Wellheads for Multiple Zone Completions

By R. K. Le ROUAX
Cameron Iron Works, Incorporated

INTRODUCTION

The first duals which were the direct forerunners of the present multiple parallel string technology, were set in the latter part of 1952 in the South Texas tidal waters near Matagorda Island. These were clamp type duals set at about 5000 feet. Since that time, multiple string completions have demonstrated their feasibility and economy and they have become almost mandatory for off-shore programs.

The downhole features of multiple completions such as packers, slide valves, tubing joint clearance, and the like, have been adequately covered in previous papers and literature. However, due to the rapidly changing state of the art and the almost infinite variety as to pipe sizes, working pressures, and types of completions, little has been published to date concerning wellheads for parallel multiple completion. The purpose here is to outline major design considerations and describe generally the equipment available. Concentric dual hookups will not be covered since the wellheads and Xmas trees differ little from single zone arrangements.

DESIGN LIMITATIONS

The major limitation in dual hanger design is the center spacing of the tubing strings at the wellhead. Two things control this: The first is the size of the top joint of the casing and the size of the two tubing strings. This establishes the maximum center-to-center dimension.

The second is the minimum center-to-center dimension which is established by the tree and, more particularly, by the valves. The reason this is a limitation is that a straight-through bore in the tree and hanger and into the tubing is considered mandatory so that any tools used on single completions can also be used on either side of a dual parallel installation.

Fig. 1 shows the method used to arrive at the maximum center spacing for 2-3/8 inch X 2-3/8 inch in 7 inch, for two strings of 1.900 inch in 5-1/2 inch, and for a 2-3/8 inch X 2-7/8 inch combination in 7-5/8 inch. Note that the nominal bore of the heaviest weight casing is used in these calculations rather than the drift diameter. So far as is known, no difficulty has arisen from this approach.

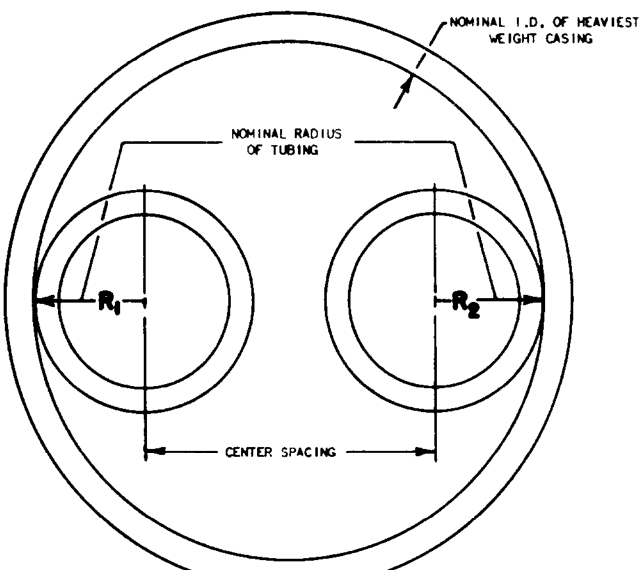
The situation as far as the valves are concerned is not as simple. The first dual trees were made using separate valves. At this time valves allowed about 4 inches to 4-1/4 inches center spacing for a 2 X 2 combination, considerably larger than the 3-35/64 inch centers shown in Fig. 1. This made necessary the use of 8 inch nominal connections at the tubing head with consequent increase in cost and size of the wellhead and also required the use of oversized joints at the top of the oil string.

Some valves are a little slimmer than others and, having different methods of sealing are, therefore, more adaptable to duals than others. The plug valve, of course, is less adaptable because of its necessary large body diameter. During this early period, individual valves were notched slightly to pull centers in. Shortly after this, the solid block valves, that is valves referred to as dual blocks, or dual bore valves, made their appearance to fit the center lines established by the casing-tubing combination.

The reason that dual solid block valves can be on closer centers than separate valves is that the metal between one run and the sealing means of the valve on the opposite run can serve as wall section for both. While on separate valves one run must be contained in a separate tubular member and the valve body must contain the sealing means for the other, and neither can reinforce the other.

Valve manufacturers then followed with intensive programs for establishing designs, experimenting with and testing recessed body individual valves for the center lines on which the dual block valves were being made. Today nearly all valve manufacturers have recessed body valves for duals available in most sizes and pressure ratings.

The net result on the part of the valve makers has been the provision of a variety of valves for a number of different applications. The maximum center line spacing dictated by the pipe combinations has been adopted and has resulted in what are known as "Standard Centers" for dual completions.



CENTER SPACING = NOMINAL CASING I.D. − R_1 − R_2

1. 2-3/8 X 2-3/8 IN 7" - 38#

   CENTER SPACING = 5.920 − 1.1875 − 1.1875 = 3.545 ≈ 3-35/64

2. 1.900 X 1.900 IN 5-1/2" - 23#

   CENTER SPACING = 4.670 − .950 − .950 = 2.770 ≈ 2-25/32

3. 2-3/8 X 2-7/8 IN 7-5/8" - 39#

   CENTER SPACING = 6.625 − 1.1875 − 1.4375 = 4.000

FIG. I

The fact remains, however, that for simply hanging and packing two strings, closer centers could be used, making the use of smaller oil strings possible. This could only be accomplished at some sacrifice of versatility in the hanger and would cause restrictions as to types of tubing joints and the like. From the standpoint of safe design and economy, the centers now used appear adequate.

DESIGN CONSIDERATIONS

Once a center-to-center dimension has been established for a particular hookup, design of the hanger can begin. One of the first considerations is possible utilization of standard or existing equipment which may already be designed or on hand. This usually results in greater economy and faster delivery.

Considering for the moment separately run strings which are the norm nowadays, the first step is getting the tubing in the hole. Depending on the type suspension, is there room to run the string through? Can the couplings get through the hanging means and into the casing without hanging up or binding?

Having established this, we next turn our attention to the principal consideration, the actual means of suspension; is there room enough to provide adequate slips to suspend the loads without bottlenecking and, in the case of mandrel types, is there sufficient bearing area so that load can be supported without damage to the hanger or its seat? Also, is the assembly loaded symmetrically so that the hanger mandrels retain their proper position for later assembly of matching parts?

The next consideration is the sealing means. How is the hanger to be sealed? Will it be high or low pressure, and must it be sealed off prior to removal of preventers? And last, are there any special features about the hanger, that is, will the tubing be run and landed under pressure? Is rotation of either or both strings required? Will the strings be set in tension, and is the tubing program to be changed later?

Generally speaking, when designing a hanger as much versatility as possible is built in. This, in conjunction with the various string combinations, etc., has resulted in a very large number of different hangers. The following will be a description of the major species and their capabilities and limitations.

TYPES OF HANGERS

The first type (Fig. 2) and probably the first historically, consists of a separate hanger flange which is

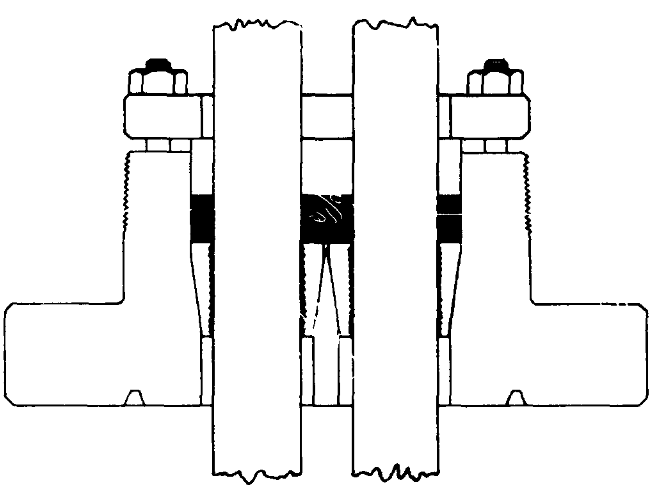


FIG. 2

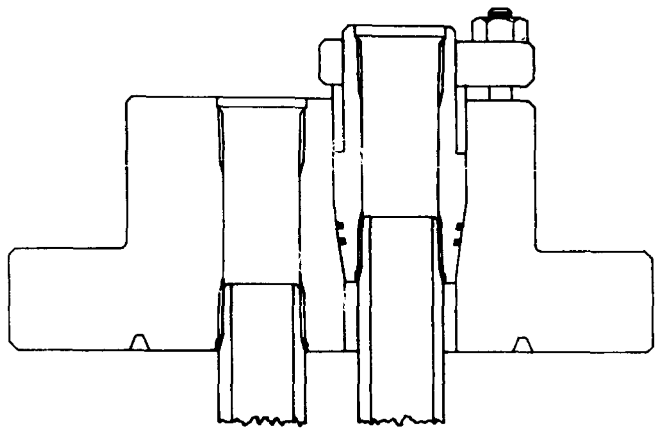


FIG. 3

installed on top of the tubing head and contains slips and packing. This arrangement is still used extensively for low pressure hookups. With this type, pressure control is limited since the blowout preventers must be removed from the tubing head in order to attach the hanger flange. This, incidentally, could be a stripping job if the packer must be started in the hole on the number one string. The male threads are for attaching blowout preventers.

This hanging arrangement lends itself very well to tension setting, rotation of the strings is easy, holddown on the two strings is limited to what the slips and packing arrangement can apply, and packoff is not secured until after preventers are removed. Gas vent strings are easy to furnish in this assembly. Gas lift valves can be run on number one string only, unless they are the concentric type, not exceeding coupling diameter. This hanger has an advantage in that with proper connections at the bottom of the tree, one string can be pulled while the other string is still producing.

Fig. 3 shows a variation of the preceding hanger. The number one string is threaded directly into the flange and the number two string hung off in a mandrel. It can be seen that with this arrangement the number one string must be run to bottom before the flange can be attached. This is a stripping job and the preventer must be removed with the number one string in place. Once the flange is in place, number two string is run and landed with the mandrel.

Tubing back pressure valves are possible in this arrangement for pressure control. Lockdown of the mandrel is not obtained until preventers are removed. Tension setting of the tubing strings is difficult with this hanger. Rotation is possible on number two string with preventers in place and on number one string only after preventers are removed. The same limitations on gas lift valves applies as on the first type discussed and gas vent strings are easily furnished in this hanger also. Like the preceding hanger, the independent tree feature also applies.

Fig. 4 shows a type intermediate between the flange type and the bowl type. This hanger has some of the advantages of each. Pressure control is more effective here, since the preventers need not be removed until both strings are in place. Holddown of the hanger is not obtained, however, until preventers are removed and the holddown flange shown on the left side of the illustration, or the cap shown on the right side, is installed. Tension setting is difficult with this type hanger and rotation is possible on both strings. The same limitations on gas lifters apply on this hanger as on the two preceding ones. A gas vent string is possible.

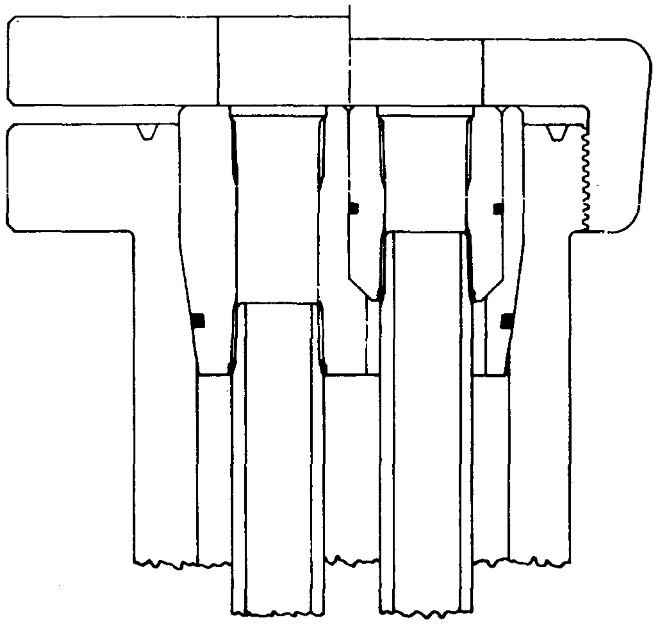


FIG. 4

The fourth type (Fig. 5) is the first true bowl type hanger. This type, along with the split types which follow, requires one feature which the preceding types do not require; the bowl or halves must be oriented with respect to the tubing head flange so that the bolt holes will line up between the tubing head flange and the lower flange of the Xmas tree when the tubing hanger centers are lined up with the centers of the dual run in the tree.

This aligning and locating feature was one of the first real design problems in this type of equipment. Many types of aligners are now in use. Some consist of a simple key or pin in the bore of the head, others involve screws energized from the outside. Still others use wedges, or cam surfaces, providing all degrees of installation ease. Some require careful hand alignment to be sure that the locating pin enters a slot in the side of the hanger bowl; others need a little help and then the head and hanger combination automatically locates; and others are fully automatic.

This hanger (Fig. 5) is a very common type. Full pressure control is possible because tubing back-pressure valves can be used and the whole assembly can be locked down prior to removing preventers. Tension setting is difficult and rotation can be accomplished only by the use of oversized preventers above

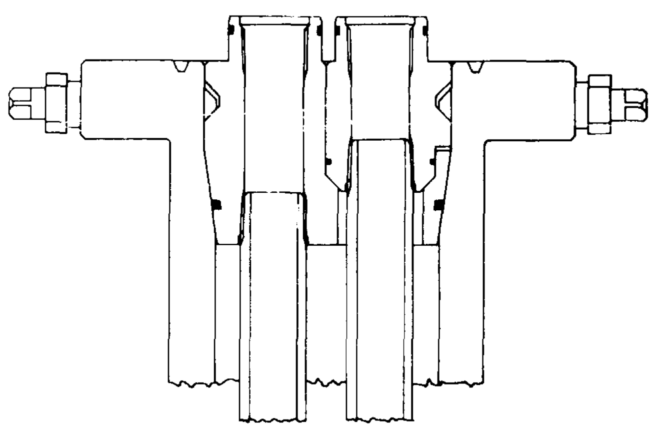


FIG. 5

the head. Gas lift valves can be run on number one string. Gas vent strings can be supplied in this hanger.

Fig. 6 shows another hanger which is common. It consists of a lower bowl with two holes through it capable of passing couplings. Two identical mandrels fit in these pockets, followed by a packing sandwich which seals the annulus. The same comments apply to this hanger as to the preceding hanger with the exception that either string can be rotated easily. Modifications of this type hanger can be furnished for setting the strings in tension.

The hanger shown in fig. 7 is a variation of the one in fig. 6, made principally for handling gas lift mandrels. This hanger can be furnished with tubing back-pressure valves and the assembly buttoned down and sealed off prior to removal of preventers. The lower bowl has two holes through it. The hole under the number two string is an elongated hole large enough to pass gas lift mandrels.

If, for example, gas lifts were run on both strings, the number one string would be run first and the lower bowl stripped over the last joint and landed in the head; this would be followed by the mandrel suspending number one string. The number two string could then be run with the number two mandrel, which carries the packing sandwich, following down.

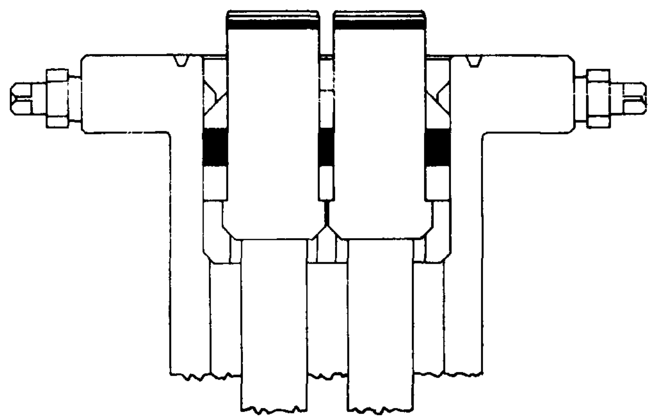


FIG. 6

Tension setting is difficult with this type of hanger. Rotation is possible on number one string. To rotate the number two string, the hanger would have to be picked up into an oversized preventer above the head. No provision is made for a gas vent string.

The last type hanger (Fig. 8) is a split type. In some respects it is the most versatile multiple string hanger. Pressure control is complete throughout, holddown is provided, tension setting is accomplished in the same manner described previously and rotation for packer disengagement requires, as does the preceding hanger, oversized preventers above the tubing head. This hanger was designed expressly for running gas lift valves, so eccentric gas lift mandrels can be run on either string, and either string can be pulled completely independent of the other.

As mentioned before, the hangers discussed represent the major species of hangers available for multiple completions today. There are many variations on each to accomplish different objectives, and no attempt has been made to explore all the variations.

The preceding discussion has been directed toward duals or duals with gas vent string. However, it can be seen that triples and quadruples can be furnished in similar type hangers.

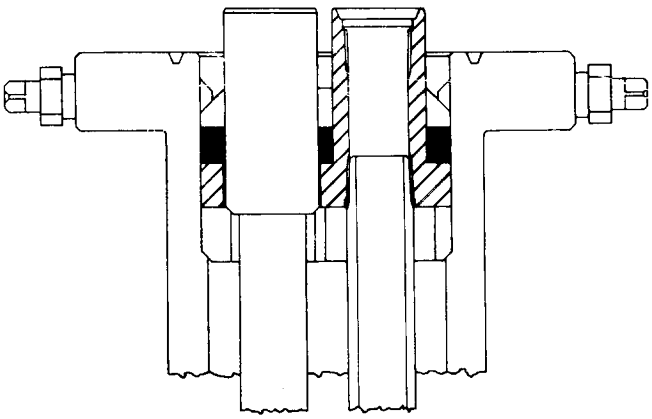


FIG. 7

the major species of hangers available for multiple completions today. There are many variations on each to accomplish different objectives, and no attempt has been made to explore all the variations.

The preceding discussion has been directed toward duals or duals with gas vent string. However, it can be seen that triples and quadruples can be furnished in similar type hangers.

The packing mechanisms used on the various hangers depend on the space available and upon the pressure at which the assembly is intended to work. It is possible to pressure test some assemblies prior to putting the well on production.

Some tubing and casing combinations do not lend themselves to straight-through hanging along the lines outlined previously. In these cases, it is sometimes possible to make an eccentric spool which has the bottom flange shifted to one side with respect to the top flange. This permits the tubing to hang straight.

Since 2 inch equipment is most commonly available nowadays, eccentric nipples can be used, for example, to hang 1-1/2 inch tubing inside 5-1/2 inch, utilizing 2 inch equipment. This may save time and prove to be more economical. Eccentric nipples can also be used in other combinations in order to use standard equipment.

In considering eccentric nipple use, some types of tubing threads should not be used since, when made up, they will stop in one position only. This is important inasmuch as eccentric nipples must have a particular orientation with respect to the hanger for successful suspension.

XMAS TREES

There are three basically different types of multiple Xmas trees. The first is the separate run type in which each half of the tree is completely independent of the other half. These are economical hookups and are used extensively for lower pressures. The second type is used for higher pressures. It is composed of dual port valves and dual bore tee.

Each element is separate from the other, each having two passageways through it connected at the ends, usually with a 6 inch or 8 inch API flange with means for isolating each run. The third type is the solid block tree wherein adapter flange, valves, dual tee, and wing valves are all in one body. It is economical in the majority of sizes and pressure ratings and offers the greatest safety in that the number of connections is minimum.

Referring to the separate run type, there are three sub-species: first, the all-threaded; second, the all welded; and third, the type utilizing some connection other than threads. This can be unions, 5-bolt flanges, 2-bolt flanges, or any connection not requiring rotation of the parts to disengate.

There is another common sub-specie, a variation of the solid block type which may be referred to as a fabricated tree. While each run is separate from the other, in this type they are attached, generally by welding at the bottom to a flange with dual passageways; and at the top there is a solid tee with two passageways through it. These generally are more economical than the dual ported types and this is especially true in the triples.

Xmas Tree Connections

There are several different ways of making connections between elements in multiple trees. One is a type known as the seal-sub in which a short sub fits in pockets in the two adjacent pieces and establishes a pressure-tight connection between them by means of a steel and synthetic rubber seal. This type assures absolute alignment of the tree members.

Another is the metal ring gasket, which provides a metallic seal between elements and permits some misalignment. A third type has one end threaded and the other packed with some externally energizable sealing means.

Xmas Tree Components

The standard single completion elements for trees are available also for duals. For example, flow controllers; available are split single wing flow controllers, split double wing flow controllers, solid dual bore single wing flow controllers, and solid dual bore flow controllers for double wing installations. Xmas tree top adaptors are quite variable. At the present time each manufacturer offers one or more types. Their common characteristic is their necessarily small diameter; therefore, greater length and higher strength materials are required.

Auxilliary Equipment

Material currently available makes multiple completions as safe as singles. There are rams for sealing around two strings simultaneously. Rams for sealing on one string offset on some standard center are also available. Using offset rams, the rams are switched from one side of the preventer to the other when changing from the number one to the number two string. These are made for most sizes of preventers on standard tubing centers.

Also available are special small strippers for hangers

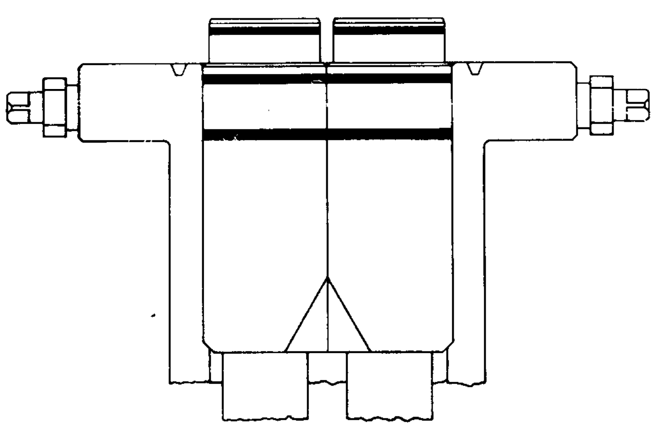


FIG. 8

and eccentric stripper flanges for lubricating tubing in under pressure. For example, equipment is now available for lubricating in and landing three strings of tubing under pressure.

Tubing heads with dual bore rams and dual hanger preparation offer complete safety for completions requiring movement of tubing under pressure. The "wrap around" tubing hangers which perform similarly, once installed, are being made for duals, triples, and quadruples.

Most manufacturers offer single string hangers to fit inside heads prepared for dual completion equipment. All the major types of hangers and packings are available.

CONCLUSION

Figures from one wellhead manufacturer on domestic sales indicate that about one-fourth of the trees set in 1958 were multiple completion types. If this is typical, it means that approximately 40 per cent of new completions are being done through multiple zone wellheads.

At the present time, the use of multiple completion equipment is still on the increase. Recent developments include a 10,000 psi triple completion, dual completion equipment for two strings of 2 inch for 15,000 psi working pressure, and equipment for a quintuple parallel tubing string completion, plus more varieties of duals, triples and quadruples.