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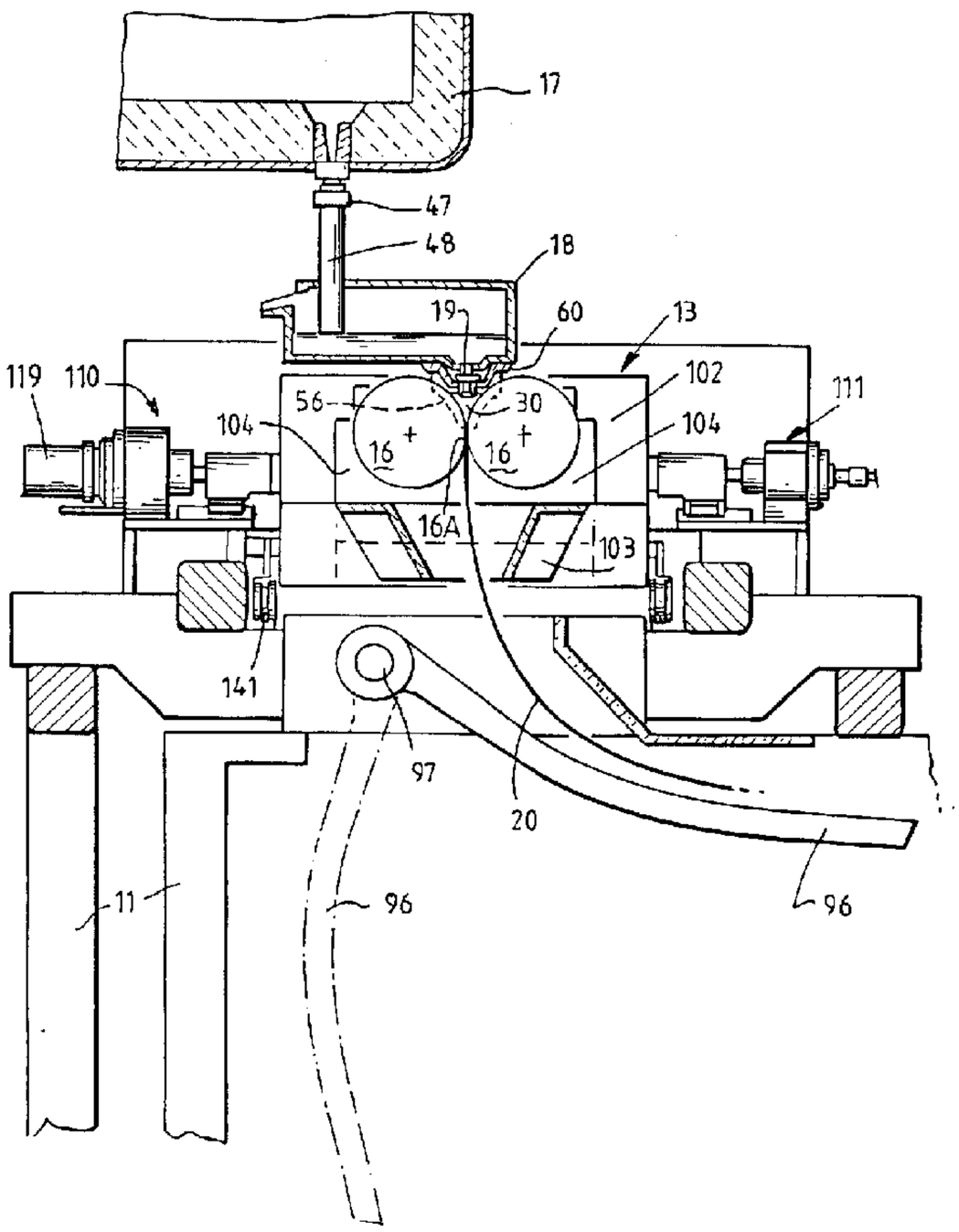
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(54) **STRIP CASTING APPARATUS**



(57) Twin roll strip caster comprising parallel casting rolls (16) one of which is mounted on moveable roll supports (104) which allow it to move bodily toward and away from the other roll (16). A pair of roll biasing units (110) comprising compression act on roll supports (104) to bias the moving roll (16) toward the other roll. Biasing units (110) comprise compression springs (112) acting on roll supports (104) through thrust transmission structures (122) and thrust reaction structures (121). The positions of thrust reaction structures (121) are set by hydraulic cylinder units (119) operable vary the position of each reaction structure (121). to replicate movements of the respective thrust transmission structure 122 so as to maintain a constant compression of the biasing springs (112) regardless of lateral movements of the roll supports (104).

ABSTRACT

Twin roll strip caster comprising parallel casting rolls (16) one of which is mounted on moveable roll supports (104) which allow it to move bodily toward and away from the other roll (16). A pair of roll biasing units (110) comprising compression act on roll supports (104) to bias the moving roll (16) toward the other roll. Biasing units (110) comprise compression springs (112) acting on roll supports (104) through thrust transmission structures (122) and thrust reaction structures (121). The positions of thrust reaction structures (121) are set by hydraulic cylinder units (119) operable vary the position of each reaction structure (121) to replicate movements of the respective thrust transmission structure 122 so as to maintain a constant compression of the biasing springs (112) regardless of lateral movements of the roll supports (104).

STRIP CASTING APPARATUS

TECHNICAL FIELD

This invention relates to the casting of metal strip. It has particular application to the casting of metal strip by continuous casting in a twin roll caster.

In a twin roll caster molten metal is introduced between a pair of contra-rotated horizontal casting rolls which are cooled so that metal shells solidify on the moving roll surfaces and are brought together at the nip between them to produce a solidified strip product delivered downwardly from the nip between the rolls. The term "nip" is used herein to refer to the general region at which the rolls are closest together. The molten metal may be poured from a ladle into a smaller vessel or series of smaller vessels from which it flows through a metal delivery nozzle located above the nip so as to direct it into the nip between the rolls, so forming a casting pool of molten metal supported on the casting surfaces of the rolls immediately above the nip and extending along the length of the nip. This casting pool is usually confined between side plates or dams held in sliding engagement with end surfaces of the rolls so as to dam the two ends of the casting pool against outflow, although alternative means such as electromagnetic barriers have also been proposed.

The setting up and adjustment of the casting rolls in a twin roll caster is a significant problem. The rolls must be accurately set to properly define an appropriate width for the nip, generally of the order of a few millimetres or less, and there must also be some means for allowing at least one of the rolls to move outwardly against a biasing force to accommodate fluctuations in strip thickness particularly during start up.

Usually, one of the rolls is mounted in fixed journals and the other is rotatably mounted on supports which can move against the action of biasing means to enable that roll to move laterally to accommodate

fluctuations in strip thickness. The biasing means may be in the form of helical compression springs or alternatively, may comprise a pair of pressure fluid cylinder units.

A strip caster with spring biasing of the laterally moveable roll is disclosed in Australian Patent Application 85185/98. In that case the biasing springs act between the roll supports and a pair of thrust reaction structures, the positions of which can be set by operation of a pair of powered mechanical jacks to enable the initial compression of the springs to be adjusted to set initial compression forces which are equal at both ends of the roll. The positions of the roll supports need to be set and subsequently adjusted after commencement of casting so that the gap between the rolls is constant across the width of the nip in order to produce a strip of constant profile. However, as casting continues the profile of the strip will inevitably vary due to eccentricities in the rolls and dynamic changes due to variable heat expansion and other dynamic effects. Previously, there has been no means to provide dynamic wedge or profile control to suppress strip profile fluctuations during casting. By the present invention, it is possible to provide a very effective means for such dynamic profile control.

DISCLOSURE OF THE INVENTION

According to the invention there is provided apparatus for continuously casting metal strip comprising a pair of parallel casting rolls forming a nip between them; metal delivery means to deliver molten metal into the nip between the rolls to form a casting pool of molten metal supported on casting roll surfaces immediately above the nip; pool confining means to confine the molten metal in the casting pool against outflow from the ends of the nip; and roll drive means to drive the casting rolls in counter-rotational directions to produce a solidified strip of metal delivered downwardly from the nip; wherein at least

one of the casting rolls is mounted on a pair of moveable roll carriers which allow that one roll to move bodily toward and away from the other roll, wherein there is a pair of roll biasing units acting one on each of the pair of moveable roll carriers to bias said one roll bodily toward the other roll, and wherein each roll biasing unit comprises a thrust transmission structure connected to the respective roll carrier, a thrust reaction structure, compression spring means acting between spring abutments on the thrust reaction structure and the thrust transmission structure to exert a thrust on the thrust transmission structure and the respective roll carrier, thrust reaction structure setting means operable to vary the position of the thrust reaction structure, and control means to control operation of the setting means such that movements of the thrust transmission structure are replicated as movements of the thrust reaction structure whereby movements of the thrust transmission structure do not significantly affect the biasing force imposed thereon by the compression spring.

Preferably, the setting means is a pressure fluid actuable means acting between the thrust reaction structure and a fixed structure.

The pressure fluid actuable means may be provided by a fluid cylinder and piston unit connected at one end to a fixed structure, the other end of that unit either forming or being connected with the thrust reaction structure.

The control means may comprise a first position sensor to sense the position of the thrust transmission structure, and means to operate the fluid pressure means such that a movement sensed by the sensor is replicated by a movement of the thrust reaction structure.

The roll carriers may comprise a pair of roll end support structures for each of the rolls disposed generally beneath the ends of the respective roll.

Each pair of roll end support structures may

carry journal bearings mounting the respective roll ends for rotation about a central roll axis.

The casting rolls and roll carriers may be mounted on a roll module installed in and removable from the caster as a unit. In that case, the thrust transmission structure of each biasing unit may be disconnectable from the respective roll carrier to enable the module to be removed without removing or dismantling the roll biasing units.

In apparatus in accordance with the invention both of the casting rolls may be biased by respective pairs of biasing units. Alternatively, one of the rolls may be restrained against lateral bodily movement and the other allowed to move laterally against spring biasing forces in accordance with the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be fully explained one particular embodiment will be described in some detail with reference to the accompanying drawings in which:

Figure 1 is a vertical cross section through a strip caster constructed in accordance with the present invention.

Figure 2 is an enlargement of part of Figure 1 illustrating important components of the caster.

Figure 3 is a longitudinal cross section through important parts of the caster.

Figure 4 is an end elevation of the caster;

Figures 5, 6 and 7 show the caster in varying conditions during casting and during removal of the roll module from the caster;

Figure 8 is a vertical cross-section through a roll biasing unit incorporating a roll biasing spring; and

Figure 9 is a schematic representation of essential components of the caster.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The illustrated caster comprises a main machine frame 11 which stands up from the factory floor (not shown) and supports a casting roll module in the form of a cassette 13 which can be moved into an operative position in the caster as a unit but can readily be removed when the rolls are to be replaced. Cassette 13 carries a pair of parallel casting rolls 16 to which molten metal is supplied during a casting operation from a ladle (not shown) via a tundish 17, distributor 18 and delivery nozzle 19 to create a casting pool 30. Casting rolls 16 are water cooled so that shells solidify on the moving roll surfaces and are brought together at the nip between them to produce a solidified strip product 20 at the roll outlet. This product may be fed to a standard coiler.

Casting rolls 16 are contra-rotated through drive shafts 41 from an electric motor and transmission mounted on the main machine frame. The drive shaft can be disconnected from the transmission when the cassette is to be removed. Rolls 16 have copper peripheral walls formed with a series of longitudinally extending and circumferentially spaced water cooling passages supplied with cooling water through the roll ends from water supply ducts in the roll drive shafts 41 which are connected to water supply hoses 42 through rotary glands 43. The roll may typically be about 500 mm diameter and up to 2000 mm long in order to produce strip product approximately the width of the rolls.

The ladle is of entirely conventional construction and is supported on a rotating turret whence it can be brought into position over the tundish 17 to fill the tundish. The tundish may be fitted with a sliding gate valve 47 actuable by a servo cylinder to allow molten metal to flow from the tundish 17 through the valve 47 and refractory shroud 48 into the distributor 18.

The distributor 18 is formed as a wide dish made of a refractory material such as magnesium oxide (MgO).

One side of the distributor 18 receives molten metal from the tundish 17 and the other side of the distributor 18 is provided with a series of longitudinally spaced metal outlet openings 52. The lower part of the distributor 18 carries mounting brackets 53 for mounting the distributor onto the main caster frame 11 when the cassette is installed in its operative position.

Delivery nozzle 19 is formed as an elongate body made of a refractory material such as alumina graphite. Its lower part is tapered so as to converge inwardly and downwardly so that it can project into the nip between casting rolls 16. Its upper part is formed with outwardly projecting side flanges 55 which locate on a mounting bracket 60 which forms part of the main frame 11.

Nozzle 19 may have a series of horizontally spaced generally vertically extending flow passages to produce a suitably low velocity discharge of metal throughout the width of the rolls and to deliver the molten metal into the nip between the rolls without direct impingement on the roll surfaces at which initial solidification occurs. Alternatively, the nozzle may have a single continuous slot outlet to deliver a low velocity curtain of molten metal directly into the nip between the rolls and/or it may be immersed in the molten metal pool.

The pool is confined at the ends of the rolls by a pair of side closure plates 56 which are held against stepped ends 57 of the rolls when the roll cassette is in its operative position. Side closure plates 56 are made of a strong refractory material, for example boron nitride, and have scalloped side edges to match the curvature of the stepped ends of the rolls. The side plates can be mounted in plate holders 82 which are movable by actuation of a pair of hydraulic cylinder units 83 to bring the side plates into engagement with the stepped ends of the casting rolls to form end closures for the molten pool of metal formed on the casting rolls during a casting operation.

During a casting operation the sliding gate valve

47 is actuated to allow molten metal to pour from the tundish 17 to the distributor 18 and through the metal delivery nozzle 19 whence it flows onto the casting rolls. The head end of the strip product 20 is guided by actuation of an apron table 96 to a pinch roll and thence to a coiling station (not shown). Apron table 96 hangs from pivot mountings 97 on the main frame and can be swung toward the pinch roll by actuation of an hydraulic cylinder unit (not shown) after the clean head end has been formed.

The removable roll cassette 13 is constructed so that the casting rolls 16 can be set up and the nip between them adjusted before the cassette is installed in position in the caster. Moreover when the cassette is installed two pairs of roll biasing units 110, 111 mounted on the main machine frame 11 can be rapidly connected to roll supports on the cassette to provide biasing forces resisting separation of the rolls.

Roll cassette 13 comprises a large frame 102 which carries the rolls 16 and upper part 103 of the refractory enclosure for enclosing the cast strip below the nip. Rolls 16 are mounted on roll supports 104 which comprise a pair of roll end support structure 90 carrying roll end bearings 100 by which the rolls are mounted for rotation about their longitudinal axis in parallel relationship with one another. The two pairs of roll supports 104 are mounted on the roll cassette frame 102 by means of linear bearings 106 whereby they can slide laterally of the cassette frame to provide for bodily movement of the rolls toward and away from one another thus permitting separation and closing movement between the two parallel rolls.

Roll cassette frame 102 also carries two adjustable stop means 107 disposed beneath the rolls about a central vertical plane between the rolls and located between the two pairs of roll supports 104 so as to serve as stops limiting inward movement of the two roll supports thereby to define the minimum width of the nip between the

rolls. As explained below the roll biasing units 110, 111 are actuable to move the roll supports inwardly against these central adjustable stop means but to permit outward springing movement of one of the rolls against preset biasing forces.

Each adjustable stop means 107 is in the form of a worm or screw driven jack having a body 108 fixed relative to the central vertical plane of the caster and two ends 109 which can be moved on actuation of the jack equally in opposite directions to permit expansion and contraction of the jack to adjust the width of the nip while maintaining equidistance spacing of the rolls from the central vertical plane of the caster.

The caster is provided with two pairs of roll biasing units 110, 111 connected one pair to the supports 104 of each roll 16. The roll biasing units 110 at one side of the machine are constructed and operate in accordance with the present invention. These units are fitted with helical biasing springs 112 to provide biasing forces on the respective roll supports 104 whereas the biasing units 111 at the other side of the machine incorporate hydraulic actuators 113. These actuators are operable to hold the respective roll supports 104 of one roll firmly against the central stops and the other roll is free to move laterally against the action of the biasing springs 112 of the units biasing 110.

The detailed construction of biasing units 110 is illustrated in Figure 8. As shown in that figure, the biasing unit comprises a spring barrel housing 114 disposed within an outer housing 115 which is fixed to the main caster frame 116 by fixing bolts 117.

Spring housing 114 is formed with a piston 118 which runs within the outer housing 115. Spring housing 114 can be set alternatively in an extended position as illustrated in Figure 8 and a retracted position by flow of hydraulic fluid to and from the cylinder 118. The outer end of spring housing 114 carries a pressure fluid operable

means in the form of an hydraulic cylinder unit 119 operable to set the position of a spring reaction plunger 121 connected to the piston of unit 119 by a connecting rod 130.

The inner end of the spring 112 acts on a thrust transmission structure 122 which is connected to the respective roll support 104 through a load cell 125. The thrust structure is initially pulled into firm engagement with the roll support by a connector 124 which can be extended by operation of a hydraulic cylinder 123 when the biasing unit is to be disconnected.

When biasing unit 110 is connected to its respective roll support 104 with the spring housing 114 set in its extended condition as shown in Figure 8 the position of the spring housing 114 and cylinder unit 119 is fixed relative to the machine frame and the position of the spring reaction plunger 121 can be set to adjust the effective gap between the spring abutments on the reaction plunger and the thrust transmission structure 122. The compression of the spring 112 can thereby be adjusted to vary the thrusting force applied to the thrust transmission structure 122 and the respective roll support 104. With this arrangement the only relative movement during casting operation is the movement of the roll support 104 and thruster structure 122 as a unit against the biasing spring. Since the biasing unit acts to bias the roll support 104 inwardly against the stop it can be adjusted to preload the roll support with a required spring biasing force before metal actually passes between the casting rolls and that biasing force will be maintained during a subsequent casting operation.

In accordance with the present invention, dynamic wedge or profile control is achieved by continuous operation of the hydraulic cylinder unit 119 to vary the position of the spring reaction plunger to replicate movements of the thrust transmission structure 122 due to lateral movements of the roll support 104. Any inward or

outward movement of roll support 104 will cause a corresponding inward or outward movement of the cylinder of cylinder unit 119 and therefore of spring reaction plunger 121 so as to maintain a constant compression of the compression spring 112. Accordingly, it is possible to maintain a constant biasing force at each end of the roll regardless of movements of the roll mountings and dynamic wedge control can therefore be achieved. It is not possible to achieve this result by endeavouring to control biasing forces generated by a pressure fluid biasing system. Such control would be dependant on measured force signals that would necessarily have errors which would feed back through the control system. The use of springs in combination with a continuous setting means in accordance with the present invention enables very accurate setting of constant biasing forces which can be maintained throughout a casting operation. It is possible to use very low stiffness springs and because the two compensation or control systems for the two roll ends operate completely independently there is no cross-talk between the two.

As illustrated diagrammatically in Figure 9, the control means can be comprised of position sensors 150, sensing the position of the thrust transmission structures 122 and connected into a control circuit which controls the operation of the cylinder unit 119 so that the movements of the thrust transmission structures 122 are replicated by the cylinders of units 119. The control circuit may comprise controllers 151 connected to the sensors 150 and to the cylinder units 119 to operate the cylinders 119 during casting so as to replicate movements of the thrust transmission structures 122. Controllers 151 may also receive input signals from a logic device 152 to allow operation of the cylinders for initial setting of the roll supports (input point 153) prior to casting and subsequent adjustment for static wedge adjustment after casting (input point 154).

The control means may also cause cylinder unit

119 to be operated to impose additional movements on the spring reaction plunger 121 to produce variations in the biasing force to compensate for variations in strip thickness across the whole width of the strip or at the corresponding edge of the strip due to deformation variations at the ends of the rolls during casting. Variations in strip thickness can be sensed by X-ray sensors which scans across the strip downstream from the caster and feed signals to an input point 155 of the logic device 152 of the control circuit as also indicated in Figure 9. The thickness variations due to roll deformation will be generally sinusoidal in the longitudinal direction of the strip so as to produce sinusoidal control signals which can be used to control operation of cylinder units 119 to impose a corresponding and compensating sinusoidal movement on the spring reaction plunger 121. To achieve appropriate strip thickness control, the control signals must be applied to the cylinder units 119 in proper phase relationship with the rotation of the rolls, ie during each rotation the pattern of the control signals must be matched with the pattern of roll end movements caused by the roll deformations. Proper phase matching is achieved by applying the signals at an initial phase relationship with a reference signal producing one pulse per revolution of the rolls and then varying the phase relationship to produce a minimisation of the amplitude of thickness variations. This may be achieved by tracking or plotting an amplitude error signal.

The construction units of biasing units 111 forms no part of the present invention. Full details of these units and the manner in which the roll cassette frame 102 can be moved into and out of the casting machine are described in Australian Patent Specification 85185/98.

CLAIMS:

1. Apparatus for continuously casting metal strip comprising a pair of parallel casting rolls forming a nip between them; metal delivery means to deliver molten metal into the nip between the rolls to form a casting pool of molten metal supported on casting roll surfaces immediately above the nip; pool confining means to confine the molten metal in the casting pool against outflow from the ends of the nip; and roll drive means to drive the casting rolls in counter-rotational directions to produce a solidified strip of metal delivered downwardly from the nip; wherein at least one of the casting rolls is mounted on a pair of moveable roll carriers which allow that one roll to move bodily toward and away from the other roll, wherein there is a pair of roll biasing units acting one on each of the pair of moveable roll carriers to bias said one roll bodily toward the other roll, and wherein each roll biasing unit comprises a thrust transmission structure connected to the respective roll carrier, a thrust reaction structure, compression spring means acting between spring abutments on the thrust reaction structure and the thrust transmission structure to exert a thrust on the thrust transmission structure and the respective roll carrier, thrust reaction structure setting means operable to vary the position of the thrust reaction structure, and control means to control operation of the setting means such that movements of the thrust transmission structure are replicated as movements of the thrust reaction structure whereby movements of the thrust transmission structure do not significantly affect the biasing force imposed thereon by the compression spring means.

2. Apparatus as claimed in claim 1, wherein the setting means is a pressure fluid actuable means acting between the thrust reaction structure and a fixed structure.

3. Apparatus as claimed in claim 2, wherein the fluid actuable means is provided by a fluid piston and

cylinder unit connected at one end to the fixed structure, the other end of that unit either forming or being connected with the thrust reaction structure.

4. Apparatus as claimed in claim 2, wherein the control means comprises a position sensor to sense the position of the thrust transmission structure, and means to operate the fluid pressure means such that a movement sensed by the sensor is replicated by movement of the thrust reaction structure.

5. Apparatus as claimed in claim 2, wherein the fluid actuable means is operable to impose additional movements on the thrust reaction structure to produce variations in the biasing force to compensate for variations in strip thickness during casting.

6. Apparatus as claimed in claim 5, wherein there is strip thickness sensing means to produce signals indicative of strip thickness and the control means utilises those signals to cause the operation of the fluid actuable means to impose said additional movements on the thrust reaction structure.

7. Apparatus as claimed in claim 1, wherein the roll carriers comprise a pair of roll end support structures for each of the rolls disposed generally beneath the ends of the respective roll.

8. Apparatus as claimed in claim 7, wherein each pair of roll end support structures carries journal bearings mounting the respective roll ends for rotation about a central roll axis.

9. Apparatus as claimed in claim 1, wherein the casting rolls and the roll carriers are mounted on a roll module installed in and removable from the caster as a unit.

10. Apparatus as claimed in claim 9, wherein the thrust transmission structure of each biasing unit is disconnectable from the respective roll carrier to enable the module to be removed without removing or dismantling the roll biasing units.

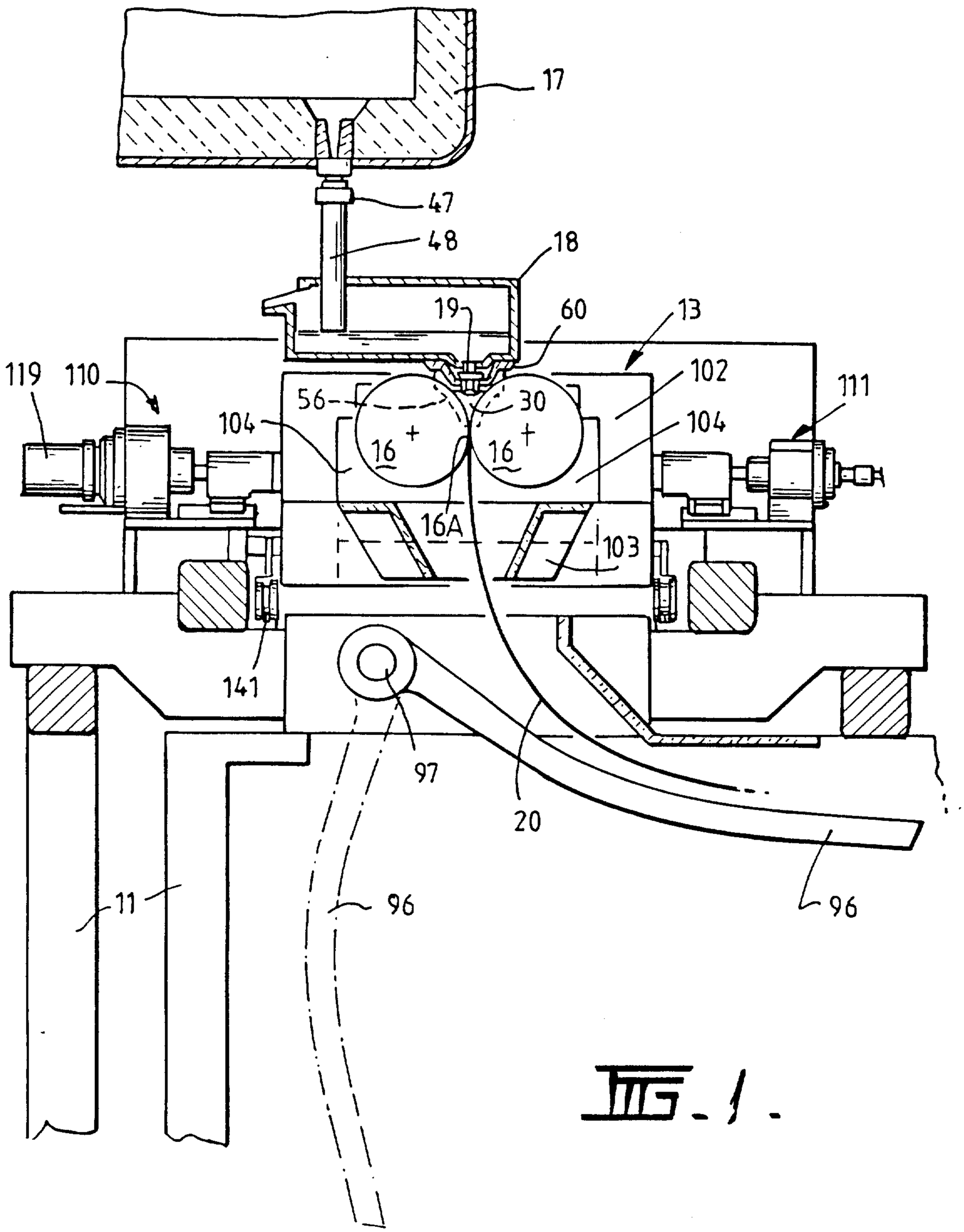
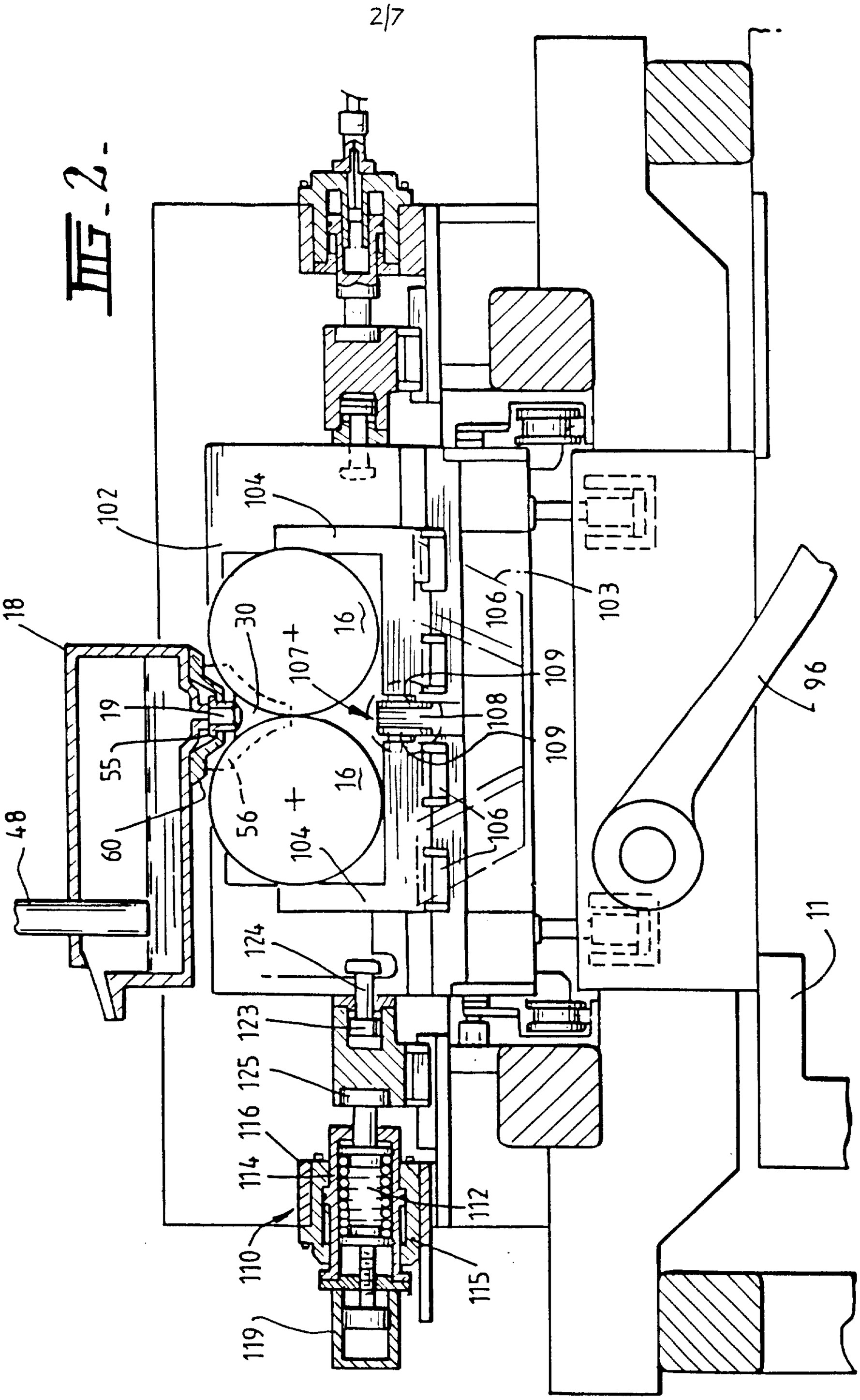

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FIG. 1.

FIG. 2.


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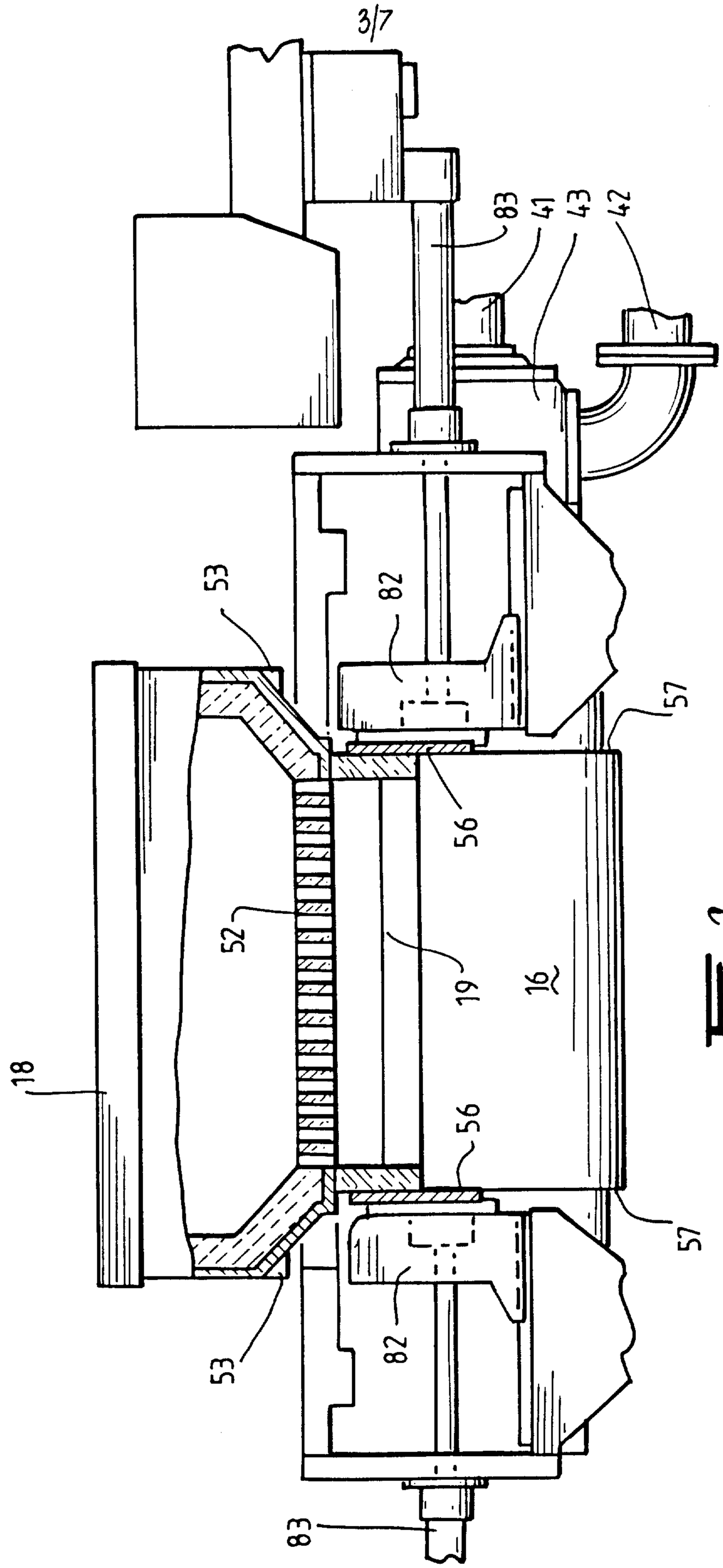


Fig. 3.

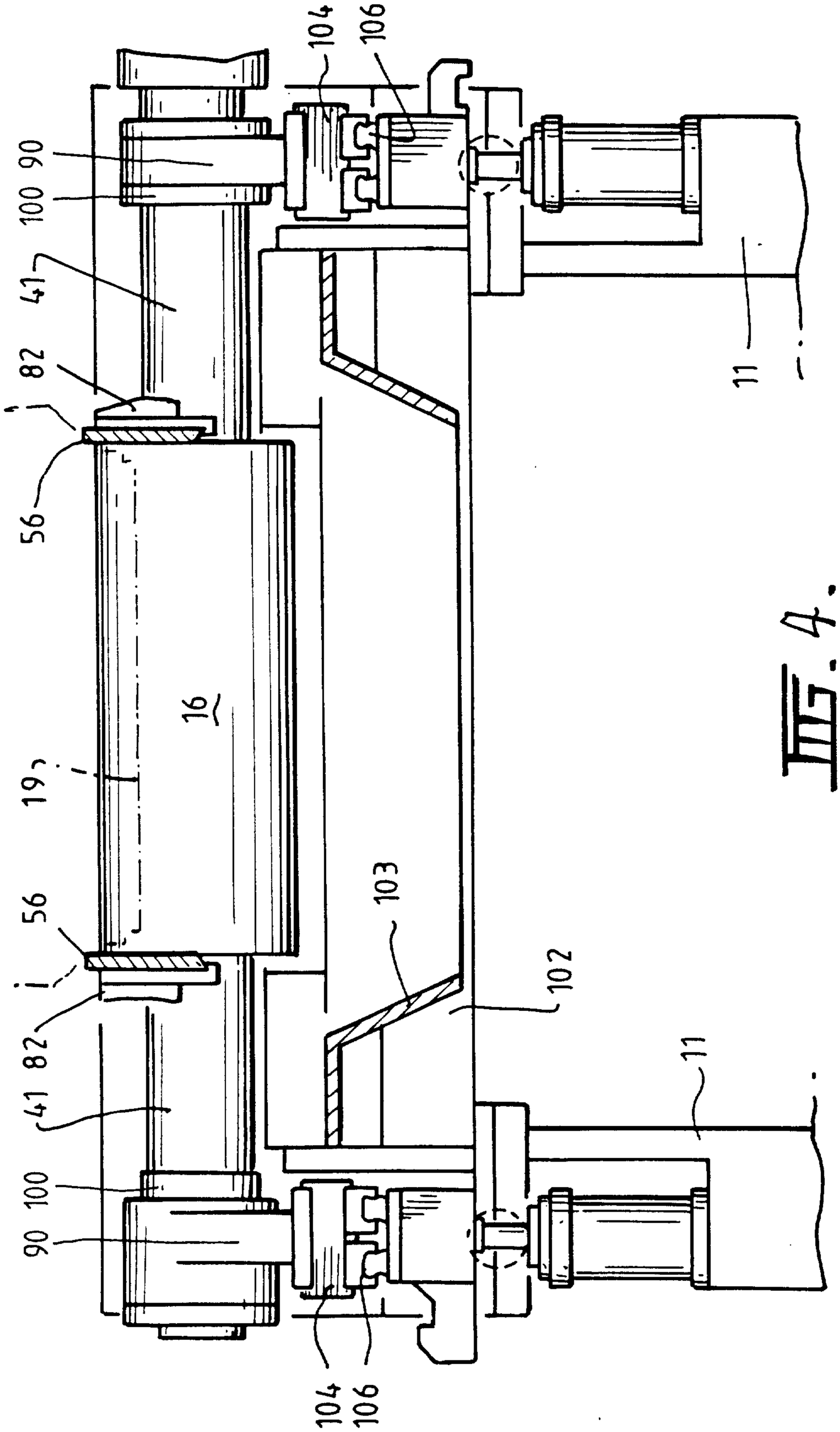


FIG. 4.

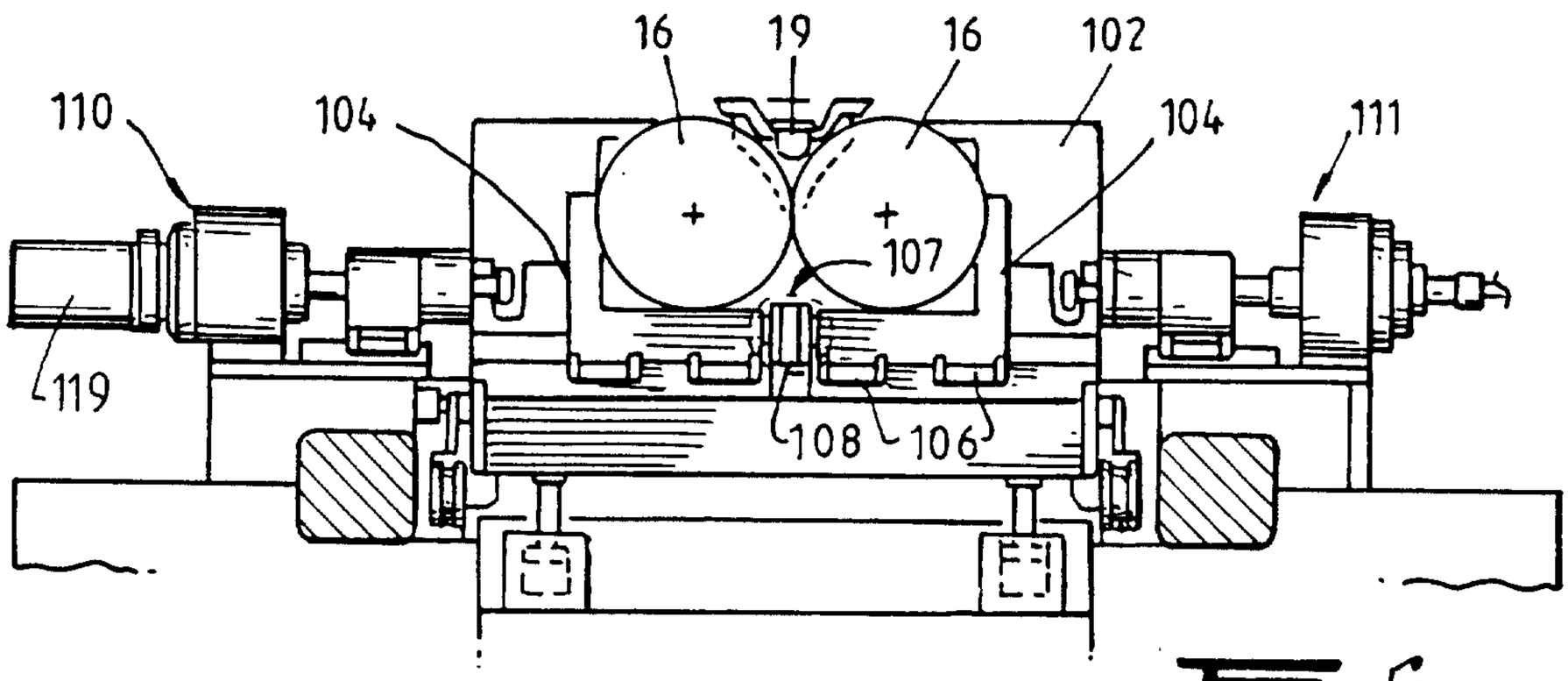


FIG. 5.

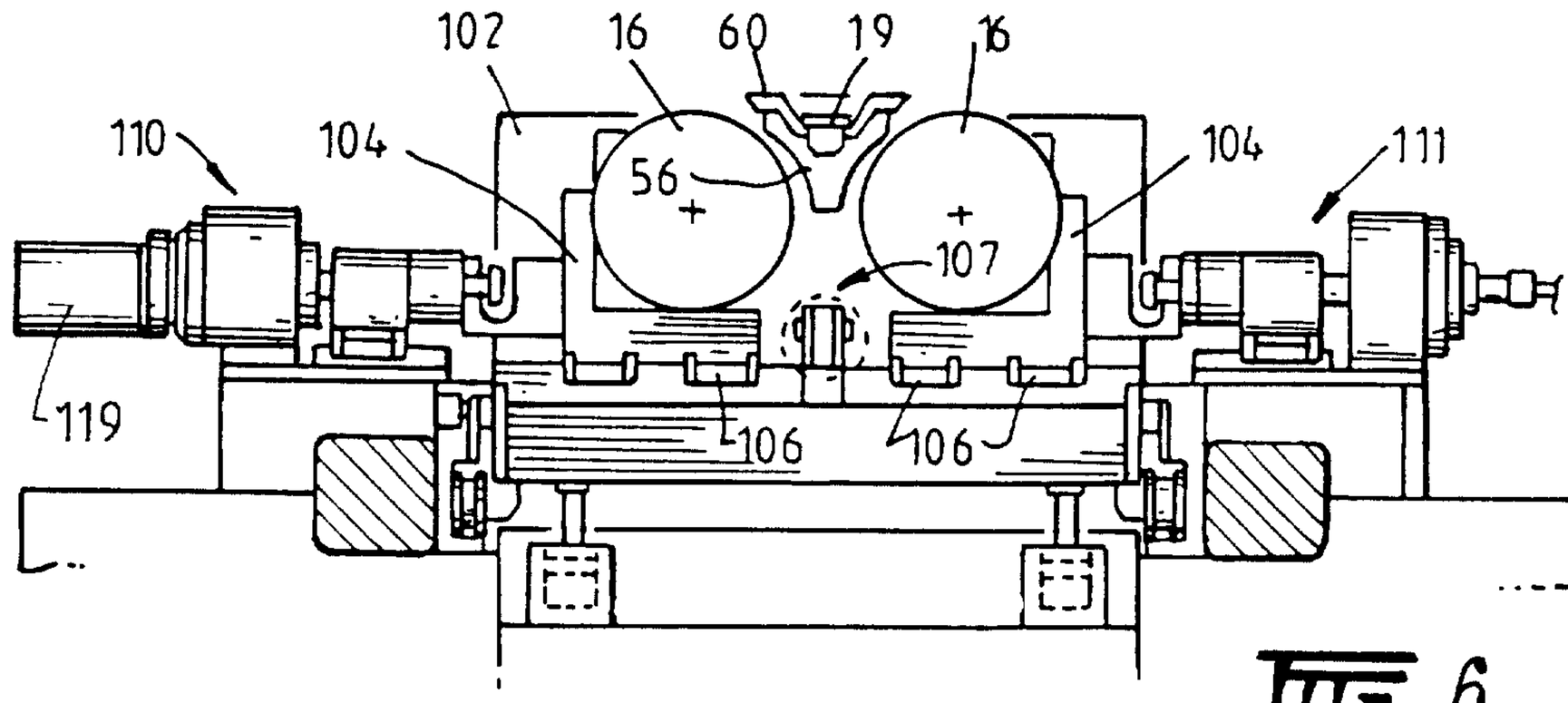


FIG. 6.

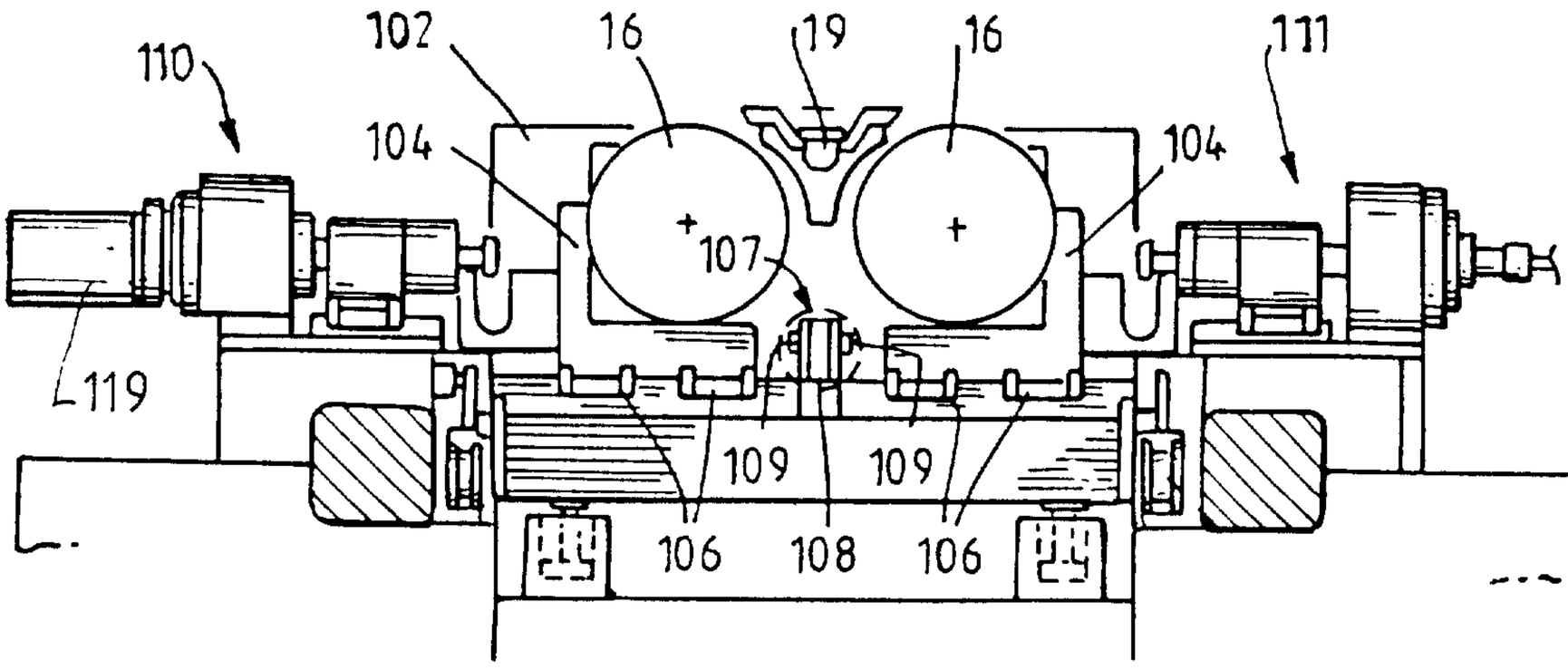


FIG. 7.

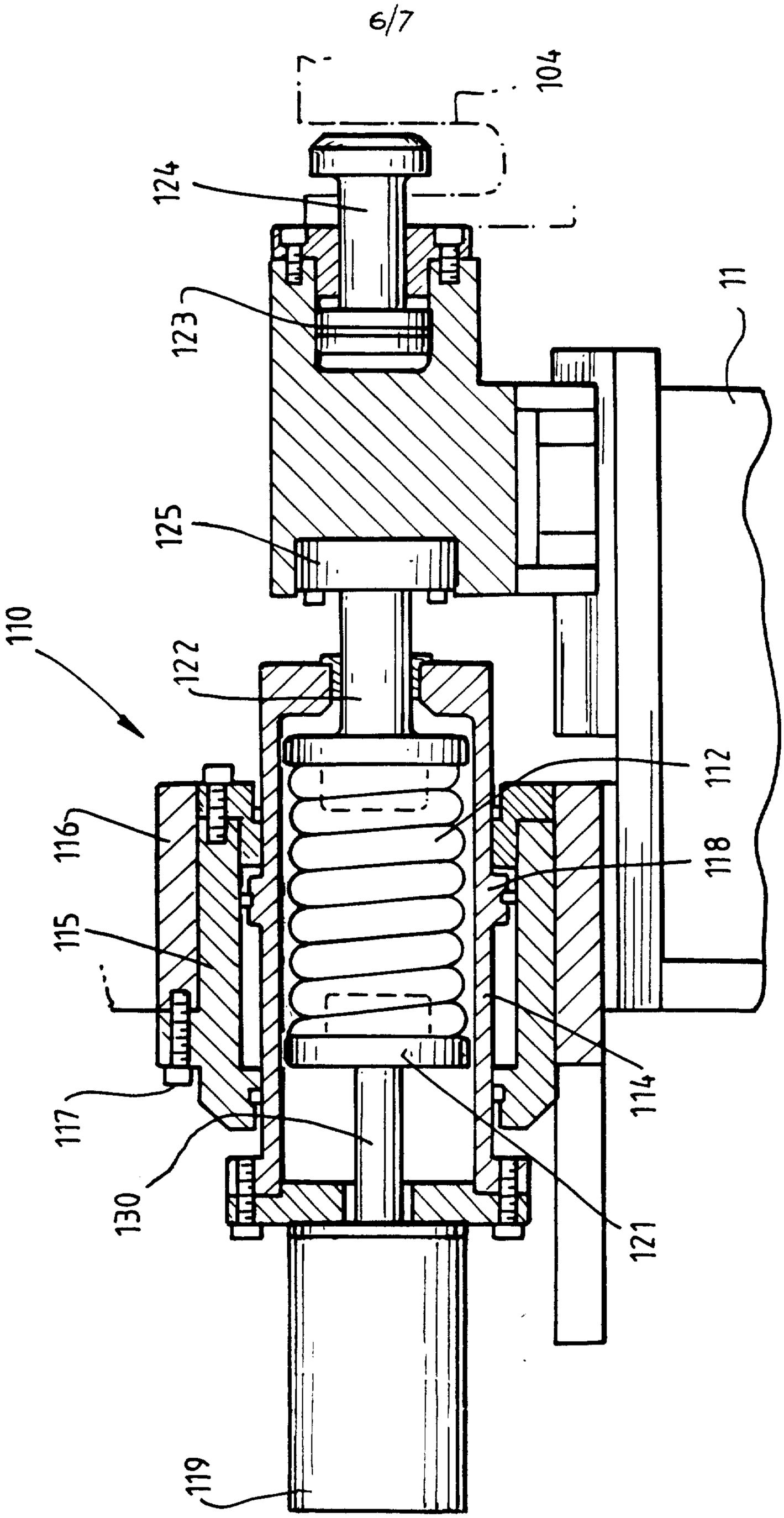


FIG. 8.

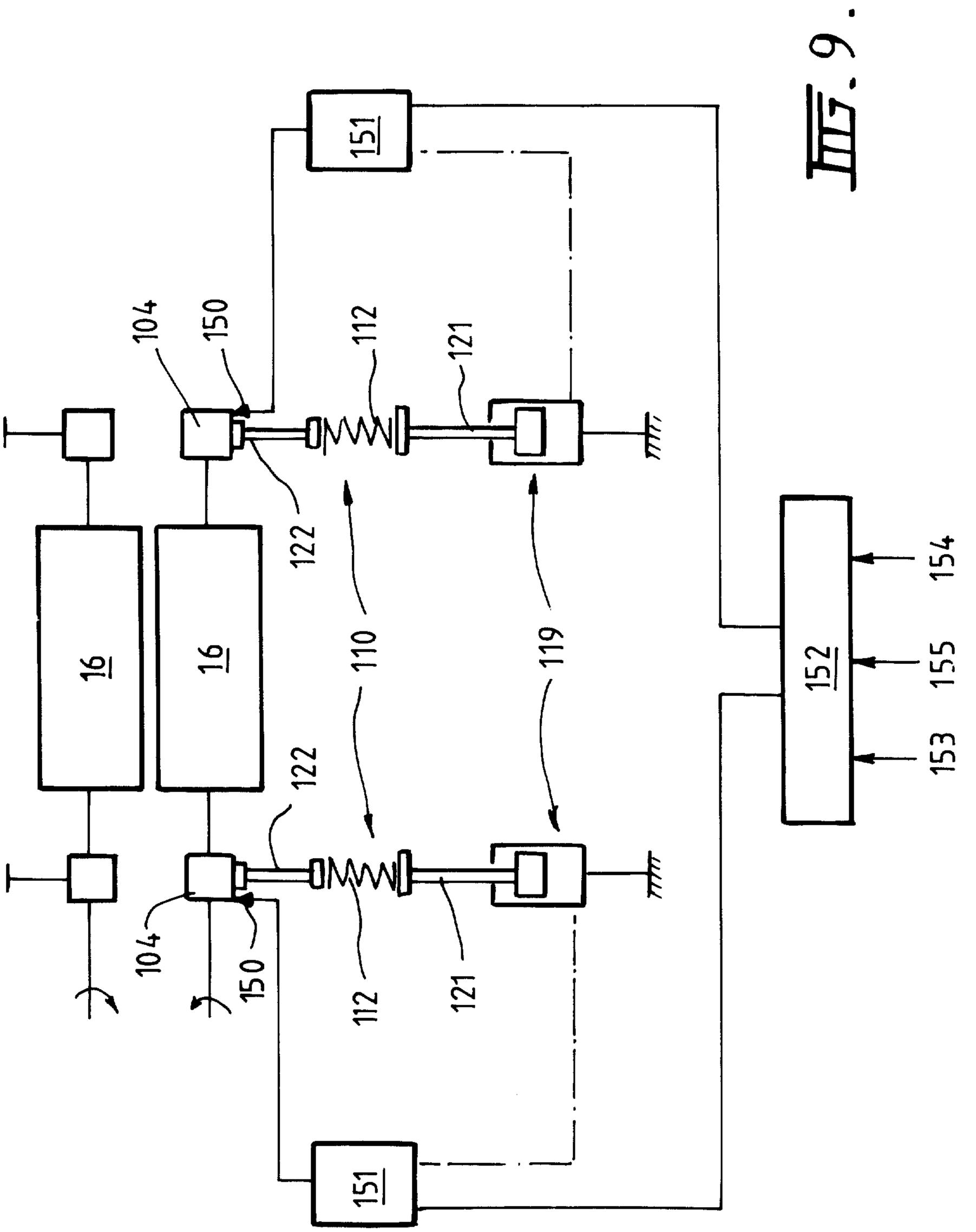


Fig. 9.