure in the casing. It also prevents the backflow of cement into the casing after the plugs have been bumped and the surface pressure has been released, commonly referred to as u-tubing. Float equipment is manufactured in a single valve configuration, or in a double valve configuration for added redundancy.

Float equipment is manufactured to match the casing specifications; to equal or exceed the material grade, post-drillout inner diameter drift and burst, collapse, tensile and torque ratings.

Applications

- Running the casing to depth and cementing the wellbore
- Used in primary cementing to prevent flow back of cement slurry when displacement stops

Features and Benefits

- Compliant with API 10F specification
- Can be supplied in various combinations and is available in all grades of steel and desired API or premium thread connections
- Available as autofill, differential fill, orifice type, or conventional
- Available in an ultra-high backpressure configuration with 10,000 psi differential pressure
- PDC drillable as standard, special non drillable options also available for specific applications
- Available in double-valve configuration for added redundancy
- Wide variety of shoe nose geometries, materials, and jets for different applications
- Ball catcher or ball deflector to prevent setting balls from fouling float valve
- Rotating or non-rotating profile to receive matching wiper plug

Floating Casing

The ability of the float equipment to prevent backflow can be used to provide buoyancy during installation, commonly referred to “floating casing” or “running evacuated casing”. Buoyancy occurs because the by air inside the casing is much lighter than the fluid in the annulus and it is beneficial in reducing the load on the rig installing the casing, as well as reducing torque and drag in long horizontal wells. Higher performance float equipment is used when floating casing because the one-way check valves experience significantly higher differential pressure compared to when casing is not floated in.

Guide Shoe

A guide shoe is a float shoe without any one-way check valves used to guide the casing through the open hole during installation down to the final setting depth but does not prevent backflow of fluid from the annulus into the casing during casing installation. A guide shoe is typically used together with a float collar.

Reamer Shoe

A guide shoe is a float shoe without any one-way check valves used to guide the casing through the open hole during installation down to the final setting depth but does not prevent backflow of fluid from the annulus into the casing during casing installation. A guide shoe is typically used together with a float collar.

Cement-Filled and Non-Cement Filled

The Float equipment can be either cement-filled or non-cement filled. Cement-filled float equipment is, as the name implies, filled with cement during manufacturing. This "cement" is technically concrete, as it is a mix of cement, coarse aggregate (gravel) and fine aggregate (sand). The concrete used is significantly stronger that cement.

Non-cement filled float equipment is, as the name implies, not filled with cement during manufacturing. It typically consists of machined aluminum, which provides a high strength and favorable drill-out time and drill-out bit-damage. Non-cement filled float equipment has improved impact resistance, and typically also has a higher backpressure rating compared to cement-filled float equipment. Float equipment can be manufactured with ball deflectors, ball catchers or baffle plates to prevent setting balls dropped into the casing to activate hydraulic equipment from fouling the one-way check valve mechanism.

Non-cement filled single valve and double valve float shoe with eccentric aluminum nose

Cement filled single valve and double valve float shoe with eccentric aluminum nose

Cement-Filled and Non-Cement Filled

Cement filled single valve and double valve float collar

Non-cement filled single valve and double valve float collar with latch in profile

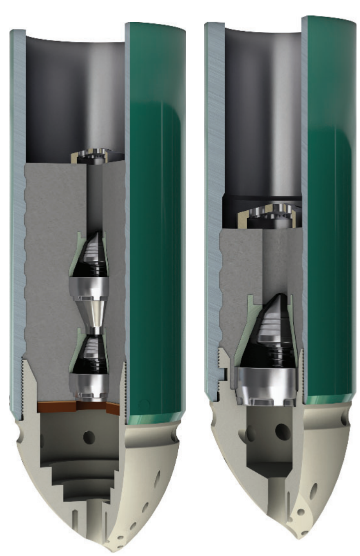
Drillability

Most types of float equipment can be drilled out with either roller cone or PDC drill bit, although some types can only be drilled out with one or the other. There are even some types of float equipment for production casing sizes that cannot be drilled out with either roller cone or PDC drill bit, referred to as non-roller cone drillable and non-PDC drillable. The type of non-roller cone drillable and non-PDC drillable float equipment is generally used on the final casing size for the well and is not planned to be drilled out. If for some reason this type of equipment must be removed a junk mill is typically used, with or without cutting inserts.

Nose Geometries and Jet Configurations

Many different types of guide shoes, float shoes and reamer shoes have been developed to overcome various wellbore difficulties. Variations in nose material and geometry and the inclusion and the direction of jets is optimized to solve different wellbore challenges. Up-jets, side-jets and down-jets ensure reliable circulation even if the casing is set on bottom of the wellbore with the main bore obstructed. Down-jets aid in washing through obstructions and are most frequently found on reamer shoes. Up-jets are frequently added to improve circulation of cement around the bottom of the casing, thereby improving the strength of the cement. The round nose is the standard nose geometry for guide shoes, float shoes and reamer shoes and is suitable for wellbores without any ledges, washed out areas (washouts) or other challenging obstructions. Ledges are generally a result of interbedded salt, mudstone, dolomite, or anhydrite sections in the wellbore which creates localized instability. If ledges and washouts are expected the eccentric nose is recommended, this nose geometry is also referred to as the “lipstick style”. The eccentric nose geometry allows the casing to be rotated off ledges and washouts a round nose wouldn’t be able to pass through. Eccentric noses are generally made of aluminum for improved strength, although many types of composites are frequently used. Composite noses have reduced strength compared to aluminum but offers improved drill-out time and reduced drill-out bit-damage. The round nose geometry has the lowest drill-out time and drill-out bit-damage. A bladed nose geometry, seen as an “X” when viewed from below, is used prevent the casing from rotating during specific operations, generally rotationally activated equipment located in the casing string. Setting weight down onto a shoe with a bladed nose geometry results in the blades digging into the formation, creating a rotational anchor that can resist rotation of the casing.

Cement filled single valve and double valve float shoe with cement round nose



Cement filled single valve and double valve float shoe with eccentric composite nose

Cement filled single valve and double valve float shoe with eccentric aluminum nose

Float Equipment Types

There are several different types of float equipment valves. Broadly they are divided into four categories: autofill, non-autofill, orifice, and differential fill.

Autofill float equipment, as the name implies, fills automatically while the casing is installed. Autofill float equipment has two states: pre-conversion and post-conversion. Autofill float equipment in the pre-conversion state allows flow into and out of the casing. After conversion, in the post-conversion state, the autofill float equipment operates identical to non-autofill float equipment where the one-way check valves only allow flow from above. When casing is installed in a wellbore it acts as a piston, displacing part of the fluid in the wellbore and forcing it to flow up the annulus of the well and creating pressure spikes referred to as surge pressure. Autofill float equipment in the pre-conversion state reduces the surge pressure during casing installation because the fluid in the wellbore can flow into the casing when displaced, thus less fluid is displaced up the annuls. This also minimizes overflow of fluid onto the rig floor. In close tolerance applications, where the annulus is small, the surge pressure can become sufficiently high to damage the formation at common installation speeds. Autofill float equipment is therefore commonly used in close tolerance applications to reduce surge pressure, protecting the exposed formation from damaging surge pressure, and increasing casing installation speed. Once the casing is landed at final depth circulation is established to clear any cuttings debris from inside the casing, and the autofill float equipment is converted with a ball dropped from surface or by increasing flow rate to a pre-determined rate which activates a mechanism at the float equipment. The most common type of autofill float equipment is the inner tube spring-loaded flapper valve type, where an inner tube holds one or two flapper valves in the open position. The inner tube has a ball seat profile and when a conversion ball lands and pressure is increased to a pre-determined value, the inner tube is pushed out of the float equipment and the spring-loaded flapper valves closes. In this post-conversion state, the autofill float equipment operates identical to non-autofill float equipment where the one-way check valves only allow flow from above. This mechanism ensures positive sealing in vertical, horizontal, and deviated wells. The conversion ball can reach the inner tube ball seat by being dropped from surface and circulated down, or by releasing from a wire or cage directly above the float equipment at a pre-determined flow rate.


Cement filled single valve float collar, orifice

For **non-autofill type float equipment**, the ball-and-seat type was historically popular. In this design a ball is floating in a trapped space and seals on a ball seat profile when flow from below pushes the ball up into the seat. However, this type is unsuited for most of today's deviated and horizontal wellbores and is only used for near-vertical or vertical wells. Today the most frequently used type is the non-autofill spring loaded plunger-type. A spring installed below a plunger exerts constant upwards push on an elastomer coated plunger against a geometrically matching sealing profile. Flow from above pushes the plunger down, away from the sealing profile, allowing fluid to bypass. Without flow from above, the spring pushes the plunger into the sealing profile, and pressure from below acts to increase the force on the plunger into the sealing profile. The plunger is typically made of phenolic material for low pressure application and aluminum for high pressure applications.

Orifice float equipment is run at the bottom of a tieback casing string, just above the tieback seal assembly. Orifice float equipment has one or more small bypass tunnels (orifices) through the float equipment which bypasses the one-way check valves, therefore orifice float equipment never provides a seal. It provides restricted rate fill-up of the tieback through an orifice while running in and minimizes overflow of fluid onto the rig floor. At the end of displacement, the float valve controls u-tubing of cement into the casing until the tieback seals are stabbed in. The orifice ensures that the tieback seals can be inserted into the tieback by eliminating hydraulic lock.

Differential float equipment is float equipment with a differential valve. This type of equipment maintains a constant differential pressure between the inside and outside (annulus) of the casing in favor of the annulus. The differential valve is specified as a percentage, typically 80-90%. For example, with a 90% differential valve in the float equipment the casing will only fill with fluid to 90% of the full vertical height. Differential float equipment provides buoyance, minimizes overflow of fluid onto the rig floor and reduces surge pressure.

Industry Standard

The American Petroleum Institute (API) specification 10F "Cementing Float Equipment Testing" specifies testing parameters for float equipment. Specification API 10F includes two distinct types of testing. The first test qualifies the durability of the valves under high-rate, high-solids mud flow, and the second test confirms the ability of the valve to hold differential pressure from below. There are four different types of categories for non-autofill float equipment: flow durability, forward flow rate, temperature, and pressure. There are five different types of categories for autofill float equipment: flow durability, forward flow rate, temperature, pressure, and reverse flow rate. The float equipment offered by Baker Hughes meets the API 10F specifications of the rating provided, for example D24 R10 T400 P7.5 is for non-autofill float equipment and represents 24-hour flow durability, 10 barrels per minute forward flow rate, 400°F temperature rating and 7,500 psi backpressure rating. Although 7,500 psi backpressure rating is the highest rating in specification API 10F Baker Hughes also offers higher ratings.

Table Specifications for Float Equipment

Specifications	API 10F 4th Edition	
	Category	Rating
Flow Durability Tests for Float Equipment	D8	8 hours
	D12	12 hours
	D24	24 hours
	D36	36 hours
Reverse Flow Duration for Casing Fill-up Equipment	AF4	4 hours
	AF8	8 hours
	AF12	12 hours
Forward Flow Rates for Flow Durability Testing	R6	6 bbl/min (1.0 m^3/min)
	R10	10 bbl/min (1.6 m^3/min)
	R15	15 bbl/min (2.4 m^3/min)
	R20	20 bbl/min (3.2 m^3/min)
Temperature of Static High-temperature Tests	T200	200°F (93°C)
	T300	300°F (150°C)
	T350	350°F (177°C)
	T400	400°F (205°C)
Pressure of High-pressure Tests	P1.5	1,500 psi (10,300 kPa)
	P3	3,000 psi (20,700 kPa)
	P5	5,000 psi (34,500 kPa)
	P7.5	7,500 psi (51,700 kPa)
	P10 (non-API 10F)	10,00 psi (69,000 kPa)

Cement Wiper Plugs

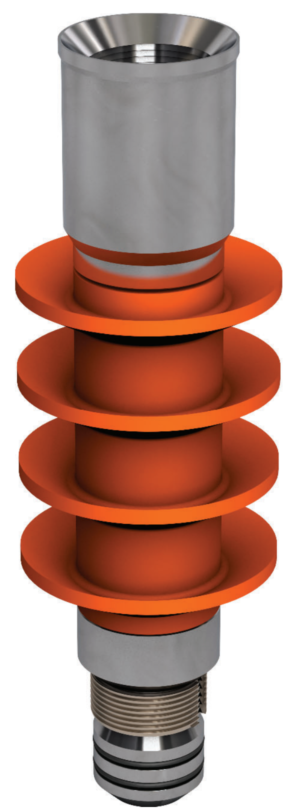
Cement wiper plugs, also referred to only as wiper plugs, separate the cement slurry from other fluids during the cement displacement, wipe the inside of the casing clean between different fluids, and land either in a landing collar or a float collar. When they land, they generate a pressure spike observed at surface which confirms that the wiper plug has landed in the correct landing profile. Conventional wiper plugs are designed to wipe longstring casings and are therefore referred to as longstring wiper plugs. Conventional bottom plugs incorporate a bypass mechanism, usually a rubber diaphragm with reliably burst pressure, while conventional top plugs have a solid core without a bypass mechanism. In some applications the landing collar contains the bypass mechanism for the bottom plug, and not to bottom plug itself. A float collar does not contain a bypass mechanism for the bottom plug. Bottom plugs are dropped ahead of the cement, and the top plug is dropped after the cement. Multiple bottom plugs can be used, but only one top plug.

At the end of the cement pumping operation the top plug lands in a landing collar or float collar creating a pressure-seal and circulation is no longer possible, this is referred to as plug bump and indicates displacement has been completed. The plug nose profile must be compatible with the landing seat profile, and any previous wiper plug, to create the pressure-seal. Upon plug bump pressure is typically applied at surface for a short period of time, typically 5 min, to confirm the top plug has landed in the designated landing profile. The maximum pressure and temperature a wiper plug can withstand after plug bump is referred to as the pressure and temperature “bump rating” of the wiper plug. Non-rotating profiles prevent the wiper plug from spinning when drilled out and may reduce drill-out time. If non-rotating wiper plugs are used the plug nose non-rotating profile and the landing seat non-rotating profile must be compatible.

For standard applications the components in top and bottom plugs are designed for easy drillout with all bit types, including PDC drill bit, with minimal wear on the drill bit. In some specialized applications for smaller production casing sizes where the wiper plugs are not intended to be drilled out, non-drillable wiper plugs are sometimes used to achieve higher pressure ratings. A liner is a casing string that does not extend to the surface. Liners are run on drill pipe and typically drill pipe wiper plugs will wipe the drill pipe before latching into liner wiper plugs at the bottom of the drill pipe and wipe the casing to the landing seat profile. Due to the difference in internal diameter between drill pipe and casing in most application it is not possible or practical to launch plugs from surface capable of wiping both the drill pipe and liner.

Surface release cement plugs. Bottom plug in red with rupture diaphragm and top plug in black with solid core

Specifications for Float Equipment	
Equipment Type	**Casing Size Offering**
Float Equipment	2-7/8 to 42”
Longstring Wiper Plugs	2-7/8 to 42”
Liner Wiper Plugs	3-1/2 to 16”



Longstring latch-in wiper plug

2-Plug Liner Wiper Plug System

Liner Wiper Plug Examples		
System Type	Drillable Lead Follow Plug System	LFC Plug System
Fin OD (inch)	9.187	
Minimum ID (inch)	2.068	1.64
Plug Body Material	Free Machining AL Alloy	Regular AL Alloy
LWP Fin Material	High Temp Urethane	Nitrile
PDP Fin Material	Nitrile	
Lead LWP Release Pressure (psi)	1,000	1,200
Follow LWP Release Pressure (psi)	1,200	1,265
Lead LWP Bypass Pressure (psi)	1,500	N/A
Lead LWP Bypass Area (square inches)*	4.4	3
Max. Ball Diameter (inch)	2	1.5
Max. Flow Rate (BPM)	12.6	8
Max. time at Flow Rate (hrs)	16	12
Liner Size (inch)	9.625	
Liner Weight Range (lb/ft)	40.0-58.4	All Weights
Pressure Rating from Above (psi)	6,500	3,000
Temperature Rating (°F/°C)	300/150	300/149

2-plug liner wiper plug system with drill pipe launch adaptor

Bakerline™ Centralizers and Stop Collars

Bakerline™ Centralizers and Stop Collars are fit-for-purpose casing accessories used to effectively centralize the casing they are installed on in a wellbore. The centralizers provide standoff between the casing and the previous casing string (in the cased hole section), and between the casing and the open hole (in the open hole section).

Centralizers can also reduce the torque and drag when installing casing and minimize differential sticking. Stop collars are restraining devices that prevent the centralizers from moving away from the pre-determined position on the casing. In some applications stop collars are not used, and instead the centralizers are allowed to ride freely between the casing collars.

Applications

- Running the casing to depth and cementing the wellbore
- Used in primary cementing to centralize the casing within casing or wellbore.

Features and Benefits

- Aid in fluid displacement through the annulus due to proper standoff. This helps equalize cement distribution around the casing string, improving the cement job and the resulting annular isolation.
- Help pass through general obstruction in the wellbore by preventing tool hang-up
- Help reduce differential sticking due to proper standoff
- Special centralizers are used to reduce torque and drag when running casing

Hinged bow-spring centralizer

Heavy duty set screw stop collar

Stop Collar Hinged Bolt

Rigid Spiral Centralizer Pressed

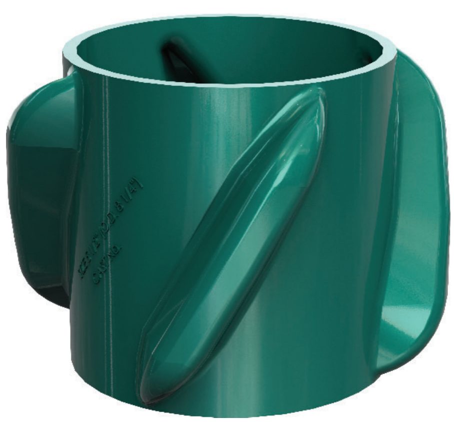
Purpose of Centralizers

Casing centralizers are used to improve displacement efficiency, to prevent differential pressure sticking and to keep casing out of key seats. Without centralization the casing will contact the previous casing string and the open hole in all but the most vertical wells as it falls to the low side of the well due to gravity.

When cementing such casing the spacer and cement follows the path of least resistance and travels up the wide side of the annulus, leaving drilling fluid on the narrow side. The lack of complete drilling fluid removal around the circumference of the casing results in mud channels in the cemented annulus. In the areas where the casing is in contact with the previous casing and the open hole there will be no cement sheath in the annulus.

The mud channels in the cemented annulus and lack of cement sheath in the annulus results in ineffective pressure isolation between the wellbore and the casing, which in turn can cause a variety of challenges. Centralization is also an important countermeasure to differential sticking, where differential pressure across the mud cake creates a force holding the casing in place. Differential sticking of casing occurs in a permeable zone when the casing contacts the mud cake and filtrate loss causes cake thinning and increased contact area that in turn increases the force holding the casing to the open hole.

Slip-on solid centralizer (pressed)



Slip-on solid centralizer (cast)

Purpose of Stop Collars

The purpose of stop collars is to restrict the movement of centralizers. Centralizers are fixed to a desired location on the casing either by the casing collars (external outer diameter upset of the casing connection) or mechanical stop collars, or a combination of both. One method involves straddling the centralizer over the casing collar. Using the casing collar as a restraining device is only possible with extern upset casing connections where the outer diameter of the collar is raised up from the outer diameter of the casing joint. The restraining device should be located within the bow-spring type centralizers so the centralizer will be pulled (not pushed) into the hole. Therefore, the bow-spring type centralizer should not be allowed to ride free on a casing joint.

Installation Method

Centralizers and stop collars are either solid body, split body (also referred to as "clamshells") or hinged body. Solid body types, also referred to as "one-piece centralizers" or "slip-on centralizers", can only be installed by sliding onto a casing joint from the top or bottom. Split body, also referred to as "two-piece centralizers", and hinged body types can be installed anywhere on the casing joint without needing to slide them onto a casing joint from the top or bottom.

Solid body types generally have higher mechanical strength than split body or hinged body types as there is no split or hinge in the design and are less likely to become damaged or break off the casing joint when impacted by high forces. When centralizers or stop collars break off the casing joint, they can result in stuck pipe incidents, as the debris is often too large and dense to be circulation out of the well up the annulus and wedges in the annulus. Partially loose stop collars can also significantly scratch the casing, potentially negatively impacting the performance ratings of the casing. To reduce the likelihood of such stuck pipe incidents, the performance parameters of the selected centralizers and stop collars should not be exceeded.

Hinged bow-spring centralizer

Centralizer Types

There are three general types of centralizers: bow-spring, solid and rigid. The semi-rigid centralizer is a subcategory of the rigid centralizer type. Bow-spring centralizers are compressible while solid and rigid centralizers are not. Bow-spring and rigid centralizers are deformable, while solid centralizers are not.

The bow-spring type has a greater ability to provide positive standoff when the borehole is enlarged, while the solid and rigid type provides more positive standoff where the borehole is to gauge. Solid and rigid centralizers have a smaller outer diameter than the inner diameter they will be installed in, and they are not compressible. Therefore, unlike bow-spring centralizers, solid and rigid centralizers do not contribute to centralize the casing unless they are in contact with the casing or open hole they are inside.

Bow-Spring Centralizers
This type of centralizer, as the name implies, consists of several bows acting as springs. Simply put, for the most common type of bow-spring centralizer, the bows are created by compressing a strip of metal lengthwise and fixing the two compressed ends inside a rigid frame that is fixed to the casing. The bows are manufactured with a larger outer diameter than the inner diameter they will be installed in, therefore they exert an outward force against the casing or open hole they are inside that moves the casing they are fixed to towards the center of the casing or open hole.

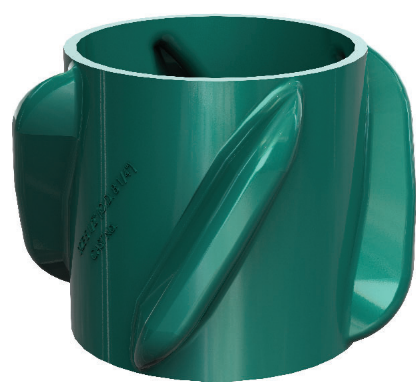
Solid Centralizers
This type of centralizer, as the name implies, have solid non-flexible bodies and blades and do not experience deformation when run through restrictions.

Rigid Centralizers
This type of centralizer has rigid bands or bars fixed to two end-collars and experience deformation when run through restrictions because they are not solid.

Semi-Rigid Centralizers
Semi-rigid centralizers have flexible spring bows attached to two end-collars. The bows-spring form two equal-length bows between the end rings. When semi-rigid centralizers experience sufficient load the two equal-length bows flex inwards until the bows contact, and is supported, by the casing. At this point the semi-rigid centralizers behave as rigid centralizers.

Non-welded hinged bow spring centralizer

Non-welded hinged semi-rigid bow spring centralizer



Non-welded slip-on rigid centralizer

Stop Collar Types

Stop collars restrict the movement of centralizers by “holding on” to the casing. The holding force is the maximum force the stop collar can withstand before moving, and a high holding force is desirable. Stop collars are made of different materials, with ductile iron, mild steel and steel being the most common.

The four main types of stop collars are the slip-on set screw stop collar, hinged spiral nail stop collar, hinged bolt stop collar, and slip-on two-piece threaded stop collar.

The slip-on set screw stop collar has threaded holes where set screws are tightened against the casing. Increasing the size and/or number of set screws in the stop collar increases the holding force.

The hinged spiral nail stop collar has a spiral nail that is driven between the clamp and the casing to produce the holding force when the hinge is closed around the casing.

Spiral nail stop collar

The hinged bolt stop collar has a bolt that is tightened to create a tight fit onto the casing, in the same way a hose clamp is tightened around a hose.

The slip-on two-piece threaded stop collar has two pieces that are slipped onto the casing and when threaded together grip tightly onto the casing. All stop collars may have dogs (or teeth) on the inside of the inner diameter that bite into the casing. This stop collar type is not used in applications where corrosion problems are expected.

Bolt stop collar

Close-Tolerence

The Special close-tolerance centralizers and close-tolerance stop collars are typically used in tight-tolerance applications where standard equipment is too large. While bow-spring type centralizers should not be allowed to ride free on a casing joint this is commonly done for rigid centralizers. Centralizer subs is a type of close-tolerance centralizer. Slip-on two-piece threaded stop collar is typically preferred in close-tolerance applications as it provides the highest holding force for a given outer diameter.

Set screw stop collar

Heavy duty set screw stop collar

Slip-on solid centralizer (cast)

Specifications	
Equipment Type	**Casing Size Offering**
Centralizers	2-3/8 to 36”
Stop Collars	2-3/8 to 36”

Industry Standard

The industry standards used for centralizers and stop collars are American Petroleum Institute (API) specification 10D “Specification for Bow-string Casing Centralizers”, recommended practice 10D-2 “Recommended Practice for Centralizer Placement and Stop-collar Testing” and technical report 10TR5 “Methods for Testing of Solid and Rigid Centralizers”. Specification 10D provides minimum performance requirements, test procedures and marking requirements for bow-spring centralizers. Recommended practice 10D-2 provides calculations for determining centralizer spacing, based on centralizer performance and desired standoff, in deviated and dogleg holes. It also provides a procedure for testing stop collars and reporting test results.

Technical report 10TR5 provides information for the selection and use of solid or rigid centralizers, and standardized testing methods to verify functionality and reliability of centralizers. Three main concepts regarding centralizers are starting force, running force, and restoring force. Starting force is the maximum force required to insert a centralizer into a specified wellbore diameter. Running force is the maximum force required to move a centralizer through a specified wellbore diameter. Restoring force is the force exerted by a centralizer against the casing to keep it away from the wellbore wall.

Specialty Centralizers and Stop Collars

Varieties in geometry, materials and manufacturing methods have been developed to meet the demands of different applications. Examples include polyester powder coating for friction reduction; induction furnace casting to avoid changing the characteristics of the metal; aluminum, zinc or composite centralizers for reduced static and dynamic coefficients of friction; external roller centralizers for torque and/or drag reduction; internal bearing centralizers and stop collars to reduce torque when rotating; spiral vanes/blades; straight vanes/blades and different number of vanes/blades and vanes/blades height.

Integrated Shoetrack Tool

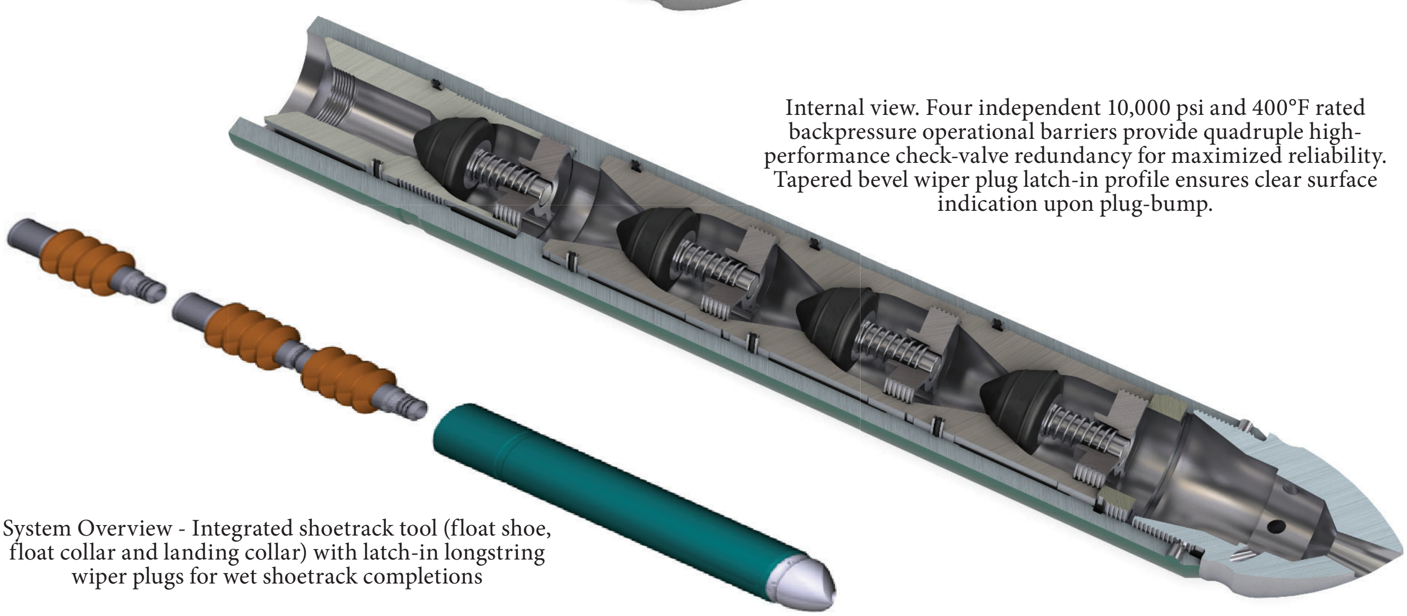
The Baker Hughes Integrated Shoetrack Tool is an integrated float shoe, float collar, and landing collar that provides a quadruple set of operational barriers. The compact tool minimizes the shoetrack length resulting in optimized acreage utilization and increased reservoir production. It is run as the bottommost part of a liner or longstring completion for un-cemented completions, cemented completions with cemented shoetrack, or cemented completion with intentional wet shoetrack. Each of the four independent high-pressure valves are rated to 10,000 psi differential pressure compliant with API 10F 4th Edition, the industry standard for float equipment.

The valves are self-energized in the closed position by spring force, and therefore the Integrated Shoetrack Tool is equally well suited for horizontal, deviated, or vertical wells. Due to the high pressure-rating of the valves it is well suited for uncemented completions in high-pressure formations where the shoetrack is relied upon to hold back the formation pressure for an extended period without the aid of cement in and around the shoetrack. For the same reason it is also well suited for applications where the completion is run-in-hole with fully evacuated casing, commonly referred to as casing flotation, where a lack of a hydrostatic fluid column inside the lower part of the casing results in significantly higher differential pressure applied to the float equipment.

The upward or downward facing side ports with 360° flow area create a jetting action to assist with cutting removal and the flow of cement while cementing, and also provide a secondary circulation path in the unlikely event that the main port is obstructed. The flush non-upset outer diameter of the Integrated Shoetrack Tool minimizes drag while running in hole, while the high-strength eccentric aluminum guide nose navigates through troublesome wellbore conditions.

When used on cemented longstring completions the integrated wiper plug latch-down profile, modular wiper plug configuration and variable burst-pressure options allow the system to accommodate an unlimited number of rupture disk cement wiper plugs. The seal and mechanical slip-latch on the nose of each wiper plug provide a pressure tight seal between each wiper plug, resulting in a clear surface pressure indication upon plug bump.

External view. Multiple nose configurations and flow port options are available



Internal view. Four independent 10,000 psi and 400°F rated backpressure operational barriers provide quadruple high-performance check-valve redundancy for maximized reliability. Tapered bevel wiper plug latch-in profile ensures clear surface indication upon plug-bump.

System Overview - Integrated shoetrack tool (float shoe, float collar and landing collar) with latch-in longstring wiper plugs for wet shoetrack completions

When used on cemented longstring completions with intentional wet shoetrack a pre-determined wet shoetrack volume of cement-retarded displacement fluid is pumped after pumping cement and dropping a wiper plug. This is typically followed by a wiper plug with a high burst pressure. Upon plug bump of the final wiper plug, the burst disk can be blown out, or the plug can be left intact downhole to be blown out as part of the subsequent hydraulic fracturing operation.

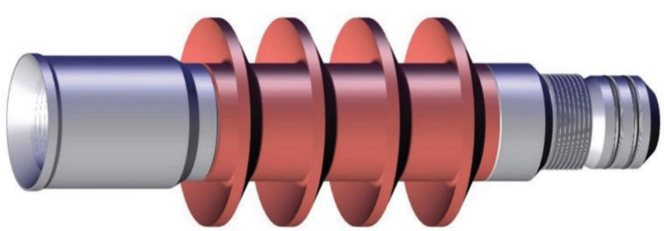
This operation results in an unrestricted flow path into the formation, even after cement around the completion string has fully cured, consequentially eliminating the need for a dedicated tubing conveyed perforation (TCP) trip, a pressure-actuated sliding sleeve (toe sleeve), or a wet shoe sub.

Applications

- Uncemented completions, cemented completions with cemented shoetrack, or cemented completion with intentional wet shoetrack
- Liner or longstring completions
- Horizontal, deviated or vertical wells
- Unconventional reservoirs requiring cost effective and reliably interventionless formation access post-cementing
- Plug-and-perf multi-stage hydraulic fracturing completions
- Proppant or acid hydraulic fracturing

Features and Benefits

- Increases reservoir production through compact size of integrated float shoe, float collar, and landing collar, optimizing acreage utilization
- No internal connections eliminate tensile and torque limitations, and connection leak paths
- Four independent operational barriers rated to 10,000 psi and 400°F provides redundancy and reliability through
- Large flow area results in low circulation pressure and high debris tolerance
- Tapered bevel wiper plug latch-in profile ensures clear plug-bump surface indication



Single fin latch-in longstring rupture disk wiper plug

Double fin latch-in longstring rupture disk wiper plug

Case study: Permian Basin, United States

Integrated Shoetrack Tool delivers flawless wet shoe injectivity where competitor struggle

A major operator in the Permian Basin in Texas reached out to Baker Hughes after experiencing major reliability issues with a competitor's wet shoetrack system on their cemented 5-1/2-in. longstring completion strings. The issues occasionally required the customer to drill out cement in the casing and deploy tubing conveyed perforation (TCP) to create injectivity to the formation.

The operator needed a durable and reliable system that didn't plug-up or restrict flow while cementing or during pre-stimulation ("toe-prep") operations. The system also needed to be as compact as possible without sacrificing the number or capability of the operational barriers in the shoetrack. As a final requirement the outer diameter of the system could not be larger than the casing collars, to maximize the ability to make it to total depth.

Baker Hughes recommended the customer run the **Integrated Shoetrack Tool** with two rupture disk wiper plugs, the first with a 1,000-psi rupture disk and the second with a 3,000-psi rupture disk. The entire shoetrack was reduced to 3.8 feet and consisted of; a single mandrel with no internal connections; 4x independent check valves rated to 10,000 psi backpressure and 400°F; and an eccentric aluminum nose ("lipstick style") with a main port and 6 up-jets to successfully navigate challenging downhole conditions.

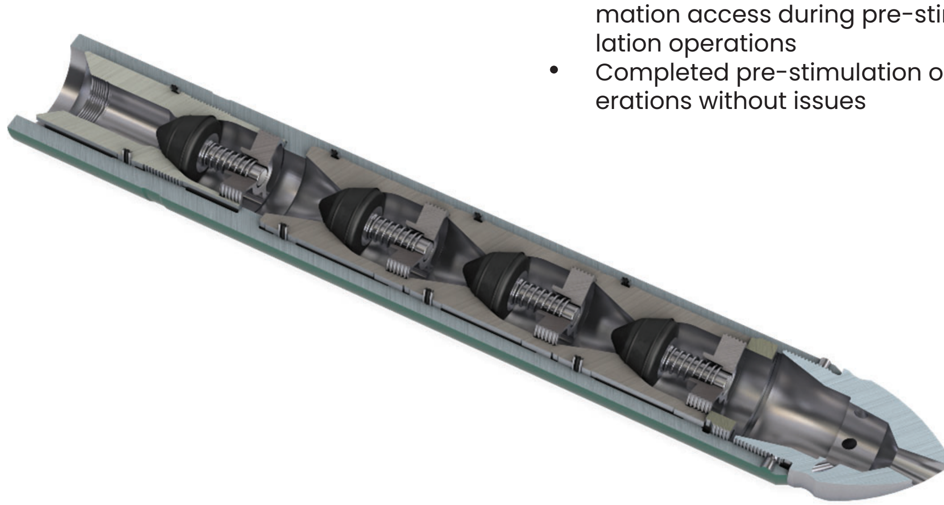
This system configuration eliminated any tensile, torque, burst, collapse and circulating pressure limitations, as the ratings were higher than that of the premium connection used by the customer.

After picking up the first casing joint with the Integrated Shoetrack Tool pre-bucked onto the bottom, the 5-1/2-in. longstring was ran through the 7-5/8-in. parent casing set at 8,596 ft measured depth (MD) and through the 6-3/4-in. open hole to 11 ft above the 19,366 ft total depth (TD).

A glass disk casing flotation sub was installed at 11,247 ft MD from the shoetrack to land at 8,108 ft MD. The casing string was ran fully evacuated ("empty") below the flotation sub and filled with mud on top, therefore the check valves in the shoetrack experienced a differential pressure equal to the full hydrostatic pressure in the annulus during the entire operation. The true vertical depth (TVD) was 8,596 ft, the mud weight was 9.4 ppg, the well's maximum inclination was 90° (horizontal), and the bottom hole temperature was 185°F. The calculated capacity of the casing string was 429 bbls.

It took 26.5 hours from testing floats at the rig floor to reaching TD. At TD the flotation sub was burst, the air circulated out at 5 bpm with 1,100 psi pump pressure, and the cement job began.

The first wiper plug was dropped after pumping the cement, followed by 5 bbls of retarded water, and then dropping the second wiper plug. The first wiper plug was landed in the shoetrack and blown out. Once the second wiper plug landed, it was bumped but purposefully not blown out. The floats were confirmed to be holding and the equipment rigged down.



10 weeks later the pre-stimulation crew arrived, blew out the second wiper plug and pumped 700 bbls of fresh water with acid sweeps, pumping at 20 bpm with 5,500 psi surface pressure.

Based on the flawless installation and pre-stimulation operation the customer is now making plans to install more of these systems.

Challenges

- Reliability issues with competitor's system during the cement job and pre-stimulation operations resulting in costly remediation and intervention
- Overcoming torque and drag due to high tortuosity in the wellbore
- Drive operational efficiency
- Preserve 4x independent high-performance operational barriers in the shoetrack while minimizing its length and outer diameter

Results

- Installed longstring successfully
- and efficiently to total depth
- Pumped cement and bumped the wiper plugs on time without issues
- Created an intentional wet shoetrack for interventionless formation access during pre-stimulation operations
- Completed pre-stimulation operations without issues

Case study: Permian Basin, United States

Integrated Shoetrack Tool delivers flawless wet shoe injectivity on cemented 5-1/2-in liner installation

A major operator in the Permian Basin in Texas desired to change the toe injectivity technique on their 5-1/2-in cemented liners from pressure-activated toe sleeves to wet shoes in order to reduce the maximum outer diameter of the completion string and the overall pre-stimulation ("toe-prep") cost.

The operator needed a durable and reliable system that didn't plug-up or restrict flow during cementing or toe-prep operations. The system also needed to be as compact as possible without sacrificing the number or capability of the operational barriers in the shoetrack. As a final requirement the outer diameter of the system could not be larger than the casing collars to maximize the ability to make it to total depth, a problem with the existing pressure-activated toe sleeves.

Baker Hughes recommended the customer run the Type III Landing Collar, an internal bypass sub, and the Integrated Shoetrack Tool, an integrated float shoe, float collar and landing collar.

The entire shoetrack was reduced to less than 10 feet. The Integrated Shoetrack Tool was 3.8 feet and consisted of; a single mandrel with no internal connections; 4x independent check valves rated to 10,000 psi backpressure and 400°F; and an eccentric aluminum nose ("lipstick style") with a main port and 6 up-jets to successfully navigate challenging downhole conditions.

After picking up the first casing joint with the Integrated Shoetrack Tool and Type III Landing Collar pre-bucked onto the bottom, the 5-1/2-in. liner was ran through the 7-5/8-in. parent casing set at 10,444 ft measured depth (MD) and through the 6-3/4-in. open hole to 10 ft above the 21,133 ft total depth (TD).

A glass disk casing flotation sub was installed 10,742 ft from the shoetrack to land at 10,381 ft MD. The casing string was ran fully evacuated ("empty") below the flotation sub and filled with mud on top, therefore the check valves in the shoetrack experienced a differential pressure equal to the full hydrostatic pressure in the annulus during the entire operation.

The true vertical depth (TVD) was 10,997 ft, the mud weight was 12.5 ppg, and the well's maximum inclination was 90° (horizontal). The combined calculated capacity of the drill pipe and casing string was 381 bbls.

It took 21.5 hours from testing floats at the rig floor to reaching TD. At TD the flotation sub was burst, and the air was circulated out at 8 bpm with 2,780 psi pump pressure. The first liner setting ball was circulated down to the running tools and the liner hanger was set. Next the second liner setting ball was circulated down to the running tools and the running tool was released, disconnecting the drill pipe from the liner casing.

After confirming the drill pipe was released from the liner casing, the cement job began. After pumping the cement, the drill pipe pump down plug was dropped. It was chased with the displacement fluid and wiped the drill pipe until latching into the liner wiper plug at the bottom of the running tool. At a pre-determined pressure, the liner wiper plug sheared off the running tool and the plugs travelled together wiping the liner casing until bumping in the Type III Landing in the shoetrack.

After holding pressure for 5 min to confirm the plugs were bumped, pressure was increased to a pre-determined pressure where the internal bypass of the Type III Landing Collar shifted open. Once open a 5 bbls wet shoe was pumped through the shoetrack and into the open hole. Next the floats were confirmed to be holding, then the liner top packer was mechanically set, and the drill pipe tripped out of the well. Several weeks later the pre-stimulation crew arrived and performed the required pre-stimulation operation without issues.

Following the flawless installation and subsequent pre-stimulation operation the customer decided to make this their standard 5-1/2-in liner system in this area. An additional 20 identical liner systems were installed over the following 120 days, with additional systems planned.

Challenges

- Large outer diameter of pressure-activated toe sleeves increased torque and drag during installation of 5-1/2-in. liner in 6-3/4-in open hole
- Needed to drive operational efficiency. Pre-stimulation equipment and operation was too costly
- Needed to preserve 4x independent high-performance operational barriers in the shoetrack while minimizing its length and outer diameter

Results

- Installed 5-1/2-in liner successfully and efficiently to total depth
- Shoetrack equipment outer diameter did not exceed the casing collars (no upset)
- Set hanger and released running tool
- Pumped cement and bumped liner wiper plug
- Created an intentional wet shoetrack for interventionless formation access during pre-stimulation operations
- Completed pre-stimulation operations without issues

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