The Thru-Tubing Bridge Plug

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INTRODUCTION

What is a "workover"? Generally, the term "workover" creates a mental picture of a pulling unit, or workover rig in the process of pulling the production string so that remedial work can begin. Actually, a workover is any operation which attempts to reestablish or increase oil or gas production from a previously completed well.

There are many reasons why the production of a well may decline, or cease altogether. For each of these reasons, there may be several different approaches used in attempting to correct the problem. A factor not always considered is that many workovers can be accomplished without moving a rig, killing the well, or pulling the tubing.

Since the advent of permanent-type completions in 1953, many engineering advances have been made in thru-tubing devices. Perforating guns, bridge plugs, patching devices, diagnostic instruments, and wireline pressure control equipment have been greatly improved. From this evolution of improvements in all phases of operation, a workover system has evolved that can be termed an "Electrical Workover System"[1]. As the name implies, the heart of the system is the use of an electrical monocable with which the various services are run in the well. Applicable in many wells, this "electrical workover system" offers an effective and economical means of performing mechanical repairs, making reservoir evaluations, effecting recompletions, or stimulating production.

Where applicable, this system is more economical than conventional workover methods.

In addition to speed and economy, operational safety and dependability are assured through use of improved cables, pressure control equipment and portable derricks.

The electrical workover system can be thought of as having three interconnecting capabilities:

1. Operational Capability—to include cables, pressure control equipment, and derrick trucks.
2. Diagnostic Capability—Tools such as production logging devices, cement bond, gamma ray—neutron, and others provide valuable information for accurate definition of downhole problems and conditions existing in a well.
3. Repair Capability—After diagnosis and definition of a production problem the choice of remedial methods must be made. If diagnosis indicates that thru-tubing repair is applicable or reperforation is in order, substantial savings may be achieved.

This paper concerns itself with the "Thru-Tubing Bridge Plug" (hereafter referred to as "TTBP"), a device in the "Repair Capability" category. Although the TTBP has been around for a good number of years, it has been only in the past decade that significant advances in design have been made. These advances have led to the plug becoming one of the more important repair services that can be performed by electric wireline. The downhole conditions and problems that are met by TTBP's are also discussed. Design of an actual plug called the Schlumberger Plus Plug is reviewed. Clearer insight should be gained into the techniques used to build a plug in casing or open hole.

BACKGROUND

Two common problems that exist in producing wells are excessive water production and the necessity for abandonment of a depleted zone before completing a new zone in a well. It was early recognized that the use of a TTBP would be an ideal solution to these problems when considered from an economical and operational standpoint.

Early attempts to produce the necessary equipment for a reliable TTBP were many. The metal petal basket, or umbrella device, as shown in Fig. 1 was one product that evolved from these attempts. Basically, it operates as follows: The metal petal basket goes in the hole in a closed position, and is electromechanically opened to form an inverted "umbrella" shape. It then hooks or catches in a casing collar and thus becomes anchored in position. Sand and cement are then deposited on the "umbrella" with a dump bailer to form the bridging plug. Quite often, downhole conditions caused the plug to fail. Further improvements were deemed necessary before the industry would accept the technique as a reliable means of plugging-off an undesired zone.

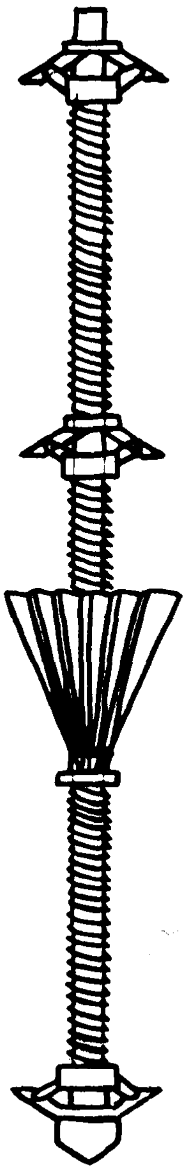


FIGURE 1

THRU-TUBING BRIDGE PLUG DEVELOPMENT

Schlumberger and other wireline service companies have each applied considerable engineering effort toward development of a reliable method of plugging of holes, open or cased, by going through tubing. Some basic design criteria for the TTBP were:

1. The plug must be able to pass through a minimum restriction of 1-25/32 in.
2. Movement of the plug while cement is hardening must be prevented.
3. Well fluids must be prevented from percolating through the cement plug while it is hardening.
4. The amount of well fluid commingling with the cement used to form the plug must be reduced.
5. Holes from 3-½ in. to 9-⅝ in. in size must be plugged off.
6. The TTBP should be easily drillable.

The most important design criteria were points 2 and 3 as these problems were believed to have been the major causes of failures in previous TTBP's. It has been well documented that percolation of fluids in a well continues for long periods of time even when the well is shut-in at the surface. A well dead at the surface is not necessarily dead downhole.

THE THRU-TUBING PLUS PLUG

At Schlumberger, the design approach was: Transport an inflatable bag through tubing into the well. Inflate the bag with cement that has not been contaminated by well fluids. Have a mechanically timed vent valve that allows fluid percolation through the plug while the cement in the bag is hardening, and then closes after a predetermined length of time. The bag, with hardened cement in it, now serves as a platform for dumping additional cement to form a high-strength plug.

Major design problems were the bag, mechanically timed vent valve, and perfection of a cement mixture that would retain its pumpability at high temperatures and pressures. The cement should expand as it hardens and must have low retrogression characteristics. The transport system must keep the cement from becoming contaminated with wellbore fluids.

The final device, termed "The Plus Plug", works as follows: The plug consists of a mandrel which supports an inflatable packer bag. The bag is inflated with cement from a positive displacement dump bailer. The bag serves as a support for the column of cement which forms the actual cement plug. The collapsed assembly will pass through a 1-25/32 in. seating nipple. The plug can be set at pressures up to 15,000 psi, temperatures to 350°F and in casing or open hole from 3-½ in. to 9-⅝ in.

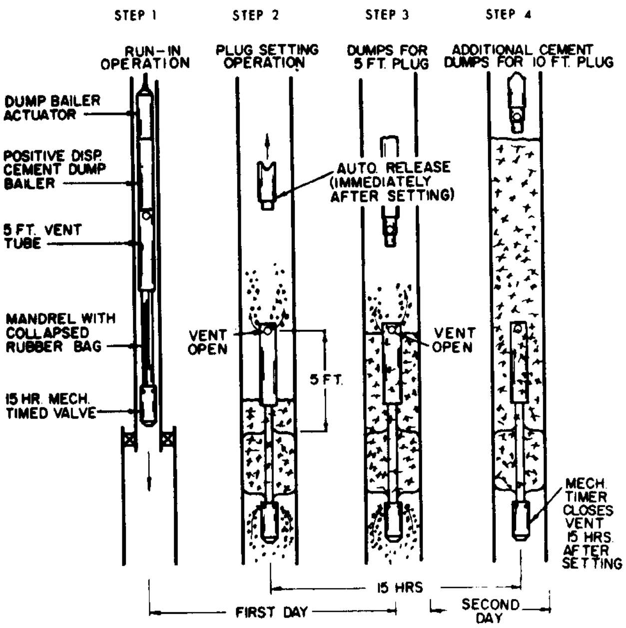
The sequence of operation for the Plus Plug is as follows: (see Fig. 2)

Step 1—The tool assembly, consisting of the dump bailer actuator, positive-displacement dump bailer, 5-ft vent tube, mandrel, the collapsed packer bag, and vent valve is lowered into the hole and positioned by collar locator at the appropriate depth.

Step 2—The positive-displacement dump bailer is actuated, forcing cement into the bag which inflates to the ID of the casing or wall of the hole. After the bag is filled, cement is dumped around the mandrel and vent tube. The dump bailer-actuator system then disengages and is retrieved from the hole.

Step 3—Subsequent dump bailer runs place an additional 5-ft column of cement around the vent tube. As the cement hardens into a rigid plug, any percolation of fluids, up or down, occurs through the venting system, thus allowing a solid plug to be formed.

Step 4—After 15 hours the timer closes the vent tube valve and the initial portion of the plug is in place. An additional five feet of cement is then dumped on top of this plug. Ten feet of cement on top of the cement-filled bag will hold a differential pressure of 5000 psi.



THRU-TUBING BRIDGE PLUG TOOL PRINCIPLE OF OPERATION

FIGURE 2

Major advantages in the system are:

1. Cement forced into the bag is never in contact with wellbore fluids; hence it does not become contaminated.
2. Cement is specially formulated to expand as it sets, causing continuous tightening of the plug until final curing takes place.
3. The vent passage through the plug permits well fluids to move through the plug without contaminating the initial 5-ft column of cement. It also eliminates the piston effect of moving fluids, which could displace the plug.
4. The closed vent tube valve prevents the movement of well fluids through the cement dumped on the final dump bailer runs.

PRECOMPLETION PLANNING FOR ELECTRICAL WORKOVERS

Proper thru-tubing bridge plug usage is achieved through precompletion planning. As stated previously, the plugs are used to reduce or eliminate water production, and to plug off depleted zones before perforating a new zone.

In precompletion planning, attention is paid to the minimum restrictions allowed in the production tubing, the placement of the production packer, and the length of the tail pipe. Having carefully considered these factors, the operator is in a position to perform electrical workovers such as the TTBP when well problems develop.

Quite often the TTBP is used in emergency-type situations. The operator is reaching for a quick solution to a problem that was not anticipated. Most often the alternate solution is to kill the well and pull tubing, a solution that can be extremely costly. Not only is there the expense of the rig workover but the possibility exists that the well may not produce again once it has been killed.

Even though an operator may never have the need for an electrical workover, he should plan the completion for use of the system whenever possible.

APPLICATIONS AND LIMITATIONS

The normal time required for setting a TTBP is two days. The first day is used rigging up surface equipment (wireline truck, derrick truck, BOP and riser) setting the plug and dumping the first five feet of cement. The operation is normally shut down overnight to allow hardening of cement, and in the case of the Plus Plug, to allow the vent tube valve to close. On the second day, the remaining five feet of cement is dumped, thus completing the 10 ft cement plug. If reperforating is required, it can be performed on the second or third day, the governing factors being well depth, pressure expected, and number of intervals to be perforated.

The most common failure experienced with the TTBP is up or down movement of plugs. If a plug moves down, another can be set on top of it. If it moves up and covers the zone of interest, it can usually be pumped or pushed down. Plugs move for reasons such as:

1. Excessive pressure buildup above or below the plug before cement becomes hard
2. Poor wall conditions
3. Contaminated cement will not set up.

The most common problems experienced in setting plugs are:

1. Crooked tubing will not allow passage of plug-setting equipment.
2. Highly deviated (< 30°) holes do not allow for easy building of a proper cement plug, especially in larger casings. (More cement dump runs must be made to get a reliable plug.)
3. Lack of reliable downhole information; e.g., minimum restrictions, position of gas lift valves, packer positions, etc.
4. Amount of cement that can be dumped on one run is governed by many factors; e.g., size of tubing, working pressure, derrick height, temperature, etc.
5. Set-up or curing time of cement is too slow.

It is good operating practice to run a slickline gauge before attempting a TTBP, or any electrical workover tool.

TTBP's come in all sizes, shapes and forms. Temperature and pressure ratings also vary. A wireline representative should be consulted when use of a TTBP is under consideration. The Schlumberger Plus Plug was designed to operate at pressures up to 15,000 psi and temperatures up to 350°F. In West Texas, Plus Plugs have been set at pressures of 7000 psi and temperatures up to 351°F. To date, the deepest Plus Plug in West Texas is set at a depth of 22,300 ft.

The following West Texas field examples are presented to illustrate applications of TTBP using the Plus Plug.

Example 1—Elimination of Water and Restoration of Production (Fig. 3)

An oil well in Lea County, New Mexico was drilled to 12,830 ft in the late 1960's, then selectively perforated from 12,657 ft to 12,820 ft. After producing water-free for a period of time, water production began and quickly became excessive.

In early 1971 a Packer Flowmeter/Fluid Analyzer Service was run to determine the source of water. The bottom three perforations were found to be producing 103 BWPD. The remaining perforations were contributing 8 BWPD. Total production at this time was 111 BWPD and 192 BOPD.

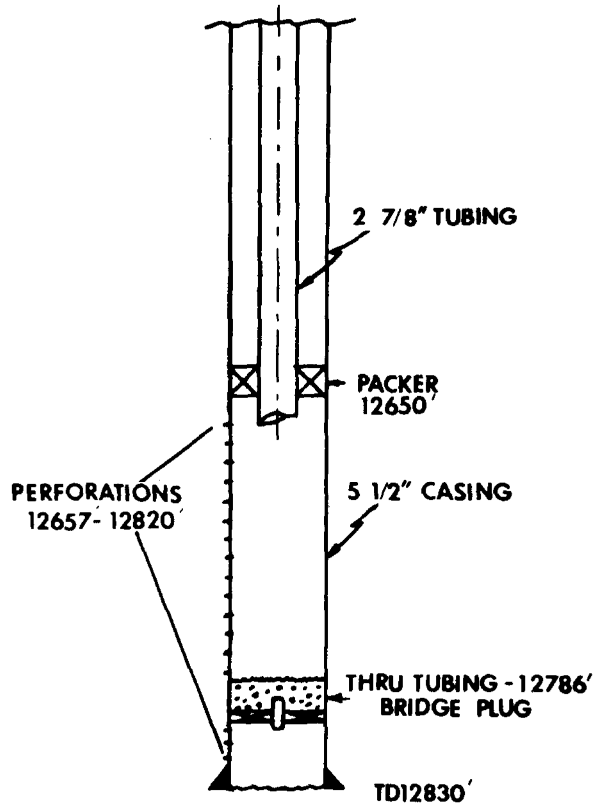


FIGURE 3

Water production continued to increase until mid-1971 when flow ceased due to excessive water.

A Thru-Tubing Plus Plug was set at a depth of 12,786 feet which was just above the three lower perforations.

After the plugging operation, the well was placed back on production and produced at a rate of 110 BOPD with no water. Cost of the plugging operation was $4300.

Example 2—Reduction in Water Production (Fig. 4)

This new Mexico well was completed as a gas producer in the middle 1960's. In 1967, production was 6 MMCFGPD, 200 BWPD, and 20 BOPD. Flowing pressure was 4200 psi, with a shut-in pressure of 6200 psi. The 200 BWPD was a source of concern because the well was originally water-free.

A Packer Flowmeter/Fluid Analyzer was run to determine the production profile. Results showed all zones to be producing water, with the lower perforations being the larger contributors. No remedial action was taken at this time.

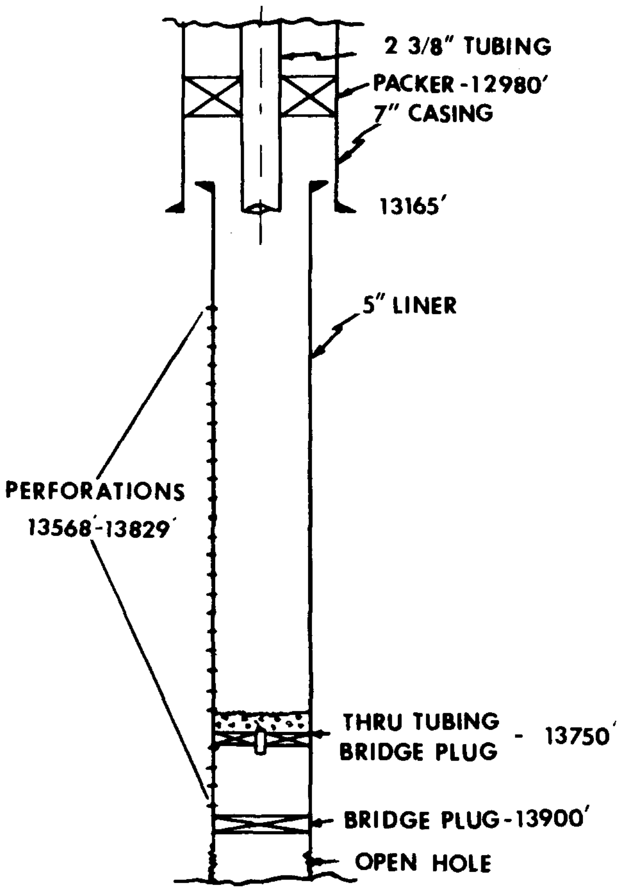


FIGURE 4

Water production continued to increase until in mid-1971 the well was making 960 BWPD, 5.5 MMCFPD and 8 BOPD. Flowing pressure was 4700 psi. It was then decided to perform an electrical workover, utilizing the TTBP, in an attempt to reduce the now excessive production of water.

The Thru-Tubing Plus Plug was run under pressure and set at 13,750 ft. This eliminated the four bottom perforations. The well was then placed back on production. No immediate change was observed in the production rate. After several weeks, water production began decreasing. At last report, in late 1971, the water production had decreased to 450 BWPD, with gas and oil holding at original rates.

In this well it appears that some of the upper perforated intervals became charged with water from the lower intervals. Thus, as these intervals deplete themselves of charged water, the well returns to a normal water production rate.

A conventional workover on this well would have called for killing the well, pulling the tubing and packer, squeezing, reperforating, and reestablishing production. Cost of the electrical workover utilizing the TTBP was $6000.

Example 3—Restoration of Production and Elimination of Water (Fig. 5)

In this example, it took both the electrical workover system and conventional workover system to put a West Texas well back on the line.

The well was drilled in the 1940's and completed as a dual oil well. Both zones produced as expected for many years and then excessive water production began in each zone. In late 1970, the lower zone production was 163 BOPD and 94 BWPD. However, water production continued to increase until early 1971, when the lower zone quit flowing. It was decided at this time to set a TTBP to eliminate the water and get the lower zone back on production.

The lower zone was originally an openhole completion. Fortunately, the production string had been set into the top of the producing formation. This allowed setting a TTBP and reperforating, (a good example of the importance of complete well records).

Before setting the TTBP it was necessary to cut off the bottom of the long tubing string with a tubing cutter because of a "no-go" device. After doing this, the Thru Tubing Plus Plug was run and set at the bottom of the 7-in. production string. Working room was very close. The bottom of the 7-in. string was at 9646 ft, so the top of the TTBP was set at 9644-½ ft. A 7-ft cement plug was then deposited on the bag, which put the top of the plug at 9637-½ ft. The well was then perforated from 9632-9636 ft, one hole per foot. The well was then put on production at a rate of 118 BOPD with no water.

After producing for several months the lower zone began to develop a high GOR. The upper zone production went to water.

A workover rig was moved onto the well. The well was killed; both tubing strings and the packer were removed. A 5-in., 15-lb/ft liner was run from 9534 ft to 9799 ft, and cemented with 100 sacks. The well was then completed as a single from 10,686 ft to 10,758 ft; in all, six holes were opened in this interval.

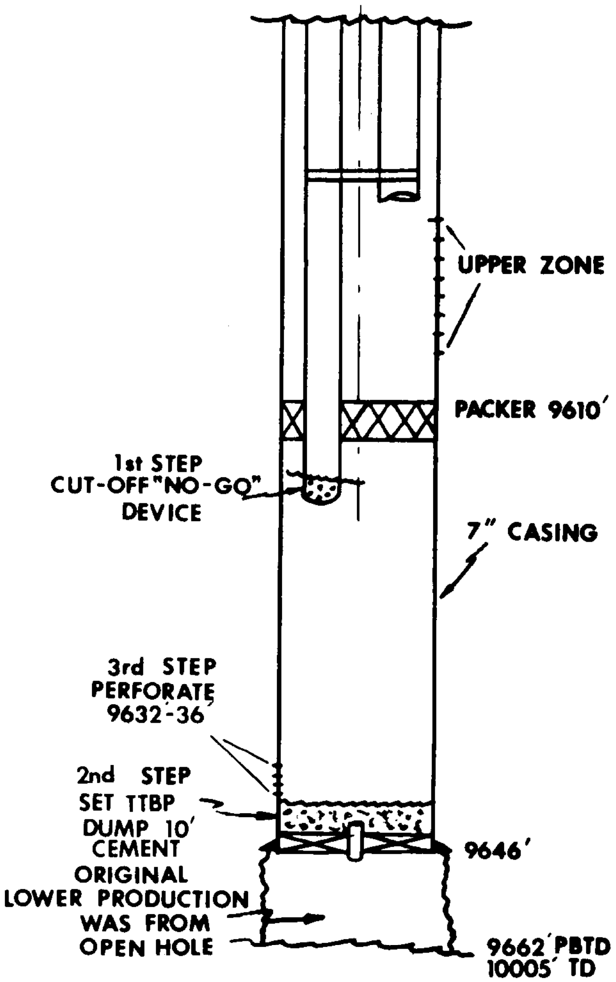


FIGURE 5

A production packer was set and tubing run. The interval was acidized and the well swabbed. Swabbing produced a flow of 134 BWPD and 87 BOPD. It was decided to set a Thru-Tubing Plus Plug above the bottom four intervals in an attempt to eliminate the water.

After setting the Plus Plug at 9724 ft and dumping 10 ft of cement, the well was swabbed and for six hours flowed 110 BOPD, but then went to a rate of 63 BOPD and 30 BWPD. The well was then acidized and began producing at a rate of 162 BOPD and no water.

At a later date, the well was perforated higher and now produces at a rate of 410 BOPD with no water. Perseverence paid off.

Example 4—Recompletion (Fig. 6)

The versatility of electrical workover systems is demonstrated in this West Texas example.

A dual oil well, drilled in the late 1940's lost its lower zone production in early 1971. The last potential, run in 1968, had shown the lower zone to be producing at a rate of 185 BOPD and 53 BWPD. It was decided to utilize a TTBP to eliminate the water and get the well back on production.

It was first necessary to cut off the bottom of the long tubing string to eliminate a "no-go" device. After doing this, the Thru-Tubing Plus Plug was set at 9675 ft and 10 ft of cement was dumped on the plug. Original production had been from zones located between 9687 ft to 9751 ft.

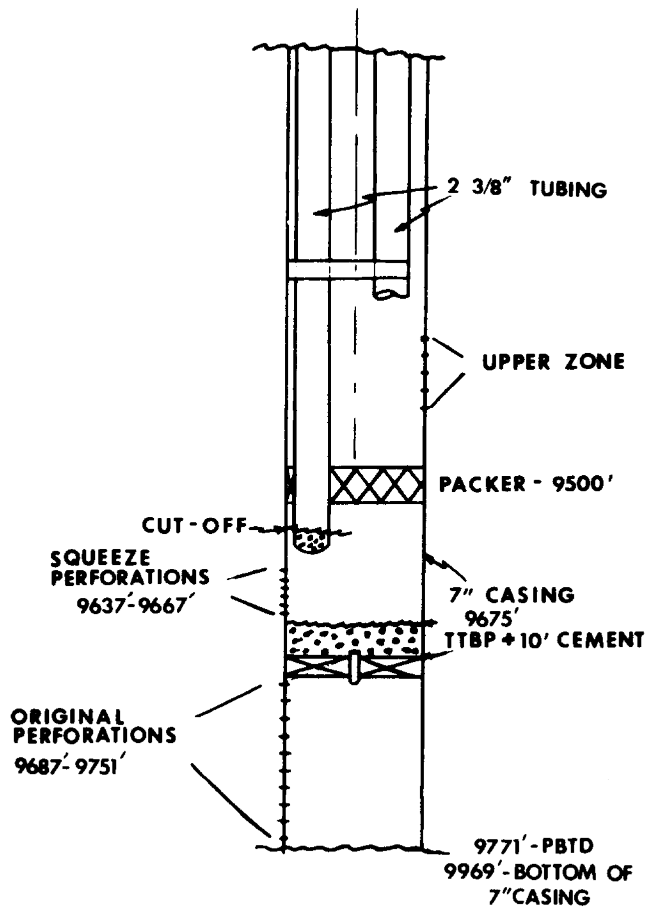


FIGURE 6

During the original completion of the well, squeeze perforations had been made from 9637 ft to 9667 ft. By use of a Thru-Tubing Dump Bailer, acid was deposited opposite these perforations and pressure was applied to the long string. The old perforations broke down and took the acid. The well then came in at 197 BOPD from this lower zone with no water.

SUMMARY

The electrical workover system provides an economical method for performing workovers. Future use of the system should be considered during precompletion planning for all wells.

The Thru-Tubing Bridge Plug is one of many devices that can be used during an "electrical workover". Its principal uses are for plugging back to recomplete and to eliminate water production. Through improvements in hardware and technique, the device has acquired a high degree of reliability.

REFERENCE

1. Fischer, J. S., Waelder, F. J., and McGuire, J. A.: Improving Production with Electrical Workover Systems, SPE 2414, July 1969.