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(54) **SYSTEM FOR RUNNING TUBULAR MEMBERS**

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(63) Continuation-in-part of application No. 10/337,404, filed on Jan. 6, 2003, which is a continuation of application No. 09/850,247, filed on May 7, 2001, now Pat. No. 6,513,590, which is a continuation-in-part of application No. 09/829,107, filed on Apr. 9, 2001, now Pat. No. 6,491,103.

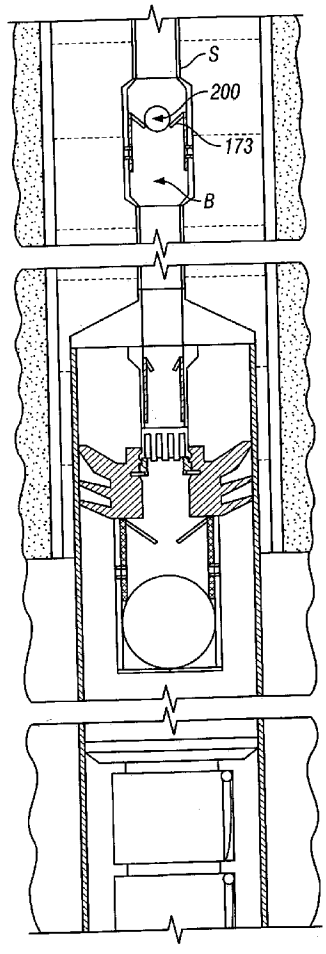
Publication Classification

(51) **Int. Cl.**[7] **E21B 33/12**

(52) **U.S. Cl.** **166/193**; 166/177.3

(57) **ABSTRACT**

The present invention relates to a wiper plug and internal drop ball mechanism that may be used in conjunction with a downhole surge reduction tool to run, hang, and cement casing liners in a wellbore. The apparatus of the present invention comprises a wiper plug assembly removably attached to the drill string within the casing liner, a drop ball sub attached below the wiper plug assembly which releases a float valve actuator ball having a diameter larger than the drill string, and float equipment having a plurality of flapper valves. The apparatus of the present invention may further comprise a diverter tool connected between the drill string and the casing liner.



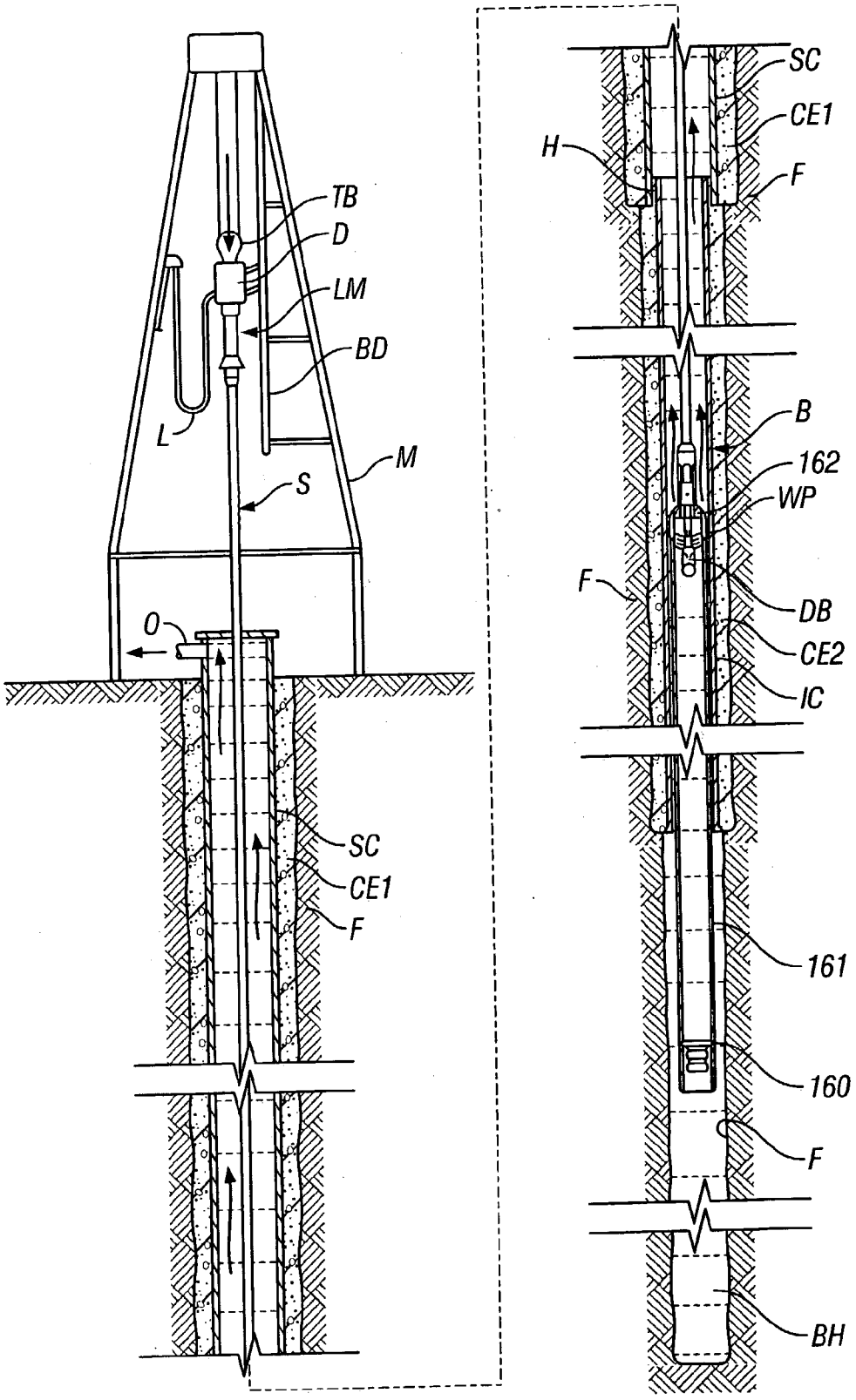


FIG. 1

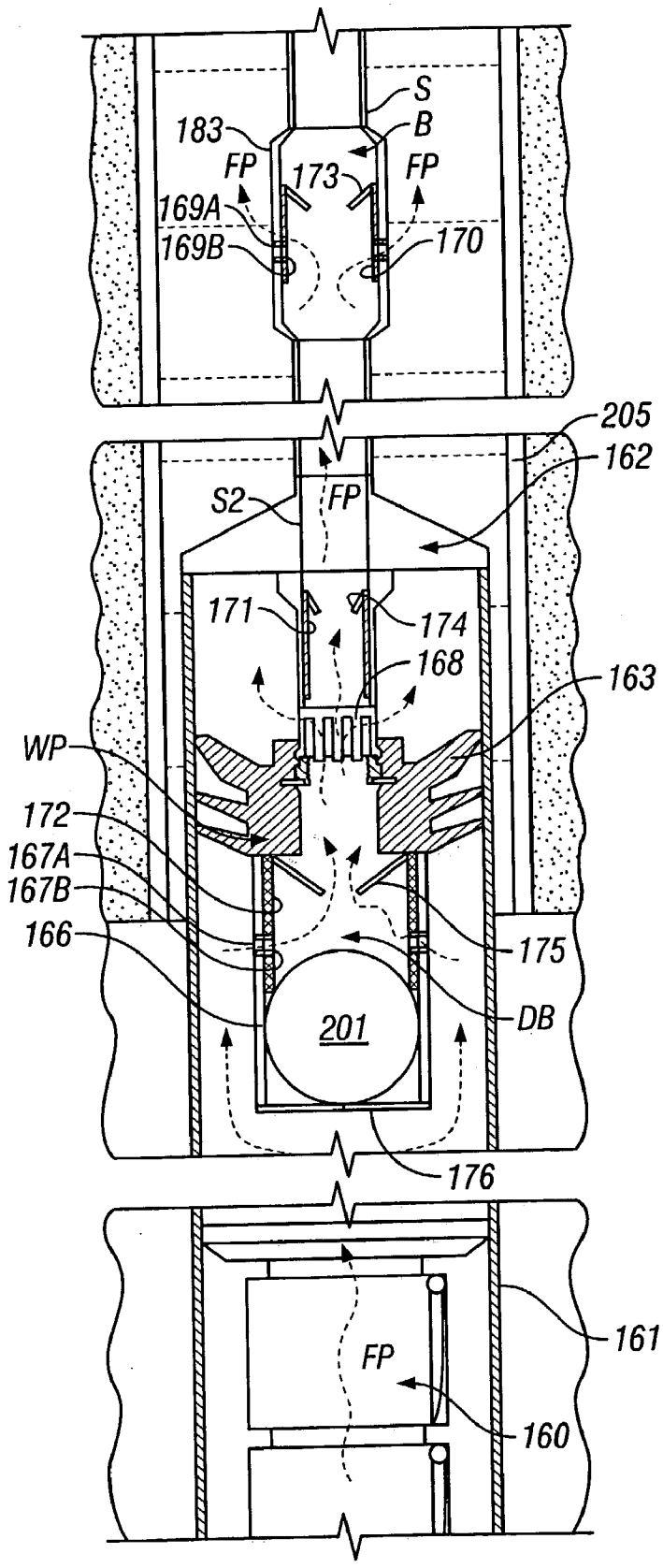

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FIG. 2

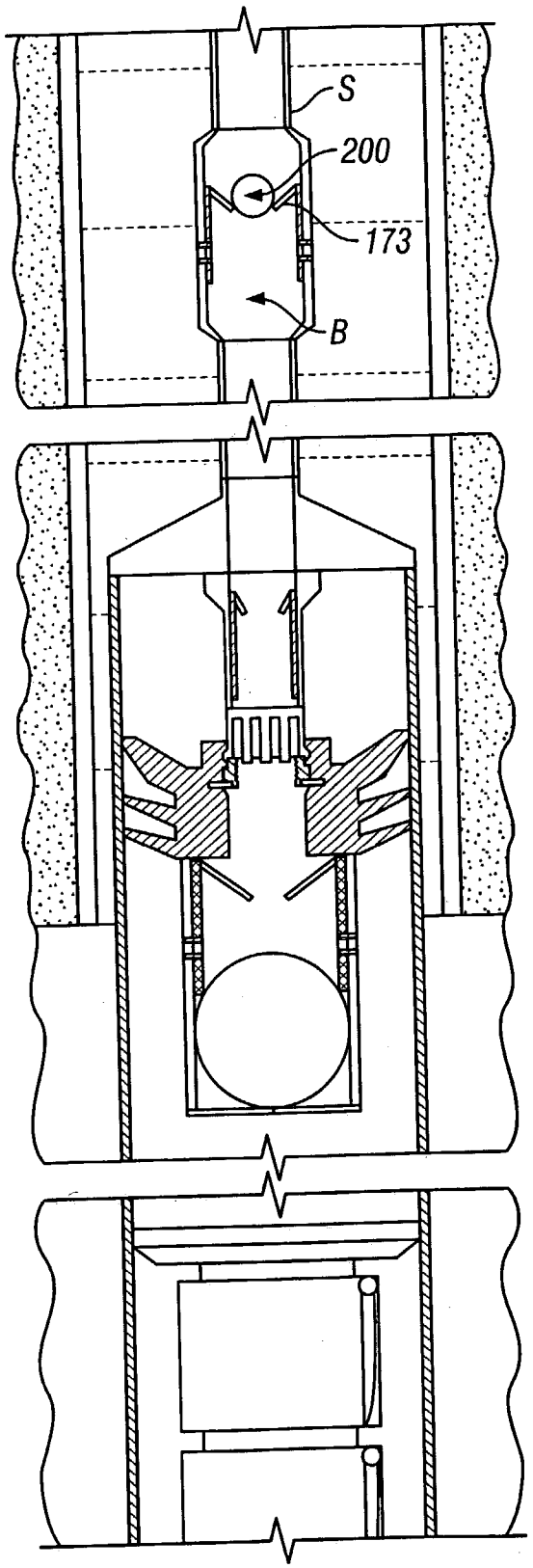


FIG. 3

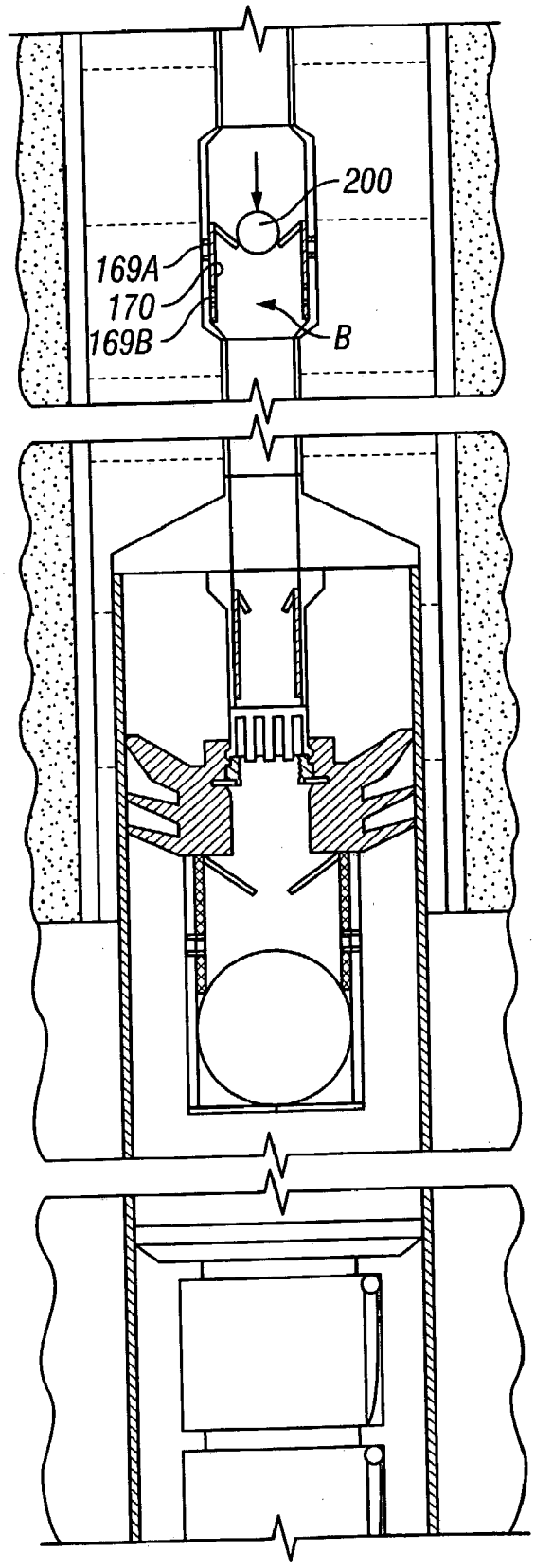


FIG. 4

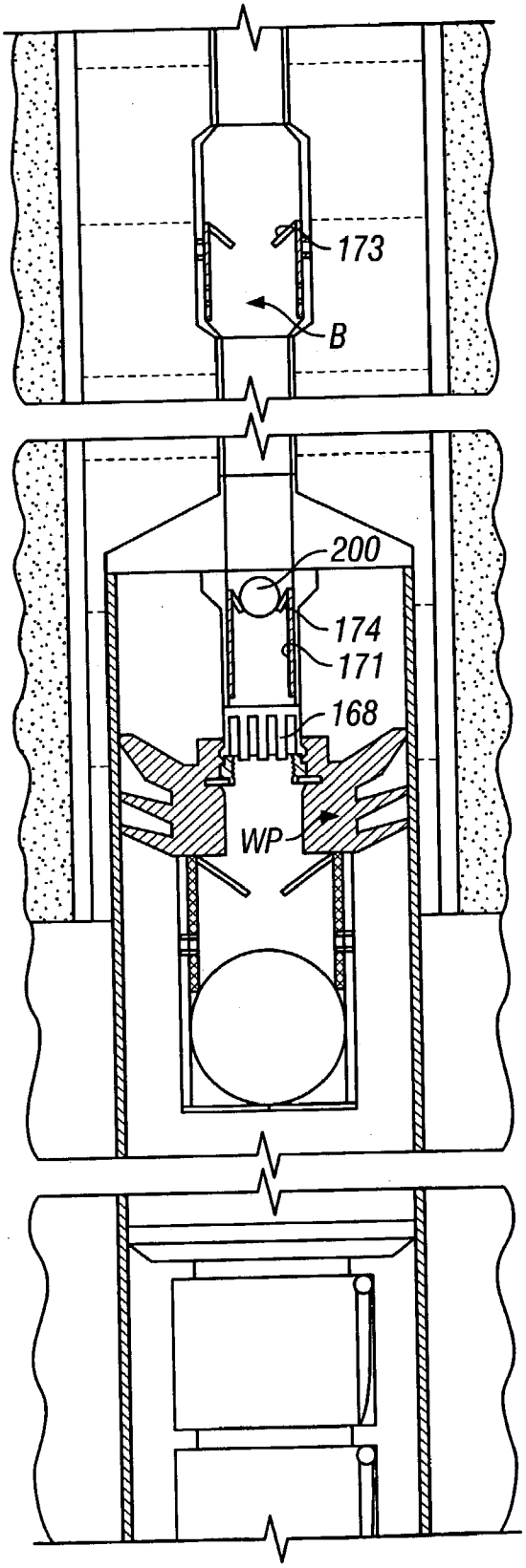


FIG. 5

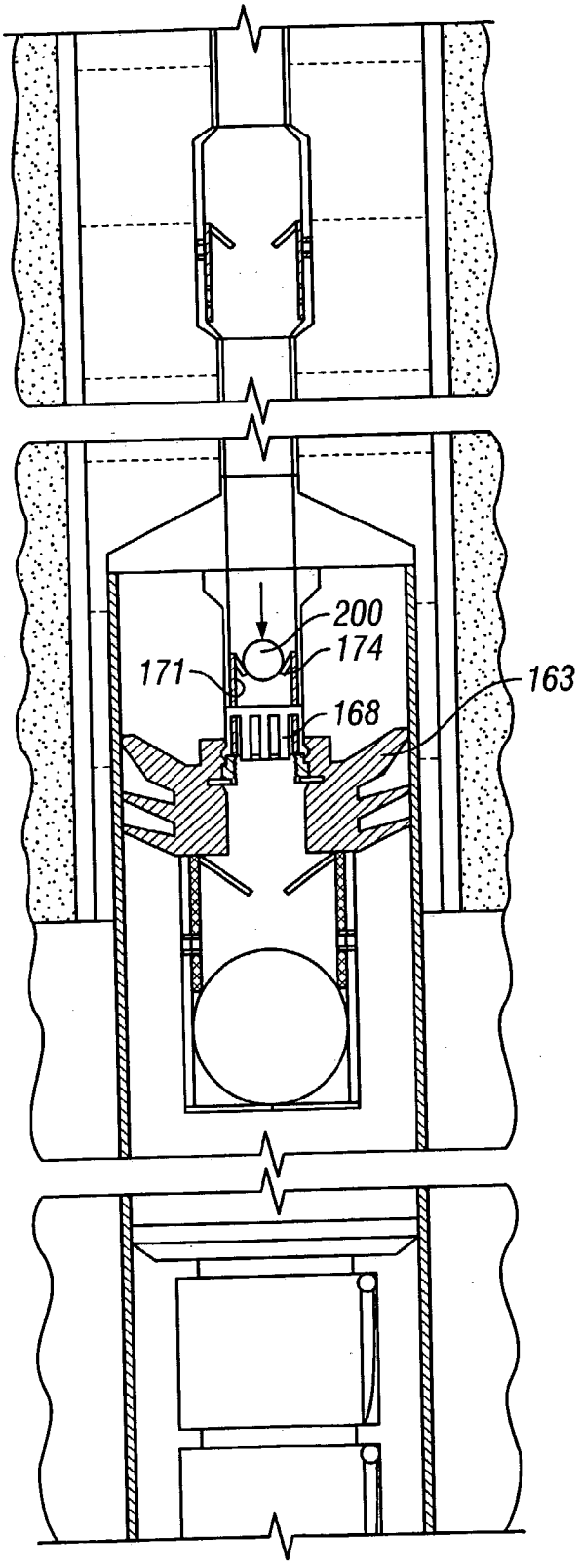


FIG. 6

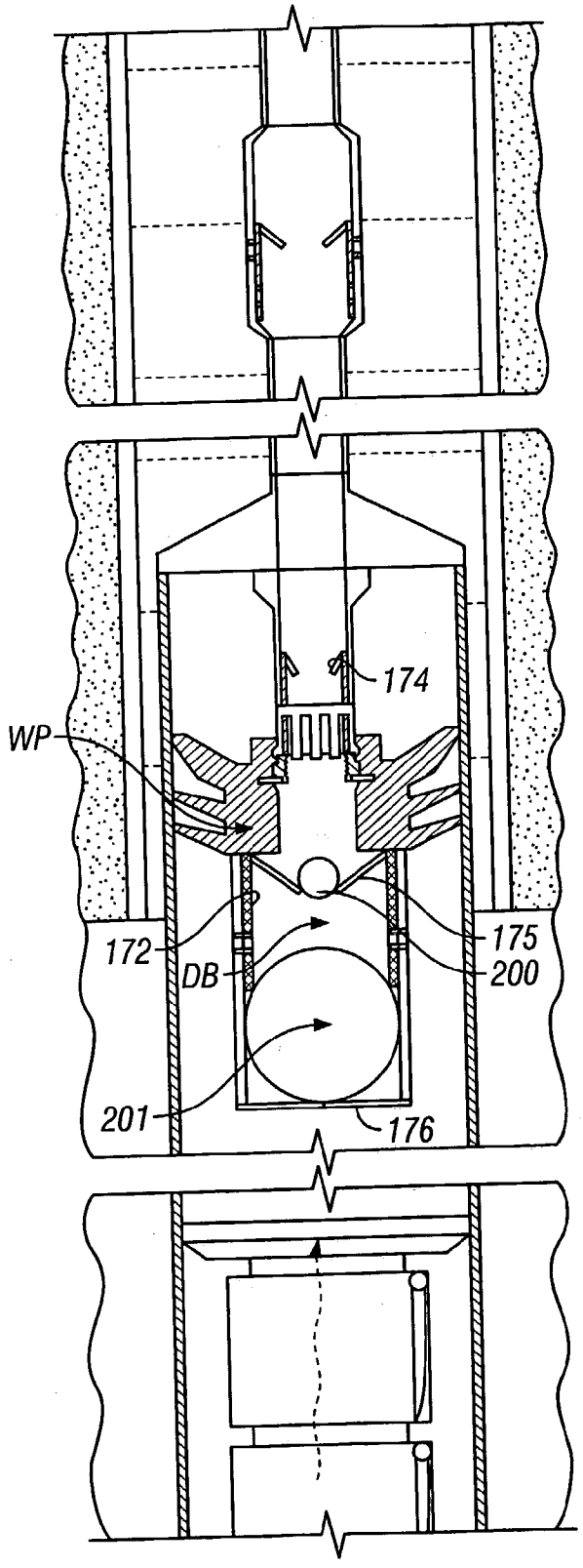


FIG. 7

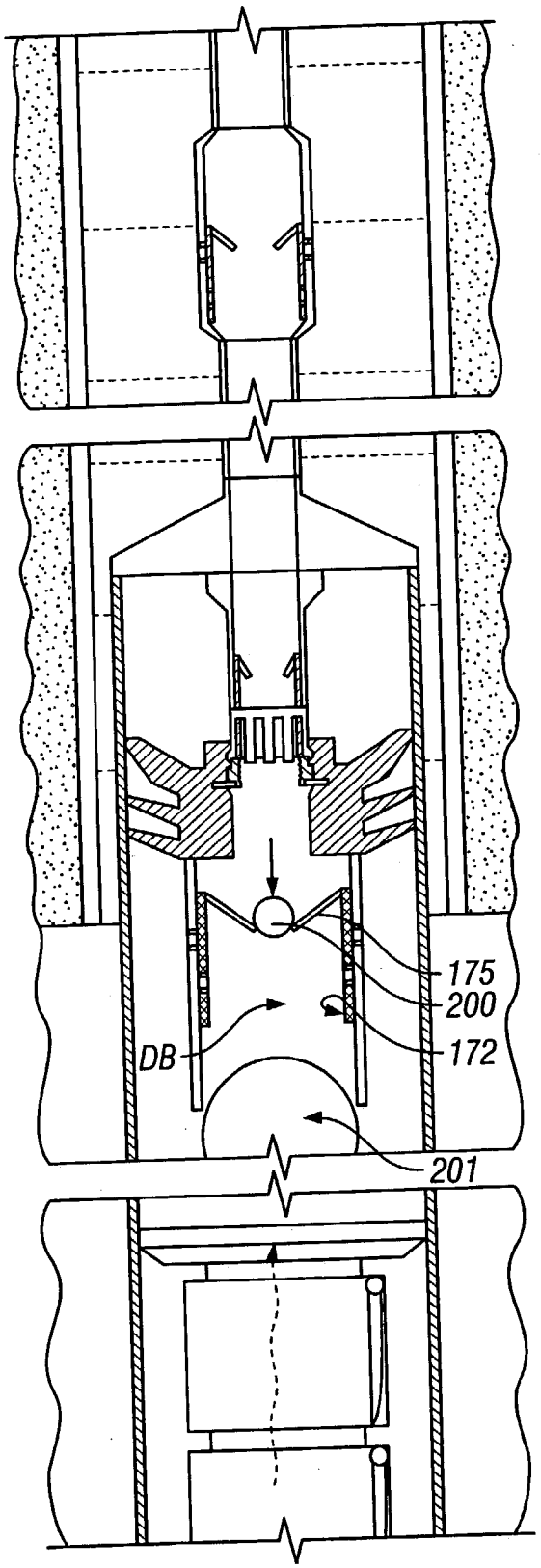
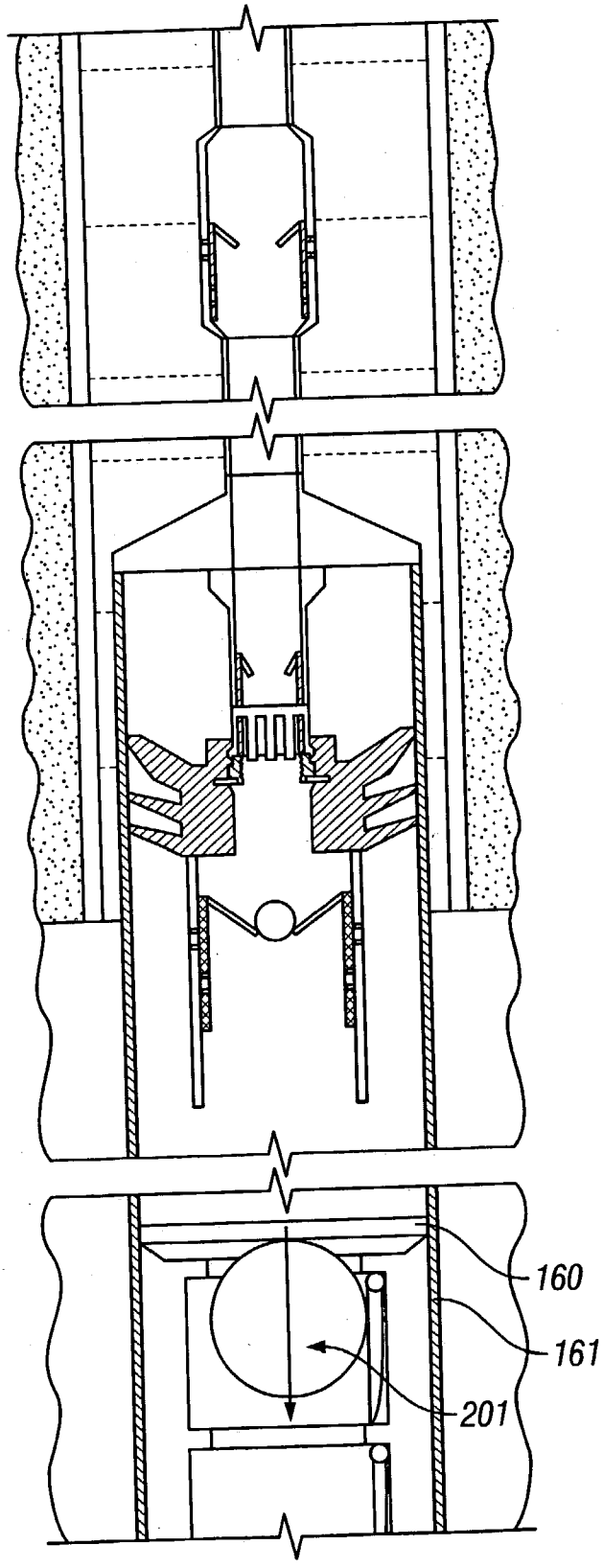


FIG. 8



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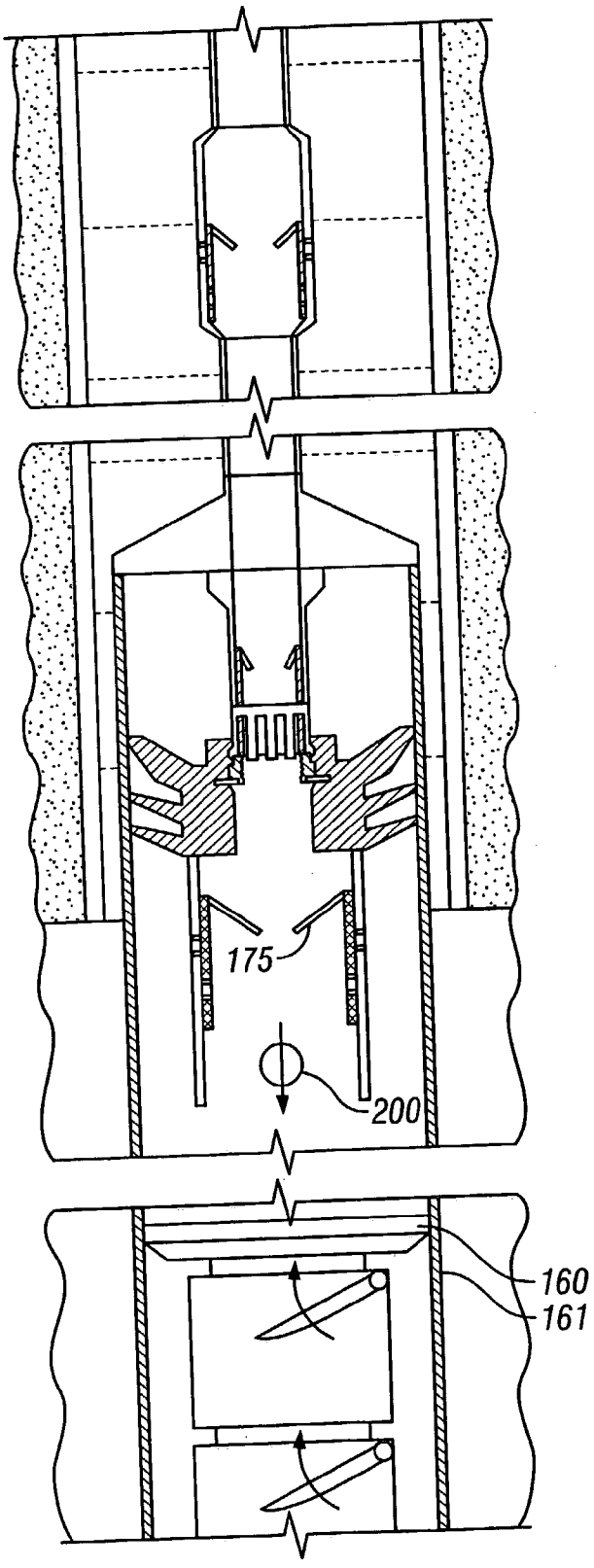

FIG. 10

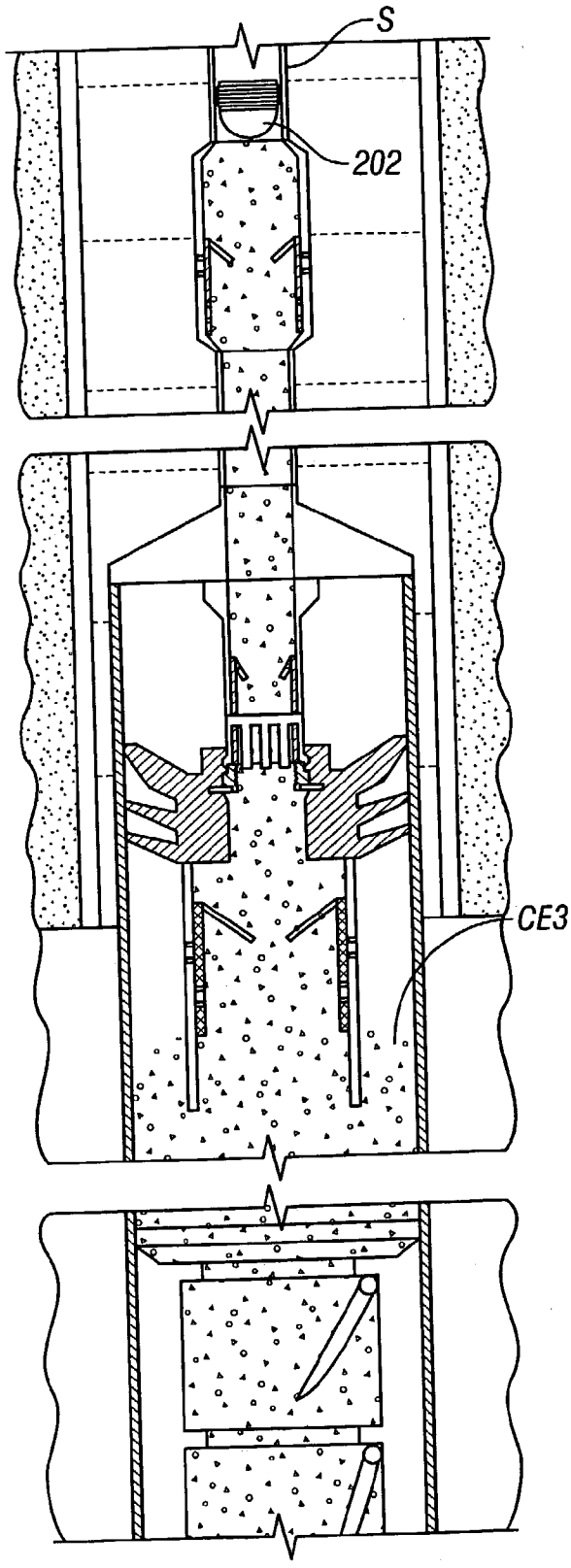

FIG. 11

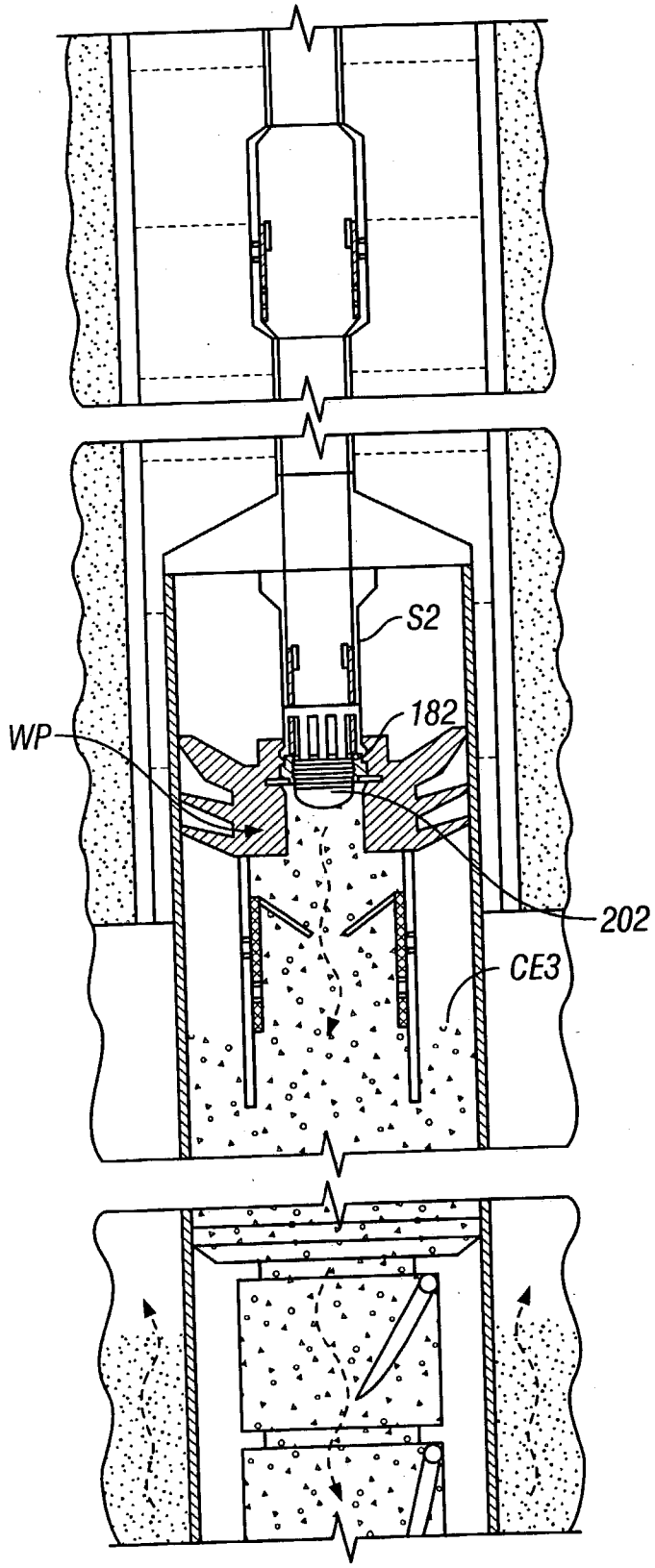

FIG. 12

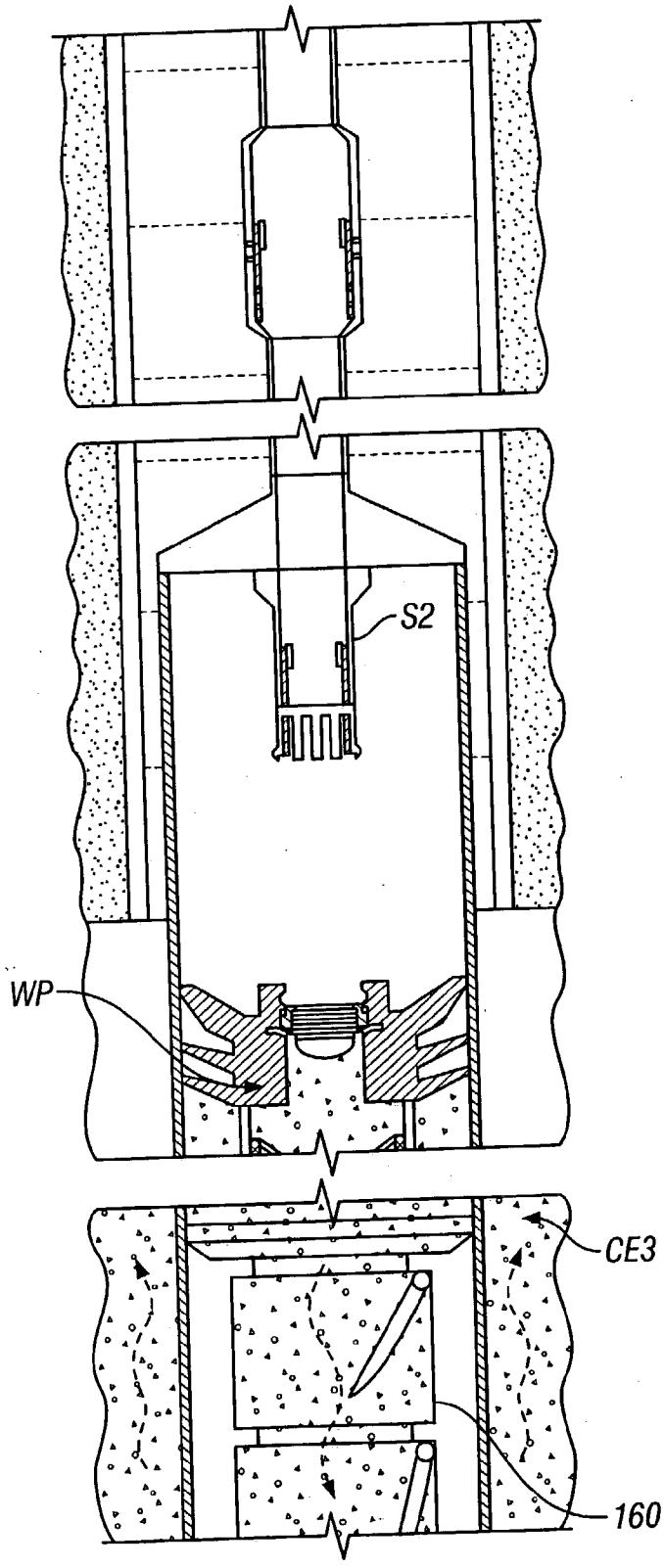

FIG. 13

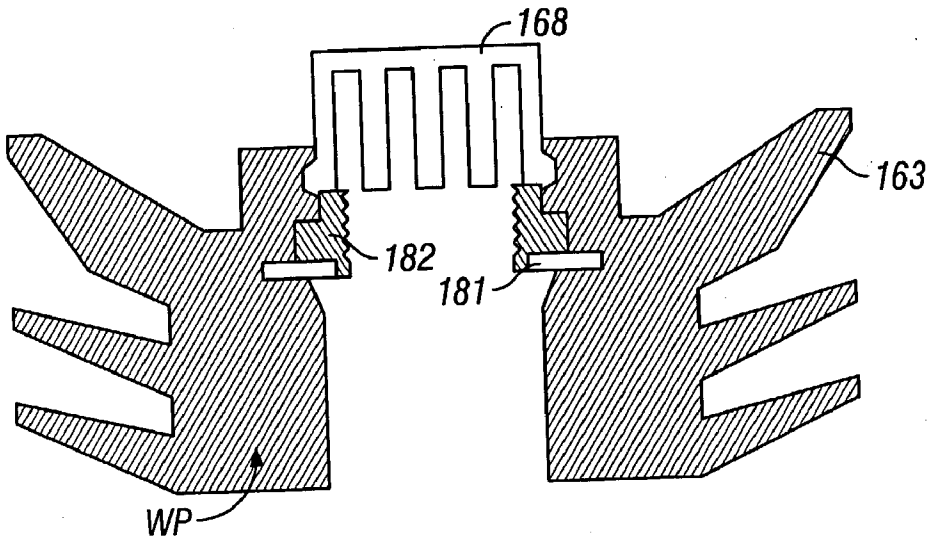

FIG. 14A

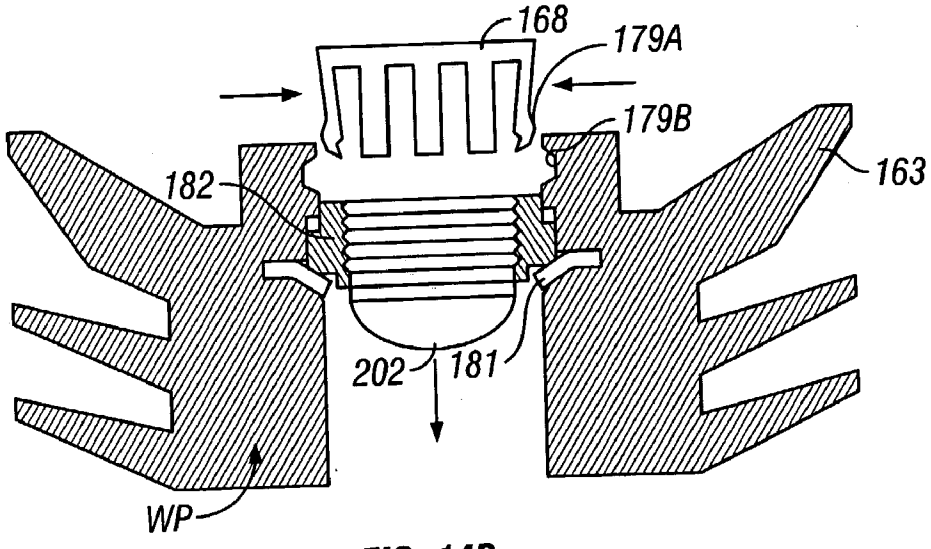

FIG. 14B

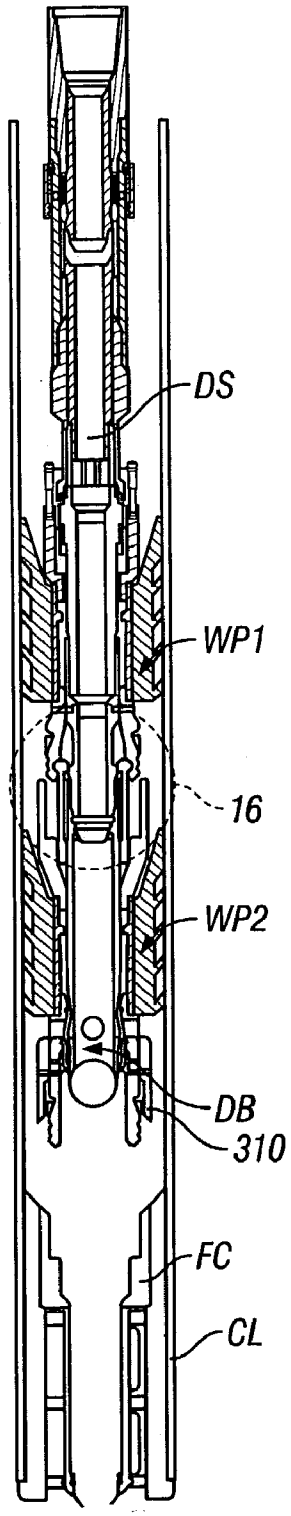

FIG. 15

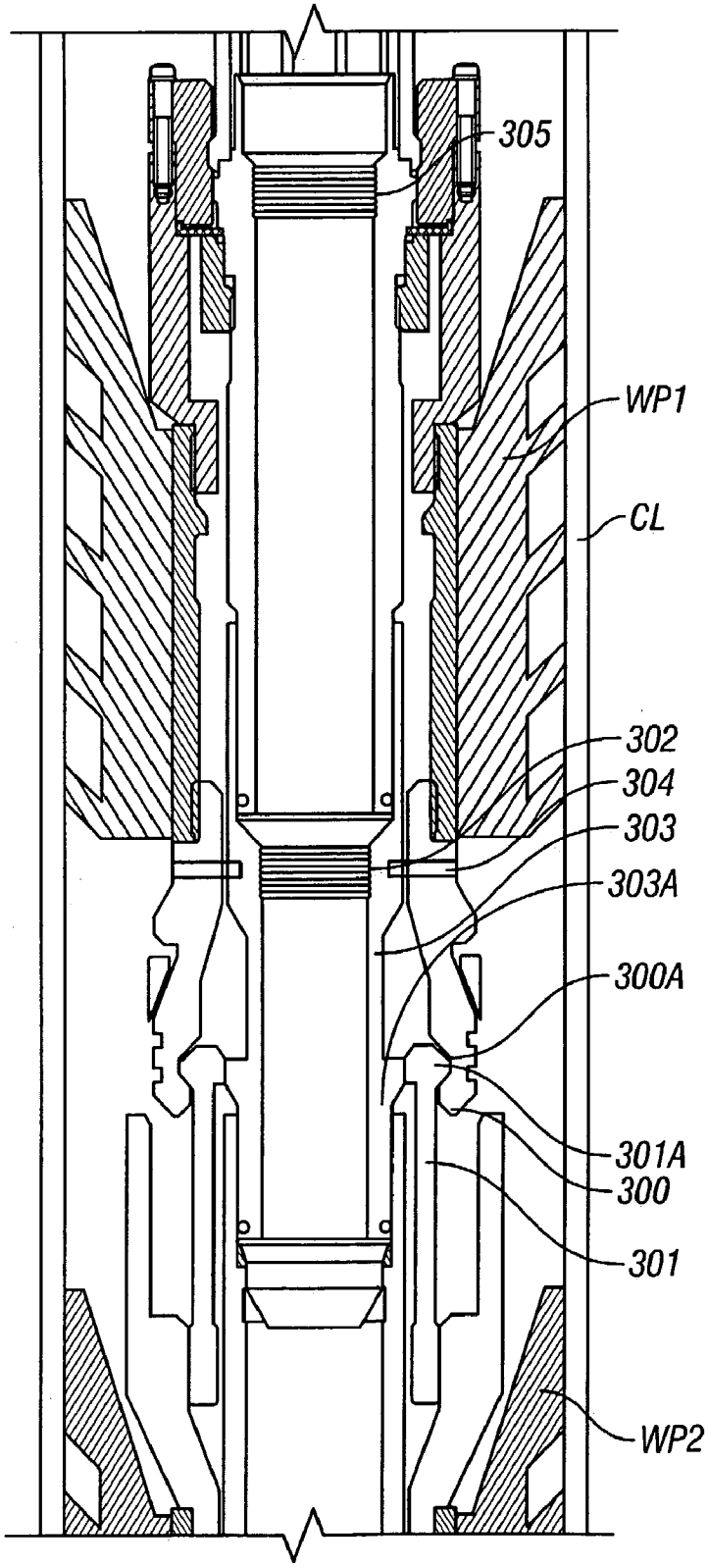

FIG. 16

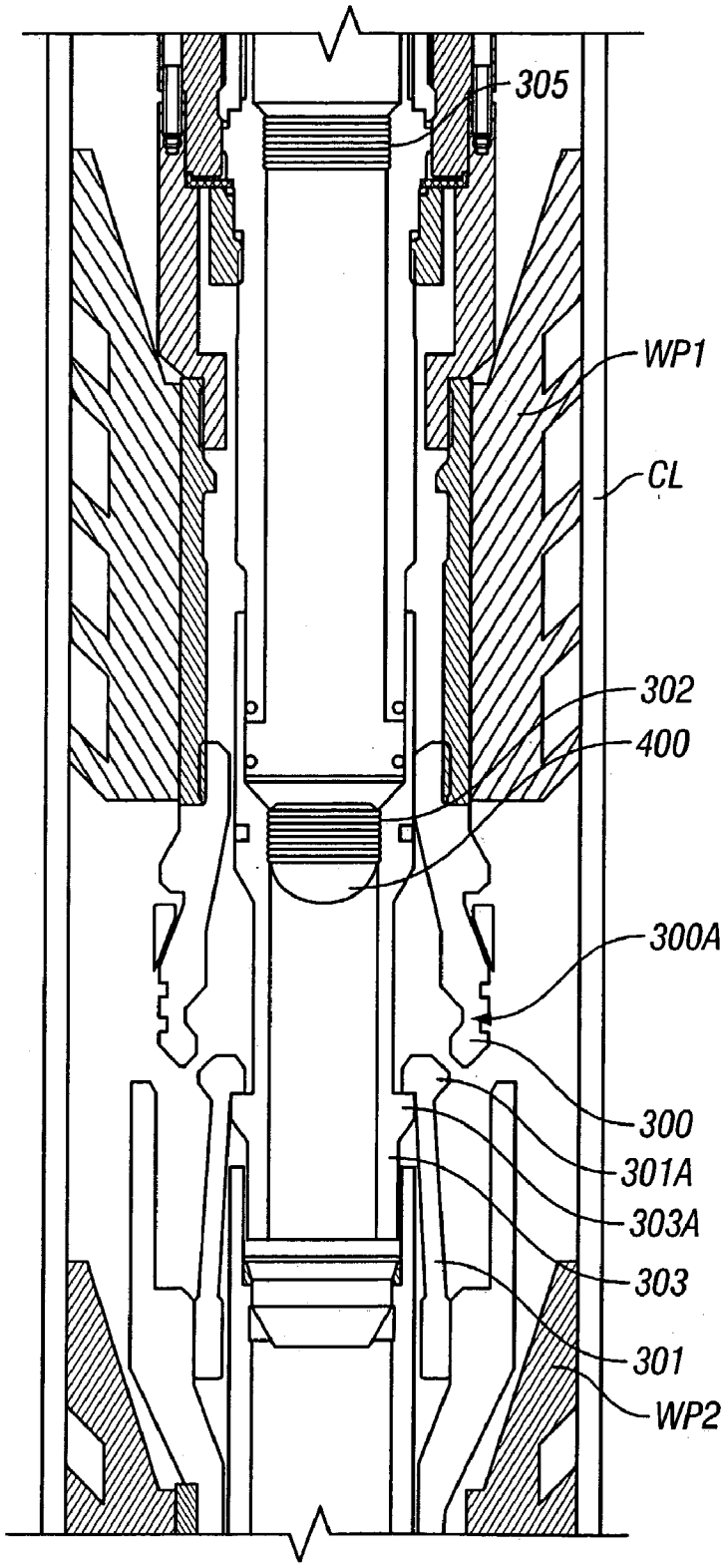

FIG. 17

FIG. 18

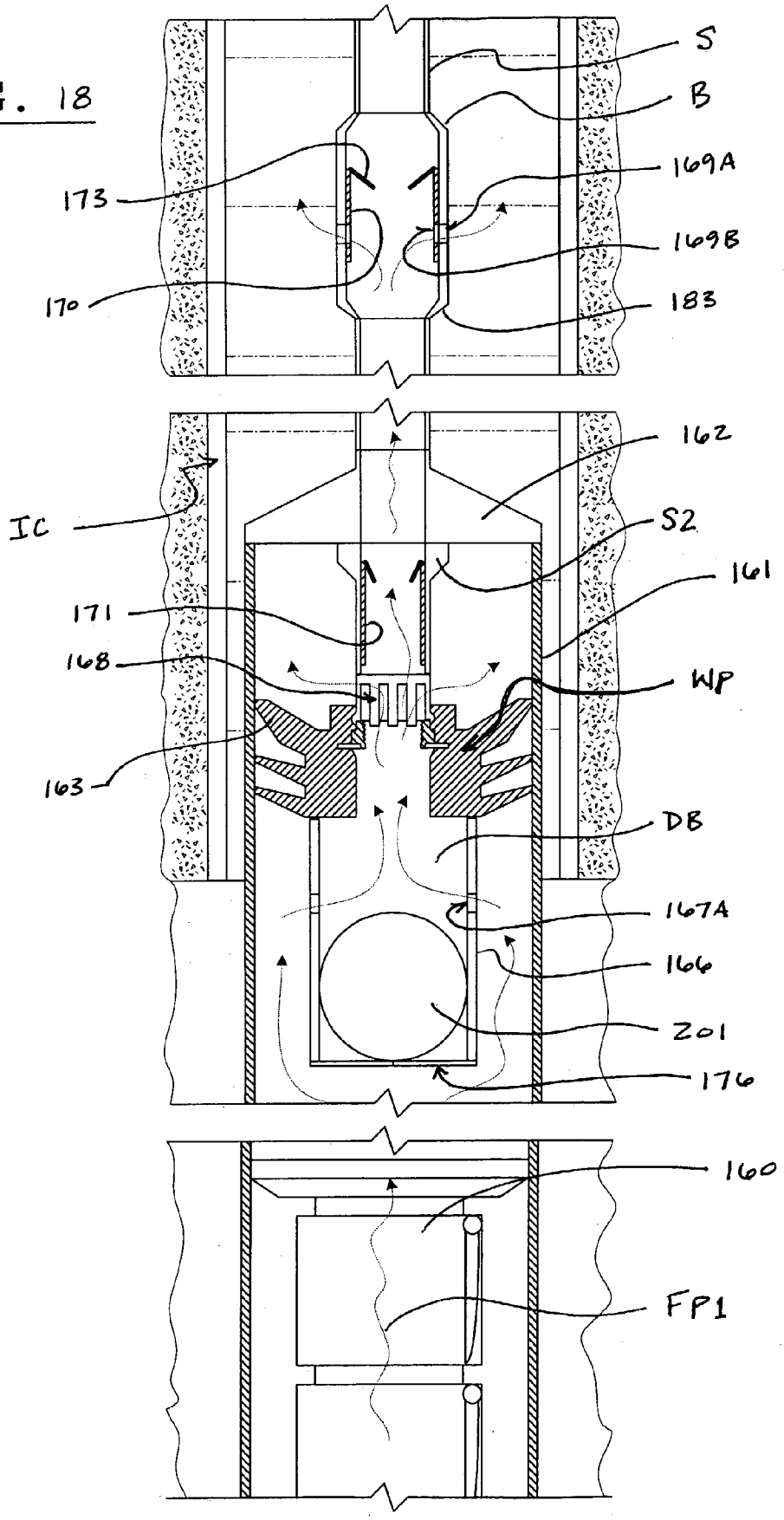
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FIG. 19

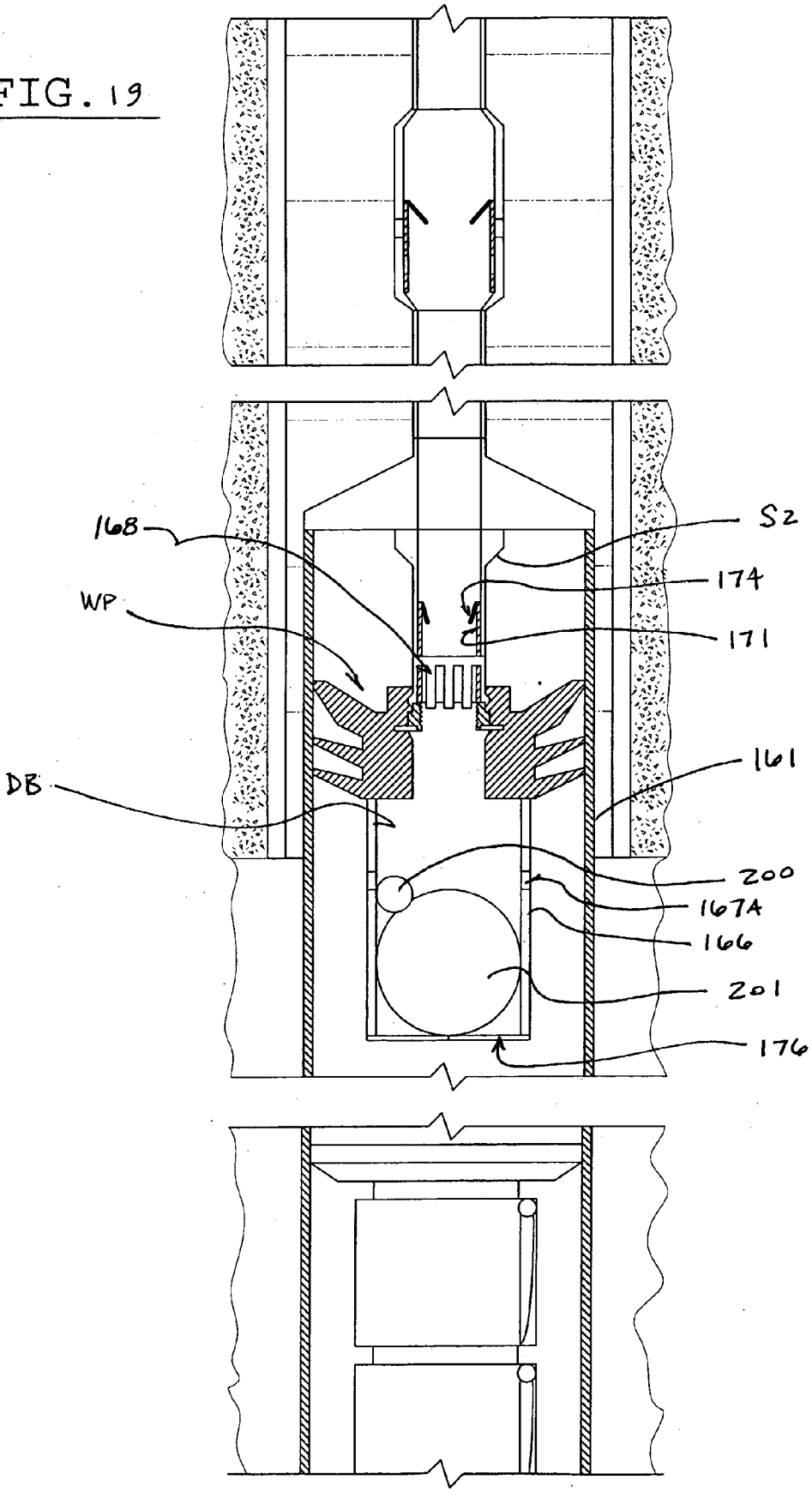


FIG. 20

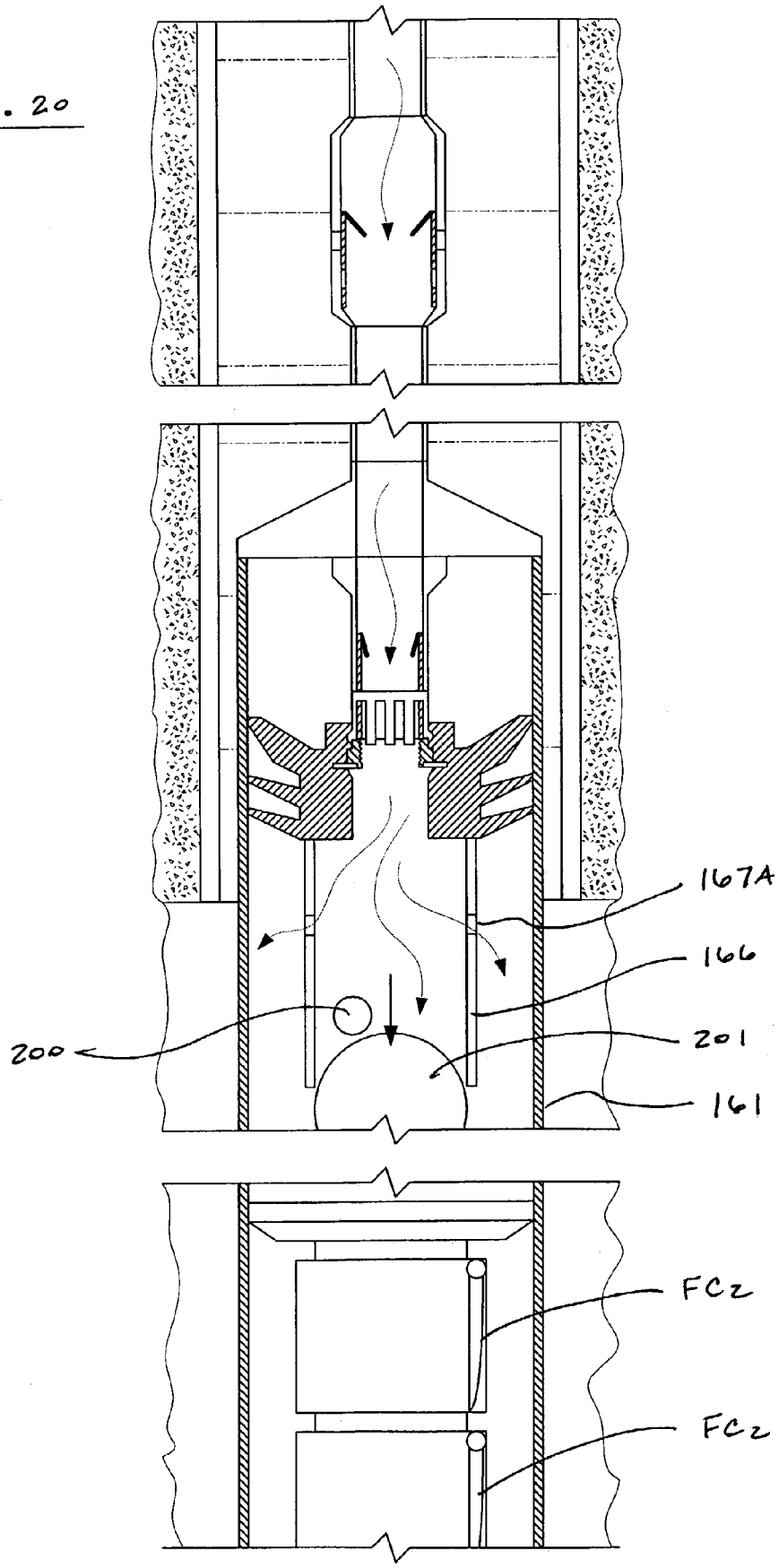


FIG. 21

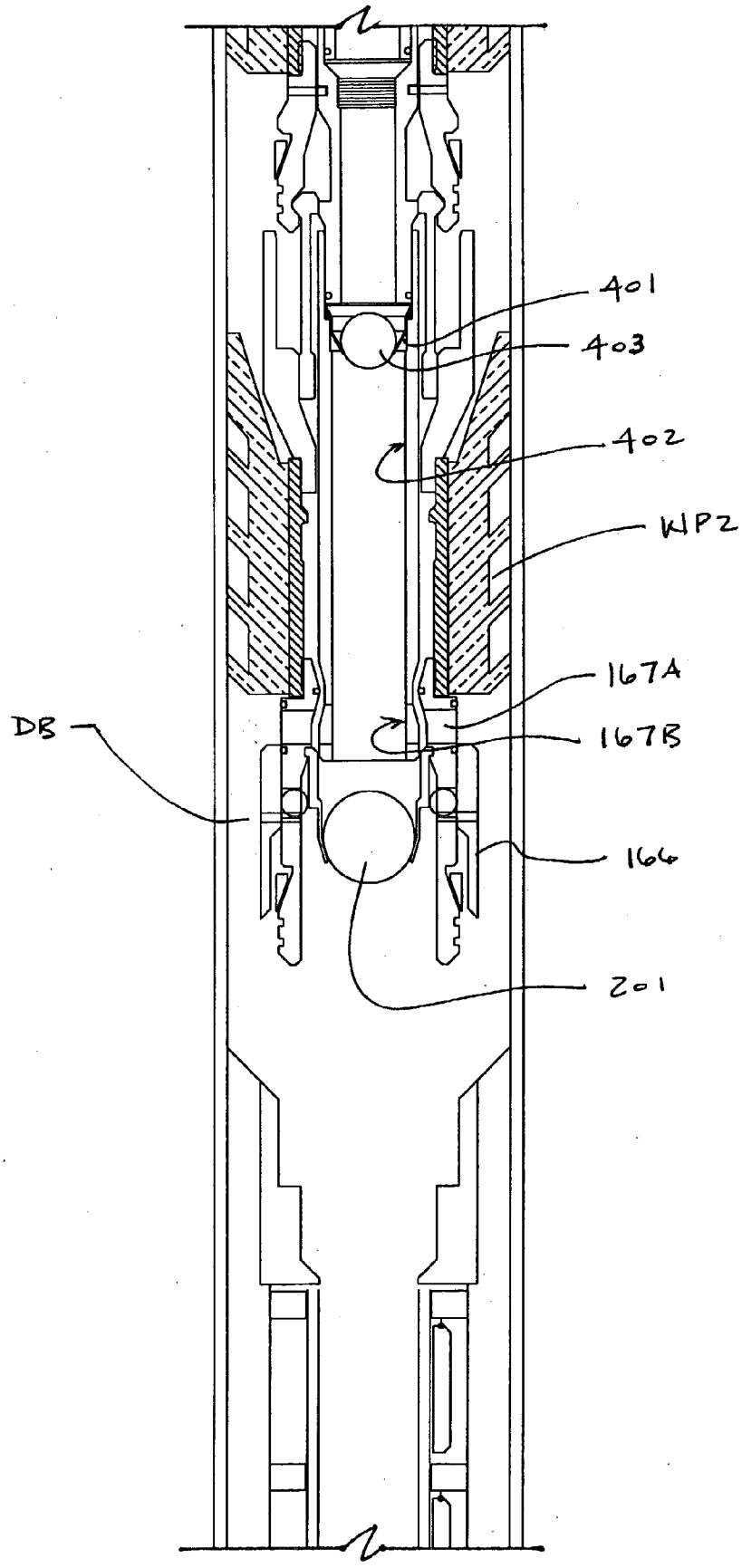


FIG. 22

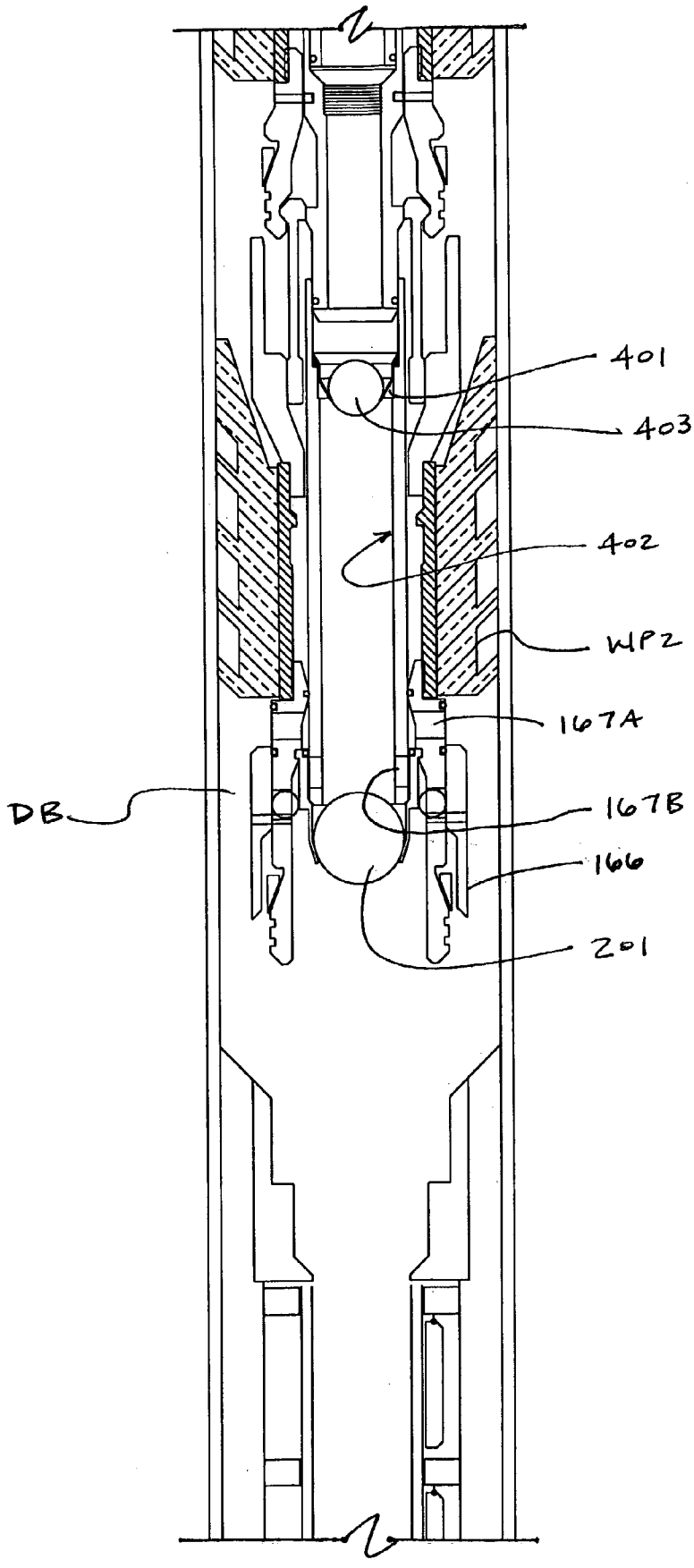


FIG. 23

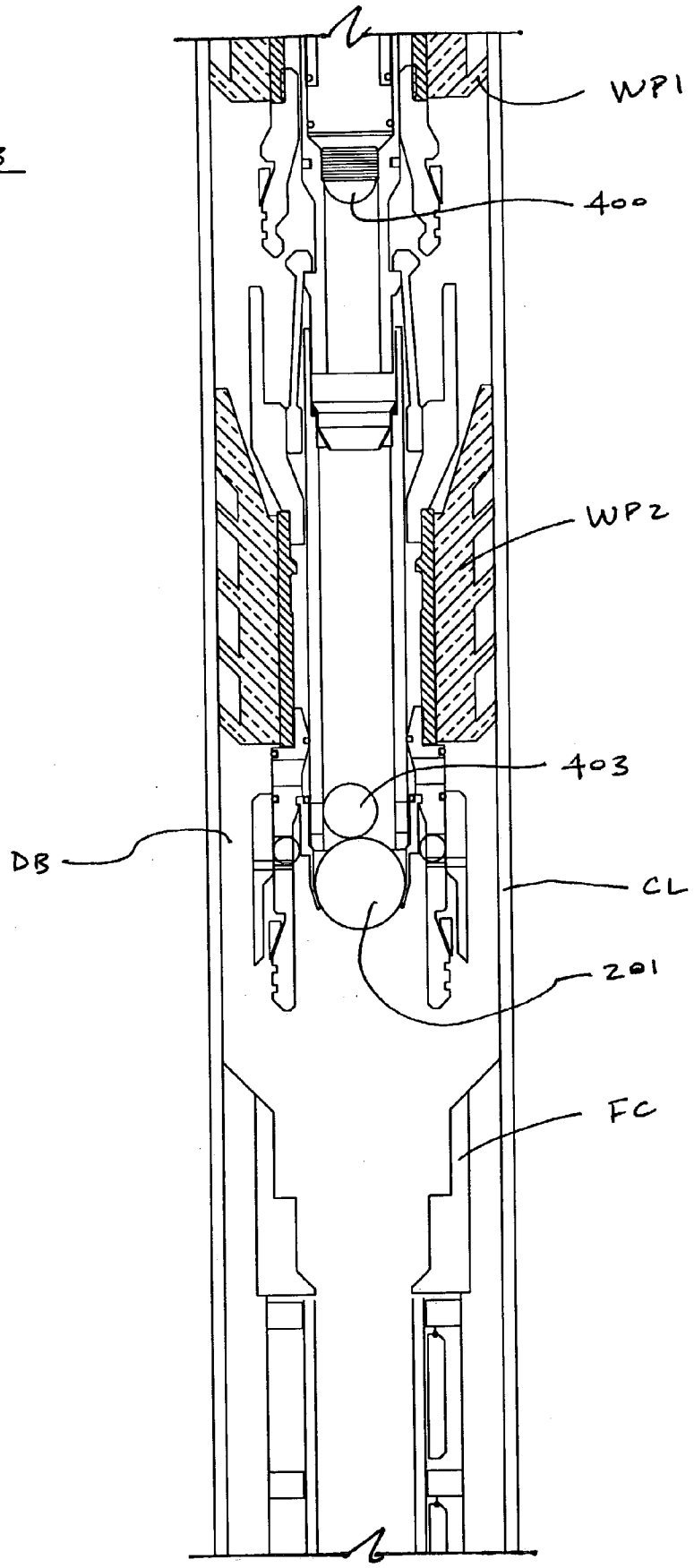


FIG. 24

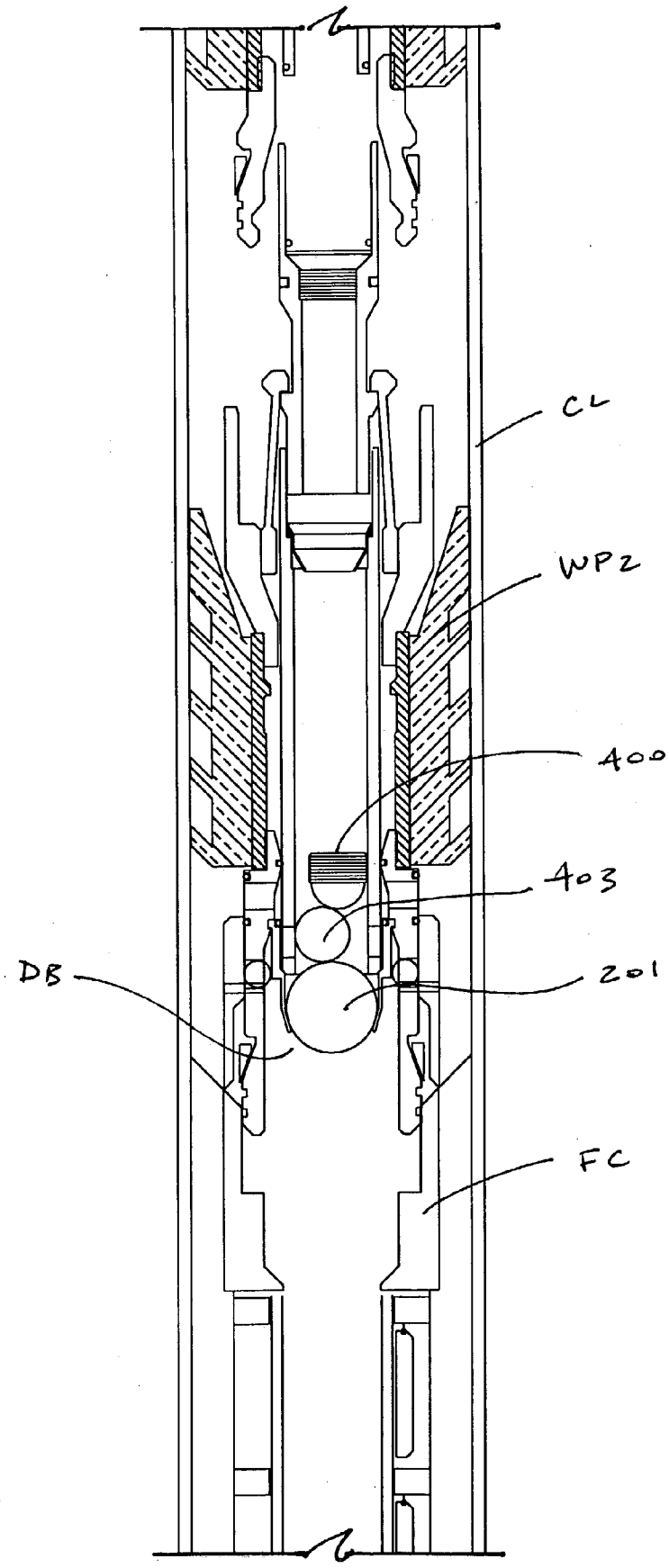


FIG. 25

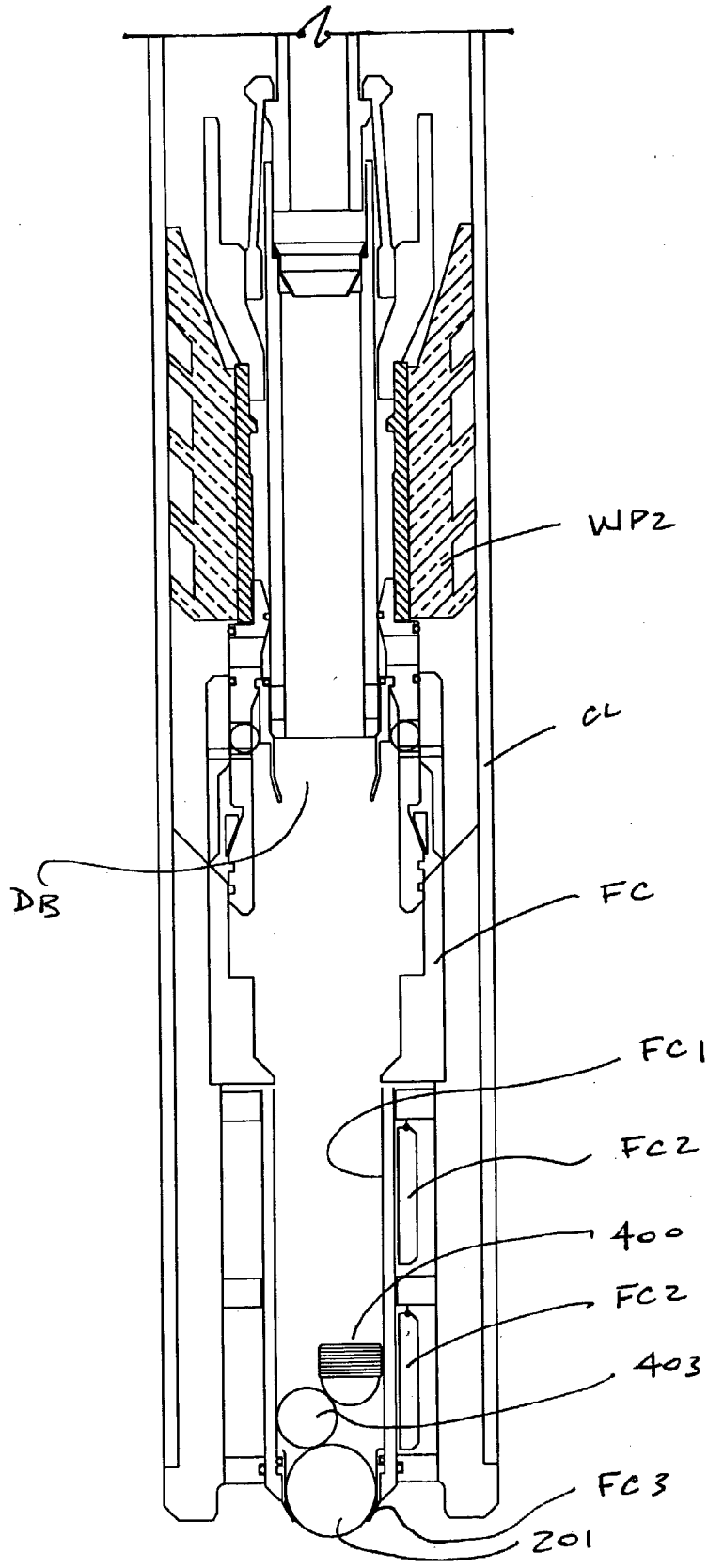
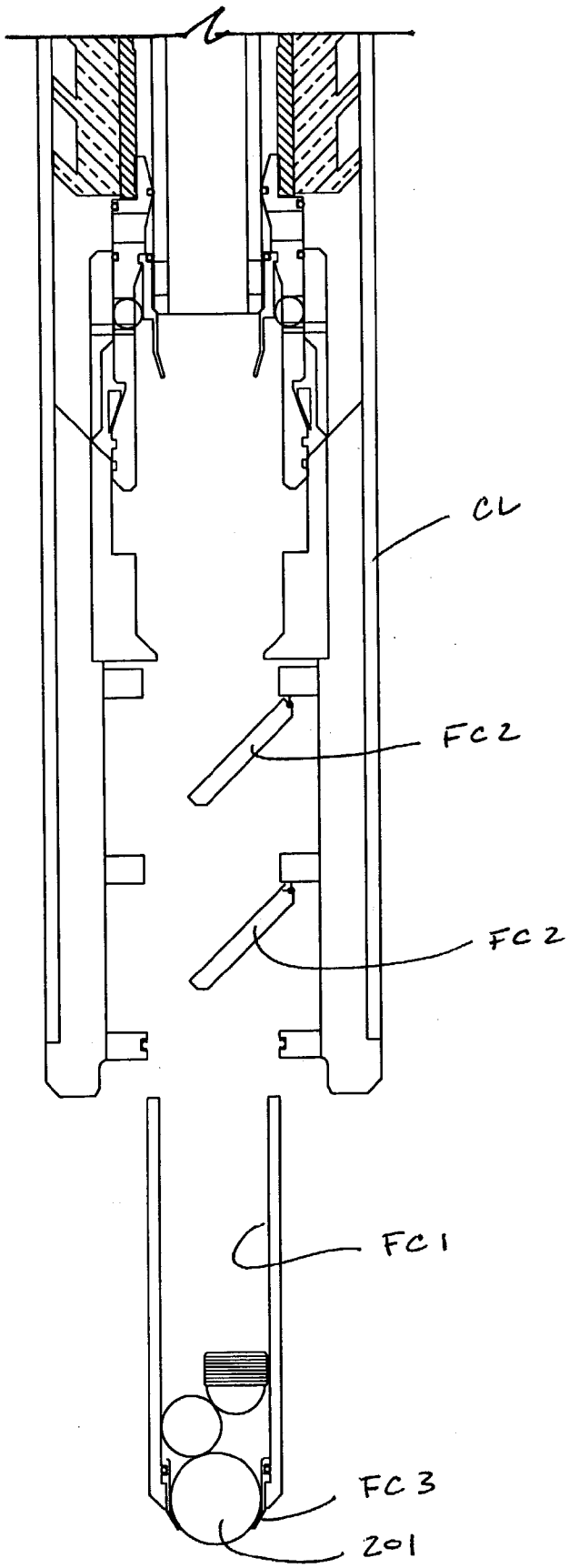


FIG. 26



SYSTEM FOR RUNNING TUBULAR MEMBERS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation-in-part of U.S. patent application Ser. No. 10/337,404 filed Jan. 6, 2003, which was a continuation of U.S. patent application Ser. No. 09/850,247 filed May 7, 2001, which was a continuation-in-part of U.S. patent application Ser. No. 09/829,107 filed Apr. 9, 2001, now U.S. Pat. No. 6,491,103.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an apparatus for running tubular members such as drilling/production liners or subsea casing strings in a wellbore. More particularly the present invention relates to a wiper plug and internal drop ball mechanism that may be used in conjunction with the running and cementing of such tubular members in a wellbore.

[0004] 2. Description of the Prior Art

[0005] In oilfield applications, a "casing liner,""drilling/production liner," and a "subsea casing string" are tubular members which are run on drill pipe. The terms "casing liner" and "drilling/production liner" are usually used with respect to drilling operations on land, while the term "subsea casing string" is used with respect to offshore drilling operations. For ease of reference in this specification, the term "liner" is used to denote either a "casing liner," a "drilling/production liner," or a "subsea casing string."

[0006] Prior art drop ball-actuated float equipment for use in cementing liners in place includes, for example, a float shoe or float collar which has one or more flapper valves and which is located at or near the bottom of the liner. The flapper valve or valves are conventionally held open by a breakable plastic tab which is actuated (i.e., broken) by a drop ball when the cementing operation is to begin. The industry has traditionally used systems where a drop ball is released at the surface, and the drop ball must be small enough in diameter to pass through the smallest restriction in the drill string, which usually is the diameter of the bore in the running tool. The size of such restrictions has, therefore, limited the maximum size of the opening in a float collar or shoe. In the case of a 13⅜" liner, the maximum diameter of a drop ball is somewhere between 2 and 3 inches. Due to the small diameter bore of traditional float equipment and the highly contaminated environment in which such equipment is used, the valves in traditional float equipment tend to become plugged with cuttings and contaminants.

[0007] As a liner is lowered into the wellbore, the fluid in front of the liner must be displaced to flow through the opening in the float equipment as well as around the outside annulus defined by the wellbore and the liner. The flow resistance of the two flow paths may be high and thus causes a pressure known as surge pressure to build up below the liner. This surge pressure can: (a) cause damage to the formation; (b) result in loss of expensive drilling fluid; and (c) result in the liner sticking against the side of the borehole, which means the liner does not go to the bottom of the hole.

[0008] U.S. Pat. No. 5,960,881, which is incorporated herein by reference, discloses a downhole surge pressure reduction system to reduce the pressure buildup while running in a tubular member such as a casing liner. The system is typically located immediately above the top of the casing liner. Nonetheless, any plugging of the float equipment at the lower end of the casing liner can, and very well may, render the surge pressure reduction system of the '881 patent ineffective.

[0009] The method and apparatus according to the present invention overcomes the plugging problem and allows enhanced passage of fluid through the tubular member and into the surge pressure reduction tool.

SUMMARY OF THE INVENTION

[0010] In accordance with the present invention, apparatus is provided for running a tubular member through a wellbore containing drilling fluid using a drill string.

[0011] Apparatus in accordance with the present invention comprises a running tool connected to the top of the tubular member having an axial bore therethrough.

[0012] Apparatus in accordance with the present invention further comprises a wiper plug assembly which includes a wiper plug releasably suspended from a running tool within the tubular member and a receptacle sleeve to receive a drill pipe dart. During cementing operations, the wiper plug assembly receives the drill pipe dart and is released from the drill string at the top of the tubular member. The wiper plug assembly is then pumped downward forcing cement out of the bottom of the tubular member and into the annulus between the tubular member and the borehole.

[0013] One end of the wiper plug assembly is connected to the running tool attached to the tubular member. The running tool for the wiper plug comprises an axially indexing sleeve and a plurality of wedge-shaped fingers which releasably engage the wiper plug receptacle sleeve. During running in of the tubular member, the drilling fluid flows from the tubular member upward through the ports between the fingers and into the void above the wiper plug fins. To isolate the wiper plug fins from internal pressure during cementing operations, the drill pipe sleeve is indexed axially downward to block the ports between the fingers.

[0014] Apparatus in accordance with the present invention also comprises a drop ball sub attached to and below the wiper plug assembly within the tubular member. The drop ball sub releases a float equipment actuator ball which is larger in diameter than the smallest restriction in the drill string. When released, the actuator ball drops to the bottom of the tubular member where it actuates float equipment. Once actuated, flapper valves in the float equipment prevent the back flow of cement traveling downward through the tubular member.

[0015] Apparatus in accordance with the present invention may further comprise a surge pressure reduction device or diverter tool connected between the drill string and the running tool. When the diverter tool is in an open port position, the drilling fluid may flow upward from inside the diverter tool into the annulus between the casing cemented in place and the drill string. When in a closed port position, the device provides passage for fluid to travel downward through the drill string.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] In the accompanying drawings:

[0017] **FIG. 1** is an elevation view of an, embodiment of the system of the present invention for running of a tubular member downhole.

[0018] **FIG. 2** is an elevation view of an embodiment of the present invention illustrating flow path of the drilling fluid facilitating surge pressure reduction as tubular member is run downhole.

[0019] **FIG. 3** is an elevation view of an embodiment of the present invention illustrating a drop ball seated in a yieldable seat of surge reduction apparatus with the ports of that apparatus in open position.

[0020] **FIG. 4** is an elevation view of an embodiment of the present invention illustrating the surge reduction apparatus of **FIG. 3** with the ports of that apparatus in closed position.

[0021] **FIG. 5** is an elevation view of an embodiment of the present invention illustrating second drop ball seated in yieldable seat of a collet finger sleeve with the ports in open position.

[0022] **FIG. 6** is an elevation view of an embodiment of the present invention illustrating the collet finger sleeve blocking the collet finger ports.

[0023] **FIG. 7** is an elevation view of an embodiment of the present invention illustrating the drop ball seated in yieldable seat of a drop ball sub apparatus with the port of that apparatus in open position.

[0024] **FIG. 8** is an elevation view of an embodiment of the present invention illustrating a flapper valve actuator ball being forced through a yieldable seat and drop ball sub apparatus with ports in closed position.

[0025] **FIG. 9** is an elevation view of an embodiment of the present invention illustrating the flapper valve actuator ball engaging a float collar.

[0026] **FIG. 10** is an elevation view of an embodiment of the present invention illustrating a drop ball being pressured through yieldable seat in the drop ball sub apparatus.

[0027] **FIG. 11** is an elevation view of an embodiment of the present invention illustrating a dart being pumped downhole behind cement.

[0028] **FIG. 12** is an elevation view of an embodiment of the present invention illustrating the dart of **FIG. 11** being pumped downward through drill string and engaging a seat in a wiper plug assembly.

[0029] **FIG. 13** is an elevation view of an embodiment of the present invention illustrating a wiper plug assembly being wound downward through a tubular member and forcing cement downward through float equipment, out of tubular member, and upwards into annulus between tubular member and formation.

[0030] **FIG. 14A** is an enlarged section view of the wiper plug assembly with collet fingers engaging wiper plug upper flange.

[0031] **FIG. 14B** is an enlarged section view of the dart engaging wiper plug assembly with collet fingers moving radially inward and releasing wiper plug.

[0032] **FIG. 15** is an elevation view of an embodiment of the present invention illustrating a dual wiper plug apparatus.

[0033] **FIG. 16** is an enlarged section view of the latching mechanism connecting the upper liner wiper plug to the lower liner wiper plug.

[0034] **FIG. 17** is an enlarged section view of the latching mechanism as it releases the lower liner wiper plug from the upper liner wiper plug.

[0035] **FIG. 18** is an elevation view of an embodiment of the present invention without an actuator ball sleeve illustrating flow path of the drilling fluid facilitating surge pressure reduction as tubular member is run downhole.

[0036] **FIG. 19** is an elevation view of an embodiment of the present invention without an actuator ball sleeve illustrating the drop ball resting on the actuator ball with the collet finger sleeve blocking the collet finger ports.

[0037] **FIG. 20** is an elevation view of an embodiment of the present invention without an actuator ball sleeve illustrating a flapper valve actuator ball being forced through a yieldable seat.

[0038] **FIG. 21** is an enlarged section view of the four plug embodiment of the present invention illustrating the drop ball seated in yieldable seat of a drop ball sub apparatus with the port of that apparatus in open position.

[0039] **FIG. 22** is an enlarged section view of the four plug embodiment of the present invention illustrating the drop ball seated in yieldable seat of a drop ball sub apparatus with the port of that apparatus in closed position.

[0040] **FIG. 23** is an enlarged section view of the four plug embodiment of the present invention illustrating a dart being pumped downward through drill string and engaging a seat in the lower liner wiper plug assembly.

[0041] **FIG. 24** is an enlarged section view of the four plug embodiment of the present invention illustrating the latching mechanism as it releases the lower liner wiper plug from the upper liner wiper plug and moving axially downward to engage the float equipment.

[0042] **FIG. 25** is an enlarged section view of the four plug embodiment of the present invention illustrating actuator ball engaging the float equipment.

[0043] **FIG. 26** is an enlarged section view of the four plug embodiment of the present invention illustrating the actuator ball activating the flapper valves of the float equipment.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

[0044] A description of certain embodiments of the present invention is provided to facilitate an understanding of the invention. This description is intended to be illustrative and not limiting of the present invention. In the appended claims, the term "tubular member" is intended to embrace either a "casing liner," a "subsea casing string," or a "drilling/production liner."

[0045] With reference first to **FIG. 1**, the general components of a system are illustrated in which apparatus in accordance with the present invention is used. A mast M suspends a traveling block TB. The traveling block, in turn,

supports a top drive TD which moves vertically on a block dolly BD. An influent drilling fluid line L supplies the top drive TD with drilling fluid from a drilling fluid reservoir (not shown). A launching manifold LM connects to a drill string S. The drill string S comprises numerous pipes which extend down into the borehole BH, and the number of such pipes is dependent on the depth of the borehole BH. A flow diverting device B is connected between the bottom end of drill string S and the top of running tool **162**. A tubular member, such as casing liner **161**, is suspended from running tool **162**. Float equipment, e.g. float collar **160**, is fastened near the bottom of the casing liner **161**.

[**0046**] Solidified cement CE**1** fixes a surface casing SC to the surrounding formation F. The surface casing SC contains an opening O in the uppermost region of the casing adjacent to the top. The opening O controls return of drilling fluid as it travels up the annulus between the drill string S and the surface casing SC.

[**0047**] Solidified cement CE**2** fixes an intermediate casing IC to the surrounding formation F. The intermediate casing IC is hung from the downhole end of the surface casing SC by a mechanical or hydraulic hanger H.

[**0048**] The annulus between the drill string S and the intermediate casing IC is greater in area than the annulus between the casing liner **161** and the intermediate casing IC. While the present invention is not intended to be limited to use in tight or close clearance casing runs, the benefits of the present invention are more pronounced in tight clearance running, since as the area is reduced and the pressure (pressure is equal to weight/area) is increased.

[**0049**] Referring now to **FIG. 2**, apparatus in accordance with the present invention comprises running tool **162** which is connected to the top of casing liner **161** and which has an axial bore therethrough. In one embodiment of the present invention, a flow diverter tool B is removably connected between drill string S and running tool **162**, and in another embodiment of the present invention, no such diverter tool is employed. Diverter tool B, when used, is preferably a diverter device as disclosed in the '881 patent. The diverter tool B comprises a housing **183** having at least one housing flow port **169**A, a yieldable seat **173**, and a sleeve **170** having at least one sleeve flow port **169**B. When diverter tool B is in the "open port position," sleeve **170** is arranged such that housing flow port **169**A and sleeve flow port **169**B are aligned. This provides passage for drilling fluid to flow from inside of housing **183** to annulus between drill string S and the cemented in place casing **205**. When the diverter tool B is in the "closed port position," sleeve **170** has been indexed axially downward so that housing flow port **169**A and sleeve flow port **169**B are not axially aligned and the flow passage is blocked.

[**0050**] Wiper plug assembly WP is suspended inside casing liner **161** from running tool **162** by the running tool S**2** for the wiper plug, one end of which is connected to running tool **162**. As described in U.S. patent application Ser. No. 09/541,526, file Apr. 3, 2000, the wiper plug WP is releasably connected to the second end of the running tool S**2** by collet fingers **168**. The openings or ports between collet fingers **168** provide communication to the void above wiper plug fins **163**. Drilling fluid flowing upward from drop ball sub **166** to flow diverter device B passes through the ports between collet fingers **168** and fills the void above wiper plug fins **163**. When casing liner **161** has been lowered to full depth, sleeve **171** may be indexed axially downward to block flow through the ports between collet fingers **168**, thereby isolating the wiper plug fins **163** from internal pressure.

[**0051**] Drop ball assembly DB is attached to the bottom of wiper plug assembly WP. The drop ball assembly DB comprises a housing **166** having at least one housing flow port **167**A, a yieldable seat **175**, a sleeve having at least one sleeve flow port **167**B, an actuator ball **201**, and a second yieldable seat **176**. Before the release of actuator ball **201**, sleeve **172** is arranged in the "open port position" such that housing flow port **167**A and sleeve flow port **167**B are aligned. These aligned ports provide a passage for drilling fluid to flow as discussed below.

[**0052**] Float equipment **160**, which may for example be a float collar, is located at or near the bottom of casing liner **161** and contains flapper valves which are actuated by the release of actuator ball **201**. The diameter of actuator ball **201** is greater than the smallest diameter in the drill string and corresponds to the diameter of the bore of the float equipment. The diameter of the bore of the float equipment is also greater than the smallest diameter in the drill string.

[**0053**] Still referring to **FIG. 2**, in operation, apparatus in accordance with one embodiment of the present invention is intended to be run down a borehole through drilling fluid while in the open port position. In the "open port position," sleeve **170** of flow diverter device B (when used), sleeve **171** of wiper plug assembly WP, and sleeve **172** of drop ball sub DB are positioned such that drilling fluid may follow flow path FP upward through the bore of float equipment **160**. Following the flow path, drilling fluid then flows into the housing of drop ball sub DB above actuator ball **201** via aligned housing flow port **167**A and sleeve flow port **167**B, and through the bore in the wiper plug. Drilling fluid then fills the void above the wiper plug fins **163** via the openings between collet fingers **168**. The drilling fluid then flows through drill string S**2** and running tool **162**, into diverter device B, and finally out of diverter device B into the annulus between drill string S and the cemented-in-place casing **205** via aligned flow hole **169**A and flow port **169**B. The benefits of surge pressure reduction are thus provided.

[**0054**] In the embodiment of the present invention where no diverter tool is utilized, drilling fluid flows through drill string S**2** and running tool **162** and through drill string S.

[**0055**] Referring to **FIG. 3**, once the casing liner has been lowered to full depth and cementing operations are ready to begin, a drop ball **200** is dropped down drill string S and into yieldable seat **173** of flow diverter device B. If a diverter tool is not used, the first landing point for drop ball **200** is yieldable seat **174**. The diameter of drop ball **200** is less than the smallest diameter of any restriction in drill string S. For example, a 2¼ inch diameter drop ball may be used for a drill string with inside diameter of 3 inches.

[**0056**] Referring now to **FIG. 4**, drilling fluid is pressurized to a predetermined level above drop ball **200** such that sleeve **170** is moved axially downward blocking housing flow holes **169**A. The flow diverter device B is now in the "closed port position."

[**0057**] Referring to **FIG. 5**, drilling fluid above drop ball **200** is further pressurized such that the yieldable seat **173**

expands, and drop ball **200** passes through yieldable seat **173** and lands in yieldable seat **174** of collet finger sleeve **171**. Drilling fluid is then pressurized above drop ball **200** such that sleeve **171** is moved axially downward which closes the ports formed by the spaces between collet fingers **168** as illustrated in **FIG. 6**.

[**0058**] Referring to **FIG. 7**, drilling fluid above drop ball **200** is further pressurized such the yieldable seat **174** expands and drop ball **200** passes through expanded yieldable seat **174** and lands in seat **175** of drop ball sub **176**. Drilling fluid is then pressurized to a predetermined level above drop ball **200** such that sleeve **172** is moved axially downward. As sleeve **172** moves downward, the sleeve engages float valve actuator ball **201** and forces the ball through yieldable seat **176** as illustrated in **FIG. 8**.

[**0059**] With reference to **FIG. 9**, the float valve actuator ball **201** is released from drop ball sub **166** and moves downward toward the bottom of casing liner **161** where ball actuates flapper valves of float equipment **160**. Float valve actuator ball **201** then continues to bottom of casing liner **161** and exits casing liner **161** where it may subsequently be grinded into filings by downhole drill equipment.

[**0060**] With reference to **FIG. 10**, drilling fluid above drop ball **200** is further pressurized such that yieldable seat **175** is expanded and drop ball **200** passes through the expanded seat **175**, and exits casing liner where it may subsequently be grinded into filings by downhole drill equipment. At this time, the cementing operations are ready to commence.

[**0061**] With reference to **FIG. 11**, once cement pumping is complete, a drill pipe dart **202** is inserted into top of drill string S and displaced downward by drilling fluid so that dart **202** establishes a barrier between drilling fluid and cement CE**3**. With reference to **FIGS. 12 and 14**A, once the dart **202** reaches wiper plug assembly WP, the dart engages a receptacle sleeve **182**. The dart **202** conventionally comprises a nose section with a barbed "shark tooth" profile "c-ring" for connection with receptacle sleeve **182** and elastomer o-ring seals. The receptacle sleeve **182** comprises a mating tooth profile for connection with the dart **202** and a seal bore for receiving the O-rings. In this way, the dart **202** and receptacle sleeve **182** form a sealed mechanical connection.

[**0062**] With reference to **FIGS. 13 and 14**B, a yieldable, disk-shaped flat washer **181** supports dart receptacle sleeve **182** in the wiper plug assembly WP. Flat washer **181** is mounted in such a way that force imparted by dart **202** is carried through the washer **181**. As drilling fluid is further pressured above dart **202**, the flat washer **181** yields and deflects slightly downward. The deflection of the flat washer **181** allows the receptacle sleeve **182** to move slightly downward. The dart receptacle sleeve **182** serves as a backup to collet fingers **168** formed on the end of the drill string S**2**. The collet fingers **168** are formed such that their lower outer ends comprise wedge surfaces **179**A, which are captured in a mating recess **179**B in the top flange portion of the wiper plug assembly WP. As the dart receptacle sleeve **182** displaces downward due to the pressure above the dart **202**, the radial support for the collet fingers **168** is lost. The loss of radial support allows the wedge surfaces **179**A to force the collet fingers **168** radially inward thereby releasing the wiper plug assembly WP from the drill string S**2**.

[**0063**] With reference still to **FIG. 13**, once released from drill string S**2**, the wiper plug WP maybe pumped down the casing liner **161** thereby displacing cement CE**3** in the casing liner down through the flapper valves of float equipment **60**. The flapper valves of the float equipment **160** should prevent any "back-flow" or "u-tube action" of the cement.

[**0064**] Once the wiper plug WP has been pumped to the bottom of the casing liner, the cement is allowed to harden, thereby completing the hanging and cementing job.

[**0065**] In another embodiment of the present invention, the drop ball sub is used to launch an actuator ball without the sliding sleeve **172** (**FIG. 2**). Referring to **FIG. 18**, the drop ball assembly DB is attached to the bottom of wiper plug assembly WP and comprises a housing **166** having a set of housing flow holes **167**A, an actuator ball **201**, and a yieldable seat **176**. The set of housing flow holes **167**A are sized to permit the creation of a pressure differential between the annular space within the housing **166** and the space outside the housing when drilling fluid pressure is increased above the actuator ball **201** to launch the actuator ball through the yieldable seat **176**. In a preferred embodiment, the set of housing flow holes comprises four holes of 1 inch diameter size such that the actuator ball may be launched at a pressure differential of approximately 100 psi. However it is intended that the holes may be sized to accommodate whatever pressure differential is required to launch the actuator ball.

[**0066**] With reference to **FIG. 19**, once drop ball **200** is used to move the sleeve **171** axially downward to close the ports formed by the spaces between collet fingers **168**, drilling fluid above drop ball **200** is further pressurized such that the yieldable seat **174** expands and drop ball **200** passes through expanded yieldable seat **174**. The drop ball **200** lands on top of the actuator ball **201** within the drop ball housing **166** thus creating a clear bore through drill string S**2**. Drilling fluid is then pressurized to a predetermined level above actuator ball **201** such that the actuator ball is forced through yieldable seat **176** as illustrated in **FIG. 20**. This is accomplished by pumping drilling fluid from the drill string into the drop ball housing **166** at a rate greater than the rate at which the drilling fluid can exit the housing via the set of flow ports **167**A. This creates a pressure differential where the drilling fluid pressure is greater within the drop ball housing **166** than in the annular space between the drop ball housing and the casing liner **161**. When the drilling fluid pressure differential within the drop ball housing **166** is increased to a predetermined level, the yieldable seat yields to launch the actuator ball from the drop ball housing. In a preferred embodiment, the yieldable seat **176** of the drop ball housing **166** is fabricated to yield at a pressure differential of approximately 100 psi.

[**0067**] With reference to **FIG. 20**, the float valve actuator ball **201** is released from drop ball sub DB and moves downward toward the bottom of casing liner **161** where ball actuates the flapper valves FC**2** of float equipment **160** as illustrated in **FIG. 10**. Float valve actuator ball **201** and drop ball **200** then continue to bottom of casing liner **161** and exit casing liner where they may subsequently be grinded into filings by downhole drill equipment. At this time, the cementing operations are ready to commence.

[**0068**] The foregoing has described what may be referred to as a "two plug system" having one wiper plug and one dart which is used in the release of the wiper plug. With

reference to **FIG. 15**, another embodiment of the present invention comprises an upper liner wiper plug WP1 and a lower liner wiper plug WP2. This type of system may be referred to as a "four plug system" since it comprises two wiper plugs and two drill pipe darts to release the wiper plugs.

[**0069**] The four plug system of **FIG. 15** operates in substantially the same way as the two plug system. In both the two plug system and the four plug system, the apparatus is first run down a borehole until it reaches the required depth to hang a casing liner. At this depth, a drop ball is pumped down the drill string into yieldable seat of drop ball sub. Drilling fluid pressure is increased behind the drop ball to release an actuator ball from the drop ball sub to activate flapper valves of float collar.

[**0070**] With reference to **FIG. 15**, the four plug system comprises an upper liner wiper plug WP1 attached to drill string DS, a lower liner wiper plug WP2 attached to the upper liner wiper plug by release mechanism (see **FIG. 16**), and a drop ball sub DB attached to the bottom of the lower liner wiper plug.

[**0071**] With reference to **FIGS. 15 and 17**, after the flapper valve actuator ball **310** is released, a first drill string dart **400** is pumped down the drill string and into casing liner CL where the first dart engages a lower liner wiper plug WP2. Drilling fluid pressure is increased above the first dart **400** so that the lower liner wiper plug WP2 is released from an upper liner wiper plug WP1 and is pumped downward through the casing liner CL to displace contaminating drilling mud from the interior of the casing liner. At the bottom of the casing liner CL, drilling fluid pressure is further increased above the first dart **400** so that the lower liner wiper plug latches to the float collar FC. Next, cement is pumped downward through the casing liner CL and into the annulus between the borehole and the casing liner. Then, a second drill string dart (not shown) is pumped down the drill string and into the casing liner CL where the second dart engages an upper liner wiper plug WP1. Drilling fluid pressure is increased above the second dart so that the upper liner wiper plug WP1 is released from the drill string DS and is pumped downward through the casing liner CL to displace cement from the interior of the casing liner. At the bottom of the casing liner CL, drilling fluid pressure is again increased above the second dart so that the upper liner wiper plug WP1 latches to the lower liner wiper plug WP2.

[**0072**] With reference to **FIG. 16**, the release mechanism for releasing lower liner wiper plug WP2 from upper liner wiper plug WP1 comprises lower liner fingers **301** having wedge-shaped ends **301**A, upper liner finger receivers **300** having wedge-shaped recesses **300**A, a lower liner dart receptacle **302**, and a sleeve **303** having radial protrusions **303**A. Initially, the wedge-shaped ends **301**A of lower liner fingers **301** engage the wedge-shaped recesses **300**A of upper liner fingers **300**. The protrusions **303**A of sleeve **303** prevent the lower liner fingers **301** from moving radially inward and lock the wedge shaped-ends **301**A in the wedge-shaped recesses **300**A. The sleeve **303** is itself restrained by shear pins **304**.

[**0073**] With reference to **FIG. 17, a** drill pipe dart **400**, having a diameter less than the diameter of upper liner receptacle **305**, is dropped into the drill string and lands in lower liner dart receptacle **302**. Drilling fluid pressure is increased above dart **400** to shear pins **304** (shown in **FIG. 16**). Sleeve **303** is now unrestrained. Drilling fluid pressure is further increased above dart **400** to push sleeve **303** downward so that protrusions **303**A move below wedge-shaped ends **301**A of lower liner fingers **301**. The lower liner fingers **301** are now free to move radially inward to disengage with wedge-shaped recesses **300**A of upper liner fingers **300**. Drilling fluid pressure above dart **400** is increased to pump the released lower liner wiper plug WP2 downward displacing drilling mud from the inside walls of the casing liner CL. Once the lower liner wiper plug WP2 reaches the bottom of the casing liner CL, drilling fluid pressure is further increased above the dart **400** to latch the lower liner wiper plug to float collar FC (shown in **FIG. 15**). Cementing operations may then be commenced.

[**0074**] With reference to **FIG. 15**, the upper liner wiper plug WP1 may then be released from the drill string DS by following the same procedure described above to release wiper plug WP (shown in **FIGS. 12, 13, 14**A, and **14**B) in the two plug system. Once the upper liner wiper plug WP1 is pumped to the bottom of the casing liner CL and is latched to the lower liner wiper plug WP2, the cement is allowed to harden, thereby completing the hanging and cementing job.

[**0075**] In another embodiment of the four plug system, before the float equipment is activated, the lower liner wiper plug assembly is pumped downward such that the drop ball sub engages the float equipment and then releases the actuator ball to activate the flapper valves of the float equipment. Referring to **FIG. 21**, before the release of the lower liner wiper plug WP2, a drop ball **403** is dropped from the drill string into the yieldable seat **401** of the sliding sleeve **402**. Drilling fluid is then pressurized to a predetermined level above drop ball **403** such that sleeve **402** is moved axially downward blocking the set of housing flow holes **167**A. The drop ball sub DB is now in the "closed port position" (as shown in **FIG. 22**). Drilling fluid pressure is increased above the drop ball **403** such that the seat **401** yields thereby permitting the drop ball to pass through and land on the actuator ball **201**. Cementing operations can now commence.

[**0076**] With reference to **FIG. 23**, after the drop ball sub DB is set to the closed port position, a first drill string dart **400** is pumped down the drill string by cement and into casing liner CL where the first dart engages a lower liner wiper plug WP2. Cement pressure is increased above the first dart **400** so that the lower liner wiper plug WP2 is released from an upper liner wiper plug WP1 and is pumped downward through the casing liner CL to displace contaminating drilling mud from the interior of the casing liner. At the bottom of the casing liner CL, cement pressure is further increased above the first dart **400** so that the lower liner wiper plug latches to the float collar FC.

[**0077**] Referring to **FIG. 24**, cement pressure is again increased to a predetermined level above the first dart **400** to release the first dart **400** from engagement with the lower liner wiper plug WP2. The dart **400** lands in the drop ball sub DB near the drop ball **403** and above the actuator ball **201**.

[**0078**] Referring to **FIG. 25**, cement pressure is increased to a predetermined level above the actuator ball **201** to launch the actuator ball from the drop ball sub DB into the axial bore of the float collar FC. The actuator ball **201** lands in the seat FC**3** of the actuating sleeve FC**1** of the float collar FC.

[0079] Referring to **FIG. 26**, cement pressure is again increased to a predetermined level above the actuator ball **201** to displace the actuating sleeve FC1 from the bore of the float collar FC thus allowing the flapper valves FC2 of the float collar to activate to any back-flow of the cement. The upper liner wiper plug is released and the cementing job is completed as described above.

What is claimed is:

1. A drop ball mechanism for use within a tubular member being run on a drill string in a wellbore containing drilling fluid, comprising:

a wiper plug assembly releasably connected to the drill string within the tubular member near the top of the tubular member; and

a drop ball housing connected to the wiper plug assembly below the wiper plug assembly and having an axial bore therein and a set of flow holes formed therein for establishing communication between the axial bore of the drop ball housing and the tubular member below the wiper plug assembly, said drop ball housing including a drop ball having a diameter greater than the inside diameter of the drill string, said set of flow holes having a diameter to permit the creation of a pressure differential between the axial bore of the drop ball housing and the tubular member below the wiper plug assembly when drilling fluid is pumped from the drill string into the drop ball housing, said pressure differential being of sufficient magnitude to cause the drop ball to release from the drop ball housing.

2. The drop ball mechanism of claim 1, wherein the tubular member comprises float equipment attached to the tubular member near the bottom of the tubular member, said float equipment having an axial bore through which drilling fluid may flow, said axial bore having a diameter greater than the inside diameter of the drill string, said float equipment including a plurality of flapper valves which are activated by the drop ball after it is released from the drop ball housing.

3. The drop ball mechanism of claim 2, wherein the wiper plug assembly has an axial bore therethrough and a receptacle in the axial bore for receiving a drill pipe dart.

4. Apparatus for running a tubular member in a wellbore containing drilling fluid using a drill string, comprising:

a running tool connected to the top of the tubular member and having an axial bore therethrough;

float equipment attached to the tubular member near the bottom of the tubular member, said float equipment having an axial bore therethrough which drilling fluid and cement may flow, said axial bore having a diameter greater than the inside diameter of the drill string, said float equipment including a plurality of flapper valves;

a wiper plug assembly releasably connected to the drill string within the tubular member near the top of the tubular member, said wiper plug assembly having an upper end, a lower end, and an axial bore formed therethrough, said wiper plug assembly having a receptacle in said axial bore for receiving a drill string dart to release the wiper plug assembly from the drill string and to move the wiper plug assembly downward to engage the float equipment; and

a drop ball mechanism connected to the lower end of the wiper plug assembly, said drop ball mechanism including a releasable drop ball having a diameter greater than the inside diameter of the drill string, said drop ball being released to activate the flapper valves of the float equipment once the wiper plug assembly engages the float equipment.

5. The apparatus of claim 4, wherein the drop ball mechanism further comprises a drop ball housing for releasably connecting the drop ball to the lower end of the wiper plug assembly, said drop ball housing having a set of flow holes formed above the drop ball through which drilling fluid may flow into the bore of the wiper plug.

6. The apparatus of claim 5, further comprising a diverter tool connected between the drill string and the running tool, said diverter tool having an open port position and a closed port position, said diverter tool being in the open port position during the running in of the tubular member.

7. The apparatus of claim 4, wherein the diverter tool comprises:

a housing connected to the drill string, said housing having a set of housing flow holes formed therein;

a sleeve within the housing having a set of sleeve flow ports formed therein; said sleeve being initially positioned within the housing such that an open port position exists;

a yieldable drop ball seat connected to the sleeve; and

an axial indexing means to move the sleeve between the open port position and the closed port position.

8. The apparatus of claim 4, further comprising a wiper plug release mechanism for releasing the wiper plug from the drill string, said release mechanism comprising:

a plurality of fingers which are formed on the end of the drill string such that an opening exists between each adjacent finger, said fingers having lower outer ends that have wedge-shaped surfaces for engagement with the dart receptacle of the wiper plug; and

a yieldable, circular flat washer in the wiper plug which supports the receptacle and which allows the fingers to disengage from the receptacle when the dart is received and when pressure is increased behind the dart.

9. Apparatus for running a tubular member in a wellbore containing drilling fluid using a drill string, comprising:

a running tool connected to the top of the tubular member and having an axial bore therethrough;

float equipment attached to the tubular member near the bottom of the tubular member, said float equipment having an axial bore therethrough which drilling fluid and cement may flow, said axial bore having a diameter greater than the inside diameter of the drill string, said float equipment including a plurality of flapper valves;

an upper liner wiper plug assembly having an upper end which is releasably connected to the drill string within the tubular member near the top of the tubular member, a lower end, and an axial bore formed therethrough, said upper liner wiper plug assembly including a receptacle in said bore for receiving a drill string dart;

a lower liner wiper plug assembly having an upper end which is releasably connected to the lower end of the

upper liner wiper plug assembly, a lower end, and an axial bore formed therethrough, said lower liner wiper plug assembly including a receptacle in said bore for receiving a drill string dart to release the lower liner wiper plug assembly from the drill string and to move the lower liner wiper plug assembly downward to engage the float equipment; and

a drop ball mechanism connected to the lower end of the lower liner wiper plug assembly, said drop ball mechanism including a releasable drop ball having a diameter greater than the inside diameter of the drill string, said drop ball being released to activate the flapper valves of the float equipment once the lower liner wiper plug assembly engages the float equipment.

10. The apparatus of claim 9, further comprising a diverter tool which is connected between the drill string and the running tool, said diverter tool having an open port position and a closed port position, said diverter tool being in the open port position during the running in of the tubular member.

11. The apparatus of claim 10, wherein the diverter tool comprises:

a housing which is connected to the drill string, said housing having a set of housing flow holes formed therein;

a sleeve within the housing having a set of sleeve flow ports formed therein, said sleeve being initially positioned within the housing such that an open port position exists;

a yieldable drop ball seat which is connected to the sleeve; and

an axial indexing means to move the sleeve between the open port position and the closed port position.

12. The apparatus of claim 10, wherein the upper liner wiper plug is releasably connected to the drill string by a mechanism which comprises:

a plurality of fingers which are formed on the end of the drill string such that an opening exists between each adjacent finger, said fingers having lower outer ends that have wedge-shaped surfaces for engagement with the dart receptacle of the upper liner wiper plug; and

a yieldable, circular flat washer in the upper liner wiper plug which supports the receptacle and which allows the fingers to disengage from the receptacle when the dart is received and when pressure is increased behind the dart.

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