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(54) **FIXED CUTTER DRILL BIT HAVING ROLLING CUTTERS**

(57) A bit for drilling a wellbore includes: a shank (3) having a coupling formed at an upper end thereof; a bit body (2) mounted to a lower end of the shank; a gage section (5) forming an outer portion of the drill bit; and a cutting face (4) forming a lower end of the drill bit. The cutting face (4) includes: a plurality of blades (7p, 7s) protruding from the bit body, each blade extending from a center of the cutting face to the gage section; a plurality of shear cutters (8a, 8b) mounted along each blade; and a plurality of rolling cutters (9). Each rolling cutter includes: a housing (13) mounted to a respective blade; a seat (14) mounted in the housing; and a ball (12) kept between the housing and the seat and having a portion protruding from the housing.

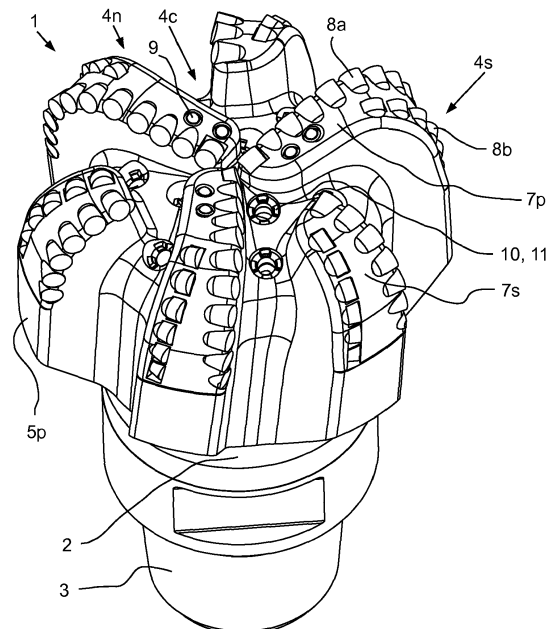


FIG. 1A

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Description**BACKGROUND OF THE DISCLOSURE****Field of the Disclosure**

[0001] The present disclosure generally relates to a fixed cutter drill bit having rolling cutters.

Description of the Related Art

[0002] US Pat. No. 6,935,441 discloses a rotary drag bit and method for drilling subterranean formations including a bit body being provided with at least one cutter thereon exhibiting reduced, or limited, exposure to the formation, so as to control the depth-of-cut of the at least one cutter, so as to control the volume of formation material cut per bit rotation, as well as to control the amount of torque experienced by the bit and an optionally associated bottomhole assembly regardless of the effective weight-on-bit are all disclosed. The exterior of the bit preferably includes a plurality of blade structures carrying at least one such cutter thereon and including a sufficient amount of bearing surface area to contact the formation so as to generally distribute an additional weight applied to the bit against the bottom of the borehole without exceeding the compressive strength of the formation rock.

[0003] US Pat. No. 8,794,356 discloses earth-boring tools including a body, one or more blades projecting outwardly from the body, and cutting elements carried by the blade. The cutting elements include at least one shearing cutting element and at least one gouging cutting element. Methods of forming an earth-boring tool include mounting a shearing cutting element comprising an at least substantially planar cutting face to a body of an earth-boring tool, and mounting a gouging cutting element comprising a non-planar cutting face to the body of the earth-boring tool. The gouging cutting element may be positioned on the body of the earth-boring tool such that the gouging cutting element will gouge formation material within a kerf cut in the formation material by the shearing cutting element, or between kerfs cut in the formation material by a plurality of shearing cutting elements

SUMMARY OF THE DISCLOSURE

[0004] The present disclosure generally relates to a fixed cutter drill bit having rolling cutters. In one embodiment, a bit for drilling a wellbore includes: a shank having a coupling formed at an upper end thereof; a bit body mounted to a lower end of the shank; a gage section forming an outer portion of the drill bit; and a cutting face forming a lower end of the drill bit. The cutting face includes: a plurality of blades protruding from the bit body, each blade extending from a center of the cutting face to the gage section; a plurality of shear cutters mounted along each blade; and a plurality of rolling cutters. Each rolling cutter includes: a housing mounted to a respective

blade; a seat mounted in the housing; and a ball kept between the housing and the seat and having a portion protruding from the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

Figures 1 A and 1 B illustrate a fixed cutter drill bit having rolling cutters, according to one embodiment of the present disclosure.

Figure 2A illustrates a cutting face of the fixed cutter drill bit. Figure 2B illustrates one of the rolling cutters.

Figures 3A and 3B illustrate a second fixed cutter drill bit having rolling cutters, according to another embodiment of the present disclosure.

Figures 4A-4C illustrate a cutting face of the second fixed cutter drill bit.

Figures 5A and 5B illustrate drilling of a wellbore using the second fixed cutter drill bit.

DETAILED DESCRIPTION

[0006] Figures 1A and 1 B illustrate a fixed cutter drill bit 1 having rolling cutters 9, according to one embodiment of the present disclosure. Figure 2A illustrates a cutting face 4 of the fixed cutter drill bit 1. The drill bit 1 may include a bit body 2, a shank 3, the cutting face 4, and a gage section 5. The shank 3 may be tubular and include an upper piece and a lower piece connected to the upper piece, such as by threaded couplings secured by a weld. The bit body 2 may be made from a composite material, such as a ceramic and/or cermet body powder infiltrated by a metallic binder. The bit body 2 may be mounted to the lower shank piece during molding thereof. The shank 3 may be made from a metal or alloy, such as steel, and have a coupling, such as a threaded pin, formed at an upper end thereof for connection of the drill bit 1 to a drill collar 6 (Figure 5A). The shank 3 may have a flow bore formed therethrough and the flow bore may extend into the bit body 2 to a plenum thereof. The cutting face 4 may form a lower end of the drill bit 1 and the gage section 5 may form an outer portion thereof.

[0007] Alternatively, the bit body 2 may be metallic, such as being made from steel, and may be hardfaced.

The metallic bit body may be connected to a modified shank by threaded couplings and then secured by a weld or the metallic bit body may be monoblock having an integral body and shank.

[0008] The cutting face 4 may include one or more (three shown) primary blades 7p, one or more (three shown) secondary blades 7s, fluid courses formed between the blades, shear cutters 8, and rolling cutters 9. The cutting face 4 may have one or more sections, such as an inner cone 4c, an outer shoulder 4s, and an intermediate nose 4n between the cone and the shoulder. The blades 7p,s may be disposed around the cutting face and each blade may be formed during molding of the bit body 2 and may protrude from the bit body. The primary blades 7p may each extend from a center of the cutting face, across the cone 4c and nose 4n sections, along the shoulder section 4s, and to the gage section 5. The secondary blades 7s may each extend from a periphery of the cone section 4c, across the nose section 4n, along the shoulder section 4s, and to the gage section 5. Each blade 7p,s may extend generally radially across the cone 4c (primary only) and nose 4n sections with a slight spiral curvature and along the shoulder section 4s generally longitudinally with a slight helical curvature. Each blade 7p,s may be made from the same material as the bit body 2.

[0009] The shear cutters 8 may include a set of leading cutters 8a for each blade 7p,s and a set of backup cutters 8b for each blade. The leading cutters 8a may be mounted in pockets formed along leading edges of the blades 7p,s, such as by brazing. The backup cutters 8b may be mounted in pockets formed along portions of the blades 7p,s in the shoulder section 4s, such as by brazing. The backup cutters 8b may extend into portions of the blades 7p,s in the nose section 4n. Each backup cutter 8b may be aligned with or slightly offset from a respective leading cutter 8a. Each shear cutter 8 may include a superhard cutting table, such as polycrystalline diamond, attached to a hard substrate, such as a cermet, thereby forming a compact, such as a polycrystalline diamond compact (PDC). The cermet may be a carbide cemented by a Group VIII metal.

[0010] One or more (nine shown) ports 10 may be formed in the bit body 2 and each port may extend from the plenum and through the bottom of the bit body to discharge drilling fluid 8 along the fluid courses. A nozzle 11 may be disposed in each port 10 and fastened to the bit body 2. The ports 10 may include an inner set of one or more (three shown) ports disposed adjacent to the center of the cutting face 4 and an outer set of one or more (six shown) ports disposed at the periphery of the cone section 4c.

[0011] The gage section 5 may include a plurality of gage pads 5p and junk slots formed between the gage pads. The junk slots may be in fluid communication with the fluid courses formed between the blades 7p,s. The gage pads 5p may be disposed around the gage section and each pad may be formed during molding of the bit

body 2 and may protrude from the outer portion of the bit body. Each gage pad 5p may be made from the same material as the bit body 2 and each gage pad may be formed integrally with a respective blade 7p,s.

[0012] One or more (pair shown) of the rolling cutters 9 may be mounted to each primary blade 7p in pockets formed in a bottom of a portion thereof in the cone section 4c, such as by brazing. The rolling cutters 9 may each be in a backup position relative to a respective leading cutter 8a and may be aligned with or slightly offset from the respective leading cutter.

[0013] Figure 2B illustrates one of the rolling cutters 9. Each rolling cutter 9 may include a ball 12, a housing 13, and a seat 14. The housing 13 may be cylindrical and have a bore formed therethrough. The housing 13 may have a chamfer 13c formed in an outer surface thereof adjacent to a bottom thereof and a trap 13t formed in an inner surface thereof adjacent to the bottom thereof. The housing 13 may be made from a ceramic or cermet, such as a carbide or carbide cemented by metal or alloy.

[0014] The seat 14 may be cylindrical and have a cradle 14c formed in a bottom thereof and a grooved profile 14g formed in an outer surface thereof adjacent to a top thereof. The cradle 14c may have a curvature conforming to an outer surface of the ball 12. The seat 14 may be made from a metal or alloy, such as steel. The steel of the seat 14 may be plain carbon, stainless, or low alloy, such as chromoly steel. The seat 14 may further have a stress relief, such as a hole, formed therein adjacent to the cradle 14c. The cradle 14c may have an abrasion-resistant coating deposited thereon, such as a ceramic, cermet, or diamond-like carbon. An outer diameter of a mid and lower portions of the seat 14 may be slightly less than an inner diameter of an upper and mid portions of the housing 13 to form a sliding fit therebetween. An outer diameter of the grooved profile 14g may be slightly greater than the inner diameter of the upper and mid portions of the housing 13 to form an interference fit therebetween, thereby mounting the seat 14 in the housing.

[0015] The ball 12 may be made from a cermet or ceramic, such as silicon nitride, alumina (i.e., corundum), a cemented carbide (i.e., cobalt-tungsten carbide), or zirconia. A diameter of the ball 12 may be slightly less than the inner diameter of the upper and mid portions of the housing 13 to form a sliding fit therebetween. A minimum inner diameter of the trap 13t may be slightly less than an outer diameter of the ball 12 to keep the ball between the trap 13t and the cradle 14c. A diameter of the ball 12 may range between one-half and twenty-five millimeters. To assemble the rolling cutter 9, the ball 12 may be inserted into the housing bore from the upper end thereof and the ball may drop into engagement with the trap 13t. The cradle 14c may then be inserted into the housing bore from the upper end thereof and the seat 14 slid into the housing 13 until the grooved profile 14g engages an inner surface of the housing. The seat 14 may then be tapped or pressed into the housing 13.

[0016] To reduce friction and wear among the rolling

ball 12, the cradle 14c, and the trap 13t, a solid lubricant (not shown) may be introduced. The solid lubricant may be h-BN, molybdenum (Mo), molybdenite, MoS₂, graphite, PTFE, Talc, CaF₂, CeF₃, or WS₂. The solid lubricant may be infused into the ball 12, infused into the abrasion-resistant coating of the cradle 14c, deposited on the abrasion-resistant coating of the cradle 14c, infused into the seat 14, infused into the housing 13, and/or deposited onto the trap 13t.

[0017] Each rolling cutter 9 may be mounted in the respective primary blade 7p such that the bottom of the housing 13 is flush with the bottom of the blade. A portion of each ball 12 may protrude from a bottom of the respective primary blade 7p and may be under exposed relative to the respective leading cutter 8a. The diameter of each ball 12 may be less than a diameter of the respective leading cutter 8a. Each rolling cutter 9 may be oriented so that a longitudinal axis thereof is perpendicular to the bottom of the respective blade 7p.

[0018] Alternatively, the materials of the housing 13, the seat 14, and the ball 12 may be selected to minimize friction and wear between the members and may be dependent on the specific drilling conditions. Alternatively, each rolling cutter 9 may be mounted in the respective primary blade 7p such that the top or any other portion of the chamfer 13c is flush with the bottom of the blade. Alternatively, each ball 12 may be equally exposed or over exposed relative to the respective leading cutter 8a. Alternatively, the seat 14 may be thermally fit in the housing 13. Alternatively, the cermet or ceramic of the ball 12 may be silicon carbide or tungsten carbide. Alternatively, the ball 12 may be made from a superhard material, such as synthetic diamond. Alternatively, one of the solid lubricants may be deposited on the cradle 14c instead of the abrasion-resistant coating. Alternatively, the seat 14 may be made from a cermet or ceramic, such as tungsten carbide, alumina, silicon nitride, zirconia, silicon carbide, boron nitride, or chromium nitride. Alternatively, the housing 13 may be made from a metal or alloy, such as steel, and case hardened or hardfaced. Alternatively, the blades 7p,s may be radially straight (no spiral curvature).

[0019] Figures 3A and 3B illustrate a second fixed cutter drill bit 15 having rolling cutters 19, according to another embodiment of the present disclosure. Figures 4A-4C illustrate a cutting face 16 of the second fixed cutter drill bit 15. The second drill bit 15 may include the bit body 2, the shank 3, a cutting face 16, and a gage section 20. The cutting face 16 may form a lower end of second drill bit 15 and the gage section 20 may form an outer portion thereof.

[0020] The cutting face 16 may include one or more (three shown) primary blades 17p, one or more (three shown) secondary blades 17s, fluid courses formed between the blades, the shear cutters 8, and rolling cutters 19. The cutting face 16 may have one or more sections, such as the inner cone 4c, the outer shoulder 4s, and the intermediate nose 4n between the cone and the shoulder. The blades 17p,s may be disposed around the cutting

face and each blade may be formed during molding of the bit body 2 and may protrude from the bit body. The primary blades 17p may each extend from a center of the cutting face, across the cone 4c and nose 4n sections, along the shoulder section 4s, and to the gage section 20. The secondary blades 17s may each extend from a periphery of the cone section 4c, across the nose section 4n, along the shoulder section 4s, and to the gage section 20. Each blade 17p,s may extend generally radially across the cone 4c (primary only) and nose 4n sections with a slight spiral curvature and along the shoulder section 4s generally longitudinally with a slight helical curvature. Each blade 17p,s may be made from the same material as the bit body 2.

[0021] The shear cutters 8 may include a set of the leading cutters 8a for each blade 17p,s and a set of the backup cutters 8b for each blade. The leading cutters 8a may be mounted in pockets formed along leading edges of the blades 17p,s, such as by brazing. The backup cutters 8b may be mounted in pockets formed along portions of the blades 17p,s in the shoulder section 4s, such as by brazing. The backup cutters 8b may extend into portions of the blades 17p,s in the nose section 4n. Each backup cutter 8b may be aligned with or slightly offset from a respective leading cutter 8a. The backup cutters 8b may be located adjacent to trailing edges of the respective blades 17p,s.

[0022] One or more (nine shown) ports 21 may be formed in the bit body 2 and each port may extend from the plenum and through the bottom of the bit body to discharge drilling fluid 8 along the fluid courses. The nozzle 11 may be disposed in each port 21 and fastened to the bit body 2. The ports 21 may include an inner set of one or more (three shown) ports disposed adjacent to the center of the cutting face 4, an outer set of one or more (five shown) ports disposed at the periphery of the cone section 4c, and an intermediate one of the ports disposed at an intermediate location in the cone section.

[0023] The gage section 20 may include a plurality of gage pads 20p and junk slots formed between the gage pads. The junk slots may be in fluid communication with the fluid courses formed between the blades 17p,s. The gage pads 20p may be disposed around the gage section and each pad may be formed during molding of the bit body 2 and may protrude from the outer portion of the bit body. Each gage pad 20p may be made from the same material as the bit body 2 and each gage pad may be formed integrally with a respective blade 17p,s.

[0024] A set of the rolling cutters 19 may be mounted to each blade 17p,s in pockets formed in a portion thereof across the nose section 4n and along a portion of the shoulder section 4s, such as by brazing. Each set may be extended along the rest of the shoulder section 4s by one or more (pair shown) protectors 22 mounted in pockets formed in the respective blade 17p,s, such as by brazing. The shoulder portion of each blade 17p,s occupied by the rolling cutters 19 may be adjacent to the nose section 4n and the shoulder portion of each blade occu-

pied by the protectors 22 may be adjacent to the gage section 20. The number of rolling cutters 19 in the shoulder portion of each blade 17p,s may be greater than the number of protectors 22 in the shoulder portion thereof. Each protector 22 may be made from a ceramic, cermet, or synthetic diamond. The rolling cutters 19 in the shoulder section 4s may each be located between a respective leading cutter 8a and a respective backup cutter 8b and may be aligned with or slightly offset from the respective leading cutter. The rolling cutters 19 in the nose section 4n may be located behind a respective leading cutter 8a but there may or may not be a respective backup cutter 8b located behind each rolling cutter (as shown, no respective backup cutter on primary blades 17p and respective backup cutter on secondary blades 17s).

[0025] Each rolling cutter 19 may include a ball 23, a housing 24, and a seat (not shown). The seat of each rolling cutter 19 may be similar to the seat 14. The housing 24 may include a cylindrical upper portion 24y for mounting to the blades 17p,s, a conical lower portion 24n for protruding from the blades, and a bore formed there-through. The conical portion 24n may converge from a base adjacent to the cylindrical portion 24y to a tip adjacent to the ball 23. The housing 24 may also have a trap (not shown) formed in an inner surface thereof adjacent to the tip of the conical portion 24n. The housing 24 may be made from a ceramic or cermet, such as a carbide or carbide cemented by metal or alloy.

[0026] The ball 23 may be made from a cermet or ceramic, such as silicon nitride, alumina (i.e., corundum), a cemented carbide (i.e., cobalt-tungsten carbide), or zirconia. A diameter of the ball 23 may be slightly less than the inner diameter of the upper and mid portions of the housing 24 to form a sliding fit therebetween. A minimum inner diameter of the trap may be slightly less than an outer diameter of the ball 23 to keep the ball between the trap and the cradle of the seat. A diameter of the ball 23 may range between one-half and ten millimeters. To assemble the rolling cutter 19, the ball 23 may be inserted into the housing bore from the upper end thereof and the ball may drop into engagement with the trap. The cradle may then be inserted into the housing bore from the upper end thereof and the seat slid into the housing 24 until the grooved profile of the seat engages an inner surface of the housing. The seat may then be tapped or pressed into the housing 24.

[0027] To reduce friction and wear among the rolling ball 23, the cradle, and the trap, one of the solid lubricants discussed above may be introduced. The solid lubricant may be infused into the ball 23, infused into the abrasion-resistant coating of the cradle, deposited on the abrasion-resistant coating of the cradle, infused into the seat, infused into the housing 24, and/or deposited onto the trap.

[0028] Each rolling cutter 19 may be mounted in the respective blade 17p,s such that the conical portion 24n protrudes from the blade and the tip of the conical portion is slightly under exposed relative to the respective leading cutter 8a. A portion of each ball 23 may be over ex-

posed relative to the respective leading cutter 8a. Each backup cutter 8b may be slightly over exposed relative to the respective rolling cutter 19 (and the respective primary cutter 8a). The diameter of each ball 23 may be less than a diameter of the respective leading cutter 8a, such as less than or equal to one-half the diameter of the respective leading cutter. Each rolling cutter 19 may be oriented so that a longitudinal axis thereof is perpendicular to an adjacent surface of the respective blade 17p,s.

[0029] Figures 5A and 5B illustrate drilling of a wellbore 27 using the second fixed cutter drill bit 15. The second drill bit 15 may be assembled with one or more drill collars 6, such as by threaded couplings, thereby forming a bottom hole assembly (BHA) 25. The BHA 25 may be connected to a bottom of a pipe string 26, such as drill pipe or coiled tubing, thereby forming a drill string. The pipe string 26 may be used to deploy the BHA 25 into a wellbore 27. The second drill bit 15 may be rotated, such as by rotation of the drill string from a rig (not shown) and/or by a drilling motor (not shown) of the BHA 25, while drilling fluid 28, such as mud, may be pumped down the drill string. A portion of the weight of the drill string may be set on the second drill bit 15. The drilling fluid 28 may be discharged by the second drill bit 15 and carry cuttings up an annulus 29 formed between the drill string and the wellbore 27 and/or between the drill string and a casing string and/or liner string 30.

[0030] As the second drill bit 15 engages a bottom of the wellbore 27, each leading cutter 8a may shear material from a formation 31 adjacent to the wellbore 27, thereby forming a kerf 32 therein. The respective ball 23 may engage the formation 31 adjacent the kerf 32 and gouge 33 and/or crush 34 the formation, thereby facilitating subsequent cutting by the respective backup cutter 8b and/or the next leading cutter 8a. Further, rolling of the balls 23 relative to the housings 24 may reduce friction, thereby improving efficiency of the second drill bit 15. Further, as the leading cutters 8a become worn, the rolling cutters 19 may assume some of the duty of the leading cutters.

[0031] To ensure that the rolling cutters 19 effectively gouge 33 and/or crush 34 the formation 31, the second drill bit 15 may be configured such that the weight exerted thereon (WOB) divided by a contact area of the balls 23 with the formation 31 is greater than a compressive strength of the formation.

[0032] Alternatively, the materials of the housing 24, the seat, and the ball 23 may be selected to minimize friction and wear between the members and may be dependent on the specific drilling conditions. Alternatively, each backup cutter 8b may be equally exposed relative to the respective rolling cutter 19. Alternatively, the seat of the rolling cutter 19 may be thermally fit in the housing 24. Alternatively, the cermet or ceramic of the ball 23 may be silicon carbide or tungsten carbide. Alternatively, the ball 23 may be made from a superhard material, such as synthetic diamond. Alternatively, one of the solid lubricants may be deposited on the cradle instead of the abra-

sion-resistant coating. Alternatively, the seat of the rolling cutter 19 may be made from a cermet or ceramic, such as tungsten carbide, alumina, silicon nitride, zirconia, silicon carbide, boron nitride, or chromium nitride. Alternatively, the housing 24 may be made from a metal or alloy, such as steel, and case hardened or hardfaced. Alternatively, the blades 17p,s may be radially straight (no spiral curvature).

[0033] Alternatively, either rolling cutter 9, 19 may be used with other types of downhole tools, such as reamers or stabilizers.

[0034] Alternatively, the leading cutters 8a may be omitted from the second drill bit 15, the sets of rolling cutters 19 on the primary blades 17p may be extended to the center of the cutting face 16, and the sets of backup cutters 8b on the primary blades may be extended to the center of the cutting face.

[0035] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope of the invention is determined by the claims that follow.

Claims

1. A bit for drilling a wellbore, comprising:

a shank having a coupling formed at an upper end thereof;
a bit body mounted to a lower end of the shank;
a gage section forming an outer portion of the drill bit; and
a cutting face forming a lower end of the drill bit and comprising:

a plurality of blades protruding from the bit body, each blade extending from a center of the cutting face to the gage section;
a plurality of shear cutters mounted along each blade; and
a plurality of rolling cutters, each rolling cutter comprising:

a housing mounted to a respective blade;
a seat mounted in the housing; and
a ball kept between the housing and the seat and having a portion protruding from the housing.

2. The bit of claim 1, wherein:

the cutting face has sections including an inner cone, an outer shoulder, and an intermediate nose between the cone and the shoulder, and the rolling cutters are located in the cone section.

3. The bit of claim 2, wherein:

each shear cutter is a leading cutter, each rolling cutter is in a backup position relative to a respective leading cutter, and each rolling cutter is aligned with or slightly offset from the respective leading cutter.

4. The bit of claim 3, wherein a portion of each ball protrudes from a bottom of the respective blade and is under exposed relative to the respective leading cutter.

5. The bit of any preceding claim, wherein:

each housing is cylindrical and has a chamfer formed in a lower end thereof, and a portion of the chamfer is flush with a bottom of the respective blade.

6. The bit of claim 1, wherein:

the cutting face has sections including an inner cone, an outer shoulder, and an intermediate nose between the cone and the shoulder, and a set of the rolling cutters is mounted to each blade across the nose section and along at least a portion of the shoulder section.

7. The bit of claim 6, wherein:

the bit further comprises one or more protectors extending each set along a rest of the respective shoulder section, and the shoulder portion of each blade occupied by the rolling cutters is adjacent to the nose section and the shoulder portion of each blade occupied by the protectors is adjacent to the gage section.

8. The bit of claims 6 or 7, wherein:

each shear cutter is a leading cutter, each rolling cutter is located behind a respective leading cutter, and each rolling cutter is aligned with or slightly offset from the respective leading cutter.

9. The bit of claim 8, wherein a portion of each ball is over exposed relative to the respective leading cutter.

10. The bit of claim 9, wherein:

the bit further comprises a plurality of backup shear cutters extending along shoulder sections of each blade, and the rolling cutters in the shoulder section are each located between a respective leading cut-

ter and a respective backup cutter and are each aligned with or slightly offset from the respective leading cutter.

11. The bit of claim 10, wherein each backup cutter is slightly over exposed relative to the respective rolling cutter. 5

12. The bit of any of claims 6 to 11, wherein:

each housing has a cylindrical upper portion mounted to the respective blade and a conical lower portion for protruding from the respective blade, and
the conical portion converges from a base adjacent to the cylindrical portion to a tip adjacent to the ball. 10 15

13. The bit of any preceding claim, wherein:

each housing is made from a ceramic or cermet, and
each ball is made from a ceramic or cermet. 20

14. The bit of any preceding claim, wherein:

each seat is made from a metal or alloy,
each seat has a cradle with a curvature conforming to the respective ball, and
each cradle is coated with a ceramic, cermet, or diamondlike carbon. 25 30

15. A method of drilling a wellbore using the bit of any preceding claim, comprising:

connecting the bit to a bottom of a pipe string, thereby forming a drill string;
lowering the drill string into the wellbore until the drill bit is proximate a bottom thereof;
rotating the bit and injecting drilling fluid through the drill string; and
exerting weight on the bit,
wherein the rolling cutters gouge or crush a formation adjacent to the wellbore. 35 40 45

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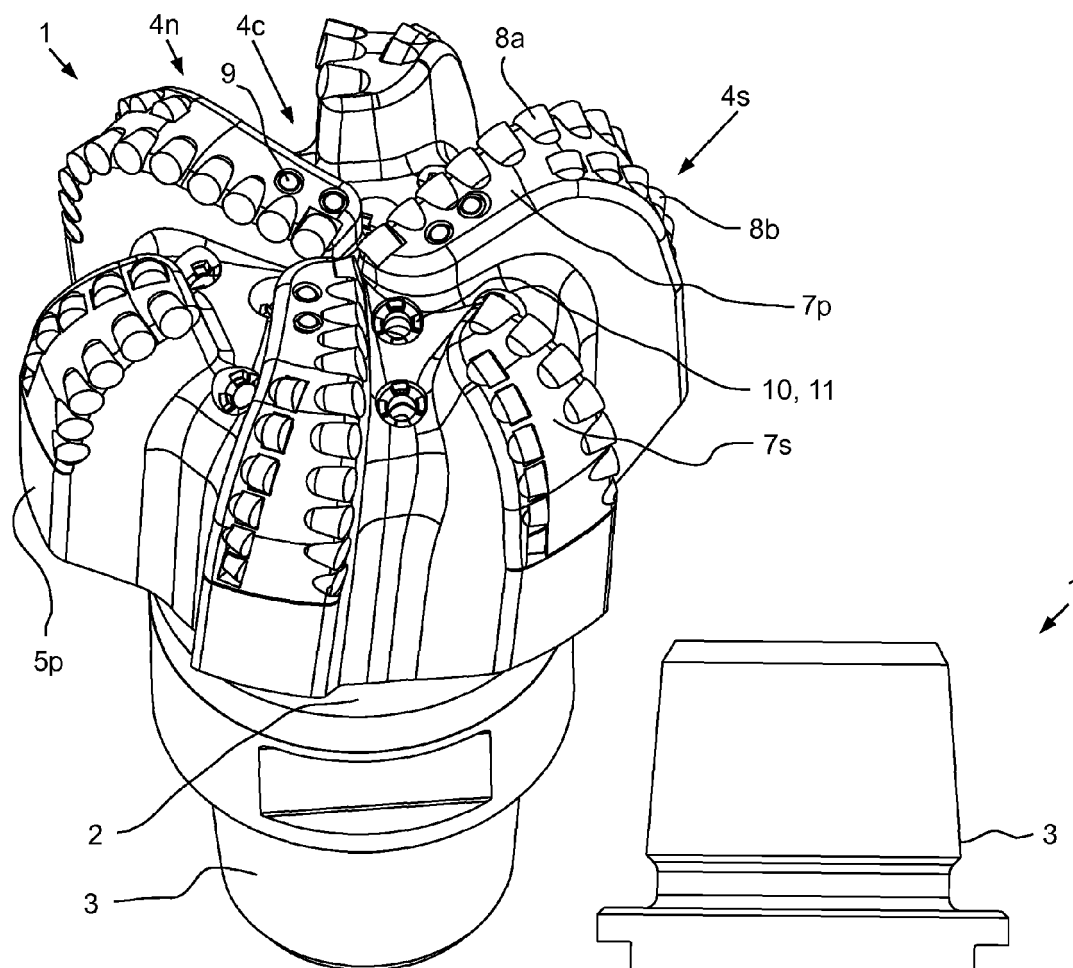


FIG. 1A

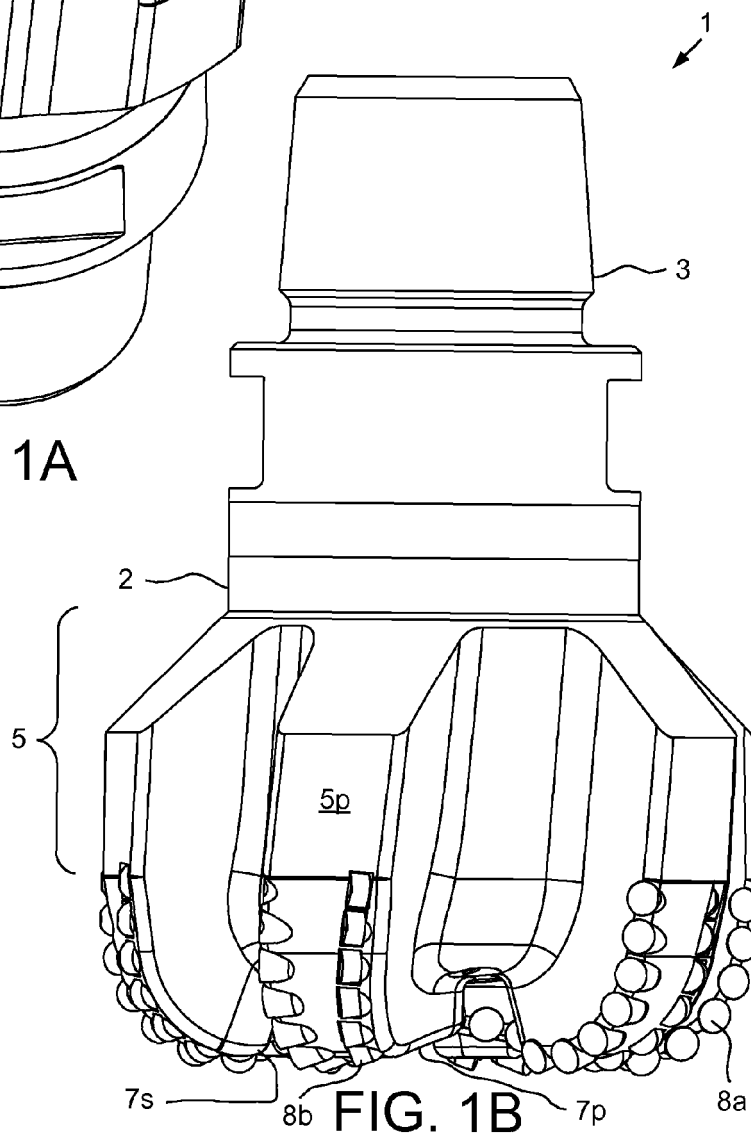


FIG. 1B

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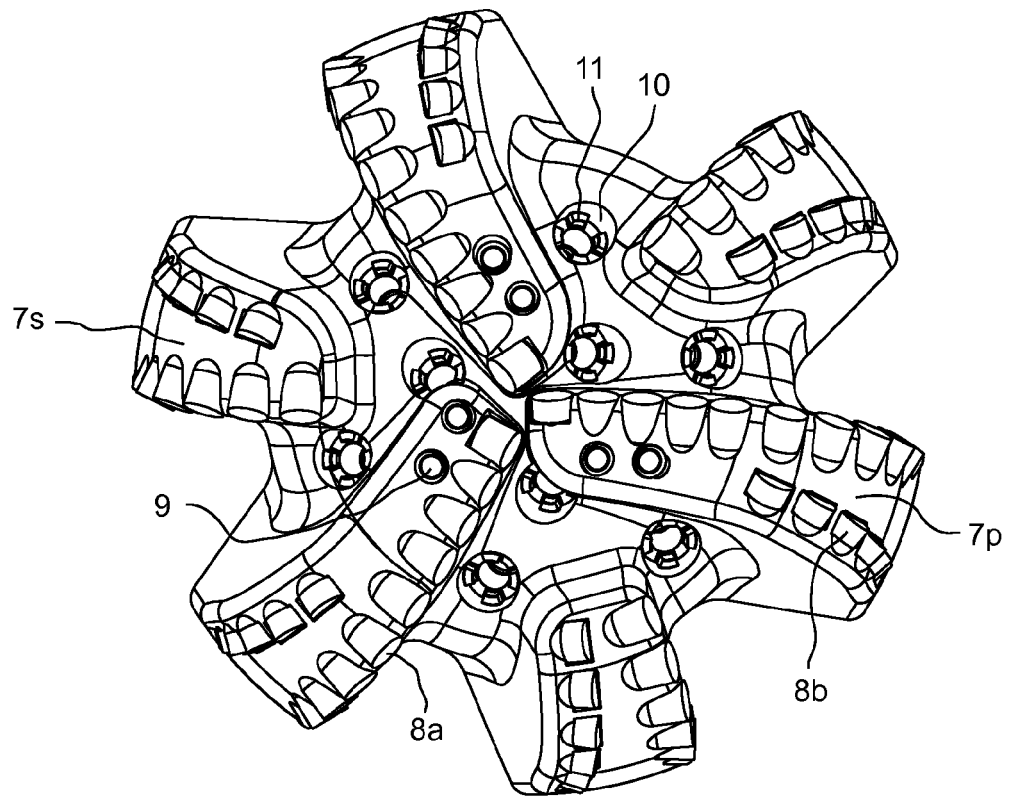


FIG. 2A

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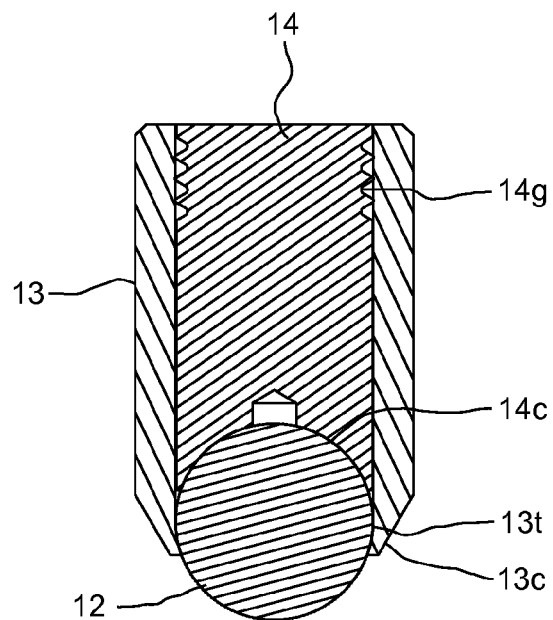


FIG. 2B

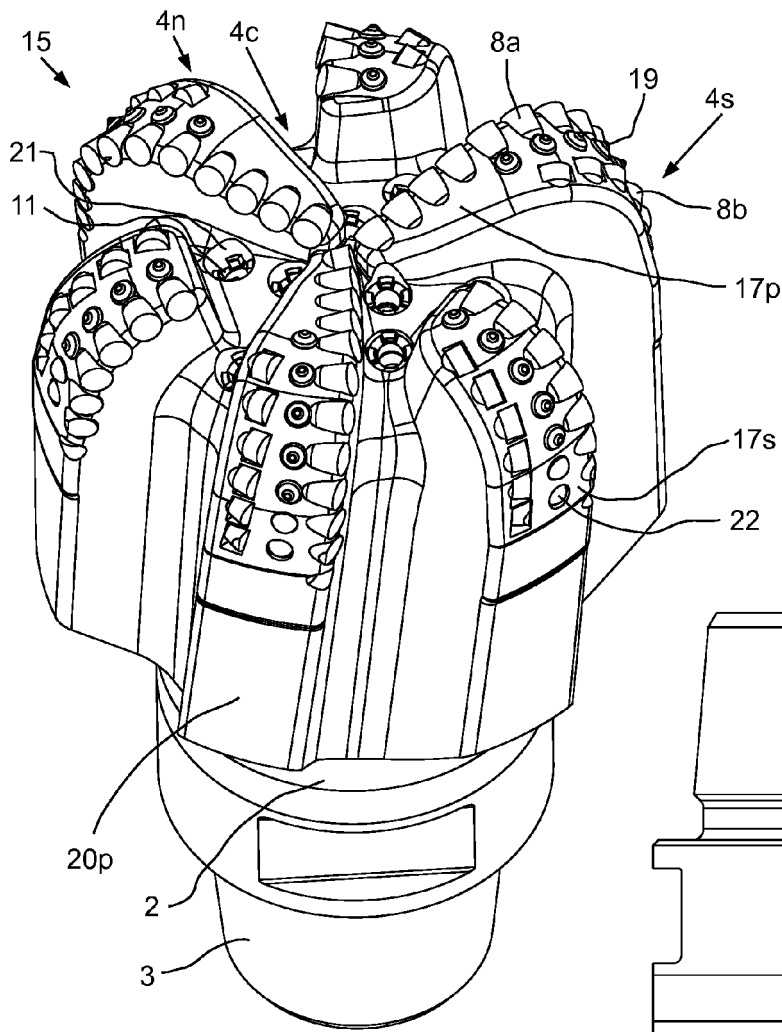


FIG. 3A

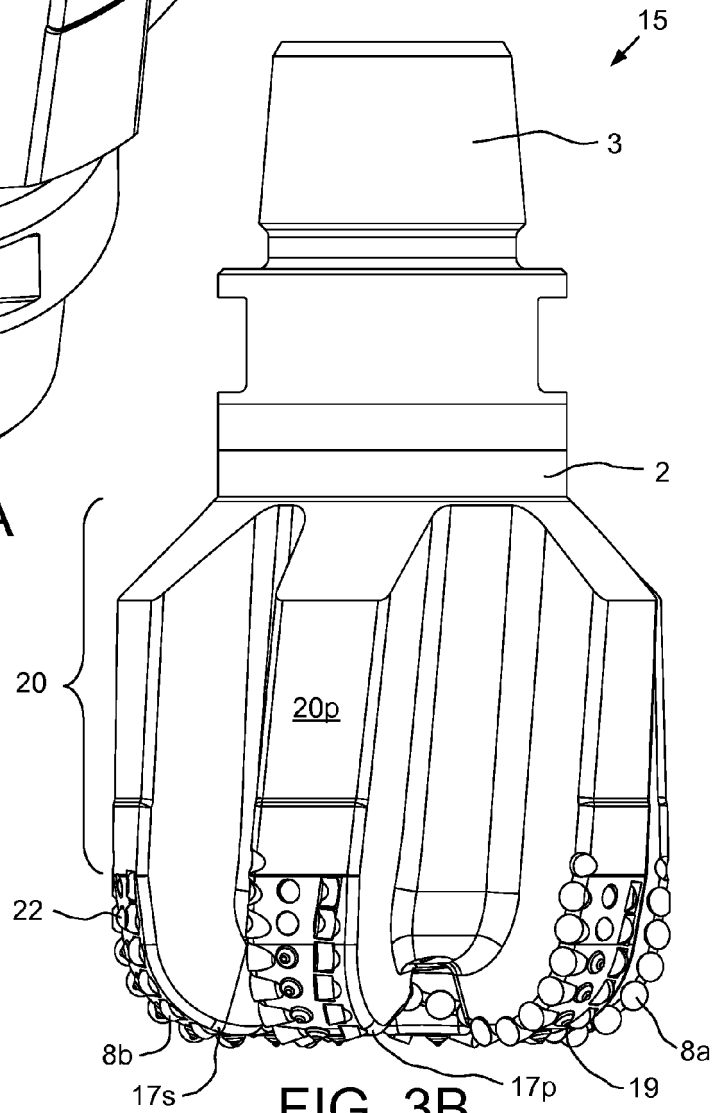


FIG. 3B

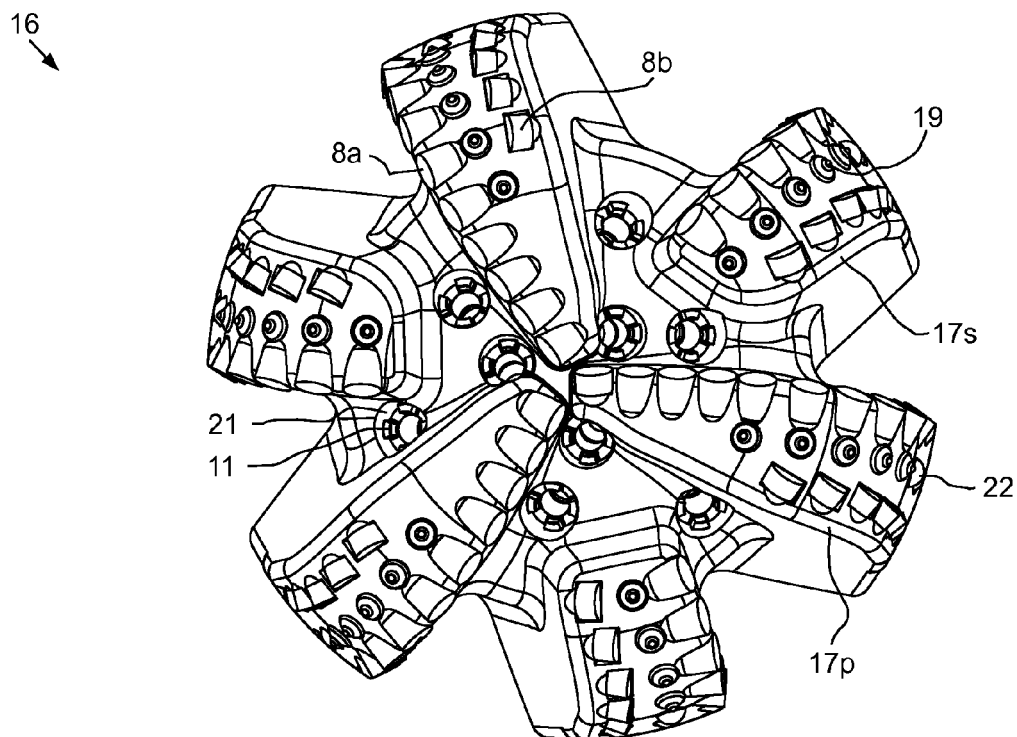


FIG. 4A

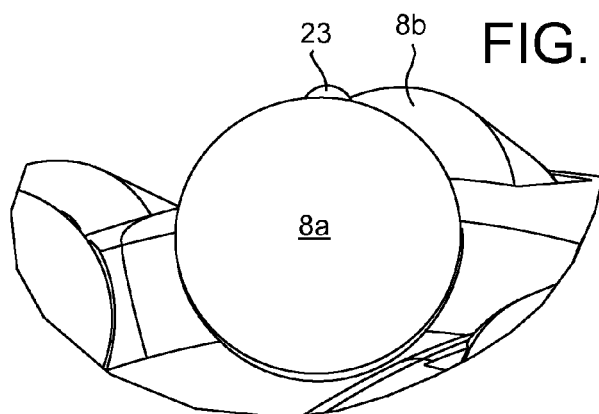


FIG. 4B

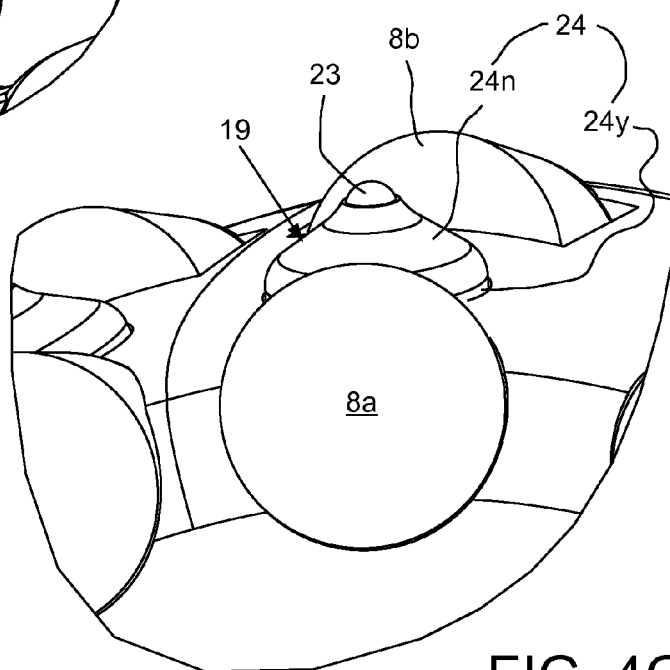


FIG. 4C

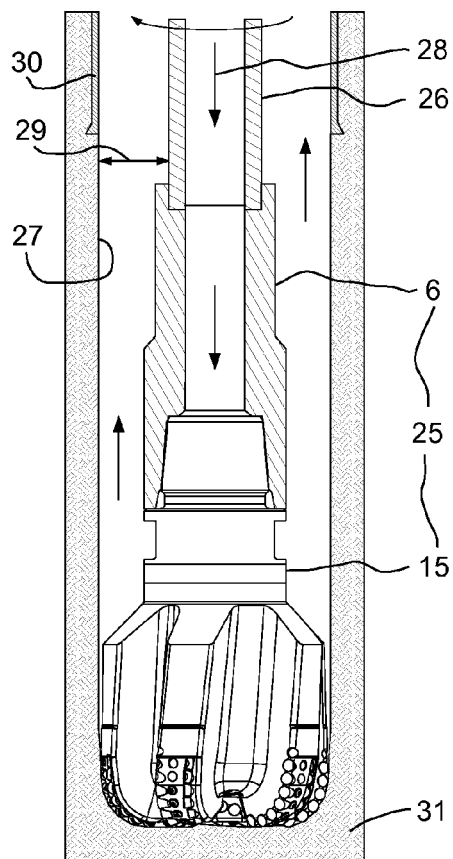


FIG. 5A

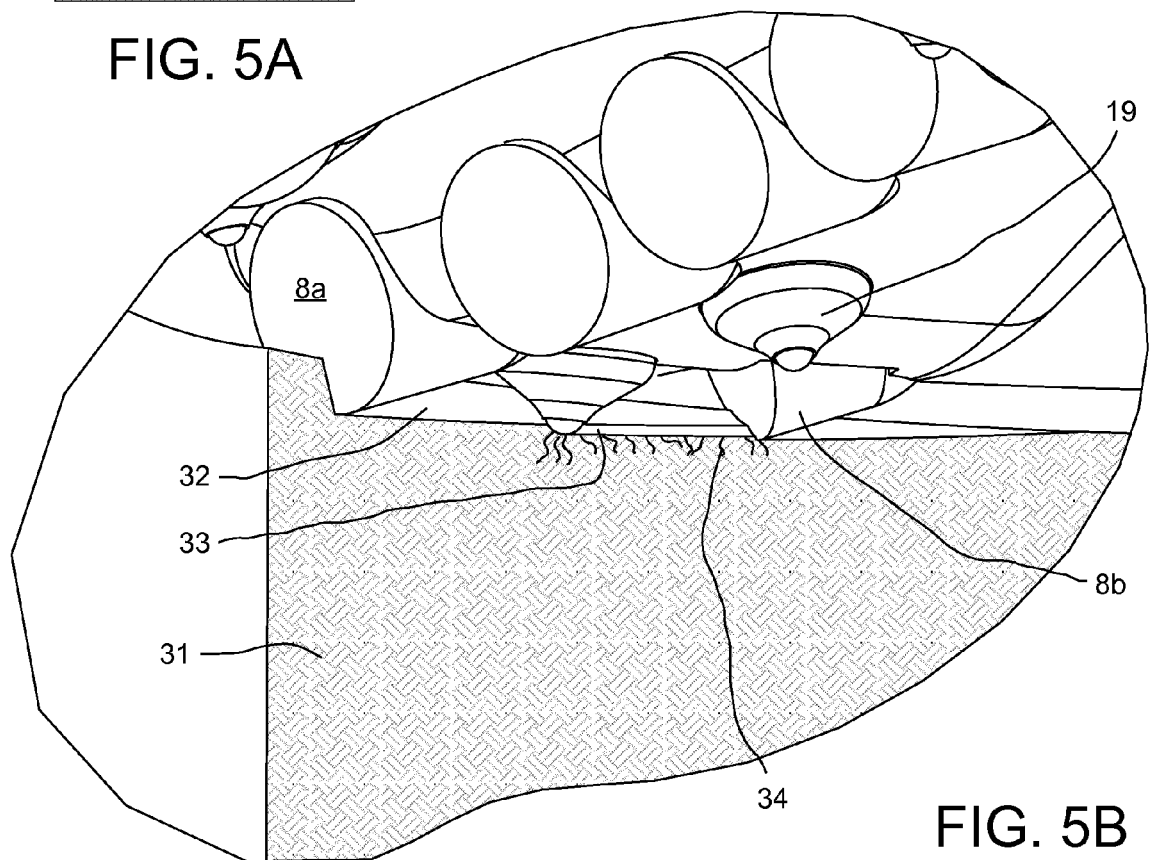


FIG. 5B



EUROPEAN SEARCH REPORT

Application Number
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			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 25 October 2016	Examiner Patrascu, Bogdan
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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REFERENCES CITED IN THE DESCRIPTION

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