Working Out of a Tight Spot

For more than 80 years, jars have been widely accepted in the drilling industry as inexpensive contingencies to save rig time and to protect the drillstring and wellbore from damage in the event of stuck pipe. Advances in technology and increased understanding of the dynamics of successful jarring operations have extended the application of jars to horizontal and highly deviated wells. Challenges to optimal use of jars remain, however, and both the art and the science of jarring continue to evolve.

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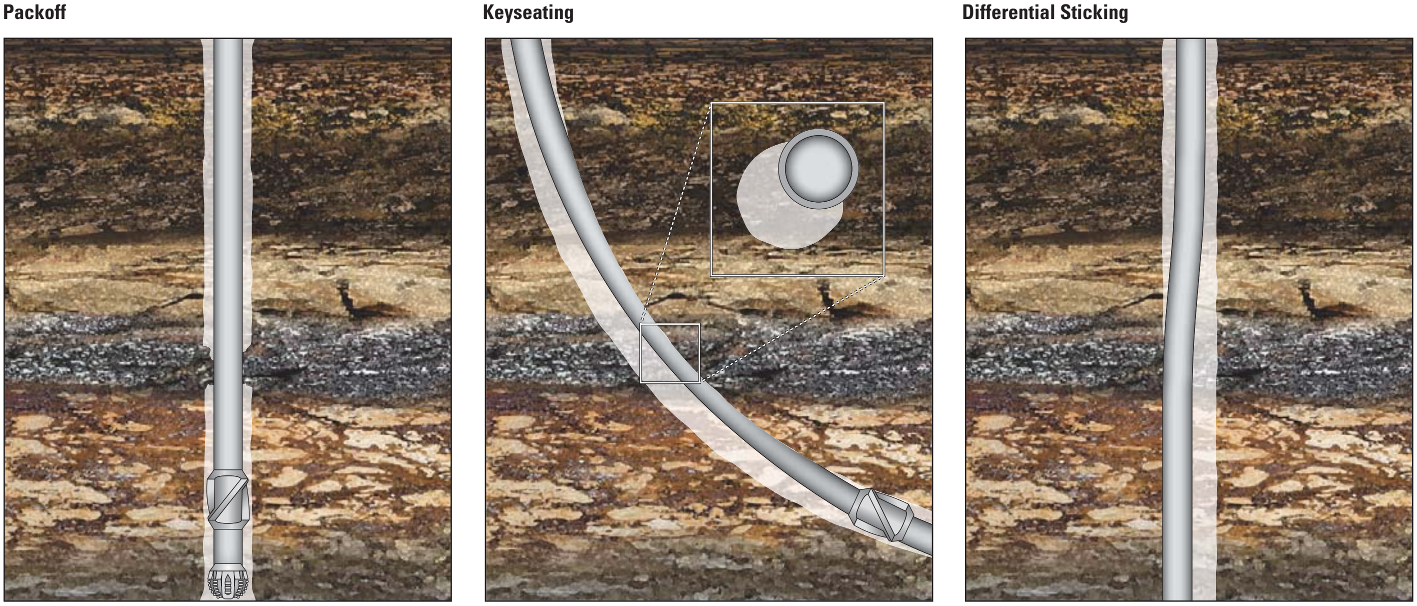
Accelerator AP, AP Impact, Hydra-Jar AP and Jar-Pact are marks of Schlumberger.

1. Shivers RM III and Domangue RJ: "Operational Decision Making for Stuck-Pipe Incidents in the Gulf of Mexico: A Risk Economics Approach," *SPE Drilling & Completion* 8, no. 2 (June 1993): 125–130.
2. Bradley WB, Jarman D, Plott RS, Wood RD, Schofield TR, Auflick RA and Cocking D: "A Task Force Approach to Reducing Stuck Pipe Costs," paper SPE/IADC 21999, presented at the SPE/IADC Drilling Conference, Amsterdam, March 11–14, 1991.
3. Bowes C and Procter R: *1997 Drillers Stuck Pipe Handbook*. Houston: Schlumberger (1997): 13.
4. Clausen J, Rebellon J, Blanc J and Barton S: "Novel Drilling Technology Delivers a Step Change in Challenging Deepwater Operations," paper SPE 142501, presented at the SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, September 25–28, 2011.

Drilling jars serve a single purpose: to free stuck pipe. Jarring is the process of dynamically transferring strain energy stored in the drillstring to a device—a jar—that concentrates kinetic energy at the point where the pipe is stuck. Most operators include jars in their drilling BHAs as precaution against the likely occurrence of stuck pipe. It is estimated that drillstrings become stuck an average of once for every three wells drilled, costing operators hundreds of millions of dollars per year.[1] Approximately 50% of stuck pipe incidents occur during tripping, 20% while reaming and working pipe and 10% while drilling ahead.[2] Jarring is the last line of defense against downtime, expensive fishing operations, sidetracking or well abandonment. Although E&P companies go to great lengths to avoid costs that result from stuck pipe, drilling teams are generally unfamiliar with the mechanics and dynamics of jars and untrained in optimizing jarring operations.



^ Stuck pipe mechanisms. Pipe may become stuck in the hole, unable to be moved up or down or rotated, for a variety of reasons. Packoff (*left*) may occur when an unconsolidated formation—loosely packed with little or no bonding between particles, pebbles or boulders—falls into the wellbore. Packoff can also occur when formation cuttings or debris settle around the BHA. Keyseating (*center*) may happen when the drillpipe rotates against a single point on the borehole wall where it wears a groove, or keyseat (*inset*), into the wall. When the drillstring is pulled out of the hole, the tool joints or sections of the BHA of larger diameter than the drillstring are unable to move through the keyseat. In this case, the drillstring may be moved down or rotated but cannot be pulled upward and thus is stuck in the hole. Differential sticking (*right*) may result when a force created by the hydrostatic pressure of the drilling fluid in the wellbore is greater than the pore pressure of a permeable formation. This overbalance presses the drillstring against the wellbore and is often initiated when the drillstring is stationary or moving very slowly and comes in contact with a permeable formation or a thick mud filtercake.

Consequently, operators don't always realize the full value of their contingency plan, and millions of dollars remain at risk.

Service companies are partnering with operators to dramatically reduce operational risk, downtime and cost by educating rig personnel and by encouraging the proper and timely use of jar placement analysis programs that have become the preventive component of jar contingency plans. Having a broader understanding of geology, wellbore and BHA geometry and the implications of jar placement will enable drilling engineers to design BHAs that optimize penetration rates and wellbore placement while providing maximum protection against potential downhole events that undermine drilling performance.

This article reviews causes of stuck pipe and the types of jars available and discusses jarring forces and the importance of planning and analyzing jar placement in the drillstring. Case histories from Canada, Oman and the US demonstrate the benefits of successful jarring operations.

Stuck Pipe Basics

When the static force necessary to move a drillstring exceeds the rig's capabilities or the tensile strength of the drillpipe, the drillstring becomes stuck. The pipe can no longer be moved up or down or be rotated. Pipe can become stuck while drilling, making a connection, logging or testing or during any operation in which equipment is in the hole. There are two primary types of pipe sticking: mechanical and differential.

Mechanical sticking is usually encountered while the drillstring is being moved and is caused by a physical obstruction or restriction. Three mechanisms are responsible for stuck pipe: packoff, bridging and wellbore geometry interference (above). Packoff occurs when an unconsolidated formation, formation cuttings or debris in the wellbore settle around the BHA and fill the annulus between the drillstring and the wellbore. It typically takes place after the mud pumps have been off for an extended period during operations such as pulling out of hole. Bridging results when medium to large pieces of formation, cement or junk fall into the wellbore and block the annulus.

Wellbore geometry interference may arise when the shape or size of the well and that of the BHA are incompatible. Often the interference is caused by keyseat sticking when the hole deviates from true vertical. A keyseat is an indentation or groove cut into the formation in which larger diameter components of the drillstring, such as collar connections and the BHA, can become wedged. Other causes of interference include undergauge hole, stiff drilling assembly, mobile formations, ledges, doglegs and casing failures.

Differential sticking occurs when the pipe is stationary or moving very slowly. It is caused by drilling fluid overbalance—when hydrostatic pressure in the mud column is greater than the pore pressure in the permeable formation—which pushes the pipe into the wellbore wall.[3] Aggravating conditions include high overbalance pressures, thick filtercake, high-density drilling fluids and muds with high solids content.

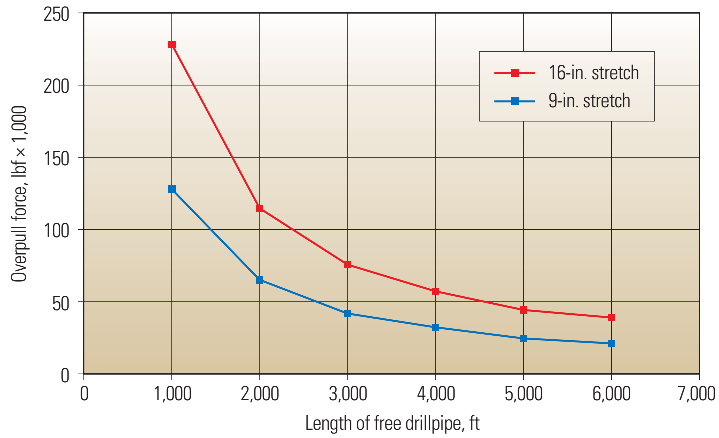
When engineers have an understanding of the potential mechanisms and causes of stuck pipe, they may be able to optimize placement of jars early enough in the design process to maximize jarring effectiveness. Operators that have this knowledge may also better select the appropriate jarring forces and durations for the hole conditions once a drillstring becomes stuck.

How Jars Work

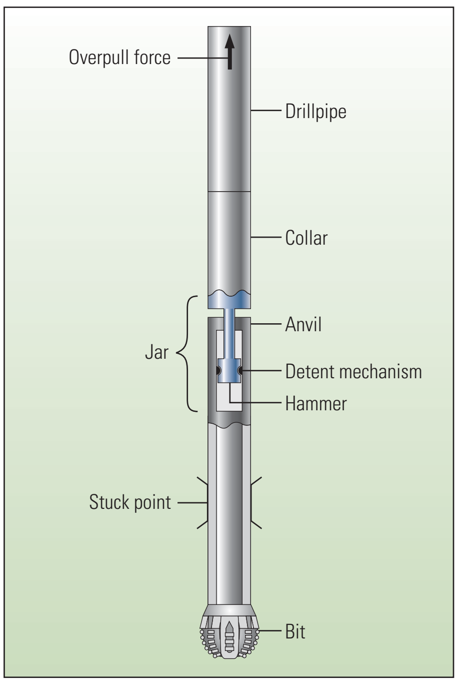
Although drilling jars have been in use since the 19th century, modern jars did not emerge until the 1930s. In 1931, engineers designed a jar that consisted of a telescoping mandrel held in place by a mechanical latch-type device. Numerous improvements since that time have enabled jars to handle the demands created by increasingly complex wells.[4]

Today, a jar consists of a mandrel that slides within a sleeve and an internal detent mechanism that briefly delays the movement of the mandrel before releasing it.[5] The mandrel is often referred to as a hammer and the sleeve as an anvil. This nomenclature helps explain how energy is released from the drillstring and transferred to the stuck pipe (below).[6]

Jars operate on the principle of stored potential energy. The potential energy available to the jar comes from overpull or set-down values applied at surface.[7] Jars can strike, or fire, upward, downward or both. The jar is run in the drillstring either in tension or in compression. If run in tension, the mandrel is completely extended. If run in compression, it is completely closed. In either position, mandrel movement is prevented until jarring becomes necessary and drillers apply additional tension or compression to the drillstring.[8]



^ Acquiring strain energy. The energy available to the jar comes from the overpull force applied at surface to stretch the drillpipe. The type and length of drillpipe affect the amount it can stretch and the energy it can store. This graph for 5-in., 19.5-lbm/ft drillpipe compares two stretch lengths attainable for different applied overpull as a function of the length of free drillpipe above the stuck point. For a given stretch, the overpull force, and thus the energy available for jarring, decreases with increasing length of free drillpipe.



^ Jarring assembly. A typical jarring assembly consists of a mandrel, or hammer, that slides within a sleeve, or anvil, and a detent mechanism. The detent restricts the movement of the mandrel briefly before releasing it. The time delay enables the drillpipe to store potential energy. The sudden release of the detent mechanism causes the mandrel to accelerate rapidly for a distance of 25 to 50 cm [10 to 20 in.] before it slams against the sleeve, releasing the stored energy and imparting an impact force at the stuck point. Upward motion of the mandrel causes the hammer to slam into the anvil, producing an upward force on the drillstring. Downward mandrel motion produces the opposite effect.

To fire a jar upward, the driller slowly applies overpull to the top of the string while the BHA remains stationary. The detent in the jar restricts the movement of the mandrel for a brief time, causing the drillpipe to physically stretch and store strain energy (above). This phase, often called the loading phase, typically lasts only a few seconds but when the rig crew uses hydraulic jars, which have long delay times, the loading phase can last for several minutes.[9]

The next phase, sometimes referred to as the preimpact phase, begins when the detent releases and concludes with jar impact. This phase typically lasts from 50 to 200 ms. The mandrel accelerates, and the energy stored in the stretched drillstring is suddenly released, setting into motion the drillpipe mass and the collar or heavyweight drillpipe (HWDP) mass directly above the jar. These masses gain momentum during free travel.

When the motion stops, an impact load, comparable to a hammer striking an anvil, is imparted. The time interval of this impact phase is typically 10 to 50 ms. The impact generates a shock wave that travels up and down the drillstring. This process provides a sudden release of energy at the stuck point.

The postimpact phase lasts for a matter of seconds until the drillstring has returned to a state of complete rest. During the next phase, resetting, the drillstring is lowered until string weight imposes a compressive force on the jar, which resets it for the next jarring cycle.

When jarring downward, instead of overpull applied to the drillpipe, the weight of the toolstring is released, delivering a compressive force at the sticking point in an effort to release the stuck tool by driving it downward. The jarring process is repeated—in some cases hundreds of times—until the stuck pipe is freed or, if jarring has not been successful, the operator decides to pursue a different course of action.

Two quantities that are generated by jarring combine to overcome the sticking force and move stuck pipe: impact and impulse. The first quantity, impact, is the peak force caused by the collision of the hammer with the anvil. The second quantity, impulse, is the change in momentum during the impact phase measured by the area under the load versus time curve (next page, top right). Both impact and impulse are influenced primarily by the number of drill

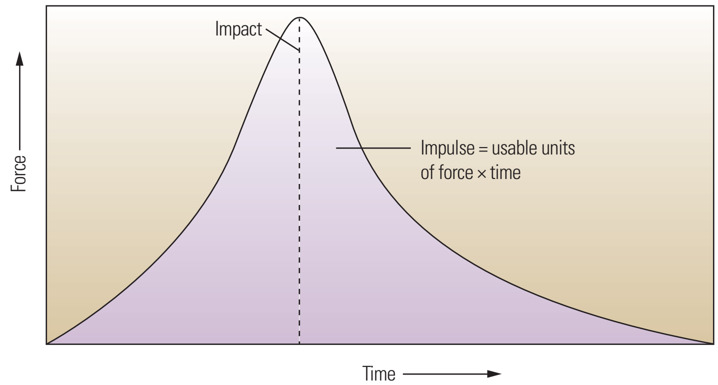
5. A detent is a device that positions and holds one mechanical part in relation to another so that the device can be released when a force is applied to one of the parts. An example of a detent in a common object is the release mechanism in umbrellas.
6. Kalsi MS, Wang JK and Chandra U: "Transient Dynamic Analysis of the Drillstring Under Jarring Operations by the FEM," SPE *Drilling Engineering* 2, no. 1 (March 1987): 47–55.
7. Overpull is the amount of pull on the moving pipe that is in excess of its weight in air or fluid. Set-down weight, also referred to as slack-off or released drillstring weight, is the weight of the drillstring and BHA available at the stuck point or at bottomhole if the pipe is free.
8. Schmid JT Jr: "Designing BHAs for Better Drilling Jar Performance," *World Oil* 195, no. 5 (October 1982): 100–104.
9. Aarrestad TV and Kyllingstad Å: "Loads on Drillpipe During Jarring Operations," *SPE Drilling & Completion* 9, no. 4 (December 1994): 271–275.
10. Newman KR and Procter R: "Analysis of Hook Load Forces During Jarring," paper SPE/IADC 118435, presented at the SPE/IADC Drilling Conference and Exhibition, Amsterdam, March 17–19, 2009.

collars above the jar; fewer drill collars result in a higher impact force, but more drill collars deliver a greater impulse. In successful jarring operations, a compromise is achieved through proper jar placement and regulating the number of drill collars to maximize how the impact and impulse forces work together to free the pipe.

The magnitude of the impact delivered by the jars is limited by the overpull or slack-off weight available. A properly designed jarring assembly usually exerts more force when jarring upward than downward because the driller can pull on the drillpipe with a force of up to 90% of the yield strength of the pipe. However, the available slack-off weight, and resulting compressive force, is much less than the total toolstring weight because of buckling limitations of the drillstring above the jar, drill collar length configuration and the relative position of the drill collars and the jar.[10] Jarring is most effective when it is performed in the opposite direction to that which the drillpipe was traveling when the pipe became stuck; that is, jarring upward is most effective if sticking occurred while running the drillstring into the hole, and jarring downward is most effective if sticking occurred while running out.

Two resistance forces can affect jarring. A high differential pressure between the inside and the outside of the jar, acting on the total sealed cross-sectional area at the mandrel, may create a force sufficient to open the jar and lift the drillstring. This is called jar pump open force, or jar extension force. When jarring upward, the operator must add the pump open force to the surface overpull to obtain actual tension at the jar. When jarring downward while circulating, drillers must slack off more weight at the surface to overcome the pump open force acting in the opposite direction.

Pump open force can sometimes aid in upward jarring. In cases of severe differential toolstring sticking or drag, overpull cannot fire a mechanical jar or induce a large enough blow from a hydraulic jar. A jar may sometimes be fired by increasing the mud pump rate, which increases pump force, or by a combination of increasing mud pressure and applying tension to the drillstring. Drag on drillpipe increases overpull requirements. In vertical wells, drag can be negligible, but drag in directional wells often increases the overpull required to fire the jar by as much as 10%.

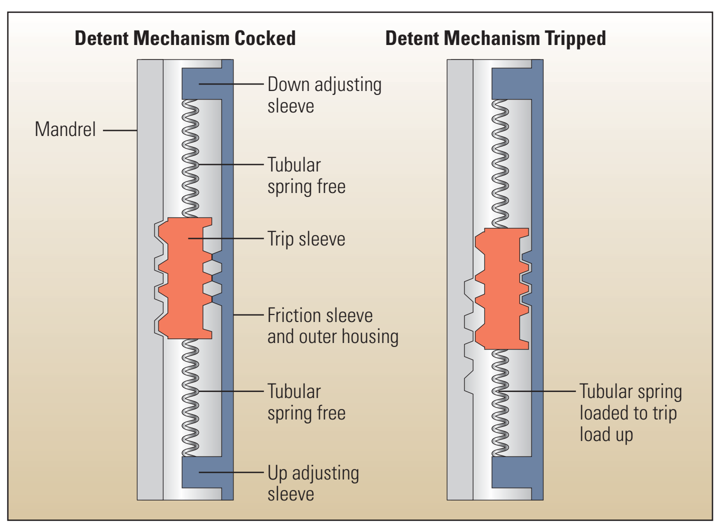


^ Impact and impulse. When jars are activated, the aim is to create an impact force to overcome the force causing the pipe to stick. The impulse, with units of force x time, is momentum, and must be sufficient to move the pipe. Both impact and impulse are influenced primarily by the number of drill collars above the jar and by jar placement.

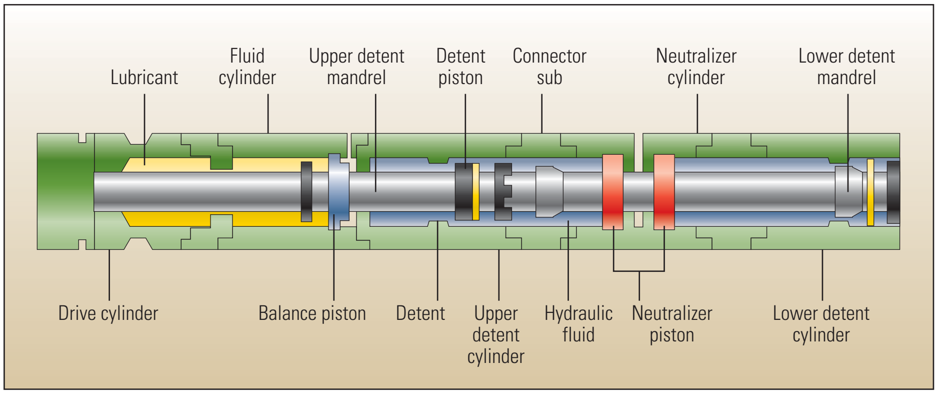
Types of Jars

Jars are classified by function and by actuation method. Drilling and fishing jars have similar designs and deliver approximately the same impact, but are constructed differently and have different functions. Drilling jars are the length of standard drillpipe, are durable enough to withstand drilling stresses and are run as components of the BHA. They may be fired and reset several times during a single jarring operation. Fishing jars are shorter than standard drillpipe, cannot withstand drilling forces and are run only after the pipe above the stuck point has been disconnected and retrieved from the hole. They are typically designed to jar upward only.

Mechanical and hydraulic jars function similarly, but differ in their detent mechanisms. Mechanical jars are actuated using a series of springs, locks and rollers with release mechanisms. The mechanical jar fires upward at a preset tensile force and downward at a preset compressional force; these normally exceed the tensile or compressional forces reached while drilling. Firing is dependent on load only, not on length of time. During drilling, the mechanical jar is either cocked or extended to its fully open or fully compressed position (below). Although



^ Mechanical jar. When a mechanical jar detent mechanism is cocked (*left*), the tubular springs hold the trip sleeve against the mandrel, which prevents the jar from firing. By maintaining an applied tensile or compressional force that is less than the set tubular spring force, the jar may be run in and out of the hole without fear of tripping the jar. When applied tension is greater than the preset tubular spring force, the trip sleeve is forced upward or downward, allowing the mandrel to slide free (*right*) and the jar to be fired.



^ Double-acting hydraulic Hydra-Jar AP tool. The drive cylinder consists of a section that allows for free axial extension and retraction of the jar mandrel while allowing torque to be transmitted through the tool. The upper fluid cylinder and balance piston maintain a pressure balance with that of the borehole. The upper detent cylinder includes a restriction called the detent. When overpull tension is applied, the detent piston is pulled toward the detent, metering the hydraulic fluid through the detent piston and allowing stretch to accumulate in the drillstring. The detent piston moves through the cylinder at a slow rate until it clears the detent, tripping the jar and firing upward. The lower detent mandrel and cylinder perform the same functions as their upper counterparts, but allow for downward jarring.

mechanical jars are still preferred for some niche applications, including high-temperature wells, many engineers favor hydraulic jar technology for most applications.

Hydraulic jars were introduced in the 1940s to increase the impact loads, which are limited by latching mechanisms of mechanical jars. Hydraulic jars were designed, therefore, not to trip at a preselected threshold. Instead, they operate using a piston pulling through a restriction in a hydraulic fluid reservoir in the detent mechanism. When tension or compression is applied to the tool in the set position, the fluid from the high-pressure side of the reservoir is compressed and passes into the low-pressure side through an orifice between the reservoirs. The orifice causes a fluid flow restriction, resulting in a time delay that enables potential energy to be stored in the drillpipe. Varying the metering rate of the fluid through the orifice affects the magnitude of impact at the stuck point.

The metering stroke is the overall distance traveled by the hydraulic jar and the fluid.[11] When the stroke reaches a certain distance, the piston moves from the restrictive area into a larger area, allowing the compressed fluid to flow freely around the piston. The jar fires, and pressure between the two sides equalizes. The timing and force with which the jar fires determine the magnitude of the applied tension or compression.[12] The driller influences overpull on the jar, which in turn influences the flow rate of the fluid through the orifice and the speed and force at which the jar fires. The magnitude of the impact is proportional to overpull. Greater overpull produces quicker jar firing and a more forceful impact. Any applied force can fire the jar, and drillers can vary the final force delivered to the stuck point.

Expanding the Limits of Hydraulic Jars

The progress of oil and gas exploration and development into deeper waters, more hostile downhole environments and complex wellbore geometries has generated demand for tools, including jars, able to perform reliably, efficiently and safely under higher downhole stresses. Jar manufacturers have responded with tools that can perform reliably in a variety of drilling environments: on land or offshore and in vertical, horizontal or deviated and ultradeep or high-pressure, high-temperature (HPHT) wells.

Hydraulic jars provide significant performance and operational benefits over mechanical jars but have some limitations. Friction generated by resistance to flow through the restriction during the metering stroke raises the temperature in the jar. When jars overheat, operators must cease jarring until the hydraulic fluid cools. To minimize the effects of the heat buildup, Houston Engineers developed the Hydra-Jar AP double-acting hydraulic drilling jar (above). The tool includes a unique temperature compensation design and high-temperature seals.

Jars may be run either in compression or in tension, providing the flexibility for optimized placement in the drillstring. Additionally, because the tool works without applied torque, the drillstring is not rotated during jarring, thus directional drilling tool orientation is not changed. To ensure that the Hydra-Jar AP drilling jar performs effectively and reliably in specific applications, engineers developed Jar-Pact BHA impact placement software. This software models the placement of the AP Impact advance performance system. Using data from the operator's well plan—including borehole and BHA parameters—the software recommends the optimal placement for the tools to avoid locating them in or near the drillstring neutral point or transition zone.[13] The software also ensures that the ratio of the hole and tool diameters is within recommended guidelines.

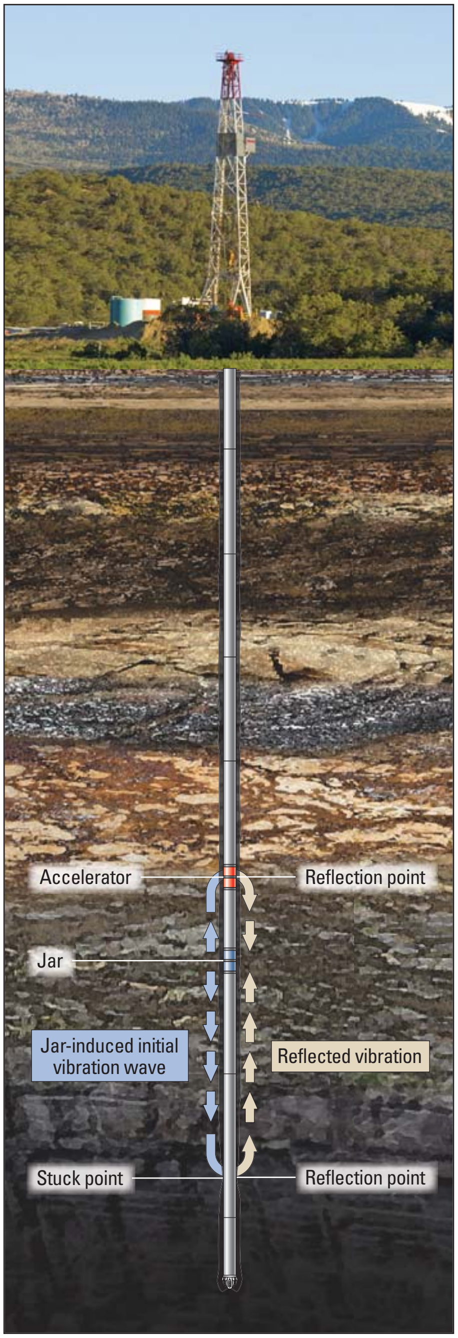
Although operators strive to jar pipe free quickly with as few firings as possible, experiences in a well in western Canada illustrate the strength and repeatability of advanced hydraulic drilling jars. Apache Canada included a Hydra-Jar AP tool in the drillstring in a borehole as a precautionary measure while drilling in the dolomite-carbonate Keg River Formation in Alberta, Canada. During drilling, the string became packed off by calcium carbonate buildup after several lost circulation pills were pumped to stop fluid loss.[14] A combination of backreaming and impacts from the Hydra-Jar AP tool helped free the stuck pipe. The jar fired more than 200 times over a seven-hour period, with no loss of impact force. The pipe was freed, and drilling continued to TD without a fishing job, minimizing lost time and rig expense.

Jar Acceleration Tools

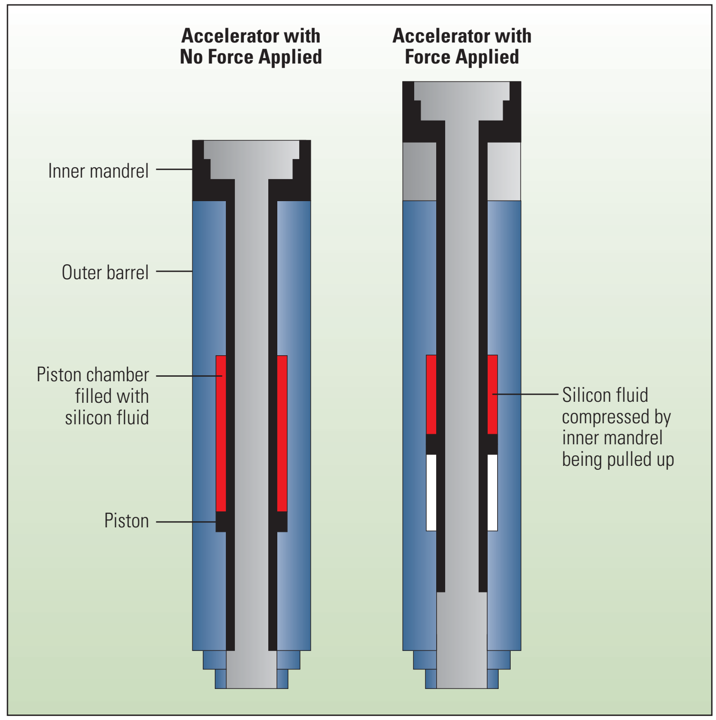
For a jar to impart peak impact at any given load, the mandrel must still be accelerating when it hits the sleeve. If terminal velocity is reached prior to impact, the jar impact will be limited. Because drill collars have been replaced by lighter HWDP in many BHAs, it is often the case that working weight is no longer sufficient to generate enough jar impact or impulse levels. Adding a jar accelerator to the BHA significantly amplifies jar impact and impulse and reflects shockwaves downward toward the stuck point (next page, left). It also takes stress off the drillstring and surface equipment and protects the topdrive from wear.

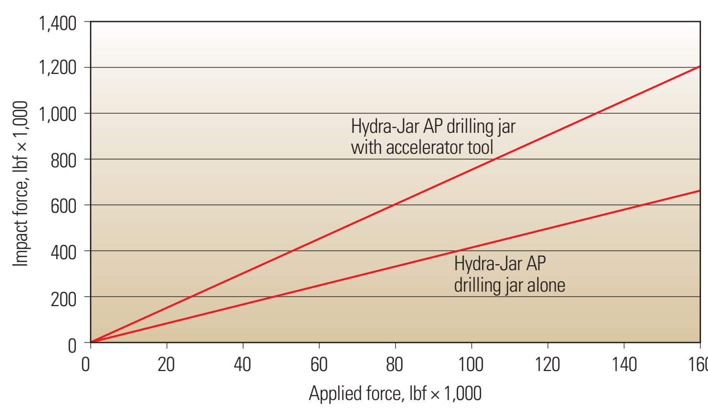
The Schlumberger Accelerator AP impact tool is an example of a jar accelerator tool. It is a compact, high-load rate spring tool that is placed directly above the jar and the mass of HWDP.

When a load is applied to a jar accelerator tool impact system, the load compresses the fluid, gas or spring inside the accelerator tool, thereby storing potential energy in the tool. The jar and accelerator are coordinated so that when the jar releases for impact, the stored potential energy in the accelerator is also released. The potential energy stored in and released from the accelerator tool accelerates the working mass above the jar much more efficiently than does energy stored in the drillstring because it eliminates the wellbore friction and drag generated over hundreds of meters of drillpipe. Using the accelerator tool can effectively double the impact force of a jar (below).



^ Stopping vibrations. When a jar is fired, it induces an initial wave of vibrations downward and upward along the drillstring. The downward wave is reflected upward from the stuck point. In addition to increasing jar efficacy, an accelerator effectively prevents the initial waves and reflected waves from reaching the drill floor by acting as a hydraulic disconnect within the drillstring.





^ Amplifying jar impact. The accelerator tool consists of an outer barrel and an inner mandrel connected by a piston chamber filled with silicon fluid (*top left*). When a force is applied to the accelerator tool (*top right*), the silicon liquid is compressed by the moving piston, storing the energy of the applied tension and providing extra stretch to the drillstring. When the force is released, the silicon liquid expands, and, like a spring, moves the piston back to its original position. This movement amplifies the final impact and impulse released (*bottom*) by a jar as a result of adding the energy stored in the accelerator to the energy stored in the pipe.

11. Adelung D, Askew W, Bernardini J, Campbell AT Jr, Chaffin M, Hensley R, Kirton B, Reese R and Sparling D: "Jars, Jarring and Jar Placement," *Oilfield Review* 3, no. 4 (October 1991): 52–61.
12. Adelung et al, reference 11.
13. A transition zone is the area of the drillstring between the neutral point and the state of either tension or compression. The location of the transition zone varies throughout the drilling process.
14. Cook J, Growcock F, Guo Q, Hodder M and van Oort E: "Stabilizing the Wellbore to Prevent Lost Circulation," *Oilfield Review* 23, no. 4 (Winter 2011/2012): 26–35.

In contrast to the experience of Apache Canada, engineers at Arbaj Energy Services found quick jarring success through use of an accelerator tool. In a well in Oman, the drillstring became packed off and stuck when it was picked up 16 m [53 ft] to perform a flow check after drilling a long vertical section from 957 m [3,140 ft] to TD at 3,590 m [11,800 ft]. Circulation, rotation and upward and downward movement were lost. After initial attempts to free the BHA, the operator replaced a failed drilling jar and intensifier with a Hydra-Jar AP and Accelerator AP impact tool and performed a Jar-Pact placement analysis to optimize impact and impulse values at the stuck point.

Based on the results of the Jar-Pact analysis, the BHA above the stuck point was backed off one drill collar above the top stabilizer at a depth of 3,536 m [11,601 ft], and the pipe was pulled out of hole. The Hydra-Jar AP and Accelerator AP tools were deployed as a fishing assembly, which was run into the hole and engaged around the stuck BHA. Although the initial plan called for jarring downward for eight hours and then upward for another eight hours, the stuck BHA began to move after only one hour of downward jarring. Within six hours, a 14-m [46-ft] pocket had been created, enabling the operator to regain circulation and rotation of the BHA. The successful jarring operation saved Arbaj Energy Services more than US$ 1.3 million by avoiding a costly sidetrack.

Although jar accelerators are recommended for use in all types of holes, they are particularly beneficial in high-angle and horizontal wells, plastic salt sections, areas with a high probability of differential sticking, wells with a high degree of string drag and in downward jarring applications. Experiences in one West Texas, USA, well serve to highlight the benefits of forethought. Engineers had deployed a Hydra-Jar AP double-acting hydraulic drilling jar and an Accelerator AP tool in the toolstring to reduce potential topdrive damage resulting from jarring operations and to increase the likelihood of successfully freeing pipe that they thought might become stuck while drilling an 8½-in. hole through the Akota Shale section. Heaving shale caused the BHA to become stuck while a connection was being made, and the rig was unable to circulate. Jarring began immediately. The energy stored in the accelerator tool added to the energy already stored in the drillstring to provide up to twice the impact at the stuck point than would have been available without an accelerator. However, because the accelerator is a telescoping component, it absorbed the refractory force that otherwise would have been sent up the drillstring to the surface equipment. With the jar and accelerator combination, the drillstring was freed in 45 min, with no damage to the topdrive. Drilling was able to proceed, and the operator averted a potential sidetrack operation.

Jar Placement Guidelines

Jar design and jar placement are the largest determining factors in the success or failure of a jarring operation. Yet, since their introduction, methods of jar deployment have depended more on driller experience and common practice than on engineering analysis—partly because industry professionals have insufficient understanding of the design and dynamics of jars. Because jars appear solid, like drill collars, users often assume they are as strong as drill collars. However, unlike drill collars, the internal workings of jars are complex, with numerous connections and inherent weakpoints. Additionally, the threads on the internal connections of jars are not as strong as the API threads used to connect joints of drillpipe.

Jarring success rates vary, but Schlumberger engineers have determined that 65% of failures are related to improper jar placement. The difference between proper and improper jar placement can translate to savings or losses of hundreds of millions of dollars per year for today's operators. Yet the intricacies of jar placement are typically misunderstood and often overlooked, and published recommendations on jar placement, based on proven successes, are difficult to find.[15]

Directional drilling companies and their clients often begin planning a directional well months in advance with attention to BHA designs that will propel the well from its starting point to TD. However, the jar is often placed in the BHA as an afterthought by engineers more concerned with placing the jar so it does not impede drilling than maximizing the impact and impulse that are critical to successful jarring. If engineers run a jar placement analysis, they often do so immediately prior to tripping, which greatly reduces chances a jar will be optimally placed.

The role of engineering analysis in determining proper jar placement is increasing, as is the need for running analysis earlier in the well planning process. Because the dynamic response of a drillstring to the various forces associated with jarring is complex, there is growing industry demand for jar placement software programs that are sophisticated in their functionality yet easy to use. Simple formulae may aid in the placement and use of jars; however, more-complex questions cannot be answered with simple engineering tools. These questions are best resolved through finite element analysis, which is integral to modern jar placement and analysis software programs. These programs can help the driller investigate and evaluate the effectiveness of the jarring operation at various jar locations in the BHA (next page).

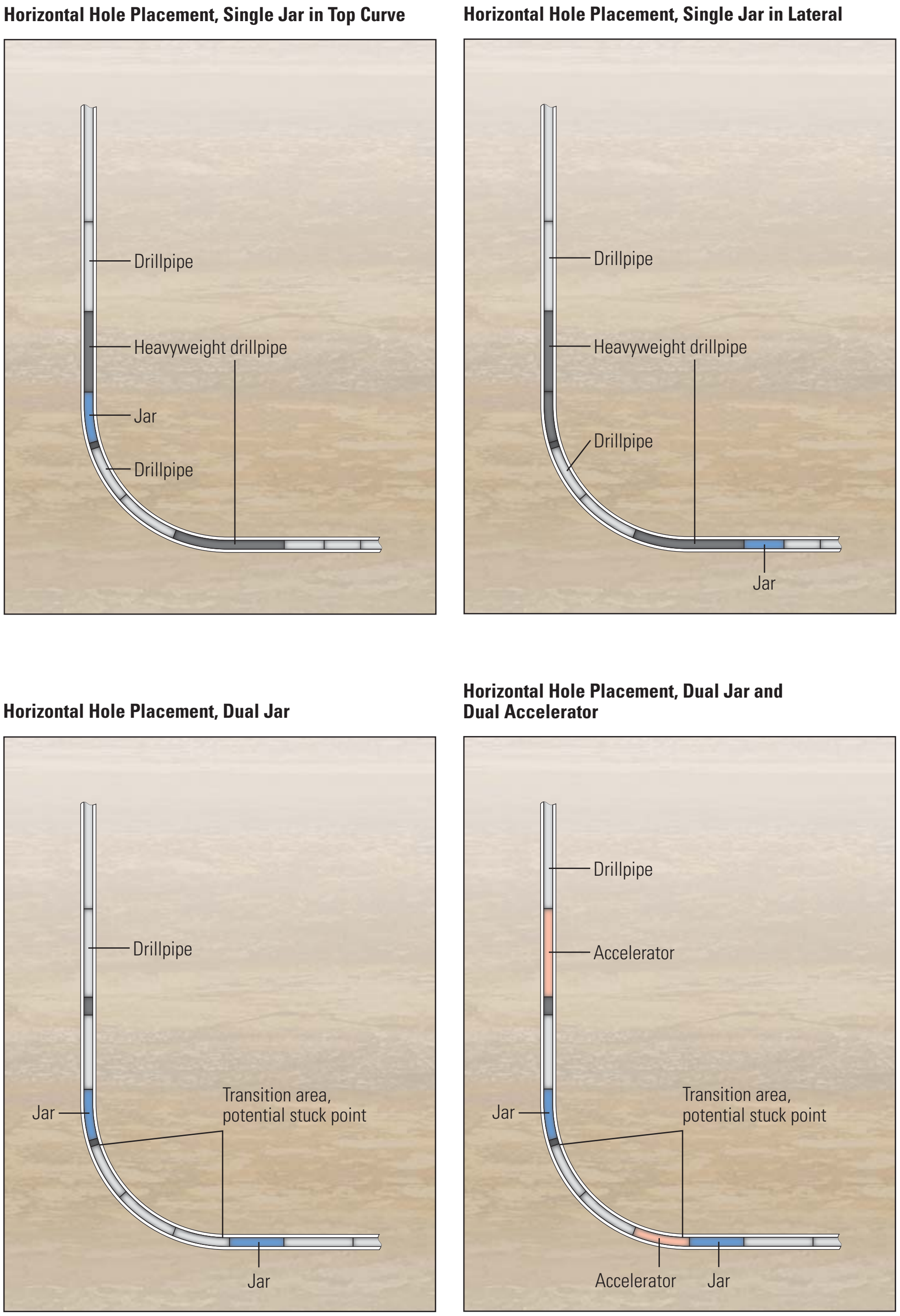
In the absence of jar placement software, certain guidelines have been developed for jar placement. The first step is to consider several basic questions:

- What mechanism is most likely to result in the drillstring becoming stuck?
- Is the drilling jar to be run in tension or compression?
- Where is the neutral point in relation to the drilling jar when drilling?
- How does pump pressure affect the jarring action?
- Are the BHA design and the drilling parameters within the specifications of the drilling jar and accelerator tool design constraints?
- Is the wellbore interval of concern vertical, deviated or horizontal?
- Are the drilling conditions downhole hostile? For example, are temperatures or pressures extremely high? Does the mud have high solids content? Is hydrogen sulfide [H_2S] present or suspected?

In addition to these basic questions, four fundamental guidelines help optimize jar placement. The first is to place a minimum of 10% to 20% of the expected jar overpull as hammer weight above the jar, which ensures that an adequate weight will produce optimal impacts. This hammer weight range has been found to provide the ideal mass while maintaining adequate velocity for delivering optimal impacts to the stuck point.

The second guideline is never place the jar too close to the neutral point. Many drillpipe failures occur around the neutral point because lateral vibrations tend to be more severe in this area. Additionally, placing the drilling jar too

15. Bouaziz S, Cummings J, Rebellon J, Barton S and Yankow A: "Advancements in Downhole Drilling Tool Placement for Highly Deviated Wells and ERD Applications," paper SPE 144030, presented at the SPE North American Unconventional Gas Conference and Exhibition, The Woodlands, Texas, USA, June 14–16, 2011.
16. Askew WE: "Computerized Drilling Jar Placement," paper IADC/SPE 14746, presented at the IADC/SPE Drilling Conference, Dallas, February 10–12, 1986.



^ Jar placement. High-angle and long-reach wells challenge conventional wisdom and assumptions about jar placement that are the legacy of many years of vertical drilling. For example, in horizontal wells, a single jar can be placed in either the upper curve (*top left*) or lateral section (*top right*). Placing a single jar in the upper curve protects the lower BHA and reduces the threat of not getting enough weight or overpull to operate the jar. However, jarring in the lateral section is relatively ineffective and impacts at the stuck point are almost always less than needed. Placing the jar in the horizontal section poses a greater risk of not being able to overcome the hole drag to fire the jar. More recently, operators are commonly placing jars in both the curve and the lateral (*bottom left*). Dual jar placement protects both the curve and the lateral while delivering stronger impacts at the stuck point. Adding an accelerator tool above each jar (*bottom right*) doubles the impacts of both jars by minimizing velocity losses caused by drag and increasing the efficiency of the lower jar. When running the dual jar option, it is important to maintain sufficient spacing between the two jars to avoid damaging the lower jar with impacts generated by the upper jar.

close to the neutral point will result in the jar continuously cycling between compression and tension, which can accelerate fatigue damage and decrease operational life; it may also cause the drilling jar to fire unexpectedly. Maintaining 20% of weight on bit (WOB) between the drilling jar and neutral point will ensure that the jar is outside the neutral point transition zone. Jar placement should be reconsidered when changes are made to WOB or the BHA.

The third and fourth guidelines are never to place stabilizers or other BHA components—if they have an outer diameter larger than that of the jar—above the drilling jar, and always to keep any stabilizer at least 28 m [92 ft] away from the drilling jar. A jar should never be used as a crossover between drill collars and HWDP or two different sizes of collars. High bending stresses that occur in these locations can increase the risk of tool damage.

Next Steps

The proliferation of highly deviated wells and extended-reach drilling associated with deepwater operations and the discovery and development of shale plays have brought about new and increased drilling challenges, including the possibility of pipe becoming stuck in two different sections of the wellbore. The art and experience that an oilfield fishing hand brings to fishing operations have a value that can never be overestimated. However, given the demands, risk and cost of today's drilling operations, experience may not be enough. Experience tends to be based on surface measurements, which may not reflect what is happening downhole.[16] Conventional knowledge and assumptions about jar placement may not apply to these new drilling environments.

While placing a jar in the BHA can act as a precaution against wellbore damage, lost time and costs associated with stuck pipe, the placement of the jar must be carefully considered and analyzed for its benefits to be fully realized. As drillers learn more about the intricacies of jarring, and as jar providers and drilling companies collaborate sooner and more strategically in the well planning process, jarring success rates will rise, and damage and costs associated with stuck pipe events will decline. —JF