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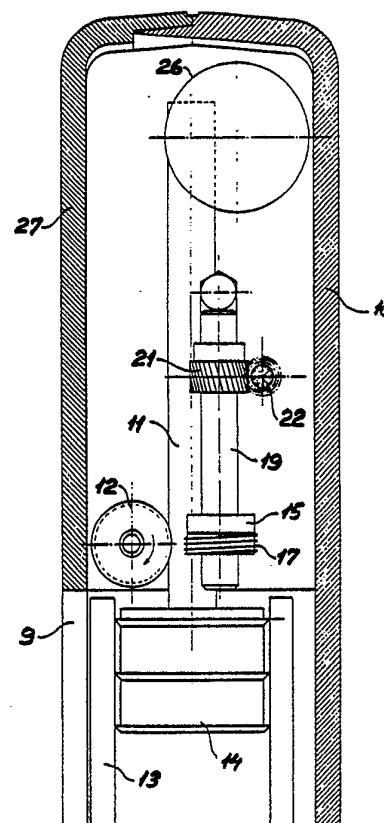
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(54) Title: A DRIVE MECHANISM FOR AXIAL MOVEMENT OF A ROD, IN PARTICULAR AN INFUSION PUMP

(57) Abstract

In a drive mechanism of the type where a rotating drive wheel deforms and partly works into engagement with a rod of deformable material to axially displace the rod as the drive wheel rotates, the drive wheel is a wheel (15) which is provided with worm threads (17) and whose axis of rotation is substantially parallel with the said rod (11). According to the invention, such a structure results in an unprecedented great metering accuracy with indication of very small doses from e.g. an injection syringe (13) whose plunger (14) is driven by said rod (11). The invention is characterized in that the worm threads work into the deformable material of the rod under the action of essentially completely continuous forces. The preferred embodiment comprises two worms (in Fig. 4 behind the worm (17) on the opposite side of the rod (11) driven by their respective shafts (19), which are driven by a common worm (22) via helical toothed wheels (21). An antibackup roller (12) placed in an opening cover (27) serves to press the rod (11) down between the two worms so as to provide some wedge effect. Complete balance in the mechanism is obtained because the two worms rotate in the opposite direction.



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A drive mechanism for axial movement of a rod, in  
particular an infusion pump

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The invention concerns a drive mechanism for axial move-  
5 ment of a rod, in particular a plunger rod for an infusion  
pump. For example the British Patent Specification  
2 077 599 discloses an automatic infusion pump to receive  
an infusion syringe, said pump comprising a battery and  
a control circuit for a motor driving a gear which drives  
10 an axially grooved drive wheel whose axis of rotation is  
perpendicular to the plunger rod of the infusion syringe.  
In this known apparatus the plunger rod is pressed against  
the drive wheel so that the cams of said wheel pene-  
trate into the plunger rod consisting of plastics which  
15 is cold deformed by the penetration of the cams.

Provided that the gear has been manufactured with great  
accuracy, this known apparatus can give a tolerance of  
about 5% of the injected amount per unit of time when the  
20 unit of time is of the order of several hours. In certain  
medicaments, e.g. insulin, however, it is desirable to  
obtain a corresponding metering accuracy even if the  
mentioned unit of time is only about one hour. Since the  
patient carries the infusion pump on him, the pump should  
25 be as compact as possible, and this entails in practice  
that the diameter of the known drive wheel is about 5 mm  
and that an average of four of its about 30 cams or teeth  
engage the plunger rod. Further, the drive wheel is only  
to rotate about 1/200 of an entire revolution for the pump  
30 to deliver an international unit of insulin, and it will  
therefore be appreciated that the desired accuracy is  
difficult to obtain since not only are huge requirements  
made of the tolerance of the drive wheel tooth cross-  
section, but also any inhomogeneity in the plunger rod  
35 material affects the deformation of the material by each  
tooth during the entire travel thereof through the mate-  
rial. It will moreover be appreciated that also variations

in the effective pitch diameter of the drive wheel because of e.g. eccentricity, bearing wear or impurities in the bottom of the axial grooves of the wheel greatly affect the accuracy of the apparatus.

5

The object of the invention is to provide a drive mechanism of the above-mentioned type which significantly improves the accuracy over the prior art, while no huge tolerance requirements are made of the gear transmission of the  
10 mechanism.

This object is achieved by the use of a worm drive, as stated in the characterizing portion of claim 1, because precisely the use of a worm drive known per se for an  
15 apparatus, in which the flanks of one or more worm threads penetrate evenly into the rod material by cold deformation thereof, provides more and surprising advantages than those already known in connection with non-self-cutting worm gears.

20

First, the relative or short term accuracy is improved since each track formed by the worm threads in the plunger rod has a constant cross-section over a substantial portion of the engagement between the track and the worm, and  
25 since more thread flanks than in the prior art engage the rod material, axial flowing of the rod material because of the counter pressure of the plunger rod will be less pronounced. Second, also the absolute or long term accuracy is improved because the transmission does not depend upon  
30 a pitch diameter, but only upon the pitch of the worm threads. Finally, it may be stated that the worm mechanism is self-cleaning, and that the large transmission allows the other toothed wheels of the gear transmission to be manufactured with small tolerance requirements and  
35 optionally to be plastics moulded.

The friction between the worms and the plunger rod has been found to be relatively great with respect to the energy consumption for the advance of the plunger rod, and particularly in case of mechanisms driven by  
5 batteries it is desirable to reduce the frictional energy. This can be obtained by reducing the axial length of the drive worms, whereby, however, the displacement of the plunger rod material will have a relatively great influence on the accuracy, which accordingly varies with the  
10 rotation of the drive worms. Since the invention also comprises smoothing of this variation, the characterizing portion of claim 1 sets forth a combination of features providing a significantly greater accuracy with respect to the prior art.

15 As stated in claim 2, the smoothing of the thread inlet is preferably obtained by mutual angular displacement. To obtain equilibrium for lateral forces, the embodiment defined in claim 3 is preferably used, and this embodiment  
20 also entails that the plunger rod is wedged down between the drive worms.

Claim 4 defines alternative features for smoothing of the worm thread inlet so that the metering accuracy is not  
25 affected by discontinuous thread inlets.

The thread inlet may be made additionally even by making the drive worms single conical or double conical. The single conical form stated in claim 5 involves a noticeable  
30 advantage at the thread inlet, while the double conical form stated in claim 6 also involves smoothing of the thread outlet.

The effect of discontinuous inlets and outlets can be  
35 further reduced by the features defined in claim 7, which require the presence of two or more worms.

Claim 8 defines details in a preferred embodiment which is particularly inexpensive to manufacture, in particular for infusion syringes. Especially in connection with the infusion syringe, the invention provides the additional  
5 advantage that the counter pressure caused by blocking or by homing of the infusion syringe plunger is transformed to a force which is substantially parallel with the axis of the worm, and which is therefore easy to detect, e.g. by means of the features stated in claim 9.

10

The invention will be explained more fully by the following description of some embodiments with reference to the drawing, in which

15 figs. 1 and 2 show a known, automatic infusion pump,

fig. 3 is an explanatory sketch of the prior art,

figs. 4 and 5 show sections through a preferred embodiment  
20 of the mechanism of the invention,

fig. 6 is a bottom view of the mechanism of figs. 4 and 5, while

25 figs. 7-9 are explanatory sketches of alternative embodiments of the drive mechanism of the invention.

The known structure shown in fig. 1 comprises a housing 1 with a cavity 2 to receive a carpule 3 for an infusion  
30 syringe, which moreover comprises a plunger 4 and an associated plunger rod 5 preferably made of plastics. The numeral 6 designates a slide which in the extended position allows the carpule and the plunger rod to be received in the apparatus, following which the slide can be pushed  
35 into position, as appears from fig. 2. The slide 6 is arranged to urge the plunger rod 5 down toward a drive

roller 7 driven by a motor in the housing 1 via a gear. The housing moreover accommodates electronic means to control the motor so that a specific dosis per unit of time is metered or a predetermined dosis is dispensed each  
5 time a switch 8 is activated. The apparatus is designed to be carried by a patient, e.g. a diabetic, and the infusion syringe is connected via a plastics hose with a needle inserted into the patient. It is therefore desirable that the apparatus is as compact as possible,  
10 and that metering as accurate as possible can be obtained.

In practice, the drive roller 7 is only about 5 mm in diameter (see fig. 3), and for the apparatus to dispense an international unit of insulin the roller is just to  
15 be rotated about 1/200 of an entire revolution. Since only few teeth of the roller 7 are engaged with the plunger rod 5, it is very difficult with this art to obtain an accuracy of about 5%, based on an insulin unit. There are several sources of inaccuracy, one of them being that each  
20 of the drive roller teeth works into the plunger rod 5 by cold deformation of it, said cold deformation continuing over the entire travel of the tooth through the material. The transmission ratio depends on a pitch diameter, which varies with the function of the depth of tooth penetration  
25 into the plunger rod, and it will therefore be appreciated that impurities in the bottom of the teeth, like drive roller bearing wear, affects the accuracy. All these drawbacks are remedied by the mechanism of the invention, a preferred embodiment of which is shown in figs. 4-6.

30 Since the invention concerns the drive engagement with the cold deformable plunger rod alone, only this drive mechanism is shown in figs. 4-6, while it will be appreciated that figs. 4-6 are taken of an apparatus which  
35 might otherwise be constructed as explained in connection with figs. 1 and 2. In fig. 4 the numerals 9 and 10

designate the top side and the underside, respectively, of a housing of the type shown in fig. 1. Fig. 4 shows a section through the housing, a plunger rod 11 being visible which is placed in the apparatus together with the associated plunger 14 and the carpule 13. A roller 12 serves to press the plunger rod 11 down between two worm wheels 15, 16 (fig. 5), which are each provided with one or more threads 17, 18 designed to cut into the relatively soft plunger rod material, which is preferably plastics. Each of the worm wheels 15, 16 is placed on an associated shaft 19, 20 rotated in opposite directions of rotation by means of a common worm or toothed wheel gear. More particularly, the shaft 19 has a helical toothed wheel 21 which is driven by a toothed wheel 22, which is in turn attached to a shaft 23 supporting an additional worm wheel 24 driving the shaft 20. As appears from the arrows in fig. 5, the worms 15, 16 are driven in opposite directions, thereby preventing the plunger rod 11 from being subjected to a rotational force. The shaft 23 is driven via a toothed wheel 28 via an additional gear transmission by a motor, which is schematically shown at 26.

As appears from fig. 5, the antibackup roller 12 is journaled in a slide 27 (for clarity, this does not appear clearly from fig. 4). The slide 27 serves the same purpose as the slide 6 from fig. 1 so that the plunger rod 11 is kept in place and wedged between the two worm wheels 15, 16. It will thus be appreciated that the plunger rod 11 is driven axially when the shaft 23 rotates, the threads 17, 18 on the worms 15, 16 cutting into the plunger rod 11 while cold deforming it. Fig. 6 is a schematic bottom view of the mechanism of fig. 5, showing clearly the engagement between the wheels mentioned in connection with fig. 5 and the plunger rod 11. Because of the large transmission in the worms, it will be appreciated that

the (not shown) toothed wheels in the gear transmission between the toothed wheel 28 and the motor 26 can be made of plastics.

- 5 Fig. 6 moreover shows a pair of embodiments of pressure bearings for the shafts 19 and 20, respectively. The shaft 19 can be journalled like the shaft 20, but, in the drawing, it is journalled against a fixed steel ball 29. If the needle should be blocked, or the plunger 14 has bottomed  
10 in the carpule 13, a strong counter pressure will be generated in parallel with the shafts 19, 20, which can be detected by means of the pressure bearing embodiment shown in fig. 6 for the shaft 20. The latter pressure bearing comprises a seat rim 30 for the steel ball 31,  
15 which is pressed against this seat by means of a spring 32 whose spring force is adjustable by means of a screw 33. Connection of electric leads to the seat rim 30 and the screw 33, respectively, results in the generation of an electric interruption if the shaft 20 is urged to the  
20 right by a force exceeding the spring force set by the screw 33. Thus, an alarm for the patient is obtained in a very simple manner, and overloading of the mechanism is avoided.
- 25 The most essential advantages of the mechanism of the invention have already been mentioned in the preamble to the description, and they will therefore just be repeated briefly here in relation to the embodiment described above. First, the transmission ratio is very well-defined and  
30 depends upon the pitch of the threads on the worms 15, 16, independent of the depth of penetration of the threads into the plunger rod 11. The thread inlet and outlet problems have also been mentioned before, but it has been found in practice that the described embodiment involves  
35 a suitable reduction in the action upon the thread inlets in that the thread inlets are mutually angularly displaced,

which means that the beginning of the threads (34, 35 in fig. 5) is mutually rotated through an angle of  $180^\circ$ . Preferably, the envelopes of the threads are conical, the vertex being in the direction of the carpule, and the included angle being just a few degrees. The combination of this slightly expanding pitch diameter and the angularly displaced inlets has been found to be particularly advantageous. Corresponding measures may also be taken in connection with the thread outlets, but this is not necessary to obtain the desired accuracy in practice.

Some alternative embodiments will be described below in connection with figs. 7-9. Fig. 7 shows an explanatory sketch of an embodiment comprising three worm wheels 36, 37, 38 designed to drive a plunger rod 39. The plunger rod 39 might be made of a hard material on whose exterior a sleeve 40 of a cold deformable material is placed. Of course, the embodiment shown in fig. 7 is not suitable in connection with the slide described previously, but is useful in a mechanism where the plunger rod is introduced axially with respect to the drive worms 36-38. Provision of several worms results in further smoothing of the inlets, merely by displacing these mutually in an angle of about  $120^\circ$  when three worms are provided.

Fig. 8 is a schematic view of an embodiment in which the axis of rotation of the worm 41 forms an acute angle with the plunger rod 42. The thread 43 is shown with a very great pitch for clarity, and when the axis of rotation of the worm is rotated through the said angle the threads form grooves in the plunger rod 42, said grooves being perpendicular to the plunger rod so that the drive force on the plunger rod 42 is approximately parallel with the direction of movement of the plunger. The numeral 44 designates the grooves produced by the thread 43 in the plunger rod 42, and when the worm 41 extends beyond the area

where it cooperates with the plunger rod 42, discontinuous thread inlet and outlet can be obtained, which is symbolized by the solid lines on the worm, these lines representing the extent of the thread cooperation with the plunger rod 42.

Fig. 9 shows an additional embodiment of a worm mechanism of the invention, where it can be seen that the worm 45 has a barrel-shaped cross-section, which means that the diameter of the threads is greatest at the centre and decreases toward the ends of the worm. The plunger rod is represented at 46, and it will therefore readily be seen that the grooves 47 in the plunger rod are produced continuously as the worm 45 rotates, and the thread emerges continuously and evenly from the grooves 47.

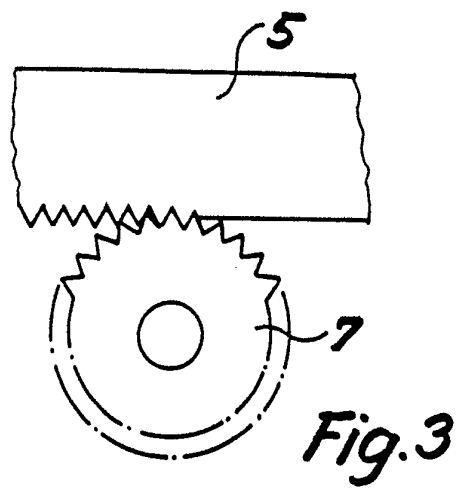
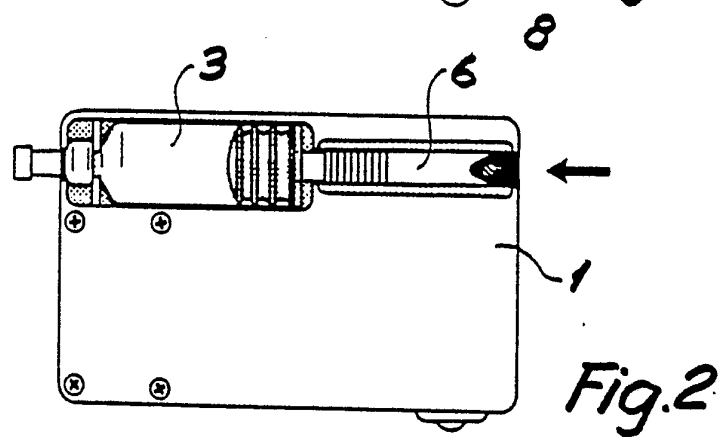
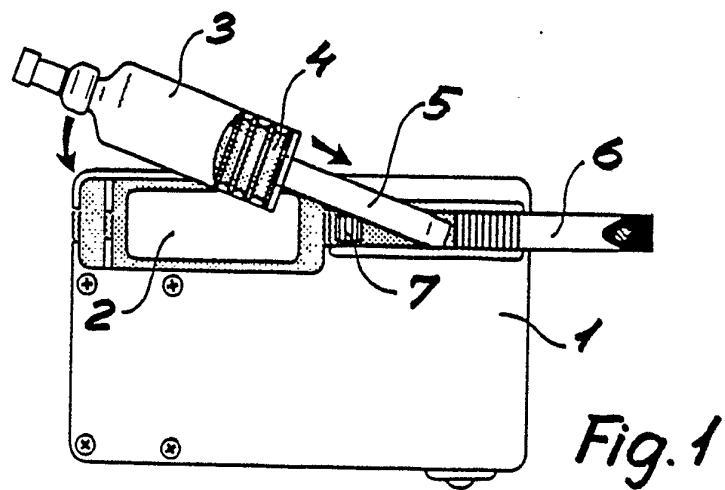
It will be appreciated that the variants shown in figs. 8 and 9 might be incorporated in embodiments of e.g. the type shown in figs. 4-6 and 7, thus providing a wide spectrum of optional variations with respect to the desired accuracy and the manufacturing price.

P a t e n t   C l a i m s  
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1. A drive mechanism for axial advance of a plunger rod, in particular for an injection syringe, said mechanism comprising rotating drive means designed to penetrate into the plunger rod to thereby produce depressions for  
5 engagement with projections on the drive means, c h a r a c t e r i z e d in that the drive means consist of one or more drive worms so shaped that, in operation, a substantially uniform plunger rod and drive means engagement with respect to the rotation of the drive means  
10 is produced by the penetration.
2. A drive mechanism according to claim 1, c h a r a c - t e r i z e d by several drive worms with substantially uniform mutual angular displacement between the respective  
15 thread inlets.
3. A drive mechanism according to claim 1 or 2, c h a r a c t e r i z e d by two drive worms designed to cooperate with the said material in regions with a  
20 mutual arc distance of about 120, and by a releasable, idle antibackup roller designed to press the rod against the drive worms.
4. A drive mechanism according to claims 1-3, c h a r a c -  
25 t e r i z e d in that the axis of rotation of the drive worms forms an acute angle with the rod corresponding to the pitch of the worm threads, and that the worm threads extend a distance axially beyond said region where the worm threads penetrate into the said material.
- 30 5. A drive mechanism according to claims 1-4, c h a r a c - t e r i z e d in that the pitch diameter of the drive worm increases in a direction away from the thread inlet.

6. A drive mechanism according to claim 5, c h a r a c -  
t e r i z e d in that the pitch diameter of the drive  
worm decreases in a direction toward its thread outlet.
- 5 7. A drive mechanism according to claims 2-6, c h a r a c -  
t e r i z e d in that the thread inlet and the thread  
outlet of the worm are mutually angularly displaced.
- 10 8. A drive mechanism according to claim 3 and any of  
claims 5-7, c h a r a c t e r i z e d in that the axes  
of the two drive worms are parallel with the rod, and that  
the worms are driven in opposite directions of rotation by  
means of their respective associated toothed wheels, -said  
toothed wheels being driven by a common, additional worm drive.
- 15 9. A drive mechanism according to any of the preceding  
claims, c h a r a c t e r i z e d in that the worm is  
journalled in a pressure bearing containing a pressure  
detector for axial pressure.

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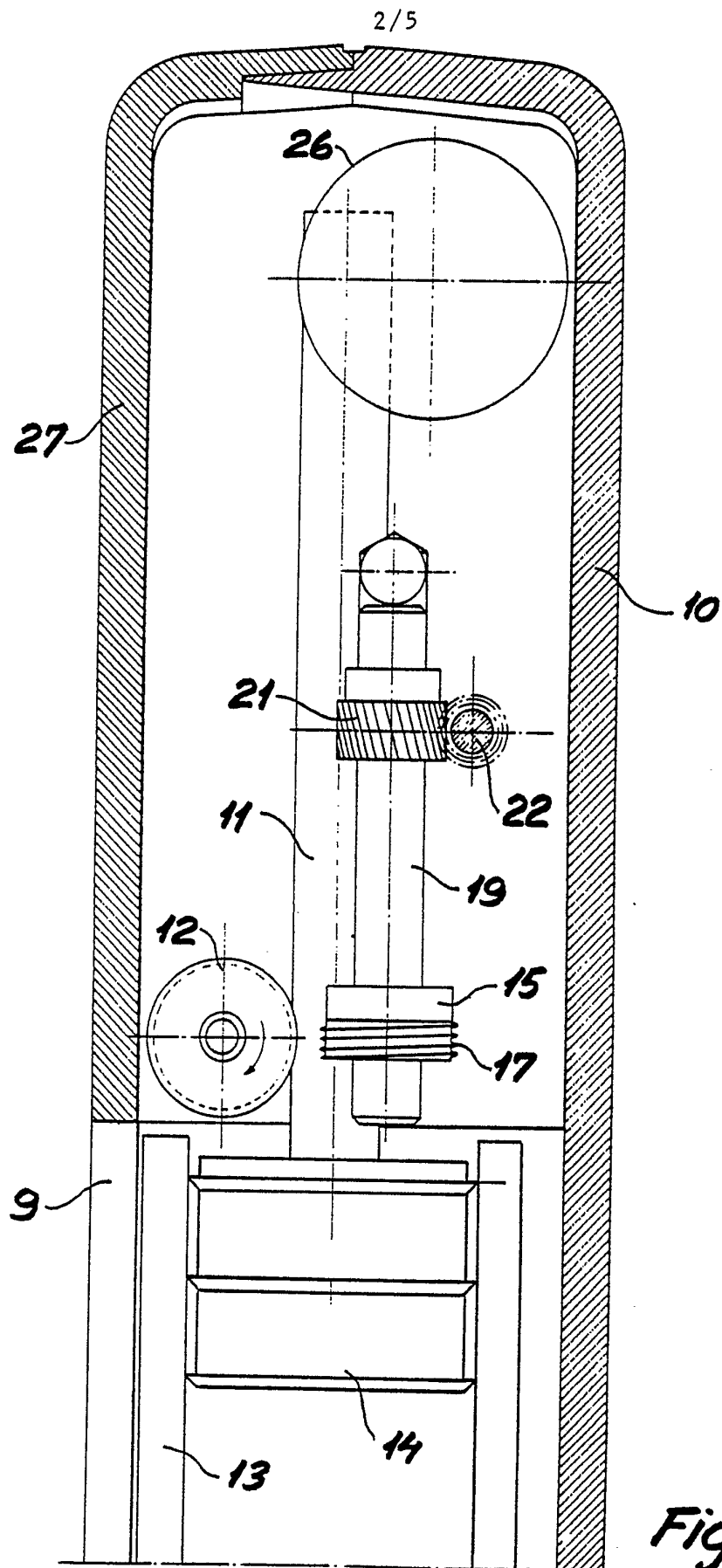
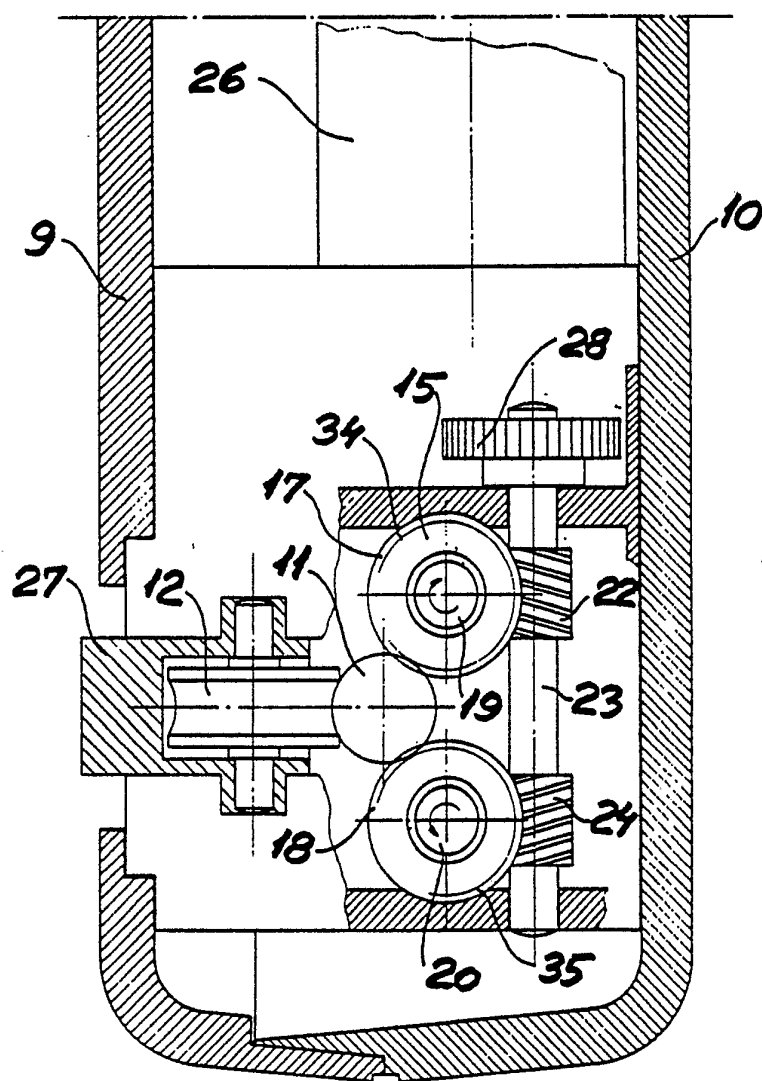


Fig. 4

*Fig. 5*

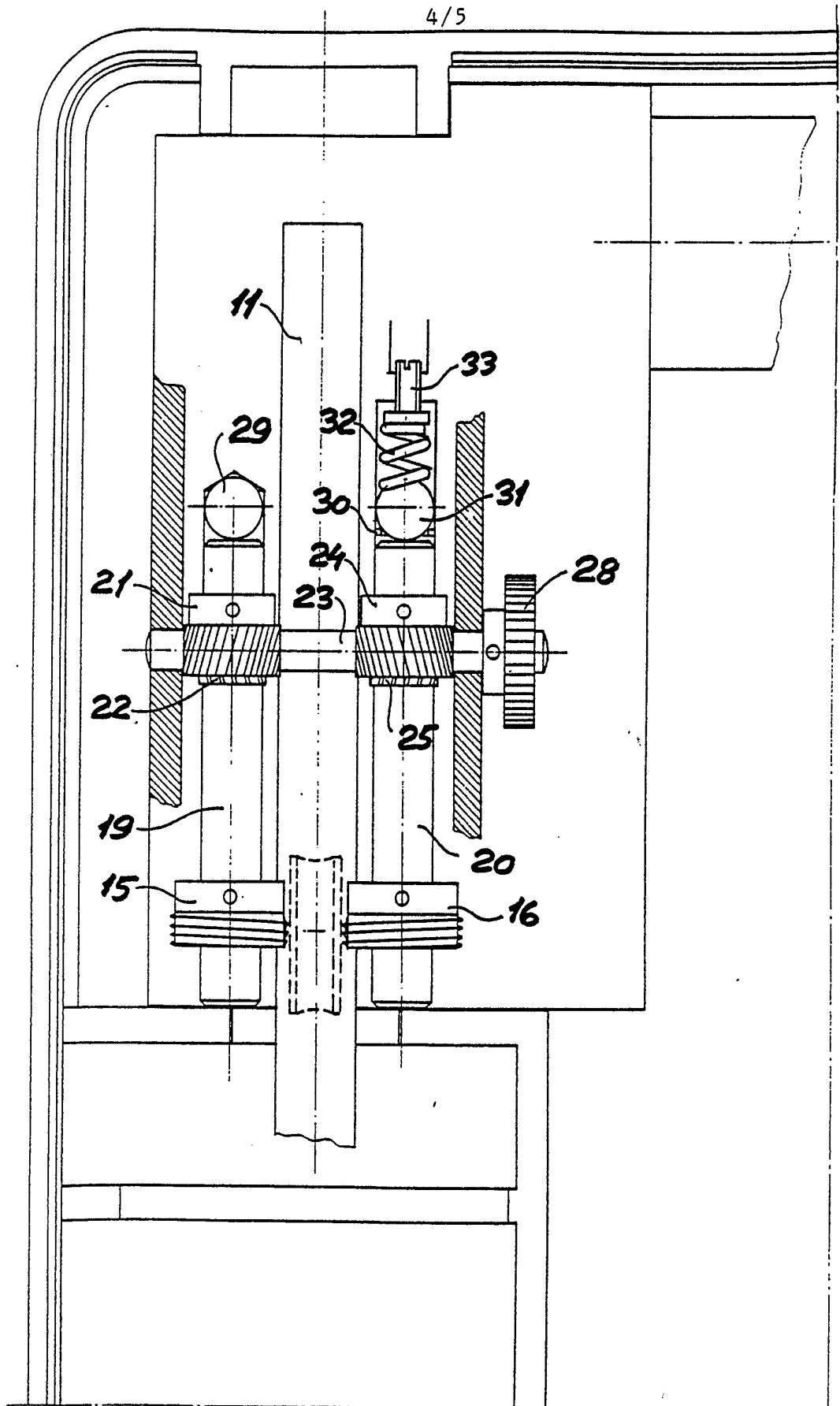
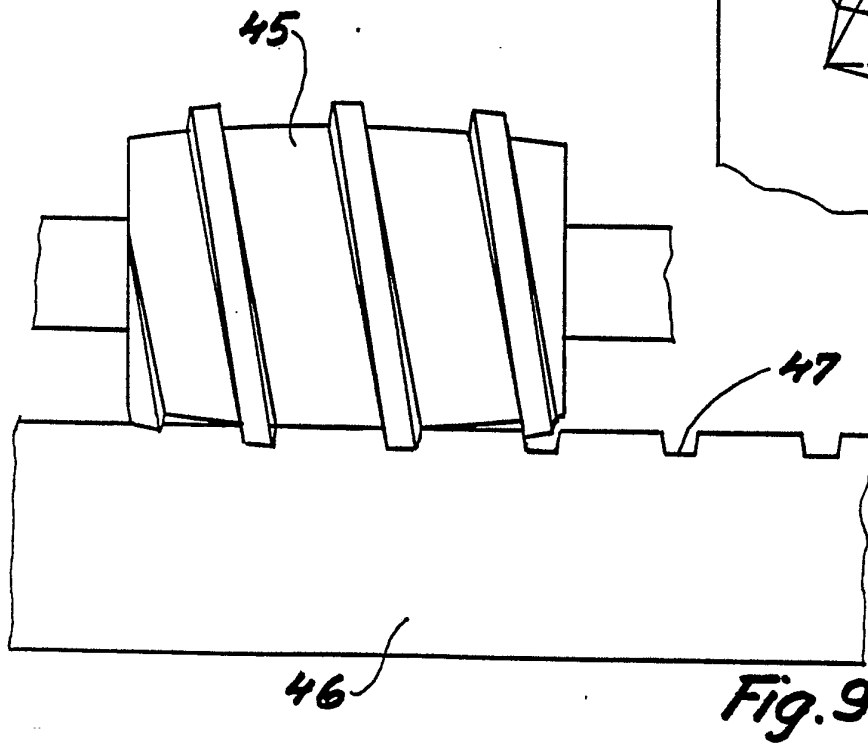
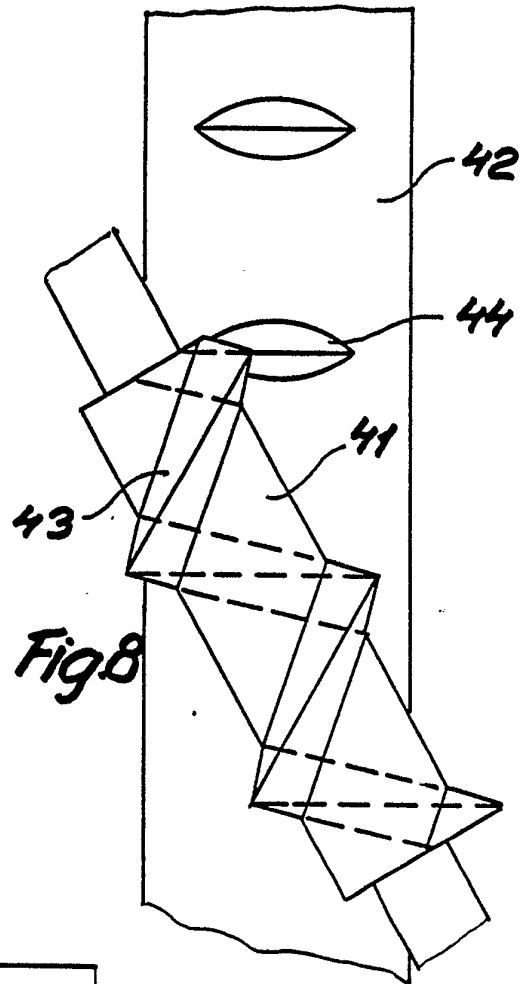
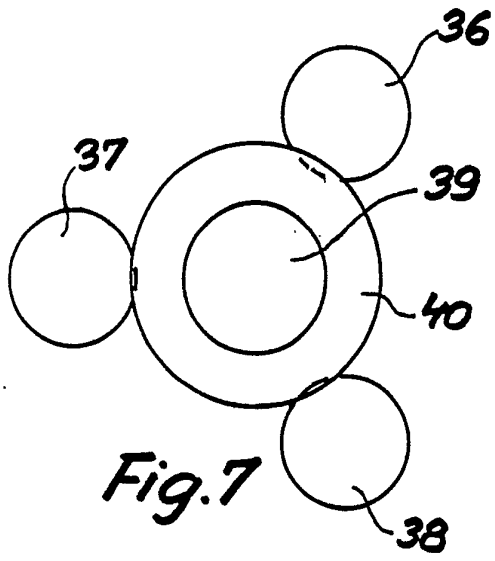


Fig. 6


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# INTERNATIONAL SEARCH REPORT

PCT/DK85/00103

International Application No

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC 4		
A 61 M 5/20, A 61 M 1/00		
<b>II. FIELDS SEARCHED</b>		
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Classification System	Classification Symbols	
IPC 4 US C1	A 61 M 1/00, 5/20; B 01 J 4/00-/02 128:214F, 218A, 218R, 236; 604:131, 151, 154-155	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
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<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> *		
Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No. 13
Y	GB, A, 2 077 599 (NATIONAL RESEARCH DEVELOPMENT) 23 December 1981 & EP, 0042282 JP, 57029367 US, 4416662 CA, 1163161	1-3
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