**Backoff Basics**

Before the driller and pipe recovery specialist can free stuck pipe, they need one key piece of information: where is the free point?

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The free point of a stuck pipe is the deepest point at which the pipe can be recovered. It can be estimated using surface manipulation of the pipe and measured more accurately downhole using wireline tools.

An approximate measure of free pipe, developed in the mid-1930s and still used today, is based on how much the string stretches when pulled. The amount of stretch is proportional to the length of pipe that is free.

This is calculated by first ensuring that the drillpipe is in tension and marking its position relative to the drill floor. Then a known overpull is applied and the amount of stretch measured. The length of stretch, divided by the length of free pipe is equal to the weight of overpull, divided by the nominal weight per unit length of the string multiplied by a coefficient derived from the modulus of elasticity of the string.¹

In a related technique, two overpulls, of say 10 and 20 tons, are made. The difference between the two pulls and the two stretches is then used in the calculation. Elasticity coefficients can be found in a number of charts or nomographs. The larger the nominal weight of the string, the lesser the elasticity of the string.

The accuracy of such calculations is affected by friction, hole deviation and the amount of twist in the string. However, Elf reports that a result within 5 to 10% can be rapidly obtained and used as a starting point for more accurate measurements.²

To find the free point with greater accuracy, the industry has for many years employed wireline tools run inside the pipe. The simplest free point indicator tools have been around since the 1930s. They consist of a mandrel incorporating a single low-voltage strain gauge or microcell. At the top and bottom of the mandrel are friction springs or magnets, usually 52 in. [132 centimeters (cm)] apart, designed to hold the tool rigidly against the pipe during measurements.

When an upward pull or right-hand torque is applied at the surface, pipe above the stuck point twists or stretches. The strain gauge element measures the movement in the 52-in. section of pipe between the anchors or magnets. This movement induces a change in current that is measured at surface. When the tool is located in stuck pipe, surface manipulation induces no movement in the tool and therefore no change in current. Successive measurements at different depths can therefore be used to locate the depth of the free pipe to within about 1 ft [30 cm].

Prior to use, the tool has to be zeroed. This is achieved by taking a number of readings where the pipe is certainly free. This provides an average reading for free pipe. Values for stuck or partially stuck pipe will differ from this average.

Sonic tools have also been used to indirectly measure the free point in a manner similar to a cement bond log. The tool employs a single transmitter and receiver. The time-amplitude measuring system is designed to give preference to the signal conveyed by the pipe rather than the formation. At a stuck point, the received signal amplitude is reduced, giving a measure of pipe binding. This offers information on stuck intervals rather than stuck points.³

Since the mid-1980s, a more accurate method for finding where the pipe is stuck has been available. The Free Point Indicator Tool (FPIT) is run from a standard logging unit using seven-conductor cable (next page). It enables independent and simultaneous measurement of stretch and torque, monitoring transfer of torque (to the left or right) from the surface down the string (see "How the FPIT Tool Measures the Free Point," page 50). Measurement of both left and right torque allows testing the ability of a string to convey torque needed for backoff, the controlled unscrewing of a pipe joint. In some cases, a string can take right-hand torque deeper than left-hand torque, which can hamper a backoff.

The exact point chosen as the free point can vary according to what action is planned once the free point has been found.
The Free Point Indicator Tool (FPIT) sonde is equipped with a dual set of motorized anchors designed to transmit to two internal sensors any axial and angular deformations of the supporting wall. The anchors can operate within an internal diameter range of 1 1/2 to 8 in. [38 to 127 mm].

The FPIT tool is rated to 30,000 psi when run alone, or 20,000 psi when combined with an explosive backoff string. It can tolerate up to 350°F [177°C]. A collar-locating function is incorporated into the tool, which can often be run in combination with an explosive backoff string or with some types of explosive cutters.

For example, if the torque and stretch readings fall at different depths and the pipe is to be backed off, the usual practice is to choose the uppermost as the free point. This is because backoff requires both the ability to transmit torque and pull downhole. However, if the pipe is to be cut, the stretch readings, which are deeper, predominate because no torque transmission is required.

The first backoffs were performed by simply turning the pipe in reverse direction until it unscrewed. A version of this process may still be applied if the pipe is completely plugged—termed blind backoff. In the early 1940s, explosive cord was run on electric line for the first time. Initially, this was detonated prior to torquing the drillpipe with the aim of jarring the appropriate pipe joint. The process was found to be more successful if the pipe was reverse torqued before the explosive was detonated. Thus string shot came into existence.

There are three determinants of a successful backoff: a string shot blast sufficient to permit unscrewing of the pipe, distribution of string weight so that the joint to be unscrewed is neutral (or just slightly in tension) and adequate left torque at the backoff point prior to firing the string shot.

String shot consists of an appropriate number and length of high-explosive detonating cords, such as Primacord, attached to a metal bar about 3 ft [1 m] long. This is positioned next to the tool connection to be unscrewed. Reverse torque is applied to the pipe and the explosive detonated. The pressure shock waves produced by the explosion loosen the joint causing it to unscrew.

Shot sizes vary depending on the pipe to be backed off, the mud weight and backoff depth. As a rule, 100 grains [0.22 ounces] of explosive are required per inch of pipe outside diameter. Charts offer more accurate guidelines to determine shot size. Up to about seven strings each with 50 grains [0.11 ounces] of charge can be run below the FPIT tool. Beyond this, the blast imposes too severe a shock on the tool. In these cases, after the free point is identified, the tool is pulled out of the hole prior to running only the string shot and collar locator.

The weight that must be pulled during backoff can be calculated from the weight and buoyancy of the pipe that is to be recovered. Pulling this weight puts all joints above the backoff point in tension and the joint to be unscrewed in neutral. Joints in tension are less likely to unscrew accidentally. The common practice is then to add from 5000 lb to about 10% of the string weight to the pull. Some experts claim this additional weight makes up for friction losses between the pipe and the hole wall and for the small amount of loss that occurs when weight is transferred from elevators to slips. Another theory holds that extra pull must be applied that is equal to the hydrostatic pressure multiplied by the seal surface area of the joint to be unscrewed. A further practice sets the overpull at the weight of the free pipe in air—based on the logic that buoyancy is not effective in the stuck pipe. In any case, the end result is usually a pipe in some degree of tension.

In this article FPIT (Free Point Indicator Tool) is a mark of Schlumberger, and Primacord is a mark of the Ensign-Bickford Company.

How the FPIT Tool Measures the Free Point

With an outside diameter of 1 3/8 in. (3 cm), the Free Point Indicator tool design permits it to be used in pipe with an inside diameter up to 5 in. (12 cm). A recent modification has extended this to 7 in. (18 cm) for limited cases.

The tool uses two sets of arms that can be opened inside the pipe to give positive anchoring. These anchors replace the springs and magnets used in other wireline tools. Springs can encounter problems passing through small diameters, such as jars, while magnets cannot be used in nonmagnetic collars and plastic-lined tubulars. Both springs and magnets are difficult to pass down highly deviated wells. The anchors eliminate these problems and enable the tool to be used in horizontal wells and deployed from floating rigs. If, for some reason, the anchors lock and cannot be released after the measurements have been made, there are two shear pins set to release the arms at 1000 and 2000 lb of overpull on the wireline.

When both upper and lower anchors are opened, the pipe is gripped over an 84-in. (213-cm) spacing. Upper and lower subassemblies within that space then become axially and angularly mobile with respect to one another. The deformations transmitted to the tool are measured in microstrains per 1000 lb of pull. A microstrain is a measure of relative elongation of the pipe between tool anchors, reported as $10 \times 10^{-6}$ inches per inch. Measurement of such small distances is based on differential mutual induction between coils of a Kelvin transformer.

The transmitter coils are part of the upper assembly (attached to the top anchor), and the receiver coils are part of the lower assembly (attached to the bottom anchor). These move when the string is stretched or torqued and measure the change in magnetic field that occurs (above, right).

 FPIT stretch sensor (left) and torque sensor (right).

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<tr>
<th>Pipe in</th>
<th>Depth, ft</th>
<th>Free inch stretch</th>
<th>Free inch torque</th>
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<tr>
<td>-10</td>
<td>13500</td>
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The FPIT log. A is heavyweight drillpipe, B is drill collar and C is stabilizer.
How much backoff torque to apply depends on the type of pipe in the hole, pipe depth and hole deviation. Key considerations are the pipe’s grade and condition and the weight to be pulled. For steel drillpipe, recommendations range from one half to three-quarters of a turn per thousand feet up to 4000 ft [1220 m] depth, rising to a full rotation per thousand feet at a depth of over 9000 ft [2740 m].

Before reverse torque is applied, tightening of the joints is recommended to avoid accidentally backing off the wrong joint. This is carried out using 30% more torque to the right than will later be applied to the left. By imparting a known number of right-hand turns, working the pipe and then counting the number of turns that are conveyed back to the drill floor, the effectiveness of the tightening process can be monitored and continued until all turns come back. At this point the string is fully tightened. The FPIT tool can also be used to monitor the transmission of torque.

Left-hand turns, made before firing the string shot, also need to be worked downhole. Torque is applied in increments to avoid exceeding the limit of safe torque at surface. The pipe is worked between the maximum safe pull and the backoff pull. Keeping weight below the backoff pull minimizes the chance of unscrewing a joint higher up the hole.

With all the torque worked down, the string shot is fired and the tool moved some 30 ft up the hole. If the threaded connection has only partially unscrewed, the backoff is completed using the rotary table or tongs. To check that the pipe has backed off at the intended joint, a casing collar locator tool can be used to measure the depth of a collar one joint above the intended backoff point. After pulling the string 10 ft [3 m] out of hole, the depth of the same collar can be rechecked. If it has moved, the planned backoff has been achieved.

When the tool joints are weak or especially when torque cannot be transmitted all the way down in deep, highly deviated wells, the most practical way of separating the string is to sever it. To do this, explosive severing tools plus mechanical, chemical and jet cutters are used.4

For most drillpipe and all drill collars, explosive severing tools are most common. These use Primacord and explosive pellets in a tool that can be up to 5 ft [1.5 m] long. On detonation, the explosion is designed to blast the pipe apart rather than cut it. One of the key limitations of these tools is temperature. Above 400°F [204°C], high-temperature explosive has to be deployed; this yields reduced energy on detonation and seriously impairs severing success.

Chemical cutters are run on a wireline and generally used for smaller tubulars like tubing and small drillpipe. Their key advantage is the cleanliness of the cut, which aids fishing. There is no flare, burr or swelling and an overshoot can be used without first dressing the top of the pipe. The cutter is positioned using a collar locator. Then, a solid propellant is activated electrically and forces a chemical—usually bromine trifluoride—through a catalyst and then through nozzles onto the pipe walls.

Chemical cutters will not operate in dry pipe—they require at least 100 ft [30 m] of fluid above the anchored tool—and are of limited use when hydrostatic pressure exceeds 6000 psi or the mud is thick. But the main drawback of chemical cutters is their size—like explosive cutters, they generally require a clean, fullbore pipe.

Jet cutters differ from severing tools in their use of a shaped explosive charge. This is deployed on a wireline to slice through stuck pipe. As with chemical cutters, these tools are usually used to cut only smaller diameter tubulars. Such cuts leave the end of the pipe with a flare that has to be milled prior to fishing.

Mechanical cutters date from the 1950s when they were the primary method of cutting a string. Today, they are most frequently used on stuck tubing. Short sections of pipe may be cut externally by combining the cutters with a wash-pipe assembly. For an internal cut, the tools are run on a small-diameter work string—often sucker rods. The time taken to pick up this work string means that this technique has largely been superseded by the much faster wireline options. —CF