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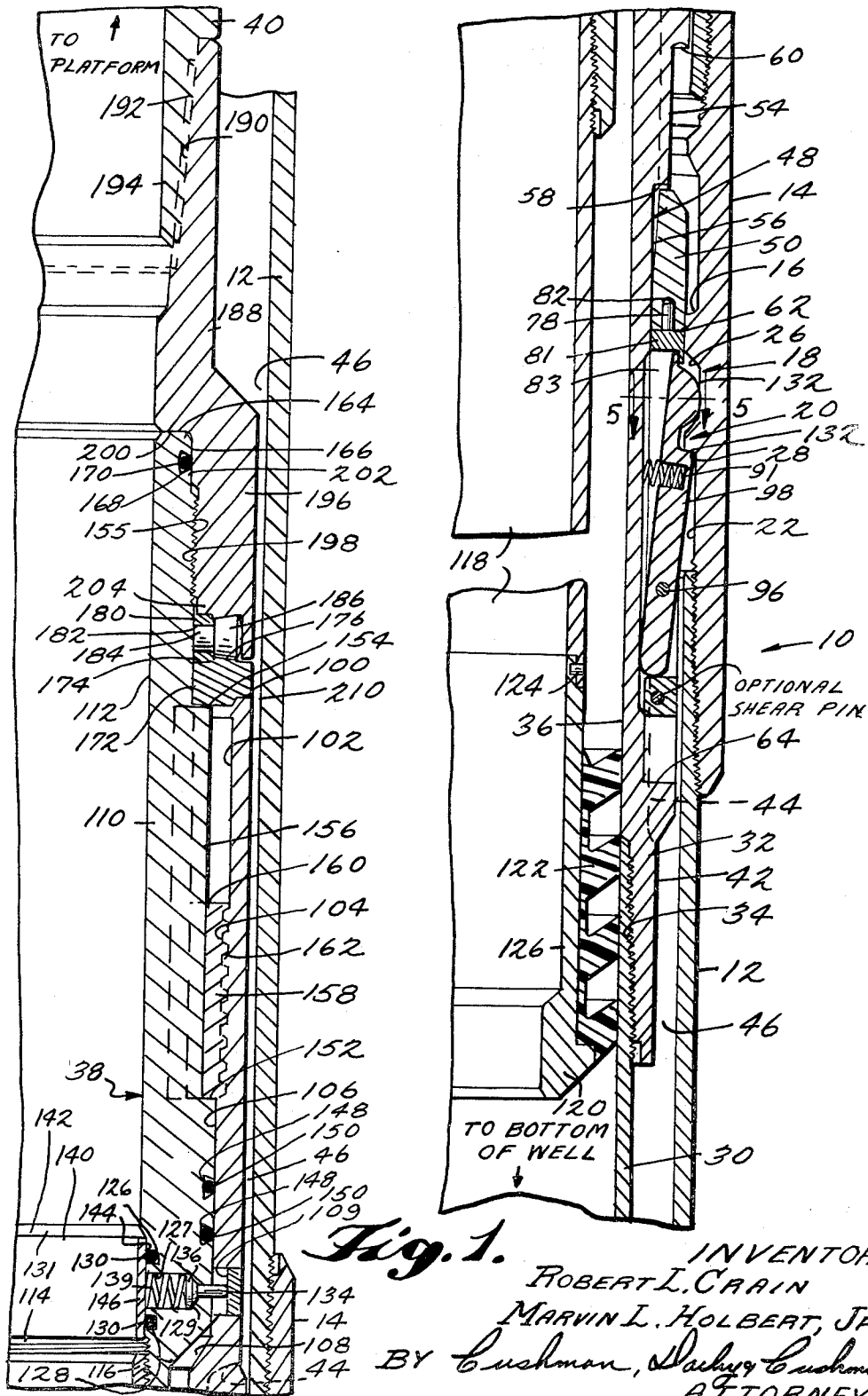
R. L. CRAIN ETAL

3,489,221

WELL COMPLETION APPARATUS AND METHOD

Filed June 17, 1968

4 Sheets-Sheet 1



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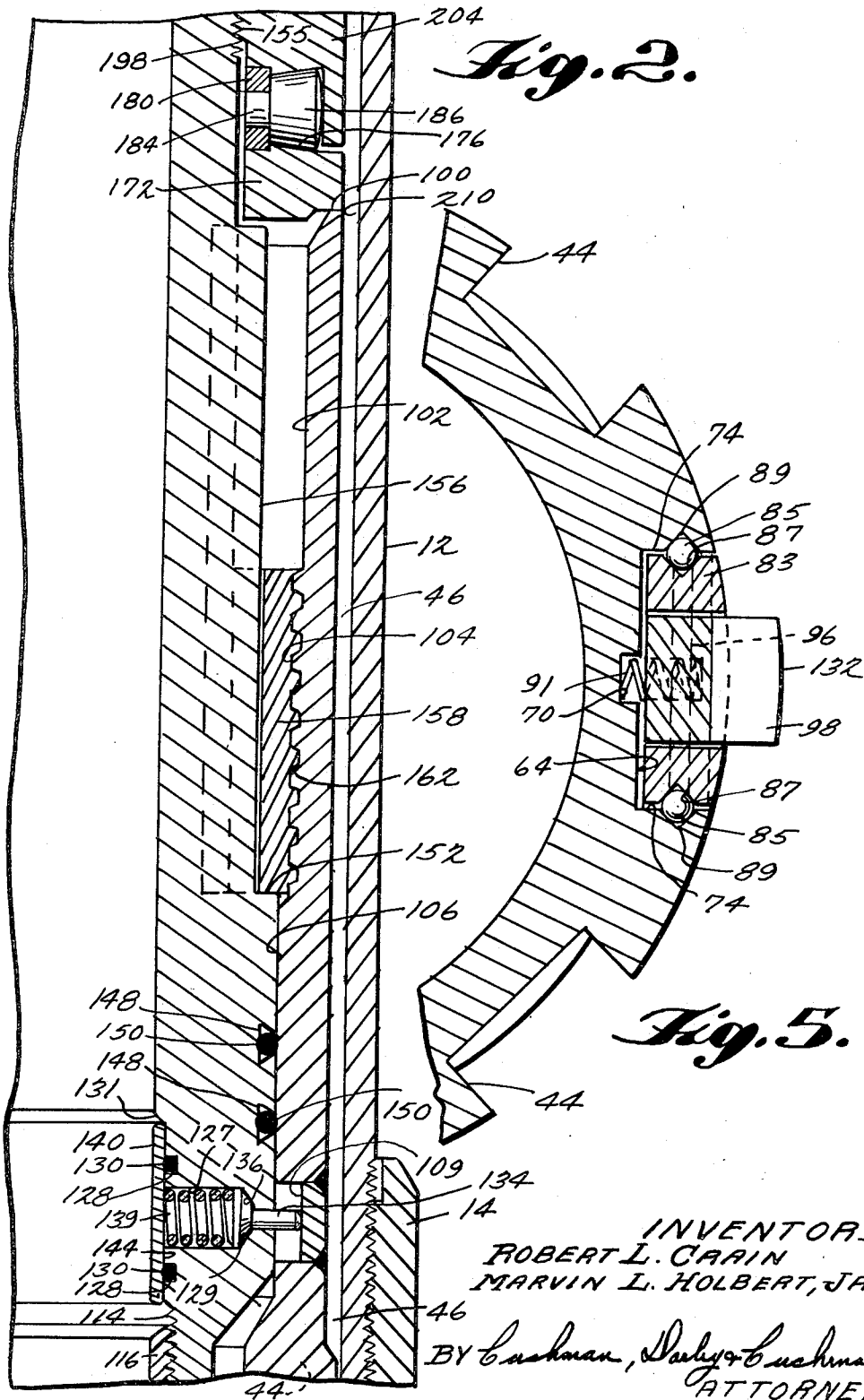
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WELL COMPLETION APPARATUS AND METHOD

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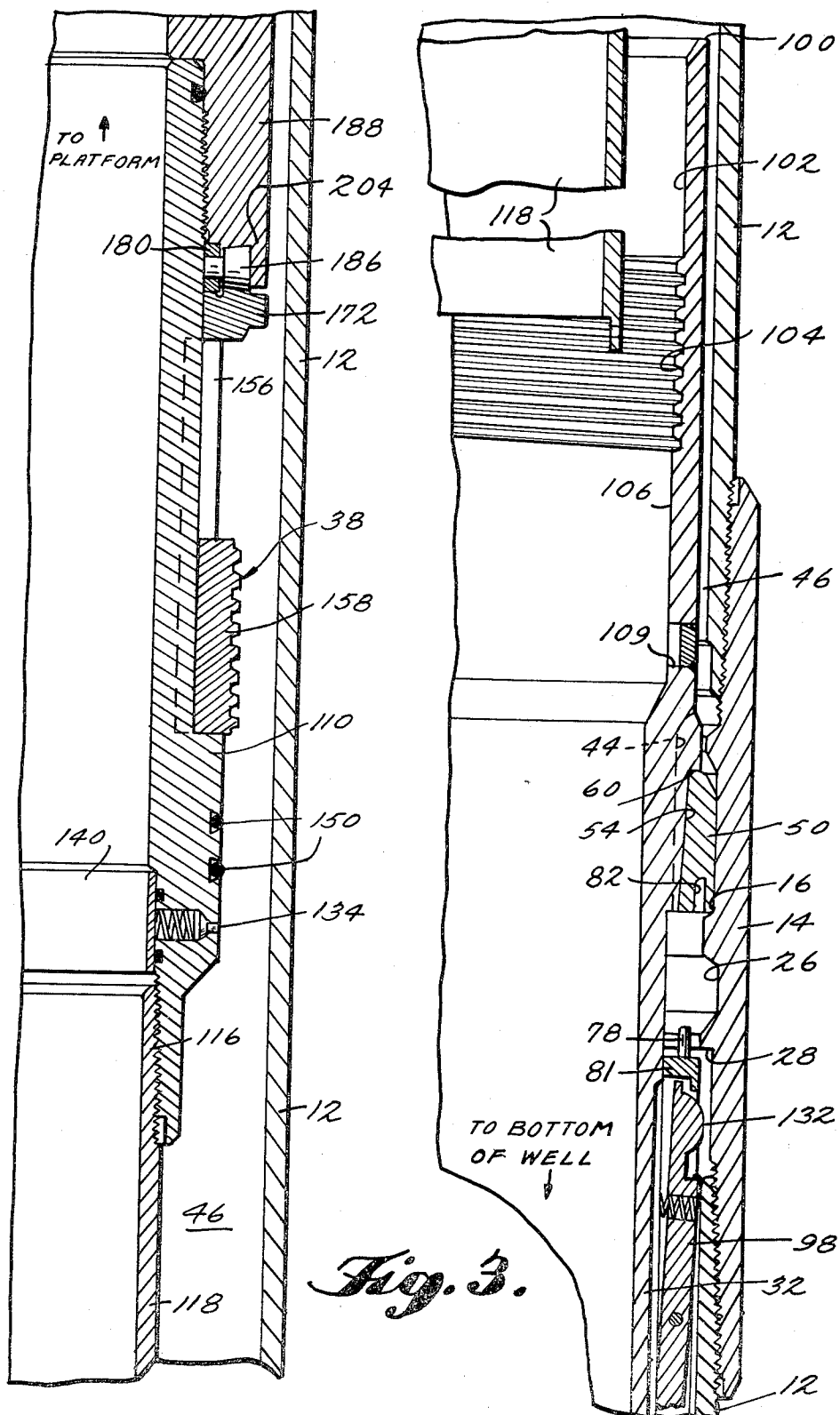
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WELL COMPLETION APPARATUS AND METHOD

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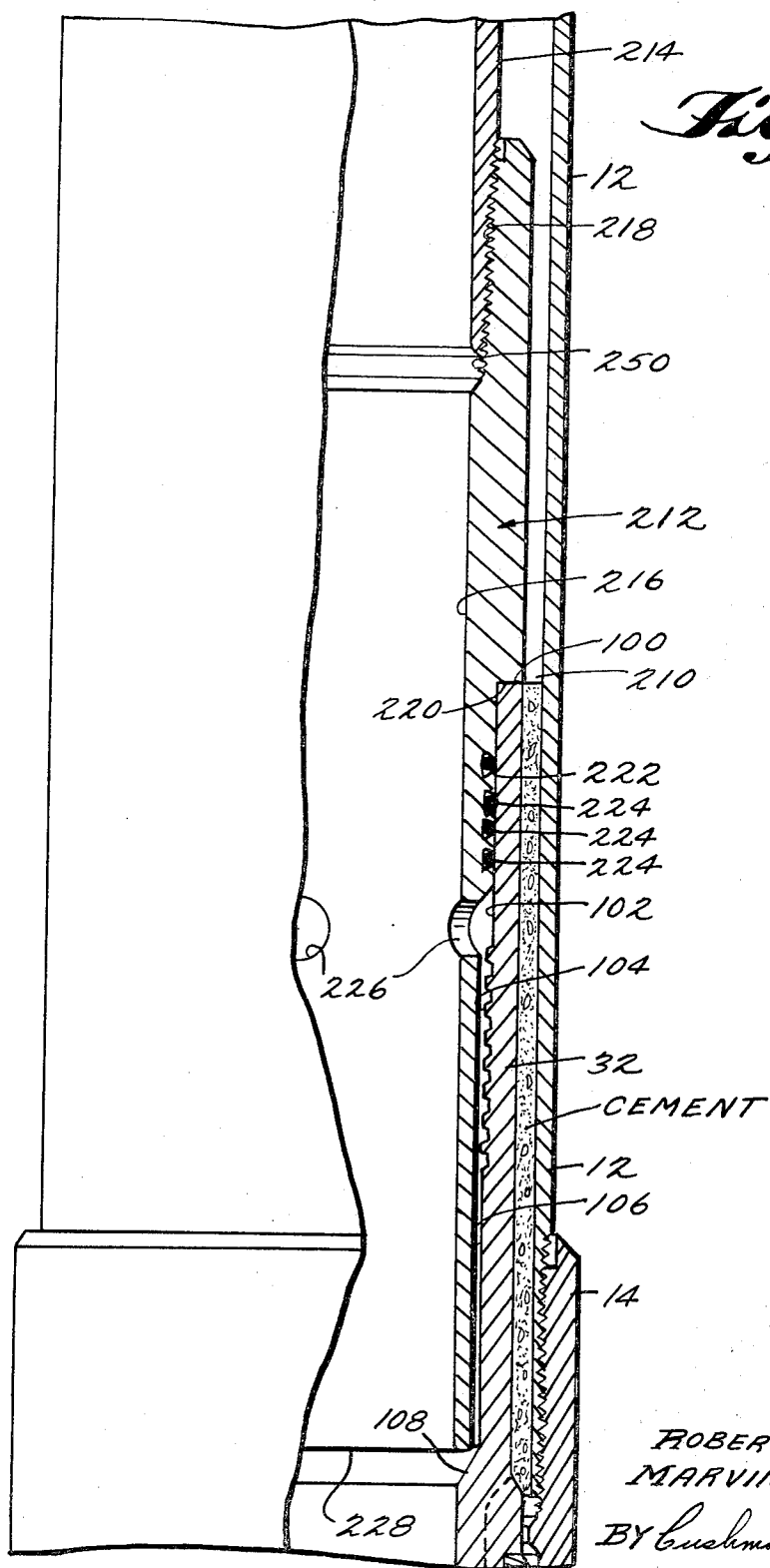
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WELL COMPLETION APPARATUS AND METHOD

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3,489,221

WELL COMPLETION APPARATUS AND METHOD

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10 Claims

ABSTRACT OF THE DISCLOSURE

An initially restrained, pawl-actuated ring supports a down-hole casing liner hanger in the bore of an outer string of casing. The hanger setting tool includes a replaceable shear pin assembly for preventing backing out of the tool during running. A floating nut and roller bearing assembly are provided to removably secure the setting tool and hanger to one another and to support the tool during the process of disengaging the threaded securement of the floating nut and the liner hanger. Cementing procedures using the apparatus are also described.

BACKGROUND OF THE INVENTION

During the drilling of a well whether on land or under water, upon reaching various levels, the drilled portion is cased and the casing/formation annulus is cemented. Successive casings are of progressively smaller diameter and are concentric with previously emplaced casings.

With the drilling of wells beyond ten thousand feet becoming quite usual, the use of casing liners has become a popular way of keeping casing costs down and facilitating cementing. Generally, once the well has been made sufficiently deeper to receive a casing liner, the latter is lowered into the well on a running tool and attached near its upper end to the next outer casing string near the lower end of said next outer casing string. The liner/formation annulus may then be cemented and the tool withdrawn from the well. After further drilling, this may be repeated for yet another casing liner.

When a decision is made that the well which has been drilled should be completed, so it may be produced from casing strings having tie-back subs on the lower ends thereof may be run into the well, tied back into the upper ends of the respective liners and these strings cemented to progress completion of the well. Once this has been done, the well may be conventionally further completed.

Although the use of liners is now conventional, unsatisfactorily solved problems have remained in supporting, attachment, cementing and tying back into casing liners; and it is to these problems that the present invention is primarily addressed.

The inventors herein are aware of the down-hole hanger disclosed in the copending U.S. patent application of Pitts et al., Ser. No. 539,242, filed Feb. 18, 1966, and of the tie-back sub apparatus disclosed in the copending U.S. patent applications of Quebe et al., Ser. No. 553,245, filed May 26, 1966, now Patent No. 3,400,950, and of Harwell Jr., Ser. No. 553,224, filed May 26, 1966, now abandoned which are discussed in greater detail hereinafter, insofar as they relate to the subject matter disclosed herein.

SUMMARY OF THE INVENTION

In preferred embodiment the invention provides an initially restrained, pawl-actuated ring which supports a

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down-hole casing liner hanger in the bore of an outer string of casing. The hanger setting tool includes a replaceable shear pin assembly for preventing backing out of the tool during running. A floating nut and roller bearing assembly are provided to removably secure the setting tool and hanger to one another and to support the tool during the process of disengaging the threaded securement of the floating nut and the liner hanger. Cementing procedures using the apparatus are also described.

An object of the invention is the provision of liner hanger means that provide maximum support with a minimum liner/outer casing annulus, for example equipment for hanging a 7-inch O.D. liner in a 9 $\frac{1}{2}$ inch O.D. outer casing is shown in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a fragmenting vertical sectional view, with parts in elevation, of a hanger liner being lowered in a well and hung in an outer casing, down hole via an expandible ring casing hanger, using a novel running tool.

FIGURE 2 is a fragmentary vertical sectional view on a larger scale, of a portion of the apparatus of FIGURE 1.

FIGURE 3 is a fragmentary vertical sectional view similar to FIGURE 1, showing a later stage wherein the tool has been raised somewhat to facilitate cementing.

FIGURE 4 is a fragmentary vertical sectional view of the hanger, liner and casing of FIGURE 3, showing a later stage wherein a casing string having a tie-back sub on its lower end has been connected to the upper end of the bore of the liner hanger.

FIGURE 5 is a fragmentary sectional view taken substantially on line 5—5 of FIGURE 1.

DESCRIPTION OF PREFERRED EMBODIMENT

In FIGURE 1 a petroleum well is shown at 10 during a stage of completion wherein an outer string of casing 12 is already in place in the well and, for instance, extends upward to a well-drilling platform, located above the figure. Between its upper extent and the upper extent of the figure, a conventional blowout preventer stack is interposed in the string 12 in order to provide for control of the well during later drilling stages. The BOP Stack may be, for instance, installed as described in chapter 8 of Prevention and Control of Blowouts, first edition, Petroleum Extension Service, The University of Texas, Austin (1958), for instance, using equipment as described in appendix A thereof.

Near the lower end of the casing string 12, for instance, between the last and next-to-last joints thereof, there is interposed a tubular, casing liner hanger housing 14. In the example shown, the housing 14 is in the form of a collar having two box ends adapted to threadably receive adjacent pin ends of the casing. The threading between the housing 14 and casing is of the same hand as that between the other, conventionally connected joints of the casing string 12.

The housing 14 has a circumferential, radially inwardly opening support ring landing groove 16 and pawl tripping groove means 18, 20 communicating with its central bore 22. The groove 16 is spaced vertically above the groove means 18, 20 in the inner peripheral surface 24 of the housing 14.

(The landing and tripping grooves are as further described using numerals 12 and 14 in the above-mentioned Pitts et al. U.S. patent application, excepting that the tripping groove means herein are shown comprising an upper, radially inwardly concave portion 26 having means

slightly therebelow, which define an annular, axially downwardly facing radial shoulder 28.) The concave portion 26 and shoulder 28, as juxtaposed, made a "key combination" found or closely approached nowhere else along the length of the bore of the casing string 12. Thus an increased assurance is provided that the complementarily keyed pawl of the liner hanger described hereinafter will accidentally prematurely trip during running or manipulating of the liner. In some instances, the outer casing string 12 may be the outermost casing which has been driven, vibrated, or otherwise emplaced in the earth and which may be commonly referred to as a surface casing; in other instances, the outer casing string 12 may be one emplaced subsequently to the surface casing and which extends downwardly through the bore of the surface casing. In either case, once the casing string 12 has been emplaced and secured in the well, drilling operations may be conducted down through the bore of the casing string 12 and continued until sufficient hole has been made to receive a next inner casing string, or in the present instance, initially a casing liner.

A string of inner casing 30 is made-up at the surface and lowered into the well through the bore of outer casing 12. As shown, a novel tubular, casing liner hanger 32 is secured to the upper end of the casing 30, the joint shown being a threaded one comprising internal threads 34 in the bore 36 of the hanger 32 near the lower end thereof. Other means of securement could be used, for instance, using a slip-and/or weld-type suspension. In FIGURES 1 and 2, the liner hanger 32 is shown removably secured to a novel running tool 38 to be further described hereinafter. The tool 38 is in turn secured at its upper end to the lower end of a string of drill pipe 40. Thus upon completion of making up the liner 30 at the surface, a pre-assembled liner installing assembly consisting of the liner hanger and setting tool 38 are secured to the upper end thereof and a string of drill pipe 40 made up above the running tool and used to lower the liner, liner hanger, and running tool into the well.

As an aside, it should be observed that "tool" as used to describe the element 38 is a term of petroleum well art and does not necessarily denote that the element is a tool in the technical sense. The element 38 could also be properly referred to as a lowering bushing.

The liner hanger 32 is longitudinally grooved at angularly spaced points along its radially outer surface 42 to provide a plurality of longitudinally extending, radially outwardly opening circulating flutes 44 for facilitating circulation of such fluids as drilling mud and cement axially past the liner hanger 32 in the annulus 46 between the outer casing internal peripheral surface and the exterior of the drill pipe, running tool, liner hanger and casing liner. Preferably, the maximum outer diameter of the liner hanger 32 is slightly less than the diameter of the outer casing string internal bore so that the liner hanger acts to some extent as a centralizer as the casing liner is being run.

The liner hanger 32 is girdled at its midsection by a radially outwardly opening circumferential groove 48 which receives an axially and radially once-split, expandable support ring 50, i.e. of C shape. The ring 50 is constructed of elastic, hard metal or the like so as to be self-expanding, from a forced radial contraction, upon removal of the contracting force.

As best illustrated in FIGURE 2 (and in FIGURE 1 of the aforementioned U.S. patent application of Pitts et al.) the groove 48 is characterized by having an upper region 54 in which the radial depth of the groove is less than the radial thickness of the ring 50, a lower region 56 in which the radial depth of the groove (measured from the maximum outer diameter of the liner hanger 32) is greater than the radial thickness of the support ring 50. Between the regions 54 and 56 is a downwardly facing annular transitional surface 58. The groove 48 is delimited by an upper, downwardly facing annular, radi-

ally directed shoulder 60 and a lower, upwardly facing annular radially directed shoulder 62. In the preferred embodiment of the invention as illustrated, a longitudinally elongated radially outwardly opening generally rectangular pocket 64 is formed in one of the ribs 39, the pocket 64 at its upper extent intersecting the groove 48 at the latter's lower extent. The split support ring 50 is received in the groove 48 so as to have its two split ends lie axially above and longitudinally centrally of the pocket 64.

The means for temporarily retaining the self-expandable support ring 50 in a retracted condition adjacent the surface 56 of the groove 48 while the casing liner is being brought to emplacement at the desired location in the well are mounted in the pocket 64 and include a pair of generally vertically directed parallel retaining pins 78. The two pins 78 are shown being generally cylindrical in their upper region to be received in two downwardly opening, vertically directed sockets 82 in the ring 50 near the ends. In order to radially contract the ring so the pins 78 can be inserted, a pair of radially outwardly facing sockets (not shown) may be formed in the radially outer surface 86 of the ring 50 near the ends for receiving a two pronged ring contracting tool (not shown) whose design particularities do not form a part of the present invention.

The pins 78 project upwardly from the upper stringer 81 of a rectangular frame 83 vertically slidably received in the pocket 64 via ball means 85 protruding from sockets 87 in the frame 83 to ride in vertical facing grooves 89 in the sidewalls 74 of the pocket 64. A dog pin 96 pivotally mounts the pawl 98 within the frame 83 and a coil spring 91 received between the pocket 64, surface 70 and the back of the pawl above the pin 96 urges the nose means of the pawl radially outwardly of the frame. Further details of the exterior of the liner hanger, support ring and pawl assembly may be as exhaustively described in the aforementioned U.S. patent application of Pitts et al., particularly on page 9, line 7—page 18, line 12, with reference to FIGURES 1-8 thereof. Suffice it to say here that the drill string, running tool, liner hanger and casing liner, which may be conveniently referred to as the liner-installing assembly, are lowered into the well until the liner hanger is sufficiently below its seating position that, upon being picked up somewhat, the upper convex and lower angular nose means 132 on the pawl 98 are received in and engage in the corresponding groove means 26, 28 of the bore of the outer casing. Since upon lifting the liner-installing assembly up further, the engagement of the pawl 98 causes the frame 83 and pins 78 to remain at the height shown in FIGURE 1, the pins 78 are pulled from the sockets 82 and the ring 50 becomes free to expand into the support ring landing groove 16 and to seat upon the lower, upwardly facing shoulder therein. With the ring 50 in the groove 16, lowering of the liner-installing assembly brings the outwardly and downwardly facing, tapering surface 54 to bear upon the radially inner surface of the ring, camming it outwardly more firmly into the groove 16. Continued downward movement will bring the liner hanger shoulder 60 to rest upon the upper end surface of the ring 50 (FIGURE 3) thus supporting the liner and liner hanger via the ring 50 on the groove 16.

Near its annular upper end surface 100, the liner hanger 32 bore has an unthreaded portion 102 lying axially above an interiorly threaded portion 104 of at least slightly shorter axial extent. Below the threaded portion 104, the bore is again smooth at 106 and at the lower extent of the portion 106 undergoes a diameter reduction axially downwardly to provide an upwardly, inwardly facing annular seat 108. A short distance above the seat 108, at least one, and within the scope of the invention a plurality of angularly spaced, radially inwardly opening sockets 109 are formed in the liner hanger, opening through the surface 106.

The setting tool 38 includes a tubular body 110 having a throughbore 112 provided near its lower end with internal threading 114 to receive the upper exteriorly threaded end 116 of a tail pipe 118. (The latter is shown in the figure with a center portion removed, in practice it would be, for instance, 10 feet long.) The lower end of the tail pipe 118 is provided with a tubular cement plug 120 having an exterior, circumferential wiper 122 in resilient contact with the peripheral surface of the bore of the casing liner. The cement plug forms an axial extension of the tail pipe and is pinned thereto by frangible pins 124. Internally, the cement plug throughbore 126, is provided with an annular, upwardly facing shoulder for receiving a conventional wiper plug during cementing.

Above the threading 114, at the level of the liner hanger sockets 109, a corresponding number of radial openings 127 are provided through the body 110. The openings 127, each undergo a diameter reduction as they proceed outwardly to provide an annular, radially inwardly facing shoulder 129 in each. The shoulder shown is frusto-conical, decreasing gradually in diameter as it proceeds radially outwardly respecting the body 110. Above and below the openings 127, the peripheral surface of the bore 112 is provided with circumferentially extending, radially inwardly opening grooves 126, 128 which receive O-rings 130. Above the groove 126, the bore 112 is shown reduced slightly in diameter to provide an annular, downwardly facing shoulder 131.

In preassembling the setting tool 38 to the liner hanger, a shear pin 134, for instance made of brass, is inserted into each opening 127 from interiorly of the body 110. Each shear pin 134 has an enlarged head 136 adapted to seat against the shoulder 129; the shear pin shank 138 extending radially outwardly of the body and into a respective socket 109. A coil spring 139 is received in each opening 127 radially inwardly of and bearing against the head 136 of the shear pin 134 therein. An annular band 140 is then slid into the bore 112 from the lower end thereof and into a position wherein its upper end 142 abuts the shoulder 131 and the radially outer surface 144 thereof is in sealing engagement with the sealing rings 130. The radially outer surface 144 of the band 140 engages the radially inner ends of the springs 139 compressing these springs to retain the shear pins in position as shown in the figures. The radially inner peripheral surface 146 of the band 140 is of at least as great a diameter as the throughbore 112 above the shoulder 132 in order to avoid restriction of the bore.

The band 140 is most easily installed before the tail pipe 118 is screwed into place. As shown, the tail pipe throughbore is of the same diameter as the bore 112 of the body 110 above the shoulder 132, and when in place, the upper end of the tail pipe lies immediately below the lower end of the band 140. Thus the tail pipe upper end is positioned to positively prevent such axially downward movement of the band 140 as would permit breaching of the seal at 126 or freeing of the springs 139.

Exteriorly, above the openings 128, the body 110 is provided with circumferential, radially outwardly opening grooves 148 which receive O-rings 150 positioned and adapted to seal against the surface portion 106 of the liner hanger bore. Alternatively, the grooves 148 could be in the surface and face radially inwardly, the O-rings 150 then being mounted to seal against a corresponding smooth surface on the body 110.

Still with reference to FIGURES 1 and 2, above the grooves 148, radially adjacent the lower extent of the threading 104, the exterior of the body undergoes a reduction in diameter to provide an annular, upwardly facing shoulder 152. A further reduction occurs at 154, adjacent the upper extent of the unthreaded portion 102, to provide an upwardly facing shoulder. Between the levels of the shoulders 152 and 154, the body is longitudinally grooved to provide spline 156. The grooves angularly between adjacent splines proceed upwardly

through the shoulder 154. The longitudinal ribs 156 may alternatively be separate elements force fit into longitudinal grooves in the exterior of the body and protruding therefrom. A nut having a correspondingly longitudinally ribbed and grooved bore 160 is axially slidable downwardly from the shoulder 154 to the position shown in FIGURE 3. The nut 158 is exteriorly provided with threading 162 which is complementary to the threads 104 on the liner hanger. (The hand or sense of the threads 104, 162 is opposite from the remainder of all of such other threaded connections shown in FIGURES 1-3 which cannot be tack welded to prevent their untimely unthreading.) In the example shown, the threading 104, 162 is left-hand Acme threading. To advance the nut from the disengaged position shown in FIGURE 3, down to the engaged position shown in FIGURES 1 and 2 requires rotating the body 110 and liner hanger with respect to one another. (Obviously, this step would be performed before the shear pins 134 are installed as described above.)

Adjacent its upper axial end 164, the body 110 exterior has a smooth portion 166, circumferentially grooved at 168 to receive an O-ring 170. Below this, and above the shoulder 154, the body is exteriorly threaded at 155. An annular bearing ring 172 is received coaxially about the body 110 and is of such diameter, shape, and width as to initially rest upon the shoulder 154 and to project radially outwardly therebeyond. When the body 110 and liner hanger 32 are assembled to one another as described above, the radially outer portion of the lower edge of the bearing ring 172 becomes supported by the liner hanger, for instance at the upper end of the liner hanger. The levels of the supports for the bearing ring on the body and liner hanger are such that, upon assembly of these parts, support of the bearing ring is transferred from the body to the liner hanger.

The bearing ring 172 upper surface is shown circumferentially notched at 174 near the radially inner extent thereof. Adjoining the notch 174, the surface has an annular frusto-conical portion 176 facing upward and slightly radially outward, for instance at an angle declined 7 degrees, 35 minutes from the horizontal, measured from the longitudinal axis of the body 110. The notch 174 accommodates a bearing roller mounting ring 180 which has a plurality of angularly spaced, radially outwardly opening trunnion receiving sockets 182 therein which receive the trunnions 184 of tapered roller bearings 186 configured to roll upon the bearing ring surface portion 176, about radial, horizontal axes coincident with the longitudinal axes of the respective tapered roller bearings 186.

The setting tool shown is completed by a tubular connection collar 188, for instance made from a 4½ A.P.I. I.F. tool joint. As shown the collar 188 has an upper, box end 190 threaded at 192 to receive the lower, externally threaded pin end 194 of the drill string and a lower, bell end 196 internally threaded at 198 to connect to the threading 155. The threading 198 terminates below the upper, downwardly axially facing annular shoulder 200 of the end 196, to provide a smooth region 202 adapted to be sealingly engaged by the O-ring 170 when the shoulder 200 contacts the upper end of the body 110.

Alternatively, the O-ring 170 would be carried in a groove in the smooth region 202 for sealing engagement with the surface 166.

It should now be noted that the radially inner corner of the axially lower end 204 of the collar 188 is circumferentially grooved (similar to the notch 174) to receive the upper end of the roller bearing mounting ring 180 and (similar to the surface portion 176, but inclined to receive the tapered roller bearings 186 rollingly thereagainst). The unrelieved radially outer corner of the collar 188 lower end lies radially adjacent the outer, larger diameter end of the roller bearings to confine them.

During lowering of the liner-installing assembly into

the well, the weight of the liner is transmitted to the setting tool body via the liner hanger threaded engagement with the floating nut which is supported on the shoulder 152. Upon setting of the liner hanger, the weight of the liner is transmitted to the outer casing string via the support of the liner hanger on the ring 50 received in the groove 16.

After the liner has been set, by expansion of the ring 50 and supporting of the liner hanger thereon as described above, the setting tool may be released by rotating the drill string in such sense (right-hand in the illustrated embodiment) as will shear the pins 134 and cause the floating nut 158 to rotate and thus move upwardly along the longitudinal keys as it unthreads from the liner hanger 32 into the space radially adjacent the body unthreaded portion 102, thus releasing the tool. During this releasing operation, the part of the weight of the drill pipe not carried from above is supported, via the tapered roller bearings 186 and bearing ring 172, upon the axially upper end surface of the liner hanger.

The drill pipe and setting tool may now be picked up if desired; however, in the preferred procedure, the liner is cemented before the drill pipe and setting tool are picked up.

In the cementing operation, conventional cement slurry is pumped down the drill pipe from above and followed with a conventional wiper plug, for instance one as shown on page 442 or page 4735 of the Composite Catalog of Oil Field Equipment and Services, 1968-1969 edition, Gulf Publishing Co., Houston, Tex. When the wiper plug engages the cement plug 122, at the end of the tail pipe 118, the shear pins 124 break allowing the cement plug 120 to be pumped to the bottom of the liner 30. This pumping forces the cement out of the bottom of the liner (for instance, through a back-pressure valve such as is shown on page 305 or page 440 of the aforementioned Composite Catalog) and up in the annulus between the liner and the formation and between the liner and the bore of the outer string of casing 12, thus cementing the liner in place. The cement is preferably forced up to at least the level 210 (via the flutes 44) to secure the hanger. Before the excess cement has set, the drill pipe is picked up enough to remove the setting tool from the liner hanger and bring the lower end of the tail pipe 118 approximately to, or slightly below, the level of the ring 50 (FIGURE 3). At this stage, by closing the rams of the blowout preventer around the drill pipe, pressure is built up between the casing 12 and the drill pipe, forcing any excess cement from above the level 210 down the annulus, between the separated lower end of the connection collar 188 and upper end of the liner hanger, back through the tail pipe and up to the surface through the drill pipe. The setting tool may now be lifted to the surface on the drill pipe, leaving the liner cemented in position.

At a later stage of completion of the well, it may be desired that a full string of inner casing be provided and cemented. In such case, referring to FIGURE 4, a tie-back sub 212 may be made up on the lower end of a string casing 214, run into the hole and pushed into place as shown. As alternatives to the tie-back arrangement shown in FIGURE 4, those of the stab-in type shown in the copending U.S. patent application of Quebe et al., Ser. No. 553,245 filed May 26, 1966, or the copending U.S. patent application of Harwell, Ser. No. 553,224, filed May 26, 1966, could be used, however the arrangement shown in FIGURE 4 is preferred.

The tie-back sub 212 is a tubular part having a through-bore 216 which is internally threaded at 218 adjacent the upper end thereof for securing the sub 212 to the lower end of the casing string 214 in communication with the bore thereof. Intermediate its upper and lower ends, the sub 212 exteriorly undergoes a reduction in diameter to provide an annular, coaxial, axially downwardly facing shoulder 220. A short distance below the shoulder

220, the exterior of the sub 212 is circumferentially grooved at 222 (four grooves being shown) to receive O-rings 224. Just below the grooves 222, at least one and preferably a plurality of angularly spaced circulation ports 226 are provided radially through the tie-back sub 212. Between the radially inner extent of the shoulder 220 and the lowermost of the grooves 222, the exterior diameter of the sub 212 is but slightly smaller than the diameter of the smooth surface 102 on the liner hanger and the O-rings 224 protrude from the grooves 222 sufficiently to resiliently sealingly engage the liner hanger surface 102. The configuration of the sub is such that, when in place as shown in FIGURE 4, its lower end 228 lies close to or rests upon the seat 108 and the sub 212 exterior shoulder 220 rests upon the liner hanger annular upwardly facing surface 100. As shown, the tie-back sub provides a substantially unconstricted, smooth transition between the bore of the inner casing 214 and the bore of the liner 30.

With the sub 212 pushed into place as shown in FIGURE 4, the inner casing string 214, 212, 30 may be pressured up to confirm that a complete seal has been established and that the tie-back sub is in the correct location. Upon confirmation, the pressure may be released and arrangements made for cementing the newly emplaced upper part of the casing string (214, 212). After conventionally introducing cement into the annulus between the inner and outer casing strings upwardly from the level 210 to which the liner had previously been cemented, the casing string 214 and sub 212 are picked up, for instance about 6 inches, until the circulation ports 226 are in communication with the inter casing annulus above the set cement level 210. With the sub raised to this position, cement is circulated through the ports 226 and up the inter casing annulus. After cementing, the casing 214 is slacked off, so that the sub 212 again comes to rest as shown, forming a seal in the top of the liner hanger at 224, 102. If a plug is used to follow the cement, a conventional baffle plate or drillable bridge (for instance as shown on page 305 or page 437 of the aforementioned Composite Catalog) can be inserted in the axially short, radially, inwardly opening circumferential groove provided at 250 between the lower pin end of the casing string 214 and the lower extent of the internally threaded box of the upper end of the sub 212.

It should now be apparent that the well completion apparatus and method as described herein above possesses each of the attributes set forth in the specification under the heading "Summary of the Invention" hereinbefore. Because the well completion apparatus and method of the invention can be modified to some extent without departing from the principles of the invention as they have been outlined and explained in this specification, the present invention should be understood as encompassing all such modifications as are within the spirit and scope of the following claims.

What is claimed is:

1. A liner hanger installing assembly, comprising in combination:

- (a) a first part being a tubular liner hanger having securing means thereon for independently supporting a casing liner therefrom, and support means on said tubular liner hanger for mounting said tubular liner hanger downhole in a well; and
- (b) a second part being a tubular setting tool having securing means thereon for mounting the setting tool to a pipe for lowering the installing assembly into a well;
- (c) means removably supportingly interconnecting said tubular liner hanger and said tubular setting tool, including:
 - an annular upwardly facing circumferential shoulder on said liner hanger;
 - bearing means carried exteriorly circumferentially on said setting tool and being supported on said

liner hanger shoulder to transmit downward axial force from said setting tool to said liner hanger and to facilitate angular rotation; said setting tool having a lower portion removably received in the bore of said liner hanger coaxially therewith;

5 a floating nut coaxially received in the bore of said liner hanger radially between means defining facing peripheral surfaces on said liner hanger and said setting tool lower portion;

10 at least one longitudinal Key on one of said facing peripheral surfaces;

helical threading on the other of said facing peripheral surfaces generally radially adjacent said longitudinal Key;

15 said floating nut having means defining opposed peripheral surfaces;

at least one longitudinal Key receiving slot on one of said floating nut peripheral surfaces, positioned to receive said longitudinal Key;

20 helical threading on the other of said floating nut peripheral surfaces for cooperatively engaging the first-mentioned helical threading;

25 said nut being axially movable along said longitudinal Key through relative rotation of said setting tool and liner hanger, between a first position wherein the helical threading on said floating nut and said first-mentioned helical threading are cooperatively engaged and a second position wherein the helical threading on said floating nut and said first-mentioned helical threading are wholly disengaged;

30 axially facing shoulder means defined on the peripheral surface of the part having said longitudinal Key, said axially facing shoulder means being adjacent one end of said Key and protruding radially sufficiently to supportingly engage said nut when said nut is in said first position thereof for dependently supporting the liner hanger from the setting tool during lowering of said liner hanger installing assembly;

35 said setting tool being axially upwardly withdrawable from said liner hanger when said nut is in said second position thereof.

2. The combination of claim 1, wherein said longitudinal Key is in said setting tool; wherein said nut threading is exteriorly provided thereon; and wherein said axially facing shoulder means underlies said nut and faces axially upwardly, whereby said nut, when in the second position thereof, is removable from the well upon said setting tool.

3. The combination of claim 1 wherein the liner hanger support means comprises: an elastic hard metal support ring mounted on said liner hanger; surface means on each said support ring and said liner hanger, said surface means being engageable to support said liner hanger on said support ring; said support ring being split so as to have two adjacent ends; means on said liner hanger disengageably engageable with said support ring when engaged with said support ring when engaged therewith to thereby impart self-expansibility to said support ring, said support ring being thereby arranged to expand upon disengagement of said engageable means from said support ring.

4. The combination of claim 1, wherein said bearing means include a bearing ring having an annular lower end surface and an annular upper end surface, said bearing ring lower end surface normally being supported upon said liner hanger shoulder; means defining an upwardly facing shoulder on said setting tool exteriorly thereof beneath and normally spaced at least slightly axially from said bearing ring, said setting tool shoulder being positioned to supportingly engage said bearing ring annular lower end surface when said setting tool is withdrawn axially upwardly from said liner hanger to retrieve said bearing means with said setting tool.

5. The combination of claim 4 wherein the bearing means further comprises: a plurality of roller bearings received upon and rollable circumferentially about said bearing ring annular upper end surface; means defining an axially downwardly facing circumferential shoulder on said setting tool received upon said roller bearings; and retainer means between said bearing ring and said setting tool for angularly spacing and radially confining said roller bearings.

6. The combination of claim 1 further including: a shear pin initially received between and extending into both said setting tool and said liner hanger, when said nut is in said first position thereof, for preventing premature movement of said nut from said first position toward said second position.

7. The combination of claim 6 further comprising: means defining at least one opening radially through said setting tool; means defining at least one radially inwardly opening, radially directed socket in said liner hanger in axial alignment with said setting tool opening; said shear pin being completely received in said opening and said socket from the bore of said setting tool; and removable cover plate means mounted in the bore of said setting tool radially inwardly of and bridging the inner end of said opening, for retaining said shear pin positioned in said opening and said socket.

8. The combination of claim 7 wherein said setting tool further includes a tubular tail pipe having exterior threading thereof adjacent the upper end thereof; said setting tool below said opening being interiorly threaded for cooperating with said exterior threading on the tail pipe to secure the tail pipe to the remainder of the setting tool; means defining a circumferential, axially downwardly facing shoulder on said setting tool in the bore thereof a short distance above said opening; the bore of said setting tool above said downwardly facing shoulder being substantially equal in diameter to the bore of said tail pipe; said cover plate means comprising an annular band having an internal diameter substantially equal to the diameter of the bore of said pipe and an external diameter substantially equal to the diameter of the bore of said setting tool below said downwardly facing shoulder, whereby said annular band may be slipped into the bore of said setting tool before threaded securement of said tail pipe to said setting tool and so that said cover plate is maintained in position covering said opening by being confined between said downwardly facing shoulder and the upper end of said tail pipe.

9. In the completion of a petroleum well having a first, outer casing string received and mounted therein, the method comprising:

- (a) lowering a liner including a liner hanger mounted thereon into the well through the bore of the first outer casing string on the lower end of a tubular assembly, until the liner hanger is near the lower end of the first, outer casing string;
- (b) transferring support of the lowered liner and liner hanger from said tubular assembly to said first, outer casing string;
- (c) forcing cement down the bore of said tubular assembly and liner, out the lower end of the liner and upwardly around the liner and liner hanger;
- (d) disconnecting the tubular lowering assembly from the liner and lifting the former upward to provide a gap between the upper extent of the liner and the tubular lowering assembly;
- (e) withdrawing excess cement adjacent and above said gap through said gap, via the bore of tubular lowering assembly and
- (f) retrieving the tubular lowering assembly from the well.

10. As subsequent steps of the method defined in claim 9:

- (g) lowering an inner casing string, having a lower portion connectable with the liner into the well

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through the bore of the first, outer casing string
until said lower portion enters the bore of liner;
(h) cementing the inter casing annulus between the
first, outer casing string and said inner casing string
above the level of cementing provided by steps (c)
and (e) and circulating cement outwardly from said
lower portion into said inter casing annulus; then
(i) further lowering said inner casing string until
said lower portion seats upon the liner, and
(j) sealing between lower portion and said inner cas-
ing string.

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