This invention relates to the drilling and completion of a well. More particularly, it relates to improvements in apparatus and methods especially well suited for the offshore drilling and underwater completion of wells from a floating vessel.

As pointed out in Patent No. 2,808,229, for example, this offshore technique has many advantages over the drilling and completion of a well from a stationary platform above the water level. For one thing, the load of the well casing is carried at the ground level below the water surface, rather than by means of slender columns extending upwardly to the water level. Also, at least in some jurisdictions, this underwater completion technique may be advantageous in that the resulting wellhead presents a minimum obstruction.

In the drilling of any well, including one at an offshore location, successively smaller holes are drilled into the ground and lined with concentrically disposed casings. In accordance with the practice described in the aforementioned patent, the first or outermost of the casings is cemented or otherwise secured in the largest and uppermost hole. The remaining casings are in turn lowered into the holes successively drilled within the first one and suspended within this first casing and one another from a wellhead member known as the casing head and supported on the first casing.

This suspension is accomplished by the support of a hanger at the upper end of the casing upon a seat in the casing head. One type of hanger comprises a solid mandrel or "boll weevil" connected as by threading to the casing. Another type of hanger which is adapted to be wrapped around the casing for supporting it at any point along its length, is particularly advantageous when, for example, the casing may be stuck at a level in the hole wherein its upper end is spaced above the seat in the hanger from which it is to be suspended. More particularly, when the casing reaches a desired level and as it is suspended from the elevators, this last-mentioned type of hanger may be latched about it and released to slide down the casing onto its seat in the head. Then, as the weight of the casing is slacked off, the hanger is caused to grip and thereby suspend the casing from the head.

Ordinarily, the drill and completion program of any well is carried out through one or more blowout preventers above the casing head, each preventer having a bore corresponding to that of the head. As the hanger for one casing is landed within its head, the preventer equipment is removed from above it and replaced by another head for the next smaller casing. Additional and correspondingly smaller preventer equipment is, in turn, mounted on each smaller head, this procedure being repeated until the requisite number of casings have been suspended.

It has been suggested that this procedure be simplified by the installation of a single casing head having a plurality of vertically spaced-apart seats for supporting successive casing hangers. In this manner, the same preventer equipment may be installed above the head initially retained therein during the suspension of the successive casings. One difficulty with this suggestion is that it has heretofore been at least impractical to land a "wrap-around" type of hanger within a composite head of this type. Obviously, such an installation would be further complicated by the necessity of landing such a hanger within a wellhead below water level. As a result, these prior underwater completion techniques have included the use of the solid mandrel or boll weevil type hanger, despite its shortcomings.

An object of this invention is to provide wellhead equipment for suspending casings at any point along their lengths in those instances, such as underwater completions, wherein the use of wrap-around type hangers is impractical.

A further object is to provide wellhead equipment which allows an operator to suspend several casings successively and at any point along their lengths, all without removing and replacing the preventer equipment.

Another object is to provide wellhead equipment including one or more casing hangers which may be lowered with the casing to be anchored in the initial hole drilled beneath the water level and actuated from above the water level or other remote location in a manner to suspend one or more of the casing strings.

Still another object is to provide such equipment which, in addition to functioning in the manner above noted, will center or properly align the casing to be suspended prior to the disposal of the hanger in casing supporting position.

A still further object is to provide such equipment which, in addition to suspending a casing at any desired point along its length, is useful in holding a hanger for the next hanger or tubing to be run, or a part associated with such hanger, down upon its seat in the wellhead.

Yet another object is to provide such equipment in which the hangers are shielded against fluid and objects normally passing through the head during certain operations, such as drilling and cementing, preliminary to the running and suspension of the casing.

Still another object is to provide equipment and a method of using same for cementing the casing through some means other than the drill string, and particularly in a manner which enables the use of a standard cementing plug.

Other objects, advantages and features of this invention will be apparent to one skilled in the art upon consideration of the written specification, the attached claims and the annexed drawings.

In the drawings, wherein like reference characters are used throughout to designate like parts:

FIG. 1 is a vertical sectional view of an offshore well site at which a first casing as well as equipment constructed in accordance with the present invention and connected above such casing are being stripped over a drill string for anchoring within an initial hole drilled by the string in the ground beneath the water level;

FIG. 2 is a cross-sectional view of the wellhead equipment on an enlarged scale, and taken along broken line 2—2 of FIG. 1, as it is lowered with the casing, and with the casing hanger of such equipment in a retracted and shielded position;

FIG. 3 is a view similar to FIG. 1, but wherein the wellhead equipment and casing have been landed at the subsurface level, the drill string removed therefrom, and the casing cemented in place to anchor it as well as the wellhead equipment at such level;

FIG. 4 is another view similar to FIG. 3, but wherein pressure control equipment has been lowered onto and connected with the upper end of the wellhead and a drill string has been lowered through the pressure control equipment, wellhead, and casing for drilling a further hole;

FIG. 5 is a view similar to FIG. 4, but wherein another casing has been lowered into the further hole and the hanger within the wellhead has been extended and
dropped into a position to suspend this casing as it is being cemented in place; FIG. 6 is a cross-sectional view of the wellhead equipment upon an enlarged scale, as seen along broken line 6—6 of FIG. 5, and showing the casing hanger in its surface casing suspending position;

FIG. 7 is another cross-sectional view of such equipment, as seen along broken line 6A—6A of FIG. 5, and showing a system for actuating rams connected with separate parts of the hanger;

FIG. 7 is a view similar to FIG. 5, but in which the rams have been retracted and a casing cutter has been lowered into the position of the second casing for severing it at a level just above the suspending hanger;

FIG. 8 is a view similar to FIG. 7, but in which the upper portion of the second casing has been severed and removed, a tubing has been run and suspended within the second casing by means of a tubing hanger landed in the wellhead, and the rams have been reextended to engage and hold the tubing hanger down in its landed position;

FIG. 9 is a view similar to FIG. 8, but showing completion equipment which has replaced the pressure control equipment above the wellhead; and

FIG. 10 is a vertical sectional view of another well completed in accordance with this invention, but wherein the wellhead equipment includes an additional hanger for suspending another casing intermediate the outer and inner casings of FIGS. 1 to 9.

With reference now particularly to FIG. 1, a hole 20 has been drilled at the subsurface level by means of a drill string 22 having a bit 24 at its lower end and operated from a vessel above the water level in a manner presently known in the art and described in some respects in the aforementioned Patent No. 2,808,229. The drill string 22 carries a retractable underreamer 23 to make a hole larger than the bit 24 so that the casing string 25 may be easily stripped down over the drill string into the hole and the bit withdrawn therethrough. Thus, as can be seen from a comparison of FIGS. 1 and 3, the casing string 25 is lowered within the hole 20 until a landing base 26 at its upper end comes to rest upon the subsurface level 21 surrounding the hole.

As previously noted, this much of the method is well known in the art. In accordance with the present invention, however, a casing head 27 is connected to and mounted above the surface casing 25 by any suitable means so that both the conductor casing and casing head are lowered as a unit into the landed position shown in FIG. 3. The aforementioned base 26 may be carried by the casing head 27, as shown, or, if desired, by the surface casing 25.

The apparatus for so lowering this assembly, and also for making and breaking the connections with the upper end of the casing head 27, is indicated generally by reference character 28. Preferably, it is similar to that shown in our copending application, Serial No. 746,997, filed July 7, 1958, now Patent No. 3,096,999, and assigned to the assignee of the present application. However, although this particular apparatus is preferred inasmuch as it does not require for its operation hydraulic actuators or the like, any suitable means may be employed by this purpose.

At any rate, the apparatus 28 includes a flange 29 secured to and surrounding the casing head 27 and suspended from the lower end of two or more flexible cables 30, which may be let out or taken in by suitable means on the vessel at the water level for lowering or raising the assembly including the casing head 27 and surface casing 25. These lines 30 are, in turn, surrounded by sleeves 31 on laterally extending arms 32 suspended from the lower ends of additional flexible lines or cables. These arms 32 are mounted on and extend outwardly from a collar or sleeve 34 which carries and fits closely about a series of circumferentially arranged locking dogs 35. The dogs are, in turn, provided with lower and upper locking shoulders 36 and 37, respectively, for engaging and thus connecting the oppositely facing flanges 38 and 39, respectively, on the upper end of casing head 27 and the lower end of a fitting 40 connected to the lower end of a tubular member 41 which extends upwards to above the water level.

At the time the assembly is lowered on the lines 30, the lines 33 are slacked off by suitable means above the water level. This, of course, permits the collar 34 to move downwardly to lock the dogs in the position of FIG. 1, and thus connect the tubular member 41 to the assembly for lowering therewith, the weight of the collar and arms 32 maintaining the collar, and thus the dogs, in the locking position.

However, in a manner more fully described in the aforementioned copending application, the lines 33 may be taken up to lift the collar 34 into engagement with the upper projecting ends 35a of the dogs and then cam them inwardly to release locking shoulder 36 on the lower end of each dog from the flange 38 and thereby disconnect the fitting 40 from the lower end of the casing head 27. Continued lifting of the cables 33 raises the upper ends 35a of the dogs as well as the upper end of the collar into engagement with the underside of flange 40a on the fitting 40 to thereby raise the fitting and tubular member 41 along with the dogs and collar to above the water level.

When so raised, the dogs 35 are releasable from the fitting 40 for connection to other parts for lowering into connection with the upper end of the casing head 27. As the other parts are so lowered, they are carried from the upper ends 35a of the dogs as well as the upper end of collar 34, and, when such parts land on the upper end of the casing 27, continued letting out of the cables 33 will lower collar 34 over the downwardly tapered surfaces of the locking dogs to cam them into locking engagement with the flange 38 on the upper end of the casing head 27. As will be understood, during this reciprocation of the lines 33, the sleeves 31 on the arms 32 will slide upwardly and downwardly over the lines or cables 30 which are anchored at their lower ends to the landed assembly, including conductor 25 and head 27, and held fast at their upper ends in the collar 34.

Continuing now with a detailed description of the method of the present invention, when the conductor casing and casing head have been landed in the position shown in FIG. 3, the drill string 22 is removed therefrom at a casing and casing conductor head downwardly through the tubular extension 41 into the casing head 27 and the conductor casing 25 and into the annular space between said casing and the hole 20. As well known in the art, when the cement sets, it will thereby anchor the conductor casing within the hole. In accordance with the present invention, however, the landing base 26 comprises a shrut of generally conical shape which directs and confines the cement to an area on the subsurface level 21 which surrounds the hole 20. This will, of course, strengthen the anchoring of the assembly by providing a much larger area of interface between the cement and the ground.

The casing head 27 comprises a body 42 of generally tubular configuration having an annular recess 43 therein to receive a casing hanger 44 which includes a plurality of slips 45 held in retracted position within the recess 43. The slips 45 are shielded in their retracted position by means of a sleeve or liner 46 disposed across the recess 43 in the body of the casing head 27. The slips 45 and the liner 46 form at least a substantial continuation of the inner diameter through the tubular extension 41 and casing 25, so that the cement 47 may be forced downwardly by means of a plug 48 slidable through these members.

This particular method of anchoring the surface casing
at the underwater level 21 is preferred over prior procedures which conduct cement downwardly through the drill string 22, not only because it permits the cementing plug 14 to be used, but also because it avoids fouling the drill pipe.

As can be seen from the drawings, the upper end of the liner 46 has a downwardly facing shoulder 46z which is located upon a seat in the bore of the casing head 27 just above the recess 43. When so located, the liner extends below the recess to prevent the cement from being forced upwardly into the recess. The inner diameter of the liner is provided with groove 47 or other means for connection with a suitable pulling tool, whereby it may be removed from across the recess 43 in a subsequent portion of the method to be described hereinafter.

However, this liner is positioned across the recess when the casing head 27 is lowered with the casing 25 into the anchored position of FIG. 3, and is releasably held down in such position, if desired, by any suitable remotely actuated apparatuitus common for this purpose.

It is contemplated, however, that certain aspects of the method of this invention may be practiced in connection with a cementing procedure much like that heretofore employed, and particularly wherein the cement is conducted downwardly through the drill string and upwardly between the surface casing and hole 20 for sealing off the annular space therebetween. Apparatus suitable for this purpose is shown in the aforementioned Patent No. 2,808,229. For that matter, it is further contemplated that certain aspects of this method may be practiced in connection with the anchoring of the surface casing and casing head by some means other than cementing.

At any rate, upon anchoring of the surface casing 25 and casing head 27, the tubular member 41 is disconnected from the upper flange 38 of the casing head 27 and removed upwardly therefrom, in a manner previously described.

At the water level, the dogs 35 of the apparatus 28 are connected with suitable pressure control equipment of the character shown in FIG. 4, and described generally below, and the cables 33 are let out, guidedly lower the pressure control equipment onto the upper end of the casing head 27 and lock the lower flange 49 of such equipment to the upper flange 38 of the casing head 27 in a manner previously described. During such lowering, outwardly projecting parts (90° from that shown in FIG. 4) on the equipment are supported upon the upper ends 35a of the dogs and the upper end of the collar 34. If desired, the equipment may also have a flange 49g guidably slideable over the cables 30 and 33.

This pressure control equipment 49 includes a pair of vertically spaced-apart, ram-type blowout preventers 50 and 51 together with a universal type of preventer 52 disposed above the preventer 51, each of the preventers having a bore therethrough which forms a substantial continuation of the bore through the casing head 27 and casing 25. The upper preventer 52 may be of a construction similar to one manufactured and sold by the Hydril Company, and shown and described on pages 282-287 of the 1960-61 Edition of the Composite Catalog of Oil Field Equipment and Services. The preventers 50 and 51 may, on the other hand, comprise any suitable construction having a pair of oppositely disposed rams 53 and 54 each extendible and retractable between operative and inoperative positions. As indicated in FIG. 4, a tubular member 56 extends from the upper end of preventer 52 and, similarly to the tubular member 41, has a bore (not shown) which forms a continuation of the bore of the casing head and surface casing.

The rams of one such preventer may be "blind" rams in the sense that they seal off against one another across an open hole, while the rams of the other preventer must be "pipe" rams in the sense that each has a corresponding groove therearcross for fitting about a pipe and sealing across the annular space between the pipe and preventer body. As shown in the aforementioned publication, the annular sealing element of the preventer 52 is movable between a position in which it provides a full open bore through the preventer body and a position for sealing about pipes of various size and configuration so that it is "universal" in operation.

With pressure control apparatus of the type above described connected to the upper end of the casing head 27, as shown in FIG. 4, the drill string 22 is lowered down through such equipment, as well as the casing head and surface casing for drilling a further hole of the well, as shown in FIG. 5. When this further hole has reached a desired depth, the drill string 22 is removed from within the surface casing, casing head, pressure control equipment 49 and the tubular extension 56 thereabove which extends to the water level. Then, a production casing 57 is lowered through this same equipment and into the further hole 55, as shown in FIG. 5, for suspension from the casing head 27 by means of the slips of the casing hanger 44.

For this purpose, the slips 45 are moved from the retracted position of FIGS. 1, 3 and 4 out of the recess 43 and into a conical bowl 58 within the bore of the body of the casing head 27. In this latter position, the slips grip and thereby suspend the surface casing 25 within the annular space between the heads and surface casing. This annular seal thus confines mud in the annular space above the cement 59 which is conducted downwardly through the production casing 57 and upwardly between such casing and the hole 55. There is an outlet 60 from a continuation of this annular space between casing 57 and casing 25 and just beneath the casing hanger, and a valve 61 at such outlet controls the flow therethrough from as well as to the annular space. Upon this suspension of the production casing 57, the cement 59 is forced into the annular space by means of a plug 62 movable downwardly through the conductor casing. Obviously, when the cement hardens, the casing 57 is thereby anchored within the hole 55 concentrically of the surface casing 25 extending upwardly therefrom. As well known in the art, and as indicated at 57a in FIG. 8, the casing 57 is then perforated in a conventional manner for communicating its bore and the production zone 57b.

With reference more particularly to the details of the casing hanger 44, the slips 45 are movable from the retracted position (FIG. 2) within the recess 43 to the casing suspending position (FIG. 6) wherein they seat upon the bowl 58 within the annulus between the head and surface casing. Obviously, before the slips can be so moved, it is necessary to remove the liner 46 upwardly the pressure control equipment 49 and the tubular extension 56 which, as previously mentioned, are at least substantially fully opened.

As also previously mentioned, a suitable pulling tool may be lowered through the equipment shown in FIG. 4 for the purpose of latching with the groove 47 prior to raising it. Ordinarily, this operation would be performed after pulling of the drill string but before running of the production casing. Because, at this stage, the liner has served its purpose in shielding the hanger 44 against damage by the drill bit. At the same time, the production casing 57 shields the hanger against cement 59.

The slips 45 of the casing hanger 44 are moved from retracted to operative position by means of rams 63 or the like mounted on the casing head and fluid actuated from a source above the water level. For this purpose, there is one such ram for each slip, as indicated on the left side of FIG. 2. As best shown in this same figure, each ram comprises a piston 65 which is guidably slideable within a cylinder 65 formed in a boss 66 extending outwardly from the head, and a stem 67 on the piston extending sealably through an opening in the head for reciprocation and connection at its inner end with the slip it operates.
Each ram is caused to move inwardly and outwardly by means of suitable fluid lines 65a and 65b connecting with the cylinder 65 on opposite sides of the piston 64, as shown in FIG. 6A.

Each ram stem 67 has a skirt 68 which extends downwardly therefrom for engagement with the slip it operates when the ram is retracted within the casing 45. More particularly, each skirt 68 is received within grooves formed in a plate 69 connected to the upper end of the slip, whereby the slip is free to slide downwardly with respect to the ram, while at the same time being guided in its vertical movement by virtue of the fitting of the grooves over the opposite edges of the skirt 68. As best shown by a comparison of FIG. 5 with FIGS. 1, 3 and 4, each slip will disengage from its skirt as it is guided thereby downwardly into seating engagement on the bowl 58. Thus, any forces which would tend to expand the seated slips are in no way transmitted to the rams 63. Also, and for a reason which will be appreciated from the description to follow, this separation of the slips from the rams enables the latter to be withdrawn into substantially the position they occupied when engaged with the retracted slips.

More particularly, each slip 45 is of such circumferential extent that the opposite edges of adjacent slips will be almost in abutment with one another when seated upon the bowl 58, as shown in FIG. 6. Obviously, some small clearance is desired between the slips so as to accommodate tolerances in the casing to be suspended by the slips. However, this spacing is sufficiently small that any resultant sealing members 73 disposed laterally across each slip and circumferentially coextensive therewith may be expanded into engagement with one another at their opposite ends to provide a continuous annular seal across the annular space between the body of the casing head above the seat 58 and the production casing 57.

The hanger having slips of the general construction shown in the drawings is described in detail in U.S. Patent No. 2,920,909 issued to Herbert Allen on January 12, 1960. Thus, as indicated in FIG. 5, each slip comprises a body 74 having an outer tapered surface for sealing on the bowl 58 and supporting the seal element 73. Two sets of slip segments 75 and 76 are supported by the body, one above the seal element 73 and the other below such seal element and suspended from the upper slip segment 75. As shown and described in the aforementioned patent, the slip segments of this slip are automatically operable, upon disposal of the slip within the bowl 58, to cause the teeth on the slip segments to grip the casing 57 and compress the seal elements 73 into the continuous annular seal above described. Obviously, other slips of the so-called "automatic" variety are also usable in suspending the production casing 57. For that matter, the means for sealing the annular space about the casing may be separate from the slip segments of the hanger.

The upper end of each ram has an inwardly projecting part 77 having wings 78 extending from each side thereof and curved or otherwise formed about their inner ends for engaging and at least approximately centering the casing 57 as the slips 45 are moved out of the recess and into seated position within the bowl 58 (see FIG. 6A). For this purpose, the innermost dimension of the part 77, including wings 78, is disposed just radially inwardly of the innermost dimensions of the slip 45 operated by the ram so that such inner abutment part 77 will engage the casing 57 before the engagement therewith of the slips 45.

As shown in FIG. 6A, each of the fluid lines 65a and 65b for each of the cylinders is connected to a common line for extension to suitable pumping equipment at ground level, and each piston 64 of substantially the same design is operable to retract the rams 63. As best shown in FIG. 5, the fluid lines are connected to each piston. Thus, even though one piston may lag the others as the rams are actuated to move the several pistons inwardly, the oppositely disposed and equal forces on the several rams will cause the inner ends 77 thereof to assume the balanced position shown in FIG. 6A in which they hold the casing substantially centered within the casing head. As can also be seen from FIG. 6A, the inner ends 77 of the rams extend laterally a substantial amount so as to extend about most of the circumference of the casing in its centered position, and also to prevent the casing from being pushed to one side or the other of a centered position, despite the aforementioned possibility of one piston lagging the other.

As will be noted from FIG. 2, the slips 45 are arranged in annular patterns when disposed in both their retracted and extended positions. More particular, the innermost limit of their annular pattern when retracted (FIG. 2) is disposed concentrically outwardly of the outermost limit of their annular pattern when extended into seating position (FIG. 6), so that there is a full opening through the head when the slips are so retracted. Also, as the linkage connecting the slips folds between expanded and collapsed positions, it remains at least substantially within these innermost and outermost limits, whereby the recess 43 need be substantially no larger than that necessary to accommodate the slips. Still further, the arms 70 making up the linkage swing about axes parallel to the axis of the bore of the head 27 so that they take up a minimum of vertical space within the recess 43. Each of these characteristics contributes to the novel design of this particular hanger since the minimum dimensions of the recess 43 are important in keeping the cost as well as the necessary pressure holding capacity of the head to a minimum.

When the production casing 57 has been suspended and cemented in place in the manner above described, each of the rams 63 is retracted within the production casing 57, wherein the inner portion 77 thereof is disposed within the recess 43 and outside of the bore of the body of the casing head. At this time, a casing cutter 79 is lowered down over the outside of the production casing 57 for cutting or severing it at a location above the casing hanger 44. For this purpose, the cutter comprises a tubular carrier 80 rotatable by suitable means at the water level and having an annular cutter element 81 mounted on its lower end. The lower end of the cutter element seats upon the upper end of the casing hanger 44 so as to determine the location of the cut longitudinally of the production casing. The cutting element is preferably of such construction that when it has severed the casing, it will support the severed portion for removal upwards through the casing head and pressure control equipment with the tubular carrier 80.

At this time, tubing hanger 83 is lowered with tubing hanger 83 through the pressure control equipment 49 and the casing head 27 into the casing 57, as shown in FIG. 8. This tubing carries a packer 84 on its lower end for sealing the annular space between the tubing and production casing 57 above the perforations 57a communicating with the production zone. The packer is located in this position longitudinally of the production casing by the landing of the tubing hanger 83 on a conical bowl 85 on the bore of the casing head 27 above the annular recess 43 therein.

More particularly, the tubing hanger 83 is of the solid
mandrel type having a conical seat about its outer side for seating in the bowl 85 and a bore 86 therethrough, the lower end of the bore being threaded or otherwise prepared for connection to the upper end of the tubing 82. The upper end of the tubing hanger bore 86 is also prepared for reassemblable connection to a fitting 87 connected on the lower end of a tubular running string 88 which extends to the water level. As can be seen from FIG. 6, a back pressure valve 89 of any suitable construction is secured within a restriction 90 in the bore 86 of the tubing hanger. As well known in the art, this back pressure valve 89 is run into the well with the tubing hanger and then removed therefrom when the well is brought in, as will be described hereinafter. The connection of the fitting 87 to the upper end of the bore 86 of the tubing hanger 83 may be of any suitable construction, as, for example, that shown in Patent No. 2,644,524, which would permit the connection to be made without rotation of the fitting.

As indicated by the broken lines 91 in FIG. 8, the outer periphery of the tubing hanger 83 is grooved to bypass fluid from the annular space between tubing 82 and production casing 57 into the annular space above the tubing hanger between the tubular extension 88 and the pressure control equipment 49. Thus, upon running of the tubing, and prior to setting of the packer 84, which may be of any conventional "hook wall" variety, the drilling mud in the tubing is displaced upwardly through the annular space. As will be described hereinafter, upon replacement of the pressure control equipment with the permanent completion equipment, this bypass connection forms an annular space leading to an outlet at a portion of such equipment above the water level.

The lower end of the tubing hanger 83 is provided with an annular groove thereabout to form an upwardly facing shoulder 92 adapted to be engaged and thus held down by a downwardly facing shoulder 93 on the inner portion 77 of each ram as the rams are moved back into the extended position of FIG. 8. Thus, upon setting of the packer 84, the inner ends 77 of the rams are moved into the annular groove in the hanger to maintain the latter in its seated position upon bowl 85. Obviously, the rams may be retracted from the position shown in FIG. 8 to permit the hanger and tubing 82 to be pulled, if desired.

With the tubing hanger 83 held down in the manner described, the landing string 88 and fitting 87 are disconnected and removed from the tubing hanger, and the pressure control equipment 49 as well as the extension thereabove are disconnected from the casing head 27 and raised to water level. Of course, this latter procedure is carried out in a manner similar to that described in connection with the raising of the tubular extension 41 shown in FIGS. 1 and 3. When these parts have been so removed, and with particular reference to FIG. 8, the back pressure valve 89 will contain the well fluid pressure admitted to the tubing 82 through perforations 57a, the packer 84 will prevent this same well fluid pressure from communicating with the annular space between the tubing 82 and casing 57, and the casing hanger 44 will, as previously described, contain the fluid pressure within the annular space between the production casing 57 and surface casing 25.

At this time, the wellhead is prepared for the installation of the permanent completion equipment including the production platform shown in FIG. 9. If shown in FIG. 9, 87 shown in FIG. 9, this forming the shows a hanging structure 94, which generally similar to fitting 40, for engagement by the upper ends of the dogs. Another casing 96 connected to the bore of the fitting 94 and spaced within the outer casing 95 for lowering therewith extends upwardly for connection to the lower end of a tubing head 97 above the water level 98. More particularly, the tubing head 97 is disposed within a platform 99 having a floor 100 and lateral bracing 101 which is connected to the outer casing 95. As shown in FIG. 9, the platform 99 has further support through pilings 102 which project downwardly through the water for support at the subsurface level 21. When the connection has been made with the fitting 27, the upper ends of the cables 30 may be anchored to the platform floor and the cables 33 adjustable suspended therefrom by clamps 33a or the like.

A tubular extension 103 is connected by a fitting 104, which may be identical to the fitting 87 for landing string 88 (FIG. 8), to the upper end of the bore 86 through tubing hanger 83. The upper end of tubing extension 103 is connected in any suitable manner to the lower end of the bore 105 through upper tubing hanger 106 landed within a conical bowl 107 in the upper end of the bore through tubing head 97. Thus, the tubing extension 103 and inner casing 96 form an annular space which provides a continuation of the bypass provided by grooves 91 in the tubing hanger 83 and connects with an outlet 108 in the tubing head 97, the outer casing 96 being protected against mechanical damage by the casing 95. More particularly, this outlet is beneath the tubing hanger 106 which seals off the annular space and the flow through this outlet is controlled by a suitable valve 109 on the platform 99.

This permanent completion equipment also includes a conventional Christmas tree 112 connected above the tubing head 97, such tree including the usual master valve, flow wings and chokes illustrated in FIG. 9. The tubing head 97 carries several locking screws 114 movable inwardly to bear upon and hold the upper tubing hanger 106 down in seated position on the bowl 107. Also, the lower end of the Christmas tree 112 is counterbored at 115 to closely receive and seal with respect to an upwardly extending neck 116 on the upper tubing hanger 106.

As also shown in FIG. 9, the bore 113 through the tree forms a substantial continuation of the bore 105 in head 97 and the inner diameter of tubular extension 103, all of which are of a size to pass the back pressure valve 89. Thus, upon the installation of a blowout preventer and stripper head 117 above the Christmas tree, a suitable tool 110 may be run on a string 111 under pressure into the tubular extension 103 for connection with the back pressure valve 89. When so connected, this tool is operable to release the valve from its connection with the tubing hanger 83 and withdraw it upwardly through the tubular extension 103, Christmas tree 112 and stripper head. Obviously, upon removal of the back pressure valve 89 from the upper end of the tubing 82 and replacement of the stripper head with a cap, the well is prepared for production through the various valve controls of the Christmas tree, in a manner well known in the art.

Although, in the equipment just described, the Christmas tree and platform thereabout are disposed above the water level 98, this invention also contemplates that the Christmas tree may be installed just above the casing head 27 anchored at the under water level. In this latter case, of course, suitable lines may be provided for conveying fluid from the Christmas tree to a gathering system above or below the water level 98.

The equipment shown in FIG. 10 corresponds in both construction and use to that previously described in connection with FIGS. 1 to 9. It differs therefrom in that it involves the suspension and cementing of an inner string of casing intermediate the previously described surface casing and producing casing. However, as will be described below, and as contemplated by the present invention, an additional hanger for suspending the interme-
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The casing head 133 is disposed within the casing head which is mounted upon and lowered with the surface casing run into the first hole drilled at the subsurface level.

Although such equipment is also described in connection with the underwater completion of a well, it may be used in an offshore completion and for the purposes previously noted. Thus, as will be appreciated from the description to follow, such use of the equipment enables the installation of two or more casings without the necessity of changing the blowout preventer equipment above the casing head.

As shown in FIG. 10, however, three successively smaller holes 116, 119 and 129 have been drilled into the land 21 below the water level. The largest and uppermost hole 118 receives a surface casing 121 which is anchored in such hole by means of cement 122. The next lower hole 119 receives an intermediate casing 123 anchored therein by cement 124, while the smallest and lowermost hole 120 receives production casing 125 anchored therein by means of cement 126. This last-mentioned cement was forced downwardly through the casing 125 by a cement plug 127, in a manner previously described. Perforations 128 through the production casing and cement 126 connect the production zone 129 with the interior of the tubing 130 which is packed off at 131 within the casing 125 and above the perforations for extension upwardly through the production casing and equipment to be described for conducting the well fluid to above the water level.

As in the case of the equipment described in connection with FIGS. 1 to 9, the surface casing 121 is located within the first drilled hole 118 by means of a landing base 132 of shroud-like construction. Also, this landing base is connected about a casing head 133 mounted on the upper end of casing 121 for lowering therewith. This lowering of the assembly including casing 121 and hanger 133 is accomplished by suitable apparatus 134 which may be identical to that apparatus 28 previously described.

The intermediate casing 123 is suspended within the casing head 133 by means of a hanger 135 similar in construction to the hanger 44 described in connection with FIGS. 1 to 9. Thus, this hanger is seated within a conical bowl 132b in the head 133 for gripping the intermediate casing 123 and sealing across the annular space between the intermediate casing and surface casing 121 to confine fluids within such annular space for connection with the valve-controlled outlet 137.

As in the equipment of FIGS. 1 to 9, the casing head 133 has a recess 136 thereabout above the seat 136 for receiving the slips of the hanger in a retracted position prior to lowering the intermediate casing 123. More particularly, and similar to the aforementioned hanger 44, the slips are shielded during drilling and cementing operations by means of a liner (not shown) and disposable across the recess 136. Then, when the liner has been removed and the intermediate casing 123 has been run, the rams 139 are moved inwardly to move the slips of the hanger 135 inwardly into casing gripping position. As previously described, the inner ends of the rams 139 are adapted to engage the casing so suspended for at least approximately centering it, and the slips of the hanger are guided during inward movement and then released from the rams as they drop into the seat or bowl 136. The rams 139 are then retracted to permit a casing cutter similar to the one previously described to be lowered through the casing head for severing the intermediate casing 123 at a point just above the upper end of the hanger 135.

However, as distinguished from the casing head 27 of FIGS. 1 to 9, the casing head 133 has another recess 140 thereabout to receive the slips of another hanger 141 when disposed in their retracted position. More particularly, the slips of the hanger 141 are adapted to grip and thus suspend the production casing 125, as shown in FIG. 10. In a manner to be described below, this hanger also cooperates with other parts to seal off the annular space between the intermediate and production casings.

Although the casing hanger 141 may be identical in construction to the casing hanger 135, and thus the casing hanger 44 previously described, it is adapted to seat within a separate bowl 142 landable within a conical seat 143 in the bore of the head 133 between the upper and lower recesses 140 and 138, respectively. More particularly, the bowl has an inner conical seat 144 to land the outer conical surfaces on the slips of the upper hanger 141 so that the conical seat 143 is formed integrally with the bore of the head beneath the lower recess 138. This bowl 142 is lowered through the upper end of the casing head 133 and into landed position after the intermediate casing 123 has been suspended in the manner previously described. As will be understood, the use of this bowl 142 enables the radial extent of the upper casing hanger 141 and upper recess 140 to be substantially no greater than that of the lower hanger 135 and lower recess 138, respectively.

Thus, upon landing of the bowl 142, the production casing 125 is lowered within the intermediate casing and the upper casing 125 has reached the desired level, the rams 145 engageable with the slips of the upper casing hanger 141 are actuated to move such slips inwardly from retracted position within upper recess 140 into the bowl 142 for sealing in the conical recess 144 thereof. As in the case of the slips of the hanger 135, the slips of hanger 141 are released from the rams 145 as they drop into the bowl, and the inner portions of the rams are useful at least approximately centering the casing 125 as it is suspended within the head. Also, upon retraction of the rams 145 the casing 125 may be severed at the location shown and in the manner previously described.

The bowl 142 is provided with means 142a thereabout for sealing with respect to the seat 143. Thus, with the slips of hanger 141 sealing off the annular space between surface casing 123 and the bowl, the space between such casing and the intermediate casing 123 is also sealed off beneath the hanger 141. If desired, the recess 138 in the head which connects with the upper end of this space may be provided with a valve-controlled outlet similar to that shown at 137.

The lower end of the bowl 142 has an annular groove 146 to provide an upwardly facing shoulder engageable by a downwardly facing shoulder on the inner end of each of the rams 135. Thus, when the bowl 142 has been landed upon seat 143 of the casing head, the rams 139 may be moved back into an extended position for holding the bowl down in such seated position, similarly to the manner in which the tubing hanger 83 in the apparatus of FIGS. 1 to 9 is held down in its seated position.

The upper end of the tubing 130 is connected to the lower end of a tunneling hanger 147 which is, in turn, connected to the lower end of a tubular extension 148 to form a continuation of the flow path through the tunneling upwardly to water level. As in the case of the tubing of the equipment shown in FIGS. 1 and 9, this tubular extension 148 is surrounded by an intermediate casing 149 and an outer casing 150, both of which are connected at their lower ends to a fitting 151 mounted above and connected by the apparatus 134 to the upper end of casing 133.

This tubing hanger 147 is landed within the conical seat 151 in a bowl 152 which, in turn, is lowered onto a seat 153 in the upper end of the casing head 133 of upper recess 140. As shown in FIG. 10, this bowl 152 may be held down in its seated position by the inner ends of the rams 145 similarly to the manner in which the bowl 142 is held down by the rams 139. As indicated at 152a, this bowl has bypass grooves for connecting the upper end.
of the annular space between casing 125 and tubing 130 with the lower end of the annular space between tubular extension 148 and casing 149.

Obviously, the apparatus just described, and particularly the tubular extension 148 of the production tubing 130 may be connected to a Christmas tree either above the water level, as shown in FIG. 9, or below water level and immediately above the equipment of FIG. 10. It is also obvious, of course, that the several parts shown in FIG. 10 may be disposed in the position shown in a manner previously described in connection with the disposal of the parts shown in FIGS. 1 through 9. It is still further apparent that additional equipment, and particularly a casing head, may be constructed in accordance with the present invention for suspending three or more casings within a surface casing upon which the casing head is mounted and lowered into landed position.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the method and apparatus. It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth and shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. Wellhead equipment, comprising a head having a bore therethrough and a recess therein communicating with the bore, a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, and a plurality of reciprocable rams for moving said slips out of the recess and into the bowl to suspend a casing therefrom, said means comprising cylinders on the head each having a piston reciprocably slidable therein and having a stem connected to a slip, means for reciprocating the pistons within the cylinders including fluid lines interconnecting the cylinders on opposite sides of each piston therein, each such line having a common connection to a fluid pumping system, each piston being limited in its movement to casing suspending position, all of said pistons having substantially equal pressure responsive areas thereon and all of said piston stems having casing guiding means on their inner ends extending laterally so as to surround a major portion of the casing when all are engaged therewith.

2. Wellhead equipment, comprising a head having a bore therethrough and a recess therein communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, and a plurality of reciprocable rams for moving said slips out of the recess and into the bowl to suspend the casing, the inner end of each ram having a part thereon disposed radially inwardly of the slip moved thereby for engaging the casing prior to the engagement therewith of said slip to align it with respect to the bore as said rams move the slips out of the recess.

3. Wellhead equipment, comprising a head having a bore therethrough and a recess communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, a plurality of rams reciprocably mounted on the head, each ram having a dependent skirt, and means providing grooves on each slip vertically slidable over the skirt of a ram for movement inwardly with the ram and out of the recess for dropping freely into the bowl to suspend a casing therefrom.

4. Wellhead equipment, comprising a head having a bore therethrough and a recess therein communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, and means in the recess supporting the hanger and reciprocable rams having means detachably connected to the slips for moving said slips radially inwardly from the recess and relative to said supporting means into the bore and permitting vertical movement of the slips relative to the rams so that the slips will drop into the bowl as rams are moved radially inwardly of the recess supporting means to suspend a casing therefrom, and means connecting the slips to one another as they move from the recess for movement downwardly with one another as they drop into the bowl.

5. Wellhead equipment, comprising a head having a bore therethrough and a recess in the head communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, means detachably connected to the slips for moving them out of the recess and onto the bowl to suspend the casing, and means carried in the head for radial extension into the bore to force the casing into a centered position with respect to the bore upon detachment of the slips from said moving means so that said slips may drop onto the bowl through an annular space between the casing and bore of the head.

6. Wellhead equipment of the character defined in claim 5, wherein said casing forcing means comprises parts on the slip moving means.

7. Wellhead equipment, comprising a head having a bore therethrough and a recess in the head communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, a plurality of rams mounted on the head and releasably connected to the slips, means for reciprocating the rams to move said slips out of the recess and into the bore for dropping freely onto the bowl to suspend the casing therefrom, and means including parts on the rams for holding the casing in a centered position within the bore as the slips are released therefrom.

8. Wellhead equipment, comprising a head having a bore therethrough and a recess in the head communicating with the bore, a bowl in the head communicating with the bore beneath the recess, a casing hanger within the recess, a casing hanger comprising a plurality of slips and means connecting each slip to its adjacent slips to prevent their movement axially relative to one another during movement out of the recess and into the bore and during dropping onto the bowl.

9. Wellhead equipment, comprising a head having a bore therethrough and a recess in the head communicating with the bore, means providing a bowl in the head communicating with the bore beneath the recess, a casing hanger within the recess, a liner removably disposed across the recess when the hanger is disposed therein, and means on the head detachably connected to the hanger for moving said hanger, upon removal of the liner from across the recess, out of the recess and into the bore for dropping freely into the bowl to suspend the casing therefrom.

10. Wellhead equipment, comprising a head having a bore therethrough and a recess in the head communicating with the bore, a bowl in the head communicating with the bore beneath the recess, a casing hanger comprising a plurality of slips within the recess, a sleeve mounted across the recess when the slips are disposed therein and movable upwardly through the head, and rams reciprocably mounted on the head and detachably connected to the slips for extension inwardly, when the
sleeve is so moved upwardly through the head, to move said slips out of the recess and into the bore for dropping freely into the bowl to suspend a casing therefrom.

10. Wellhead equipment, comprising a head having a bore therethrough and a pair of recesses in the head communicating with the bore in vertically spaced-apart relation, a sleeve removable and disposed across each recess, a bowl in the head communicating with the bore beneath the lower recess, a seat in the head communicating with the bore between the upper and lower recesses and substantially aligned with the bowl therebelow, a first casing hanger in the lower recess, means on the head for moving the first hanger out of the lower recess and into the bowl to suspend a casing therefrom, a second bowl landable on the seat, a second casing hanger in the upper recess, means on the head for moving the second hanger out of the upper recess and into the second bowl to suspend a second casing therefrom within the first-mentioned casing, and means on said first hanger moving means for engaging the second bowl to hold it down on its seat.

12. Wellhead equipment, comprising a head having a bore therethrough and a pair of recesses in the head communicating with the bore in vertically spaced-apart relation, a sleeve removable and disposed across each recess, a bowl in the head communicating with the bore beneath the lower recess, a seat in the head communicating with the bore between the upper and lower recesses and substantially aligned with the bowl therebelow, a first casing hanger in the lower recess, means on the head for moving the first hanger out of the lower recess upon removal of the sleeve thereacross and into the bowl to suspend a casing therefrom, a second bowl landable on the seat, a second casing hanger in the upper recess, and means on the head for moving the second hanger out of the upper recess upon removal of the sleeve thereacross and into the second bowl to suspend a second casing therefrom within the first-mentioned casing.

13. Wellhead equipment, comprising a head having a bore therethrough and a pair of recesses in the head communicating with the bore in vertically spaced-apart relation, a first bowl in the head communicating with the bore beneath the lower recess, a seat in the head communicating with the bore between the upper and lower recesses and substantially aligned with the bowl therebelow, a first casing comprising a plurality of slips in the lower recess, reciprocable rams on the head for moving the slips out of the lower recess and into the first bowl to suspend a casing therefrom, a second bowl landable on the seat, a second casing comprising a plurality of slips in the upper recess, additional reciprocable rams on the head for moving the slips out of the upper recess and into the second bowl to suspend a second casing therefrom within the first-mentioned casing, another seat in the head communicating with the bore above the upper recess, a third bowl landable on the other seat, and a tubing hanger landable on the third bowl and having means thereon for suspending a tubing within the second casing when so seated, said third bowl having upwardly facing shoulder means thereon, and each of said additional rams having an inner end engageable with said shoulder means to hold the third bowl down on the other seat.

15. Wellhead equipment, comprising a head having a bore therethrough and a recess therein communicating with the bore, a bowl in the head communicating with the bowl beneath the recess, a casing hanger in the recess, means on the head for moving the hanger from the recess into the bowl to suspend a casing therefrom, another bowl in the head above the recess, a tubing hanger landable on the seat to suspend a tubing within the casing and providing a by-pass between the tubing hanger and seat communicating at one end with the annular space between the casing and tubing, a fitting connectable above the head and having an upward extension thereon, another head mounted on the extension and having a bowl therein, another hanger landable in the last-mentioned bowl and suspending a tubing extension therefrom for connection with the tubing hanger to provide a continuation of the tubing suspended therefrom and an annular space between the tubing and fitting extension connecting with the other end of the by-pass, an outlet from the upper end of the last-mentioned annular space, and a master valve above the other tubing hanger.

17. Wellhead apparatus of the character defined in claim 16, including means within the tubing hanger for connection to a back pressure valve of a size to pass the tubing extension.

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