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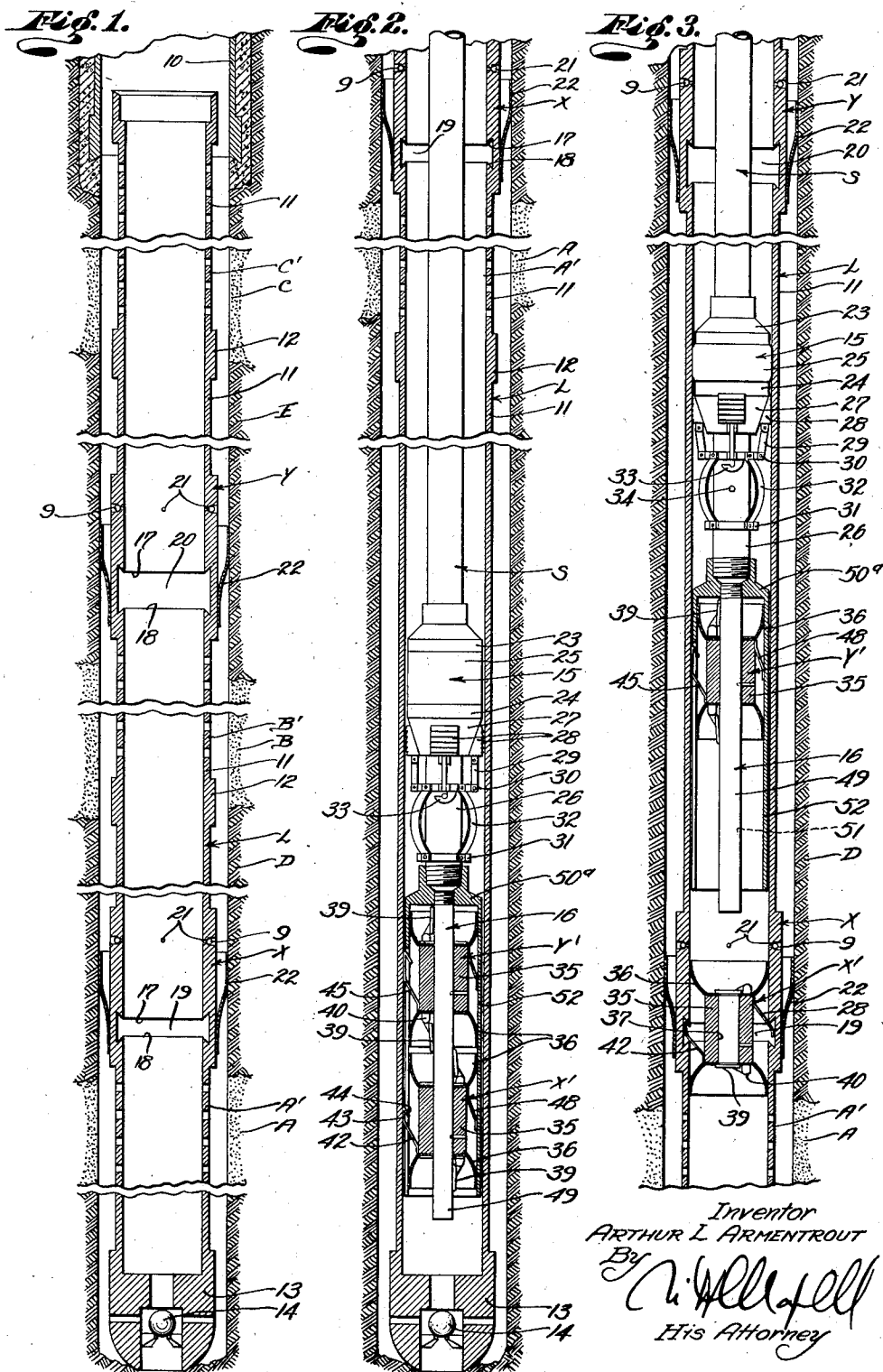
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2,295,822

APPARATUS FOR CEMENTING OBJECTS IN WELL BORES

Filed Sept. 14, 1940

2 Sheets-Sheet 1



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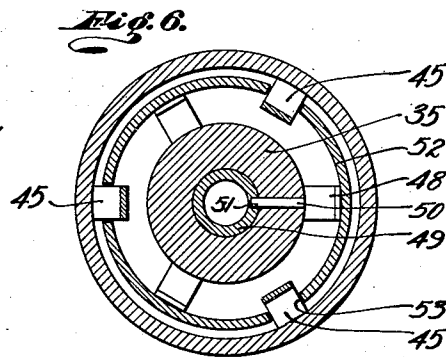
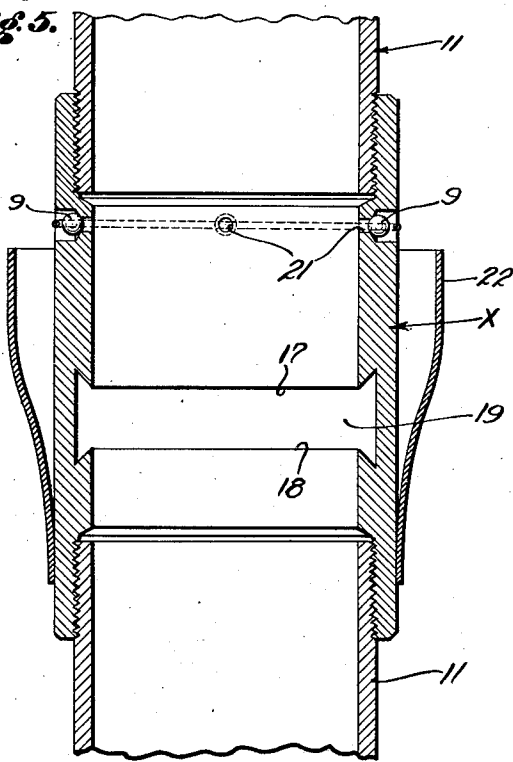
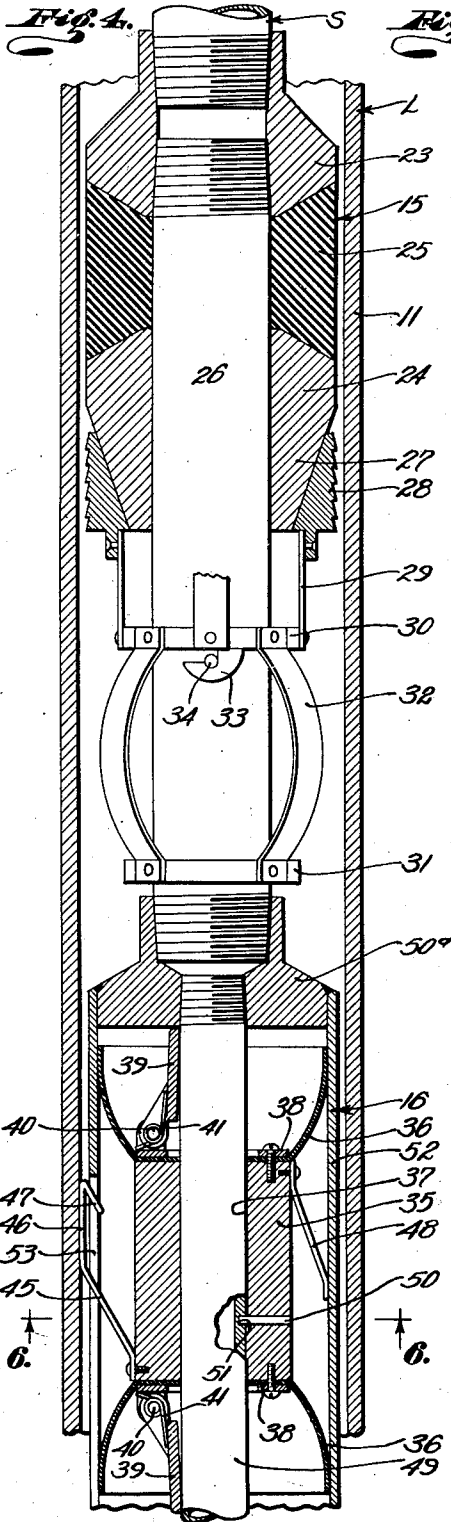
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2 Sheets-Sheet 2



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2,295,822

APPARATUS FOR CEMENTING OBJECTS IN WELL BORES

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14 Claims. (Cl. 166—1)

This invention relates to the art of cementing wells and has particular reference to a method and apparatus for cementing casings, liners, and like objects in well bores. A general object of the invention is to provide a rapid, efficient method and a simple, practical apparatus for cementing objects in wells.

Another object of this invention is to provide a practical method for performing multiple stage cementing operations for the purpose of cementing water strings or casings and for cementing casings and liners at spaced levels to isolate spaced productive zones and to prevent the migration of water and other unwanted fluids to such zones.

Another object of this invention is to provide a multiple stage cementing method of the character referred to wherein each stage or charge of cement slurry is separately and individually delivered to the well and individually placed in the selected portions of the annular space between the wall of the well bore and the lining or well casing. In the method of the present invention the charges or bodies of cement slurry are individually passed down the well one at a time for separate delivery to their respective places and there is no danger of such charges becoming stalled or blocked in the well.

Another object of the invention is to provide a cementing method of the character referred to in which the cement slurry is effectively prevented from passing down in the casing or liner beyond the correct or intended point or points of discharge.

Another object of this invention is to provide a method of the character referred to in which the individual bodies or charges of cement slurry may be as small or as large as believed necessary and may be individually increased, as found necessary.

Another object of this invention is to provide a cementing method of the character referred to in which the interior of the well casing or liner and the cementing tool may be flushed free of excessive cement slurry following each stage cementing operation.

Another object of this invention is to provide a cementing method of the character referred to that is particularly adapted to "spot" or place bodies of cement slurry around a well liner at spaced levels or depths to isolate spaced productive zones of the well.

Another object of the invention is to provide a well cementing method of the character referred to that is characterized by the employment

of a single tubular string which serves to conduct the charges of cement slurry to their respective places in the well, to carry the circulation fluid or flushing fluid, to carry the bridging plugs and packer and to control and support the control means and protective means for the bridging plugs.

Another object of this invention is to provide apparatus for carrying on multiple stage cementing operations that is safe and dependable and that is easily controlled.

Another object of the invention is to provide multiple stage cementing apparatus that does not require the installation of complicated valves, or the like, on the casing, liner, or other object installed in the well.

Another object of this invention is to provide a multiple stage cementing apparatus embodying novel and effective means for successively latching or locking the bridging plugs at their respective stations in the casing or liner.

Another object of the invention is to provide multiple stage cementing apparatus in which the bridging plugs and their latches are fully housed and protected by novel means on the cementing string so that they are not worn or fouled when the apparatus is lowered into the well and are controlled so that they are freed for engagement in the casing or liner only upon reaching their respective stations.

Another object of the invention is to provide a cementing apparatus of the character referred to that is operable to accurately spot or locate one or more bodies of cement slurry at selected or pre-determined points in the well.

The various objects and features of my invention will be fully understood from the following detailed description of a typical preferred manner of carrying out the method and a typical form of apparatus of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a vertical sectional view of a portion of a well bore with a liner arranged therein preparatory to the cementing operation, the liner and other parts being diagrammatically shown. Fig. 2 is a view similar to Fig. 1 with the cementing apparatus in position in the liner. Fig. 3 is a view similar to Fig. 2 showing one of the bridging plugs engaged or latched in the liner and illustrating the packer set so that cement slurry may be discharged under pressure above the set plug for discharge into the well. Fig. 4 is an enlarged fragmentary vertical detailed sectional view of the cementing apparatus showing the

packer in the unactuated state and showing one of the bridging plugs in the carrier. Fig. 5 is an enlarged fragmentary vertical detailed sectional view of a portion of the liner showing one of the shouldered ported parts and Fig. 6 is a transverse detailed sectional view taken as indicated by line 6-6 on Fig. 4.

The method and apparatus of the invention have a wide range of application, being useful in carrying on various well cementing operations. For example, the invention may be employed in the multiple stage cementing of a casing for any required distance, may be employed in the spotting of cement for any purpose, for the repair of leaks in a well casing, for the cementing of a liner, etc. In the following detailed disclosure I will describe the invention employed as illustrated in the drawings to cement a well liner at spaced levels to isolate spaced productive zones of the well, it being understood that this is but a typical use or application of the invention.

The portion of the well bore illustrated penetrates three spaced productive zones A, B and C, separated by non-productive strata D and E, which may or may not be water bearing. The lower portion of the water string or well casing 10 is cemented in the well at or above the upper end of the productive zone C. The liner L for the open productive portion of the well is a long tubular member or assembly received in the productive part of the well with some clearance to provide or leave an annular space. The liner L may rest on the bottom of the well bore and the liner may be proportioned to have its upper part protrude into the well casing 10. It is to be understood that the liner L may be suspended or supported in the well in any of the well known manners and if desired may be sealed or packed off in the casing 10.

The present invention is not primarily concerned with the material or structure of the liner L. However, it will be assumed that the liner L is formed of a readily drillable material such as aluminum, an aluminum alloy or the like, and is made up of several tubular lengths or sections 11 joined by threaded couplings 12. The liner L is provided with spaced perforated portions A', B' and C' at the productive zones A, B and C respectively, to admit the well fluid. A float shoe 13 is provided on the lower end of the liner L and has a valve 14 serving to prevent the entrance of fluid to the interior of the liner and adapted to permit the outflow of fluid. The liner L is equipped with other elements which are employed in the cementing operations as will be later described.

The cementing apparatus of the invention may be said to comprise, generally, shouldered and ported parts X and Y on the liner L at or opposite the non-productive zones D and E, a fluid conducting operating string S, an expansible and contractible packer 15 carried by the string S to seal with the interior of the liner L, a plurality of bridging plugs X' and Y' for latching or locking with the shouldered parts X and Y, respectively, and means 16 on the string S carrying the plugs X' and Y' to successively engage with the parts X and Y.

The shouldered and ported parts X and Y are arranged to be in those portions of the well which pass through what I will term non-productive zones D and E, being connected or assembled in the liner L to occupy such positions when the liner is finally set or hung in the well. The invention contemplates the forming and mounting

of the parts X and Y in any preferred manner. In the particular case illustrated each part X and Y is an integral nipple or coupling-like element interposed between and connecting adjacent sections 11 of the liner L. The parts X and Y may be screw-threaded with the adjacent sections 11 of the liner L and may be formed of readily drillable material, for example, they may be formed of the same material as the liner sections. Each part X and Y has a pair of vertically spaced opposing internal shoulders 17 and 18. In practice I prefer to form a groove in the internal surface of each part X and Y and to shape the grooves so that their end walls constitute the shoulders 17 and 18. Thus the part X is provided with an internal groove 19 and the part Y has a similar internal groove 20. The grooves 19 and 20 are annular so that the shoulders 17 and 18 are continuous. In accordance with the invention the grooves 19 and 20 are graduated in width to be selectively engaged by lock means on the plugs X' and Y'. In the construction illustrated the groove 20 in the upper part Y is considerably wider than the groove 19 in the part X.

One or more ports 21 are provided in each of the shouldered parts X and Y. There is preferably a plurality of circumferentially spaced ports 21 provided in each part X and Y. The ports 21 are spaced some distance above the grooves 19 and 20 and are provided to discharge the cement slurry into the annular space between the wall of the well and the liner L. Each port 21 is equipped with a suitable inwardly seating check valve 9 to prevent the return of the delivered or discharged cement slurry. It may be desirable or necessary to provide a cement retainer or basket 22 on or adjacent each part X and Y below the ports 21 to limit the downward flow of the cement slurry discharged from the ports. In the drawings I have shown baskets 22 of conventional form secured to the parts X and Y below the ports 21 and designed to seal with the wall of the well. It is to be understood that where the liner L is drillable all of the elements associated with the liner may be formed of readily drillable material.

The string S serves as an operating string for the packer 15, the plugs X' and Y' and the means 16, and operates as a conduit for delivering the cement slurry and flushing fluid to the liner L. The string S may be made up of suitable well pipe or tubing connected in the usual way by threaded couplings. The string S is proportioned to be received in the casing 10 and liner L with substantial clearance. It is to be understood that the string S is tubular and continuous and that pumps or other means are provided at the upper end of the well for supplying fluid under pressure to the string S.

The packer 15 is operable to seal with the interior of the liner L and is arranged to be manipulated and controlled by the string S. The packer 15 as shown in Fig. 4 includes an abutment or collar 23 fixed to the string S, a sleeve 24 shiftable with respect to the string and a body of packing 25 between the collar 23 and the sleeve 24. The collar 23 may be threaded to the lower end of the string S and a mandrel 26 may be threaded in the lower end of the collar 23 to extend downwardly through the packer 15. The mandrel 26 constitutes a downwardly extending continuation of the string S and is tubular to conduct fluid. The lower end of the collar 23 is tapered or sloped upwardly and outwardly. The

shiftable abutment or sleeve 24 is arranged on the mandrel 26 at a point below the collar 23. The upper end of the sleeve 24 slopes downwardly and outwardly. The packing 25 is arranged on the mandrel 26 between the collar 23 and the sleeve 24 and is an annular or tubular body of resilient compressible material. The upper and lower ends of the packing 25 are concave to receive or cooperate with the tapered opposing ends of the collar 23 and sleeve 24. The tapered ends of the collar 23 and the sleeve 24 cooperating with the cupped or concave ends of the packing 25 are effective in expanding the packing. When the packing 25 is in its normal unexpanded state its periphery is spaced from the interior of the liner L, leaving a free annular passage. When the packing 25 is compressed its periphery is brought into sealing contact with the interior of the liner L.

The packer 15 further includes a gripping means or slip means for holding the sleeve 24 against downward movement whereby the string S may be lowered to actuate or compress the packing 25. The lower portion of the sleeve 24 is shaped to constitute a cone 27 and a set of slips 28 is arranged on the cone. Reins 29 depend from the slips 28 and are secured to a ring 30 which freely surrounds the mandrel 26. A second ring 31 is arranged around the mandrel 26 below the ring 30. A series of leaf springs 32 extends between and connects the rings 30 and 31. The springs 32 are bowed outwardly to frictionally engage the interior of the lining L and this engagement resists movement of the rings and the slips 28. Latch means is provided to control the slips 28. A hook-like latch 33 is secured to the ring 30 and is engageable with a pin 34 on the mandrel 26. When the latch 33 is in cooperation with the pin 34 the slips 28 are retained in their retracted positions illustrated in Fig. 4. The pin 34 is disengageable from the latch 33 by manipulation of the string S and subsequent downward movement of the string S results in expansion or actuation of the slips 28 by the cone 27. The slips 28 gripping in the liner L are operable to hold the sleeve 24 against downward movement and continued or subsequent downward movement of the string S results in compression of the packing 25 so that it seals with the interior of the liner L. The packer 15 is such that the packing 25 returns to its initial size when relieved of the compression forces by upward movement of the string S. Following such retraction of the packing 25 the string S may be manipulated to release the slips 28 and re-engage the pin 34 with the sleeve 33 to again hold the slips in their released positions.

The bridging plugs X' and Y' are adapted to form barriers or partitions across the interior of the liner L below the discharge ports 21 so that cement slurry or other fluid under pressure delivered to the interior of the liner above the plugs is obliged to discharge laterally through the ports. The plugs X' and Y' may be alike in construction.

Each plug X' and Y' comprises an elongate central core or body 35 and sealing cups 36 on the opposite ends of the body, see Fig. 4. The plug bodies 35 are smaller in diameter than the liner L and have central longitudinal openings 37. The sealing cups 36 of the plugs X' and Y' are arranged on the bodies 35 to seal with the interior of the liner L for the purpose of preventing fluid under pressure from passing the plugs in either direction. The cups 36 have flat central portions clamped against the ends of the plug

bodies 35 by plates 38. The rims or walls of the cups 36 are flared to effectively seal with the surrounding internal surface of the liner L. The cups 36 at the upper ends of the plug bodies 35 face upwardly to be actuated or expanded by downwardly directed fluid pressure while the cups 36 at the lower ends of the plug bodies face downwardly to be expanded by upwardly directed fluid pressure.

Valves 39 control the upper and lower ends of the openings 37 in the plugs. The valves 39 may be flapper type valves pivotally supported on the plates 38 at 40 to seal against the plates 38 or the ends of the plug bodies 35. Springs 41 are associated with the pivotal mountings 40 to urge the valves 39 to their closed positions. The bridging plugs X' and Y' and the parts associated therewith are formed of readily drillable material to be drilled up by conventional well drilling tools. It is to be understood that there is a plug provided to engage in each shouldered part of the liner L and that the apparatus may embody any required number of bridging plugs of the character just described.

Each bridging plug X' and Y' is equipped with a latch means or lock means for cooperating with its respective shouldered part of the liner L. A plurality of spring latching or locking elements 42 is provided on the plug X' to engage in the groove 19 of the shouldered part X. The locking elements 42 are spaced around the plug body 35 and have their lower ends suitably secured to the lower part of the plug body. The spring elements 42 extend upwardly and outwardly and then straight up, each having a substantially straight vertical part 43. The parts 43 form shoes that are adapted to ride on the internal surfaces of the casing 10 and the liner L when the apparatus is moved through the well. In accordance with the invention the parts 43 are proportioned to enter the groove 19 in the liner part X and the groove 20 or any other like grooves above the part X. The lock elements 42 are shaped to ride downwardly past the grooves 19 and 20 and any other similar grooves and operate to selectively enter their respective groove 19 upon subsequent upward movement. The spring locking elements 42 are shaped to latch or lock in the groove 19 when the shoe parts 43 enter the groove. Each lock element 42 has a downwardly and inwardly turned nose 44 at the upper end of its shoe part 43. The walls or shoulders 17 and 18 of the groove 19 are preferably undercut and the noses 44 are sloped or shaped to lock under the shoulder 17. The engagement of the noses 44 with the shoulder 17 dependably locks the plug X' against upward movement in the liner L.

The bridging plug Y' is provided with a plurality of spring locking elements 45 similar to the above described elements 42. The locking elements 45 are spaced about the body 35 of the plug Y' and have their lower ends secured to the lower part of the plug body. The elements 45 slope upwardly and outwardly and have substantially vertical shoes 46 adapted to ride on the internal surface of the casing 10 and the liner L. The shoes 46 are proportioned to readily enter the groove 20 in the shouldered part Y but their length is such that they cannot enter the groove 19 or other similar grooves that may be provided in the liner below the groove 20. Downwardly and inwardly directed noses 47 are provided on the upper ends of the shoes 46 to cooperate with the shoulder 17 of the groove 20. The walls or shoulders 17 and 18 of the groove 20 are un-

dercut and the noses 47 are adapted to engage the undercut shoulder 17 to dependably lock the plug Y' against upward movement in the liner.

The plugs X' and Y' are further provided with means cooperable with the shouldered parts X and Y, respectively, to latch or hold the plugs against downward movement. Each plug X' and Y' has a number of downwardly and outwardly sloping latch fingers or lock fingers 48 for cooperating with the shoulders 18. The fingers 48 are spaced between the lock elements 42 and 45 and are suitably attached to the upper portions of the plug bodies 35. The outer or lower parts of the fingers 48 may be straight or substantially vertical to better lock with the shoulders 18. The fingers 48 are adapted to engage with the shoulders 18 of the related parts X and Y to dependably support or hold the plugs X' and Y' against downward movement.

The means 16 serves to support the plugs X' and Y' and to house and protect the plugs when the tool or equipment is manipulated in the well. The means 16 is such that the plugs X' and Y' may be individually released when engaged in their respective shouldered parts X and Y as the stage cementing operations progress. In the preferred form of the invention the means 16 includes a stem or tube 49 connected with the lower end of the mandrel 26 and extending downwardly therefrom. A head or collar member 50^a may serve to connect the tube 49 with the mandrel 26. The tube 49 is proportioned to be received in the openings 37 of the plug bodies 35. The plugs X' and Y' are arranged on the tube 49 from its lower end, the plug Y' being arranged above the plug X'. As illustrated in Figs. 2, 3 and 4 of the drawings the tube 49 passing through the openings 37 holds the valves 39 in their open positions. The openings 37 shiftably or slidably receive the tube 49 so that the plugs may be successively disengaged from the tube. The tube 49 serves as a fluid conductor constituting a continuation of the string S and being operable to discharge the flushing fluid, cement slurry, etc. from the lower end of the tool.

Means are provided for releasably securing the plugs X' and Y' to the tube 49. Shear pins 50 are arranged through radial openings in the plug bodies 35 to engage in openings or sockets 51 in the wall of the tube 49, see Fig. 4. The pins 50 serve to retain the plugs X' and Y' in their initial positions on the tube 49 until after the plugs have been latched or locked in their respective shouldered parts X and Y of the liner L whereupon the pins may be broken to permit the withdrawal of the tube 49 from the plugs.

The means 16 further includes a housing or cage 52 for the series of plugs X' and Y'. The cage 52 is a tubular element whose upper end is fixed to the collar member 50^a as by welding. The cage 52 surrounds the tube 49 with substantial clearance leaving a chamber or space which houses the bridging plugs X' and Y'. As illustrated, the cage 52 may be somewhat shorter than the tube 49 so that the tube continues downwardly for the discharge of the fluid. In the preferred construction the cage 52 is proportioned to be received in the liner L with considerable clearance, leaving an annular space for the flow or passage of fluid. The cage 52 is proportioned to receive the plugs X' and Y' so that the cups 36 and the latch fingers 48 of the plugs may bear outwardly against its internal surface.

The plug enclosing cage 52 is formed to permit the engagement of the lock elements 45 with

their shouldered parts X and Y. Longitudinally extending slots 53 are provided in the cage 52 to freely receive or pass the outer portions of the latch elements 42 and 45. The slots 53 extend to the lower end of the cage 52 so that the cage may be moved upwardly from the plugs X' and Y' as the lock elements 42 and 45 successively engage in the shouldered liner parts X and Y. The slots 53 expose the shoe parts of the elements 42 and 45 for free engagement with the internal surface of the liner so that the lock elements may engage in the parts X and Y. It will be observed that the cage 52 fully and effectively houses the plugs X' and Y' to prevent wearing of the plugs and fouling of the plugs during movement of the apparatus in the well.

The operation of the apparatus and the method of the invention, employed as illustrated in the drawings, may be said to comprise, generally, the setting or positioning of the liner L in the well, the lowering of the string S in the well to bring the packer 15 to a position below the lowermost ports 21, the actuation of the packer 15, the delivery of cement slurry under pressure through the string S to the lower portion of the liner L for discharge from the shoe 13, the releasing of the packer 15 and the raising of the apparatus to bring the packer to a position above the part X and to cause the plug X' to latch in the part X, the actuation of the packer 15, the passage of cement slurry under pressure down through the string S for delivery to the ports 21 of the part X, the releasing and raising of the packer 15, the repeating of the cementing operations at the part Y' and at the shouldered liner parts thereabove, followed by the withdrawal of the string S and the removal of the bridging plugs X' and Y'. In addition to these general operations the liner L and the cementing equipment may be flushed or washed preparatory to and following each stage cementing operation.

Assuming that the liner L is set or positioned in the well and that the liner and well are conditioned for the reception of the cement slurry, the string carrying the cementing equipment is run down in the well to a position such as illustrated in Fig. 2 of the drawings. The string S is lowered to bring the packer 15 below the part X and to bring the discharge end of the tube 49 adjacent the shoe 13. If desired or necessary, fluid may be pumped down through the string S to discharge from the tube 49 to flush the lower portion of the liner and to clean the cementing apparatus. The string S is turned a short distance and moved downwardly to release the pin 34 from the latch 33 and subsequent downward movement of the string sets the slips 28 and compresses the packing 25. With the packer 15 set or actuated to seal with the interior of the liner L a suitable distance above the shoe 13 a quantity of cement slurry under pressure is pumped down through the string S to discharge into the liner at or above the shoe 13. This cement slurry passes through the valve 14 into the well and flows up around the lower portion of the liner. This body of cement slurry serves to seal off the well below the lower productive zone A. Following the delivery of the first body of cement slurry, the string S is manipulated to release the packer 15 and to re-engage the pin 34 with the latch 33, whereupon water or flushing fluid may be pumped down through the string S to remove excessive cement from the lower part of the liner and to flush the cementing tool. The flushing

fluid is free to pass upwardly in the liner around the cage 52 and around the retracted packer 15.

With the first cementing operation completed the string S is raised to move the cementing tool up through the liner L to a position where the packer 15 is above the shouldered part X. During this upward movement of the string S the shoe parts 43 of the lock elements 42 spring outwardly into the groove 19 of the part 48 and the pointed upper ends of the elements 42 engage under the shoulder 17 of the part X. The engagement of the elements 42 in the part X latches the plug X' in the part X and of course resists upward movement of the string S. This sudden resistance to upward movement of the string S informs the operator that the plug X' has latched in the part X. An upward pull of increased intensity is then placed on the string S to insure the breaking of the shear pin 50 so that the continued upward movement of the string S withdraws the tube 49 and the cage 52 from the plug X'. This frees the latch fingers 48 of the plug X' and the fingers engage in the groove 19 to prevent downward movement of the plug X' in the liner. The sealing cups 36 of the plug X' are automatically conditioned to seal with the interior of the liner L and the valves 39 of the plug X' automatically close when the tube 49 passes upwardly from the plug.

Following the setting or latching of the bridging plug X' the string S is again manipulated to actuate the packer 15 so that the packer is made to seal with the interior of the liner L above the plug X'. A quantity of cement slurry under pressure is then passed down through the string S to discharge in the liner L adjacent and above the bridging plug X'. This cement slurry under pressure is free to discharge through the ports 21 of the part X to surround and seal about the liner in the unproductive zone D. It will be observed that the bridging plug X' and the packer 15 limit or prevent movement of the cement slurry up and down in the liner obliging the cement slurry under pressure to pass out through the ports 21 in the part X. Pressures that may develop in the liner L below the part X cannot interfere with the cementing operation, the plug X' serving to effectively hold back such pressures. If it is believed that additional cement slurry should be delivered to the well the operator may pump such additional cement slurry down through the string S to increase the volume of cement discharged into the well at the zone D. The basket 22 associated with the part X limits the down flow of the cement slurry and a body or column of cement slurry builds up around the liner in the stratum or zone D. Following the cementing operation in the zone D the string S is manipulated to release the packer 15 and washing fluid may be pumped down through the string to wash away excessive cement and to clean the cementing tool.

Following the above operations the string S is raised to bring the bridging plug Y' to the shouldered part Y. When the plug Y' reaches the part Y its lock elements 45 snap into the groove 20 and the noses 47 engage under the shoulder 17. The engagement of the lock parts 45 in the groove 21 suddenly offers increased resistance to upward movement of the string S informing the operator of the engagement of the plug Y' in the part Y. An increased upward pull is then put on the string S to break the shear pin 50 and the string is moved upwardly to withdraw the tube 49 and the cage 52 from the

latched plug Y'. The string S is moved upwardly to completely free the tube 49 from the plug Y' and is then manipulated to actuate the packer 15.

The apparatus is then ready for the third cementing operation. A selected quantity of cement slurry is pumped down through the string S to discharge from the tube 49 above the plug Y'. The cement slurry under pressure passes out through the ports 21 in the part Y to seal off around the liner in the stratum of zone E. Following the cementing operation at the zone E the string S is manipulated to release the packer 15 and washing fluid may be pumped down through the string S to wash away excessive cement slurry from the liner and the tool. The string S may then be withdrawn from the well. To condition the liner L for production the frangible or drillable plugs X' and Y' are removed. The plug X' and Y' may be removed by drilling them out with a suitable drilling tool or by breaking them out. This conditions the well for production or for the installation of additional equipment.

When the method and apparatus of the invention are employed to close or repair a leak in a previously set well casing, or the like, the location of the leak is first ascertained. The apparatus of the invention is assembled to embody a single plug, say the plug X', the plug being proportioned to seal or close the casing. The string S carrying the apparatus is then lowered through the casing to bring the sleeve 52 below the coupling in the casing below and closest to the leak. As well known to those skilled in the art the couplings of well casings form or have internal grooves similar to the grooves 19 and 20, above described. When the string S has been lowered to the position above mentioned, it is raised until the lock parts 43 of the plug X' engage in the casing coupling below the leak. An up-pull is then put on the string S to break the shear pin 50 and the string S is moved upwardly to draw the sleeve 52 upwardly from the plug X'. This allows the spring fingers 48 to engage in the casing coupling. The packer 15 is then set or actuated at a point above the leak in the well casing and cement slurry under pressure is pumped down the string. The plug X' set in the casing below the leak prevents the cement slurry from flowing down the casing and the plug X' and the packer 15 closing off the casing below and above the leak oblige the cement slurry under pressure to pass out through the leak. The cement slurry thus discharged into the well at the leak closes or seals the leak. Following the delivery of the cement slurry the packer 15 is released and the string S is withdrawn from the well. The plug X' is then removed from the well, for example, it may be drilled up by a well drilling tool. From the above it will be apparent that the method and apparatus are useful in installing a single plug and in "spotting" cement slurry at any selected point in a well.

Having described only a typical preferred manner of carrying out the method and a typical form of apparatus of the invention, I do not wish to be limited to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims:

Having described my invention, I claim:

1. Apparatus of the character described com-

prising an elongate tubular object to be installed in a well and having a plurality of longitudinally spaced ported parts, a bridging plug for each of said parts having means for locking in the same, a tubular well string for conducting fluid into the well and adapted to be entered into said object and means on the string for simultaneously carrying the several bridging plugs to be successively locked in their respective ported parts as the string is moved in the well.

2. Apparatus of the character described comprising an elongate tubular object to be installed in a well and having a plurality of longitudinally spaced ported parts, a bridging plug for each of said parts having means for locking in the same, a tubular well string for conducting fluid into the well, means for detachably securing the plugs to the string to be run into the well thereon and to be successively locked in their respective ported parts as the string is moved upwardly in said object, and a packer on the string above the last named means for sealing with the interior of said object.

3. Apparatus of the character described comprising an elongate tubular object to be installed in a well and having a plurality of longitudinally spaced ported parts, a bridging plug for each of said parts having means for locking in the same, a tubular well string for conducting fluid into the well, means on the string for supporting the plugs on the string for detachment therefrom when the locking means are made operative and supporting the plugs in the order to be successively locked in their respective parts when the string is moved upwardly in said object, and a releasable packer on the string above the last named means operable by manipulation of the string to seal with the interior of said object and releasable by manipulation of the string.

4. In apparatus of the character described, a tubular object to be installed in a well, said object having a series of longitudinally spaced internal grooves, said grooves being graduated in width from one end of the series to the other, a plurality of plugs for installation in said object, there being a plug for installation in the object at each groove, a tubular well string for simultaneously moving the plugs in the object and adapted to conduct fluid into the well, and a lock means on each plug for engaging with its respective groove, the lock means of the plurality of plugs being graduated in size so that the plugs are successively locked at their respective grooves upon movement of the string in one direction in the object.

5. In apparatus of the character described, a tubular object to be installed in a well, said object having a series of longitudinally spaced internal grooves, said grooves being graduated in width from one end of the series to the other, a plurality of plugs for installation in said object, there being a plug for installation in the object at each groove, a lock means on each plug for engaging in its respective groove to secure the plug in the object, a tubular well string to be run into the object and adapted to conduct fluid into the well, and means securing the plugs to the string releasable by manipulation of the string when the plugs are secured in the object, the lock means of the series of plugs being graduated in size and the plugs being arranged in order on the string so that the plugs may be successively locked at their respective grooves by longitudinal movement of the string in one direction.

6. In apparatus of the character described, a tubular object to be installed in a well, said object having a series of longitudinally spaced internal grooves, said grooves being graduated in width from one end of the series to the other, a tubular well string adapted to conduct fluid into the well, a plurality of plugs for installation in said object, there being a plug for installation in the object at each groove, a lock means on each plug engaging in its respective groove to secure the plug in the object, sealing parts on the plugs for sealing with the interior of the object, means for securing the plugs to the string releasable by manipulation of the string when the plugs are locked at their respective grooves, and a cage on the string for housing the plugs to protect their sealing parts, the lock means of the plugs being graduated in size and the plugs being arranged in order on the string so that the plugs may be successively locked at their respective grooves by longitudinal movement of the string in the object.

7. In apparatus of the character described, a tubular object to be installed in a well, said object having a series of longitudinally spaced internal grooves, said grooves being graduated in width from one end of the series to the other, a tubular well string adapted to conduct fluid into the well, a plurality of plugs for installation in said object, there being a plug for installation in the object at each groove, a lock means on each plug engaging in its respective groove to secure the plug in the object, sealing parts on the plugs for sealing with the interior of the object, means for securing the plugs to the string releasable by manipulation of the string when the plugs are locked at their respective grooves, a cage on the string for housing the plugs to protect their sealing parts, the lock means of the plugs being graduated in size and the plugs being arranged in order on the string so that the plugs may be successively locked at their respective grooves by longitudinal movement of the string in the object, and means on the string above the cage for sealing with the interior of the object.

8. Apparatus of the character described for use in a tubular object in a well having spaced shoulders and a port, the apparatus comprising a tubular well string for conducting fluid into the well, a plug for the object, lock means on the plug for cooperating with the shoulders to lock the plug in the object, means attaching the plug to the string at a point above the lower end of the string, so that the plug may be run into the object on the string and fluid may be passed down the string to discharge into the well below the plug and so that the plug may thereafter be raised by the string to have its lock means cooperate with the shoulders, the last named means being releasable by manipulation of the string following such locking so that the string may be raised through the locked plug to bring the lower end of the string to a point above the plug, and a packer on the string operable to seal with the interior of the object above the plug whereby fluid passed down the string to discharge therefrom above the plug to flow from said port cannot flow upwardly in said object.

9. Apparatus of the character described for use in a tubular object in a well having spaced shoulders and a port, the apparatus comprising a tubular well string for conducting fluids into the well, a plug for the object, lock means on the plug for cooperating with the shoulders to

lock the plug in the object, the lock means including a resiliently mounted lock part for engaging one of said shoulders, means attaching the plug to the string at a point above the lower end of the string, so that the plug may be run into the object on the string and fluid may be passed down the string to discharge into the well below the plug and so that the plug may thereafter be raised by the string to have its lock means cooperate with the shoulders, the last named means being releasable by manipulation of the string following such locking so that the string may be raised through the locked plug to bring the lower end of the string to a point above the plug, and a packer on the string operable to seal with the interior of the object above the plug whereby fluid passed down the string to discharge therefrom adjacent the plug to flow from said port cannot flow upwardly in said object.

10. Apparatus of the character described for use in a tubular object in a well having spaced shoulders and a port, the apparatus comprising a tubular well string, a plug for the object, lock means on the plug for cooperating with the shoulders to lock the plug in the object, the lock means comprising a lock part on the plug for engaging upwardly against one shoulder and a lock part for engaging downwardly against the other shoulder, means attaching the plug to the string at a point above the lower end of the string, so that the plug may be run into the object on the string and fluid may be passed down the string to discharge into the well below the plug and so that the plug may thereafter be raised by the string to have its lock means cooperate with the shoulders, the last named means being releasable by manipulation of the string following such locking so that the string may be raised through the locked plug to bring the lower end of the string to a point above the plug, and a packer on the string operable to seal with the interior of the object above the plug whereby fluid passed down the string to discharge therefrom above the plug to flow from said port cannot flow upwardly in said object.

11. Apparatus of the character described for use in a tubular object in a well having spaced shoulders and a port, the apparatus comprising a tubular well string for conducting fluid into the well, a plug for the object, lock means on the plug for cooperating with the shoulders to lock the plug in the object, the lock means comprising parts engaging upwardly and downwardly against said shoulders, sealing means on the plug for sealing with the interior of the object, means for securing the plug to the string and designed to release under an upward strain when said upwardly engaging part is in cooperation with its shoulder, and means for holding the

downwardly engaging part retracted and releasable from the same upon disengagement of the string from the plug.

12. Apparatus of the character described for use in a tubular object in a well having spaced shoulders and a port, the apparatus comprising a tubular well string for conducting fluid into the well, a plug for the object, lock means on the plug for cooperating with the shoulders to lock the plug in the object, the lock means comprising parts engaging upwardly and downwardly against said shoulders, sealing means on the plug for sealing with the interior of the object, means for securing the plug to the string and designed to release under an upward strain when said upwardly engaging part is in cooperation with its shoulder, and means for holding the downwardly engaging part retracted and releasable from the same upon disengagement of the string from the plug, the last named means comprising a cage housing the plug.

13. In apparatus of the character described, a tubular object adapted for installation in a well, a shouldered part on the object, a tubular well string for conducting fluid into the well, a bridging plug for closing said object, means on the plug for locking with said shouldered part to lock the plug in the object, and releasable means attaching the plug to the string at a point above the lower end of the string so that the string may be employed to lower the plug through the object to a point below said part and then used to conduct fluid downwardly for discharge into the object below the plug, and so that the string may thereafter be raised to cause the first named means to lock the plug in said shouldered part and release the releasable means whereby the string may be withdrawn upwardly through the plug to discharge fluid above the plug.

14. In apparatus of the character described, a tubular object adapted for installation in a well, a shouldered and ported part on the object, a bridging plug for closing said object, means on the plug for locking with the shouldered part, a tubular well string adapted to be lowered into said object, releasable means for securing the plug to the string at a point above the lower end of the string so that the string may be employed to run the plug into said object to have its lock means lock with the shouldered part, the last named means being releasable following said locking so that the string may be withdrawn upwardly through the plug, and a packer on the string for sealing with the interior of said object above said part whereby fluid may be passed down the string to discharge from the string above the plug and pass out through the port of said part.

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