

April 28, 1959

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2,884,074

DEEP WELL CASING ORIFICE AND CHECK VALVE

Filed June 17, 1953

2 Sheets-Sheet 1

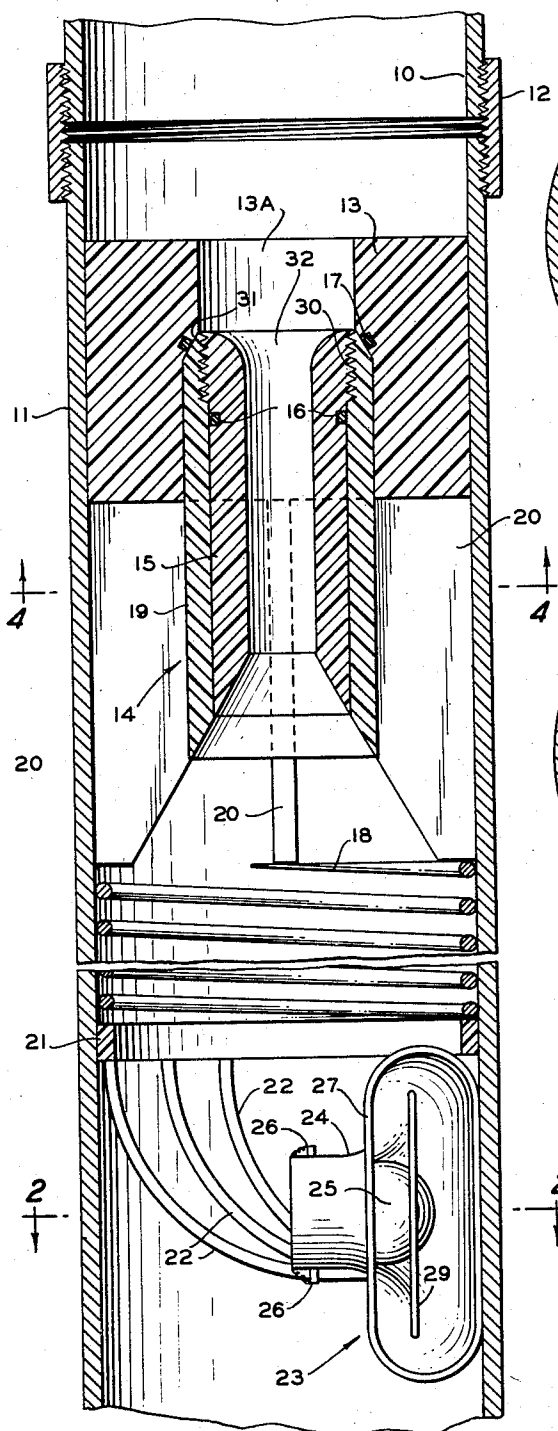


FIG. 1

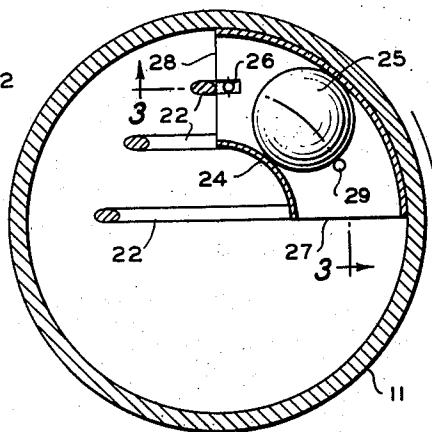


FIG. 2

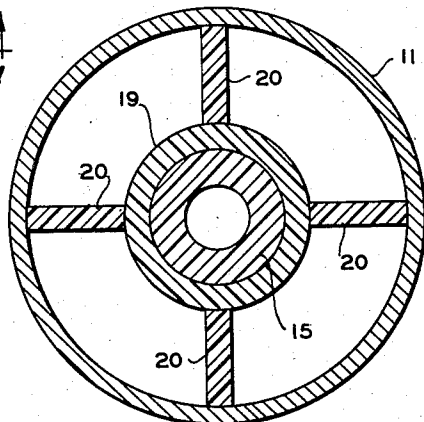


FIG. 4

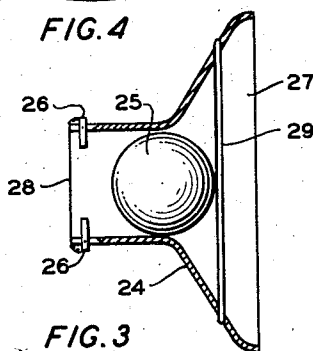


FIG. 3

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2 Sheets-Sheet 2

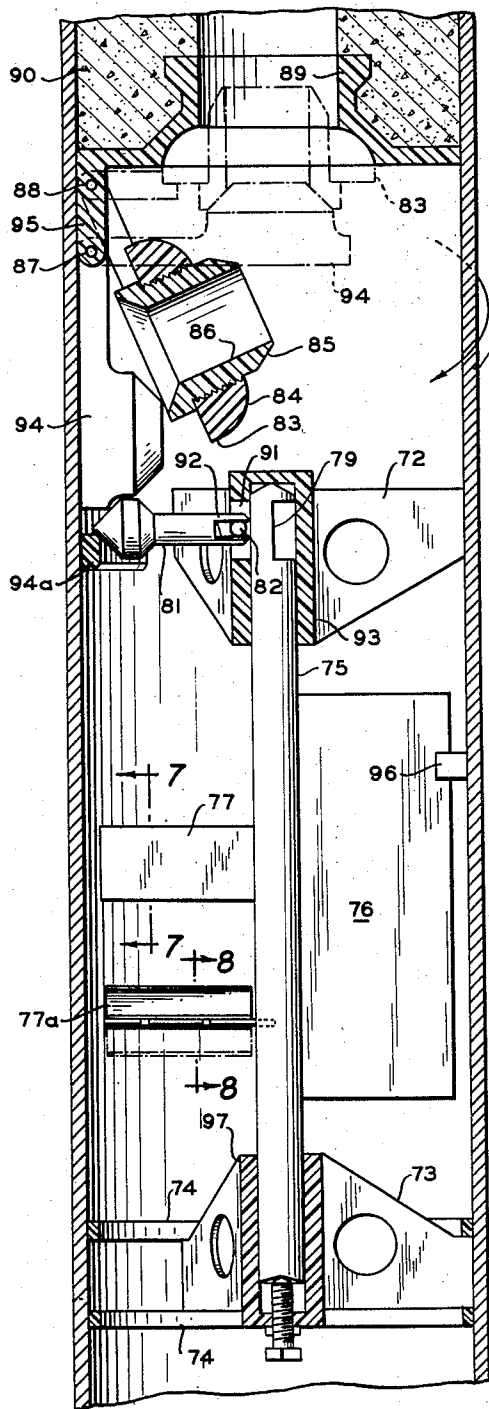


FIG. 6

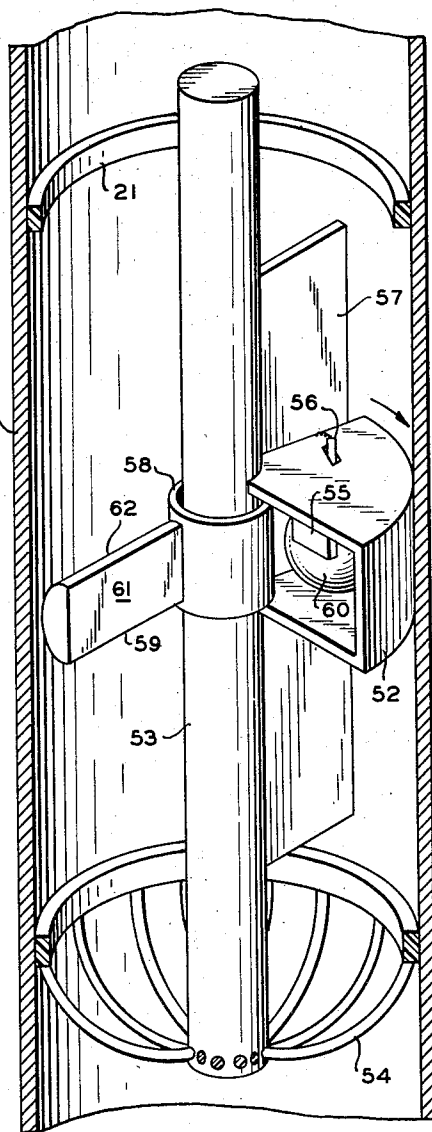


FIG. 5



FIG. 7

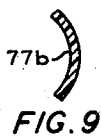


FIG. 9

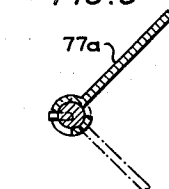


FIG. 8

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2,884,074

DEEP WELL CASING ORIFICE AND CHECK VALVE

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Application June 17, 1953, Serial No. 362,265

22 Claims. (Cl. 166—224)

This invention relates to a check valve type insertable orifice for use with deep well casing. In one aspect it relates to a check valve type insertable orifice for use in running and in cementing deep well casings. In another aspect it relates to a check valve type insertable orifice for use in conjunction with deep well casing wherein downward flow of well fluid and/or cement is substantially unobstructed while upward flow of fluid is restricted or completely shut-off.

According to our invention we provide a deep well casing bottom fill and check valve assembly in the form of a casing shoe or collar in which a spring loaded insertable orifice provides control of flow of drilling fluid into a casing being run while a check valve is provided to seat against the insertable orifice to check upward drilling fluid flow after the casing is bottomed and to check back flow of cement during cementing operations. The insertable orifice is unseated against the bias of its spring by downflowing drilling fluid for free fluid circulation. The check valve, in the form of a valve ball, or spring loaded hinged flapper, is locked in an inoperative position before the assembly is run into the well and is rendered operative for seating by rotation of the casing.

Usually the casing cannot be run completely open, since, when the casing is nearly as large as the hole, i.e., the annulus between the casing and the walls of the well is small in comparison to the cross section of the casing, the displaced drilling fluid will flow up through the casing and overflow on the drilling rig floor.

According to our invention we have devised embodiments of check valves for use in conjunction with mud flow constrictors which can be placed into operation merely by rotating the casing.

An object of our invention is to provide a casing bottom fill and check valve assembly for use in conjunction with deep well casing.

Another object of our invention is to provide a casing bottom fill and check valve assembly for use with deep well casings which valve can be placed into operation without having to pull the casing and without need of separate actuating tubing, cables or other devices.

Yet another object of our invention is to devise such a casing bottom fill and check valve assembly which is relatively simple and easy to manufacture.

Still other objects and advantages of our invention will be obvious to those skilled in the art upon reading the following specification and drawing, which respectively describes and illustrates preferred embodiments of our invention.

In the drawing Figure 1 is an elevational view, partly in section of one embodiment of our invention.

Figure 2 is a cross-sectional view taken on the line 2—2 of Figure 1.

Figure 3 is an elevational sectional view, of a portion of my apparatus taken on the line 3—3 of Figure 2.

Figure 4 is a cross sectional view taken on the line 4—4 of Figure 1.

Figure 5 is a sectional elevational view, in perspective, of another embodiment of our invention.

Figure 6 is a longitudinal view, partly in section, of another embodiment of our invention.

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Figure 7 is a sectional view of a portion of the apparatus of Figure 6 taken on the line 7—7.

Figure 8 is a sectional view of a portion of the apparatus of Figure 6 taken on the line 8—8.

Figure 9 is a sectional view of another embodiment of sweep arm.

Referring now to the drawing and specifically to Figure 1 reference numeral 11 is intended to identify a casing collar, a casing nipple or a casing shoe. As will hereinafter be indicated this apparatus element will be termed a casing nipple but it is to be understood that it is a nipple, collar or shoe. The nipple 11 is threaded and attached by element 12 to the lower end of the section of well casing 10. Inserted and rigidly affixed to the inner wall of nipple 11 at a point near its top is an annular seat member 13. This member 13 has a conduit 13A disposed axially throughout its length. The upper portion of this conduit is of smaller diameter than the lower portion, the two sections being connected by a beveled section 31 which is intended to serve as a seat for an adapter member 19. This beveled section may contain an O-ring sealing element 17 disposed as illustrated. The adapter element 19 is an annular element having one end beveled in such a manner as to seat against the seat 31 of the seating member 13. This adapter 19 is rigidly attached to guide members 20 which are fins for maintaining the adapter 19 centered with respect to the nipple. This adapter 19 is rigidly fastened to said guides and this assembly is identified in the drawing by reference numeral 14 and is termed an orifice adapter assembly.

Disposed within the adapter 19 is an insertable orifice member 15. It is preferable to attach the orifice member 15 to the adapter 19 by threads 30, as shown, for ease of assembly and disassembly. An O-ring 16 may be provided in the orifice member 15 for effecting a seal between the insertable orifice member 15 and the adapter 19. The lower end of this insertable orifice member 15 should preferably be beveled as is the lower end of the adapter 19 so that this combination of apparatus parts can serve as a seat for the ball of a ball check valve. A compression spring 18 is provided as shown resting upon spring stop 21 for biasing the orifice adapter assembly into a closed position with respect to the seating member 13. The spring 18, however, is not an especially strong spring but is designed specifically so that when drilling mud or other fluid is pumped downward in the nipple 11 the orifice adapter assembly will be moved downward against compression of the spring 18 to such an extent that the orifice adapter assembly clears the seating member 13 so that the down flowing fluid will be unobstructed in its downward flow. Spring 18, however, should be sufficiently strong that when the liquid ceases to be pumped downward in said nipple that the orifice adapter assembly is moved upward into its normal sealing relation with respect to seating member 13. The downward movement of this orifice adapter assembly 14 ordinarily takes place at such times as when this assembly is used in well casing cementing operations or when circulating and conditioning mud during or subsequent to casing running.

As stated above since there is a tendency for drilling mud to flow up a casing during casing running operations the use of such an insertable orifice assembly as the orifice adapter assembly 14 restricts the flow of mud from the hole into the casing to such an extent that the mud rises in the annulus outside the casing and the excess mud overflows from this annulus through a conduit provided to the mud pit rather than from the open end of the casing. In this manner mud is not overflowed from the top of the casing on to the drilling platform. The diameter of the orifice of the insertable orifice member 15 is so selected that the mud is permitted to flow through this orifice

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fice at such a rate as to maintain approximately a constant level of mud in the casing with respect to the surface of the ground. One advantage of my invention is that by use of the adapter element 19 I can insert an orifice member 15 of any desired predetermined diameter to control the flow of mud into the casing from the well at any desired rate.

When the casing running operation has been completed and it is desired to cement the casing to the bore hole cement is pumped into the top of the casing in a conventional manner. When the required amount of cement has been added a cementing follow plug is inserted into the casing and forced down the casing by pumping mud into the top of the casing. When this plug reaches the seating member 13 the cement has been forced through the apparatus in the nipple 11, that is, through the upper portion of the conduit 13A and through the orifice conduit 32 with the orifice adapter assembly moved downward against compression of spring 18 and under the bottom rim of the nipple to the annulus outside the nipple and casing.

The check valve of my apparatus may be operated to prevent back flow of cement from said annulus up through the nipple and into the casing. Apparatus 23 is a check valve ball holder. This element 23 comprises a shell or housing 24 which contains a valve ball 25. Upon reference to Figures 2 and 3 the construction and operation of this ball retainer may be seen. The housing member 24 is in general funnel shaped. The large diameter end 27, however, is not circular in cross-section but is elongated as may be seen in Figure 1. In this elongated section 27 is rigidly disposed a restraining pin or rod 29 to prevent the ball 25 from falling out the large diameter end. One or more spring loaded dogs or retainer pins 26 are provided in the small diameter and circular end 28 of housing 24. These retainer pins 26 are intended to prevent the ball 25 from inadvertently rolling out of the housing 24. The diameter of ball 25 is so selected that it serves as a valve when contacting the lower beveled ends of the insertable orifice member 15 and adapter 19 to close off the apparatus against upflow of fluid. When it is desired to place this check valve in operation it is merely necessary to rotate the well casing and nipple 11 in a clockwise direction when looking downward. This clockwise rotation tends to flow a relatively large volume of heavy mud into the flared or large diameter end 27 of housing 24 and force the ball from the housing through the small diameter end 28. When the ball is out of this housing it may rise upward through the fluid in the nipple 11 due to the difference between the density of the ball and the density of the liquid in the nipple, or in case the liquid is flowing upward in the nipple the ball will be carried upward to its seat against the orifice adapter 14 and shut-off all upward liquid flow. When this ball is placed in operation against its seat pressure from the surface of the ground need not be imparted to the drilling mud in the well casing to prevent back flow of cement into the nipple and up the casing. At points below the small diameter opening 28 of the housing 24 is provided a grating 22 to prevent the ball from moving downward in case the fluid in the nipple flows downward. It is preferred to make the ball 25 of such material that it will be specifically lighter than the cement slurry and mud so that it will tend to move upward when freed.

When this apparatus has been used in casing cementing operations, as just described, and it is desired to drill the well still deeper a problem exists in removing all of the apparatus within the nipple 11 so that the drill may be lowered to proceed with the drilling operation. In this case all or substantially all of the apparatus elements within the nipple 11 are constructed of material which can be removed easily by normal operation of the drill. That is, these apparatus parts should not be made of steel but are made of such plastic, resinous or polymer materials as Bakelite, or the like, or even metals such as

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those which can be easily drilled out by a conventional oil well drill. This material should be quite strong in nature to withstand pressures exerted during the use of the apparatus as a blow out preventer and in cementing operations, but yet should be of such a nature that it can be ground up by the drill and removed from the well in the normal process of mud circulation. When a well has been drilled deeper in a manner as just described and it is desired to run additional casing, a flow restrictor and check valve apparatus similar to that just described is used in running the new casing. Of course the diameter of the nipple containing the second orifice and check valve apparatus is smaller than the one used in the upper casing string. Any number of sizes of casing and sizes of orifice and check valve assemblies may be used as desired.

On reference to Figure 2 of the drawing the ball containing housing 24 may be clearly seen in relation to the wall of the nipple 11 and in order to release the ball the casing and nipple 11 are rotated clockwise (when looking downward), and in the direction indicated, and the ball exits from the housing 24 by way of the small diameter opening 28.

In Figure 5 of the drawing is illustrated another embodiment of valve ball containing and releasing mechanism. This apparatus is similar in general operation to that just described in relation to Figure 1. The mechanical construction, however, is quite different. The valve and orifice mechanism of this embodiment of my invention may be exactly like that described in relation to Figure 1.

The main difference between the embodiments of Figures 5 and 1 is in the valve ball holder and releasing mechanism. This ball holding and releasing assembly (Figure 5) comprises a cage member 52 which is rigidly attached to the inner wall of the nipple 11 in any manner desired. To the other end of this cage member 52 is rigidly attached a shaft 53. This shaft is disposed axially and should preferably be coincident with the central axis of the nipple 11. In one open side of the cage 52 is disposed a rigidly attached stop member 55 to prevent a ball 60 from rolling out of the cage inadvertently. On the opposite open side of the cage is disposed one or more spring loaded ball retainers 56 for preventing the ball from rolling out of the other side of the cage inadvertently. A paddle arm or baffle 57 having a relatively large surface is provided in close proximity to the side of the cage containing the spring loaded dogs 56. This paddle arm 57 is rigidly attached to a collar or ring 53 which in turn is attached to a sweep arm 59. The paddle 57 and the sweep arm 59 may be attached to collar 58 about 180° apart for balance, if desired. These elements may, however, be attached to the collar 58 in different relative angular positions. This assembly however, should be reasonably well balanced so that when collar 58 is intended to rotate with respect to the shaft 53 rotation will be free.

One important point of novelty of this embodiment of my apparatus is the shape or configuration of the sweep arm 59. The side of the sweep arm closest to the cage 52 is a plane side 61 and the plane is disposed vertically or substantially so. The side (61) nearest cage 52 works event better when convex, making the total configuration of sweep arm 59 that of a cylinder. The vertical dimension of this sweep arm 59 is sufficiently small that the sweep arm can enter the cage under the stationary ball retainer 55. The opposite side 62 of the sweep arm may appear to be generally cylindrically in shape, however, it may or may not be. It is preferred that this surface (side 62) should exert an airfoil type of action when fluid flows upward or downward in nipple 11. When fluid flows upward or downward in this apparatus this sweep arm 59 tends to rotate in a clockwise direction, when looking down on the assembly, and this tendency in rotation holds the paddle arm 57 against the open end of the cage 52 containing the spring loaded ball retainers

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56. In this manner the ball is easily and definitely retained in the cage 52 at all times when fluid is flowing through the well casing and the nipple. When it is desired to close the ball valve it is merely necessary to rotate the casing and nipple 11 in a clockwise direction, when looking downward. When the nipple rotates in this direction the cage 52 moves but the paddle arm 57 holds its assembly relatively stationary and does not rotate due to the combined inertia of the mud and the paddle and/or sweep arms. Upon continued rotation of nipple 11 in this clockwise direction the sweep arm 59 enters the cage 52 and pushes the ball 60 against the spring loaded ball retainers 56 which yield and allow the ball to exit from the cage. Due to the ball having a lower density than the fluid passing through the nipple the ball tends to rise upward and to become seated against the beveled seat of the orifice adapter assembly and to close off this apparatus against upward flow of fluid. The ball is preferably released while the casing can be rotated, i.e., before installing the cementing head on the casing. The ball may also be allowed to check the flow of fluid at such time as a blow out of mud is anticipated or occurring. A grating element 54 is provided as illustrated below the cage 52 to prevent the ball from passing downward in this apparatus. The apparatus parts of Figure 5 are made of material drillable by conventional drill bits so that drilling can be continued following cementing operations. Figure 7 is a sectional view of the sweep arm 77 of Figure 6.

The side of a sweep arm closest to cage 52 can be concave to make both sides of the sweep arm arcuate in shape, and the arm of more or less uniform thickness. See sweep arm 77b of Figure 9.

In Figure 6 a casing or nipple member 71 is in general similar to nipple 11 of Figures 4 and 1. In the lower portion of this nipple 71 is provided a pair of rings 74 mounted as illustrated to hold a spider element 73 immovable with respect to nipple 71. This spider element 73 holds rigidly a bearing 97 for supporting and guiding a cam shaft 75 as shown. The upper end of this cam shaft is held in proper position by a more or less similar bearing element 93 which is held immovable with respect to nipple 71 by spider 72. This upper cylindrical bearing element 93, however, differs from bearing 97 in that it has opening 91 in one side as shown. Within the opening 91 and attached to bearing 93 is a more or less rounded element 82 to serve as a guide for the yoke end of a cam rod 81. The cam rod 81 is intended to touch the circular surface of cam shaft 75 at a point near its top. When the shaft 75 is in the position illustrated in Figure 6, the cam rod 81 is at the left extremity of its movement. The left hand end of the cam rod rests on support 94a to bias valve 94 open. When the shaft 75 rotates, with respect to nipple 71, 180° from the position shown in Figure 6, the cam rod 81 is moved by the spring loaded hinged valve 94 from left to right and the yoke end 92 of the cam rod moves toward cam 79 and then the cam rod 81 drops, thereby releasing valve 94 to close. Element 94a can be a segment or portion of a ring fastened to the wall of nipple 71, or it may be integral with the wall. The cam 79, as shown, is substantially a slot in shaft 75 into which yoke 92 moves under certain conditions.

The upper end of the nipple 71 contains an annular member 90 more or less similar to member 13 of Figure 1, and this annular member is provided with a seat element 89, as shown. A flapper section choke element 83, hinged at 88, is intended to rotate upward to such an extent that a surface for example, spherical surface 84 contacts a corresponding surface of the seat member 89, to insert a choke orifice 86. The insertion of this choke orifice 86 is intended to restrict up flowing drilling mud from the well through the nipple 71 into the casing, not shown, in Figure 6. This hinged flapper choke body 83

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is preferably spring loaded at the hinge point 88 in such a manner that the flapper choke body 83 tends to be in a seated position at all times except during downflow of liquid through the nipple.

When it is desired to close off entirely the upflow of fluid through the nipple a hinged flapper float valve 94 is provided. This flapper float valve is preferably spring loaded and is attached to hinge arm 95 at the hinge point 87 in such a manner that the valve 94 tends to be biased in a closed position. Hinge arm 95 is integral with member 89 which in turn is held rigid with respect to the nipple 71.

This valve 94 is placed in an open position before this apparatus assembly is lowered into the well. To open the valve 94 and to hold it open the valve 94 is pulled downward off of its seat against the flapper choke body 83 against the bias of the spring hinge 87 and the lower end of the valve body 94 is placed between the cam rod 81 and the wall of the nipple 71. To hold the cam rod 81 in that position the cam shaft 75 is rotated to the position shown in Figure 6. In this manner the floating flapper valve 94 is substantially in a cocked position the trigger being actuated at such time as when the cam surface 79 of shaft 75 rotates 180° from its position shown in Figure 6. When this cam so rotates the spring of the spring loaded hinge 87 tends to rotate the flapper valve thereby pushing the cam rod 81 from left to right and releasing the flapper valve 94. After its release this valve rises upward due to its buoyancy in the fluid and/or due to the upward flowing fluid in the nipple and/or to the biasing effect of the spring loaded hinge 87.

Figure 8 is a cross sectional view of the hinged flapper 77a which may be used in conjunction with the sweep arm 77 or in place of the sweep arm.

Likewise, sweep arm element 77b, Figure 9, can be used in conjunction with the sweep arm 77 or flapper 77a, or in place of these.

When this valve check assembly is being lowered down a well containing drilling mud a hinged flapper element 77a operates to hold a paddle element 76, which is attached to cam shaft 75, against a stop member 96 rigidly disposed with respect to nipple 71 so that the cam shaft 75 will not rotate. When fluid flows upward the hinged flapper rises as indicated by the solid lines and when fluid flows downward the flapper drops to the position indicated by the broken lines both positions tending to rotate the paddle arm to hold it against stop 96 as illustrated in Figure 6.

When it is desired to close the flapper valve 94, it is merely necessary to rotate nipple 71, to which are rigidly attached spiders 72 and 73, in a clockwise direction when looking downward. This clockwise rotation moves the spiders 72 and 73, the bearings 93 and 97, the cam rod 81 and its support 94a also in a clockwise direction. Pin 82 moves with bearing 93. When the casing, the nipple 71, spiders 72 and 73, bearings 93 and 97, flapper valve 94 and the cam rod 81 have been rotated approximately 180°, the yoke end 92 of the cam rod 81 has also moved around the shaft 75 preparatory to entering the cam 79 in the upper end of the cam shaft 75. Following such rotation the spring loaded flapper valve 94 pushes cam rod 81 so that the yoke end 92 enters the cam, thereby releasing the flapper float valve 94. When this flapper float valve is thus released it rotates upward and seats against the choke orifice 86 of spring loaded hinged choke element 83 positioned as shown by the corresponding broken lines of Figure 6 to shut off upward flow of fluid.

During the above mentioned rotation of nipple 71 the drilling mud within nipple 71, the shaft 75 and the paddle or baffle 76 (also sweep arm 77 and hinged flapper 77a) do not rotate, or at least do not rotate as rapidly as the nipple 71.

For supporting the spring loaded hinge elements 87

and 88 a hinge arm 95 integral with the member 89 is provided as shown.

The taper surface 85 on the end of the choke element 86 is provided so that this choke element can be rotated upward without interference with any portion of the seat element 89. Seating element 89 is positioned as shown with respect to an annulus of drillable material 90, similar to the drillable annulus 13 of Figure 1.

As mentioned in relation to Figures 5 and 1, following a cementing operation, if it is desired to drill a well deeper after using this choke valve apparatus it is merely necessary to drill out all of the apparatus parts within the nipples 71 and 11. Thus apparatus elements 72, 73, 74, 75, 76, 77, 77a, 81, 82, 83, 86, 87, 88, 89, 90, 92, 93, 94, 94a, 95, 96, and 97 should be constructed of such material as can be drilled out by a conventional drilling bit. Such drillable material may be Bakelite or other resinous polymer copolymer or drillable metal. The material however, should be sufficiently strong to withstand casing running and cementing operations such as herein described.

One important advantage of the apparatus of my invention is that for example, in Figure 6 the choke element 86 may be made of any inside diameter desired. That is, the diameter of the opening through the choke element 86 may be relatively large to restrict flow of fluid slightly or this opening may be relatively small to restrict to a greater extent flow of liquid from the well into the nipple and casing.

The relatively large areas of the paddle arms 57 of Figure 5 and 76 of Figure 6 tend to hold the sweep arms 59 and 77, respectively, stationary while the casing is being rotated since rapid rotation of the casing tends to rotate the casing and the nipples around the column of mud, i.e., without rotating the mud. Also the mass inertia of the paddle and/or sweep arms resist rotation. In this manner the sweep arms and the paddles are held relatively immovable while the nipples rotate to release the valve ball or the flapper float valve to close off all upward fluid flow.

If, after a cementing job, it is desired not to drill the well deeper this check valve choke assembly may be allowed to remain in the well and the casing above the cemented section perforated in a conventional manner to permit flow of production fluid from a formation into the casing.

While one sweep arm has been shown in the apparatus of Figure 5 our invention should not be so limited since under some conditions it is advantageous to provide a second sweep arm. For example, where the velocity of the fluid flowing past the sweep arm is not very great a second sweep arm assists in making certain that the ball of Figure 5 is maintained in cage 52. This second sweep arm should preferably be positioned on the ring 58 at such a position that the two sweep arms and the baffle 57 will balance so that this sweep arm-baffle assembly will rotate with respect to shaft 53 with the least possible resistance.

One or more sweep arms 77b, similar to sweep arm 59, can be attached to shaft 75 of Figure 6 in place of the hinged flapper 77a as shown. The sweep arms should, obviously, be balanced and so disposed as to tend to rotate the baffle 76 to keep same against stop 96 as shown. A hinged flapper similar to flapper 77a or a sweep arm similar to arm 77b can be used in conjunction with or in place of arm 59 of Figure 5.

In the embodiment illustrated in Figure 5, the ball check valve is intended to operate upon first and rapid rotation of casing in the direction indicated by the arrow. However, upon interchanging positions of the stop 55 and the spring loaded dog 56, and interchanging positions of the sweep arm 59 and the baffle 57, and reversing sweep arm 59 the opposite operation is possible and is sometimes advantageous. By opposite operation, we mean the casing 11 and ball cage 52 are rotated in the direc-

tion indicated by the arrow for a number of revolutions and until it is reasonably certain that the fluid contents of the pipe 11 are rotating with the casing, and then suddenly ceasing rotation. Under this condition the fluid contents will continue to rotate and carry the baffle away from adjacent the end of the cage 52 having the spring loaded dog 56 and the sweep arm 59 will enter the back side of the cage and push out the valve ball. This operation might be more certain under some conditions other than that described hereinbefore when it is easier to stop rotation of the casing quickly than to start its rotation with rapid acceleration.

On reference to the embodiment of our invention illustrated in Figure 6, one or more sweep arms 77 may be used in conjunction with or in place of the hinged flapper 77a. Whether a hinged flapper 77a or one or more sweep arms 77 are used with baffle 76 or a large sweep arm in place of baffle 76, these elements should be positioned at such intervals around the circumference of shaft 75 that the shaft assembly is balanced so that it may rotate with a minimum possible resistance.

The embodiment illustrated in Figure 6 may also be modified so that the check valve 94 can be released from a rapidly rotating assembly by quickly stopping the rotation in a manner similar to that described above in relation to the apparatus of Figure 5. In the case of Figure 6, the stop 96 is positioned adjacent the back side of baffle 76 in place of adjacent the front side and hinged flapper 77a is reversed so that shaft 75 will tend to rotate anticlockwise. Tendencies of rotation anticlockwise will hold the baffle against the stop. Upon rotation of the casing under this condition the stop will rotate the baffle assembly which rotation will rotate the fluid contents of this mechanism. Upon quickly stopping this casing rotation the fluid will continue to rotate and the baffle will move in a clockwise direction and the valve release mechanism will function to release valve 94.

When handling the mechanisms of Figures 5 and 6 in the warehouse and prior to running in a well, one or more pins may be provided to prevent undesired rotation of the shaft 75 of Figure 6 and of collar 58 of Figure 5. Upon reference to Figure 6, a pin may be inserted in a threaded opening in the wall 71 at a point near stop 96 but on the side of baffle 76 opposite the stop 96. When a pin is inserted in this manner the baffle cannot rotate in either direction. When this assembly is assembled in a casing string the pin can be removed and a threaded plug inserted in the wall 71 to plug the hole left by removal of the pin. A similar threaded pin and plug may be employed in the apparatus of Figure 5 to prevent anticlockwise rotation of baffle 57 and premature release of the ball 60. The pin is removed and the opening plugged just prior to running into the well.

In the several embodiments of check valve ball release means, it is necessary to stop drilling fluid circulation prior to rotation of the casing to release the valve ball. As mentioned hereinbefore, the ball should be specifically lighter than the fluid in the orifice-valve assembly so that when the ball is released it will rise upward to its seat whether or not well fluid is entering the casing from the bottom.

To determine the diameter of the passageway 32 of Figure 1 and the inside diameter of the choke element 86 of Figure 6, a calculation involving several variables must be made. A sample calculation, illustrating the method of calculations which has been successful in field tests follows:

ρ =Drilling fluid density (lbs./gal.)=9.2
 T_y =Drilling fluid yield value (lbs./ft.²)=.0385
 r =Drilling fluid rigidity (lbs./ft. sec.)=.0097
 L =Depth of hole (ft.)=6942.
 V =Casing running speed (ft./sec.)=2.
 a =Average cross section of pipe (ft.²)=.068
 A =Average cross section of annulus (ft.²)=.392

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V_a —Equivalent fluid velocity in annulus (ft./sec.)
 (DAT)—Diameter of annulus between casing and hole (in.)=4.

D —Diameter of hole (in.)=11.

d_o —Outside diameter of pipe (in.)=7.

d_i —Inside diameter of pipe (in.)=6.06

g —Acceleration due to gravity (ft./sec.²)=32.2

$$V_a = V \frac{a}{A} + \frac{1}{2} = 2 \frac{.068}{.392} + .5 = 1.35$$

P_a —Pressure drop in annulus, lbs. per square in.

$$= \frac{LTy}{2.25(DAT)} + \frac{32rVaL}{g(DAT)^2} = \frac{6942(.0385)}{2.25(4)} + \frac{32(.0097)(1.35)(6942)}{32.2(4)^2} = 35.3$$

P_p —Pressure drop in pipe, lbs. per sq. in. = $\frac{LTy}{2.25di}$

$$+ \frac{32rVL}{g(di)^2} = \frac{6942(.0385)}{2.25(6.06)} + \frac{32(.0097)2(6942)}{32.2(6.06)^2} = 23.2$$

P_c —Pressure drop across choke, lbs. per sq. in. = $P_a - P_p$
 = 35.3—23.2=12.1

D_c —Diameter of choke, in. = $2\sqrt{\frac{Q}{\pi c}} \sqrt{\frac{16.76\rho}{P_c}}$

Q —quantity of fluid through choke (Ft.³/sec.)

$$= \frac{\pi}{576} D^2 V = \frac{\pi}{576} (6.06)^2 2 = .400$$

C —Discharge coefficient of choke=0.9

$$D_c = 2\sqrt{\frac{.400}{0.9(\pi)}} \sqrt{\frac{16.76 \times 9.2}{12.1}} = 2(.375)1.89 = 1.42 \text{ in.}$$

While certain embodiments of our invention have been described for illustrative purposes the invention obviously is not limited thereto.

We claim:

1. A deep well casing choke and check assembly comprising, in combination, a housing member having an axial conduit therethrough, means to attach said housing member to a well casing, an annular collar attached rigidly to the upper inner wall of said housing member, a taper section in the inner circumferential wall of said collar and facing downward, an annular orifice adapter, said orifice adapter being adapted to seat against said taper section, an annular removable orifice member threaded to said orifice adapter, a compression spring biasing said orifice adapter in a seated position with respect to said taper section, a valve ball, the lower end of said orifice member serving as a seat for said valve ball, retaining and releasing means for retaining said valve ball and for releasing same upon rotation of said elongated housing member, said valve ball retaining and releasing means comprising, in combination, a generally funnel shaped housing open at both ends and supported by the wall of said housing member, the axis of said generally funnel shape member being concentric with said housing member, a rod means attached to said generally funnel shape member at the large diameter end thereof to retain the valve ball in the small diameter end thereof, a hinged dog in the small diameter end of said generally funnel shaped member, said hinged dog being adapted to operate to permit exit of said valve ball upon rotation of said housing member in such a direction that fluid in said housing member enters said generally funnel shape housing through the large diameter end, said valve ball being adapted to rise and to seat against said orifice member to close same against upward flow of fluid therethrough and said orifice member and said orifice adapter being adapted to move downward against the bias of said spring under the influence of downward flow of fluid in said housing member.

2. A deep well casing choke and check valve assembly comprising, in combination, a housing member having

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an axial conduit therethrough, means to attach said housing member to a well casing, an annular collar attached rigidly to the upper inner wall of said housing member, said annular collar terminating in a lower plane surface and having a cylindrical conduit therethrough, the circle of juncture of said conduit and said plane surface being adapted to serve as a seat, a hinged orifice member, said hinged orifice member being adapted to rotate to and from said seat, said orifice member when seated providing for a restricted flow of fluid upward in said housing member, a rotatable check valve, said check valve being adapted to seat against said orifice member to check upward fluid flow therethrough, said orifice member being spring loaded to bias said orifice member against its seat, said rotatable check valve also being spring loaded to bias said check valve in closed relation with respect to said orifice member, said orifice member and said rotatable check valve being adapted to rotate away from their seats upon downward flow of fluid in said housing member, and means to hold said check valve in an unseated position in respect to said orifice member, said means comprising a cam shaft disposed axially in said housing member and having a cam slot, said shaft being held against axial movement by bearing support means, said shaft being rotatable with respect to said bearing support means, said bearing support means being rigidly supported by the wall of said housing member, a radially disposed cam rod having one end adjacent the cam slot end of said cam shaft and the other end being adapted to hold said check valve in an unseated position when the cam slot of said cam shaft is out of operation with respect to the cam end of said cam rod, an elongated flat paddle rigidly attached to said cam shaft, the longitudinal axis of said paddle being disposed axially with respect to said housing member and the other axis of said paddle being disposed radially with respect to said housing member, a sweep arm rigidly attached to said cam shaft, a stop element disposed rigidly on the inner wall of said elongated housing member intermediate the ends of said paddle in such a manner as to stop rotation of said cam shaft when said paddle touches said stop element, said sweep arm being so disposed with respect to said cam shaft as to rotate same in a clockwise direction and to maintain said paddle against said stop element under the influence of flow of fluid in said housing member, and upon rotation of said housing member and said cam rod, said cam rod rotates around said cam shaft to cooperate with the cam slot of said shaft to release said spring loaded valve to permit same to close against said orifice member under the bias of said spring of said valve closure element.

3. A deep well valve assembly comprising, in combination, a housing member, means to attach said housing member to a well casing, a valve seat supported by the inner wall of said housing member, a spring loaded hinged valve within and supported by said housing below said valve seat, said valve being adapted to seat fluid-tight against said valve seat, a cam shaft disposed axially in said housing member, a cam rod supported by said housing intermediate said cam shaft and said valve, said cam shaft engaging said rod against said valve thereby locking said valve in its open position, said housing member, said valve seat, said valve and said cam rod being adapted to rotate around said cam shaft, a cam slot in one side of said cam shaft at the level of said cam rod, said spring loaded valve being adapted to push one end of said cam rod into said cam slot upon rotation of said cam rod to the cam slot side of said cam shaft thereby releasing said valve for seating against said seat.

4. In subsurface apparatus for filling a conduit string with fluid in a well bore: a tubular member adapted to form part of the conduit string and having means thereon for attachment to an adjacent conduit string section; said tubular member having a valve seat thereon fixed with respect thereto and a valve member movable longi-

tudinally out of engagement from said seat and longitudinally into engagement with said seat to restrict upward flow of fluid through said seat; flow control means providing a restricted passage in said tubular member through which fluid can flow upwardly and by-pass said valve member when said valve member engages said seat; and valve means movable to a position across said restricted passage to close said restricted passage.

5. In the subsurface apparatus of claim 4, a cage supported by the inner wall of said tubular member and fixed thereto below said restricted passage, said valve means being a valve ball releasably supported within said cage, an axially disposed support member within and supported rotatably by said housing member below said restricted passage, an air foil sweep arm and a baffle member fixed to said support member, said sweep arm being adapted to enter said cage, said sweep arm also being adapted to rotate said baffle member to position same against said cage thereby maintaining said valve ball within said cage during flow of fluid through the assembly, said baffle member being adapted to rotate away from against said cage and to rotate said sweep arm into the side of said cage remote from said baffle member to free said valve ball from within said cage.

6. In the subsurface apparatus of claim 5, a spring biasing said movable valve member into engagement with said seat and said flow control means being insertable for ease of removal.

7. In the subsurface apparatus of claim 4, a cage supported by the inner wall of said tubular member and fixed thereto below said restricted passage, said valve means being a valve ball releasably supported within said cage, said cage being in general funnel shaped with one end having a greater cross sectional area than the other end, the axis of said cage being substantially horizontal, stop means in the greater cross sectional area end of said cage to retain said ball therein, said ball being of smaller diameter than the diameter of said other end of the cage, and said ball being adapted to move from said other end of the cage upon rotation of said tubular member around its axis in such a direction that the greater cross sectional area end of said cage is the leading end.

8. In the subsurface apparatus of claim 7, a spring biasing said movable valve member into engagement with said seat and said flow control means being insertable for ease of removal.

9. In the subsurface apparatus of claim 4, wherein said valve means is a ball valve.

10. In the subsurface apparatus of claim 4, wherein said valve means is a spring loaded flapper valve.

11. In subsurface apparatus for filling a conduit string with fluid in a well bore: a tubular member adapted to form part of the conduit string and having means thereon for attachment to an adjacent conduit string section; said tubular member having a valve seat thereon fixed with respect thereto and a valve member movable longitudinally out of engagement from said seat and longitudinally into engagement with said seat to restrict upward flow of fluid through said seat; flow control means providing a restricted passage in said tubular member through which fluid can flow upwardly and by-pass said valve member when said valve member engages said seat; and valve means movable upwardly into engagement with said flow control means to close said restricted passage.

12. In the subsurface apparatus of claim 11, wherein said valve means is a ball valve.

13. In the subsurface apparatus of claim 11, wherein said valve means is a spring loaded flapper valve.

14. In subsurface apparatus for filling a conduit string with fluid in a well bore: a tubular member adapted to form part of the conduit string and having means thereon for attachment to an adjacent conduit string section; said tubular member having a valve seat thereon and a

valve member movable longitudinally out of engagement from said seat and longitudinally into engagement with said seat to restrict upward flow of fluid through said seat; said valve member having a restricted passage therethrough through which fluid can flow upwardly in said tubular member; and valve means movable to a position across said restricted passage to close said restricted passage against upward flow of fluid there-through.

15. In the subsurface apparatus of claim 14, wherein said valve means is a ball valve.

16. In the subsurface apparatus of claim 14, wherein said valve means is a spring loaded flapper valve.

17. A deep well casing choke and check valve assembly comprising, in combination, a housing member, means to attach said housing member to a well casing, an annular collar fixed to the upper inner wall of said housing member, the lower end of said collar having a seat, a hinged orifice member supported by said housing member and being adapted to rotate to and from said seat, a hinged check valve, said valve being adapted to seat against said orifice member to check upward fluid flow, said orifice member and said check valve being adapted to rotate away from their seats upon downward flow of fluid through said housing member, and means to hold said check valve in an unseated position, said means comprising a rotatable cam shaft disposed axially in said housing member and having a cam slot, said shaft being supported rotatably and against axial movement by support bearings, said bearings being supported by said housing member, a radially disposed cam rod, one end of said cam rod bearing against said check valve to hold same in its open position, the other end of said cam rod being in contact with a cylindrical surface on one side of said cam shaft, a cam slot in said cam shaft on the side thereof opposite the point of contact of said cam rod with the surface of said cam shaft, a paddle attached longitudinally to said cam shaft, a lug fixed to the inner wall of said housing member, said lug being adapted to contact said paddle and stop its rotation, a sweep arm having one airfoil side and one plane side fixed to said cam shaft in such a manner as to bias said paddle against said lug upon flow of fluid through said housing member, and said cam rod being adapted to move along its axis away from said check valve upon rotation of said housing member, said check valve and said cam rod with respect to said cam shaft until said cam slot faces said cam rod thereby freeing said check valve.

18. A deep well casing choke and check valve assembly comprising, in combination, a housing member having an axial conduit therethrough, means to attach said housing member to a well casing, an annular collar attached rigidly to the upper inner wall of said housing member, a taper section facing downward in the inner circumferential wall of said collar, a movable orifice member in said conduit below said taper section, said taper section being adapted to serve as a seat for said orifice member and a spring biasing said orifice member against its seat to restrict upward flow of fluid and to permit unseating of said orifice member against the bias of said spring to allow free flow of fluid downwardly in said housing member, an annular valve seating surface being provided on the downward facing side of said orifice member, a valve check element and means to release said valve check element upon rotation of said housing member around its longitudinal axis, said valve check element comprising a valve ball and said means to release said valve check element comprising, in combination, a ball holding cage disposed circumferentially within and attached to said housing member and below said orifice member, both ends of said cage being open to circumferential flow of fluid, a stop element rigidly mounted in one end of said cage to retain the valve ball in said cage, an elongated, flat paddle adjacent the other end of said cage, said paddle having its longitudinal axis disposed axially with respect to said housing member and

its other axis substantially radially thereto, a sweep arm rigidly attached to said paddle, said sweep arm having one plane surface side and one side convex outward, one axis of said plane surface side being disposed axially with respect to the longitudinal axis of said housing member and the other axis being horizontal, said plane surface side of said sweep arm facing the stop element end of said cage, the axis of the convex outward side of said arm being approximately parallel to said other axis of said plane surface side, said paddle and said sweep arm being rotatable in a manner generally circumferentially with respect to said housing member, said sweep arm being adapted to rotate away from the adjacent end of said cage upon flow of fluid longitudinally in said housing member to maintain said paddle adjacent said other end of said cage, said cage being disposed with respect to said sweep arm in such a manner that upon rotation anticlockwise, looking downward, of said sweep arm with respect to said housing member, said sweep arm enters said cage to discharge said valve ball from said cage.

19. The deep well casing choke and check valve assembly of claim 18 wherein the sweep arm has one side convex and the other side concave, the concave side of said sweep arm facing said stop element end of said cage.

20. A deep well casing choke and check valve assembly comprising, in combination, a housing member having an axial conduit therethrough, means to attach housing member to a well casing, an annular collar attached rigidly to the upper inner wall of said housing member, said annular collar terminating in a lower plane surface and having a cylindrical conduit therethrough, the circle of juncture of said cylindrical conduit and said plane surface being adapted to serve as a seat, a hinged orifice member supported by said housing member, said orifice member being adapted to rotate to and from said seat, said orifice member when seated providing for a restricted flow of fluid upward in said housing member, a rotatable check valve, said valve being adapted to seat against said orifice member to check upward fluid flow therethrough, said hinged orifice member being spring loaded to bias said orifice member against its seat, said rotatable check valve also being spring loaded to bias said check valve in closed relation with respect to said orifice member, said orifice member and said rotatable check valve being adapted to rotate away from their seats upon downward flow of fluid in said housing member, and means to hold said check valve in an unseated position in respect to said orifice member, said means comprising a rotatable cam shaft disposed axially in said housing member, said shaft having a cam slot and being held against axial movement by bearing support means, said bearing support means being rigidly attached to the wall of said housing member, a radially disposed cam rod having one end adjacent the cam slot of said cam shaft and the other end being adapted to hold said check valve in an unseated position when the cam slot of said cam shaft is out of operation with respect to the cam end of said cam rod, an elongated flat paddle rigidly attached to said cam shaft, the longitudinal axis of said paddle being disposed axially with respect to said housing member and the other axis of said paddle being disposed radially with respect to said housing member, a hinged flapper attached rigidly to said cam shaft, a stop element disposed rigidly on the inner wall of said housing member intermediate the ends of said paddle in such a manner as to stop clockwise rotation, when looking downward, of said cam shaft when said paddle touches said stop element, said hinged flapper being adapted to rotate said cam shaft in a clockwise direction and to maintain said paddle against said stop element under the influence of flow of fluid in said housing member, and upon rotation of said housing member and said cam rod, said cam rod being adapted to cooperate with the cam slot of said shaft to release the spring loaded valve thereby permitting same to close against said orifice member under the bias of said spring of said valve.

21. A deep well casing choke and check valve assembly comprising, in combination, a housing member having an axial conduit therethrough, means to attach said housing member to a well casing, an annular collar attached rigidly to the upper inner wall of said housing member, said annular collar terminating in a lower plane surface and having a cylindrical conduit therethrough, the circle of juncture of said conduit and said plane surface being adapted to serve as a seat, a hinged orifice member supported by said housing member, said orifice member being adapted to rotate to and from said seat, said orifice member when seated providing for a restricted flow of fluid upward in said housing member, a rotatable check valve, said check valve being adapted to seat against said orifice member to check upward fluid flow therethrough, said hinged orifice member being spring loaded to bias said orifice member against its seat, said rotatable check valve also being spring loaded to bias said check valve in closed relation with respect to said orifice member, said hinged orifice member and said rotatable check valve being adapted to rotate away from their seats upon downward flow of fluid in said housing member, and means to hold said check valve in an unseated position in respect to said orifice member, said means comprising a rotatable cam shaft disposed axially in said housing member, said shaft having a cam slot and being held against axial movement by bearing support means, said bearing support means being rigidly attached to the wall of said housing member, a radially disposed cam rod having one end adjacent the cam slot end of said cam shaft and the other end being adapted to hold said check valve in an unseated position when the cam slot of said cam shaft is out of operation with respect to the cam end of said cam rod, an elongated flat paddle rigidly attached to said cam shaft, the longitudinal axis of said paddle being disposed axially with respect to said housing member and the other axis of said paddle being disposed radially with respect to said housing member, a sweep arm attached rigidly to said cam shaft, said sweep arm having one plane surface, one axis of said plane surface being disposed radially and the other axis longitudinally with respect to said cam shaft, the other surface of said sweep arm being convex outward and its longitudinal axis being disposed substantially radially with respect to said cam shaft, a stop element disposed rigidly on the inner wall of said elongated housing member intermediate the ends of said paddle in such a manner as to stop clockwise rotation, when looking downward, of said cam shaft when said paddle touches said stop element, said sweep arm being adapted to rotate said cam shaft in such a direction that the convex surface of said sweep arm is the leading surface under the influence of flow of fluid in said housing member, said cam shaft being rotated under the influence of said flow of fluid to hold said paddle against said stop element and to maintain said cam slot of said cam shaft inoperable with respect to said cam rod, and upon rotation of said housing member and said cam rod until said cam rod rotates around said cam shaft to cooperate with the cam slot of said shaft to release the spring loaded valve and permit same to close against said orifice member under the bias of said spring of said valve.

22. The deep well casing choke and check valve assembly of claim 21 wherein the sweep arm has one side convex and the other side concave, the concave side of said sweep arm facing said stop element.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,884,074

April 28, 1959

Roy A. Bobo et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 62, for "event" read -- even --; column 7, line 18, after "polymer" insert a comma; column 9, line 5, for "do-" read -- do-- --; column 13, line 27, before "housing" insert -- said --.

Signed and sealed this 13th day of October 1959.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents