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Mehta

(54) SOLENOID HOUSING AND METHOD OF MAKING THE SAME

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(60) Provisional application No. 61/472,844, filed on Apr. 7, 2011.

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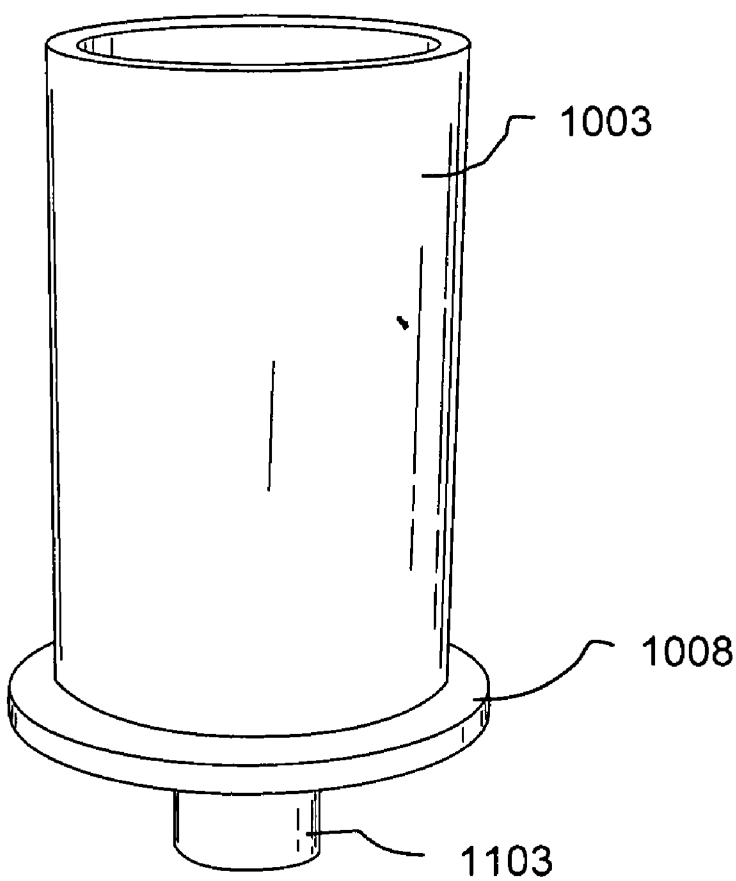
H01H 49/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H01F 7/126*** (2013.01); ***H01H 50/02*** (2013.01); ***H01H 49/00*** (2013.01); ***B21J 5/06*** (2013.01); ***B21J 15/02*** (2013.01); ***B23P 17/04*** (2013.01)

(57) **ABSTRACT**

The invention relates to a solenoid housing fabricated by a method which allows a manufacturer to produce a high performing product while minimizing manufacturing complexity and time. The instant invention uses cold-forging techniques to reduce the need for fine machining processes.



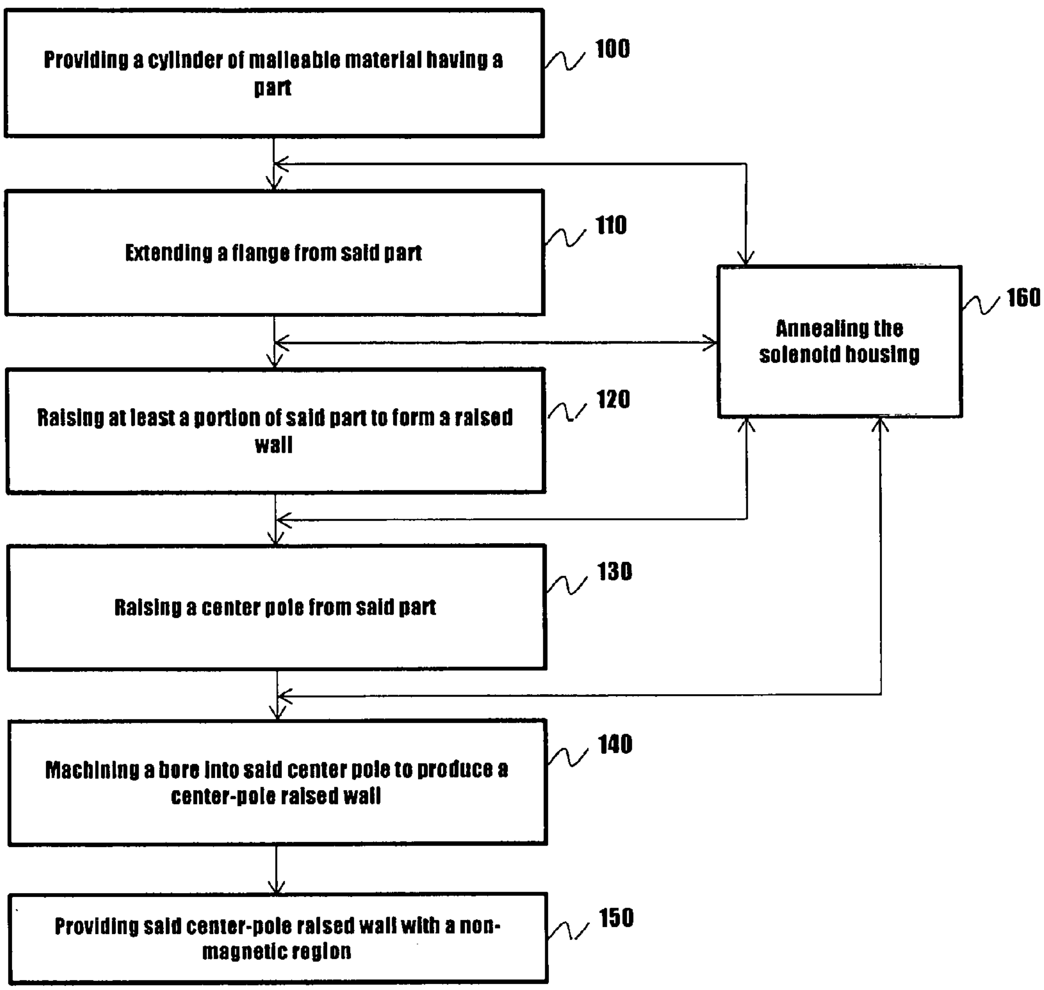

Providing a cylinder of malleable material having a part
100
Extending a flange from said part
110
Raising at least a portion of said part to form a raised wall
120
Raising a center pole from said part
130
Machining a bore into said center pole to produce a center-pole raised wall
140
Providing said center-pole raised wall with a non-magnetic region
150
Annealing the solenoid housing
160

FIG. 1

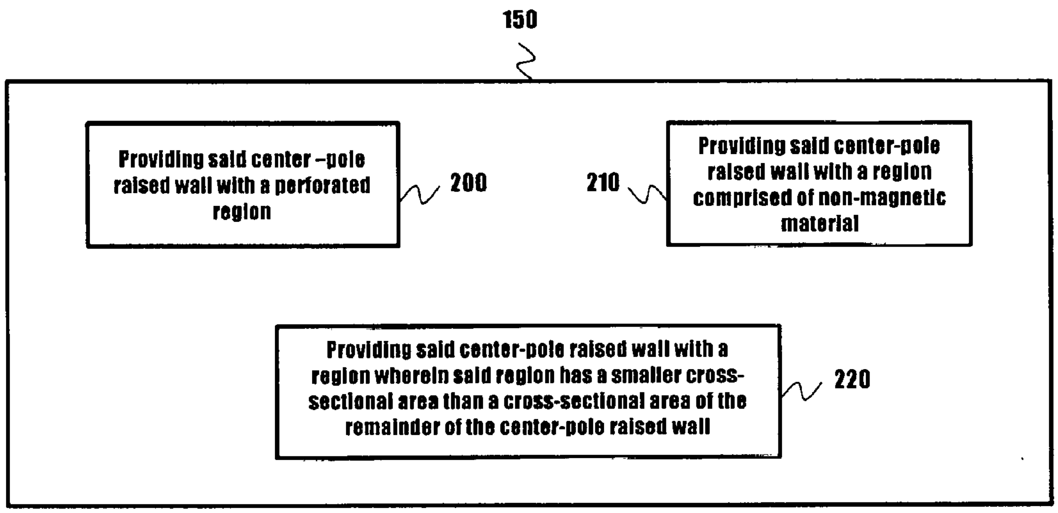

150
Providing said center –pole raised wall with a perforated region
200
210
Providing said center-pole raised wall with a region comprised of non-magnetic material
Providing said center-pole raised wall with a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the center-pole raised wall
220

FIG. 2

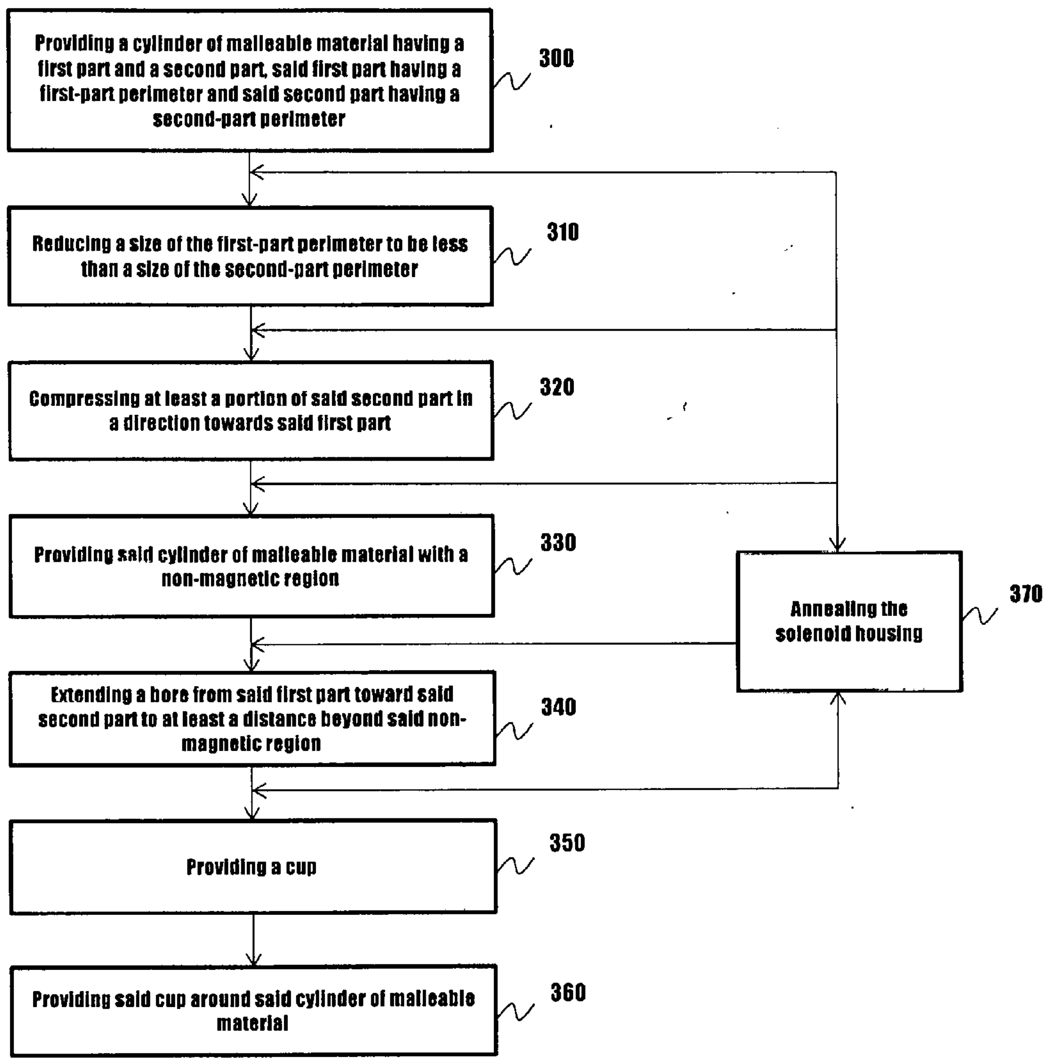

Providing a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter
300
Reducing a size of the first-part perimeter to be less than a size of the second-part perimeter
310
Compressing at least a portion of said second part in a direction towards said first part
320
Providing said cylinder of malleable material with a non-magnetic region
330
Extending a bore from said first part toward said second part to at least a distance beyond said non-magnetic region
340
Providing a cup
350
Providing said cup around said cylinder of malleable material
360
Annealing the solenoid housing
370

FIG. 3

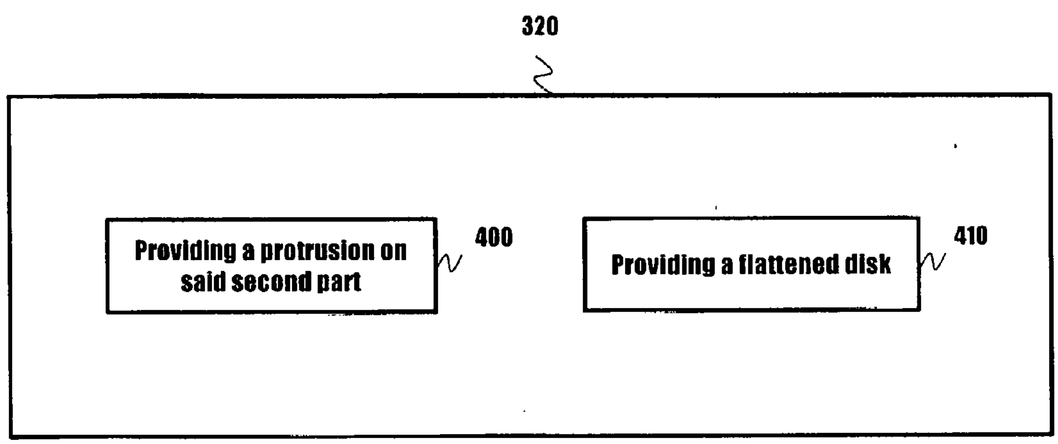

320
Providing a protrusion on said second part
400
Providing a flattened disk
410

FIG. 4

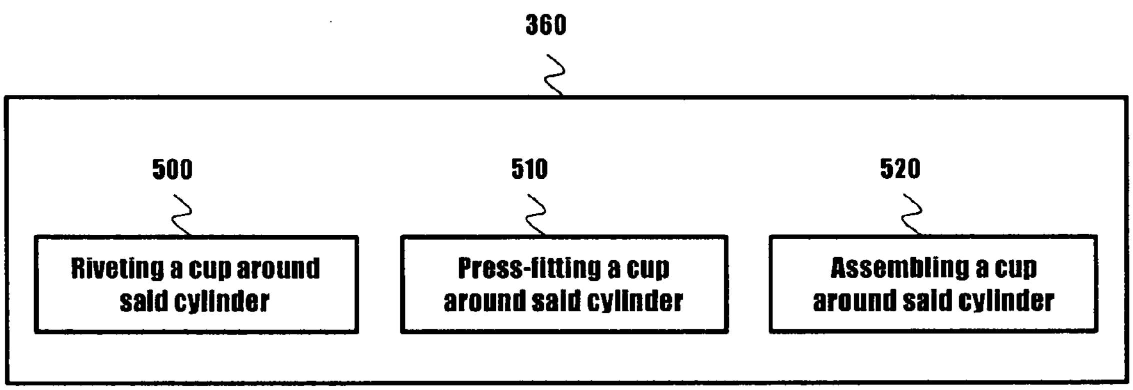

360
500
Riveting a cup around said cylinder
510
Press-fitting a cup around said cylinder
520
Assembling a cup around said cylinder

FIG. 5

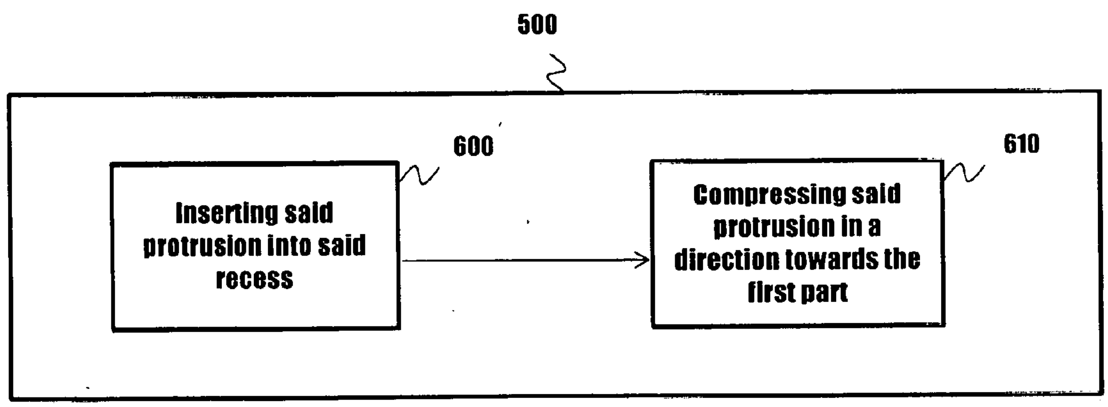

500
600
Inserting said protrusion into said recess
610
Compressing said protrusion in a direction towards the first part

FIG. 6

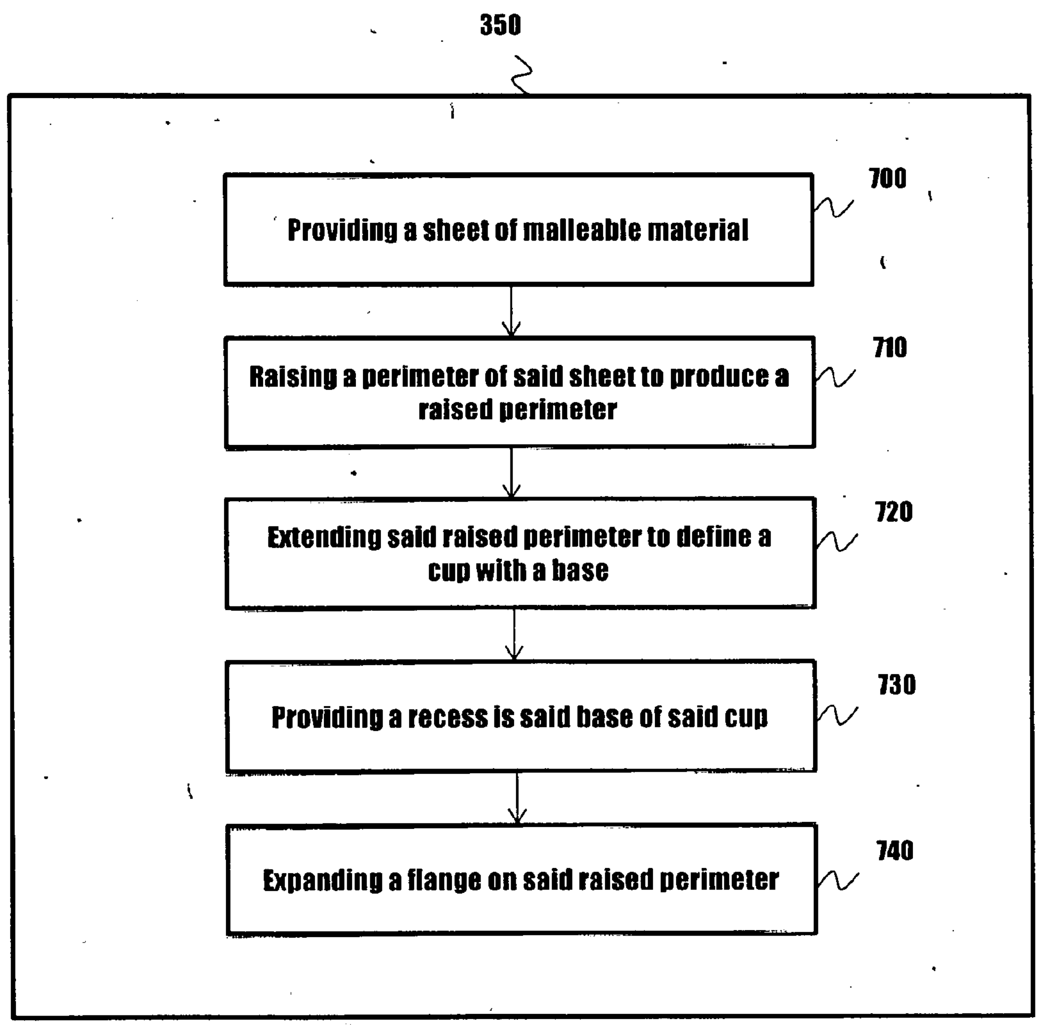

350
Providing a sheet of malleable material
700
Raising a perimeter of said sheet to produce a raised perimeter
710
Extending said raised perimeter to define a cup with a base
720
Providing a recess is said base of said cup
730
Expanding a flange on said raised perimeter
740

FIG. 7

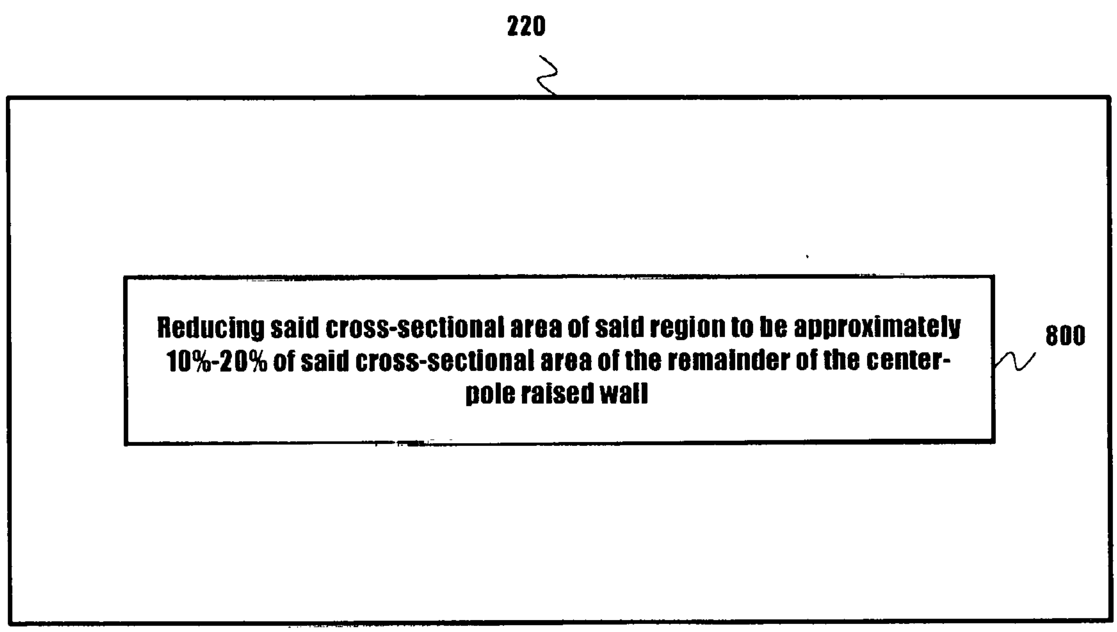

220
Reducing said cross-sectional area of said region to be approximately 10%-20% of said cross-sectional area of the remainder of the center-pole raised wall
800

FIG. 8

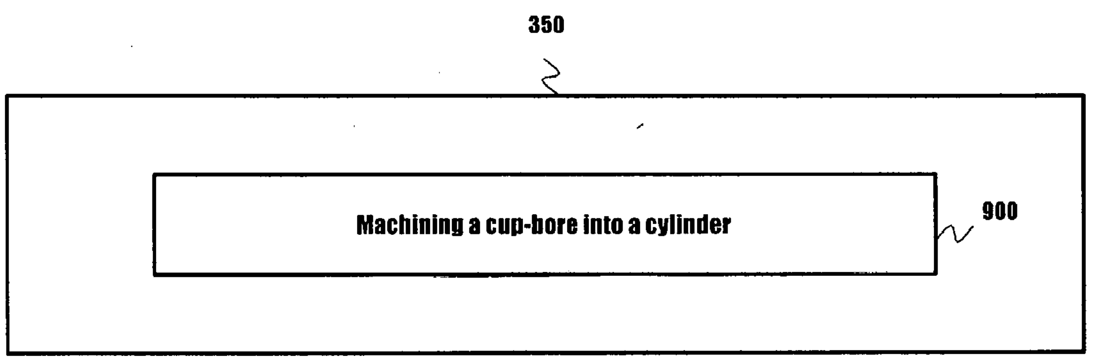


FIG. 9

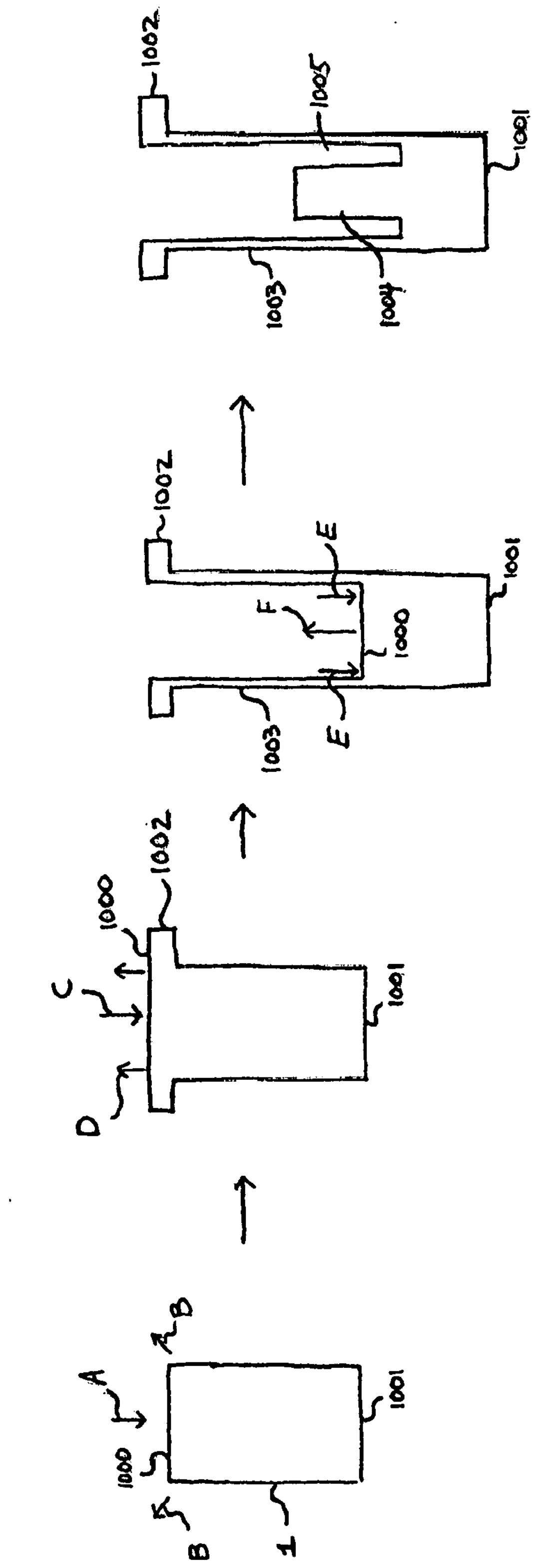

1
1000
A
B
B
1001
1000
1002
C
D
1001
1002
1003
1000
E
E
F
1001
1002
1003
1004
1005
1001

FIG. 10

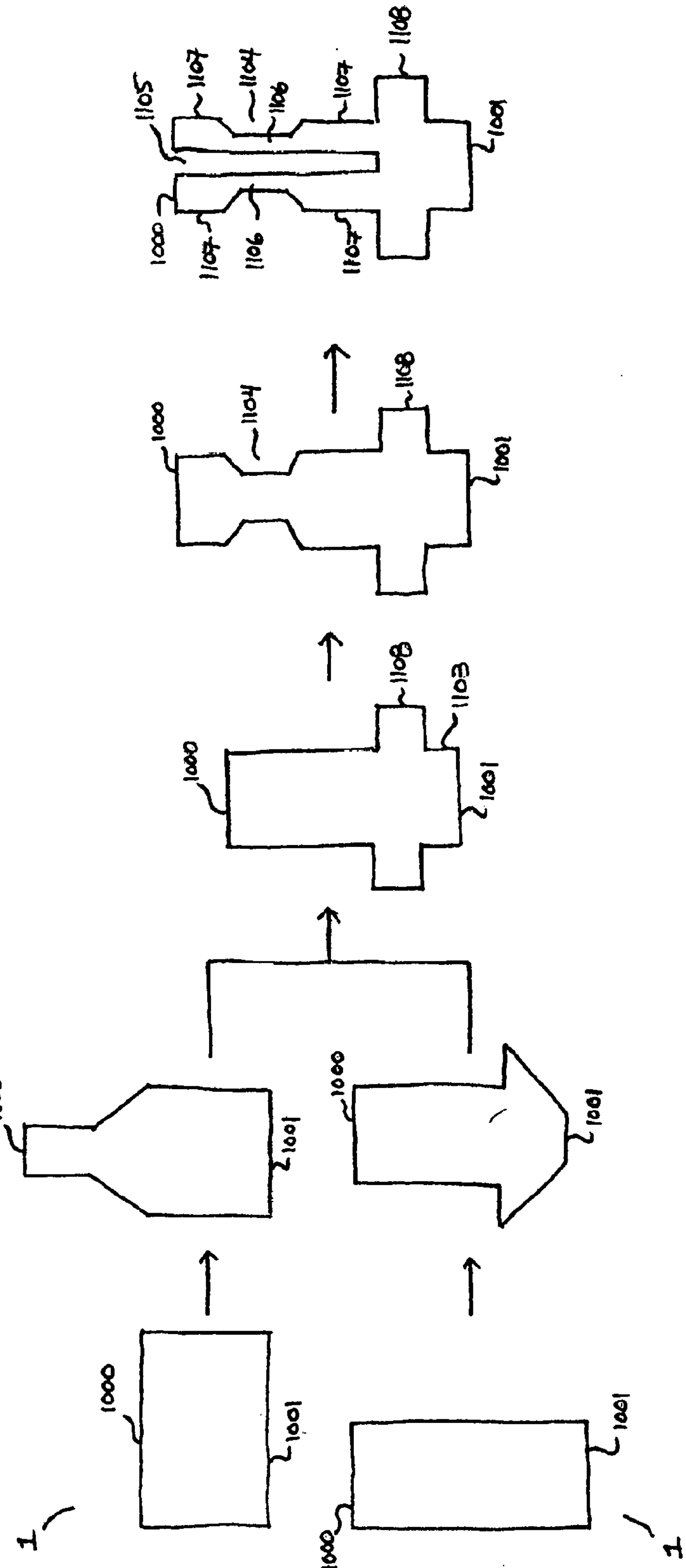


FIG. 11

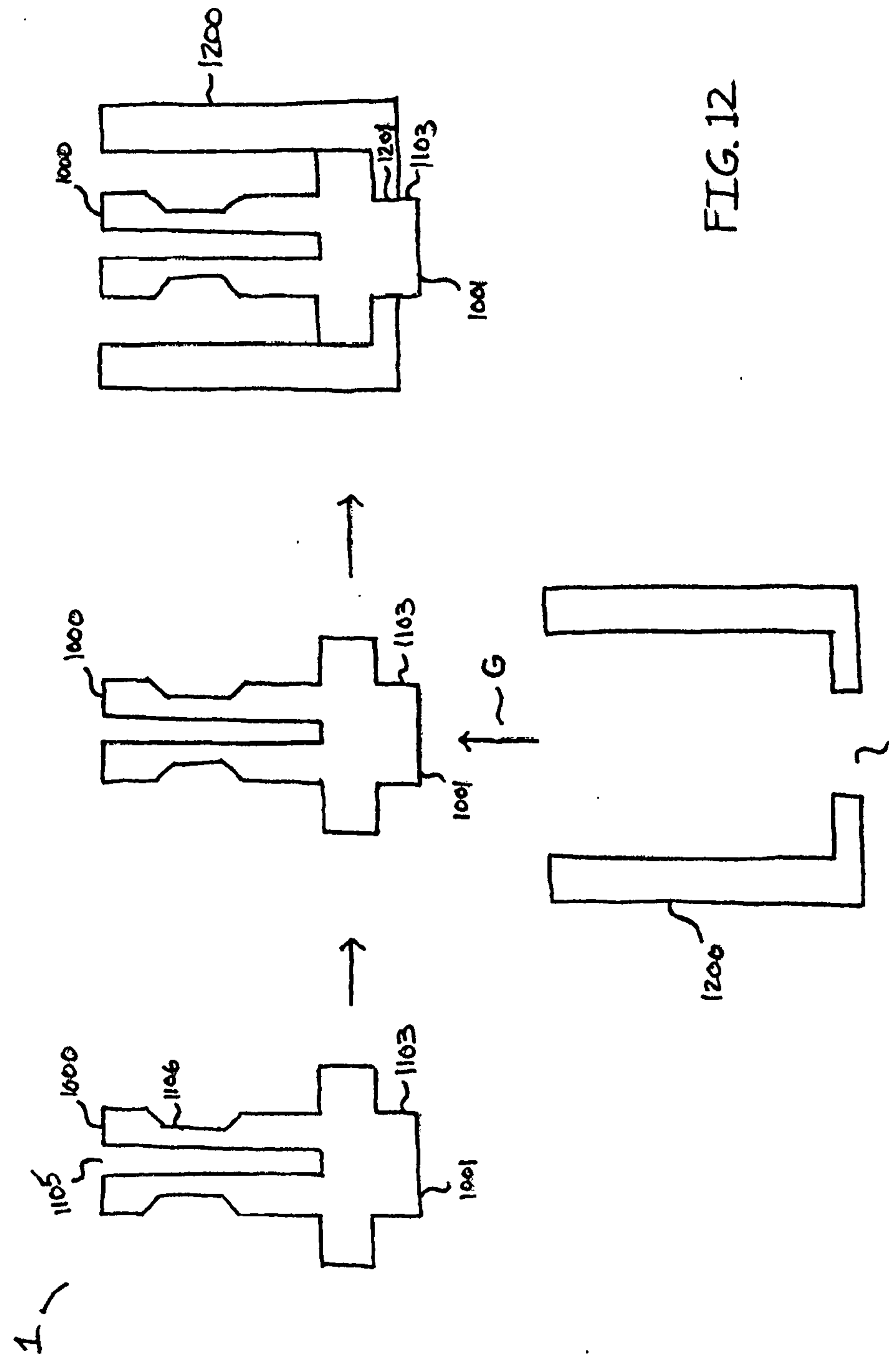


FIG. 12

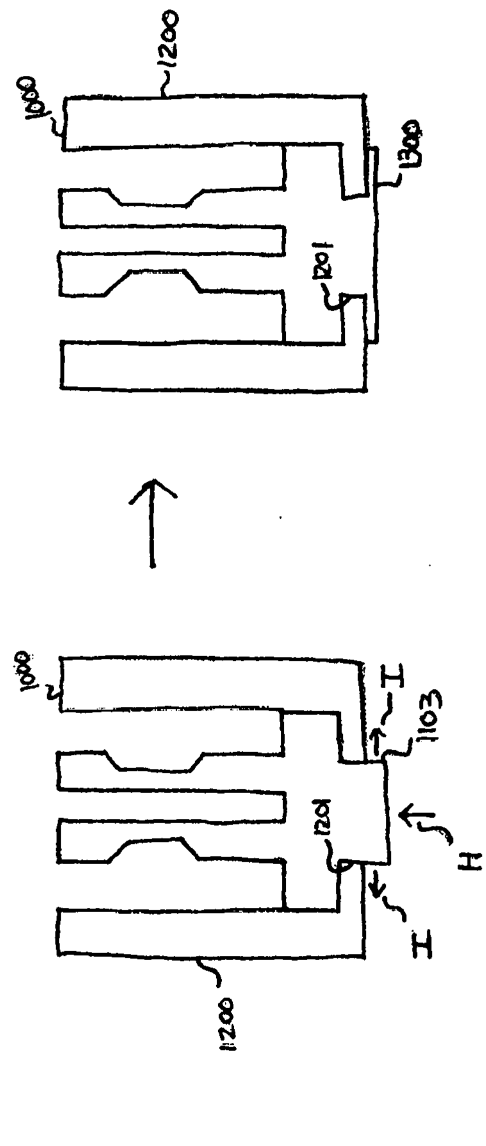


FIG. 13

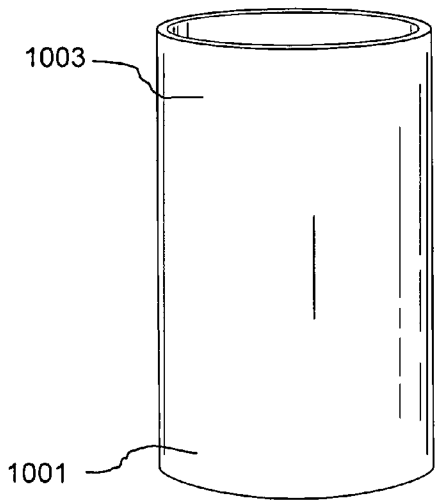


FIG. 14

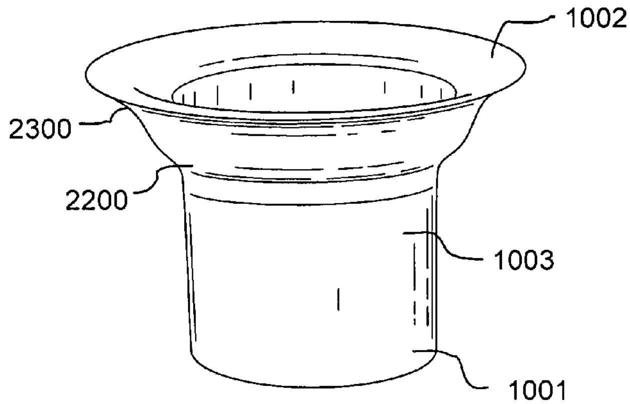


FIG. 15

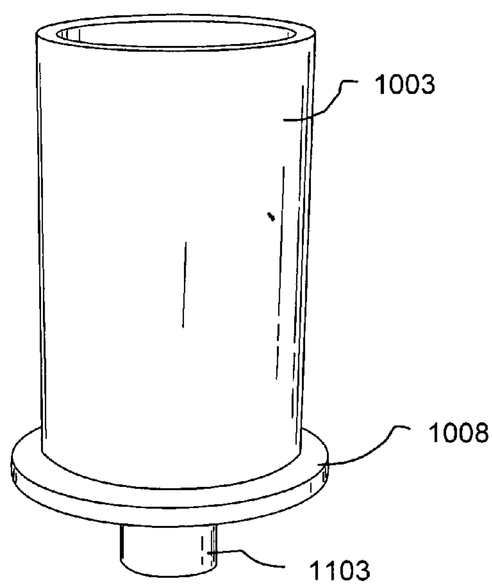


FIG. 16

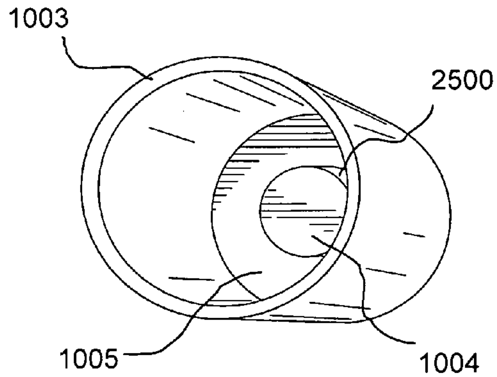


FIG. 17

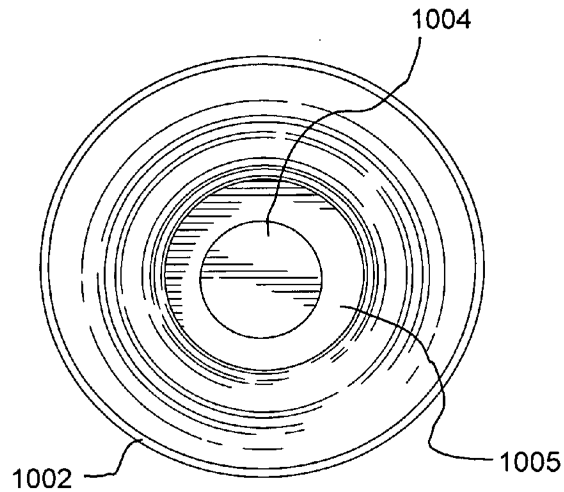


FIG. 18

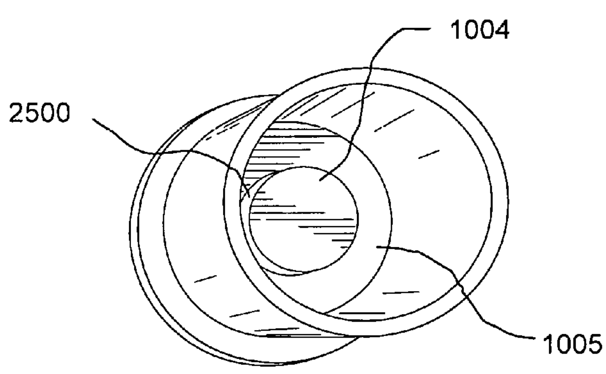


FIG. 19

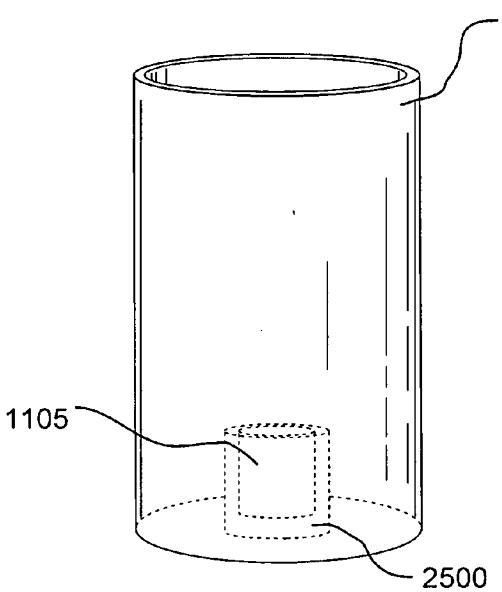


FIG. 20

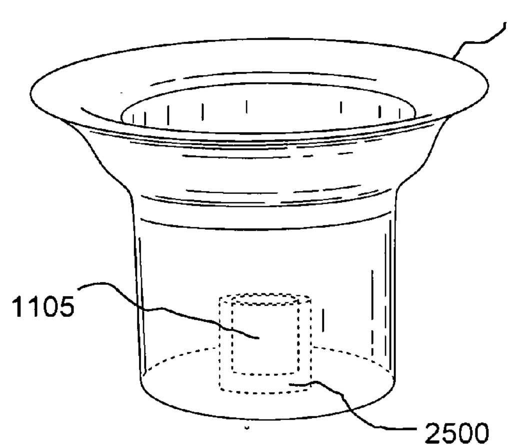


FIG. 21

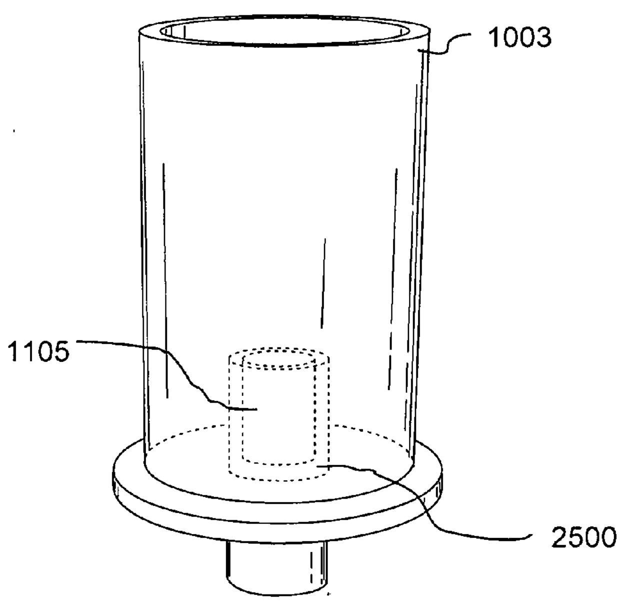


FIG. 22

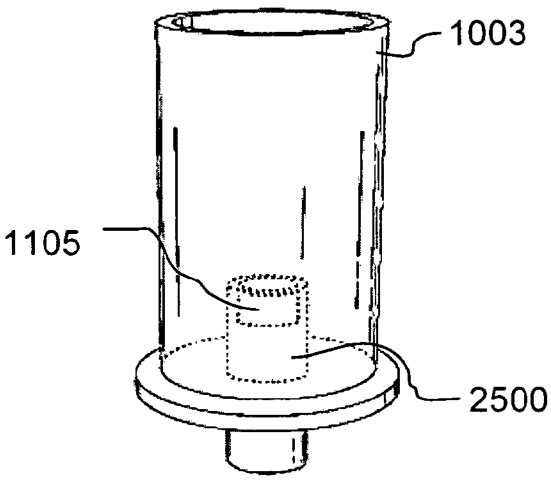


FIG. 23

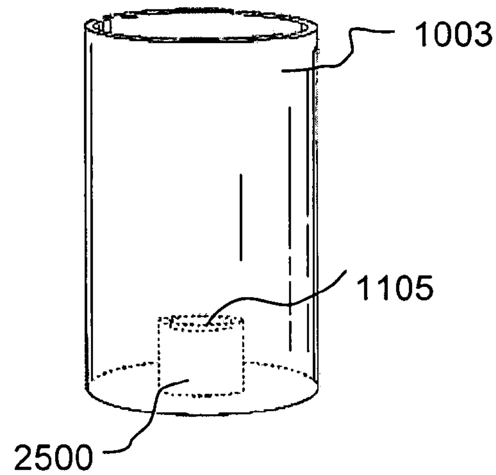


FIG. 24

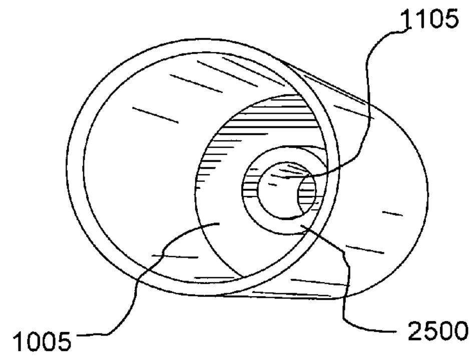


FIG. 25

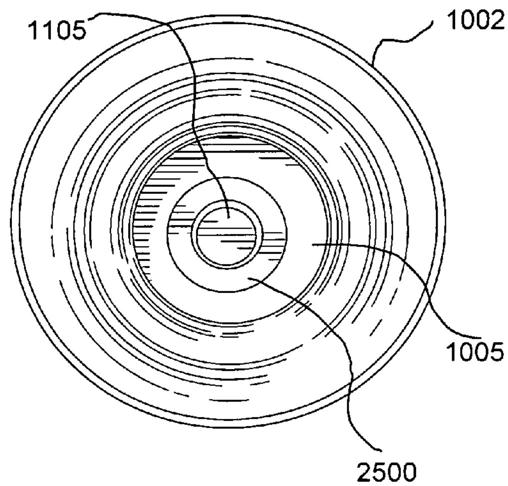


FIG. 26

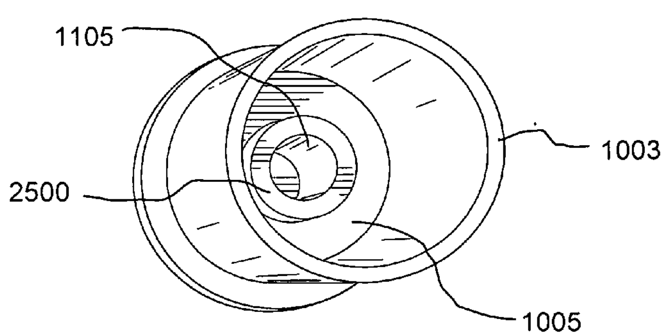
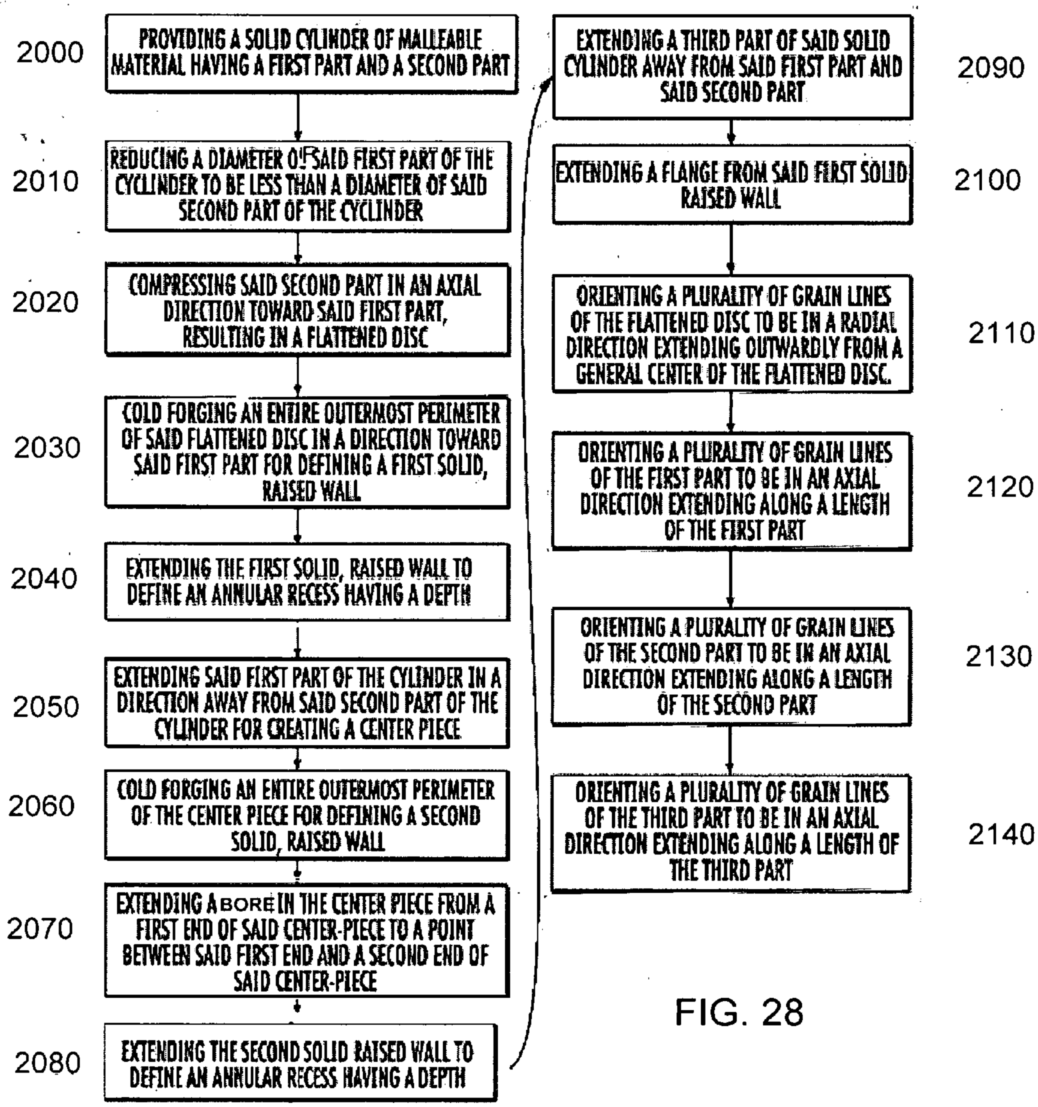


FIG. 27



2000
PROVIDING A SOLID CYLINDER OF MALLEABLE MATERIAL HAVING A FIRST PART AND A SECOND PART
2010
REDUCING A DIAMETER OF SAID FIRST PART OF THE CYLINDER TO BE LESS THAN A DIAMETER OF SAID SECOND PART OF THE CYLINDER
2020
COMPRESSING SAID SECOND PART IN AN AXIAL DIRECTION TOWARD SAID FIRST PART, RESULTING IN A FLATTENED DISC
2030
COLD FORGING AN ENTIRE OUTERMOST PERIMETER OF SAID FLATTENED DISC IN A DIRECTION TOWARD SAID FIRST PART FOR DEFINING A FIRST SOLID, RAISED WALL
2040
EXTENDING THE FIRST SOLID, RAISED WALL TO DEFINE AN ANNULAR RECESS HAVING A DEPTH
2050
EXTENDING SAID FIRST PART OF THE CYLINDER IN A DIRECTION AWAY FROM SAID SECOND PART OF THE CYLINDER FOR CREATING A CENTER PIECE
2060
COLD FORGING AN ENTIRE OUTERMOST PERIMETER OF THE CENTER PIECE FOR DEFINING A SECOND SOLID, RAISED WALL
2070
EXTENDING A BORE IN THE CENTER PIECE FROM A FIRST END OF SAID CENTER-PIECE TO A POINT BETWEEN SAID FIRST END AND A SECOND END OF SAID CENTER-PIECE
2080
EXTENDING THE SECOND SOLID RAISED WALL TO DEFINE AN ANNULAR RECESS HAVING A DEPTH
2090
EXTENDING A THIRD PART OF SAID SOLID CYLINDER AWAY FROM SAID FIRST PART AND SAID SECOND PART
2100
EXTENDING A FLANGE FROM SAID FIRST SOLID RAISED WALL
2110
ORIENTING A PLURALITY OF GRAIN LINES OF THE FLATTENED DISC TO BE IN A RADIAL DIRECTION EXTENDING OUTWARDLY FROM A GENERAL CENTER OF THE FLATTENED DISC
2120
ORIENTING A PLURALITY OF GRAIN LINES OF THE FIRST PART TO BE IN AN AXIAL DIRECTION EXTENDING ALONG A LENGTH OF THE FIRST PART
2130
ORIENTING A PLURALITY OF GRAIN LINES OF THE SECOND PART TO BE IN AN AXIAL DIRECTION EXTENDING ALONG A LENGTH OF THE SECOND PART
2140
ORIENTING A PLURALITY OF GRAIN LINES OF THE THIRD PART TO BE IN AN AXIAL DIRECTION EXTENDING ALONG A LENGTH OF THE THIRD PART

FIG. 28

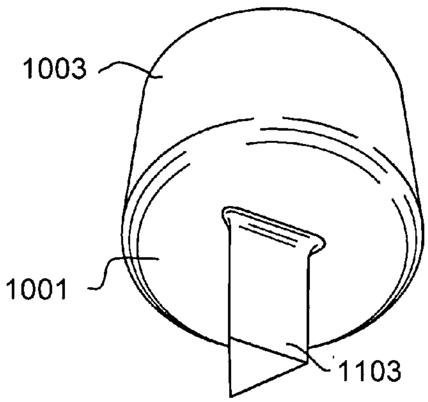


FIG. 29A

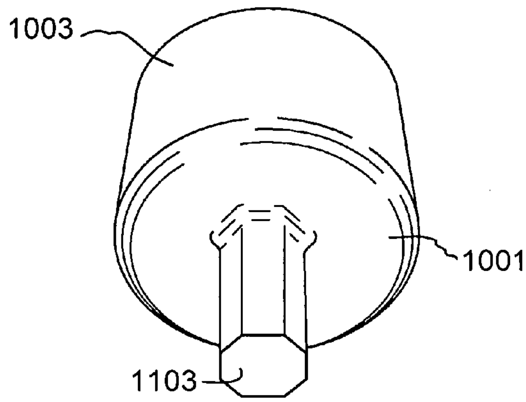


FIG. 29B

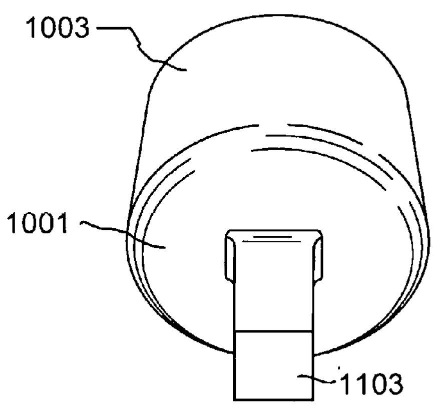


FIG. 29C

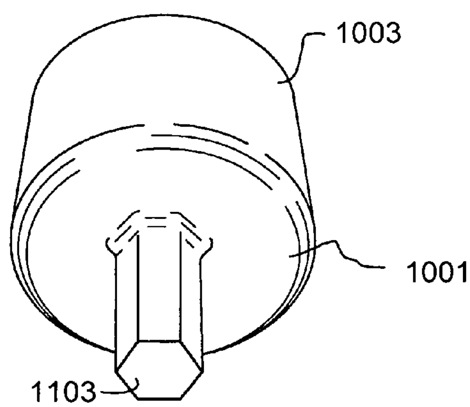


FIG. 29D

SOLENOID HOUSING AND METHOD OF MAKING THE SAME

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of and claims priority to U.S. patent application Ser. No. 14/146,122, filed Jan. 2, 2014 and titled "Solenoid Housing and Method of Making the Same," which is a continuation-in-part of and claims priority to U.S. patent application Ser. No. 13/439,409, filed Apr. 4, 2012, now U.S. Pat. No. 8,643,452, issued on Feb. 4, 2014 and titled "Solenoid Housing with Elongated Center Pole," which claims priority to and the benefit of U.S. Provisional Patent Application No. 61/472,844, filed Apr. 7, 2011 and titled "Solenoid Housing with Elongated Center Pole." The contents of the above-referenced patent applications and issued patent are relied upon and incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

[0002] The field of the invention relates to advantageous methods of fabricating solenoid housings.

BACKGROUND OF THE INVENTION

[0003] Solenoid assemblies are typically found in a myriad of modern products, from the control of anti-lock braking systems and automatic transmissions in automobiles, to pressurized water control in irrigation systems, to more general uses such as in doors, windows, many hydraulic controls, and the like.

[0004] Solenoid housings are typically used in car control systems, such as doors, windows, hydraulic controls, engine control, and the like. Other uses include refrigerators, washers, and dryers. Further uses include electrically actuated valves/switches, door holders, speakers, and CRT monitors.

[0005] Solenoids typically make use of a high magnetic reluctance region to facilitate movement of an armature along a set path in response to the application of an electric current. This region can be referred to as an "air gap" because empty space is commonly used as the high magnetic reluctance region. Such an arrangement with a literal air gap, however, may lead to certain difficulties in both construction and operation of the solenoid. Certain prior art teachings disclose the air gap may be achieved through a two piece construction of the solenoid with a gap left between the two pieces. Each piece may have a different conformation, meaning that separate, specialized manufacturing processes could be required for each piece. Further, if the two pieces need to be aligned properly to allow for easy movement of the armature through each piece and across the air gap, extra calibration and alignment procedures may be necessary. All of these additional steps generally increase manufacturing complexity, meaning more time and cost may be necessary to produce a single solenoid than if said extra calibration and alignment procedures were eliminated.

[0006] There may be the fear of decreased manufacturing efficiency and operational lifetimes associated with these prior art solenoids as well. For example, if a solenoid were produced in a two-piece arrangement with a certain degree of allowed deviation from the ideal alignment of the first and second piece, solenoids may be produced outside of this tolerance, and the time and cost necessary to produce said solenoid would have been wasted. Further, since a two-part construction like the one described above may be unlikely to produce ideal alignments on a consistent basis, the average operation lifetimes of the solenoids may decrease by general wear and tear (caused by frictional forces of the armature on the solenoid housing after days, months, or years of repeated rubbing due to misaligned solenoid components).

[0007] Further, traditional solenoid housing manufacturing and assembly is typically a multi-stage machining and welding process requiring a series of highly specialized machines, skilled manufacturing personnel, and time to perform each manufacturing step to produce a quality, reliable product. For example, the lathes which can be used for machining a central armature path in prior art processes are often expensive and require a large amount of space for proper operation, and welding methods may need to be completed in tight spaces and with little room for error or inconsistency in the weld. The imprecision and complexity of the prior art processes may produce solenoids and solenoid housings with inherent structural weaknesses, and produce them at a disadvantageously high rate. These manufacturing deficiencies may lead to premature operational failure of the prior art solenoid housings or a high rejection rate during the assembly process.

[0008] What is desired, therefore, is a method of making a solenoid housing which eliminates much of the manufacturing complexity found in the prior art. It is further desired that this novel method of making a solenoid housing improve the operation and increase the expectant operational lifetime of said solenoid housing.

SUMMARY OF THE INVENTION

[0009] It is therefore an object of the invention to provide a method of producing a solenoid housing utilizing cold-forging methods to eliminate multi-component fabrication and assembling, as well as provide a suitable analogue for the air gap.

[0010] In one embodiment, the method of providing a solenoid housing of the instant invention comprises the steps of providing a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter, reducing a size of the first-part perimeter to be less than a size of the second-part perimeter, compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk, providing said cylinder of malleable material with a non-magnetic region, extending a bore from said first part toward said second part to at least a distance beyond said non-magnetic region. In a further embodiment, the step of compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk also comprises the step of providing a protrusion on said second part.

[0011] In another embodiment, a cup is provided around the cylinder of malleable material. In another embodiment, the above-mentioned cup is produced using a method comprising the steps of providing a sheet of malleable material, raising a perimeter of said sheet to produce a raised perimeter, extending said raised perimeter to define a cup with a base, and providing a recess in said base of said cup. In one embodiment, the cup is produced through a machining method which provides a cup-bore into a cylinder of suitable material. In a further embodiment, the cup is provided to the cylinder of malleable material though a method selected from the group consisting of assembling, riveting, press-fitting, and combinations thereof. In one embodiment, the riveting method further comprises the steps of inserting said protrusion into said recess and compressing said protrusion in a direction towards the first part. In yet another embodiment, the non-magnetic region is provided by selecting from the group consisting of: a perforated region, an area comprised of non-magnetic material, a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the cylinder of malleable material, and combinations thereof.

[0012] In a further embodiment, the method includes annealing the housing after at least one of the steps of any of the following: providing a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter; reducing a size of the first-part perimeter to be less than a size of the second-part perimeter; compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk; providing said cylinder of malleable material with a non-magnetic region; and extending a bore from said first part toward said second part to at least a distance beyond said non-magnetic region.

[0013] In yet another embodiment, the method includes a step of providing said cylinder of malleable material with said region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of said cylinder of malleable material further comprises the following step: reducing said cross-sectional area of said region to be approximately 10%-20% of said cross-sectional area of the remainder of the cylinder.

[0014] In one embodiment, this invention is a solenoid housing comprising a raised wall having a first end and a second end; a center-piece having a first end and a second end; a flattened disk at said second end of said raised wall and said second end of said center-piece; and wherein said center-piece, flattened disk, and raised wall are formed of a one-piece construction. In another embodiment, the center-piece includes a bore. In yet another embodiment, the bore extends from the first end of the center-piece to a point between the first end and the second end of the center-piece. In yet another embodiment, the raised wall includes a flange. In yet another embodiment, the flange is generally perpendicular to the flattened disc.

[0015] In one embodiment, the invention is a method of providing a solenoid housing, comprising the steps of: providing a solid cylinder of malleable material having a first part and a second part; reducing a diameter of said first part of the cylinder to be less than a diameter of said second part of the cylinder; compressing said second part in an axial direction toward said first part, resulting in a flattened disc; cold forging an entire outermost perimeter of said flattened disc in a direction toward said first part for defining a first solid, raised wall; extending said first part of the cylinder in a direction away from said second part of the cylinder for creating a center piece; cold forging an entire outermost perimeter of the center piece for defining a second solid, raised wall; extending the first solid, raised wall to define an annular recess having a depth; and wherein the first part, second part, center-piece, first solid raised wall, and second solid raised wall are all integrally connected as a single piece. In yet another embodiment, there is a further step of extending the second solid raised wall to define an annular recess having a depth. In yet another embodiment, there is a further step of extending a bore in the center-piece from a first end of the center-piece to a point between the first end and a second end of the center-piece. In yet another embodiment, the method of providing a solenoid housing includes a step of extending a third part of the cylinder away from the first and second parts. In yet another embodiment, there is a further step of extending a flange from the first solid raised wall.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The features of the invention believed to be novel and the elements characteristic of the invention are set forth with particularity in the claims. The figures are for illustration purposes only. The invention itself, however, both as to organization and method of operation, may be understood by reference to the detailed description which follows taken in conjunction with the accompanying drawings in which the drawings show typical embodiments of the invention and are not intended to be limited of its scope.

[0017] FIG. **1** shows a method of providing a solenoid housing consistent with one embodiment of the instant invention.

[0018] FIG. **2** shows a further embodiment of the method of providing a solenoid housing from FIG. **1**.

[0019] FIG. **3** shows a method of providing a solenoid housing consistent with one embodiment of the instant invention.

[0020] FIG. **4** shows a further embodiment of the method of providing a solenoid housing from FIG. **3**.

[0021] FIG. **5** shows a further embodiment of the method of providing a solenoid housing from FIG. **3**.

[0022] FIG. **6** shows a further embodiment of the method of providing a solenoid housing from FIG. **5**.

[0023] FIG. **7** shows a further embodiment of the method of providing a solenoid housing from FIG. **3**.

[0024] FIG. **8** shows a further embodiment of the method of providing a solenoid housing from FIG. **2**.

[0025] FIG. **9** shows a further embodiment of the method of providing a solenoid housing from FIG. **3**.

[0026] FIG. **10** shows a flowchart depicting the production of a solenoid housing consistent with the method as depicted in FIG. **1**.

[0027] FIG. **11** shows a flowchart depicting the production of a solenoid housing consistent with the method as depicted in FIG. **3**.

[0028] FIG. **12** shows a flowchart depicting the production of a solenoid housing consistent with the method as depicted in FIG. **3**.

[0029] FIG. **13** shows a flowchart depicting the production of a solenoid housing consistent with the method as depicted in FIG. **6**.

[0030] FIG. **14** is a side view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0031] FIG. **15** is a side view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0032] FIG. **16** is a side view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0033] FIG. **17** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0034] FIG. **18** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0035] FIG. **19** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0036] FIG. **20** is a side-view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0037] FIG. **21** is a side-view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0038] FIG. **22** is a side-view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0039] FIG. **23** is a side-view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0040] FIG. **24** is a side-view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0041] FIG. **25** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0042] FIG. **26** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0043] FIG. **27** is a top-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0044] FIG. **28** is s a flowchart depicting the production of a solenoid housing consistent with the method as depicted in FIG. **1**.

[0045] FIG. **29**A is a bottom-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0046] FIG. **29**B is a bottom-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0047] FIG. **29**C is a bottom-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

[0048] FIG. **29**D is a bottom-down view of an embodiment consistent with the method of providing a solenoid housing from FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

[0049] In describing the various embodiments of the instant invention, reference will be made herein to FIGS. **1-29** in which like numerals refer to like features of the invention.

[0050] The instant invention generally relates to an improved method of making a solenoid housing, including fabrication of features such as the center pole for providing a path along which an armature will actuate and an outer cup enclosing the center pole as well as a space in which a solenoid coil will be held. In one embodiment of the instant invention, a cold-forging method has been found which allows for simplified fabrication of the solenoid as a one-piece construction from a single billet of malleable material. This embodiment is shown in FIG. **1**, which depicts the step of providing **100** a cylinder of malleable material having a part. The cylinder is comprised of any malleable material suitable for use as a solenoid housing. In some embodiments, the malleable material is a low carbon steel. Herein, the cylinder of malleable material and all method steps for modifying said cylinder of malleable material will be described and portrayed as having a basic, curved cylindrical shape; that is to say that the ends of the cylinder are circles. However, the specific shape of the cylinder is not meant to be limited to this embodiment. In other embodiments, the outline of the cylinder is selected from the group consisting of a square, rectangle, triangle, pentagon, hexagon, octagon, polygon, and combinations thereof. The specific shape of the cylinder of malleable material is a design choice well within the abilities of one of ordinary skill in the art. In some embodiments, the part is provided as a region at or near the one of the ends of the cylinder of malleable material. In a further embodiment, the cylinder can be defined as having a first part and a second part, wherein the first part is subjected to the various cold-forging and machining steps that will be described herein, and the second part is in most cases held immobile.

[0051] After the cylinder is provided **100**, a flange is extended **110** from the part. In one embodiment, this is performed by compressing part of the cylinder in a direction towards the remainder of the cylinder and holding said remainder of the cylinder of malleable material stationary in a form which only allows movement by the material comprising the part. In some embodiments, the flange is a raised perimeter which extends from the part in an axial direction, a radial direction, or both. In one embodiment, the flange expands to provide a constant perimeter around a circumference of the part.

[0052] At least a portion of the part is then raised **120** to form a raised wall. In some embodiments, the first part is raised by immobilizing a portion of the cylinder in a form and compressing the part in a direction towards the remainder of the cylinder with a die having a smaller diameter than the cylinder itself. When axially aligned with the cylinder of malleable material, compression of the die into the part forces material to extrude upwards around the outer edges of the die itself. The form, meanwhile, substantially prevents movement of the remainder of the cylinder of malleable material. The result of this compression step is a raised wall which extends the more the die compresses the part. The height of the raised wall is a function of the amount of material in the cylinder and the desired design of the solenoid housing. After raising step **120**, the cylinder has been transformed into a hollow, cup-shaped housing with a flange around the top and a base of some thickness at the bottom.

[0053] A center pole is then raised **130** from the part. An annular die is used to raise this center pole from the material within the hollow, cup-shaped housing itself. Compression of the part in raising step **120** as described above moved the part of the cylinder to the bottom or floor of the hollow cup. In raising step **130**, a hollow die again compresses the part. Material displaced by the compression in raising step **130** is extruded through the cavity within the hollow die in a direction opposite the direction of compression. The compression step continues until the center pole is raised to the desired height.

[0054] FIG. **10** is provided to pictorially demonstrate an embodiment of method steps **100-130** from FIG. **1**. For the purposes of disclosing the following embodiment, the cylinder of malleable material will be described has having a first part and a second part. However, this description is not meant to provide any additional limitations into the embodiments described above or as claimed. In this embodiment, cylinder of malleable material **1** is subjected to force A at first part **1000** in a direction towards second part **1001**. By immobilizing second part **1001** and a desired length of cylinder **1**, first part **1000** is extended in directions B, resulting in flange **1002**. A force C, brought by a die (not pictured) having a diameter which is less than that of cylinder **1**, causes a section of first part to extend in a direction D and produce a first-part raised wall **1003**, while the remainder of first part **1000** is compressed towards second part **1001**. Center pole **1004** is then created by application of a force E by a hollow die (not pictured). Again, with second part **1001** held stationary, material displaced by said annular die will cause first part **1000** to extend in a direction F. In one embodiment, first annular recess **1005** which results from this method step becomes the receptacle for the solenoid coil (not pictured).

[0055] In one embodiment as shown in FIG. **10**, flange **1002** is generally perpendicular to first raised wall **1003**. This embodiment offers the most control over dictating a flow of energy through the solenoid housing because it allows the greatest disbursement of magnetic energy in a radial direction away from the solenoid housing after passing through the first raised wall **1003** and contributes to the best life expectancy of the solenoid housing. Flange **1002** includes other angles between approximately 0° and approximately 180° with respect to first raised wall **1003**. In one embodiment, flange **1002** includes an angle approximately 30° with respect to first raised wall **1003**. This embodiment slightly disburses the flow of magnetic energy in a direction radially away from the solenoid housing and helps contribute to a much longer life-expectancy of the solenoid housing. In one embodiment, flange **1002** includes an angle approximately 60° with respect to first raised wall **1003** for moderately disbursing the flow of magnetic energy in a direction radially away from the solenoid housing but results in a slightly longer life-expectancy. In another embodiment, flange **1002** includes an angle at approximately 120° with respect to first raised wall **1003** for slightly disbursing magnetic energy in a direction axially away from the solenoid housing helps contribute to a slightly longer life-expectancy of the solenoid housing. In another embodiment, flange **1002** includes an angle at approximately 150° with respect to first raised wall **1003** for moderately disbursing magnetic energy in a direction axially away from the solenoid housing helps contribute to a much longer life-expectancy of the solenoid housing.

[0056] Flange **1002** may include a plurality of angles. In a preferred embodiment as shown in FIG. **15**, flange **1002** includes two angles with respect to first raised wall **1003**. In one embodiment as shown in FIG. **15**, first angle **2200** is smaller than second angle **2300** and is ideal for directing the flow of magnetic energy axially away from the solenoid housing. Second angle **2300** is greater than first angle **2200** and is ideal for directing the flow of magnetic energy radially away from the solenoid housing. In this embodiment where first angle **2200** is smaller than second angle **2300**, there is a greater need for magnetic energy to flow radially away from the solenoid housing while still maintaining some axial flow of magnetic energy away from the housing. In other embodiments, first angle **2200** is greater than second angle **2300**. In this embodiment, there is a greater need to direct the flow of magnetic energy radially away from the solenoid housing while still maintaining some axial flow away from the solenoid housing.

[0057] In one embodiment, before or after at least one of method steps **110**, **120**, and **130**, cylinder **1** is annealed **160**. The annealing step **160** is performed to reduce stress on the malleable material during each of these steps, lessening the risk that the material will become brittle and liable to crack or fail in subsequent cold-forging steps. In some embodiments, annealing step **160** is performed by heating cylinder **1** to approximately 850° C., allowing said cylinder **1** to stay at that temperature before cooling said material to 720° C., and subsequently allowing said cylinder **1** to stay at that temperature before cooling cylinder **1** down to room temperature. In one embodiment, an annealing step is performed before and after each of method steps **110**, **120**, and **130**.

[0058] In some embodiments, center pole **1004** created by method step **130** is modified to provide a path through which an armature is actuated. As depicted in FIG. **1**, a bore **1105** is machined **140** into said center pole **1004** to produce a center-pole raised wall **2500**. In alternative embodiments, the bore **1105** is provided via a cold-forging step, or a combination of a cold-forging step and a machining step.

[0059] In a further embodiment, the center-pole raised wall **2500** is provided **150** with a non-magnetic region. The non-magnetic region is used to approximate an air gap and generate the force which actuates an armature through the solenoid assembly. In one embodiment, the air gap is approximated by providing **200** said center-pole raised wall with a perforated region, providing **210** said center-pole raised wall with a region comprised of non-magnetic material, or providing **220** said center-pole raised wall with a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the center-pole raised wall **2500**, and combinations thereof.

[0060] In one embodiment, providing step **220** is performed by reducing the cross-sectional area of said region to be approximately 5-25% of the cross-sectional area of the remainder of the center pole raised wall **2500**. In a further embodiment, the cross-sectional area of the region is reduced **800** to be approximately 10-20% of the cross-sectional area of the center-pole raised wall **2500**, as depicted in FIG. **8**. Providing non-magnetic regions within these ranges strikes an optimal balance between performance and manufacturing ease and time. As has been previously discussed, the non-magnetic region on the center-pole raised wall approximates an air gap to facilitate movement of an armature through the solenoid assembly. The relative saturation of the air gap to its surroundings creates an electromotive force which acts upon the armature within the solenoid assembly. Due to air's high magnetic reluctance, an actual air gap saturates immediately. In the instant embodiment, thinning a region of the center-pole raised wall **2500** creates an air gap analogue by reducing said region's ability to hold magnetic flux. The magnetic reluctance of region is effectively increased, the result being that the magnetic flux saturates much quicker through the thin-walled region than the remainder of the center-pole raised wall.

[0061] When the center-pole raised wall **2500** is thinned to a width of about 30% or higher, said region remains permeable enough for magnetic flux so as to be an unsuitable air gap analogue; performance of the solenoid suffers significantly. The resulting electromotive force is weak and the response time delayed, sacrifices which are not offset by the ease of manufacturing gained by eliminating the complicated air gap fabrication process. However, by thinning the cross-sectional area of a region on the center-pole raised wall to approximately 5-25%, and more particularly to approximately 10-20%, the air gap is approximated to a degree such that performance closely mirrors that of an actual air gap. Non-magnetic regions with a cross-sectional area of approximately 25% that of the remainder of the center-pole raised wall provide a sufficient analogue to an air gap. However, performance increases are achieved with walls approximately 20% the cross-sectional area of the remainder of the center-pole raised wall or lower. Further, these thin walls of approximately 20% the cross-sectional area of the remainder of the center-pole raised wall maintain the increased structural rigidity and durability inherent in the substantially continuous path along which the armature may actuate. A one piece construction is significantly more resistant to misalignment than a two piece construction and results in a longer operational lifetime.

[0062] Complications arise when the relatively thin walls of the non-magnetic region are fabricated to widths less than 5% of the remainder of the center-pole raised wall. As thinner and thinner walls are achieved, the likelihood of introducing structural weaknesses to the solenoid housing increases. When producing walls with widths less than 5% of the remainder of the center-pole raised wall, there is a significant increase in the likelihood that the forces exerted on the solenoid housing by the fabrication method itself will result in warping or fracturing of the center pole. A solenoid which suffers this warping or fracturing is inoperable and must be rejected. By manufacturing the non-magnetic region at widths of 5% or above, however, the housing retains sufficient structural rigidity to survive the fabrication process, resulting in a low rate of failure during production. The rate of failure decreases even further when the center-pole raised wall is provided at a width greater than 10%. Levels of performance for those solenoid housings with non-magnetic regions between 10-20% remain acceptably high compared to their air gap analogues.

[0063] FIG. **3** depicts another embodiment of the instant invention for providing a solenoid housing comprising a step of providing **300** a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter. As described above, the cylinder of malleable material may be comprised of any suitable material and any suitable shape. In one embodiment, the malleable material is low carbon steel.

[0064] In some embodiments, the method of the instant invention comprises the step of reducing **310** a size of the first-part perimeter to be less than a size of the second-part perimeter. At least a portion of the second part is then compressed **320** in a direction towards the first part. In one embodiment, such as the one depicted in FIG. **4**, compression step **320** provides **410** a flattened disk to said second part, provides **400** a protrusion on said second part, or both. Steps **310** and **320** are advantageous with certain sizes of starting billet cylinders of malleable material. Whether method steps **310** and **320** are advantageous is determined by the ratio of the axial length of the cylinder (L) to the width of the cylinder (D), or the value of L/D. Where the cylinder is provided with an L/D of less than or equal to 2, the above method steps **310** and **320** are useful. FIG. **11** pictorially shows method steps **310** and **320**, as well as an alternative embodiment where L/D is greater than 2. In this latter embodiment, second part **1001** is compressed upwards towards first part **1000**, with the displaced matter of cylinder **1** forced into a generally conical formation. Further compression of the second part in a direction of the first part with an appropriately shaped die (not pictured) yields the same housing conformation as that from method steps **310** and **320**, including flattened disk **1108** and protrusion **1103**. In some embodiments, protrusion **1103** is a stabilizing feature in subsequent fabrication steps, as will be discussed below. These two methods allow for greater freedom when selecting the starting cylinder of malleable material for performing the instant invention.

[0065] A non-magnetic region is then provided **330** on said cylinder **1**. As previously described in connection with FIG. **2**, in one embodiment the non-magnetic region is provided through use of a perforated region, a region comprised on non-magnetic material, a region with a smaller cross-sectional area than the cross-sectional area of the remainder of cylinder **1**, and combinations thereof. In one embodiment, production of the non-magnetic region begins by providing a notch about the circumference of cylinder **1**. A bore is then extended **340** through said first part **1000** in a direction towards said second part **1001**. In one embodiment, said bore is extended a distance from said first part towards said second part such that said bore goes beyond the non-magnetic region.

[0066] This series of steps is best exemplified in FIG. **11**. In one embodiment, the notch **1104** is provided to cylinder **1** through a cold-forging method, a machining method, or a combination of both. The depth and shape of notch **1104** is a matter of design choice. A bore **1105** is applied and extended to some distance beyond notch **1104**. In one embodiment, bore **1105** is extended via a machining step. In a further embodiment, bore **1105** is extended substantially all the way through cylinder **1**. The width of bore **1105** is a matter of design choice and depends heavily on the armature to be utilized in the solenoid and the depth of notch **1104**.

[0067] As described above, in one embodiment, the non-magnetic region is provided through use of a region with a smaller cross-sectional area than the remainder of cylinder **1**. The cross-sectional areas of the non-magnetic region and the remainder of cylinder **1** refer to the cross-sectional areas of **1106** and **1107** respectively after a bore is extended **340** in cylinder **1**. Bore **1105** turns cylinder **1** into a hollow tube at least as far as bore **1105** is made in cylinder **1**. In one embodiment, the cross-sectional area of non-magnetic region **1106** is at least 5-25% of the cross-sectional area of the remainder **1107** of cylinder **1**. In a further embodiment, the cross-sectional area of non-magnetic region **1106** is 10-20% of the cross-sectional area of the remainder **1107** of cylinder **1**. In other embodiments, notch **1104** is filled with non-magnetic material, such as aluminum-bronze. In these embodiments, the cross-sectional area of region **1106** is advantageously reduced to zero or at least near zero. Region **1106** is therefore exclusively non-magnetic material in this embodiment, with the original malleable material of cylinder **1** completely removed.

[0068] In much the same way as described above, in some embodiments, the solenoid housing is annealed **370** before or after at least one of the steps of **300**, **310**, **320**, **330**, and **340**. In a further embodiment, annealing step **370** occurs before and after each of steps **310**, **320**, **330**, and **340**.

[0069] In one embodiment, a cup is provided **350** for assembly with or placement around cylinder **1**. In some embodiments, such as the embodiment shown in FIG. **7**, the cup is provided by a cold-forging method. In this embodiment, a sheet of malleable material is provided **700**. A perimeter of the sheet is then raised **710** to produce a raised perimeter. In some embodiments, said raised perimeter extends around at least a portion of said sheet of malleable material. In a further embodiment, the raised perimeter extends around the entire perimeter of the sheet. The raised perimeter is then extended **720** to define a cup with a base. A recess is then provided **730** is said base of said cup. In one embodiment, the recess is provided by a punching method or a machining method. The size of the recess is a matter of design choice. However, the purpose of the recess is to accept the protrusion provided in method step **400**, as will be discussed below. Therefore, the recess is at least large enough to accept the protrusion. In further embodiments, the perimeter of the recess is also smaller than the perimeter of the flattened disk.

[0070] In one embodiment, a flange is then expanded **740** on said raised perimeter. In some embodiments, expansion step **740** provides a flange by expanding the material already present in said raised perimeter. In further embodiments, expansion step **740** is combined with a step of removing excess material from the raised perimeter (not pictured). Excess material is removed to produce a solenoid housing with the desired shape or dimension. In one embodiment, for example, excess material is removed from the cup such that the heights of the cup and the cylinder of malleable material are approximately the same.

[0071] In another embodiment, as depicted in FIG. **9**, the cup is provided **900** through a machining method which machines a cup-bore into a cylinder of suitable material.

[0072] The cup provides the outer housing for the solenoid assembly, encloses the solenoid coil, and provides protection for the coil and armature assembly. The shape and size of the sheet of malleable material is a matter of design choice and greatly depends on the shape of cylinder **1** and the intended use of the solenoid itself.

[0073] The application of the cup to cylinder **1** is pictorially demonstrated in FIG. **12**. As can be seen in this figure, cylinder **1** has already been provided with bore **1105**, non-magnetic region **1106**, and protrusion **1103**. Cup **1200** is provided with an inner diameter at least large enough to accept flattened disk **1108**. In some embodiments, the outer diameter of flattened disk **1108** and the inner diameter of cup **1200** are essentially equal to ensure a tight fit between the two pieces. Cup **1200** is also provided with a recess **1201**. In some embodiments, recess **1201** is at least large enough to accept all of protrusion **1103**. In one embodiment, protrusion **1103** has a length greater than the depth of recess **1201**. As depicted in FIG. **12**, cup **1200** is inserted along direction G so as to fit snuggly around cylinder **1**.

[0074] The interaction between recess **1201** and protrusion **1103** holds cylinder **1** and cup **1200** in alignment. In one embodiment, cup **1200** and cylinder **1** are then held in place via a riveting step, a press fitting step, an assembling step, and the like, as seen in FIG. **5**. In one embodiment, cup **1200** is attached through a riveting method as shown in FIG. **6**, which provides a more secure and permanent fit between the two pieces. In this embodiment, protrusion **1103** is inserted **600** into recess **1201** and the perimeter of protrusion **1103** is compressed **610** in a direction towards first part **1000**, such as via a cold-forging method. In some embodiments, compression step **610** enlarges the perimeter to a size larger than the perimeter of the recess (also known as the recess perimeter), thus preventing cup **1200** from disengaging from cylinder **1**. This embodiment is also depicted in FIG. **13**, where cup **1200** is already in place on cylinder **1**. Application of force H causes expansion of protrusion **1103** in direction I. The resulting protrusion-end perimeter **1300** holds cup **1200** securely in place and limits movement of cup **1200** in relation to cylinder **1**.

[0075] In another embodiment, cup **1200** and cylinder **1** are held together via a press-fitting step **510**. Press-fitting step **510** relies on the frictional interaction between the outer perimeter of protrusion **1103** and the inner circumference of recess **1201**. In yet another embodiment, cup **1200** and cylinder **1** are assembled **520**, and are kept stationary relative to each other by interaction with other components in the solenoid assembly or apparatus into which the solenoid assembly is incorporated.

[0076] As shown in FIG. **28**, another embodiment of the method comprises steps of providing **2000** a cylinder of malleable material having a first part and a second part, reducing **2010** the diameter of the first part of the cylinder to be less than the diameter of the second part of the cylinder, compressing **2020** the second part in an axial direction toward the first part, resulting in a flattened disc generally perpendicular to the first part; raising **2030** an entire outermost perimeter of the flattened disc in a direction toward the first part for defining a first raised wall; extending **2040** the first raised wall to define a first annular recess **1005** having a first depth; extending **2050** the first part in a direction away from the second part for creating a center piece; raising **2060** an entire outermost perimeter of the center piece for defining a second raised wall; extending **2070** a bore in the center piece; extending **2080** the second raised wall to define a second annular recess **1105** having a second depth; extending **2090** a third part of the solid cylinder away from the first and second parts; extending **2100** a flange from the first raised wall; orienting **2110** a plurality of grain lines of the flattened disc; orienting **2120** a plurality of grain lines of the first part; orienting **2130** a plurality of grain lines of the second part; orienting **2140** a plurality of grain lines of the third part.

[0077] In some embodiments, the compressing **2020** step resulting in a solid, flattened disc **1108**. In other embodiments, the flattened disc **1108** is hollow. In yet other embodiments, the flattened disc **1108** is generally perpendicular to the first and second parts. In yet other embodiments, the flattened disc **1108** is generally parallel to the first and second parts.

[0078] In some embodiments, the step of raising **2030** a first raised wall **1003** is performed by a method of cold forging. In other embodiments, the step is performed by a method of extruding. In yet another embodiment, step **2030** may be performed by compressing the first part in a first location toward the second part in an axial direction for defining the first raised wall **1003**. In some embodiments, the first raised wall **1003** is solid. In other embodiments, it is hollow.

[0079] In some embodiments, the step of extending **2050** the first part of the cylinder in a direction away from the second part of the cylinder creates center-piece **1004**. Center piece **1004** includes second raised wall **2500** as shown in FIGS. **17-25**. In other embodiments, this center piece **1004**

is of a generally circular shape. In yet other embodiments, the center piece **1004** is generally square shaped. In yet other embodiments, the center piece **1004** is generally triangle shaped. The center piece **1004** may be of any shape depending on the preference of the manufacturer and the objectives sought.

[0080] Center piece **1004** aids in directing the flow of magnetic energy through the base of the solenoid housing and into the first raised wall **1003**. The flow and direction of magnetic energy is dictated by the size and shape of center piece **1004**. In one embodiment, center piece **1004** has a bore **1105** as shown in FIGS. **20-25**. In yet other embodiments, center piece **1004** does not have a bore as shown in FIGS. **17-19** and is instead solid but still includes second raised wall **2500**.

[0081] Center piece **1004** may extend any distance from a first location of the second part to a point between the first location of the second part and an upper portion of the first raised wall **1003**. In one embodiment as shown in FIG. **20**, center piece **1004** extends approximately one-quarter of an axial length of the first raised wall **1003**. A center piece **1004** of approximately this axial length is best for distributing magnetic energy toward the first raised wall **1003**. In some embodiments, center piece **1004** extends approximately halfway between a first location of the second part and an upper portion of the first raised wall **1003**, which provides the best balance of retaining magnetic energy within the center piece **1004** and distributing magnetic energy toward the first raised wall **1003**. In yet other embodiments, center piece **1004** shares a generally even plane with the upper portion of first raised wall **1003**. A center piece **1004** that shares a generally even plan with the upper portion of first raised wall **1003** is best for retaining magnetic energy within the center piece **1004** and distributing very little magnetic energy toward the first raised wall **1003**.

[0082] In a further embodiment, the center-piece **1004** is provided **150** with a non-magnetic region. The non-magnetic region is used to approximate an air gap and generate the force which actuates an armature through the solenoid assembly. In one embodiment, the air gap is approximated by providing **200** the center piece **1004** with a perforated region, providing **210** the center piece **1004** with a region comprised of non-magnetic material, or providing **220** the center piece **1004** with a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the center piece **1004**, and combinations thereof.

[0083] In one embodiment, providing step **220** is performed by reducing the cross-sectional area of said region to be approximately 5-25% of the cross-sectional area of the remainder of the center piece **1004**. This range provides a substantial dampening in the flow of magnetic energy but is more difficult to achieve. In a further embodiment, the cross-sectional area of the region is reduced **800** to be approximately 10-20% of the cross-sectional area of the center piece **1004**, as depicted in FIG. **8**. This range provides less dampening of the magnetic energy than the 5-25% range but is easier to manufacture. Providing non-magnetic regions within these ranges strikes an optimal balance between performance and manufacturing ease and time.

[0084] In one embodiment, the first annular recess **1005** created by extending **2040** step has a first depth and the second annular recess **1105** created by extending **2060** step has a second step. In one embodiment, the first depth of first annular recess **1005** is substantially similar to the second depth of second annular recess **1105** as shown in FIGS. **20-22**. This embodiment is ideal for inhibiting the flow of magnetic energy from the center piece **1004** to the first raised wall **1003**. In another embodiment, the first depth of first annular recess **1005** is different from the second depth of second annular recess **1105** as shown in FIGS. **23-24**. This embodiment is ideal for distributing the flow of magnetic energy through from the center piece **1004** to the first raised wall **1003**.

[0085] In some embodiments, the step of raising **2060** a second raised wall **2500** is performed by a method of cold forging. In other embodiments, the step is performed by a method of extruding. In yet another embodiment, step **2060** may be performed by compressing the center-piece **1004** in a first location toward the second part in an axial direction for defining the second raised wall **2500**. In some embodiments, the second raised wall **2500** is solid. Second raised wall **2500** may extend any distance from a first location of the second part to a point between the first location of the second part to an upper portion of the first raised wall **1003**. In one embodiment as shown in FIG. **20**, second raised wall **2500** extends approximately one-quarter of an axial length of the first raised wall **1003**. Second raised wall **2500** of approximately this axial length permits the greatest amount of magnetic energy flow through the solenoid housing. In some embodiments, second raised wall **2500** extends approximately halfway between a first location of the second part and an upper portion of the first raised wall **1003**. Second raised wall **2500** of approximately this axial length permits some flow of magnetic energy but not the most possible. In yet other embodiments, second raised wall **2500** shares a generally even plane with an upper portion of first raised wall **1003**. Second raised wall **2500** that shares a generally even plan with an upper portion the first raised wall **1003** provides the greatest inhibitory effect of the magnetic flow and direction.

[0086] In some embodiments, step **2070** of creating a bore **1105** in the center piece is performed by a method of extruding. In other embodiments, it is performed by a step of compression. Bore **1105** may be extended **2070** from a first end of the center piece to a point between the first end and a second end of the center piece. In one embodiment as shown in FIG. **24**, bore **1105** is an indentation in a top surface of the center piece **1004**. In this embodiment, bore **1105** is best at distributing a flow of magnetic energy through the solenoid housing. In another embodiment, bore **1105** extends approximately one-third through the center piece. In this embodiment, bore **1105** is best at permitting a slight amount of magnetic energy flow through the solenoid housing. In another embodiment as shown in FIG. **23**, bore **1105** extends approximately halfway through the center piece and offers the best balance between retaining magnetic energy in the center piece **1004** and distributing it toward the first raised wall **1003**. In yet other embodiments as shown in FIGS. **20-22**, bore **1105** extends from the first end of the center piece to the second end of the center piece **1004**, allowing the greatest amount of magnetic energy flow through the solenoid housing.

[0087] In one embodiment, a third part **1103** is extended **2090** in a direction away from the first and second parts. Third part **1103** may be a solid protrusion as shown in FIGS. **11-12** and FIGS. **29**A-**29**D. In some embodiments, third part **1103** has a generally triangular shape as shown in FIG. **29**A.

In other embodiments, third part **1103** has a generally octagonal shape as shown in FIG. **29**B. In yet other embodiments, third part **1103** has a generally square shape as shown in FIG. **29**C. And in yet other embodiments, third part **1103** has a generally hexagonal shape as shown in FIG. **29**D. And in yet other embodiments, third part **1103** has a generally circular shape.

[0088] In one embodiment, third part **1103** has a circumference that is less than a circumference of the first raised wall **1003** as shown in FIGS. **29**A-**29**D. In yet another embodiment, third part **1103** has a circumference that is approximately equal to a circumference of the first raised wall **1003** as shown in FIGS. **11-12**. In yet another embodiment, third part **1103** has a circumference that is greater than a circumference of the first raised wall **1003**.

[0089] FIGS. **14-27** represent the physical embodiments of steps **2060**, **2070**, and **2080** for forming a second raised wall **2500**. In one embodiment as shown in FIGS. **25-27**, the second raised wall **2500** is shown to be a cylindrical cup, having a bore **1105** in the middle for accepting actuator assemblies and the like. However, in other embodiments, as shown in FIGS. **17-19** the second raised wall **2500** could be center piece **1004**, having no bore in the middle and remaining substantially solid throughout for substantially inhibiting magnetic flow. In one embodiment, the second raised wall **2500** is reverse extruded through a die. The specific size and shape of the die will determine the physical dimensions of the second raised wall **2500**, and the design and control of each of these variables is well within the ability of one of ordinary skill in the art. An additional embodiment could have the second raised wall **2500** fashioned using a machining method as is well known in the art. In this embodiment, there would be no need to raise the second part of the cylinder to define the raised wall or compress the second part of the cylinder with an annular die to create the raised wall. Instead, the second part of the cylinder would be machined away in the desired areas to define the second raised wall **2500**.

[0090] In a further embodiment, the second raised wall **2500** is provided **150** with a non-magnetic region. The non-magnetic region is used to approximate an air gap and generate the force which actuates an armature through the solenoid assembly. In one embodiment, the air gap is approximated by providing **200** the second raised wall **2500** with a perforated region, providing **210** the second raised wall **2500** with a region comprised of non-magnetic material, or providing **220** the second raised wall **2500** with a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the second raised wall **2500**, and combinations thereof.

[0091] In a further embodiment, the method orients a plurality of grain lines of the flattened disc to be in a generally radial direction extending outwardly from a general center of the flattened disc. In some of these embodiments, the method further orients a plurality of grain lines of the first part to be in a generally axial direction extending along a length of the first part. Orienting the plurality of grain lines of the flattened disc in a generally radial direction further facilitates transmission of the electromagnetic field because the electromagnetic field passes along the generally radial direction of the grain lines as the energy moves toward either raised wall. The grain lines may be oriented in a randomized, perpendicular, or angular relation relative to the travel of the electromagnetic field, in which case the grain lines inhibit the flow of the electromagnetic field rather than facilitate the flow.

[0092] Once again, it is contemplated that the features of the solenoid housing may be provided in any particular order. Reversing these steps will not substantively change the integrated valve sleeve produced by the instant method.

[0093] While the present invention has been particularly described, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications, and variations as falling within the true scope and spirit of the present invention.

What is claimed is:

1) A method of providing a solenoid housing, comprising the steps of:

providing a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter;

reducing a size of the first-part perimeter to be less than a size of the second-part perimeter;

compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk;

providing said cylinder of malleable material with a non-magnetic region; and

extending a bore from said first part toward said second part to at least a distance beyond said non-magnetic region.

2) The method of providing a solenoid housing according to claim **1**, wherein the step of compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk also comprises the following step:

providing a protrusion on said second part.

3) The method of providing a solenoid housing according to claim **2**, further comprising a step of:

providing a cup around said cylinder of malleable material.

4) The method of providing a solenoid housing according to claim **3**, wherein the step of providing a cup around said cylinder of malleable material further comprises the steps of:

providing a sheet of malleable material;

raising a perimeter of said sheet to produce a raised perimeter;

extending said raised perimeter to define a cup with a base;

and providing a recess in said base of said cup.

5) The method of providing a solenoid housing according to claim **3**, wherein the cup is provided by machining a cup-bore into a cylinder.

6) The method of providing a solenoid housing according to claim **3**, wherein the step of providing a cup around said cylinder of malleable material is performed by a method selected from the group consisting of:

assembling, riveting, press-fitting, and combinations thereof.

7) The method of providing a solenoid housing according to claim **4**, wherein the step of providing a cup around said cylinder of malleable material is performed by a riveting method and further comprises the steps of:

inserting said protrusion into said recess; and

compressing said protrusion in a direction towards the first part.

8) The method of providing a solenoid housing according to claim **7**, further comprising the step of:

providing said cylinder of malleable material with a non-magnetic region selected from the group consisting of:

a perforated region, an area comprised of non-magnetic material, a region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of the cylinder of malleable material, and combinations thereof.

9) The method of providing a solenoid housing according to claim **1**, wherein a step of annealing the solenoid housing is performed following at least one of the following steps:

providing a cylinder of malleable material having a first part and a second part, said first part having a first-part perimeter and said second part having a second-part perimeter;

reducing a size of the first-part perimeter to be less than a size of the second-part perimeter;

compressing at least a portion of said second part in a direction towards said first part to produce a flattened disk;

providing said cylinder of malleable material with a non-magnetic region; and

extending a bore from said first part toward said second part to at least a distance beyond said non-magnetic region.

10) The method of providing a solenoid housing according to claim **8**, wherein the step of providing said cylinder of malleable material with said region wherein said region has a smaller cross-sectional area than a cross-sectional area of the remainder of said cylinder of malleable material further comprises the following step:

reducing said cross-sectional area of said region to be approximately 10%-20% of said cross-sectional area of the remainder of the cylinder.

11) A solenoid housing comprising:

a raised wall having a first end and a second end;

a center-piece having a first end and a second end;

a flattened disk at said second end of said raised wall and said second end of said center-piece; and

wherein said center-piece, flattened disk, and raised wall are formed of a one-piece construction.

12) The solenoid housing according to claim **11**, wherein said center-piece includes a bore.

13) The solenoid housing according to claim **11**, wherein said bore extends from said first end of said center-piece to a point between said first end and said second end of said center-piece.

14) The solenoid housing according to claim **11**, wherein said raised wall includes a flange.

15) The solenoid housing according to claim **14**, wherein said flange is generally perpendicular to said flattened disc.

16) A method of providing a solenoid housing, comprising the steps of:

providing a solid cylinder of malleable material having a first part and a second part;

reducing a diameter of said first part of the cylinder to be less than a diameter of said second part of the cylinder;

compressing said second part in an axial direction toward said first part, resulting in a flattened disc;

cold forging an entire outermost perimeter of said flattened disc in a direction toward said first part for defining a first solid, raised wall;

extending said first part of the cylinder in a direction away from said second part of the cylinder for creating a center piece;

cold forging an entire outermost perimeter of the center piece for defining a second solid, raised wall;

extending the first solid, raised wall to define an annular recess having a depth; and

wherein the first part, second part, center-piece, first solid raised wall, and second solid raised wall are all integrally connected as a single piece.

17) The method of providing a solenoid housing according to claim **16**, further comprising the step of:

extending the second solid raised wall to define an annular recess having a depth.

18) The method of providing a solenoid housing according to claim **16**, further comprising the step of:

extending a bore in the center piece from a first end of said center-piece to a point between said first end and a second end of said center-piece.

19) The method of providing a solenoid housing according to claim **16**, further comprising the step of:

extending a third part of said cylinder away from said first part and said second part.

20) The method of providing a solenoid housing according to claim **16**, further comprising the step of:

extending a flange from said first solid raised wall.

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