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(54) **DOWNHOLE MATERIAL-DELIVERY SYSTEM FOR SUBTERRANEAN WELLS**

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(57) **ABSTRACT**

Methods for releasing tracers into a well for diagnostic studies during subterranean-well operations comprise filling one or more hollow bodies with substances The system that comprise a cementing-plug-launching system, a drill string, casing, coiled tubing, wireline or combinations thereof. After the system is lowered into the well, the tracer substance may be remotely and safely released into the well.

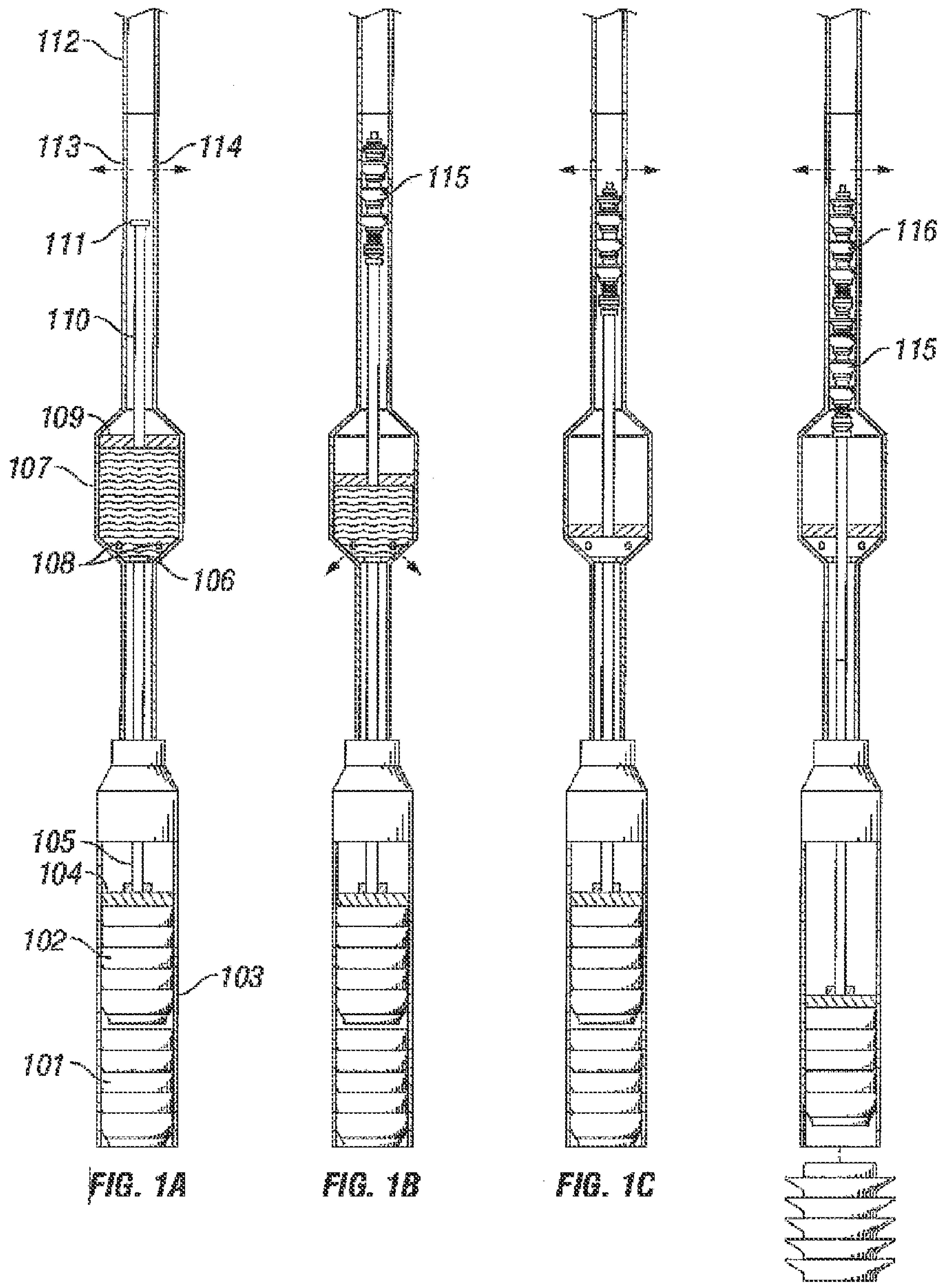

FIG. 1A FIG. 1B FIG. 1C FIG. 1D

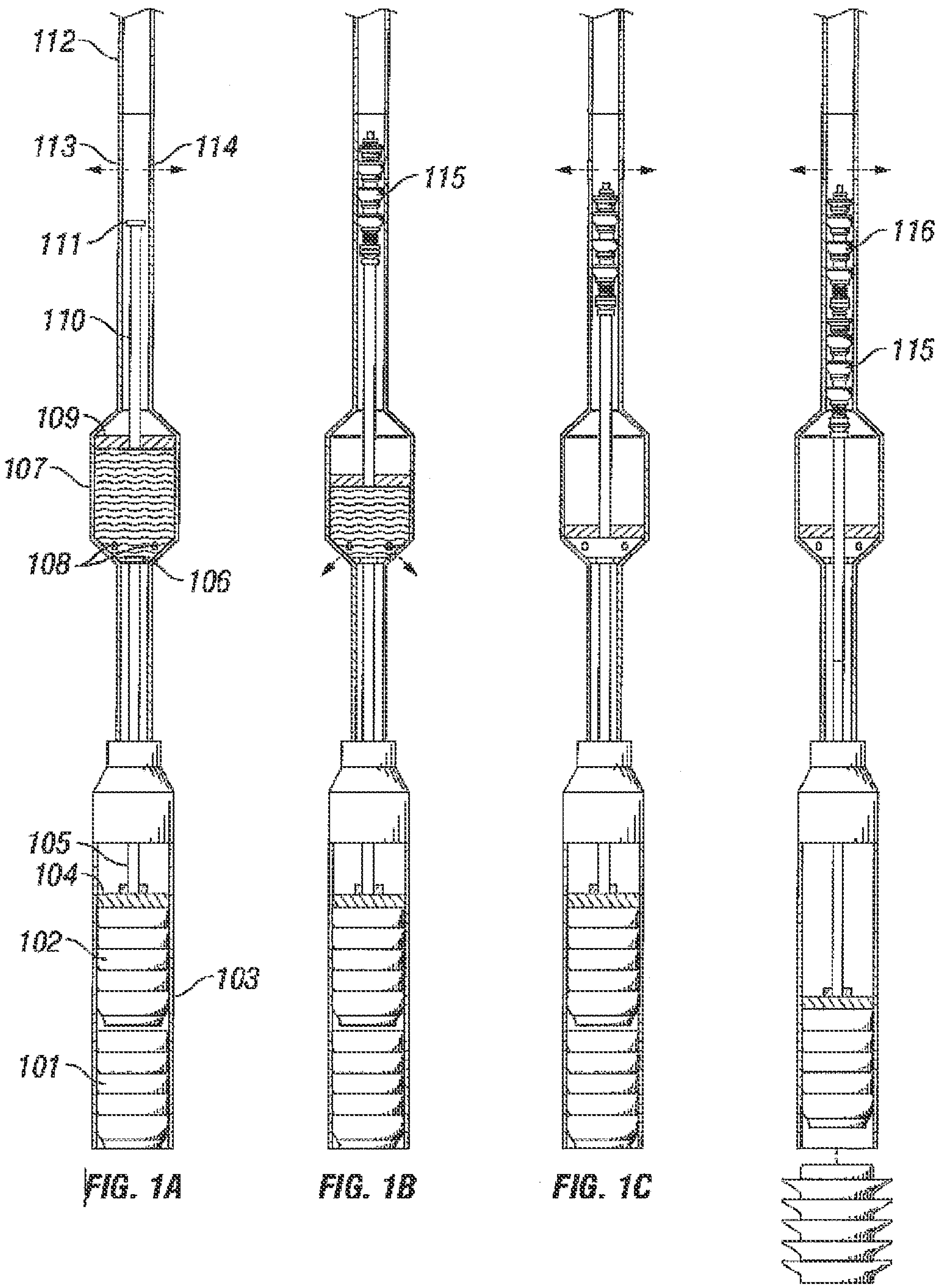
112
113
114
111
110
109
107
108
106
105
104
102
103
101
FIG. 1A
115
FIG. 1B
FIG. 1C
116
115
FIG. 1D

FIG. 1

FIG. 2

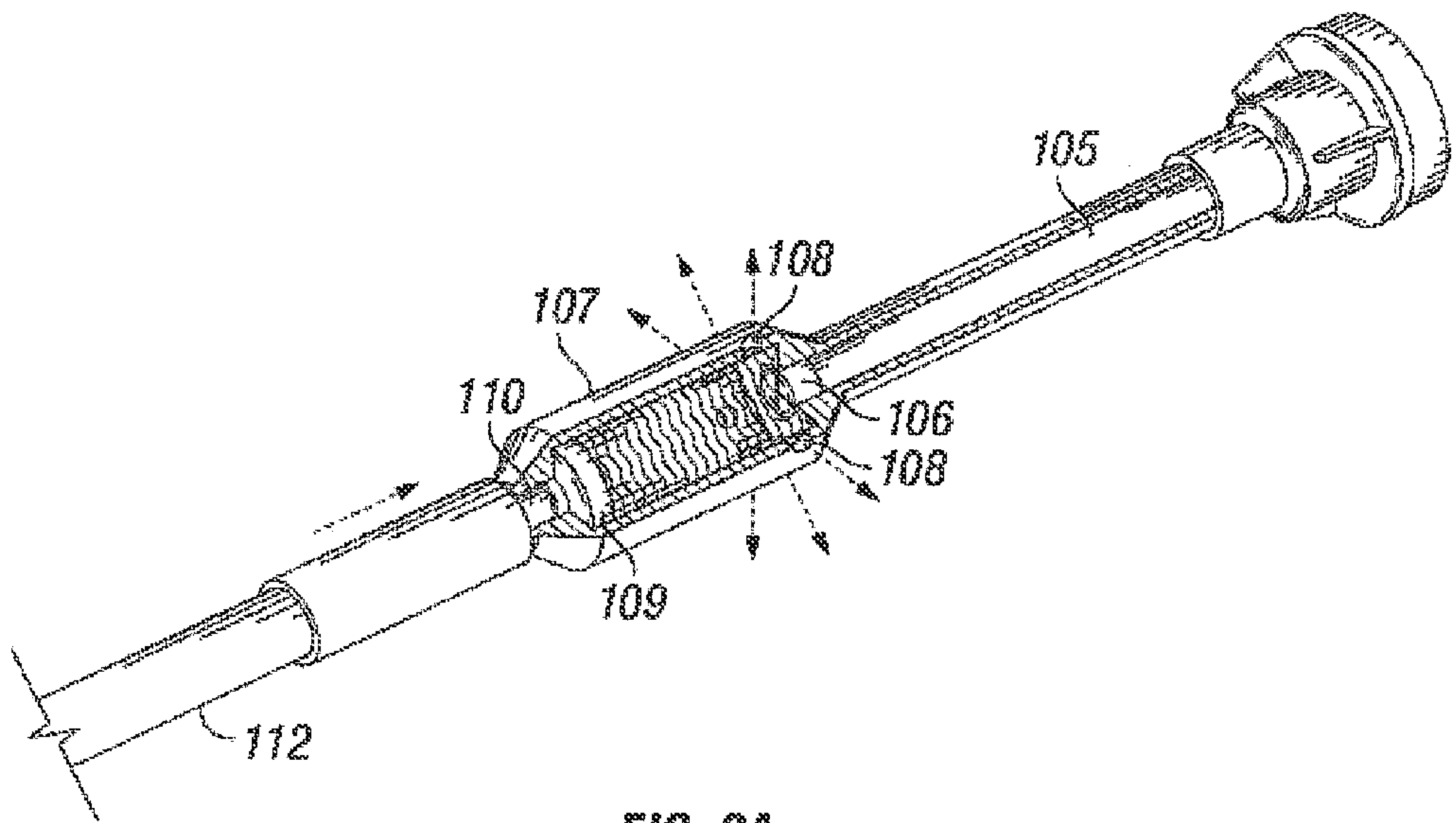

FIG. 2A

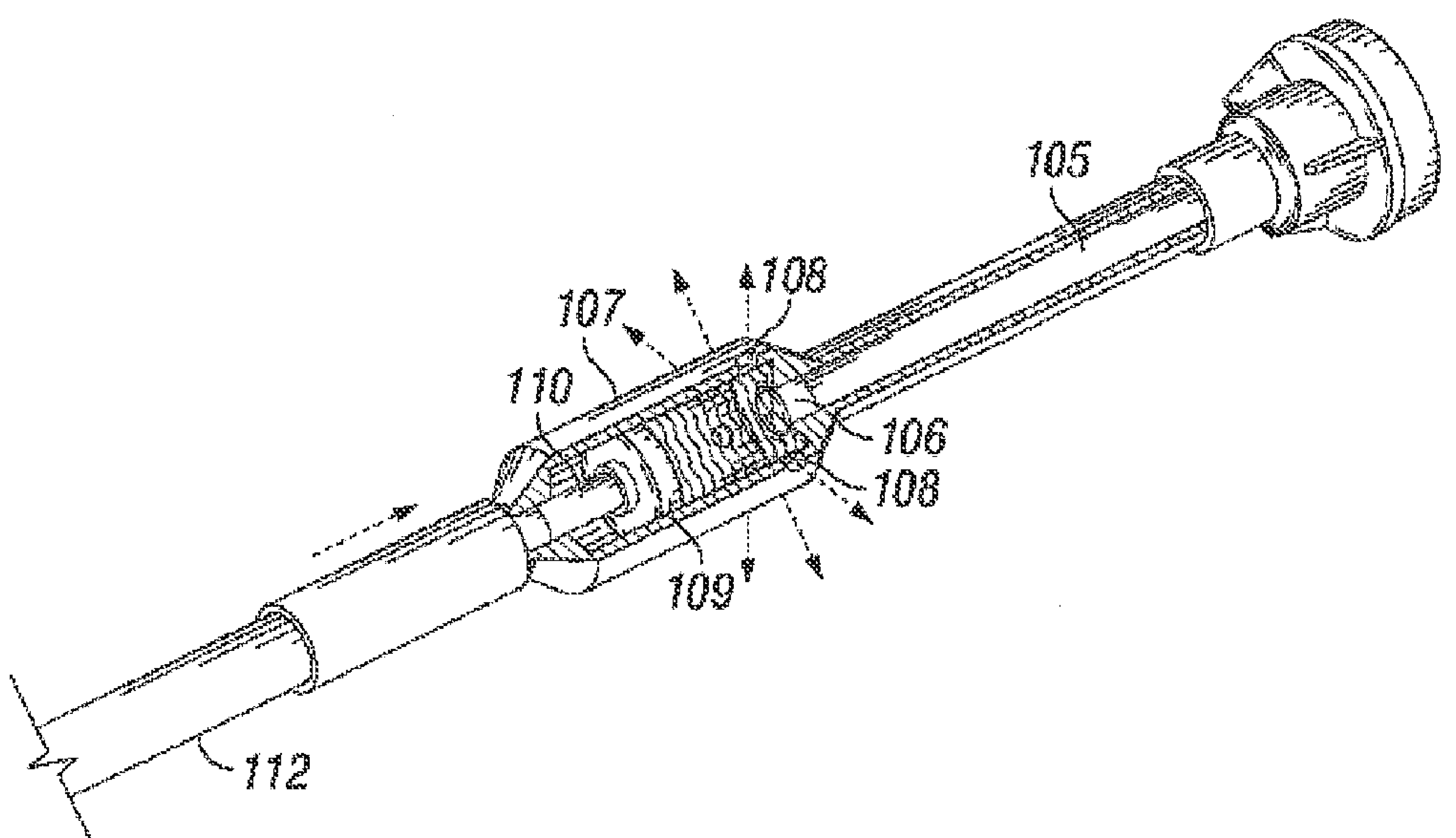

FIG. 2B

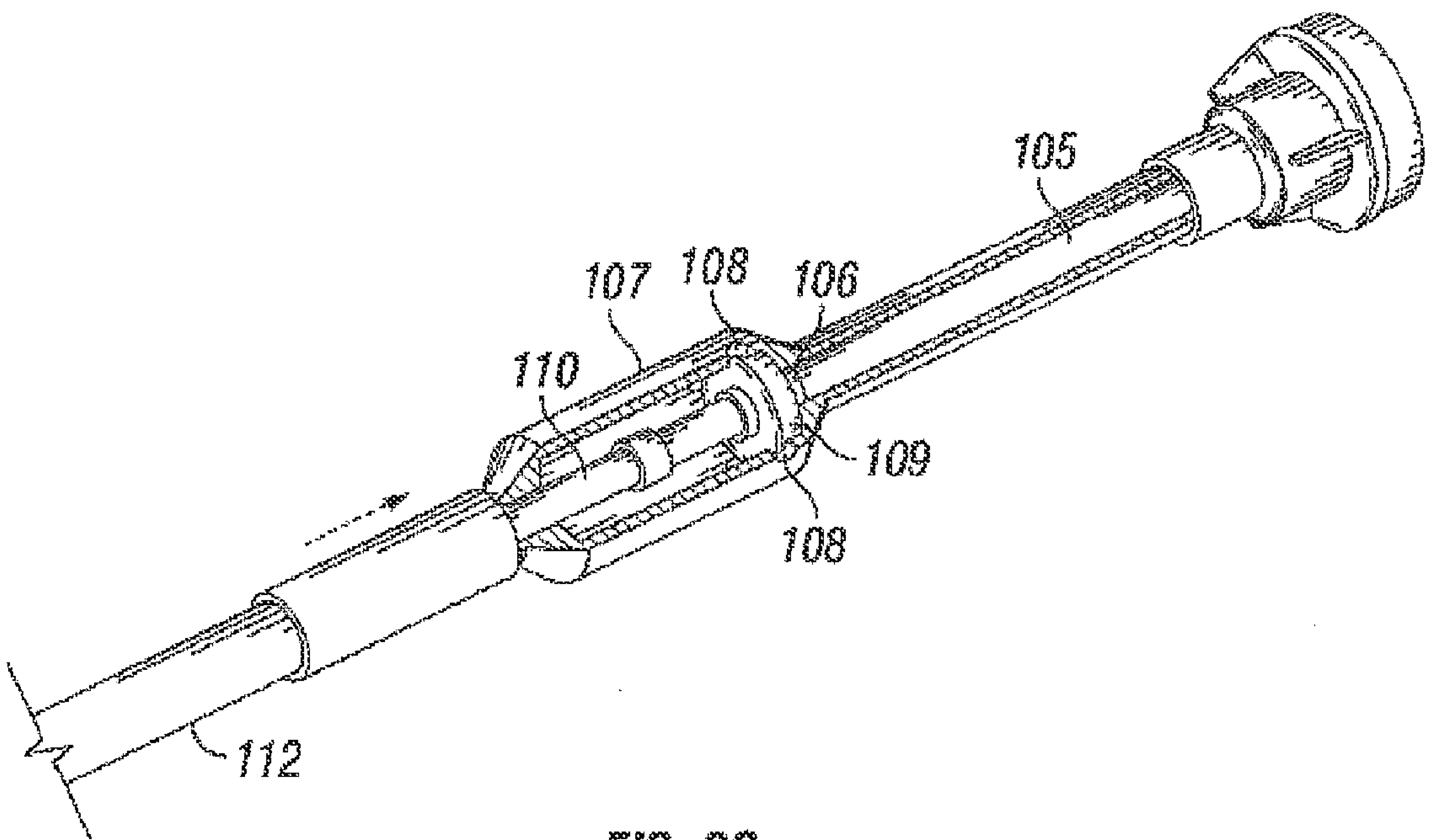

FIG. 2C

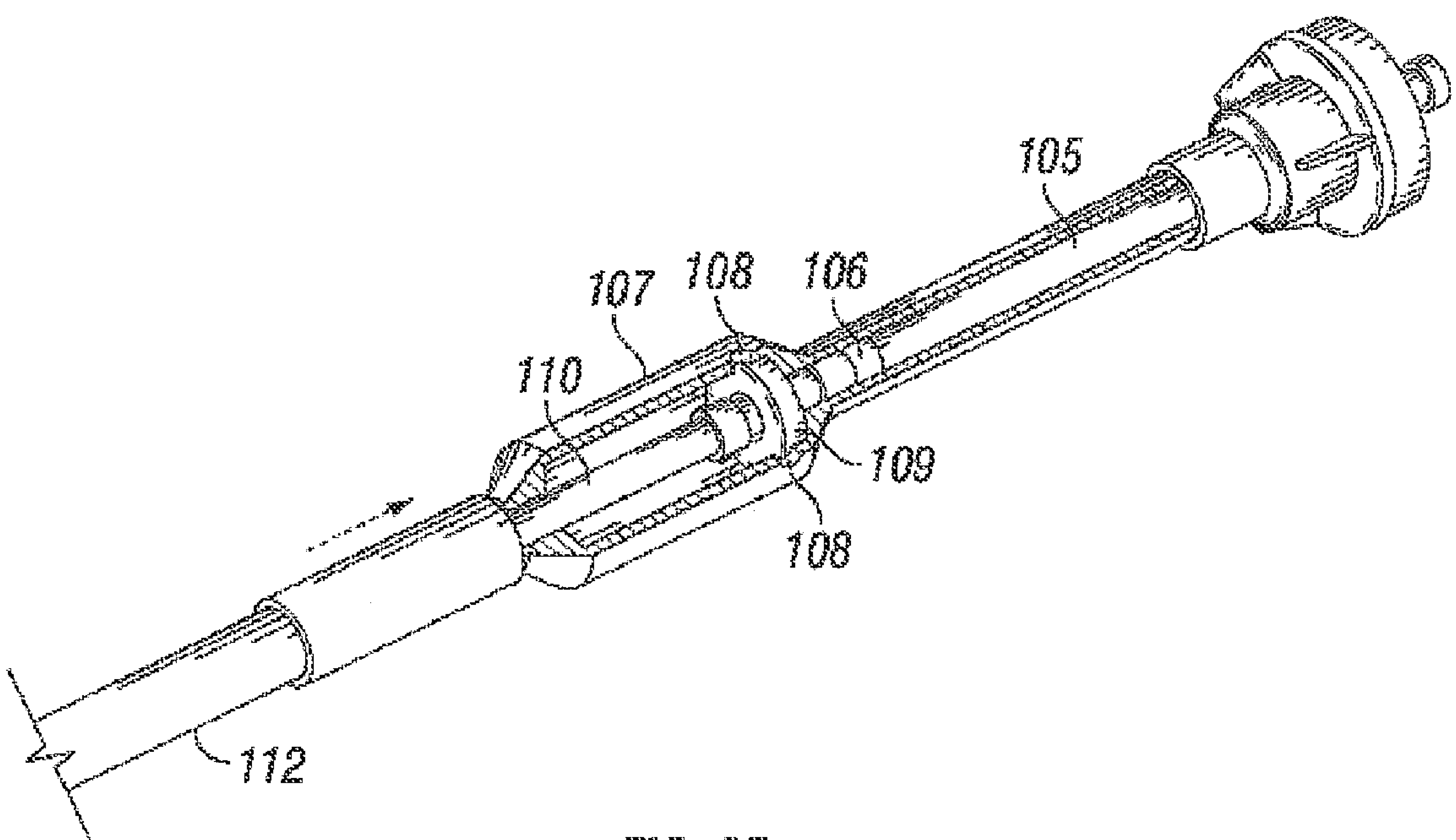

FIG. 2D

DOWNHOLE MATERIAL-DELIVERY SYSTEM FOR SUBTERRANEAN WELLS

BACKGROUND OF THE INVENTION

[0001] The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

[0002] The present invention is related in general to equipment for servicing subterranean wells. Particularly, the invention relates to an apparatus and methods for dispensing a material into a process-fluid stream.

[0003] Well construction, production and workover operations frequently involve the injection or circulation of process fluids that perform various functions. Common process fluids include, but are not limited to, drilling fluids, cement slurries, spacer fluids, chemical washes, matrix-acidizing fluids, hydraulic-fracturing fluids, completion fluids, formation-consolidation fluids and carrier fluids for sand control.

[0004] Under various circumstances, it is necessary to inject limited amounts of a material into the well. Such circumstances include (but are not limited to) injecting tracers to help operators monitor the status of a well-service operation, and introducing an activator such as a crosslinker to change the properties of the process fluid, filter cakes along the formation wall, or even fluids within the formation. Some of these materials may be hazardous. For example, they may be radioactive, flammable, corrosive, explosive or poisonous. Under these circumstances, devices and methods for isolating the hazardous substances from wellsite personnel would be desirable.

[0005] The material may be a fluid, a solid or both. In some cases the solid may be suspended in a fluid. In the case of fluids and solid suspensions, there are several common placement methods. One method is to pump a plug of material down the well, using process fluid as a displacement medium. A disadvantage of this technique is that the material may become diluted with process fluid during its journey to the intended well location, or it may react with components in the wellbore during transit. In addition, if the well is deep, a large volume of process-fluid may be required to transport the plug to the intended well location. If, for example, lost-circulation difficulties are being experienced, pumping large volumes of process fluid may damage the well.

[0006] Another material-transport method involves lowering a small-diameter tube (often coiled tubing) into the well, and pumping the material down the tube to its intended destination. The use of tubing solves many of the problems associated with pumping plugs, but the cost and risk of hanging a small-diameter tube into a wellbore is substantial. Also, the material to be injected may be corrosive and, as tubing walls tend to be thin compared to drillpipe or casing, the tube may become damaged.

[0007] Yet another material-transport method involves encapsulation. Placing a coating around the material, or making the material the internal phase of an emulsion, may provide protection as the material travels to its destination downhole. Methods for releasing the material may include time, temperature, shear, pH change and irradiation. However, these release mechanisms are not always reliable. If a wellbore operation is delayed, the material may be release prematurely. Also, the temperature at the intended destination may not be accurately known, and may change with time. The intended location may not be at the bottom of the well. Under these circumstances, shearing at a drill bit would not be the optimal solution. Chemical triggers and equipment for irradiation may not be available at the well site.

[0008] Thus, despite the valuable contributions of the prior art, there is a need for improved techniques by which a material may be safely delivered to an intended downhole location without having to contend with the problems and uncertainties described above.

SUMMARY OF THE INVENTION

[0009] The present invention provides the aforementioned need.

[0010] Embodiments relate to methods for measuring process-fluid loss in a subterranean well.

[0011] Further embodiments relate to the launching of tracers downhole in order to diagnose the location and/or severity of loss zones.

[0012] Even further embodiments pertain to improving wellsite safety when using hazardous substances to be launched downhole.

[0013] All aspects of the invention may be applied in oil and gas wells, geothermal wells, water wells, and wells for chemical waste disposal, enhanced recovery of hydrocarbons and carbon sequestration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** illustrates one example of the method by which a material may be launched into a process-fluid stream.

[0015] FIG. **2** presents an alternate view of the example shown in FIG. **1**.

DETAILED DESCRIPTION

[0016] During primary cementing it is usually desirable to minimize commingling between the various process fluids that travel through the casing—for example, drilling fluid and cement slurry. One way to minimize commingling involves using wiper plugs to separate fluids as they travel down the casing. Wiper plugs also clean the inner surface of the casing. Most cementing operations involve two wiper plugs: a bottom plug that separates cement slurry from drilling fluid, and a bottom plug that separates cement slurry from displacement fluid.

[0017] After the casing is installed in the wellbore, the annulus between the casing and the wellbore wall (or another casing string) is usually filled with drilling fluid. When primary cementing begins, the bottom plug is first launched into the casing, followed by the cement slurry. The cement slurry may be preceded by a spacer fluid, a chemical wash or both. The function of the bottom plug is to scrape traces of drilling fluid from the internal surface of the casing, and to prevent contact between the drilling fluid and the cement slurry.

[0018] The bottom-plug launching and conveyance through the casing arises from pressure applied by the cement slurry. When the bottom plug completes its journey through the casing, it becomes seated on float equipment installed at the bottom of the casing. Continued pumping exerts sufficient pressure to rupture a membrane at the top of the bottom plug, allowing the cement slurry to flow through an interior passage in the bottom plug, exit the bottom of the casing and continue into the annulus.

[0019] After sufficient cement slurry to fill the annulus has been pumped into the casing, the top plug is launched into the casing, and a displacement fluid is pumped behind the plug. The displacement fluid forces the plug through the casing.

The function of the top plug is to scrape traces of cement slurry from the internal surface of the casing, isolate the cement slurry from the displacement fluid and, upon landing on the bottom plug, seal the casing interior from the annulus. Unlike the bottom plug, the top plug has no membrane or interior passage through which fluids may flow.

[0020] A thorough description of the primary cementing process and the equipment employed to perform the service may be found in the following references. (1) Piot B. and Cuvillier G.: "Primary Cementing," in Nelson E. B. and Guillot D. (eds.): *Well Cementing*-2nd Edition, Houston: Schlumberger (2006): 459-501. (2) Leugemors E., Metson J., Pessin J.-L., Colvard R. L., Krauss C. D. and Plante M.: "Cementing Equipment and Casing Hardware," in Nelson E. B. and Guillot D. (eds.): *Well Cementing*-2nd Edition, Houston: Schlumberger (2006): 343-434.

[0021] Wiper plugs are usually launched from a cementing head that is attached to the casing near the drilling rig. The casing rises from the bottom of the open hole to the rig floor. However, for subsea completions, the problem becomes more complicated, and fluid isolation becomes more and more critical as water depth increases. It thus becomes impractical to launch wiper plugs from the surface. Therefore, the cementing head containing the wiper plugs rests on the seafloor, and the top of the casing ends at the mudline. Drillpipe connects the top of the casing to the rig floor on the surface. During the cementing process, darts are released into the drillpipe on surface, travel through the drillpipe to the seafloor and, upon arrival, trigger the release of the wiper plugs.

[0022] After the first dart is launched, cement slurry is pumped behind it. When the first dart lands inside the cementing head, the bottom plug is released. The second dart is launched after sufficient cement slurry has been pumped to fill the annulus. A displacement fluid is pumped behind the second dart. When the second dart arrives, the top plug is released. A brief peak in surface pressure indicates when each wiper plug has been launched. This process is detailed in the following references: (1) Buisine P. and Lavaure G.: "Equipment for Remote Launching of Cementing Plugs into Subsea Drilled Wells," European Patent Application 0 450 676 A1 (1991); (2) Brandt W. et al.: "Deepening the Search for Offshore Hydrocarbons." Oilfield Review (Spring 1998) 10, No. 1,2-21.

[0023] The present example of the method is designed to be compatible with the aforementioned plug-launching sequence but shall not be limited to it. The apparatus, shown in FIG. **1**A, comprises a system for launching cementing plugs in a subterranean well, wherein at least one a bottom plug **101** and a top plug **102** are launched from a plug basket **103**. The first portion of the apparatus comprises a plug basket **103** that initially contains the bottom plug **101** and the top plug **102**. A plug piston **104** is driven by a main rod **105**, equipped with a main rod head **106**. Above the main rod head **106** is at least one hollow body **107** that may contain one or more substances. The body is equipped with injectors **108**. The injectors have check valves to prevent the influx of wellbore fluids into the interior of the hollow body **107**. A piston **109** is fitted inside the hollow body, and is connected to a dart rod **110**. A dart-rod head **111** is fitted on top of the dart rod. The dart rod and dart-rod head are enclosed inside a first tubular body **112**. Flow ports **113** and **114** in the first tubular body allow process fluids to flow outside of the apparatus.

[0024] The second portion of the apparatus comprises a material-injection dart **115**. The third portion of the apparatus comprises a bottom dart **116**. The fourth portion of the apparatus comprises a top dart (not shown).

[0025] After assembly, the apparatus is installed inside a casing string (not shown) (FIG. **1**, Step A). Outside of the casing string is an annular region (not shown). The other side of the annular region may comprise the borehole wall or another casing string. A first process fluid flows through the first tubular body **112** and out through ports **113** and **114** into the annulus between the first tubular body and the casing interior. Process fluid bypasses the plug-launching system, and then flows toward the float collar (not shown) at the end of the casing string.

[0026] Step B depicts the arrival of a fluid-injection dart **115**, landing on dart-rod head **116**, installed on the dart rod **110**. The dart obstructs fluid flow through ports **113** and **114**. Further pumping of process fluid forces the fluid-injection dart downward, thereby forcing the dart rod **110** downward, thereby causing the reservoir piston **109** to move downward and force the material through the additive injectors **108**, and outside of the apparatus.

[0027] Step C shows that, once the fluid-injection dart has cleared flow ports **113** and **114**, the reservoir piston **109** has moved sufficiently far to expel all of the substance from the hollow body **107**. At this point, the main rod **106**, the top plug **102** and the bottom plug **101** have not been affected. However, the dart rod and the main rod are touching.

[0028] Step D shows the aftermath of the bottom-dart **116** arrival and displacement. As the bottom dart traveled into the apparatus, shear pins connecting the dart rod **110** and the reservoir piston **109** broke, thereby allowing the dart rod to continue moving downward. Continued downward movement of the dart rod forced the main rod **105** to also move downward, forcing the piston **104** to move downward and launch the bottom dart.

[0029] The cementing process may then continue in the manner well known in the art, whereby the bottom plug and top plug are launched. An alternate view of the sequence is shown in FIG. **2**.

[0030] Embodiments relate to methods for measuring process-fluid loss in a subterranean well. Process-fluid loss may include lost circulation (loss of whole process fluid to the formation) or fluid-loss (loss of the fluid phase of the process fluid, leaving suspended solids in the wellbore). This embodiment involves selectively releasing one or more tracers into the process fluid at desired locations in the vicinity of the loss zones. This technique is advantageous because it isolates the tracers from wellsite personnel, and allows more accurate diagnostic studies.

[0031] In this embodiment, the apparatus may comprise one or more hollow bodies, each containing the same tracer or different tracers. Or, one body may comprise multiple internal chambers containing the same tracer or different tracers. The hollow bodies are preferably filled with tracer at a secure location. Later they may be incorporated into a system that may comprise one or more members of the list comprising a cementing-plug-launching system, a drill string, casing, coiled tubing and a wireline. The system may then be lowered into the well. The internal chamber may also be filled extemporaneously by the well site personnel when needed.

[0032] During the circulation of process fluid in the wellbore, the first tracer may be injected at a location above the loss zone, and the second tracer may be injected at a location below the loss zone. As the process fluid circulates to surface, the relative concentrations of the two tracers in the process fluid may be monitored at a location above the loss zone. The concentration measurements would allow one to calculate the rate at which process fluid is being lost to the formation. Lower relative second-tracer concentrations would likely indicate more severe process-fluid-loss situations. The tracers may be released in bursts or continuously.

[0033] Another strategy comprises releasing one or more tracers into the process-fluid above the loss zone. Monitoring the tracer concentration in process fluid at a point above the location where the tracer was released may allow one to establish a baseline value in the process fluid. Next, one or more tracers may be released into the process fluid below the loss zone. Monitoring the tracer concentration at the same point above the loss zone may allow one to calculate the rate at which process fluid is being lost to the formation. Again, the lower the tracer concentration, the more severe the loss situation may be.

[0034] Skilled persons in the art will recognize that the present invention is not limited to the aforementioned tracer-release scenarios.

[0035] The tracer-concentration measurements may be performed with process-fluid samples that have been removed from the well. Alternatively, downhole sensors may be employed to perform the measurements remotely.

[0036] The tracers may comprise (but would not be limited to) radioactive compounds, transition-metal compounds, organic compounds, dyes or combinations thereof. The chamber may also be a vehicle by which microelectric mechanical systems (MEMS) are introduced into the wellbore. In this instance, the MEMS may be employed as tracers.

[0037] There are several methods by which release of the tracer may be initiated downhole. Release may be initiated directly or indirectly by process-fluid flow. Or, release may be initiated by means that are independent of process-fluid flow. Such means may include (but would not be limited to) electric motors, magnetic fields and explosive devices. One of the major advantages of the present embodiments is that the tracer is launched directly down the well, accordingly, it just has to travel up the annulus to be measured on surface. In the prior art, the tracer is usually incorporated to process fluid on surface or pumped as a pill between two fluids. The problem is that the tracer or the fluid containing the tracer has to travel down the casing, pass the wellhead and then come up the annulus to surface. Reducing the time the tracer spends within the process fluid and the journey it has to go through limits the losses and the parameters to take into account while assessing the diagnostic.

[0038] Embodiments provide methods for improving wellsite-personnel safety during subterranean-well operations.

[0039] Indeed, as mentioned earlier, the methods may involve the launching of tracers such as radioactive tracers; furthermore one may envisage storing further hazardous substances into at least one body with at least one internal chamber. The body is preferably filled with the hazardous substance at a secure location away from wellsite personnel. Such locations may include (but would not be limited to) remote facilities away from the wellsite and isolated areas in the vicinity of the wellsite. After filling, the body is sealed and incorporated into a system from which the hazardous substance will be dispensed downhole. Such systems may comprise one or more members of the list comprising a cementing-plug-launching system, a drill string, casing, coiled tubing and a wireline. The system containing the sealed body is then lowered into the well, and the hazardous substance is released from the sealed body at one or more desired locations.

[0040] There are several methods by which release of the hazardous material may be initiated downhole. Release may be initiated directly or indirectly by process-fluid flow. Or, release may be initiated by means that are independent of process-fluid flow. Such means may include (but would not be limited to) electric motors, magnetic fields and explosive devices.

[0041] The hazardous material may be in the form of a fluid, particles, fibers or combinations thereof. Envisioned hazardous materials include (but would not be limited to) radioactive, flammable, explosive, corrosive and poisonous materials, or combinations thereof.

[0042] The material may be as said earlier a tracer for diagnostic studies. Such tracers may be (but would not be limited to) one or more members of the list comprising radioactive compounds, transition-metal compounds, organic compounds and dyes.

[0043] Fibers may be dispensed by the apparatus of the invention for applications including (but not limited to) curing lost circulation, improving fluid-loss control and as diverting agents. Having fibers dispensed in a controlled manner, close to the formation being treated, may be advantageous.

[0044] The material may further comprise one or more microelectric mechanical systems (MEMS). MEMS are mechanical devices that are built onto semiconductor chips, whose sizes are measured in micrometers. The MEMS may be suspended in a fluid inside the body. When dispensed into the well, MEMS may perform, for example, pressure, temperature, chemical, optical and vibration measurements, record data and transmit information to the surface. In the context of the invention, strategic release of MEMS at a desired location may provide valuable information concerning the well-service operation. The MEMS may be recovered at the surface for data recovery during process-fluid circulation, or they may be monitored remotely while they are circulating in the well.

[0045] An example of the method comprises incorporating the body within a cementing-plug-launching system. The launching system of this particular embodiment is designed to operate in a subsea environment—one in which it may be particularly advantageous to have the ability to remotely dispense a material into the wellbore. This example relies on process-fluid flow to initiate material release.

[0046] The preceding description has been presented with reference to presently preferred embodiments of the invention. Persons skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described structures and methods of operation can be practiced without meaningfully departing from the principle, and scope of this invention. Accordingly, the foregoing description should not be read as pertaining only to the precise structures described and shown in the accompanying drawings, but rather should be read as consistent with and as support for the following claims, which are to have their fullest and fairest scope.

1. A method for measuring process-fluid loss in a subterranean well having a wellbore, comprising:

i. at a secure location, placing one or more tracers into at least one body with at least one internal chamber;

ii. incorporating the body into a system comprising one or more members of the list comprising a cementing-plug-launching system, a drill string, casing, coiled tubing and a wireline;
iii. lowering the system into the well;
iv. releasing one or more tracers into the well; and
v. monitoring the tracer concentrations in process fluids circulating past the borehole wall.

2. The method of claim **1**, wherein one tracer is released above the loss zone, and a different tracer is released below the loss zone.

3. The method of claim **2**, wherein the tracer concentrations are monitored in process fluid located above the loss zone.

4. The method of claim **1**, wherein one or more tracers are released above the loss zone.

5. The method of claim **1**, wherein one or more tracers are released below the loss zone.

6. The method of claim **1**, wherein the tracer comprises one or more members of the list comprising: radioactive compounds, transition-metal compounds, organic compounds and dyes.

7. The method of claim **1**, wherein the tracer release is initiated by process-fluid flow.

8. The method of claim **1**, wherein the tracer release is initiated by means that are independent of process-fluid flow.

9. The method of claim **8**, wherein the independent means comprise one or more members of the list comprising electric motors, magnetic fields and explosive devices.

10. The method of claim **1**, further comprising the release of one or more microelectric mechanical systems.

11. The method of claim **1**, wherein the process fluid is analyzed after removal from the well.

12. The method of claim **1**, wherein the process fluid is analyzed remotely by sensors in the well.

13. A method for improving wellsite-personnel safety during subterranean-well operations, comprising:
i. at a secure location, placing a hazardous substance into at least one body with at least one internal chamber;
ii. sealing the body;
iii. incorporating the sealed body into a system comprising one or more members of the list comprising a cementing-plug-launching system, a drill string, casing, coiled tubing and a wireline;
iv. lowering the system into the well; and
v. releasing the substance into the well.

14. The method of claim **13**, wherein the release of the substance into the well is initiated by process-fluid flow.

15. The method of claim **13**, wherein the release of the substance into the well is initiated by means that are independent of process-fluid flow.

16. The method of claim **15**, wherein the independent means comprise one or more members of the list comprising electric motors, magnetic fields and explosive devices.

17. The method of claim **13**, wherein the substance comprises fluids, particles, fibers or combinations thereof.

18. The method of claim **13**, wherein the substance comprises one or more tracers.

19. A method for diagnosing fluid loss in a subterranean well having a wellbore, comprising:
i. placing one or more tracers into at least one internal chamber of a system comprising one or more members of the list comprising a cementing-plug-launching system, a drill string, casing, coiled tubing and a wireline;
iii. lowering the system into the well;
iv. releasing one or more tracers into the well; and
v. monitoring the tracer concentrations in process fluids circulating past the borehole wall.

20. The method of claim **19** wherein the diagnosis is the severity of the fluid loss zone, or the location of the fluid-loss zone or both.

* * * * *