Displacement Procedures For Multiple Tubing String Completions

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INTRODUCTION

Well completions with two or more zones produced through independent tubing strings have been accepted by the oil industry as one of the ways to offset the upward spiral of operation costs. There is no indication that the trend to multistring completions will be reversed. If anything, the percentage of wells with two or more tubing strings will increase substantially over the next few years. In addition, there should be a large number of single tubing string wells recompleted as multiple producers to save drilling costs.

Though the term, "multiple string completion" is self-explanatory, it describes a wide range of conditions. Tubing programs consist of from two to five strings of tubing ranging in size from 1.660 in. OD to 3-1/2 in. OD. The inner casing string in which the tubing is run varies from 4-1/2 in. OD to 10-3/4 in. Shut-in tubing pressures range from zero to 10,000 psi. To satisfy the wide variation of the requirements, the manufacturers of completion equipment have been called upon to design an almost infinite number of special purpose products.

If the motivation behind multistring wells is economics, the key to their success is the equipment with which they are performed. Multistring packers, wellhead equipment, Christmas tree valves, and various types of downhole components have been developed within the last ten years which enable safe, efficient, and economical completions.

WELLHEADS

During the initial stages of multistring completions, the tubing strings were run strapped together. The wellhead equipment was comparatively simple and offered little protection against blowouts. With a few exceptions, which will be discussed later, it is now standard practice to run the tubing strings independently. Wellhead equipment which is relatively simple to install has been developed. It can be divided into two basic categories; equipment which is made for installations with complete pressure control, and simpler wellheads for pumping installations where pressure control during completion is not so critical.

With the first type of equipment, it is possible to run and suspend the tubing strings and pack off the casing annulus before the blowout preventers are removed. A large percentage of dual tubing string wells and practically all of the triple, quadruple, and quintuple string wells utilize this type of assembly. Some versions of "controlled completion" wellheads have been produced which provide for running side-ported gas lift valves, setting one or more tubing strings in tension through preventers, running centralizers, in the case of tubingless completions, and a number of other functions which are sometimes a requirement.

The simpler wellhead equipment for low pressure or pumping installations generally consists of a tubing head adapter with slip or mandrel suspension for the tubing strings. The Christmas trees for pressure control, where they are required, are made up of screwed fittings and valves. Connections for blowout preventers are sometimes provided for protection during the running of the second (or third) tubing string; but, more often than not, conventional blowout preventer equipment is not used.

PACKERS

One of the reasons for running parallel tubing strings for production, rather than using one tubing string and the casing annulus, is the advantage of keeping high pressure and corrosive fluids isolated from the inner casing string. It is becoming common practice in multistring wells to separate each producing zone by means of a packer. Two or more sands can be selectively produced through a common tubing string by use of side door chokes and single string packers.

A large number of packers are manufactured which were designed for, or can be adapted to, multiple string wells. They can be separated generally into two broad categories; permanent and retrievable. It is not the purpose of this paper to debate the merits of one type over the other. There are advantages to each.

The packer manufacturers have displayed great ingenuity in overcoming some of the obvious design problems. The one thing that should be emphasized is that the selection of the packer sometimes limits the displacement methods which can be used. This can be avoided by selecting the method of displacement and determining the adaptability of the packer prior to the time the well is started.

DISPLACEMENT METHODS

One primary difference between single and multistring completions is the method used for displacing the mud in the tubing string after the tubing string is suspended in the wellhead. Since packers are commonly used in multistring wells, the problems of displacement are akin to single string wells with a packer.

Single String Displacement

After running and spacing a single tubing string, a stuffing box type of tubing hanger is installed in the uppermost wellhead body. After the preventers are removed, the tubing string is attached to the Christmas tree which provides control of the well pressure. The Christmas tree and tubing string can be picked up sufficiently to disengage the seal nipple at the lower end of the tubing from the packer. Water or oil is pumped down the tubing string, displacing the heavier mud up the casing annulus and out of the tubing spool outlets. Pressure control of the annulus is provided by the stuffing box tubing hanger which is designed so that tubing can be moved through it while still maintaing a seal.

After the mud is displaced, the Christmas tree and tubing are lowered until the Christmas tree can be bolted to the top flange of the tubing spool. Since the tubing string has already been spaced out, the seal nipple is simultaneously properly positioned within the packer bore.

Formation pressure is often enough to overcome the reduced hydrostatic head imposed by the displacement fluid, and the well starts producing. The tubing pressure is controlled by the Christmas tree valves which were previously installed.

MULTIPLE STRING DISPLACEMENT METHODS

The above single string displacement method has been used with slight variation for a number of years. The same requirement for displacement exists on all multistring installations; because of the space limitations, the procedure is somewhat more complicated.

Several displacement methods which are currently in use for multiple string completions are described in the following text. As stated before, wellhead equipment, packers, and accessory downhole equipment will sometimes limit the displacement methods which can be employed. Consideration should be given to these points in pre-well planning and equipment specifications.

Swabbing

After the tubing strings are run and suspended and the Christmas tree installed, the weighting material within the tubing strings can be removed by a swab run on a wire-line. The swab is lowered through the mud within the tubing and then pulled out, thus bailing out the mud above it. The number of trips required with the swab, to equalize the hydrostatic head to that of the formation pressure, is dependent on the depth of the well, the weight of the mud and the zone pressure.

Though displacement by swabbing is a simple procedure requiring little additional material, there is always a possibility of getting a swab stuck in a restriction in the tubing or of breaking the swab line, thereby causing a delay in the completion. Because of the time requirements and other factors, swabbing is not commonly used for displacement in deeper wells unless it is used in conjunction with one of the other displacement methods to be described.

Circulating Valves

The use of wire-line operated circulating valves run on the tubing strings has the distinct advantage of allowing displacement with complete pressure control. There are several ways which circulating valves can be used.

In a dual string well with two packers, a circulating valve can be positioned on the long tubing string between the packers, as shown in Fig. 1. After both tubing strings are set and the Christmas tree bolted on, the mud can be displaced by pumping down the long tubing string, out the sleeve valve and up the short string. When the mud in both tubing strings has been displaced by water or oil, the circulating valve can be closed by a tool run on a wire-line.

If desired, a second circulating valve can be run on the short tubing string above the top packer. The second valve permits displacing the mud in the casing annulus above the upper packer. Quite frequently it is advisable to have water with an inhibiting agent or oil in the annulus to prevent corrosion and/or to facilitate pulling the packer at a subsequent date.

The disadvantage of circulating valves is the same disadvantage that is present when any apparatus with moving parts is used downhole. Failure of a circulating valve to close when it is supposed to can be time consuming and expensive since it probably will mean pulling one or more of the tubing strings.

Tubing String Manipulation

The same basic principle of raising the tubing strings, previously described for a single string, is practiced in multistring completions although the procedure is more involved.

1. Individual Tubing String Manipulation. When this method is used, the long tubing string is displaced after it is run into the well prior to its suspension in the tubing head. Pressure control within the tubing string is provided by a back-pressure valve within the tubing or tubing hanger or by the master valve of the Christmas tree, depending on the type of equipment which is used. Back pressure valves are available from most wellhead manufacturers which permit fluid to be pumped into the tubing bore but prevent a backflow. These valves can be removed through the Christmas tree under well pressure.

After running, displacing, and suspending the long tubing string, the same procedure is followed with the second tubing string. Pressure is again controlled through the use of back pressure valves or by attaching the tubing string to the Christmas tree. After the mud is displaced, the tubing string is lowered so as to position the seal nipple within the packer bore. If the bottom hole pressure is not sufficient to bring the well in after replacing the mud with a lighter fluid, the fluid column will require swabbing or agitation by other means.

2. Simultaneous Tubing String Manipulation. Where two packers are used, this method of displacement is gaining industry acceptance, especially in the Gulf Coast. After both tubing strings have been run, spaced, suspended, and the Christmas tree installed, the lower flange of the wellhead body, shown in Fig. 2, is unbolted. A lift flange is attached to the top of the dual Christmas tree and both tubing strings, together with the Christmas tree, are lifted until the seal nipples are free of the packers.

After lifting the tubing spool and Christmas tree, a dual stuffing box tubing hanger is made up around each of the tubing strings and installed in the wellhead body, as

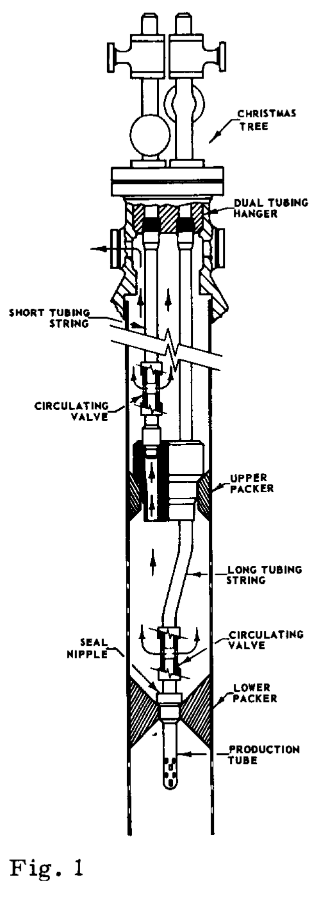


Fig. 1

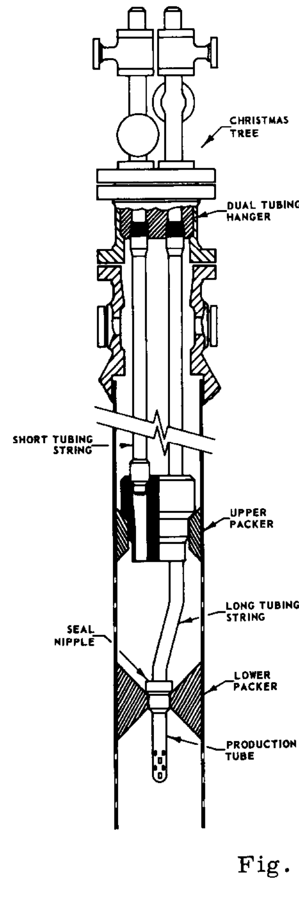


Fig. 2

shown in Fig. 3. The stuffing box hanger, which is actuated by anchor screws in the wellhead body, provides a pressure seal between the casing annulus and the tubing strings. With both tubing strings clear of the packers and the casing annulus packed off, water or oil can be pumped through the Christmas tree into the tubing string, up the casing annulus and through the outlet on the wellhead body.

After displacement, the Christmas tree and the attached tubing strings are lowered until the wellhead body flange can be bolted to the tubing hanger body flange (Fig. 4). At the same time the seal nipples on the bottom of the tubing strings engage the packer bores to effect a seal.

The advantage of this method of completion is that the entire operation is carried out with complete pressure control. Tubing strings are run and suspended with blowout preventer protection. Circulating is done through the Christmas tree with one or more valves for protection in case the well starts producing prematurely.

On the other hand, this procedure requires wellhead material not required for other techniques. The operator will have to determine for himself whether the possible savings in time will compensate for the cost of the additional equipment.

Hydraulic-Set Packers

Another method of multistring displacement which has been recently introduced utilizes hydraulic-set packers. One of the foremost requirements for any completion method is to offer complete protection against blowouts.

In most of the quadruple string wells, and on the one quintuple well which has been completed to date, the packers are made up on the tubing strings and run simultaneously with all strings of tubing. The obvious advantage in running the tubing strings simultaneously rather than individually is to eliminate the problems that are incurred when stabbing a seal nipple into a multiport packer.

The chief difference between the displacement procedure for wells with hydraulic-set packers and others previously described is that it is not necessary to pick up the tubing strings in order to displace. The packers are not set until the mud is circulated out of the tubing strings. The packers can be set selectively, when required, by means of hydraulic pressure applied from the surface.

The most common way of setting hydraulic packers is to pump a plastic ball down the tubing until it seats in the packer. The application of additional pressure within the tubing creates a differential across the packers, causing it to set. After setting, the ball can be flowed out or swabbed out of the tubing.

As with other displacement plans, it is up to the judgment of the operator to weigh the advantages which are offered against the cost of the required equipment.

The preceding discussion of displacement methods cover those which are most commonly in use. Although the procedures which are outlined on the illustrations deal mainly with two strings of tubing, the displacement methods which are outlined would be equally applicable for wells with three, four, or five tubing strings.

Wellhead equipment for simultaneous manipulation of three strings has already been developed. It would be relatively simple to design comparable equipment for four strings of tubing if it is not already a reality. The basic equipment used when displacing by swabbing or by circulating valves is the same, regardless of the number of tubing strings in the well.

DESIGN LIMITATIONS

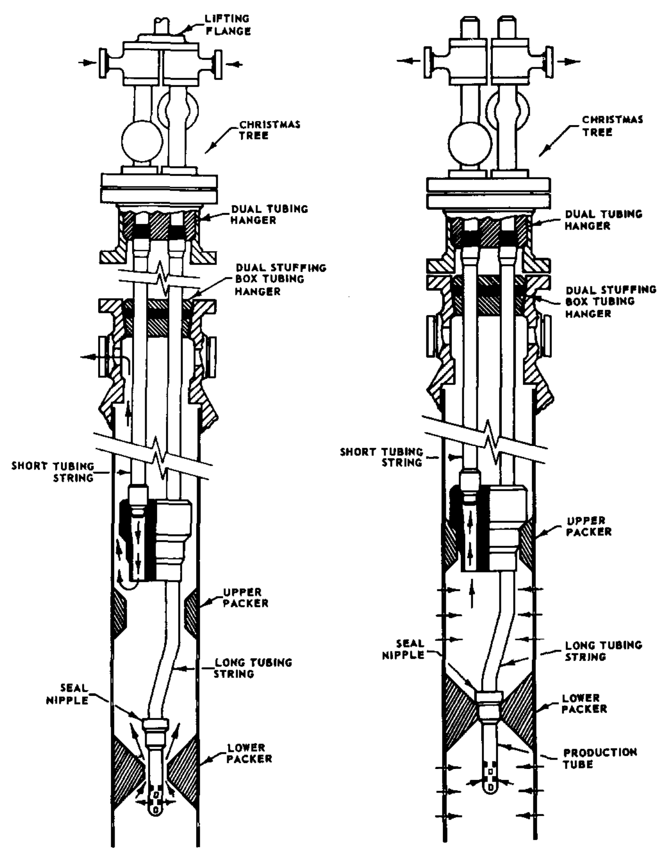
In the relatively short time that multiple completions increasing the size or number of the tubing strings and decreasing the size of the casing in which they are run. This is in agreement with the economy concept of multistring completions; however, as the trend continues, it imposes severe limitations on the designers and the manufacturers of packers, wellhead equipment, Christmas tree valves, and similar material.

Because of the space limitation inherent in multistring completions, it has been necessary to sacrifice some of the features of comparable single string equipment. Working stresses are higher and, in general, the equipment requires much more care in installing to avoid damage.

To illustrate this point more specifically, consider the wellhead aspect of a typical dual string installation. A conventional tubular program is two strings of 2-3/8 in. OD tubing suspended within 7 in. casing. Most wellhead manufacturers provide a 6 in. nominal tubing head and dual tubing hanger to accommodate this combination. A 6 in. nominal tubing hanger must be less than 7-1/16 in. OD in order to pass through a 6 in. blowout preventer. The wellhead body member which supports the dual tubing hanger must have a 6-3/8 in. minimum bore to be full-opening for the 7 in. casing. In a normal completion cycle, tubing collars are passed through the hangers so it is necessary to provide within the hanger two ports, each larger than 3-1/16 in.

In addition to clearance for the tubing strings and collars, some types of tubing hangers provide for passage of side-pocket gas lift valves and similar tools. Other requirements are to support the tubing hanger within the tubing spool body, to seal the annulus by means of a packing unit, and to furnish a locator mechanism for orienting the tubing ports with respect to the tubing spool.

The foregoing is an example of the design problems encountered by wellhead manufacturers. With two long tubing strings and a possibility of an additive pressure load applied



on top of the tubing hanger (in the event of a tubing bore seal failure), it is obvious that the load limit for hangers of this size is rapidly being reached. Wellhead designers are trapped between a fixed area for supporting the tubing strings and increasing tubing and pressure loads.

The problem of diminishing design area is not confined to wellhead products alone, but affects practically all other equipment which is manufactured specifically for multistring completions. This includes packers, circulating valves, Christmas tree valves, gas lift valves, etc.

RECOMMENDATION FOR NEW WELLS

In spite of the demands made of existing multistring equipment, for the most part it has been adequate for initial completions. Whether or not dual work-over programs can be carried out without delays has not yet been fully determined. It is the opinion of the author that more efficient equipment could be supplied if larger casing were run than that currently being used. Since this would add to the cost of new wells and is impossible in the case of old wells being recompleted as duals, it is not likely that this practice will become popular.

As a less expensive alternative, if two or three joints of larger casing could be run in the top of the oil string, it would greatly ease the design problems of the wellhead and Christmas tree manufacturers even though the situation confronting the manufacturers of packers and downhole equipment would be unchanged. Such a solution would only slightly increase the well cost and the additional expense would be more than offset by having trouble-free completions and work-overs.

It is the desire of every equipment manufacturer to provide the tools with which the most efficient completions can be made. Conversely, it should be every operator's responsibility to ascertain that his completion method allows the most efficient and economical utilization of these tools. Any completion practice or tubing program which reduces the equipment cost at the expense of ruggedness and ease of installation is not the most economical one over a long term. Multiple completions and the equipment which enables them to be performed should be examined very thoroughly before drilling is started, to eliminate false economy.