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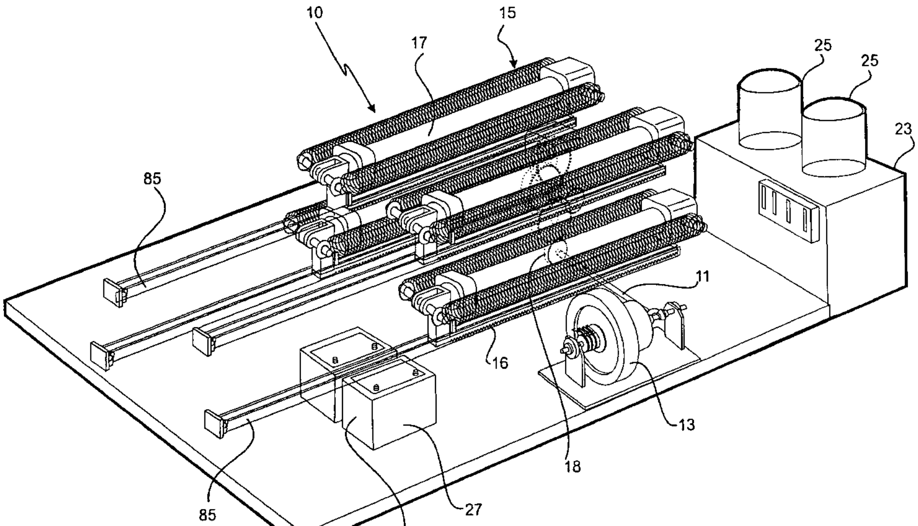

(57) **Abstract:** An engine (10) which can deliver mechanical work for an extended duration in comparison to the duration of energy input into the engine. The engine (10) includes a drive shaft (11) through which it delivers mechanical work. The drive shaft (11) is drivingly connected to an electrodynamic machine (13) for generating electrical energy. The drive shaft (11) is driven by a drive system (15) which incorporates various drive mechanisms (16), power means (17) for operating the drive mechanisms (16) and gearing (18) for drivingly connecting the drive mechanisms (16) to the drive shaft (11). The various drive mechanisms (16) are operated in a pre-determined sequence by the power means (17). Each drive mechanism (16) is in the form of a rack and pinion mechanism. The power means (17) for operating the drive mechanisms (16) comprises spring structure associated with each rack of the rack and pinion mechanisms. The power means (17) also comprises a hydraulic ram for loading each of the spring structures.

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Title

SPRING MOTOR FOR GENERATING ELECTRICAL ENERGY

Field of the Invention

This invention relates to a machine capable of sustained delivery of mechanical energy with intermittent energy input. The invention also relates to a method of operation of such a machine.

The machine operates as an engine for delivery of mechanical work for an extended duration in comparison to the duration of energy input into the engine.

Background Art

With a typical engine, input energy is delivered to the engine in a substantially constant manner for conversion into output energy (in the form of mechanical work). By way of example, in the operation of an electric motor, input electrical energy is delivered continuously to the motor for conversion into output energy in the form of mechanical work.

There are circumstances where it is desirable to have an engine which can provide a sustained energy output with only intermittent energy input. One such circumstance is where an engine is required to drive an electrodynamic machine for producing electrical power at a location where a reticulated power supply is unavailable. Some of the electrical power so produced can be utilised to operate the source providing the intermittent input energy.

Disclosure of the Invention

The present invention provides a machine comprising:

a drive shaft;

a first gear train and a second gear train both drivingly connected to the drive shaft;

the first gear train having a first input shaft;

the second gear train having a second input shaft;

a first drive mechanism drivingly connected to the first input shaft;

a second drive mechanism drivingly connected to the second input shaft; and

a power means for operating the first and second drive mechanisms to sequentially move through power and return strokes whereby upon each power stroke the drive mechanisms respectively apply torque to the first and second input shafts.

Preferably, the sequence in which torque is applied to the first and second input shafts is such that torque is initially delivered to both the first and second input shafts and subsequently to only one of the input shafts. This is achieved by one drive mechanism completing its power stroke after completion of the power stroke by the other drive mechanism. Conveniently, said one drive mechanism has completed about one-half of its power stroke at the stage where the other completes its power stroke.

The transmission ratio between the first drive mechanism and the drive shaft, and the transmission ratio between the second drive mechanism and the drive shaft, can each be selected according to the particular application of the engine.

The first and second gear trains may share some common gears.

The first drive means may comprise a first rack and pinion mechanism. With this arrangement, the pinion of the first rack and pinion mechanism is drivingly connected to the first input shaft.

The second drive mechanism may comprise a second rack and pinion mechanism. With this arrangement, the pinion of the second rack and pinion mechanism is drivingly connected to the second input shaft.

The power means may comprise a spring structure associated with each rack and loading means for loading the spring structure to generate a spring force therein, wherein the spring force is utilised to drive the rack in one direction to provide the power stroke for effecting rotation of the respective pinion.

Preferably, the pinions are adapted to freewheel with respect to their respective input shafts upon movement of the racks in the reverse direction (being the return stroke). The freewheeling action of each pinion with respect to its input shaft may be provided by a clutch mechanism operating between the pinion and the input shaft.

The first and second racks preferably undergo their return strokes in unison.

The spring structure may be of the type which is loaded in tension or of the type which is loaded in compression.

The spring structure may be in any appropriate form, such as, for example, a mechanical spring, a pneumatic spring, a body of elastic material such as rubber, or any combination thereof. Where a mechanical spring is utilised, it can be of any suitable type, such as a helical spring or a coil spring.

The loading means for loading the spring structure may comprise a power mechanism including a telescopic ram, whereby operation of the ram effects rapid loading of the spring structure. Conveniently, the ram comprises a hydraulic ram. The hydraulic ram is preferably included in a hydraulic circuit which further includes a hydraulic pump driven by an electric motor. The electric motor may be powered from an electrical supply generated by an electrodynamic machine driven by the engine.

The machine may further comprise

a third gear train and a fourth gear train both drivingly connected to the drive shaft;

the third gear train having a third input shaft;

the fourth gear train having a fourth input shaft;

a third drive mechanism drivingly connected to the third input shaft;

a fourth drive mechanism drivingly connected to the fourth input shaft,

wherein the power means drives the third and fourth drive mechanisms to sequentially move the third and fourth through power and return strokes whereby upon each power stroke the third and fourth drive mechanisms apply torque to the third and fourth input shafts.

The various drive mechanisms are preferably arranged to operate in a pre-determined sequence.

Preferably, the pre-determined sequence is such that torque is initially delivered to both the first and second input shafts and subsequently to only first input shaft during which stage torque is initially delivered to both the third and fourth input shafts and subsequently to only the third input shaft during which stage torque is initially delivered to both the first and second input shafts and subsequently to only the first input shaft.

The third and fourth gear trains may share some common gears with each other and may also share some common gears with the first and second gear trains.

The present invention also provides a machine comprising a drive shaft, and first, second, third and fourth drive mechanisms drivingly connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanisms, the drive mechanisms being operable to perform their respective power strokes in a cycle whereby the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke during which stage the third and fourth drive mechanisms operate together during part of their power strokes and thereafter the fourth drive mechanism completes its power stroke while the third drive mechanism continues its power stroke during which stage the first and second drive mechanisms operate together during part of their power strokes to repeat the cycle.

The invention also provides a method of operating a machine having a drive shaft, and first and second drive mechanisms operatively connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanism, the method comprising the steps of operating the machine in an operating cycle in which the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke, and following completion of the power stroke of the first drive mechanism the first and second drive means operate together during part of their power strokes to repeat the cycle.

The invention also provides a method of operating a machine having a drive shaft, and first, second, third and fourth drive mechanisms operatively connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanisms, the method comprising the steps of operating the machine in an operating cycle in which the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke during which stage the third and fourth drive mechanisms operate together during part of their power strokes and thereafter the fourth drive mechanism completes its power stroke while the third drive mechanism continues its power stroke during which stage the first and second drive mechanisms operate together during part of their power strokes to repeat the cycle.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of several specific embodiments thereof, as shown in the accompanying drawings in which:

Figure 1 is a schematic perspective view of an engine according to a first embodiment;

Figures 2 to 9 schematically illustrate drive mechanisms forming part of the engine of Figure 1 in various operating conditions;

Figure 10 is a schematic view of gearing forming part of the engine, with two drive transfer paths being identified within the gearing;

Figure 11 is a view similar to Figure 10 with the exception that two other drive transfer paths are identified;

Figure 12 is a schematic perspective view of a drive mechanism of the engine according to a second embodiment, the drive mechanism being shown in one operating condition;

Figure 13 is a view similar to Figure 12 with the exception that the drive mechanism is shown in another operating condition; and

Figure 14 is a schematic perspective view of an engine according to the second embodiment.

Best Mode(s) for Carrying out the Invention

The first embodiment, which is shown in Figures 1 to 11 of the accompanying drawings, is directed to an engine 10 which can deliver mechanical work for an extended duration in comparison to the duration of energy input into the engine.

The engine 10 includes a drive shaft 11 through which it delivers mechanical work. In this embodiment, the drive shaft 11 is shown drivingly connected to an electrodynamic machine 13 for generating electrical energy, some of which is used to operate the engine 10 as will be explained in more detail later. The electrodynamic machine 13 may be of the type disclosed in international application PCT/AU00/00778, the contents of which are incorporated herein by way of reference.

The drive shaft 11 is driven by a drive system 15 which incorporates various drive mechanisms 16, power means 17 for operating the drive mechanisms 16, and gearing 18 for drivingly connecting the drive mechanisms 16 to the drive shaft 11.

The engine 10 further comprises a hydraulic circuit which incorporates a reservoir 23 to contain a supply of hydraulic fluid and electrically operable hydraulic pumps 25 for pumping the hydraulic fluid through the hydraulic circuit. The hydraulic pumps 25 receive electrical energy for their operation from an electrical supply 27. The electrical supply 27 in this embodiment comprises an electrical storage means in the form of batteries 30 which are continuously charged using electricity generated by the electrodynamic machine 13. Surplus electricity generated by the electro-dynamic machine 13 can be used for other purposes such as lighting or powering electrical equipment.

The various drive mechanisms 16 comprise a first drive mechanism 31, a second drive mechanism 32, a third drive mechanism 33 and a fourth drive mechanism 34.

The first drive mechanism 31 is in the form of a first rack and pinion mechanism 35 comprising a first rack 37 and a first pinion 39 in engagement with the rack 37. The first pinion 39 is mounted onto a first input shaft 41 through a clutch mechanism 43. The clutch mechanism 43 allows torque transmission from the first pinion 39 to the first input shaft 41 upon rotation of the pinion in one direction while allowing the pinion to freewheel on the first input shaft upon rotation of the pinion in the reverse direction so as not to transmit torque thereto.

The second drive mechanism 32 is in the form of a second rack and pinion mechanism 45 comprising a second rack 47 and a second pinion 49 in engagement with the second rack 47. The second pinion 49 is mounted onto a second input shaft 51 through a clutch mechanism 53. The clutch mechanism 53 allows torque transmission from the second pinion 49 to the second input shaft 51 upon rotation of the pinion in one direction while allowing the pinion to freewheel on the second input shaft upon rotation of the pinion in the reverse direction so as not to transmit torque thereto.

The third drive mechanism 33 is in the form of a third rack and pinion mechanism 55 comprising a third rack 57 and a third pinion 59 in engagement with the third rack 57. The third pinion 59 is mounted onto a third input shaft 61 through a clutch mechanism 63. The clutch mechanism 63 allows torque transmission from the third pinion 59 to the third input shaft 61 upon rotation of the pinion in one direction while allowing the pinion to freewheel on the third input shaft upon rotation of the pinion in the reverse direction so as not to transmit torque thereto.

The fourth drive mechanism 34 is in the form of a first rack and pinion mechanism 65 comprising a fourth rack 67 and a fourth pinion 69 in engagement with the fourth rack 67. The fourth pinion 69 is mounted onto a fourth input shaft 71 through a clutch mechanism 73. The clutch mechanism 73 allows torque transmission from the fourth pinion 69 to the fourth input shaft 71 upon rotation of the pinion in one direction while allowing the pinion to freewheel on the fourth input shaft upon rotation of the pinion in the reverse direction so as not to transmit torque thereto.

Each rack 37, 47, 57 and 67 comprises a rigid rack bar 81 having rack teeth 83 along one face thereof. The rigid rack bar 81 is guidingly supported for axial movement in a guide structure 85.

The first input shaft 41 and the third input shaft 61 are defined by a common shaft 91 on which a drive gear 93 is rigidly mounted. With this arrangement, the drive gear 93 is caused to rotate upon rotation of the first input shaft 41 and is also caused to rotate upon rotation of the third input shaft 61. The drive gear 93 is in meshing engagement with a driven pinion 95 rigidly mounted on a first lay shaft 97. A drive gear 99 is rigidly mounted on the first lay shaft 97 and is in meshing engagement with a driven pinion 101 rigidly mounted on a second lay shaft 103. A drive gear 105 is rigidly mounted on the second lay shaft 103 and is in meshing engagement with a driven pinion 107 mounted on the drive shaft 11.

A drive gear 111 is rigidly mounted on the second input shaft 51 and is in meshing engagement with the driven pinion 95.

A drive gear 113 is rigidly mounted on the fourth input shaft 71 and is in meshing engagement with a driven pinion 115 rigidly mounted on the first lay shaft 97. The drive gear 111 on the second input shaft 51 and the drive gear 113 on the fourth input shaft 71 have the same number of teeth and the same pitch circle diameter. Similarly, the driven pinions 95 and 115 on the first lay shaft 97 have the same number of teeth and the same pitch circle diameter.

With this arrangement of gearing, each drive mechanism 31, 32, 33 and 34 is drivingly connected to the output shaft 11. More particularly, the first drive mechanism 31 is drivingly connected to the output shaft 11 through a first gear train within the gearing 18, the first gear train providing a first drive path which is depicted by a broken line in Figure 10 and which is identified by reference numeral 121. Similarly, the second drive mechanism 32 is drivingly connected to the output shaft 11 through a second gear train within the gearing 18, the second gear train providing a second drive path which is depicted by a dotted line in Figure 10 and which is identified by reference numeral 122. The third drive mechanism 33 is drivingly connected to the output shaft 11 through a third gear train within the gearing 18, the third gear train providing a third drive path which is depicted by a broken line in Figure 11 and which is identified by reference numeral 123. The fourth drive mechanism 34 is drivingly connected to the output shaft 11 through a fourth gear train within the gearing 18, the fourth gear train providing a fourth drive path which is depicted by a dotted line in Figure 11 and which is identified by reference numeral 124.

The gearing between the first input shaft 41 and the second input shaft 51 provides a transmission ratio of 1:10. In other words, the second input shaft 51 undergoes ten revolutions for each revolution of the first input shaft 31. Similarly, the gearing between the second input shaft 51 and the drive shaft 11 provides a transmission ratio of 1:10. In other words, the drive shaft 11 undergoes 10 revolutions for each revolution of the second input shaft 51.

The gearing between the third input shaft 61 and the fourth input shaft 71 provides a transmission ratio of 1:10. In other words, the fourth input shaft 71 undergoes 10 revolutions for each revolution of the third input shaft 61. Similarly, the gearing between the fourth input shaft 71 and the drive shaft 11 provides a transmission ratio of 1:10. In other words, the drive shaft 11 undergoes 10 revolutions for each revolution of the fourth input shaft 71.

The power means 17 for operating the drive mechanisms 16 comprises a spring structure 130 associated with each of the racks 37, 47, 57 and 67.

The power means 17 also comprises a power mechanism 133 for loading each of the spring structures 130. The power mechanism 133 comprises a hydraulic ram 135, the cylinder 137 of which is fixed to a supporting structure (not shown). The extensible rod 139 of each hydraulic ram 135 is connected to a mounting lug 141 provided on one end of each rack 37, 47, 57 and 67. With this arrangement, extension of each hydraulic ram 135 causes the respective rack to which it is connected to move axially along the respective guide structure 85.

Each spring structure 130 comprises two helical tension springs 145. One end of each helical spring 145 is connected to a mounting 147 on the cylinder 137 of the respective hydraulic ram 135 and the other end of the spring is connected to a mounting 149 on the rod of the hydraulic ram. With this arrangement, extension of the hydraulic ram 135 causes the springs 145 to correspondingly extend and so be loaded.

The spring force established in the loaded springs 145 subsequently causes the respective rack 37, 47, 57, 67 to move in the other direction, so undergoing a power stroke and driving the respective pinion 39, 49, 59 and 69 with which it is in meshing engagement to thereby apply torque to the respective input shaft 41, 51, 61, 71 on which the pinion is mounted.

The first and second racks 37, 47 do not operate in unison when performing a power stroke but rather in a timed sequence. The sequence is such that the second rack 47 moves at a rate faster than the first rack 37 during the power strokes thereof, the rate of relative movement between the racks being regulated by the gear ratio between each rack and the particular pinion with which it is in meshing engagement. In this embodiment, the relationship is that the second rack 47 moves at about twice the rate of the first rack 37. A similar relationship exists between the third and fourth racks 57, 67; that is, the fourth rack 67 moves at a rate faster than the third rack 57 during the power strokes thereof.

Each hydraulic ram 135 is incorporated in the hydraulic circuit referred to previously and so operates in response to fluid pressure delivered by way of the hydraulic pumps 25. A control system (not shown) is provided for operating the hydraulic rams 135 in a prescribed sequence.

Operation of the engine 10 will now be described with reference to Figures 2 to 9 of the accompanying drawings.

In Figure 2 of the drawings, the engine is shown in a condition prior to start of its operation, with each of the racks, 37, 47, 57 and 67 being at rest. To commence operation of the engine, the power means 17 associated with the first and second racks 37, 47 are operated to rapidly load the spring structures 130 associated with those racks in preparation for their power strokes, as shown in Figure 3.

The first and second racks 37, 47 then commence their respective power strokes at the same time. The second rack 47 travels at a rate which is twice that of the first rack 37 as illustrated in Figure 4. As the second rack 47 completes its power stroke, the power means 17 associated with the third and fourth racks 57, 67 then operate to cause those racks to undergo return strokes and to rapidly load the spring structures 130 associated with those racks in preparation for their power stroke, as is illustrated in Figure 5. Since the second rack 47 travels at a rate which is twice that of the first rack, it completes its power stroke at the stage when the first rack 37 has completed one half of its power stroke. At this stage, the third and fourth racks 57, 67 commence their power strokes, while the first rack 37 continues its power stroke. The fourth rack 67 travels at a rate which is twice that of the third rack 57 and so completes its power stroke when the third rack 57 has only completed one half of its power stroke, as illustrated in Figure 6. At this stage, the first rack 37 also completes its power stroke. The power means 17 associated with the first and second racks 37, 47 then operate to rapidly load the spring structures 130 associated with those racks in preparation for their next power stroke.

The first and second racks 37, 47 commence their power strokes, and the third rack 57 continues with its power stroke, as illustrated in Figure 7. The third rack 57 completes its power stroke at the same stage that the second rack 47 completes its power stroke as illustrated in Figure 8. The power means 17 associated with the third and fourth racks 57, 67 then operate to rapidly load the spring structures 130 associated with those racks in preparation for the next power stroke, as illustrated in Figure 9. The operating cycle of the engine continues in this fashion. Because of the overlap between the various power strokes, the drive shaft 11 has rotational torque applied to it substantially constantly during operation of the engine.

From the foregoing it can be seen that the hydraulic rams 135 are operated intermittently so as to load the spring structures 130 as required. The loading operation of the spring structures 130 occurs rapidly in comparison to the time taken for the loaded springs to drive the racks in the direction applying rotational torque to the respective input shafts. In other words, the return stroke of each rack is rapid while the power stroke is prolonged. In this way, there is prolonged delivery of torque to the input shafts with intermittent energy input to the spring structures by virtue of the rapid loading of the spring structures using the power mechanisms.

The present embodiment thus provides a simple yet highly effective engine which is capable of prolonged delivery of mechanical work at the drive shaft 11 with only intermittent energy input provided by the power means 17.

In the embodiment which has been described, each input shaft 41, 51, 61 and 71 has a pinion 39, 49, 59 and 69 mounted on it, and the pinion is in meshing engagement with the respective rack 37, 47, 57 and 67.

In a second embodiment, which is illustrated in Figures 12 and 13, each drive mechanism is in the form of a rack and pinion mechanism 160 comprising two racks 161, 162 and a pinion 163 in meshing engagement with the racks. One rack 161 is positioned above the pinion 163 and the other rack 162 is positioned below the pinion. The two racks 161, 162 are adapted to operate in unison but in opposite directions. In this way, the rack 161 performs its power stroke while moving in one direction and the rack 162 performs a simultaneous power stroke while moving in the opposite direction. Each rack 161, 162 has a spring structure 165 and hydraulic ram 167 associated with it in a similar fashion to the first embodiment.

Such an arrangement is advantageous as it allows greater torque to be delivered to pinion 163, and so to the input shaft to which the pinion is drivingly connected, in a shorter period of time. The arrangement is also conducive to a more compact construction of engine.

Rack and pinion mechanisms 160 according to this embodiment can replace the rack and pinion mechanisms 35, 45, 55 and 65 in the first embodiment, if desired.

Rack and pinion mechanisms 160 as illustrated in Figures 12 and 13 are also utilised in engine 170 according to a third embodiment, as illustrated in Figure 14. The engine 170 according to this embodiment has a drive shaft 171 which is drivingly connected to an electrodynamic machine 173.

The engine 170 has a first input shaft 175 which is drivingly connected to the drive shaft 171 through gearing 177, and a second input shaft 179 which is also drivingly connected to the drive shaft 171 through the gearing. A plurality of the rack and pinion mechanisms 160 are operatively connected to the first input shaft. Similarly, a plurality of the rack and pinion mechanisms 160 are operatively connected to the second input shaft. The various rack and pinion mechanisms 160 operate in timed sequence in order to apply rotational torque to the first and second input shafts 175, 179. More particularly, the rack and pinion mechanisms 160 operatively connected to the second input shaft 179 operate at a faster rate (for example, twice the rate) of the rack and pinion mechanisms 160 operatively connected to the first input shaft 175. In this way, the engine 170 operates in a somewhat similar fashion to the engine 10 of the first embodiment. Rotational torque applied to the first and second input shafts 175, 179 is transmitted through the gearing 177 to the drive shaft 171.

The gearing 177 includes a drive gear 181 which is rigidly mounted on the first input shaft 175. With this arrangement, the drive gear 181 is caused to rotate upon rotation of the first input shaft 175. The drive gear 181 is in meshing engagement with a driven gear 183 rigidly mounted on a first lay shaft 185. A drive gear 187 is rigidly mounted on the first lay shaft 185 and is in meshing engagement with a driven gear 189 rigidly mounted on a second lay shaft 191. A drive gear 193 is rigidly mounted on the second lay shaft 193 and is in meshing engagement with a driven gear 195 rigidly mounted on the drive shaft 171.

A drive gear 197 is rigidly mounted on the second input shaft 179 and is in meshing engagement with a driven gear 199 rigidly mounted on the first lay shaft 185.

While the engine 170 is shown with two rack and pinion mechanisms 160 operatively connected to the first input shaft 175, it should be appreciated that any number of such rack and pinion mechanisms can be operatively connected to the first input shaft. Similarly, while the engine 170 is shown with two rack and pinion mechanisms 160 operatively connected to the second input shaft 179, it should be appreciated that any number of such rack and pinion mechanisms can be operatively connected to that shaft.

The rack and pinion mechanisms operatively connected to each input shaft 175, 179 are intended to operate in a timed sequence so that rotational torque is delivered in a uniform manner to those shafts.

It should be appreciated that the scope of the invention is not limited to the scope of the embodiments described. For instance, while in each embodiment each drive mechanism 16 has been described as a rack and pinion mechanism, it need not be limited thereto. The rack may, for example, be replaced by a large gear wheel which meshes with the pinion. With such an arrangement, the large gear wheel may be powered by a spiral spring which can be loaded in any appropriate fashion.

It should also be appreciated that the invention is not limited to an engine for driving an electro-dynamic machine. The engine may be used to drive any appropriate load.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

The Claims Defining The Invention Are As Follows

1. A machine comprising:

a drive shaft;

a first gear train and a second gear train both drivingly connected to the drive shaft;

the first gear train having a first input shaft;

the second gear train having a second input shaft;

a first drive mechanism drivingly connected to the first input shaft;

a second drive mechanism drivingly connected to the second input shaft; and

a power means for operating the first and second drive mechanisms to sequentially move through power and return strokes whereby upon each power stroke the drive mechanisms respectively apply torque to the first and second input shafts.

2. A machine according to claim 1 wherein the sequence in which torque is applied to the first and second input shafts is such that torque is initially delivered to both the first and second input shafts and subsequently to only one of the input shafts.

3. A machine according to claim 2 wherein one drive mechanism is arranged completing its power stroke after completion of the power stroke by the other drive mechanism.

4. A machine according to claim 3 wherein said one drive mechanism is adapted to complete about one-half of its power stroke at the stage where the other

completes its power stroke.

5. A machine according to any one of the preceding claims wherein the first and second gear trains share some common gears.

6. A machine according to any one of the preceding claims wherein the first drive means comprises a first rack and pinion mechanism with the pinion thereof drivingly connected to the first input shaft.

7. A machine according to any one of the preceding claims wherein the second drive mechanism comprises a second rack and pinion mechanism with the pinion thereof drivingly connected to the second input shaft.

8. A machine according to claim 6 or 7 wherein the power means comprises a spring structure associated with the rack of each rack and pinion mechanism and loading means for loading the spring structure to generate a spring force therein, wherein the spring force is utilised to drive the rack in one direction to provide the power stroke for effecting rotation of the respective pinion.

9. A machine according to claim 6, 7 or 8 wherein the pinions are adapted to freewheel with respect to their respective input shafts upon movement of the racks in the reverse direction

10. A machine according to any one of the preceding claims wherein the first and second racks undergo their return strokes in unison.

11. A machine according to claim 8, 9 or 10 wherein the spring structure comprises a helical tension spring.

12. A machine according to any one of claims 8 to 11 wherein the loading means for loading the spring structure comprises a power mechanism including a telescopic ram, whereby operation of the ram effects rapid loading of the spring structure.

13. A machine according to claim 12 wherein the telescopic ram comprises a

hydraulic ram incorporated in a hydraulic circuit which further includes a hydraulic pump driven by an electric motor.

14. A machine according to claim 13 wherein the electric motor is powered from an electrical supply generated by an electrodynamic machine driven by the engine.

15. A machine according to any one of the preceding claims further comprising:

a third gear train and a fourth gear train both drivingly connected to the drive shaft;

the third gear train having a third input shaft;

the fourth gear train having a fourth input shaft;

a third drive mechanism drivingly connected to the third input shaft;

a fourth drive mechanism drivingly connected to the fourth input shaft,

wherein the power means drives the third and fourth drive mechanisms to sequentially move the third and fourth through power and return strokes whereby upon each power stroke the third and fourth drive mechanisms apply torque to the third and fourth input shafts.

16. A machine according to claim 15 wherein the various drive mechanisms are adapted to operate in a sequence in which torque is applied to the various input shafts is such that torque is initially delivered to both the first and second input shafts and subsequently to only first input shaft during which stage torque is initially delivered to both the third and fourth input shafts and subsequently to only the third input shaft during which stage torque is initially delivered to both the first and second input shafts and subsequently to only the first input shaft.

17. A machine comprising a drive shaft, and first, second, third and fourth drive

mechanisms drivingly connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanisms, the drive mechanisms being operable to perform their respective power strokes in a cycle whereby the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke during which stage the third and fourth drive mechanisms operate together during part of their power strokes and thereafter the fourth drive mechanism completes its power stroke while the third drive mechanism continues its power stroke during which stage the first and second drive mechanisms operate together during part of their power strokes to repeat the cycle.

18. A method of operating a machine having a drive shaft, and first and second drive mechanisms operatively connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanism, the method comprising the steps of operating the machine in an operating cycle in which the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke, and following completion of the power stroke of the first drive mechanism the first and second drive means operate together during part of their power strokes to repeat the cycle.

19. A method of operating a machine having a drive shaft, and first, second, third and fourth drive mechanisms operatively connected to the drive shaft for applying rotational torque thereto during power strokes of the drive mechanisms, the method comprising the steps of operating the machine in an operating cycle in which the first and second drive mechanisms operate together during part of their power strokes and thereafter the second drive mechanism completes its power stroke while the first drive mechanism continues its power stroke during which stage the third and fourth drive mechanisms operate together during part of their power strokes and thereafter the fourth drive mechanism completes its power stroke while the

third drive mechanism continues its power stroke during which stage the first and second drive mechanisms operate together during part of their power strokes to repeat the cycle.

20. A machine substantially as herein described with reference to the accompanying drawings.

21. A method of operating a machine substantially as herein described.

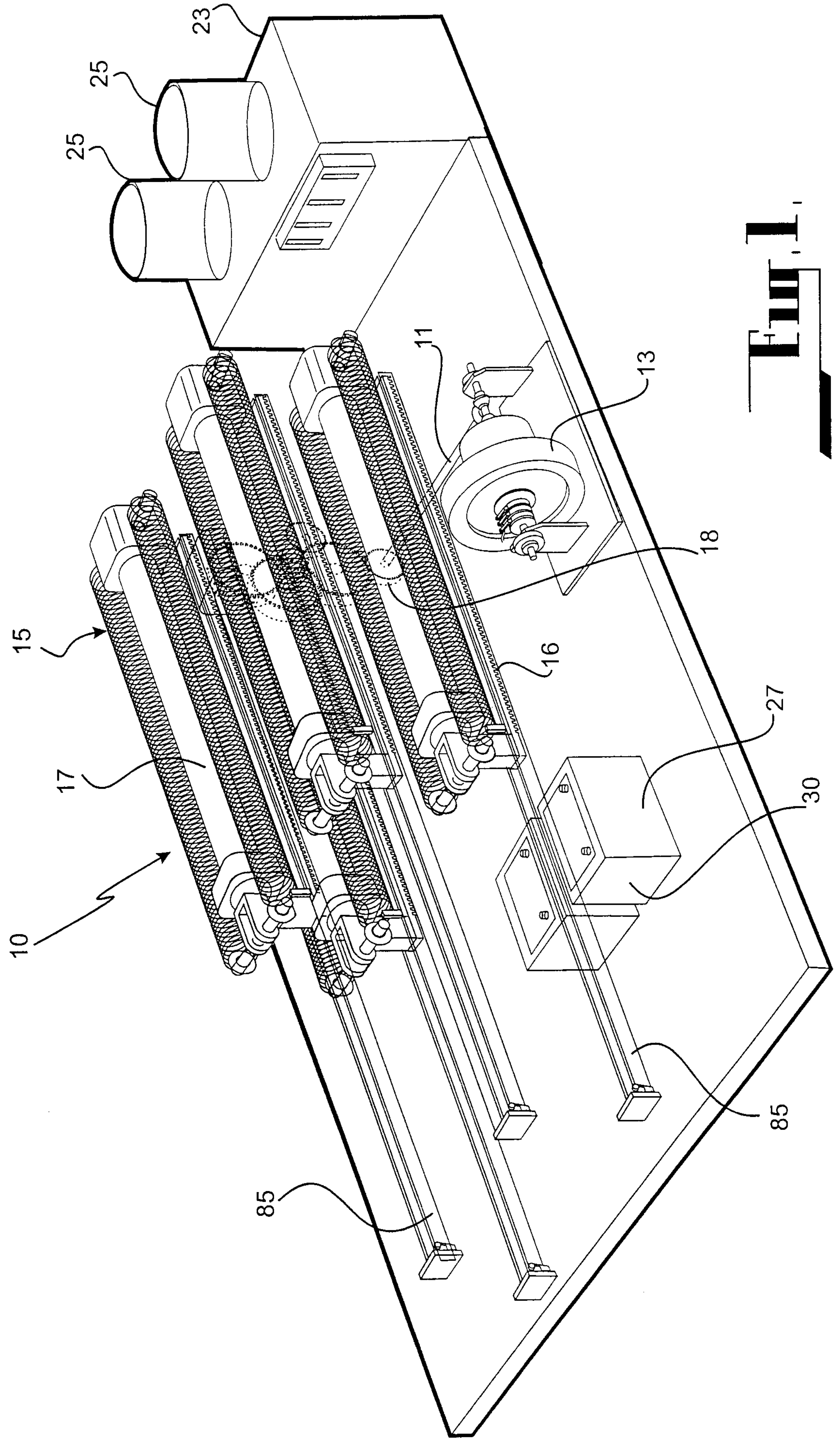

Fig 1

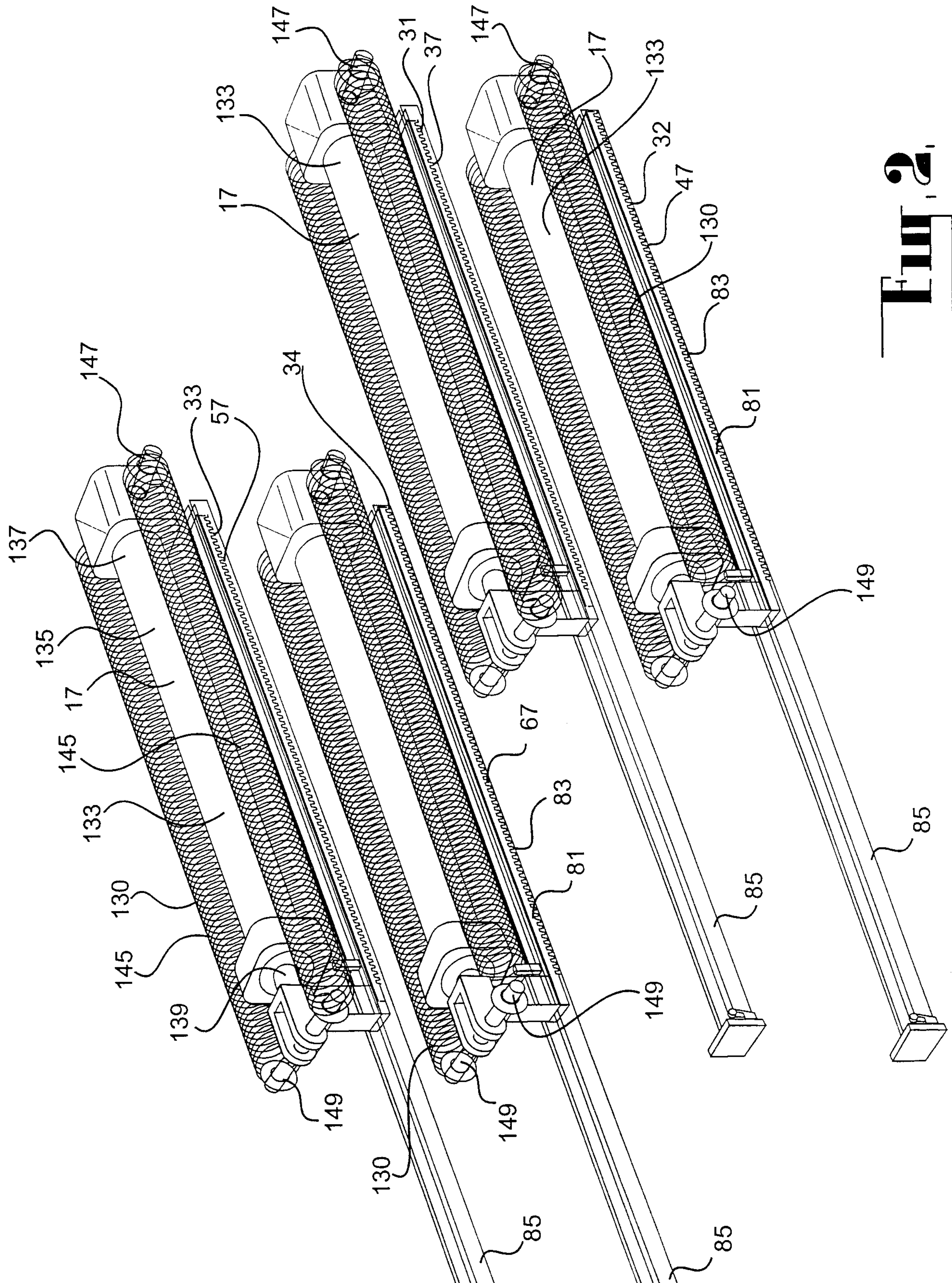
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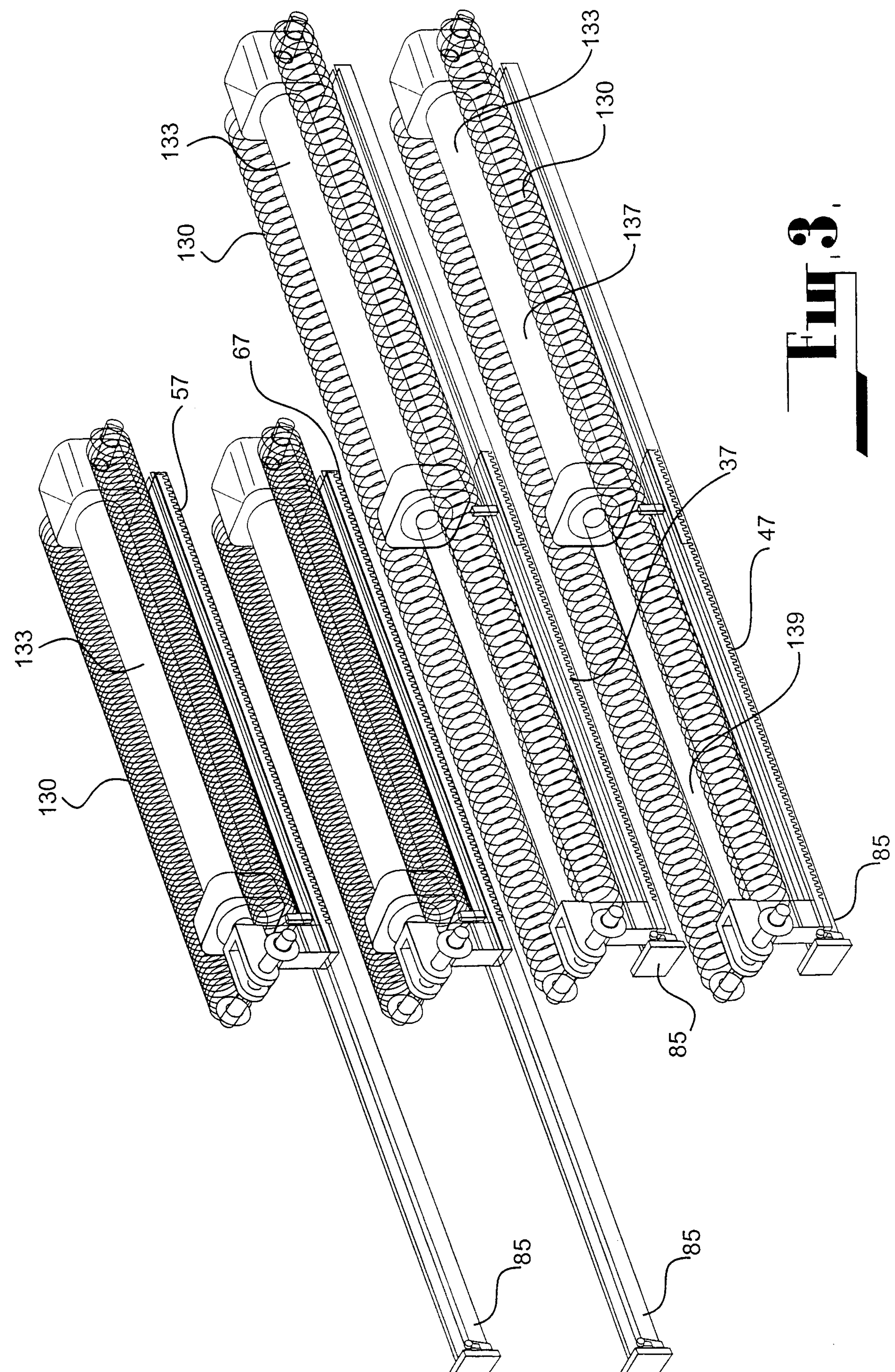
Fig 2



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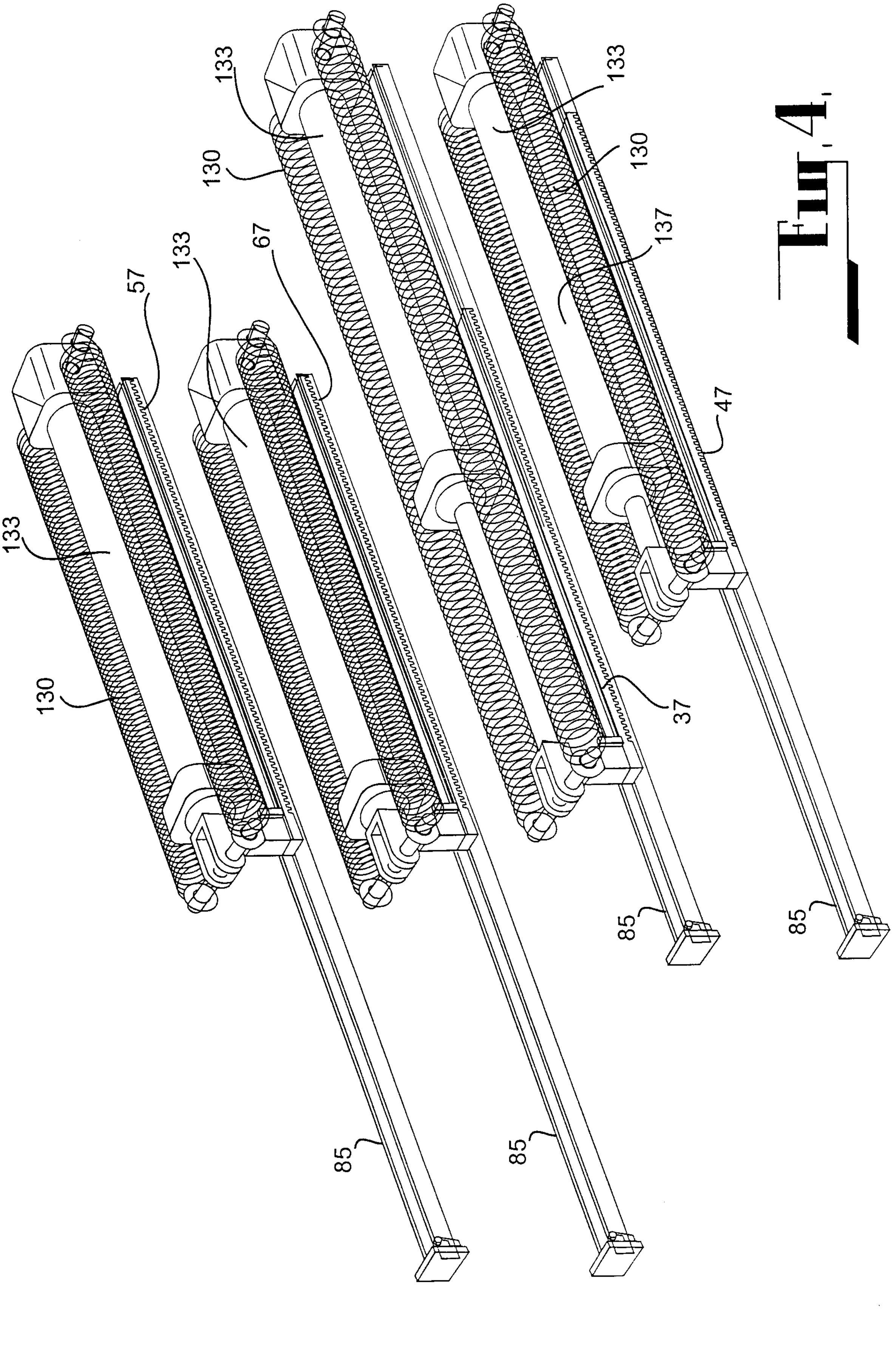

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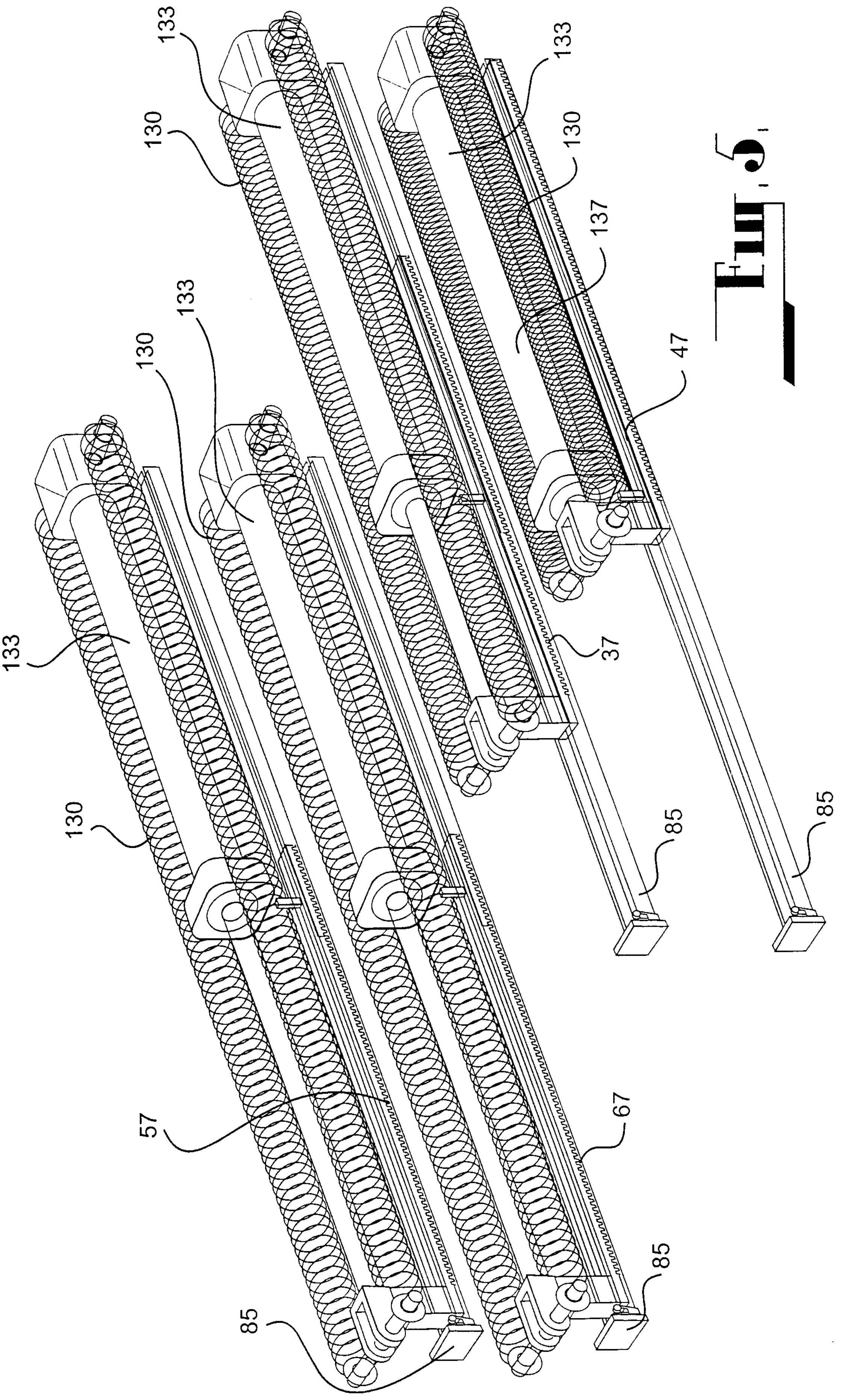
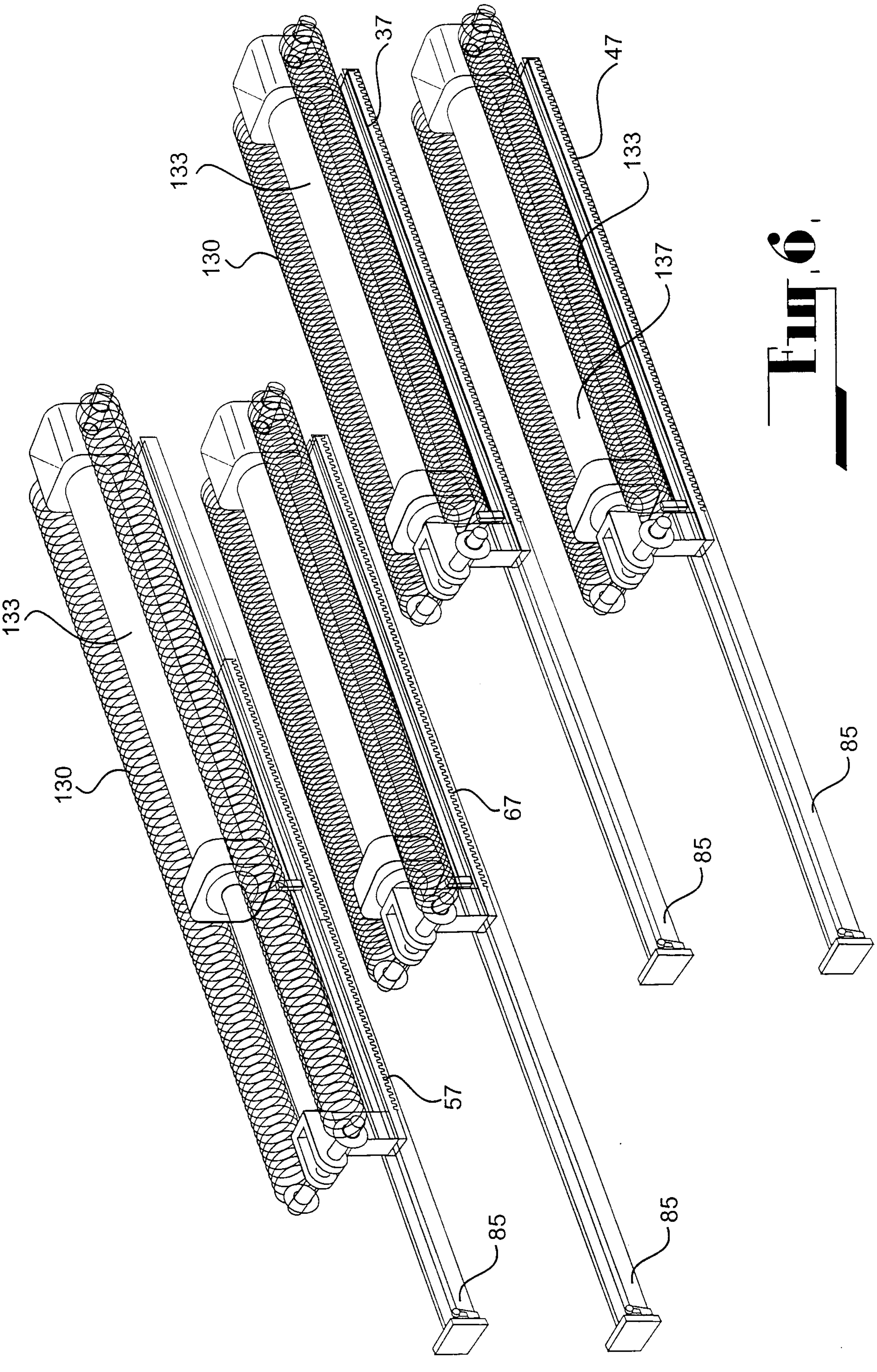


Fig. 5



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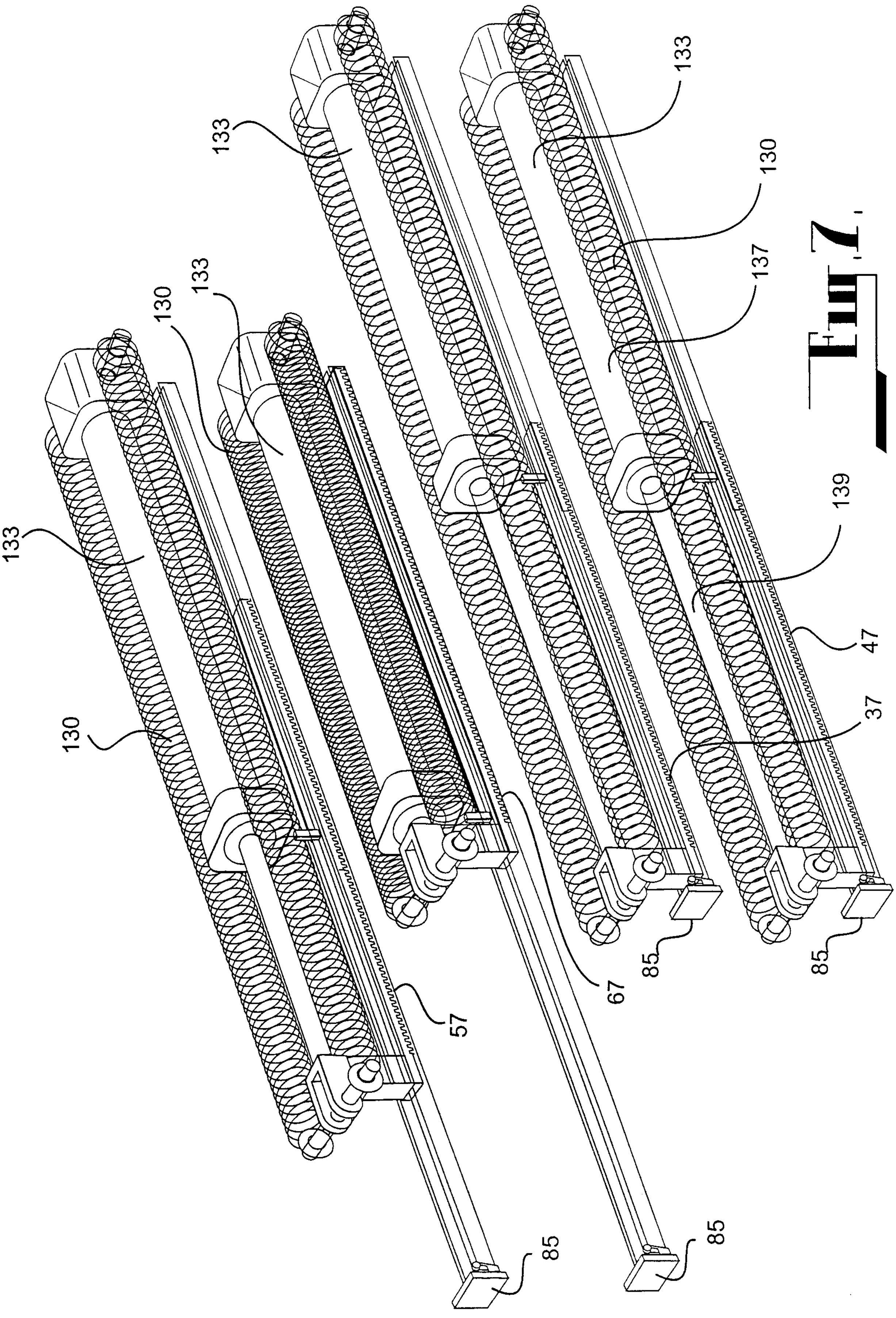

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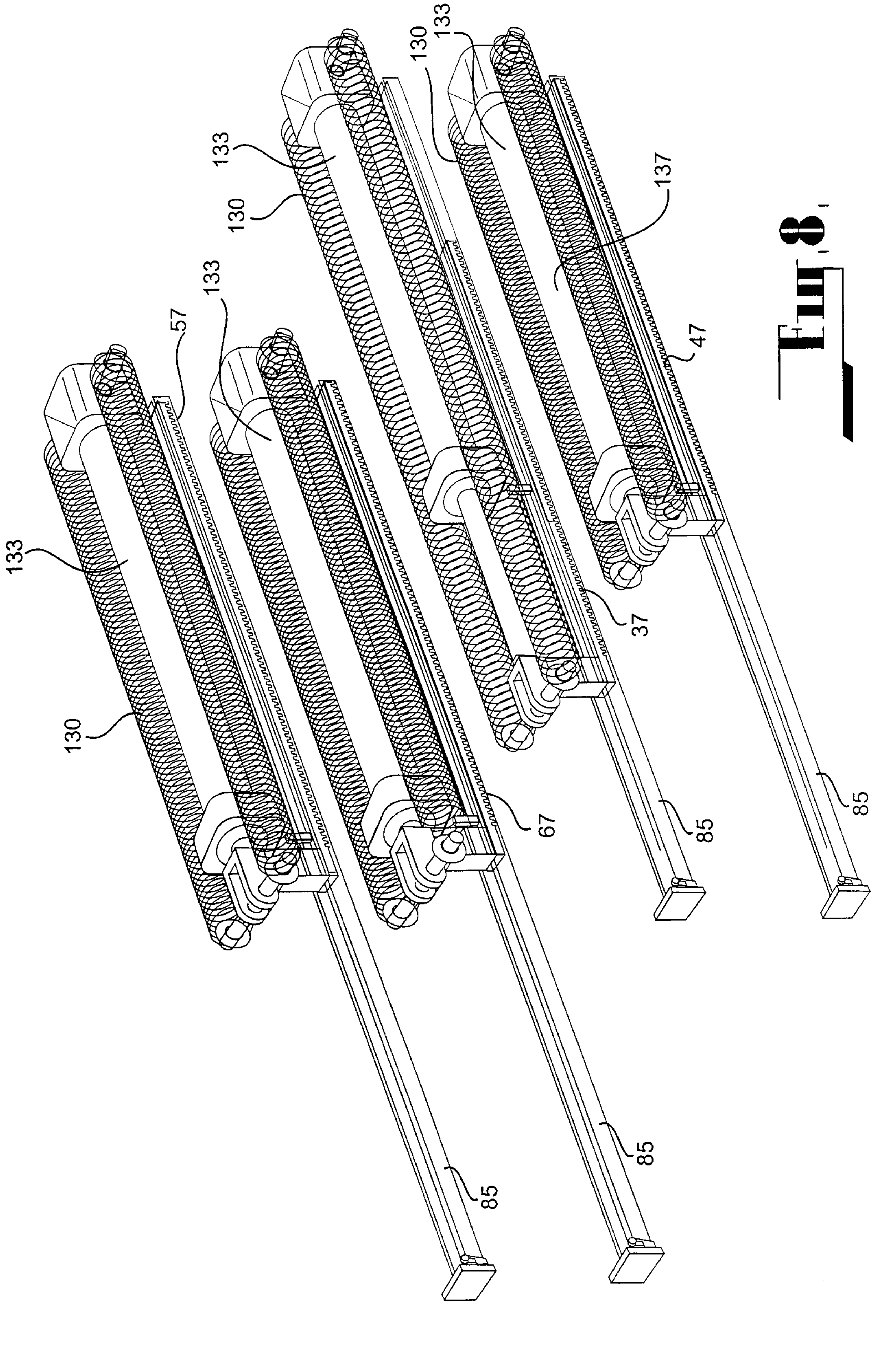

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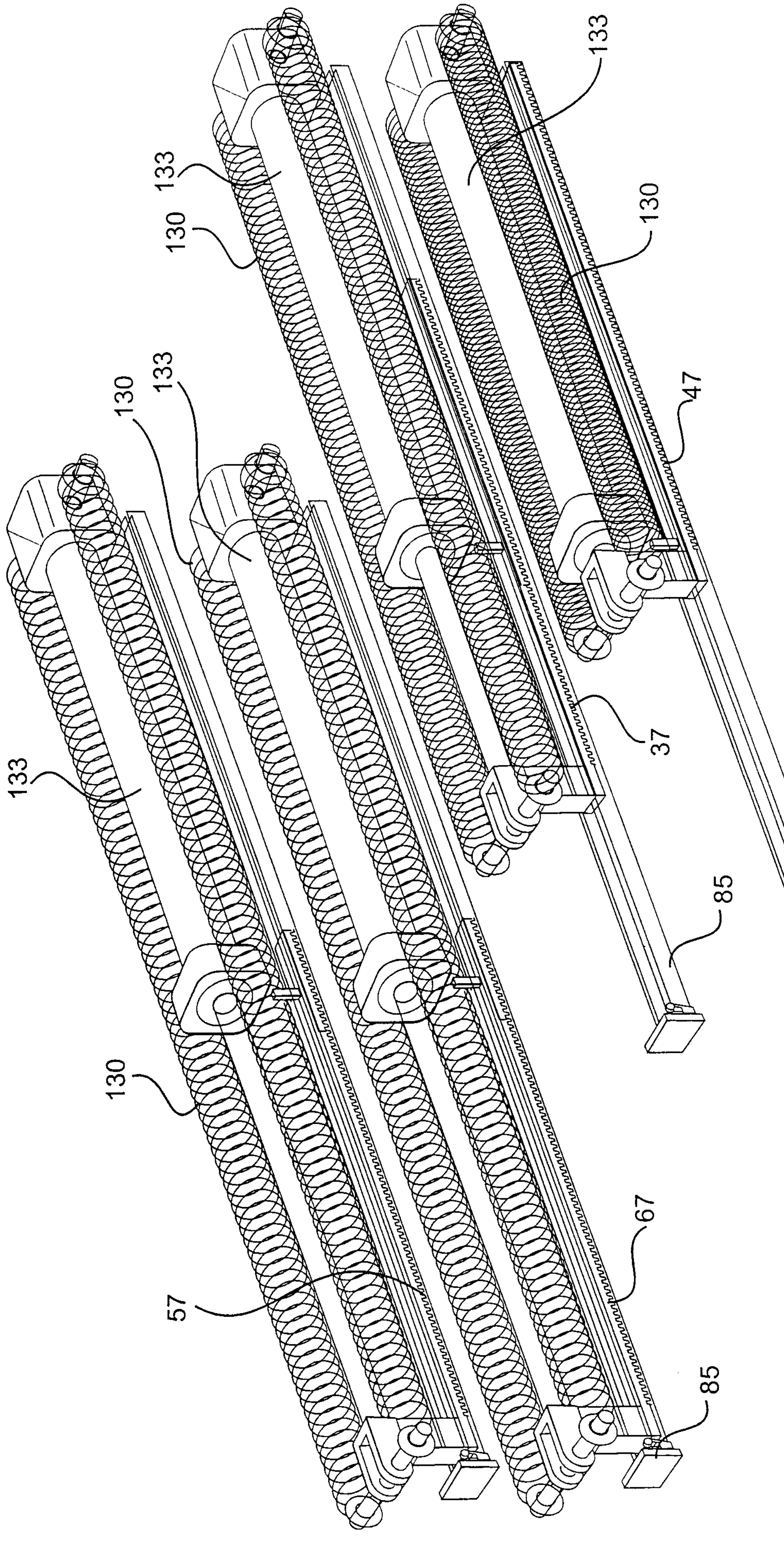

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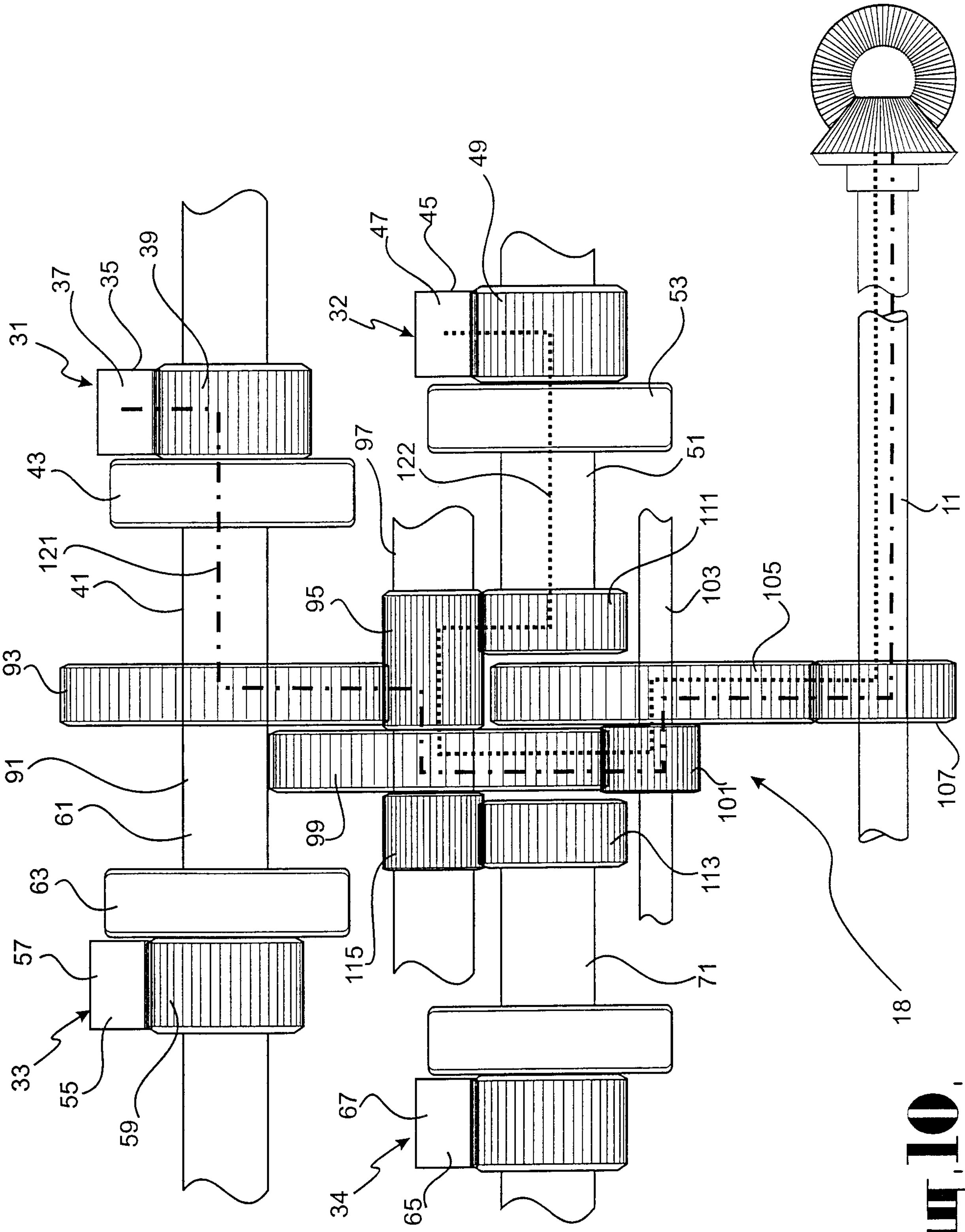
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Fig 10.

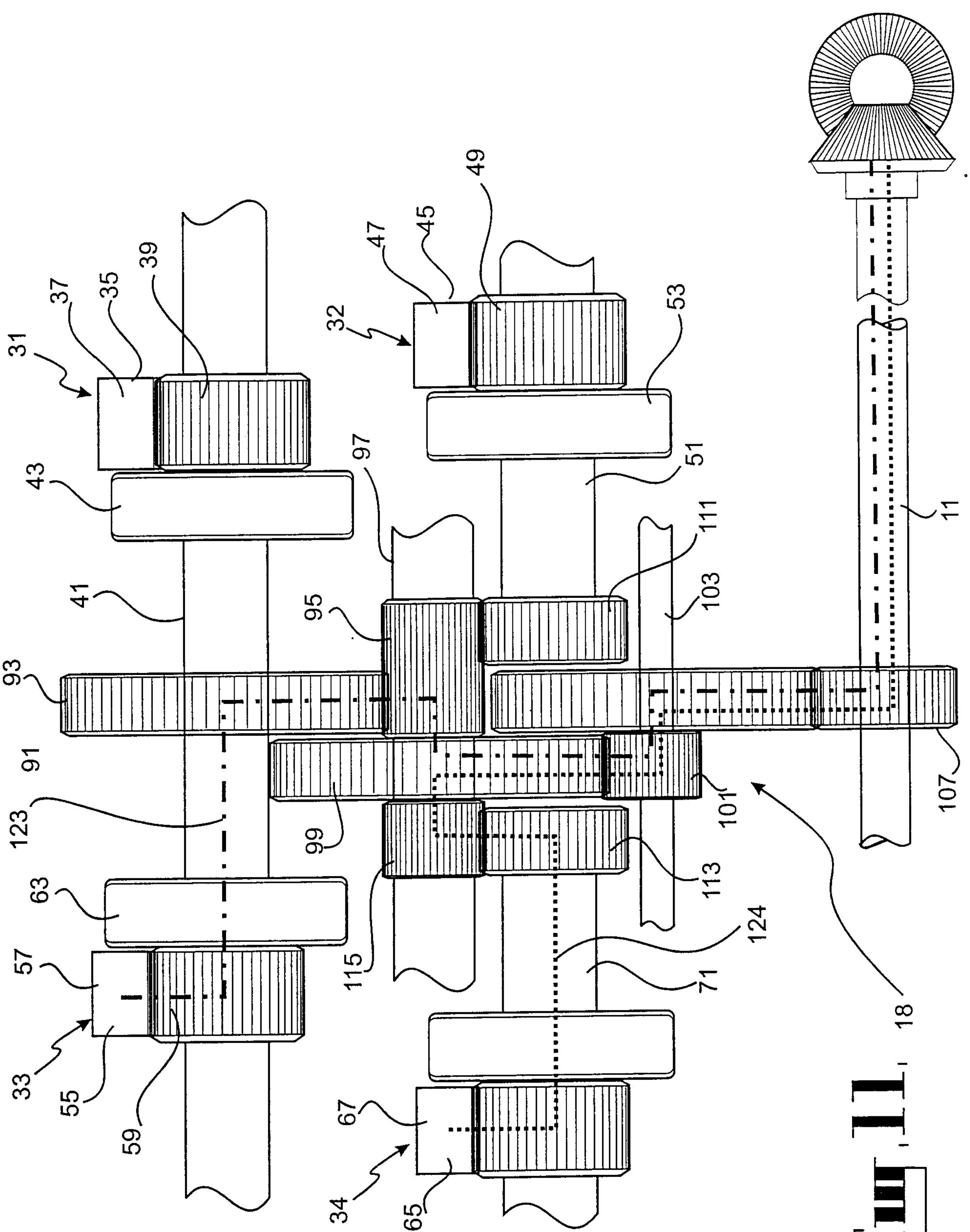
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Fig. 11

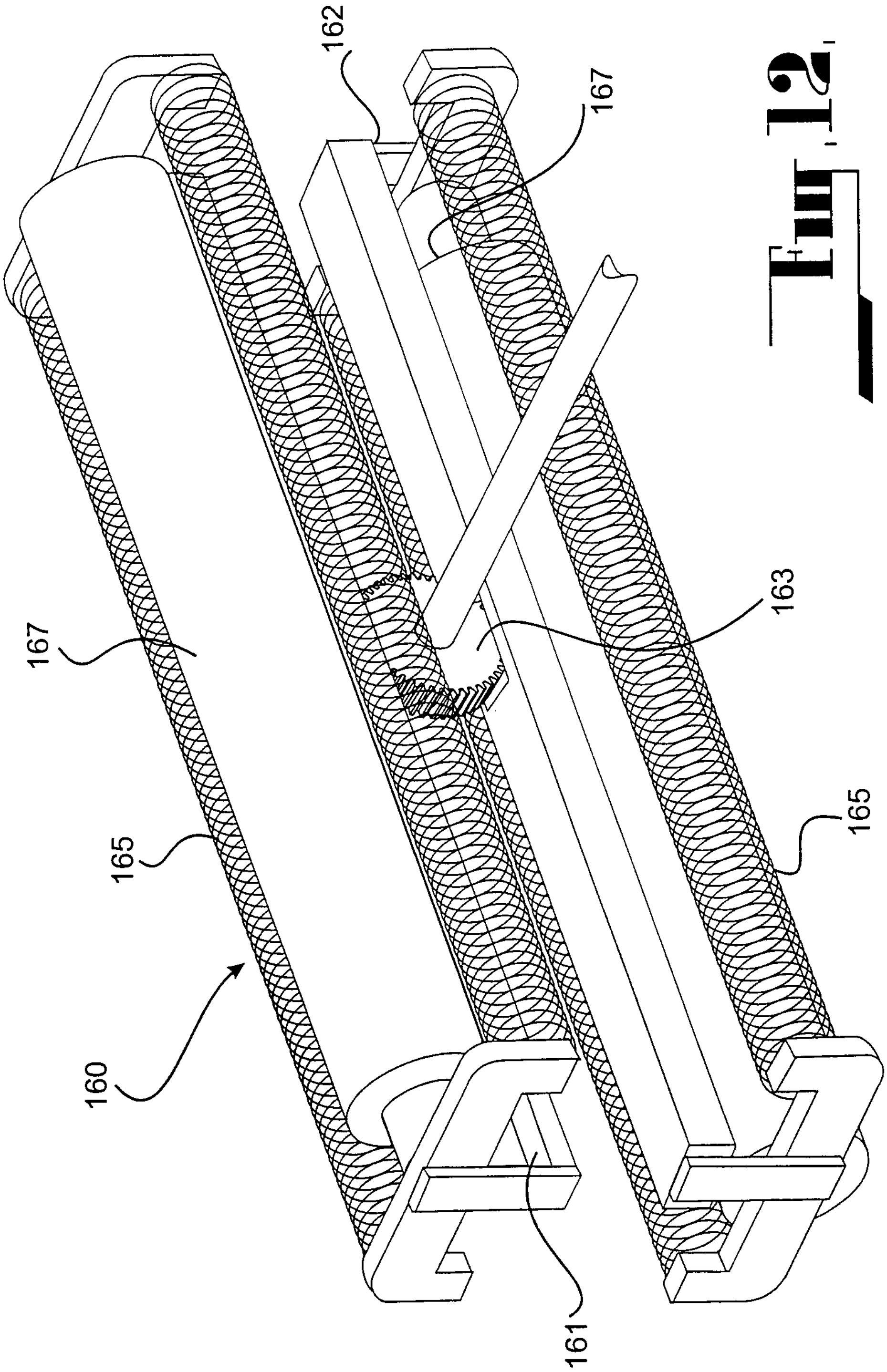

Fig 12

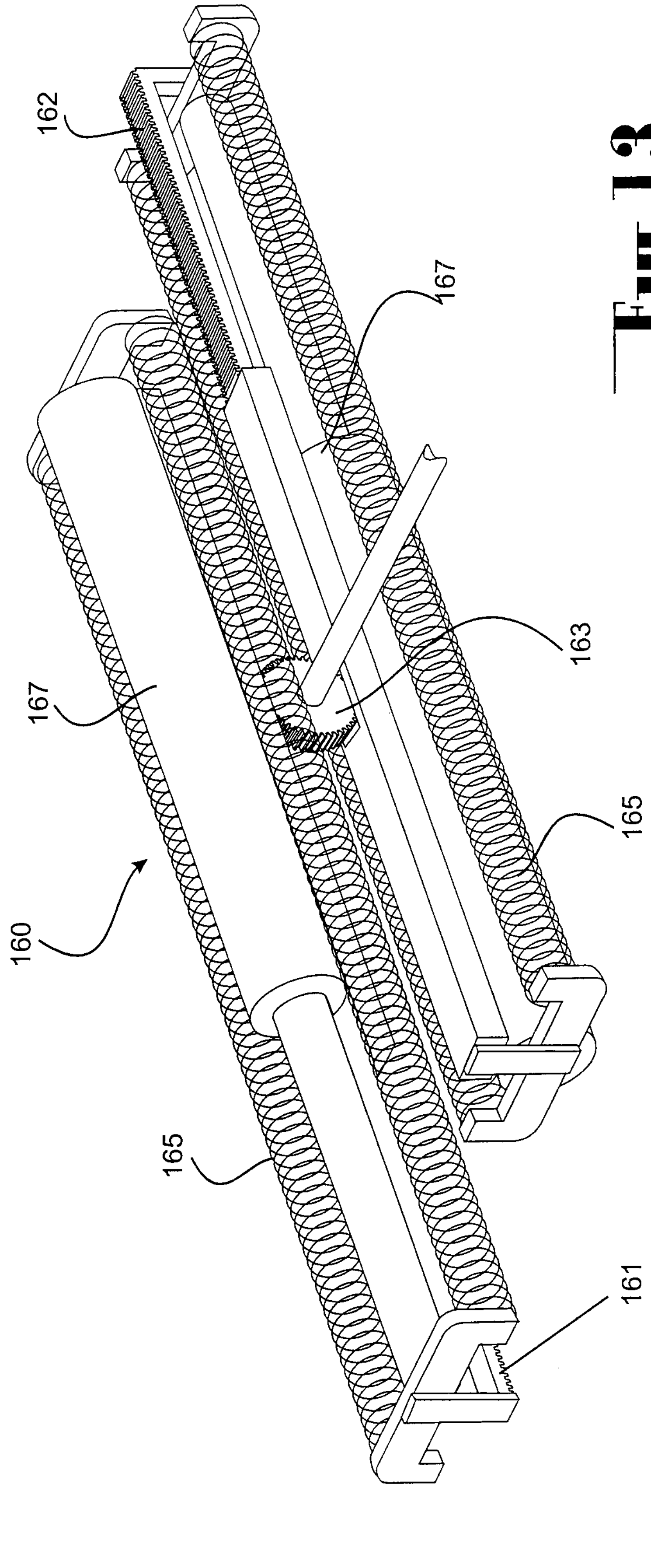

Fig. 13.

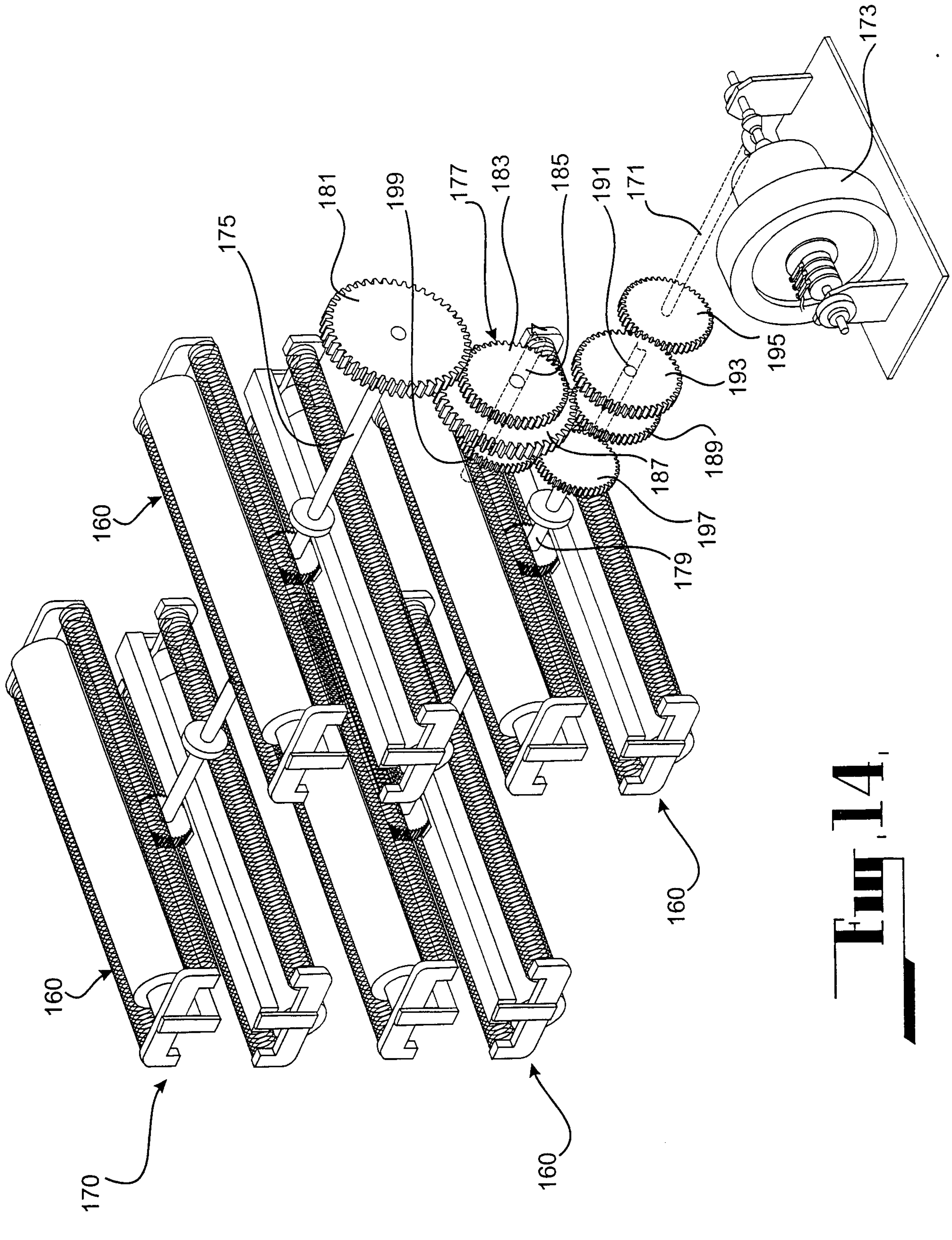
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Fig 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/01185

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: F03G 1/00, F16H 33/06

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)
F03G 1/00, 1/02, F16H 33/02, 33/06

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 practicable, search terms used)
DWPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96/27083 A (HESSABI) 6 SEPTEMBER 1996 WHOLE DOCUMENT	1,5,15
A	DE 2906563 A (BREITGRAF) 28 AUGUST 1980 WHOLE DOCUMENT	
A	EP 559947 A (THOMAS IND INC) 15 SEPTEMBER 1993 WHOLE DOCUMENT	

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2000	-1 NOV 2000
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer KURT TOBLER Telephone No : (02) 6283 2469

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/01185

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	9627083 A	AU	49439/96 A	DE	19516148 A		
EP	559947 A	BR	9202885 A	CA	2072180 A	CN	1076243 A
		JP	5280251 A	MX	9206893 A	US	5243735 A

END OF ANNEX