Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2426029 C 2009/11/24

(11)(21) 2 426 029

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2001/10/17
(87) Date publication PCT/PCT Publication Date: 2002/04/25
(45) Date de délivrance/Issue Date: 2009/11/24
(85) Entrée phase nationale/National Entry: 2003/04/15
(86) N° demande PCT/PCT Application No.: IB 2001/001946
(87) N° publication PCT/PCT Publication No.: 2002/032596
(30) Priorité/Priority: 2000/10/19 (US60/241,337)

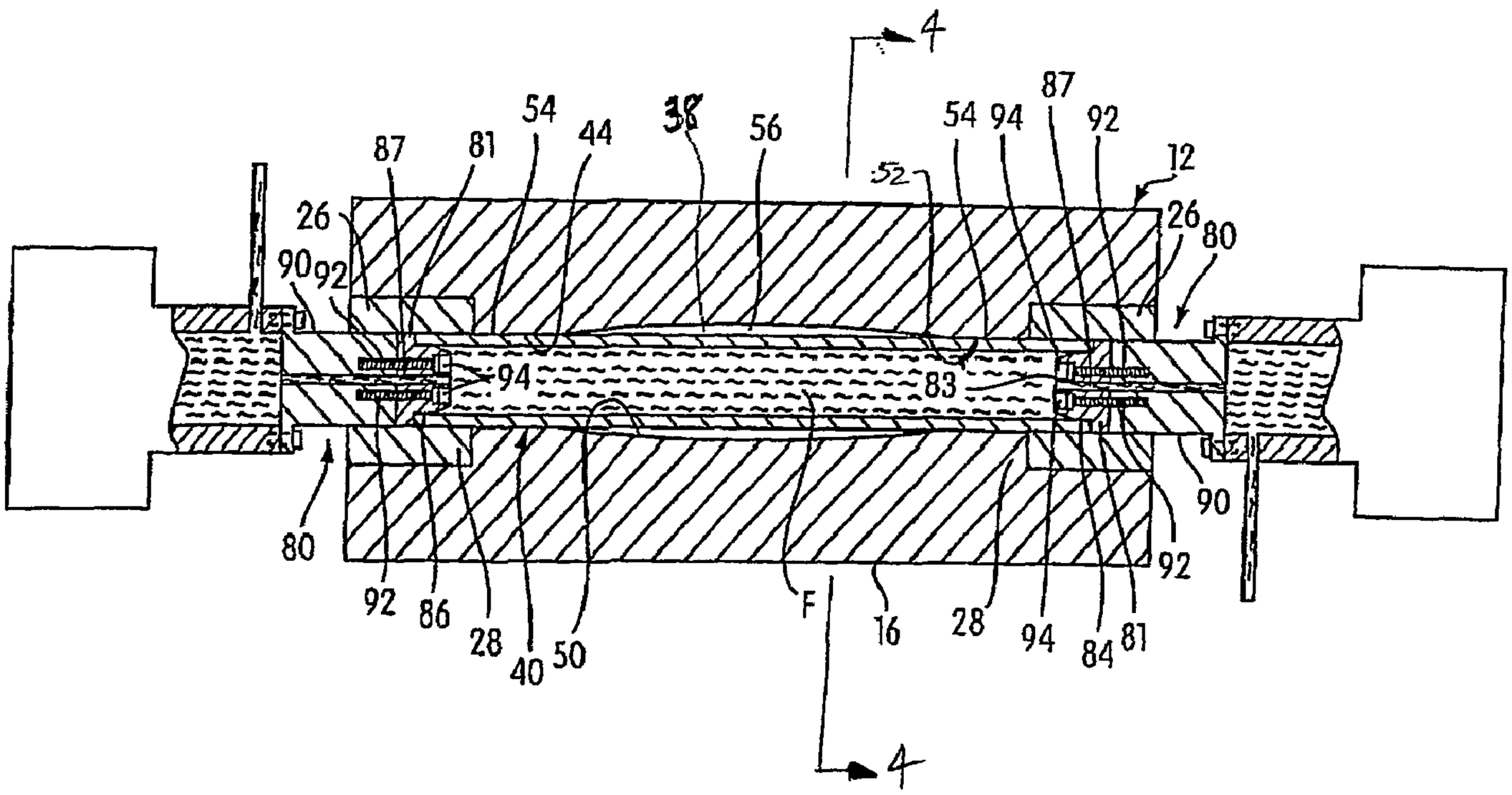
(51) Cl.Int./Int.Cl. *B21D 26/02* (2006.01)

(72) Inventeurs/Inventors:
COBB, MARK, CA;
GENSEBERGER, ERICH, CA

(73) Propriétaire/Owner:
COSMA INTERNATIONAL INC., CA

(74) Agent: BRANDT, KERSTIN B.

(54) Titre : APPAREIL ET PROCEDE D'HYDROFORMAGE DE PIECE TUBULAIRE
(54) Title: APPARATUS AND METHOD FOR HYDROFORMING A TUBULAR PART



(57) Abrégé/Abstract:
A method and apparatus for shaping a raw tube (40) into a formed part. The part can be configured within a die assembly including a hydroforming die structure (12, 14) and a pair of tube-engaging punches (81). The punches are inserted into the ends of the raw tube to shape the ends into the desired configuration. The middle portion of the raw tube is shaped into the desired configuration by hydroforming. Thus, the method and apparatus can shape the raw tube along its entire length, leaving no remnants of the raw tube that must be trimmed away.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 April 2002 (25.04.2002)

PCT

(10) International Publication Number
WO 02/032596 A1

(51) International Patent Classification[7]: B21D 26/02

(21) International Application Number: PCT/IB01/01946

(22) International Filing Date: 17 October 2001 (17.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/241,337 19 October 2000 (19.10.2000) US

(71) Applicant *(for all designated States except US)*: **COSMA INTERNATIONAL INC.** [CA/CA]; 50 Casmir Court, Concord, Ontario L4K 4J5 (CA).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **COBB, Mark** [CA/CA]; 14583 Kennedy Road, R.R #1, Inglewood, Ontario L0N 1K0 (CA). **GENSEBERGER, Erich** [AT/CA]; 21 Keily Crescent, Bolton, Ontario L7E 5S1 (CA).

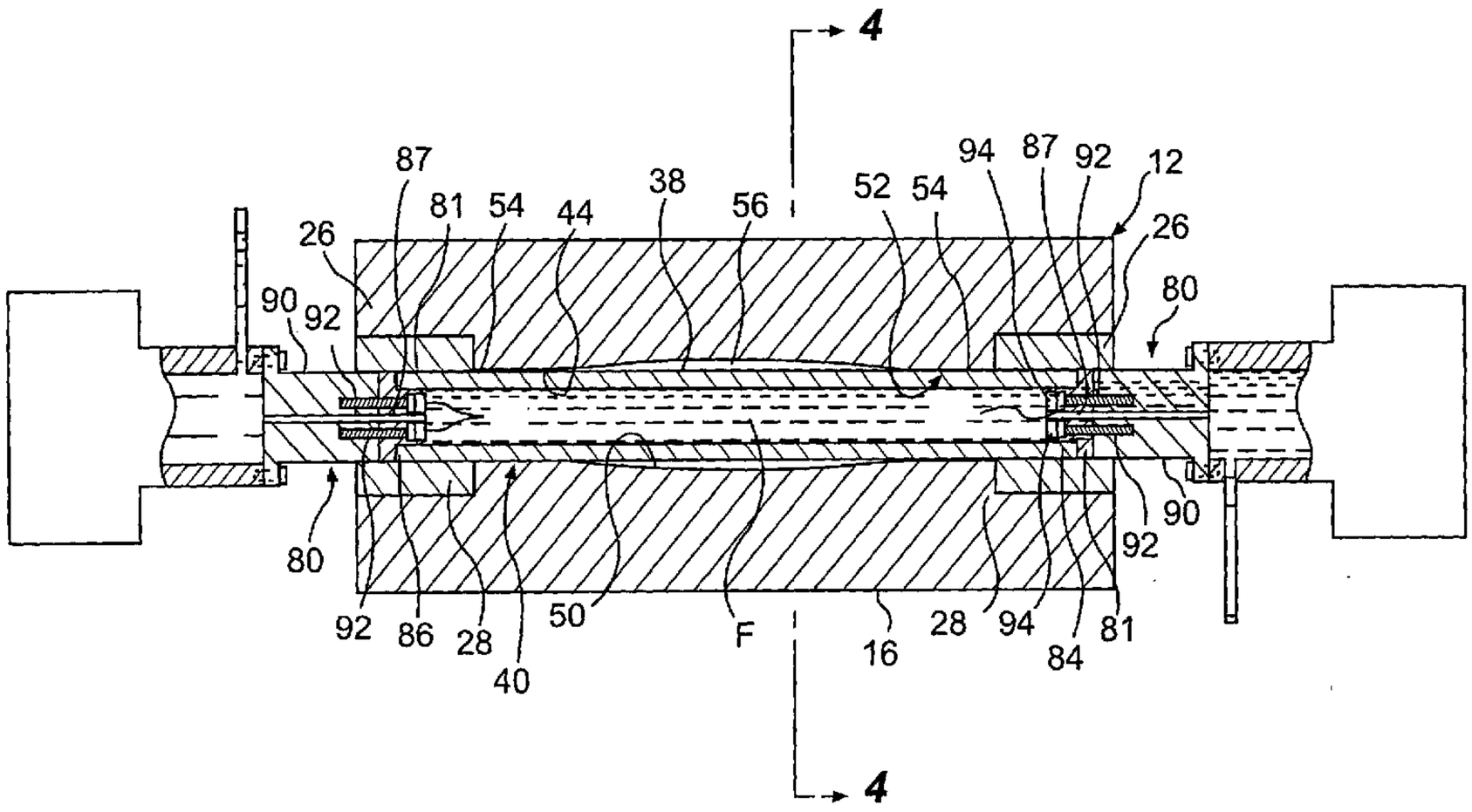
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, 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, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR HYDROFORMING A TUBULAR PART



(57) Abstract: A method and apparatus for shaping a raw tube (40) into a formed part. The part can be configured within a die assembly including a hydroforming die structure (12, 14) and a pair of tube-engaging punches (81). The punches are inserted into the ends of the raw tube to shape the ends into the desired configuration. The middle portion of the raw tube is shaped into the desired configuration by hydroforming. Thus, the method and apparatus can shape the raw tube along its entire length, leaving no remnants of the raw tube that must be trimmed away.

WO 02/032596 A1

APPARATUS AND METHOD FOR HYDROFORMING A TUBULAR PART

FIELD OF THE INVENTION

The invention relates generally to an improved apparatus and method for more efficiently hydroforming a tubular part. More specifically, the invention relates to an apparatus and method that uses a punch to shape each end of the part into the desired configuration and hold the part during hydroforming.

BACKGROUND OF THE INVENTION

Typically, to form a tubular part by hydroforming, a raw tube is positioned within a hydroforming tool and the tube is secured at its ends. The middle portion of the raw tube is then subjected to hydroforming, leaving a transitional zone between the ends of the raw tube and the hydroformed middle portion. The hydroformed part is then finished by having the two transition zones removed from the tube, leaving only the fully hydroformed middle portion. The ends of the tube can be secured by tip portions being generally wedge-shaped as disclosed in EP 1022073A1. Hydroforming is also disclosed in the U.S. Pat. Nos. 5,987,950 to Horton and 6,014,950 to Jaekel et al.

Removing the ends of the hydroformed part creates inefficiencies. For example, the cut away ends become wasted raw material. Also, cutting away ends requires additional cutting tools, which complicates the apparatus needed to create the finished part. Further, time is wasted performing the added step of cutting off the transitional zones at each end.

SUMMARY OF THE INVENTION

One object of the present invention is to provide an improved apparatus and method for forming a hollow part.

Another object of the present invention is to provide an improved apparatus and method for efficiently and cost effectively shaping a hollow part by mechanically shaping at least one end of the part and by hydroforming a portion of the part.

Still another object of the invention is to provide an apparatus and method for forming a part that uses a punch to secure each end of the part while the punch shapes the end so that each end has the same configuration as a hydroformed, middle portion.

The forgoing objects are basically attained by providing a hydroforming die assembly for hydroforming a part from a tubular blank, the part having a desired configuration different from a configuration of the blank and including a desired cross section at one end thereof, the die assembly comprising: a die structure having interior surfaces defining a die cavity, the die cavity having a cross sectional configuration conforming to the desired cross section of the part; and a pair of tube-end engaging structures disposed at opposite ends of the die cavity and constructed and arranged to engage opposite ends of the tubular blank, the tube-end engaging structures being constructed and arranged to seal the opposite ends of the tubular blank and to pressurize hydroforming fluid within the tubular blank for expanding the tubular blank into conformity with the interior surfaces of the die cavity, a first of the tube-end engaging structures having an outer cross-sectional configuration corresponding to the desired cross section at one end of the part, the first of the tube-engaging structures being movable into forced engagement with one end of the tubular blank to conform the one end of the tubular blank to the outer cross-sectional configuration of the first of the tube-engaging structures and hence the predetermined cross section at the one end of the part.

The forgoing objects are also attained by providing a method of forming a

hydroformed part comprising the steps of: providing a hydroforming die assembly for hydroforming a part from a tubular blank, the part having a desired configuration different from a configuration of the blank and including a desired cross section at one end of the part, the die assembly including a die structure having interior surfaces defining a die cavity, the die cavity having a cross sectional configuration conforming to the desired cross section of the part, and a pair of tube-end engaging structures disposed at opposite ends of the die cavity and constructed and arranged to engage opposite ends of the tubular blank, the tube-end engaging structures being constructed and arranged to seal the opposite ends of the tubular blank and to pressurize hydroforming fluid within the tubular blank for expanding the tubular blank into conformity with the interior surfaces of the die cavity, a first of the tube-end engaging structures having an outer cross-sectional configuration corresponding to the desired cross section at one end of the part; moving the first of the tube-engaging structures into forced engagement with one end of the tubular blank to conform the one end of the tubular blank to the outer cross-sectional configuration of the first of the tube-engaging structures and hence the predetermined cross section at the one end of the part; and applying pressure within the tubular blank to form the tubular blank in to the desired configuration of the part.

Other objects, advantages, and features of the invention will become apparent from the following detailed description, appended drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded perspective view showing upper and lower die structures and box-shaped punches of a hydroforming die assembly in accordance with the principles of the present invention;

FIG. 2 is a longitudinal section view of the hydroforming die assembly along section line 1-1 in FIG. 1, and including a tubular blank positioned within the lower die structure, the

upper die structure shown in the raised or fully open position, and box-shaped punches engaging the ends of the tubular blank;

FIG. 3 is a longitudinal sectional view of the hydroforming die assembly, similar to FIG. 2, but showing the upper die structure in a fully lowered position, with the tubular blank positioned within the lower die structure, the box-shaped punches inserted into the ends of the tubular blank, and fluid injected into the tubular blank;

FIG. 4 is a cross-section taken through section line 4-4 in FIG. 3 and showing an unexpanded oval tubular blank disposed within the hydroforming assembly and filled with hydroforming fluid;

FIG. 5 is a cross-section taken through line 5-5 in FIG. 9 showing the tubular blank expanded by fluid under pressure within the expansion region of the cooperating upper and lower hydroforming dies;

FIG. 6 is a partial perspective view, partially in cross-section, of a box-shaped punch engaging a tubular blank;

FIG. 7 is a longitudinal sectional view taken through line 7-7 in FIG. 6 showing a box-shaped punch;

FIG. 8 is a cross-sectional view along section line 8-8 in FIG. 9 showing the end of the tubular blank between upper and lower clamping structures with a box-shaped punch inserted therein;

FIG. 9 is a longitudinal section view showing a hydroforming step wherein the upper die structure is in the fully lowered position and a tubular blank has been hydroformed into an expanded configuration by fluid under pressure;

FIG. 10 is a longitudinal section view showing the use of hydroforming ram extenders attached to punches to permit a relatively short blank to be hydroformed in a relatively long hydroforming die assembly; and

FIG. 11 is a longitudinal section view of a hydroforming die assembly with a box-shaped punch and a round punch engaging opposite ends of a tubular blank.

DETAILED DESCRIPTION OF THE DRAWINGS

Shown generally in FIG. 1 is an exploded perspective view of a hydroforming die assembly generally indicated at 10 in accordance with the present invention. The hydroforming die assembly 10 includes a movable upper die structure 12, a movable lower die structure 14, a fixed die structure 16, and a fixed base 18 on which the fixed die structure 16 is mounted. A plurality of pneumatic or nitrogen spring cylinders 20 mount the lower die structure 14 for movement on the fixed base 18. The upper die structure 12, lower die structure 14, and fixed die structure 16 cooperate to define a longitudinal die cavity therebetween, having a substantially boxed-shaped or multifaceted cross section as will be described herein. Preferably, the upper die structure 12, lower die structure 14, fixed die structure 16, and fixed base 18 are each made of an appropriate steel material such as P-20 steel and/or 2714 steel.

As shown in FIG. 1, the upper die structure 12 defines a pair of cradle areas 22 at opposite longitudinal ends thereof. The cradle areas 22 are shaped and arranged to receive and accommodate upper clamping structures 26, at opposite longitudinal ends of the upper die structure 12. Particularly, the clamping structures 26 are each connected to the upper die structure 12 at the respective cradle areas 22, by a plurality of pneumatic or nitrogen spring cylinders 24 which permit relative vertical movement between the clamping structures 26 and the upper die structure 12.

The lower die structure 14 has similar cradle areas 30 at opposite longitudinal ends thereof which are constructed and arranged to accommodate lower clamping structures 28 in a similar fashion. As shown, the longitudinal ends, indicated at 15, forming cradle area 30 of the lower die structure 14 have a generally U-shaped configuration.

The lower clamping structures 28 each have an upwardly facing surface 34 having a cross-sectional configuration that defines one-half of a multifaceted surface configuration. In the context of the present invention, the term multifaceted means square, rectangular, parallelepiped, polygonal, or any other closed, non-circular or oval configuration. In the illustrated embodiment, surface 34 defines one half of a rectangle.

In the embodiment shown, the upper two clamping structures 26 are substantially identical to the lower clamping structures 28 but are inverted with respect thereto. More particularly, each upper clamping structure 26, has a downwardly facing surface 36 having a cross-sectional configuration that defines a second half of the multifaceted (i.e., rectangular) surface configuration. The surface 36, of each clamping structure 26, cooperates with surface 34, of the respective lower clamping structures 28, to form a multifaceted clamping surface that captures end portions of a tubular blank 40 when the upper die structure 12 is lowered.

As can be appreciated from, for example, FIGS. 2, 3, and 4, the upper die structure 12 defines a longitudinal channel 38 having a substantially inverted U-shaped cross section. The channel 38 is defined by a downwardly facing, generally horizontal longitudinally extending surface 44, and a pair of spaced, longitudinally extending vertical side surfaces 43, which extend parallel to one another from opposite sides of surface 44.

The lower die structure 14 has a central opening 42 extending vertically therethrough, between the U-shaped longitudinal ends 15. The opening 42 receives fixed die structure 16. Interior vertical surfaces 41 in the lower die structure 14 define the aforementioned central opening 42. More particularly, a pair of longitudinally extending side surfaces 41, define the lateral extremities of the opening 42. The surfaces are vertically disposed in parallel facing relationship with one another. The U-shaped end portions 15 of the lower die structure 14 define the longitudinal extremities of the opening 42, and have interior surfaces (not shown) vertically disposed in parallel facing relation to one another.

The fixed base 18 is in the form of a substantially rectangular metal slab. The fixed die structure 16 is affixed to an upper surface 46 of the fixed base 18. The fixed die structure 16 is an elongate structure which extends along a major portion of the length of the upper surface 46 of the fixed base 18, generally along the center of the fixed base 18. The fixed die structure 16 projects upwardly from the fixed base 18 and has substantially vertical side surfaces 48 on opposite longitudinal sides thereof. The fixed die structure 16 is constructed and arranged to extend within the opening 42 in the lower die structure 14, with minimal clearance between the generally vertical side surfaces 48 of the fixed die structure and vertical surfaces 41 of the lower die structure 16. Similarly, there is minimal clearance between the interior transverse side surfaces (not shown) of end portions 15 of the lower die structure 14 and the vertical end surfaces 49 of the fixed die structure 16. The fixed die structure 16, further includes an upwardly facing, generally horizontal and longitudinally extending die surface 50, which is constructed and arranged to extend in spaced facing relation to the longitudinally extending, downwardly facing die surface 44 of the upper die structure 12.

As can best be seen in FIGs. 4 and 5, the aforementioned side surfaces 41, the upwardly facing surface 50, the side surfaces 43 and downwardly facing surface 44 cooperate to define a die cavity 52, having a multifaceted cross sectional configuration substantially throughout its longitudinal extent. The die cavity surfaces define the desired shape of a part to be hydroformed from a circular or oval blank tube.

FIG. 2 shows the upper die structure 12 in an opened or raised position. In this position the hydroforming die assembly 10 enables the tubular blank 40 to be placed within the lower die structure 14.

After the blank 40 is placed in the lower die structure 14, the upper die structure 12 is lowered to form the die cavity 52. The die cavity may be ultimately smaller than what is illustrated in FIG. 4 to effect a slight crushing of the tubular blank 40 before the blank 40 is

expanded in the hydroforming operation, as disclosed in U.S. Pat. No. 5,987,950 to Horton. With the tubular blank 40 positioned between the closed upper die structure 12 and lower die structure 14, hydroforming rams 80 having punches 81 attached to mounting structures 90 are advanced from opposite sides of the hydroforming die assembly 10 to engage opposite ends of the tubular blank 40. As shown most clearly in FIGS. 6 and 7, each punch 81 includes an initial beveled portion 82 which transitions into a multifaceted, here rectangular, portion 84. A base 86 forming a lateral shoulder 88 is formed at one end of the multifaceted portion 84 opposite the initial beveled portion 82.

The punch 81 is secured to the end of the mounting structure 90 by means of mechanical fasteners 92, such as bolts, extending through counter-bored apertures 94 formed in the punch 81 and into the holder 92. Base 86 preferably has a size and shape that is complementary to the size and shape of the mounting structure 90 so as to form a smooth, uniform transition between the punch 81 and the mounting structure 90.

In the embodiment shown, the beveled portion 82 is preferably formed at an angle θ (see FIG. 7) of between about 13-17°, and most preferably, about 15° with respect to the sides of the box-shaped portion 84. The multifaceted portion 84 preferably has straight sides so as to have a perimeter that defines a multifaceted shape, such as a polygon, square rectangle, skewed parallelogram, etc. The perimeter shape of the box-shaped portion 84 corresponds substantially to the shape of the clamping surface formed by the upwardly facing surface 34 of the lower clamping structure 28 and the downwardly facing surface 36 of the upper clamping structure 26. Also, the size of the multifaceted portion 84 is defined so as to provide a sealing interference fit with the wall of the tubular blank 40, with the clamping surfaces providing external support for blank 40.

The forward end 83 of the punch 81 at the free end of the beveled portion 82 has dimensions that are smaller than the multifaceted portion 84, thus permitting the forward end 83 to be inserted into the unexpanded end of the tubular blank 40 as

shown in FIG. 2. With the forward end 83 of the punch 81 engaged with the end of the blank 40, the hydroforming ram can be further advanced under the force of hydraulic pressure, thus forcing the punch 81 into the end of the tubular blank 40 after the upper die structure 12 is lowered, as shown in FIG. 3. The beveled portion 82 of the punch 81 gradually forms the end of the blank 40 until the multifaceted portion 84 is fully inserted into the end of the blank 40. During this process, the end portions of blank 40 may be stretched outwardly as they are conformed to the multifaceted portion 84 and hence, the adjacent clamping surfaces 34, 36, as best shown in FIGS. 3 and 8. The width of the lateral shoulder 88 is preferably substantially the same as the thickness of the tubular blank 40 so that the outer surface of the tubular blank 40 transitions smoothly with the outer surfaces of the base 86 and the holder 90.

Thus, when the tube is formed over the punch to fit the finished tube shape it will not be necessary to remove the scrap portion of the blank, this eliminates the need for cut-off tooling, which saves money and time.

While the above description refers to only one punch, it should be appreciated that this discussion may apply to both punches 81 at opposite ends of the tube 40.

The tubular blank 40 may be round (circular cross section). Punches 81 have a similar height and width dimensions as the blank. The blank may be oval for punches that are rectangular or otherwise elongated along a height or width dimension. Hydroforming processes using oval tubular blanks are disclosed in U.S. Pat. No. 5,987,950, as stated above. Providing a tubular blank having an oval cross-section is advantageous in comparison with the conventional circular cross-section because it provides a circumference that conforms more closely to the final cross sectional perimeter of the generally box-shaped (not square) cross-sectional shaped die cavity 52. Thus, less expansion of the blank 40 is required when expanding the blank into conformity with the

surfaces forming cavity 52. In addition, the closer conformity of blank 40 and cavity surfaces allows the blank to be more easily expanded into the corners of the cavity 52, where expansion becomes most difficult due to the increasing frictional surface contact between the exterior surface of the blank and cavity surfaces during expansion of the blank 40.

As can be seen in FIG. 3, when the blank 40 is substantially rigidly held in place between die structures 12 and 14 and the hydroforming cylinders or rams 80 are telescopically and sealingly inserted into both opposite ends of the blank 40, so that beveled surfaces 82 engage the opposite edges of blank 40. The rams 80 are forced inwardly to cause the opposing edges of blank 40 to ride down surface 82 until it engages surface 88 and thus converts the end portions of the blank into the exterior shape of portion 84 of punch 81. The hydroforming cylinders then preferably pre-fill, but do not pressurize to any large extent, the tubular blank 40 with hydroforming fluid (preferably water) as indicated by reference character F. The hydraulic fluid is injected through a channel 87 formed in one or both punches 81 which communicates with a channel 97 formed in the corresponding mounting structure 90. Although the pre-filling operation is preferred to reduce cycle times, and to achieve a more smoothly contoured part, for some applications the upper die structure 12, may be fully lowered before any fluid is provided internally to tubular blank 40.

End portions of the sealed die cavity 52 are generally rectangular in shape as defined by surface portions 54 having generally the same size and shape as the clamping surfaces 34, 36 of the clamping structures 28, 26, respectively. Thus, the portions 54 define areas of the die cavity which have a cross-sectional area that is the same as or only slightly larger than the area defined by the cross-sectional shape of the end portions of the tubular member 40 after the punches 81 have been forced into the ends of the tubular member as illustrated in FIG. 6. Otherwise stated, the portions 54 of the die cavity 52 define areas of the die cavity which are used to expand the tubular blank 40 during the hydroforming process only to the extent

required to convert the shape of the blank from a round or oval cross section to a multifaceted (here rectangular) cross sectional configuration. Because the end portions of the blank 40 fitted with punches 81 (as illustrated in FIG. 6) will form the shape desired for the final part to be hydroformed, and will not constitute an unexpanded portion that must be cut off after the hydroforming process so that the remaining uncut portions of the tube correspond to the desired part, substantial scrap material is saved. Each unexpanded surface portion 54 of the die structure defines a shape consistent with the shape of the portions 84 and 86 of the punch 81.

The cavity 52 may also include an enlarged portion 56 towards the longitudinally central portions thereof. With the upper die structure 12 closed with respect to the lower die structure 14 and with the punches 81 sealingly inserted into the ends of the blank 40, the fluid F can be pressurized to expand the tubular blank 40 into conformity with the surfaces defining die cavity 52 (see FIGS. 5 and 9). The tubular blank 40 is expanded into the non-round, multifaceted (e.g., rectangular) of the die cavity 52. If the hydroforming assembly includes a die cavity with an enlarged portion 56, the blank 40 will be enlarged in that area. Because the portions 54 of die cavity 52 define shapes that are consistent with the shape of the multifaceted portion 84 of the punches 81, the hydroformed member has a consistent shape out to its ends, and it is not necessary to cut the end portions off. If a portion of the blank is to be significantly enlarged in its cross-sectional perimeter (e.g., greater than 5% relative to the original blank perimeter), it may be preferred that the longitudinal ends of the blank be pushed inwardly toward one another to replenish wall thickness as the blank is expanded. If the blank is not to be enlarged, but is only expanded into conformity with a multifaceted die cavity, longitudinal movement of the ends during expansion of the blank may not be necessary. More particulars on the preferred hydroforming process are disclosed in U.S. Pat. No. 6,014,879 to Jaekel et al.

In accordance with another embodiment, if a significant amount of perimeter expansion is required at one end of the tube part so that substantial wall thickness replenishment is required thereat, it is generally preferred to employ a circular or oval punch, as opposed to a multifaceted punch. This is because material flows more effectively and evenly toward the enlargement area from a rounded end than from a box-shaped end. Such a hydroforming configuration is shown in FIG. 11, in which the surrounding die structures are not shown for clarity of the illustration. The arrangement shown includes one hydroforming ram 80 having a beveled, rectangular-shaped punch 81 and a rectangular-shaped mounting structure 90, as shown and described previously. The arrangement also includes a second hydroforming ram 100 that includes a cylindrical base portion 112 and a smaller cylindrical portion 102 with an insertion bevel 116 formed at the end. A circular, annular sealing shoulder 114 that engages the end of the tubular blank 40′ is defined between base portion 112 and cylindrical portion 102.

At the end of the blank 40′ engaged by the multifaceted punch 81, the die structure (not shown) presents a surface configuration that forms the blank 40′ such that the cross sectional configuration at portion 110 of the blank is expanded only to the extent that the rounded cross section of the blank is converted to a multifaceted cross section. The portion 110 is joined by a gradually tapered segment 108 which extends to an enlarged rectangular-shaped cross sectional portion 106. Conversely, at the end of the blank 40′ engaged by the cylindrical punch 100, the die structure presents a surface configuration that forms a relatively short, non-enlarged cylindrical portion 105 of the blank. The blank then transitions from the rounded perimeter shape at 105 to the rectangular cross section at area 106. The cylindrical punch 100 allows for the relatively large expansion of enlarged area 106 and the abrupt transition region 104 because longitudinal pushing at the end of the tubular member 40′ is

more effective for replenishing wall thickness if the punch is round. The cylindrical end portion of the formed member shaped by the cylindrical punch 100 would typically be cut off during a subsequent finishing operation.

The box-shaped end formed by the rectangular-shaped punch 81, on the other hand, can be tailored to the desired final member shape so the end need not be cut off.

As shown in FIG. 10, one or more ram extenders 120 can be installed between the punch 81 and the holder 90. The extenders 120 have a rectangular-shaped cross sectional configuration that conforms with the rectangular-shaped cross sections of the mounting structure 90 and the base 86 of the punch 81. Accordingly, the hydroforming rams 80' can extend further into the relatively unenlarged portions 54 of the die cavity 52 to accommodate hydroforming of shorter tubular blanks 40' within the same die cavity 52. Of course, the extended hydroforming blanks 80' cannot extend to an enlarged area 56 of the hydroforming cavity 52 or the seal between the end of the tubular blank 40' and the shoulder 88 of the punch 81 will be lost as the tubular blank expands into the enlarged area 56.

Thus, the present invention includes a hydroforming die assembly for hydroforming a part from a tubular blank comprising a die structure having interior surfaces defining a die cavity, the die cavity having a cross sectional configuration conforming to the predetermined cross section of the part, the part having a predetermined configuration different from a configuration of the blank and including a predetermined cross section at one end thereof.

It should be appreciated that the foregoing detailed description and accompanying drawings of the preferred embodiments are merely illustrative in nature, and that the present invention includes all other embodiments that are within the spirit and scope of the described embodiments and appended claims.

Claims

What is claimed is:

1. A hydroforming die assembly (10) for hydroforming a part from a tubular blank (40), said part having a desired configuration different from a configuration of said blank and including a desired cross section at one end thereof, said die assembly (10) including a die structure having interior surfaces defining a die cavity (52), said die cavity (52) having a cross sectional configuration conforming generally to the desired exterior shape of said part, said die assembly (10) further comprising:

a pair of tube-end engaging structures (81) disposed at opposite ends of said die cavity (52) and constructed and arranged to engage opposite ends of said tubular blank (40), said tube-end engaging structures (81) being constructed and arranged to seal said opposite ends of said tubular blank (40) and to pressurize hydroforming fluid within said tubular blank (40) for expanding said tubular blank (40) into conformity with said interior surfaces of said die cavity (52), a first of said tube-end engaging structures (81) having an outer cross-sectional configuration corresponding to said desired cross section at said one end of said part, said first of said tube-end engaging structures 81 being movable into forced engagement with one end of said tubular blank 40 to conform said one end of said tubular blank 40 to said outer cross-sectional configuration of said first of said tube-engaging structures 81 and hence said predetermined cross section at said one end of said part.

2. A hydroforming die assembly (10) according to claim 1, wherein said first tube-end engaging structure (81) has an exterior surface including a beveled portion (82) which is partially inserted into said one end of said tubular blank (40), said first tube-end engaging structure (81) being moved further into said one end of said tubular blank (40) so as to cause inner surface portions of said one end of said tubular blank (40) to slide in forced relation along said beveled portion (82) and cause said one end of said tubular blank (40) to be deformed i) over said first tube-end engaging structure (81) and ii) into conformity with said exterior surface of said first tube-end engaging

structure (81), and wherein one end of said die cavity (52) receives said first tube-engaging structure (81), said interior surfaces of said die cavity (52) at said one end of said die cavity (52) having a configuration conforming to an exterior surface configuration of said part at said one end of said part.

3. A method of producing a hydroformed part using a hydroforming die assembly (10) for hydroforming a part from a tubular blank (40), the part having a desired configuration different from a configuration of the blank and including a desired cross section at one end of the part, the die assembly (10) including a die structure having interior surfaces defining a die cavity (52), the die cavity (52) having a cross sectional configuration conforming to the desired cross section of the part, the method comprising the steps of:

providing a pair of tube-end engaging structures (81) disposed at opposite ends of the die cavity (52) and constructed and arranged to engage opposite ends of the tubular blank 40, the tube-end engaging structures (81) being constructed and arranged to seal the opposite ends of the tubular blank (40) and to pressurize hydroforming fluid within the tubular blank (40) for expanding the tubular blank (40) into conformity with the interior surfaces of the die cavity (52), a first of the tube-end engaging structures 81 having an outer cross-sectional configuration corresponding to the desired cross section at one end of the part;

moving the first of the tube-engaging structures (81) into forced engagement with one end of the tubular blank (40) to conform the one end of said tubular blank (40) to the outer cross-sectional configuration of the first of the tube-engaging structures (81) and hence the predetermined cross section at the one end of the part; and

applying pressure within the tubular blank (40) to form the tubular blank (40) in to the desired configuration of the part.

4. A method according to claim 3, further comprising the step of:

incorporating the part into a product without cutting off the one end of the part formed by the forced engagement of the first of the tube-engaging structures (81).

5. An assembly according to claim 1, wherein

a first of said tube-engaging structures (81) has a forward end (33) and a lateral shoulder (88) protruding from a multifaceted portion (84) such that the first of said tube engaging structures (81) can be inserted into said tubular blank (40) continuously from the forward end (33) of said tube-engaging structure to said lateral shoulder (88) along said multifaceted portion (84) until said lateral shoulder (88) abuts said tube-engaging structure (81) and halts further insertion of said first of said tube-engaging structures (81) relative to said tubular blank (40).

6. A method according to claim 3, wherein

the moving of the first of the tube-engaging structures (81) includes inserting the first of the tube-engaging structures (81) into the tubular blank (40) continuously from a forward end (33) of the first of the tube-engaging structures (81), along a multifaceted portion (84) of the first of the tube-engaging structures (81), and to a lateral shoulder (88) of the first of the tube-engaging structures (81) that protrudes from the multifaceted portion (84), until the lateral shoulder (88) abuts the end of tubular blank (40) and halts further insertion of the tube-engaging structure (81) relative to the tubular blank (40).

7. A method according to claim 3, wherein

the moving of the first of the tube-engaging structures (81) into forced engagement with one end of the tubular blank (40) is a complete insertion of the first of the tube-engaging structures (81) into the tubular blank (40) and a complete reconfiguration of the one end of the tubular blank (40) into the final, desired configuration of the part by fully forcing the one end of the tubular blank (40) to conform to the outer surface of the first of the tube-engaging structures (81) and to the inner surface of the die cavity (52).

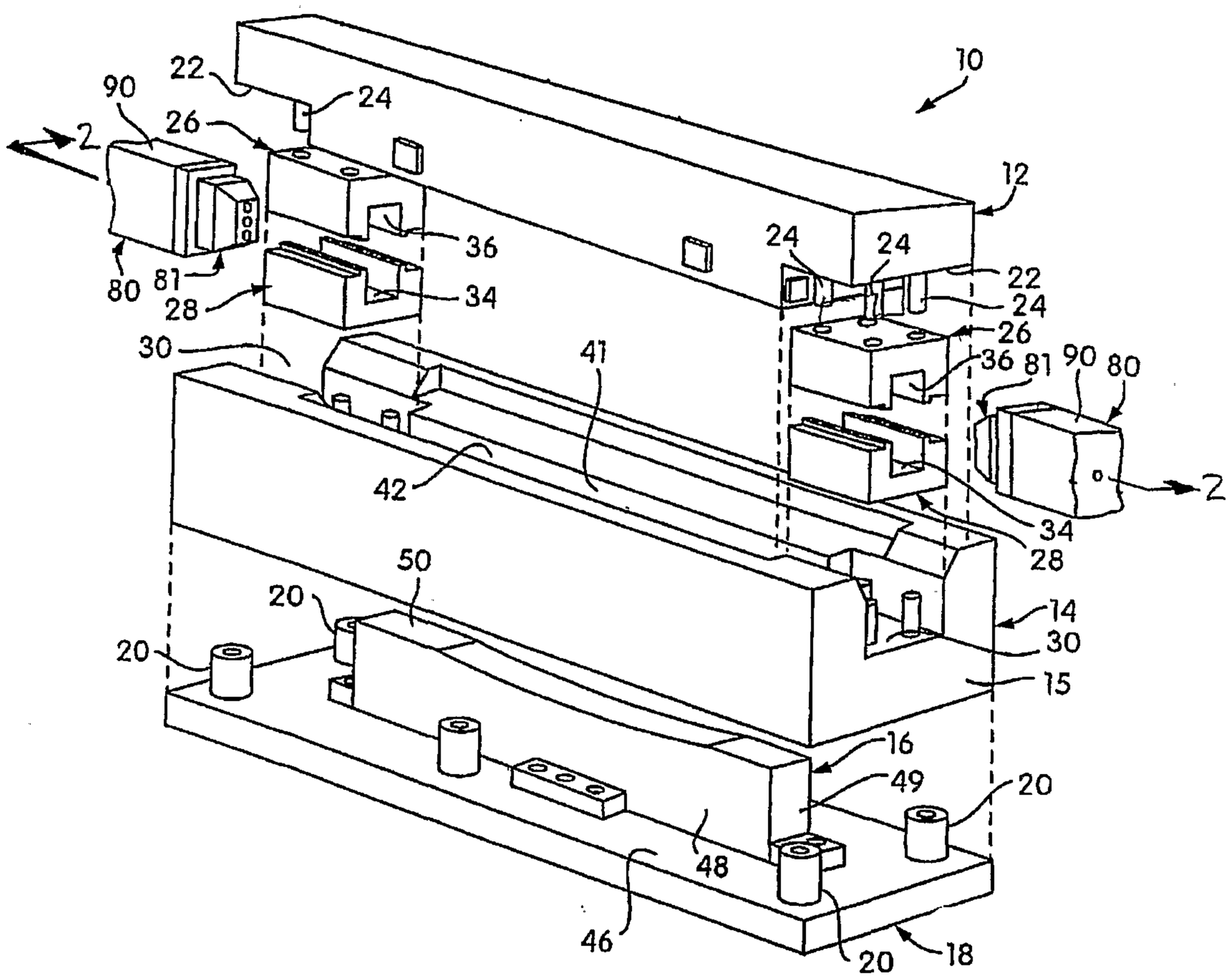

10
22
90
24
26
2
12
36
80
81
34
28
24
24
22
24
26
30
36
81
90
80
41
42
2
34
28
50
20
14
20
30
15
16
49
20
48
46
20
18

FIG. 1

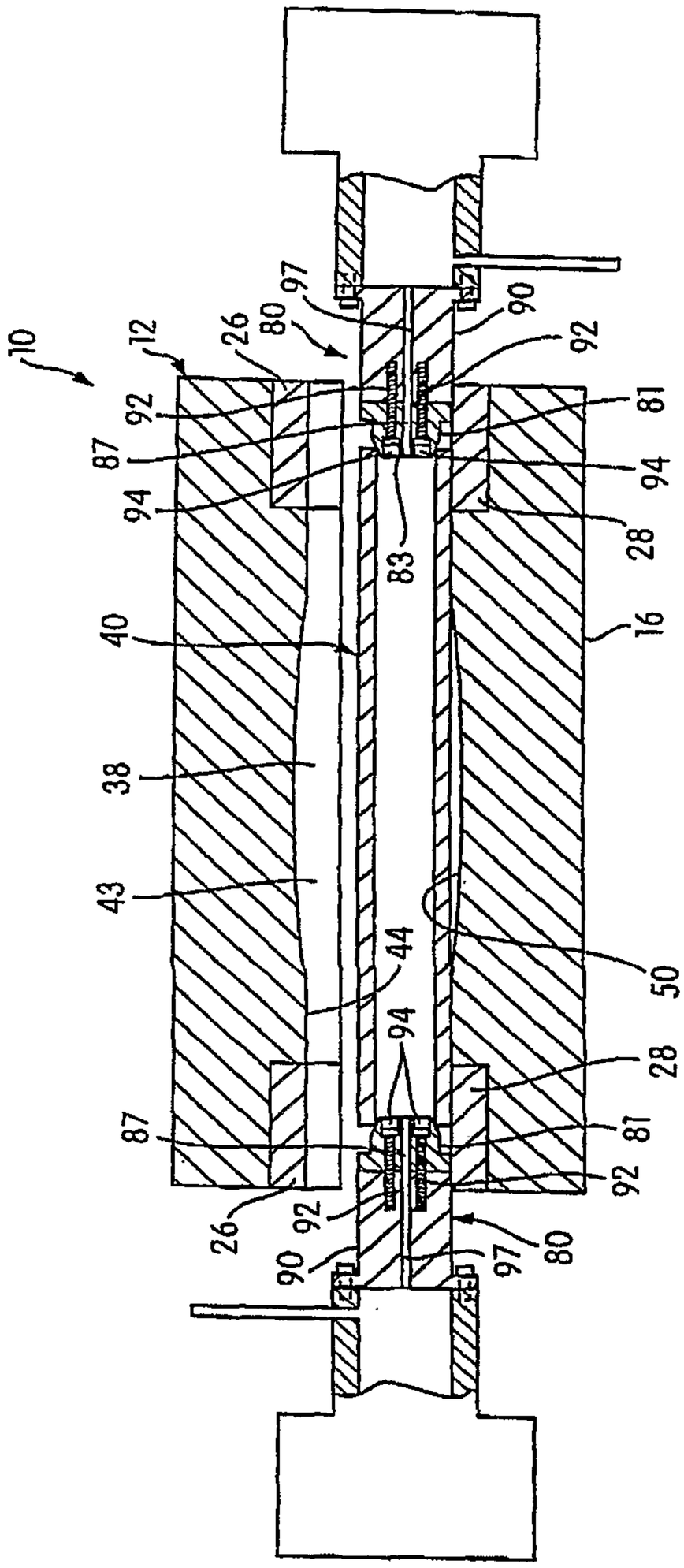


FIG. 2

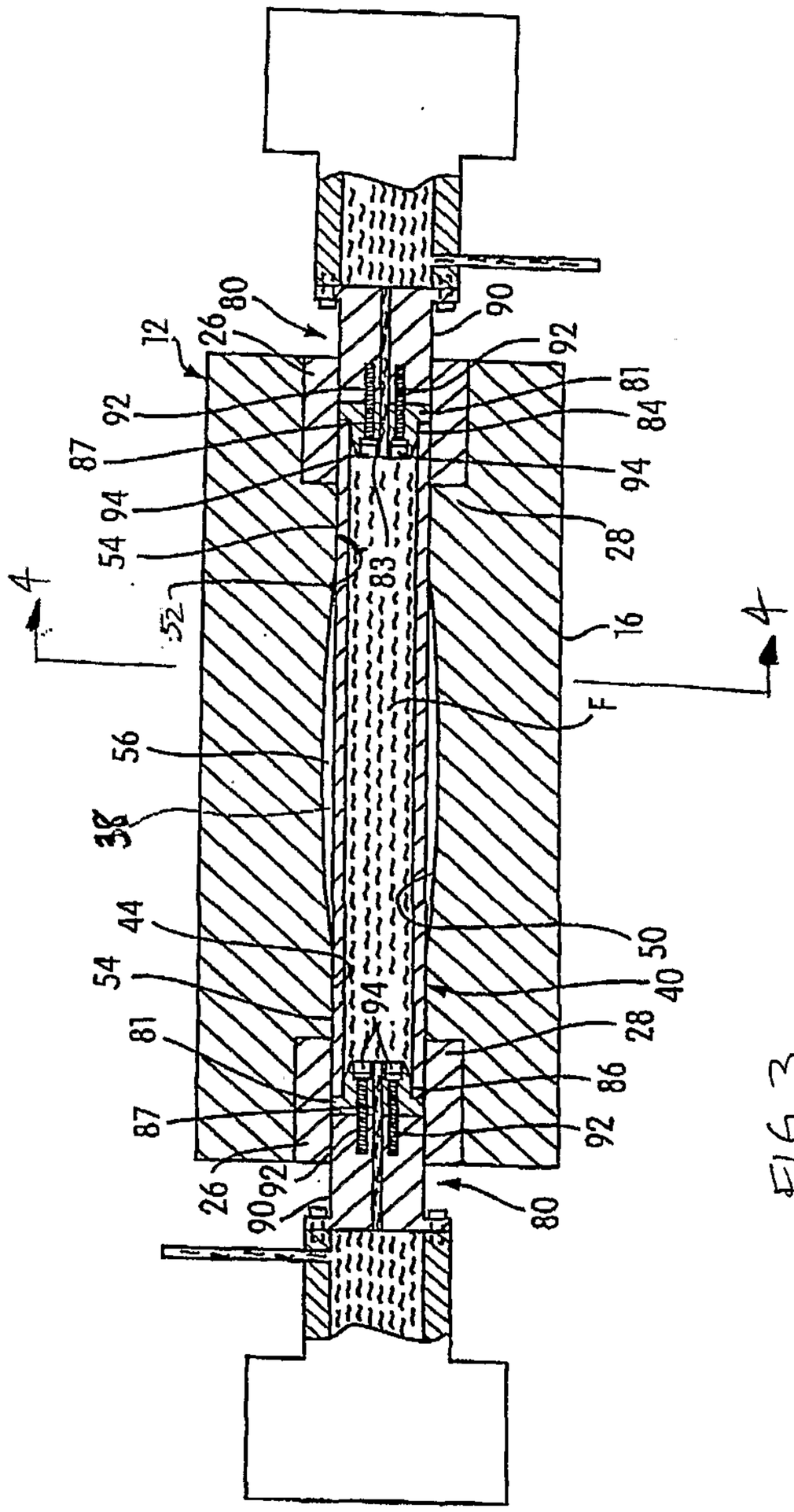


FIG. 3

FIG. 4

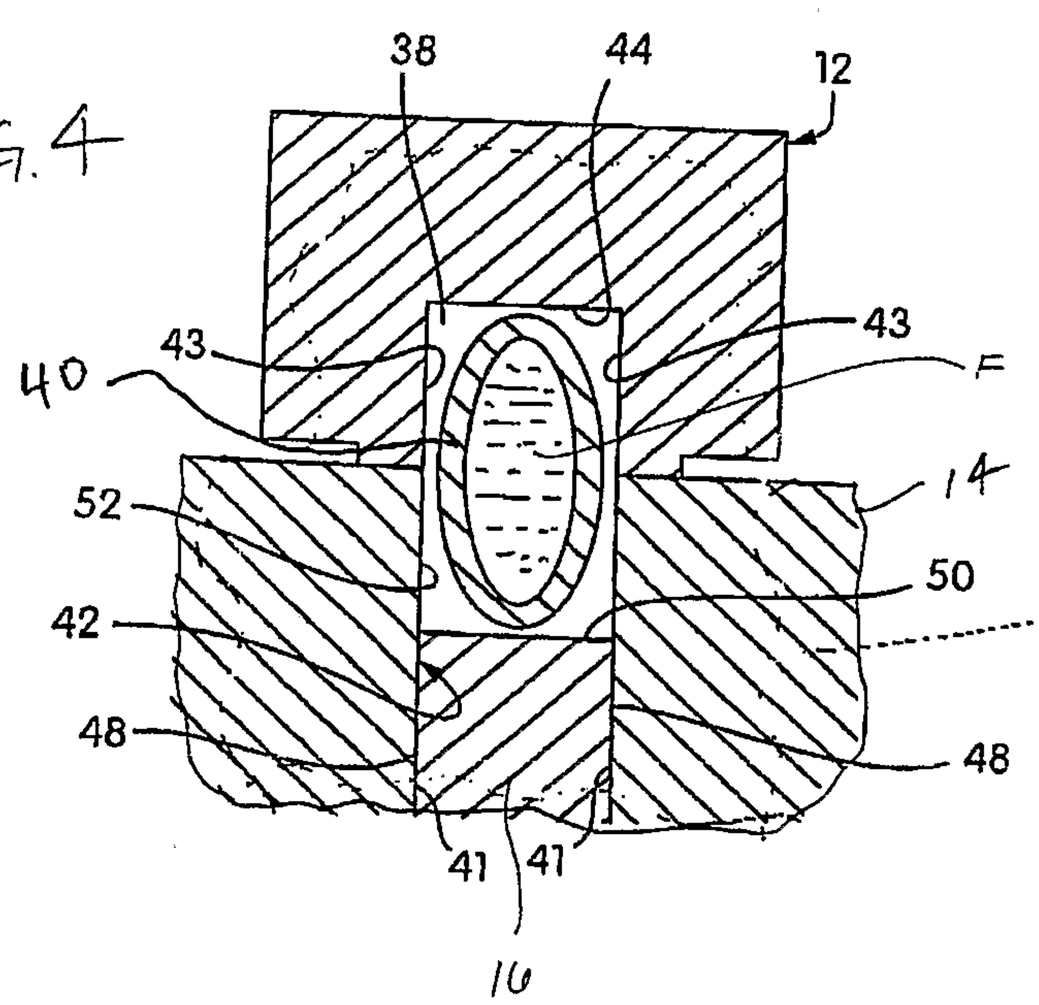
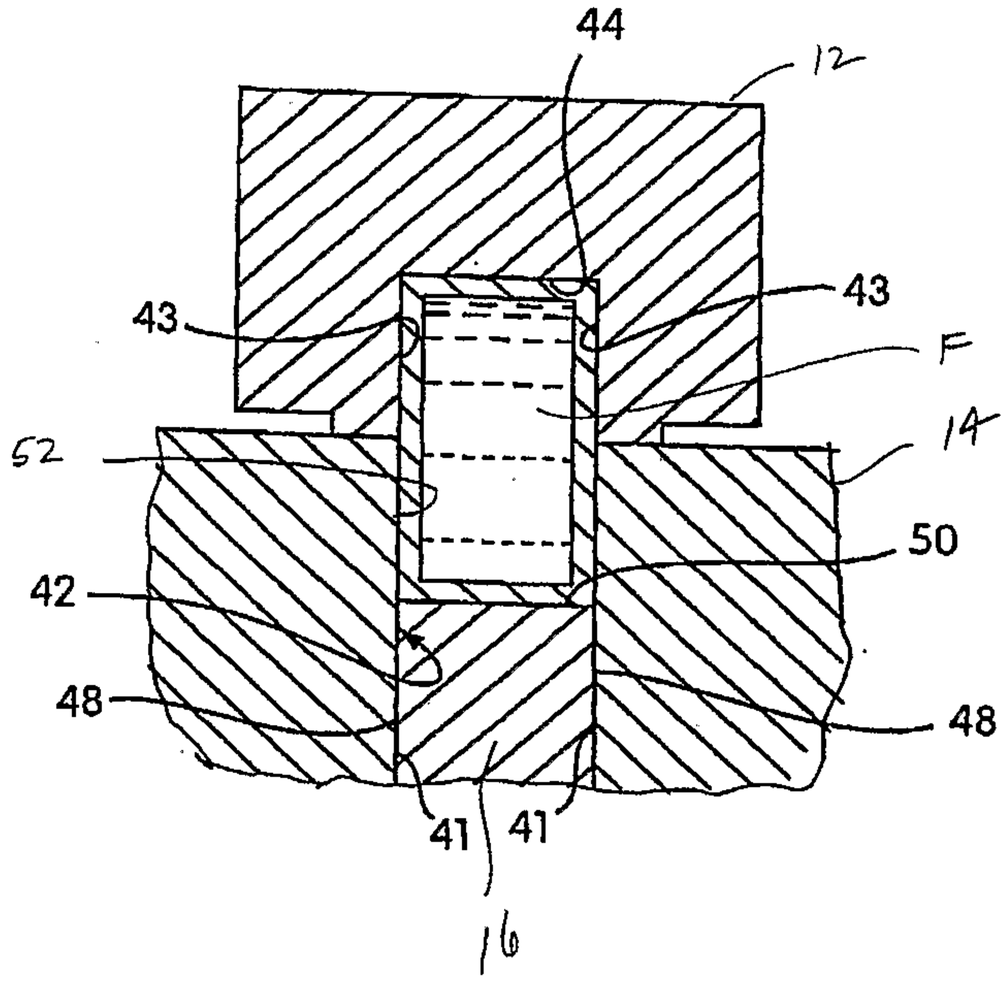

38
44
12
43
43
40
F
14
52
50
42
48
48
41
41
16

FIG. 5


12
43
43
F
14
52
50
42
48
48
41
41
16

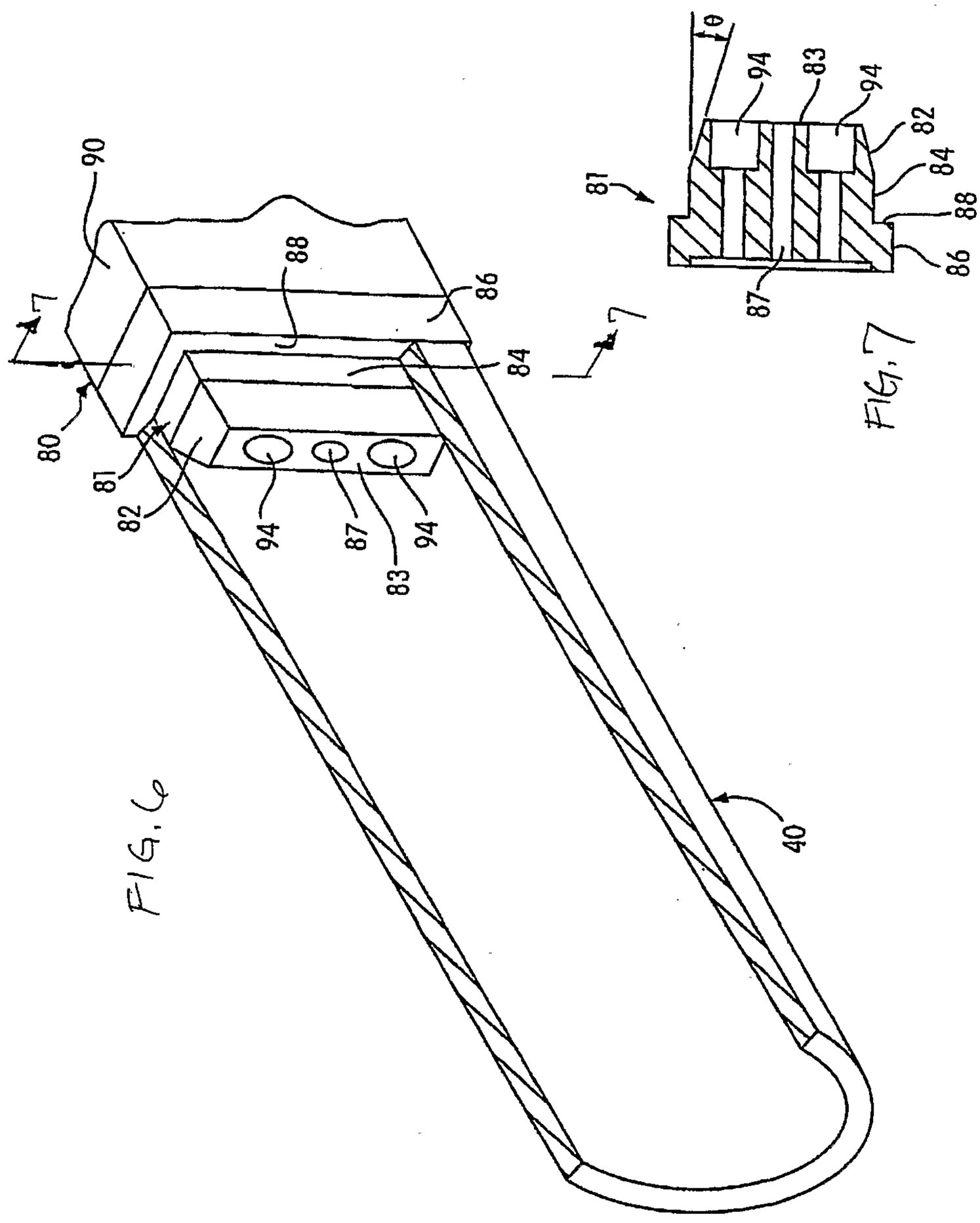


FIG. 6

FIG. 7

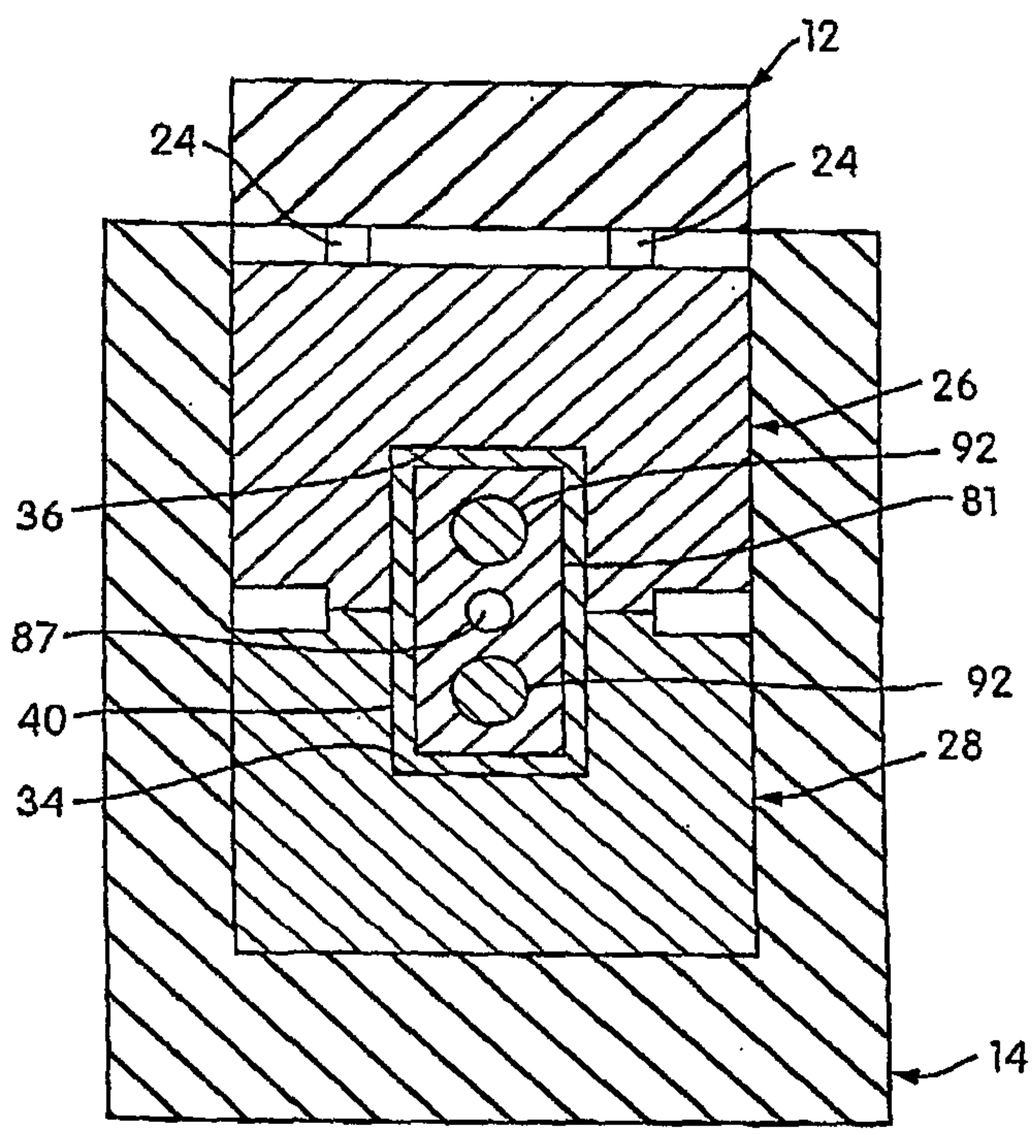


FIG. 8

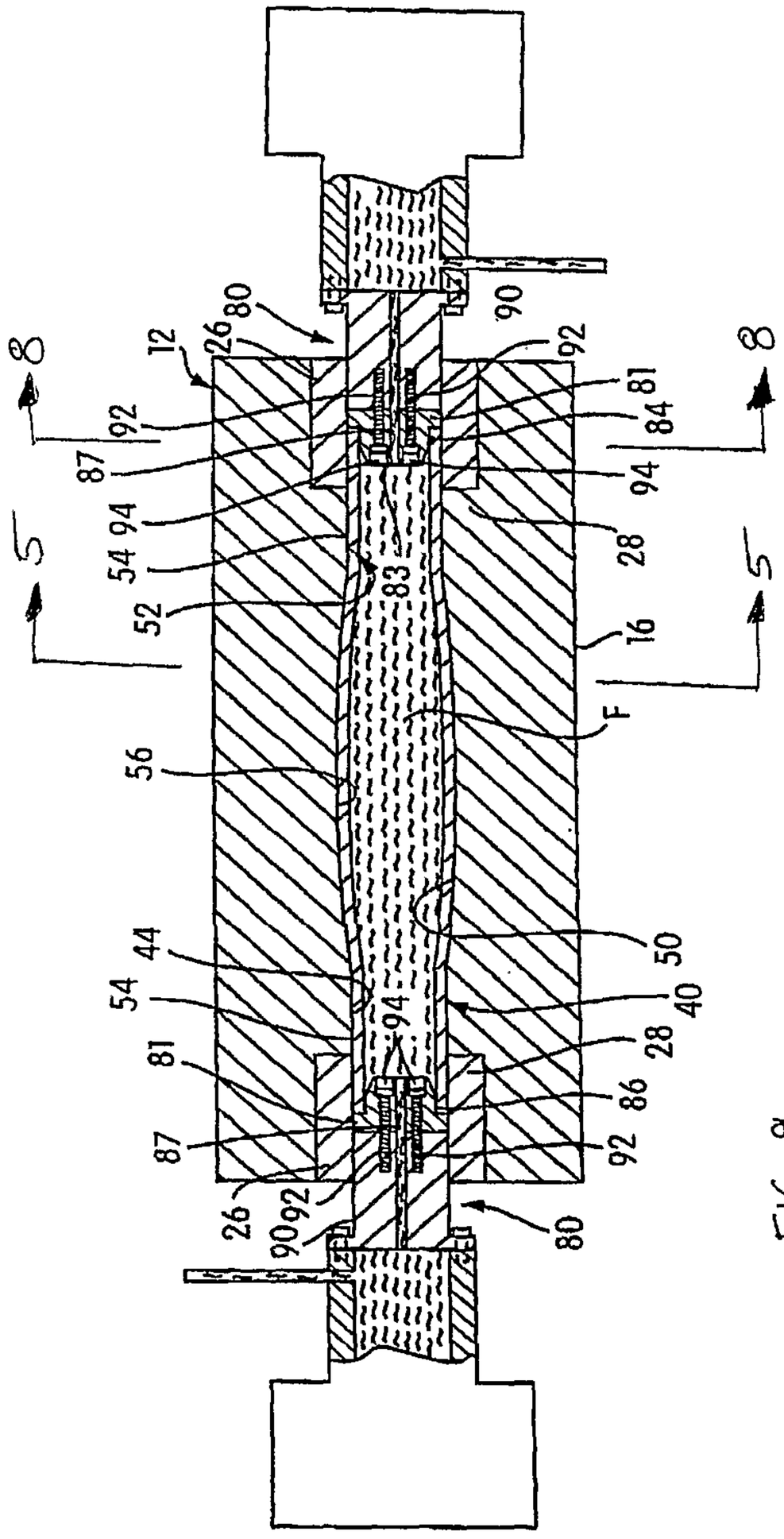

8
8
5
5
12
26
80
90
92
92
81
84
87
94
94
54
28
52
83
16
56
F
44
54
50
40
94
81
28
86
87
92
26
90
92
80

FIG. 9

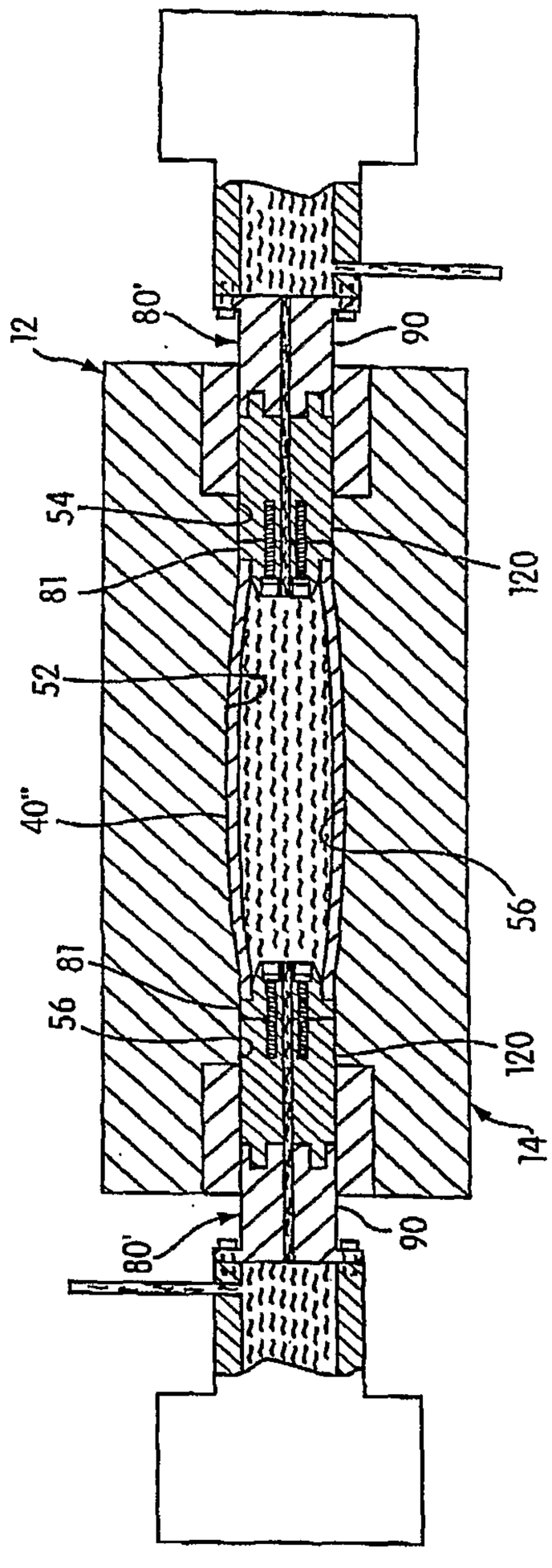


FIG. 10

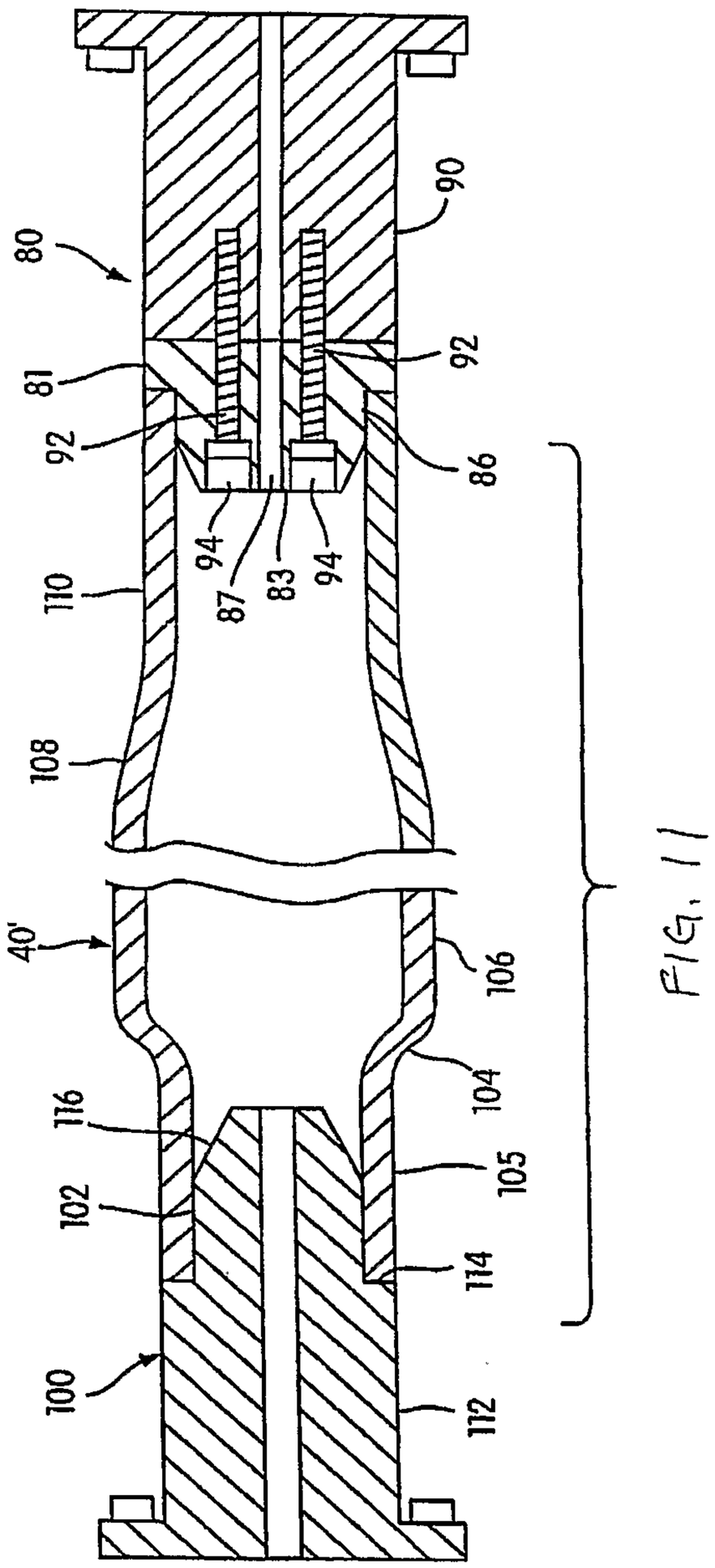
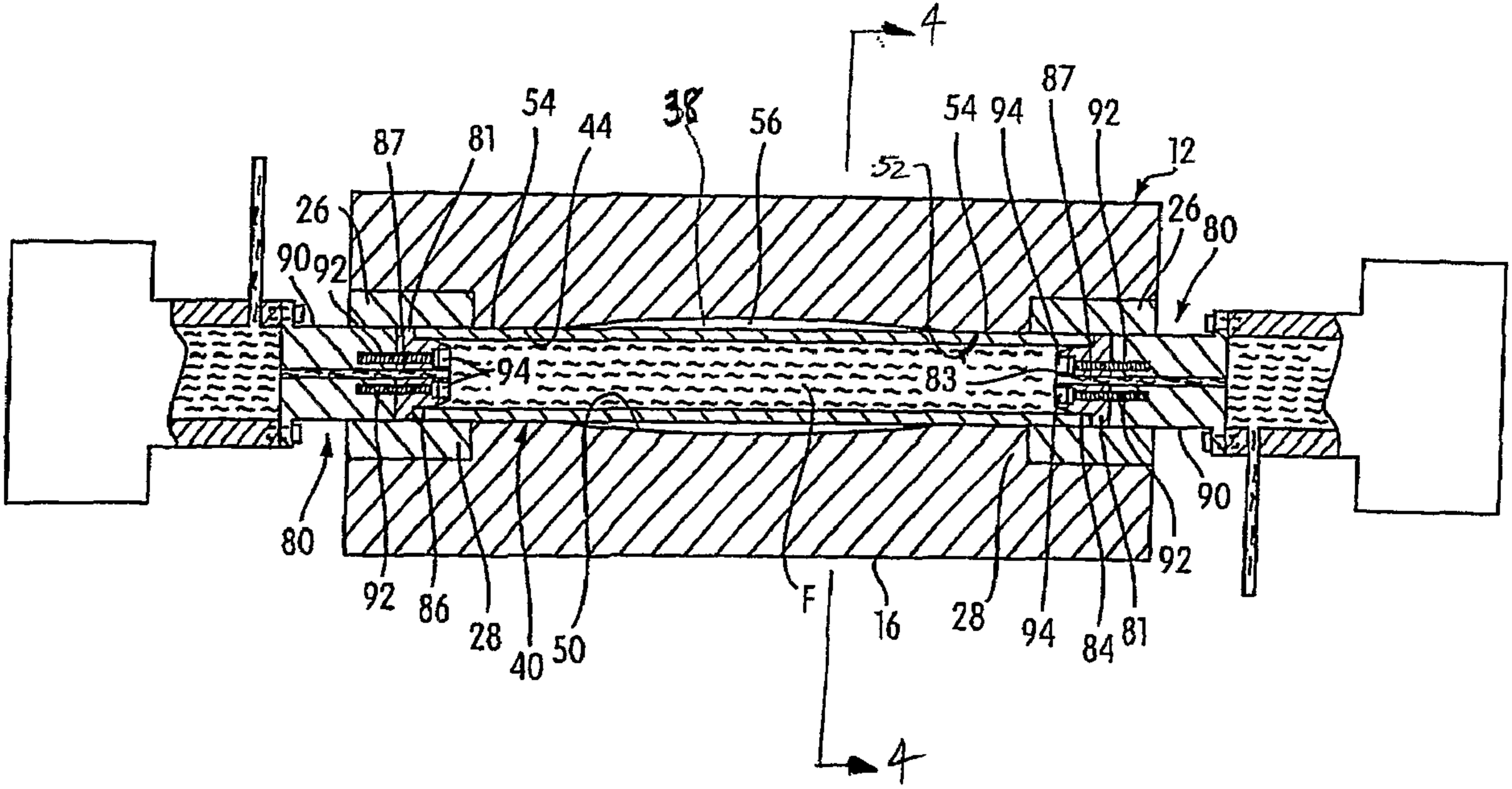

80
81
92
110
108
40'
116
102
100
90
92
86
94
87
83
94
106
104
105
114
112

FIG. 1


4
87
54
44
38
56
54
94
87
92
12
87
81
52
26
26
80
90
92
94
83
80
92
86
28
40
50
F
16
28
94
84
81
92
90
4