1 571 092

PATENT SPECIFICATION

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(54) OPTICAL FIBRES BUNDLE POSITIONING FERRULE

(71) We, THOMSON-CSF, a French Body Corporate, of 173, Boulevard Haussmann—75008 Paris—France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This is an addition to British Patent No. 1,478,135, in which is described a positioning ferrule for a single optical fibre.

According to claim 1 of Patent No. 1,478,135, there is provided a positioning ferrule for an optical fibre having a protective sheath, said ferrule having an external cylindrical surface of revolution around an axis for doing duty as a positional datum, and comprising:—

An external body terminating in a flat front face, containing a cylindrical bore substantially coaxial to said external cylindrical surface and having an outer surface, said outer surface including said external cylindrical surface;

a right circular cylindrical internal body fitted in the bottom of said bore; and a piston sliding in said bore for providing a compression strain of said internal body;

said front face, said internal body and said piston respectively having a first, a second and a third cylindrical hole coaxial to said external surface for receiving said optical fibre without said protective sheath; and

said internal body being arranged for closely squeezing said optical fibre in said second cylindrical hole under the action of said compression strain and thus positioning said optical fibre substantially coaxial to said external surface.

The present addition more specifically relates to a positioning ferrule for a bundle of optical fibres having a protective sheath, in place of a single optical fibre.

According to one aspect of the present invention, there is provided a positioning ferrule as claimed in claim 1 of Patent No. 1,478,135 and intended for use with a bundle of optical fibres having a protective sheath in place of a single optical fibre, wherein said piston further comprises a fourth cylindrical hole substantially centered on said axis for receiving said bundle of optical fibres, said piston having a body having a deformable part and said external body having a deformable part at the place occupied by said deformable part of said piston when said piston is resting on said internal body for crimping said external body onto said piston during fitting of said ferrule onto said bundle, and indentations being provided in said fourth hole on the deformable part of said piston for wedging, during said crimping operation, onto the protective sheath of the bundle.

According to a second aspect of the present invention, there is provided a positioning ferrule as claimed in claim 1 of Patent No. 1,478,135 and intended for use with a bundle of optical fibres having a protective sheath, in place of a single optical fibre, the ferrule being modified in that the cross-section of said second cylindrical hole is a regular hexagon, a flat facet parallel to one of the side of said hexagon and to said axis being arranged on the external periphery of said external body. In this case, the piston further comprises a fourth cylindrical hole substantially centered on said axis for receiving said bundle of optical fibres, said piston having a deformable part and said external body having a deformable part at the place occupied by said deformable part of said piston when said piston is resting on said internal body for crimping said external body onto said piston during fitting of said ferrule onto said bundle, and indentations being provided in said fourth hole on the deformable part of said piston for wedging, during said crimping operation, onto the protective sheath.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figures 1 to 3 are as shown and described

in the specification of our Patent No. 1,478,135.

Figure 4 is a sectional view of a bundle of fibres in the form of a compact hexagonal assemblage according to the prior art.

Figures 5 and 6 are two sectional views of the ferrule according to the present invention before and after fitting to the bundle of fibres.

Figures 7a and 7b are two sectional views of the front part of the ferrule according to the present invention modified to allow the marking of a direction characteristic of the compact assemblage.

Figure 8 shows a tool according to the invention intended for the manufacture of the ferrule shown in Figures 7*a* and 7*b*.

Figure 4 is a section through a bundle of fibres in the form of a compact hexagonal assemblage which is the type of assemblage obtainable with the ferrule according to the invention.

It is known that an arrangement of this type is the most compact which it is possible to obtain with fibres of circular cross-section. When, as is the case with the bundle shown in Figure 4, the number N of fibres of the bundle is determined by the relation:

$$N=1+3\ n\ (n-1)$$

(in the present case

$$n=3 \text{ and } N=19),$$

the fibres may be assembled in the form of a regular hexagon H of which the apothem a is determined by the relation

$$a=r[1+(n-1)\sqrt{3}],$$

where $2r$ is the diameter of the fibres. Accordingly, the bundle may be inscribed in a circle C of radius

$$R=(2n-1)r.$$

Figures 5 and 6 are two sectional views along the axis of the terminal according to the invention, respectively before and after it has been fitted to the bundle of fibres.

As shown in Figure 5, the ferrule according to the invention consists of three separate parts, all three being bodies of revolution about an axis AA: an external body 2, a deformable disc or internal body 3 and a piston 4.

The external body 2 comprises a cylindrical element 20 which forms the positioning reference of the ferrule and which is intended to fit into a female part of the connecting element. A screwthread 201 enables a fixing element to be screwed on during the connection. The front surface 21 comprises a cylindrical orifice 221 for the passage of the bundle of fibres. The cylindrical external surface 20 and the orifice 221 are designed to have substantially the same axis AA. The diameter of the orifice 221 is larger by 3 to 10% than the diameter of the circle circumscribing the bundle in its compact hexagonal arrangement. A recess 22 formed around the orifice 221 is intended to receive a polymerisable resin of which the function during positioning of the bundle will be explained hereinafter. The external body 2 has at its rear a thin deformable element 25, which is intended to enable the ferrule to be crimped onto the pistons. The external body is formed internally with a cylindrical cavity of revolution 23, 24 of which at least the part 23 is by design substantially coaxial with the surface 20. The outer part is made of a substantially unbreakable material, for example a lead brass, such as the brass U Z 39 Pb 2 to enable the rear part 25 to undergo the crimping operation without any risk of breakage.

The disc 3 is disposed in the front part of the cavity 23 and conforms closely to the base thereof. It is made of a material which is capable of undergoing, by compression, significant temporary or permanent deformation. It comprises an orifice 30 of circular cross-section which has the same diameter as and is strictly coaxial with the orifice 221 and which is provided on its rear part with a chamfer 300 to facilitate introduction of the bundle of fibres.

The piston 4 is made of a hard metal, for example a brass of conventional type. It is formed by a body of revolution about the axis AA and is designed to slide freely in the parts 23 and 24 of the cavity formed in the external body 2. It comprises two bores 40 and 41 which are aligned with the axis AA and which are larger in diameter than the bundle of fibres respectively provided with and free of its sheath or envelope. These two bores communicate through a conical part 410 which facilitates introduction of the envelope-free bundle from the part 40 into the part 41. At its rear end, the piston 3 terminates if a deformable part formed by a frustoconical part 42 formed with four slots parallel to the axis which divide it into four quadrants. Of these four slots, only the slot 420 is visible in the Figure 5. In the vicinity of this frustoconical part, the bore 41 comprises indentations 421 which may be formed by a screwthread. The frustoconical part 42 as a whole forms a clamp which, by virtue of the play allowed by the slots, surrounds the envelope of the bundle during the crimping operation under the action of the deformable part 25.

In one particular embodiment of the ferrule according to the invention, a

screwthread 411 enables the piston 4 to be screwed into the external body 2.

So far as the manufacture of the external body 2 and the positioning of the disc 3 in the cavity 23 are concerned, the invention provides a precise sequence of operations carried out on a precision lathe to ensure that the cylindrical surfaces of revolution 20, 23 and 30 are substantially coaxial.

A cylinder roughly shaped to dimensions larger than the overall dimensions of the external body 2 is fitted onto the lathe with which it remains integral until the turning operations are over.

The first operation comprises boring out the cavities 23 and 24. The disc 3, which is not bored and which has been turned to such a diameter that it can be force-fitted into the cavity 23, is introduced by means of a guide plunger, which may be the piston 4 before boring of the parts 40 and 41, or a part of identical shape. With the guide plunger remaining in position to hold the disc 3, the orifices 221 are simultaneously bored out in the front surface 21 and 221 in the disc 3, after which the front surface 21 and the recess 22 are shaped. Finally, the external surface of the workpiece is turned to its final dimensions, after which the workpiece may be removed from the lathe for screwthreading the part 201 and, optionally, the part 411.

Positioning of the ferrule onto the fibre in order to end up with the arrangement shown in Figure 6 is carried out as follows.

The bundle is first freed from its plastic envelope over a length greater than the useful length and is then degreased by successive soakings in isoamyl acetate and ethylalcohol. It is then introduced into the ferrule arranged in the manner shown in Figure 4, i.e. with the piston 4 simply resting in the absence of pressure on the disc 3. By virtue of the conical part 410 and the chamfer 300, the envelope-free part enters progressively into the bore 40 of the piston 4 and then into the orifices 30 and 221 formed respectively in the disc 3 and the front surface 21. When the envelope 10 comes into contact with the conical part 410, the front of the bundle projects appreciably beyond the front surface 21 of the ferrule.

In a first embodiment of the ferrule, in which the screwthread 411 does not exist, the successive compression and deformation of the deformable discs 3 takes place at the same time as the crimping operation. Under the action of the flange to be crimped, the element 25 of the outer part is deformed and applies a pressure to the frustoconical part 42 of the piston. This pressure has a two-fold effect:—

the first effect is to cause the piston 4 to slide frontwards into the cavities 23 and 24 so that, as shown in Figure 6, it compresses the disc 3, deforms it and forces the orifices 30 tightly to surround the bundle 11;

the second effect, as also shown in Figure 6, is to deform the frustoconical part 42 (this deformation being facilitated by the four slots, such as 420) and to force the indentations 421 to become wedged in the envelope 10 of the bundle.

This embodiment is valid in cases where, as mentioned above, the diameter of the orifice 30 which is by design equal to the diameter of the orifice 221 does not exceed by more than 10% the diameter of the circle circumscribing the bundle in its compact hexagonal arrangement, which leads to slight deformations of the disc. For example, this embodiment may be used in cases where the orifices 221 and 30 are bored to a diameter of 610 μm for a bundle of N=37 fibres with a diameter d of 85 μm; this value of N corresponds to a value of n equal to 4 because:

$$N=1+3n(n-1)=1+3\times4\times3=37$$

which, for the diameter D of the circle circumscribing the bundle in its compact hexagonal arrangement, leads to a value:

$$D=(2n-1)d=7\times85=595\ \mu m.$$

By contrast, the second embodiment of the ferrule, characterised by the existence of the screwthread 411, enables much greater deformation of the disc 3 to be obtained. In this case, the diameter of the orifices 221 and 30 may exceed by 25 to 30% the diameter of the circle circumscribing the bundle in its compact hexagonal arrangement. For example, the second embodiment may be used, still with the orifices 221 and 30 bored to a diameter of 610 μm, for a bundle of N=19 fibres (i.e. n=3) of diameter D=5×85=425 μm. In this case, compression of the disc 3 is obtained, after positioning of the bundle and before crimping, by screwing the piston 4 into the outer part 2 by way of the screwthread 411.

With the bundle of fibres thus held in the ferrule under the double effect of the disc 3 and the clamp 42, a drop of a polymerisable resin (for example an epoxy resin derived from biphenol A and epichlorhydrin, known under the registered Trade Mark "Araldite") is deposited into the recess 22. After cold polymerisation of the resin, the bundle of fibres is divided at the level of the drop. The front surface is then optically polished so that the orifices of the fibres of the bundle and the front surface 21 of the element form a common plane having an optical polish.

It is possible to use for the disc 3 a material having a high elastic deformation limit provided that the deformation is perfectly isotropic. Accordingly,

polymerised materials such as polytetrafluorethylene or polyamino-11-undecanoic acid known under the respective registered Trade Marks of "Teflon" and "Rilsan", are perfectly suitable. They should be kept permanently compressed, as shown in Figure 5.

However, it is also possible to use for the disc 3 materials which are deformable in such a way that their elastic deformation limit is exceeded during the compression applied by the piston. Accordingly, the material is caused to flow and the disc retains a permanent deformation when the piston 4 ceases to exert its effect. Certain soft metals or alloys, namely indium, lead or tin-lead alloys, satisfy this requirement in their cold state. Certain polymerised materials softened by heat also meet this requirement. It is possible for example to machine the disc in polytetrafluorethylene and to obtain compression by heating the ferrule for 10 to 15 minutes at a temperature of 100°C. In cases where a disc permanently deformed in this way is used, construction of the ferrule may be simplified by leaving out the rear parts 25 of the outer part and 42 of the piston which are intended for crimping. In this case, the piston 4 and the envelope 10 are fixed to one another and to the outer part by depositing onto the rear end of the piston a drop of a varnish (which can be a varnish known under the registered Trade Mark "Loctit") which, by penetrating into the interstices between the envelope and piston and between the piston and the outer part by capillary action, subsequently holds these three parts together.

When the ferrule according to the invention is intended to form part of a connector for directly coupling two identical bundles in the absence of any auxiliary elements, such as a lens or single optical mixing fibre, it is essential to provide the ferrule with a mark which defines a direction parallel to one of the sides of the hexagon characterising the compact bundle of fibres, in such a way that the fibres orifices of each of the bundles be automatically arranged opposite one another.

Figures 7*a* and 7*b* show the modifications which are thus made to the front part of the ferrule shown in Figure 4 to enable it to be marked with a direction characteristic of the compact hexagonal assemblage of fibres of the bundle. Figure 7*a* is a section through the front part of the ferrule before it is fitted onto the bundle, whilst Figure 7*b* is a section taken along a plane perpendicular to the axis AA and marked PP in Figure 7*a*.

As shown in Figures 7*a* and 7*b*, two modifications are made to the ferrule shown in Figure 5.

The first modification comprises replacing, in the disc 3, the cylindrical bore of revolution 30 shown in Figure 5 by a bore 31 of which the cross-section is in the form of a regular hexagon strictly centred on the axis AA and circumscribing the circle forming the cross-section of the bore 221 in the outer part 2.

The second modification comprises forming on the external body 2, between the cylindrical reference surface 20 and the screwthread 201, another cylindrical surface of revolution 230 comprising a flat facet 231 strictly parallel to one of the facets of the regular hexagonal prism forming the bore 31.

During positioning of the bundle of fibres in the ferrule and during the subsequent compression of the disc 3 by the piston 4, the hexagonal bore contracts and orients the hexagonal assemblage of fibres of the bundle parallel to its facets, i.e. parallel to the flat 231. If two ferrules conforming to the arrangement shown in Figures 7*a* and 7*b*, disposed at the ends of two identical bundles, are assembled by a connector, which constrains the two identical flats 231, to be arranged in a same plane then the two compact assemblages of fibres are assembled end to end, since the two hexagons are coinciding with one another. Each fibre of a bundle is thus situated in the extension of a fibre of the other bundle.

In order to obtain the ferrule shown in Figures 7*a* and 7*b*, it is advisable to modify the sequence of manufacturing operations mentioned above in the following manner.

The external body 2 is turned and the disc 3 is fitted and bored in the same way as described above, except that the front surface 21 and the recess 22, are not shaped so as to obtain a bore 221 of greater depth. It is then removed from the lathe.

In addition, a tool of the type shown in Figure 8 is made up, comprising at the end of a sleeve 50 a cylindrical part of revolution 51 of which the diameter is such that it slides easily in the cavity 23 of the external body 2, followed by a regular hexagonal prism 52 with the dimensions of the hexagonal bore to be formed in the disc 3. The tool terminates in a cylindrical surface of revolution 53 machined in such a way as to slide easily in the cavity 23 of the outer part and separated from the prism by a groove 523. The cylinders 51 and 53 and the prism 52 are machined in such a way that they have a common axis. A flat 501 strictly parallel to one of the facets 520 of the hexagonal prism 52 is cut into the sleeve 50.

The tool shown in Figure 8 is then introduced into the cavity 23 of the outer part 2. The end 53 penetrates successively into the bore of the disc 3 and then into the bore 221 of the front surface. It is thus

guided with extreme precision and the prism 52, acting as a punch, cuts the hexagonal bore 31 into the disc 3. The chips formed are forced into the groove 523. With the flat 501 as reference, the external body is formed with the flat facet 231 which is thus parallel to one of the facets of the hexagonal bore 31 in the disc 3. The external body 2 is then set up on the lathe again to machine the front surface 21 and the recess 22.

The ferrule described above remains useable even when the difference in the diameters of the fibres of the bundle reaches a few percent. The assemblage of fibres thus remains compact and hexagonal to a very considerable extent and the deviation between the axis of the central fibre and the axis of the reference cylinder 20 remains less than 10 μm.

WHAT WE CLAIM IS:—

1. A positioning ferrule as claimed in claim 1 of Patent No. 1,478,135 and intended for use with a bundle of optical fibres having a protective sheath, in place of a single optical fibre, wherein said piston further comprises a fourth cylindrical hole substantially centered on said axis for receiving said bundle of optical fibres, said piston having a deformable part and said external body having a deformable part at the place occupied by said deformable part of said piston when said piston is resting on said internal body for crimping said external body onto said piston during fitting of said ferrule onto said bundle, and indentations being provided in said fourth hole on the deformable part of said piston for wedging, during said crimping operation, onto the protective sheath.

2. A ferrule as claimed in claim 1, which further comprises means for causing said piston to compress said internal body.

3. A ferrule as claimed in claim 2, wherein said means is provided by said deformable part of said piston being frustoconical in shape, the deformation of said deformable part of said external body during said crimping operation displacing said piston frontwards to compress said internal body.

4. A ferrule as claimed in claim 2, wherein said means includes an outer screwthread on said piston and an inner screwthread formed in said cylindrical bore for receiving said outer screwthread, the compression of said internal body occurring when said piston is screwed into said external body by means of said outer and inner screwthreads.

5. A ferrule as claimed in any one of the preceding claims, wherein said first cylindrical hole opens onto a cylindrical recess substantially centered on said axis, said recess being positioned in said front face for receiving a polymerisable material arranged around said bundle of optical fibres after insertion thereof into said first, second and third cylindrical holes and into said recess and after compression of said internal body by said piston.

6. A positioning ferrule as claimed in claim 1 of Patent No. 1,478,135 and intended for use with a bundle of optical fibres having a protective sheath, in place of a single optical fibre, the ferrule being modified in that the cross-section of said second cylindrical hole is a regular hexagon, a flat facet parallel to one of the sides of said hexagon and to said axis being arranged on the external periphery of said external body.

7. A ferrule as claimed in claim 6, wherein said piston further comprises a fourth cylindrical hole substantially centered on said axis for receiving said bundle of optical fibres, said piston having a deformable and said external body having a deformable part at the place occupied by said deformable part of said piston when said piston is resting on said internal body for crimping said external body onto said piston during fitting of said ferrule onto said bundle, and indentations being provided in said fourth hole on the deformable part of said piston for wedging, during said crimping operation, onto the protective sheath.

8. A ferrule as claimed in claim 7, wherein said first cylindrical hole opens onto a cylindrical recess substantially centered on said axis, said recess being positioned in said front face for receiving a polymerisable material arranged around said bundle after insertion thereof into said first, second and third holes and into said recess and after compression of said internal body by said piston.

9. A ferrule as claimed in claim 6, 7 or 8, which further comprises means for causing said piston to compress said internal body.

10. A ferrule as claimed in claims 7 and 9, wherein said means is provided by said deformable part of said piston being frustoconical in shape, the deformation of said deformable part of said external body during said crimping operation displacing said piston frontwards to compress said internal body.

11. A ferrule as claimed in claim 9, wherein said means includes an outer screwthread on said piston and an inner screwthread formed in said cylindrical bore for receiving said outer screwthread, the compression of said internal body occurring when said piston is screwed into said external body by means of said outer and inner screwthreads.

12. A ferrule as claimed in any one of the preceding claims, which further comprises said bundle of optical fibres inserted in said first, second and third holes and in said recess and squeezed by said internal body and a polymerised material arranged in said

recess around said bundle, wherein said front face, the external surface of said polymerised material and the surfaces forming the openings of said bundle are formed into an optically polished surface.

13. A ferrule as claimed in claim 12 when appendant to any one of claims 1 to 5, wherein said first, second and third cylindrical holes each have circular cross-sections with diameters larger than the diameter of a circle circumscribing the fibres of said bundle, which fibres are disposed in a compact hexagonal arrangement.

14. A ferrule as claimed in claim 12 or 13, wherein the orifices of the fibres forming said bundle are disposed in the plane of said front face in the form of a substantially compact hexagonal assemblage, the periphery of said bundle in said plane being inscribable in a regular hexagon centered substantially on said axis of said external cylindrical surface.

15. A ferrule as claimed in claim 12, 13 or 14, wherein said internal body is a body which has undergone permanent deformation.

16. A ferrule as claimed in claim 12, 13 or 14, wherein said internal body is kept in a state of elastic deformation by the pressure applied by said piston.

17. A ferrule as claimed in any one of claims 12 to 16 as appendant to claim 1, wherein the sheath of said bundle enters said ferrule and is kept fast therewith by said indentations.

18. A positioning ferrule as claimed in claim 1 of Patent No. 1,478,135 and intended for use with a bundle of optical fibres having a protective sheath, in place of a single optical fibre, substantially as hereinbefore described with reference to Figures 5 and 6, or with reference to Figures 5 and 6 modified in accordance with Figures 7a and 7b of the accompanying drawings.

HASELTINE, LAKE & CO.,
Chartered Patent Agents,
Hazlitt House,
28, Southampton Buildings,
Chancery Lane,
London, WC2A 1AT.
also
Temple Gate House,
Temple Gate,
Bristol, B31 6PT.
and
9, Park Square,
Leeds, LS1 2LH,
Yorkshire.
Agents for the Applicants.

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1571092 COMPLETE SPECIFICATION
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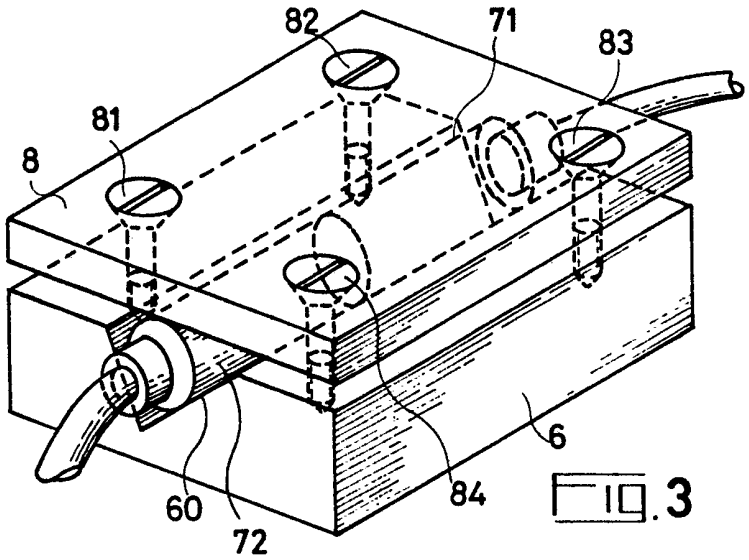


FIG.3

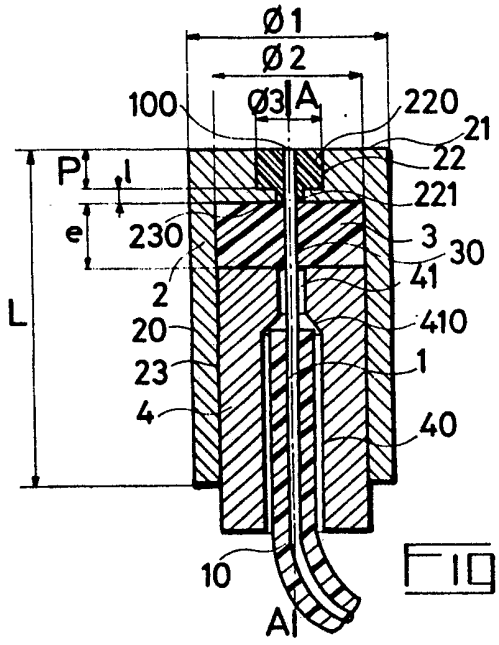


FIG.1

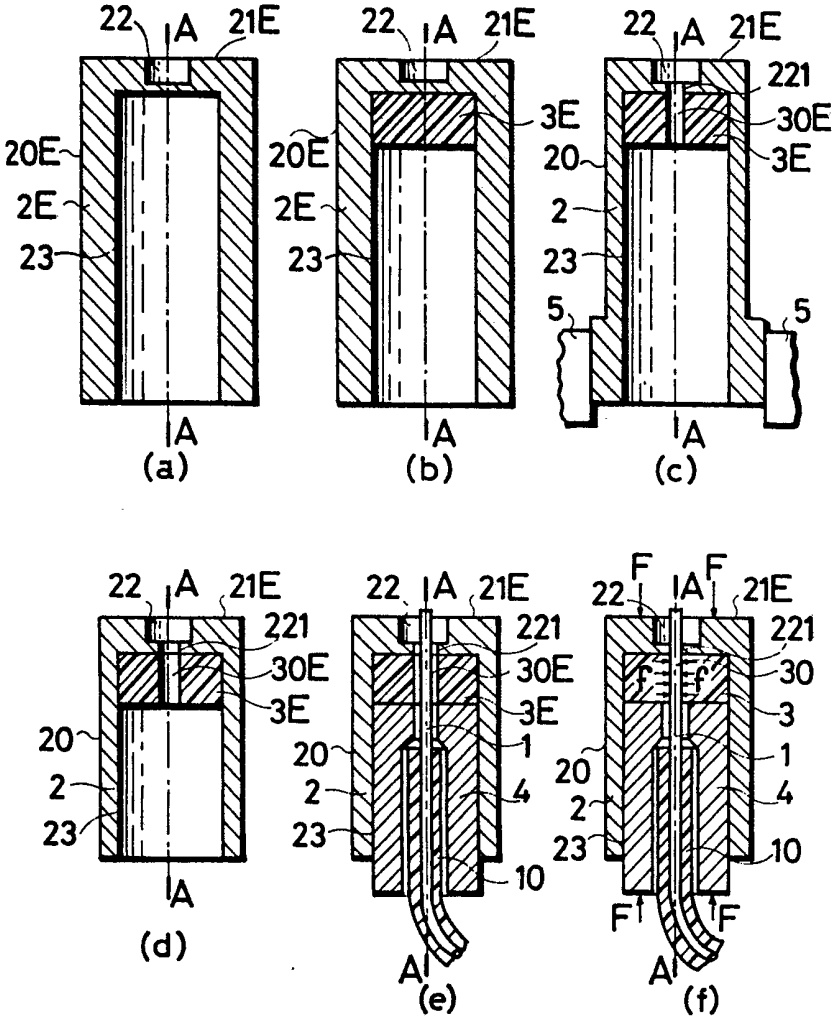


FIG. 2

1571092 COMPLETE SPECIFICATION
6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 3

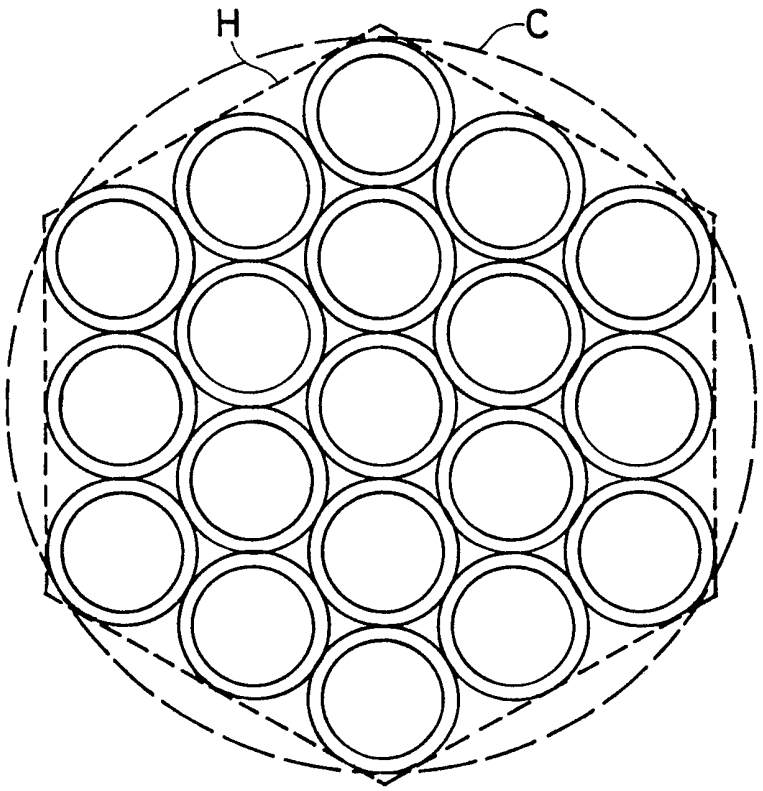


FIG. 4

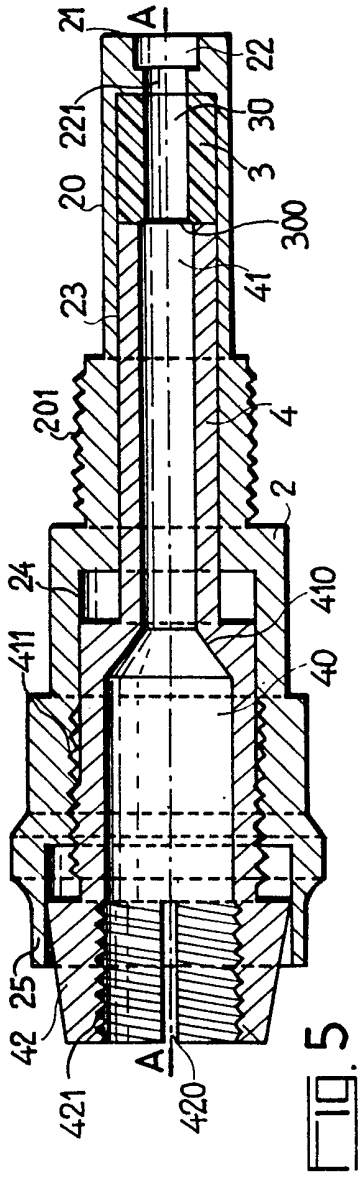

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FIG. 5

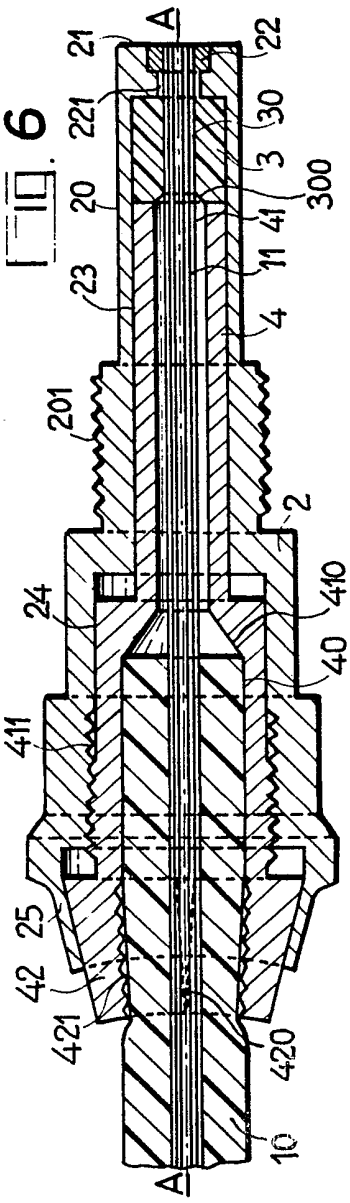

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FIG. 6

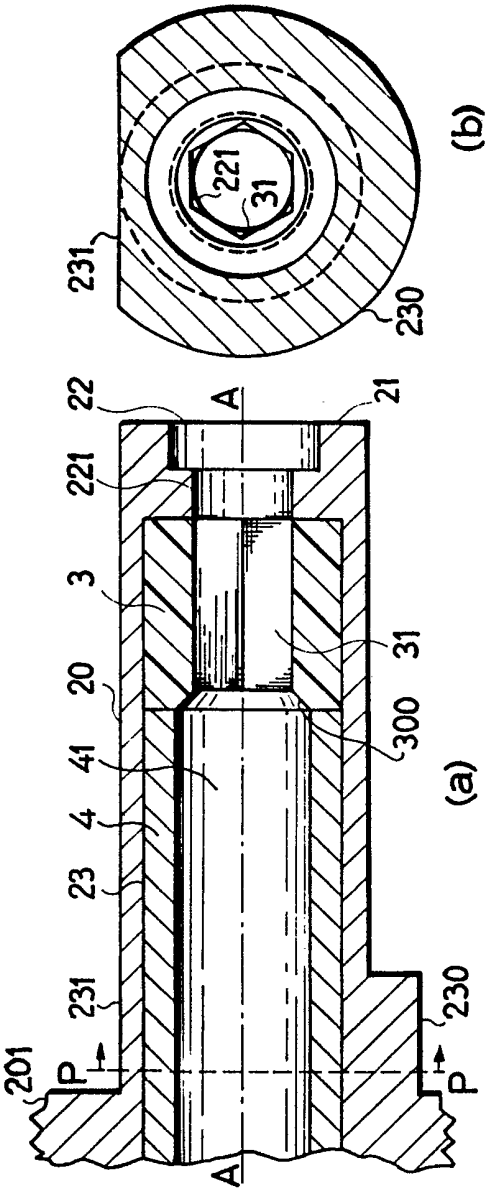


FIG. 7

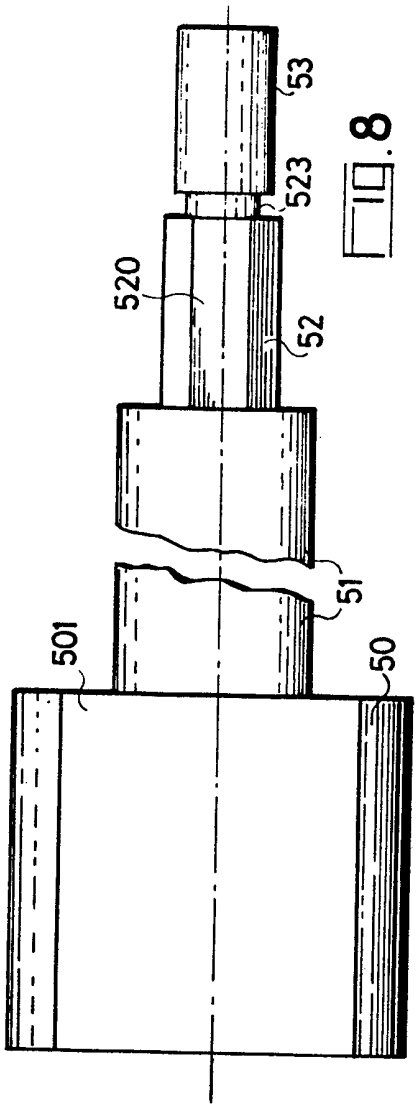


FIG. 8