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SWAB CUP ASSEMBLY

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This is a continuation-in-part of applicant's copending application entitled, "Well Swab Assembly," filed November 24, 1961, Serial No. 154,528. Related subject matter is disclosed in applicant's copending application entitled, "Swab Cup," filed April 25, 1963, Serial No. 275,581.

This invention relates to an improved swab cup assembly for cleaning and removing fluid from oil well tubing.

As it is well known in the oil industry, tubing installed in an oil well frequently requires swabbing, such as during completion of a well and during workaround of an old and partially depleted well. Swabbing involves the lowering of one or more swab cup assemblies through the tubing on a wire line until the desired depth is reached, and then raising the assembly through the tubing. Each swab cup assembly normally comprises a mandrel having one or more bypass passageways therethrough, and a tubular swab cup slidingly supported on the mandrel in order that the swab cup will be raised on the mandrel during downward movement of the assembly to open the bypass passageways through the mandrel and allow the assembly to "settle" through fluid standing in the tubing. When the desired depth is reached, tension is placed on the wire line to raise the well swab mandrel and move the mandrel upwardly a short distance through the swab cup. As a result, the bypass passageways through the mandrel are closed and the complete swab cup assembly forms what may be considered a piston in the tubing. Fluid is removed from the tubing by pulling upwardly on the wire line until the swab cup assembly reaches the upper end of the tubing.

In the prior swab cup assemblies of others, the sealing members of the swab cup extend outwardly into contact with the inner walls of the tubing in the relaxed conditions of the cups; that is, even when the cups are moving downwardly through a tubing, as indicated above, fluid is bypassed through passageways in the swab cup mandrel during downward movement of the assembly through a tubing in order that the assembly will "settle" or be moved downwardly to the desired depth. These bypass passageways are normally in the form of flutes or grooves formed in the outer periphery of the mandrel which are open at their upper and lower ends when the swab cup is in an upper position on the mandrel, such as when the assembly is being moved downwardly through fluid standing in a tubing, and these bypass passageways are closed when the swab cup is in a lower position, such as during upward movement of the assembly through the tubing. The bypass passageways are so formed that the fluid flowing therethrough must make two substantially ninety degree turns which provide substantial resistance to the fluid flow. Furthermore, the space available for the bypass passageways in the mandrel, while still providing sufficient tensile strength in the mandrel, is limited to such a degree that it takes an undue amount of time to lower one of these swab cup assemblies through an oil well tubing. The available space is further limited with the advent of lightweight metal for the mandrels, such as aluminum, which has a lower tensile strength than steel—the time-honored material used for swab cup mandrels.

The present invention contemplates a swab cup assembly wherein at least the primary bypass passageway for downward movement of the assembly is in the form of an annular passageway formed between the outer periphery of the swab cup assembly and the inner periphery of the tubing. This form of bypass passageway provides the least resistance to flow of fluid therethrough and can be formed of substantially greater cross-sectional area than the common bypass passageways in a swab cup mandrel. In a preferred embodiment of this invention, the swab cup comprises two flexible lips and a supporting column of resilient material, wherein the outer diameters of both of the lips and the column are substantially less than the inner diameter of the tubing in which the swab cup is used to provide an unrestricted annular bypass passageway around the assembly. With this construction, the mandrel may be a solid rod of uniform cross-sectional area throughout its length to provide the maximum tensile strength. If desired, however, and if sufficient tensile strength is available, additional bypass passageways may be provided in the mandrel to further increase the total bypass passageway cross-sectional area and further enhance the speed of downward movement of the assembly through fluid standing in a tubing.

As indicated above, the present invention contemplates a swab cup having two flexible lips and a supporting column. One of the lips, the uppermost lip, is responsive to fluid pressure above the lip for downward and outward flexure into sealing engagement with the inner walls of the tubing, which provides an initial seal of the assembly in the tubing. As soon as the upper lip makes the initial seal, the second, or intermediate lip, which is positioned immediately below the upper lip, is mechanically flexed downwardly and outwardly into sealing engagement with the inner walls of the tubing to provide a secondary or additional seal of the assembly in the tubing. The resilient column is positioned below the intermediate lip to provide support for the intermediate lip and is also sized to be distorted into sealing engagement with the inner walls of the tubing when a substantial fluid load is imposed on the assembly to further augment the seal of the assembly in the tubing. With this type of construction, the upper, pressure responsive lip may be formed sufficiently thin and sufficiently flexible to be promptly moved into sealing engagement with the tubing with a very slight upward movement of the assembly in the tubing, since this upper lip does not need to carry any appreciable fluid load. Furthermore, this upper, pressure responsive lip may be extended radially outward beyond the intermediate lip and column to increase the time of response of the lip and, in such event, is made sufficiently thin and flexible as not to materially restrict the annular bypass passageway formed around the swab cup assembly.

An object of this invention is to decrease the time required in lowering a swab cup assembly through a well tubing having fluid standing therein.

Another object of this invention is to provide a swab cup assembly wherein at least the primary bypass passageway for the assembly is provided in the form of an annulus between the assembly and the inner walls of the tubing in which the assembly is used.

A further object of this invention is to decrease the resistance to flow of fluid past a swab cup assembly during downward movement of the assembly through an oil well tubing.

Another object of this invention is to provide a swab cup assembly which can be moved downwardly in an oil well tubing in a minimum of time and yet provide a fluid-type seal around the inner periphery of the tubing almost immediately upon upward movement of the assembly.

A further object of this invention is to provide a swab cup assembly which will provide an almost immediate seal of the assembly in the tubing upon upward movement.
of the assembly in the tubing, yet the assembly will lift a large amount of fluid in the tubing and will not unload the fluid.

Another object of this invention is to provide a swab cup assembly which is initially sealed in an oil well tubing with a pressure to fluid pressure above the assembly, and wherein this initial seal is augmented by two additional mechanically formed seals as the pressure above the assembly is increased to prevent the assembly from dumping its fluid load.

A still further object of this invention is to provide a swab cup assembly which will have the maximum strength for lifting large fluid loads; which is simple in construction and which may be economically manufactured.

Other objects and advantages of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings which illustrate the invention.

In the drawings:

Figure 1 is an elevational view of a swab cup assembly constructed in accordance with this invention, with a portion of the assembly being shown in section and with the assembly being shown in an oil well tubing in the position the assembly assumes during downward movement of the assembly through the tubing.

Figure 2 is an enlarged cross-sectional view through one side of the swab cup showing the relaxed condition of the column and its relative position with respect to an oil well tubing in which the cup is used.

Figure 3 is a view similar to Figure 2, illustrating the provision of an initial seal of the swab cup in the tubing by fluid pressure above the cup.

Figure 4 is a view similar to Figure 3 showing the next position of the swab cup as the swab cup is moved upwardly in a lifting operation.

Figure 5 is a view similar to Figure 4 showing a further position of the swab cup during an initial lifting of fluid in a tubing to illustrate the beginning of the mechanical seal obtained by the intermediate lip.

Figure 6 is a view similar to Figure 5 showing the completion of the seal provided by the intermediate lip and the initial distortion of the supporting resilient column.

Figure 7 is a view similar to Figure 6 showing the position of the intermediate lip and the resilient column when the swab cup is fully loaded, and illustrating the lack of necessity of the pressure responsive lip at this stage of lifting.

Figure 8 is a partial cross-sectional view through a swab cup showing a modified construction.

Figure 9 is a view similar to Figure 8 of an additional embodiment of this invention.

Referring to the drawings in detail, and particularly Figure 1, reference character 10 generally designates a swab cup assembly shown disposed in an oil well tubing 12. The assembly 10 comprises a mandrel 14 in the form of a solid rod of a suitable material, such as steel or aluminum, extending downwardly from a socket 16 of conventional construction which is utilized for connection with a wire line (not shown) for raising and lowering the assembly 10 in the tubing 12. The lower end 18 of the mandrel 14 is threaded to receive a nut 20 which provides a lower stop or support as will be hereinafter described.

A swab cup, generally designated by reference character 22, is positioned on the mandrel 14 between the socket 16 and the nut 20. The swab cup 22 comprises a body 24 of resilient material molded around a reinforcing sleeve 26. Thus, the body 24 is tubular in form and may be easily molded around the sleeve 26. The sleeve 26 has an inner diameter of a size to provide a sliding fit of the sleeve on the mandrel 14 and is of a length to extend substantially from the socket 16 to the nut 20 when the mandrel 14 is a solid rod of uniform cross-section and without the usual bypass passageways (not shown).

As will be understood by those skilled in the art, the sleeve 26 will be of a size to slide up and down on the mandrel 14 when the mandrel is provided with flutes or grooves (not shown) in the usual fashion. It will also be observed that the resilient body 24 is of substantially the same length as the sleeve 26.

A first lip 28 is formed around the resilient body 24 near the upper end 30 of the body. The lip 28 is thus, a circumferential type of lip and extends upwardly and outwardly from the body 24 in the relaxed condition of the lip. It will also be observed that the lip 28 has an outer diameter less than the inner diameter of the tubing 12, as will be discussed more in detail below.

An intermediate lip 32 is formed around the body 24 immediately below the first lip 28 and has a thickness greater than the thickness of the first lip 28. In a preferred embodiment, the lip 32 is about twice as thick as the lip 28. Thus, the intermediate lip 32 is not as flexible as the first lip 28, but is also extended upwardly and outwardly from the body 24, although at a slightly smaller angle than the first lip 28. The intermediate lip 32 has an outer diameter less than the inner diameter of the tubing 12 and, in a preferred embodiment, is of the same diameter of the first lip 28 in the relaxed condition of the lips.

A resilient column 34 is formed around the body 24 immediately below the intermediate lip 32 to provide support for the intermediate lip 32 and, hence, the first lip 28, as will be hereinafter described. The outer diameter of the column 34, in the relaxed condition of the column, is less than the inner diameter of the tubing 12, and preferably substantially the same diameter as the lips 28 and 32. It will also be noted that the column 34 has a length along the axis of the body 24 substantially greater than the thickness of the intermediate lip 32. The length of the column 34, measured along the axis of the sleeve 26, is preferably at least twice the thickness of the intermediate lip 32. It will be understood that the lips 28 and 32 and the column 34 are molded integrally with the body 24 around the sleeve 26 in a one-step molding operation to provide economy in manufacture.

Figure 2 illustrates the relative sizes and functions of the lips 28 and 32 and the column 34 in greater detail. The upper or first lip 28 is a thin, flexible lip responsive to fluid pressure on its outer surface 35 across the annular area designated by A for flexure downwardly and outwardly along a radius 36 which extends outwardly beyond the inner wall of the tubing 12. Thus, the lip 28 will be distorted against the inner wall of the tubing 12 when flexed downwardly by fluid pressure to provide an effective fluid seal, as will be described. In the relaxed condition of the lip 28, a clearance B is provided between the outer periphery of the lip and the inner wall of the tubing 12 for the bypass of fluid around the assembly 10. This clearance B is large in total cross-sectional area, compared with the usual bypass passageways through a swab cup mandrel. For example, in a swab cup assembly for use in a two inch I.D. tubing, the clearance B may be on the order of one-eighth inch, which makes a bypass passageway around the cup having a total cross-sectional area approximately equal to the area of a one inch diameter passageway. This may be compared with a conventional swab cup construction where-in the bypass passageways are formed in the mandrel. In the usual swab cup, the mandrel for use in two inch I.D. tubing is a one inch diameter rod having flutes in the outer surface thereof, and these flutes provide bypass passageways having a total cross-sectional area of substantially less than the cross-sectional area of the mandrel, in order that the mandrel will have sufficient strength to lift large fluid loads. In the present swab cup construction, the mandrel may be on the order of three-
quarter inches in diameter which will provide sufficient tensile strength, even when using aluminum.

The intermediate lip 32 is also a flexible lip which is flexed downwardly and outwardly along a radius 38 when force is applied to the upper surface 40 of the lip, as will be described. It will be observed that the radius 38 extends partly upwardly and outwardly along the entire outer periphery of the tubing 12 which will provide less distortion of the lip 32 when the lip is forced downwardly and outwardly in lifting a fluid load, as will be described. It will be observed that the clearance B is also provided between the outer periphery of the lip 32 and the inner wall of the tubing 12 in the same manner as with the first lip 28.

The outer diameter of the resilient column 34 corresponds to the outer diameters of the lips 28 and 32 to provide an extension of the clearance B defined above. The upper end 42 of the column 34 is extended slightly upwardly and outwardly from the body 24, such that the extreme upper end portion 44 of the column will be flexed downwardly and outwardly along a radius 46 when a downward force is applied to the surface 42. However, the radius 46 does not extend to the inner wall of the tubing 12 and will, thus, not provide a seal with the tubing 12 by simply flexing the upper end portion 44 of the column 34 in the manner of the lip 28. However, the column 34 will be distorted into sealing engagement with the inner wall of the tubing 12 when the swab cup assembly is lifting a full fluid load, as will be hereinafter described.

FIG. 5 illustrates the initial response of the lip 28 when the assembly 10 is first started moving upwardly in the tubing 12, assuming the tubing 12 has fluid therein. The flow of fluid downwardly around the lip 28 creates a pressure differential, such that fluid pressure acts on the upper face 35 of the lip 28, as indicated by the applied force P, to flex the lip 28 downwardly substantially along the radius 36. As soon as the upper outer edge 48 of the lip 28 engages the inner wall of the tubing 12, the lip is sealed to the tubing and the pressure differential across the lip will increase to provide an increased force in the direction indicated by the arrows P.

The increased pressure force on the upper face 35 of the lip 28 distorts the lip as illustrated in FIG. 4 to bring the entire outer periphery of the lip into sealing engagement with the tubing 12. This further distortion of the lip 28 also brings the lip 28 into contact with the upper face 40 of the intermediate lip 32 to impose a mechanical load on the lip 32 as indicated by the arrows L. This mechanical load initiates a downward and outward flexing of the intermediate lip 32 along the radius 38. The force imposed on the intermediate lip 32 is described as a mechanical load since it is normally applied by the upper lip 28, rather than being applied directly by fluid pressure.

As the pressure P increases by upward movement of the assembly 10, the upper lip 28 is forced on downwardly against the intermediate lip 32 and the next seal is provided by the upper outer edge 50 of the lip 32 engaging the inner wall of the tubing 12. This operation is illustrated in FIG. 5. It will, thus, be seen that the seal provided by the upper lip 28 is augmented by the intermediate lip 32 to further assure that no fluid will bypass downwardly around the assembly 10 during upward movement of the assembly in the tubing 12. The intermediate lip 32 maintains contact with the inner walls of the tubing 12, this lip makes contact with the upper face 42 of the column 34 and imposes a load (indicated by the lower arrows designated L) on the upper end portion 44 of the column. This latter load starts the deflection of the upper end portion 44 of the column 34 and initiates distortion forces in the column 34 as indicated by the arrows D.

FIG. 6 indicates the position of the intermediate lip 32 when the entire outer periphery of the lip is in contact with the inner wall of the tubing 12 to provide an efficient seal augmenting the seal provided by the upper lip 28. This figure also illustrates that at this time the upper lip 28 is actually extended downwardly below the horizontal, but is supported by the intermediate lip 32 and the column 34 to prevent damping of the fluid load carried by the assembly.

FIG. 7 illustrates the fully loaded condition of the swab cup 22 when lifting a heavy fluid load. It will be observed that the column 34 has been loaded by the intermediate lip 32 to such an extent that the upper end portion 44 of the column has been distorted outwardly into sealing engagement with the inner wall of the tubing 12 to further enhance or augment the seal of the assembly in the tubing. It should be pointed out here that the column 34 is of a length to function primarily as a column in compression, as contrasted with a flexing member, such as the lip 32 or the lip 28. The upper end portion of the column 34 will flex only slightly by virtue of the initial position of this portion of the column. The major deformation of the column 34 is obtained by virtue of the resilient material in the lower portion of the column providing displacement of the portion 44 outwardly against the tubing 12. When compression is applied to the upper end of the column 34, the resilient material reacts in the nature of a liquid and will be displaced along the path of least resistance, which, in this case, is generally outward toward the inner wall of the tubing 12.

FIG. 7 also illustrates that when the swab cup 22 is fully loaded, the upper lip 28 is not necessary to provide an efficient seal of the assembly in the tubing. Thus, when the assembly enters a coupling recess in a tubing string (not shown), the upper lip 28 may flex upwardly as illustrated by the dash lines in FIG. 7, and the fluid pressure will then act on the upper end of the intermediate lip 32 to retain the seal of the lip 32 and column 34 while the swab cup 22 is moving into the coupling recess. It may also be noted that the lip 32 and column 34 will also be unloaded when they enter the coupling recess and will, thus, allow a very minor amount of fluid to bypass the assembly at this time. However, the lip 28 will immediately enter the next upper joint of tubing and reseal the assembly in the tubing string upon continued upward movement of the swab cup assembly, such that the amount of fluid lost or bypassed around the assembly while the assembly is traversing a coupling recess is very minor compared with the total fluid load which is being lifted by the swab cup assembly.

FIG. 8 illustrates a modified swab cup 22a which is constructed in the same manner as the previously described swab cup 22, except for a modification in the upper or first lip which has been designated by reference character 28a. In this embodiment, the upper lip 28a is extended outwardly beyond the outer peripheries of the intermediate lip 32 and column 34 to enhance the response of the upper lip to fluid pressure above the lip. In this embodiment, the upper lip 28a is made sufficiently flexible that it will flex upwardly and inwardly as indicated by the dash lines to a position which will provide the clearance B all along the height of the assembly when the assembly is being moved downwardly in the tubing 12. The lip 28a will, thus, be flexed upwardly and inwardly by fluid pressure and will not materially restrict the bypass passageway around the assembly.

Another embodiment is illustrated in FIG. 9 and has been designated by reference character 232. This cup is similar to the cup 22, except for modification in the construction of the upper lip, which has been designated as 28b, and the intermediate lip, which has been designated 32b. It will be observed that in this construction, the upper lip 28b is extended downwardly beyond the inner wall of the tubing 12 in the relaxed condition of the lip, but is made sufficiently thin and flexible as to be easily deflected upwardly and inwardly, as indicated.
by the arrow, during downward movement of the swirl cup in the tubing 12. The intermediate lip 32b has also been extended outwardly beyond the periphery of the column 34 to enhance the response of this lip to the load provided by the upper lip 28b. The intermediate lip 32b is also sufficiently thin and flexible as to be flexed upwardly and inwardly, as indicated by the arrow, upon downward movement of the swirl cup in the tubing 12. It will be observed that both of the lips 28b and 32b are formed thinner than the corresponding lips in the preferred embodiment to provide an increase in flexibility. Also, each of these lips 28b and 32b may be tapered to be thinner near their outer peripheries, to further enhance their flexibility if desired. During downward movement of the modified cup 22b, both of the lips 28b and 32b will be flexed inwardly by the upward flow of fluid until the clearance B is provided around the entire periphery of the cup, such that an adequate bypass passage is provided.

From the foregoing it will be apparent that the present invention provides a swirl cup assembly which may be lowered through fluid standing in an oil well tubing in a minimum of time. The swirl cup provides a primary bypass passage in the form of an annulus which will provide the least resistance to flow of fluid past the assembly during the downward movement of the assembly in an oil well tubing. The maximum strength of the assembly will be provided, particularly in the mandrel of the assembly, such that the assembly can be used to lift unusually large fluid loads. It will also be apparent that the present swirl cup assembly will provide a quick and efficient seal with the tubing during the initial upward movement of the assembly to provide a minimum of lost motion during a swabbing operation. The initial seal of the assembly is obtained by fluid pressure and this seal is augmented by another mechanical seal when the assembly is used to lift large fluid loads. When lifting any type of load, the swirl cup assembly will not dump any portion of the fluid, except for a very slight amount when the assembly is being moved through a coupling recess in the tubing string, or when the cup is overloaded and the resilient material is stripped off. It will also be apparent to those skilled in the art that although I have shown only one swirl cup in the drawings, two or more of the swirl cups may be used in tandem relation to further increase the amount of fluid which can be lifted, and to further minimize any loss of fluid as the swirl cup is being moved through a coupling recess. Changes may be made in the combination and arrangement of parts or elements as heretofore set forth in the specification and shown in the drawings without departing from the spirit and scope of the invention as defined in the following claims.

I claim:

1. In a swirl cup assembly for swabbing fluid from a well tubing by pulling the assembly upwardly through the tubing, the combination of:
   a body of a size to move freely through the tubing;
   a first, flexible annular lip of resilient material formed around the body extending upwardly and outwardly from the body and being responsive to fluid pressure above the lip for downward flexure into sealing engagement with the inner wall of the tubing;
   an intermediate annular lip of resilient material formed around the body below the first lip having a thickness greater than the thickness of the first lip; said intermediate lip being extended upwardly and outwardly from the body and having an outer diameter, in its relaxed condition, less than the inner diameter of the tubing for the bypass of fluid therearound on the downward movement of the body through the tubing, said intermediate lip being of a size to be mechanically flexed downwardly and outwardly by the first lip into sealing engagement with the inner wall of the tubing; and
   a column of resilient material secured around the body below the intermediate lip in a position to support the intermediate lip when the intermediate lip is flexed into sealing engagement with the inner wall of the tubing; said column, in a relaxed condition, having an outer diameter less than the inner diameter of the tubing for the bypass of fluid therearound during downward movement of the body through the tubing.

2. A swirl cup assembly as defined in claim 1 wherein the first lip, the intermediate lip and the column are of the same outer diameter in their relaxed conditions.

3. A swirl cup assembly as defined in claim 1 wherein the intermediate lip is approximately twice as thick as the first lip.

4. A swirl cup assembly as defined in claim 3 wherein the column is of a length, measured upon the axis of the body, at least four times the thickness of the first lip.

5. A swirl cup assembly as defined in claim 1 wherein the column is of a size to be deformed into sealing engagement with the inner wall of the tubing when placed under compression by the intermediate lip.

6. A swirl cup assembly as defined in claim 1 wherein the body is a tubular body of resilient material and the first lip, the intermediate lip and the column are integral portions of the body; and characterized further to include a reinforcing sleeve bonded to the inner periphery of the body.

7. A swirl cup assembly as defined in claim 6 characterized further to include a solid mandrel of uniform cross-sectional area slidingly fitting in the sleeve for raising and lowering the swirl cup assembly through the tubing.

8. A swirl cup assembly as defined in claim 1 wherein the first lip has a greater outer diameter than the intermediate lip in the relaxed conditions of the lips.

9. A swirl cup assembly as defined in claim 1 wherein the first lip has an outer diameter substantially corresponding to the inner diameter of the tubing in the relaxed condition of the first lip.

10. A swirl cup assembly as defined in claim 1 wherein the outer diameter of the intermediate lip is greater than the outer diameter of the column in the relaxed condition of the intermediate lip and the column.

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