Feb. 5, 1963 E. N. JONES 3,076,503

WELL TREATING APPARATUS AND METHOD

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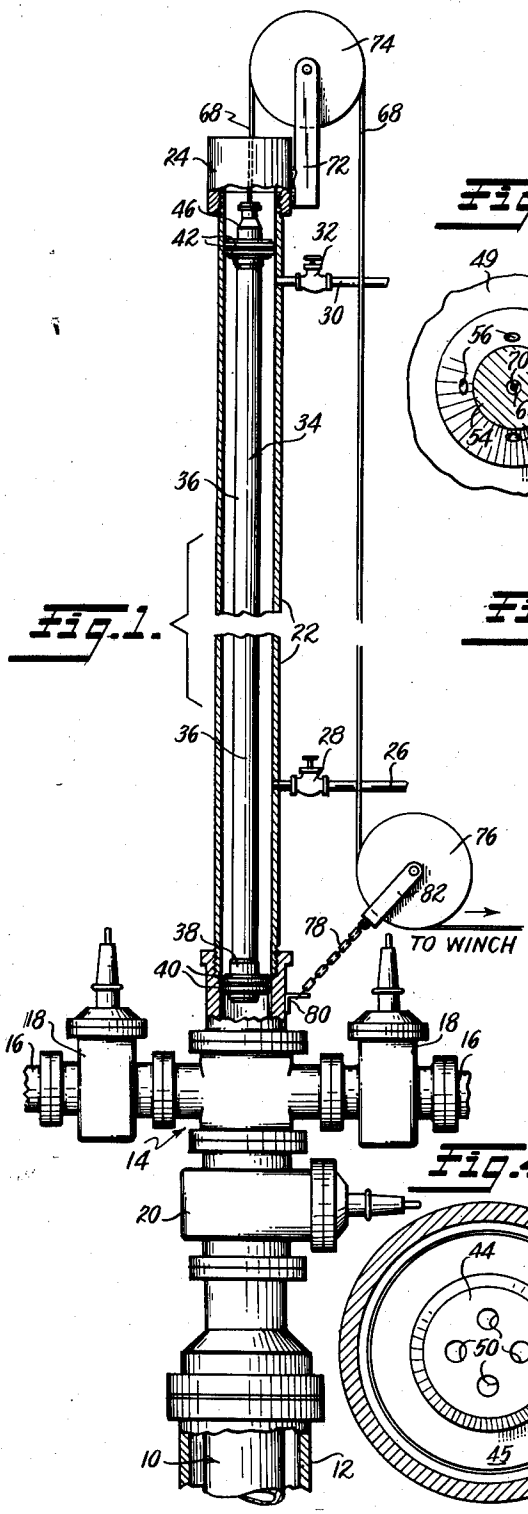


Fig. 1.

Fig. 3.

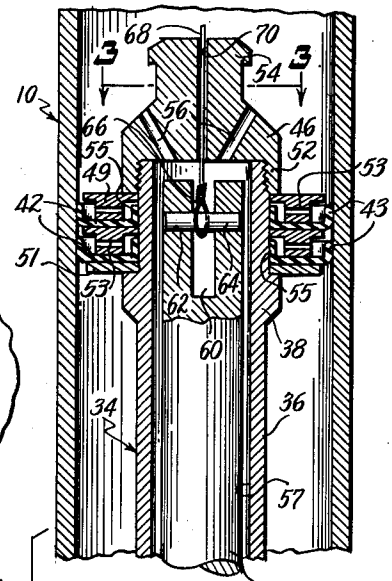


Fig. 2.

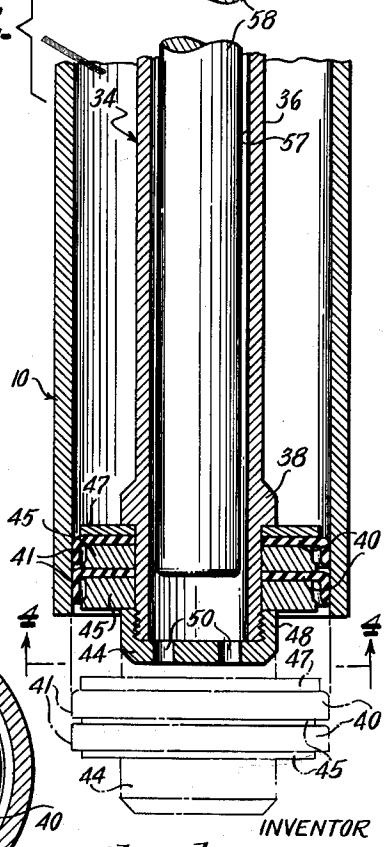


Fig. 4.

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Fig. 5.

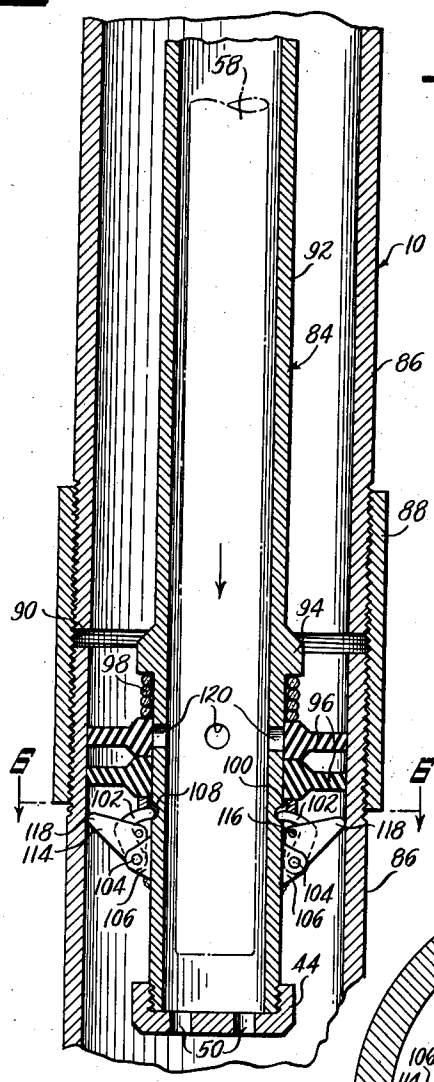


Fig. 7.

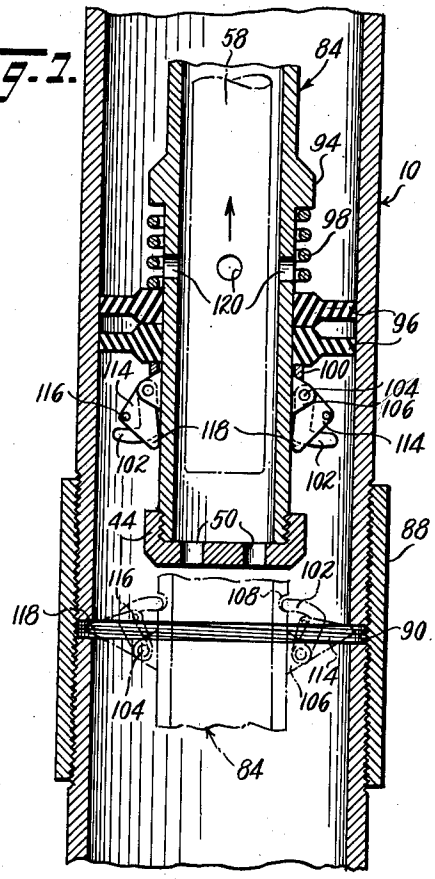


Fig. 6.

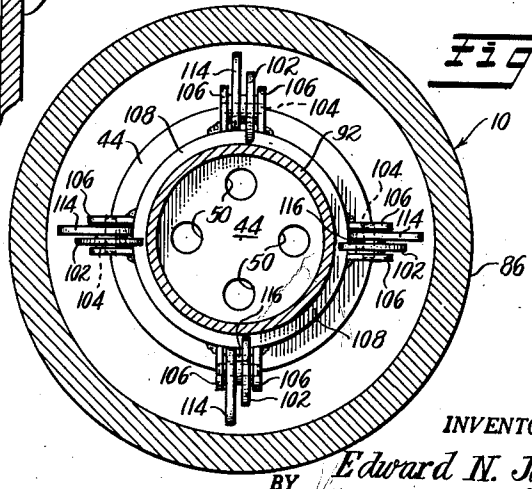
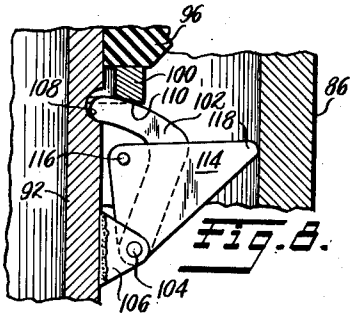


Fig. 8.



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WELL TREATING APPARATUS AND METHOD

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21 Claims. (Cl. 166—1)

This invention relates to a well treating apparatus and method, and more specifically to an apparatus which may be lowered into a well tubing to coat the internal wall of the tubing in situ, with a corrosion inhibitor, and to a method of coating the internal wall of the tubing, in situ.

In using well tubing, especially tubing used in oil wells, it frequently becomes necessary to apply a coating on the inner wall thereof. This coating may be a corrosion inhibitor which protects the metal well tubing against attack from the corrosive substances found in certain oil, or a sealing compound to seal points in a string of tubing where leaks may exist.

Previous practice involved the coating of the interior of the tubing on the surface and then lowering the string of piping into the well bore. It has been found that various operations used in connection with lowering of the string of piping into the well bore, such as bending, trucking, etc., produce minute cracks in the protective coating, which are not readily perceptible. Localized pitting occurs at these minute cracks, frequently causing undesirable leaks and requiring the replacement of the tubing.

It is an object of the invention to provide a novel well treating apparatus which can be lowered into a string of well tubing, in situ, to apply a corrosion inhibitor coating on the interior wall of the tubing.

It is a further object of the invention to provide a novel well treating apparatus which can be lowered into a string of well tubing, in situ, containing oil, to apply a corrosion inhibitor coating on the interior wall of the tubing, in which the oil, gas, or other fluids in the tubing can pass through the apparatus when it is lowered or raised in the tubing.

It is a further object of the invention to provide a novel well treating apparatus for lowering into a well tubing, in situ, to apply a corrosion inhibitor coating on the interior wall of the tubing, in which the force of gravity is employed for lowering the treating apparatus.

It is a further object of the invention to provide a novel well treating apparatus for lowering into a well tubing, in situ, to apply a predetermined quantity of corrosion inhibitor coating, including replaceable parts to accommodate different predetermined quantities of inhibitor.

It is a further object of the invention to provide a novel arrangement for charging a well treating apparatus intended to be lowered into a well tubing, in situ, to apply a corrosion inhibitor on the interior wall of the tubing.

It is a further object of the invention to provide a novel well treating apparatus for a producing oil well adapted to carry a charge of treating liquid to apply a coating on the interior wall of a well tubing, in situ, as the apparatus is lowered, in which excess liquid can be dumped at the bottom of the string of tubing to form a reservoir of coating liquid which may be carried up by the oil in the well to further coat the tubing.

It is a further object of the invention to provide a novel well treating apparatus adapted to carry a charge of treating liquid to apply a coating on the interior of a string of well tubing in situ as the apparatus is lowered therein, in which the apparatus includes structure, cooperable with the string of tubing, permitting the dumping of any unused portion of liquid at any joint in the string of tubing, or at the bottom of the string of tubing.

It is a still further object of the invention to provide a

novel method of coating a string of well tubing in a producing oil well, in situ, by passing a coating apparatus therethrough to apply a protective coating thereon and in dumping excess material at the bottom of the tubing to be carried up by the oil in the well to form a further coating on the well tubing.

Other and further objects of the invention wil be apparent from the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a view, partially in section, of the upper end of a well tubing, showing one form of a novel well treating apparatus in charging position in the lubricating housing;

FIG. 2 is an enlarged sectional view of the novel well treating apparatus of FIG. 1 within the well tubing;

FIG. 3 is a sectional view through the upper end of the well treating apparatus taken on the line 3—3 of FIG. 2;

FIG. 4 is a sectional view through the well tubing looking toward the lower end of the well treating apparatus, taken on the line 4—4 of FIG. 2;

FIG. 5 is a sectional view of the lower end of a modified form of well treating apparatus employing a novel dumping valve, showing the valve in closed position;

FIG. 6 is a transverse sectional view on the line 6—6 of FIG. 5;

FIG. 7 is a sectional view, similar to FIG. 5, showing the apparatus in its dumping positions; and

FIG. 8 is an enlarged detail view illustrating a latch and tripping mechanism.

Referring to FIG. 1 of the accompanying drawing, the numeral **10** designates a string of well tubing surrounded by the usual casing or protector string **12**, representing the conventional practice in producing oil wells. The upper end of the well tubing **10** is connected with the conventional Christmas tree **14**, having branch lines **16** controlled by individual gate valves **18**. A master gate valve **20** is provided to control the flow through the upper end of the well tubing.

A lubricator **22** is secured to the upper end of the Christmas tree **14**, as by being threaded therein. The lubricator **22** has the same internal diameter as the well tubing **10** and is arranged coaxially therewith. The upper end of the lubricator is closed by a stuffing box **24** to prevent the loss of fluid from the system. The side wall of the lubricator has a lower pipe connection **26** with a valve **28** therein, and an upper pipe connection **30** with a valve **32** therein.

One form of well treating apparatus, forming the subject matter of this invention, is shown in FIGS. 1 and 2, and is designated in its entirety by the numeral **34**. This apparatus comprises an elongated tubular member **36**, preferably of cylindrical form, provided with flanges **38** spaced inwardly from the opposite ends thereof, as more clearly shown in FIG. 2. A pair of L-shaped sealing rings **40** is inserted over the lower end of the tubular member **36**, and a pair of U-shaped sealing rings **42** is inserted over the upper end of the tubular member, the inner ring in each base being adapted to rest against one of the flanges **38**. The rings **40** and **42** have outer axially extending flanges **41** and **43**, having an outer diameter which is equal to the inner diameter of the well tubing **10**, whereby the flanges engage the inner surface of the well tubing to prevent the flow of gas or liquid past the sealing rings. An end cap **44**, having an internally threaded sleeve extension **48**, is threaded on the lower end of the tubular member **36**, and retains the sealing means **40** in position against the lower flange **38** by means of a pair of spacers **45** and a flange engaging ring **47**. The lower end cap **44** has a plurality of apertures **50** therein for a

purpose to be set forth hereinafter. An upper end cap **46**, having an internally threaded sleeve portion **52**, is threaded over the upper end of the tubular member **36**, so that the sleeve portion **52** retains the upper sealing means **42** in position against the upper flange **38** by means of a pair of T-shaped spacers **49** and a flange engaging ring **51**. The spacers **49** are provided with a plurality of apertures **53** to allow the passage of fluid under pressure to force the sealing flanges **55** tightly against the tubular member **34**. Upper end cap **46** is provided with a fishing head **54** and with a plurality of apertures **56** for a purpose to be set forth hereinafter.

The hollow tubular member **36** and the end closure caps **44** and **46** enclose an interior chamber **57** adapted to receive a weight or driving bar **58**. The driving bar is intended to deliver a blow to the lower end cap **44** to be raised and dropped within the chamber **57** in order to force the well treating device **34** through the well tubing, and for this purpose the driving bar is shorter than the axial distance between the end caps **44** and **46** to permit axial movement of the driving bar in chamber **57**. An axial bore **60** is provided in the upper end of the driving bar **58**, and a transverse bore **62** crosses said axial bore. A tight fitting pin **64** is passed through the transverse bore **62**, passing through a loop **66** on one end of a cable **68** within said bore **60**. The cable **68** passes through an opening **70** in the upper end cap **46** and through an opening in stuffing box **24**, as shown in FIG. 1. The cable extends over an upper pulley **74** supported at **72** from the stuffing box and over a lower pulley **76** to a winch, not shown. Lower pulley **76** is pivotally supported on a U-shaped mounting **82**, which mounting, in turn, is secured by means of a chain **78** to a bracket **80** carried by the Christmas tree **14**.

It will be noted, with reference to FIG. 2, that the driving bar **58**, which may be circular in cross section, has a smaller cross sectional area than chamber **57**, thereby providing an annular clearance between the outer surface of driving bar **58** and the internal wall of the tubular member **36**. This annular clearance, together with the apertures **50** in lower end cap **44** and the apertures **56** in the upper end cap **46**, provide an uninterrupted passage for fluid flow through the well treating apparatus from one end thereof to the other end.

In operation, the well treating apparatus **34** may be held in its upper position in the lubricator **22**, as shown in FIG. 1, so that the upper sealing means **42** are slightly above the point of entry of pipe connection **30**. The pipe connections **26** and **30** should be placed so that they can simultaneously register with the annular space formed by the upper and lower sealing means **42** and **40**, tubular member **36**, and the lubricator **22**. In this position, the valves **28** and **32** in the connections **26** and **30**, respectively, may be opened to permit the charging of the well treating apparatus with any liquid coating material or with a suitable corrosion inhibiting material such as, for example, the amines or any other generally accepted treating compound, including plastics, rosins, sodium silicates, and other compounds that will produce a film on the internal wall of the well tubing, which material enters through the supply connection **26**. Gases or other substances, which may be in the space being charged, are forced outwardly through the upper connection **30**, which functions in the nature of an equalizing or bleeding line. When the well-treating apparatus is charged, valves **28** and **32** may be closed and the well treating apparatus may be lowered into the well tubing **10** through the open master gate valve **20**. By releasing the tension on the cable **68**, the force of gravity is usually sufficient to lower the well treating apparatus through the well tubing **10**. If resistance is met to prevent this downward movement, the driving bar **58** can then be raised and dropped, which will produce a sufficient driving force to overcome any resistance that may be encountered. The sealing means **40** and **42** prevent the loss of liquid between them and the intermixture of the fluid carried by the well treating apparatus with the fluids in well tubing **10**. A very thin film of the corrosion inhibiting material or other material is formed on the wall of tubing **10**, as the device is lowered into the well. Larger quantities are released at the joints, where the spaced ends of adjoining pipe sections form pockets, which quantities are free to flow down the interior of the tubing **10** and cling to the tubing wall because of the affinity of the coating material with the material of the tubing wall. These sealing means may be made or rubber, leather, canvas, or other appropriate material that will permit the application of a coating of the desired thickness on the internal wall of the well tubing. As the well treating apparatus is being lowered, the flanges **41** on the lower sealing means **40** are effective to wipe the internal wall of the well tubing **10** free of any moisture or oil and replace it with a protective coating that will prevent the corrosive materials found in some oils from attacking the wall of the well tubing. When the well treating apparatus is raised, the flanges **43** on the sealing rings perform a similar function. The use of a pair of sealing means functions in the nature of labyrinthine packing to prevent the mixing of the material carried by the treating apparatus with water or other substances present within the well tubing. As the well treating apparatus is lowered or raised in the well tubing, various fluids in the well tubing, such as oil or gases, are permitted to pass from one end of the well treating apparatus to the other end through the apertures **50** and **56** in the lower and upper end caps **44** and **46** and by way of the clearance surrounding the driving bar **58**.

The well treating apparatus is selected to have a capacity in excess of that required to coat the interior wall of the tubing **10** as the apparatus is lowered, so that there remains a considerable quantity of treating liquid in the treating apparatus when it reaches the bottom of the string of well tubing **10**. By lowering the well treating apparatus to a position in which the lower sealing means **40** are below the lower end of the well tubing **10**, as shown in phantom lines in FIG. 2, the excess quantity of well treating liquid remaining in the well treating apparatus can be dumped into the bottom of the well, which, in this case, may be assumed to be a producing oil well, and the well treating liquid may be assumed to be a corrosion inhibitor having a higher affinity for the material of the well tubing than for the oil. The corrosion inhibitor may, or may not, be miscible with the oil, but in either event the inhibitor will be carried up with the oil in the pumping operation, and, because of its higher affinity for the material of the well tubing, the inhibitor will maintain a protective coating thereon. The operation above described not only contemplates the use of a coating apparatus to apply a coating of protective material along the entire internal wall of a tubing to protect the tubing against the corrosive effects of the oil passing therethrough, but also as a means to form a reservoir of protective material at the bottom of the well which may be carried up with the oil, as it is pumped, to maintain and/or to replenish the protective coating on the interior of the well tubing, and to apply a similar protective coating along the various connecting conduits branching from the Christmas tree **14** and the various storage tanks into which they discharge.

The well treating apparatus disclosed can be modified to carry different quantities of treating material. For this purpose, tubular member **34** may be replaced by a similar tubular member **34** of greater or less axial length, and of the same diameter, which can be readily attached to the end caps **44** and **46**. If necessary, a different length driving bar **58** can be substituted in such modification. It is obvious that other equivalent arrangements can be provided for permitting flow past the driving bar **58**, such as one or more axial bores extending from one end to the

other of the driving bar, or by axially extending grooves on the periphery of the driving bar.

A modified form of well treating apparatus is shown in FIGS. 5, 6, 7 and 8 in which the reference numeral **84** designates the apparatus in its entirety.

The well tubing **10** is composed of a string of pipes or pipe sections **86**, which are connected in end-to-end relationship by threaded couplings **88** engaging the external threaded ends of the pipe sections. The pipe sections are not in abutting relation, but are spaced slightly to form an annular groove **90** bounded by the spaced ends of the pipe sections and by the interior wall of the threaded coupling **88**. Advantage is taken of these annular grooves to enable the dumping of the charge of treating liquid at various selected points in the well tubing, as will be described hereinafter.

The well treating apparatus comprises an elongated tubular member **92** having flanges **94** spaced from the ends thereof. The upper end of the tubular member **92** is not shown in FIGS. 5 and 7, but the flange **94** thereon is spaced from the upper end the same distance as the upper flange **38** in FIG. 2, and cooperates with an end cap **46** to retain a pair of upper end sealing rings in position. The lower flange **94** is spaced farther from the end than the upper flange. A pair of sealing rings **96** is disposed between the flanges **94** and the ends of the tubular member. These sealing rings may be of any conventional design, and are shown as having a widened base portion surrounding the tubular member **92** to assure stability and to serve as spacing means to provide a labyrinth seal. A helical spring **98** surrounds the tubular member **92**, with its upper end abutting the lower flange **94** and its lower end engaging the base of the upper sealing ring **96** to urge both sealing rings against a spacer ring **100** and toward the lower end of the tubular member.

A plurality of latch members **102** are provided between the spacer ring **100** and the lower end of the tubular member **92**. These latch members are generally L-shaped in configuration, and are pivotally connected for swinging movement on pivots **104** supported by spaced ears **106**. The ears **106** are welded to the external wall of the tubular member **92** at spaced intervals, as shown in FIG. 6. The free ends of the latch members engage an annular groove **108** provided in the external wall of the tubular member, and are engaged by the lower surface of the spacer ring **100**, which ring is urged against the free ends of the latch members **102** by the helical spring **98** acting through the sealing rings **96**. The lower surface of the spacer ring is beveled at **110**, as shown in FIG. 8, and the points of contact between the beveled end **110** and the free end of the latch members **102** are spaced radially inwardly of the pivots **104**, so that the spring force gives rise to a radially inward component which forces the free ends of the latch members into the groove **108**.

A tripping lever **114** is pivotally mounted on the pivots **104** adjacent each latch member. The tripping levers are generally triangular in configuration, as more clearly shown in FIG. 8, being pivoted for swinging movement at one corner. Another corner carries a tripping pin **116** extending transversely of the plane of the lever **114** and adapted to extend between the adjacent latch member **102** and the tubular member **92**. The third corner **118** is adapted to ride along the interior wall of the well tubing **10** when the well treating apparatus is lowered, the tripping levers **114** tending to swing away from the tubular member **92** by force of gravity.

A plurality of apertures **120** are provided in the tubular member **92** between the lower flange **94** and the ears **106** in a position to be covered by the base of the uppermost of the sealing rings **96**, as shown in FIG. 5, which ring base constitutes a movable valve member.

In operation, the well treating apparatus of FIGS. 5–8 may be lowered in the well tubing **10** in the same manner as in the modification of FIGS. 1–4, to coat the internal wall with a coating material, such as, for example, a corrosion inhibitor, which also collects in the annular grooves **90** to protect the threaded coupling and runs down over the interior wall of the pipe sections **86**. The sealing means are in the position shown in FIGS. 5 and 8 with the coil spring **98** in its compressed state and the latch members **102** in their latching position. The base of the upper sealing ring **96** closes the apertures **120**, preventing the loss of the liquid in the annular space encompassed by the top and bottom sealing rings, the tubular member **92** and the well tubing **10**.

As the tripping levers **114** pass the joints between pipe sections **86**, the outer corners **118** are permitted to swing outward, as shown in phantom lines in the lower part of FIG. 7, until stopped by the tripping pins **116** engaging the latch members **102**. The weight of the tripping lever **114** is insufficient to overcome the force of the spring **98** tending to retain the latch members **102** in the groove **108**.

If it is desired to dump the contents of the well treating apparatus at any particular joint, the apparatus is lowered until the tripping corners **118** of the tripping levers **114** drop into the annular groove **90** of that joint, as shown in phantom lines in the lower portion of FIG. 7. The well treating apparatus may thereupon be drawn upwardly, as indicated by the arrow. The tripping corners **118** will engage the lower end of the pipe section **86** above the groove **90**, whereupon further upward movement of the well treating apparatus will cause the tripping levers **114** to swing in a downward direction about the pivots **104**. Tripping pins **116** on the tripping levers **114**, engaging the latch members **102**, will swing the latch members downwardly out of contact with the spacer ring **100**, whereupon the sealing rings **96** will be free to move downwardly by the force of spring **98** to the position shown in FIG. 7 to uncover the apertures **120**. The liquid in the well treating apparatus will thereupon gravitate through the apertures **120**, hollow interior of the tubular member **92** and the apertures **50** in the lower end cap **44** into the bottom of the well. The same operation can take place at the bottom of the well tubing **10** in which event the tripping corners **118** engage the lower end of the well tubing and cause the tripping levers **114** to trip the latch members **102**.

The axial length of the groove **90** is less than the distance between the upper and lower edges of each ring **96** at the lower end of the tubular member **92**, to assure that each sealing ring **96** is at all times in sealing relation with the internal wall of the well tubing **10**.

The dimensions of the latch members **102** and the tripping levers are designed so that they may swing from the latching position in FIG. 5 to the unlatching position in FIG. 7, through the groove **90**, without interference by the coupling sleeve **88**.

From the foregoing, it is apparent that a novel well treating apparatus and method have been disclosed, which are eminently suitable for applying a coating to well tubing, in situ, and which apparatus may be raised or lowered without interference by any liquid or gases under pressure in the well. It will be understood that various changes may be made in the details of construction and in arrangement of the parts disclosed herein without departing from the principles of the invention and the scope of the annexed claims.

I claim:

1. A method of applying a coating to a well tubing, in situ, comprising the steps of charging a well treating apparatus with a charge of coating material having a greater affinity for the material of the well tubing than for the substance in the well, said charge being in excess of that required to coat the well tubing; passing the well treating apparatus through that portion of the well tubing to be treated to simultaneously displace any well fluid present and to apply the coating material to the portion of the well tubing from which well fluid has been displaced; and discharging the excess of the coating mate-

rial into the well below the well tubing, whereby such excess coating material may form a reservoir to be carried along with the substance pumped from the well to further coat the well tubing and the connecting conduits.

2. A well treating apparatus for applying a corrosion-inhibiting coating to the interior of a well tubing, in situ, comprising an elongated tubular member having a cross sectional area which is less than the internal cross sectional area of the well tubing, and sealing means on the opposite ends of said tubular member having an external diameter substantially the same as the internal diameter of the well tubing, providing an annular chamber between said end sealing means, tubular member and well tubing adapted to receive coating material, the portion of said tubular member between said end sealing means being imperforate and the ends of the tubular member exteriorly of said annular chamber being open for the passage of fluid therethrough when the apparatus is lowered and raised in the well tubing.

3. A well treating apparatus as recited in claim 2, including closure caps for the ends of the tubular member, said closure caps having apertures therethrough for the passage of fluid.

4. A well treating apparatus as recited in claim 2, including flanges carried by and spaced from the ends of the tubular member forming abutments for the sealing means, closure caps for the ends of said tubular member, said closure caps including means to clamp the sealing means against said flanges, and apertures in said closure caps for the passage of fluid through the well treating apparatus as said apparatus is lowered or raised through the well tubing.

5. A well treating apparatus as recited in claim 2, including closure caps for the ends of the tubular member, said closure caps having apertures for the passage of fluid through the treating apparatus, one of said closure caps including a head for receiving a fishing tool.

6. A well treating apparatus as recited in claim 2, including upper and lower closure caps for the ends of the tubular member, said closure caps having apertures for the passage of well fluid through the treating apparatus, and a driving bar within said tubular member operable to deliver a blow to the lower end cap to drive the tubular member through the well tubing, said driving bar being constructed and arranged to permit well fluid flow through said tubular member.

7. A well treating apparatus as recited in claim 6, in which the driving bar has a cross sectional area smaller than the interior cross sectional area of said tubular member.

8. A well treating apparatus as recited in claim 6, in which the driving bar has a length shorter than the space between said end caps, remotely actuated means connected to said driving bar to reciprocate the same relative to the tubular member, and an opening through one of said end caps for the passage of said remotely actuated means.

9. A well treating apparatus as recited in claim 8, in which said opening is in the upper end cap, and is smaller than the cross sectional area of the driving bar, whereby said remotely actuated means serves the additional function of engaging the driving bar with the upper end cap for raising said well treating apparatus.

10. A well treating apparatus as recited in claim 2, including remotely actuated means to discharge the contents of the well treating apparatus while in a well tubing.

11. A well treating apparatus as recited in claim 10, in which said remotely actuated means comprises a valve, and means carried by said tubular member and coacting with a portion of the well tubing upon upward movement of the tubular member to actuate the valve.

12. A well treating apparatus as recited in claim 11, in which said valve comprises an opening in the tubular member controlled by the sealing means on the lower end, said sealing means being mounted for axial sliding movement on the tubular member.

13. A well treating apparatus as recited in claim 11, in which said coacting means on the tubular member for actuating the valve comprises a latch member, and a latch tripping member actuatable upon upward movement of the tubular member.

14. A well treating apparatus as recited in claim 12, in which said coacting means for actuating the valve comprises a latch member and a latch tripping member on the tubular member for actuating the valve and resilient means normally urging the sealing means toward the valve opening position against restraint offered by the latch member.

15. In combination: an oil well having tubing within the boring and a lubricator above the tubing forming an extension thereof, a well treating apparatus for applying a corrosion inhibiting coating to the interior of the well tubing, in situ, said treating apparatus comprising, an elongated tubular member having a cross sectional area which is less than the internal cross sectional area of the tubing and lubricator, sealing means on the opposite ends of said tubular member having an external diameter substantially the same as the internal diameter of the tubing and lubricator providing an annular chamber between the end sealing means, tubular member and tubing or lubricator to receive and coat a protective film on the internal wall of the well tubing when the apparatus is lowered and raised in the tubing, said apparatus having a length not greater than the length of the lubricator to be accommodated therein, and a pair of axially spaced, valved, connections in the wall of the lubricator, adapted to register with the annular chamber between the sealing means, to permit the charging of the annular chamber with a well coating material and the venting of other material therefrom.

16. The combination as recited in claim 15, in which the upper valved connection is located in the lubricator in position to register with the extreme upper end of the annular chamber immediately below the upper sealing means of the well treating apparatus.

17. The combination as recited in claim 15, including a cable connected to the treating apparatus, and a pulley carried by the lubricator over which the cable passes to lower and raise the treating apparatus in the tubing and lubricator.

18. The combination as recited in claim 15, including caps on the ends of the tubular member, and apertures in said end caps for the passage of fluid therethrough when the apparatus is raised and lowered in the tubing and lubricator.

19. The combination as recited in claim 15, including caps on the ends of the tubular member, apertures in said end caps for the passage of fluid therethrough when the apparatus is raised and lowered in the tubing and lubricator, a driving bar within said tubular member being constructed and arranged to permit the passage of fluid therethrough, the axial length of said driving bar being less than the distance between the end caps, remotely actuated means connected to said driving bar to reciprocate the same, and an opening through one of said end caps for the passage of said remotely actuated means.

20. The combination as recited in claim 19, in which the construction and arrangement to permit the passage of fluid therethrough comprises a cross sectional area of the driving bar which is less than the internal cross sectional area of the tubular member to provide an annulus between the external surface of the driving bar and the internal surface of the tubular member.

21. A method of applying a coating to a well tubing, in situ, comprising the steps of: confining in a well tube an annular charge of well coating material having an axial passageway extending therethrough; and moving said annular charge of coating material through the well

tube to simultaneously displace well fluid in advance of the annular charge from the well tube axially upwardly through said passageway in said annular charge and to apply the coating material to the portion of the well tube from which the well fluid has thus been displaced.

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