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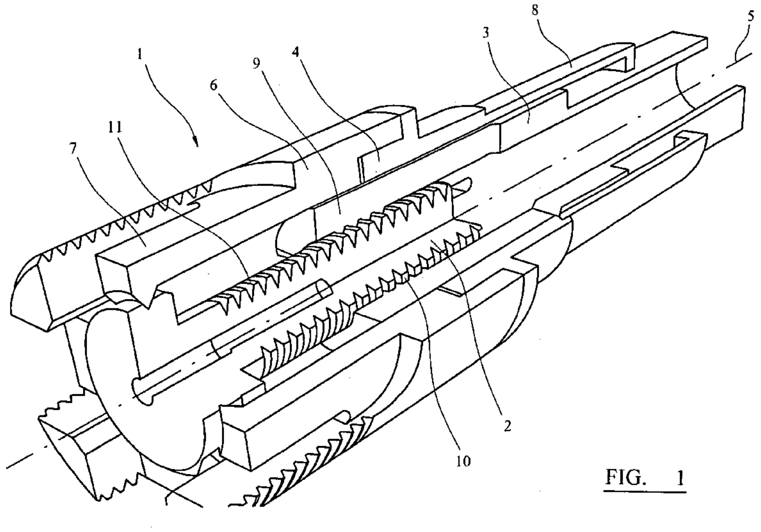

FIG. 1

(57) Abstract: A linear actuator (1) comprising a drive arm (2) and an extension arm (3) each extending along a common drive axis (5); the extension arm (3) being at least partially received in a housing (4), the housing (4) allowing displacement of the extension arm (3) along the drive axis (5) but preventing rotation of the extension arm (3) about the drive axis; the drive arm (2) and extension arm (3) being interengaged such that rotation of the drive arm about the drive axis displaces the, extension arm along the drive axis; the housing comprising a housing body (6) and a plurality of resiliently deformable gripping fingers (8) extending from the housing (4) and gripping the extension arm (3) therebetween.

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A Linear Actuator

The present invention relates to a linear actuator. More particularly, but not exclusively, the present invention relates to a linear actuator having a drive arm and an extension arm which are interengaged by threads, the extension arm being gripped by a plurality of gripping fingers which oppose rotation of the extension arm about a drive axis.

Linear actuators which convert rotary motion into linear motion are known. Simple mechanical actuators tend to suffer from a degree of backlash. This is at least partially due to 'wobble' of the extension arm within its housing. One solution to this problem is to bias the extension arm with a spring. This however increases the size of the device. Such devices are also unsuitable for use in microwave cavities where the metal spring affects the microwave resonance. An alternative solution is to use an optical or electrical feedback mechanism to compensate for the backlash. Such devices are complex and expensive.

The linear actuator according to the invention seeks to overcome the problems of the prior art.

Accordingly, the present invention provides a linear actuator comprising

a drive arm and an extension arm each extending along a common drive axis;

the extension arm being at least partially received in a housing, the housing allowing displacement of the extension arm along the drive axis but preventing rotation of the extension arm about the drive axis;

the drive arm and extension arm being interengaged such that rotation of the drive arm about the drive axis displaces the extension arm along the drive axis;

the housing comprising a housing body and a plurality of resiliently deformable gripping fingers extending from the housing and gripping the extension arm therebetween, the gripping fingers holding the extension arm in an equilibrium orientation relative to the drive axis;

the cross section of the extension arm normal to the drive axis at the point of gripping being non-circular and arranged such that as a rotational force is applied to the extension arms about the drive axis the gripping fingers oppose the rotational motion of the extension arm.

The linear actuator according to the invention is a simple mechanical device but does not suffer from backlash due to wobble of the extension arm. It is inexpensive to manufacture and is reliable. Also, it does not require the use of metallic biasing springs which make it suitable for use in

Preferably, the cross section of the gripping arm at the point of gripping an n sided polygon with n greater than or equal to three, preferably triangular, square or rectangular.

The gripping fingers can be adapted such that the force applied to the extension arm by the gripping fingers is substantially normal to the drive axis.

Preferably, the gripping fingers extend from the housing body away from the drive arm.

Alternatively, the gripping fingers extend from the housing body towards the drive arm

The gripping fingers can extend substantially parallel to the drive axis.

Preferably, each gripping finger comprises a shaft and a head extending from the shaft into abutment with the extension arm.

Preferably, the gripping fingers are deformed outwards by the extension arm when the extension arm is in the equilibrium position

The linear actuator can comprise at last three, preferably four gripping fingers.

The gripping fingers can be equally spaced about the drive axis.

Each gripping finger can contact the extension arm at multiple spaced apart points.

Preferably, each gripping finger is adapted to be deformed independently of the others.

Preferably, the housing comprises a housing body and a plurality of holding fingers extending from the housing body to grip the drive arm therebetween, the ends of the holding fingers having camming surfaces which are engaged with corresponding camming surfaces extending at least partially around the drive arm.

One of the camming surfaces can be a ridge and the other can be a groove.

Preferably, the holding fingers urge the camming surfaces into contact with each other, preferably normal to the drive axis.

The ridge and groove can be adapted such that the two sides of the ridge abut the two edges of the mouth of the groove.

The angle between the ridge faces at the point of abutment can be greater than the angle between the groove faces at the point of abutment.

The ridge and groove can be V shaped, the ridge angle being wider than the groove angle.

Each of the holding fingers can be adapted to be deformed independently of the others.

Preferably, the drive arm and extension arm are interengaged by threads.

Preferably, the end of one of the arms is split into a plurality of resiliently deformable fingers, at least one of the fingers having a thread on its inner face;

the threaded portion of the other arm being received between the fingers.

Preferably, the fingers urge the two threads together, preferably normal to the drive axis.

The two arms can be dimensioned such that the fingers are deformed outwards away from the drive axis.

The fingers can extend substantially parallel to the drive axis.

The linear actuator preferably comprises at least three, preferably four fingers.

The fingers can be equally spaced around the drive axis.

Preferably, each of the fingers is adapted to be deformed independently of the others.

Preferably, the threads are adapted such that when the ridge of one thread is received in the groove of the other thread the two sides of the ridge abut the two edges of the mouth of the groove.

Preferably, the angle between the ridge faces at the points of abutment is larger than the angle between the groove faces at the points of abutment.

Both threads can comprise V shaped ridges, the ridge angle of one thread being larger than the groove angle of the other thread.

In a further aspect of the invention there is provided a tuneable microwave resonator comprising

a microwave resonant cavity; and,

a linear actuator as claimed in any one of claims 1 to 30;

the linear actuator being arranged such that rotation of the drive arm displaces the tuning member within the cavity.

The tuning member can be a metal.

Alternatively, the tuning member can be a dielectric.

The present invention will now be described by way of example only and not in any limitative sense with reference to the drawings in which

Figure 1 shows a linear actuator according to the invention in cut away perspective view from the drive arm end;

Figure 2 shows threaded engagement between the drive arm and extension arm of a linear actuator according to the invention;

Figure 3 shows threaded engagement between the drive arm and extension arm of a further embodiment of a linear actuator according to the invention;

Figure 4 shows the end of an extension arm of a linear actuator according to the invention;

Figure 5 shows the end of a drive arm of a linear actuator according to the invention;

Figure 6 shows the drive arm and housing portions of a linear actuator according to the invention; and,

Figure 7 shows a linear actuator according to the invention in cut away perspective view from the extension arm end.

Shown in figure 1 is a linear actuator 1 according to the invention. The linear actuator 1 comprises a drive arm 2 and an extension arm 3 both partially received within a housing 4. The drive arm 2 and extension arm 3 both extend along a common drive axis 5.

The housing 4 comprises a housing body 6. A plurality of holding fingers 7 extend from the housing body 6 and grip the drive arm 2 therebetween. The holding fingers 7 constrain the drive arm 2 such that it is free to rotate about the drive axis 5 but cannot be displaced along the drive axis 5. The holding fingers 7 are described in more detail below. Similarly, a plurality of gripping fingers 8 extend from the housing body 6 and grip the extension arm 3 therebetween. The gripping fingers 8 constrain the extension arm 3 such that it is free to be displaced along the drive axis 5 but resist rotation of the extension arm 3 about the drive axis 5. Again the gripping fingers 8 are described in more detail below.

The end of the extension arm 3 is split into a plurality of independent resiliently deformable fingers 9 which extend beyond the end of the arm 3 towards the drive arm 2. In this embodiment the fingers 9 are substantially parallel to the drive axis 5. A thread 10 is arranged on the inner faces of the fingers 9.

The drive arm 2 has a threaded portion 11 on its outer face. The threaded portion 11 of the drive arm 2 is received within the fingers 9 such that the two threads 10,11 interengage. The drive arm 2 is dimensioned such that the fingers 9 are deformed outwardly away from the drive axis 5. The fingers 9 therefore urge the two threads 10,11 into interengagement. The fingers 9 are adapted such that the force applied by the fingers 9 urging the two threads 10,11 together is substantially normal to the drive axis 5.

Because of the threaded engagement between the drive arm 2 and the extension arm 3 rotation of the drive arm 2 about the drive axis 5 displaces the extension arm 3 along the drive axis 5.

The design of the two threads 10,11 of the linear actuator 1 according to the invention prevents backlash when the direction of rotation of the drive arm 2 is reversed. One embodiment of the threads 10,11 is shown in cross section in figure 3. Each thread 10,11 can be arranged on either drive arm 2 or extension arm 3.

As can be seen, as the ridge 14 of one thread 11 is urged into the groove 15 of the other thread 10 by the fingers 9 each of the two sides 16,17 of the ridge 14 abuts a corresponding edge 18,19 of the mouth of groove 15. The angle between the ridge faces 16,17 at the points of abutment is greater than the angle between the groove faces 20,21 at the point of abutment. Because the ridge 14 is in contact with both edges 18,19 of the mouth of the receiving groove 15 there is no change in relative position of drive arm thread 11 and extension arm thread 10 when the direction of rotation of the drive arm 2 is changed. Backlash is therefore eliminated in this portion of the device.

An important consideration is wear on the threads during use. With known threads, as the ridges are worn away the ridge of one thread becomes an increasingly poor fit in the groove of the other. The degree of backlash therefore increases. With the threads 10,11 according to the invention the ridge 14 of one thread 11 will always abut both sides 20,21 of the groove 15 of the other even as the threads 10,11 are worn away because of the fingers 9 urging the threads 10,11 into interengagement. This maintains zero backlash in this portion of the device.

A further important feature of the threads 10,11 of the linear actuator 1 according to the invention is that the ridge 14 of one thread 11 contacts the mouth of the groove 15 along lines at the edges 18,19 of the mouth, rather than over an extended area as with known threads. Rotation of the drive arm 2 therefore mainly imparts a force along the drive axis

5 to the extension arm 3 and only imparts a very minimal rotational force to the extension arm 3 around the drive axis 5. The importance of this is described in more detail below.

Shown in figure 4 is a further embodiment of the threads 10,11 of a linear actuator 1 according to the invention shown in cross section. In this embodiment both threads 10,11 have V shaped ridges 14 and grooves 15. The ridge angle of one thread 11 (ie the angle between ridge faces 16,17 at the point of contact of the two) is wider than the groove angle (ie the angle between the groove faces 20,21 at the point of contact of the two) of the other thread 10 so ensuring that the ridge 14 abuts both sides 20,21 of the mouth of the groove 15.

Shown in figure 5 are the fingers 9 extending beyond the end of the extension arm 3. In this embodiment the extension arm 3 comprises four fingers 9 which are equally spaced about the drive axis 5. In alternative embodiments different numbers of fingers 9 are possible. In an alternative embodiment (not shown) the end comprises three fingers 9 equally spaced about the drive axis 5. In this embodiment two of the fingers 9 of the extension arm 3 extend beyond the others to form end stops 22. The end stops 22 are on opposite sides of the drive axis 5.

Figure 6 shows the end of the drive arm 2 remote from the extension arm 3. The drive arm 2 comprises a threaded shaft portion 11 and a head portion 23. Extending from the head portion 23 parallel to the drive axis 5 are two end stops 24. Again the end stops 24 are arranged on opposite sides of the drive axis 5. As the drive arm 2 is rotated about the drive axis 5 the extension arm 3 travels along the drive arm 2 towards the drive arm head portion 23. As the extension arm 3 reaches an end of its range of motion the extension arm end stops 22 rotate into abutment with the drive arm end stops 24 preventing further rotation of the drive arm 2 and travel of the extension arm 3. Because the end stops 22,24 are arranged in pairs, the abutment does not produce an overall lateral force on the extension arm 3 normal to the drive axis 5 so preventing displacement of the extension arm 3 to one side. In embodiments with an odd number of fingers 9 the end stops 22,24 are arranged such that as the fingers 9 rotate into abutment no overall lateral force is provided to the extension arm 3.

As can be seen in figure 6, the head portion 23 of the drive arm 2 includes a groove 25 extending around the drive arm 2. The function of this groove 25 is best explained with reference to figure 7 which shows the end of the drive arm 2 received within the housing 4. As mentioned above, resiliently deformable holding fingers 7 extend from the housing body 6 to the drive arm 2 and grip the head portion 23 therebetween. At the end of each arm 7 is a camming surface 26 (in this embodiment a ridge) which engages with a corresponding camming surface 27 of the head portion 23 (in this embodiment the groove). The ridge angle of the ridge 26 is wider than the groove angle of the groove 27 such that each side of the ridge 26 abuts a corresponding edge of the mouth of the groove 27. The drive arm 2 is therefore prevented from being displaced along the drive axis 5 but is free to rotate about the drive axis 5. Because the ridge 26 and groove 27 contact each other along lines along the edges of the mouth of the groove 27 there is very little friction opposing rotation of the drive arm 2.

In this embodiment the holding fingers 7 extend substantially parallel to the drive axis 5. The head portion 23 of the drive arm 2 bends the fingers 7 outwards so that the fingers 7 urge the ridge 26 into the groove 27. The urging force is substantially normal to the drive axis 5.

In an alternative embodiment of the invention the camming surface 27 of the drive arm 2 comprises a ridge and the camming surface 26 of the holding fingers 7 comprises a groove. The holding fingers 7 are adapted such that they can each be deformed independently of each other.

Figure 8 shows the linear actuator 1 from the opposite end in cut away section. A plurality of gripping fingers 8 (in this case four fingers) extend from the housing body 6 and grip the extension arm 3 therebetween. The extension arm 3 of this embodiment is square in cross section at the point of gripping. The gripping fingers 8 each comprise a shaft 29 which extends substantially parallel to the drive axis 5. Each gripping finger 8 has a gripping head 30 which abuts the extension arm 3 and extends substantially normal to the drive axis 5. The extension arm 3 is dimensioned such that the gripping fingers 8 are bent outwards away from the drive axis 5 so urging the gripping heads 30 into abutment with the extension arm 3. The urging force is substantially normal to the drive axis 5.

Without any force applied to the extension arm 3 the gripping fingers 8 hold the extension arm 3 in an equilibrium orientation relative to the drive axis 5 as shown. If a rotational force is applied to the extension arm 3 about the drive axis 5 the gripping fingers 8 oppose rotation of the extension arm 3. This is because of the shape of the extension arm 3. As the extension arm 3 attempts to rotate, the extension arm 3 urges the gripping fingers 8 outwardly away from the drive axis 5. The gripping fingers 8 provide a restoring force returning the extension arm 3 to its equilibrium position.

If the rotational force is too great there is a danger the extension arm 3 will move from one equilibrium position to the next (in this case rotating by 90 degrees about the drive axis 5). As previously mentioned however the threads 10,11 which interengage the drive arm 2 and extension arm 3 are adapted such that the ridge of one abuts the mouth of the groove of the other along lines at the edge of the mouth. Rotating the drive arm 2 therefore produces relatively little turning force on the extension arm 3 about the drive axis 5 so preventing this from happening.

Other shapes of cross section of the extension arm 3 are possible. Most generally the cross section of the extension arm 3 at the point of gripping is non circular. The cross section of the extension arm 3 can be an n sided polygon with n greater than three, preferably triangular, rectangular or square. The housing 4 will have a corresponding number of gripping fingers 8, one for each side of the polygon. Preferably the gripping fingers 8 are equally spaced about the drive axis 5.

The gripping fingers of this embodiment are bifurcated at their ends at the point of abutment with the extension arm. This reduces friction between the extension arm and gripping fingers.

The gripping fingers 8 are adapted such that each gripping finger 8 can be resiliently deformed independently of the others.

A further advantage of the linear actuator 1 according to the invention is that both the drive arm 2 and extension arm 3 are suspended by fingers 7,8 extending from the housing body 6. Neither the drive arm 2 nor the extension arm 3 is rigidly fixed to the housing 4 at any point. The independently deformable fingers 7 allow for a small substantially conical displacement of the drive arm 2 about the drive axis 5. Similarly, the independently deformable gripping fingers 8 allow for a conical displacement of the extension arm 3 about the drive axis 5 relative to the housing. The drive arm 2 and the extension arm 3 can therefore be slightly misaligned during use without the linear actuator 1 jamming. In known linear actuators if the drive arm urged out of alignment with the extension arm during use the actuator will jam.

In an alternative embodiment of the invention the gripping fingers 8 extend from the housing body 6 to the extension arm 3 in a direction towards the drive arm 2.

In all of the above embodiments the drive arm 2 and extension arm 3 are interengaged by antibacklash threads 10,11. In alternative embodiments of the invention other types of threads are employed. In an alternative embodiment of the invention the threads of the drive arm 2 and extension arm 3 are substantially identical. In an alternative embodiment of the invention other engagement means between drive arm 2 and extension arm 3 are possible such as camming surfaces.

In the above embodiments the end of the extension arm 3 is split into fingers 8 which grip the drive arm 2. In alternative embodiments the drive arm 2 grips the extension arm 3.

In a further embodiment of the invention neither of the arms 2,3 is split into fingers. The ends of one of the arms 2,3 comprises a recess having a thread on its inner face. The threaded portion of the other arm 2, 3 is received within the recess.

A typical application of such a linear actuator 1 is in the tuning of microwave resonators. The linear actuator 1 displaces a tuning member within a microwave resonant cavity to tune the microwave resonant cavity. The tuning member can be a metal. The tuning member can be a dielectric. Typically the linear actuator 1 is arranged outside the cavity with the extension arm 3 extending into the cavity via an aperture in the cavity wall. When used in such applications the actuator 1 is manufactured from one or more plastics materials.

CLAIMS

1. A linear actuator comprising

a drive arm and an extension arm each extending along a common drive axis;

the extension arm being at least partially received in a housing, the housing allowing displacement of the extension arm along the drive axis but preventing rotation of the extension arm about the drive axis;

the drive arm and extension arm being interengaged such that rotation of the drive arm about the drive axis displaces the extension arm along the drive axis;

the housing comprising a housing body and a plurality of resiliently deformable gripping fingers extending from the housing and gripping the extension arm therebetween, the gripping fingers holding the extension arm in an equilibrium orientation relative to the drive axis;

the cross section of the extension arm normal to the drive axis at the point of gripping being non-circular and arranged such that as a rotational force is applied to the extension arms about the drive axis the gripping fingers oppose the rotational motion of the extension arm.

2. A linear actuator as claimed in claim 1 wherein the cross section of the gripping arm at the point of gripping is an n sided polygon with n greater than or equal to three, preferably triangular, square or rectangular.

3. A linear actuator as claimed in either of claims 1 or 2, wherein the gripping fingers are adapted such that the force applied to the extension arm by the gripping fingers is substantially normal to the drive axis.

4. A linear actuator as claimed in any one of claims 1 to 3, wherein the gripping fingers extend from the housing body away from the drive arm.

5. A linear actuator as claimed in any one of claims 1 to 3, wherein the gripping fingers extend from the housing body towards the drive arm

6. A linear extension arm as claimed in any one of claims 1 to 5 wherein the gripping fingers extend substantially parallel to the drive axis.

7. A linear actuator as claimed in any one of claims 1 to 6, wherein each gripping finger comprises a shaft and a head extending from the shaft into abutment with the extension arm.

8. A linear actuator as claimed in an one of claims 1 to 7, wherein the gripping fingers are deformed outwards by the extension arm when the extension arm is in the equilibrium position

9. A linear actuator as claimed in any one of claims 1 to 8, comprising at last three, preferably four gripping fingers.

10. A linear actuator as claimed in any one of claims 1 to 9, wherein the gripping fingers are equally spaced about the drive axis.

11. A linear actuator as claimed in any one of claims 1 to 10, wherein each gripping finger contacts the extension arm at multiple spaced apart points.

12. A linear actuator as claimed in any one of claims 1 to 11, wherein each gripping finger is adapted to be deformed independently of the others.

13. A linear actuator as claimed in any one of claims 1 to 12, wherein the housing comprises a housing body and a plurality of holding fingers extending from the

housing body to grip the drive arm therebetween, the ends of the holding fingers having camming surfaces which are engaged with corresponding camming surfaces extending at least partially around the drive arm.

14. A linear actuator as claimed in claim 13, wherein one of the camming surfaces is a ridge and the other is a groove.

15. A linear actuator as claimed in claim 14, wherein the holding fingers urge the camming surfaces into contact with each other, preferably normal to the drive axis.

16. A linear actuator as claimed in either of claims 14 or 15, wherein the ridge and groove are adapted such that the two sides of the ridge abut the two edges of the mouth of the groove.

17. A linear actuator as claimed in claim 16, wherein the angle between the ridge faces at the point of abutment is greater than the angle between the groove faces at the point of abutment.

18. A linear actuator as claimed in either of claims 16 or 17, wherein the ridge and groove are V shaped, the ridge angle being wider than the groove angle.

19. A linear actuator as claimed in any one of claim 13 to 18, wherein each of the holding fingers is adapted to be deformed independent of the others.

20. A linear actuator as claimed in any one of claims 1 to 19, wherein the drive arm and extension arm are interengaged by threads.

21. A linear actuator as claimed in claim 19, wherein the end of one of the arms is split into a plurality of resiliently deformable fingers, at least one of the fingers having a thread on its inner face;

the threaded portion of the other arm being received between the fingers.

22. A linear actuator as claimed in claim 21, wherein the fingers urge the two threads together, preferably normal to the drive axis.

23. A linear actuator as claimed in either of claims 21 or 22, wherein the two arms are dimensioned such that the fingers are deformed outwards away from the drive axis.

24. A linear actuator as claimed in any one of claims 21 to 23, wherein the fingers extend substantially parallel to the drive axis.

25. A linear actuator as claimed in any one of claims 21 to 24, comprising at least three, preferably four fingers.

26. A linear actuator as claimed in claim 25, wherein the fingers are equally spaced around the drive axis.

27. A linear actuator as claimed in any one of claims 21 to 26, wherein each of the fingers is adapted to be deformed independently of the others.

28. A linear actuator as claimed in any one of claims 20 to 27, wherein the threads are adapted such that when the ridge of one thread is received in the groove of the other thread the two sides of the ridge abut the two edges of the mouth of the groove.

29. A linear actuator as claimed in claim 28, wherein the angle between the ridge faces at the points of abutment is larger than the angle between the groove faces at the points of abutment.

30. A linear actuator as claimed in claim 29, wherein both threads comprise V shaped ridges, the ridge angle of one thread being larger than the groove angle of the other thread.

31. A tuneable microwave resonator comprising

a microwave resonant cavity; and,

a linear actuator as claimed in any one of claims 1 to 30;

the linear actuator being arranged such that rotation of the drive arm displaces the tuning member within the cavity.

32. A tuneable microwave resonator as claimed in claim 31, wherein the tuning member is a metal.

33. A tuneable microwave resonator as claimed in claim 31, wherein the tuning member is a dielectric.

34. A linear actuator substantially as hereinbefore described.

35. A tuneable microwave resonator substantially as hereinbefore described.

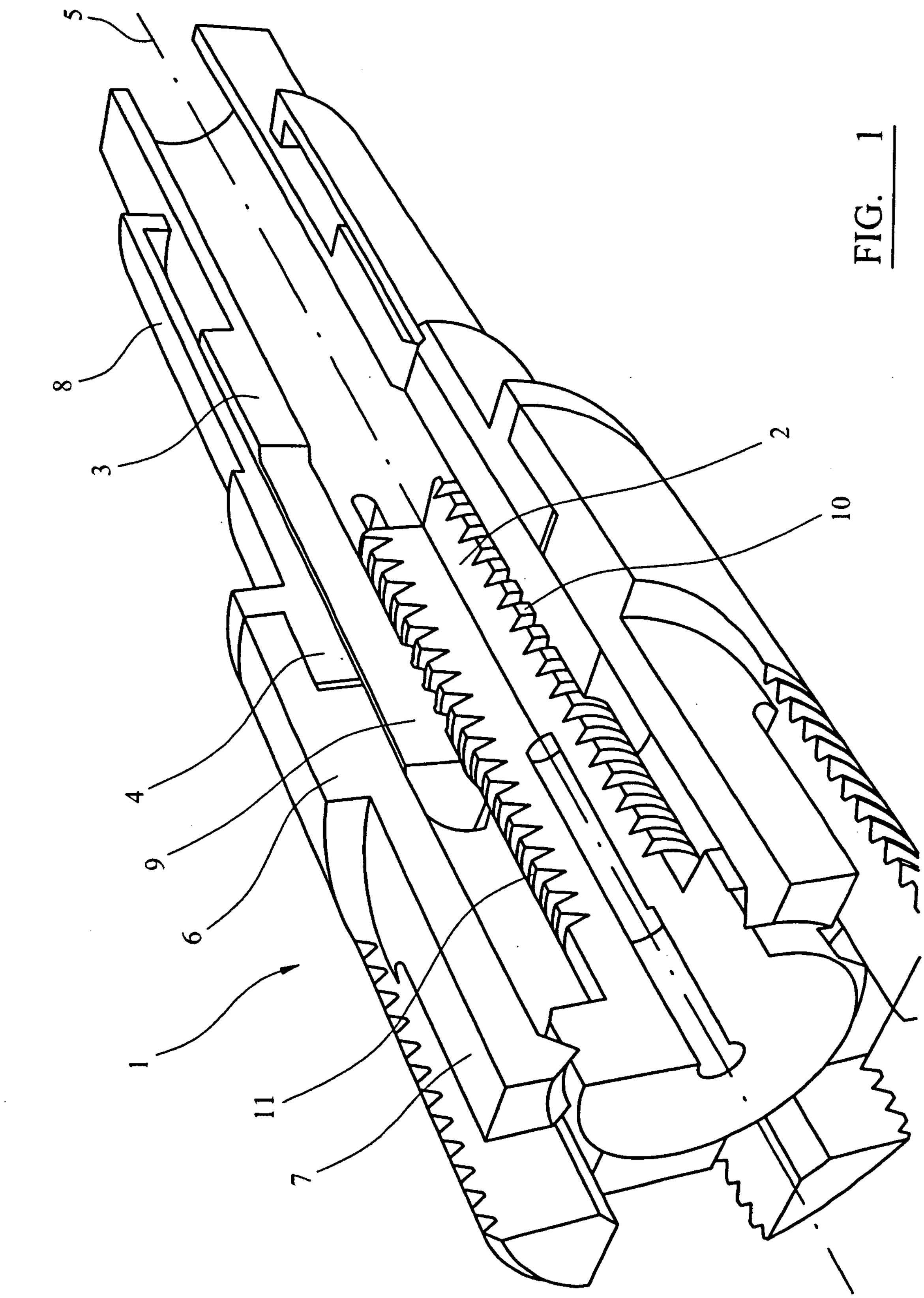

FIG. 1

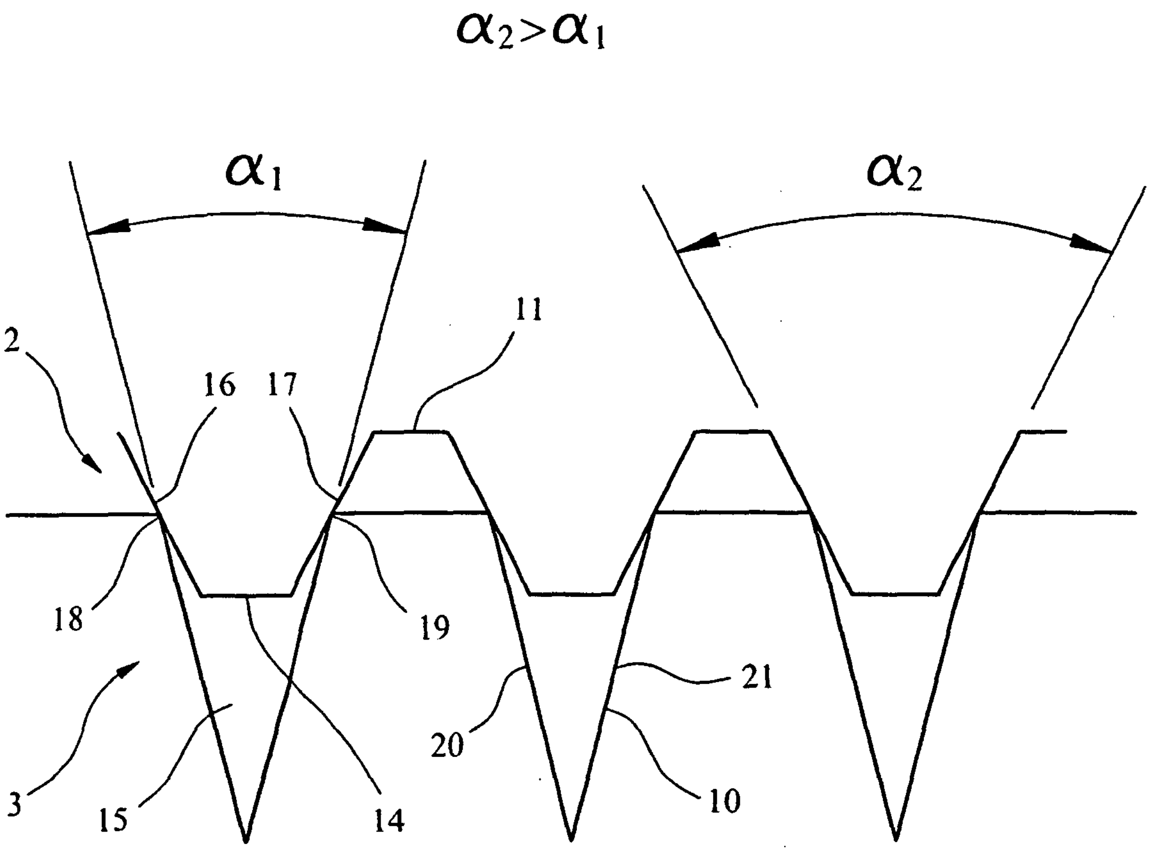

FIG. 2

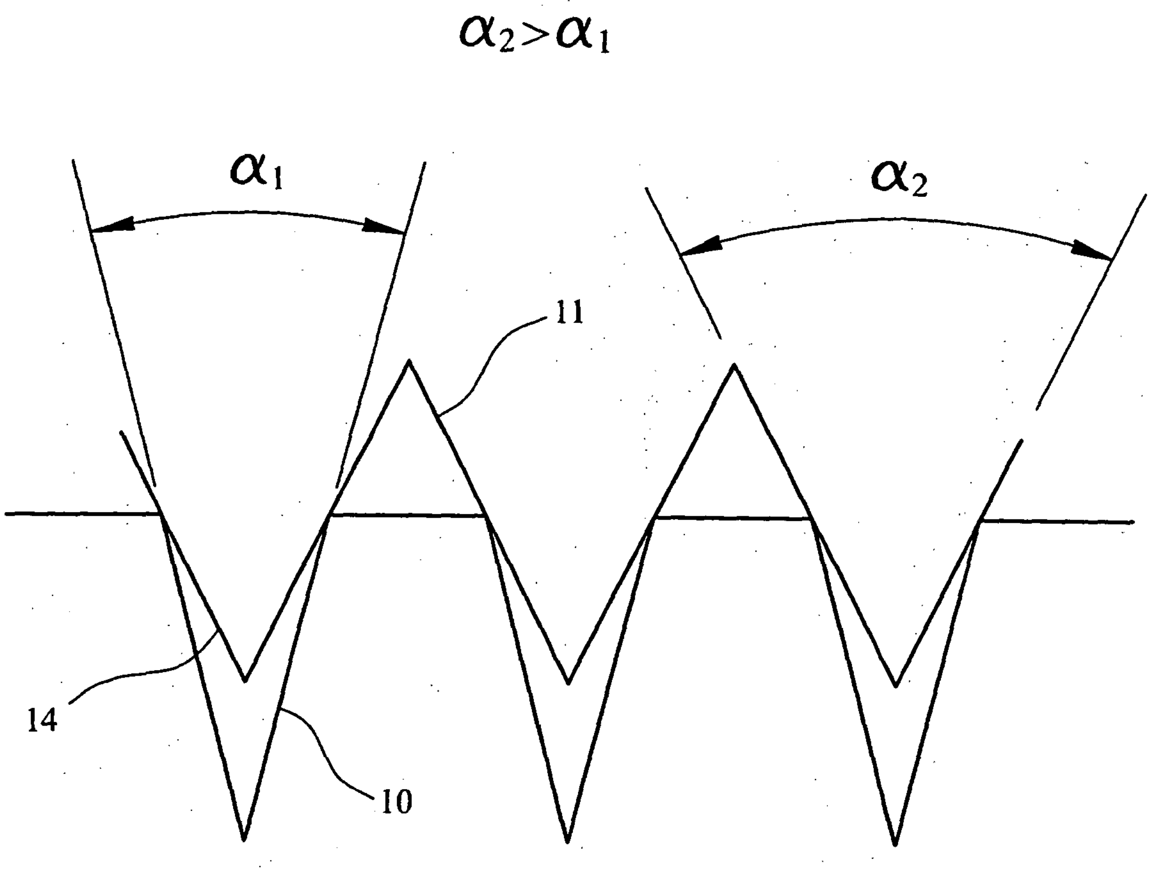

FIG. 3

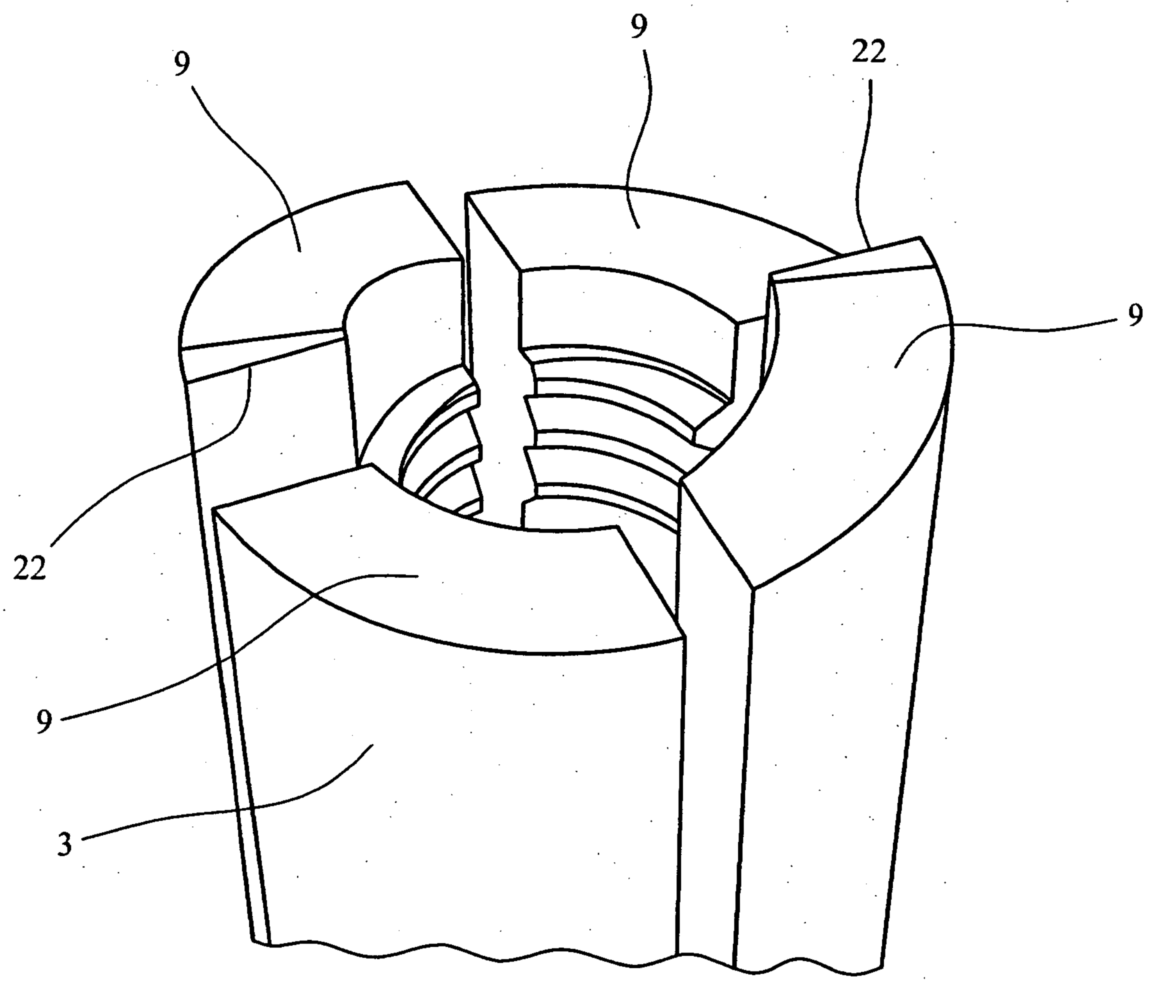

FIG. 4

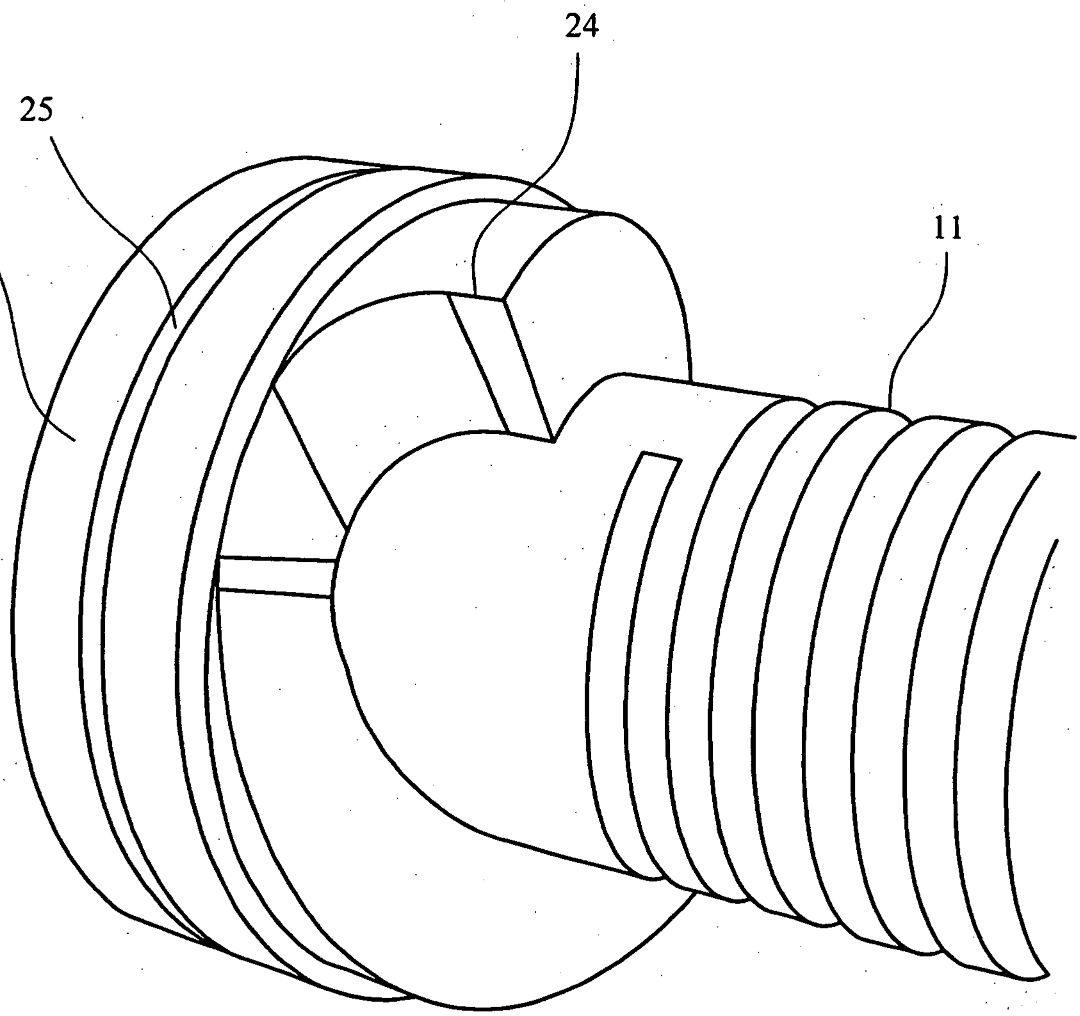

FIG. 5

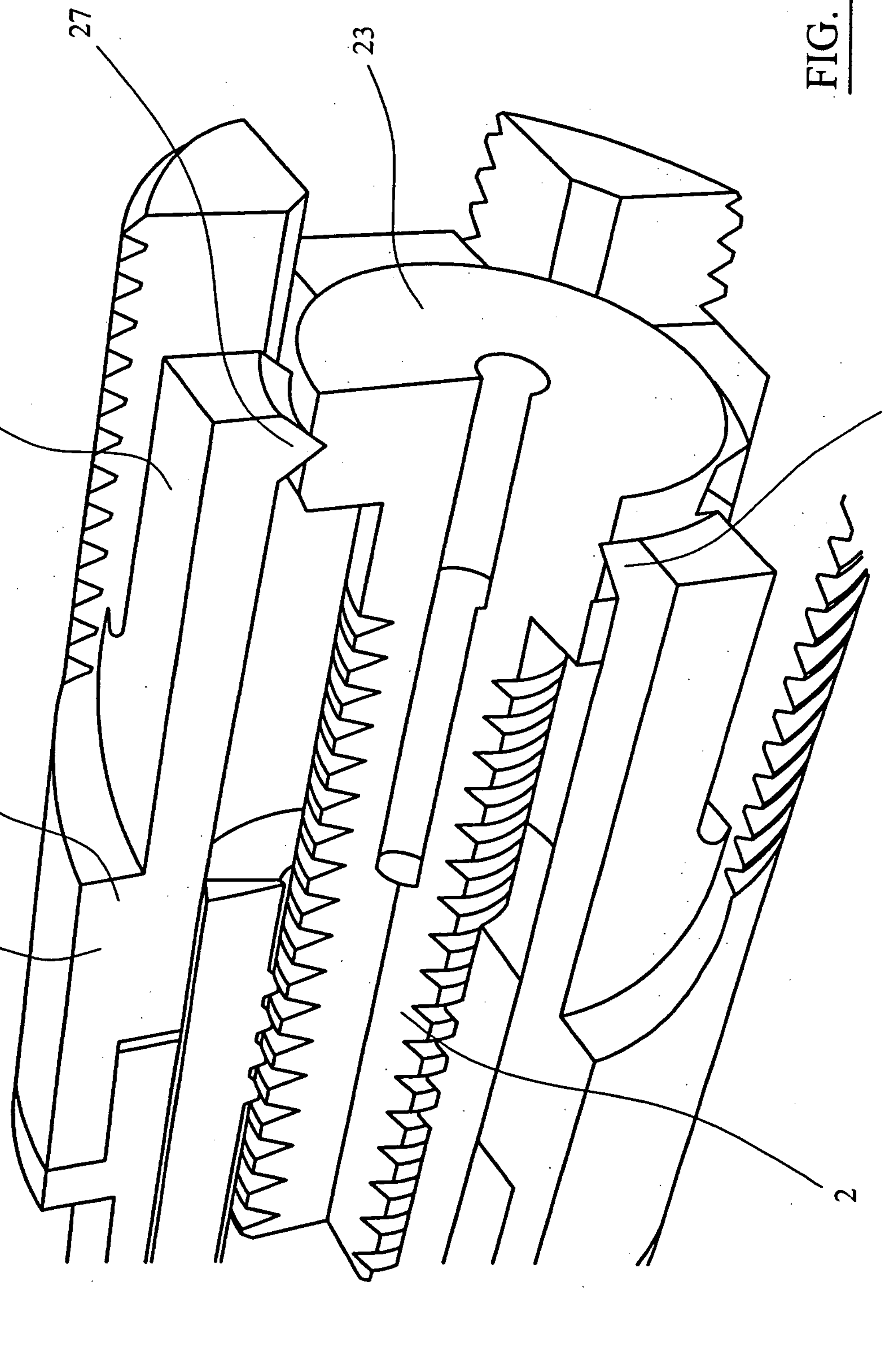

FIG. 6

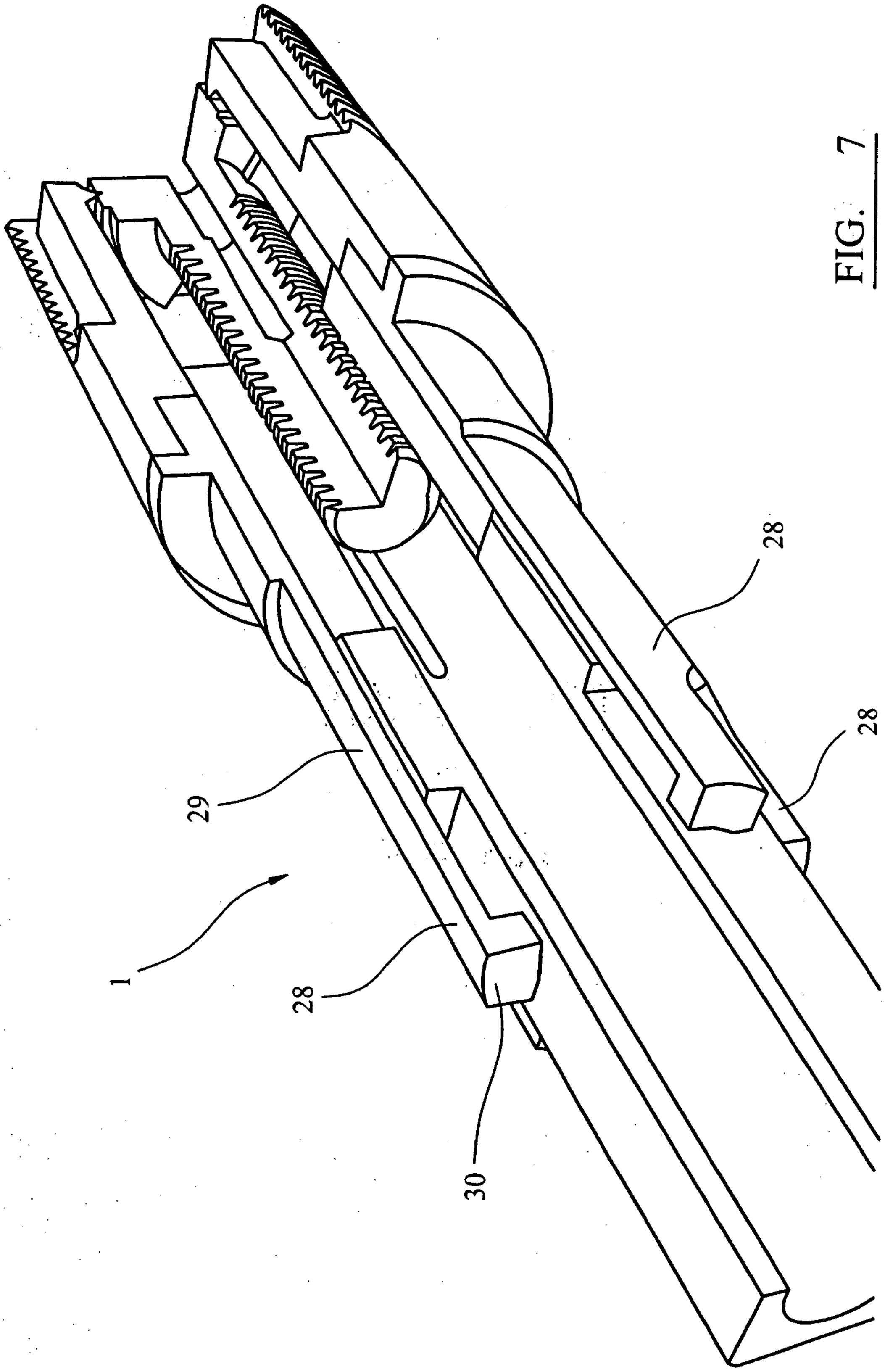

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2009/000946

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H25/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/028305 A (DEWERT ANTRIEBS SYSTEMTECH [DE]; DEWERT VERWALTUNGS GMBH [DE]; HANEBAL) 8 April 2004 (2004-04-08)	34
A	abstract	1

X	US 5 729 075 A (STRAIN ROBERT J [US]) 17 March 1998 (1998-03-17) abstract	35

A	US 4 479 398 A (WATANABE SHUNSO F [US]) 30 October 1984 (1984-10-30) abstract	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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