



- (51) International Patent Classification:
E21B 34/14 (2006.01)
- (21) International Application Number:
PCT/US2014/022022
- (22) International Filing Date:
7 March 2014 (07.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/774,729 8 March 2013 (08.03.2013) US
- (71) Applicant: **WEATHERFORD/LAMB, INC.** [US/US];
2000 St. James Place, Houston, TX 77056 (US).
- (72) Inventors: **ROSSING, Michael**; 11909 Spencer Road Fm
529, Houston, TX 77041 (US). **GARCIA, Cesar**; 11909
Spencer Road Fm 529, Houston, TX 77041 (US).
- (74) Agent: **MCDERMOTT, Sean P.**; Wong Cabello Lutsch
Rutherford & Brucquieri LLP, 20333 Tomball Parkway,
6th Floor, Houston, Texas 77070 (US).
- (81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

[Continued on next page]

(54) Title: MILLABLE FRACTURE BALLS COMPOSED OF METAL

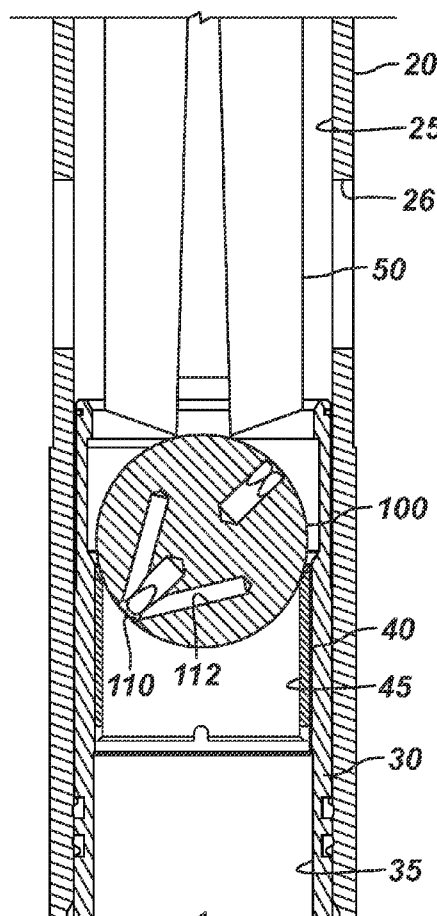


FIG. 6B

(57) Abstract: A ball is used for engaging in a downhole seat and can be milled out after use. The ball has a spherical body with an outer surface. An interior of the spherical body is composed of a metallic material, such as aluminum. The spherical body has a plurality of holes formed therein. The holes extend from at least one common vertex point on the outer surface of the spherical body and extend at angles partially into the interior of the spherical body.





SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

Millable Fracture Balls Composed of Metal**BACKGROUND OF THE DISCLOSURE**

[0001] In a staged fracturing operation, multiple zones of a formation need to be isolated sequentially for treatment. To achieve this, operators install a fracturing assembly down the wellbore, which typically has a top liner packer, open hole packers isolating the wellbore into zones, various sliding sleeves, and a wellbore isolation valve. When the zones do not need to be closed after opening, operators may use single shot sliding sleeves for the fracturing treatment. These types of sleeves are usually ball-actuated and lock open once actuated. Another type of sleeve is also ball-actuated, but can be shifted closed after opening.

[0002] Initially, operators run the fracturing assembly in the wellbore with all of the sliding sleeves closed and with the wellbore isolation valve open. Operators then deploy a setting ball to close the wellbore isolation valve. This seals off the tubing string of the assembly so the packers can be hydraulically set. At this point, operators rig up fracturing surface equipment and pump fluid down the wellbore to open a pressure actuated sleeve so a first zone can be treated.

[0003] As the operation continues, operators drop successively larger balls down the tubing string and pump fluid to treat the separate zones in stages. When a dropped ball meets its matching seat in a sliding sleeve, the pumped fluid forced against the seated ball shifts the sleeve open. In turn, the seated ball diverts the pumped fluid into the adjacent zone and prevents the fluid from passing to lower zones. By dropping successively increasing sized balls to actuate corresponding sleeves, operators can accurately treat each zone up the wellbore.

[0004] Figure 1A shows an example of a sliding sleeve 10 for a multi-zone fracturing system in partial cross-section in an opened state. This sliding sleeve 10 is similar to Weatherford's ZoneSelect MultiShift

fracturing sliding sleeve and can be placed between isolation packers in a multi-zone completion. The sliding sleeve 10 includes a housing 20 defining a bore 25 and having upper and lower subs 22 and 24. An inner sleeve or insert 30 can be moved within the housing's bore 25 to open or close fluid flow through the housing's flow ports 26 based on the inner sleeve 30's position.

[0005] When initially run downhole, the inner sleeve 30 positions in the housing 20 in a closed state. A breakable retainer 38 initially holds the inner sleeve 30 toward the upper sub 22, and a locking ring or dog 36 on the sleeve 30 fits into an annular slot within the housing 20. Outer seals on the inner sleeve 30 engage the housing 20's inner wall above and below the flow ports 26 to seal them off.

[0006] The inner sleeve 30 defines a bore 35 having a seat 40 fixed therein. When an appropriately sized ball lands on the seat 40, the sliding sleeve 10 can be opened when tubing pressure is applied against the seated ball 40 to move the inner sleeve 30 open. To open the sliding sleeve 10 in a fracturing operation once the appropriate amount of proppant has been pumped into a lower formation's zone, for example, operators drop an appropriately sized ball B downhole and pump the ball B until it reaches the landing seat 40 disposed in the inner sleeve 30.

[0007] Once the ball B is seated, built up pressure forces against the inner sleeve 30 in the housing 20, shearing the breakable retainer 38 and freeing the lock ring or dog 36 from the housing's annular slot so the inner sleeve 30 can slide downward. As it slides, the inner sleeve 30 uncovers the flow ports 26 so flow can be diverted to the surrounding formation. The shear values required to open the sliding sleeves 10 can range generally from 1,000 to 4,000 psi (6.9 to 27.6 MPa).

[0008] Once the sleeve 10 is open, operators can then pump proppant at high pressure down the tubing string to the open sleeve 10. The proppant and high pressure fluid flows out of the open flow ports 26 as the seated ball B prevents fluid and proppant from communicating further down the

tubing string. The pressures used in the fracturing operation can reach as high as 15,000-psi.

[0009] After the fracturing job, the well is typically flowed clean, and the ball B is floated to the surface. Then, the ball seat 40 (and the ball B if remaining) is milled out. The ball seat 40 can be constructed from cast iron to facilitate milling, and the ball B can be composed of aluminum or a non-metallic material, such as a composite. Once milling is complete, the inner sleeve 30 can be closed or opened with a standard “B” shifting tool on the tool profiles 32 and 34 in the inner sleeve 30 so the sliding sleeve 10 can then function like any conventional sliding sleeve shifting with a “B” tool. The ability to selectively open and close the sliding sleeve 10 enables operators to isolate the particular section of the assembly.

[0010] When aluminum balls B are used, more sliding sleeves 10 can be used downhole for the various stages because the aluminum balls B can have a close tolerance relative to the inner diameter for the seats 40. For example, forty different increments can be used for sliding sleeves 10 having solid seats 40 used to engage aluminum balls B. However, an aluminum ball B engaged in a seat 40 can be significantly deformed when high pressure is applied against it. Any variations in pressuring up and down that allow the aluminum ball B to seat and to then float the ball B may alter the shape of the ball B, compromising its seating ability or its ability to float to the surface after use.

[0011] Additionally, aluminum balls B if left downhole can be particularly difficult to mill out of the sliding sleeve 10 due to their tendency of rotating during the milling operation. For example, Figure 1C shows a mill 50 inserted into a sliding sleeve’s housing 20 after milling a ball B from an uphole sliding sleeve. Operators use the mill 50 to mill through all the balls B and seats 40 to gain full tubing access.

[0012] One problem with using aluminum balls B can be the long mill up times required per zone. For instance, milling just one frac stage when a solid aluminum ball is used can take up to an hour. During mill up, larger aluminum balls B push through the seats as a large quarter segment S of

the ball. This segment S travels down to the next seat 40 and contacts the next ball B, as shown in Figure 1C. When the mill 50 reaches this sliding sleeve, the aluminum segment S and the existing ball B tend to spin on each other and do not allow the mill 50 to grab and mill up the components quickly. As a result, milling the seats 40 and aluminum balls B can be longer than desired, which delays operators' ability to put the well in production.

[0013] Using non-metal balls may avoid the problem of longer milling times because the non-metal balls break apart easier during mill up. Yet, as noted previously, these non-metal balls may not hold the desired operating pressures and may not provide as many stages as can be obtained with the minimized aluminum ball and seat engagement.

[0014] The subject matter of the present disclosure is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE DISCLOSURE

[0015] A plug is used for engaging in a downhole seat and is milled out after use. The plug has a body with an outer surface and an interior. The plug can be a ball, and the body can be spherical. Additionally, the plug's body can be composed of a metallic material, such as aluminum.

[0016] The body has a plurality of holes formed therein. In particular, the holes extend from at least one common vertex point on the outer surface of the body and extend at angles partially into the interior of the body. The at least one common vertex point can be at least one tap hole defined in the outer surface of the body, and the plurality of holes can be a plurality of angled holes formed at an angle into the interior from the at least one tap hole. At least a portion of the holes can have a filler material disposed therein.

[0017] In one implementation, common vertex points disposed on opposing sides of the body can be used. In this case, the holes include a first set of angled holes formed at an angle into the interior from one of the

common vertex points on one of the opposing sides. Additionally, the holes include a second set of angled holes formed at an angle into the interior from the other of the common vertex points on the other of the opposing sides. The first and second sets of angled holes can be offset from one another.

[0018] Manufacturing the plug involves forming the body with the outer surface and the interior. The holes are formed in the body by extending the holes from at least one common vertex point on the outer surface of the body and extending the holes at angles partially into the interior of the body.

[0019] To extend the holes from the at least one common vertex point on the outer surface of the body, the method can involve forming at least one tap hole in the outer surface of the body and forming a plurality of angled holes formed at an angle into the interior from the at least one tap hole. In one implementation, tap holes can be formed on opposing sides of the body. In this way, a first set of angled holes can be formed at an angle into the interior from one of the tap holes, and a second set of angled holes can be formed at an angle into the interior from the other tap hole. These first and second sets of angled holes can be offset from one another.

[0020] The foregoing summary is not intended to summarize each potential embodiment or every aspect of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Fig. 1A illustrates a sliding sleeve having a ball engaged with a seat to open the sliding sleeve according to the prior art.

[0022] Fig. 1B illustrates a close up view of the sliding sleeve in Fig. 1B.

[0023] Fig. 1C illustrates a close up view of a mill entering the sliding sleeve of Fig. 1B.

[0024] Figs. 2A-2C illustrate cross-sectional views of a first embodiment of a metallic ball according to the present disclosure for actuating a sliding sleeve.

[0025] Figs. 3A-3C illustrate cross-sectional views of a second embodiment of a metallic ball according to the present disclosure for actuating a sliding sleeve.

[0026] Figs. 4A-4C illustrate cross-sectional views of a third embodiment of a metallic ball according to the present disclosure for actuating a sliding sleeve.

[0027] Figs. 5A-5C illustrate cross-sectional views of a fourth embodiment of a metallic ball according to the present disclosure for actuating a sliding sleeve.

[0028] Figs. 6A-6C illustrates a detailed view of a mill entering a sliding sleeve having the metallic ball of Figs. 3A-3C.

[0029] Fig. 7 illustrates segments or shards remaining after milling a ball according to the present disclosure.

[0030] Fig. 8 illustrates yet another embodiment of a metallic ball for actuating a sleeve and facilitating mill out according to the present disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0031] Fracture balls composed of metal, and particularly aluminum, have material removed from the ball's interior. The removal of the material can be done in various ways. In general, holes can drilled to a specified depth in the ball, but the holes do not create a through-hole in the ball, as this would compromise the sealing ability of the ball. Instead, the holes create voids (not through-holes) and allow the ball to stay intact during fracturing operations. The holes in the ball also allow the ball to break up easier during milling operations.

[0032] As noted in the background of the present disclosure, mill out of a solid metal (aluminum) ball may cause a large segment of the ball to push through the seat before being fully milled. The partially milled segment then travels to the next ball/seat below it. The segment and ball then tend spin when the mill reaches them, which increases the mill up times. However, the disclosed ball having the partial hole(s) defined therein tends

to break up into smaller pieces that allow the mill to grab them when it travels to the lower seat. Although the partial hole(s) may be beneficial for milling, the ball must still be capable of properly seating on the ball seat and preventing leakage and must be able to withstand the increased pressures of the fracture operations.

[0033] Figures 2A-2C illustrate cross-sectional views of a first embodiment of a ball 100 according to the present disclosure for actuating a sliding sleeve. The ball 100 has a solid, spherical body 102 composed of a metallic material, including, but not limited to, aluminum, aluminum alloy, steel, brass, aluminum bronze, a metallic nanostructure material, cast iron, etc. The metallic material is preferably one that can be floated to the surface and can be milled if necessary. Of course, the ball 100 can be composed of any suitable material, even ceramics, plastics, composite materials, phenolics, Torlon, Peek, thermoplastics, or the like.

[0034] Voids, spaces, or holes are defined in the body 102 to facilitate milling of the ball 100 when disposed in a ball seat of a tool, such as a sliding sleeve. Because the ball 100 has the purposes of sealingly engaging the ball seat in the sliding sleeve, the ball 100 preferably is configured to maintain or produce a sufficient seal with the ball seat when seated therein. Therefore, the voids, spaces, or holes do not pass entirely through the body 102. Instead, as shown in Figures 2A-2C, a tap hole 110 is drilled in one side of the ball's body 102. The depth of this tap hole 110 is preferably less than half the diameter of the ball 100, although it could be deeper in a given implementation.

[0035] Drilled off at angles from the tap hole 110 are a plurality of angled holes 112—four such angled holes 112 are shown in the ball 100 of Figures 2A-2C. The tap hole 110, although it may provide a desired void in the ball's body 102, is used primarily to provide a common vertex point V near the surface 104 of the ball 100 from which to form the angled holes 112. In this way, the multiple angled holes 112 do not tap multiple points on the ball's outer surface 104, which could compromise the sealing capability of the ball 100 when seated.

[0036] All the same, the tap hole 110 can be left unplugged and act as a suitable void. Alternatively, the tap hole 110 can be plugged with material, such as epoxy, resin, solder, plastic, rubber, the same metal material as the body 102, other type of metal than the body 102, or the like. The angled holes 112 can even be filled at least partially with filler material that can be readily milled.

[0037] Each angled hole 112 can be angled at about 45-degrees from the centerline of the tap hole 110, and the angled holes 112 may be offset at about 90-degrees from one another around the tap hole 110. As with the tap hole 110, the angled holes 112 may extend to less than the mid-section of the ball's body 102, but this may vary for a given implementation. The ball 100 in Figure 2A-2C essentially defines holes 110/112 or voids in half the ball's body 102.

[0038] For some exemplary dimensions for the ball 100 having a diameter of about 3-in., the tap hole 110 can be about 3/8-in. wide and can extend about 1/3 of the diameter (e.g., about 1-in.) of the body 102. The angled holes can be about 1/4-in. wide and can extend about 1.75-in. in length. Other sized balls 100 would have other dimensions, of course. In any event, balls 100 having a diameter of about 2-in. or greater would be best suited for the types of holes disclosed herein simply because balls with smaller diameters are already easier to mill.

[0039] Figures 3A-3C illustrate cross-sectional views of a second embodiment of a ball 100 according to the present disclosure for actuating a sliding sleeve. This ball 100 is similar to that discussed previously, but tap holes 110a-b are defined in opposing sides of the ball's body 102. Each tap hole 110a-b has a plurality of angled holes 112a-b in a manner similar to that discussed previously. Preferably as shown, the angled holes 112a-b are offset from one another around the axis defined by the tap holes 110a-b so that the opposing holes 112a-b do not meet with one another inside the body 102. Because the tap holes 110a-b are offset 180-degrees on opposite sides, it is less likely that both will engage the edge of a seat when landed thereon.

[0040] As before, the tap holes 110a-b can primarily provide common vertices Va-Vb from which the opposing angled holes 112a-b can be formed so that multiple tap points do not need to be made in the ball's surface 104. The ball 100 in Figure 3A-3C essentially defines holes 110a-b/112a-b or voids throughout the interior of the entire ball's body 102. If desired, the holes 110a-b/112a-b can be left empty or can be filled with a filler material, such as an epoxy, resin, plastic, rubber, other type of metal than the body's metal, or the like.

[0041] Figures 4A-4C illustrate cross-sectional views of a third embodiment of a metallic ball 100 according to the present disclosure for actuating a sliding sleeve. This ball 100 is similar to that discussed above with reference to Figures 2A-2C in that a tap hole 110 and angled holes 114 are defined in one side of the ball 100. Rather than having four angled holes as in the previous embodiment, this ball 100 has three angled holes 114 drilled at about every 120-degrees around the tap hole 110.

[0042] In other differences illustrated, the angled holes 112 can be drilled at a shallower angle from the tap hole 110. Additionally, the ends of the angled holes 112 can extend beyond the midpoint of the ball's body 102. Thus, the angled holes 112 extend nearly to the opposing side of the ball's body 102.

[0043] Figures 5A-5C illustrate cross-sectional views of a fourth embodiment of a metallic ball 100 according to the present disclosure for actuating a sliding sleeve. This ball 100 has tap holes 110a-b and angled holes 112a-b similar to the ball 100 in Figures 4A-4C and has two sets of such holes 110a-b/112a-b on opposing sides of the ball 100 similar to the ball 100 in Figures 3A-3C.

[0044] As can be seen from the various arrangements of holes in Figures 2A through 5C, the metallic ball 100 can have a plurality of holes (e.g., 112) formed or drilled partially therein. Preferably, the holes 112 do not pass entirely through the ball's body 102 and do not intersect one another 102. Instead, the holes 112 are made from one or more common vertices

V near the surface 104 of the ball 100 and spread out from one another in different directions from the common vertex V. When the holes 112 are formed from two or more common vertices Va-Bb as in Figures 3A-3C and 5A-5C, the opposing holes 112a-b preferably pass between each other in a fit pattern.

[0045] In general, the ball 100 (if solid) would have about 10x the structural strength required to achieve its purposes downhole. Removing material with the holes 110/112 could reduce the structural strength to perhaps 2 to 3 times what is needed. In any event, a given ball 100 with the holes 110/112 is preferably capable of withstanding at least 7,000-psi, and more preferably 10,000-psi, without collapsing on itself. Of course, the different diameters of balls and seats used and the associated materials will govern any such variables.

[0046] Figures 6A-6C illustrates a detailed view of a mill 50 entering a sliding sleeve having the ball 100 of Figs. 3A-3C. As shown in Figure 6A, the ball 100 is engaged in the seat 40. The tap holes 110 and/or angled holes 112 of the ball 100 can be filled with filler material (not shown). After fracturing, the ball 100 may be deformed by the applied pressure in ways not specifically shown here. For example, an outer ring may form around the ball 100 where it engages the shoulder of the seat 40, and the top of the ball 100 may be compressed outward. In any event, operators eventually run a milling tool 50 down the tubing string to mill out the ball 100 and seat 40. In general, the mill 50 can use any suitable type of bit, such as a PCD type bit.

[0047] As shown in Figure 6B, the mill 50 engages the ball 100 and bears down against it. As the mill 50 rotates, the voids in the metal body 102 of the ball 100 allow the edges and teeth of the mill 50 to engage the ball 100 so that the mill 50 can bite, grab, break, and shave away the material of the ball 100 more readily than found with a solid metal ball. Notably, the voided ball 100 may have less of a tendency to rotate with the rotation of the mill 50, which typically happens with a solid metal ball during milling operations. Also, if a portion of the ball 100 remains intact,

the holes 110/112 can allow the portion to be split when the mill 50 applies weight because the holes 110/112 create fracture planes and points for grinding up the ball 100.

[0048] Finally, as shown in Figure 6C, the mill 50 can eventually grind and break up the ball into shavings (not shown) and possible chunks C that may then fall or be pushed through the seat 40. Milling the aluminum ball B can take up to 10-min., depending of the motor, bit, flow rates, and weight on bit (WOB) used, as well as any environmental conditions.

[0049] Although these chunks C may pass to the next ball and seat downhole, their irregular shape and fragmented nature makes them easier to mill further when the mill 50 reaches the next ball and seat arrangement downhole. The chunks C and any exposed holes on the other ball create points of friction that can facilitate milling. As an example of what possible chunks C may be left of a metallic ball after milling and passing through a seat, Figure 7 illustrates several chunks of an aluminum ball after being milled out at least partially.

[0050] Again, some of the ball remains as chunks during milling that can then pass through the seat before the mill 50 actually grinds the entire ball and seat during milling operations. Rather than producing a quarter segment of the ball B as encountered with a solid metal ball when milled, the voided ball 100 produces less uniform and less substantial chunks. One chunk is shown as being flat in shape and as defining remnants of the various holes (112) formed in the ball's body 102. This makes this chunk more susceptible to further breaking and grinding during further milling stages. Other chunks are smaller pieces removed from the voided ball 100 during milling.

[0051] As an alternative to a spherical ball having holes to facilitate milling, a metallic ball 200 as shown in Figure 8 can also engage in a seat of a sliding sleeve, yet facilitate mill out when needed. The ball 200 includes a fin or tail 206 on one end of the ball 200, which would correspond to the top of the ball 200 when deployed. The base body 202 of the ball 200 is truncated, having a large portion 204 removed to below

the sealing area 208 where the ball 200 would engage a seat's shoulder. The tail 206 keeps the ball 200 oriented properly. When milled, however, less of a spherical segment of the ball 200 would pass through the seat to the next ball, which can avoid some of the problems encountered during further milling stages.

[0052] Manufacture of the balls 100/200 disclosed herein can be performed in a number of ways depending on the type of material used. For example, the balls 110/200 can be formed by casting, machining, drilling, and a combination thereof. Any holes 110/112 in the balls 110 can be formed by casting, machining, drilling, and a combination thereof. These and other such manufacturing details will be appreciated by one skilled in the art having the benefit of the present disclosure.

[0053] The foregoing description of preferred and other embodiments is not intended to limit or restrict the scope or applicability of the inventive concepts conceived of by the Applicants. It will be appreciated with the benefit of the present disclosure that features described above in accordance with any embodiment or aspect of the disclosed subject matter can be utilized, either alone or in combination, with any other described feature, in any other embodiment or aspect of the disclosed subject matter.

[0054] In exchange for disclosing the inventive concepts contained herein, the Applicants desire all patent rights afforded by the appended claims. Therefore, it is intended that the appended claims include all modifications and alterations to the full extent that they come within the scope of the following claims or the equivalents thereof.

WHAT IS CLAIMED IS:

1. A plug for engaging in a downhole seat and being milled out after use, the plug comprising:
 - a body having an outer surface and an interior,
 - the body having a plurality of holes formed therein, the holes extending from at least one common vertex point on the outer surface of the body and extending at angles partially into the interior of the body.
2. The plug of claim 1, wherein the plug is a ball, and wherein the body is spherical.
3. The plug of claim 1, wherein the body is composed of a metallic material.
4. The plug of claim 3, wherein the metallic material comprises aluminum.
5. The plug of claim 1, wherein the at least one common vertex point comprises at least one tap hole defined in the outer surface of the body, and wherein the plurality of holes comprises a plurality of angled holes formed at angles into the interior from the at least one tap hole.
6. The plug of claim 1, wherein the at least one common vertex point comprises common vertex points disposed on opposing sides of the body.
7. The plug of claim 6, wherein the plurality of holes comprises:
 - a first set of angled holes formed at angles into the interior from one of the common vertex points on one of the opposing sides;
 - and

a second set of angled holes formed at angles into the interior from the other of the common vertex points on the other of the opposing sides.

8. The plug of claim 7, wherein the first and second sets of angled holes are offset from one another.
9. The plug of claim 1, wherein at least a portion of the holes comprise a filler material disposed therein.
10. A method of manufacturing a plug for engaging in a downhole seat and being milled out after use, the method comprising:
 - forming a body having an outer surface and an interior,
 - forming a plurality of holes in the body by extending the holes from at least one common vertex point on the outer surface of the body and extending the holes at angles partially into the interior of the body.
11. The method of claim 10, wherein the plug is a ball, and wherein the body is spherical.
12. The method of claim 10, wherein the body is composed of a metallic material.
13. The method of claim 12, wherein the metallic material comprises aluminum.
14. The method of claim 10, wherein extending the holes from the at least one common vertex point on the outer surface of the body comprises forming at least one tap hole in the outer surface of the body,

15. The method of claim 14, wherein extending the holes at angles partially into the interior of the spherical body comprises forming a plurality of angled holes formed at angles into the interior from the at least one tap hole.

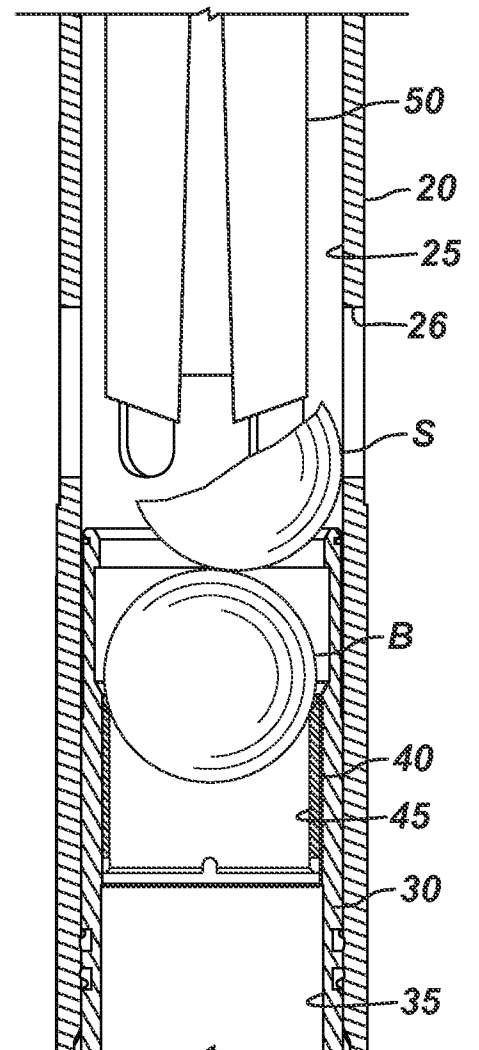
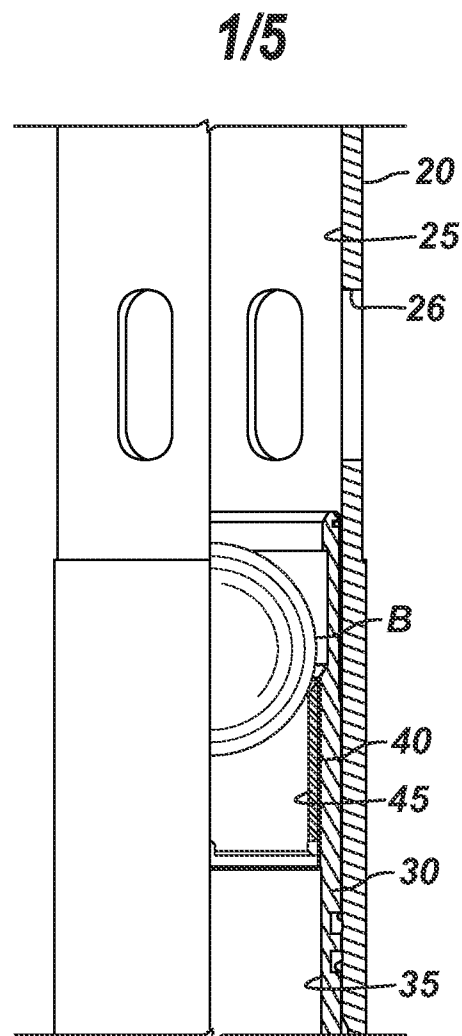
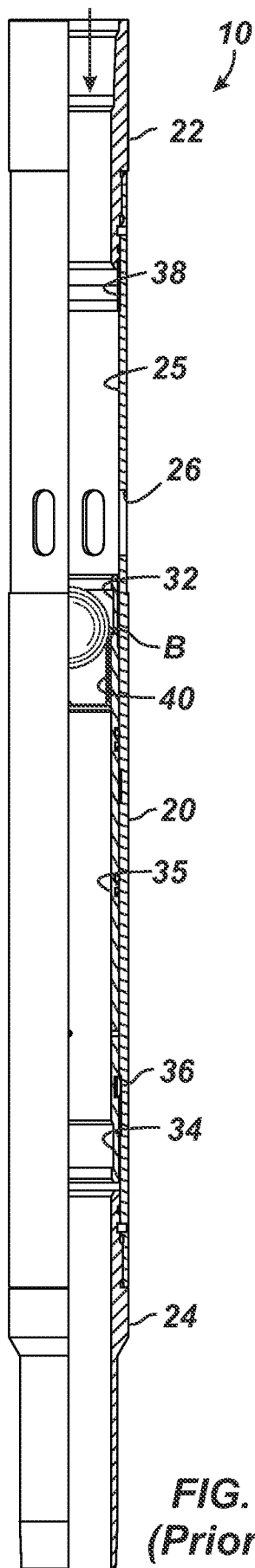
16. The method of claim 10, wherein extending the holes from the at least one common vertex point on the outer surface of the body comprises forming tap holes on opposing sides of the body.

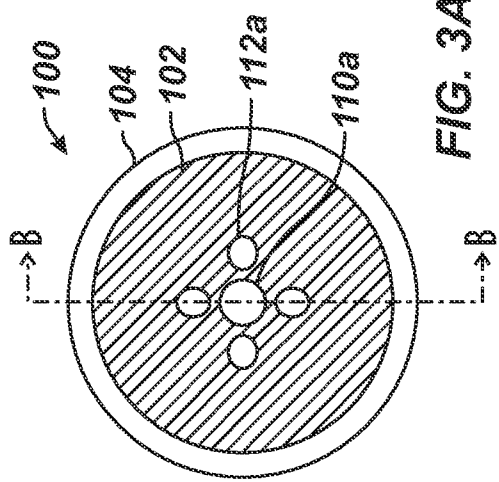
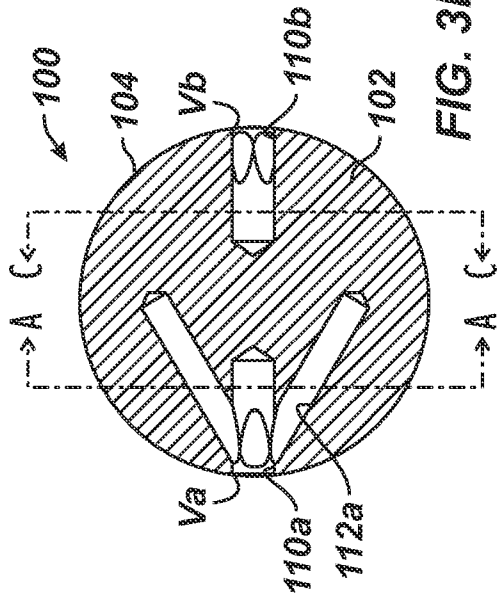
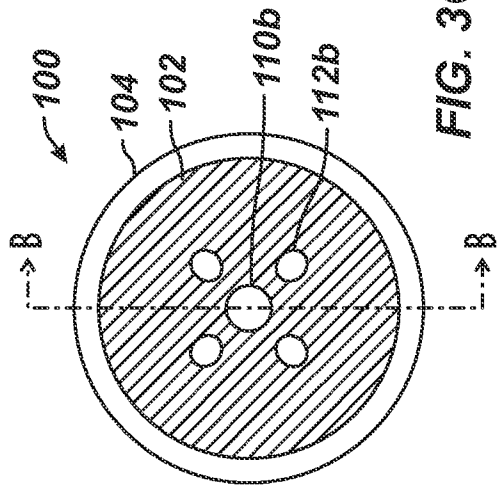
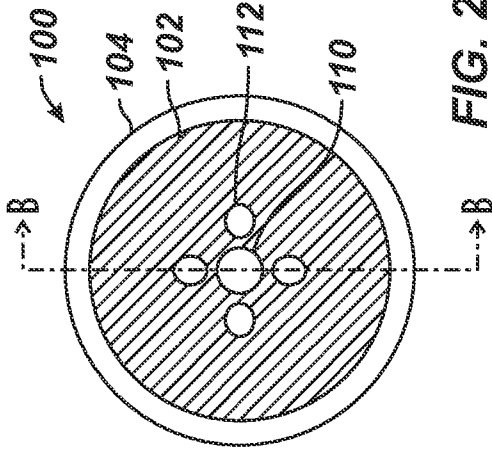
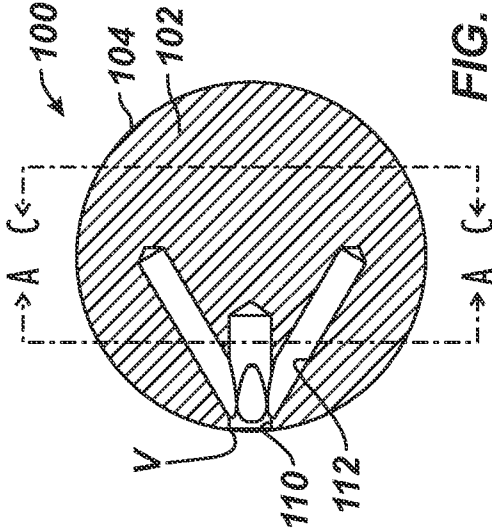
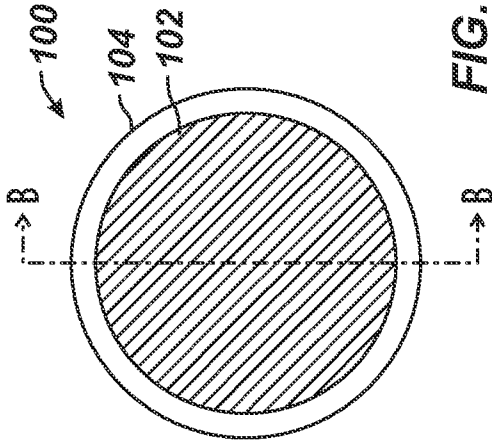
17. The method of claim 16, wherein extending the holes at angles partially into the interior of the body comprises:
forming a first set of angled holes at angles into the interior from one of the tap holes; and
forming a second set of angled holes at angles into the interior from the other tap hole.

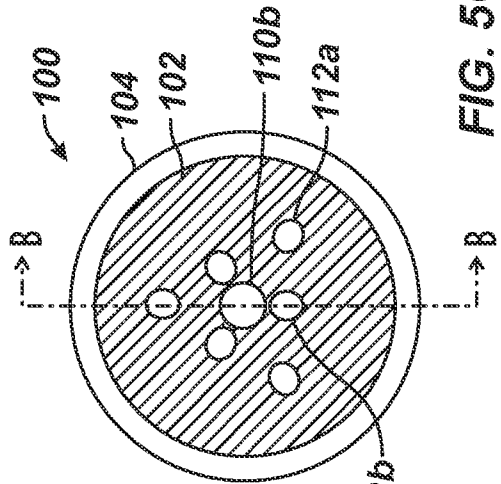
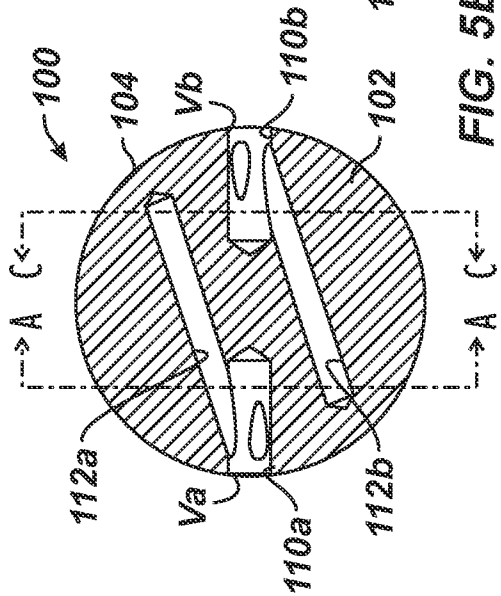
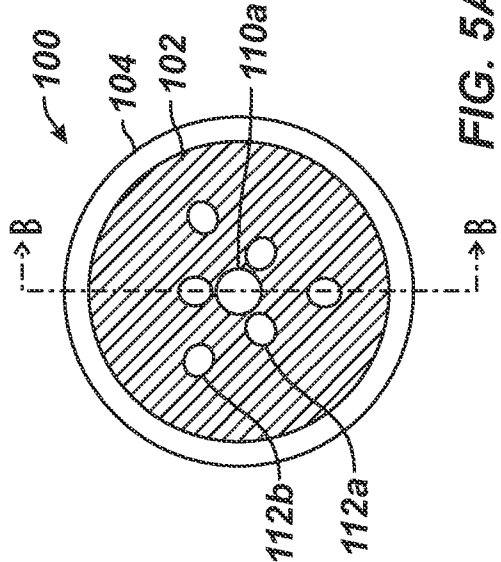
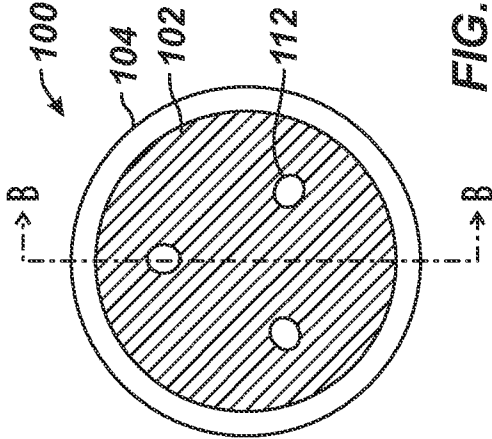
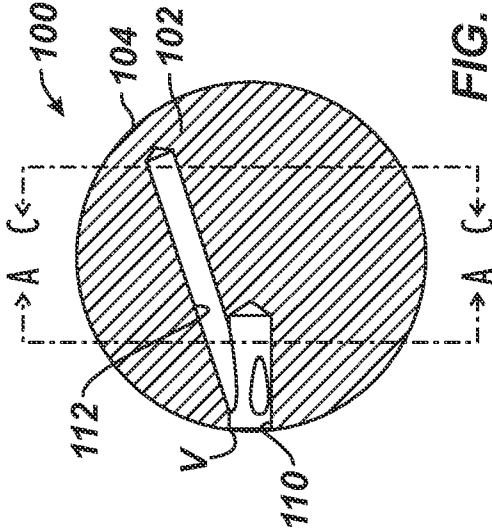
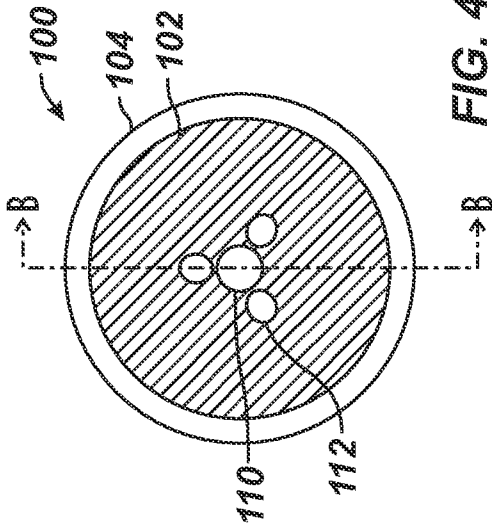
18. The method of claim 17, wherein the first and second sets of angled holes are offset from one another.

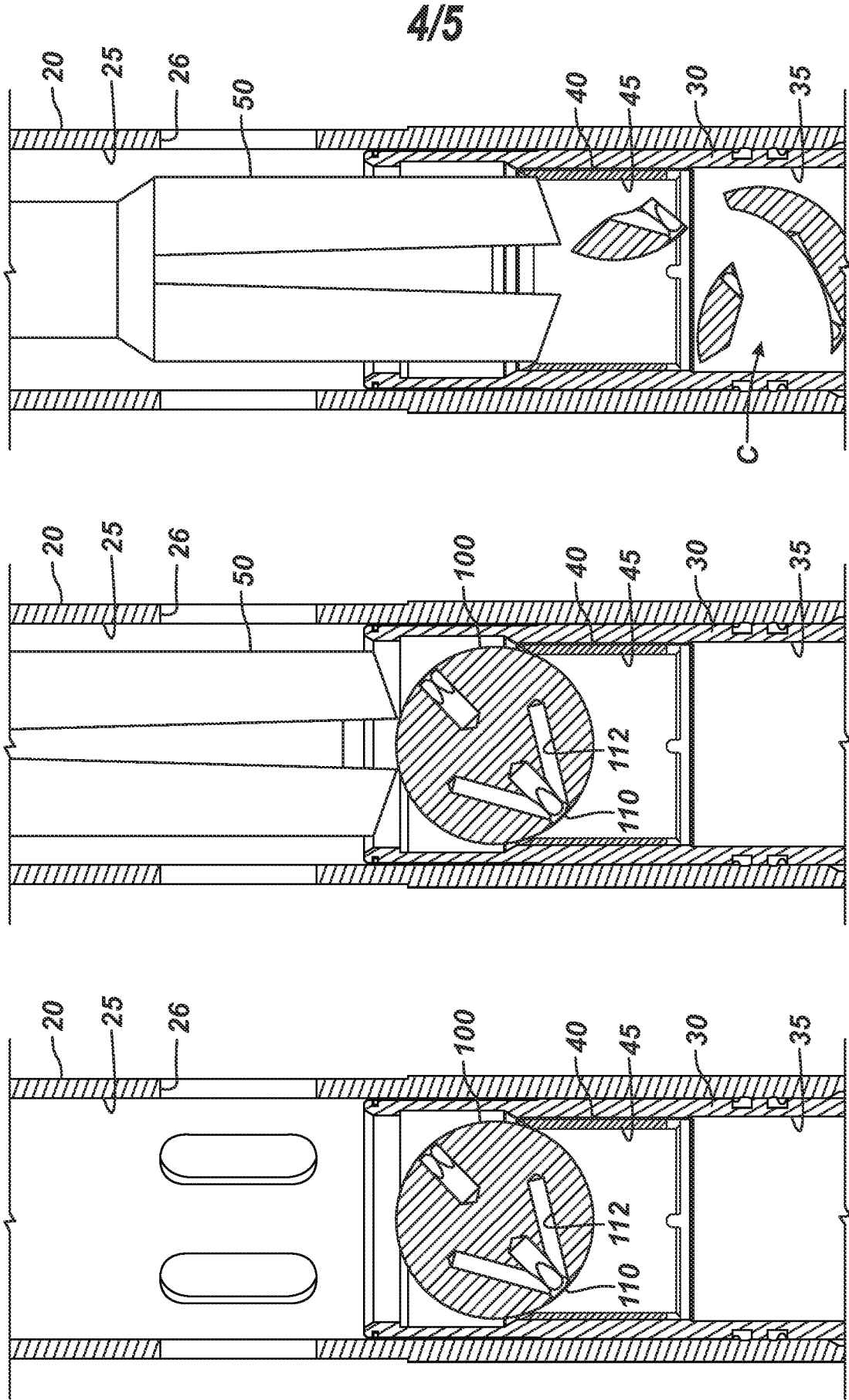
19. The method of claim 10, further comprising filling at least a portion of the holes with a filler material.

20. A plug for engaging in a downhole seat and being milled out after use, the plug comprising:
a body having an outer surface,
a top end of the body having a fin disposed thereon, and
a bottom end of the body opposite the top end having a sealing area on the outer surface, the bottom end being truncated below the sealing area.









5/5

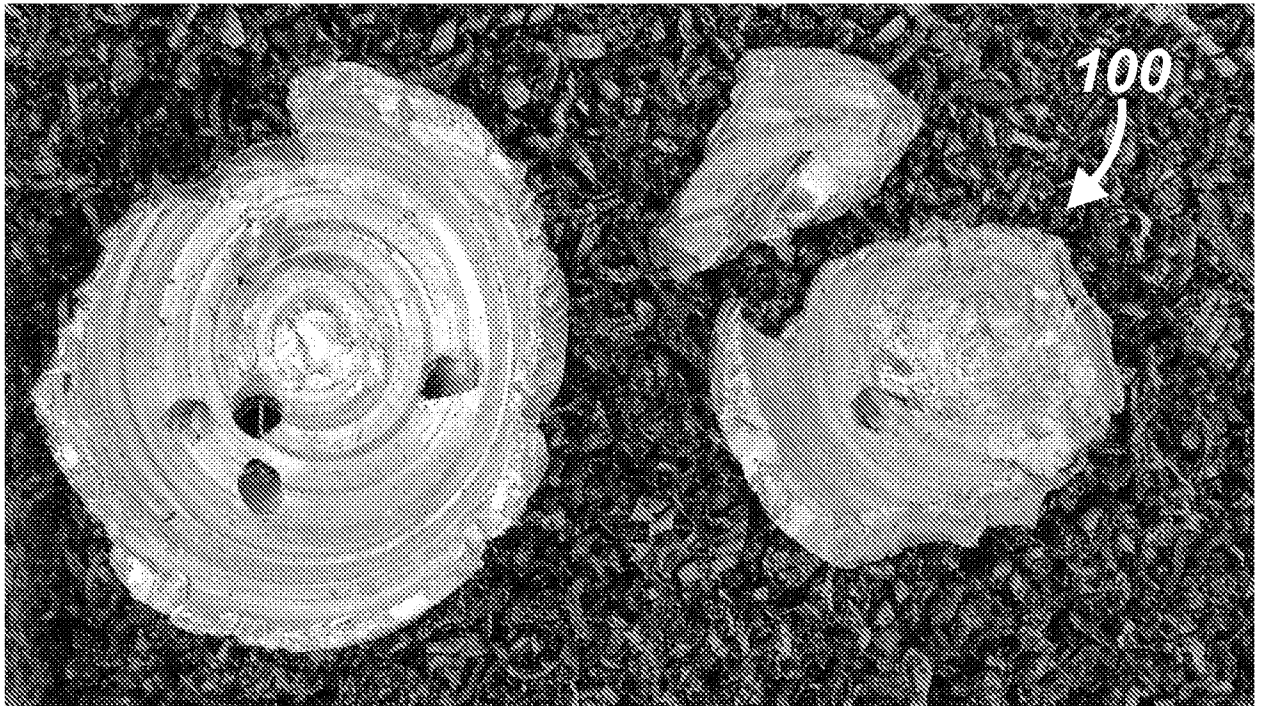


FIG. 7

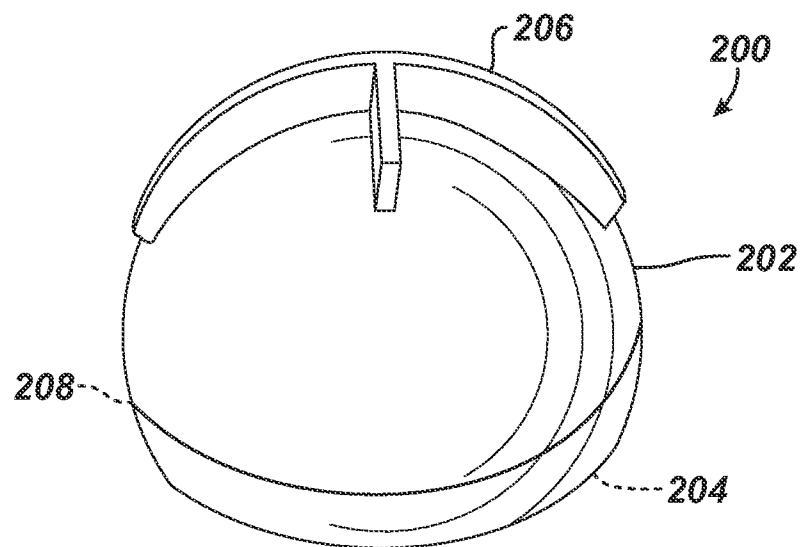


FIG. 8