This invention relates to new and useful improvements in methods and apparatus for testing well casing or pipe. It is an object of this invention to provide a new and improved apparatus and method for testing well pipe, and particularly well casing, for leaks while such pipe or casing is in a well bore and prior to cementing the pipe or casing in the well bore.

An important object of this invention is to provide a new and improved method and apparatus for temporarily closing off the lower end of a well casing or pipe string to permit the application of fluid pressure internally of the casing or pipe string to test same for leaks, and for there after opening the lower end of the casing to force cement therethrough in a cementing operation.

Another object of this invention is to provide a new and improved apparatus which is adapted to close or seal off the lower end of a well casing or pipe string in a well bore for testing the casing or pipe string for leaks but which is retrievable thereafter for opening the lower end of the well casing or pipe string.

A further object of this invention is to provide a sealing plug which is adapted to be dropped into a well casing or pipe string from the top of the well for sealing such plug at the lower end of the casing or pipe string to effect a closing of such lower end, such plug being retrievable from the casing or pipe string with an overshot or similar device lowered on a wire line or similar flexible support.

A particular object of this invention is to provide a sealing plug or closure which is adapted to be removed seated in a pipe for closing fluid flow therethrough and which has means therefor for establishing fluid communication through the plug or closure to equalize fluid pressure on each side thereof prior to removing the plug from its seated position.

Still a further object of this invention is to provide an apparatus for temporarily plugging the bottom of a casing string without interfering with the operation of float apparatus, cementing operations, and the like, wherein such apparatus is constructed from a minimum of parts which are relatively low in cost, and wherein the components of the apparatus which are attached to the casing are formed of drillable materials.

The preferred embodiment of this invention will be described hereinafter, together with other features thereof, and additional objects will become evident from such description.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein an example of the invention is shown, and wherein:

FIGS. 1-4 are schematic views illustrating the basic steps of the method of this invention, with FIG. 1 illustrating the circulation of drilling mud with the well casing on the bottom of the well bore, with FIG. 2 illustrating the sealing off of the lower end of the casing with a closure plug and the pressure testing of the casing to determine whether or not any leaks are present in the casing, with FIG. 3 illustrating removal of the closure plug from the casing after the test, and with FIG. 4 illustrating the conducting of well operations such as the cementing of the casing after the casing has been tested.

FIG. 5 is a view, partly in elevation and partly in section, illustrating the apparatus of this invention which is used in carrying out the method of this invention; FIG. 6 is a horizontal sectional view taken on lines 6-8 of FIG. 5; and FIG. 7 is a horizontal sectional view taken on lines 7-7 of FIG. 5.

In FIGS. 1-4 of the drawings, the method of this invention is schematically illustrated with respect to the above stated basic steps. Briefly, in carrying out the method of this invention, a well casing or pipe C is positioned in a well bore W. The lower end of the casing C will normally carry a conventional cement shoe or float F or other similar device, and above the cement shoe or float F, an annular seat S is mounted in the casing C. In order to test the casing C for leaks prior to the pumping of cement into the casing C for cementing the casing C in the well bore W, a closure plug P is dropped in the casing C so that it falls by gravity and automatically positions itself in the annular seat S for closing off fluid flow or communication through the lower end of the casing C. Fluid under pressure is then applied internally of the casing C above the closure plug P, and if any leaks are present, such leaks will be evident by a drop in the pressure on the pressure gauge G of any known construction at the surface of the well. If faulty casing is thus discovered, the casing C is removed and the faulty section of the casing C is replaced or repaired. However, if the casing C is not defective, then the closure plug P is removed (FIG. 3) by means of a conventional grapple tool T or overshot which is lowered on a wire line L or other flexible support. Thereafter, the usual well operations such as the cementing operations are conducted.

The apparatus for use in carrying out the method of this invention is illustrated in particular in FIGS. 5-7. Although the particular type of cement shoe or float F which is used in conjunction with the casing C forms no part of this invention, one type of cement float is illustrated in FIG. 5 for illustrative purposes. Such float F includes a cylinder 19 of a drillable material such as concrete which is formed with a bore 10a through its upper portion and an enlarged bore 10b at its lower portion. A ball valve 11 is positioned in the enlarged bore portion 10b and it is in engagement with the lower edge of the bore 10a to close same. A spring 12 or other resilient means is used for maintaining the ball 11 in its seated position. A removable nut or retainer ring 14 holds the spring 12 in position within the enlarged bore portion 10b. Thus, the ball 11 acts as a one-way valve to prevent fluid from entering the lower end of the casing C but permitting the discharge of cement or other liquid from the interior of the casing C.

The seat S, which forms a part of the apparatus of this invention, is annular in shape and it is formed with a longitudinal passage or opening 15 which is provided with an annular shoulder 15a therein. The upper end 15b of the passage or opening 15 is funnel-shaped so as to form an annular downwardly inclined surface for directing the closure plug P into the opening 15 for closing the same, as will be more evident hereinafter.

The annular seat S is secured in position near the lower end of the casing C with an annular external flange 16 between an annular seal ring 17 and another annular seal ring 18. The ring 17 is preferably an O-ring formed of rubber or other resilient flexible material which is confined below the annular flange 16 in contact with the upper portion of the sleeve or cylinder 10 of the float F to form a seal therewith. The ring 18 is normally a flat ring formed of rubber or other flexible material and it is preferably confined below the lower annular edge 19 of a section of the casing C adjacent thereto for maintaining
the seal 18 in sealing contact with the casing C and the flange 16 so as to also provide a fluid tight seal with the seat S and to hold the seat S in position in the lower end of the casing C.

The closure plug P is formed with an elongate body that includes an upper body section 20 and a lower body section 21. Such body sections 20 and 21 are maintained together, as will be more evident hereinafter, during normal use, but they are adapted to move relative to each other for controlling fluid flow through the body, as will be explained. The upper end of the upper body section 20 is formed with a fishing neck 22 of known shape and construction so that the plug P may be engaged by an over-shot or known grappling device lowered on a wire line or other flexible line L (FIG. 3). The overshoot or grappling tool T illustrated schematically in FIG. 3 of the drawings may be of any type capable of being lowered on the flexible line L for engagement with the fishing neck 22 and for subsequent retrieving of the plug P from the casing C.

The upper body section 20 includes a plurality of radially or laterally extending centralizing fingers 25 which are preferably formed of rubber or other flexible material. Such centralizing fingers 25 are positioned as best seen in FIGS. 5 and 6, at different radial positions so that there is contact with the inside of the casing C at substantially equally spaced points on the inside of the casing C. As shown in FIG. 6, each centralizing finger 25 is secured to the central upper body section 20, and preferably extends therethrough to form a projection or finger on each side of the body 20. However, it will be appreciated that various means for attaching the centralizing fingers 25, and various forms thereof, may be used within the scope of this invention. In fact, other centralizing means may be used in place of the fingers 25, as will be understood by those skilled in the art, to maintain the plug P in a substantially central position in the casing C as it is dropped or lowered in the casing C to the position shown in FIG. 5.

A valve 26 is connected to the lower end of the upper body section 20 (FIG. 5) by any suitable means such as the threads 26c, or the valve 25 may be formed integrally with the upper body section 20. The valve 26 is reduced in cross-sectional area as compared to the cross-sectional area of the upper body section 20 so as to leave the annular end 2a of the upper body section 20 exposed for providing a shoulder. The valve 26 is formed at its lower end with a conical head 26a and a shoulder 26b, and a spring 27 or other resilient means, the purpose of which will be explained hereinafter, is preferably positioned on the shoulder 26b and around the stem of the valve 26.

The lower body section 21 is provided with a longitudinal opening 21a which extends from the lower end of the lower body section 21 upwardly to an enlarged diametrical opening or chamber 21b. A tapered or conical seat 21c is formed at the upper end of the passage 21a and below the enlarged diameter portion or chamber 21b. A seal ring formed of rubber or other flexible material such as an O-ring 20 is positioned on the conical seat 21c to provide a resilient seating surface for the conical head 26a of the valve 25, as will be explained. One or more lateral ports 21d are provided in the lower body section 21 for establishing fluid communication from the area externally of the body of the plug P to the longitudinal passage 21a. The lateral port or ports 21d and the longitudinal passage 21a thus provide a by-pass opening or passage through the plug P.

The upper end of the lower body section 21 is provided with an internal bore 21e through which the stem of the valve 26 extends. Such bore 21e is of a smaller diameter than the diameter of the chamber 21b so as to provide an annular shoulder 21f on the upper end of the chamber 21b for engagement by the resilient spring 27.

Thus, the spring 27 is confined between the shoulder 21f and the shoulder 26b on the valve 26, and such spring 27 is maintained under compression so as to constantly urge the valve head 26a into seating and sealing engagement with the resilient flexible seal ring 30 for thereby closing the passage of fluid through the longitudinal passage 21a in a downward direction. When it is desired to open the passage 21a for by-passing fluid from one or more of the ports 21d through the passage 21a, the upper body section 20 is moved upwardly and away from the lower body section 21 in opposition to closing the spring 27. Such movement moves the head 26a of the valve 25 away from the seat 30 and permits the fluid communication between the ports or ports 21d and the opening 21a.

The plug P, when in the seated position as shown in FIG. 5 of the drawings, is thus maintained in a position with the by-pass opening closed by reason of the action of the spring 27 maintaining the head 26a in seating and sealing contact with the ring 30. The lower end of the lower body section 21 is provided with an annular seal ring 35 such as an O-ring formed of rubber or other flexible material for sealing engagement with the wall of the bore or opening 15. Such ring 35 maintains such seating contact with the opening 15 when the plug P rests in its seated position with the lower end of the lower body section 21 upon the annular shoulder 15a of the annular seat S. Therefore, when the plug P is in its seated position with its lower end in the annular seat S, fluid flow is prevented from passing around the exterior of the plug P to the area below the plug P, and that closes the lower end of the casing C.

The operation or use of the apparatus of this invention is believed evident from the previous description of the method of this invention, but referring specifically to the operation of the apparatus disclosed in FIGS. 5–7 of the drawings, such operation or use involves first the positioning of the annular seat S in the secured or mounted position at the lower end of the casing C, normally above a cement shoe or float P of any known construction. Thereafter, the casing C with the annular seat S in position is lowered into the well bore W and during such lowering, mud circulation is maintained as desired. This is illustrated in particular in FIG. 1 of the drawings to show the positioning of the casing C ultimately at the bottom of the well bore C. However, in carrying out the method of this invention, and using the apparatus of this invention, the sections of casing C may be tested, section-by-section rather than testing the entire casing string at one time.

In any event, when it is desired to test the casing C, the closure plug P is dropped in the casing C and it falls by gravity therein. The centralizing fingers 25 maintain the body of the plug P in substantially the central portion of the casing C as it is dropped or lowered. Therefore, when the lower end of the plug P reaches the annular seat S, the lower end thereof is sufficiently aligned with the annular seat S to be guided into the opening 15 of the seat S by the funnel-shaped or conical inclined surface 15b. There is therefore an automatic positioning of the closure plug P in the annular seat S, and when the sealing surface or ring 35 engages with the wall of the opening 15, the opening 15 is closed so that further downward fluid flow through the opening 15 is prevented. It will be appreciated that the spring 27 maintains the valve head 26a in the seated position in contact with the seal ring 30 and therefore prevents any flow through the by-pass opening provided by the port or ports 21d and the longitudinal passage 21a.

With the closure plug P in its position closing the opening 15 of the annular seat S, fluid under pressure is admitted into the casing C above the closure plug P and the amount of the pressure is indicated by the gauge G as schematically shown in FIG. 2 of the drawings. The usual well head equipment will of course be used and
such has not been illustrated in FIG. 2, except schematically. If the casing C is free from leaks, the gauge pressure will remain at a fixed value and the operator at the surface of the well will know that the casing C is satisfactory. However, if the casing C does have a leak, the gauge pressure P will fall off indicating that some of the fluid pressure is being lost through an opening or defective joint between sections of the casing. If such occurs, the plug P must be removed to prevent the lifting of the casing C with the fluid therein. Therefore, the retrieving or grappling tool T is lowered on the wire line L as schematically illustrated in FIG. 3 and it automatically engages the fishing neck 22 of the plug P. Upon initial engagement with the fishing neck 22, the upper body section 20 is moved upwardly, but normally in view of the greater fluid pressure within the casing C as compared to the fluid pressure externally of the casing C, the lower body section 21 remains in its seated position so that there is a movement of the body section 20 away from the body section 21. Such movement also causes a movement of the valve 25 upwardly with respect to the lower body section 21 and therefore an unseating of the valve head 26 from the annular flexible seal ring 30. Such movement of the valve 25 opens the by-pass flow through one or more of the openings 21d and into the chamber 21f and then through the longitudinal passage 21e. Such by-pass flow permits an equalization of the fluid pressure above and below the plug P so that there is no resistance to the movement of the plug P upwardly thereafter.

The plug P may then be readily moved upwardly by raising the flexible line or wire line L upwardly with known equipment at the surface of the well. With the plug P removed from the annular seat S, the fluid within the casing C is permitted to flow downwardly and out of the casing C is permitted to flow downwardly and out of the casing C into the annular flexible seal ring 30. Such flow is controlled by the operation of the cement shoe or float F. In the form of the invention illustrated, the amount of the fluid which will be discharged from the casing C will depend upon the strength of the spring 12, but it will be understood that other known types of cement shoes or float controls are provided for controlling the amount of the fluid within the casing C as desired. In any event, the casing C is withdrawn from the well bore W and the defective casing section is repaired or replaced. Then, the casing string is returned to the well bore W and again the plug P is dropped into position such as shown in FIG. 2 of the drawings and the casing C is again tested with fluid pressure. If the casing C is then satisfactory, the plug P is again removed, subsequent to the equalization of the pressure above and below the plug, as explained, and thereafter the usual well head equipment is placed above the casing C as schematically shown in FIG. 4. Cementing operations, or any other well operations which are normally performed, may then be carried out as schematically shown in FIG. 4 to cement the casing C in position or to do whatever is desired by way of well operations. In this connection, it should be pointed out that the annular seat S and all of the parts connected therewith are formed of a material which is capable of being drilled out of the lower end of the casing C with the usual drill bits. Therefore, the material of the annular seat S must be a drivable material such as a soft metal, such as brass, or a synthetic resin or plastic material such as Bakelite. Normally, the cement shoe or float F is also formed of a drivable material so that the entire lower end of the casing C may be opened for subsequent operations there-through as desired.

When it is desired to test the casing, section by section, as the casing sections are added to the string, the procedure is the same as described above except that the plug P is dropped to close the lower end of the casing after only one or two casing sections are in the well bore. The casing section or sections are then pressure tested, and subsequently, after each additional section of casing is added, the fluid pressure is applied to the entire casing string. If a defect is indicated, it will thus be evident that the section of casing, or the joint between such section and the section therebelow, is defective. Therefore, it is unnecessary to remove the entire casing string to replace or repair the defective portion of the casing. Such procedure continues until the casing string has reached the bottom of the well bore so that the entire casing string in the well bore is thus tested prior to the cementing or other well operations.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and it is thus obvious to persons skilled in the art that various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. An apparatus for use in testing well casing in a well bore, comprising a drivable valve seat in said well casing, said valve seat having an annular portion in contact with the inside of the well casing and substantially entirely removable therefrom by drilling, a closure plug comprising an elongate body composed of an upper body section and a lower body section movably longitudinally relative to each other, said upper body section constituting the upper end of said elongate body and having a fishing neck at the top thereof, said lower body section having a closure seating surface exteriorly thereof and a by-pass opening internally thereof for by-passing fluid flowing said seating surface, a plurality of laterally extending centralizer elements mounted on said upper body for guiding said plug as it falls by gravity in the well casing to seat said closure seating surface on said valve seat, said upper body section having a valve connected therewith which is adapted to extend into said by-pass opening to close same, resilient means for urging said valve into the closed position in said by-pass opening, and means on said upper body section and said lower body section for preventing separation thereof for moving same upwardly relative to the lower body section in opposition to the urging of said resilient means to move said valve upwardly for opening said by-pass opening and for thereafter unseating the closure seating surface from said valve seat.

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