April 16, 1968 S. H. SMITH 3,378,072

METHOD AND APPARATUS FOR SEVERING WELL CASING IN A SUBMARINE ENVIRONMENT

Filed Sept. 9, 1966 2 Sheets-Sheet 1

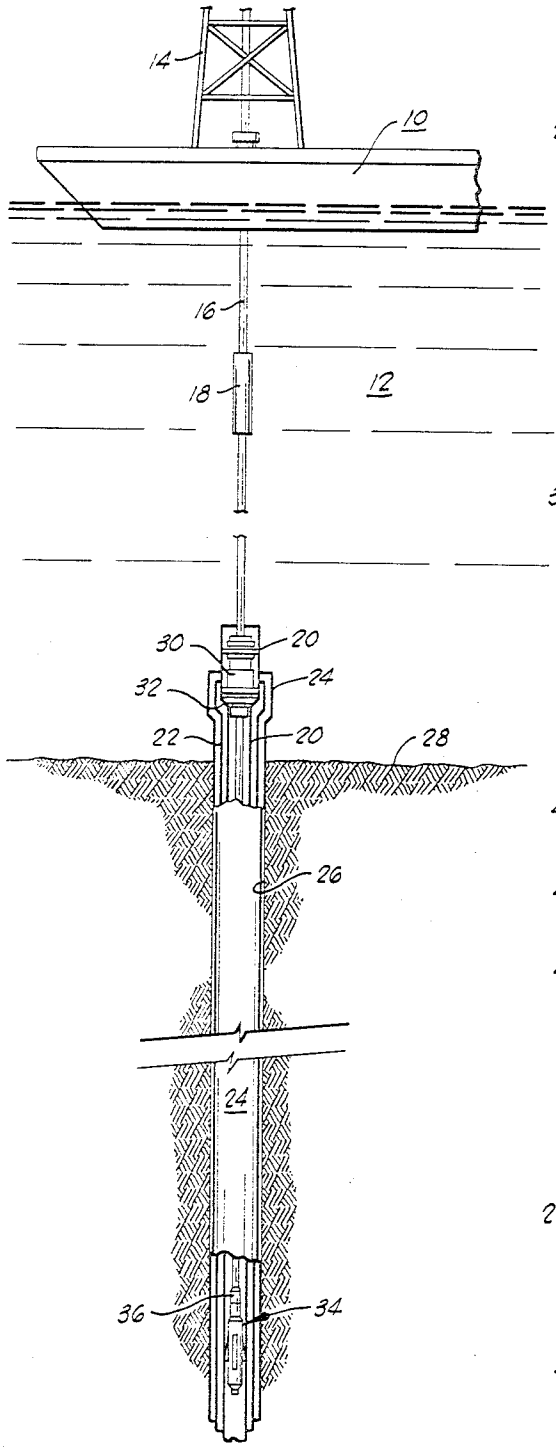

Fig. 1

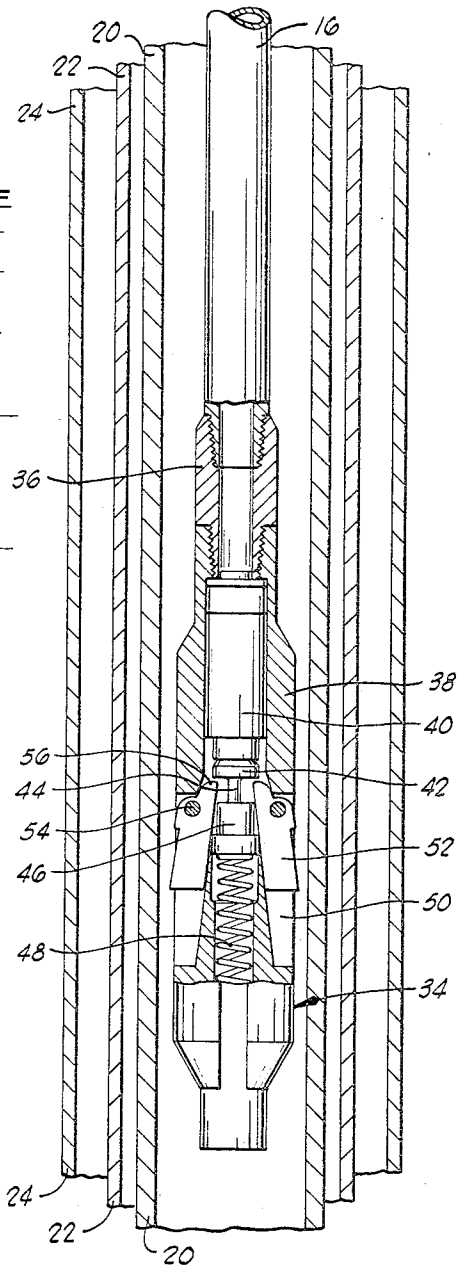

Fig. 2

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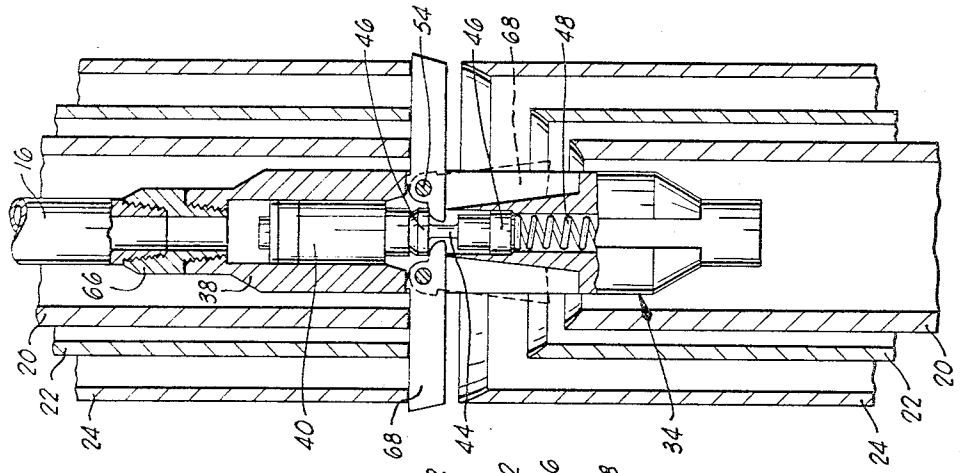

FIG. 5

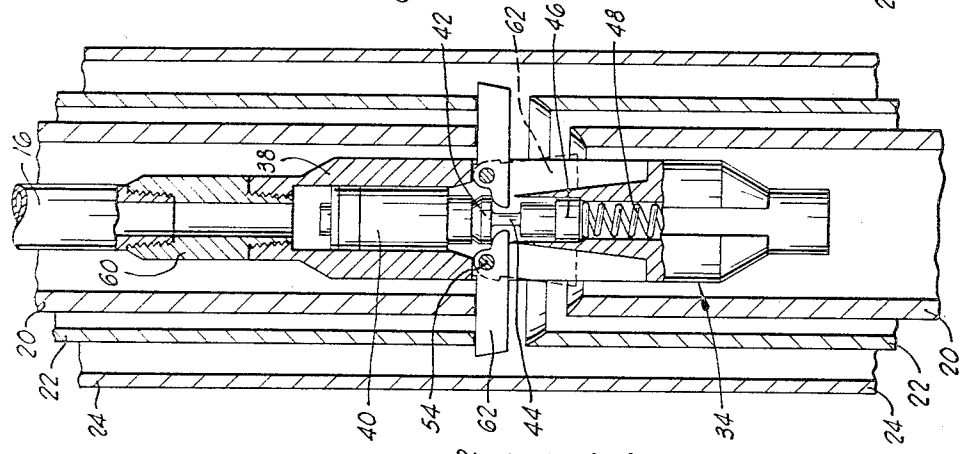

FIG. 4

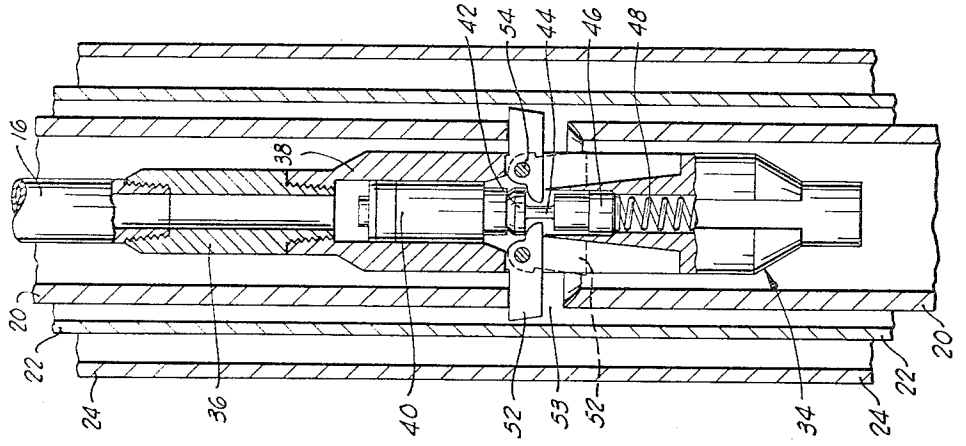

FIG. 3

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METHOD AND APPARATUS FOR SEVERING WELL CASING IN A SUBMARINE ENVIRONMENT

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5 Claims. (Cl. 166—35)

This invention relates to off-shore or submarine hydrocarbon exploration and production techniques, and more specifically, but not by way of limitation, relates to a method and apparatus which can be employed for cutting or severing a well casing extended into the floor of the ocean or sea for the purpose of recovering hydrocarbons.

With the relatively recent advent of exploration and production of petroleum from subterranean deposits located beneath the oceans and seas, radical modifications in conventional drilling and production techniques used in onshore exploration and production have been demanded. Many problems which are not experienced in traditional drilling and production have been encountered in the case of offshore operations.

One of the difficulties which has been experienced in offshore drilling and production is the problem of providing a sufficiently stable platform or supporting structure on which the drilling equipment may be mounted, and from which the drill string or production tubing can be extended and made to function effectively. In relatively deep waters where the use of a supporting structure rested upon the bottom of a body of water becomes impractical, drilling has been attempted and carried out with some success from floating platforms. In this case, however, difficulties and relatively greater expense continue to result from the necessity to accommodate the drilling equipment and steps employed to wave and swell action which continually change the position of the drilling barge or other point of origin of the drill string with respect to the location on the bottom of the ocean or sea where the actual bore hole is to be formed. Telescoping slip joints and similar structures have been provided in drill strings to permit a certain amount of play and variation in length of the string to randomly occur as may be required as a result of the constantly shifting position of the drilling platform. There has also been recently developed, a swivel structure which is incorporated in the drill string and which cooperates with or rests upon the borehole casing to limit the movement of that portion of the drill string which is positioned within the casing, and thus make easier to carry out certain operations which must be carried out down hole by reason of improved stability in the location of the downhole tools.

An operation which frequently must be conducted following a drilling operation which, for one reason or another has been terminated and no further utilization of the well head equipment contemplated, is the severance or cutting of the borehole casing at some point below the well head so that the upper portion of the casing and the valuable well head equipment attached thereto can be recovered from the ocean floor and reutilized in other drilling and production operations. The difficulty of successfully and economically accomplishing such cutting and severance of the well casing has been considerably augmented in the case of offshore wells by the fact that it is the usual and conventional practice in such wells to provide a plurality of concentric casing strings, all of which must be cut through in order to permit the well head equipment which is attached to the top of these casing strings to be extracted or recovered from the ocean floor. The equipment which has been most widely employed for the purpose of cutting the casing a short distance below the well head has been a cutter tool usually

including a plurality of cutter knives which are pivotally attached to the body of the cutting tool and can be extended radially outwardly therefrom into contact with the casing preparatory to the cutting operation. The tubing string which carries the cutting tool is then rotated within the casing so that the knives bear against the casing as they are rotated and eventually cut or abrade through the casing and permit the severed upper portion thereof to be removed.

While, in a few instances, cutting tools of this type have been satisfactory for the severance of the well casing, great difficulty has been experienced in reliably and quickly cutting through those casing structures most widely used in offshore drilling which include a plurality of concentric tubular casing members which must all be cut before the well head equipment can be freely moved. With the cutting tools and techniques previously in use, severing this multiple casing structure has been a time consuming and expensive operation, and it has been extremely difficult on many occasions to know with certainty whether the cutting tool has completely severed the several concentric casing structures, with the result that frequently the operation is carried on much longer than necessary in order to be relatively assured of this fact.

The difficulty which has been experienced in the severance of the several concentric casing strings with the cutting tools previously in use has been largely due to the limited space which is available within the innermost casing string, and the inability, because of such space limitations, to obtain adequate leverage and cutting efficiency with cutting knives sufficiently large to extend completely through the outermost of the casing strings in the final phases of the cutting operation.

The present invention involves an improved technique or method for accomplishing this severance or cutting of a submarine well casing of the type in which several tubular casing members are telescopingly disposed relatively to each other. The method which is employed in carrying out the technique permits such multiple concentric casing strings to be cut through in a much shorter time than prior techniques in use have permitted, and further gives a much greater assurance at the surface control point of the effectiveness and the success of the cutting operation, and of its progress over each interval of time.

Broadly described, the method of the present invention comprises initially suspending at a fixed, preselected location in the innermost casing string of the several concentric (or in some instances eccentric) casing strings, a cutting tool of the type having pivotally secured thereto at least one elongated cutting member. The point at which the cutting tool is positioned within the innermost casing string will be selected according to current conventional practices, and will be based upon the necessary depth within the casing at which the cutting operation must be conducted in order to permit complete removal of the well head equipment.

With the cutting tool positioned in this preselected position, and with the cutting members pivotally carried thereby being of a preselected length which is correlated to the diameter of the innermost of the casing strings, the cutting members are pivotally extended into contact with the internal wall of the innermost casing string preparatory to cutting through this casing string. The length of the cutting members is selected to provide maximum leverage against the innermost casing string, and thus to provide the most efficient cutting action through this tubular element. The cutting tool is then rotated within the innermost casing string to cause the cutting members carried thereby to cut through the innermost casing string to form an axially extending opening which

extends around the entire circumference of the casing string.

Upon completion of the cutting action by the cutting member, the cutting tool is removed from the well casing, and at least one other elongated cutting member have a preselected length which is greater than the length of the first mentioned cutting members is pivotally secured to the cutting tool. The tool is then again lowered to a preselected point or location within the innermost casing string. The preselected point or location of the cutting tool at this time will, as a general rule, be above the location which it occupied during the initial cutting operation, but in any event, the location of the pivotal axes of the several new and longer cutting members attached to the cutting tool will be above the location of the pivotal axes of the shorter cutting members used during the first cutting operation to cut through and around the innermost casing string. The cutting members are then pivotally extended outwardly from the body of the cutting tool into the axially extending opening formed during the initial cutting operation with the preselected location of the cutting tool having been chosen to permit the new, longer cutting members to be extended through the axially extending opening in the innermost casing string. With the relatively longer cutting members extended into cutting position, the cutting tool is then rotated to cause the new cutting members to cut through at least one of the outer casing strings which surrounds the innermost casing string.

The described sequence of steps may be repeated several times with a substitution of a new and longer cutting member on the cutting tool if such repetition is required in order to completely cut through a plurality of telescoped casing strings.

Though not an entirely critical or essential method of accomplishing such positioning, the preselection of the position which is to be occupied by the cutting tool in the well casing, and the manner in which the tool is brought to this position preferably entail mounting the cutting tool on the lower end of a tubing string which can be extended from the drilling platform or barge into the well casing, and which carries intermediate its length, an extensible slip joint, a supporting swivel assembly and an interconnecting sub which is located between the swivel assembly and the cutting tool. The swivel assembly is then rested upon a shoulder or abutment formed on the casing at some point, and acts as a point of suspension for that part of the tubing string which extends below the swivel assembly. To adjust the position of the cutting tool and the cutting members carried thereby with respect to the casing and the previous holes which have been cut therein by cutting members of other lengths, the length of the connecting sub which is positioned in the tubing string between the swivel assembly and the cutting tool is then varied to raise or lower the cutting tool to the required location.

The described method permits the length of the cutting members and their position within the multiple casing structure to be selected to yield maximum efficiency and optimum cutting performance. Though, of course, some time is involved in pulling the tubing string upon which the cutting tool is mounted for the purpose of exchanging the variable length cutting members, and exchanging the connecting subs connected in the string so as to adjust the position of the cutting tool relative to the casing, the time involved in such pulling and changing operations is more than offset and compensated by the efficiency obtained in the cutting operation, and the certainty with which the crew operating the cutting tool can be apprised of its effectiveness and time of cutting the plural casing strings.

From the foregoing description of the invention, it will have become apparent that it is an important object of the present invention to provide an improved method of severing or cutting well casing located in a submarine environment.

An additional object of the present invention is to provide a rapid and certain method for cutting through a plurality of telescoped casings positioned in the earth below a relatively deep body of water, such as an ocean or sea, at a minimum of expense and at a maximum rate.

A further object of the invention is to provide a method of cutting through, or severing, several telescoping tubing strings at a common location and from the inside outwardly with minimum wear occurring to the cutting elements used to accomplish such severance of the telescoped tubing strings.

In addition to the foregoing described objects and advantages, other meritorious features and beneficial results which can be obtained using the present invention will become apparent as the following detailed description of the invention is read in conjunction with the accompanying drawings which illustrate a typical embodiment of the invention.

In the drawings:

FIG. 1 is a schematic illustration, partly in elevation and partly in section, of a typical off-shore well installation, and illustrating a cutting tool used in performing the method of the present invention and suspended in a multiple casing well bore from a floating drilling barge.

FIG. 2 is an enlarged detailed view, partially in section and partially in elevation, depicting a typical cutting tool which can be used in practicing the method of the present invention, and illustrating this tool and its relation to the concentric casing strings employed for casing an offshore oil well as the tool appears immediately prior to the commencement of a casing cutting operation.

FIG. 3 is a view similar to FIG. 2, but illustrating the use of the cutting tool in performing the first step of the casing cutting method of the present invention.

FIG. 4 is a view similar to FIGS. 2 and 3, but illustrating the cutting tool after it has been modified by the attachment of longer cutting members thereto and showing the tool as it is used in carrying out a subsequent step of the casing cutting operation.

FIG. 5 is a view of the cutting tool and telescoped casings similar to FIGS. 2–4, but illustrating the tool as further modified by the addition of yet longer cutting members, and showing the tool as it is being employed in the final step of the cutting operation.

Referring now to the drawings in detail, and initially to FIG. 1, a drilling barge or platform **10** is illustrated as floating on the surface of a body of water **12**. A drilling rig **14** is mounted on the deck of the drilling barge **10** and supports a downwardly extending drilling string **16**. The drilling string **16** includes along its length an extensible slip joint or telescoping connection **18** which permits the overall length of the drilling string to vary as the drilling barge **10** may be caused to rise or fall with respect to the bottom of the body of water by wave action, swells, etc.

The drilling string **16** extends downwardly into an inner casing **20** which is coaxially positioned inside an intermediate or central casing **22** and an exterior or outer casing **24**, this telescoping casing construction being typical of that currently widely used for marine petroleum production. The exterior casing **24** is positioned in a bore hole **26** which extends into the bottom **28** beneath the body of water **12**.

A marine swivel assembly **30** is connected in the drilling string **16**, and is dimensioned to bear against and rest upon an upwardly facing shoulder **32** formed in the inner casing **20**, preferably adjacent the upper end thereof. The function and mode of use of the marine swivel assembly **30** is explained in detail in my copending application for United States Letters Patents, Ser. 374,719, filed June 12, 1964, now Patent No. 3,301,324. It will suffice for purposes of explanation of the present invention to point out that the swivel assembly **30** functions to provide a fixed point of suspension support within the well casing for that portion of the drilling string **16** which extends downwardly from the swivel assembly. Thus, the swivel

assembly 30 in conjunction with the extensible slip joint 18 permit a relatively fixed location to be assumed by the cutting tool carried on the lower end of the drilling string 16 and hereinafter described.

Secured to the lower end of the drilling string 16, and positioned in the FIG. 1 illustration below the well head at the top of the casing, is a cutting tool designated generally by reference character 34. The cutting tool 34 is illustrated as secured to the drilling string 16 through a connecting sub 36 of the box and pin type (see FIG. 2). It should be pointed out, however, that the location of the connecting sub 36 in this specific position relative to the drilling string 16 and cutting tool 34 is not critical or required for the performance of the method of the present invention, it only being necessary that the connecting sub be positioned in the drilling string at some point between the swivel assembly 30 and the cutting tool 34. The role played by the connecting sub 36 in the practice of the method of the invention will be hereinafter described in greater detail.

In FIG. 2 of the drawings, some of the structural details of the cutting tool 34 are illustrated, and the tool is shown in the position which it should occupy at the commencement of the casing cutting operation. Although a variety of types of cutting tools can be employed in practicing the present invention, the type illustrated for explanatory purpose is one in which a tubular body 38 surrounds a slidingly mounted piston 40 which can be caused to reciprocate in the tubular body by fluid directed through the drilling string 16 from the drilling barge 10. The piston 40 carries at its lower end a downwardly facing knife actuating member 42. The knife actuating member 42 is connected through a relatively small diameter rod 44 to a knife movement limiting member 46. A helical compression spring 48 is provided in the lower portion of the bore in the tubular body 38 and bears against the knife movement limiting member 46 for the purpose of resiliently biasing the piston 40 to its inoperative position as depicted in FIGURE 2 when the fluid pressure directed against the piston via the drilling string 16 is relieved.

The cutting tool 34 has a plurality of axially extending slots 50 formed in the sides thereof for the accommodation of an equal number of cutting members or knives 52 which are pivotally secured to the tubular body 38 of the cutting tool by means of pivot pins 54. The cutting members or knives 52 each carry at their end most closely adjacent the pivot pins 54, an arcuately shaped or tapered ear 56 which extends into the slot or open space formed between the knife actuating member 42 and the knife movement limiting member 46. The ears 56 are thus positioned to be engaged by the knife actuating member 42 at such time as the piston 40 is moved downwardly within the tubular body 38 by the impress of fluid pressure directed through the drilling string 16. This construction and mode of operation of cutting tools of the general type described are well understood in the drilling technology at the present time, and constitute no part of the present invention except as tools of such general character are utilized in the practice of the method of the invention, and in the overall apparatus employed therefor as hereinafter described in greater detail.

A preferred method of practicing the present invention can best be related by referring conjunctively to the several figures of the drawings in explaining the sequence of performance of the several steps utilized. The occasion for using the method of the invention for severing or cutting the concentric casing strings arises at such time as a cased well has reached the end of its period of usefulness. At this time, it is economically desirable to recover the expensive well head equipment (not illustrated) which is positioned at the top of the casing, and it is also frequently necessary to remove the projection portion of the casing and the well head equipment from the bottom of the ocean or sea in order to comply with certain legal requirements which apply to offshore drilling and production activities. In general, the casing cutting operation will be carried out a relatively short distance below the well head, it only being necessary to be certain that the concentric casing strings are severed or cut at a location sufficiently low in the casing to permit these strings to be concurrently pulled from the bottom together with the well head equipment secured to the upper end thereof.

Knowing the depth within the casing where the cutting operation is to be carried out, the length of the drilling string 16 between the swivel assembly 30 and the cutting tool 34 is selected to effectively locate the cutting tool at the desired position in the casing when the swivel assembly 30 rests upon the casing shoulder 32 in the manner illustrated in FIG. 1. Concurrently with the makeup of the drilling string 16 to meet the requirements of positioning the cutting tool 34 at the desired location, a relatively long connecting sub 36 is included in the tubing string 16 between the swivel assembly 30 and the cutting tool 34. Then the drilling string 16 with the cutting tool 34 attached thereto is run into the inner casing 20 until the swivel assembly 30 supports the lower portion of the drilling string and the cutting tool 34 within the casing in the manner illustrated in FIG. 1.

A suitable hydraulic fluid is next directed down through the drilling string 16 against the piston 40 so as to move the piston downwardly in the tubular body 38 and thus extend the cutting members 52 against the internal wall of the inner casing string 20. The angle made by the longitudinal axis of each of the cutting members 52 with the substantially vertical axis of the drilling string and of the tubular body 40 of the cutting tool 34 will be a relatively acute or slight angle at the time of initial contact of the cutting members with the inner casing string 20. With the cutting members 52 continuously biased against the inner casing 20 by fluid pressure, the drilling string 16 is then rotated by a suitable rotary table or other equipment carried on the drilling barge 10, and such rotation of the drilling string causes the cutting tool 34 to be rotated within the inner casing 20. This rotational movement of the cutting tool 34 causes the cutting members 52 to bite into the inner casing 20, and cut through the casing until the cutting members have assumed a radially outwardly extending position such as that depicted in FIG. 3.

When the cutting members 52 have reached the outwardly extending position shown in FIG. 3, an axially extending slot or opening 53 has been cut into the inner casing 20, and such slot extends completely around this inner casing or, stated differently, the casing has been severed or cut into an upper and a lower portion. It is important to note at this point in the discussion of the present invention that the length of the cutting members 52 is initially selected with a knowledge of the internal diameter of the inner casing 20 so that sufficient leverage can be obtained on the cutting members to assure that they will cut easily and quickly through the inner casing. The limitations of diametric space within the inner casing 20 are such that the optimum length for the cutting members 52 utilized in the described initial cutting step can frequently not be sufficiently great that such cutting members can extend to, or contact, the intermediate or central casing string 22. This is the situation which is illustrated in FIG. 3. On other occasions, however, it may be possible that some cutting of the central or intermediate casing string 22 can be accomplished with the initially used cutting members 52.

The cutting tool 34 may be, and preferably is, constructed with fluid bypasses (not shown) which become open to the fluid driving the piston 40 at such time as the piston reaches its lowermost position and the cutter members 52 are fully outwardly extended as depicted in FIG. 3. The occurrence of some bypass or bleeding off of the power fluid at this time will permit a positive indication to be obtained on the drilling barge 10 of the

fact that the cutting members 52 have accomplished and completed their cutting operation, and that at least the inner casing string 20 has been cut through. A further indication of the achievement of this status also results from a reduction in the torque which must be applied to the drilling string 16 in order to drive it in rotary motion.

Upon completion of the step of the process by which the inner casing string 20 is cut through in the manner described, the drill string 16 is removed from the well casing and that portion of the string between the swivel assembly 30 and the cutting tool 34 broken down and again made up, this time to include a relatively shorter connecting sub 60 than the connecting sub 36 which was utilized initially for the cutting operation by which the inner casing string 20 was severed. The cutting members 52 utilized on the cutting tool 34 are also replaced so that relatively longer cutting members or knives 62 are pivotally mounted on the tubular body 40 in place of the shorter cutting members 52 which were originally employed (see FIG. 4). The length of the cutting members 62 which are used in the second cutting operation is selected so that these cutting members are substantially longer than the cutting members initially used, and also so that, in most instances, though not necessarily all, the cutting members 62 will extend to, and be able to sever, the intermediate or central casing string 22 during the subsequent cutting operation to be described. The size of the connecting sub 60 is selected to correlate with the length of the cutting members 62 which are used so that the free ends of the cutting members 62 will be able to pass through the axially extending slots or openings 53 formed in the inner casing string 20, and will either initially be in a position in the annulus between the inner and intermediate casing strings 20 and 22, or will bear against the internal surface of the intermediate casing string. Viewed in another way, the sub 60 is selected so that without alteration of any other part of the portion of the drill string 16 which is positioned between the swivel assembly 30 and the cutting tool 34, the length of this portion of the string is shortened so as to bring the cutting tool to a relatively higher position in which the longer cutting members 62 can move into and through the relatively small slot or opening formed through the inner casing string 20 by the initial cutting operation using the relatively shorter cutting members 52.

With the lower portion of the drilling string 16 made up in the described fashion, the drilling string is again lowered into the inner casing string 20 until the swivel 30 comes to rest upon the supporting shoulder 32 of the well casing. The hydraulic fluid is then again directed through the hollow interior of the drilling string 16 against the piston 40 and forces the piston downwardly against the ears 56 of the cutting members 62. Thus, the cutting members 62. Thus, the cutting members 62 are biased radially outwardly so that their upper edge bears against, or is in contact with the downwardly facing upper edge of the slot 53, which was cut through the inner casing string 20 during the initial cutting operation. The drilling string 16 is then rotated, and the rotative motion of the cutting tool 34 secured thereto coupled with the constant outward bias of the cutting members 62 results in the slot or opening 53 being enlarged in an axially upward direction, and also results in the tips of the cutting members 62 being extended further in a radial direction with respect to the cutting tool 34 and with respect to the inner casing string 20.

Where the cutting members 62 are of sufficient length to extend into contact with the intermediate or central casing string 22, the cutting action of these members will continue on the inner surface of the intermediate casing string until this casing string has been cut through, and the cutting members 62 attain the horizontal status depicted in full lines in FIG. 4 of the drawings. Thus, both the inner and intermediate casing strings 20 and 22 have then been cut completely through, and there remains only the outer casing string 24 which has not been severed. It should be pointed out here, however, that in some types of casing installations, the intermediate casing string 22 may be sufficiently larger than the inner casing string 20 that the cutting members 62 which are necessarily used in the second step of the cutting procedure will not reach to, or engage, the intermediate casing string 22. In such eventuality, the steps of the method as hereinafter described are nevertheless followed, and eventually cutting members of sufficient size to extend through and sever all of the telescoped casing strings will be utilized, and all of the casing strings will be cleanly and efficiently cut at the desired location.

The attainment by the cutting members 62 of the fully extended, substantially horizontal position shown in FIG. 4 will be known at the surface from the torque reduction and the hydraulic power fluid pressure reduction hereinbefore described. At this time, the fluid pressure on the piston 40 is released to permit the spring 48 to bias the cutting members 62 to their retracted positions, and the drilling string 16 is again withdrawn from the well casing to permit a relatively shorter connecting sub 66 to be connected in the string in place of the connecting sub 60. Also after the removal of the drilling string 16 from the well, new cutting members 68 of yet greater length are pivotally secured on the tubular body 38 of the cutting tool 34 with the cutting members 68 being selected to permit them to extend through the opening in the inner and intermediate casing strings 20 and 22, and into contact with the outer casing string 24. The length of the connecting sub 66 is selected so that the lower free ends of the cutting members 68 will be adjacent, or slightly above, the lower edge of the slot or opening 53 formed in the internal casing string 20 when the swivel assembly 30 occupies its position of support at the top of the well casing.

With the drill string 16 made up in this way, the string is again lowered into the casing until the swivel 30 comes to rest on the supporting shoulder 32. When the drilling string 16 is thus positioned, the cutting tool 34 will occupy the position illustrated in FIG. 5, and the cutting members 68 carried thereby will be in their retracted positions as shown in dashed lines in FIG. 5. The hydraulic fluid is then directed through the hollow interior of the tubular drilling string 16 to bias the piston 40 forcibly downwardly and cause the relatively long cutting members 68 to be pivoted outwardly through the openings previously cut in the internal and intermediate casing strings 20 and 22, and to bear against either the internal surface of the outer casing string 24, or against the upper edges of the openings cut through the inner and intermediate casing strings 20 and 22. In either event, with the continued downward bias of the piston 40 by hydraulic pressure, the rotation of the drilling string 16 is commenced, and the cutting members 68 commence to either enlarge the slots or openings formed through the inner and intermediate casing strings 20 and 22, or to cut through the outer casing string 24, or both of these reaming and cutting operations may occur simultaneously.

After a brief period of rotation of the drill string 16 with continued downward bias of the piston 40, the cutting members 68 are ultimately completely extended so that they occupy the horizontal status depicted in FIG. 5. At this time, all of the telescoped casing strings 20, 22, and 24 have been completely cut through by the cutting operations hereinbefore described. The completion of the cutting of the outer casing string 24 is reflected on the drilling barge 10 by a reduction in the torque required to rotate the drilling string 16, and by a reduction in the pressure being applied to the hydraulic fluid which biases the piston 40 downwardly. At this time, the hydraulic pressure on the piston 40 can be released to permit the spring 48 to bias the piston upwardly and the cutting members 68 to be retracted. The tubing

string and the cutting tool 34 carried thereby can then be retrieved from the well casing, and appropriate tools can be connected to the well head or equipment attached thereto to lift the upper portion of the severed casing and the well head equipment to the surface so that it can be loaded on to the drilling barge 10 and thus completely salvaged.

From the foregoing description of the invention it will have become apparent that this invention provides a highly effective method for quickly cutting through a plurality of concentrically or eccentrically disposed strings of well casing so that the portion of the casing strings adjacent the well head can be removed from the earth, and all of the equipment which is secured to the well head can be recovered. The method can be easily practiced, involves a minimum of wear and breakage of apparatus used in practicing the method, and affords positive and easily recognized indication to operating personnel of the times at which the several cutting steps involved in the method have been completed.

Although certain specific aspects of the method of the invention have been hereinbefore defined in order to provide typical examples of the manner in which the invention is to be practiced, it will be understood that various changes and modifications can be made in the steps of the method used without departing from the basic principles of the invention. All changes and modifications of this type are therefore deemed to be circumscribed by the spirit and scope of the invention except as the same may be necessarily limited by the appended claims, or reasonable equivalents thereof.

What is claimed is:

1. The method of cutting a well casing of the type which includes a plurality of telescoped casing strings, said method comprising:

(a) suspending at a fixed, preselected point in the innermost of said casing strings, a cutting tool having pivotally secured thereto at least one elongated cutting member of a preselected length correlated in length to the diameter of the innermost of said telescoped casing strings to provide efficient cutting of said cutting member through said innermost casing string;

(b) pivoting said elongated cutting member to a position in which the cutting member contact the internal wall of said innermost casing string;

(c) rotating the cutting tool to cause said elongated cutting member to cut through said innermost casing string through its entire circumference and to form an axially extending opening through said innermost casing string; then

(d) pivotally securing to said cutting tool, at least one other elongated cutting member having a preselected length which is greater than the length of said first-mentioned cutting member;

(e) positioning said cutting tool in said innermost casing string at a preselected point above said first-mentioned preselected point and selected to permit said other cutting member to extend upon pivotation through the axially extending opening formed in said innermost telescoped casing string by said first-mentioned cutting member;

(f) pivoting said other cutting member through the axially extending opening formed in said innermost casing string by said first mentioned elongated cutting member; and

(g) rotating the cutting tool to cause said other cutting member to cut through at least one of the casing strings which surrounds said innermost casing string.

2. The method defined in claim 1 wherein the initial suspension of said cutting tool in said innermost casing string at a preselected point is accomplished by:

(a) making up an elongated tubing string having an outside diameter less than the diameter of said innermost casing string and having said cutting tool secured to an end thereof, and including in said tubing string, a swivel assembly rotatably carried by said tubing string and diametrically dimensioned to permit said swivel assembly to engage the well casing, said tubing string further being made up to include a connecting sub removably included in said tubing string between the cutting tool and the swivel assembly; then

(b) lowering the tubing string in the innermost casing string until said swivel assembly engages the casing to arrest the downward movement of said cutting tool at said preselected location.

3. The method defined in claim 2 wherein the positioning of said cutting tool at a preselected point in said innermost casing string at a point above said first-mentioned point and after said cutting member have been secured to said tool is accomplished by withdrawing said tubing string from the well casing and repeating the steps of claim 2 with a new connecting sub being connected in said tubing string during such repetition of steps, which new connecting sub is of shorter length than said first mentioned connecting sub initially included in said tubing string and described in claim 2.

4. The method defined in claim 1 wherein the successive steps set forth in claim 1 in clauses (d), (e), (f) and (g) are repeated a plurality of times until all of said telescoped casing strings are cut through.

5. The method of cutting through a plurality of telescoped casing strings in well bore with a rotary cutting tool positioned in the innermost casing string, said method comprising:

(a) securing a rotary cutting tool of the type having at least one elongated cutting member pivotally secured thereto to one end of an elongated tubing string which is diametrically dimensioned to permit said tubing string to be positioned in the innermost casing string;

(b) connecting in said tubing string intermediate its length, a means for supporting a portion of the tubing string from a point of suspension which is adjacent the upper end of the well casing;

(c) removably connecting in said tubing string between said supporting means and said rotary cutting tool, a connecting sub having a length selected to position said cutting tool at the location in said innermost casing string where it is desired to cut through said telescoped casing strings when said tubing string is positioned in the innermost casing string with said supporting means engaging the well casing to support the portion of said tubing string carrying the rotary cutting tool in said innermost casing string;

(d) lowering said tubing string into said innermost casing string with said rotary cutting tool positioned at the lower end thereof until said supporting means engages said casing to support the lower portion of said tubing string in said casing;

(e) extending the elongated cutting member of said rotary cutting tool into contact with the inner wall of said innermost casing string;

(f) rotating said tubing string to cause the elongated cutting member of said rotary cutting tool to cut through the innermost casing string; then

(g) withdrawing said tubing string and rotary cutting tool from the innermost casing string;

(h) substituting for the elongated cutting members initially in use on said cutting tool, other elongated cutting members of greater length than said first-mentioned cutting members, and substituting for said first-mentioned connecting sub, another connecting sub of shorter length than said first-mentioned connecting sub, the lengths of said other cutting members and said second-mentioned connecting sub being such that said other cutting members can be pivotally extended through the opening initially cut in said innermost casing string after said tubing

string is relowered into said innermost casing string with said supporting means positioned therein at the same location relative to said innermost well casing as it initially occupied when the tubing string was initially lowered into said innermost casing string;

(i) relowering said tubing string into said innermost casing string to a position such that said supporting means is again located at the same point it occupied relative to said casing after said tubing string was initially lowered into said innermost casing string;

(j) extending said other elongated cutting members into the openings cut into said innermost casing string by the first-mentioned cutting members; and

(k) rotating said tubing string to cause said other cutting members to enlarge the opening cut through said

innermost casing string by said first-mentioned cutting member and to cut through at least one additional string of said telescoped casing strings.

References Cited

UNITED STATES PATENTS

2,690,218	9/1954	Robishaw	166—35
3,331,439	7/1967	Sanford	166—55.8
3,332,492	7/1967	Thomas	166—55.8 X
3,338,305	8/1967	Pittman et al.	166—35

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