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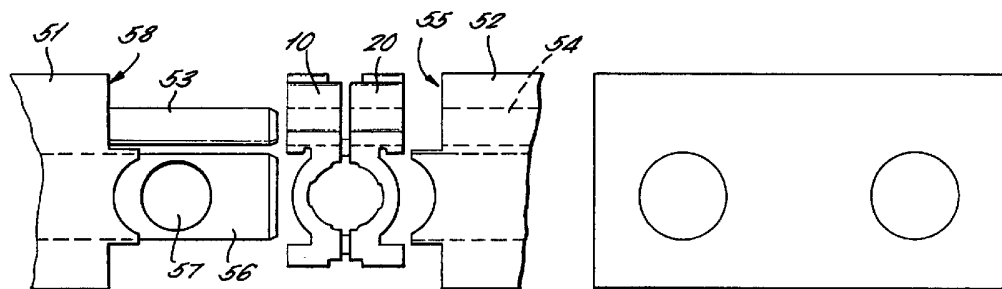
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(54) Title: A METHOD OF MANUFACTURE OF A METALLIC COMPONENT APPARATUS FOR USE IN THE METHOD AND METHOD OF FINISHING A METALLIC COMPONENT



(57) Abstract: The present invention provides, with reference to Figure 8, a method of manufacture of a metallic component(10) comprising casting the component (10) with a chosen shape and configuration; and engaging, in the absence of external heating, a die tool (53, 56) with a selected part of the cast component (10) whilst applying pressure to the cast component (10) to deform the component (10) so that in the region of the die tool (53, 56) the shape and configuration of the selected surface part is set by the die tool (53, 56). In the method the component (10) could be formed from wrought metal instead of cast. The present invention also relates to a method of forming a gear in which washers are forced against planar side surfaces of a gear wheel to deform the metal of the washers to flow into the indentations on the side surfaces of the gear wheel. Metal components manufactured by the method of the invention can be used in the manufacture of a gearbox, preferably along with a gear manufactured by the above-mentioned method. The present invention also provides apparatus for use in the methods of manufacture. The present invention further provides a method of finishing metallic components in which, in the absence of external heating, a ram is used to apply a force on an external surface of the components to deform the components whilst die spigots inserted through apertures in the components keep the apertures aligned.



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A Method of Manufacture of a
Metallic Component, Apparatus
for use in the Method and a
Method of Finishing a Metallic
Component

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The present invention relates to a method of
manufacture of a metal component, to apparatus for use
in the method and to a method of finishing a metallic
component.

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Casting is a good way of making metal components
in large numbers. However, the tolerance levels
achievable with casting processes are not always
suitable for certain engineering products , for
instance when axial alignment between apertures is
crucial. However, machining operations are generally
costly and complex and the machining of a previously
cast component removes much of the benefit of forming
the component by casting in the first place.

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The present invention provides in a first aspect
a method of manufacture of a metallic component
comprising: casting the component with a chosen shape
and configuration; and engaging, in the absence of
external heating, a die tool with a selected surface
part of the cast component whilst applying pressure to
the cast component to deform the component so that in
the region of the die tool the shape and configuration
of the selected surface part is set by the die tool.

30

Sometimes it is convenient in a manufacturing
process to take a shaped component of wrought metal
and finish the process by machining the wrought metal
component. However, machining operations are time
consuming and expensive.

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- 2 -

The present invention provides in a second aspect a method of manufacture of a metallic component comprising: forming from wrought metal the component with a chosen shape and configuration; and engaging,
5 in the absence of external heating, a die tool with a selected surface part of the wrought metal component whilst applying pressure to the wrought metal component to deform the component so that in the region of the die tool the shape and configuration of
10 the selected surface part is set by the die tool.

The present invention provides in a third aspect a method of forming a gear comprising: machining a metal blank to form a component comprising a
15 cylindrical hollow shaft having a gear wheel integral therewith which extends radially outwardly from a midpoint of the shaft, the gear wheel having indentations provided on generally planar side surfaces thereof; sandwiching the gear wheel between a
20 pair of washers; and applying a pair of conical or frusto-conical end stops to the machined component to engage apertures at the ends of an axial passage through the machined component, the end stops acting to align the axis of the shaft with a chosen axis;
25 then applying a pair of tools to the washers to force the washers against the generally planar side surfaces of the gear wheel of the machined component to deform the metal of the washers to flow into the indentations on the side surfaces and thereby to secure the washers
30 on the gear wheel.

The present invention provides in a fourth aspect apparatus for use in the manufacture of metallic
35 components using a method as described above, the apparatus comprising: a first pair of aligned rams, one of which has extending forwardly from a front face

- 3 -

thereof a cylindrical spigot die and a blade die and the other of which has a bore and a slot in a front face thereof to receive respectively the spigot die and the spigot blade; and a second pair of aligned
5 rams, one of which has extending forwardly thereof a cylindrical spigot die and the other of which has a bore in a front face thereof to receive the spigot die; wherein the first pair of aligned rams are not aligned with the second pair of aligned rams; and the
10 die blade has an aperture through which the cylindrical spigot die of the ram of the second pair of rams can extend in use of the apparatus.

In a fifth aspect the present invention provides
15 a method of finishing first and second metallic components which in a finished product are attached to one another, the method being conducted prior to the attachment together of the components to form the finished product and the method comprising the steps
20 of: bringing together the first and second metallic components, each component having been previously formed with a desired shape and configuration; during the bringing together of the first and second metallic components aligning together first and second
25 apertures in the components to form a first pair of aligned apertures; during the bringing together of the first and second metallic components aligning together third and fourth apertures in the components to form a second pair of aligned apertures; inserting a first
30 die spigot through the first pair of aligned apertures; inserting a second die spigot through the second pair of aligned apertures; and, in the absence of external heating, using a ram to apply a force on an external surface of the first and second components
35 to deform the metal of the components whilst the previously inserted first die spigot ensures that the apertures of the first pair of aligned apertures

- 4 -

remain aligned and the previously inserted second die spigot ensures that the apertures of the second pair of aligned apertures remain aligned; withdrawing the die spigots after deformation of the metal has ceased; and separating the first and second components to be attached to each other later in the assembly of the finished product.

In all of the above aspects the present invention provides for the manufacture of engineering of high tolerance engineering products from previously die cast or wrought metallic components. This enables quick and cost effective manufacturing.

The present invention provides in a sixth aspect a gear for a gearbox, the gear comprising an externally toothed periphery and a threaded central bore therethrough, the internal thread of the central bore being flow formed.

The present invention will now be described by way an example of a method of manufacture of a gearbox and by way of an example of apparatus used in the method, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a die cast metallic component;

Figure 2 is a perspective view of a pair of die cast metallic components, including the component of figure 1, assembled together;

Figure 3 is a cross-section through a gearbox having a casing formed from the assembled metallic components of figures 1 and 2;

- 5 -

Figure 4 is a perspective view of the exterior of the gearbox of figure 3;

5 Figure 5 shows the gearbox of figures 3 and 4 in use;

Figure 6 shows a cross-section through a part of the arrangement of figure 5;

10 Figures 7,8,9,10,11,12,13,14 and 15 show successive stages in a method of cold deformation used to convert e.g. the die cast metallic component of figure 1 into a component suitable to form part of the casing of the gearbox of figures 3 and 4;

15 Figure 16 shows a cross-section through apparatus used to manufacture a gear of the gearbox illustrated in figures 3 and 4;

20 Figure 17a and 17b illustrate a modification of the apparatus of Figure 16.

Turning first to figure 1 there can be seen in the figure a die cast metallic component 10 prior to deformation thereof in a method according to the present invention(as described below). The component has a two integral cylindrical spigots 11,12. The spigots 11,12 extend perpendicularly away from a planar face 13 of the component and each spigot e.g. 11 has an outermost portion 14 of a first diameter and a root portion 15 of a larger diameter. The spigots are designed to engage in two apertures in a mirror-image component. The component 10 has two cylindrical apertures 16 and 17 for receiving spigots of the mirror-image component. Each aperture e.g. 16 has a first portion 18 of a first diameter (which matches the diameter of a root portion of a spigot) and a

- 6 -

second portion which is of a second smaller diameter (which matches the diameter of an outer portion of a spigot). The diameters of the portions of the apertures will be designed deliberately smaller than the diameters of the portions of the spigots so that the spigots must be deformed on insertion into the apertures and thereby form an interference fit.

Figure 2 shows the component 10 engaged with a mirror-image component 20, the spigots of one engaged in the apertures of the other. It can be seen that together the components form two pairs of aligned apertures, a pair of apertures 21 and 22 aligned with each other and a pair of apertures comprising aperture 23 and an aligned aperture (not shown in figure 2, but indicated at 25 in figure 3). The purpose of these apertures in a gearbox 30 having a casing made from the components is seen in figure 3 where it can be seen that a worm gear 24 has ends journalled in the apertures 23 and 25. The worm gear 24 meshes with a rotating nut 27 the ends of which are journalled in the apertures 21,22. This is shown most clearly in figure 4. Thus the alignment with each other of the apertures of each pair of apertures is crucial.

Figures 5 and 6 show the gearbox 30 in use. A lead screw 26 is fixed at each end by a bracket ,e.g the bracket 28 in figure 6, to a slider 29 slidably mounted on a fixed rail 31. The gearbox 30 is secured in a compartment in the rail, typically with an elastomeric shroud surrounding the gearbox 30 and securing the gearbox 30 in place in the compartment in the fixed rail 31 whilst allowing for some relative motion therebetween to allow for some adjustment of alignments. The fixed rail 31 will be secured to a floor of a passenger compartment of an automobile and a car seat will be secured to the slider 29. The lead

- 7 -

screw passes through an aperture in the rotating nut 27 (see figure 3) and a screw thread on the exterior of the lead screw 26 engages a mating thread on the interior of the rotating nut 27. Rotation of the rotating nut causes linear motion of the lead screw and thereby sliding of the slider 29 and the seat mounted thereon. A flexible drive shaft 32 is shown in figure 5. This is connected at one end to an electric motor (not shown) and at the other end to the worm gear 24. Thus the worm gear 24 can be driven to rotate by the electric motor and thereby to drive the rotating nut 27 to rotate and the lead screw and the slider 31 to move linearly.

The die cast components e.g. 10 fresh from the die are not good enough in themselves to serve (without further treatment) as the parts of the casing of the gearbox 30. As mentioned above the alignment between the apertures needs to be precise. Also the inward facing surfaces of the apertures need to have a good surface finish to reduce friction between them and the components journalled in them. Furthermore the inwardly facing flat surfaces of the housing parts ,e.g. the surface 13 of the component 10, must act as reaction surfaces for end faces of the rotating nut and thus must be flat and regular and have a good surface finish. Furthermore there must be strict tolerance applied to the distance between the facing surfaces if the gearbox is to dispense with the need for spacers e.g washers interposed between the rotating nut and the reaction surfaces.

To achieve the necessary tolerances and surface finishes a pair of matched die cast components such as 10 are put through a cold deformation process as will now be described with reference to figures 7 to 15. The use of the term 'cold deformation' indicates that

- 8 -

the process takes place in the absence of external heating, although the deformation itself may generate some heat.

5 In figure 7 it can be seen that the two die cast components 10,20 are brought together to the point at which the root portions of the spigots just engage the perimeters of the matching apertures. The assembled components 10,20 are then engaged by two pairs of
10 sprung blocks 40,41 and 42,43. Each pair of blocks has a spring 44,45 acting between them. Initially each the blocks of each pair are brought together under the action of a pair of hydraulic rams, either 47,48 or 49,50 and then the springs 44,45 force them apart to
15 engage facing surfaces of the two components 10,20. The sprung blocks are mounted on rails e.g 46 and are slid along the rails by use of the hydraulic actuators to a working position in which they are engaged by latches. The hydraulic rams then force the sprung
20 blocks together to release the components 10,20 and the sprung blocks are withdrawn along the rails to pick up a next pair of die cast components.

Next , as shown in figure 8, a pair of hydraulic
25 rams 51,52 are brought together. The ram 51 has protruding therefrom a die spigot in the form of a cylindrical rod 53 which is advanced through the aligned apertures 23,25 of the components 10 and 20 and engages in a matching cylindrical bore 54 in an
30 end face 55 of the ram 52. The ram 51 also has protruding therefrom a die blade in the form of a plate 56 which is advanced through the gap defined between those parts of the components 10,20 which together form the apertures 21,22. The plate 56
35 engages in a matching slot in the end face 55 of the ram 52. The plate 56 has an aperture 57 which aligns with the apertures 21,22 when the plate 56 is fully

- 9 -

advanced. The end face 58 of the ram 51 has flat portions designed to engage flat end portions of the facing end surface of the component 10 and the ram 51 has arcuate portions designed to engage an arcuate portions of the facing end surface of the component 10. Similarly the end surface of the ram 52 has flat portions designed to engage flat end portions of the facing end surface of the component 20 and an arcuate portion designed to engage the arcuate facing end surface of the component 20. The plate 56 is a super finished die blade machined to a very close tolerance. The rod 53 is a super finished die spigot again machined to a very close tolerance.

Figure 9 shows portions of two more hydraulic rams 60,61. The ram 61 has a die spigot in the form of a cylindrical rod 62 protruding therefrom. As the two rams 60,61 are brought together the rod 62 extends through the apertures 21 and 22 and also through the aperture 57 in the plate 56 previously inserted in the gap between the frames forming the apertures 21,22. The cylindrical rod 62 extends into a bore in an end surface of the ram 60. The rams 60,61 have flat end surfaces which engage the flat end surfaces of the components 10,20. The cylindrical rod 62 is a super finished die spigot machined to a close tolerance.

Figure 10 is a view from below showing how the two pairs of hydraulic rams 51,52 and 61,62 are used. The ram 51 is first pushed forward to the illustrated position, inserting the plate 56 (shown in figure 10) and the rod 53 (not shown in figure 10) through apertures in the assembled components 10,20. Then the ram 52 is brought forward into position abutting the component 20, with the plate 56 sliding into a slot in the end face of the ram 52 and the rod 53 into a bore. Then the ram 61 is advanced with the rod 62 passing

- 10 -

through apertures in the assembled components 10,20 and the aperture 57 in the plate 56. Finally the ram 60 is advanced to engage the components 10,20 , with the rod 62 sliding into the bore in the end face of the ram 60.

Figure 11 shows that the hydraulic rams 60,61 are first used to apply equal and opposite pressure to deform the components 10,20 so that inward facing surfaces thereof engage faces of the die blade 56 and deform to a shape and spacing defined by the die blade 56. Then the hydraulic rams 51,52 are used to apply equal and opposite pressure on the components 10,20. The material of the components 10,20 is deformed so that the spigots e.g. 11,12 of one component e.g 10 are forced into the matching apertures of the other component e.g 20. This is best shown in figure 10. The material in the vicinity of the die spigot 62 deforms to take the shape of and be defined by the spigot 62 and thereby form journal pads for the rotating nut. This process gives a very good level of tolerance to the journal pads. The planar end surfaces are also deformed to take the shape of the facing ram surfaces and acquire a high dimensional tolerance in the process and a better surface finish and surface hardness. The contact areas between the rams 51,52 and the components 10,20 must be carefully proportioned to allow for local distortion of the planar faces 70,71,72 and 73 (see figure 12) whilst allowing full deformation and material flow in the formation of the journal pads.

One pair of hydraulic rams is used to apply pressure to the components 10,20 and then the other pair is used to apply pressure in a repeated manner, switching between the pairs of rams repeatedly over several cycles.

- 11 -

Figure 13 illustrates a next stage in the procedure. In this stage the ram 60 is retracted away from the components 10,20. A further small ram 80 is slidable in the bore in the ram 60 which receives the end of the die spigot 62. The further ram 80 and the die spigot 62 both have concave end surfaces. A carbide ball 81 is raised from a ball store into alignment with the ram 80 and the spigot 62 and then engaged by them. The carbide ball 81 has a diameter marginally greater than the diameter of the apertures 21,22 (but less than the diameter of the aperture 57). The ball 81 is forced through the apertures 21,22 by the hydraulic ram 80. The carbide ball 81 burnishes the journal pads provided by the peripheral surfaces of the apertures 21,22 giving the surfaces an improved finish and an improved hardness. Once it has passed through the apertures 21,22 then the ball 82 is released and drops back down into the ball store.

Figure 14 illustrates the penultimate stage in the procedure in which the ram 52 is retracted from engagement with the components 10,20. A ram 90 is slidable in the bore in the ram 52 which receives the die spigot 53. The ends of both the ram 90 and the die spigot 53 are concave. A carbide ball 91 is raised from a ball store into alignment with the ram 90 and the die spigot 53. The ram 90 is advanced to trap the carbide ball 91 between the ram 91 and the die spigot 53. The ram 90 is then further advanced (with the die spigot 53 simultaneously retracted) so that the ball 91 is forced through the apertures 23,25. The ball has a diameter marginally greater than the diameter of the apertures 23,25. The carbide ball burnishes the bearing surfaces of the apertures to improve the surface finish and the surface hardness.

Finally, as shown in figure 15, the hydraulic

- 12 -

rams 51,52 and 60,61 are all withdrawn and the components 10,20 forcibly separated. At this stage the components are suitable for use as the two halves of the casing of the gearbox. The alignment of the apertures 23,25 has been assured by the deformation of metal onto the die spigot 53. The diameters of the apertures 23,25 are assured to a very close tolerance. The inner surfaces of the apertures are burnished to high degree of surface finish and thus provide good bearing surfaces to receive the ends of the worm gear 24. The spacing between the two inner surfaces of the casing which act as the thrust surfaces for rotating nut 27 is assured to a high tolerance by the deformation of the surfaces against the die blade 56. The diameters of the apertures 21,22 are defined to close tolerances by the deformation of material against the die spigot 62. The inner surfaces of the apertures 21,22 are burnished and have a good surface finish and surface hardness and thus make good journal pads for the ends of the rotating nut 27.

The worm gear 24 and the rotating nut are placed between the two deformed components 10,29 along with a suitable grease and the components are then secured together with the spigots of each engaging in the apertures in the other.

The good dimensional tolerances of and the good surface finishes of the casing parts enable the construction of a seven piece gearbox. The gearbox is a reduction gearbox stepping down a rotational speed of e.g. 3200 rpm of an electric motor to a lower speed of revolution of the lead screw.

The deformation of the material of the components 10,20 is plastic deformation. However, during the forming process various components such as

- 13 -

the ram surfaces, the die spigots and the blade spigot will deform elastically. This elastic deformation must be taken into account in creating these components to ensure that accuracy in the dimensions of the finished parts is achieved.

The process described above is conducted without application of heat to the components 10,20 and is essentially a cold deformation process. Internal stresses can build up in the components 10,20. To avoid these stresses leading to fatigue problems in the finished product it may be desirable to anneal the components.

Whilst above the process is conducted on cast components, the process is also suitable for use to finish components initially made from wrought metal.

Figure 16 shows apparatus for forming a rotatable nut 27 suitable for use in the gearbox described above. The nut 27 is formed by first machining a steel blank to form a component having a cylindrical shaft with an integral gear wheel extending radially from a midpoint of the shaft. External teeth are rolled on to the peripheral surface of the gear wheel. A bore is machined through the cylindrical shaft and tapped and case hardened. Alternatively and preferably, the internal thread in the bore through the shaft is flow formed. The gear wheel has a pair of generally planar side surfaces which are provided with radially extending indentations.

The machined blank is next sandwiched between a pair of steel or bronze washers 107,108 and the assembly of blank and washers is located on a conical end stop 100 which protrudes into the axial passage passing through the component 27. A second conical end

- 14 -

stop 101 is provided on a sprung member 102 slidably mounted in a ram 103. The sprung member is biased forwardly of the ram by a spring 104. As the ram 103 is advanced the conical end stop 101 engages the component 27 by engaging in an aperture in an end surface opening on to the inner passage therethrough. The two conical end stops 100 and 101 act to centre the component 27 precisely in place in the machine tool.

The hydraulic ram 103 continues to advance, with the sprung member 102 retracting into the ram 103 against the biasing force of the spring 104. Eventually a tool 105 mounted on the ram 103 engages the washer 107 and a tool 106 engages the other washer 108. The tools 105,106 cause local deformation of the material of the washers 107,108 the material of which flows into the indentations on the planar side surfaces of the gear wheel of the component. The washers 107,108 are thus fixed to the component 27.

In a modification of the figure 16 apparatus is shown in figures 17a and 17b. In the modification both of the conical end stops 100 and 101 are mounted on sprung biased slidable members in an identical fashion, although for simplicity only the member 102 is illustrated. In figure 17a it can be seen that in addition to the biasing spring 104 there is provided a cup spring 109. For the initial movement of the member 102 relative to the ram 103 the cup spring 109 does not impinge on the member 102. However, the cup spring 109 does come into play for the last part of the motion of the member 102. The cup spring 102 will be a stiff spring. Under the influence of cup spring both of the conical end stops 100,101 will apply radially outward forces on the skirts 110 and 111 of the rotating nut 27. These forces will cause the material

- 15 -

of the skirts to expand radially so that the exterior diameter of the skirts is set exactly to the diameter of bores in the tools 105 and 106.

5 By using the apparatus of figures 16,17a and 17b the rotating nut 27 can be provided with thrust washers 107,108 which provide surfaces engageable with reaction surfaces of the gearbox casing, the washers being composed of a material with good frictional and
10 wear characteristics.

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- 16 -

Claims

1. A method of manufacture of a metallic component comprising:

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casting the component with a chosen shape and configuration; and

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engaging, in the absence of external heating, a die tool with a selected surface part of the cast component whilst applying pressure to the cast component to deform the component so that in the region of the die tool the shape and configuration of the selected surface part is set by the die tool.

15

2. A method as claimed in claim 1 in which:

20

first and second components are cast each with a chosen shape and configuration;

the cast components are brought into abutment with each other whilst aligning with each other a first pair of apertures in the cast components;

25

a first die tool is inserted through both of the first pair of aligned apertures;

30

pressure is applied on an external surface of each of the pair of cast components in order to deform the metal of the components and in order to force a first interior surface part of each component against the previously inserted first die tool; and

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the first die tool is withdrawn after the application of pressure has ceased.

- 17 -

3. A method as claimed in claim 2 wherein:

the cast components when brought together bring into alignment a second pair of aligned apertures in the components;

the first die tool has an aperture therethrough which aligns with the second pair of aligned apertures when the first die part has been inserted through both of the first pair of aligned apertures;

a second die tool is inserted to through one of the second pair of aligned apertures, through the aperture in the first die tool and then through the other of the second pair of apertures;

pressure is applied to the external surface of each of the cast components to deform the metal of the components and to force a second interior surface part of each cast component against the second die part; and

the second die tool is withdrawn after the application of pressure has ceased and before the withdrawing of the first die tool.

4. A method as claimed in claim 3 wherein:

a first pair of aligned rams are used to apply pressure on first parts of the external surfaces of the cast components in order to force the first interior surface parts against the first die tool;

a second pair of aligned rams ,unaligned with the rams of the first pair, are used to apply pressure on second parts of the external surfaces of the cast components, the second external surface parts being

- 18 -

spaced from the first external surface parts, the second pair of aligned rams being used to force the second interior parts of the interior surfaces of the cast components against the second die part; and

5

the first and second pairs of rams are used sequentially with one pair of rams applying pressure for a first time period and the other set of rams applying pressure for a second later time period.

10

5. A method as claimed in claim 3 or claim 4 wherein the first pair of aligned apertures are aligned along a first axis and the second pair of aligned apertures are aligned along a second axis perpendicular to the first axis.

15

6. A method as claimed in any one of claims 3 to 5 wherein:

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the cast components when brought together bring into alignment a third pair of apertures in the components;

a third die tool is inserted through both of the third pair of aligned apertures; and

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pressure is applied to the exterior surfaces of the cast components to deform the metal of the components and to force third interior surface parts of the components against the third die tool; and

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the third die part is withdrawn after the application of pressure has ceased.

7. A method as claimed in claim 6 wherein the third die tool is a cylindrical spigot and the third interior surface parts are peripheral surfaces defining the third pair of aligned apertures and the

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- 19 -

apertures of the third aligned pair are circular in cross-section.

8. A method as claimed in any one of claims 3 to 7 wherein the second die tool is a cylindrical spigot and the second interior surface parts are peripheral surfaces defining the second aligned pair of apertures and the apertures of the second aligned pair are circular in cross-section.

9. A method as claimed in any one of claims 2 to 8 wherein the first die tool is a die blade having a pair of spaced apart flat side surfaces and the first interior surface parts of the cast components are forced against the flat side surfaces of the die blade in order to set accurately a spacing between the first interior surface parts by deformation of the metal of the components.

10. A method as claimed in any one of claims 2 to 9 wherein:

after deformation of the metal of the cast components by forcing of interior surfaces against one or more die tools, a ball is forced through at least one pair of aligned apertures, the ball having a diameter marginally greater than the diameter of the aligned apertures and the ball burnishing the peripheral surfaces defining the apertures.

11. A method of manufacture of a metallic component comprising:

forming form wrought metal the component with a chosen shape and configuration; and

engaging, in the absence of external heating, a die

- 20 -

tool with a selected surface part of the wrought metal component whilst applying pressure to the wrought metal component to deform the component so that in the region of the die tool the shape and configuration of the selected surface part is set by the die tool.

12. A method as claimed in claim 11 in which:

forming from wrought metal first and second components each with a chosen shape and configuration;

the wrought metal components are brought into abutment with each other whilst aligning with each other a first pair of apertures in the wrought metal components;

a first die tool is inserted through both of the first pair of aligned apertures;

pressure is applied on an external surface of each of the pair of wrought metal components in order to deform the metal of the components and in order to force a first interior surface part of each component against the previously inserted first die tool; and

the first die tool is withdrawn after the application of pressure has ceased.

13. A method as claimed in claim 12 wherein:

the wrought metal components when brought together bring into alignment a second pair of aligned apertures in the components;

the first die tool has an aperture therethrough which aligns with the second pair of aligned apertures when

- 21 -

the first die part has been inserted through both of the first pair of aligned apertures;

5 a second die tool is inserted to through one of the second pair of aligned apertures, through the aperture in the first die tool and then through the other of the second pair of apertures;

10 pressure is applied to the external surface of each of the wrought metal components to deform the metal of the wrought metal components and to force a second interior surface part of each wrought metal component against the second die part; and

15 the second die tool is withdrawn after the application of pressure has ceased and before the withdrawing of the first die tool.

20 14. A method as claimed in claim 13 wherein:

a first pair of aligned rams are used to apply pressure on first parts of the external surfaces of the wrought metal components in order to force the first interior surface parts against the first die tool;

25 a second pair of aligned rams ,unaligned with the rams of the first pair, are used to apply pressure on second parts of the external surfaces of the wrought metal components, the second external surface parts being spaced from the first external surface parts, the second pair of aligned rams being used to force the second interior parts of the interior surfaces of the wrought metal components against the second die part; and

35 the first and second pairs of rams are used

- 22 -

sequentially with one pair of rams applying pressure for a first time period and the other set of rams applying pressure for a second later time period.

5 15. A method as claimed in claim 13 or claim 14 wherein the first pair of aligned apertures are aligned along a first axis and the second pair of aligned apertures are aligned along a second axis perpendicular to the first axis.

10

16. A method as claimed in any one of claims 13 to 15 wherein:

15

the wrought metal components when brought together bring into alignment a third pair of apertures in the components;

20

a third die tool is inserted through both of the third pair of aligned apertures; and

25

pressure is applied to the exterior surfaces of the wrought metal components to deform the metal of the components and to force third interior surface parts of the components against the third die tool; and

30

the third die part is withdrawn after the application of pressure has ceased.

17. A method as claimed in claim 16 wherein the third die tool is a cylindrical spigot and the third interior surface parts are peripheral surfaces defining the third pair of aligned apertures and the apertures of the third aligned pair are circular in cross-section.

35

18. A method as claimed in any one of claims 13 to 17 wherein the second die tool is a cylindrical spigot

and the second interior surface parts are peripheral surfaces defining the second aligned pair of apertures and the apertures of the second aligned pair are circular in cross-section.

5

19. A method as claimed in any one of claims 12 to 18 wherein the first die tool is a die blade having a pair of spaced apart flat side surfaces and the first interior surface parts of the wrought metal components are forced against the flat side surfaces of the die blade in order to set accurately a spacing between the first interior surface parts by deformation of the metal of the components.

10

15 20. A method as claimed in any one of claims 12 to 19 wherein:

after deformation of the metal of the wrought metal components by forcing of interior surfaces against one or more die tools, a ball is forced through at least one pair of aligned apertures, the ball having a diameter marginally greater than the diameter of the aligned apertures and the ball burnishing the peripheral surfaces defining the apertures.

20

25

21. A method of forming a gear comprising:

machining a metal blank to form a component comprising a cylindrical hollow shaft having a gear wheel integral therewith which extends radially outwardly from a midpoint of the shaft, the gear wheel having indentations provided on generally planar side surfaces thereof;

30

35 sandwiching the gear wheel between a pair of washers; and

5 applying a pair of conical or frusto-conical end stops to the machined component to engage apertures at the ends of an axial passage through the machined component, the end stops acting to align the axis of the shaft with a chosen axis; then

10 applying a pair of tools to the washers to force the washers against the generally planar side surfaces of the gear wheel of the machined component to deform the metal of the washers to flow into the indentations on the side surfaces and thereby to secure the washers on the gear wheel.

15 22. A method as claimed in claim 21 wherein:

the pair of tools each comprise a central aperture therethrough;

20 when the tools engage the washers then the end portions of the hollow shaft of the cast component are received in the central apertures of the tools; and

25 pressure is applied on the end stops to exert radial forces on the hollow shaft ends and to force them into engagement with the cylindrical surfaces defining the central apertures in the tools.

30 23. A method as claimed in claim 21 or claim 22 wherein the gear wheel has external teeth rolled on a peripheral surface thereof.

35 24. A method as claimed in any one of claims 21 to 23 wherein the washers are of a different metal to the machined component.

25. A method as claimed in any one of claims 21 to 24 wherein the machined component has an internal screw

- 25 -

thread flow formed on the surface defining the bore through the hollow shaft.

26. A gearbox comprising a casing made from metal components cast then deformed in the manner claimed in any one of claims 1 to 10.

27. A gearbox comprising a casing formed of metal components cast then deformed in the manner claimed in claim 6 , the gearbox comprising a worm gear journaled in the third pair of aligned apertures which meshes with a rotating nut journaled in the second pair of aligned apertures.

28. A gearbox as claimed in claim 27 wherein the rotating nut is made by the method of any one of claims 21 to 25.

29. A gearbox comprising a casing made from metal components formed from wrought metal then deformed in the manner claimed in any one of claims 11 to 20.

30. A gearbox comprising a casing formed of metal components made from wrought metal then deformed in the manner claimed in claim 16 , the gearbox comprising a worm gear journaled in the third pair of aligned apertures which meshes with a rotating nut journaled in the second pair of aligned apertures.

31. A gearbox as claimed in claim 30 wherein the rotating nut is made by the method of any one of claims 21 to 25.

32. Apparatus for use in the manufacture of metallic components using a method as claimed in claim 6 or claim 16, the apparatus comprising:

a first pair of aligned rams, one of which has extending forwardly from a front face thereof a cylindrical die spigot and a die blade and the other of which has a bore and a slot in a front face thereof to receive respectively the die spigot and the die blade; and

a second pair of aligned rams, one of which has extending forwardly thereof a cylindrical die spigot and the other of which has a bore in a front face thereof to receive the die spigot; wherein

the first pair of aligned rams are not aligned with the second pair of aligned rams; and

the die blade has an aperture through which the cylindrical die spigot of the ram of the second pair of rams can extend in use of the apparatus.

33. Apparatus for use in the method of manufacture of metallic components claimed in claim 12 or claim 22, the apparatus comprising:

a pair of opposed tools at least one of which is mounted on a ram, each of the tools having a central aperture therethrough;

a pair of spring biased conical or frusto-conical end stops extending one each through the central apertures in the tools and slidable relative to the tools to be retractable into the tools.

34. Apparatus as claimed in claim 33 wherein a pair of springs is used to bias each of the end stops, one spring of the pair acting throughout relative movement between the end stops and the tools and the other spring acting only during the last part of the

relative movement prior to and during engagement of a metallic component by the tools.

35. A method of finishing first and second metallic components which in a finished product are attached to one another, the method being conducted prior to the attachment together of the components to form the finished product and the method comprising the steps of:

bringing together the first and second metallic components, each component having been previously formed with a desired shape and configuration;

during the bringing together of the first and second metallic components aligning together first and second apertures in the components to form a first pair of aligned apertures;

during the bringing together of the first and second metallic components aligning together third and fourth apertures in the components to form a second pair of aligned apertures;

inserting a first die spigot through the first pair of aligned apertures;

inserting a second die spigot through the second pair of aligned apertures; and

in the absence of external heating, using a ram to apply a force on an external surface of the first and second components to deform the metal of the components whilst the previously inserted first die spigot ensures that the apertures of the first pair of aligned apertures remain aligned and the previously inserted second die spigot ensures that the apertures

of the second pair of aligned apertures remain aligned;

5 withdrawing the die spigots after deformation of the metal has ceased; and

10 separating the first and second components to be attached to each other later in the assembly of the finished product.

36. A gearbox having a casing comprising first and second metallic components finished by the method of claim 35.

15 37. A gear for a gearbox, the gear comprising an externally toothed periphery and a threaded central bore therethrough, the internal thread of the central bore being flow formed.

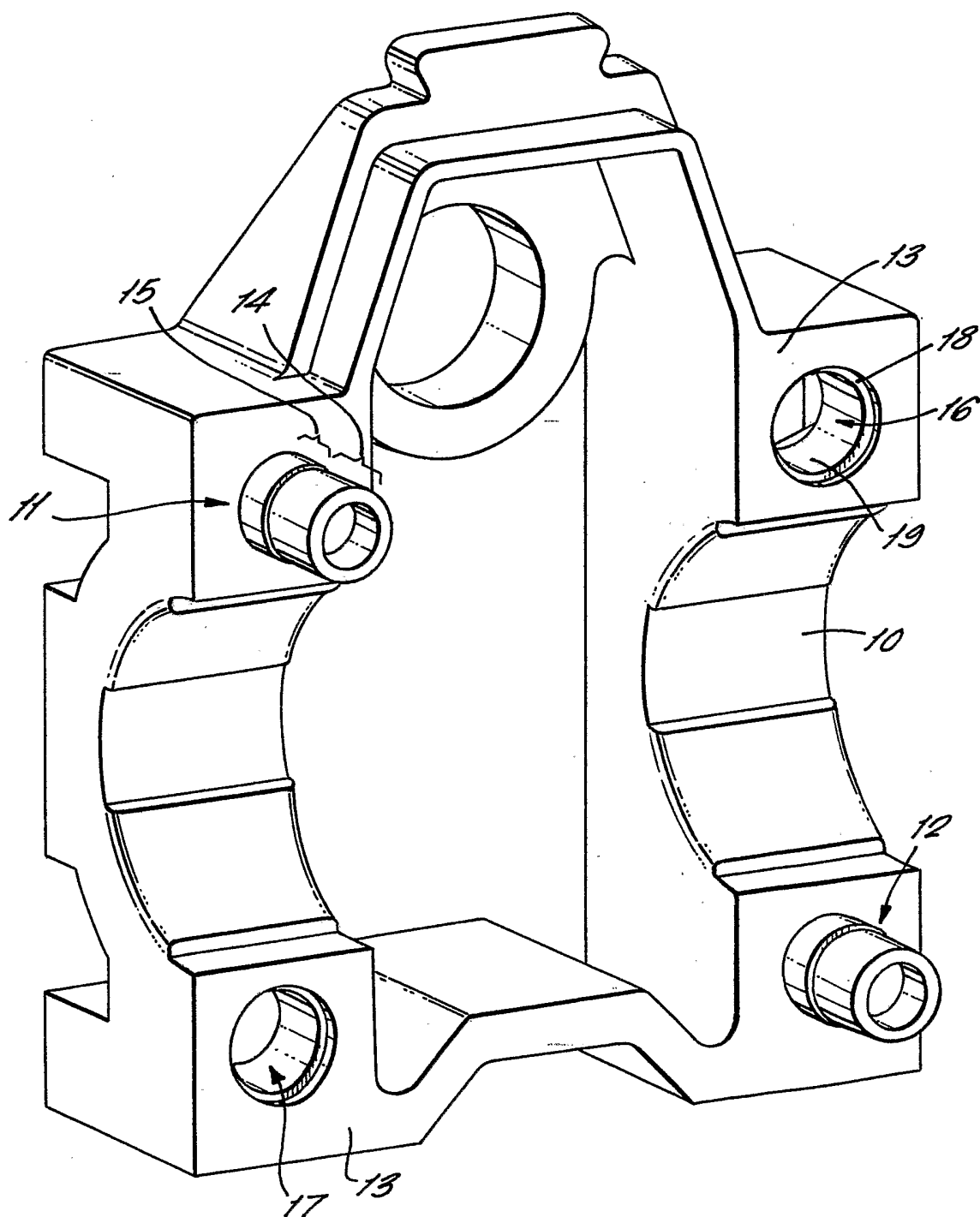
20 38. A gearbox comprising the gear of claim 37 and an externally threaded lead screw which engages the flow formed internal thread of the gear.

25 39. A method of manufacture of a metallic component substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

30 40. A gearbox substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

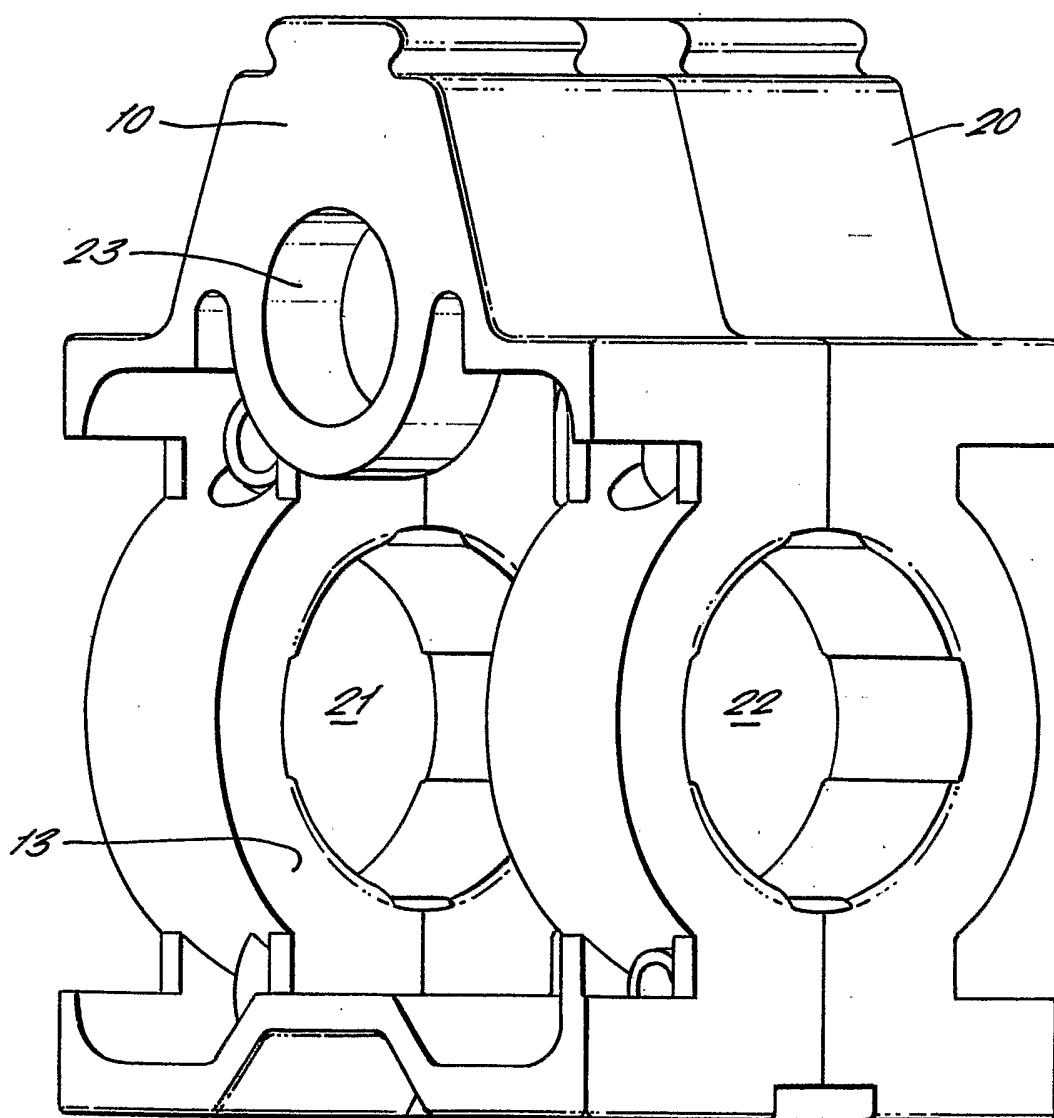
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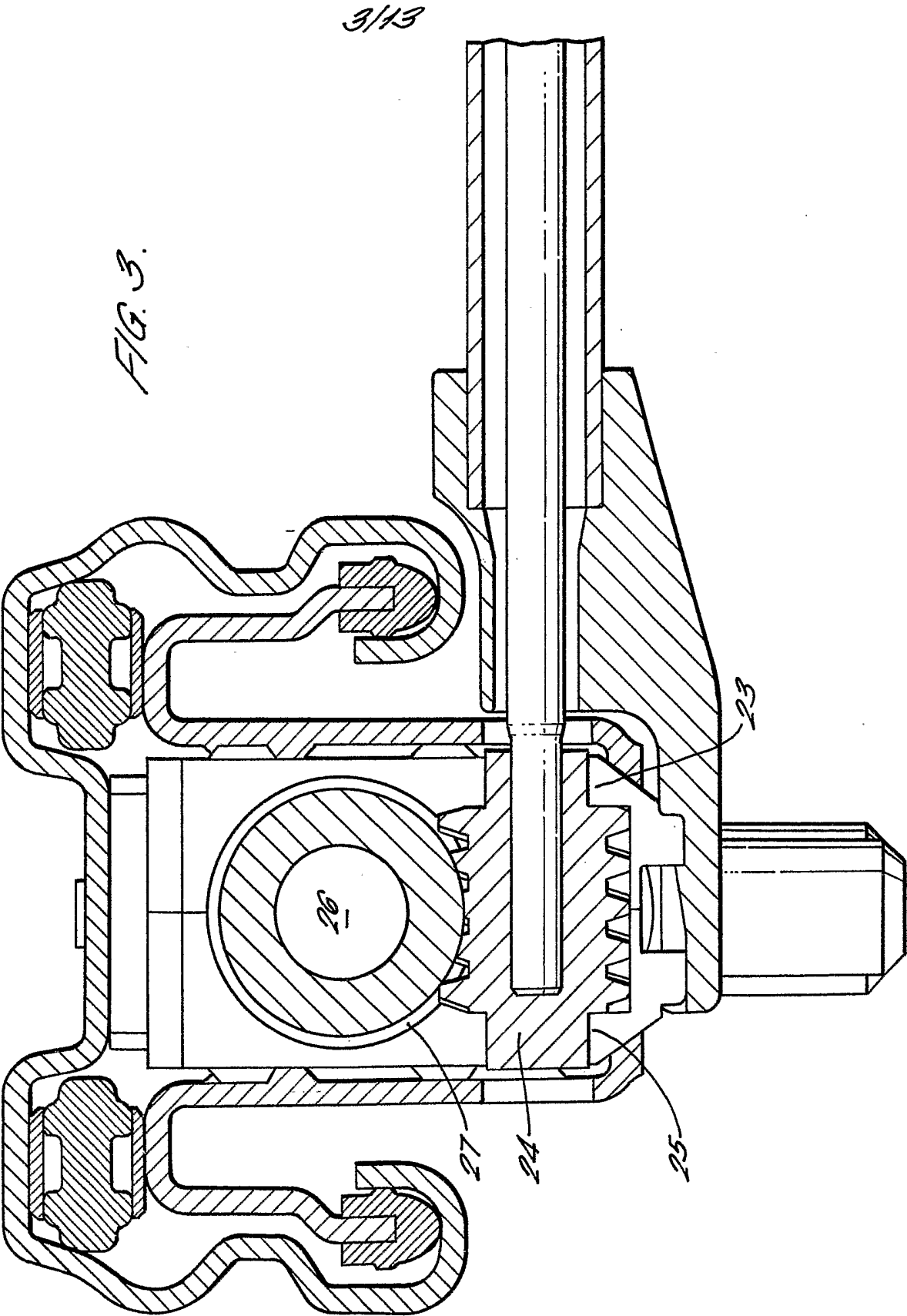
FIG. 1.



2/13

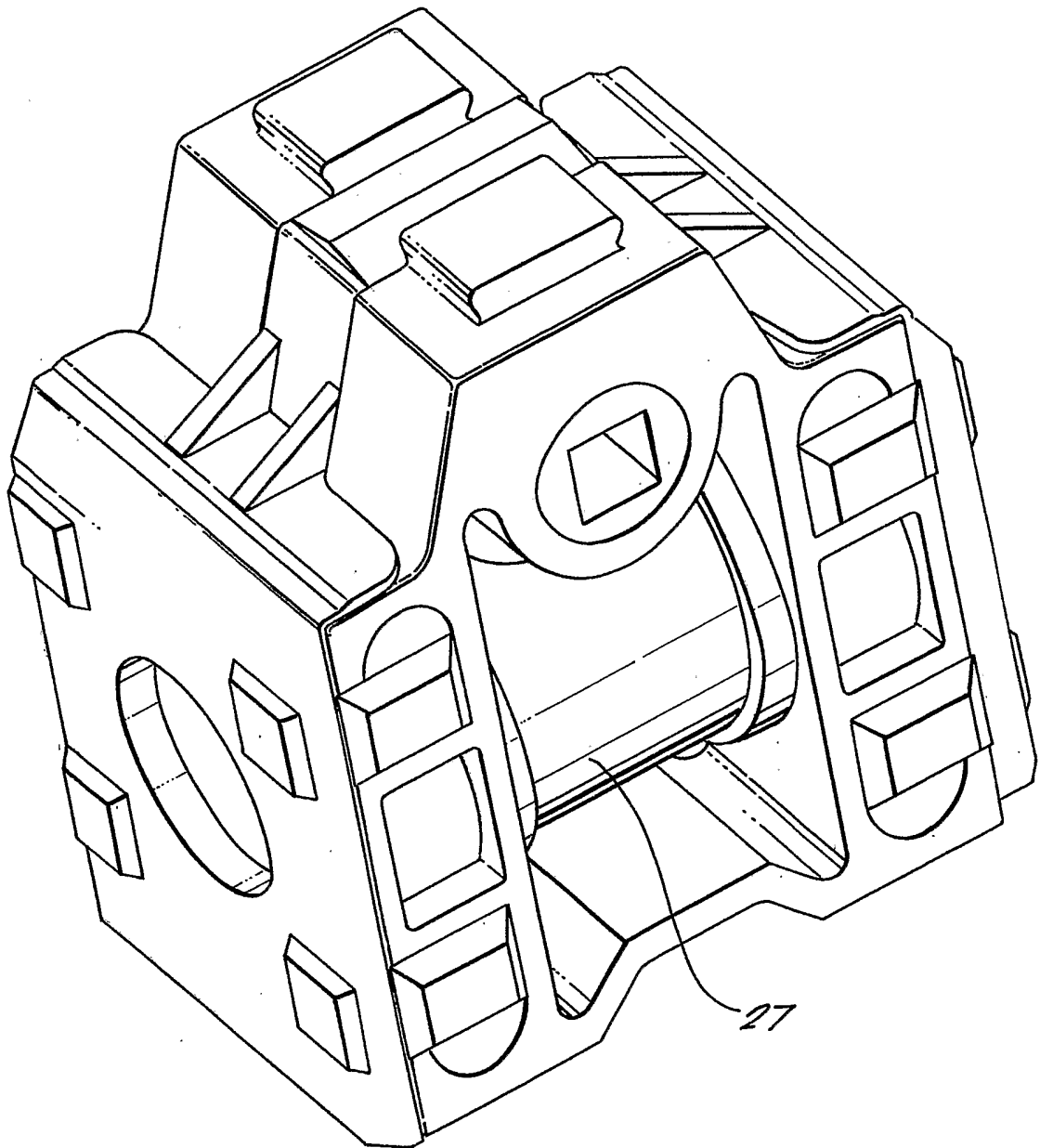
FIG. 2.





4/13

FIG. 4.



5/13

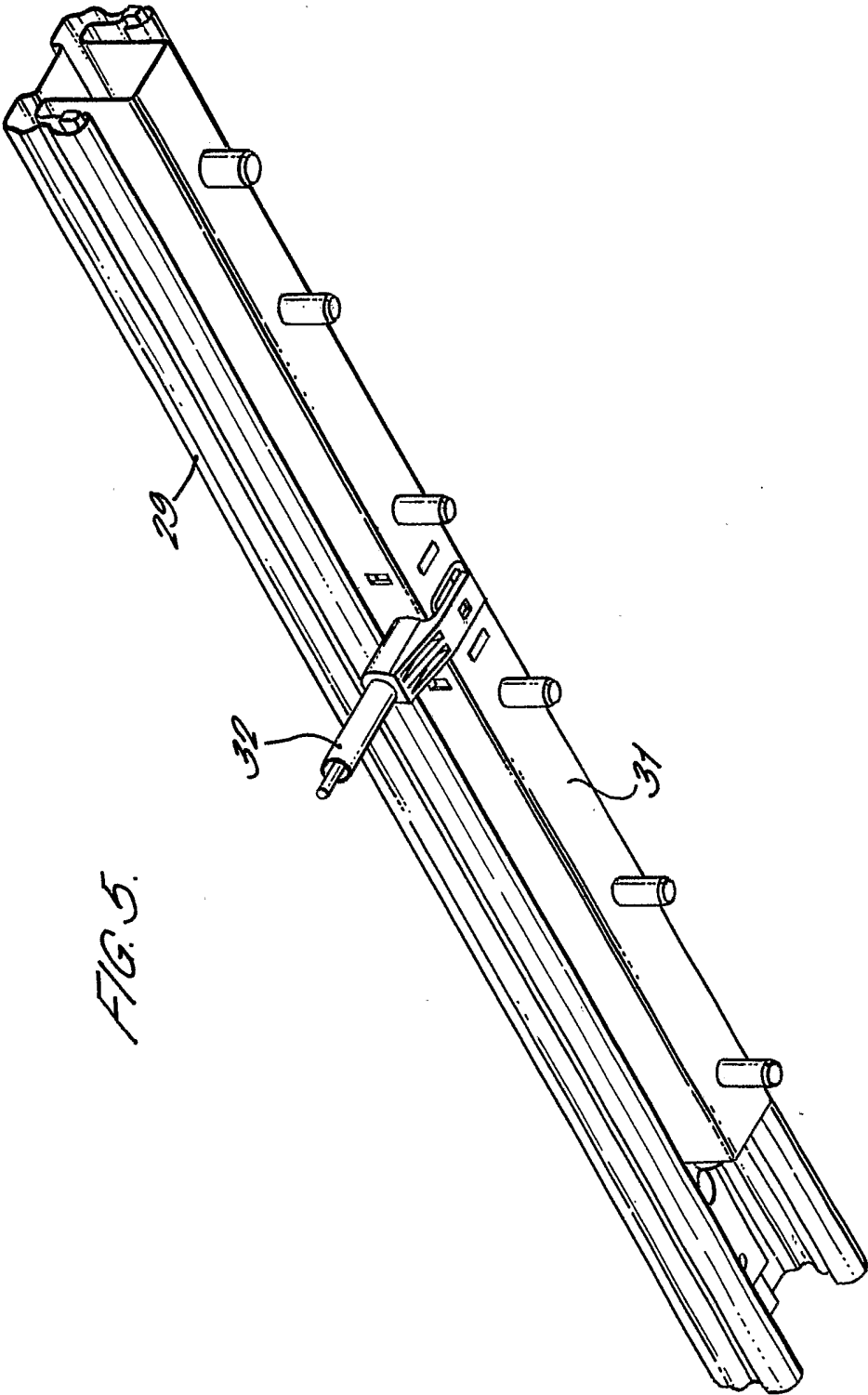
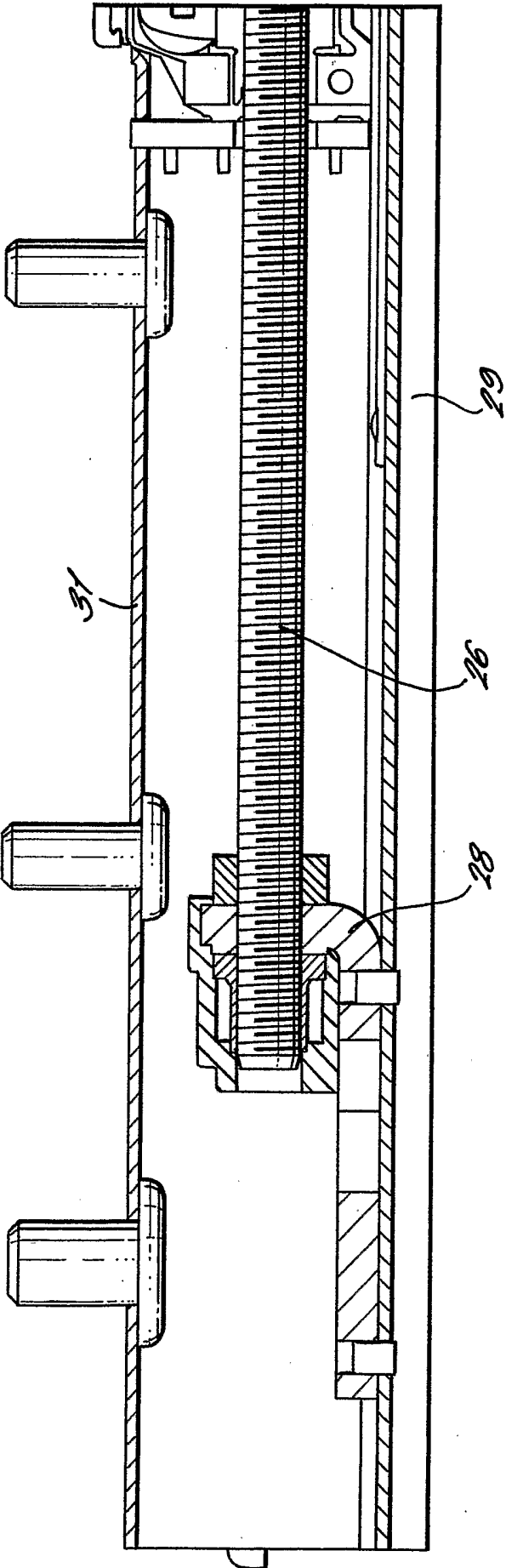


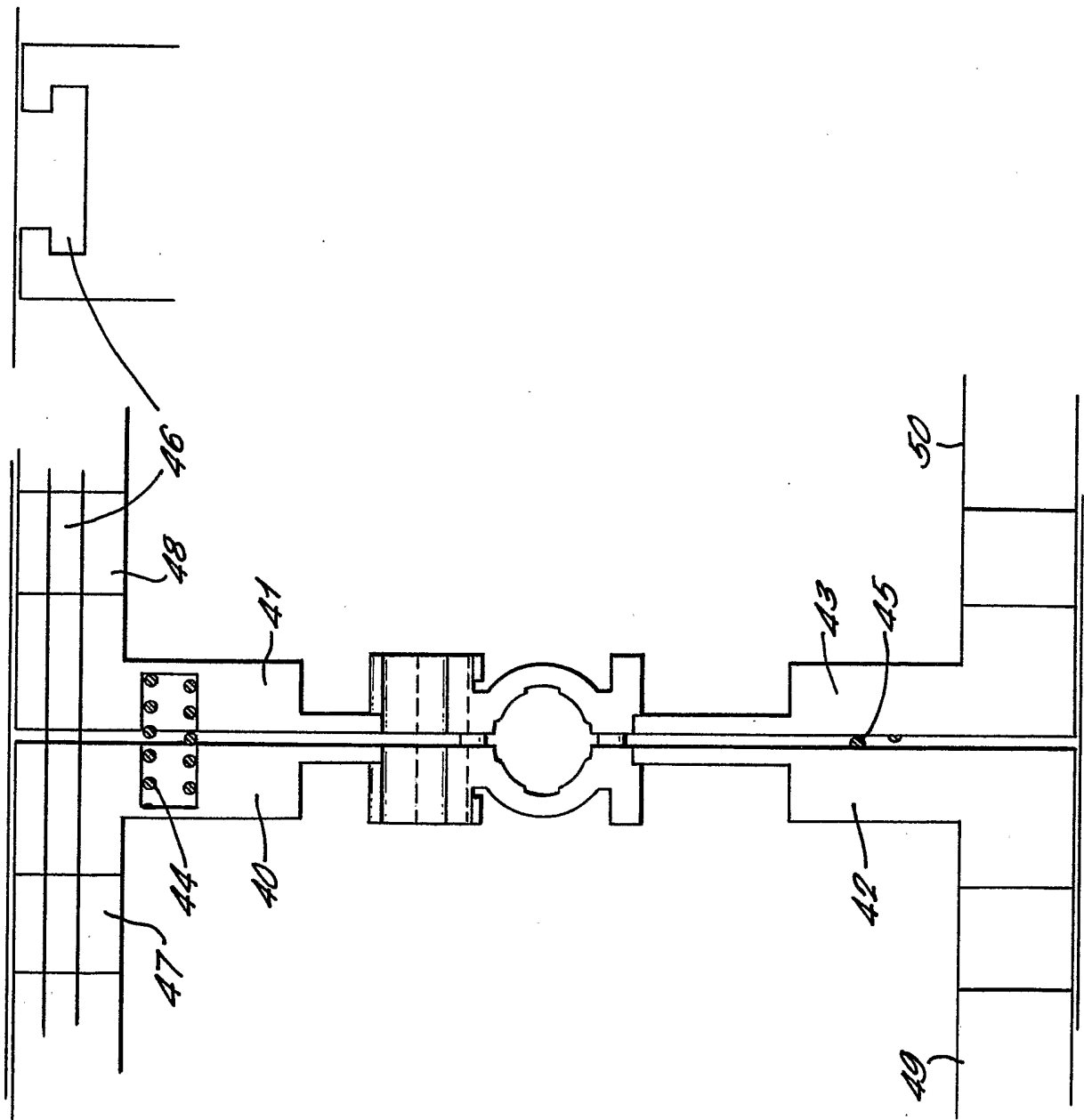
FIG. 5.

6/13

FIG. 6.

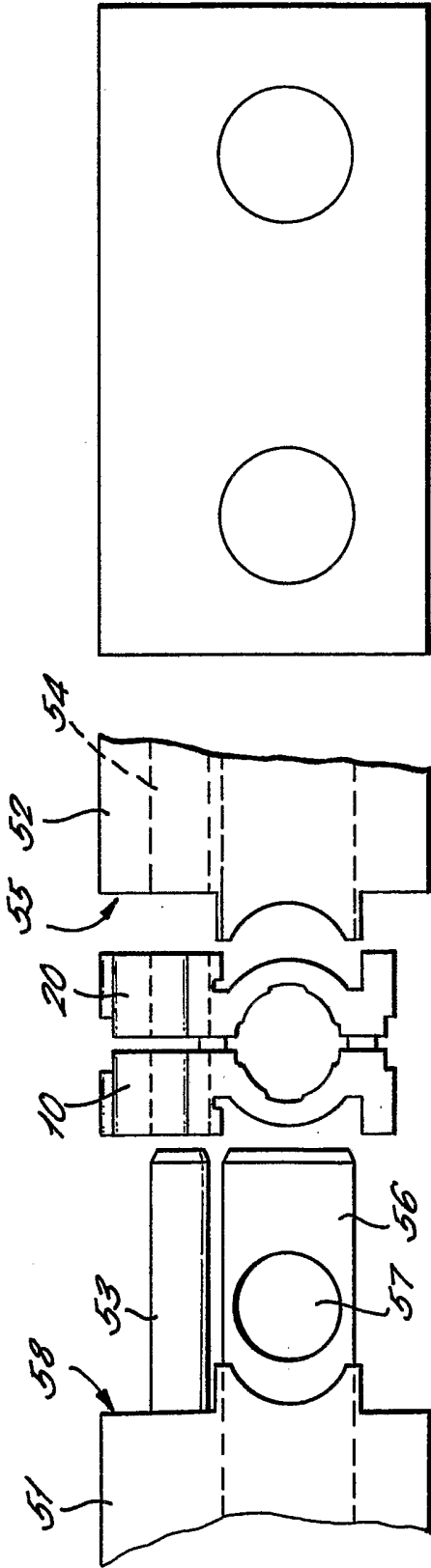


7/13



8/13

FIG. 8.



9/13

FIG. 9.

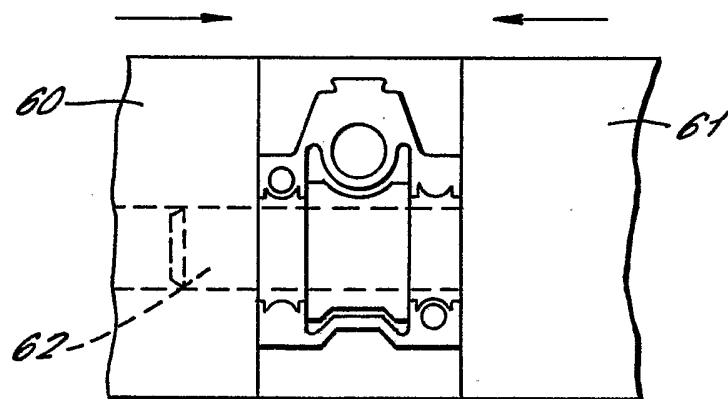
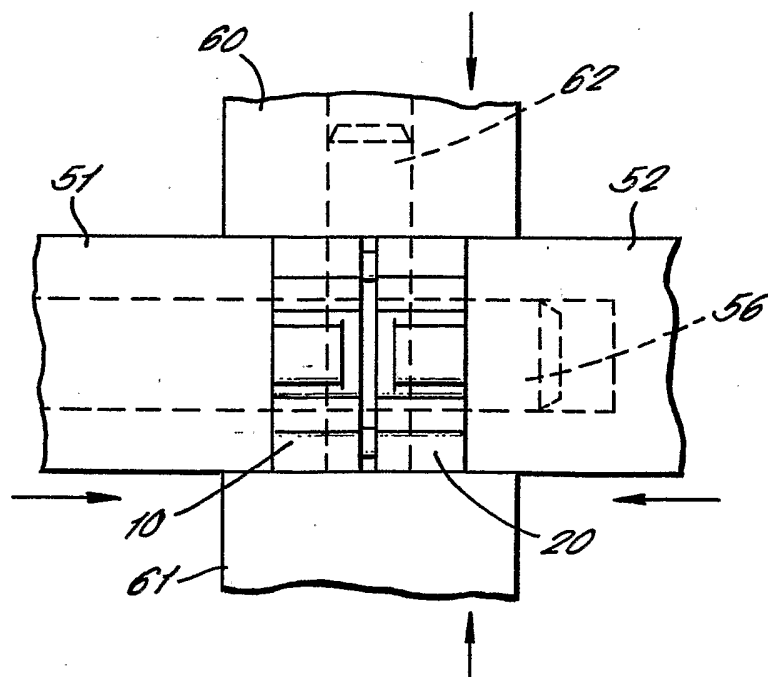


FIG. 10.



10/13

FIG. 11.

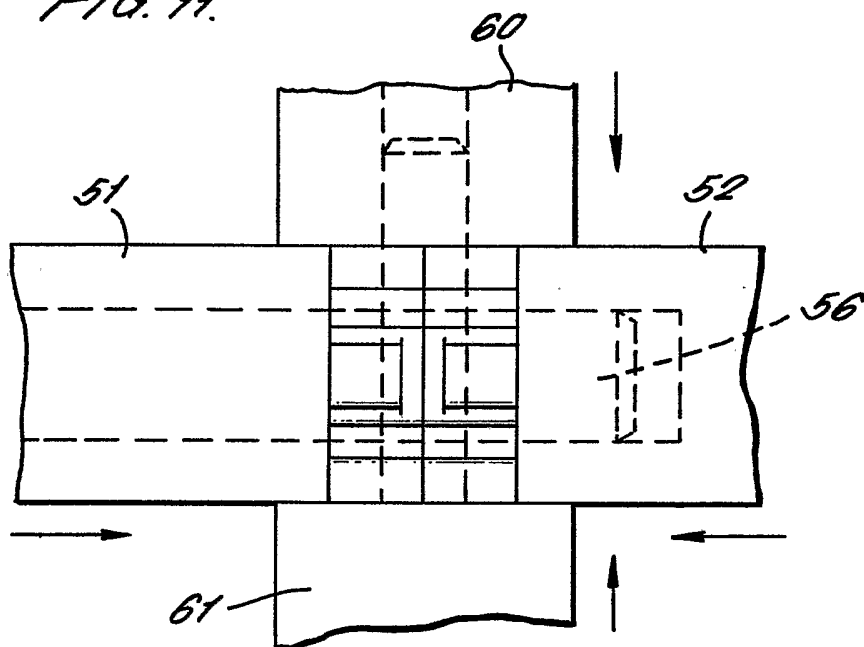
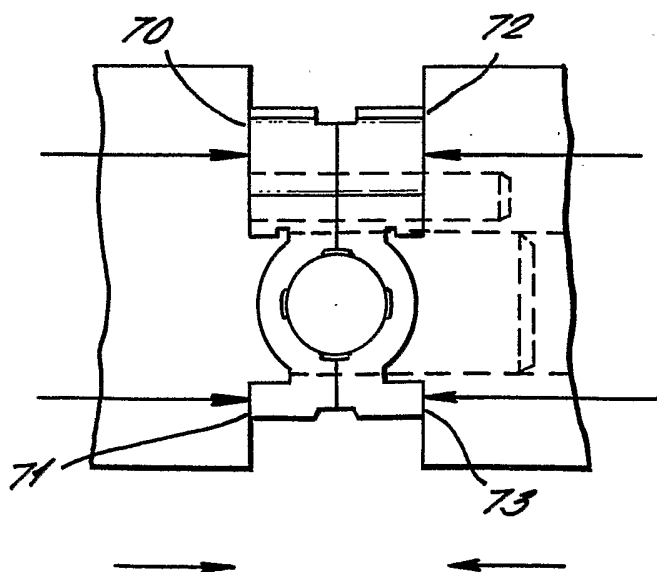


FIG. 12.



11/13

FIG. 13.

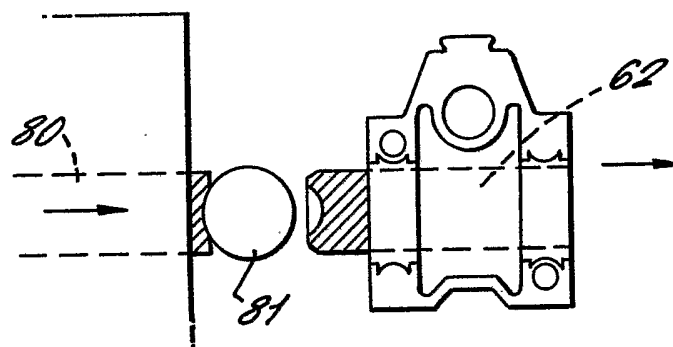


FIG. 14.

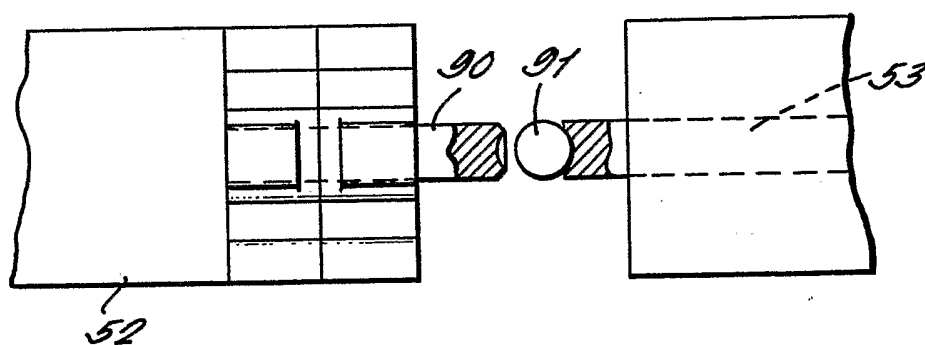
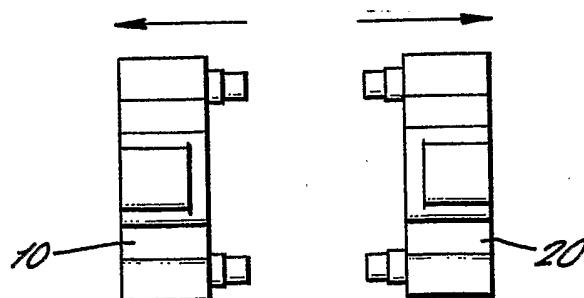
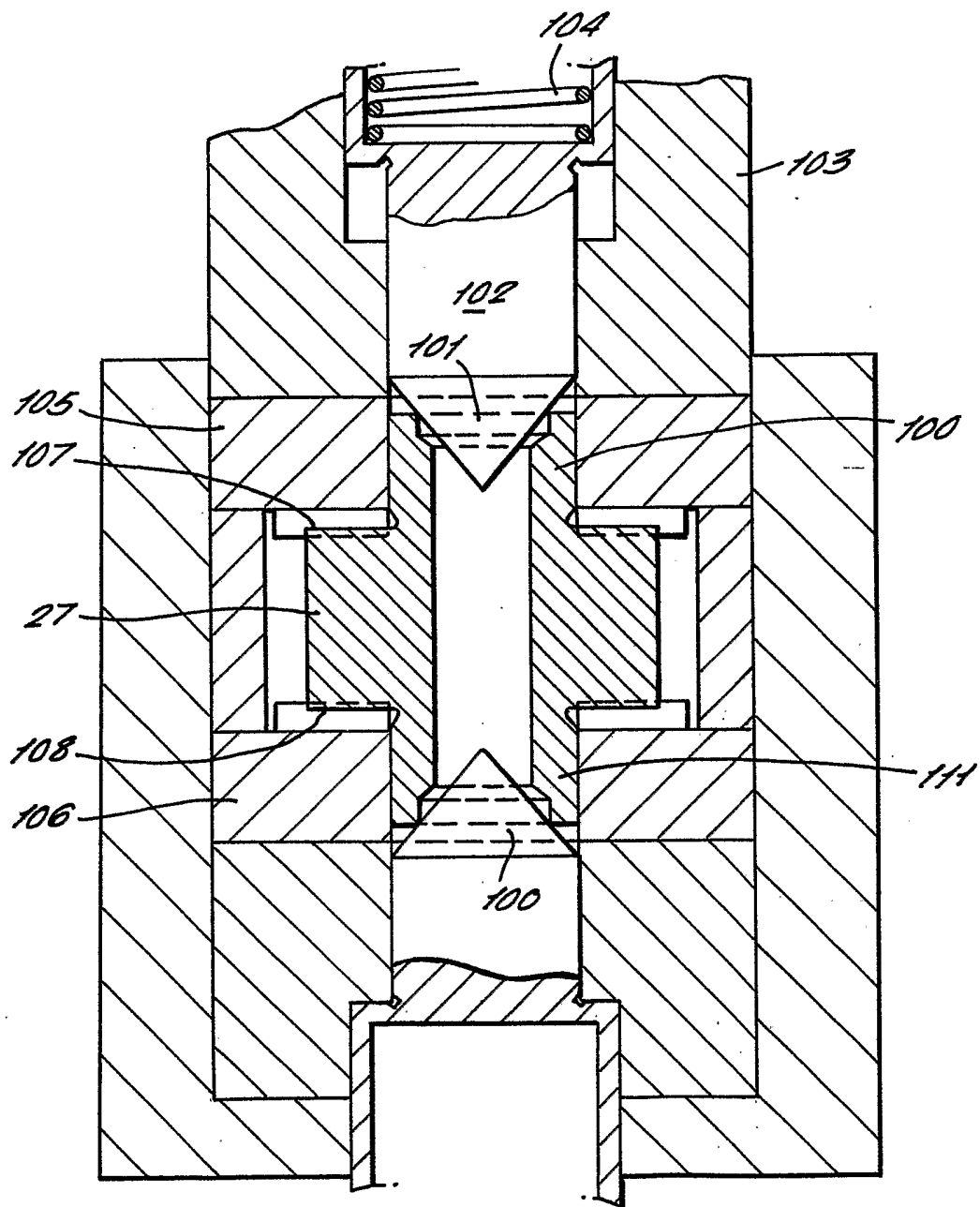


FIG. 15.



12/13

FIG. 16.



13/13

FIG. 17a.

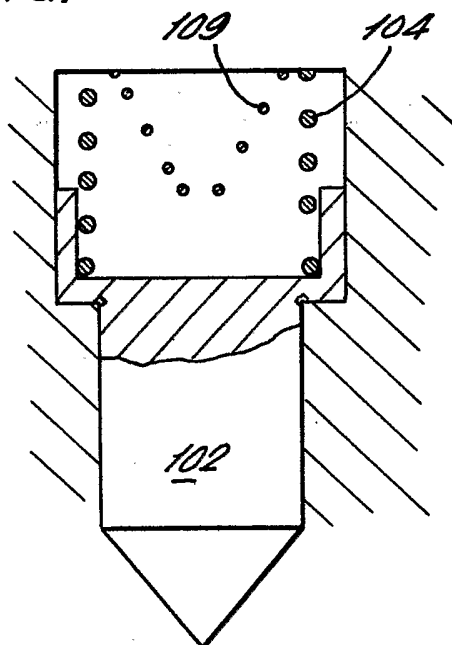


FIG. 17b.

