Production Improvement with Electrical Workover Systems

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INTRODUCTION

What is a workover? In the minds of many people in our industry, the term "workover" creates a mental picture of a workover rig in the process of pulling the production string "so we can get down to work". Actually, a workover is any operation which tries to reestablish or to increase oil or gas production from a previously completed well.

There are many reasons why the production of a well may have declined or ceased altogether. For each of these problems, there may be several different methods available for correction of the problem. What is not always considered is that many workovers may be accomplished without moving in a rig, killing the well, or pulling the tubing.

Since the advent of permanent-type completion techniques in 1953, many advances have been made in thru-tubing perforators, bridge plugs, patching devices, and diagnostic instruments. Great strides have also been made in surface pressure-control equipment. Today a complete package of thru-tubing electrical wireline services constitutes an Electrical Workover System. Applicable in many wells, this electrical workover system offers an effective and economical means to perform mechanical repairs, to make reservoir evaluations, to effect recompletions, or to stimulate production. Where applicable, this system is more economical than conventional methods.

CAPABILITIES

Interest in thru-tubing workover procedures has grown for several reasons. In addition to speed and economy, operational safety and dependability are assured through use of improved cables, pressure control equipment, and portable derricks. Diagnostic logs pinpoint production problems. And, to remedy these problems, thru-tubing devices effect repairs.

Thus, the electrical workover system is made up of three interconnected capabilities:

1. operational capability
2. diagnostic capability
3. repair capability

Operational Capability

Rugged small-diameter electrical cables, improved surface pressure-control equipment, and small portable derrick trucks (Fig. 1) permit operations in wells below 20,000 feet and at surface pressures to 15,000 psi. Small, skid-mounted equipment and portable derricks are now used routinely in offshore wells.[1] Surface pressure-control equipment has progressed from the mechanical packing gland system, through development of the flow tube (Fig. 2), to the present Dynamic Well Control, which has a working pressure of 15,000 psi with a test rating of 22,500 psi. Operations can be performed with virtually no cable friction and no loss of wellbore fluids, even in a dry gas environment.[2]

Operations are also performed on a routine basis in pumping wells. However, for such operations, offset wellheads must be installed and the tubing anchors removed. With adequate space for tool passage between the tubing and casing, wireline tools may then be safely introduced through the tubing-casing annulus.

Diagnostic Capability

Diagnostic techniques have progressed from the first thru-tubing gamma-ray logging tools until today there is a large assortment of evaluation tools. Thru-tubing gamma ray-neutron, cement bond, production logging tools,[3,4] and a new Thermal Decay Time Tool* provide much valuable information for the engineer involved in remedial work. These diagnostic tools permit accurate definition of downhole problems and conditions so that wireline repair techniques may be applied in the most efficient manner. An ac-

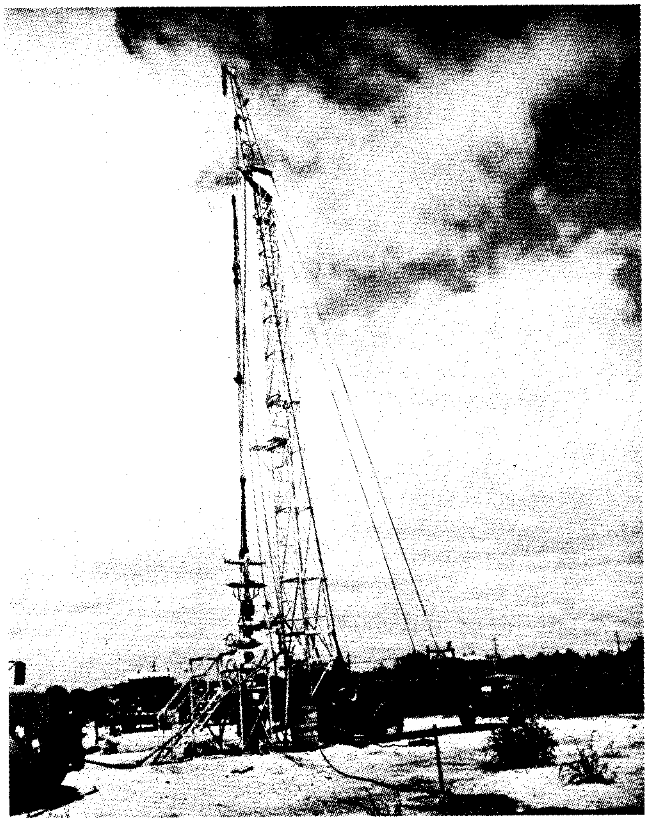

FIGURE 1

Typical Set-Up of Electrical Workover Systems in Operation. Shows Hoist Unit, Portable Derrick Truck and Pressure Control Assembly.

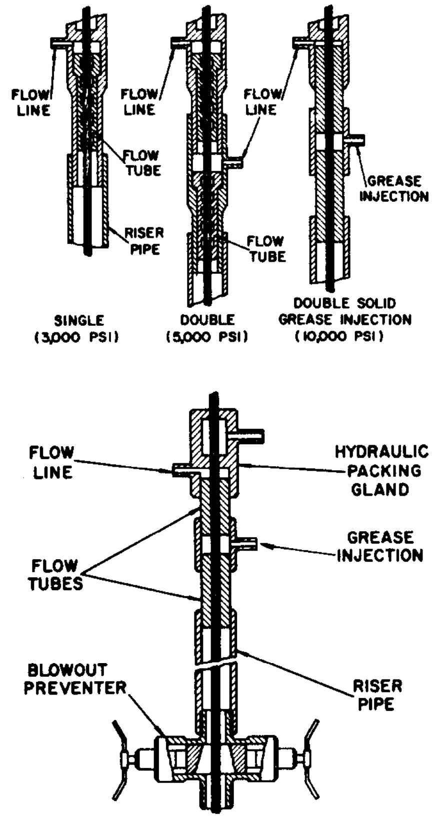

FIGURE 2

Evolution of Flow Tube Designs.

curate knowledge of the downhole situation is important for efficient application of repair procedures.

*A new device which promises to be very useful in remedial work is the Thermal Decay Time Logging Tool,[5,6] the TDT.™ The application of this diagnostic tool is expanded by the recent introduction of a thru-tubing version, which is 1-11/16 in. in diameter.

Thermal neutron decay time (T) is a parameter particularly sensitive to the amount of chlorine in the formation water. Other factors being equal, T is a function of water saturation and, in a manner analogous to resistivity, can be used to detect hydrocarbons. When porosity and water salinity are known, water saturation can be computed. The TDT tool emits bursts of high-energy neutrons, then measures the time (T) required for a certain percentage of them to be absorbed by the formation. Borehole and casing effects are usually negligible with this logging system.

The TDT curve is very similar in appearance to resistivity curves, thus these logs are easily correlated with open-hole logs run in the same well and with logs from adjacent wells.

The TDT log is also very useful in detecting changes in hydrocarbon saturation in formations in old fields. In Fig. 3 the TDT was run eight years after the electrical survey. Production from the lower zone has raised the oil-water contact to a point about midway in the sand. This information permits an estimate of the remaining life of the well, as well as a calculation of the residual oil saturation in the depleted section. Even more interesting is an upper zone located some 300 feet above the lower pay. The 1960 electrical survey showed it to be water-bearing with a show at the top. The 1968 TDT shows a distinct oil-water contact ten feet lower. The zone apparently has been charged with oil from another source, possibly from the pay sand below.

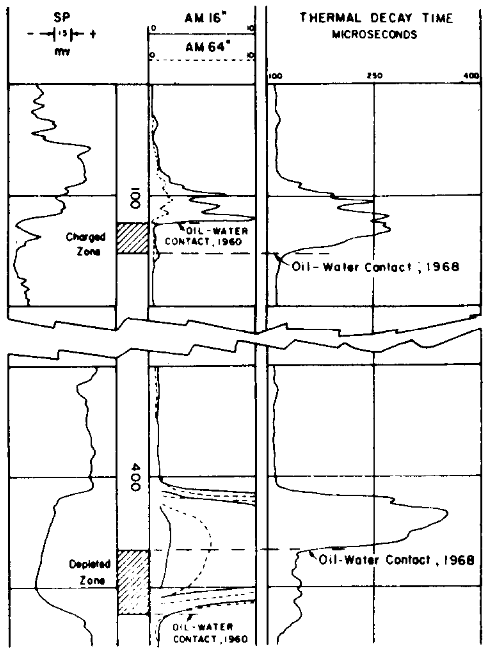

FIGURE 3

Changing Oil-Water Contacts Indicated by Comparison of TDT Log With Electrical Survey Which Was Run Eight Years Earlier.

The TDT tool is available in both a 3-3/8-in. diameter for casing work and a 1-11/16-in. size for logging through 2-in. production tubing. The small-diameter tool can be used to log below packers and also through the tubing and casing with virtually no loss of quality. This makes it very useful as a reservoir monitoring device. Final evaluation of old wells prior to abandonment can be done economically, particularly when performed as a multi-well project. Such evaluations are augmented by the use of the wireline formation tester to check potentially productive intervals revealed by the thermal decay time log.

Repair Capability

After diagnosis and definition of a production problem, the choice of remedial methods must be made. In many cases there will be several approaches from which to choose. If diagnosis indicates that thru-tubing repair is applicable, substantial savings may be achieved. However, even when a rig must be moved onto the well, the knowledge of producing conditions downhole simplifies repair procedures.

In many cases, where water or gas shut-off is desired or a depleted zone is to be abandoned before opening a new zone, a new thru-tubing bridge plug called the PLUS PLUG offers significant advantages.

This thru-tubing bridge plug employs a new concept. The design eliminates the possibility of the cement plug being contaminated or disturbed by movement of well fluids while setting up. This percolation of fluids which occurs in most wells, even when they are shut in at the surface, is believed to have been the major cause of failure of previous types of thru-tubing plugs.

The plug (Fig. 4) consists of a mandrel which supports an inflatable bag. The bag is inflated with cement by a new positive-displacement dump bailer and supports the column of cement which forms the plug. The entire plug and setting assembly will pass through a 1-25/32 in. seating nipple. The plug can be set at pressures up to 15,000 psi and temperatures to 300°F in casings from 3-1/2 in. to 9-5/8 in.

The sequence of operation of this thru-tubing bridge plug is shown in Fig. 5.

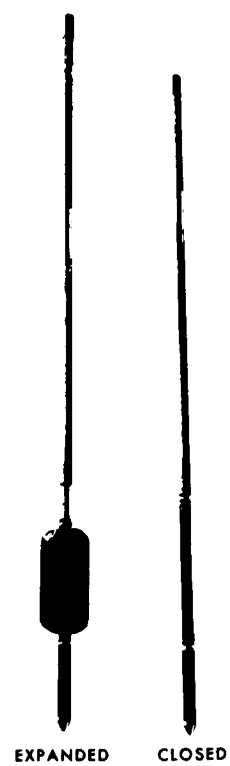

FIGURE 4

Plus Plug—A New Through Tubing Bridge Plug.

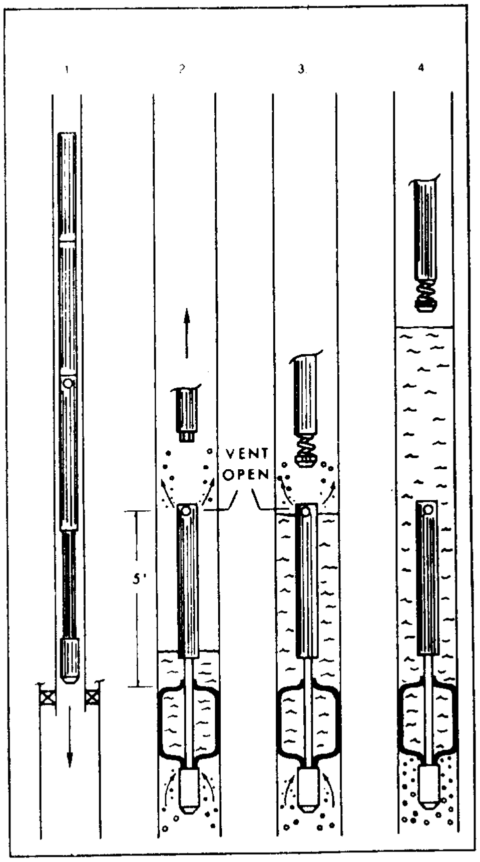

FIGURE 5

Operational Sequence in Setting a Plus Plug.

Step 1—The tool assembly—consisting of the dump bailer actuator, positive-displacement dump bailer, five-foot vent tube, mandrel supporting the collapsed packer bag, and mechanically timed vent valve—is positioned in the well.

Step 2—The positive - displacement dump bailer is actuated, forcing cement into the bag which inflates to the ID of the casing. The remainder of the cement is dumped around the mandrel and vent tube as the dump bailer automatically disengages for retrieval.

Step 3—Subsequent dump bailer runs place an additional five-foot column of cement around the vent tube, which is held open by a mechanically timed valve.

Step 4—After 18 hours the timer closes the vent tube valve. The expanding-type cement has now set up within the plug bag and in the column about the vent tube. An additional five feet of cement is then dumped on top of the preliminary plug and cement assembly. With ten feet of cement set on top of the cement-filled bag, the assembly will hold a differential pressure of 5000 psi. A number of advantages have been incorporated in the plug design. The cement forced into the bag is never in contact with wellbore fluids; hence it does not become contaminated. The cement is specially formulated to expand as it sets, causing continuous tightening of the plug until final curing has taken place. The vent hole through the plug permits well fluids to move through the plug without contaminating the initial five-foot column of cement about the vent tube. Finally, the mechanically timed shut-off valve prevents the movement of well fluids through the cement dumped on the final dump bailer runs.

Thru-tubing electrical repair capability now includes:

1. Reperforating old zones for stimulation. Reperforating under the ideal conditions of differential pressure into the well bore and in compatible fluid has given striking increases in deliverability in many oil and gas wells. Improved charges are used in fully retrievable steel carrier guns which are rugged, leave no debris, and cause no casing damage.
2. Perforating new sections. New zones can be opened after plugging back, or additional sections in a producing zone may be perforated.
3. A depleted zone may be abandoned with the thru-tubing bridge plug.
4. Water can be shut off with the same type of plug. The plug can be set in perforations.
5. Tubing extensions and "no go" nipples can be shot off with jet cutting tools.
6. Bridge plugs can be set in tubing.
7. Circulation can be established outside of the tubing with guns which will perforate the tubing but not the casing.
8. Tubing may be perforated for the installation of gas lift valves with these same guns.

9. Tubing stops, or artificial bottoms or reference points, for setting slick line tools such as straddle packoffs may be set with the accuracy of electrical cable operations.

FIELD EXAMPLES

Electrical workover systems have been used to solve many common production problems. Among these are:

1. Production problems involving too little production or the wrong kind of production, as in the high water-cut production of Example 1.
2. Reservoir evaluation and studies of the production mechanism, such as the changing oil-water contacts seen in Fig. 2.
3. Problems involving secondary recovery or pressure maintenance, as in the gas break-through problem of Example 2.
4. Reservoir efficiency and deliverability problems as illustrated by opening additional section in Example 3 and by perforating tubing for higher flow rates in Example 4.
5. Mechanical problems as illustrated by the tubing repair in Example 5.
6. Production problems involving high water-cut production as shown in Example 6, for a West Texas gas well.

Example 1

Example 1 (Fig. 6) illustrates how pinpoint diagnosis was the key to an economical workover. Using only thru-tubing electrical workover techniques, the oil production on this well was increased from 135 to 322 BPD and the water-cut was reduced from 10 per cent to 1.5 per cent. This Southern Oklahoma well is located close to the oil-water contact in an active water-drive reservoir. The oil production had shown marked decline as the water-cut increased. The operator needed to know where the water was breaking through and if it could be successfully shut off in order to conserve the reservoir energy and improve the oil production.

With a Packer Flowmeter-Fluid Analyzer,[3] a production profile was run to locate the water, oil, and gas entries into the casing. This profile showed all water production to be from the zone at 3887-3908 ft. A thru-tubing bridge plug was then set at 3885 ft and a cement plug was built to 3876 ft. After the well was producing at a stable rate, a second production profile was run using the packer flowmeter-fluid analyzer.

The second profile indicated that the zone 3887-3809 ft had been satisfactorily shut off and that the oil production had increased to 322 BPD. The flowing tubing pressure had also increased from 250 psi to 375 psi due to the reduction in water-cut from 10 per cent to 1.5 per cent. The workover expense paid out in six days based on the oil production increase.

Example 2

This example (Fig. 7) is from a Southern Oklahoma field. This thick sandstone reservoir is being repressured by gas injection. The gas-oil ratio in the production wells suddenly increased, indicating possible gas breakthrough. The operator needed to know which of the four perforated zones was producing most of the gas. Conventional workover methods using tubing and packers to isolate and test each zone would have been both expensive and dangerous, and would have taken several days.

Instead, the operator decided to use an electrical wireline tool to locate the gas-breakthrough zone. With the well flowing at a rate of 250 BOPD plus 1.3 MMCF/D (GOR 5200:1), a gradiomanometer survey[3] was run. Interpretation of this survey indicated that most of the gas was entering from the zone at 4926-4929 ft. The operator had received the needed information without workover rig cost or loss of production. However, he then elected to kill the well and pull the tubing and packer so that a wireline casing bridge plug could be set above the gas breakthrough zone. The tubing and packer were reinstalled and the well returned to production. Recent tests showed 107 BOPD plus 43 MCFG/D, a GOR of 400:1.

Example 3

Example 3 (Fig. 8) illustrates one of the simplest types of electrical workover—perforating additional intervals. However, a 900 per cent increase in oil and a 250 per cent increase in gas production from a 13-year old well in Central Oklahoma qualifies this as a very successful

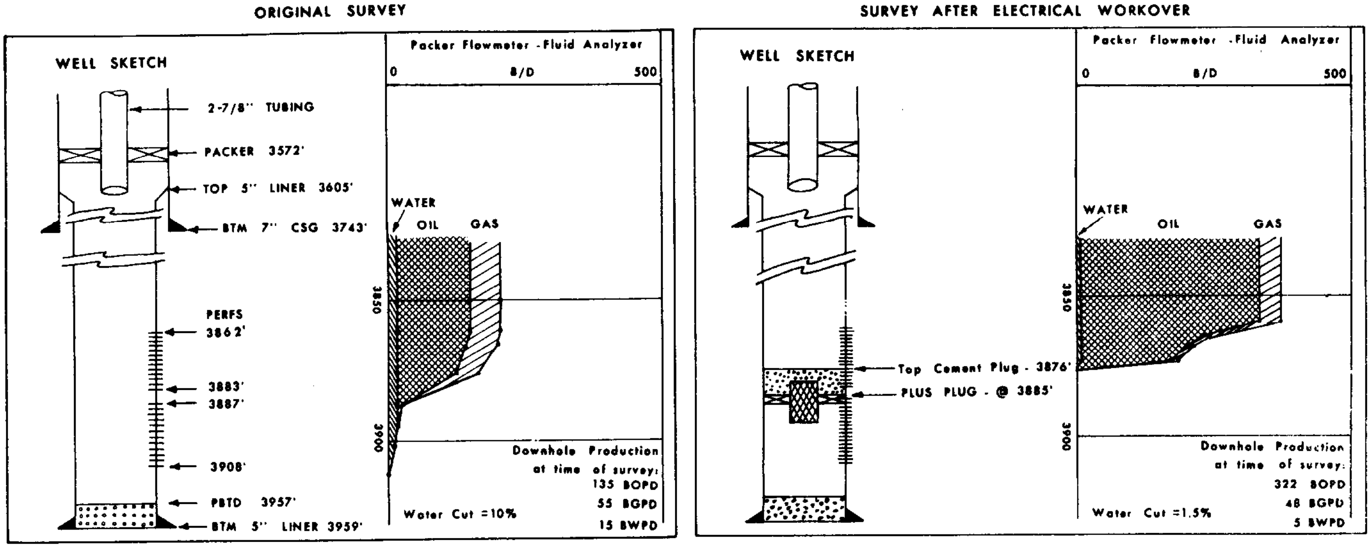

FIGURE 6

Example 1

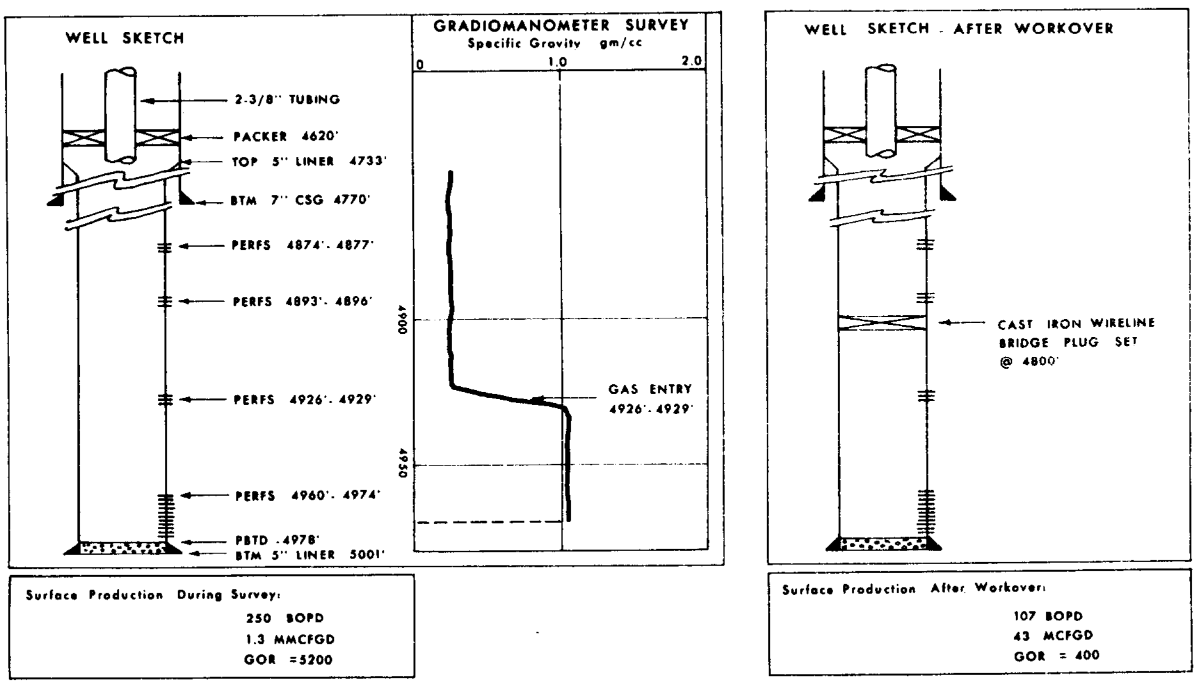

FIGURE 7

Example 2

workover. Additional success is evidenced by the fact that all work was done through tubing (and between two production packers) without interruption of well flow or workover rig expense.

The well was originally completed as a dual in the Bromide and Oil Creek sands. Production from the Bromide sand (short string) had declined to 5 BOPD and 300 MCFG/D. Examination of the microlog indicated four zones of porosity and permeability in the Upper Bromide that had not been perforated at the time of original completion. The operator decided to perforate these zones using thru-tubing guns. A mechanical orienting tool was used to avoid damage to the long string. The four zones, as indicated on the well sketch, were perforated with two Hyper-Jets per foot.

The short string production increased to 45 BOPD and 760 MCFG/D. These wireline tools eliminated the expense of removing the tubing and packers, and saved about $15,000 on the workover expense. The workover paid out in 60 days.

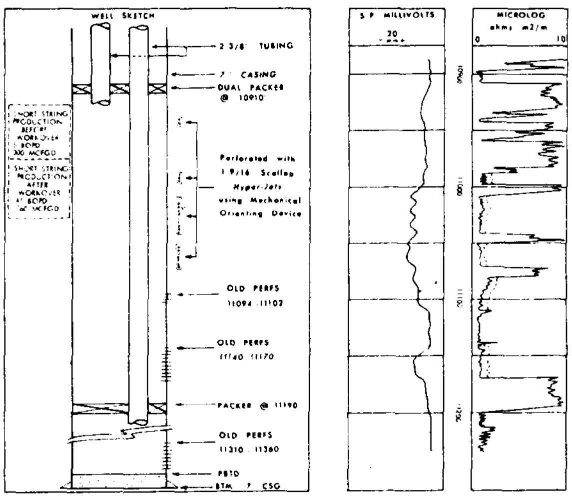

FIGURE 8

Example 3

Example 4

This example (Fig. 9) is from the Arkoma Basin in Eastern Oklahoma. The operator had several gas wells in this area and needed an increase in deliverability to satisfy purchase agreements. Most of the wells were producing through 2-3/8-in. tubing set on a permanent packer. It was suspected that the deliverability was seriously restricted by friction loss in the tubing.

To replace or remove the tubing and packer would be expensive, time consuming, and probably injurious to the formation. For these reasons the operator decided to produce through both the tubing and the tubing-casing annulus, thus reducing the friction loss and hopefully increasing deliverability.

The example well was producing at an average rate of 2 MMCFG/D. A 1-9/16-in. Scallop Tubing Puncher was lowered into the tubing on electrical wireline and eight shaped charge punchers were shot in the interval 8534-8536 ft (22 feet above the packer). Producing through both the tubing and the tubing-casing annulus, the well increased to an average 11 MMCFG/D. Four other wells in the same area were given similar electrical wireline workovers with production increases from 200 to 500 per cent. The operator's deliverability problem was solved.

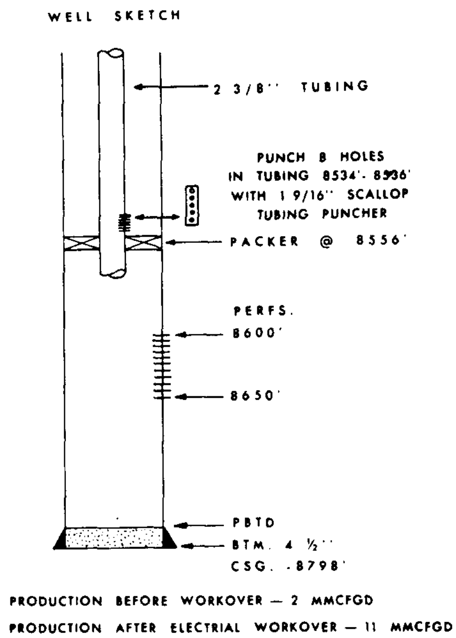

FIGURE 9

Example 4

Example 5

Example 5 (Fig. 10) is a dual completion gas well in Northern Louisiana. Several years after completion, pressure testing indicated communication between the two producing zones. The well was shut in awaiting mechanical repair. Due to the well's location, depth, and mechanical complexity, the cost estimate for a conventional workover was about $80,000.

Before commencing a conventional workover, the operator decided to use wireline tools to check the long tubing string for leaks. With the short string flowing at 3 MMCFG/D, a 1-11/16-in. OD continuous flowmeter[3] was run in the long string. The dynamic well control system was used to insure no surface production from the long string during the survey.

The spinner response indicated zero fluid flow until the tool reached a depth of 12,474 feet. At this point the spinner rate increased rapidly, indicating a high fluid flow. This rate remained constant to the bottom of the tubing. Interpretation of the flowmeter survey indicated a leak in the long tubing string at 12,474 feet allowing the production from the lower zone to commingle with that of the upper zone. Examination of the spinner response and the cable tension recording in the interval 12,474 ft-12,495 ft also showed that the leak was being partially choked as the tool moved by the hole. From these data it was deduced that the hole was relatively small.

Using the information about the location and size of the leak, the operator decided to attempt an electrical wireline repair of the tubing. A Type "G" tubing anchor was set at 12,480 feet, and a 12-foot Type "W" pack-off was installed across the leak. Both tubing strings were put back on production and pressure data indicated that the communication was stopped. The total workover cost was paid out by 30 hours of production.

Example 6

Example 6 (Fig. 11) is a gas well completed in the Ellenburger formation of West Texas. Several months after completion this well continued to produce water at a rate of 846 BWPD with 7.6 MMCFG/D. Since the total amount of water produced exceeded the volume of acid water used in the initial completion, the client was convinced the water was formation water. A Production Continuous Tool (PCT) was run to determine the zones of gas and water entry.

The PCT is a production logging tool consisting of a continuous flowmeter, gradiomanometer, high resolution thermometer, and a manometer or surface recording pressure device which records the selected sensors sequentially with one trip into the well.

The continuous flowmeter indicated a large number of perforations producing fluid. The response of the gradiomanometer and flowmeter curves indicate that the bottom four zones were producing water, and that gas was coming from the upper seven zones.

Using this information the operator began plans for an attempt to shut off the water. Due to the well's depth and mechanical complexity, an estimated cost using conventional workover methods approached $100,000. Therefore, it was decided to set a thru-tubing bridge plug between the sixth and seventh producing zone, thus, reducing the workover cost to approximately $5500.

The well was allowed to produce approximately one month. At the end of this period the water production had risen to 990 BPD with 4.4 MMCFG/D. A second survey was run to determine if the plug was leaking or if the water was

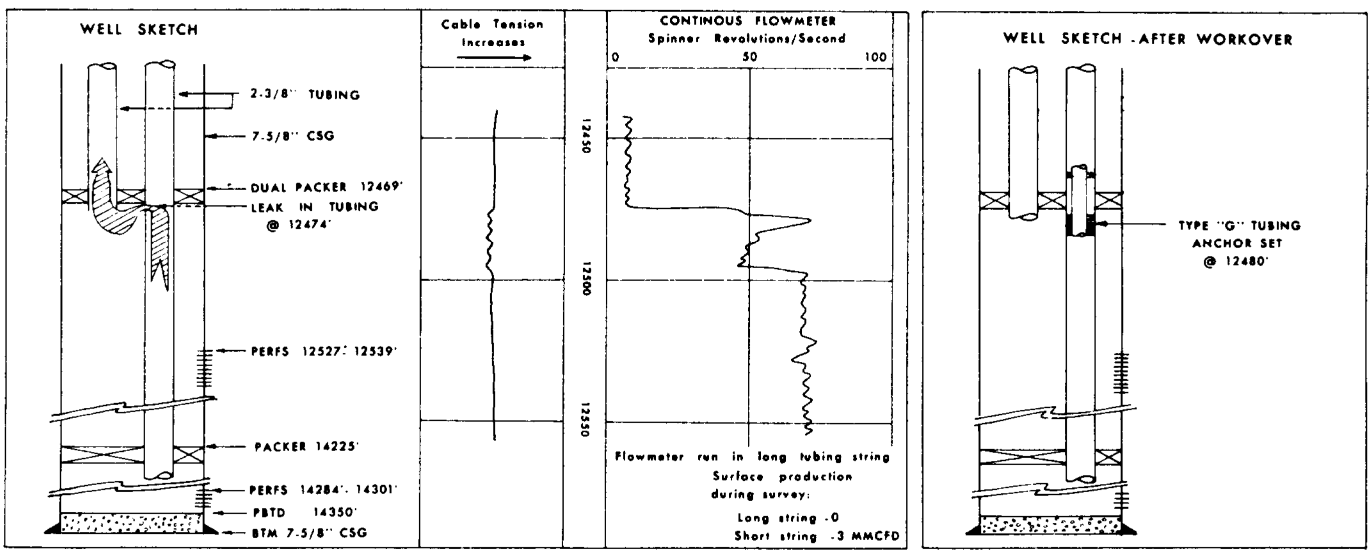

FIGURE 10

Example 5

channeling outside the pipe from below the plug. From the flowmeter and gradiomanometer surveys it was determined that the plug was not leaking; they did show, however, that the first perforation above the plug was producing water, and that gas was being produced from the remaining perforations above the plug. Even though the casing plug back did not successfully eliminate the water, the customer was well satisfied with the performance of the thru-tubing bridge plug and that of the production continuous tool. They understood the gamble involved and felt the chance for success was well worth the risk.

The word "note" on the example is used to identify the same perforation shown in each example.

SUMMARY

Electrical Workover Systems is a workover package which in many cases can improve production from a well by using only electrical wireline techniques. Operational safety and dependability are assured by improved cables, pressure control equipment, and derricks. Combining these operational facilities with diagnostic and repair capabilities today provides the industry with a complete electrical workover system. These coordinated services are available and can

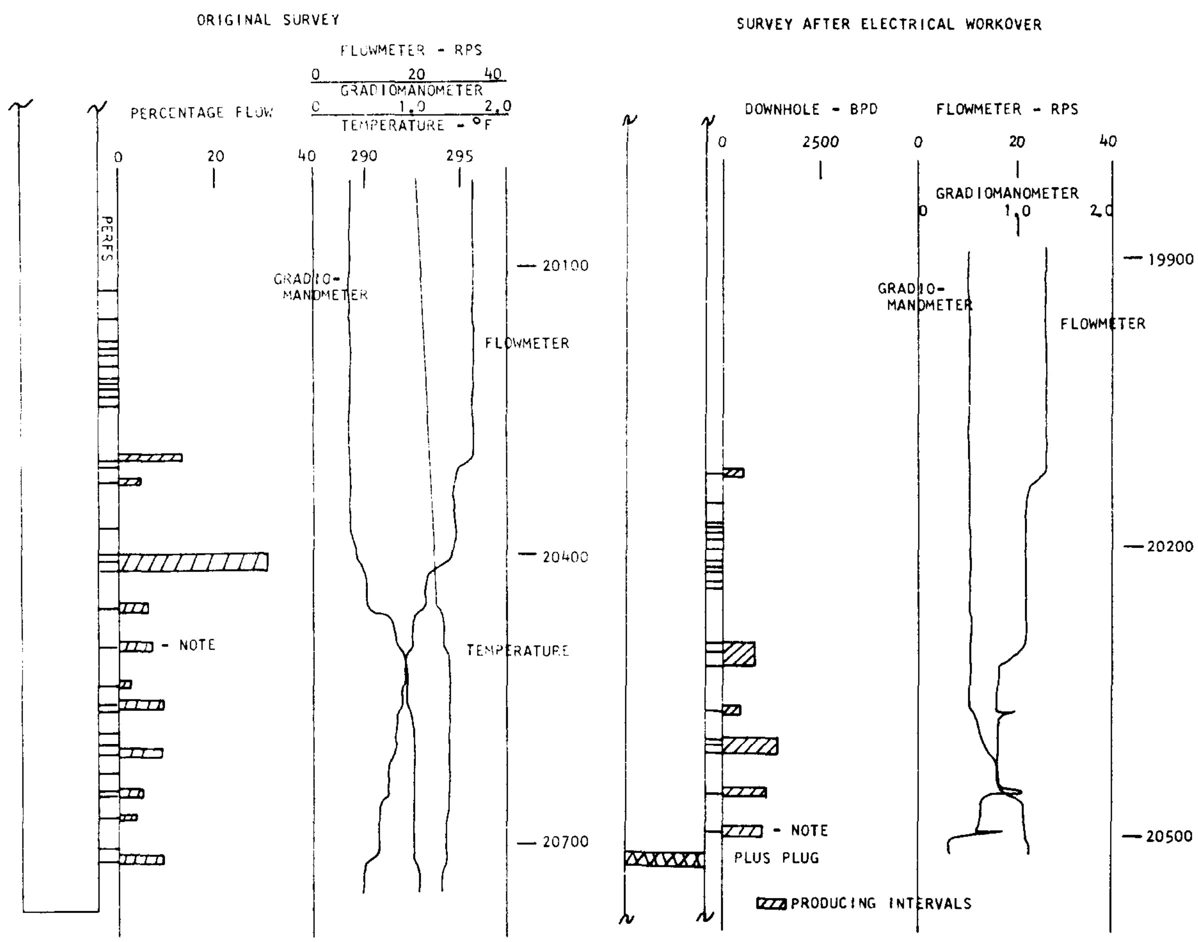

FIGURE 11

Example 6

be performed with a minimum of operator supervision. With this system entire workover jobs can, in many cases, be performed without the need for killing the well or removing the production string.

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