



Office de la Propriété

Intellectuelle
du Canada

Un organisme
d'Industrie Canada

Canadian
Intellectual Property
Office

An agency of
Industry Canada

CA 2312369 C 2006/11/28

(11)(21) 2 312 369

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 1999/09/21
(87) Date publication PCT/PCT Publication Date: 2000/04/13
(45) Date de délivrance/Issue Date: 2006/11/28
(85) Entrée phase nationale/National Entry: 2000/05/31
(86) N° demande PCT/PCT Application No.: US 1999/021907
(87) N° publication PCT/PCT Publication No.: 2000/020189
(30) Priorité/Priority: 1998/10/02 (US09/165,919)

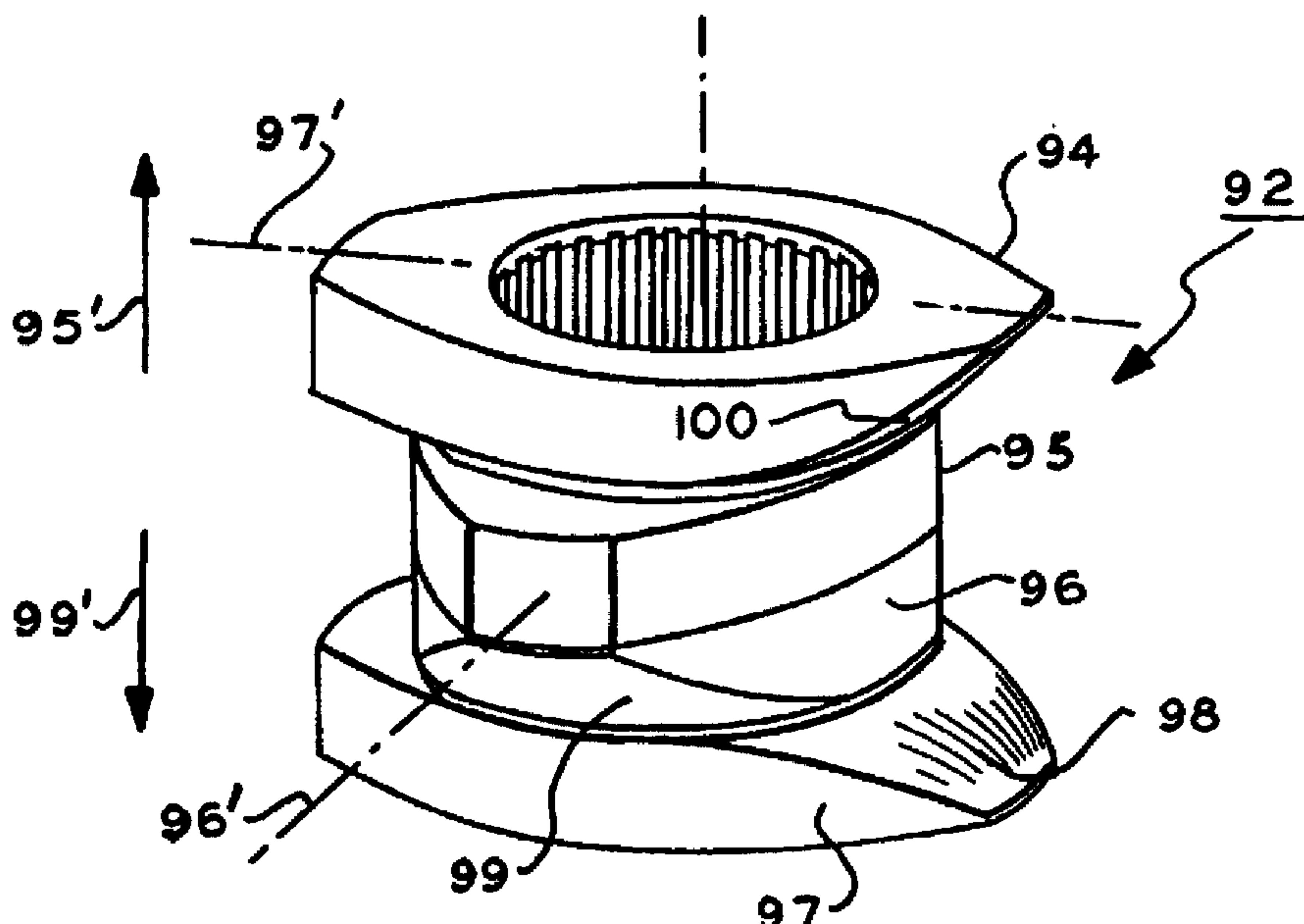
(51) Cl.Int./Int.Cl. *B29C 47/64* (2006.01),
B29C 47/60 (2006.01), *B29B 7/42* (2006.01)

(72) Inventeurs/Inventors:
KIANI, ARASH, US;
BURBANK, FREDERICK R., US

(73) Propriétaire/Owner:
KRUPP WERNER & PFLEIDERER CORPORATION, US

(74) Agent: SMART & BIGGAR

(54) Titre : ELEMENT DE MALAXAGE UTILISE DANS UNE EXTRUDEUSE A VIS SANS FIN
(54) Title: MIXING ELEMENT FOR SCREW EXTRUDER



(57) Abrégé/Abstract:

A mixing element for a screw extruder comprises a conventional element with a taper on one lobe and on one lobe broad surface. The elements may be used individually or combined in blocks, with the elements of a block oriented in various combinations. The block may comprise two or more elements. The tapered lobes provided reduced pressure and temperature of the process as compared to prior art mixing elements. Also, more graduated control over temperature and pressure are provided according to the taper, the number of element used in a process and the relative lobe orientations in a machine.

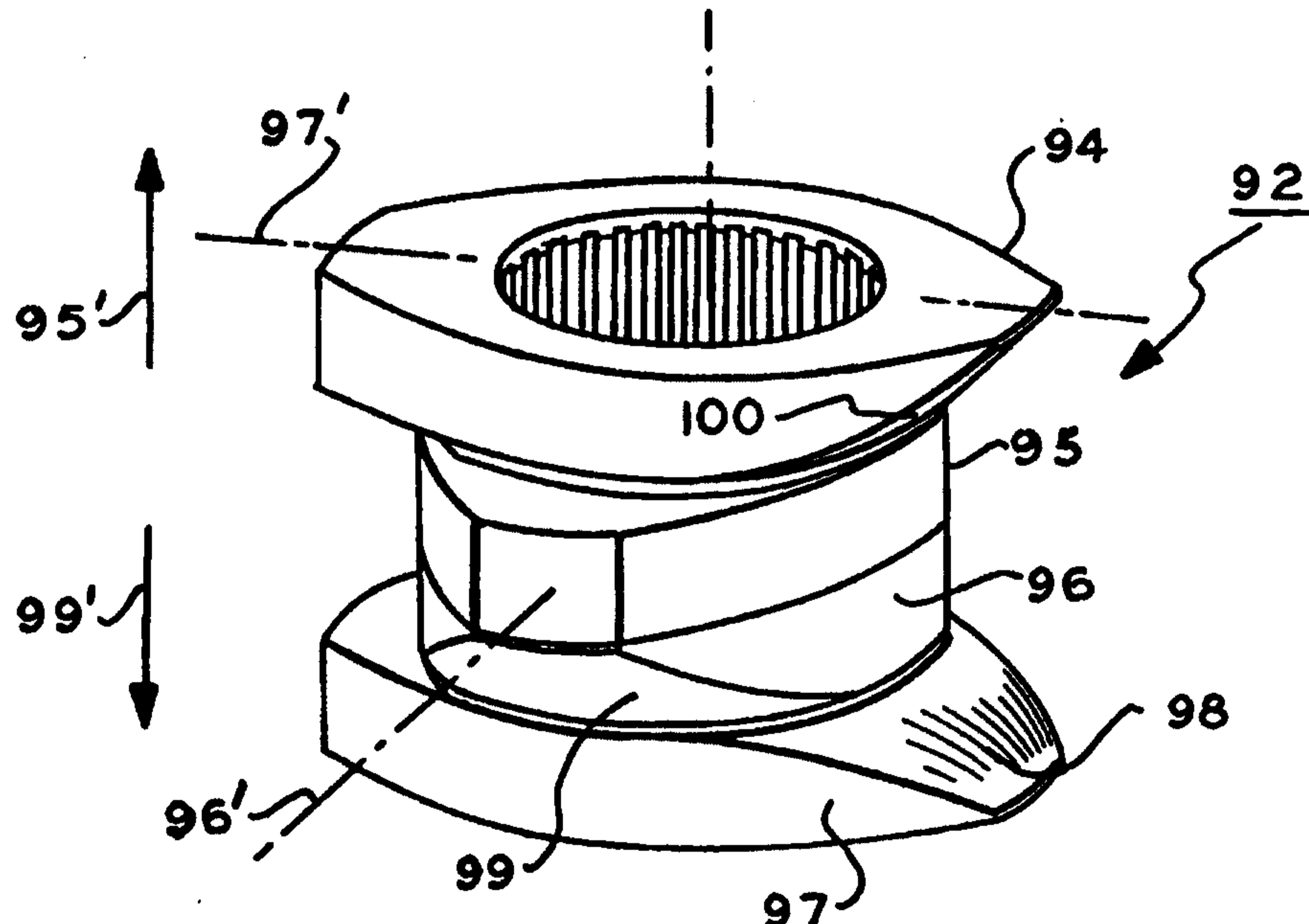
PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : B29C 47/64, B29B 7/42	A1	(11) International Publication Number: WO 00/20189
		(43) International Publication Date: 13 April 2000 (13.04.00)
(21) International Application Number: PCT/US99/21907		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 21 September 1999 (21.09.99)		
(30) Priority Data: 09/165,919 2 October 1998 (02.10.98) US		Published With international search report.
(71) Applicant: KRUPP WERNER & PFLEIDERER CORPORATION [US/US]; 663 East Crescent Avenue, Ramsey, NJ 07446 (US).		
(72) Inventors: KIANI, Arash; 72 Danbury Downs, Upper Saddle River, NJ 07458 (US). BURBANK, Frederick, R.; 9 Van Ness Avenue, Pompton Plains, NJ 07444 (US).		
(74) Agents: SQUIRE, William et al.; Carella, Byrne, Bain, Gilfillan, Cecchi, Stewart & Olstein, 6 Becker Farm Road, Roseland, NJ 07068 (US).		

(54) Title: MIXING ELEMENT FOR SCREW EXTRUDER



(57) Abstract

A mixing element for a screw extruder comprises a conventional element with a taper on one lobe and on one lobe broad surface. The elements may be used individually or combined in blocks, with the elements of a block oriented in various combinations. The block may comprise two or more elements. The tapered lobes provided reduced pressure and temperature of the process as compared to prior art mixing elements. Also, more graduated control over temperature and pressure are provided according to the taper, the number of element used in a process and the relative lobe orientations in a machine.

68975-242

MIXING ELEMENT FOR SCREW EXTRUDER

This invention relates to mixing elements for use in screw extruders.

Such extruders have mixing elements which have 5 blunt mixing surfaces which tend to generate heat due to the energy input provided as the elements rotate. Such heat can generate temperatures in excess of that desired for a given material being mixed.

The present inventors recognize a need for a 10 mixing element which can provide reduced input energy and thus heat the material to a lesser degree than prior art elements.

The invention provides a screw extruder comprising: a barrel having a first bore defining a mixing 15 axis for receiving material to be extruded; a rotatably driven shaft in the bore on the axis; and at least one mixing member for mixing said received material comprising: a central portion defining a root diameter with a shaft receiving bore releasably engaged with the shaft, said shaft 20 for rotating the at least one mixing member about the axis; and first and second end lobes extending radially from the central portion relative to the shaft receiving bore; said at least one mixing member including said end lobes and 25 central portion having opposing first and second surfaces and opposing lateral sides, said first and second surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the end lobes, said first surface 30 tapering toward the second surface defining a first surface

68975-242

taper lying between said parallel planes at the end surface of the first end lobe; and said member having a plane of symmetry.

The invention also provides a mixing member for a screw extruder defining an extrusion axis and having an axially extending screw shaft comprising: said mixing member comprising a central portion defining a root diameter with a shaft receiving bore for rotating the member about the axis; first and second end lobes extending radially from the central portion; said member including said end lobes and central portion having opposing first and second surfaces and opposing lateral sides, said first and second surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the first and second end lobes, said first surface tapering toward the second surface defining a first surface taper lying between said parallel planes at the distal end surface of the first end lobe; and said member having a plane of symmetry.

Preferably an annular flange shoulder extends from at least one of said first and second surfaces in the central lobe, and the first end lobe first surface tapers about 45° to said second surface.

The first end lobe first surface taper may define a surface of revolution.

A mixing element for a screw extruder defining an extrusion axis having an axially extending screw shaft may

68975-242

comprise a plurality of contiguous members secured to one another. The first end lobe of a first member is next adjacent to the second end lobe of a second next adjacent member.

68975-242

The first and second end lobes of a first member define a first axis therethrough and the first and second end lobes of a second member define a second axis therethrough in a further aspect, the first axis lying in a 5 first plane angularly displaced from a second plane in which the second axis lies.

The first and second axes may be normal or may be oriented about 45° relative to each other.

10 The members preferably overlie one another in a given plane.

According to one aspect of the present invention, there is provided a mixing element for a screw extruder defining an extrusion axis having an axially extending screw shaft comprising: a plurality of contiguous members secured 15 to one another; each member including: a central portion defining a root diameter with a shaft receiving bore for rotating the member; and first and second end lobes extending radially from the central portion; each member including said end lobes and central portion having opposing 20 first and second broad surfaces and opposing lateral sides, said first and second broad surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and 25 between the end lobes, said first broad surface tapering toward the second broad surface defining a tapered surface lying between said parallel planes at the end surface of the first end lobe; said member having a plane of symmetry; and said shaft receiving bores of said members being coaxial for 30 receiving said shaft.

68975-242

According to another aspect of the present invention, there is provided a mixing member for a screw extruder defining an extrusion axis and having an axially extending screw shaft comprising: said mixing member 5 comprising: a central portion defining a root diameter with a shaft receiving bore for rotating the member about the axis; first and second end lobes extending radially from the central portion; said member including said end lobes and central portion having opposing first and second surfaces 10 and opposing lateral sides, said first and second surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the first and second end lobes, said 15 first surface tapering toward the second surface defining a first surface taper lying between said parallel planes at the distal end surface of the first end lobe; and said member having a plane of symmetry.

According to still another aspect of the present 20 invention, there is provided a screw extruder comprising: a barrel having a first bore defining a mixing axis for receiving material to be extruded; a rotatably driven shaft in the bore on the axis; and at least one mixing member for mixing said received material comprising: a central portion 25 defining a root diameter with a shaft receiving bore releasably engaged with the shaft, said shaft for rotating the at least one mixing member about the axis; and first and second end lobes extending radially from the central portion relative to the shaft receiving bore; said at least one 30 mixing member including said end lobes and central portion having opposing first and second surfaces and opposing lateral sides, said first and second surfaces lying in

• 68975-242

parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the end lobes, said first surface tapering 5 toward the second surface defining a first surface taper lying between said parallel planes at the end surface of the first end lobe; and said member having a plane of symmetry.

IN THE DRAWING:

FIGURE 1 is a diagrammatic representation of a 10 prior art screw extruder apparatus;

FIGURE 2 is a diagrammatic sectional view of a prior art screw arrangement employed in the apparatus of Fig. 1;

FIGURE 3 is an isometric view of a representative 15 mixing element employed in the embodiments of Figs. 1 and 2.

FIGURE 4 is a side elevation view of a mixing element according to an embodiment of the present invention;

FIGURE 5 is a bottom plan view of the element of Fig. 4;

68975-242

FIGURE 6 is an isometric view of a plurality of the elements of Fig. 4 secured in one arrangement to form a combined mixing element;

FIGURE 7 is an isometric bottom view of the 5 element of Fig. 4;

FIGURE 8 is an isometric top view of the element of Fig. 4;

FIGURE 9 is an isometric view of a second embodiment of a plurality of elements of Fig. 4 secured in a 10 second arrangement to form a combined element; and

FIGURES 10 and 11 are side elevation views of two different screw arrangements employing a plurality of the elements of Fig. 4 in different combinations and orientations for use in extruder of Fig. 1.

15 In screw extruders, a plurality of mixing barrels are provided for mixing various materials. Such materials may include thermoplastics, rubber polymers and all other materials with viscoelastic flow characteristics.

In Fig. 1, for example, a prior art extruder 2 20 comprises an axial array of barrels 4, 5, 6, and 7 are secured together. The barrels define an axially aligned bore 8 in an hour glass configuration on axis 34 for receiving twin rotating screws such as screws 11, Fig. 2. A port 9 and a second set of twin screws 10 are normal to the 25 bore 8 axis 34 for providing a second feed location for the input materials. The port 9 and screws 10 are normal to the orientation of the twin rotating screws and bore 8 of the barrels 4-7. A drive shaft 12 drives the twin screws (not shown in Fig. 1) which typically are co-rotating, but may

68975-242

counter-rotate. The apparatus comprising the barrels, which are modular, and may be assembled in any order and number, shaft and screws are commercially available from Krupp Werner & Pfleiderer Corporation, model number ZSK 40, 5 for example, with a side feeder model ZSB 40 containing screws 10. A drive mechanism 14, which is conventional and available as Krupp Werner & Pfleiderer Corporation, model ZSK 40 drives the shaft 12 and screws 11, Fig. 2. Hoppers 17 and 19 provide the raw material to be mixed via an 10 extruder inlet hopper 21.

In Fig. 2, barrels 4-7 and a representative screw 11 of the twin screws employed in the barrels 4-7, Fig. 1, are shown. A further barrel 7' is also included. Barrel 7 receives input material through port 16. Barrel 6 may also 15 receive input material through port 18.

The screw 10 comprises a plurality of helix thread modular screw elements 22 and 24 of different axial extents. The elements are arranged in various axial lengths and combinations according to the 5 operation desired as known.

Disposed in barrel 6' and in barrel 4 are mixing elements 26 in various orientations and combinations. The elements in each barrel are juxtaposed and contiguous in relative orientations as desired for a 10 given mixing operation.

In Fig. 3, representative mixing element 26 will be described. Element 26 may comprise a hardened nitrided tool steel or other alloy plate having a central bore 28 in a root diameter region 30. The 15 bore 28 has splines 32 which mate with splines on the shaft 12, Fig. 1, so the shaft 12 can rotate the element 26 about the shaft axis 34.

The element 26 has two opposing broad surfaces 38, 40 and two opposing lateral side walls 42 and 44 20 in mirror image relation. The side walls 42, 44 taper toward each other at the element end regions. The element 26 has two end lobes 46, 48 which extend radially in opposite directions from the central portion containing the bore 28. The lateral side 25 walls 42 and 44 are curved, for example, defined by a

68975-242

radii that is the same for each side wall 42, 44, e.g., about 33 mm for an element that lies on a circular diameter d_2 of about 40 mm in one embodiment. The element may have a maximum width d_1 for example of about 26 mm between the side 5 walls across the bore 28 center.

The element 26 has a thickness such that the side walls 42 and 44 are blunt, e.g., about 0.75 inches (19 mm) thick. The end surfaces 50 and 52 are identical mirror images and lie on a circle, e.g., about 40 mm in diameter. 10 This is the diameter of the barrel bores of the extruder 2, Fig. 1, corresponding to the designation as a ZSK 40. Thus the end surfaces 50 and 52 wipe against the applicable barrel bore surface.

In a twin screw extruder, the elements 26 of the 15 two screws interengage with the end surfaces 50 and 52 wiping against mating lateral side wall surfaces on the mixing elements of the adjacent screw. In Fig. 2, for example, the end surfaces 50, 52 of the elements 26 are shown as black squares. The elements of the two adjacent 20 screws are thus complementary so as to wipe against each other during rotation to effect a kneading action of the material being mixed and extruded. Not shown are extrusion dies at the exit port of barrel 4, Fig. 2, on axis 34 for extruding the mixed material in direction 54.

25 In Fig. 2, various orientations of the elements 26, which are referred to as two lobe elements, are shown for a given implementation. However, the prior art also includes three lobe elements, not shown, which are generally triangular in plan view rather than elongated as 30 elements

extrusion dies at the exit port of barrel 4, Fig. 2, on axis 34 for extruding the mixed material in direction 54.

In Fig. 2, various orientations of the elements 5 26, which are referred to as two lobe elements, are shown for a given implementation. However, the prior art also includes three lobe elements, not shown, which are generally triangular in plan view rather than elongated as elements 26. Also, elements 26' 10 are thinner than elements 26. The elements 26 and 26' are each arranged in sets of five elements with the contiguous elements oriented 45° relative to the orientation of the next element so as to simulate a helix screw thread in barrel 6'. There are two sets 15 of elements 26 and one set of elements 26' in barrel 6', the orientation of elements 26' being opposite to that of elements 26, by way of example. The elements 26 of barrel 4 are arranged in different set orientations as shown. These sets of elements act 20 as a screw thread and push the material in the direction 54 during the kneading action. The elements of the adjacent screws in a barrel have the same pitch and 90° orientation relative to each other to insure the end surfaces 50 and 52 of one screw 25 wipe against the lateral side wall 42, 44 surface of

68975-242

the other screw element axially aligned therewith. The pitch of the elements 26 thus follow the crest of a helix whereby the elements of the adjacent screws mesh exactly with each other. In these elements the broad 5 surfaces 38 and 40 are parallel. In some elements, an upwardly extending annular spacer shoulder or rib (not shown) may be present in the root diameter region 30.

In a typical element the shear rate of the material as sheared by the elements 26 is defined by the 10 equation:

1) Shear Rate = $\frac{\pi \times D \times \text{speed (shaft rpm)}}{\text{gap (g')}} \times \text{seconds}$

gap (g') 60

where (see Fig. 3):

15 2) $D = \frac{d_1 + d_2}{2}$

and g' is the gap between adjacent elements at the broad surfaces 38 and 40. Where there is an annular shoulder in the root diameter region, such a shoulder will provide a 20 gap g' typically at about 0.75 mm in height. This height value is dependent upon the bore diameter of the associate extruder barrel. The shoulder has a surface parallel to the surfaces 38 and 40, and whereas the flat surfaces 38 and 40 will normally abut and exhibit a negligible gap g' .

Energy input is defined:

3) $E = \text{viscosity of material} \times \text{shear rate}^2 \text{ at } T^{\circ}\text{C. (Kw)}$

Thus as the gap g increases, the shear rate decreases
5 and the energy expelled during the mixing is
decreased quadratically.

To determine the temperature rise:

4) $E = M \text{ (flow rate kg/sec)} \times \text{heat capacity}$
(Kw/Kg/ $^{\circ}\text{C}$) \times change in temperature
10 (delta T $^{\circ}\text{C}$) (inlet vs. outlet
temperatures as measured)

= energy consumption

The problem with the elements 26 is that there is a
limit on the amount of energy reduction or control
15 over the energy that can be provided with such
elements. The changes in energy levels are possible
in incremental steps wherein the incremental changes
in energy consumption are relatively large regardless
of the arrangement of the elements in different
20 combinations. This incremental change in energy
affects the temperature of the material being mixed
and/or its pressure which is also a function of the
relative energy involved.

The energy level affects the temperature and
25 pressure of a material such that undesirable

68975-242

agglomerates may be formed at certain shears at too high a pressure. This creates larger particles which is a defect in the final product. Temperature controllers are employed in the prior art to maintain temperature and effect host transfer. It is necessary to empirically determine the desired pressure and temperature when the prior art elements 26 do not produce the desired control. Then the temperature needs to be controlled accordingly.

In Figs. 4, 5, 7 and 8, element 54 according to the present invention is shown. Reference numerals that are the same for element 26, Fig. 3, represent identical components. The element 54 is of material, has the overall shape and dimensions that are the same as element 26. The lateral side walls 56 and 58 have the same curvature, the element has the same length and thickness and the bore 28 is the same as element 26. The plan view outer peripheral profile, Fig. 5, is thus the same as for element 26.

The difference between element 54 and element 26 is that element 54 has a broad planar surface 40' that tapers at taper 60. In addition, the aforementioned optional upstanding root diameter spacer shoulder 62 is shown for element 54. A shoulder 62 is on each of the opposing broad surfaces 38' and 40'. Surface 40' is otherwise the same as surface 40 of element 26, Fig. 3, notwithstanding the presence of the of taper 60 in broad surface 40' and the presence of shoulder 62. Surface 38' is the same as surface 38 of element 26, Fig. 3, notwithstanding shoulder 62. The element 54 has a central portion 64 and two end lobes 66 and 68 that are symmetrical about a common axis, such as axes 80, 82, Fig. 9, and axes 96', 97', Fig. 6.

68975-242

The taper 60 is generally about at 45° in this embodiment but could be at other angles according to a given implementation. The surface 70 of the taper 60 is preferably on a surface of revolution, a circle and thus is 5 curved and not flat. However, a flat surface, other curvatures, or faceted taper may be employed in certain implementations. The surface 70 terminates at an end surface 72 which is relatively narrow. The taper 60 forms a gap g, Fig. 4, which is significantly larger than that 10 produced by the prior art element 26. This gap g thus provides a control over the energy provided by the element 54 in a manner not previously possible.

Because the taper may be at any desired angle, the gap g may be set accordingly. Also, the combination of 15 the elements 54 provides various gaps not previously possible with the elements 26. While one tapered end lobe is shown, both end lobes may also be tapered as desired for a given

WO 00/20189

PCT/US99/21907

implementation. To maintain the self wiping condition, only one taper is preferred due to the thin end surface 72 of the tapered end lobe 68. The number of tapered elements determines the energy 5 input of the extruder 2. Thus by changing the number of tapered elements employed, the energy levels are capable of being set to a wider degree than otherwise possible.

This energy control is important for polymer 10 materials, e.g., plastics or elastomers, to control the temperature and/or pressures. By controlling the maximum temperature according to the configuration of the tapered element lobes, the end properties may be properly set. To provide control over the process 15 the variables including the number of elements, the angular orientation of the elements to each other, and the number of tapered elements are determined for a given process.

The tapers provide an increased working volume 20 for a given throughput rate, and provide an increase in the incremental time the material is processed. This can be important in reactive processes which require a certain time to achieve the material melt blend. For example, in conversion of monomers to 25 polymers or polymers to polymers, the conversions are

a function of reaction times and residence time. The tapered elements provide enhanced control over these variables. That is the taper provides increased resident time and reduced pressure which may reduce 5 temperature to permit an optimum profile for a given application.

The elements 54 may be installed as single units or fabricated as blocks. For example, in Fig. 9, three elements 74, 76 and 78 identical to element 54 10 are secured, e.g., bonded, as a block 79 with their broad surfaces abutting with no root diameter shoulders therebetween. In the alternative, the block 79 may be fabricated as a one piece integral structure. Element 74 has its longitudinal axis 15 oriented 90° from the axis 82 of elements 76 and 78. The taper 84 faces in one shaft axis 86 direction. The axes 82 of elements 76 and 78 are aligned in the direction of axis 86. The taper 88 of element 76 and the taper 90 of element 78 face in the opposite 20 direction along axis 86, with the taper 90 facing in the same direction as the taper 84 of element 74. The tapered lobe of element 76 is diametrically opposite the position of the tapered lobe of element 78.

68975-242

In Fig. 6, a four element block 92 comprises elements 94, 95, 96 and 97. These elements are identical to element 54. Elements 54 and 97 have their tapered lobes in spaced overlying relation with the tapered surfaces 5 facing each other. The tapered surface of the tapered lobe of element 95 (not shown in the figure) faces in the same axial direction 95' as the surface of taper 98 of element 97. The tapered surface 99 of the tapered lobe of element 96 faces in the same axial direction 99' as the 10 surface of taper 100 of element 94.

The lobes of the elements 95 and 96 are oriented in the same axial direction along axis 96' with their tapers facing in opposite directions 95' and 99', respectively. The lobes of elements 95 and 96 are on mid 15 symmetrical width axis 96'. The elements 95 and 96 lobes are oriented 90° from the axis 97' of the lobes of elements 94 and 98. The lobes of elements 94 and 98 extend in an axial direction along axis 97' and are symmetrical with the axis. The lobes of elements 94 and 98 also are in the same 20 axial orientation but with their tapers facing in opposite directions 99' and 95', respectively. In other embodiments, the lobe axes, such as axes 96' and 97', of the different next adjacent elements may lie in orientations different than 90°, e.g., 45°.

WO 00/20189

PCT/US99/21907

In Fig. 10, screw 102 comprises conventional helix screw portions 103 and 105. Conventional mixing elements 104 in a block of five elements as described above are next to the helix screw portion 5 104. Blocks 105 and 106 are identical and each comprise five elements 54. These are the same as block 92, Fig. 6. Blocks 105 and 106 are oriented 180° apart about the shaft axis 107. Block 108 is the same as block 79 figure 9 and is oriented about axis 10 107 as shown in the figure. The splines of the elements maintain the element orientation about the shaft 107 as known.

In Fig. 11, screw 110 comprises a block 104 and a series of blocks 108 arranged in parallel and the 15 same angular orientation.

The blocks 105 and 106 provide reduced shear forces with more leakage between the elements. High pressure is minimized and provides low pressure which is important for certain materials. 100% wiping for 20 the barrel surfaces and good leakage is provided to minimize pressure build up. The full wiping occurs with the non-tapered lobes of the elements.

Process Example

EPDM	Uniroyal IM 1700
25 Carbon Black	Cabot N650

WO 00/20189

PCT/US99/21907

The EPDM was fed into barrel 7 (see Fig. 2 for position of barrels) and melted masticated in the kneading blocks in the next barrel 6'. The carbon black was fed into barrel 6. Samples were collected 5 with the blended material. The barrels were preheated to 75°C. No cooling was on. The EPDM was fed at 75 Lb. per Hr (pphr). The carbon black was fed at 40 pphr.

The following combinations were evaluated.

10 1. 80 mm axial length along axis 34, Fig. 1, of conventional kneading elements at the beginning of barrel 5.

2. 80 mm of tapered elements, Fig. 11, along the axial length of axis 34, Fig. 1, replacing the 15 conventional kneading blocks in an orientation with their tapers all facing in the same shaft 12 axial direction (axis 34, Fig. 1) with the lobes of each element oriented 90° with respect to the next adjacent element similar to axes 96' and 97', Fig. 6.

20 3. 80 mm axial length along axis 34, Fig. 1, of tapered elements arranged in 90° orientations per Figs. 6 and 10, replacing the conventional kneading blocks.

Results

The conventional elements exhibited the highest specific mechanical energy (SME) and produced the highest stock temperature in the material.

The second combination resulted in significant 5 reduction in both SME and stock temperature with both materials processed. The third combination resulted in even greater reduction in SME and stock temperature. All samples were uniformly masticated and/or mixed.

10 It will occur to one of ordinary skill that various modifications may be made to the disclosed embodiments. It is intended that the scope of the invention is as defined in the appended claims. For example, the number of elements, the number of 15 tapered lobes, their orientation and the amount of taper is determined according to a given implementation. The number of lobes also may be according to a given implementation, e.g., three lobes in a triangular orientation rather than the two 20 lobe configurations in an axial orientation as shown. In a triangular configuration, the end surfaces of the lobes may be narrower than the end surfaces of a two lobe configuration. More or fewer lobes may be provided. The thicknesses, lengths, curvatures of 25 the elements are all given by way of example and

WO 00/20189

PCT/US99/21907

depend upon the bore diameter or other parameters of
a given screw extruder or process.

68975-242

CLAIMS:

1. A mixing element for a screw extruder defining an extrusion axis having an axially extending screw shaft comprising: a plurality of contiguous members secured to one another; each member including: a central portion defining a root diameter with a shaft receiving bore for rotating the member; and first and second end lobes extending radially from the central portion; each member including said end lobes and central portion having opposing first and second broad surfaces and opposing lateral sides, said first and second broad surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the end lobes, said first broad surface tapering toward the second broad surface defining a tapered surface lying between said parallel planes at the end surface of the first end lobe; said member having a plane of symmetry; and said shaft receiving bores of said members being coaxial for receiving said shaft.
- 20 2. The element of claim 1 wherein the members overlie one another in a given plane.
3. The element of claim 2 wherein the end lobes of two adjacent members are juxtaposed.
- 25 4. The element of claim 3 wherein the tapered surface of each of the juxtaposed members face in opposite axial directions along said axis.
- 30 5. The element of claim 4 wherein the first end lobe of a first element is juxtaposed with the second end lobe of a second element and the tapered surfaces face in opposite directions.

68975-242

6. The element of claim 4 wherein the tapered surface of a first of said two adjacent members is angularly displaced from the first end lobe of a second of said two adjacent members about said shaft receiving bore.

5 7. The element of claim 4 wherein the two adjacent members each lie in a plane and including a plurality of said two adjacent members secured to each other with their respective planes in parallel relation.

8. The element of claim 3 wherein the tapered surface 10 of each of the juxtaposed members face in the same axial direction along said axis.

9. The element of claim 1 wherein the first and second end lobes of a first member define a first axis therethrough and the first and second end lobes of a second member define a second axis therethrough, the first and second axes each having an orientation, the first axis orientation being angularly displaced from the second axis orientation.

10. The element of claim 9 wherein the first and 20 second axes are normal.

11. The element of claim 9 wherein the first and second axes are oriented about 45° relative to each other.

12. The element of claim 1 including three of said members arranged in coaxial relation, the broad surfaces of 25 each of said three members having non-tapered portions, two of said members being secured in back-to-back relation with the non-tapered portions thereof abutting and with each said tapered surface of the two members facing in opposite axial directions and juxtaposed at the end lobes of the two 30 members, and a third of said members being secured in said

68975-242

coaxial relation to one of said two members in overlying relation thereto and being oriented with its first and second end lobes angularly displaced about said shaft receiving bore relative to the two members.

5 13. The element of claim 12 further including a fourth member secured to the other of said two members in mirror image relation to the third member.

14. The element of claim 12 including a plurality of sets of said three members oriented in the same angular 10 orientation about the axis through said bores.

15. The element of claim 1 wherein the first end lobe of a first member is next adjacent to the second end lobe of a second member.

16. A mixing member for a screw extruder defining an extrusion axis and having an axially extending screw shaft comprising: said mixing member comprising a central portion defining a root diameter with a shaft receiving bore for rotating the member about the axis; first and second end lobes extending radially from the central portion; said member including said end lobes and central portion having opposing first and second surfaces and opposing lateral sides, said first and second surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface 20 extending across each side of the central portion and between the first and second end lobes, said first surface tapering toward the second surface defining a first surface taper lying between said parallel planes at the distal end surface of the first end lobe; and said member having a 25 plane of symmetry.

68975-242

17. The member of claim 16 including an annular flange shoulder extending from at least one of said first and second surfaces in the central portion.

18. The member of claim 16 wherein the first surface 5 tapers about 45° to said second surface.

19. The member of claim 16 wherein the first surface taper defines a surface of revolution.

20. A screw extruder comprising: a barrel having a first bore defining a mixing axis for receiving material to 10 be extruded; a rotatably driven shaft in the bore on the axis; and at least one mixing member for mixing said received material comprising: a central portion defining a root diameter with a shaft receiving bore releasably engaged with the shaft, said shaft for rotating the at least one 15 mixing member about the axis; and first and second end lobes extending radially from the central portion relative to the shaft receiving bore; said at least one mixing member including said end lobes and central portion having opposing first and second surfaces and opposing lateral sides, said 20 first and second surfaces lying in parallel planes along said axis, each end lobe having a distal end surface, each of said lateral sides having a surface extending across each side of the central portion and between the end lobes, said first surface tapering toward the second surface defining a 25 first surface taper lying between said parallel planes at the end surface of the first end lobe; and said member having a plane of symmetry.

21. The extruder of claim 20 including a plurality of said at least one mixing member secured to the shaft in next 30 adjacent juxtaposed relation.

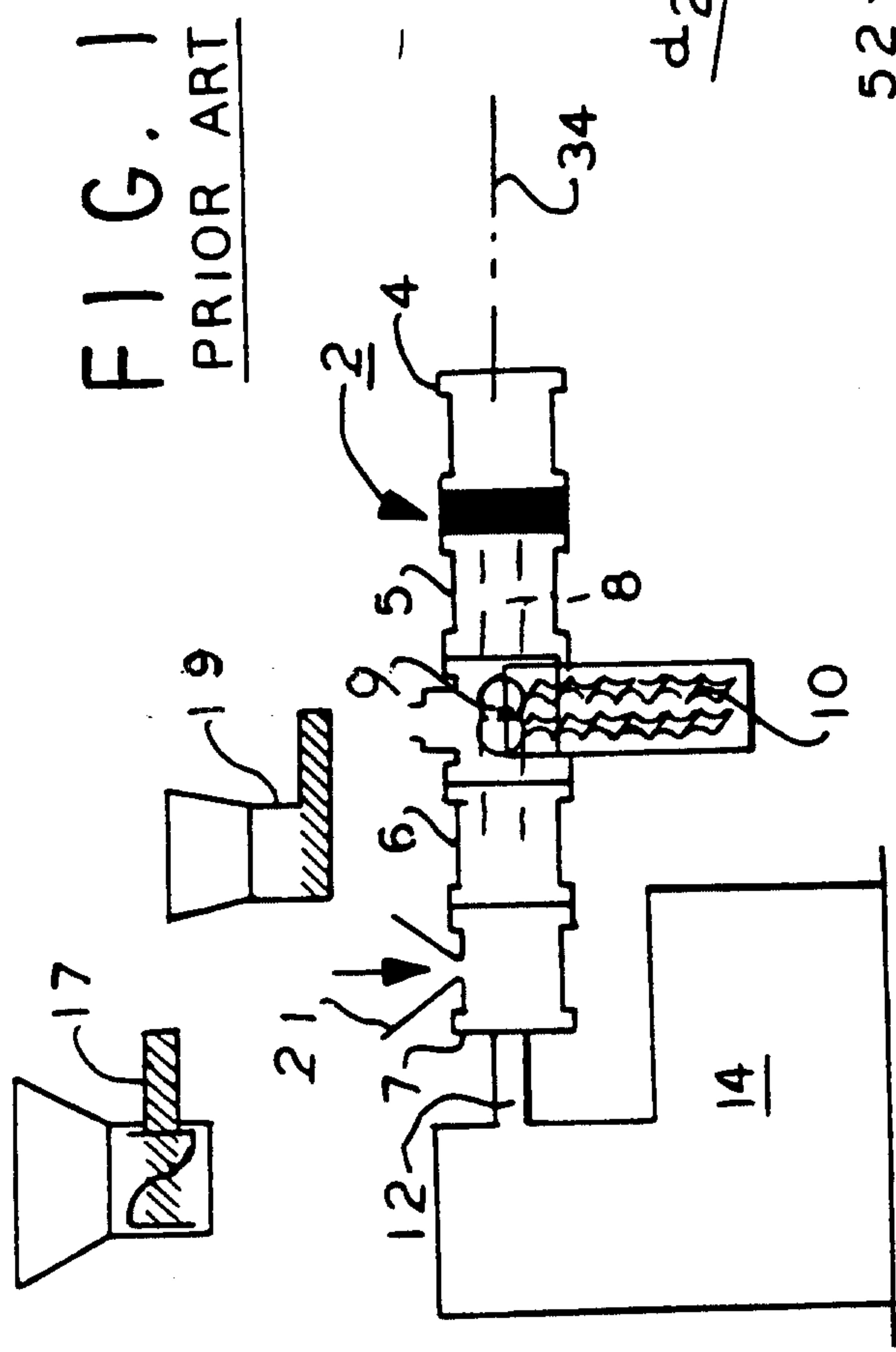


FIG. 3
PRIOR ART

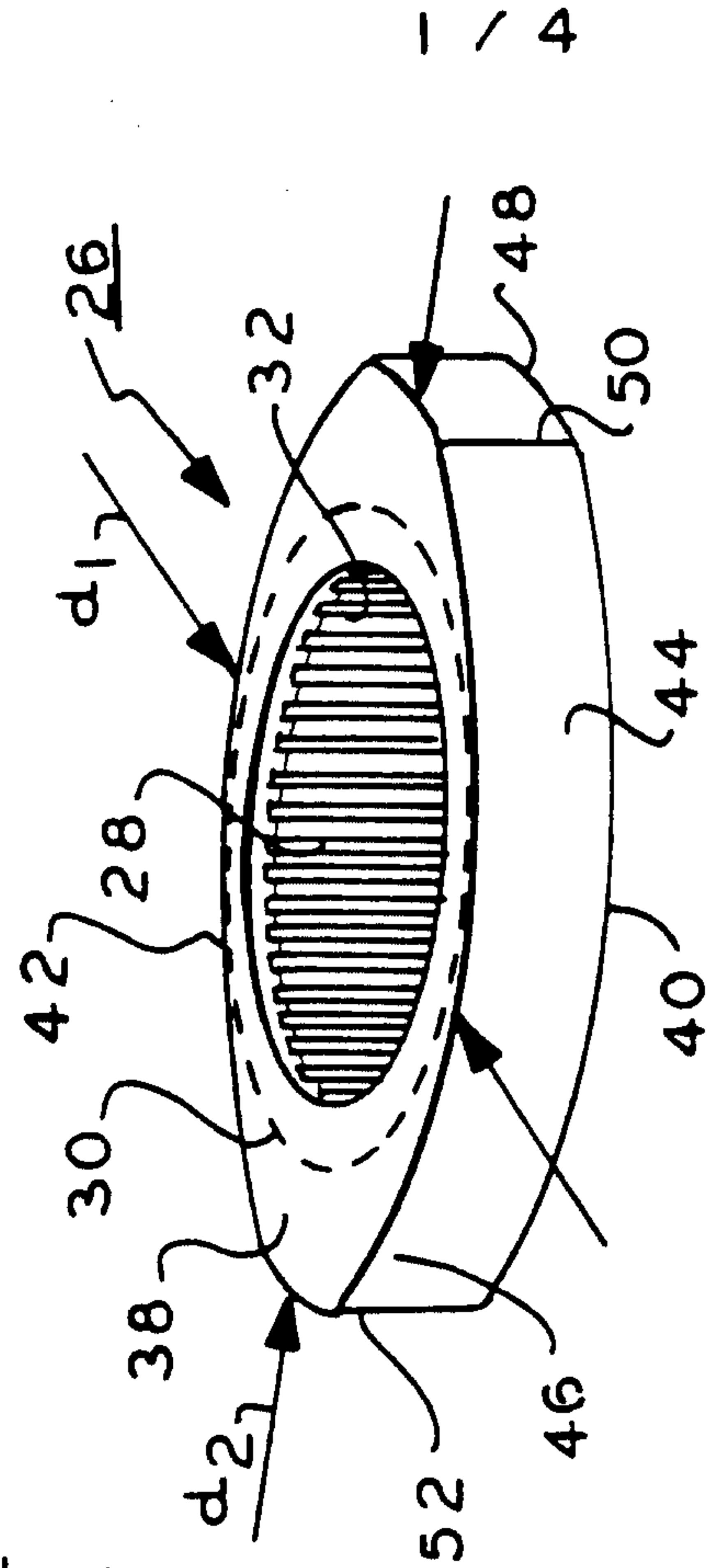
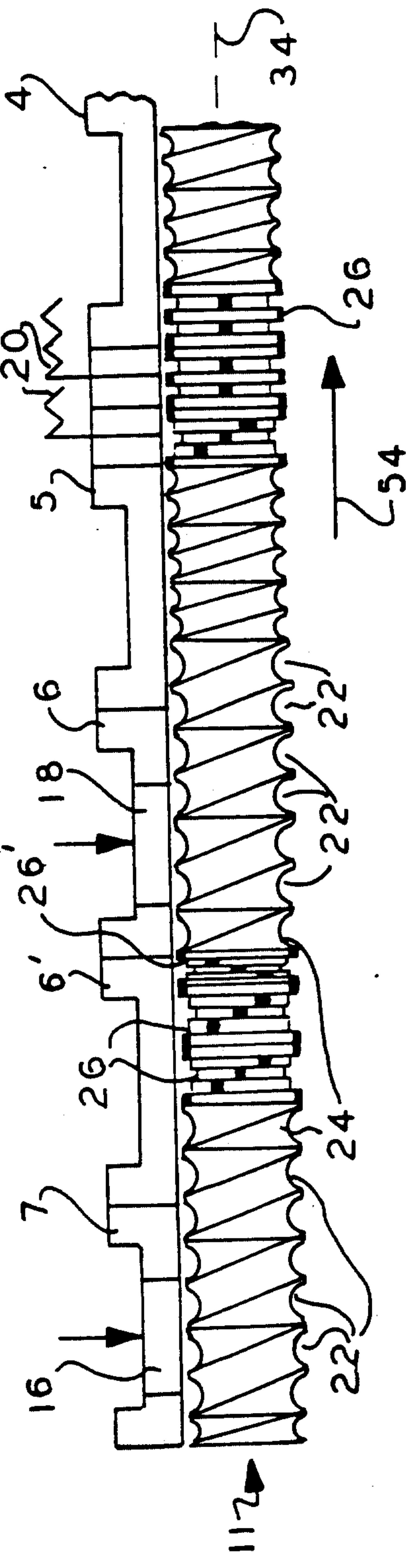


FIG. 2
PRIOR ART



2 / 4

FIG. 4

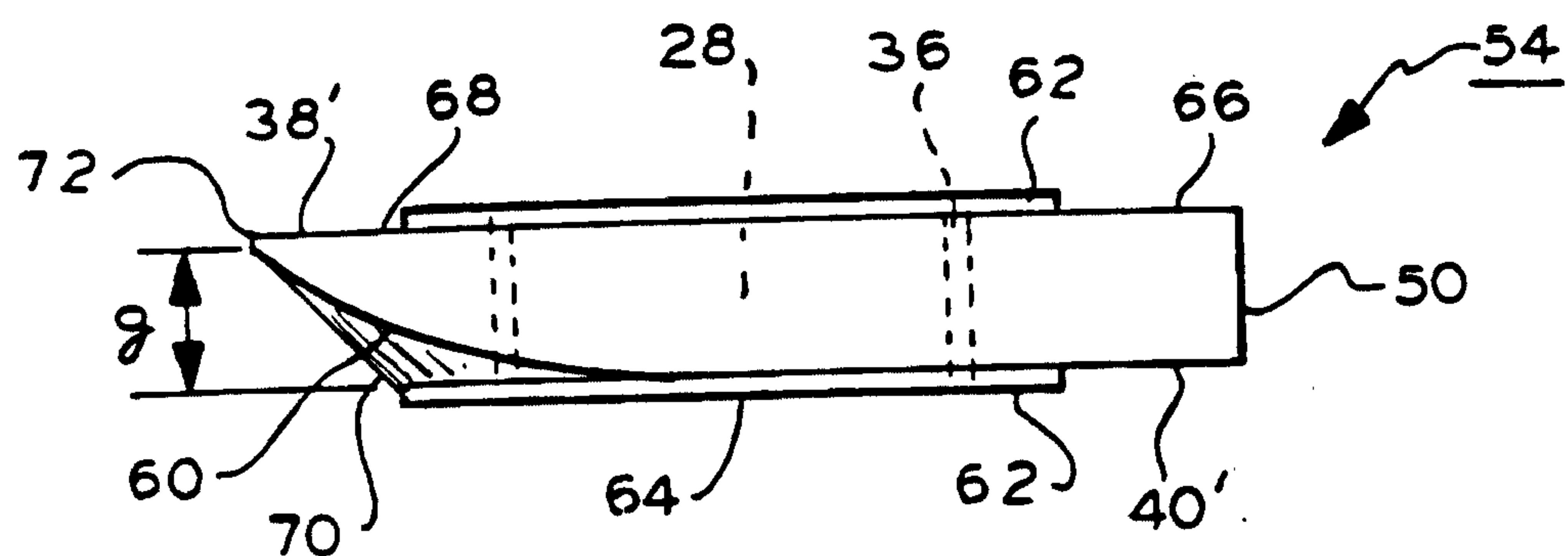


FIG. 5

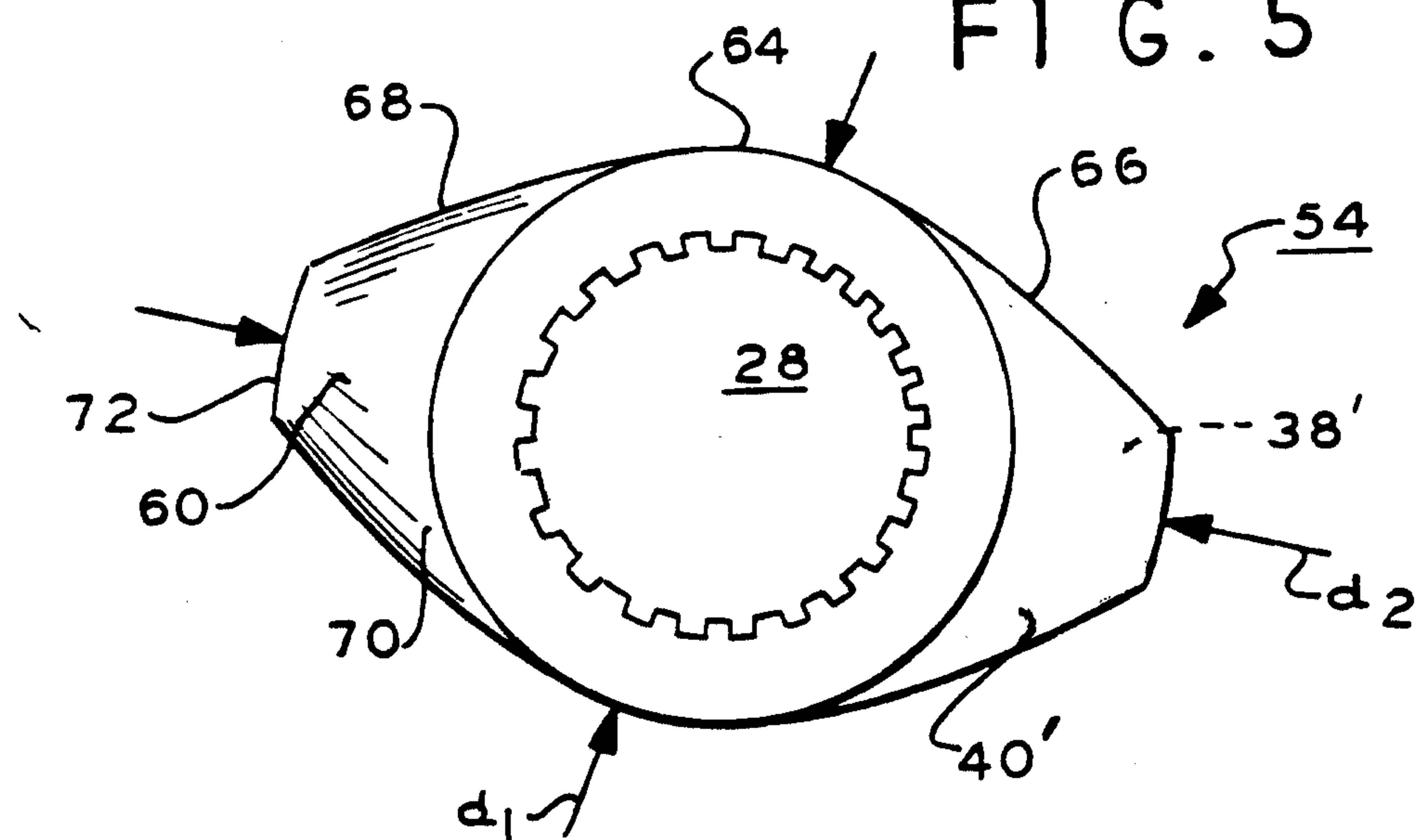
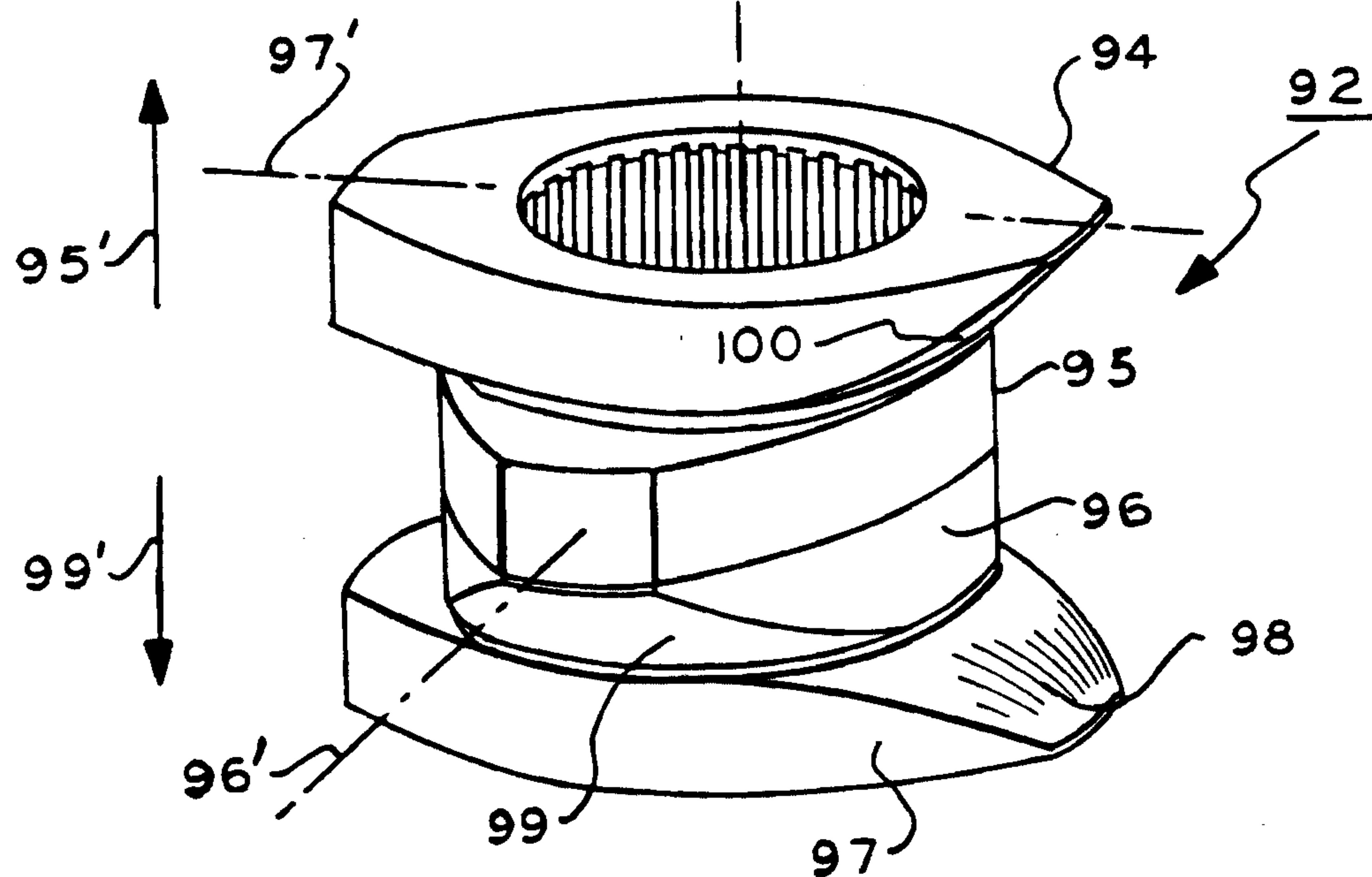


FIG. 6



+

3 / 4

FIG. 7

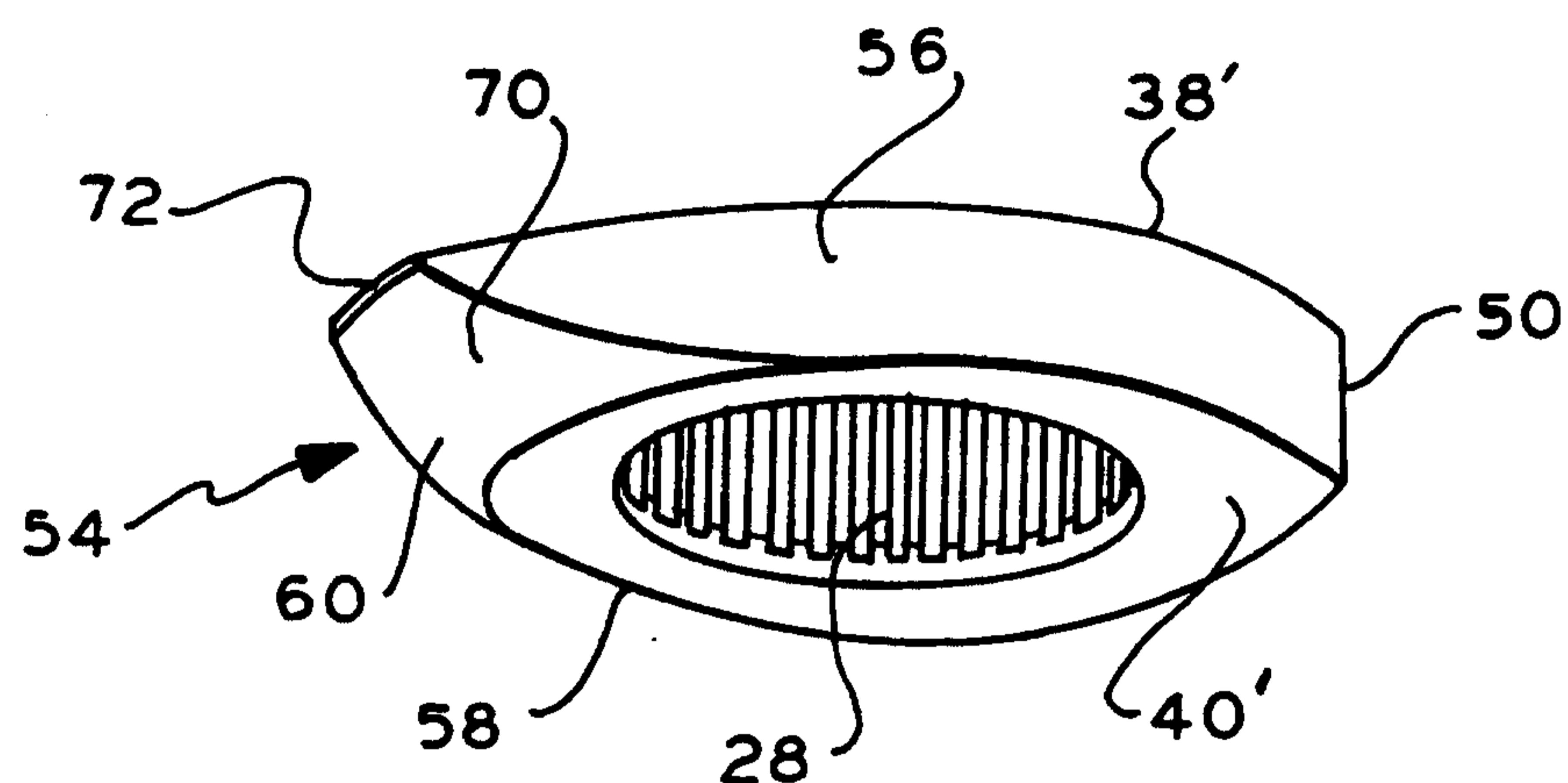


FIG. 8

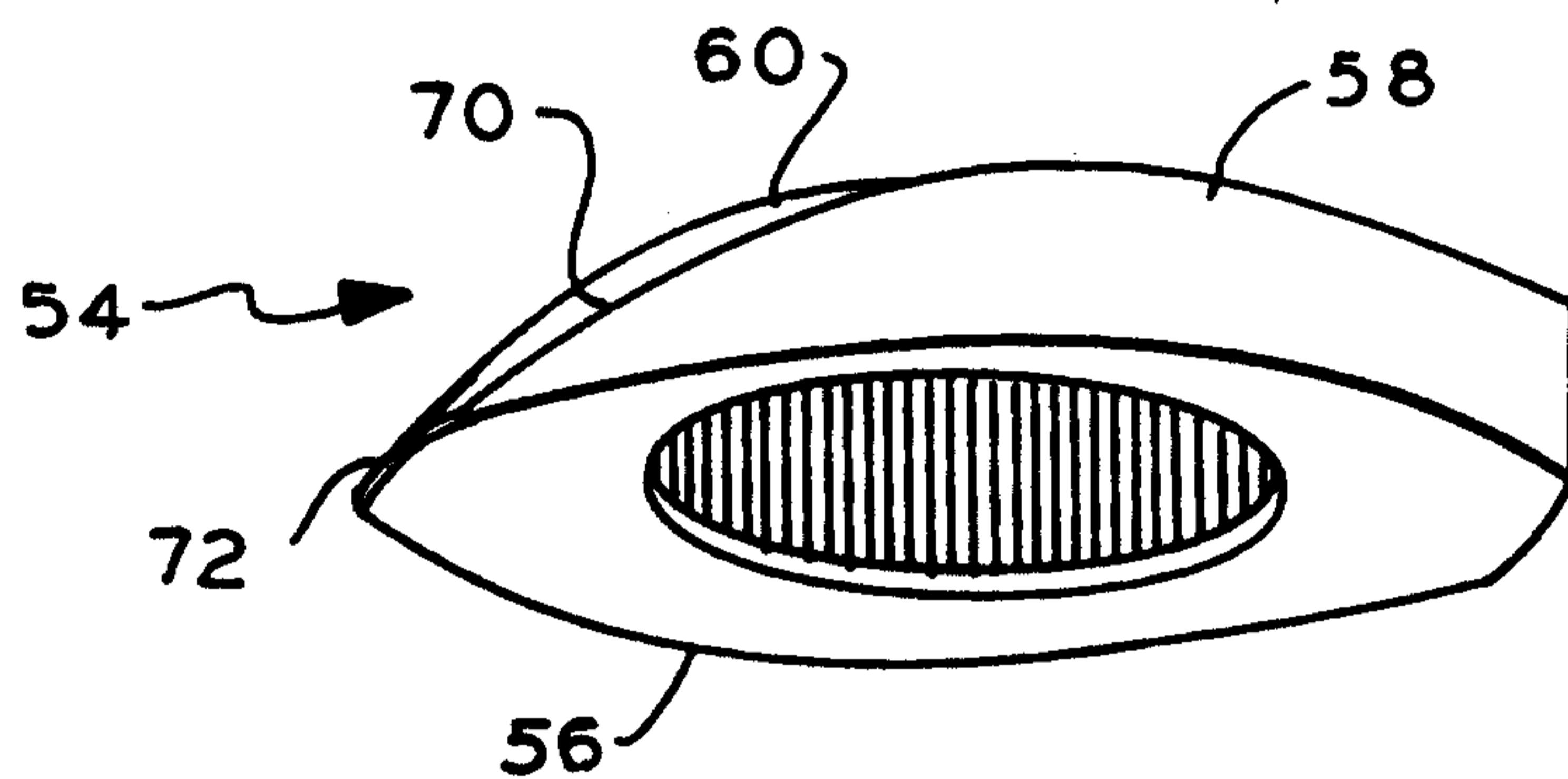
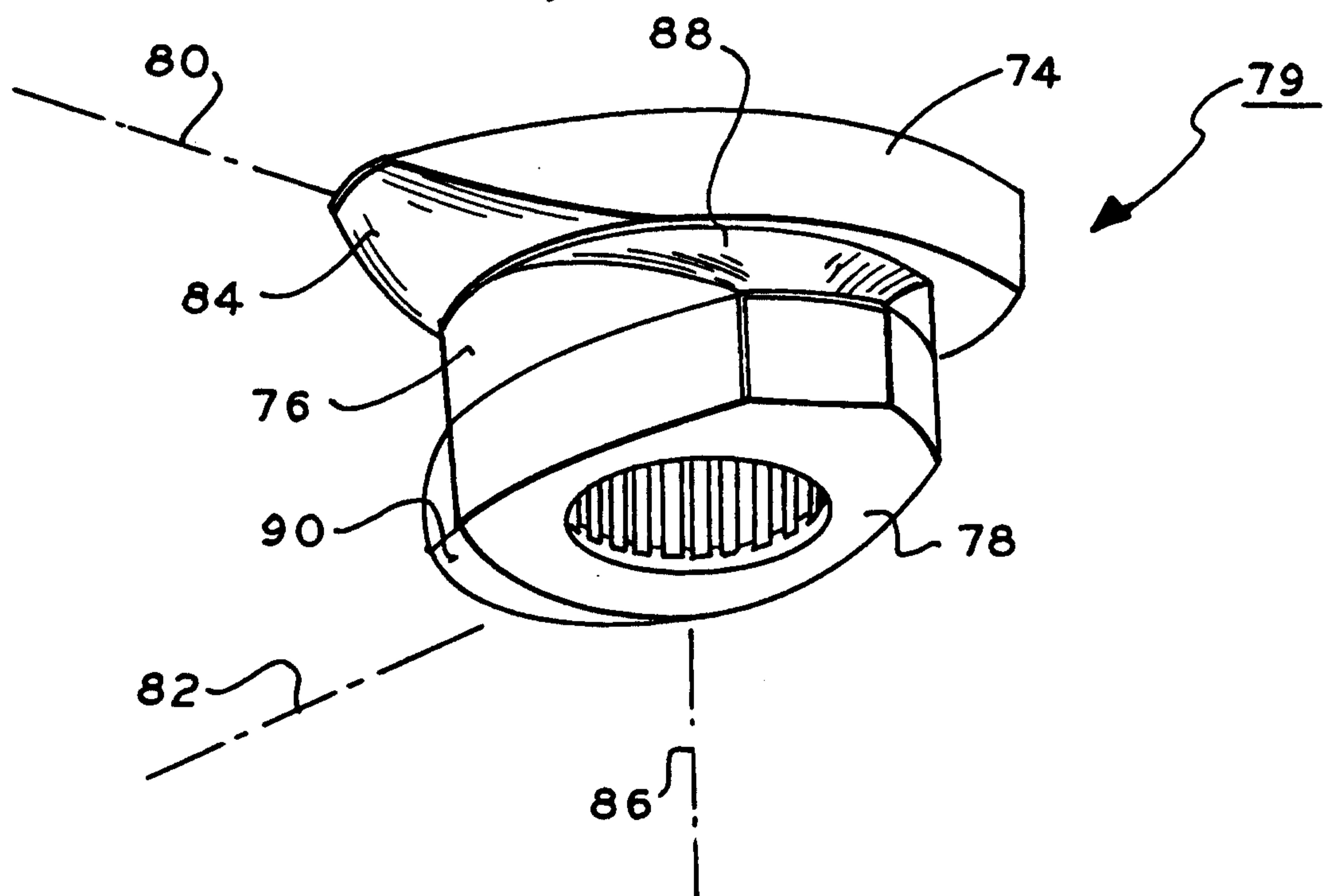


FIG. 9



4 / 4

FIG. 10

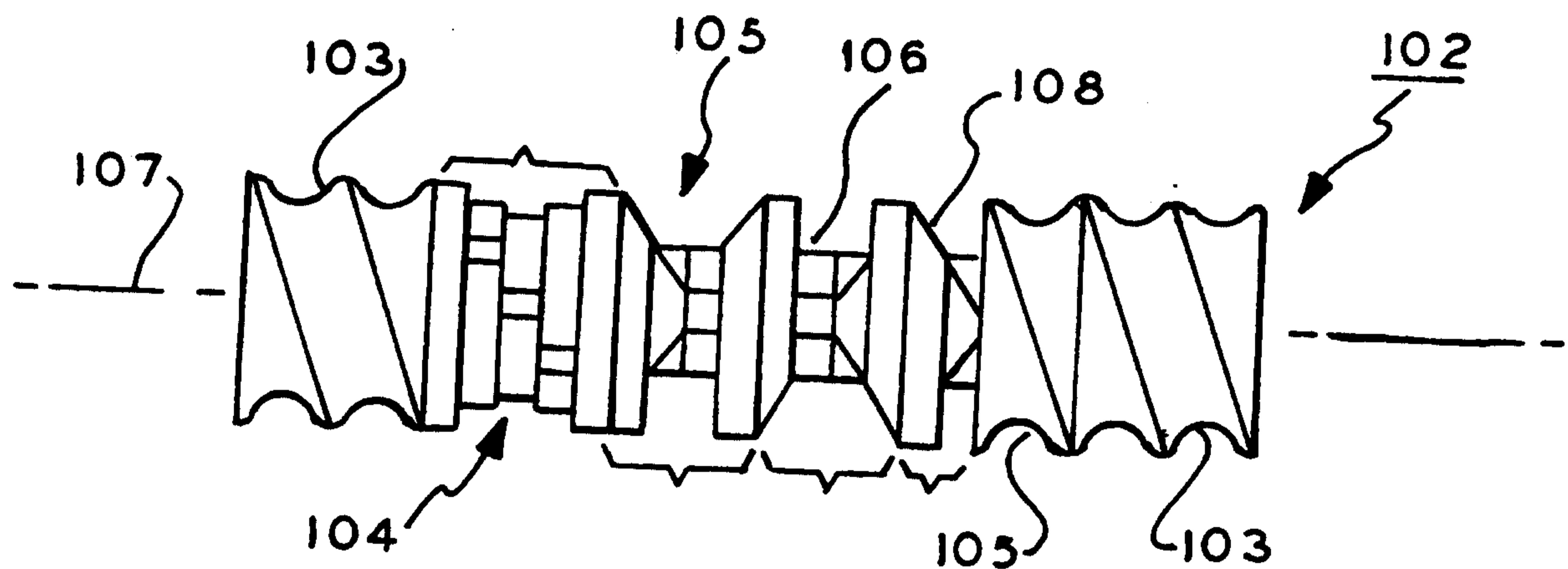


FIG. 11

