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Camilleri

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[54] **TRENCHING APPARATUS AND METHODS OF FORMING INGROUND RETAINING WALLS**

[75] Inventor: **Paul A. Camilleri**, Gold Coast, Australia

[73] Assignee: **Foundation Technology Limited**, Australia

[*] Notice: The portion of the term of this patent subsequent to May 17, 2011 has been disclaimed.

[21] Appl. No.: **724,202**

[22] Filed: **Jul. 1, 1991**

Related U.S. Patent Documents

Reissue of:

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Issued: **Jul. 4, 1989**
Appl. No.: **59,745**
Filed: **Jun. 8, 1987**

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[5] **E02F 5/08**

[52] **U.S. Cl.** **37/362**; 37/357; 37/355; 405/267

[58] **Field of Search** ..... 37/91, 90, 87, 86, 83, 37/192 R, 192 A, 191 A, 191 R, 195, 89; 405/267, 258

[56] **References Cited**

U.S. PATENT DOCUMENTS

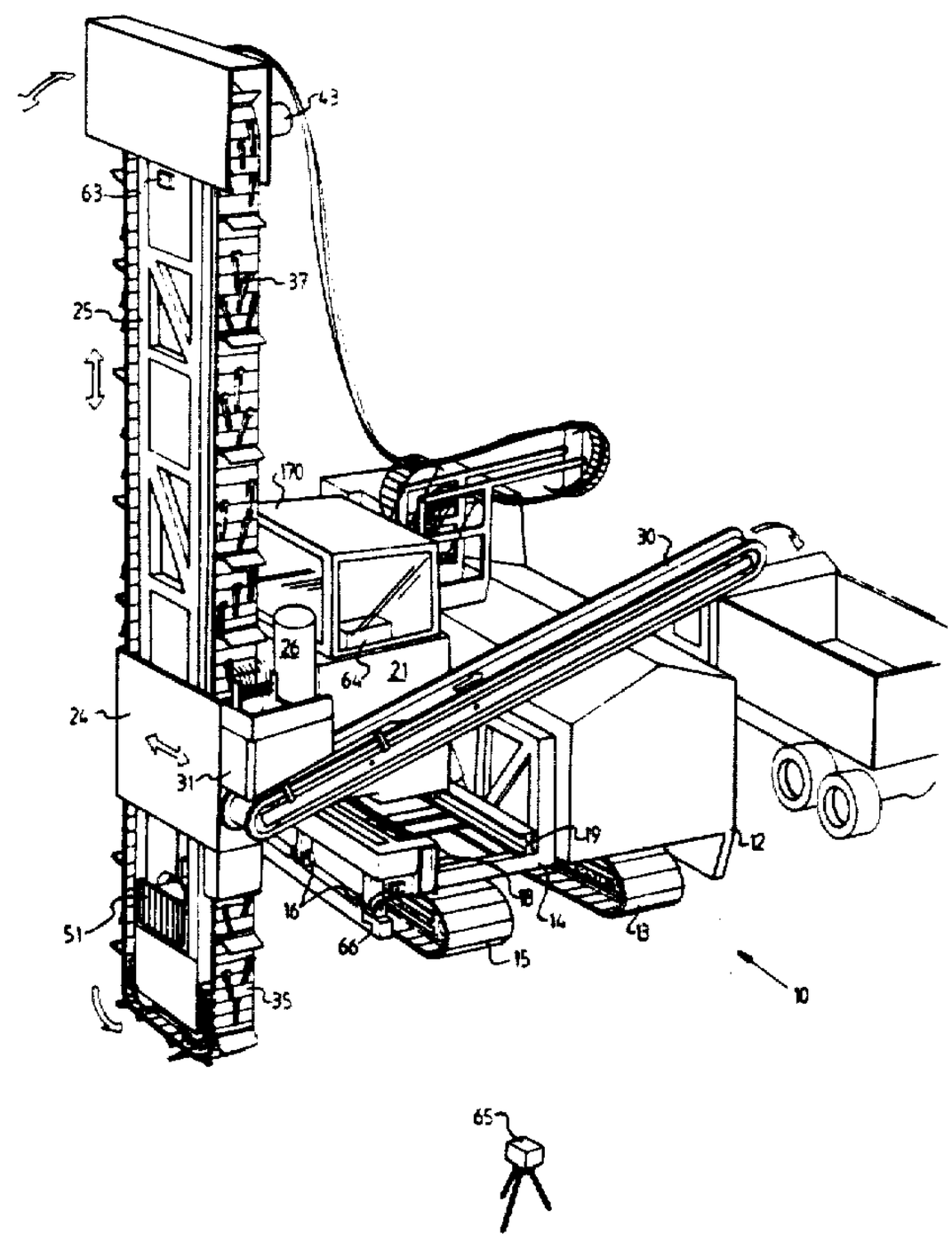
2,817,911	12/1957	Owen et al.	37/90
3,032,899	5/1962	Brinson, Sr.	37/90
3,425,572	2/1969	Brach	414/690
3,659,364	5/1972	Wilson	37/83
3,787,989	1/1974	Heckathorn	37/90
3,951,459	4/1976	Honeycutt, Jr.	37/87 X
4,236,857	12/1980	Willi	37/87 X

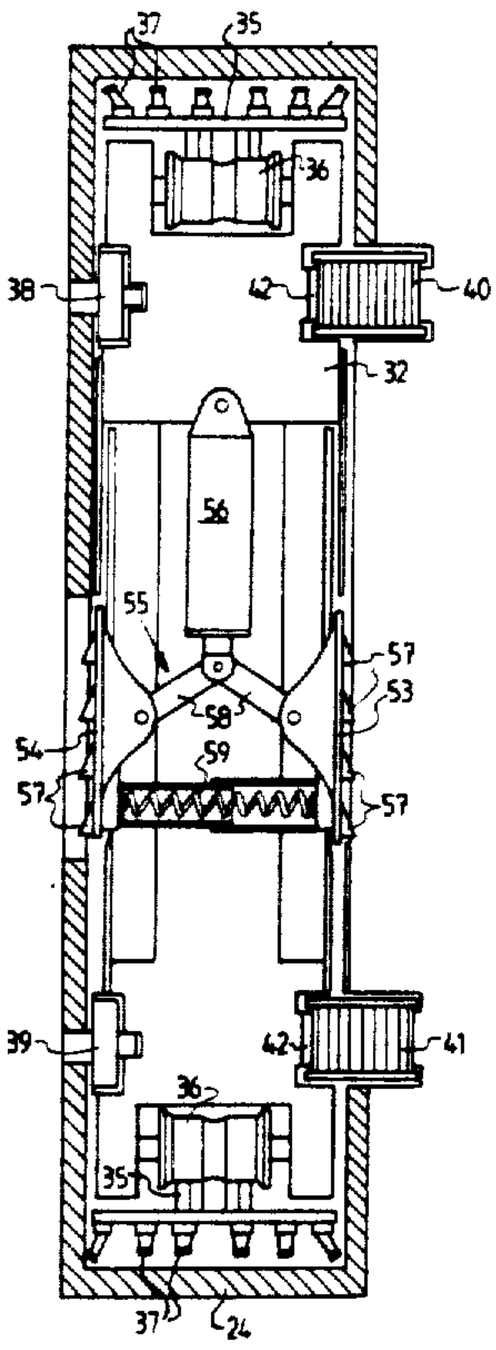
Primary Examiner—Dennis L. Taylor
Assistant Examiner—J. Russell McBee
Attorney, Agent, or Firm—Wood, Herron & Evans

[57] **ABSTRACT**

A trenching apparatus (**10**) is for excavating deep trenches in which inground concrete retaining or foundation walls may be formed. The trenching apparatus (**10**) has a crawler base (**11**) on which a carrier assembly (**14**) is pivotally supported by pivots (**16**) whereby it may be tilted by rams (**17**) to maintain the platform horizontal. An automatic control device (**64**) is provided for this purpose. The carrier assembly (**14**) has a pair of rails (**18/19**) along which a carriage (**21**) may move. The carriage (**21**) supports a sleeve (**24**) through which a trenching arm (**25**) may be lowered to excavate a trench section as the carriage (**21**) is driven along the rails (**18/19**).

14 Claims, 12 Drawing Sheets





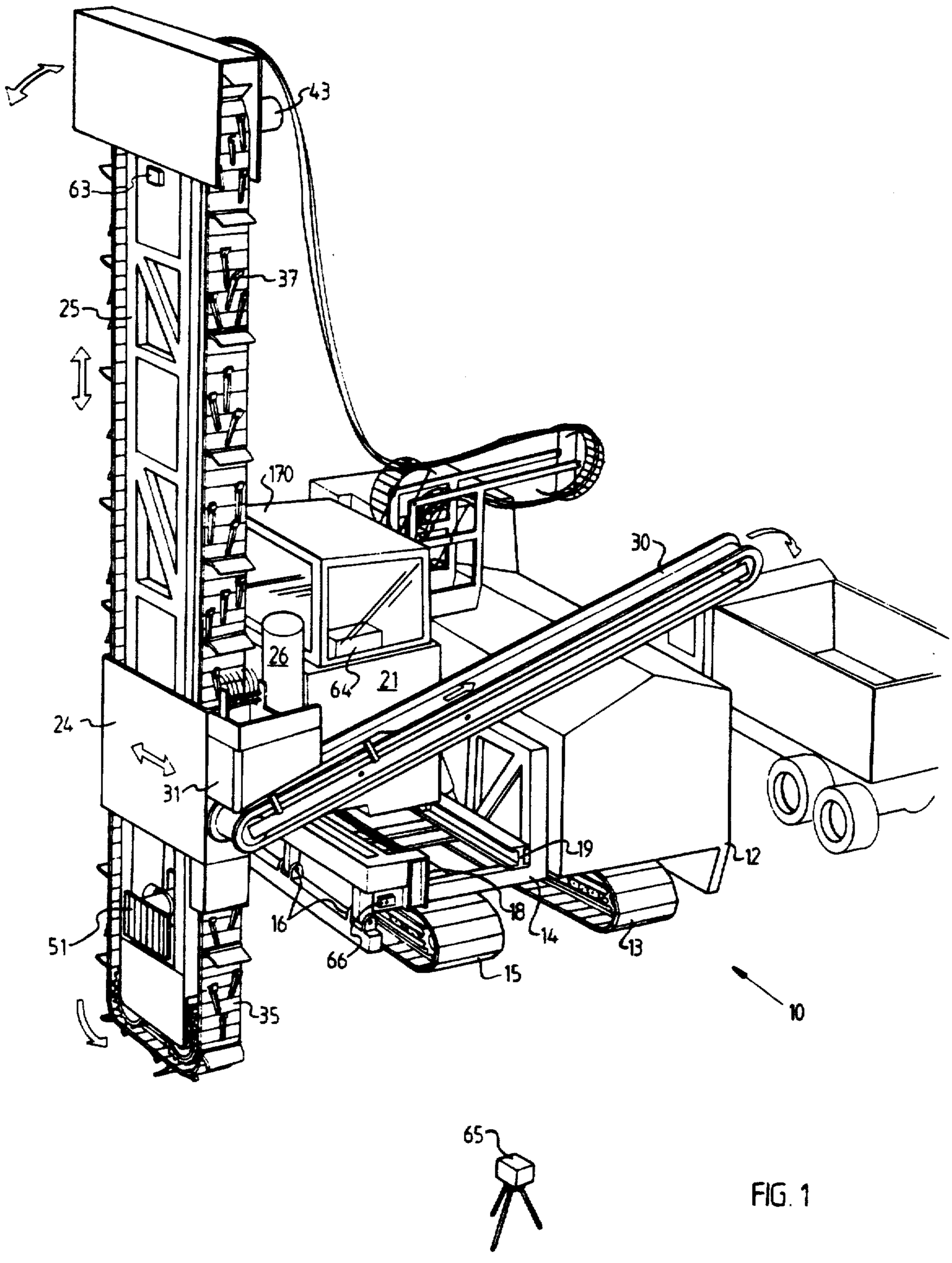


FIG. 1

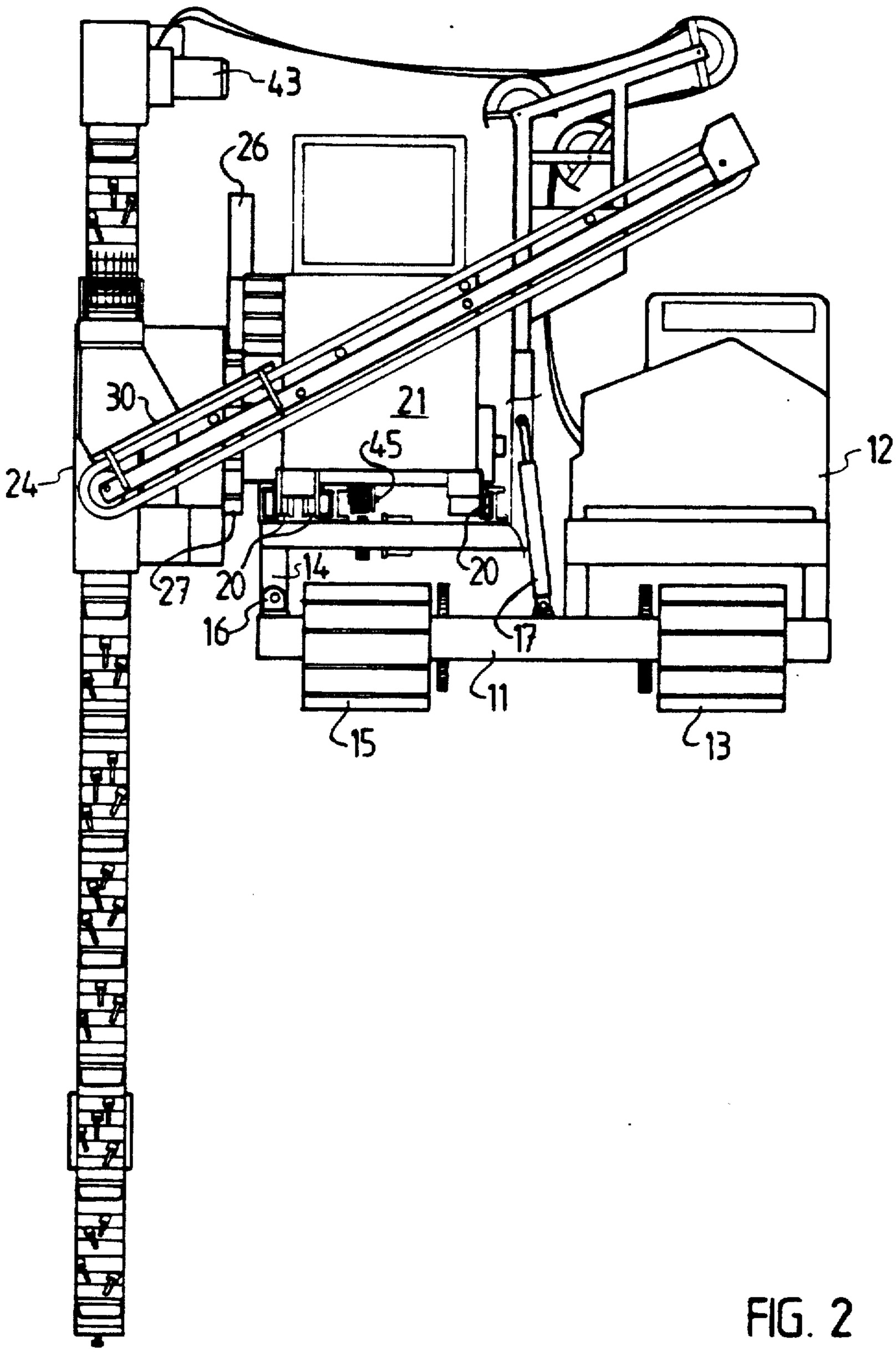


FIG. 2

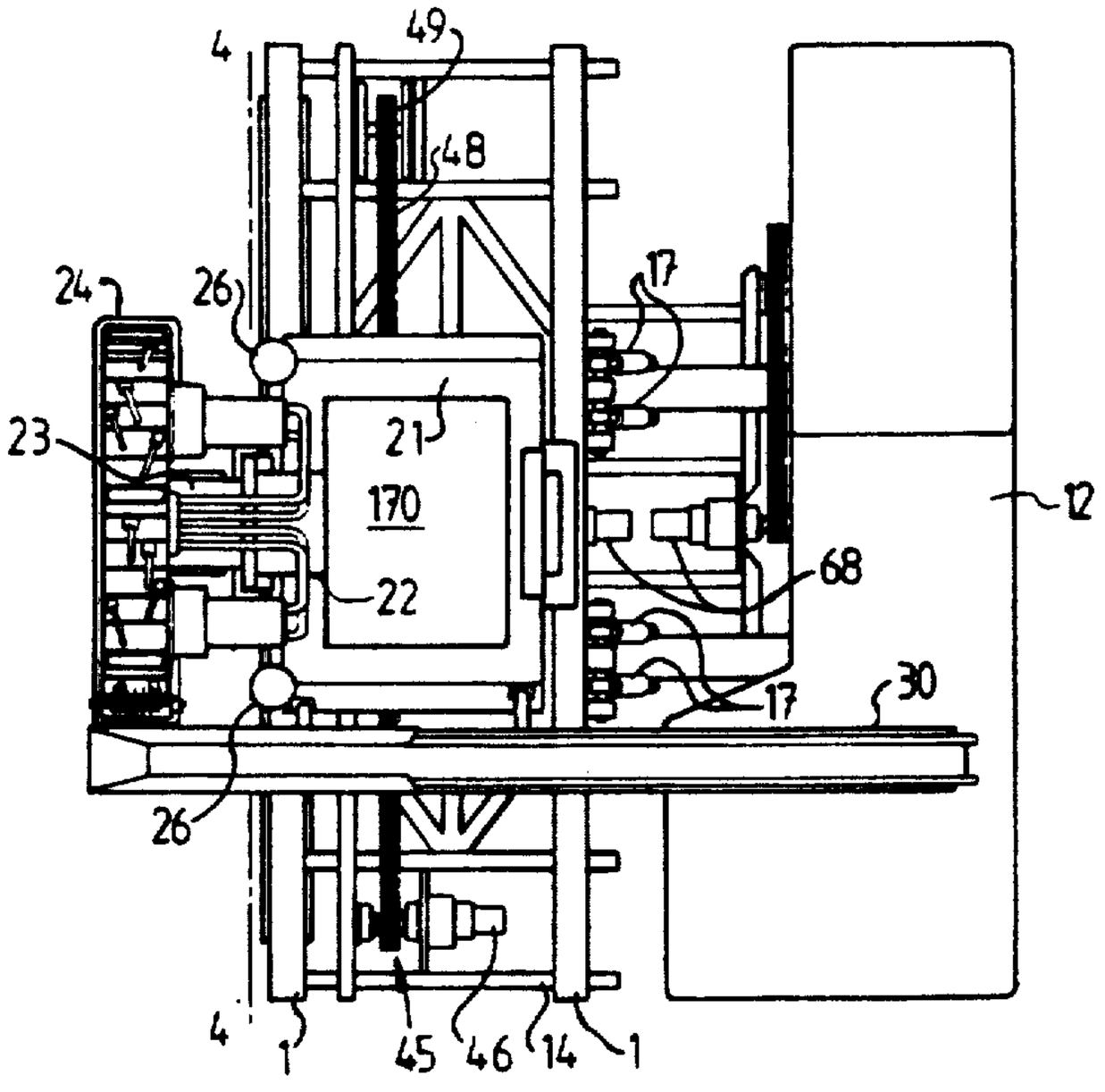

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FIG. 3

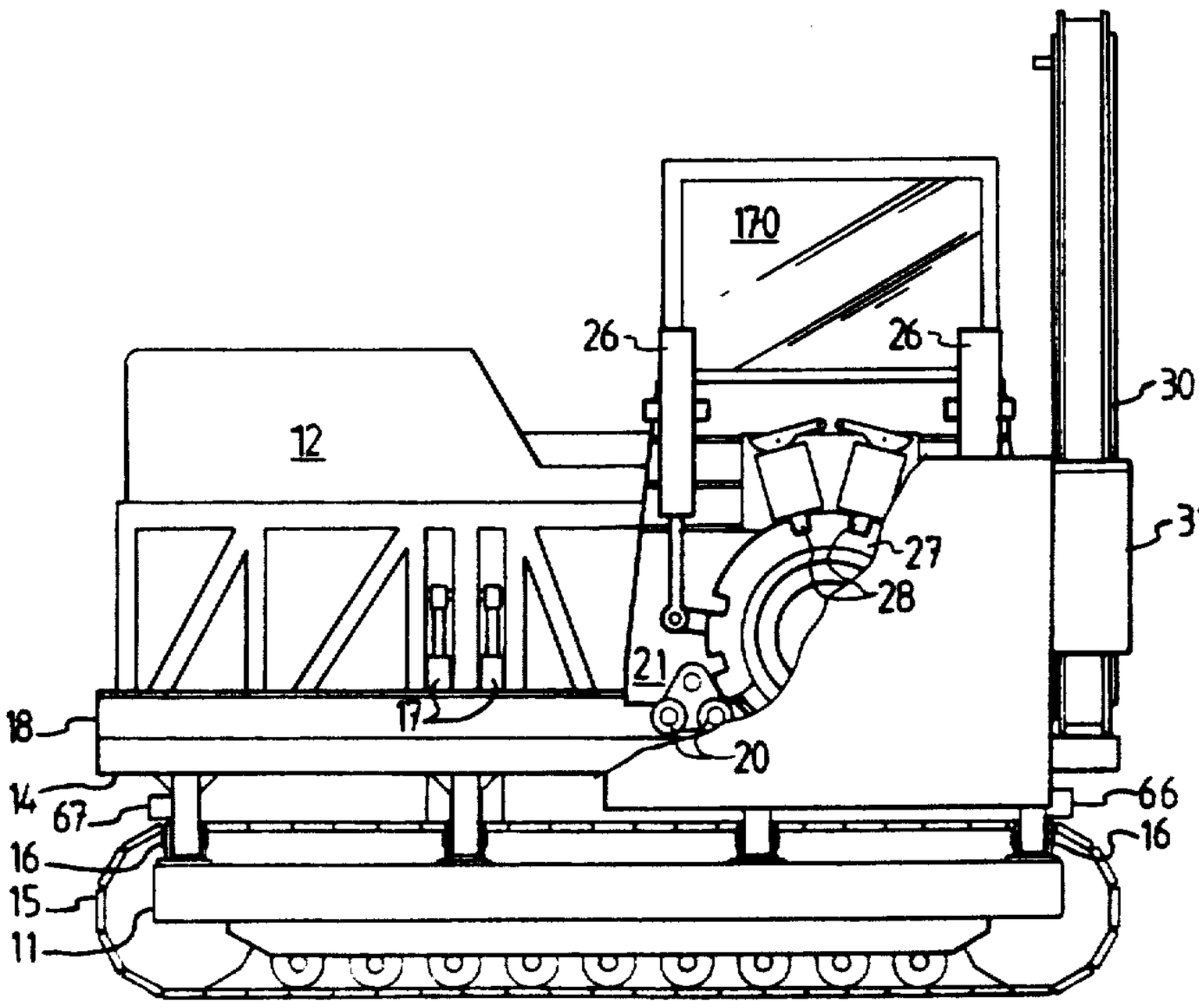
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FIG. 4

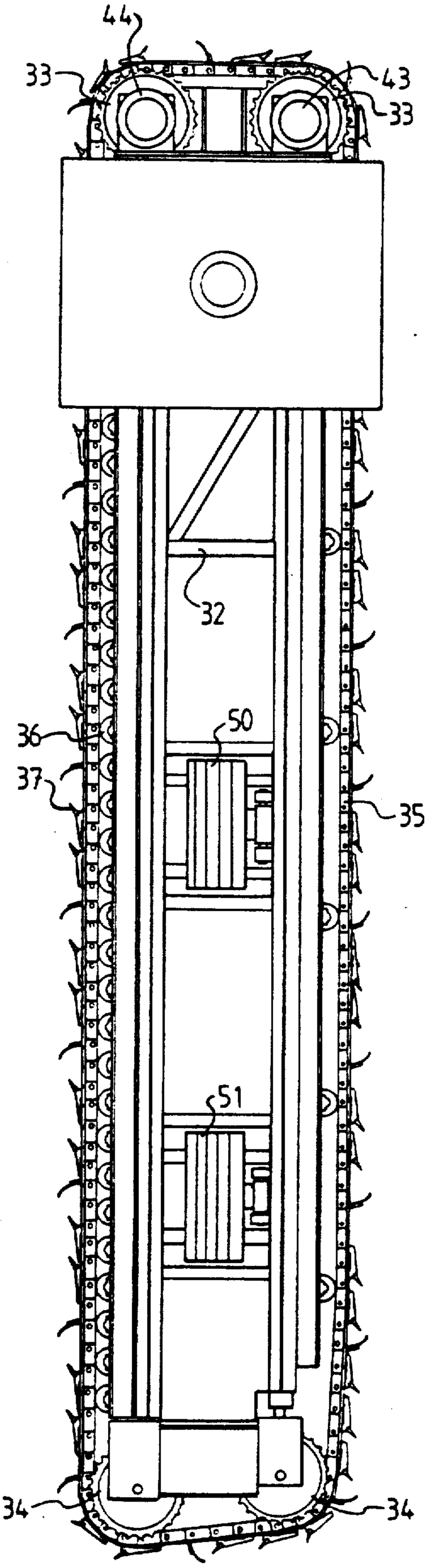

FIG. 5

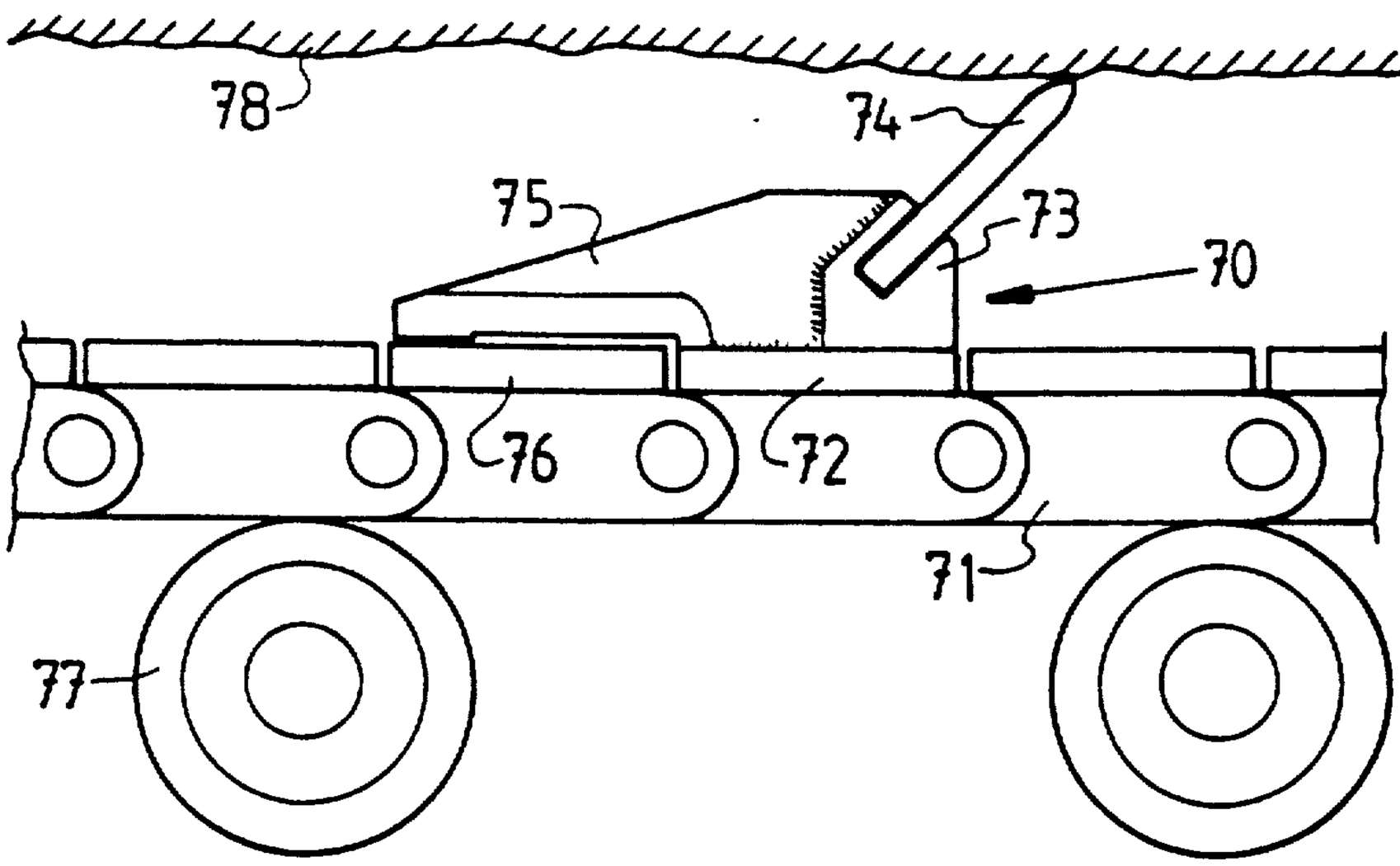

FIG. 6

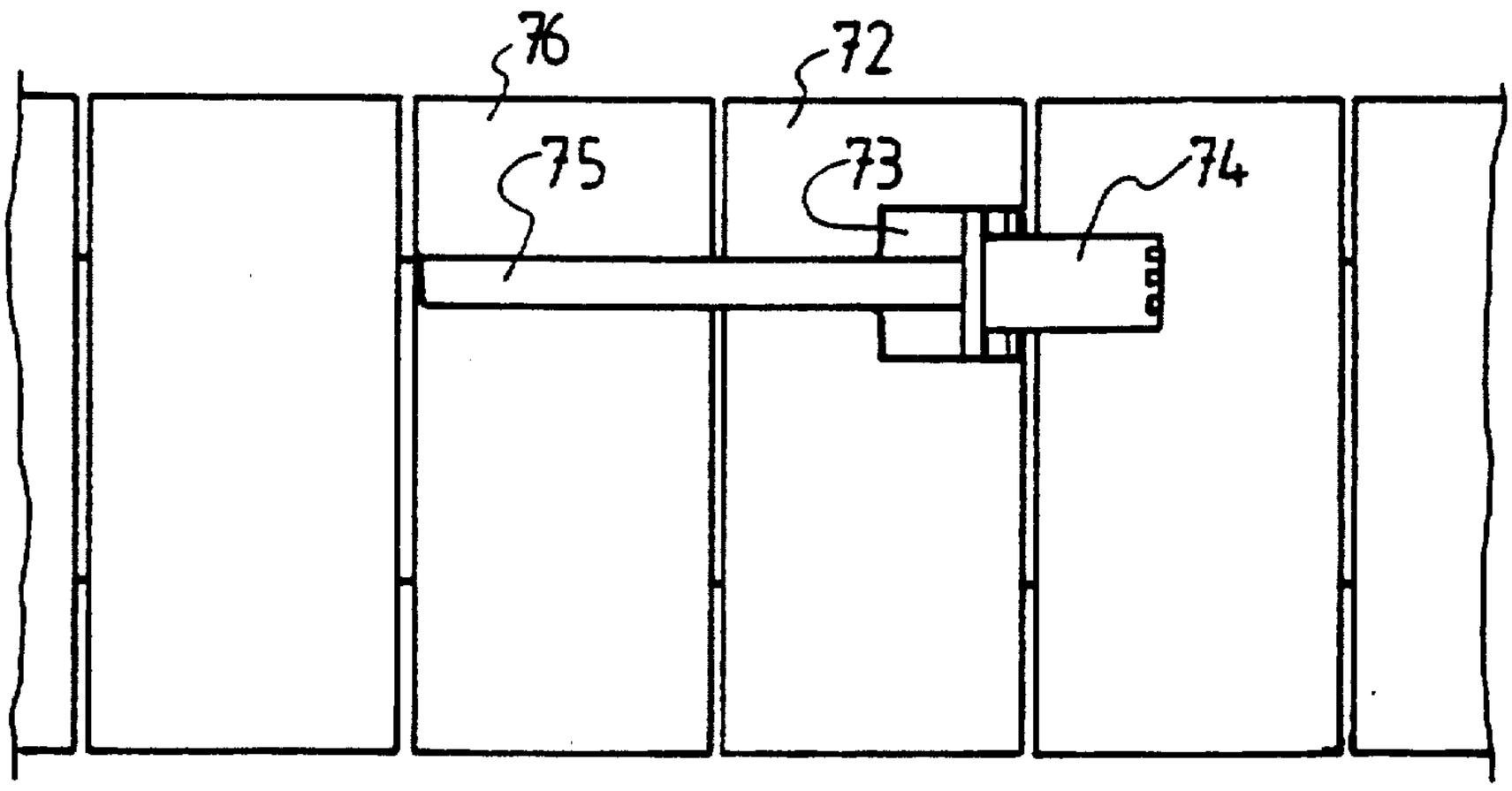

FIG. 7

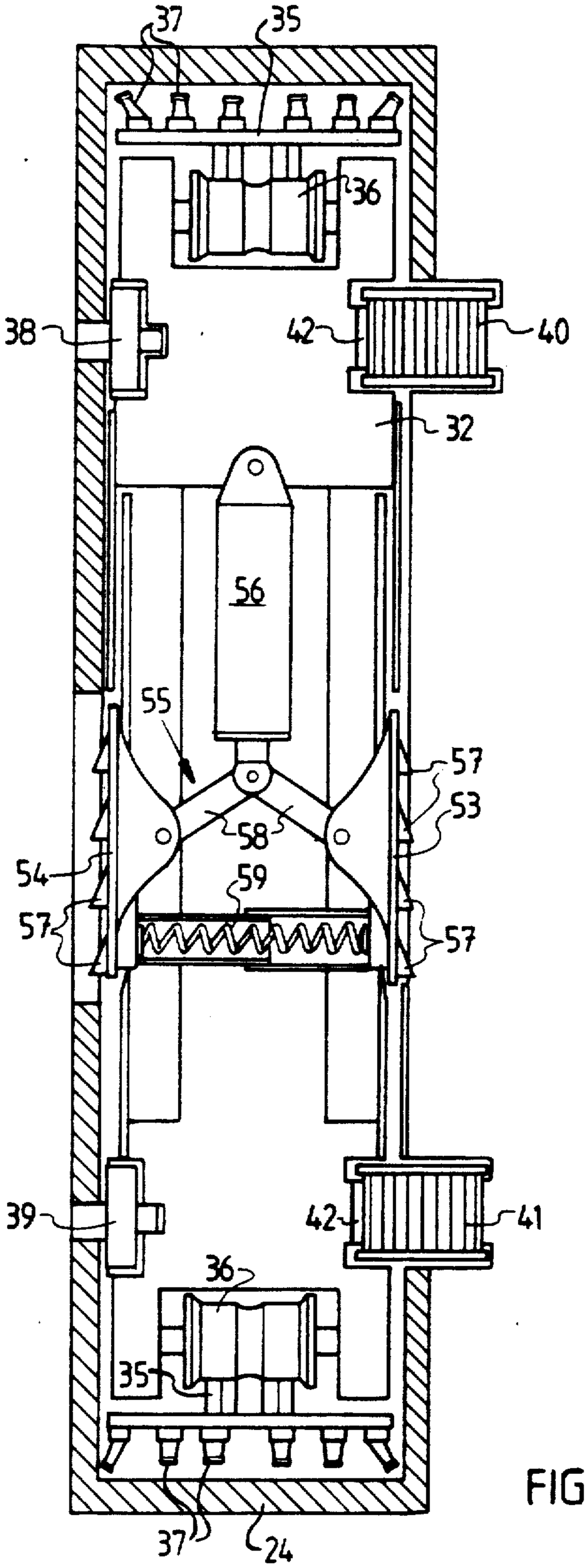

FIG. 8

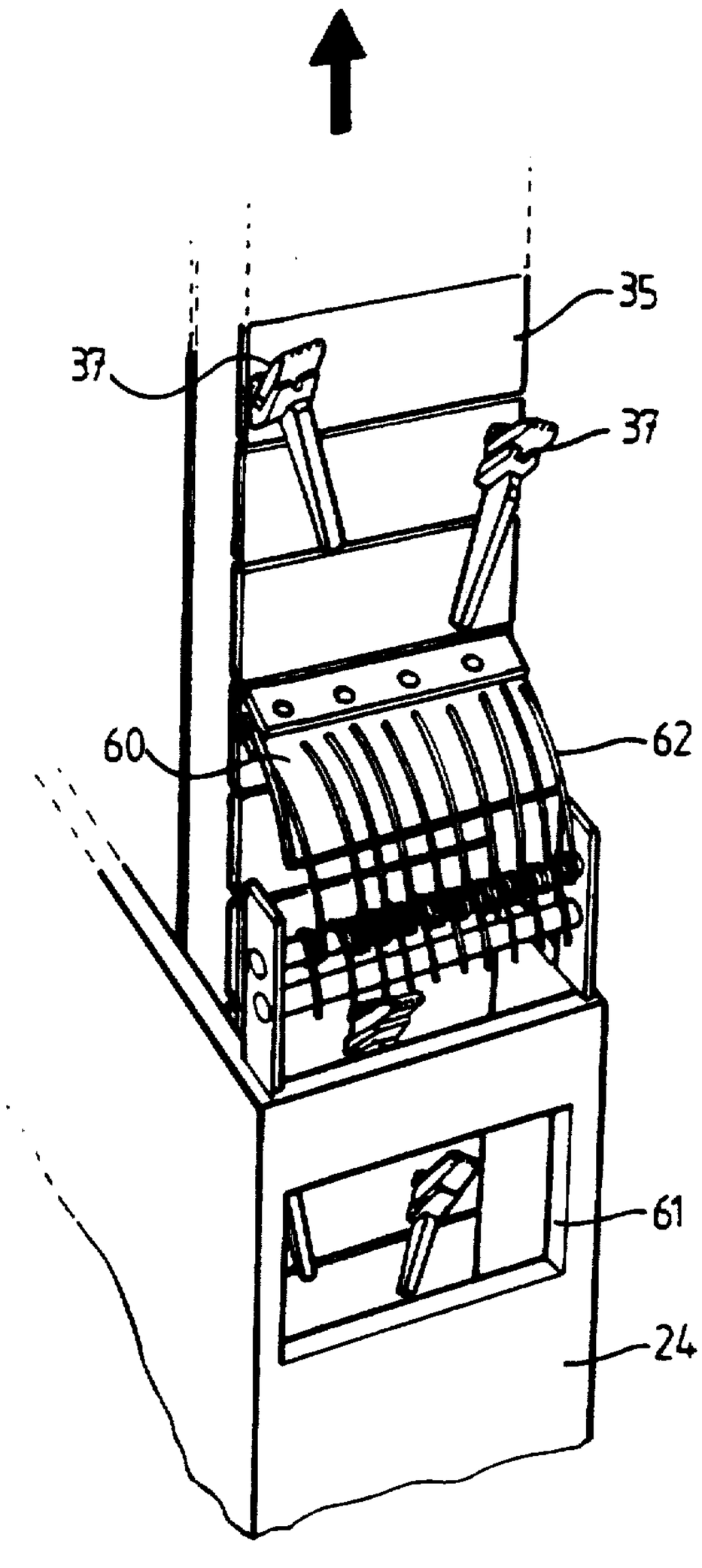

FIG. 9

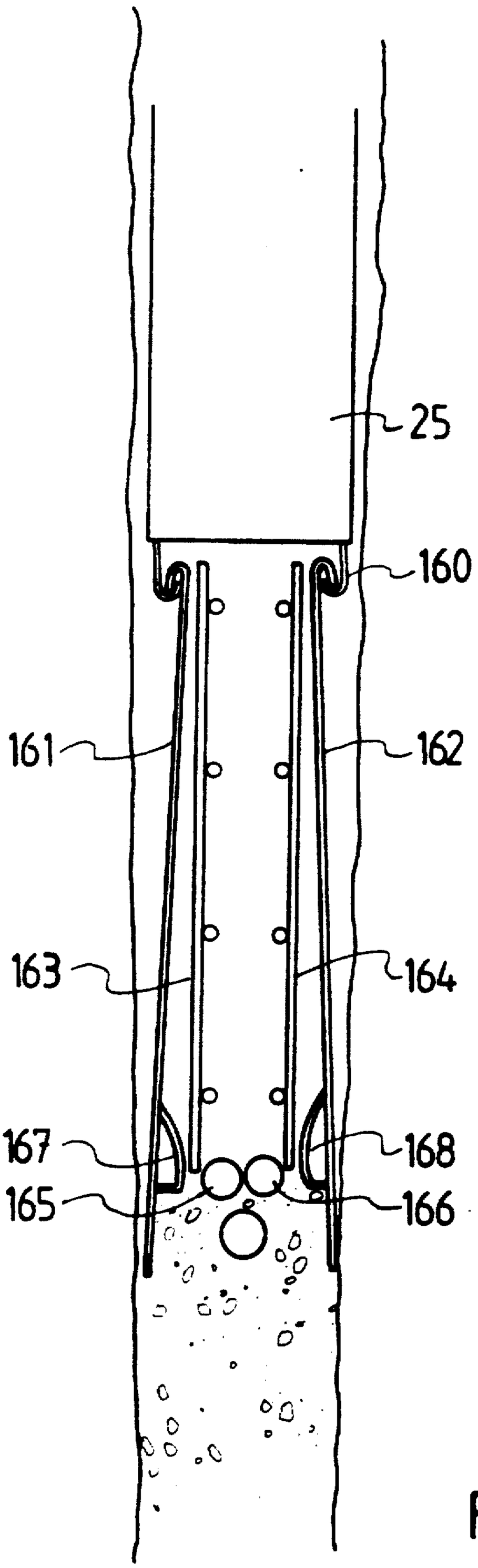

FIG. 10

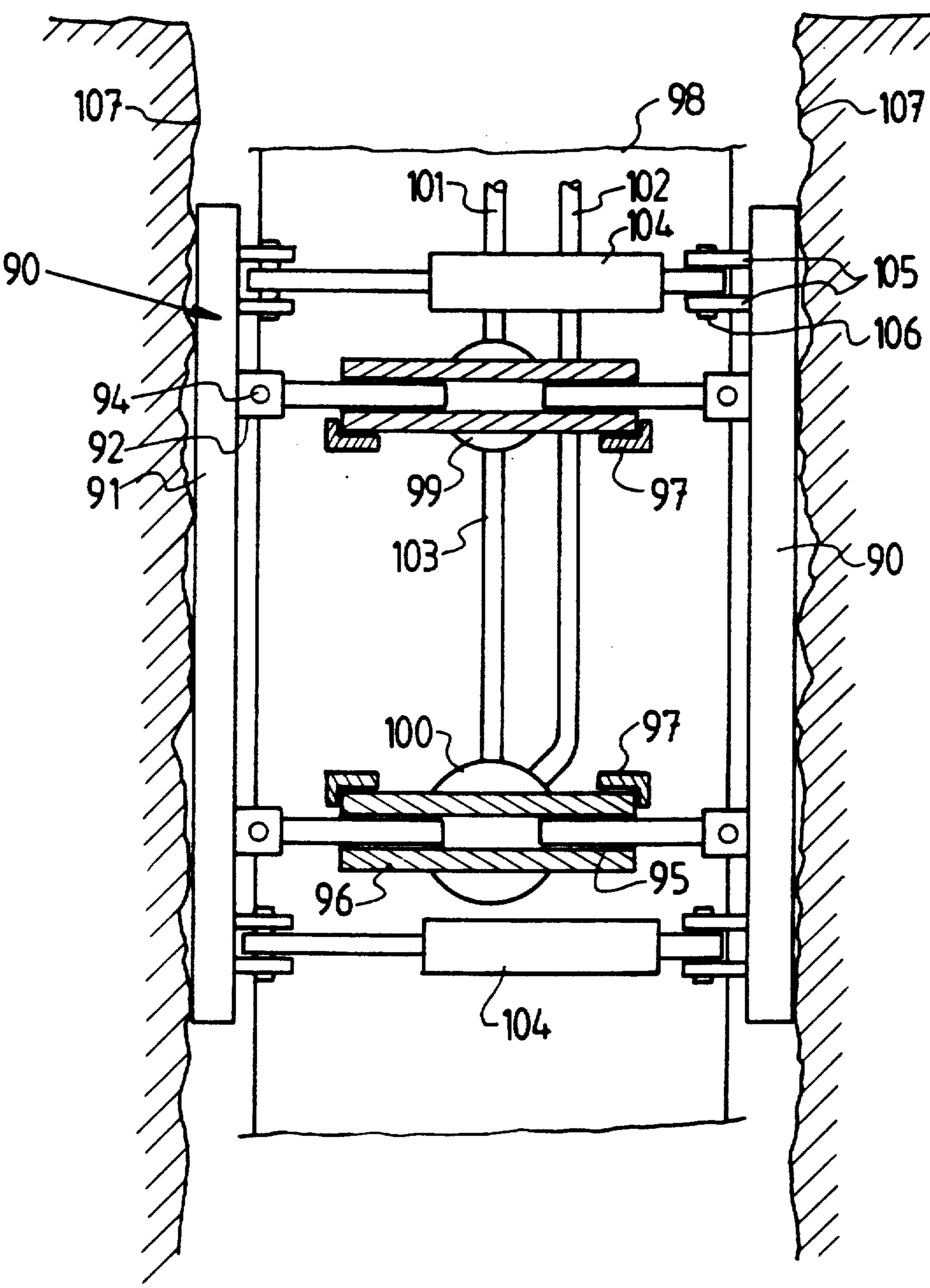
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FIG. 11

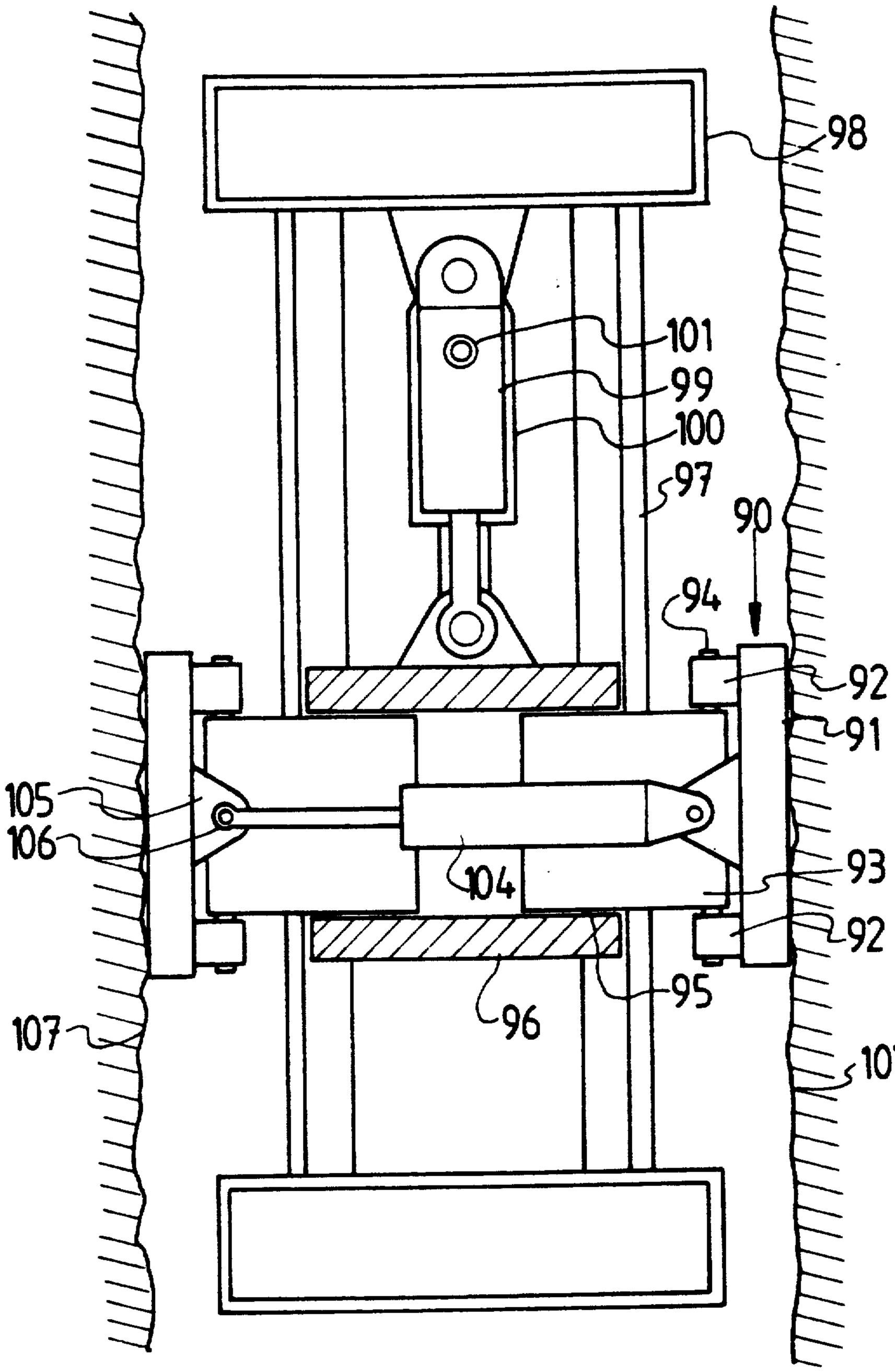

FIG. 12

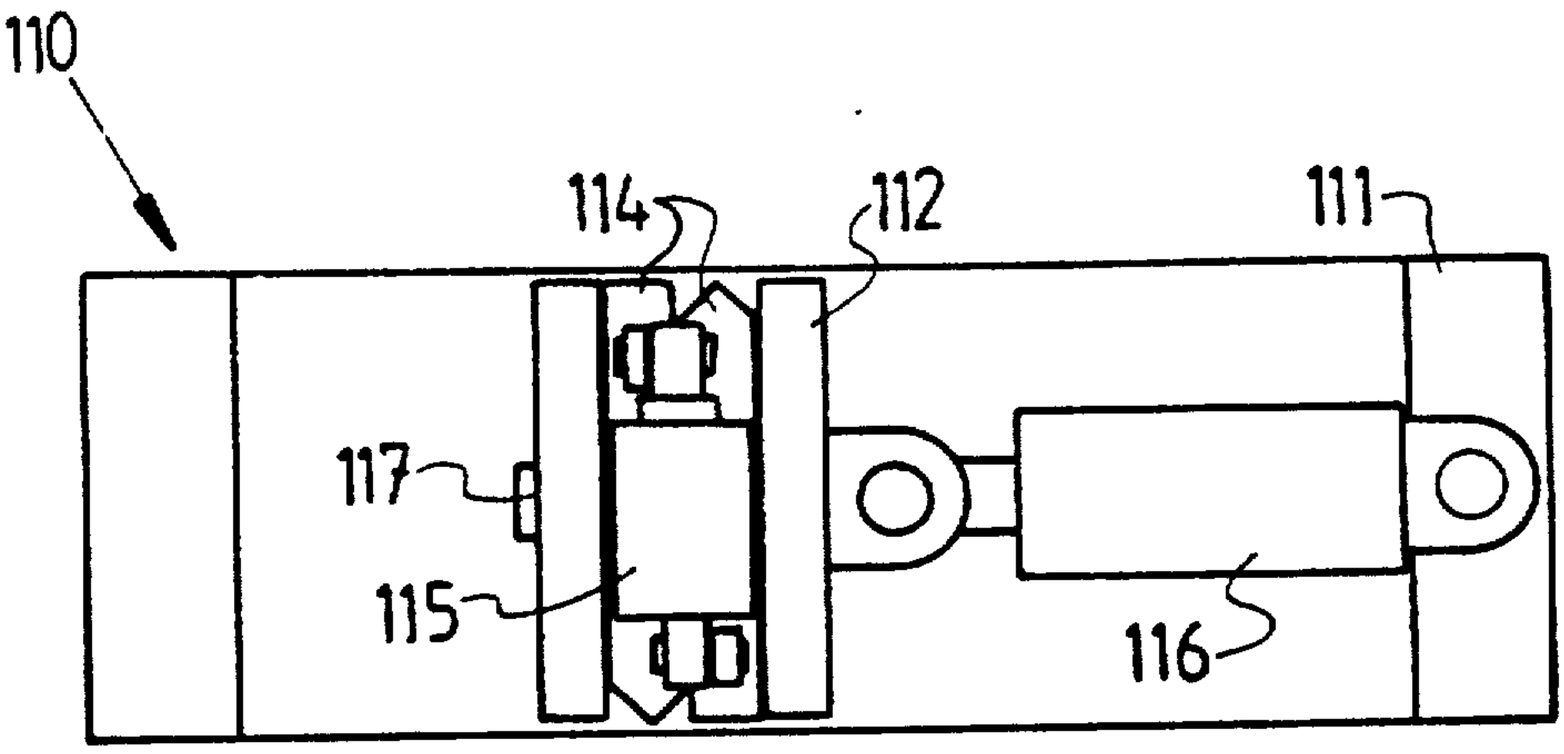

FIG. 13

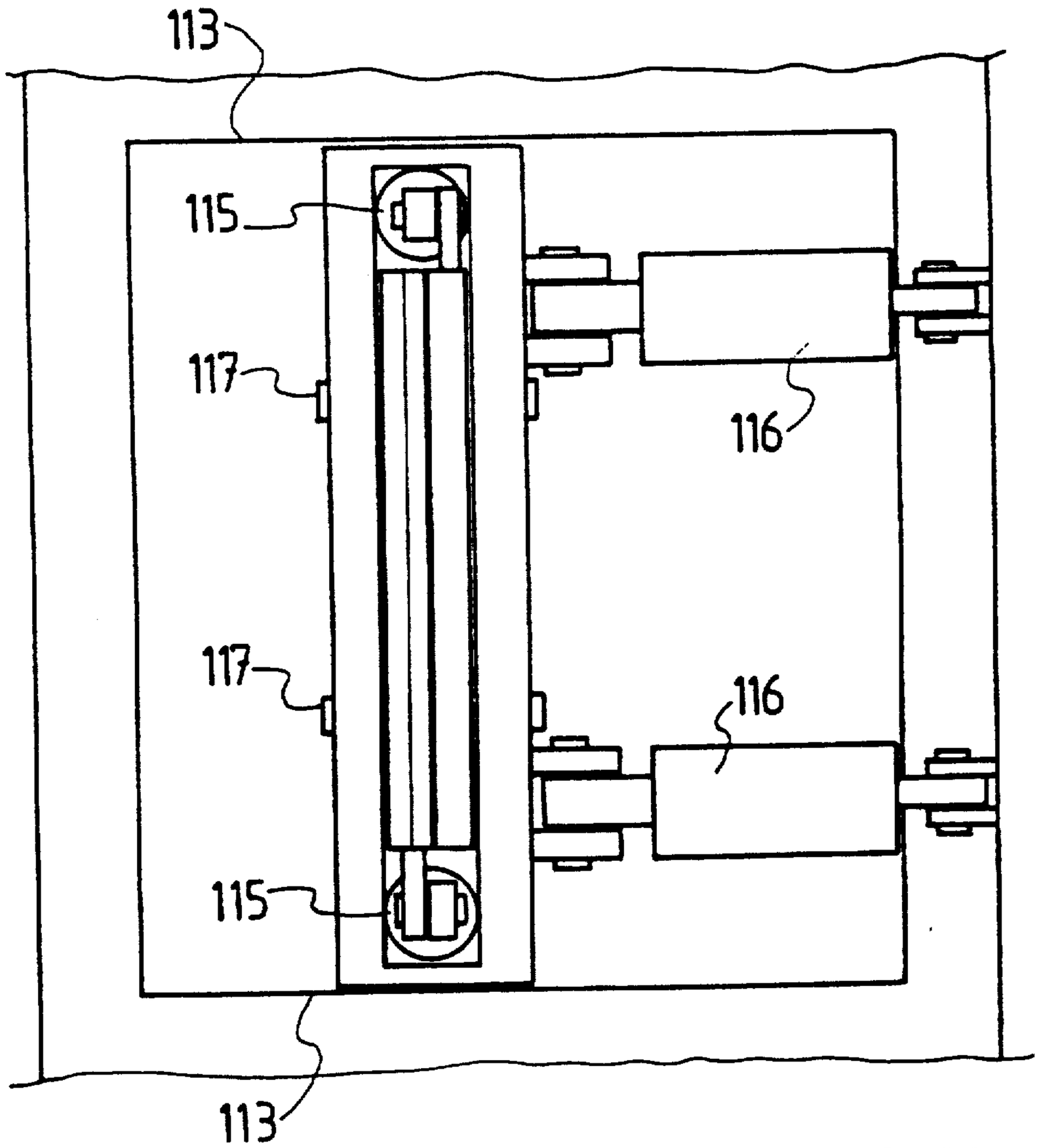

FIG. 14

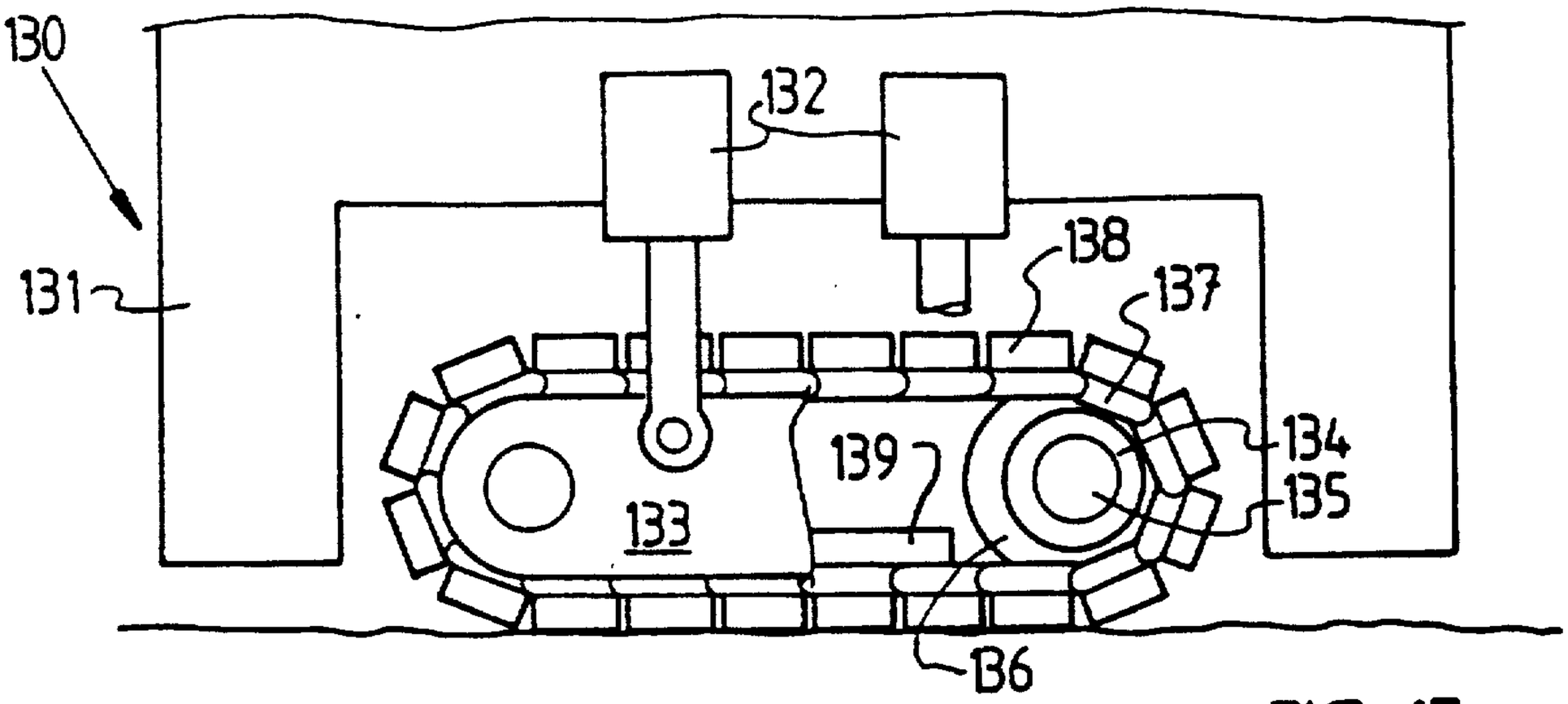
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FIG. 15

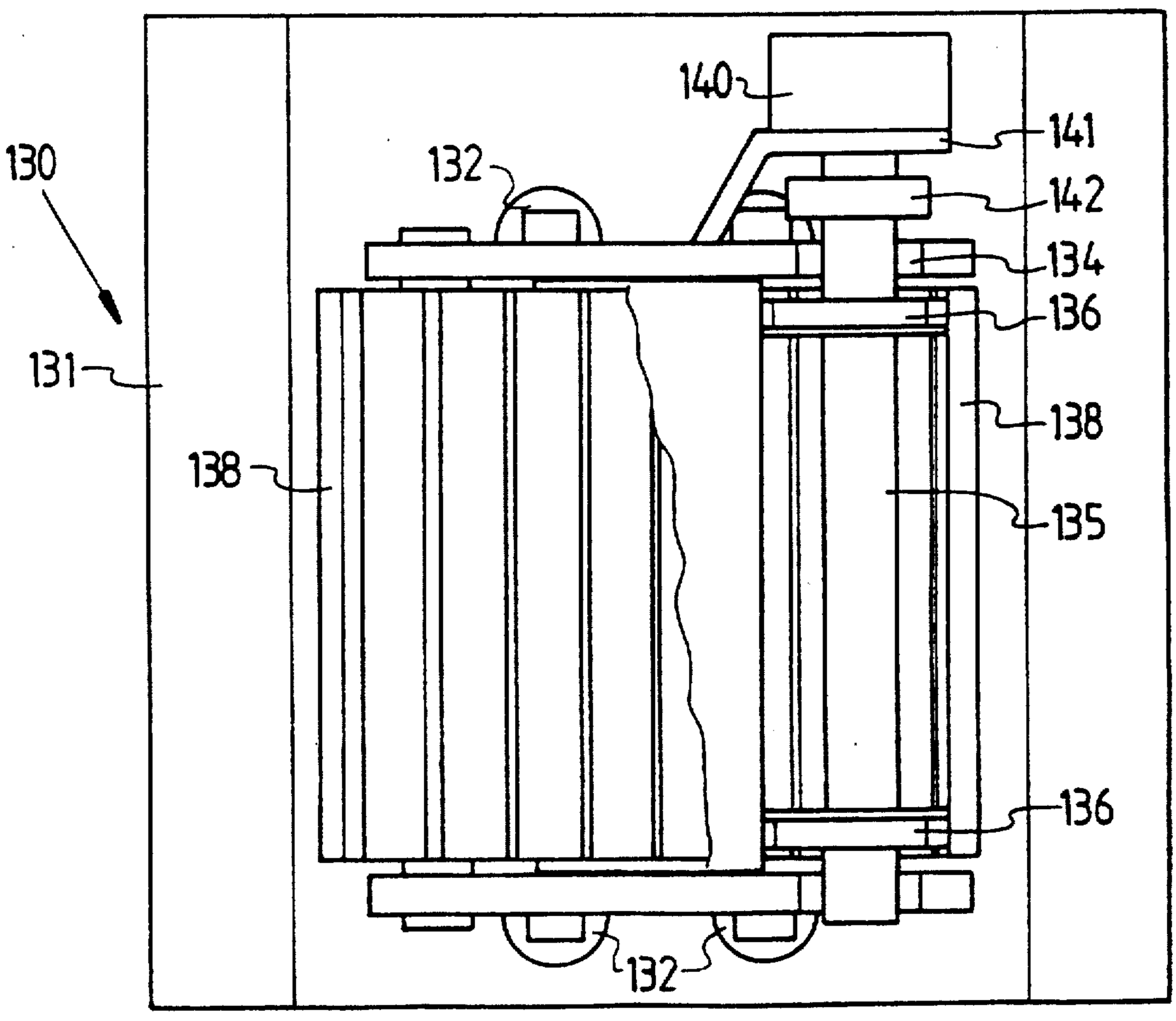
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FIG. 16

TRENCHING APPARATUS AND METHODS OF FORMING INGROUND RETAINING WALLS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

FIELD OF THE INVENTION

This invention relates to trenching apparatus and to the formation of inground retaining walls.

BACKGROUND OF THE INVENTION

In the erection of above-ground structures it is often necessary to form inground retaining walls for use as a load bearing foundation or about a site to be excavated, as a means of retaining the earth about the excavation. Where such excavations are adjacent an existing structure the retaining wall or walls along the excavation line adjacent the existing building must be formed to resist soil pressures established beneath the adjoining structure. In particular, such retaining walls must be put in place so that the soil beneath the adjoining structure will not collapse outwardly into the excavation as the latter progresses. Walls of this type may also be constructed to cut off ground water movement.

Various methods have been employed to form such walls including driving sheet piling along the excavation line to form a retaining wall, and boring a closely spaced row of holes and casting reinforced concrete piles in the respective holes to form the desired wall. If the latter process is used for retaining walls, it is necessary to add substantial horizontal strengthening to the row of piles to maintain their alignment. It is also difficult to form such walls as watertight cutoff walls. Continuous reinforced concrete walls provided excellent supporting, retaining and/or cutoff walls. However to date, it is generally not possible to form inground reinforced concrete walls economically.

Techniques for the continuous excavation of trenches of cross-section suitable for such retaining and/or cutoff walls are available. A typical machine is the subject of Australian patent application No. 41139/85. Such machines can continuously excavate a relatively deep trench along an excavation line. However, their trenching capacity is limited by flexural and machine weight considerations. Accordingly, while it may be possible to construct trenching apparatus which would excavate any desired trench, the size of the machine necessary for normal inground retaining wall trenching operations would render it impractical.

Furthermore, such trenching machines may incorporate an arm supporting an endless chain carrying cutting teeth for their trenching tools. The teeth generally project a significant distance outward from the pivots of the chain, so that cutting forces acting at a cutting tooth in a direction along the line of the chain impose bending moments which tend to flex the cutting chain in such a way as to increase the cutting depth of the cutting tooth uncontrollably, resulting in excessive loading on the cutting tooth, the chain and the trenching machine. The problem could be alleviated by using a chain of much longer pitch, but this approach would require the use iof correspondingly larger chain sprockets.

Such trenching arms must be forced forward in the excavation by advancing the machine to which the cutting arm is attached. As the depth of excavation

becomes greater, this technique places large bending moments on the cutting arm and its support structure, due to the increasing vertical offset between the centroid of the normal forces on the cutting teeth and the line of action of the advance force at ground level. This problem can be alleviated by using an advance system placed within the trenching arm below ground level to force the trenching arm forward by engaging plates with the sides of the excavation and forcing the trenching arm forward by pushing the plates rearward relative to the arm.

SUMMARY OF THE INVENTION

It is an object of the present invention to alleviate the above and other disadvantages and to provide improved trenching apparatus and methods of forming inground retaining walls which will be reliable and efficient in operation. Other objects and advantages of this invention will hereinafter become apparent.

With the foregoing and other objects in view, this invention in one aspect resides broadly in trenching apparatus including a supporting base capable of being moved in a longitudinal direction along an excavation line; a mounting device on the supporting base for mounting a carriage thereon which is restrained by said mounting device for longitudinal movement relative to the supporting base, and the carriage supporting a trenching arm assembly operable, as the carriage moves relative to the supporting base, to excavate a section of trench along an excavation line.

In a further aspect, this invention resides broadly in trenching apparatus including a supporting base capable of being moved in a longitudinal direction along an excavation line; a mounting device on the supporting base for mounting a trenching arm assembly operable to excavate a section of trench along an excavation line, the trenching arm assembly being pivotable about a longitudinal axis whereby it may be tilted relative to the supporting base.

The supporting base may include skids whereby the trenching apparatus may be moved along the excavation line or it may include wheels moveable along rails alongside the excavation line. Preferably however, the supporting base is in the form of a crawler assembly and there are provided a device for driving the crawler assembly. It is also preferred that the mounting device along which the carriage is moveable is in the form of a platform having captive rails thereon for supporting the carriage for longitudinal movement in the desired direction whereby tilting the carriage will cause a corresponding tilt in the trenching arm assembly. Of course the carriage could be slidably mounted on the mounting device if desired and a separate retaining device could be utilised to secure the carriage to the mounting device.

Preferably, the trenching arm assembly is pivotally connected to the carriage so that it may pivot about a transverse substantially horizontal axis to enable it to be rotated to a horizontal attitude for transport. If desired hydraulic rams or the like may be used to pivot the arm or it may be lifted by a crane, either separate or mounted on the trenching apparatus. Suitably, a locking device is provided to secure the arm in selected positions.

The pivotal connection between the trenching arm assembly and the carriage may also include a slide mounting whereby the vertical position of the opera-

tively disposed trenching arm relative to the pivot assembly may be adjusted to enable the depth of cut of the trenching arm to be varied.

The carriage may be provided with a drive device for advancing it along the platform. Further an advancing device may be associated with a lower portion of the trenching arm remote from its pivotal connection to the carriage and adapted for engagement with the side walls of the trench and operable to advance the lower portion of the trenching arm along the excavation line.

It is also preferred that the trenching apparatus be provided with a shield device trailed from the trenching arm assembly and engageable with the opposed walls of the trench to prevent the latter from collapsing, the shield device providing a clear space within the trench into which reinforcement may be fed. The shield device may also support a concrete discharge device through which concrete may be discharged into the trench behind the shield device.

Preferably the trenching apparatus is constructed with an elongate trenching arm which is movable between a raised travelling position wherein the trenching arm is aligned generally horizontally alongside the supporting base to enable its movement between sites and a lowered digging position. The trenching arm may be mounted so that it may be moved downwardly into the earth to its desired excavation depth at which it may be advanced forwardly along the mounting device to form a section of a trench. Generally, the desired trench walls will be substantially vertical within preset tolerances and to this end, the trenching arm may be mounted upon a platform which may tilt and be continuously adjustable so as to retain the trenching arm vertical within the desired tolerances. Laser beams may be employed so as to control the direction of the apparatus. The support platform may be mounted over crawler tracks on adjustable rams so as to maintain the platform level and thus hold the trenching arm vertical.

With the above described apparatus it is possible to excavate a trench in a way which allows steel reinforcing to be installed and concrete to be poured into the excavated trench about the reinforcing exposed beyond a clear space provided beyond the trenching arm. Thus an inground reinforced concrete wall may be formed which can be excavated on one side to provide a permanent load bearing wall about the excavation. Typical uses for this type of machine is in high rise and low rise building, where a retaining wall is desired during the construction phase as the basement is excavated and then as a permanent load bearing wall when the building is constructed to take the loads induced by the building and surrounding ground pressures. Other applications are in bridge abutments, wharf and canal walls.

So that the trenching arm may exert a forward thrust on the material to be excavated, a suitable mechanism may be located inside the frame of the arm and engageable with the side or bottom walls of the trench to provide a forward thrust. This may consist of a hydraulic cylinder attached to a linkage mechanism connected to side plates adapted, when the hydraulic cylinder is activated, to force the side plates into the side of the walls of the trench, and subsequently produce a force to thrust the trenching arm forwardly into the soil to be excavated.

The trenching arm may be located at the top by a mechanism which allows the digger arm to be lowered into the ground and removed from the ground. This may be done by a rack and pinion mechanism. This mechanism may allow the digger arm to be lowered to any predetermined point and held there if desired. The mechanism may also be connected to a laser beam control to ensure that the trenching arm maintains a consistent excavation level. The mechanism which supports the trenching arm may also be capable of rotating with the trenching arm to allow the trenching arm to lay horizontally in order that it may be transported. In this respect a curved rack and pinion arrangement may be used. This allows the trenching arm to be withdrawn from the ground and then rotated and locked into the horizontal position for transportation. The same mechanism may also allow the trenching arm to remain vertical when in operation irrespective of the attitude of the mounting base. The mounting base may be in the form of a pneumatic-tired chassis.

The deck of the machine may be hinged around the supporting base on the side adjacent the trenching arm and the other side of the deck may be mounted on hydraulic cylinders, such that the deck of the machine may be maintained level. Adjustment of the hydraulics could be automatic. The deck of the machine may house the engine, cooling system, hydraulic system and any micro-processor equipment to control the machine, such that as far as possible it operates automatically.

In another aspect, this invention reside broadly in a method of forming a reinforced concrete retaining wall including: continuously forming a trench and simultaneously maintaining the trench walls against collapse over a section thereof behind the leading end wall of the trench with a clear space therein into which reinforcement may be inserted; inserting reinforcement into the clear space, and pumping concrete into the trench rearwardly of the clear space to fill the trench as the clear space advances along the trench being formed.

The above method may be performed by excavating the trench into bedrock so that a footing of the retaining wall is keyed therein and thereby retained in place.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings, wherein:

FIG. **1** is a perspective view of a preferred form of trenching apparatus;

FIG. **2** is an end view of the trenching apparatus;

FIG. **3** is a plan view of the trenching apparatus;

FIG. **4** is a part-sectional view taken along the line **4—4** of FIG. **3**;

FIG. **5** is a broken away side view of the trenching arm;

FIG. **6** is a side view of portion of the trenching chain showing the arrangement of the cutting teeth;

FIG. **7** is a plan view corresponding to FIG. **6**;

FIG. **8** is a transverse section through a trenching arm illustrating one form of the advancing mechanism;

FIG. **9** illustrates one form of dirt conveying flap for the trenching chain and the associated cleaning apparatus;

FIG. **10** is a diagrammatic plan view illustrating one method of introducing concrete and reinforcing into the trench;

FIGS. **11** and **12** illustrate a further form of advancing mechanism;

FIGS. **13** and **14** illustrate yet another form of advancing mechanism, and

FIGS. **15** and **16** illustrate a further form of advancing mechanism.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The trenching apparatus **10** includes a crawler base assembly **11** which supports a power-pack **12** above one crawler track **13** for supplying power to the various hydraulic rams and motors incorporated in the apparatus, and a carrier assembly **14** above the other crawler track **15**. The carrier assembly is pivotally connected at **16** to the crawler base assembly for pivotal movement about a longitudinal tilt axis outwardly of the crawler track **15** and hydraulic rams **17** are provided to selectively tilt carrier assembly **14**. The latter has a pair of captive longitudinally extending rails **18** and **19** which have upper and lower rail surfaces which engage about wheels **20** mounted on a carriage **21** which is restrained by the rails **18** and **19** for longitudinal motion therealong above the crawler track **15**.

The carriage **21** is provided with a central bearing assembly **22** which supports a transversely extending pivot tube **23** which extends outwardly beyond the crawler base assembly **11** and connected fixedly to a mounting sleeve assembly **24** through which the trenching arm **25** is reciprocable. The bearing assembly **22** retains the pivot tube **23** for rotation about a transverse horizontal axis and it permits limited free axial movement of the pivot tube and thus the trenching arm, so that in use the latter may veer slightly away from the desired excavation line as a result of a side force exerted by an obstruction in the excavation and thus prevent the imposition of excessive forces on the apparatus.

Hydraulic rams **26** connected between the carriage **21** and the mounting sleeve assembly **24** may be actuated for pivoting the latter so that the trenching arm assembly may be pivoted between its substantially vertical operative trenching position, as illustrated, and a horizontal position at which it lies alongside the carrier assembly for transport purposes. As can be seen in FIG. **4**, the pivot tube **23** is provided with a notched collar **27** in which pawls **28** may engage to hold the trenching arm **25** in either its operative trenching position or its raised travelling position.

A dirt conveyor **30** is supported on the carriage **21**. The conveyor **30** extends from a lower position, adjacent an outlet chute **31** provided on the mounting sleeve assembly **24** and through which dirt may spill from the trenching chain **35**, upwardly across the power pack for discharging dirt to one side of the excavated trench.

Referring to FIGS. **5** and **8** it will be seen that the trenching arm **25** includes a trenching arm frame **32** which supports upper and lower pairs of sprockets **33** and **34** respectively, about which the segmented trenching chain **35** extends. Intermediate rollers **36** are provided for supporting the chain between the pairs of sprockets **33** and **34** and cutting teeth **37** are mounted in staggered relationship on regularly spaced segments of the chain **35**. The lower sprockets **34** are arranged so that bottom run of the trenching chain extends upwardly and rearwardly from the front lower sprocket to the rear lower sprocket. The upper sprockets **33** are driven by independent hydraulic motors **43** and **44**. The trenching arm frame **32** is provided with a spaced pair of guide rollers **38** and **39** which engage tracks **47** on the outermost face of the trenching arm frame and driven gears **40** and **41** which engage racks **42** on the inner face of the trenching arm frame **32** whereby the latter may be moved through the mounting sleeve assembly **24** so as to adjust the depth of excavation.

The carriage **21** is connected to the carrier assembly **14** by a chain drive assembly **45** having a chain **48** which extends from the carriage about a leading sprocket driven by the motor **46** mounted on the carrier assembly **14** adjacent the front of the machine and an idler sprocket **49** mounted on the carrier assembly adjacent the rear. The hydraulic motor **46** is adapted to be actuated to advance the carriage **21** along the rails **18** and **19** so as to advance the trenching arm for excavation purposes.

The trenching arm assembly **25** is also provided with advancing mechanisms **50** and **51** at spaced positions intermediate its length which may be engaged with the side walls of an excavated trench so as to push the lower portion of the trenching arm **25** forwardly into cutting arrangement with the face of the excavation. As shown in FIG. **8**, each advancing mechanism **50** and **51** includes a pair of side plates **53** and **54** supported by a linkage **55** actuated by a hydraulic ram **56** whereby the side plates **53** and **54** may be forced outwardly into engagement with the side of the trench.

The side plates are provided with barbs **57** to facilitate positive engagement with the side walls of the trench and the arrangement of the interconnected trailing links **58** is such that initial extension of the hydraulic ram forces the side plates apart until they engage the side walls of the trench whereafter further extension of the ram **56** will cause relative longitudinal movement between the side plates **53** and **54** and the trenching arm frame **32** so as to push the trenching arm into cutting relationship with the advancing face of the excavation. The side plates **53** and **54** are interconnected by a spring **59** such that a preload is applied between the side plates **53** and **54** and the side walls of the trench. Retraction of the ram **56** will draw the side plates **53** and **54** away from the side walls of the trench and move them to their forward position.

As shown in FIG. **9** the front end wall of the mounting sleeve assembly **24** is apertured at **61** to permit excavated dirt to pass thereto into the chute **31** for discharge at the opposite side of the trenching apparatus along the conveyor assembly **30**.

Dirt removed from the advancing face of the trench falls into the gap between the trench walls and the trenching chain **35**. It falls onto dirt conveying flaps **60** which are attached to the trenching chain at intervals. The upward movement of the front run of the trenching chain **35** raises these dirt conveying flaps **60** and the dirt upon them out of the excavation. Formed guides in and below the mounting sleeve assembly **24** act as a continuation of the trench to contain the dirt resting on the dirt conveying flaps **60** until it reaches a discharge port **61** in the mounting sleeve **24** above the discharge conveyor **30** from whence it falls onto the discharge conveyor **30** through the chute **31**. Dirt which remains on the dirt conveying flaps or the trenching chain is removed by rows of cleaning springs **62** attached to the mounting sleeve **24**. These cleaning springs **62** are adapted to scrape along the trenching chain **35** in their normal operating position and to spring away from the trenching chain **35** when contact is made with a digging tooth **37** or a dirt conveying flap **60**.

The transverse inclination of the trenching arm is monitored by means of an electronic level sensor **63** mounted in the trenching arm frame **32**. The output from this sensor is fed to a control computer **64**, which compares the measured inclination with the desired inclination and if necessary actuates the platform tilt

cylinders 17 to being the trenching arm back to the desired inclination. A similar system is employed to control the inclination of the trenching arm about the axis of the pivot tube 23. The output of the computer controls the relative speed of the carriage drive and the trencher arm advancing mechanism to maintain the trenching arm at the desired inclination. The alignment of the trenching apparatus with respect to the desired line of the trench is monitored by setting up a laser beam transmitter 65 on a line parallel to the excavation line of the trench and monitoring the points of intersection of the beam and two laser beam detectors 66 and 67 mounted near the front and rear of the machine. The drive motors 68 for the crawler tracks 13 and 15 are also controlled by the computer 64 to correct any errors that are detected by the system. This may be achieved after the carriage 21 has travelled the full length of the carrier and before the commencement of excavation of the next section of trench. Accordingly, the trenching apparatus 10 may excavate a zigzag path which approximates a straight line. Alternatively, the drive motors 68 may be operated as required during the excavation process to produce frequent small corrections to the direction of the excavation.

As shown in FIGS. 6 and 7, the trenching chain assembly 70 consists of an endless chain 71 to which a plate 72 is attached. The plate 72 carries a toolholder 73 in which a detachable cutting tool 74 is mounted. A bracing bar 75 is rigidly attached to the plate 72 carrying the toolholder 73 and extends in a direction along the endless chain 71 rearward from the cutting tool to contact a trailing plate 76 which is attached to the endless chain 71 behind the plate 72 when the chain is flat. The shape of the bracing bar 75 is such that it passes around the chain guide sprockets at a smaller radius than the tip of the cutting tool 74, so that it does not contact the trench face. The side of the bracing bar 75 facing the trailing plate 76 is relieved to ensure that contact between the bracing bar 75 and the trailing plate 76 occurs towards the rear of the trailing plate 76. The side of the bracing bar 75 facing the trailing plate 76 is also chamfered to reduce the possibility of excavated material lodging between the bracing bar 75 and the trailing plate 76. Idler wheels 77 run against the back of the chain 71 to force the cutting tool 74 against the face of the excavation 78.

FIG. 10 illustrates one method of introducing reinforcing and concrete into the trench rearwardly of the trenching arm 25. For this purpose the latter is provided with trailing connectors 160 for connecting shields 161 and 162 thereto, whereby the shields engage opposite walls of the trench and provide a clear space therebetween into which reinforcements 163 and 164 may be dropped. The reinforcements are fed through the gaps between rollers 165 and 166 and guides 167 and 168 on the trailing ends of the shields. As reinforcement is fed into the trench between the rollers and guides, new sections may be dropped into place between the shields. A concrete discharge chute 169 fed by a suitable concrete pump is used to continuously discharge concrete into the trench about the reinforcements. The rollers 165 and 166 and the guides 167 and 168 define a small gap therebetween through which little concrete seeps so that the space into which reinforcements are fed is kept largely clear.

In use, the trenching apparatus is driven to the site and the trenching arm 25 is aligned with the excavation line. It is then actuated and moved vertically into engagement with the earth to be excavated until it has reached the required depth which may be up to eight meters. The carriage 21 is initially arranged in its rearmost position on the rails 18 and the trenching apparatus 10 is positioned so that movement of the carriage 21 along the rails 18 and 19 will carry the trenching arm 25 along the excavation line. A portion of the trench is excavated by forcing the carriage 21 along the rails to its forward most position and by simultaneously actuating the advancing means 50 and 51 provided in the frames of the trenching arm 25. The crawler tracks 13 and 15 are then actuated and the crawler base assembly is moved forward alongside the excavation line so that the carriage is again positioned at the trailing ends of the rails 18 and 19. This process is continued until the desired trench has been formed. Of course at each move of the supporting base, the latter may be aligned to correct runoffs of the portion of the trench just excavated. Furthermore, the hydraulic rams 17 may be actuated to vary the tilt of the excavation arm relative to the supporting base so that the excavation arm can be maintained vertical or at a selected inclined position. Automatic control apparatus may be provided to maintain the desired control over the trenching arm and suitably an operator's cab 170 is supported above the carriage 21 so that an operator can maintain a close visual inspection of the trench being excavated.

When the apparatus is excavating, the chain 71 is driven parallel to the face 78 to be cut, and forced into the face 78 by the idler wheels 77. This imposes forces on the cutting tool 74 which produce a moment tending to rotate the tool holder 73 backwards by flexing the chain 71. This moment is resisted and the rotation of the chain link is limited by contact between the bracing bar 75 and the trailing plate 76. As shown in FIGS. 11 and 12, the reciprocating plate advance assembly 90 comprises plates 91 attached to pivot blocks 92 which are pivotally attached to slide blocks 93 by pivot pins 94. The slide blocks 93 are free to slide transversely in the slots 95 in the traverse blocks 96. The traverse blocks 96 are free to slide longitudinally in guides 97 attached to the trenching arm frame 98. The traverse blocks 96 are connected to the trenching arm frame 98 through the upper fluid actuator 99 and the lower fluid actuator 100. One pipe 101 of the fluid supply system is connected to the full piston area side of the upper fluid actuator 99 and the second pipe 102 is connected to the rod side of the lower fluid actuator 100. The rod side of the upper fluid actuator 99 and the full piston area side of the lower fluid actuator 100 are interconnected by a pipe 103. The relative sizes of the upper fluid actuator 99 and the lower fluid actuator 100 are such that the fluid displaced from the rod side of the upper fluid actuator 99 by a certain extension of the upper fluid actuator 99 causes an equal extension in the lower fluid actuator 100 when applied to the full piston area side of the lower fluid actuator 100. The pusher plates 91 are extended and retracted laterally by fluid actuators 104 which are attached to the pusher plates 91 through brackets 105 and clevis pins 106.

Soft-soil advance system 110, which is shown in FIGS. 13 and 14, caries within a frame 111, fixed within the trenching arm, a carriage 112 slidable longitudinally within the frame 111 on slides 113. Plates 114 are slidable laterally within the carriage 112 and constrained to move longitudinally with the carriage 112. The plates 114 are attached to lateral actuators 115 to extend and retract them. The carriage 112 is attached by longitudi-

nal actuators **116** to the frame **111**. The plates **114** are restrained from excessive lateral travel by limit pins **117** fixed in the carriage **112** and engaging with slots in the plates **114**.

The endless-chain advance system **130** illustrated in FIGS. **15** and **16** comprises a frame **131** fixed within the trenching arm, with lateral actuators **132** connected between the frame **131** and the carriers **133**. The carriers **133** support bearings **134** in which shafts **135** may rotate. The shafts **135** carry sprockets **136** which engage with endless chains **137**. Slats **138** are attached to the endless chains **137**. Pressure plate **139** is attached to carriers **133** and disposed on the inner side of the outer run of the endless chains **137**. Drive is provided by one or more rotary actuators **140** mounted to the carriers **133** by brackets **141** and coupled to the shafts **135** by couplings **142**.

To advance a trenching arm to which it is fitted, the reciprocating plate advance system is utilised by energising the lateral actuators **104** to retract the plates **91** away from the sides of the excavation **107** while the longitudinal actuators **99** and **100** draw the carriage **96** together with the slides **93** and the plates **91** forward relative to the frame **97**. The lateral actuators **104** are then extended to bring the plates **91** into contact with the walls of the excavation **107** and the longitudinal actuators **99** and **100** are employed to force the trenching arm forward relative to the plates **91** which remain stationary in the excavation. The series arrangement of the longitudinal actuators **99** and **100** and their relative piston areas ensure that the extension of both cylinders is the same so that the carriage **96** will not tilt and bind in the slides **97**.

In order to advance a trenching arm in which it is installed, the soft-soil advance system is utilised by employing the longitudinal actuators **116** to pull the carriage **112** forward in the frame **111** with the lateral actuators **115** retracted to withdraw the plates **114** within the profile of the frame **111**. The lateral actuators **115** are then extended to force the plates **114** into the side of the excavation **118**. When the plates **114** have penetrated a sufficient distance into the side of the excavation **118** to provide resistance to longitudinal movement of the plates **114** relative to the side of the excavation **118**, the longitudinal actuators **116** are energised to force the frame **111**, and thus the trenching arm, forward in the excavation. When the longitudinal actuators **116** are extended, the lateral actuators **115** are retracted to withdraw the plates **114** from the side of the excavation **118** and the cycle is repeated.

To advance a trenching arm in which it is installed, the endless chain advance system is extended from the trenching arm frame **131** by the lateral actuators **132** until the outer run of slats **138** is forced against the side of the excavation **143** by the pressure plate **139**. The rotary actuator **140** is then energised to rotate the sprockets **136** and move the outer run of the chains **137** and slats **138** backwards with respect to the frame **131**, propelling the trenching arm forwards.

It will of course be realised that while the above has been given by way of illustrative example of this invention, all such and other modifications and variations thereto as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of this invention as is defined in the appended claims.

What I claim is:

1. Trenching apparatus comprising:

a supporting base supported for longitudinal movement along an excavation line;

a carriage;

mounting means for mounting said carriage on said supporting base, said carriage being restrained by said mounting means for longitudinal movement along said supporting base; and

a trenching arm assembly supported by said carriage and operable to excavate a section of trench along said excavation line as said carriage moves longitudinally along said supporting base, said trenching arm assembly including a trenching arm frame, said trenching arm frame supporting opposed trench-engaging members which may be forced outwardly into engagement with the opposed side walls of a trench, and advancing means associated with said members for advancing said trenching arm frame.

2. Trenching apparatus according to claim **1**, wherein a shield means is connected to said trenching arm assembly for containing soil pressures in the walls of the trench being excavated, said shield means providing a clear space within the trench into which reinforcement may be fed and being provided with a concrete discharge means associated with said shield means for discharging concrete into the trench behind said shield means.

3. Trenching apparatus according to claim **1**, wherein said trenching arm assembly is pivotable about a longitudinal axis to be able to be tilted relative to said supporting base.

4. Trenching apparatus according to claim **3**, wherein said mounting means includes a platform having longitudinally extending guide rails along which said carriage may move and being provided with drive means for moving said carriage along said guide rails.

5. Trenching apparatus according to claim **4**, wherein said carriage is provided with supporting wheels captively engaged with said rails.

6. Trenching apparatus according to claim **4**, wherein said platform is pivotally connected to said supporting base for pivotal movement about a longitudinal tilt axis and being provided tilting means for controlling the pivotal movement of said platform about said tilt axis.

7. Trenching apparatus according to claim **4**, wherein a digging chain is guided about said trenching arm frame and a chain drive means drives said digging.

8. Trenching apparatus according to claim **7**, wherein said trenching arm frame is adjustably mounted on a carrier supported by said carriage wherein a depth of excavation may be varied and being provided with a depth adjustment control means for selectively positioning said trenching arm frame relative to said carrier.

9. Trenching apparatus according to claim **8**, wherein said trenching arm assembly is pivotally connected to said carriage for movement between a lowered trenching attitude and a raised travelling attitude.

10. Trenching apparatus according to claim **8**, wherein said carrier is connected to said carriage for pivotal movement about a transverse pivot axis.

11. Trenching apparatus according to claim **7**, wherein said trenching arm frame supports trenching arm advancing means remote from said carrier which is engageable with the side walls of a trench and operable to advance the trenching arm assembly.

12. A trenching apparatus, comprising:

a trenching arm assembly having an upper end and a lower end;

an above ground propulsion unit connected to said upper end of said trenching arm assembly for advancing said upper end of said trenching arm assembly along an excavation line;

digger means associated with said trenching arm assembly for initially digging said trenching arm assembly substantially vertically downwardly from ground level to a position wherein said lower end of said trenching arm assembly is located below ground; and

a below ground propulsion unit carried by said lower end of said trenching arm assembly for advancing said lower end of said trenching arm assembly, as said above ground propulsion unit advances said upper end thereof, along said excavation line.

13. A trenching method, comprising:

digging substantially vertically downwardly from ground level to a desired trench depth using a trenching arm assembly so that a below ground propulsion unit mounted to a lower end of said trenching arm assembly is located below ground level;

excavating a trench by propelling an upper end of said trenching arm assembly along an excavation line with an above ground propulsion unit, and by propelling said lower end of said trenching arm assembly along said excavation line with said below ground propulsion unit.

14. A trenching method, comprising:

digging substantially vertically downwardly from ground level to a desired trench depth using a digger mechanism associated with a trenching arm assembly so that a lower end of said trenching arm assembly is located below ground;

excavating a trench by propelling an upper end of said trenching arm assembly along a desired trench line with an above ground propulsion unit, and by propelling said lower end of said trenching arm assembly along said desired trench line with a below ground propulsion unit which is separate from said digger mechanism.

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