



TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, **Published:**

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,

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,

GW, ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

A DRILL BIT

This invention relates to a drill bit.

Geological formations do not necessarily have a homogenous structure. In some formations, particularly iron ore formations, it is more common for there to be bands of hard and soft material. This variation in structure and formation hardness creates a risk of damage for drill bits used in drilling the formation. A hammer including a conventional drill bit will power through the soft ground. However, the momentum achieved whilst powering through the soft ground provides energy which can cause failure of the drill bit when it encounters hard bands in the formation. Damage, usually catastrophic, often results to the cutter elements, especially the gauge cutter elements or gauge buttons, of the drill bit. Such gauge cutter elements are located about a periphery of the cutting face located at the working end of the drill bit. The cutter elements are called gauge cutter elements because they define the working diameter or gauge of the drill bit. So, for a 9" drill bit, the gauge cutter elements will be located about the periphery of the cutting face of the drill bit at a distance of about 4 ½ " from the centre of the drill bit.

The drill bit failure mode may be caused by hammer rotation stalling when hitting hard bands in the formation when down-feeding rapidly through the soft ground. Even where upward feed is applied to the hammer, the windup in the drill rods caused by the rotational forces applied through normal drilling parameters and the sudden release of the drill bit jammed on the hard band causes the fixed gauge cutter elements or buttons, of high hardness material such as tungsten carbide, to shear. Even the control available through use of remote controlled autonomous drilling rigs cannot address this issue which severely affects the average drill bit life and increases drilling costs. While experienced drillers may – in some cases – have the skills to avoid such problems, less experienced drillers will experience these problems on a regular basis.

It is an object of the present invention to provide a drill bit having a cutter element arrangement less susceptible to such shear failure of cutter elements.

With this object in view, the present invention provides a drill bit comprising:

a working end having a cutting face; and

a plurality of cutter elements located at said working end of said drill bit for cutting a formation, said cutter elements including face cutter elements arranged on said cutting face of said drill bit and gauge cutter elements
5 arranged on a plurality of correspondent wing pads located about a periphery of said cutting face of said drill bit wherein said gauge cutter elements are arranged in groups on their correspondent wing pad.

Cutter elements typically comprise a high hardness material, of higher hardness than the formation, to facilitate cutting. Buttons and other fixed
10 inserts may conveniently be used as cutter elements with the drill bit of the invention.

The gauge cutter elements are preferably arranged or grouped in groups of two or are paired on a wing pad, typically of semi-annular shape when viewed in plan. However, the gauge cutter elements could be grouped
15 in larger numbers on each wing pad, if required and practicable. These gauge cutter elements and wing pads advantageously face radially outward, the wing pads further advantageously having surface(s) extending at a substantial acute angle to a longitudinal axis of the drill bit.

The gauge cutter elements may have lesser dimension than face cutter
20 elements. Gauge cutter elements are so-called because they define the working diameter or gauge of the drill bit.

Therefore, in a further embodiment of the invention, the present invention provides a drill bit comprising:

a working end having a cutting face; and

25 a plurality of cutter elements located at said working end of said drill bit for cutting a formation, said cutter elements including face cutter elements arranged on said cutting face of said drill bit and gauge cutter elements defining a gauge of the drill bit wherein the gauge cutter elements have lesser dimension than face cutter elements.

30 The dimension referred to is, typically, a diameter of the cutter element when viewed in plan. Cutter elements, such as buttons, often have hemispherical or near hemispherical head portions. In such case, the diameter of the head portions of the gauge cutter elements is deliberately set less than the diameter of the face cutter elements. It may be understood,

also, that each of the grouped gauge cutter elements have lesser dimension than conventional cutter elements, the increased surface area of the grouped cutter elements reducing the tendency to shear failure under the variable hardness formation drilling conditions outlined above. At the same time, greater surface area - presented by the smaller dimension gauge cutter elements - increases cutting effect over conventional drill bits. As a result, more efficient and less costly drilling may be achieved in variable hardness formations even where less experienced drillers are employed.

Gauge cutter elements, and a portion (which may be a major portion) of the face cutter elements are conveniently concentrically arranged in rows or rings forming circles about a circular centre portion of the drill bit cutting face. Two, three or possibly more of such concentric rings of cutter elements may be provided. These rings may be further divided, preferably by exhaust grooves extending across the cutting face, into a plurality of annular sectors, each comprising a plurality of face cutter elements. Outward from the centre portion, face cutter elements may be equi-spaced within each annular sector of each ring. Cutter elements in adjacent rows or rings may be offset with respect to one another. A remaining portion of the face cutter elements may be arranged randomly in the centre portion of the face of the cutting face of the drill bit.

Each wing pad may have circumferential dimension or extent approximately equal to the spacing between two neighbouring face cutter elements located in a first ring adjacent to the pads. Inward of, and/or adjacent to, this first ring, a secondary ring may have spacing between two neighbouring face cutter elements greater than the circumferential dimension of a pad.

The rings or rows of cutter elements may be oriented at differing angles to the longitudinal axis of the drill bit, the angle for each row preferably being less than the acute angle at which wing pad surfaces extend to the longitudinal axis of the drill bit.

The drill bit is provided with means for directing pressurized fluid through its body to forcefully clear cuttings from the drill bit cutting face. The pressurised fluid is conveniently exhaust fluid, typically compressed air, from the pressurised working fluid used for operating a hammer comprising the drill

bit. This pressurized exhaust fluid may also be described as flushing fluid or flushing air. If cuttings are not cleared from the drill bit face, wear rates of cutter elements and the drill bit matrix are unacceptably high. To this end, the pressurised exhaust fluid exhaust fluid directing means delivers pressurised exhaust fluid through a primary exhaust fluid passageway to be directed through a plurality of flushing passageways conveniently diverging from the primary exhaust fluid passageway. Each flushing passageway terminates in at least one exhaust port located on the drill bit cutting face. The means for directing flushing fluid typically comprises a plurality of such exhaust ports.

The exhaust ports may direct flushing fluid at an angle diverging from a longitudinal axis of the drill bit, the flow direction of exhaust fluid through an exhaust port being conveniently determined by the angle at which a flushing passageway diverges from the longitudinal axis of the drill bit. However, in a particularly preferred and advantageous embodiment - which provides greater coverage of drill bit face area and therefore flushing of cuttings - each flushing passageway is configured to straighten the direction of exhaust fluid flow exiting through its associated exhaust port(s). The geometry of the exhaust port may be selected to take advantage of the Coanda effect, exhaust port wall(s) being aligned to direct at least a major portion of exiting exhaust fluid in a direction approaching parallel to the longitudinal axis of the drill bit. A portion of exhaust fluid flow may still be directed at an angle to the longitudinal axis of the drill bit. This feature, of directing exhaust air parallel to the longitudinal axis of the drill bit, may advantageously be included within a range of drill bits, not limited to drill bits having cutter elements arranged in groups, on wing pads, or having gauge cutter elements of lesser dimension than remaining face cutter elements as above described.

Conveniently, and advantageously, each flushing passageway of a drill bit may be provided with an inward portion and a terminal portion comprising at least one exhaust port through which exhaust fluid is directed, the inward portion having an axis diverging from a longitudinal axis of the drill bit and wherein the terminal portion has an axis intersecting with said axis of said inward portion such that the terminal portion axis intersects the drill bit cutting face inward of the intersection of the inward portion axis with said bit face. Most advantageously, the terminal portion axis approaches a direction parallel

to the longitudinal axis of the drill bit. This optimizes bit face coverage and flushing of cuttings while increasing penetration rate.

The exhaust ports are advantageously connected with associated exhaust grooves or channels extending radially outwardly (and through the rings of cutter elements) towards the periphery of the drill bit cutting face. This optimizes coverage of the drill bit cutting face optimizing flushing of cuttings away from the bit face. These exhaust grooves are generally provided as the primary exhaust or air grooves with which have the largest surface area of grooves for directing exhaust fluid about the drill bit head and cutting face.

A plurality of exhaust or air grooves may also be spaced about the periphery of the drill bit head. These, typically secondary, air grooves may be comprised in sets each having different dimension in terms of area. One set of secondary air grooves may be provided at each wing pad, each secondary air groove extending between the gauge cutter elements. Each of these grooves may have the smallest area, of the exhaust grooves, but serve an important function in clearing cuttings lodging between the paired gauge cutter elements, the primary region for wear. Clearing of such cuttings through air flow through these secondary air grooves reduces cutting regrinding and excessive wear on gauge cutter elements. A further set of exhaust grooves could include air grooves separating the paired gauge cutter elements and wing pads to reduce wear in this region.

Alternatively, or additionally to air grooves, flat headed wear buttons could be located in the side of the drill bit head conveniently proximate the paired gauge cutter elements to assist in reducing gauge cutter element and drill bit matrix wear.

The drill bit may be used in normal circulation, down-the-hole and reverse circulation hammers or other drilling apparatus. Therefore, a drilling apparatus comprising the above described drill bit forms a still further aspect of the present invention. The drill bit may be used in various drilling rigs and is particularly advantageous for use in autonomous drilling rigs, for example used for drilling iron ore bodies or geological formations of the type which have bands of hard and soft material present within them. In such case, the gauge cutter elements, being of lesser dimension than conventional, are less prone to the shear problem mentioned above.

The drill bit of the present invention will be more fully understood from the following description of a preferred embodiment thereof made with reference to the drawings in which:

Fig. 1 is a bottom or face view of a drill bit as used in the prior art.

5 Fig. 2 is a perspective view of the drill bit of Fig. 1.

Fig. 3 is a side view of a drill bit in accordance with one embodiment of the present invention.

Fig. 4 is an isometric view of the drill bit of Fig. 3.

Fig. 5 is a detail isometric view taken from Fig. 4.

10 Fig. 6 is a bottom or face view of the drill bit as illustrated in Figs. 3 to 5.

Fig. 7 is a side section view of the drill bit as illustrated in Figs. 3 to 6.

Fig. 8 is a side section view of a hammer including the drill bit as illustrated in Figs. 3 to 6.

15 Fig. 9 is a second face view of the drill bit of Figs. 3 to 8.

Fig. 10 is a side section view of the drill bit of Figs. 3 to 8 taken along section line A-A of Fig. 9.

Fig. 11 is a detail section view of the drill bit of Fig. 10 showing exhaust air passageway and exhaust air port geometry.

20 Fig. 12 is a second isometric view of the drill bit of Figs. 3 to 11.

Fig. 13 is a face view of a second embodiment of drill bit according to the invention.

Fig. 14 is a side section view of the drill bit of Fig. 13 taken along section line B-B.

25 Fig. 15 is a detail section view of the drill bit of Fig. 14 showing exhaust air passageway and exhaust air port geometry.

Fig. 16 is an isometric view of the drill bit of Figs. 13 to 15.

Fig. 17A is a face view of a further embodiment of the drill bit in accordance with a further embodiment of the present invention.

30 Fig. 17B is a detail face view of the drill bit of Fig. 17A.

Fig. 18A is an isometric view of the drill bit of Figs. 17A and 17B.

Fig. 18B is a detail isometric view of the drill bit of Fig. 18A.

Referring first to Figs. 1 and 2, there is shown a drill bit 1 for a down the hole (DTH) hammer (not shown) used in autonomous drilling of an ore body

containing iron. Drill bit 1 has, viewed rearwardly along its length, a head portion 8 and a shank 7. The surface of a portion of shank 7 is formed with spline portions 7a correspondent with, and interlocked with, driving spline portions of a drive sub (not shown) forming part of DTH hammer 10.

- 5 Drill bit head portion 8 has a cutting face 211 provided with round headed cutter elements or buttons 2, 4 of tungsten carbide or like hard material, distributed over the surface of the cutting face 211. As drill bit 1 impacts the bottom of a hole during operation of the DTH hammer, cuttings are formed and returned to the surface. Cutting face 211 also includes the
10 openings or exhaust ports to three passageways 137 which direct compressed air to assist drilling during operation of the DTH hammer.

- Cutter elements include face cutter elements 4 arranged on cutting face 211 of drill bit 1; and gauge cutter elements 2 arranged about the periphery of cutter face 211 of drill bit 1. The cutter elements 2, 4 are buttons
15 of tungsten carbide. Each cutter element 2, 4 has a head of hemispherical shape, the hemisphere having the same dimension, measured as diameter, for both gauge cutter elements 2 and face cutter elements 4.

- Each gauge cutter element 2 is arranged, individually, on a corresponding radially outwardly facing wing pad 3 arranged about the
20 periphery of the drill bit head portion 8. Such wing pads 3 may, alternatively, be considered to form chamfered or beveled portions of the drill bit head portion 8. Wing pad 3 surfaces extend at an acute angle to a longitudinal axis, L, of drill bit 1.

- The ore body contains bands of soft and hard material. Such
25 formations are challenging to drill without a strategy directed to controlling forces acting on the drill bit 1 during a drilling operation. A failure mode is caused by hammer rotation stalling when hitting hard bands in the formation when down-feeding rapidly through the soft ground. Even where upward feed is applied to the DTH hammer, the windup in the drill rods caused by the
30 rotational forces applied through normal drilling parameters and the sudden release of the drill bit 1 jammed on the hard band causes the gauge cutter elements 2 (at least) to fail under the shear forces applying in such circumstances. Even the control available through use of remote controlled

autonomous drilling rigs cannot usually address this issue which severely affects the average drill bit life and increases drilling costs.

Referring now to Figs. 3 to 8, there is shown a first embodiment of drill bit 30 for a down the hole (DTH) hammer 10 used in autonomous drilling of an ore body containing iron.

Drill bit 30 has, viewed rearwardly along its length, a head portion 30a and a shank 30c with an intermediate portion 30b and a cylindrical portion 30d. Cylindrical portion 30d is relatively short in length in comparison to the length of the intermediate portion 30b of shank 30c. Head portion 30a includes a cutting face 311. The surface of intermediate portion 30b of drill bit 30 is formed with spline portions 31 correspondent with, and interlocked with, driving spline portions 28 of a drive sub 20 forming part of DTH hammer 10. The surface of cylindrical portion 30d is generally smooth, acting as a bearing surface for spline portions 27 of first drive sub portion 21. As drill bit head portion 30a, provided with round headed cutter elements or buttons 35a, 36, 36a of tungsten carbide or like material, distributed over the surface of the cutting face 311, impacts the bottom of a hole (not shown), cuttings are formed and returned to the surface.

Cutter elements include face cutter elements 36 and 36a arranged on cutting face 311 of drill bit 30; and gauge cutter elements 35a arranged about the periphery or circumference of cutter face 311 of drill bit 30. Each cutter element 35a, 36, 36a has a head of hemispherical shape.

Gauge cutter elements 35a are arranged on radially outwardly facing and semi-annular shaped wing pads 34 of the drill bit 30. Each wing pad 34 has the same surface area as wing pads 3 of drill bit 1 (as shown in Figs. 2 and 2). Such wing pads 34 may, alternatively, be considered to form chamfered or beveled portions of the head portion 30a of the drill bit 30. Wing pad 34 surfaces extend at a substantial acute angle to a longitudinal axis, L, of drill bit 30.

It will be observed that the gauge cutter elements 35a have lesser dimension than the face cutter elements 36, 36a and the gauge cutter elements 2, of drill bit 1 shown in Figs. 1 and 2. The dimension here referred to is the diameter of the hemi-spherically shaped head of the cutter element. The diameter, D, of such hemispherical head portion of a gauge cutter

element 35a is less than the diameter, E, of the head portion of a face cutter element 35. This diameter, D, is deliberately selected for all gauge cutter elements 35a and diameter, E, is deliberately selected for all face cutter elements 36, 36a illustrated in the drawings.

5 The gauge cutter elements 35a are arranged in groups of two or are paired on each wing pad 34. Each gauge cutter element 35a, as with each wing pad 34, faces radially outward. The gauge cutter elements 35a form a circular ring or row located about, though located radially outward from, the circular centre portion 313 of the drill bit face 311. The greater numbers of
10 gauge cutter elements 35a present a greater surface area (and cutting effect) than for conventional drill bits. However, their smaller dimension – at the individual level – makes them less susceptible to shear failure during autonomous drilling of the formation.

 A major portion of the face cutter elements 36 are located in two
15 circular and concentric (with longitudinal axis, L, of drill bit 30) rows or rings 312a and 312b located about a circular and dome shaped centre portion 313 of drill bit face 311. Rings 312a and 312b of cutter elements 36 may be further divided by exhaust grooves or channels 137A into a plurality of annular sectors also indicated 312a and 312b. Here, there are three annular sectors
20 per ring 312a, 312b. Within each annular sector 312a and 312b neighbouring face cutter elements 36 are equi-spaced at a greater dimension than spacing between gauge cutter elements 35a on pads 34.

 Each wing pad 34 has circumferential dimension or extent approximately equal to the spacing between two neighbouring face cutter
25 elements 36 in any annular sector located within first ring 312a adjacent to the pads 34.

 Inward of, and adjacent to, first ring 312a, a secondary ring 312b has spacing between two neighbouring face cutter elements 36 greater than the circumferential dimension of a wing pad 34. It will be noted that face cutter
30 elements 36 located in adjacent rings 312a and 312b are arranged offset to each other. Rings 312a and 312b are oriented at differing acute angles to longitudinal axis, L, of drill bit 30, these angles being less than that at which wing pads 34 extend to longitudinal axis L.

The remaining face cutter elements 36a are arranged randomly in the circular centre portion 313 of drill bit face 311.

Referring further to Fig. 8, further description of a rotary DTH hammer 10 is provided. Hammer 10 operates with a compressed air supply, compressed air exhausted from hammer 10 working chamber portions (as described below with reference to Fig. 8) being forced through primary exhaust air passageway 20 and further flushing passageways 137, diverging from passageway 20, to assist the drilling operation through flushing of cuttings away from cutting face 311. Three further exhaust passageways 137 and associated channels 137A are provided to direct air to the cutting face 311. Exhaust air flowing through flushing passageways 137 and channels 137A is directed across the drill bit face 311 to clear cuttings away from the cutter elements 35a, 36 and 36a to be swept upward, through secondary primary exhaust grooves 37 and secondary exhaust grooves 37a located about the periphery of the drill bit head, past the drill bit 30 and hammer 10 to be recovered at the surface located drill rig. Without such flushing of cuttings, hammer 10 could become bogged and wear rates for the cutter elements 35a, 36 and 36a would reach unacceptable levels.

In the embodiment of drill bit 30 shown in Figs. 3 to 12, exhaust air flow, through exhaust ports 137 and channels 137A, is directed divergently at an angle, α , to the longitudinal axis L of the drill bit 30. This exhaust air flow direction is shown by arrows F in Figs. 10 and 11. Arrows F extend in the same direction as axis G of each exhaust passageway 137. The Applicant has found that such exhaust air flow direction, F, while being that conventionally selected, may not deliver the desired flushing of cuttings. An angular outward exhaust flow may also create borehole scouring issues if the angle, α , is too high.

A second embodiment of drill bit 730, which optimizes flushing of cuttings, is shown in Figs. 13 to 16. The drill bit 730, like drill bit 30, has a head portion 730a, shank 730c and intermediate portion 730b. Head portion 730a, at the working end of drill bit 730, is provided with face cutter elements 736, 736a - cutter elements 736a being randomly arranged in circular centre portion 711. Cutter elements 736 are arranged in two concentric rings as with the above described embodiment. Gauge cutter elements 735a are paired on

wing pads 735. The drill bit 730 includes three exhaust or flushing passageways and associated exhaust ports 739a (the same number as included in drill bit 30) in cutting face 731, the flushing passageways of drill bit 730 have different geometry to exhaust passageways/ports 137. This geometry is adopted to straighten exhaust air flow direction and optimize bit face coverage and flushing of cuttings.

Each flushing passageway is provided with an inward portion 740 and a terminal portion 739 comprising an exhaust port 739a through which exhaust air is directed. The inward portion or passageway 740 diverges from longitudinal axis, L, of the drill bit 730 at an acute angle along axis, G. The terminal portion 739 has an axis, P, extending parallel to longitudinal axis L and which intersects axis G of inward portion 740. This has maximum effect in terms of straightening exhaust air flow to achieve the flushing benefits described above. Axis P of terminal portion 739 also extends parallel to a substantially right cylindrical wall 739aa defining exhaust port 739a. The terminal portion axis P clearly intersects the drill bit cutting face 731 inward of the intersection of the inward portion axis G with drill bit cutting face 731.

In side section, exhaust port wall 739aa extends substantially parallel to longitudinal axis L of drill bit 730. Wall 739aa therefore defines a cylindrical volume with the exhaust port 739a opening along a plane perpendicular to longitudinal axis, L of drill bit 730.

The direction of exhaust air flow from exhaust passageways 740 and exhaust ports 739, as shown by flow arrows S and SA, is influenced by the geometry of both the exhaust passageway 740 and exhaust port 739a, especially noting the cylindrical exhaust port wall 739aa. Exhaust air flow therefore includes a vector directed outwardly from axis L along axis G as shown by flow arrows SA. However, this represents only a minor portion of exhaust air flow. The dominant exhaust air flow vector, shown by flow arrows S, is in straight outward direction from drill, in direction of axis P, with a Coanda effect causing flushing air flow to be directed by wall 739aa in a direction parallel to the longitudinal axis of the drill bit 730. This results in better coverage of drill bit cutting face 731 and clearance of cuttings, especially as discharged flushing air is directed through exhaust ports 739a into the associated primary exhaust grooves 737 extending radially across

cutting face 731 outward toward the periphery of the drill bit face 731. These primary exhaust grooves 737 connect with exhaust ports 739a to form an exhaust air circuit. This exhaust air entrains cuttings which are transported through a hole drilled by a hammer, having the same design as hammer 10, including drill bit 30, past the hammer and recovered at the surface.

Exhaust passageway and exhaust port geometry as above described may be employed in a range of drill bits having different design and arrangements of cutter elements than described in this specification. A drill bit having one or more exhaust ports configured, as above described, to straighten exhaust air flow through exhaust passageways and exhaust ports forms another inventive aspect.

Flushing air is also directed through secondary exhaust air grooves 738 formed and spaced around the periphery of the head 730a of drill bit 730 between the wing pads 734 carrying the paired gauge cutter elements 735a.

The drill bit may include a plurality of sets of such secondary air grooves, each air groove within a set having different dimension in terms of area than an air groove within another set. In Figs. 17A to 18B is shown a drill bit 830 with many of the same features of the drill bits 30 and 730 described above. This drill bit 830 has a cutting face 831 with cutter elements including face cutter elements 840 arranged in concentric rings about circular centre portion 811 of drill bit 830; face cutter elements 840 a randomly arranged in centre portion 811; and gauge cutter elements 835a arranged in pairs on wing pads 836. This drill bit 830 is provided with primary exhaust air grooves 837a extending radially outwardly from each exhaust port 837, secondary air grooves 838 provided at each wing pad 836 and extending between the gauge cutter elements 835a, as well as further air grooves 839 separating the paired gauge cutter elements wing pads 836. Primary exhaust grooves 837a have the largest dimension (in terms of area). Secondary air grooves 838 are smaller in dimension (in terms of area) but serve an important function in clearing cuttings lodging between the paired gauge cutter elements 835a. Clearing of such cuttings through air flow through secondary air grooves 838 reduces regrinding of cuttings and excessive wear on gauge cutter elements 835a. Alternatively, or additionally, flat headed wear buttons could be located in the side of the drill bit 830 head proximate the paired gauge cutter elements

835a to assist in reducing gauge cutter element 835a and drill bit 30 matrix wear.

Drill bit 30 cyclically impacts the formation in response to variations in compressed air pressure in variable volume chambers 63 and 66 located
5 above and below the piston 32. This pressure variation causes reciprocation of piston 32 with piston strike face 35 impacting corresponding strike face 38 of drill bit 30 during a working stroke of the piston 32. More efficient drilling by optimizing compressed air pressure during operation of the hammer is achieved by use of sealing tubes 14 and 41 (sealing tube or foot valve 841 in
10 the case of the drill bit 830 of Figs. 17A to 18B). Sealing tube 14 acts as a foot valve and is located between drill bit 30 and piston 32. Sealing tube 41 serves a similar role and is located between piston 32 and top sub 60.

The hammer 10 may have construction as further described in Australian Provisional Patent Application No. 2010904679, the contents of
15 which are hereby incorporated herein by reference.

A hammer 10 incorporating drill bit 30 is useful for autonomous drilling of geological formations having hard and soft bands as the arrangement of cutter elements, particularly noting the smaller dimension (though greater surface area) of the gauge cutter elements 35a, reduces tendency to shear
20 failure.

Modifications and variations to the drill bit of the present invention may be apparent to the skilled reader of this disclosure. Such modifications and variations are deemed within the scope of the present invention.

Claims:

1. A drill bit comprising:

a working end having a cutting face; and

5 a plurality of cutter elements located at said working end of said drill bit for cutting a formation, said cutter elements including face cutter elements arranged on said cutting face of said drill bit and gauge cutter elements defining a gauge of the drill bit arranged on a plurality of correspondent wing pads located about a periphery of said cutting face of said drill bit wherein said
10 gauge cutter elements are arranged in groups on their correspondent wing pad.

2. A drill bit as claimed in claim 1 wherein said gauge cutter elements are arranged in groups of two or are paired on a wing pad.

15 3. A drill bit as claimed in claim 1 or 2 wherein said gauge cutter elements and wing pads face radially outward, said wing pads having surfaces extending at a substantial acute angle to an axis of said drill bit.

20 4. A drill bit as claimed in any one of the preceding claims wherein said gauge cutter elements grouped on said wing pads have lesser dimension than said face cutter elements.

25 5. A drill bit as claimed in claim 4 wherein said dimension referred to is a diameter of the cutter element when viewed in plan.

6. A drill bit as claimed in any one of the preceding claims wherein said gauge cutter elements, and a portion of the face cutter elements are concentrically arranged in rows or rings forming circles about a circular centre
30 portion of the drill bit face.

7. A drill bit as claimed in claim 6 wherein said rows or rings are divided into a plurality of annular sectors each comprising a plurality of face cutter elements.

8. A drill bit as claimed in claim 7 wherein said cutter elements are equi-spaced within said annular sectors.

5 9. A drill bit as claimed in claim 7 or 8 wherein said rows or rings are divided into said plurality of annular sectors by exhaust grooves extending across said cutting face.

10 10. A drill bit as claimed in any one of claims 6 to 9 wherein a remaining portion of said face cutter elements is arranged randomly in said centre portion of the drill bit.

11. A drill bit as claimed in any one of claims 6 to 10 wherein said cutter elements in adjacent rows or rings are offset with respect to each other.

15

12. A drill bit as claimed in any one of the preceding claims provided with means for directing pressurized exhaust fluid to clear cuttings from the drill bit face.

20 13. A drill bit as claimed in claim 13 wherein said pressurised exhaust fluid directing means directs pressurised exhaust fluid, to clear cuttings, through a primary exhaust fluid passageway and a plurality of flushing passageways diverging from the primary exhaust fluid passageway, each said flushing passageway terminating in at least one exhaust port located on the drill bit
25 cutting face.

14. A drill bit as claimed in claim 13 wherein said exhaust ports direct flushing fluid at an angle diverging from a longitudinal axis of the drill bit.

30 15. A drill bit as claimed in claim 13 or 14 wherein exhaust port wall(s) are aligned to direct at least a major portion of exiting exhaust fluid in a direction approaching parallel to the longitudinal axis of the drill bit.

16. A drill bit as claimed in claim 15 wherein each flushing passageway is provided with an inward portion and a terminal portion comprising at least one exhaust port through which exhaust fluid is directed, the inward portion having an axis diverging from a longitudinal axis of the drill bit and wherein the
5 terminal portion has an axis intersecting with said axis of said inward portion such that the terminal portion axis intersects the bit face inward of the intersection of the inward portion axis with said bit face.

17. A drill bit as claimed in claim 16 wherein said terminal portion axis
10 approaches a direction parallel to the longitudinal axis of the drill bit.

18. A drill bit as claimed in any one of claims 13 to 17 wherein each said exhaust port is connected with an exhaust groove extending radially outwardly across said cutting face and through the rings of cutter elements towards the
15 periphery of said cutting face.

19. A drill bit as claimed in any one of the preceding claims wherein a plurality of air grooves is spaced about the periphery of the drill bit head.

20. A drilling apparatus comprising a drill bit as claimed in any one of the preceding claims.
20

21. A drilling apparatus as claimed in claim 20 being an autonomous drilling rig.
25

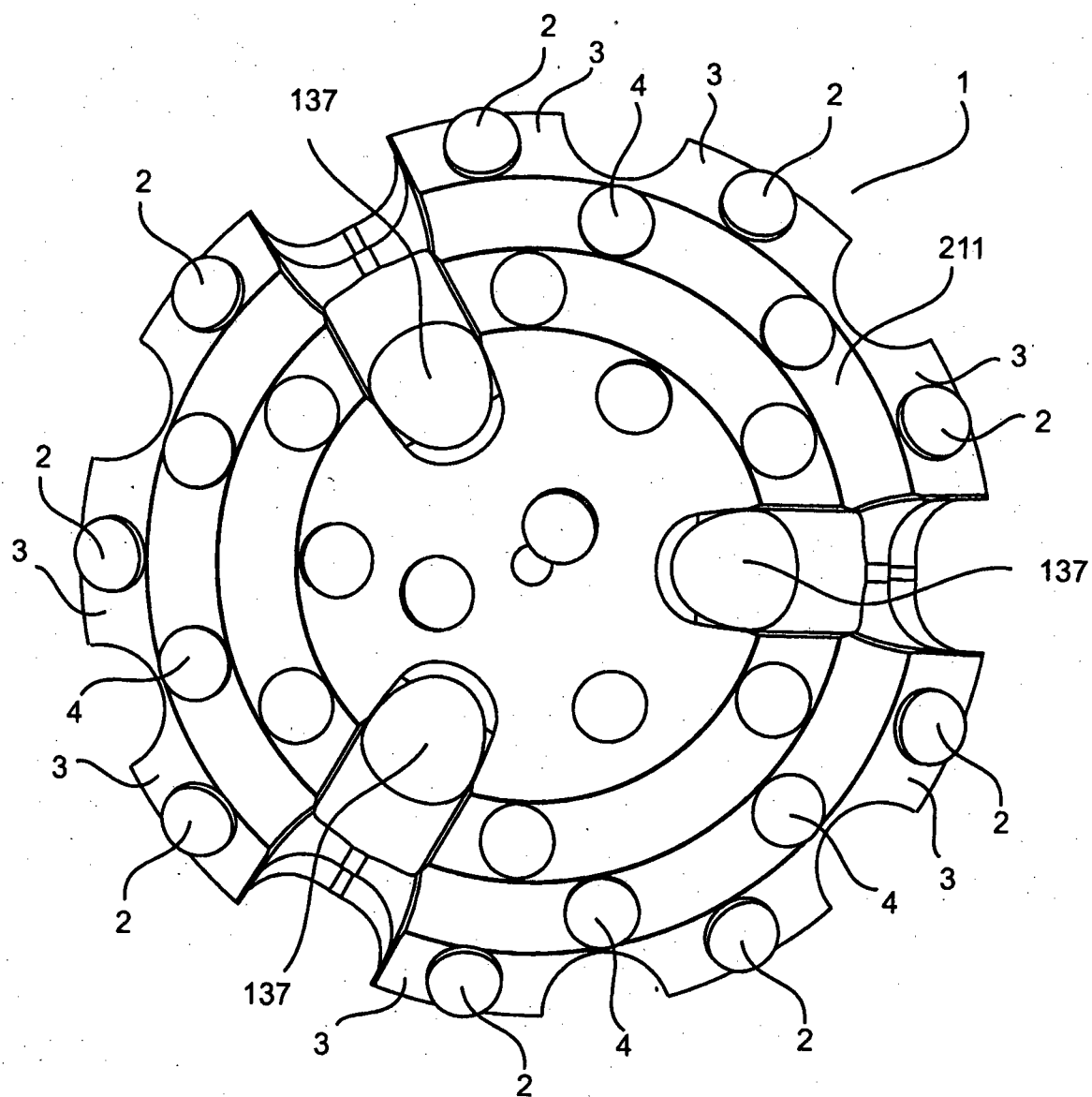


Fig. 1

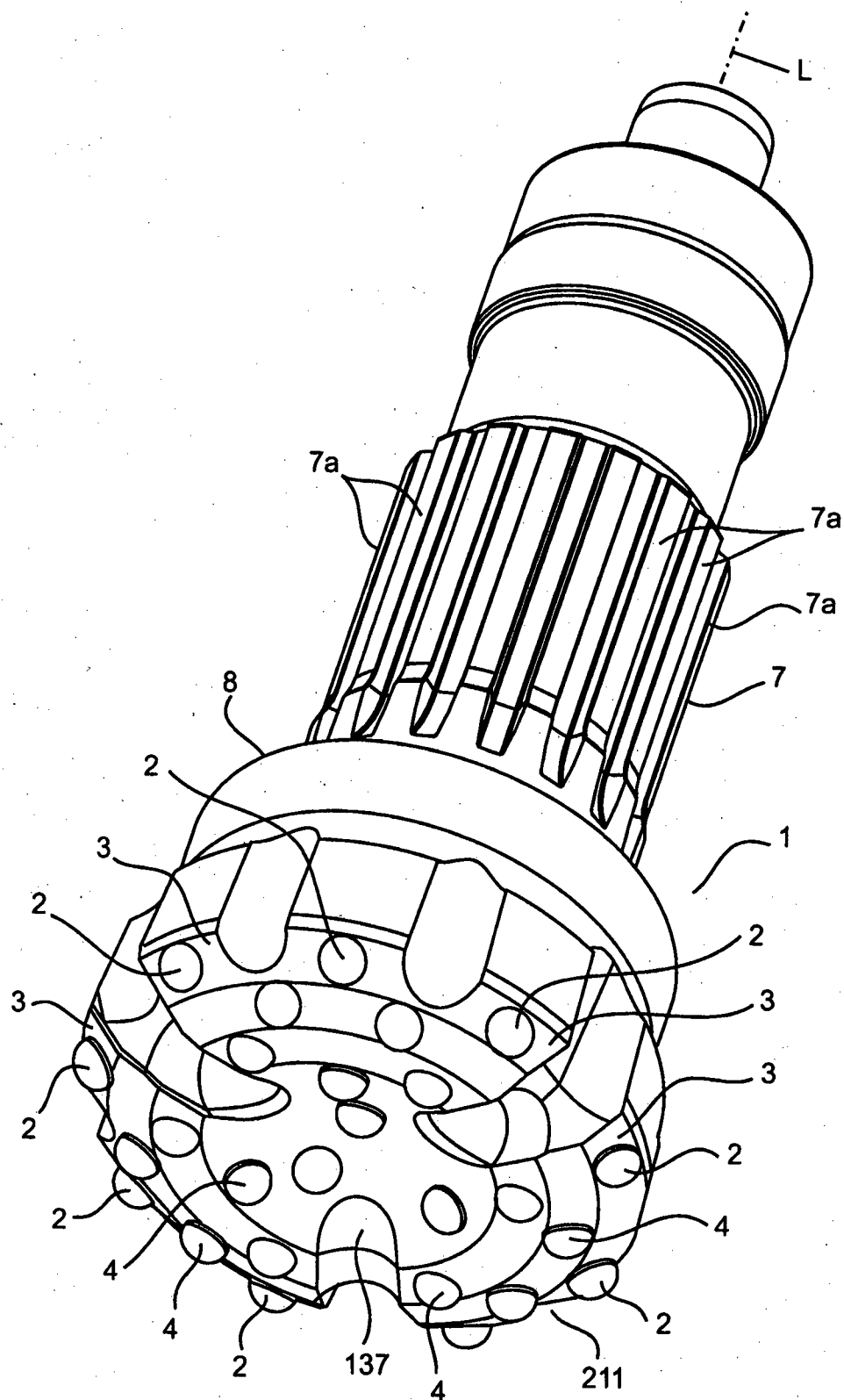


Fig. 2

3 / 13

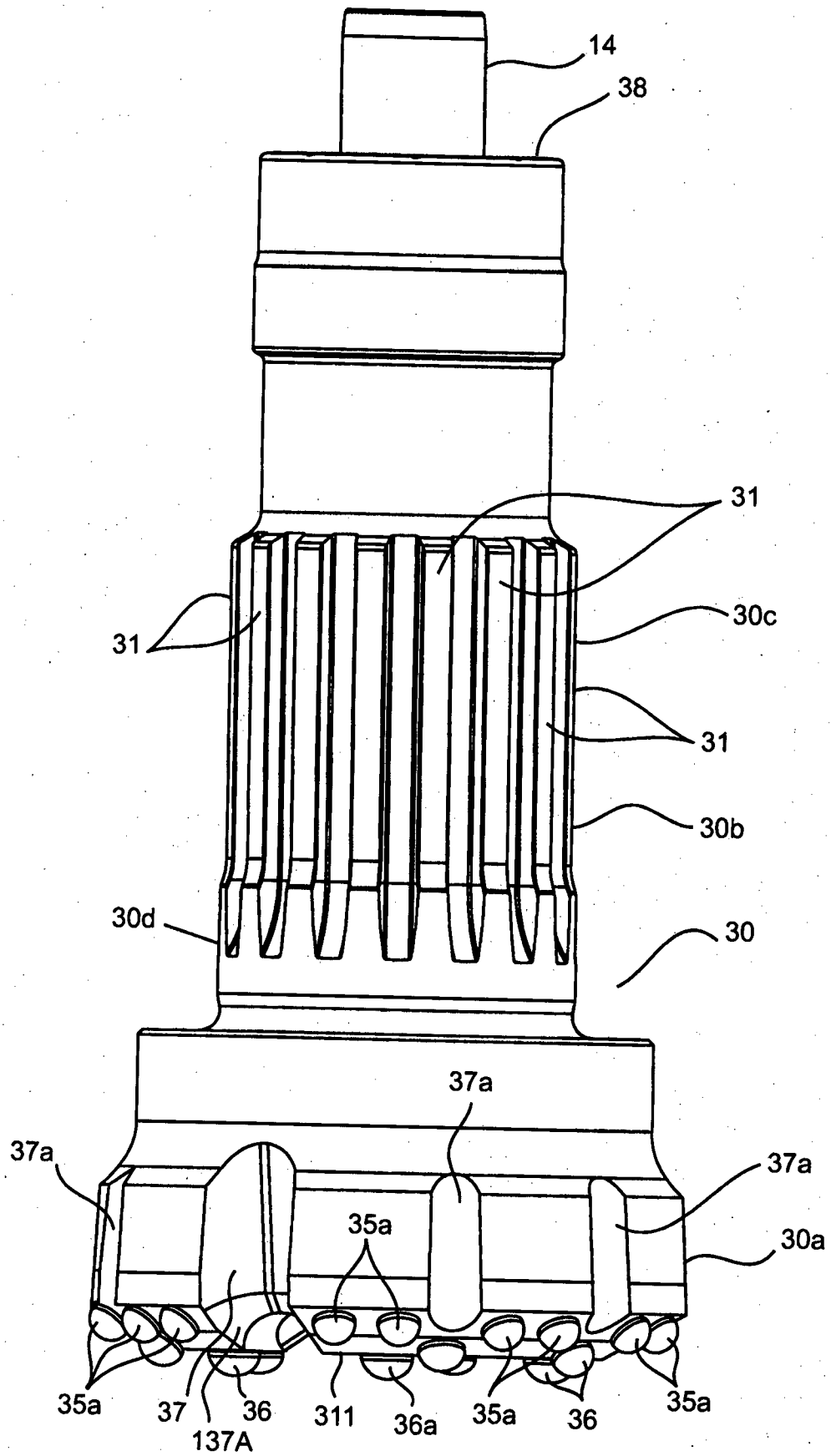


Fig. 3

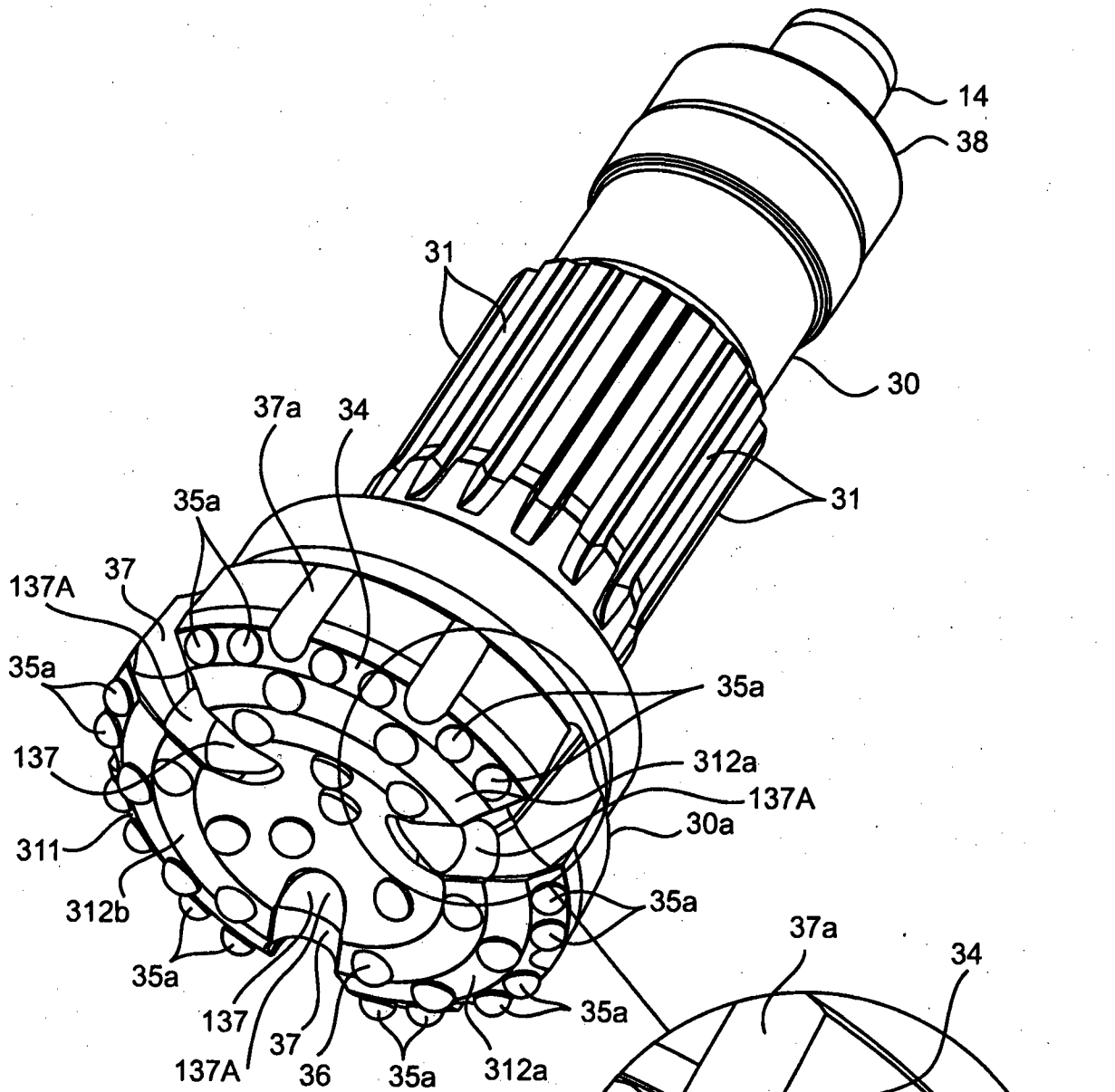


Fig. 4

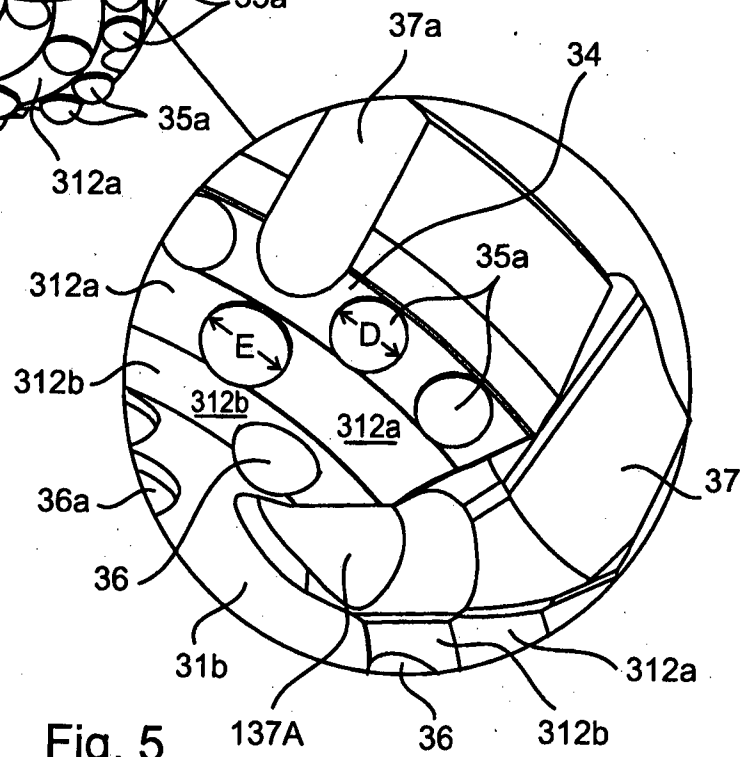


Fig. 5

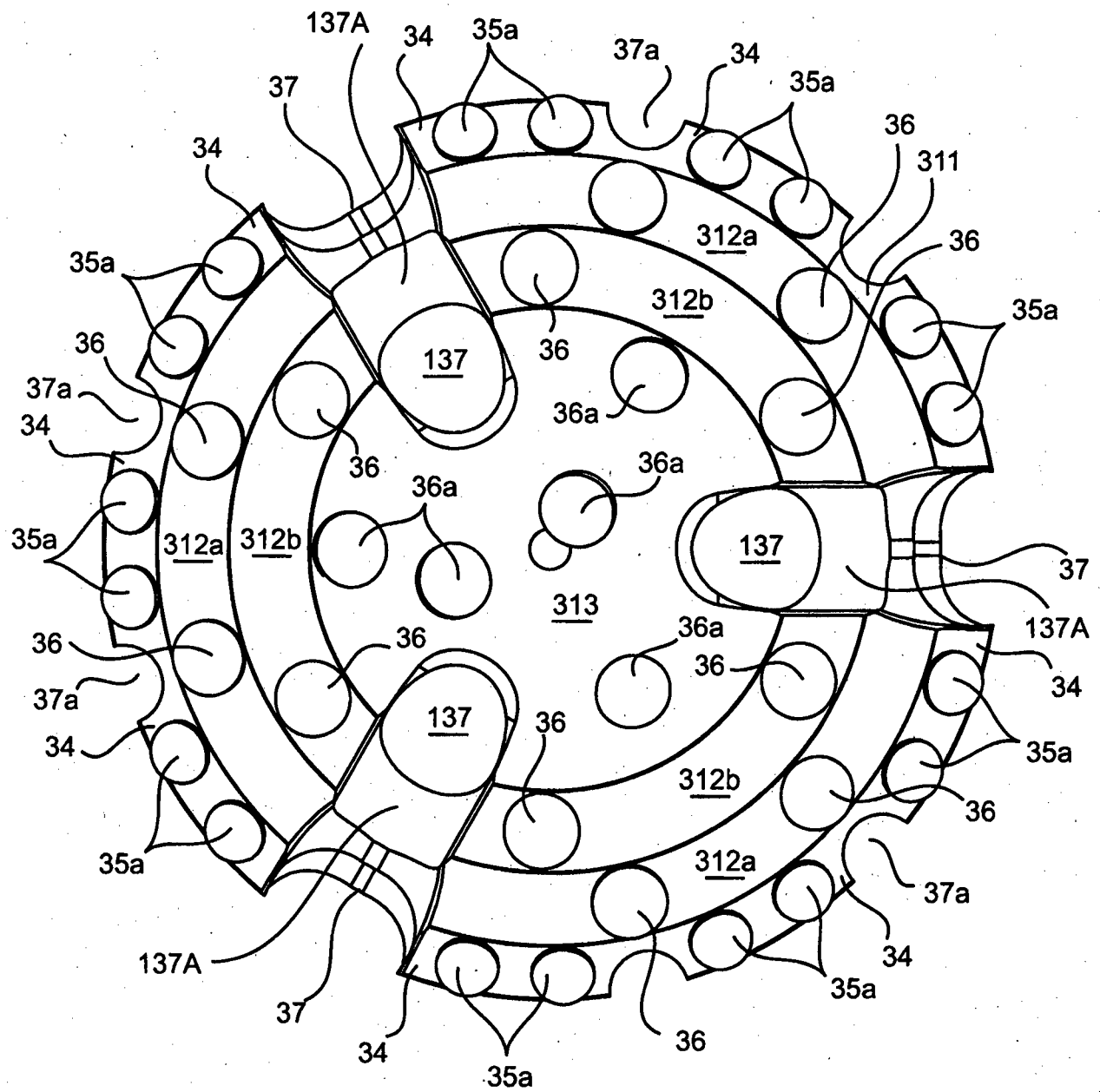


Fig. 6

7 / 13

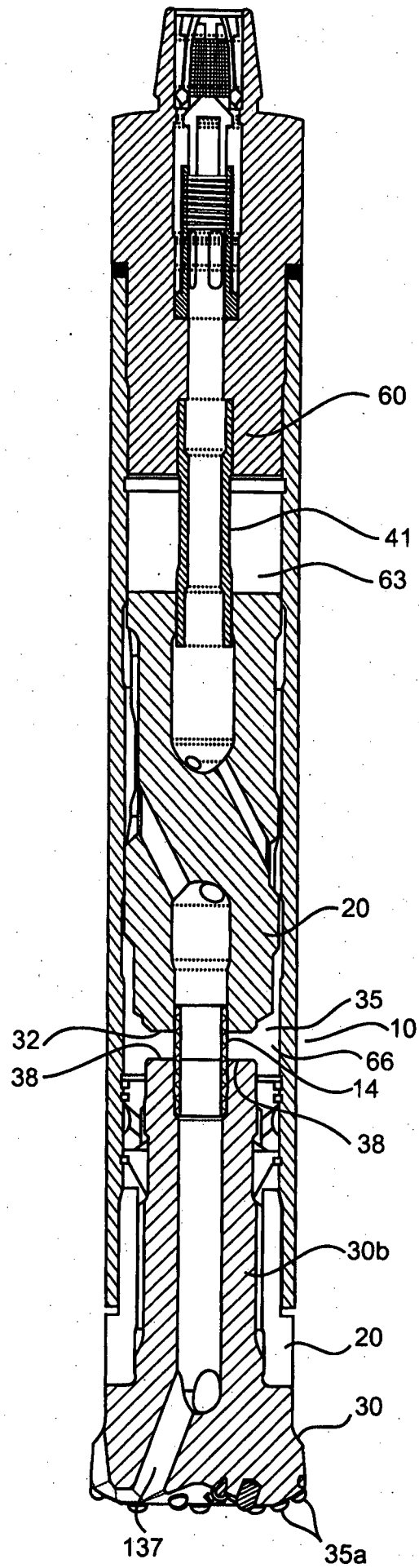


Fig. 8

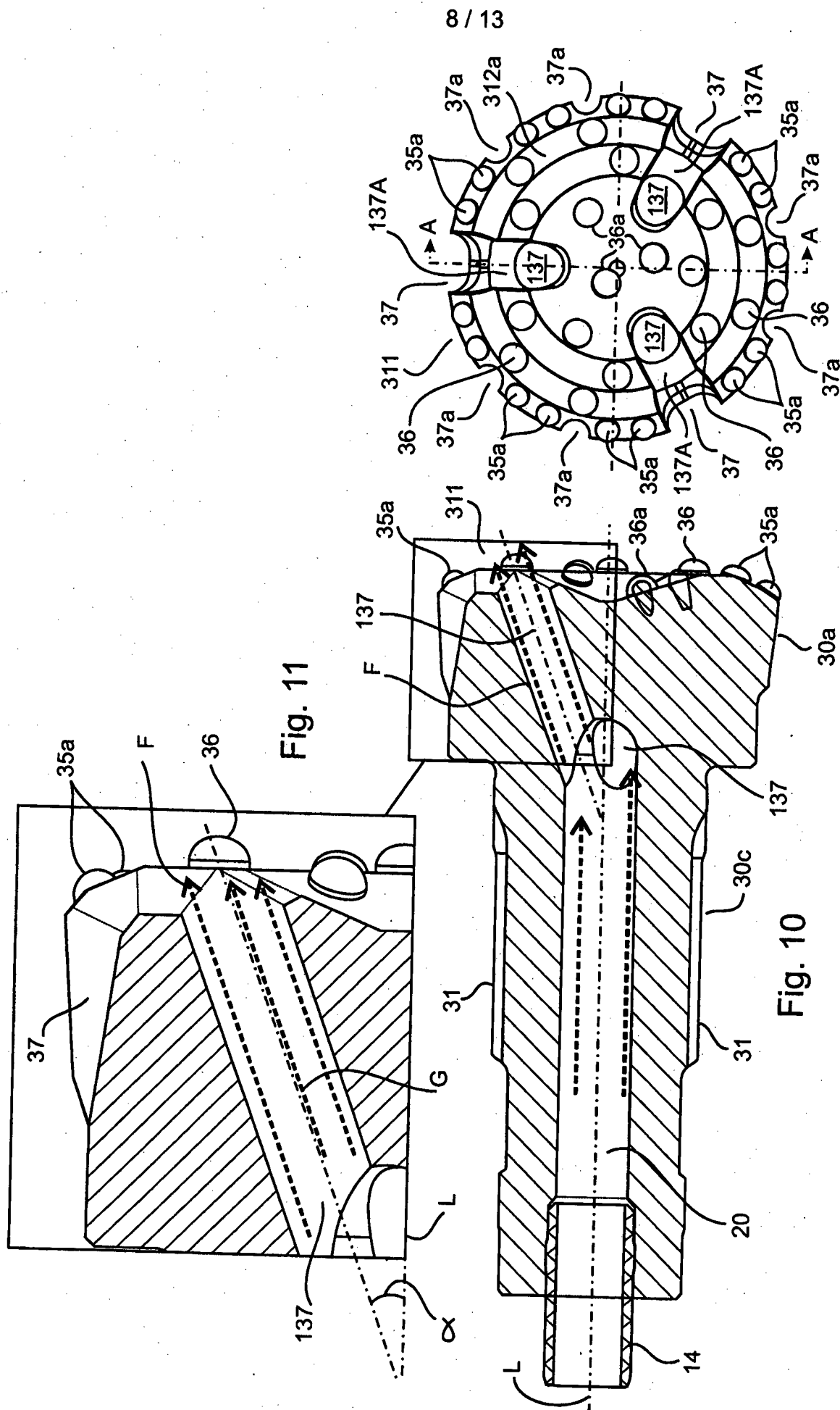


Fig. 9

Fig. 10

Fig. 11

9 / 13

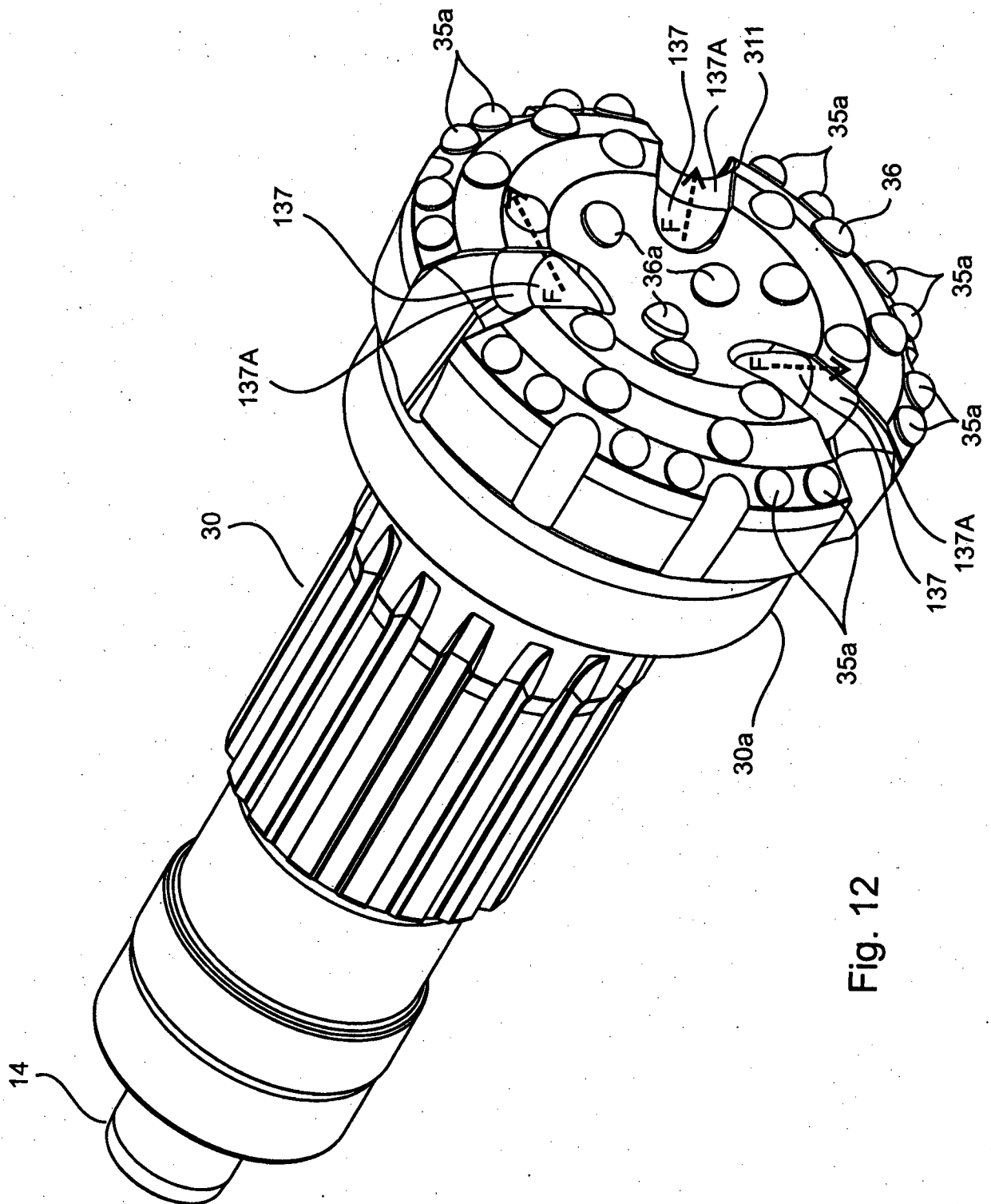


Fig. 12

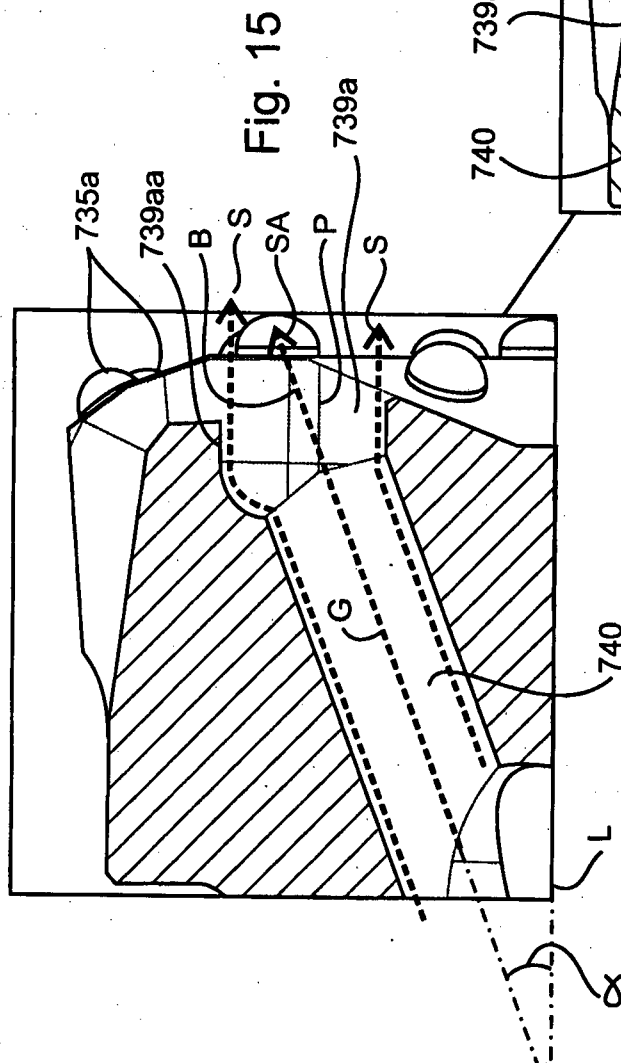


Fig. 15

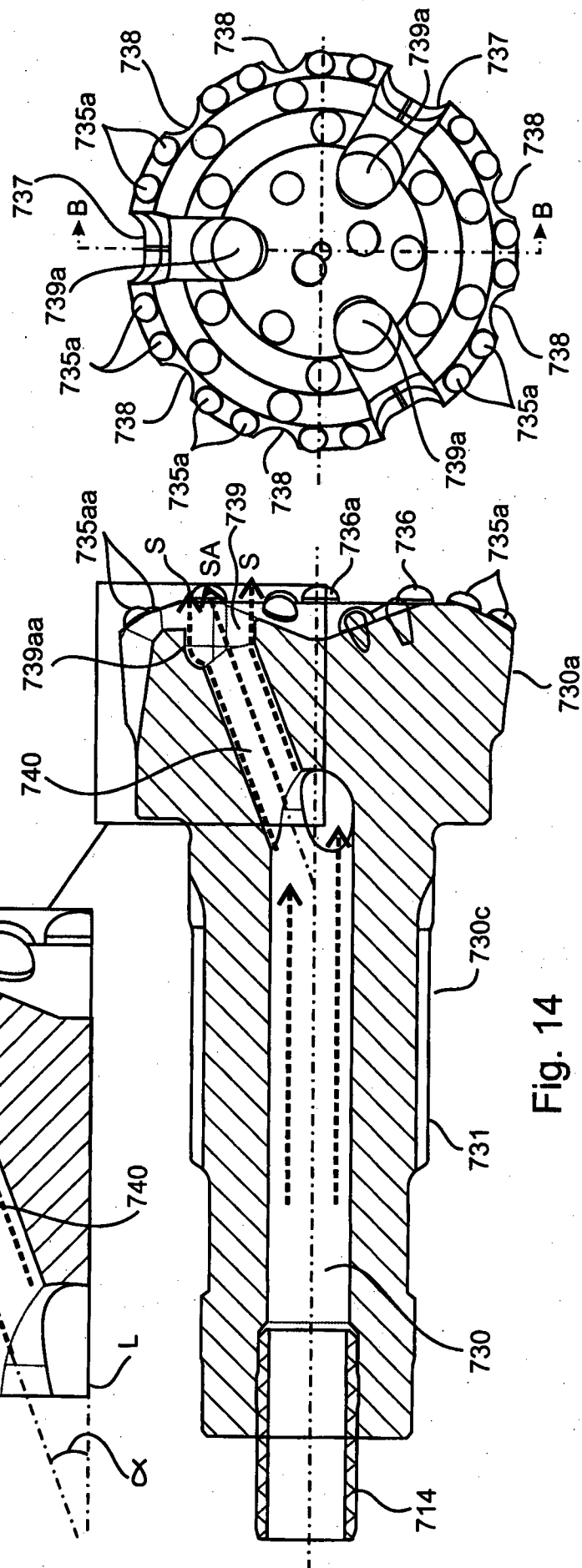


Fig. 14

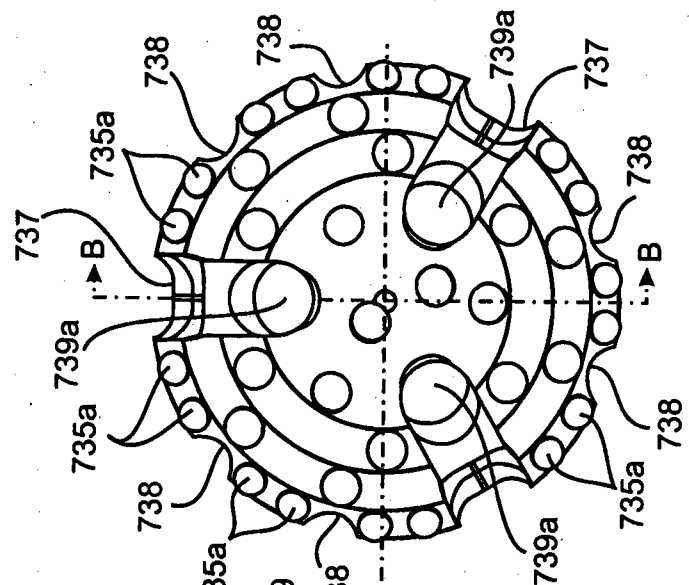


Fig. 13

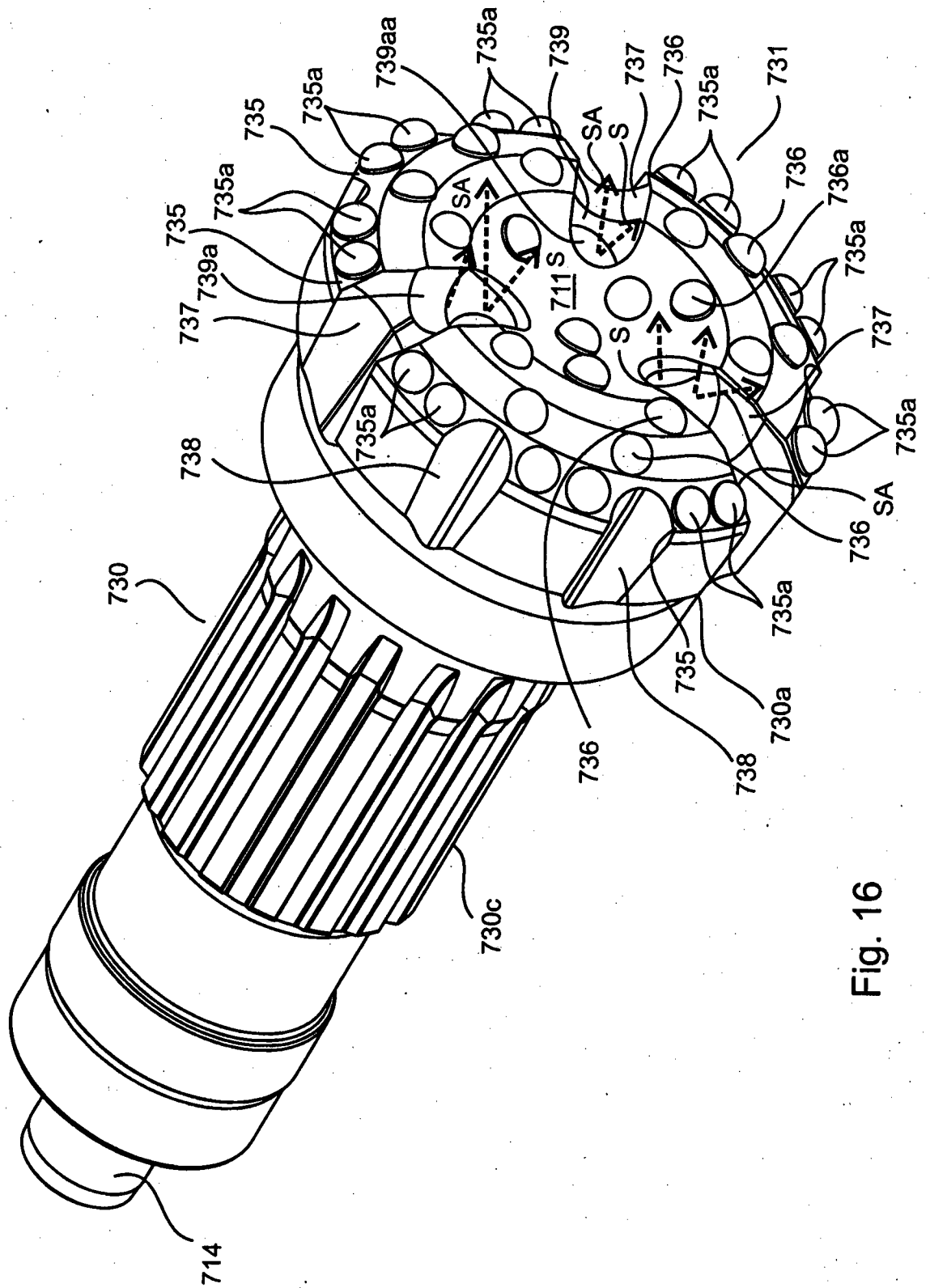


Fig. 16

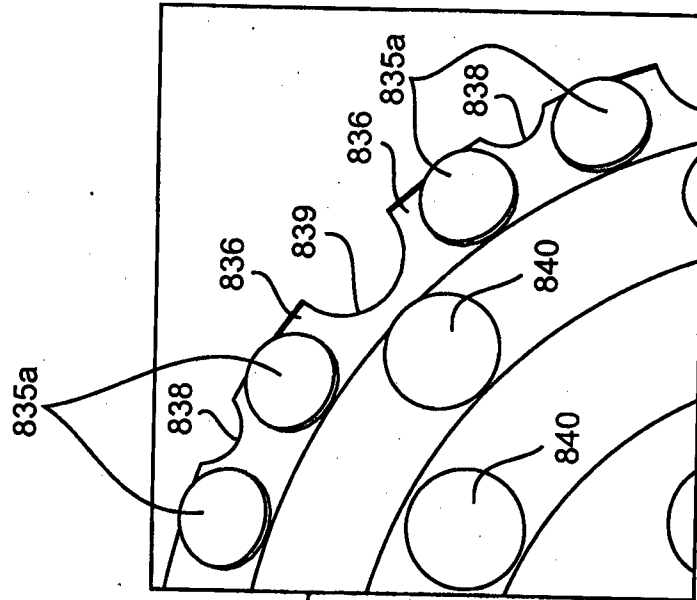


Fig. 17b

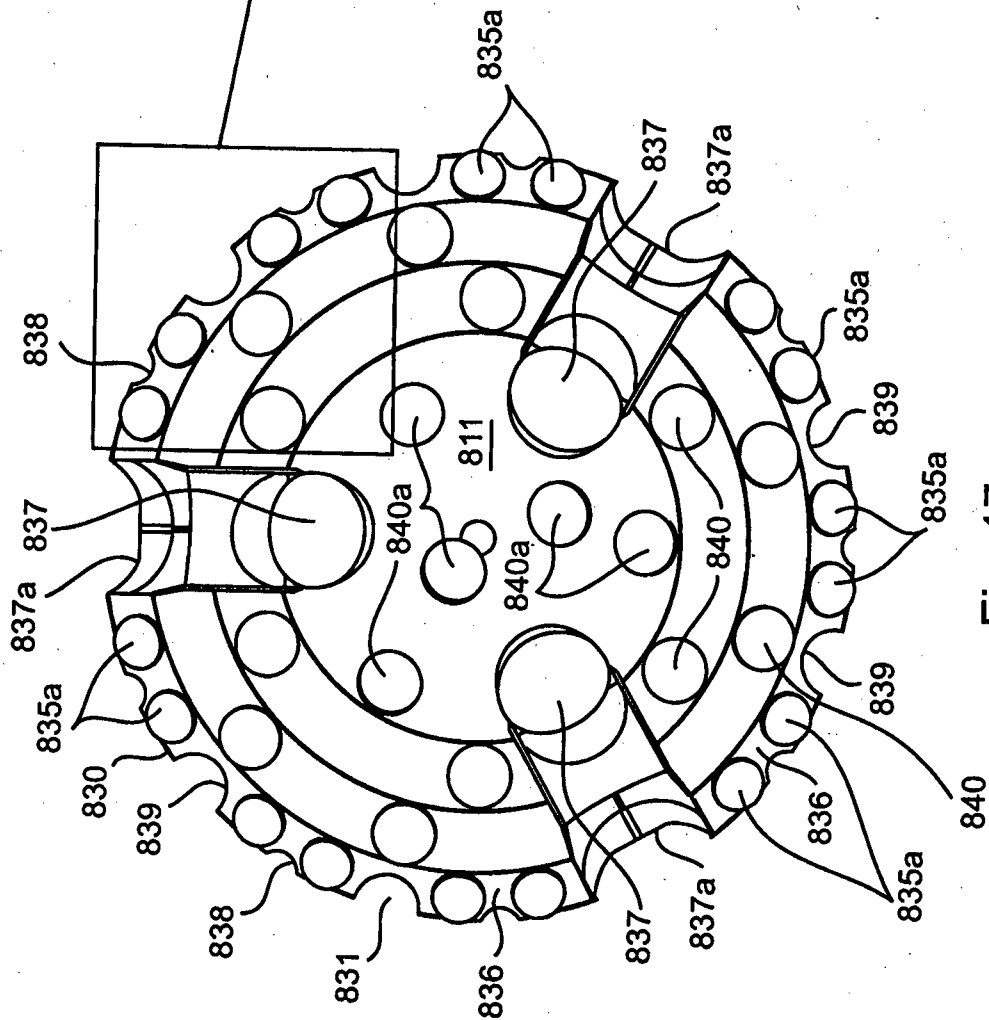


Fig. 17a

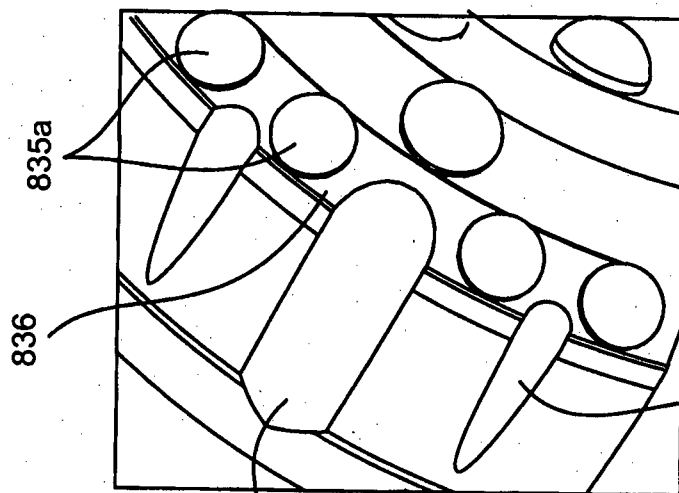


Fig. 18b

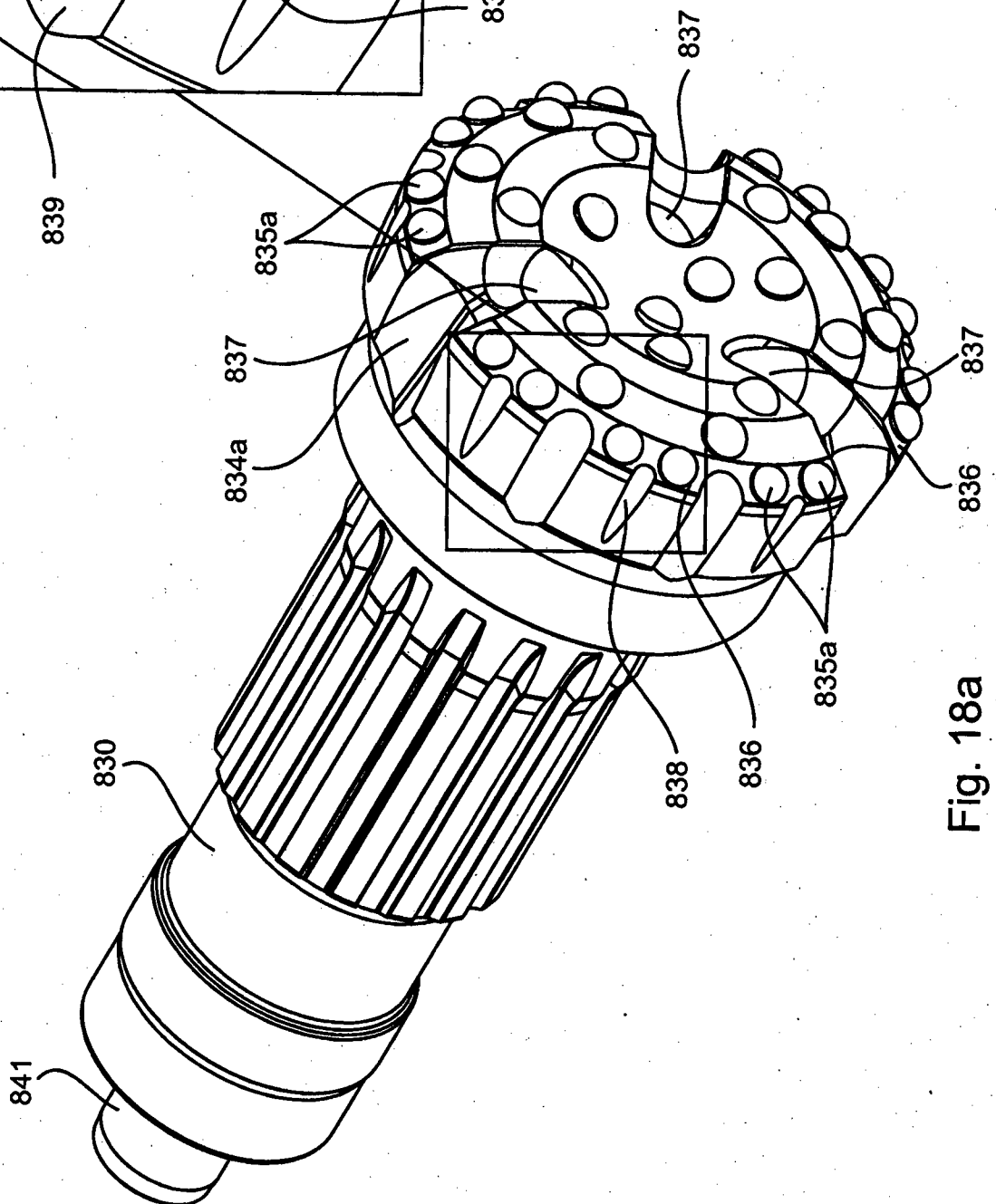


Fig. 18a

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2012/000728

A. CLASSIFICATION OF SUBJECT MATTER E21B 10/43 (2006.01) E21B 10/26 (2006.01) E21B 10/42 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPI % EPODOC: IPC & ECLA Marks: E21B10/42/LOW, E21B10/36/LOW, E21B10/26/LOW; keywords: gauge, angle, chamfer, cut, bevel, acute, incline, taper, wedge, and like terms.		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	
☒ Further documents are listed in the continuation of Box C ☒ See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 24 August 2012	Date of mailing of the international search report 29 August 2012	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaaustralia.gov.au Facsimile No.: +61 2 6283 7999	Authorized officer Alison Green AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832174	

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2012/000728
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3788409 A (CURINGTON) 29 January 1974 Col. 4. lines 5-18, Col. 6 lines 2-27, Figs. 3, 6-7, 9-10, 12	1-21
X	US 2005/0161264 A1 (BJORK) 28 July 2005 Para. 0016 -0017& Fig. 1A-1B	1-21
X	US 2007/0125580 A1 (HALL et al.) 07 June 2007 Paras. 0007, 0031, 0034, 0036 & Figs. 6-9	1-21

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2012/000728	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 3788409 A	29 Jan 1974	AU 467016 B2	13 Nov 1975
		AU 5529973 A	07 Nov 1974
		CA 968785 A1	03 Jun 1975
		GB 1418984 A	24 Dec 1975
		US 3788409 A	29 Jan 1974
		ZA 7300720 A	31 Oct 1973
US 2005/0161264 A1	28 Jul 2005	AU 2003214751 A1	20 Oct 2003
		AU 2003214751 B2	02 Oct 2008
		CA 2479778 A1	16 Oct 2003
		CN 1643232 A	20 Jul 2005
		EP 1490578 A1	29 Dec 2004
		EP 1490578 B1	12 Jul 2006
		JP 2005521818 A	21 Jul 2005
		JP 4116572 B2	09 Jul 2008
		RU 2004132211 A	20 Apr 2005
		SE 0201034 A	05 Oct 2003
		US 2005161264 A1	28 Jul 2005
		US 7207402 B2	24 Apr 2007
		WO 03085231 A1	16 Oct 2003
		ZA 200407604 A	26 Jul 2006
US 2007/0125580 A1	07 Jun 2007	AU 2007248310 A1	15 Nov 2007
		AU 2007248310 B2	07 Jun 2012
		AU 2007334141 A1	26 Jun 2008
		BR PI0709363 A2	12 Jul 2011
		CA 2647416 A1	15 Nov 2007
		CA 2672658 A1	26 Jun 2008
		CN 101454537 A	10 Jun 2009
		CN 101563520 A	21 Oct 2009
		EP 1999342 A2	10 Dec 2008
		EP 2092153 A2	26 Aug 2009
		MX 2008012078 A	06 Apr 2009
		MX 2009006368 A	26 Aug 2009
		MY 144681 A	31 Oct 2011
		NO 20084384 A	20 Oct 2008
		NO 20092420 A	25 Jun 2009

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.
Form PCT/ISA/210 (Family Annex)(July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2012/000728	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
		US 7198119 B1	03 Apr 2007
		US 2007114067 A1	24 May 2007
		US 7225886 B1	05 Jun 2007
		US 2007114071 A1	24 May 2007
		US 7258179 B2	21 Aug 2007
		US 2007114065 A1	24 May 2007
		US 7270196 B2	18 Sep 2007
		US 2007114064 A1	24 May 2007
		US 7328755 B2	12 Feb 2008
		US 2007114066 A1	24 May 2007
		US 7337858 B2	04 Mar 2008
		US 2007114068 A1	24 May 2007
		US 7360610 B2	22 Apr 2008
		US 7392857 B1	01 Jul 2008
		US 2008156536 A1	03 Jul 2008
		US 2007114062 A1	24 May 2007
		US 7398837 B2	15 Jul 2008
		US 2007221416 A1	27 Sep 2007
		US 7419016 B2	02 Sep 2008
		US 2008099245 A1	01 May 2008
		US 7419018 B2	02 Sep 2008
		US 2007221412 A1	27 Sep 2007
		US 7424922 B2	16 Sep 2008
		US 2007114061 A1	24 May 2007
		US 7426968 B2	23 Sep 2008
		US 2007242565 A1	18 Oct 2007
		US 7464772 B2	16 Dec 2008
		US 2007221417 A1	27 Sep 2007
		US 7484576 B2	03 Feb 2009
		US 2007119630 A1	31 May 2007
		US 7497279 B2	03 Mar 2009
		US 2007221409 A1	27 Sep 2007
		US 7503405 B2	17 Mar 2009
		US 2008179098 A1	31 Jul 2008
		US 7506701 B2	24 Mar 2009
		US 7506706 B2	24 Mar 2009

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Form PCT/ISA/210 (Family Annex)(July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2012/000728	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
		US 2007125580 A1	07 Jun 2007
		US 7533737 B2	19 May 2009
		US 2007221415 A1	27 Sep 2007
		US 7549489 B2	23 Jun 2009
		US 2007272443 A1	29 Nov 2007
		US 7559379 B2	14 Jul 2009
		US 2007221406 A1	27 Sep 2007
		US 7571780 B2	11 Aug 2009
		US 2007221408 A1	27 Sep 2007
		US 7591327 B2	22 Sep 2009
		US 2008142264 A1	19 Jun 2008
		US 7600586 B2	13 Oct 2009
		US 2008135295 A1	12 Jun 2008
		US 7617886 B2	17 Nov 2009
		US 2008156541 A1	03 Jul 2008
		US 7624824 B2	01 Dec 2009
		US 2008173482 A1	24 Jul 2008
		US 7641002 B2	05 Jan 2010
		US 2008142273 A1	19 Jun 2008
		US 7641003 B2	05 Jan 2010
		US 2009183920 A1	23 Jul 2009
		US 7661487 B2	16 Feb 2010
		US 2008029312 A1	07 Feb 2008
		US 7694756 B2	13 Apr 2010
		US 2009050372 A1	26 Feb 2009
		US 7730972 B2	08 Jun 2010
		US 2008302572 A1	11 Dec 2008
		US 7730975 B2	08 Jun 2010
		US 2008011522 A1	17 Jan 2008
		US 7753144 B2	13 Jul 2010
		US 2008142263 A1	19 Jun 2008
		US 7762353 B2	27 Jul 2010
		US 2009152011 A1	18 Jun 2009
		US 7900720 B2	08 Mar 2011
		US 2008142265 A1	19 Jun 2008
		US 7967082 B2	28 Jun 2011

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Form PCT/ISA/210 (Family Annex)(July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2012/000728	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
		US 2008142274 A1	19 Jun 2008
		US 8011457 B2	06 Sep 2011
		US 2009158897 A1	25 Jun 2009
		US 8020471 B2	20 Sep 2011
		US 2007229304 A1	04 Oct 2007
		US 8130117 B2	06 Mar 2012
		US 2009255733 A1	15 Oct 2009
		US 8205688 B2	26 Jun 2012
		US 2009183919 A1	23 Jul 2009
		US 8225883 B2	24 Jul 2012
		US 2007223003 A1	27 Sep 2007
		US 2007229232 A1	04 Oct 2007
		US 2008011521 A1	17 Jan 2008
		US 2009057016 A1	05 Mar 2009
		US 2009133936 A1	28 May 2009
		US 2009229883 A1	17 Sep 2009
		US 2009236148 A1	24 Sep 2009
		US 2009260894 A1	22 Oct 2009
		US 2010000794 A1	07 Jan 2010
		US 2010000799 A1	07 Jan 2010
		US 2010065334 A1	18 Mar 2010
		US 2011048811 A1	03 Mar 2011
		US 2012097453 A1	26 Apr 2012
		WO 2007058802 A1	24 May 2007
		WO 2007061612 A1	31 May 2007
		WO 2007130749 A2	15 Nov 2007
		WO 2008076625 A2	26 Jun 2008
		WO 2008085622 A1	17 Jul 2008
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			