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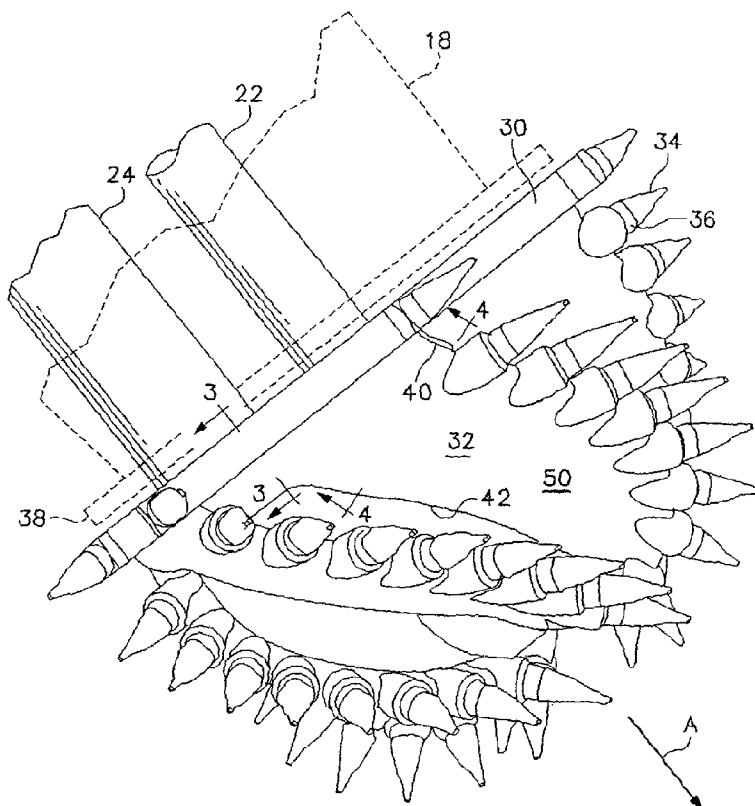
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(54) Title: DREDGE CUTTERHEAD



(57) Abstract: A dredge cutterhead has a plurality of helical arms interconnecting a hub and a ring. Each of the arms has a front leading edge for attachment of cutting teeth. In one aspect, each of the arms has a trough portion, and the arm is shaped such that dredged material is directed toward the ring along the center of the trough portion. In another aspect, the ring of the cutterhead defines an annular channel for receiving loosened material.

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DREDGE CUTTERHEAD

BACKGROUND OF THE INVENTION

The present invention relates to a dredge
5 cutterhead used to remove material from harbors, shipping
channels, and other marine environments and mining
operations.

Dredge cutterheads are generally hemispherical
with a multiplicity of hard rock cutting teeth or
10 replaceable edges projecting outwardly from helical
support arms or blades disposed about the hemispherical
surface of the cutterhead. An example of such a dredge
cutterhead is disclosed in Bowes, Jr., U.S. Patent No.
4,891,893. The cutterhead has a hub which fits around a
15 shaft that provides the torque for turning the cutterhead
in its operation of dredging. The cutterhead encounters
all kinds of materials, including rock, sand and clay
which must be removed from the bed being dredged.

Conventional cutterhead arms are shaped to
20 minimize wear, but are not designed to move material.
However, one of the problems encountered by cutterheads
is that the material loosened by the cutting teeth must
be directed into a suction pipe in order to be removed
from the bottom of the waterway. As the cutterhead moves
25 across the waterway bottom, the cutting teeth dig below
the bed to loosen material. Unfortunately, a substantial
portion of the material loosened by the cutting teeth
does not reach the suction mouth, which is generally
located adjacent to the lower side of the ring of the
30 cutterhead. Instead, some of the loosened material
quickly falls off the trailing edge of the digging arm
and tumbles onto the following arm. When the cutterhead
is operated at a steep ladder angle (for example as shown
in FIG. 1), the loosened material remains near the hub
35 end of the arm, and prevents admission of new material
into the cutterhead.

The result is that the finished bed depth provided by the dredge cutterhead is often limited to the depth of the mouth of the suction pipe, rather than the depth of cut achieved by the cutting teeth. Since the dredge cutterhead itself is large and is often operated at an inclined ladder angle during use, the difference between the depth of cut achieved by the cutting teeth and the depth of the suction mouth may be as large as three to four feet. Accordingly, in order to achieve a specified finished bed depth, it is often necessary to cut into the bed substantially below the specified finished bed depth so that a sufficient amount of material may be removed. This results in additional time and effort needed to achieve a specified finished bed depth.

One attempt to direct material inwardly from the cutterhead to the suction pipe is disclosed in Fray, U.S. Patent No. 2,090,790, which discloses a rotary cutter comprised of a plurality of blades. The body of each blade extends substantially in the line of a helix taken around the center of rotation, and the cut material accumulates within the space defined by the cutting blades, to be discharged into the usual suction pipe. Each blade provides a plurality of rib formations which are intended to propel movement of the earth or other materials being handled to the suction pipe.

Another attempt to move dredged material is disclosed in Shiba et al., U.S. Patent No. 4,702,024, which discloses scoop-in plates 7 coupled between helical vanes 3 and a ring 24. Earth and sand are scooped in by means of the scoop-in plate 7 so as to be directed toward the suction tube 5. However, the vanes themselves do not capture material so as to move the material toward the scoop-in plates.

Another dredge cutterhead has involved adding at the upper portion of the arm a wall at a sharp angle following a conventionally shaped cutterhead arm. The

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lower portion of the arm was shaped like that of a conventional cutterhead. Cross-sections of the arm of this prior art cutterhead are shown in FIGS. 10A-10D, which correspond to the locations of the cross-sections 6A-6D of the present invention. This arm shape caused dredged material to accumulate in the upper portion of the arm at the sharply angled juncture between the leading edge of the arm and the rear wall. This resulted in material jamming the interior of the cutterhead and prevented the cutterhead from removing dredged material.

What is therefore desired is a dredge cutterhead that efficiently captures the loosened material within the cutterhead, that moves the dredged material to the mouth of the suction pipe, that supports and allows for the easy replacement of standard cutting teeth and that is capable of withstanding the extreme forces encountered during dredging without breaking or becoming deformed.

SUMMARY OF THE INVENTION

The present invention overcomes the aforesaid drawbacks of the prior art by providing an improved dredge cutterhead.

According to the present invention there is provided a dredge cutterhead, comprising:

(a) a hub, a ring, and a plurality of helical arms interconnecting said hub and said ring;

(b) each of said helical arms having a leading edge and a trailing edge, and at least one of the helical arms being a driving helical arm having a trough portion located between said leading and trailing edges and extending along said driving helical arm toward said ring, said trough portion being substantially free from structures

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obstructing movement of material along said helical arm toward said ring; and

(c) each of said driving helical arms being shaped such that a net force exerted on dredged material in
5 said trough portion pushes said material toward said ring generally along the center of said trough portion as said cutterhead is rotated.

Preferably, each arm has a degree of curvature near the ring of at least 10%.

10 These aspects of the invention provide several advantages. By shaping the arm so that the net force directs material toward the ring, the arm acts like a pump vane to move material efficiently toward the mouth of the suction pipe. In addition, by providing a relatively large
15 degree of curvature near the ring, the trough portion of the arm is shaped so as to retain the dredged material within the cutterhead as it flows toward the suction pipe. Material loosened by the cutting teeth flows along the trough portion of the arm and toward the ring. The trough
20 portion prevents the loose material from spilling over the trailing edge of the arm and out of the interior of the cutterhead. The cutterhead thus improves the efficiency of dredging and achieves a deeper finished bed depth for a given depth of cut.

25 Preferably, each of the helical arms is capable of supporting a plurality of cutting teeth. An annular channel is defined by the ring for retaining loosened material.

This aspect of the invention also serves to facilitate movement of loose, dredged material from the
30 interior of the cutterhead into the suction pipe. Material loosened by the cutting teeth is transported along the arms

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toward the ring. Once the material enters the ring, the channel retains the loose material. Thus, notwithstanding the rotation of the cutterhead, the loose material remains inside the interior portion of the ring until it is removed
5 by the suction pipe.

The foregoing and other objectives, features and advantages of the invention will be more readily understood upon consideration of the following detailed

description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

5 FIG. 1 is a simplified side elevation view of a dredge showing the dredge cutterhead in operation.

 FIG. 2 is a side view of an exemplary dredge cutterhead of the present invention mounted to the end of a ladder.

10 FIG. 3 is a sectional view of the ring taken along the line 3-3 of FIG. 2.

 FIG. 3A is a sectional view of a prior art ring.

 FIG. 4 is a sectional view of an arm taken
15 along the line 4-4 of FIG. 2.

 FIG. 4A is a sectional view of a prior art arm taken at about the same location as that of FIG. 4.

 FIG. 5 is a perspective view from the rear of the cutterhead of FIG. 2.

20 FIGS. 6A-6D are cross-sections taken along the corresponding lines 6A-6A to 6D-6D of the cutterhead of FIG. 5.

 FIGS. 7A-7D are cross-sections from a prior art cutterhead taken at about the same locations along the
25 arm as those of FIGS. 6A-6D.

 FIG. 8 is a side sectional view of the cutterhead of FIG. 2.

 FIG. 9 is a simplified schematic side view of a cutterhead of the present invention with all but one arm
30 removed showing the helix angle of an arm.

 FIGS. 10A-10D show cross-sections of another prior art cutterhead corresponding to the cross-sections of FIGS. 6A-6D.

35 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

 The present invention is directed toward a dredge cutterhead that improves the ability of the

cutterhead to capture dredged, loosened material within the interior of the cutterhead and to move the loosened material toward the mouth of the suction pipe. The dredge cutterhead of the present invention may be used
5 with any conventional dredger used for cutter-suction dredging.

Referring now to the drawings, wherein like numerals refer to like elements, FIG. 1 shows a simplified representation of an exemplary cutter-suction
10 dredger 10 having a hull 12. At one end of the hull are located two spuds 14 and 16, which are elevatably movable and spaced apart in the widthwise direction of the ship. At the opposite end of the hull is located a ladder 18 which supports the dredge cutterhead 20. The ladder
15 houses a shaft 22 for supporting and rotating the cutterhead, and a suction pipe 24 and suction pump(s) 26 which remove dredged material from the cutterhead. The ladder, suction pipe and shaft are conventional and may be of any type suitable for use with a cutterhead 20.
20 Similarly, the cutterhead 20 of the present invention may be used with any conventional cutter-suction dredging craft, such as a boat or barge, and operated in any conventional manner. The cutterhead 20 cuts into the bed 11, which after dredging is deepened to the finished bed
25 depth 13.

FIG. 2 shows a side view of the cutterhead 20 at the end of the ladder 18 and supported by the shaft 22. As shown in FIGS. 2 and 5, the cutterhead has a hub 28, ring 30 and interconnecting arms 32. The hub 28 is
30 used to attach the cutterhead 20 to the shaft 22. The cutterhead 20 may be attached to the shaft 22 in any conventional manner that allows the hub 28 to be supported and rotated by the shaft 22. The arms 32 curve in a helical manner around a rotational axis A of the
35 cutterhead defined by the shaft 22. (See FIG. 2.) Protruding from the arms 32 are a plurality of adapters 34 for receiving cutting teeth 36. Cutting teeth 36

suitable for use with the present invention include any conventional cutting teeth, such as those disclosed in U.S. Patent No. 4,335,532, the disclosure of which is herein incorporated by reference.

5 Mounted at the end of the ladder 18 is a conventional backing plate 38 which covers the rear opening of the cutterhead 20. The backing plate 38 has a conventional opening (not shown), which communicates with the entrance or mouth of the suction pipe 24. Thus, the
10 backing plate 38 substantially prevents material from exiting the rear of the cutterhead except through the suction pipe mouth. The backing plate 38 and suction pipe mouth may be conventional. Material loosened by the teeth 36 enters the interior of the cutterhead 20, moves
15 along the interior surface of the arms 32, and toward the suction pipe mouth, which then removes the loosened material to the dredger 10.

 The cutterhead 20 of the present invention achieves its advantages by more efficiently moving, or
20 "pumping," the loosened material from the interior of the cutterhead along the interior surface of the arms 32 toward the suction pipe mouth, and by capturing more of the loosened material within the interior of the cutterhead. The cutterhead achieves these advantages
25 through the use of a novel arm shape and a novel ring shape.

 Turning now to the arms 32, FIG. 4 shows an exemplary cross-section of an arm 32 having a leading edge 40, a trailing edge 42, and a trough portion 44
30 therebetween. (As illustrated herein for all arm cross-section, the cross-sections are taken along a line connecting equal percentages of the length of the leading and trailing edges.) The interior surface 46 of the trough portion 44 is contoured such that the dirt and
35 rocks loosened by the cutting teeth 36 during dredging which enter the interior of the cutterhead 20 will be pushed, or "pumped," under the combined influence of

gravity, buoyancy and centrifugal force, along the interior surface 46 of the arm 32 toward the ring 30. The surface is contoured such that the slope of the surface at any point is at an angle such that the net force drives the material in the desired direction. The "pumping" nature of the arms results from a combination of the trough shape of the arm, the helix angle of the arm, and the aspect ratio (β) of the cutterhead. The resulting shape of the arm is such that the net force exerted on material within the trough portion pushes the material toward the ring generally along the center of the trough portion.

FIG. 5 shows exemplary flow vectors F showing the direction in which the material is pushed by the net force at particular locations within the trough portion. As can be seen, the net force urges the loosened material toward the ring generally along the center of the trough portion. Material at the sides of the trough portion is directed toward both the center of the trough portion and the ring, while material located at the center of the trough is directed along the center toward the ring. The interior surface 46 of the trough portion 44 is preferably smooth and free from ridges that might block or obstruct movement of the material along the arm 32 toward the ring 30.

The arm 32 thus acts like the vane of a pump and causes the loosened material, upon entering the interior of the cutterhead 20, to be captured within the interior of the cutterhead and move along the arm 32 toward the mouth of the suction pipe 24. The result is that the cutterhead 20 achieves greater efficiency during dredging by capturing material that might otherwise pass out of the cutterhead 20, and allows the cutterhead 20 to achieve a finished bed depth that is deeper than the mouth of the suction pipe 24, as shown in FIG. 1.

Turning to the arm 32 in more detail, FIGS. 6A-6D show several cross-sections of the arm 32 taken at

successive locations from the top of the arm 32 toward the bottom, as shown by lines 6A-6A to 6D-6D of FIG. 5. (As used herein, "top" refers to the end of the arm near the hub 28, and "bottom" refers to the end of the arm near the ring 30.) In contrast, corresponding cross-sections from a prior art cutterhead are shown in FIGS. 7A-7D.

The interior face 49 of the arm 32 is sufficiently curved so as to retain material loosened by the cutting teeth, thus preventing material from falling off the trailing edge of the arm and exiting the cutterhead. By "curved" is meant the degree of curvature of the interior face 49 from the leading edge 40 to the trailing edge 42 of the arm. A degree of curvature ("D.C.") of a section at any point along the arm may be determined by taking the ratio of (1) the depth of the trough portion 44 at that point and (2) the width of the interior face 49 of the arm at that point. The "depth" of the trough portion is determined by the greatest perpendicular distance between the inner-surface of the trough portion 44 and a straight line interconnecting the innermost surfaces of the leading edge and the trailing edge. For example, FIG. 6D shows a straight line 52 connecting the innermost surface 41 of the leading edge 40 with the innermost surface 43 of the trailing edge 42. The line 54 is the maximum perpendicular distance between the interior surface of the trough portion and the line 52. The degree of curvature is the ratio of the depth D, i.e., length of line 54, to the width W between the points 41 and 43, i.e., the length of line 52.

By "sufficiently curved" is meant that the arm has a degree of curvature that is sufficient to retain material within the trough portion. In general, the degree of curvature near the hub is at least about 8%, and more preferably about 10 to 12%. The degree of curvature near the ring is at least about 10%, more preferably about 15%, and even more preferably, about 20

to 25%. A degree of curvature near the ring of at least 10% insures that the net force exerted on material near the ring will urge material toward the ring, and also allows the trough portion to accommodate the material flowing down the arm and also entering the arm over the leading edge near the ring. By "near the hub" is meant within the upper 20% of the arm length adjacent to the hub 28, and by "near the ring" is meant within the lower 20% of the arm length adjacent to the ring 30. For example, as shown in FIGS. 6A-6D, the degree of curvature for an exemplary arm of the present invention ranges from a minimum degree of curvature of about 10% near the hub to a maximum degree of curvature of about 21% near the ring, and has an average degree of curvature of about 15%. In contrast, FIGS. 7A-7D show a conventional prior art arm in which the degree of curvature varies from between 2.6% to 6.0%, and has an average degree of curvature of about 4.5%.

Preferably, the degree of curvature generally increases along the arm 32 from the top near the hub 28 toward the bottom of the arm 32 near the ring 30. By "generally increases" is meant that the degree of curvature on average increases over at least the lower portion of the arm, that is from a location at about 50% of the arm length from the hub to the ring. More preferably, the degree of curvature on average increases over at least 70% of the length of the arm, and even more preferably on average increases over at least 90% of the length of the arm. While the degree of curvature increases on average, nevertheless the degree of curvature may vary over a given length, and may even decrease over short portions of the arm.

Increasing the degree of curvature along the arm allows the trough portion to retain the material flowing along the trough and admit additional loosened material entering the trough portion from the lower portion of the leading edge. Because the degree of

curvature generally increases, the maximum degree of curvature is preferably located lower than the minimum degree of curvature. The degree of curvature near the ring 30 is preferably at least 1.5 times, and even more preferably at least 2 times, the degree of curvature near the hub 28.

For example, FIGS. 6A-6D show the degree of curvature, D.C., increasing from about 9.7% near the hub 28 to about 21.2% near the ring 30. Thus, the degree of curvature near the ring 30 is about 2 times the degree of curvature near the hub 28. In contrast, for the prior art arm of FIGS. 7A-7D, the degree of curvature of the arm does not generally increase along the midportion of the arm, but instead decreases. The degree of curvature near the ring of the prior art arm is slightly less than the degree of curvature near the hub of the prior art arm. In fact, for the conventional prior art arm shown in FIGS. 7A-7D, the maximum degree of curvature is above, rather than below, the minimum degree of curvature.

Returning to the exemplary cross-section of FIG. 4, in one preferred embodiment the interior face 49 of the present invention preferably has a leading portion 48 for supporting the adapters 24, shaped similarly to the leading portion of the prior art arm 32' shown in FIG. 4A. The leading portion 48 has a thickness W_L which is similar to that of the prior art arm 32'. The thickness W_L provides support for the adapters 34 and cutting teeth 36, which are subjected to extreme forces when cutting into hard materials such as rock. In addition, the thickness of the leading portion 48 allows the arm 32 to withstand wear and abrasion encountered during dredging.

The leading portion 48 preferably curves inwardly to provide a space between each of the respective arms 32 for dredged material to enter the interior of the cutterhead. Preferably, the leading portion 48 is aligned with or follows the cutting teeth

36 of the arm, so as to minimize the wear of the arm. The leading portion 48 may have an interior radius of curvature R_L which is similar to the conventional radius of curvature of the prior art arm 32'. The radius of curvature R_L varies along the arm from the ring 30 to the hub 28, but in general is such that the arm 32 curves in a smooth helical fashion from the ring 30 to the hub 28. The width of the leading portion 48 may vary, but generally comprises from 10% to 35% of the width of the interior face 49.

In one preferred embodiment, the trough portion at any section further comprises three different areas, each having a different radius of curvature R_1 , R_2 and R_3 . The first area 56 has a radius of curvature R_1 that is much smaller than that of R_L . As shown in FIG. 4, the interior surface 46 in the first area 56 curves in a concave manner such that the thickness of the arm gradually decreases in a transverse direction. The first area 56 smoothly transitions to a second area 58 having a radius of curvature R_2 that is greater than R_1 and is similar to that of R_L . The arm 32 has a thickness W_T in the second area 58 which is thinner than the thickness W_L of the leading portion 48. The second area 58 smoothly transitions to a third area 60 having a radius of curvature R_3 , at any point along the arm, that is less than R_2 . The smaller radius of curvature R_3 for the third area 60 causes the third area 60 to curl inwardly toward the interior of the cutterhead 20. Preferably, the trailing edge 42 curves inwardly into the interior of the cutterhead 20 beyond the interior surface 46 of the leading portion 48 of the arm 32. The average radius of curvature of the trough portion 44, defined as the average of R_1 , R_2 , and R_3 , is less than the radius of curvature of the leading portion R_L .

While FIGS. 4 and 6A-6D show an arm having an interior face comprising a leading portion and a trough portion, the requisite degree of curvature may be

obtained without differentiating the arm into two such portions. Thus, the arm may have a uniform thickness. Nor is it necessary that the trailing edge curl inwardly. The interior surface 46 may be defined by any curve or combination of curves, and is not restricted to arcs and lines. While smooth surfaces are desired, it may be possible to obtain the requisite degree of curvature using a plurality of flat surfaces which transition at sharp angles along the interior surface of the trough.

10 In addition, while the figures show each arm having a trough portion, it is only necessary that a plurality of the arms be pumping in nature. Thus, for example, the cutterhead may be provided with three pumping arms having the degree of curvature described above, and three conventional arms.

The ability of the cutterhead 20 to efficiently move loosened material toward the ring, or its "pumping" nature, may be improved by optionally increasing the helix angle of the trough portion of the arm 32. As shown in FIG. 9 the helix angle of an arm 32 is the included angle γ between the tangent to the curve of interest (such as the leading edge) at a given point and a plane that is parallel to the ring of the cutterhead. A conventional average helix angle for an arm along the leading edge is typically between 135° and 140° . Increasing the helix angle of the trough portion of the arm causes the arm to act more like a closed Archimedes screw.

One method for effectively increasing the helix angle of the trough portion is to increase the width of the arm of the cutterhead from the top to the bottom of the arm. For example, FIGS. 6A-6D show the width of the arm near the ring (shown by the length of line 52 in FIG. 6D) is about 10% wider than the width of the arm near the hub (FIG. 6A). In contrast, the width of the arm for a conventional cutterhead usually decreases from near the hub toward the mid portion of the arm, as shown

in FIGS. 7A-7D. Preferably, the width of the arm near the ring is at least 5% wider than the width near the hub, more preferably at least 10% wider, and even more preferably at least 15% wider.

5 Another method for increasing the helix angle of the trough portion is to increase the helix angle of the leading edge. Preferably, the helix angle of the leading edge is at least 140°, and more preferably at least 145°.

10 Likewise, the pumping nature of the cutterhead may be improved by optionally increasing the aspect ratio (β) of the cutterhead 20. The aspect ratio of the cutterhead is the ratio of the outside diameter of the ring 30 to the height of the cutterhead 20. The height
15 of the cutterhead is the distance along the rotational axis A through the hub 28 between the top 62 of the hub and a horizontal plane defined by the bottom of the ring 30 as shown in FIG. 9. A conventional cutterhead typically has an aspect ratio of about 1.4 to 1.7. The
20 aspect ratio of the cutterhead of the present invention is preferably at least 1.7, more preferably at least 2, and even more preferably at least 2.2. Increasing the aspect ratio allows the arm to take greater advantage of the centrifugal force to push material toward the ring.

25 The flow of material into the suction mouth may be enhanced by continuing the trough portion into the ring 30. As shown in particular in FIGS. 5 and 8, the ring 30 may optionally define a plurality of notches 64 along the interior of the ring 30, each communicating
30 with a trough portion. The notches 64 improve material flow into the suction pipe mouth. Optionally, for embodiments which do not include an annular channel in the ring (discussed below), the notches may be continued through the ring so as to allow material to flow over the
35 ring and into the suction mouth.

 In another separate aspect of the invention, the ring 30 of the cutterhead 20 defines an annular

channel 66 preferably having a cross-section in the shape of a "half-pipe" as shown in FIGS. 3 and 8. As used herein, the term "ring" is used broadly to refer to the lower portion of the cutterhead which interconnects the arms. The half-pipe shape of the ring is in contrast to the prior art ring which is generally rectangular in cross-section, such as shown in FIG. 3A. As shown in FIGS. 3 and 8, the channel 66 of the present invention extends around the entire interior of the ring so as to retain loosened material. The channel 66 receives the loosened material which flows from the trough portions 44 into the channel 66, allowing the loosened material which enters the ring 30 at a location removed from the suction pipe to move along the channel 66 toward the bottom of the ring 30, where the suction mouth is located, as shown in FIG. 2. In this manner, the channel 66 further improves the efficiency of dredging by retaining the loosened material and causing the material to be directed toward the suction mouth so as to be removed. Preferably, the ring defines notches 64 which allow the channel 66 to communicate with the trough portion 44 of the arm 32.

While FIGS. 3 and 8 show that a portion of the channel 66 is formed as a result of removal of material from the inner portion 68 of the ring 30 so as to define a portion of the channel, the inner portion 68 of the ring may have a square cross-section and the channel may be formed by a lip or other structure associated with the ring in order to form a channel for receiving loosened material. The channel may also have a cross-section shape other than a half-pipe, so long as it remains capable of retaining material within the channel.

The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features

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shown and described or portions thereof, it being recognised that the scope of the invention is defined and limited only by the claims which follow.

The reference in this specification to any prior
5 publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in
10 the field of endeavour to which this specification relates.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a
15 stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A dredge cutterhead, comprising:

(a) a hub, a ring, and a plurality of helical arms
5 interconnecting said hub and said ring;

(b) each of said helical arms having a leading edge
and a trailing edge, and at least one of the helical arms
being a driving helical arm having a trough portion located
between said leading and trailing edges and extending along
10 said driving helical arm toward said ring, said trough
portion being substantially free from structures obstructing
movement of material along said helical arm toward said
ring; and

(c) each of said driving helical arms being shaped
15 such that a net force exerted on dredged material in said
trough portion pushes said material toward said ring
generally along the center of said trough portion as said
cutterhead is rotated.

20 2. The dredge cutterhead of claim 1 wherein each of said
driving helical arms has a degree of curvature that
generally increases along at least a respective portion of
each of said driving arms that is nearer to said ring than
to said hub.

25

3. The dredge cutterhead of claim 1 or 2 wherein each of
said driving helical arms has a maximum degree of curvature
and a minimum degree of curvature, and wherein said maximum
degree of curvature is located nearer to said ring than is
30 said minimum degree of curvature.

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4. The dredge cutterhead of claim 3 wherein said minimum degree of curvature is near said hub and said maximum degree of curvature is near said ring.

5 5. The dredge cutterhead of any one of claims 1-3 wherein each of said driving helical arms has a degree of curvature near said ring and a degree of curvature near said hub, and wherein said degree of curvature near said ring is at least 1.5 times as great as said degree of curvature near said
10 hub.

6. The dredge cutterhead of any one of claims 1-5 wherein each of said driving helical arms is wider near said ring than near said hub.
15

7. The dredge cutterhead of any one of claims 1-6 wherein said leading edge has a helix angle of at least 140° near said ring.

20 8. The dredge cutterhead of any one of claims 1-7 wherein said cutterhead has an aspect ratio of at least 2.0.

9. The dredge cutterhead of any one of claims 1-6 wherein said cutterhead has an aspect ratio of at least 1.7.
25

10. The dredge cutterhead of any one of claims 1-9 wherein said trough portion is thinner than a leading portion of each of said helical arms.

30 11. The dredge cutterhead of any one of claims 1-10 wherein said ring further defines a plurality of notches, each of said notches communicating with a respective trough portion.

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12. The dredge cutterhead of any one of claims 1-11 wherein said trailing edge curves inwardly into the interior of said cutterhead.

5 13. The dredge cutterhead of any one of claims 1-12 wherein said ring defines a channel extending annularly along an interior of said ring and facing openly inward from said ring toward said rotational axis of said cutterhead.

10 14. The dredge cutterhead of claim 13 wherein said channel has a cross-section shaped as a half-pipe.

15 15. The dredge cutterhead of claim 13 wherein said ring defines a notch in communication with said trough portion of a respective one of said helical arms and with said channel.

16. The dredge cutterhead of any one of claims 1-15 wherein each of said driving helical arms has a degree of curvature near said ring of at least 10 percent.

20

17. The dredge cutterhead of any one of claims 1-15 wherein each of said driving helical arms has a degree of curvature near said ring of at least 15 percent.

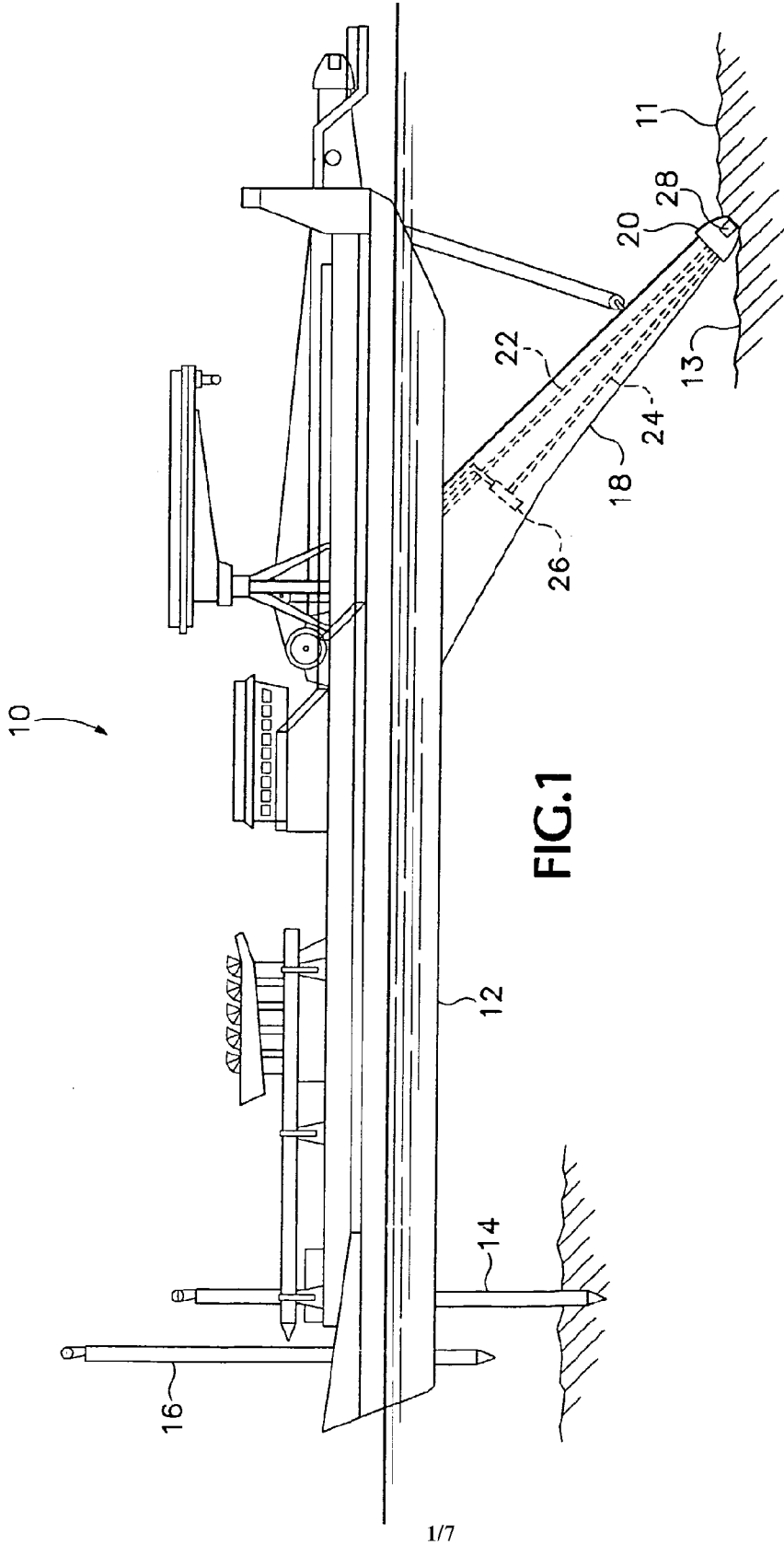
25 18. The dredge cutterhead of any one of claims 1-17 wherein a plurality of the helical arms and said driving helical arms.

19. The dredge cutterhead of any one of claims 1-17 wherein
30 each of the helical arms is one said driving helical arm.

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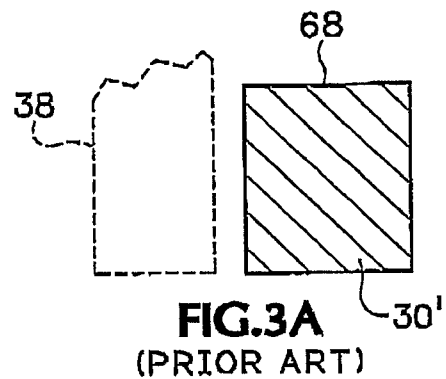
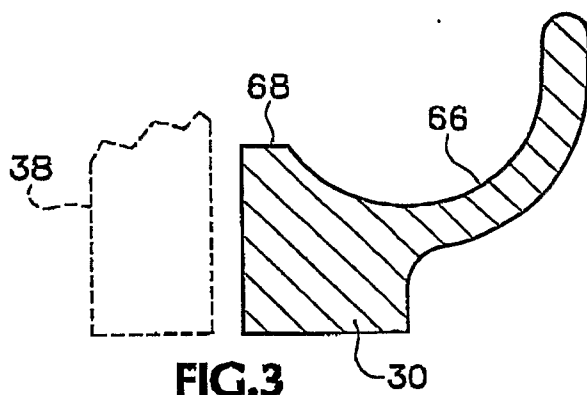
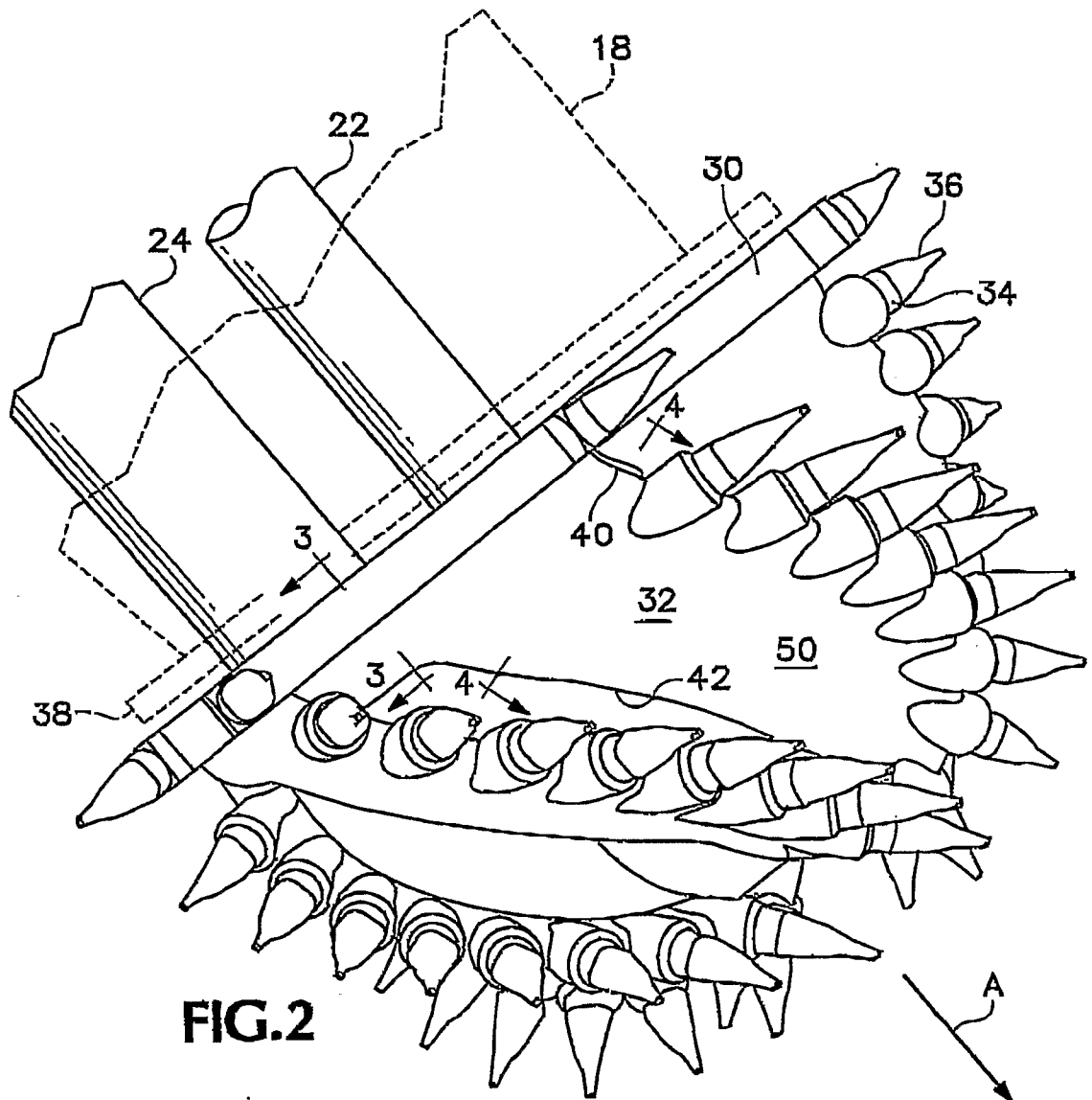
20. A dredge cutterhead substantially as hereinbefore described with reference to the accompanying drawings.

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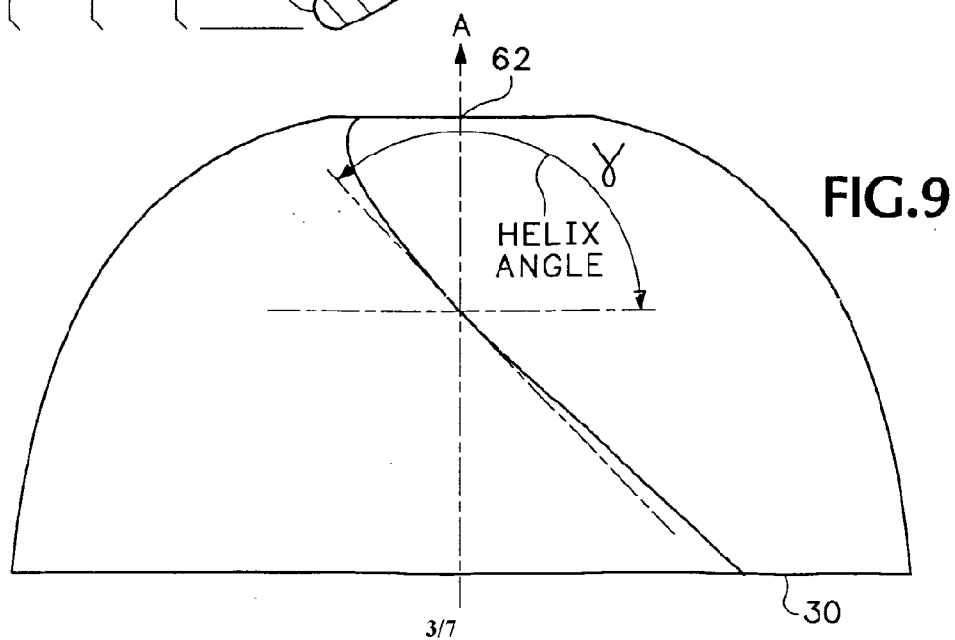
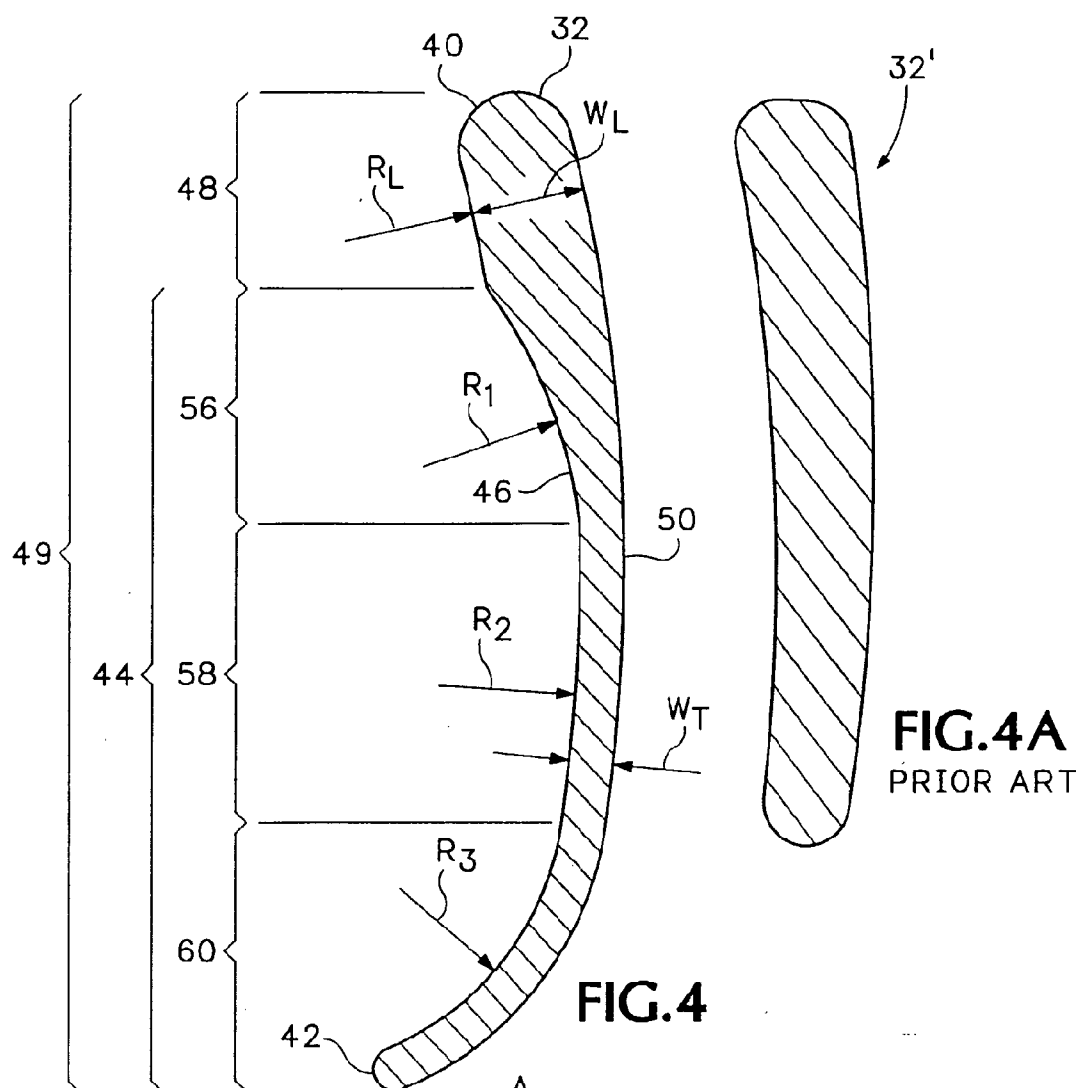


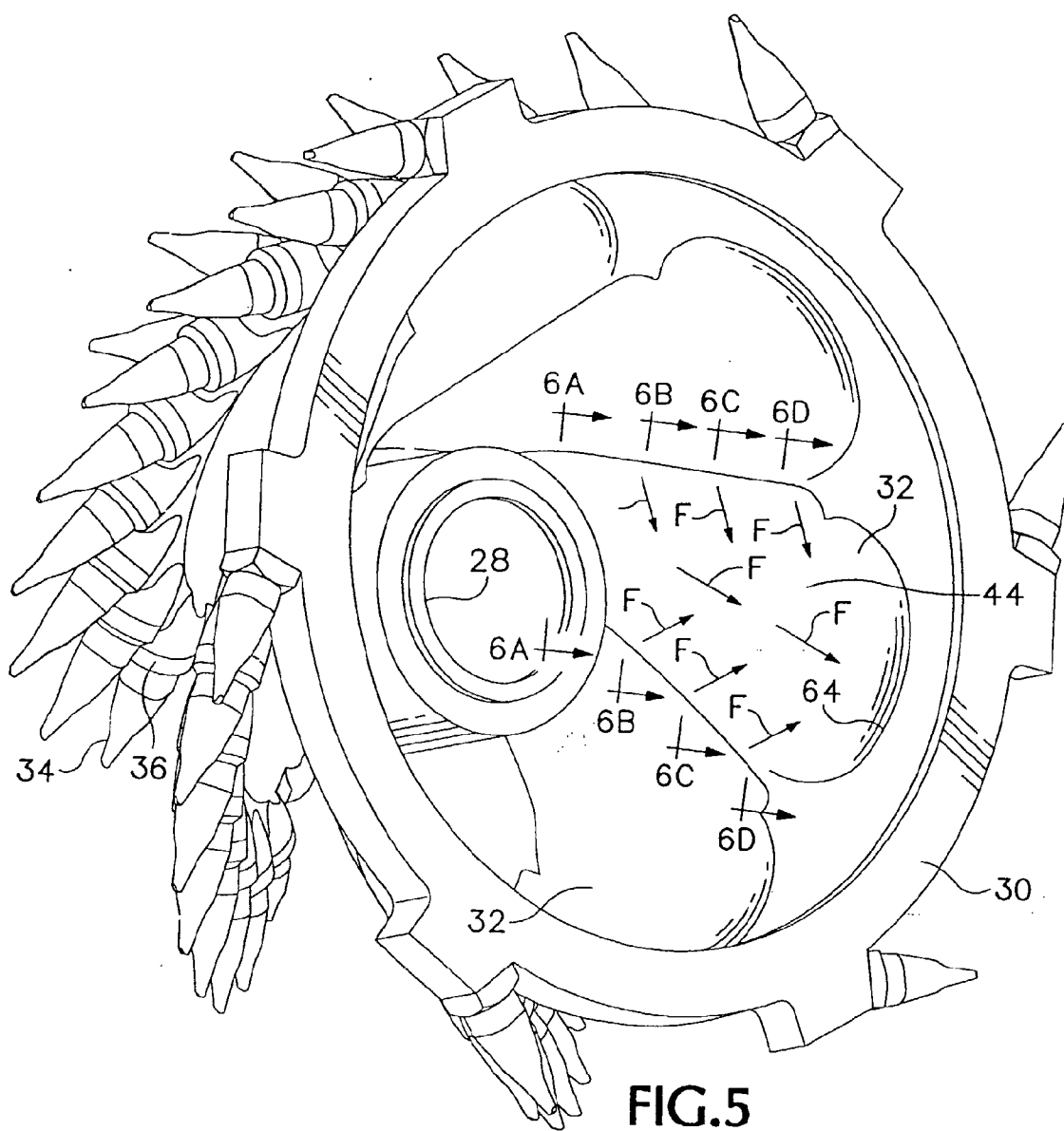
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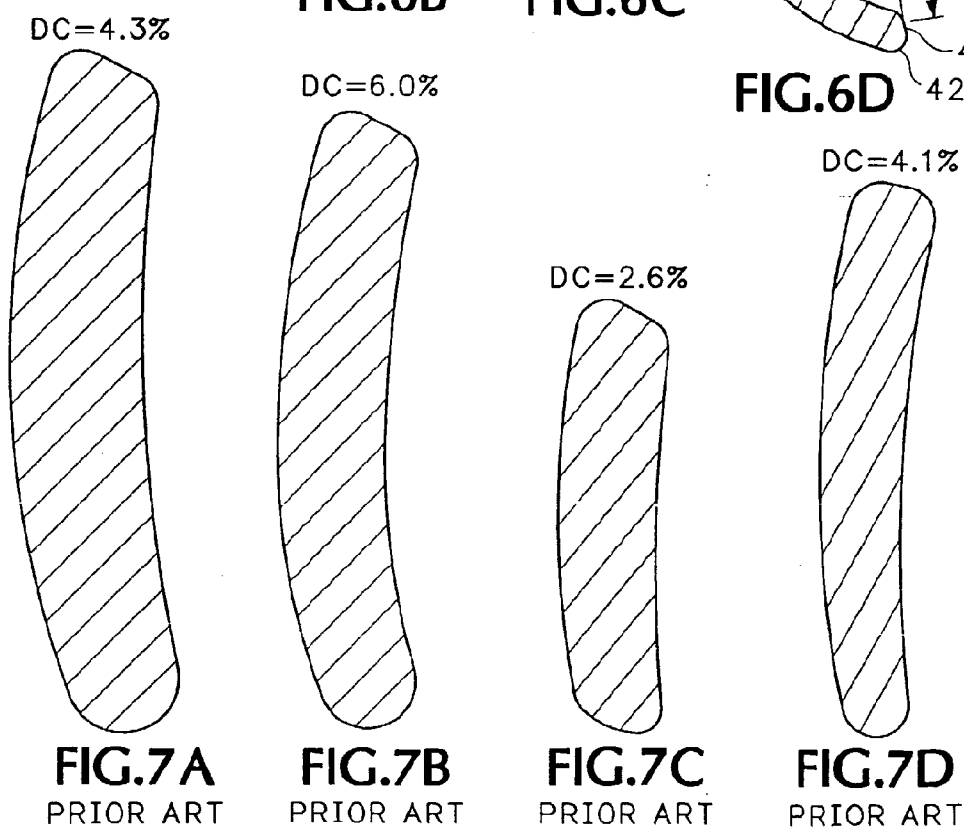
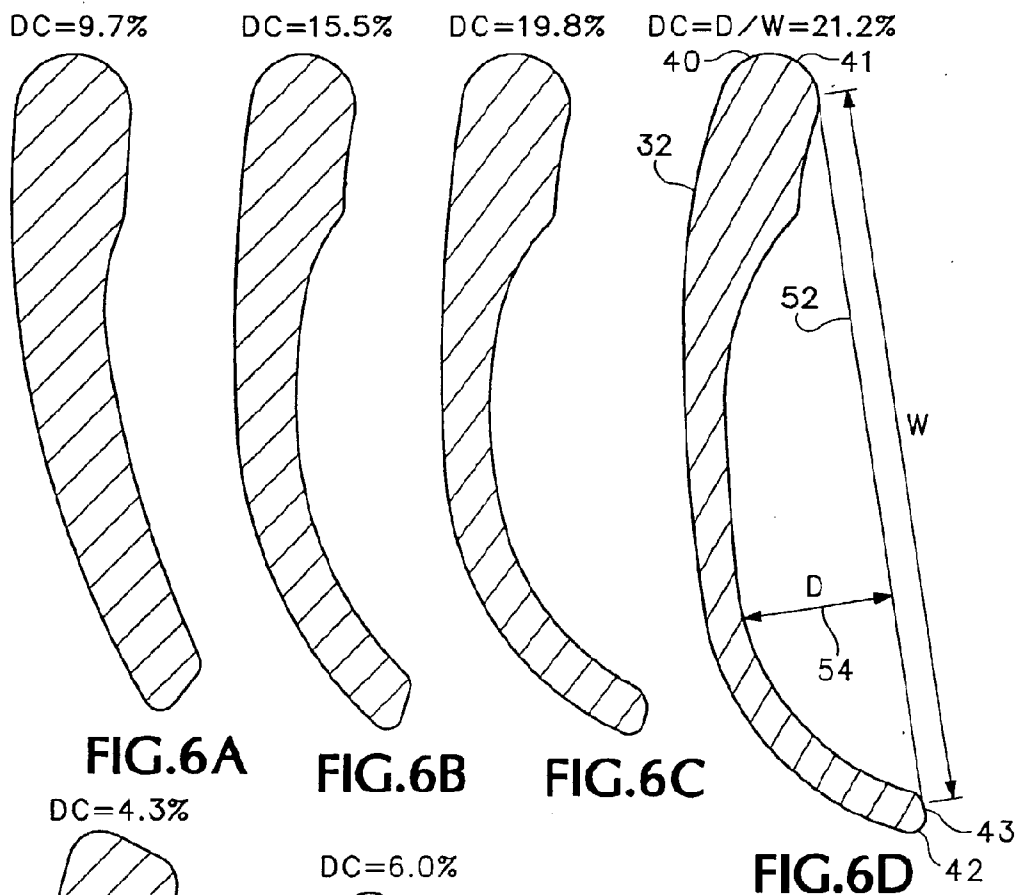
2/7



AMENDED SHEET







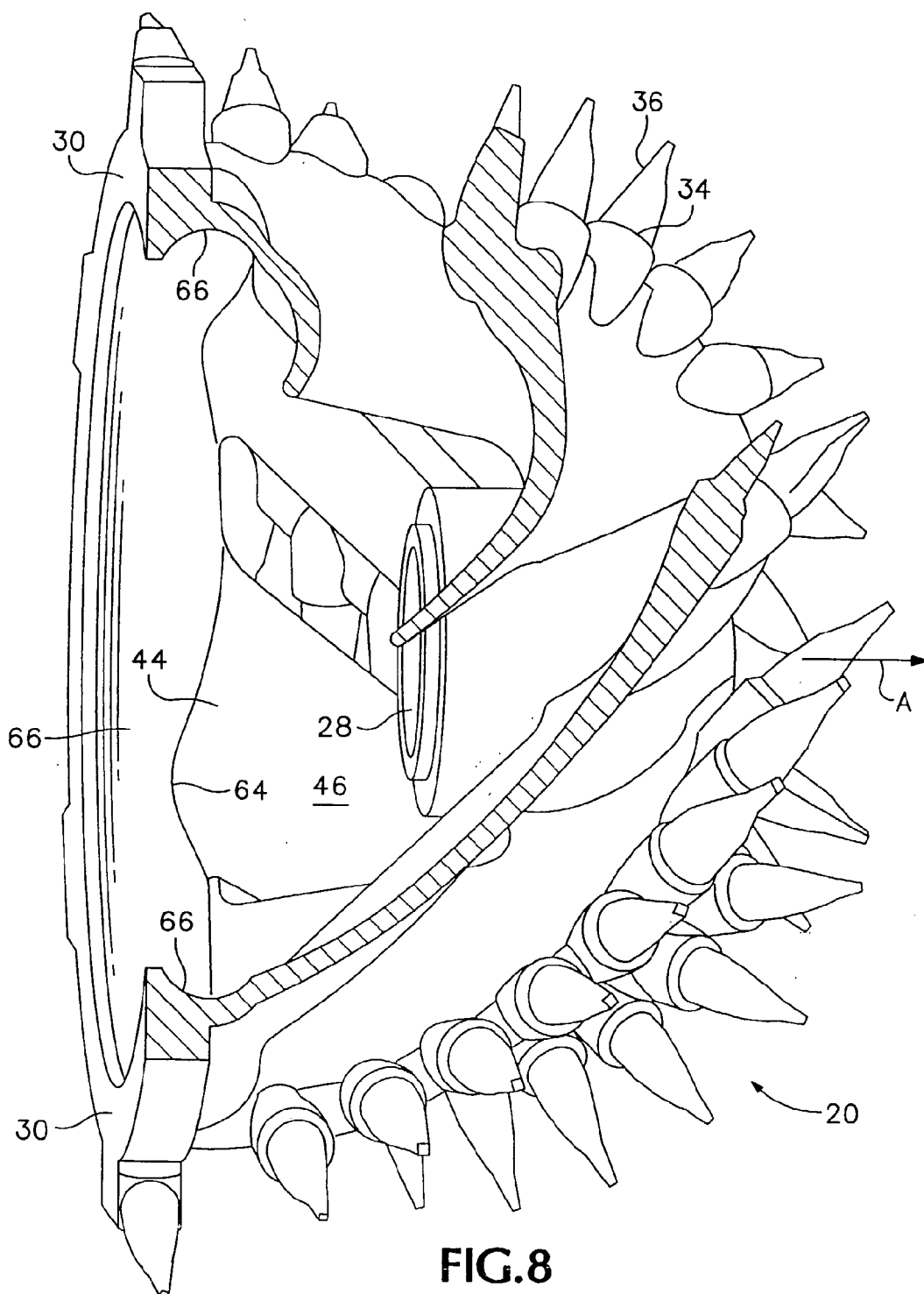




FIG. 10A
PRIOR ART

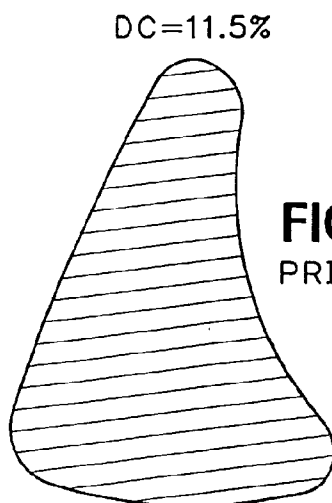


FIG. 10B
PRIOR ART

DC=3.9%

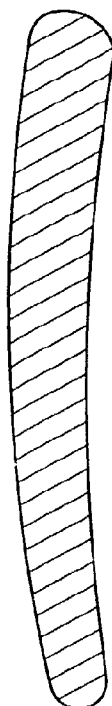


FIG. 10C
PRIOR ART

DC=4.9%

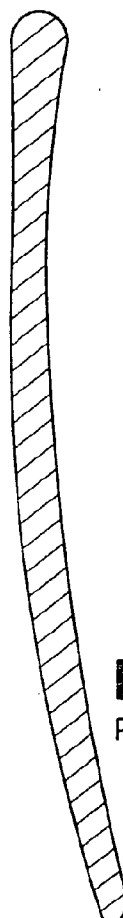


FIG. 10D
PRIOR ART