(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 December 2001 (27.12.2001)

PCT

(10) International Publication Number
WO 01/98045 A1

(51) International Patent Classification[7]: B28D 7/00, B23D 47/10, B28D 1/04

(21) International Application Number: PCT/GB01/02745

(22) International Filing Date: 21 June 2001 (21.06.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0015074.8 21 June 2000 (21.06.2000) GB
0101531.2 22 January 2001 (22.01.2001) GB

(71) Applicant and
(72) Inventor: **FOX, David, Martin** [GB/GB]; Hamilton House, 56 Lutterworth Road, Pailton, Rugby, Warwickshire CV23 0QF (GB).

(74) Agent: **HEPWORTH, John, Malcolm**; Hepworth Lawrence Bryer & Bizley, Bloxam Court, Corporation Street, Rugby, Warwickshire CV21 2DU (GB).

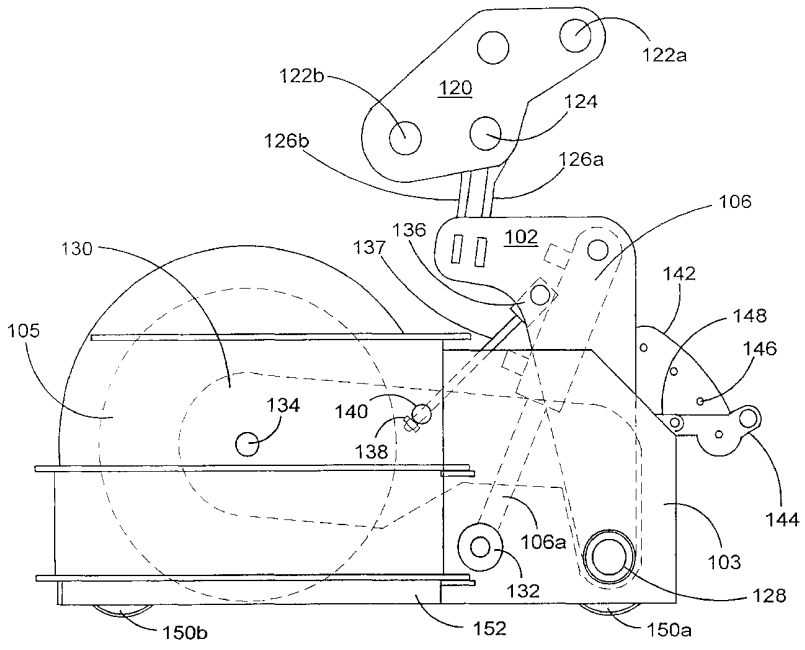
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FLUID POWERED CUTTING APPARATUS WITH CUTTING LOAD CONTROL



(57) Abstract: Fluid powered cutting apparatus comprising a fluid motor arranged so as to drive a cutting device (105) and a fluid powered actuator (106), the fluid motor and fluid powered actuator (106) being so constructed and arranged as to cause, in use, the resistance load induced on the cutting device (105) when cutting material to be regulated so as not to exceed a pre-determined value.

WO 01/98045 A1

FLUID POWERED CUTTING APPARATUS WITH CUTTING LOAD CONTROL

This invention relates to cutting apparatus. In particular, the invention relates to apparatus in which the resistance load on a cutting device attached to the apparatus is automatically regulated to not exceed a predetermined value.

When road repairs or pipe laying etc. are carried out on roads or pavements, the surface generally has to be cut, for example a trench would normally require two parallel cuts to be made to the width of the trench, thus helping to avoid damaging the surrounding area when trench material is removed. At present this is normally done by a relatively small standalone petrol engine powered single bladed saw whilst, usually, a mechanical excavator (for example a back hoe loader) waits idly to dig out the trench.

The power available to this type of saw is generally small compared to that which is available from the excavator in the form of hydraulic power that may be supplied at the end of its dipper arm, as currently provided for other known attachments such as hydraulic breakers.

Thus it is known to use various hydraulically operated attachments on existing hydraulic machines and it would be advantageous to utilise the higher power available from a machine, like an excavator, to carry out the cutting operation described above. For example, cutting at a higher rate than can be achieved by known standalone saws as well as removing the need for such saws and associated operator whilst making more productive use of the excavator.

It will be recognised by one skilled in the art that the downward load that is exerted at the end of, say, the dipper arm of a mechanical excavator is potentially very high and could easily inflict damage upon the cutting apparatus, particularly a delicate cutting blade or other cutting device mounted thereon. Likewise such a high load reduces the sensitivity of control of the cutting apparatus and lessens the level of accuracy of cut, particularly where relatively soft materials are involved.

According to a first aspect of the present invention there is provided fluid powered cutting apparatus comprising a fluid motor arranged so as to drive a cutting device and a fluid powered actuator, the fluid motor and fluid powered actuator being so constructed and arranged as to cause, in use, the resistance load induced on the cutting device when cutting material to be regulated so as not to exceed a pre-determined value. Preferably the actuator and motor may be connected to a fluid flow circuit such that an increased rotational load on the cutting device due to a cutting force induced on the device causes a change in pressure within the circuit, thereby causing the actuator to counteract the cutting force so as to reduce the load on the cutting device. More preferably the actuator may be connected to the circuit upstream of the motor.

According to an optional feature of this aspect of the present invention the flow of fluid into the actuator may be unrestricted but flow out of the actuator may be restricted.

According to a second optional feature of this aspect of the present invention the actuator may be a hydraulic ram.

According to a further optional feature of this aspect of the present invention the device may be pivotally mounted relative to the surface of the material to be cut.

According to another optional feature of this aspect of the present invention the device may be a circular saw blade.

According to a yet further optional feature of this aspect of the present invention the apparatus may be adapted for use with a hydraulic excavator or the like. Preferably the Apparatus may be secured on the backhoe dipper arm of an excavator.

According to a further optional feature of this aspect of the present invention the fluid may be hydraulic fluid.

According to a yet further optional feature of this aspect of the present invention a further cutting device may be provided.

According to a second aspect of the present invention there is provided a fluid circuit for use with a cutting apparatus comprising in series a secondary supply line for an actuator and a fluid motor for driving a cutting device, the circuit being so arranged that, in use, an increased load on the motor caused by a rotational resistance load on the device causes a change in pressure in the circuit, said change in pressure adjusting the position of the actuator so as to regulate the resistance load and hence the load on the motor. Preferably the flow into the actuator may be unrestricted, but the return flow may be restricted.

According to an optional feature of this aspect of the present invention the circuit may be further provided with a valve, the valve preventing fluid flow unless sufficient external physical pressure is applied thereto.

According to a second optional feature of this aspect of the present invention two actuators may be connected to the secondary supply line.

According to a third aspect of the present invention there is provided hydraulic cutting apparatus for use in association with a host machine, the apparatus comprising a hydraulic motor adapted to drive a cutting device, a hydraulic actuator arranged so as to move the cutting device relative to material to be cut and a hydraulic circuit, the circuit being arranged such that, in use, the rotational resistance load induced on cutting device due to a cutting force applied to the device is regulated due to counteraction of the cutting force by the actuator.

According to a fourth aspect of the present invention there is provided a method of cutting through material using cutting apparatus comprising a cutting device powered by a fluid motor and an actuator connected in series with the motor to a fluid line, the method comprising the steps of:

a) an operator of the apparatus inducing a cutting force between the running cutting device and the material to be cut, thereby inducing a frictional resistance load of the cutting device and hence a load on the motor;

b) a change in fluid pressure being induced in the fluid line by the load on the motor;

c) the change in pressure causing a change in the extension of the actuator to reduce the frictional resistance load between the material and the device, thereby reducing the load on the motor;

d) a further change in the fluid pressure being induced in the fluid line;

e) the change in pressure causing a further change in the extension of the actuator to increase the frictional resistance between the material and the device, thereby increasing the load on the motor; and

f) repeating steps b) to e) until the operator removes the device from contact with the material.

Exemplary embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a side elevation of a cutting apparatus in accordance one embodiment of the invention mounted on an arm of a host machine and located upon a surface to be cut;

FIG. 2 illustrates the apparatus of Fig. 1 with the apparatus in operation;

FIG. 3 is a front elevation of the apparatus of Fig. 1; and

FIG. 4 is a diagram of a hydraulic circuit used in the apparatus of the embodiment of Figs. 1 to 3;

FIG. 5 is a side elevation of a cutting apparatus according to a second embodiment of the invention;

FIG. 6 is a side elevation of the cutting apparatus of Fig. 5 in operation;

FIG. 7 is a plan view of the cutting apparatus of Fig. 5 shown in partial cross-section;

FIG. 8 is a side elevation of cutting apparatus according to a third embodiment of the invention shown in partial cross-section;

FIG. 9 is a side elevation of the cutting apparatus of Fig. 8 in operation;

FIG. 10 is a plan view of the apparatus of Fig. 8; and

FIG. 11 is a diagram of the hydraulic circuit used in the third embodiment.

As shown in Figs. 1 to 3 hydraulic cutting apparatus according to a first embodiment of the invention comprises a cutting device attached to a drive shaft 8 driven in this embodiment by a hydraulic motor 7. Shaft 8 and motor 7 are mounted onto side plates 2, 2a (see Fig. 3). In this embodiment, a gear arrangement transmits drive from the motor to the shaft, but in other embodiments the shaft may be driven directly.

In this embodiment, each side plate 2a has pivotally secured thereto depth regulation means comprising a pair of hydraulic actuators. As is known in the art, the actuators comprise a hydraulic cylinder 6 and ram 6a, which rams are pivotally connected to a base plate 3 standing upon the surface of the material 4 to be cut. The rams have sufficient capacity to overcome any downward load induced by the operator of a host machine to which the apparatus is secured. The side plates 2, 2a are in this embodiment rigidly connected to form a headstock and are themselves releasably pivotally connected to the dipper arm 1,1c of the host machine (not shown) by pins. The base plate 3 is further pivotally connected to the side plates 2, 2a also by pins. To provide greater manoeuvrability, wheels may be provided as appropriate on the base section.

The cutting device may be a chain saw or planer for example, but in this embodiment is a circular diamond blade or carburundum blade. Indeed, for the purposes of this invention, the term "cutting" should be understood to also include abrasive devices. For ease of reference the cutting device is generally referred to hereafter as a blade 5.

In an alternative class of embodiments, a pair of blades may be mounted at each opposite end of the drive shaft. An arrangement having a pair of blades arranged in parallel planes allows simultaneous parallel cuts to be made. Parallel cutting is a particular advantage in various operations, such as trenching. It is envisaged that the spacing between the blade may either be fixed to correspond to the width of standard excavator buckets, or may be adjustable over a range of widths.

As will be apparent to one skilled in the art, hydraulic gear motors work on the principle that hydraulic fluid (e.g. hydraulic oil or water), under pressure, is forced through a pair of intermeshing gears, one of which is attached to the output shaft of a motor, causing any mechanical device attached to the output shaft to rotate in conjunction with the gears. When the oil is first introduced to the resting motor the hydraulic pressure will rise as the mechanical parts (gears, shafts etc.) are accelerated up to running speed. The motor will generally require a fixed amount of fluid to turn by 1 revolution, so a motor requiring $10cm^3$

of fluid for 1 revolution would turn at a rate of 100 rpm if supplied with a fluid flow of 1000cm^3 per minute.

When the motor reaches its operational speed the fluid pressure reduces. Once running at speed, any resistance to rotation that is encountered, for example when plunging an attached blade into a surface, such as a road or pavement, would tend to slow down the motor, hence increasing the oil pressure needed to turn the motor at its operational speed. Similar principles apply for different types of hydraulic motors.

Referring now to Fig. 4, the motor 12 and actuator are preferably connected to the same hydraulic pressure line 10 or circuit which allows fluid to pass freely into the actuator along line 10a but in which the flow back from the actuator is restricted by virtue of combined restrictor and one-way valve arrangement 11. A return line 9 downstream of motor 12 allows the hydraulic fluid to be recirculated to a hydraulic pump on the excavator (not shown).

In operation, as seen in Fig. 2, the operator first brings the blade up to its operational speed and then extends hydraulic ram 1b on the dipper arm, thus tipping the apparatus forwards. The hydraulic rams 6a contract into cylinder 6 in conjunction with movement of the dipper arm 1, 1c bringing the cutting device into engagement with the material 4 to be cut. In this embodiment the material is tarmacadam, but in other embodiments the apparatus may be used to cut other materials such as concrete, rock, wood, plastics or metals, for example.

When the operator brings the blade 5 into contact with the material to be cut, a force is induced between the blade and the material to be cut that acts through the centre of rotation of the blade 5. This force is referred to below as the "cutting force". The hydraulic pressure required by the motor 12 to maintain a constant cutting speed will rise due to the frictional resistance to rotation of the blade 5 induced by the cutting force between the blade 5 and material to be cut 4. The degree of rotational frictional resistance is generally proportionate to the cutting force although it may alter if a particularly hard or tough piece of material to be cut

is encountered. The rotational resistance in turn induces a load on the motor 12 resulting in a back-pressure up-stream of the motor 12, causing the hydraulic fluid to flow into the actuator. This flow causes the ram 6a to extend out of cylinder 6, counteracting the downward load on the blade from ram 1b thereby reducing the cutting force with which the blade 5 contacts the material to be cut.

As this reduction in cutting force causes a proportionate reduction in the resistance to the rotation of the blade 5, the load on the motor 12 is reduced, thus reducing the hydraulic pressure in the actuator which then allows more cutting force to be applied.

Thus, the arrangement automatically regulates the frictional resistance on the blade 5 so that the operator is able to maintain a controlled and steady rate of cutting without risking damage being caused to the blade 5. It is preferred that for ease of operation, cutting occurs towards the host machine (i.e. from right to left in Fig. 2 and left to right in Figs 6 and 8 described below).

It will be appreciated by one skilled in the art that for the attachment to be operated safely enclosing guards would be provided attached to the base plate 3 and/or to side plates 2, 2a whereby the moving parts, including the cutting device are mounted inside a further housing provided by both the guards and the side plates. For the sake of clarity these guards and the pipework and fittings for the actuators and motor have not been shown.

Turning now to Figs. 5 to 7, there is shown a second embodiment of the invention comprising a variant of the apparatus of the first embodiment that operates using similar principles. Where possible like numerals have been used for like parts with the addition of the prefix "1".

Turning in particular to Figs. 5 and 7, it can be seen that the apparatus comprises a connecting portion 120 having bores 122a, 122b that may be used for releasable attachment to the end of an excavator dipper arm or the like 101, 101c. The connecting portion is preferably linked to

a headstock 102 by a linkage that in this embodiment comprises plates 126a and 126b arranged in a mutual parallel configuration and secured to the connecting portion 120 by pin 124. Advantageously, the linkage enables the headstock to pivot relative to the connecting portion 120 about an axes parallel and perpendicular to the sides of the apparatus so as to compensate for uneven ground between the apparatus and the machine to which it is secured.

The headstock 102 is in turn pivotally secured to a housing/base plate 103 by axle 128. This arrangement can be seen most clearly from Fig. 7. A pair of wheels 15a are also preferably mounted on axle 128. A further pair of wheels 150b is preferably mounted on the opposite end of housing 103 by axle 184 (the wheels are obscured by the housing in Fig. 7). As can be seen from Figs. 5 and 7, the housing 103 essentially encloses the sides and end of the apparatus.

In this embodiment, a cranked arm 130 is further pivotally journalled on to axle 128. The free end of arm 130 has mounted thereon hydraulic motor 112 and drive shaft 134. Referring to Fig. 7, it can be seen that the output shaft 156 of the hydraulic motor 112 and the drive shaft 134 are arranged in spaced parallel relationship and have mounted thereon intermeshing gears 158 and 160 to transmit drive from the hydraulic motor to the drive shaft 134. In alternative classes of embodiments, the motor 112 may directly drive the drive shaft or alternative drive transmission means such as chains or pulleys may be employed. An aperture of sufficient size to enable unrestricted relative vertical movement of the drive shaft 134 relative to the housing 103 over the required range of travel is provided in the side wall of the housing.

A cutting device which in this embodiment is a circular saw blade 105 is mounted on drive shaft 134 using suitable mounting means 182 as is known in the art. A guard 152 preferably encloses the blade but is removable to allow blades to be changed when they become worn for example. As in the first embodiment, the drive shaft may be extended through the opposite side of the housing 103 to permit a further blade to be secured thereto.

The depth regulation means is provided, in this embodiment, by a single hydraulic actuator comprising a cylinder 106 and ram 106a, the cylinder 106 being pivotally secured to a headstock 102 whilst the ram is pivotally secured to a housing 103 by pin 132. The pipework and fittings of the hydraulic circuit have been omitted for clarity, but the layout of the circuit is substantially identical to that of the first embodiment.

A tie rod 136 is in this embodiment pivotally mounted to headstock 102 and is arranged such that a female slidable portion 140 secured to arm 130 is free to move along the extent of cylindrical portion 137 of the tie rod 136. A locking nut is preferably secured to the end of the cylindrical portion to retain the female portion 140 on the rod 136. In a particularly preferred embodiment, the locking nut may be adjusted to provide a fine control of the cutting depth of blade 105. In other embodiments, the tie rod may be replaced by a slotted bar, or a flexible tie, for example.

Means is preferably provided on the apparatus to provide an indication of the current depth of cut, and to alter the maximum depth of the cut. In this embodiment, a quadrant 144 having an array of apertures 146 provided thereon is mounted on a portion of the housing 103 visible to the operator and operates in conjunction with moveable depth stop 144 to adjust the maximum cutting depth of the device. A cutting depth indicator 148 is connected via a linkage to arm 130 to provide a visual indication of the actual depth of cut at that point.

Referring to Fig. 6, in use, the operator of the apparatus first brings the blade 105 up to its operational speed, and then lowers the dipper arm of the excavator which in turn causes headstock 102 to pivot downwardly about axle 128 and by virtue of tie rod 136 lowers the arm 130 and blade 105 so as to bring blade 105 into contact with the material to be cut 104. As female portion 140 is slidable along the tie rod 136, the apparatus relies on the self weight of arm 130 to induce a cutting force, causing blade 105 to cut into the material 104.

If the operator of the apparatus induces too great a frictional resistance on the blade 105 by, for example, attempting to move the apparatus at too great a linear speed, the increased load on motor 112 causes back pressure in the hydraulic line, thus causing the actuator to extend in a similar manner to that described in the first embodiment. The extension of the actuator in turn causes headstock 102 to pivot upwardly about axle 128 which simultaneously, due to the tie rod connection between the headstock and arm 130 also lifts the blade away from the material being cut thus reducing the cutting force and the frictional resistance. In this way, the self regulation of the cutting functions in a similar manner to the first embodiment.

Turning now to the third embodiment of the invention as illustrated in Figs. 8 to 11. Like numerals have where possible been used for like parts with the addition of the prefix "2".

Referring in particular to Fig. 8, it can be seen in this embodiment that the apparatus comprises a dipper arm attachment separate from the main body of the device itself. The attachment comprises in this embodiment a connecting portion 220 pivotally secured to a dipper arm of an excavator 201, 201c by pins 222a and 222b. Secured to the end of the connecting portion 220 is a telescopic portion comprising an outer sleeve 286 and inner sleeve 288, the sleeve being biased outwardly by resilient means such as a gas strut 290. Stops are provided to retain the arm 288 within the sleeve 286. In one class of embodiments, the telescopic portion may be turned through 90° relative to the connecting portion 220 thereby enabling cutting to take place transversely rather than towards the excavator. A cross bar 292 is secured to the free end of the telescopic portion so as to engage with hooks 294 on the apparatus when it is necessary for the apparatus to be lifted and moved.

The apparatus again comprises a headstock 202 which in this embodiment is pivotally mounted to upper edge of the housing 203 by bar 296 that is journalled onto brackets 297. The opposite end of the headstock 202 is supported by resilient means such as gas strut 304 pivotally mounted at the free end of the headstock 202 by pin 306 and at its opposite end to the housing by a pin 308. The use of gas-struts to support the headstock is considered

advantageous due to the constant rate of compression under increasing loads. Thus, the headstock 202 is biased into the rest position as illustrated by Fig. 8.

A pressure plate 298 is pivotally mounted onto headstock 202 by pin 301 is arranged such that when the cross bar 292 of the telescopic portion is pressed down thereon, the plate 248 deflects towards the excavator such that pin 300 depresses hydraulic fluid flow valve 302, thereby permitting hydraulic fluid to flow through outlet 303. This arrangement is illustrated schematically in Fig. 11, and is provided as a safety device to prevent operation of the apparatus unless it is in contact with the attachment.

As in the second embodiment, arm 230 is pivotally mounted on axle 228 along with wheels 250a. A further pair of wheels 250b are rotatably mounted to the opposite end of the housing by an axle 284. A hydraulic motor, gear and drive shaft arrangement are mounted to the free end of the arm 230 in a similar manner to that described in the second embodiment.

In this embodiment, the regulating means is again a single actuator comprising cylinder 206 and ram 206a, the cylinder being pivotally mounted to the housing 203 and the ram being pivotally mounted to arm 230 by pin 232. As the actuator only has to counteract the self weight of the arm 230, it is of lower capacity than the actuators of the first two embodiments. Pin 232 is advantageously further held within a slotted portion of a tie plate 310. Tie plate 310 is in turn pivotally mounted to a lower portion of the headstock 202 by pin 312.

Means to control the depth of cut is advantageously provided in the form of a quadrant 242 having a plurality of apertures 246 provided therein and being secured to housing 203 in a position visible to the operator of the apparatus. A pivoting portion may be releasably secured to a selected one of apertures 246 and has a protrusion past which pin 306 is prevented from moving, thereby limiting the arc through which headstock 202 may pivot, thus limiting the possible depth of the cut.

Turning now to Fig. 9, the apparatus is shown in operation. In use, the operator exerts downward pressure on the pressure plate 298 in a direction X thereby opening hydraulic valve 302 allowing fluid to flow into the motor 212 to provide drive to the blade 205. Further downward pressure from the attachment pushes headstock 202 downwardly against the biasing force of gas strut 304. This movement in turn allows arm 230 to pivot downwardly due to the fact that tie bar 310 is lowered, thus enabling blade 205 to commence cutting into surface 204. As in the second embodiment, the self weight of the arm 230 is relied upon to induce a cutting force on the blade 205.

As in previous embodiments, if the frictional resistance on the blade 205 becomes too great, the back pressure in the hydraulic circuit 210 causes hydraulic fluid to flow into hydraulic cylinder 206, thus extending the hydraulic actuator, causing the arm 230 to lift, the lifting movement being unhindered by virtue of the slot 304 provided in tie bar 310. Thus self regulation of the apparatus is achieved.

One advantage of the apparatus of the third embodiment is that the operator is not required to maintain the lower end of the dipper arm at a constant height relative to the surface to be cut whilst simultaneously drawing the apparatus towards the excavator due to the telescopic portion of the apparatus. This is an operation which is difficult for inexperienced excavator operators to successfully achieve.

The apparatus of third embodiment also enables the excavator operator to reposition the excavator without having to manually detach the apparatus from the dipper arm or reposition the blade 105 in the cuts already made, thus allowing long runs of cuts to be made relatively rapidly. It is envisaged that an automatic coiling arrangement for the hydraulic line connecting the apparatus to the host machine may be provided to enable such repositioning to be safely achieved. It would also be appreciated by those skilled in the art that the pressure pad and valve arrangement provides a safety cut-out for the hydraulic circuit that stops the operation of the apparatus when the telescopic portion is lifted from the apparatus.

It will be understood that numerous changes may be made within the scope of the present invention. For example, similar self regulating arrangements may be used in a wide variety of applications from hand tools to large industrial cutting and abrasive equipment. The apparatus may be adapted for use on air or water powered tools. The arrangement of the motor and apparatus may be varied both in their physical position on the apparatus and their locations within the hydraulic circuit, and the actuator may be replaced by those of a non-linear type.

CLAIMS

1. Fluid powered cutting apparatus comprising a fluid motor arranged so as to drive a cutting device and a fluid powered actuator, the fluid motor and fluid powered actuator being so constructed and arranged as to cause, in use, the resistance load induced on the cutting device when cutting material to be regulated so as not to exceed a pre-determined value.

2. Apparatus according to claim 1 wherein the actuator and motor are connected to a fluid flow circuit such that an increased rotational load on the cutting device due to a cutting force induced on the device causes a change in pressure within the circuit, thereby causing the actuator to counteract the cutting force so as to reduce the load on the cutting device.

3. Apparatus according to claim 2 wherein the actuator is connected to the circuit upstream of the motor.

4. Apparatus according to claim 2 or claim 3 wherein the flow of fluid into the actuator is unrestricted but flow out of the actuator is restricted.

5. Apparatus according to any preceding claim wherein the actuator is a hydraulic ram.

6. Apparatus according to any preceding claim wherein the device is pivotally mounted relative to the surface of the material to be cut.

7. Apparatus according to any preceding claim wherein the device is a circular saw blade.

8. Apparatus according to any preceding claim adapted for use with a hydraulic excavator or the like.

9. Apparatus according to claim 8 for securement on the backhoe dipper arm of an excavator.

10. Apparatus according to any preceding claim wherein the fluid is hydraulic fluid.

11. Apparatus according to any preceding claim wherein a further cutting device is provided.

12. A fluid circuit for use with a cutting apparatus comprising in series a secondary supply line for an actuator and a fluid motor for driving a cutting device, the circuit being so arranged that, in use, an increased load on the motor caused by a rotational resistance load on the device causes a change in pressure in the circuit, said change in pressure adjusting the position of the actuator so as to regulate the resistance load and hence the load on the motor.

13. A circuit according to claim 12 wherein flow into the actuator is unrestricted, but the return flow is restricted.

14. A circuit according to claim 12 or claim 13 wherein the circuit is further provided with a valve, the valve preventing fluid flow unless sufficient external physical pressure is applied thereto.

15. A circuit according any one of claims 12 to 14 wherein two actuators are connected to the secondary supply line.

16. A hydraulic cutting apparatus for use in association with a host machine, the apparatus comprising a hydraulic motor adapted to drive a cutting device, a hydraulic actuator arranged

so as to move the cutting device relative to material to be cut and a hydraulic circuit, the circuit being arranged such that, in use, the rotational resistance load induced on cutting device due to a cutting force applied to the device is regulated due to counteraction of the cutting force by the actuator.

17. A method of cutting through material using cutting apparatus comprising a cutting device powered by a fluid motor and an actuator connected in series with the motor to a fluid line, the method comprising the steps of:

a) an operator of the apparatus inducing a cutting force between the running cutting device and the material to be cut, thereby inducing a frictional resistance load of the cutting device and hence a load on the motor;

b) a change in fluid pressure being induced in the fluid line by the load on the motor;

c) the change in pressure causing a change in the extension of the actuator to reduce the frictional resistance load between the material and the device, thereby reducing the load on the motor;

d) a further change in the fluid pressure being induced in the fluid line;

e) the change in pressure causing a further change in the extension of the actuator to increase the frictional resistance between the material and the device, thereby increasing the load on the motor; and

f) repeating steps b) to e) until the operator removes the device from contact with the material.

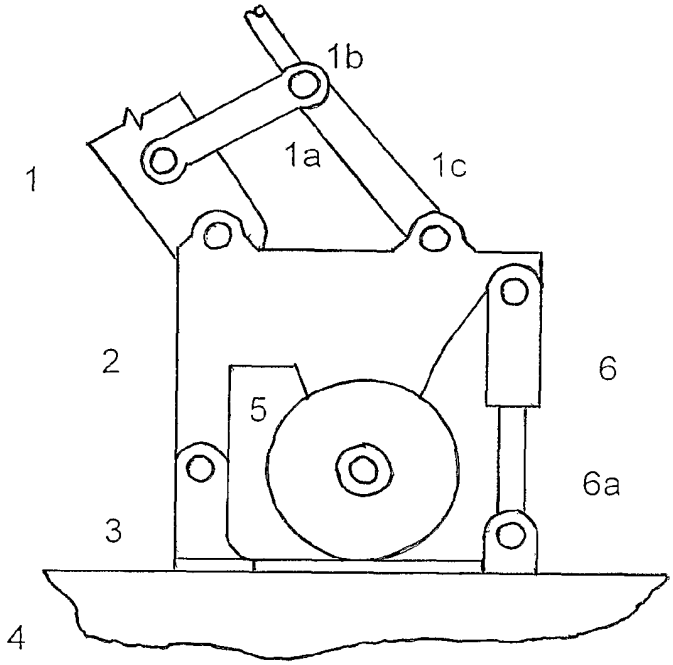


Fig. 1

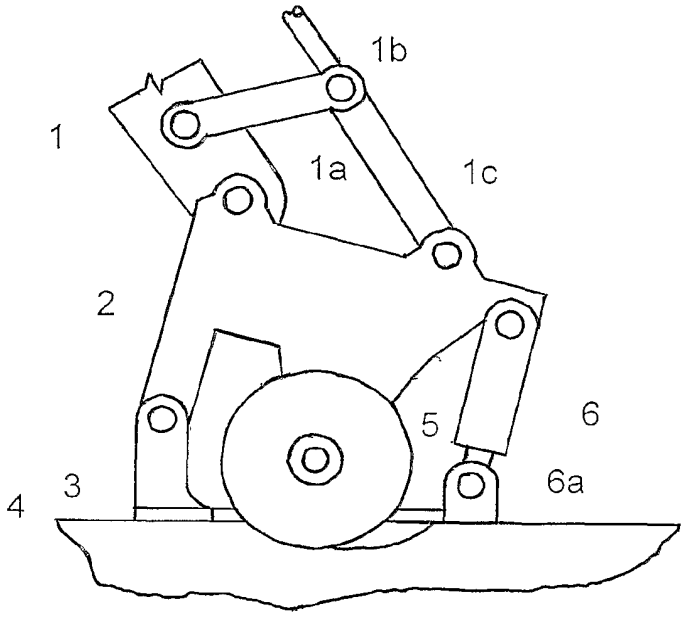


Fig. 2

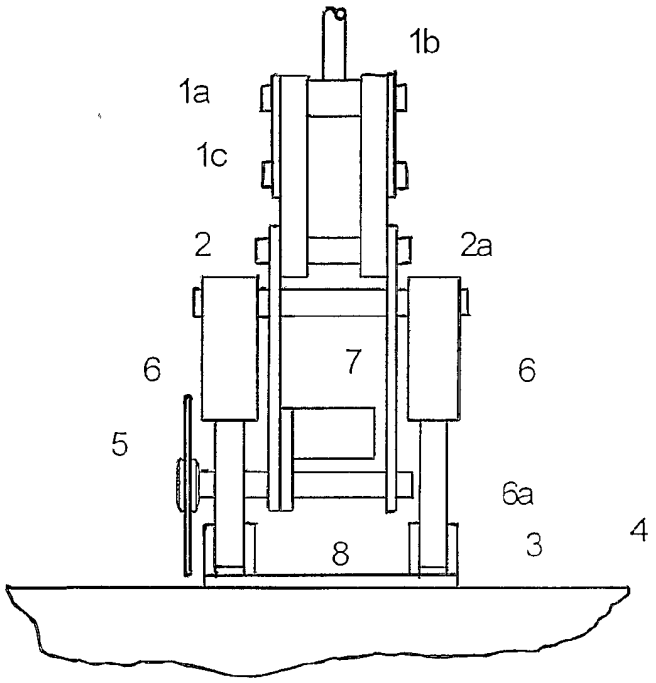


Fig. 3

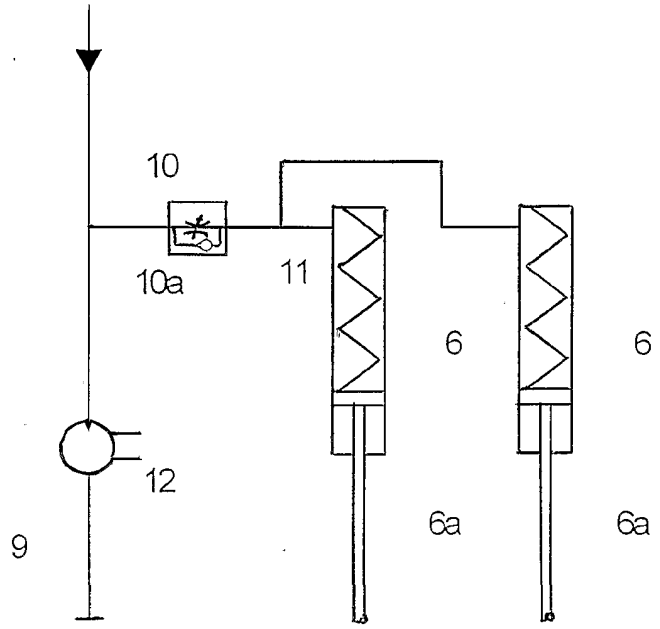


Fig. 4

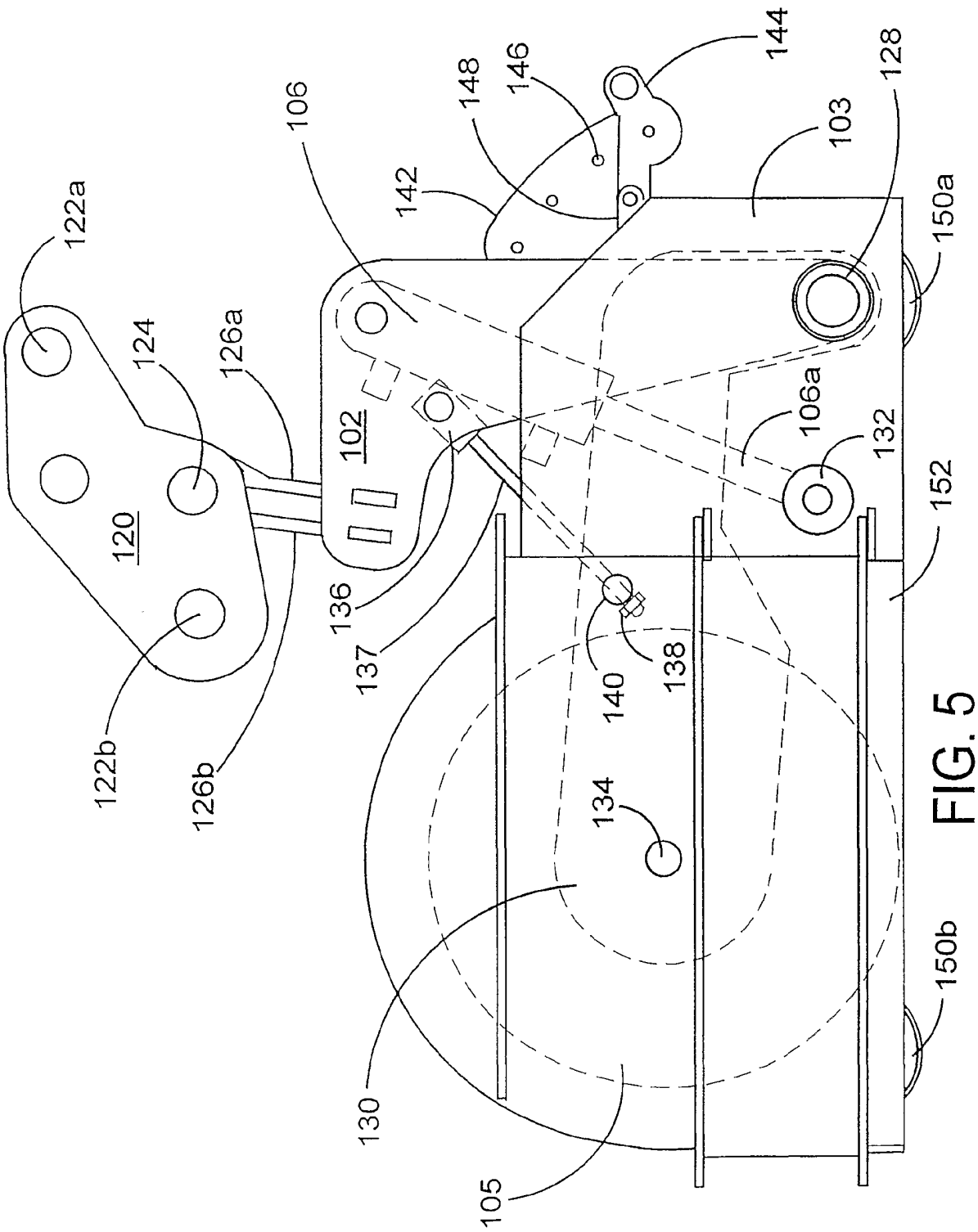

122a
124
126a
120
122b
126b
106
102
136
137
142
148
146
144
128
103
150a
106a
132
152
140
138
134
130
105
150b

FIG. 5

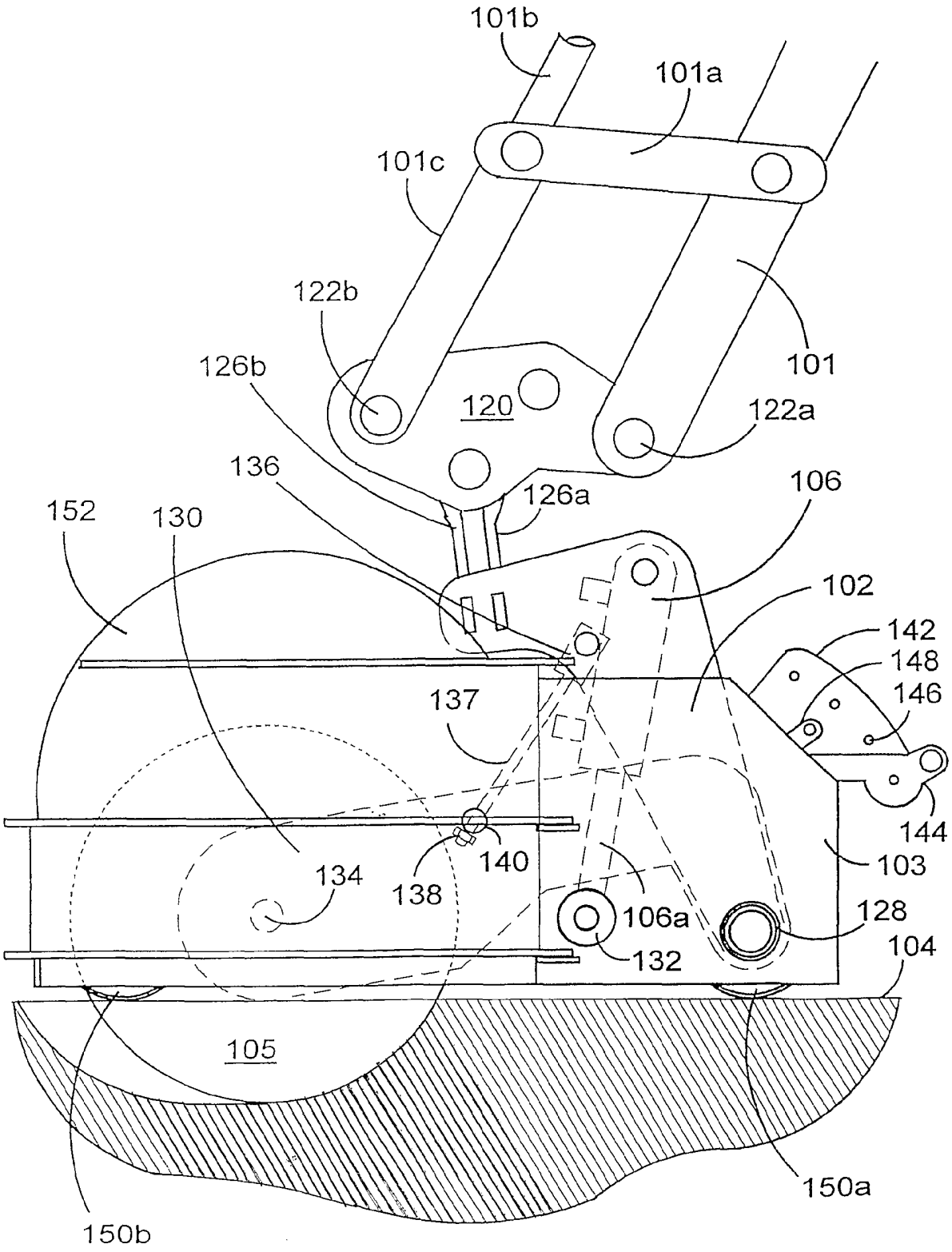

101b
101a
101c
122b
126b
101
120
122a
136
126a
106
152
130
102
142
148
137
146
144
140
103
134
138
106a
128
132
104
105
150a
150b

FIG. 6

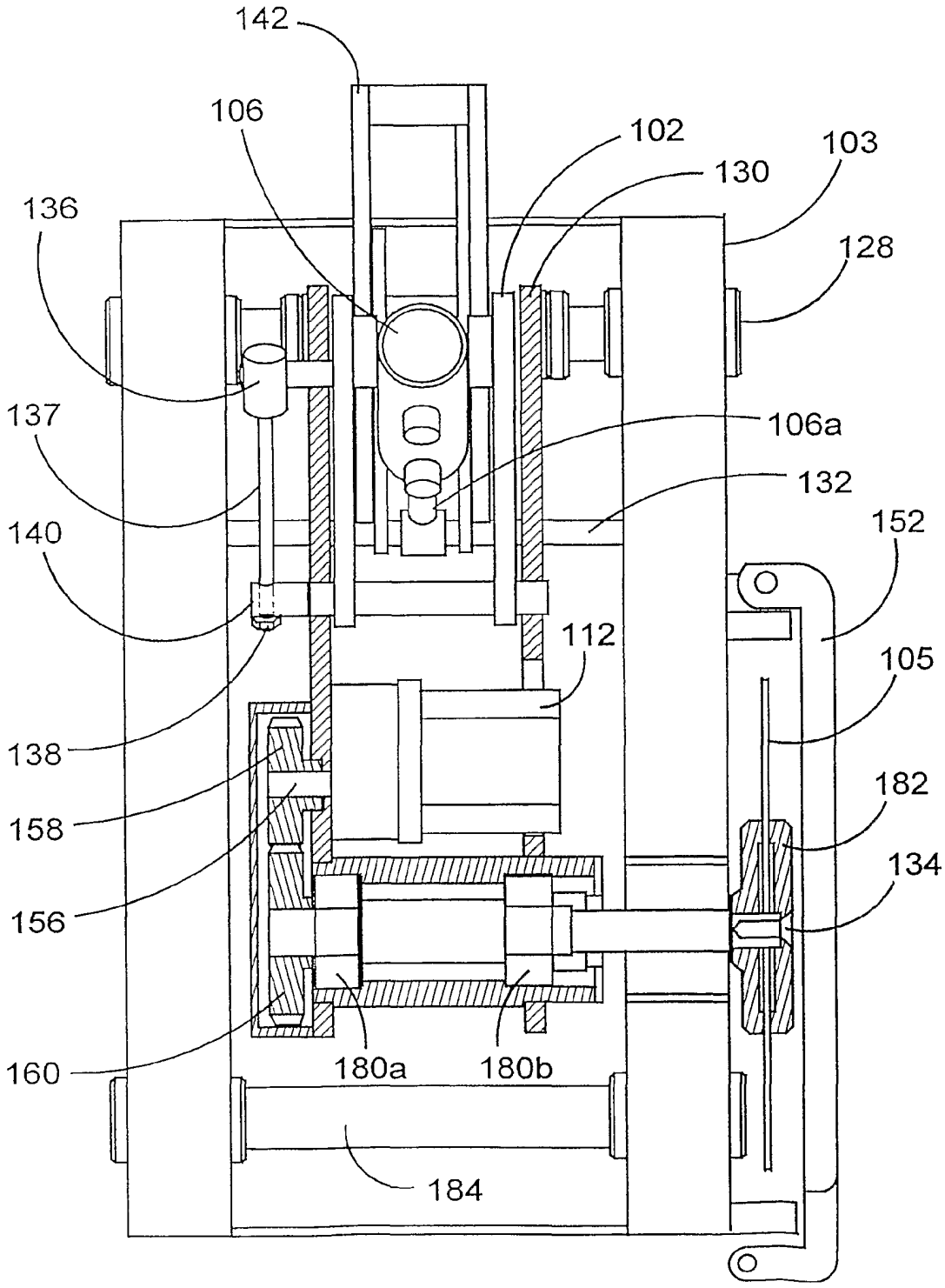

142
106
102
103
130
136
128
137
106a
132
140
152
112
105
138
182
158
134
156
160
180a
180b
184

FIG.7

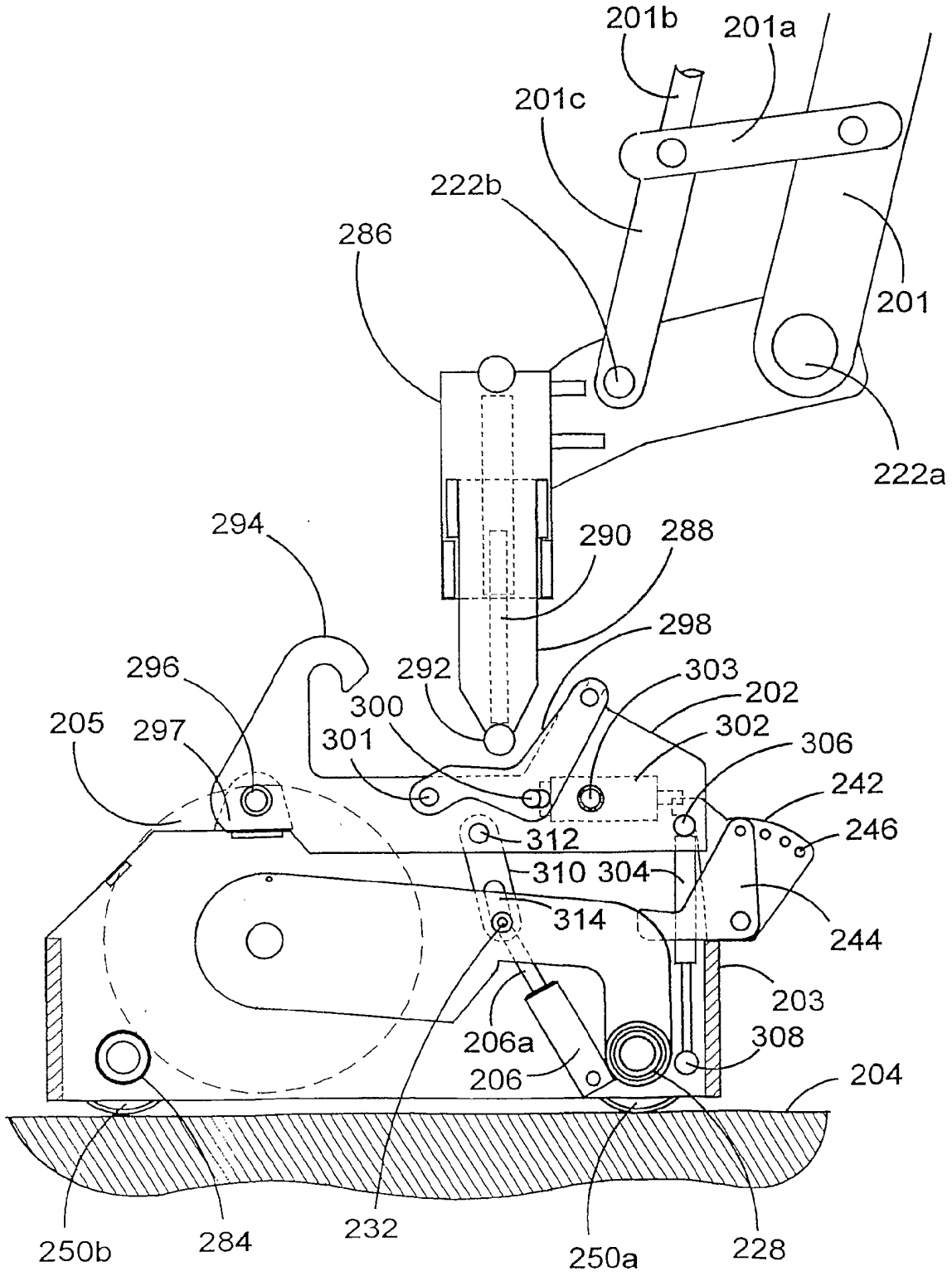

201b
201a
201c
222b
286
201
222a
294
290
288
298
296
292
303
202
300
302
205
297
301
306
242
312
246
310
304
314
244
203
206a
308
206
204
250b
284
232
250a
228

FIG. 8

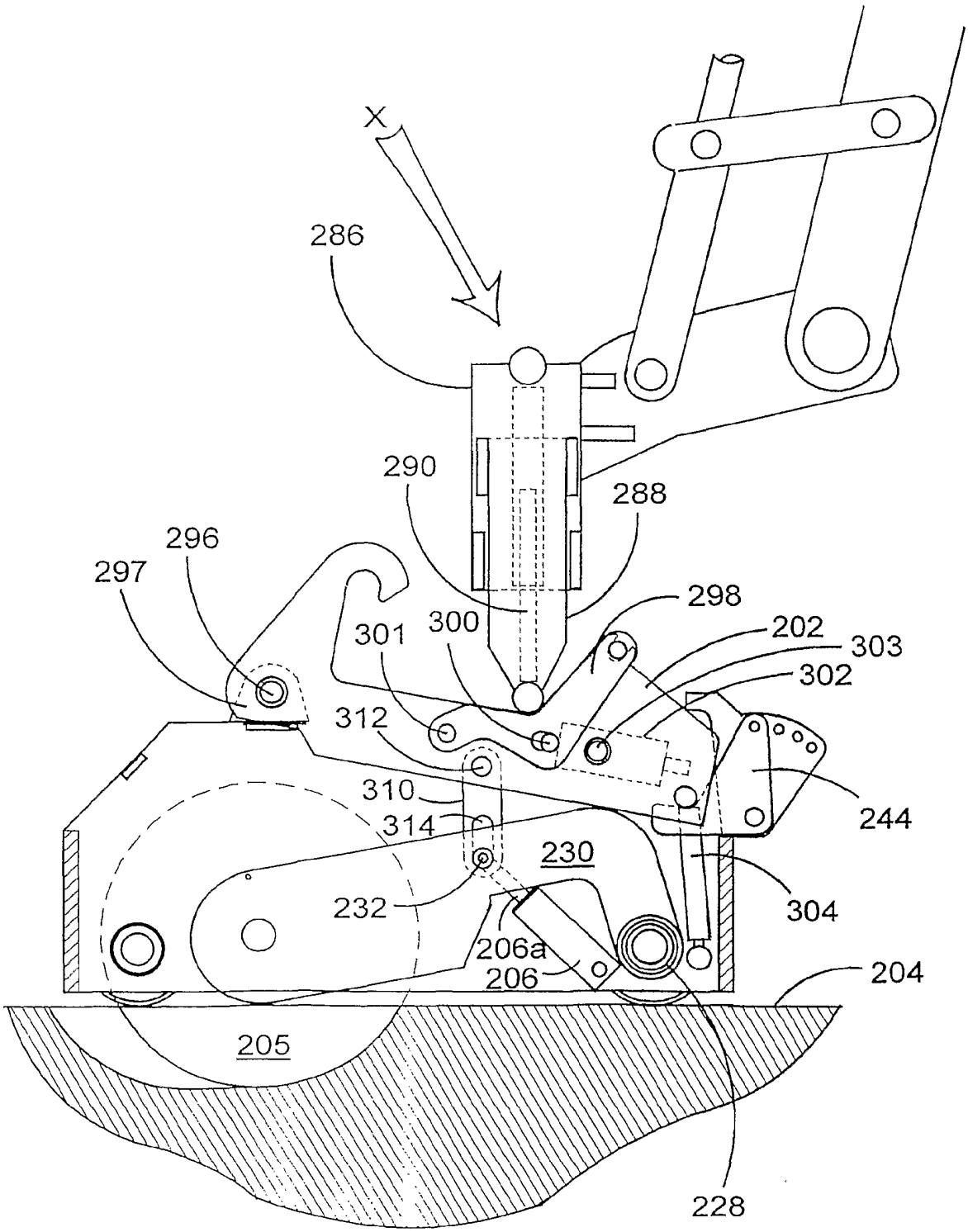

X
286
290
288
296
297
298
301
300
202
303
302
312
310
314
230
244
232
304
206a
206
204
205
228

FIG. 9

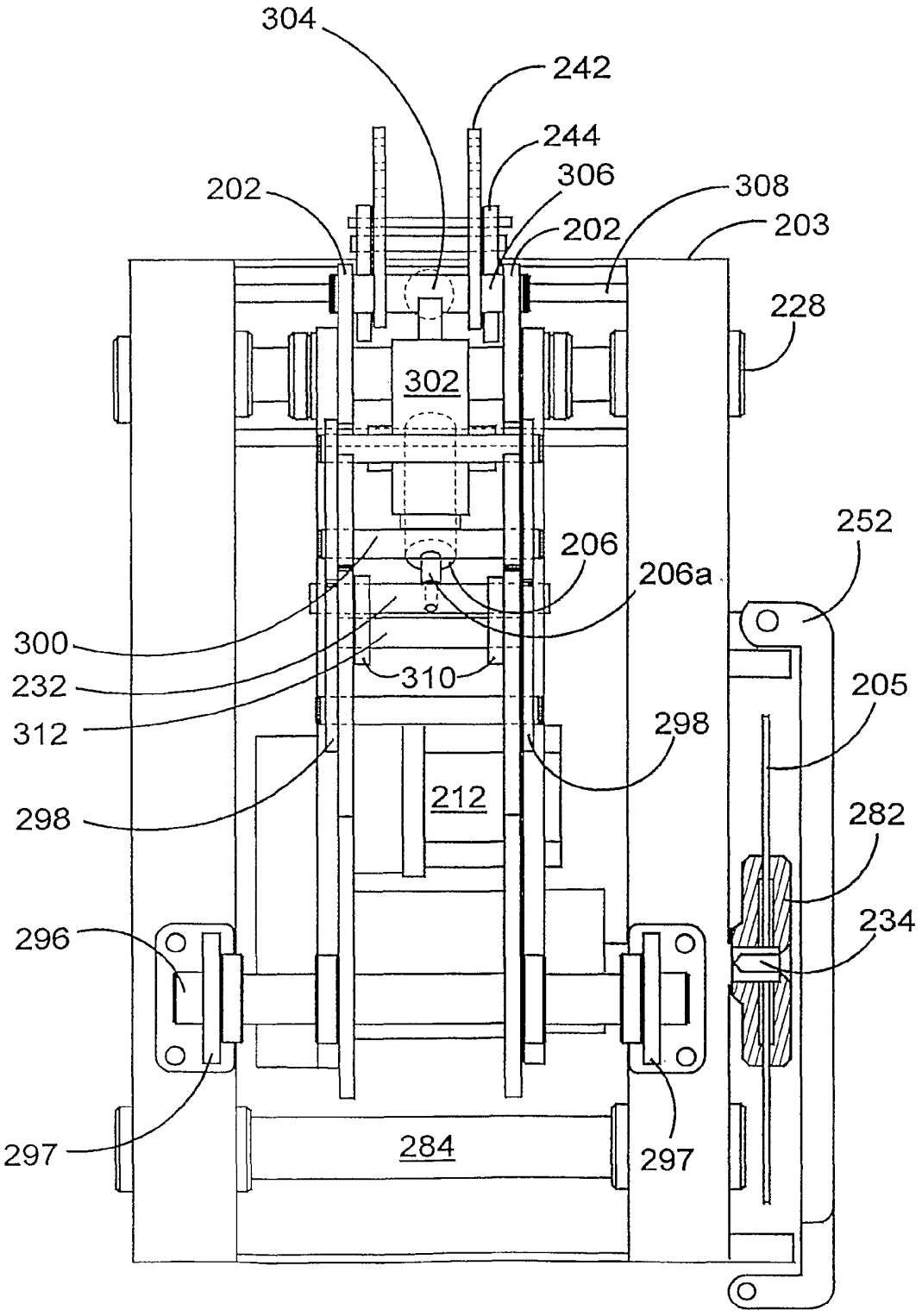

304
242
244
306
308
202
202
203
228
302
252
206
206a
300
232
312
310
205
298
298
212
282
234
296
297
284
297

FIG. 10

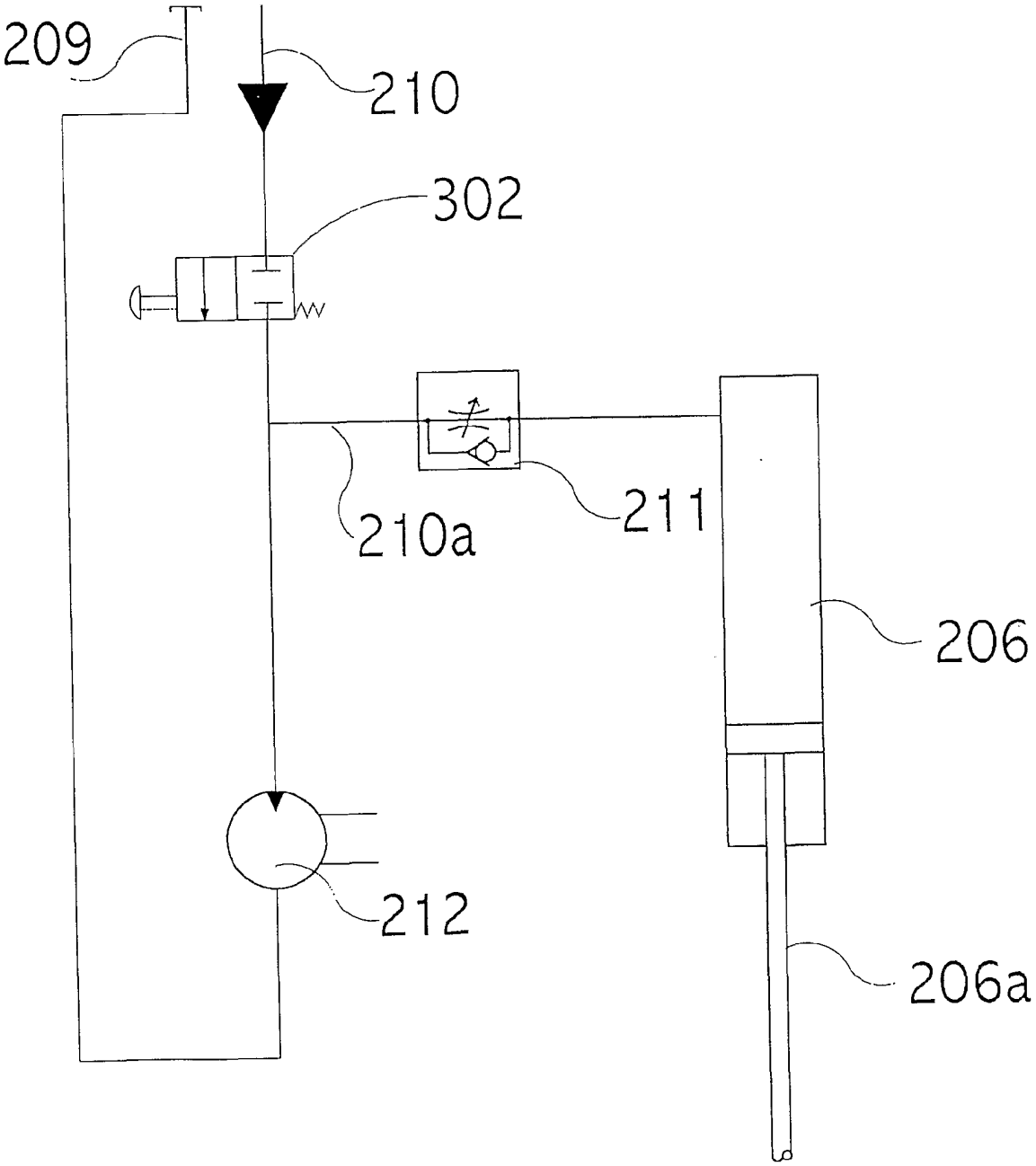


FIG. 11

INTERNATIONAL SEARCH REPORT

Int ial Application No
PCT/GB 01/02745

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B28D7/00 B23D47/10 B28D1/04

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)
IPC 7 B23D B28D

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 662 684 A (MARTEN EDWARD N) 5 May 1987 (1987-05-05) the whole document in particular column 9, line 61 -column 11, line 52 figure 10	1,2, 6-12, 15-17
A	---	5
X	US 3 877 180 A (BRECKER JAMES N) 15 April 1975 (1975-04-15) the whole document in particular column 2, line 52 -column 3, line 13	1-6,10, 12,16
A	---	7,8,17
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in 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 document 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
4 October 2001	12/10/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Rijks, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 848 845 A (KENNEDY RALPH) 18 July 1989 (1989-07-18) column 3, line 32 -column 4, line 48 figure 3	1-3,7,8, 10,12, 15-17
A	---	5
X	US 4 748 966 A (KENNEDY RALPH) 7 June 1988 (1988-06-07) column 3, line 26 -column 4, line 33 figures	1-3,6-8, 10,12, 16,17
A	---	5
X	WO 98 09041 A (MURAKAMI TAKU ;HOSHINO AKIFUMI (JP); KIMURA KEIJI (JP); UENOYAMA M) 5 March 1998 (1998-03-05) figures 25,26 -& US 6 286 905 B1 (MURAKAMI TAKU ET AL) 11 September 2001 (2001-09-11) column 9, line 47 -column 10, line 31 figures 25,26	12-14
A	---	
A	WO 94 04763 A (AUTOMAC EQUIPMENT LIMITED ;FULFORD DENNIS RODNEY (GB)) 3 March 1994 (1994-03-03) page 3, line 28 -page 6, line 16 figures	5,6, 8-10,16
A	---	
A	US 4 778 304 A (BALDI BARNEY T ET AL) 18 October 1988 (1988-10-18) column 3, line 38 - line 40 figure 2	5,7,8, 10,16
A	---	
A	US 3 752 022 A (DEMURGER J) 14 August 1973 (1973-08-14) column 2, line 59 -column 3, line 5 figure 1	12-14

INTERNATIONAL SEARCH REPORT

Int[illegible]al Application No
PCT/GB 01/02745

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4662684 A	05-05-1987	US 4542940 A	24-09-1985
		CA 1235151 A1	12-04-1988
		EP 0162729 A2	27-11-1985
		EP 0269172 A2	01-06-1988
		EP 0268334 A2	25-05-1988
		JP 61040928 A	27-02-1986
		CH 645688 A5	15-10-1984
		DE 3047176 A1	10-09-1981
		FR 2472058 A1	26-06-1981
		GB 2071182 A ,B	16-09-1981
		GB 2136475 A ,B	19-09-1984
		GB 2136476 A ,B	19-09-1984
		IT 1165572 B	22-04-1987
		JP 56128833 A	08-10-1981
		US 4640551 A	03-02-1987
US 3877180 A	15-04-1975	NONE	
US 4848845 A	18-07-1989	NONE	
US 4748966 A	07-06-1988	NONE	
WO 9809041 A	05-03-1998	WO 9809041 A1	05-03-1998
		JP 3145126 B2	12-03-2001
		US 6286905 B1	11-09-2001
WO 9404763 A	03-03-1994	AU 4727393 A	15-03-1994
		DE 69308857 D1	17-04-1997
		EP 0654105 A1	24-05-1995
		WO 9404763 A1	03-03-1994
US 4778304 A	18-10-1988	NONE	
US 3752022 A	14-08-1973	FR 2098715 A5	10-03-1972
		CA 932623 A1	28-08-1973
		DE 2137094 A1	27-01-1972
		GB 1364049 A	21-08-1974