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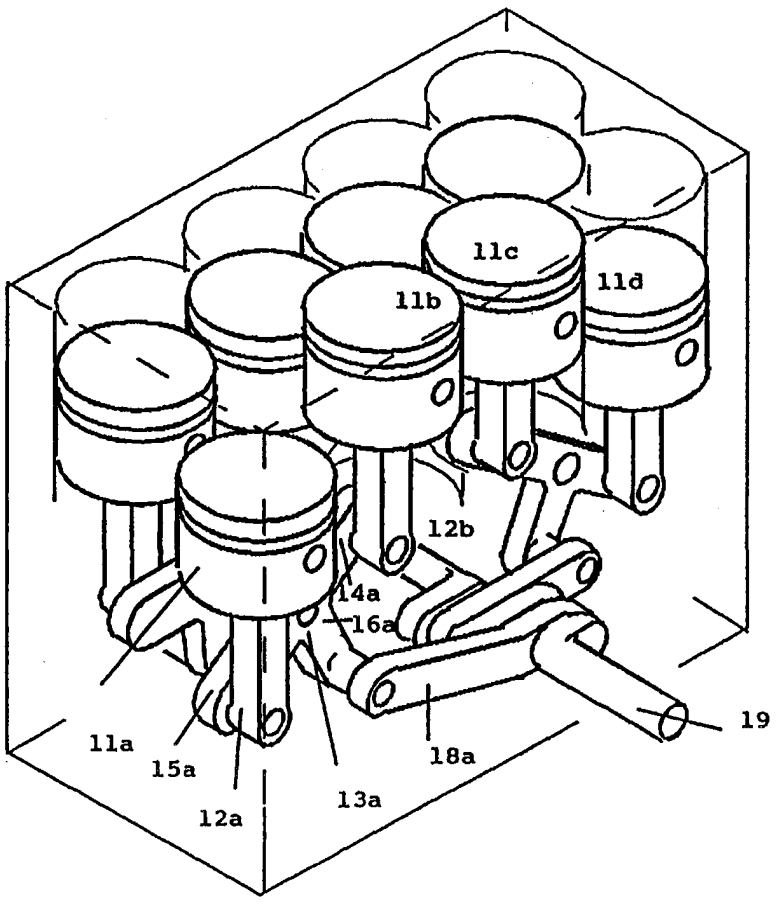
(54) Title: ROTARY TO RECIPROCATING MOTION CONVERSION LINKAGE

(57) Abstract

A linkage system for use in reciprocating piston machines is described. The linkage mechanism allows for the transmission of reciprocating motion produced by one or more pistons (11a, 11b, 11c, 11d) which is transmitted to a rocker crank (15a) whereby the reciprocating motion is transmitted via throw shaft (18a) to a crank (19). The rocker crank (16a) may have a single or double upper arm connected to one piston in the former construction and two in the latter. Various arrangements of the linkage are envisaged including inverting the rocker crank (16a) as well as reversing the orientation of the rocker crank/throw arm connection. The linkage allows for close piston spacing thereby producing a compact engine. Alternative piston arrangements are possible including inline, V and other orientations.



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ROTARY TO RECIPROCATING MOTION CONVERSION LINKAGE

Field of the Invention

The present invention relates to linkage systems for use in a reciprocating piston machine. More particularly, although not exclusively, the present invention relates to a piston to crankshaft linkage system for use in internal combustion engines. However, this application is not construed as limiting and it is envisaged that the linkage system may be used in pumps, refrigerators, compressors, Stirling engines and the like. The following discussion will, however, be directed primarily towards application of the linkage system to an internal combustion engine.

Background to the Invention

Internal combustion engines (for example in automotive applications) generally include at least one reciprocating piston connected to a connecting rod which drives a crankshaft. Such constructions are well known and presently find application in a large variety of reciprocating internal combustion engine applications as well as related applications such as those above.

While being generally satisfactory, the reciprocating action of, for example, a pair of reciprocating pistons will result in unbalanced forces and impulses being applied to the crankshaft. Further, the motion of the pistons may produce vibrations which have a large number of problematic consequences for both the operator of the engine and the structural integrity of the engine itself. The problematic effects of piston to crankshaft

linkages known in the art and are common to other reciprocating piston applications such as pumps and the like.

Also, as a consequence of known linkage systems, known reciprocating combustion engines are quite bulky as the geometry of the pistons is governed, amongst other things, by the linkage between the reciprocating piston, the connecting rod and the crankshaft. This can be a significant disadvantage in applications where a compact reciprocating piston type engine or pump is required. Such applications may be small automobiles, compact pumps, aircraft engines and the like.

Accordingly, it is an object of the present invention to provide an alternative piston to crankshaft linkage system which overcomes or at least mitigates a number of the abovementioned disadvantages, allows for the construction of a compact reciprocating piston mechanism or at least provides the public with a useful choice.

Disclosure of the Invention

In one aspect the present invention provides a piston to crankshaft linkage system comprising:

> one or more pistons each moving in a piston bore in a reciprocating manner, said one or more pistons being connected to a first arm of a rocker arm, said first arm being pivotably moveable through the range of travel of the piston(s) when the piston(s) moves in a reciprocating manner, a third arm of the rocker crank being pivotably connected to a rocker shaft connecting rod wherein said rocker shaft connecting rod is connected to a crankshaft by means of a throw connection.

In a further aspect the linkage system is adapted to connect two reciprocating pistons to a crankshaft by means of a pivotable rocker crank wherein connecting rods connected to each of the pistons are connected to a first and second arm respectively of the rocker crank wherein a third arm of the rocker crank is connected, by means of a rocker shaft connecting rod, to a crankshaft by means of a throw connection.

Preferably the rocker crank comprises a first, second and third arm, said first and second arm being substantially opposed and connected at each distal end to a first and second connecting rod connected to a first and second piston respectively, said third arm of the rocker crank pivotably connected to a crankshaft by means of a throw connection via a rocker shaft connecting rod.

In a more preferred embodiment, the piston to crankshaft linkage is adapted to link four reciprocating pistons to a crankshaft wherein said linkage comprises:

two linkage systems as described hereinbefore connected, via a two throw crankshaft connection to a crankshaft.

Preferably the axis of the crankshaft is located below the axis of the one or more rocker cranks with the rocker cranks, when viewed along the axis of the crankshaft, being substantially T-shaped.

In an alternative embodiment, the axis of the crankshaft may be located above the axis of the rocker cranks, wherein the rocker cranks when viewed along the axis of the crankshaft are substantially in the shape of an inverted T.

Brief Description of the Drawings

The present invention will now be described by way of example only and with reference to the drawings in which:

Figure 1 illustrates the mechanical operating cycle of the piston/ crankshaft linkage system.

Figure 2 illustrates a perspective wireframe representation of the linkage system.

Figure 3 illustrates a plan view, in diagramatic form, of an 8 cylinder embodiment implementing the linkage system;

Figure 4 illustrates a plan view of an 8 cylinder machine incorporating the linkage (left figure) compared with a conventional V8 layout (right figure);

Figure 5 illustrates a perspective wireframe representation of the relationship between the crank shaft planes in their preferred embodiment;

Figure 6 illustrates a plan view wireframe representation showing an alternative rocker connection;

Figure 7 illustrates diagramatically a twin cylinder example;

Figure 8 illustrates a size comparison between a four cylinder embodiment of an engine incorporating the present linkage (upper left) and a conventional in line four cylinder, with an end view of the four cylinder embodiment (bottom left);

Figure 9 illustrates a size comparison between a six cylinder machine incorporating the linkage of the present invention (left) and a conventional in line example (right);

Figure 10 illustrates an offset embodiment of the linkage having straight rocker shaft connecting rods;

Figure 11 illustrates a perspective of an eight cylinder version;

Figure 12 illustrates alternative variations of crank and rocker connecting rod linkages of which (A) corresponds to that shown in Figure 11;

Figure 13 illustrates an alternative construction for the linkage in which the crankshaft is located above the axis of the rocker arms;

Figure 14 illustrates a perspective of a detail of a rocker crank (left figure) connecting to a piston connector rod and a rocker connection rod (right figure);

Figure 15 illustrates a details of an overhung rocker crank;

Figure 16 illustrates alternative linkage layouts;

Figure 17 illustrates an alternative piston layout; and

Figure 18 illustrates an alternative rocker crank/throw rod linkage.

Referring to Figure 1, a wireframe schematic illustrating the operation of the linkage system is shown. This embodiment corresponds to a four cylinder machine which will be described in the context of a reciprocating internal combustion engine.

The majority of the accompanying figures describe a four cylinder embodiment which operates as follows:

Four cylinders 11a to 11d are attached by means of connecting rods 12a to 12d, in pairs, to a first and second rocker crank 13a and 13b. The rocker cranks 13a and 13b are substantially "T" shaped and have a first and second arm 15b and 14b respectively. Referring to the piston pair 11a and 11b, piston connecting rods 12A and 12b respectively are connected to a first and second arm of a rocker crank 15a and 14a respectively. The rocker crank 13a also comprises a third arm 16a which is connected to a rocker shaft connecting rod 18a. Rocker shaft connecting rod 18a is connected to a two throw crankshaft 20a. This is more clearly illustrated in Figure 2.

A mirror image of this action occurs in relation to the piston pair 11c and 11d. Figure 1b illustrates the point at which the cylinders 11a to 11d are at the same level and the rocker cranks horizontal. The direction of motion of the two throw cranks is shown by

the letter X with the direction of the rocker crank reciprocating action shown by the letter Y.

Referring to the sequence of Figures 1a to 1d, in Figure 1a, the pistons 11a and 11d are about to move downward and pistons 11b and 11c upward. As can be seen, the rocker cranks 13a and 13b undergo a oscillatory motion driving the crankshaft 19. In Figure 1a, the crankshaft 19 is lying flat with the rocker shaft connecting rods 18a and 18b at the outer throws. At this point, the outer pistons are fully elevated while the inner pistons are at their lowest position. Figure 1b illustrates the crankshaft 19 approaching the vertical position and the rocker cranks 13a and 13b horizontal. The rocker cranks pivot axes are indicated by the letter E. Figure 1c illustrates the crankshaft 19 fully returned (i.e. moved through 180° compared with Figure 1a) with the rocker shaft connecting rods at the innermost straight position and the rocker shafts 13a and 13b at their full opposite position when compared with their located in Figure 1a. At this point, the innermost pistons are fully elevated while the outermost pistons are fully lowered. Figure 1d illustrates the next step in this cycle following which the crankshaft is returned to its location in Figure 1a.

Figure 2 illustrates a simplified wireframe schematic showing the arrangement of the linkages according to one embodiment of the present invention.

The piston pair on the left only has been labelled for clarity and the pistons 11a and 11b have been omitted. The rocker crank 13a pivots around a point 17a which is held fixed in space. The first and second arms 15a and 14a respectively are attached to piston cranks 12a and 12b respectively. As the pistons 11a and 11b (not shown) alternately move up and down, the rocker crank 13a rocks or pivots around the axis M-M. This causes the third arm 16a to pivot back and forth whereby force is transmitted in a

reciprocating action via the rocker shaft connecting rod 18a connected to a two throw crankshaft 19 by means of the linkage 20a. The crankshaft 19 is thereby connected to (for example) an automotive gearbox as is known in the art.

Thus it can be seen that the pistons 11a to 11d can be located significantly closer than they would otherwise be in, for example, a V6 inline configuration. The reciprocating rocker crank motion is mirrored in the opposing piston pair (not labelled in Figure 2) thus providing a highly balanced sequence of impulses to the two throw crankshaft. Thus the forces involved are offset one against the other and leading to a significant reduction in vibration in the engine.

Figure 3 illustrates a top view of two piston arrays (4 x 2) using the linkage shown in Figures 1 and 2. As can be seen, the two throw crankshaft requires the rocker shaft connecting rods to be offset. This provides some degree of twisting motion in a plane perpendicular to the direction of the piston movement. The effect of this can be mitigated by using a triple throw crankshaft as is shown in Figure 6. In this case, the right hand pair of pistons (not shown) transmit their reciprocating movement to the triple throw crankshaft by means of two rocker shaft connecting rods 61 and 62. An additional method of mitigating the abovementioned effect is shown in Figures 12a to 12c whereby the rocker shaft connecting rods are bent or offset so as to provide balanced forces.

By way of comparison, Figure 4 illustrates the respective space requirements of an engine implementing the present linkage as opposed to a conventional inline V8 engine. As can be seen, the pistons may be located considerably closer and in a significantly much more compact volume than in engines implementing known linkage systems.

Further, the attendant improvements in the vibration characteristics of an engine incorporating the novel linkage provides a significant advantage.

A three dimensional schematic of the linkage is shown in Figure 11 in the particular application of an 8 cylinder reciprocating machine. Again, the specific example will be described in the context of an internal combustion engine. Also, the movement of only one pair of cylinders will be described for simplicity and clarity as it is to be understood that the opposing or mirror image pair of cylinders operates in a precisely reverse or symmetrical manner. Referring to Figure 11, pistons 11a and 11b undergo a complimentary reciprocating action. This causes the reciprocating rocking movement of the rocker crank 13a. The piston connecting rods 12a and 12b respectively are attached to first and second arms 15a and 14a respectively of the rocker crank 13a. This reciprocating movement is thus transmitted to the crankshaft by means of a two throw linkage which is connected to the third arm 16a of the rocker crank 13a by means of the rocker crank connecting arm 18a. Pistons 11c and 11d undergo a symmetrical mirror image movement. An additional array of pistons displaced axially along the crankshaft axis is connected in a similar manner. In the example shown in Figure 11, the rocker shaft connecting rod 18 is bent to provide a substantially balanced force on the two throw crank 19.

It is envisaged that the present novel linkage may be implemented with 8 (2 x 4), 12 (3 x 4) or 16 (4 x 4) pistons. In the first case, the crank planes will be separated by 90°, in the second case 60° and in the latter case 45°. The 90° example is shown in Figure 5 wherein a crankshaft 50 incorporates a double throw linkage 51 and 52 90° out of phase to one another. This construction is shown in plan form in Figure 3 whereby the front linkage 52 is horizontal and the rear linkage 53 is upright and at substantially 90°.

A two piston embodiment is shown in Figure 7 whereby pistons 71 and 72 transmit a reciprocating motion, by means of connecting rods 73 and 74 respectively, to the end of a first arm of a rocker crank 75 and 76 respectively. The second arm is not needed as the first and fourth cylinders are dispensed with. This reciprocating motion is transmitted to the two throw crankshaft 79 by means of connecting rods 78 and 77. This embodiment represents a less preferred version as the vibration is likely to be slightly increased due to the absence of the balancing forces provided by the additional first and fourth pistons. A plan view of a four cylinder (2 x 2) embodiment is shown in Figure 8 with a comparison to an inline four cylinder conventional piston layout. Similarly, a comparison between a six piston (2 x 3) array implementing the present linkage is contrasted with a six cylinder inline array. This illustrates the compact nature of an engine or pump constructed using the present linkage system.

Figure 10 illustrates yet another embodiment of a linkage according to the present invention. This example retains straight rocker shaft connecting rods, however, the cylinder pairs are offset along the axis of the crankshaft. A further embodiment is shown in figure 17 where the throw rod 81 - rocker crank 82 connections are reversed thereby allowing the pistons 80 to be arranged in line.

In an alternative embodiment, the axis of the crankshaft 19 may be located above the reciprocating axis of the rocker cranks 13a and 13b. Such a configuration is shown in Figures 13a and 13b. Such a configuration may lead to yet further improvements in the compact nature of an engine or pump constructed using the present novel linkage system. However, engines constructed in accordance with the cycle diagrams shown in Figures 13a and 13b will require slightly displaced rocker crank connecting rods so as to allow free reciprocating movement of the rocker cranks 13a and 13b in relation to the

crankshaft 19. Such modifications in the construction are considered to be within the purview of one skilled in the art and will not be discussed further.

Figure 14 illustrates details of the rocker crank to piston connecting rod and rocker crank connecting rod connection. Referring to Figure 14a, the "T" shaped rocker crank may include insert spaces for the piston connecting rods to be located therein. An alternative embodiment is shown in Figure 14b whereby the piston connecting rod and rocker crank connecting rod incorporates a clevis pin construction adapted to locate with the ends of the first, second and third arms of the rocker crank.

Figure 15 illustrates an alternative embodiment whereby the rocker crank is overhung. This corresponds to the embodiment illustrated in Figures 13a and 13b whereby the rocker crank is inverted thus allowing the crankshaft axis to be raised above the level of the rocker crank reciprocating axis. It is envisaged that this latter construction will lead to a more compact engine construction. Figure 18 illustrates an alternative construction of a rocker crank 90. The rocker crank shown is constructed in an integrated, unitary form whereby the throw rod 94 is displaced along the pivot axis. The pistons (not shown) are connected to piton shafts 93 and 92. This construction may be compared to the rockers 13a shown in Figure 11 where a shaft projects along the pivot axis, the end of the shaft being attached to the throw rod. It is considered that the construction shown in Figure 18 is stronger than that in Figure 11. Referring to Figure 18, the pivot pin 91 extends to a point adjacent the throw rod connection and the transition of the piston shaft pin body part to the throw rod body part adds mechanical strength.

While the above discussion has been detailed in relation to an internal combustion engine, it is envisaged that the present linkage system may find use in pumping systems, Stirling engines and like. The combustion engine example is not to be considered as

limiting and it is envisaged that the linkage system could be applied to the abovementioned other examples by one of ordinary skill in the art.

Thus the present invention provides for a linkage system which transmits reciprocating motion from a wide variety of piston arrays to a crankshaft in a manner which balances the momentary forces exerted on the throw linkages of a crankshaft as well as providing for a more balanced reciprocating piston movement. The present linkage system also reduces the angularity of the piston rods (i.e. the angle that the piston rod makes with the direction of movement of the pistons) thus reducing wear on the pistons and cylinders.

Two further embodiments are shown in Figures 16a and 16b. Both of these embodiments represent four cylinder (2 x 1) arrangements. Referring to Figure 16a, a "V" configuration is shown. In this situation the rocker arms third arm 160a and 160b are not perpendicular to the first and second arms of their respective rocker arms. This is to accommodate the appropriate throw required by the crankshaft 161. Configuration in Figure 16a may allow for easier servicing and/or cooling of the cylinder heads while retaining the compact nature of the linkage provided by the present invention.

Yet a further embodiment is shown in Figure 16b. In this example, a four cylinder (2 x 1) configuration is horizontally opposed and the third arm is located at one end of a corresponding first arm of a rocker arm. Thus as the cylinders undergo reciprocating motion, the rocker arm pivots back and forth with this movement being transmitted to the crankshaft by the double throw linkage. Again, this configuration provides for easier servicing, access and cooling of the cylinder heads while still retaining a compact cylinder head layout.

The alternative embodiments shown in Figure 16a and 16b may include further cylinder arrays spaced along the axis of the crankshaft. In these cases, the angles between the throw linkages will be varied according to the total number of cylinders as discussed above.

Wherein the foregoing description reference has been made to elements or intergers having known equivalents, then such equivalents are included as if they were individually setforth.

Although the invention has been described by way of example and with reference to particular embodiments thereof, it is to be understood that modifications and/or improvements may be made without parting from the scope of the appended claims.

CLAIMS:

1. A piston to crankshaft linkage system comprising:

one or more pistons each moving in a piston bore in a reciprocating manner, said one or more pistons being connected to a first arm of a rocker arm, said first arm being pivotably moveable through the range of travel of the piston(s) when the piston(s) moves in a reciprocating manner, a third arm of the rocker crank being pivotably connected to a rocker shaft connecting rod wherein said rocker shaft connecting rod is connected to a crankshaft by means of a throw connection.

2. A piston to crankshaft linkage system as claimed in claim 1 wherein the linkage system is adapted to connect two reciprocating pistons to a crankshaft by means of a pivotable rocker crank wherein connecting rods connected to each of the pistons are connected to a first and second arm respectively of the rocker crank wherein a third arm of the rocker crank is connected, by means of a rocker shaft connecting rod, to a crankshaft by means of a throw connection.

3. A piston to crankshaft linkage system as claimed in either claim 1 or claim 2 wherein the rocker crank comprises a first, second and third arm, said first and second arm being substantially opposed and connected at each distal end to a first and second connecting rod connected to a first and second piston respectively, said third arm of the rocker crank pivotably connected to a crankshaft by means of a throw connection via a rocker shaft connecting rod.

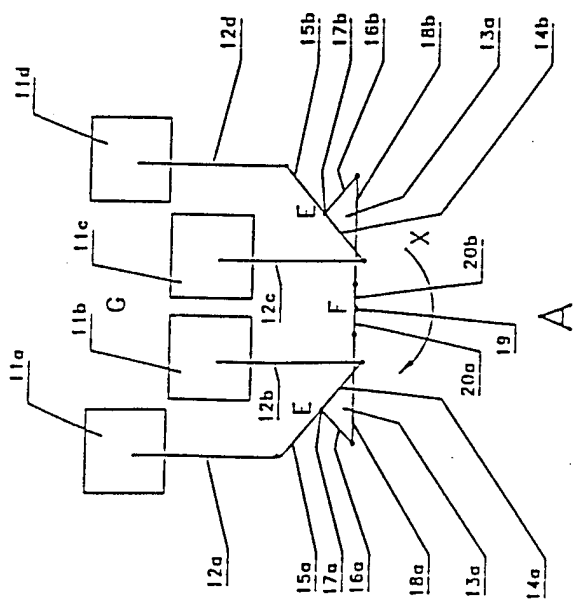
4. A piston to crankshaft linkage system as claimed in any proceeding claim wherein the piston to crankshaft linkage is adapted to link four reciprocating pistons to a crankshaft wherein said linkage comprises:

two linkage systems as described hereinbefore connected, via a two throw crankshaft connection to a crankshaft.

5. A piston to crankshaft linkage system as claimed in any proceeding claim wherein the axis of the crankshaft is located below the axis of the one or more rocker cranks with the rocker cranks, when viewed along the axis of the crankshaft, being substantially T-shaped.

6. A piston to crankshaft linkage system as claimed in claim 5 wherein the axis of the crankshaft may be located above the axis of the rocker cranks, wherein the rocker cranks when viewed along the axis of the crankshaft are substantially in the shape of an inverted T.

7. A piston to crankshaft linkage system substantially as herein described with reference to the accompanying drawings.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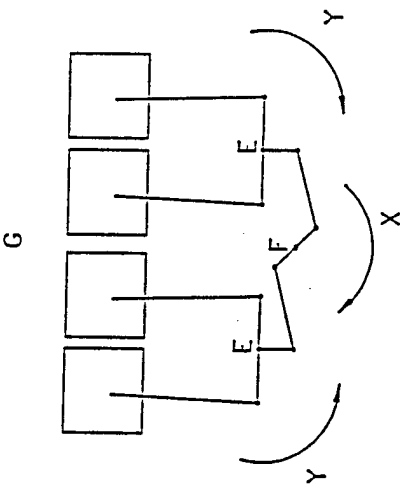
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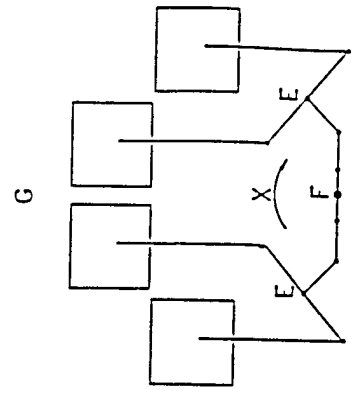
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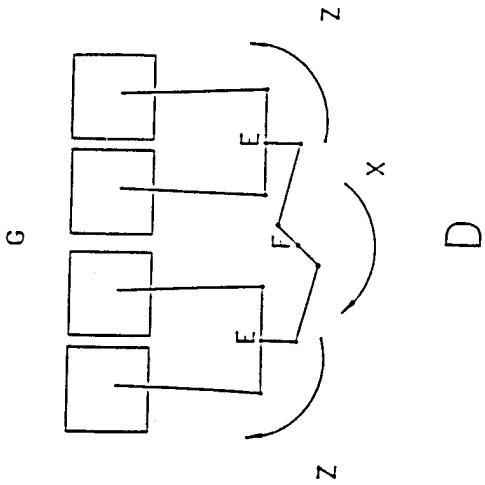
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FIG. 1

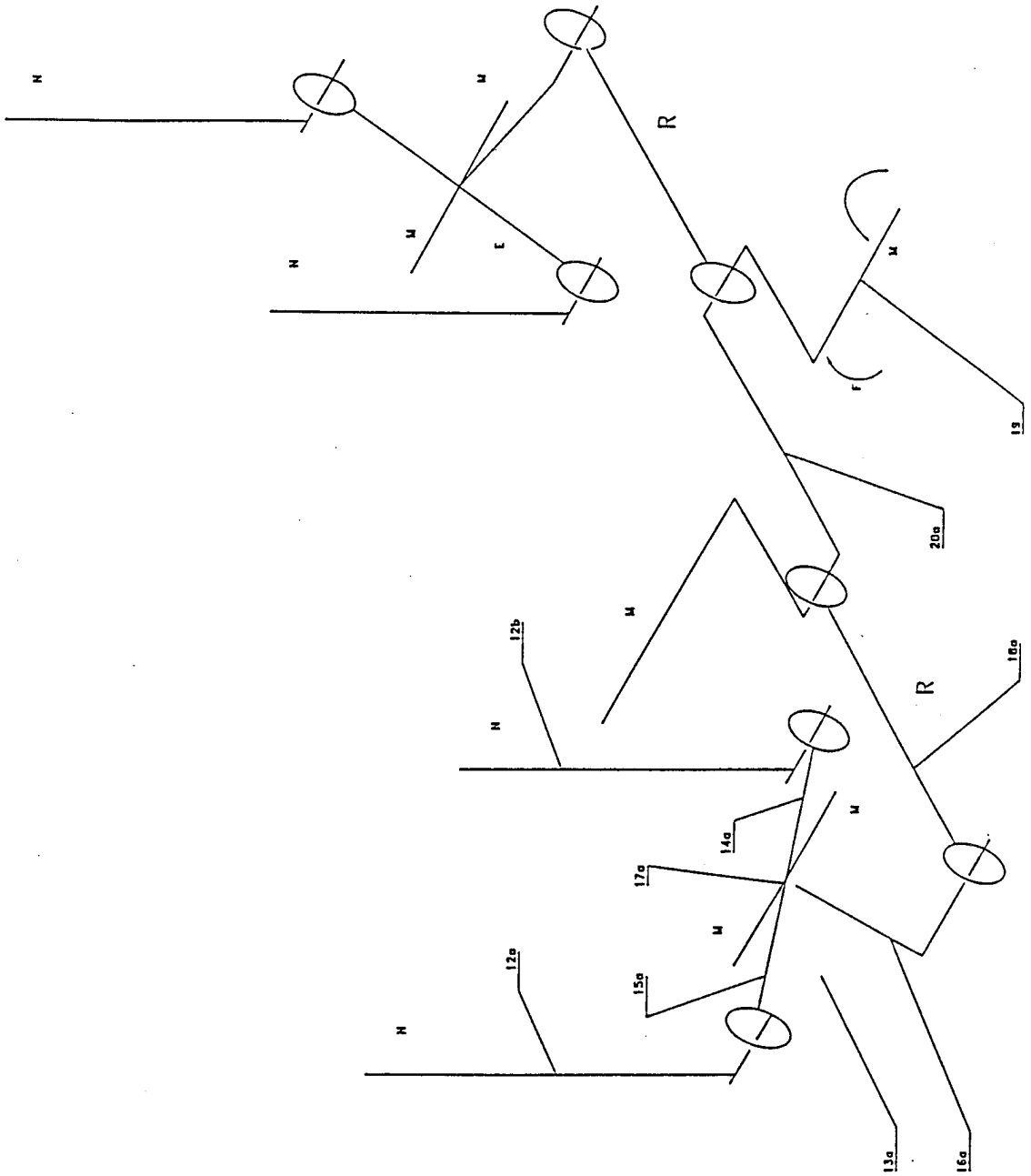


FIG. 2

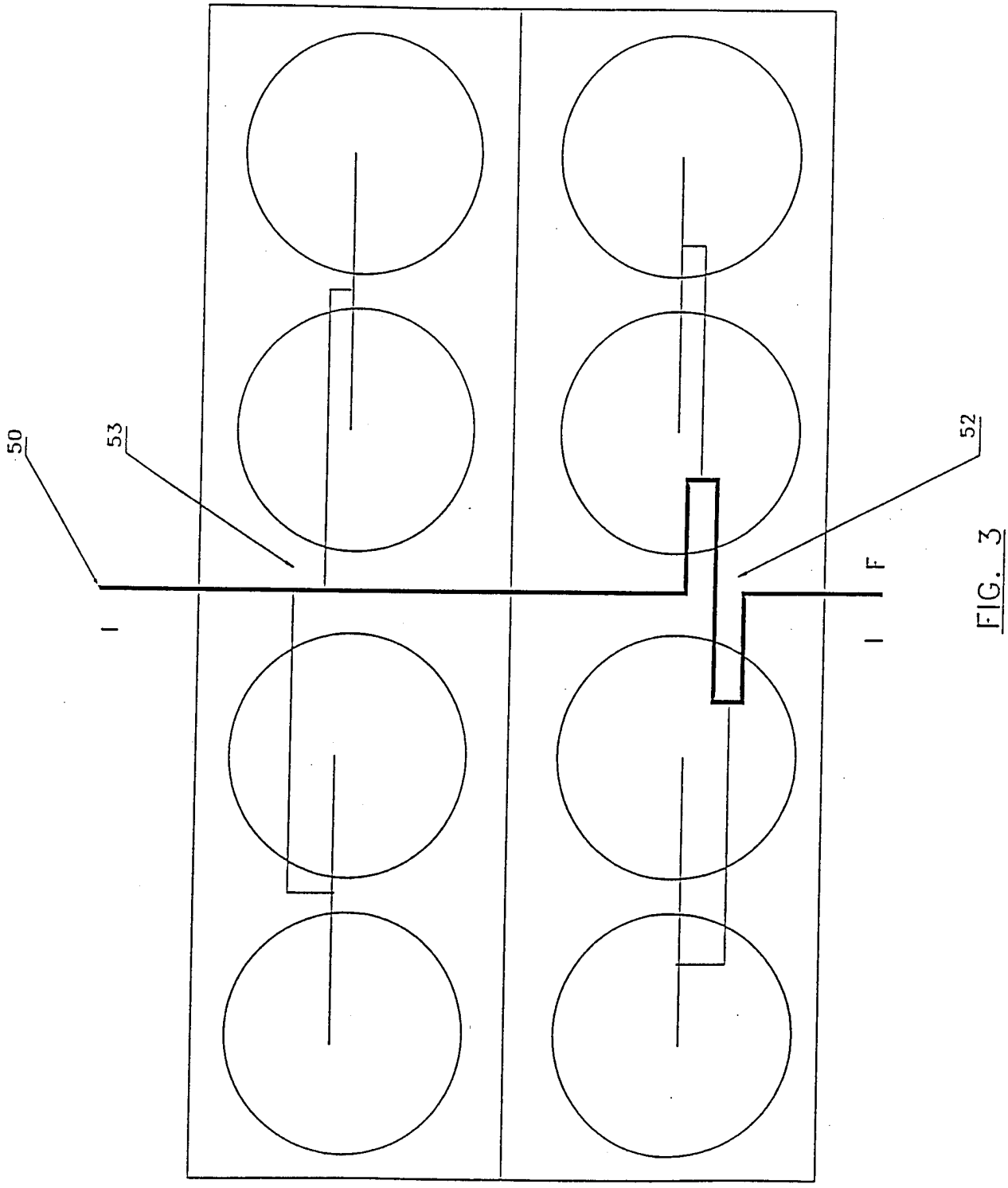


FIG. 3

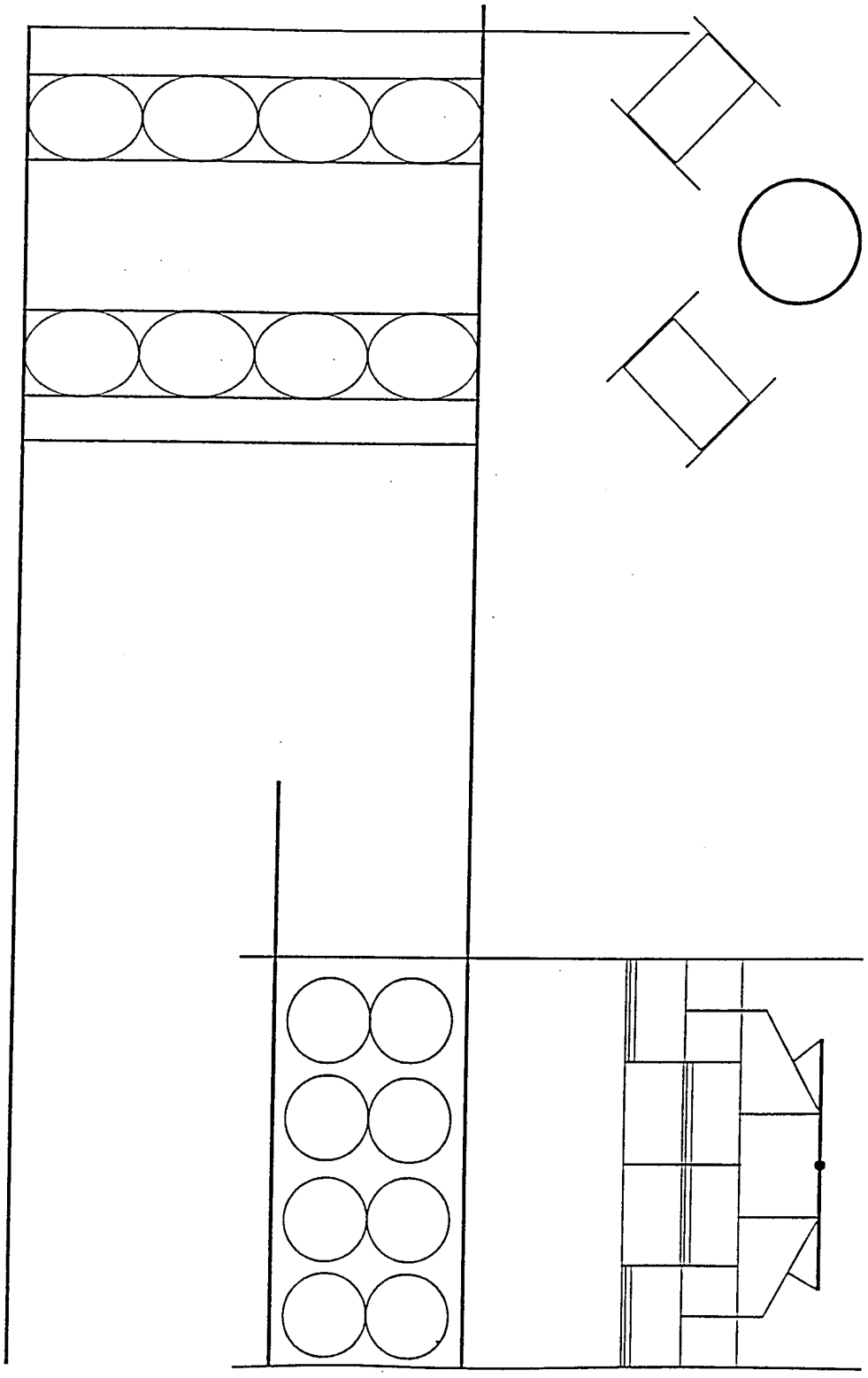


FIG. 4

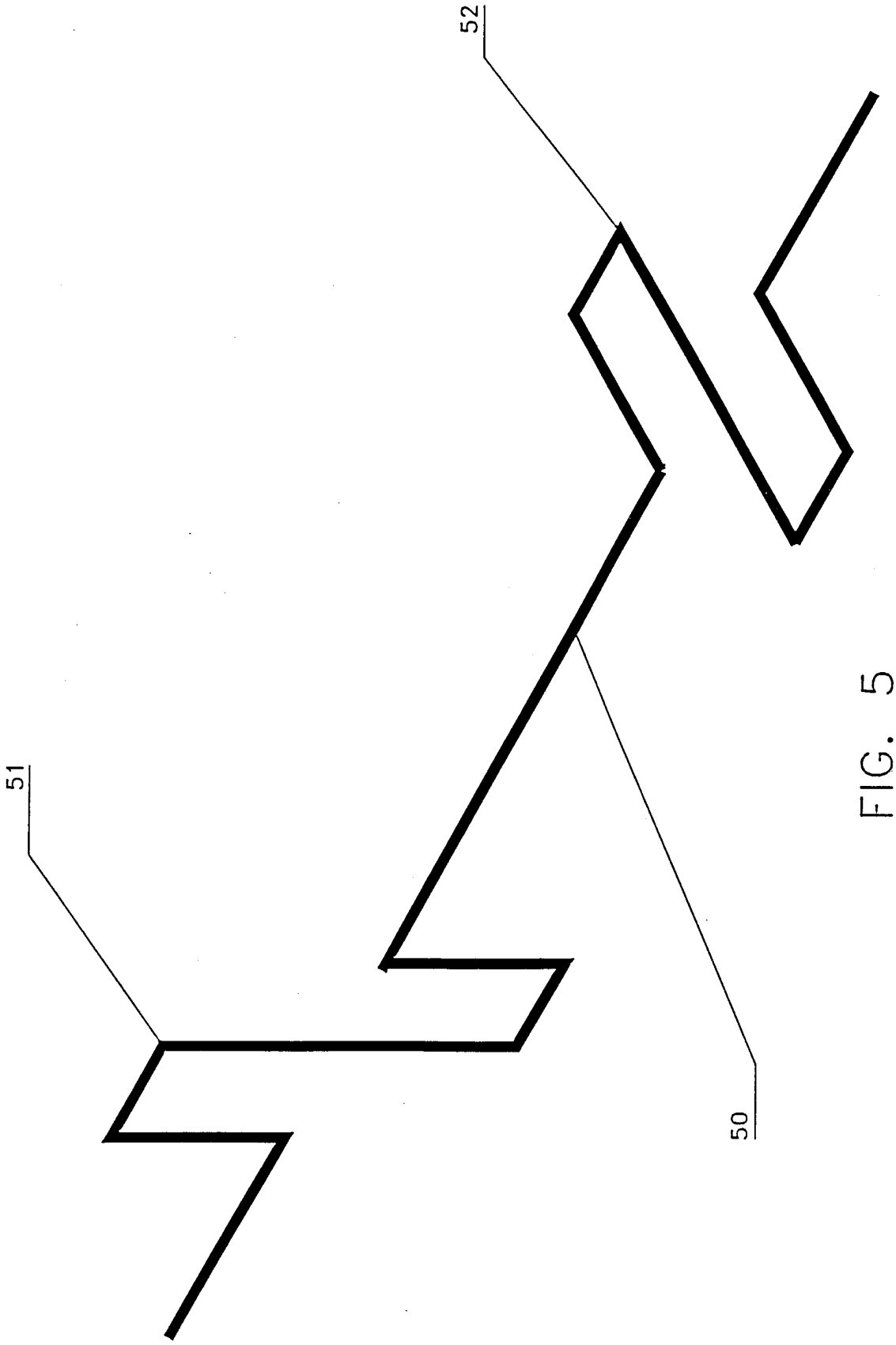


FIG. 5

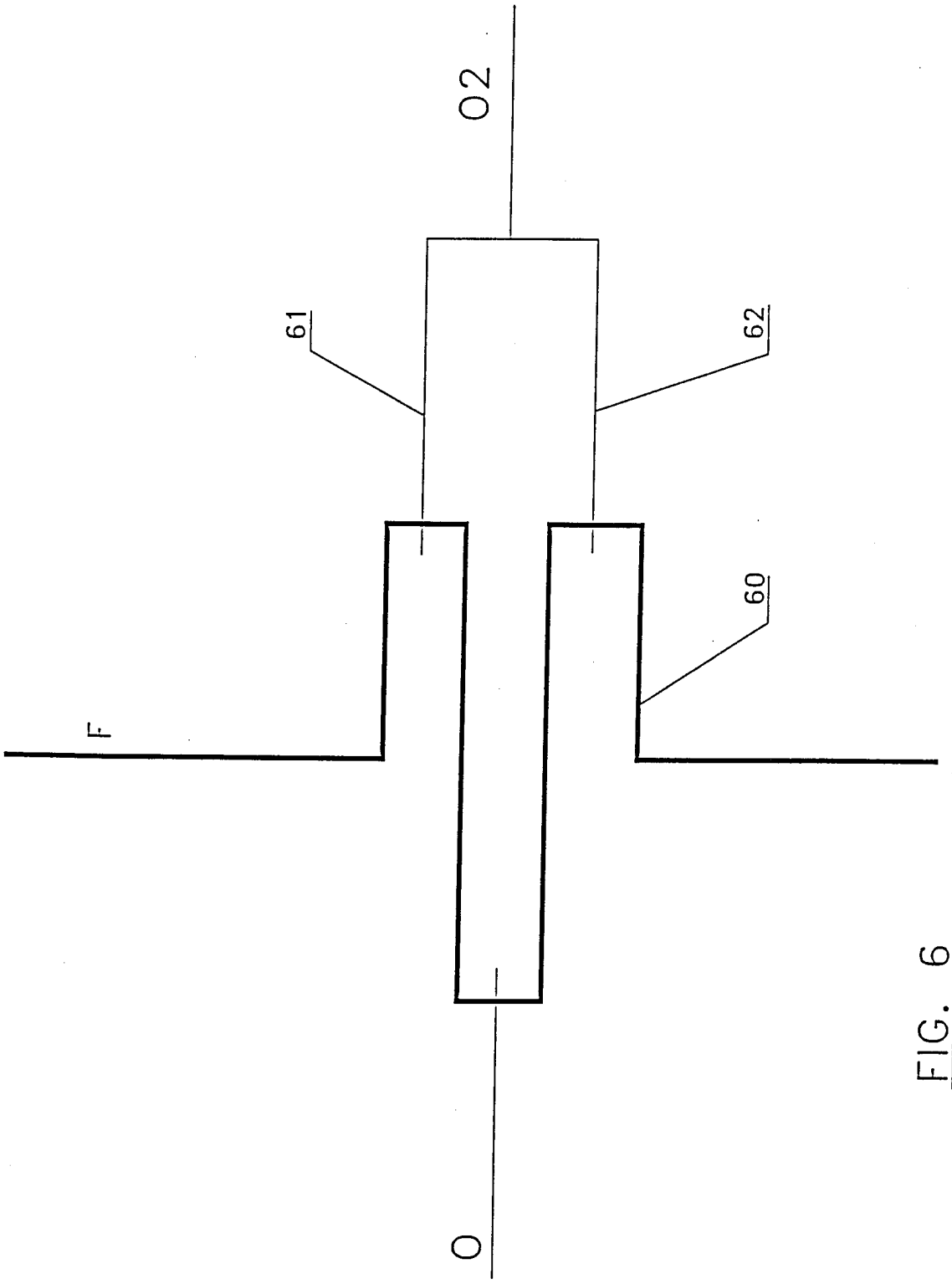


FIG. 6

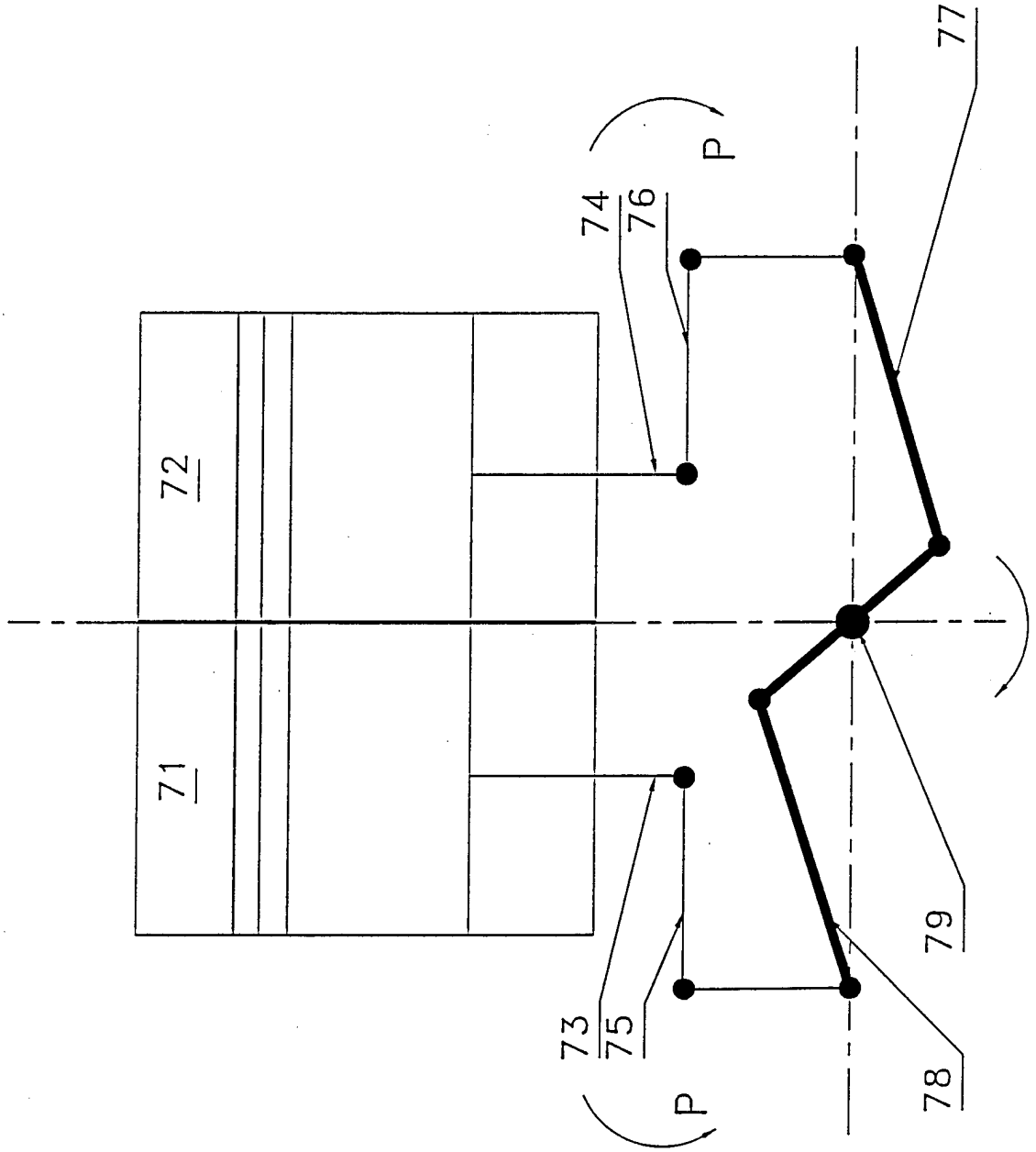
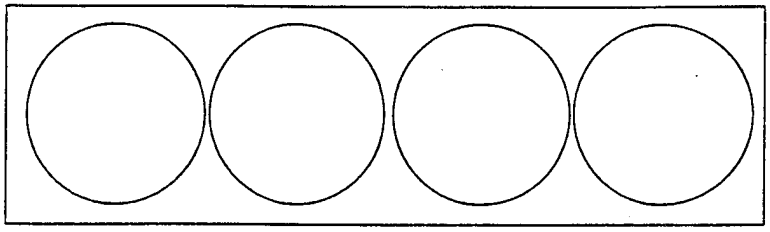
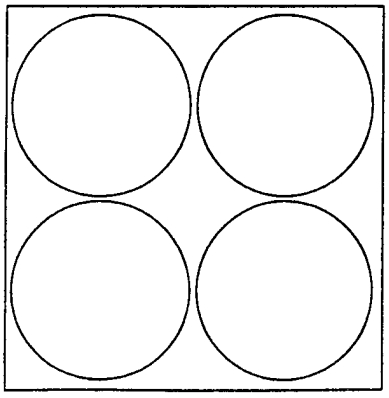


FIG. 7





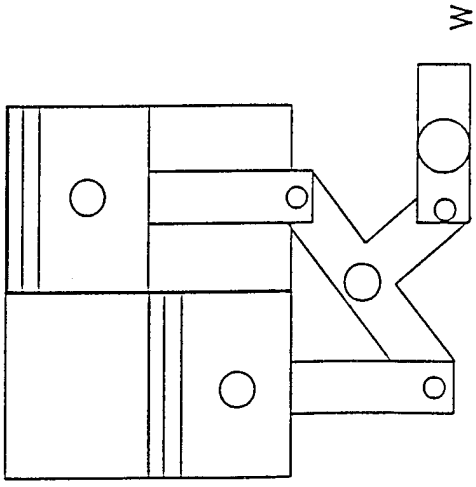
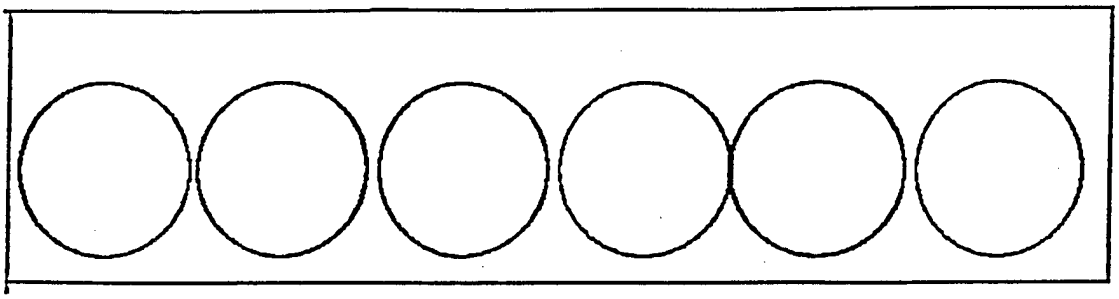


FIG. 8



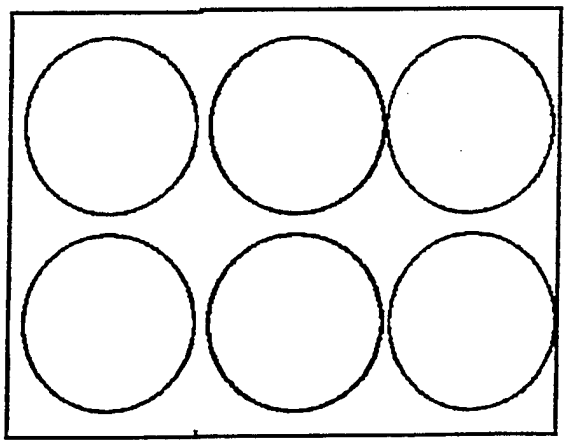


FIG.9

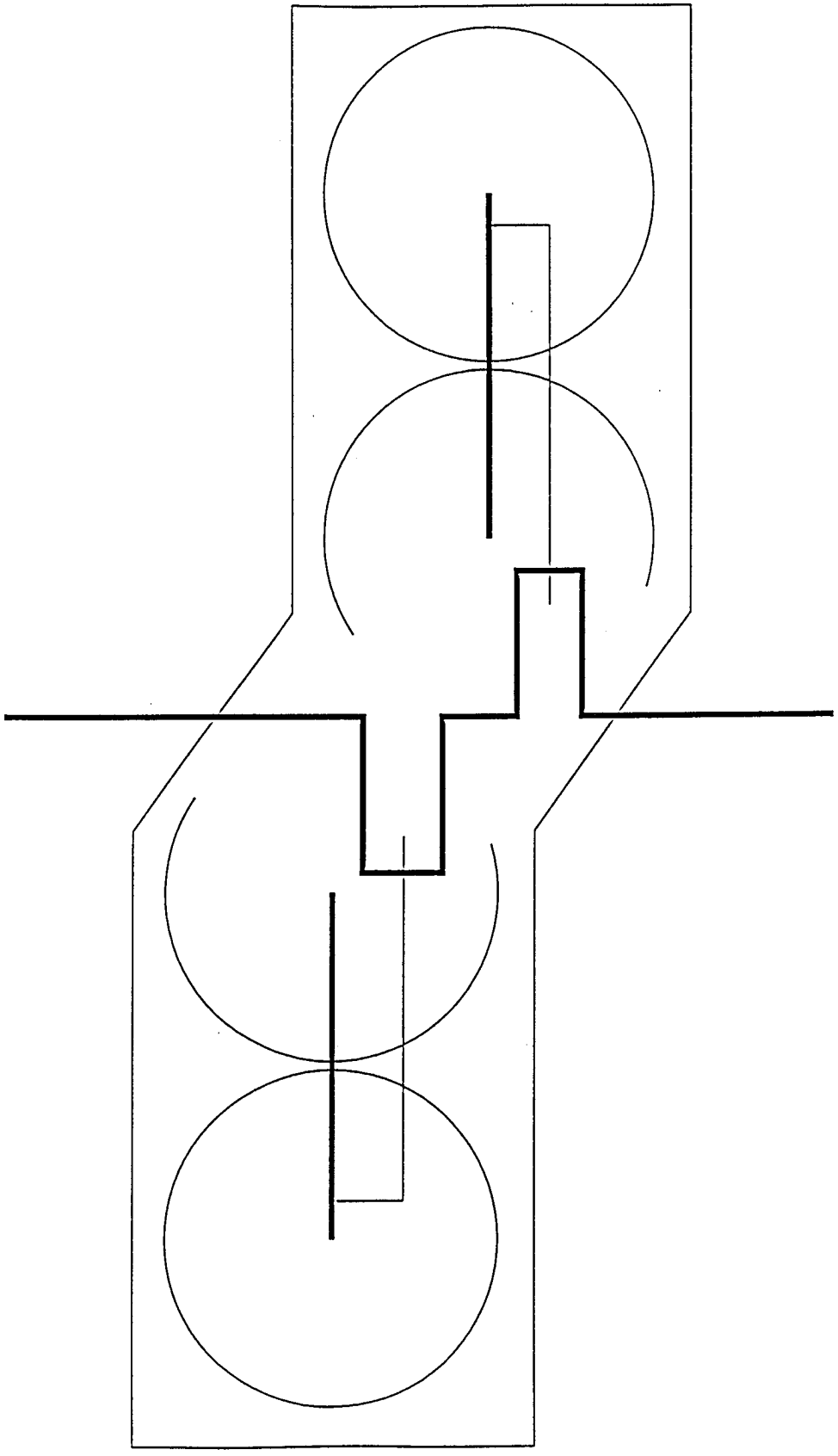


FIG. 10

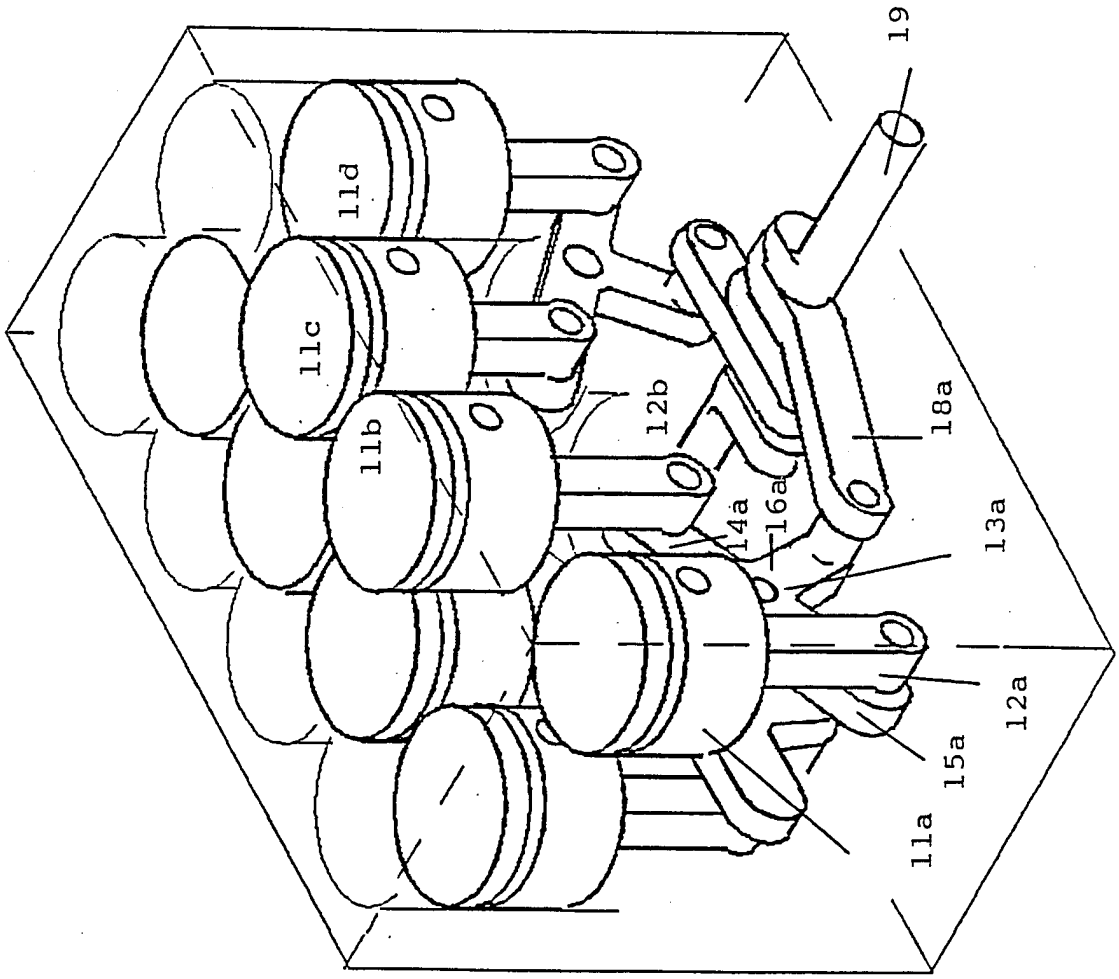


FIG.11

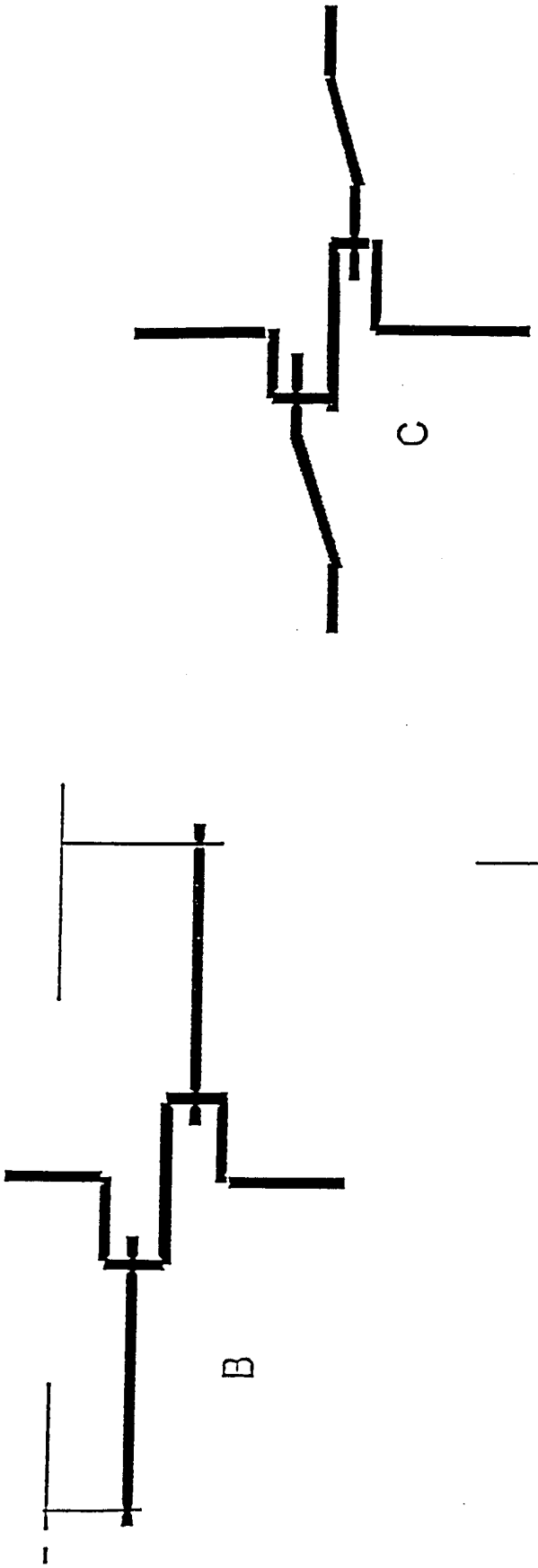


FIG.12

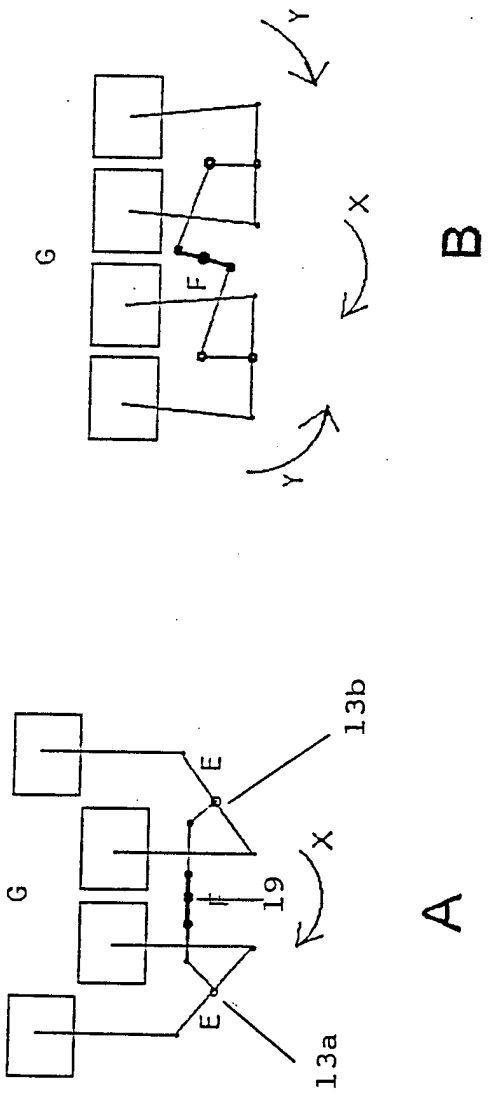


FIG. 13

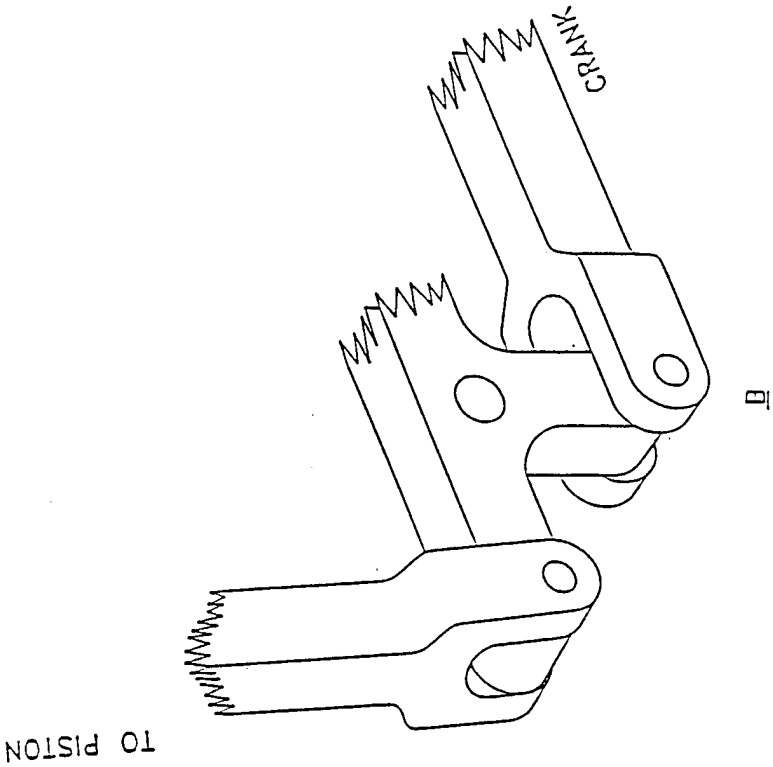


FIG. 14

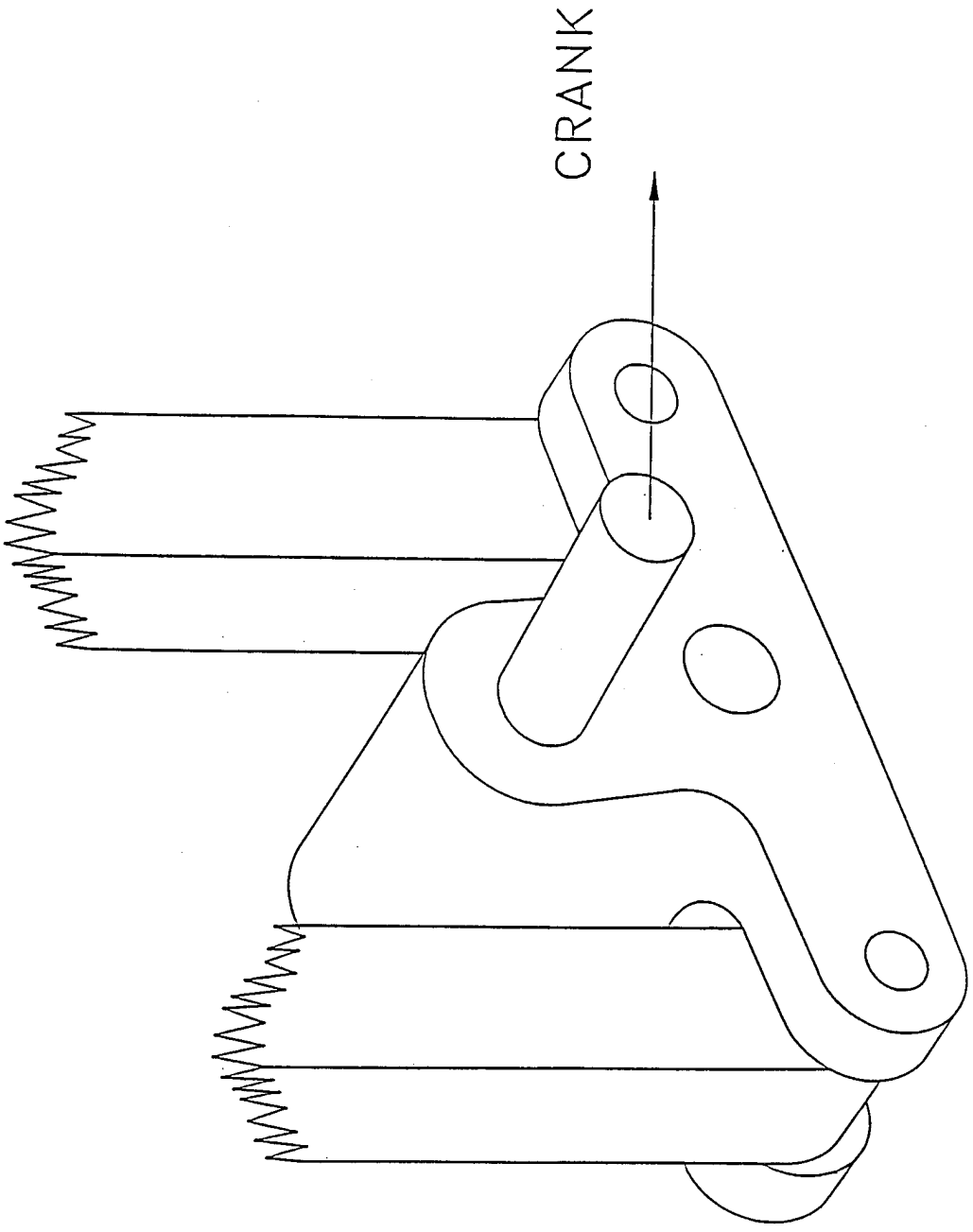
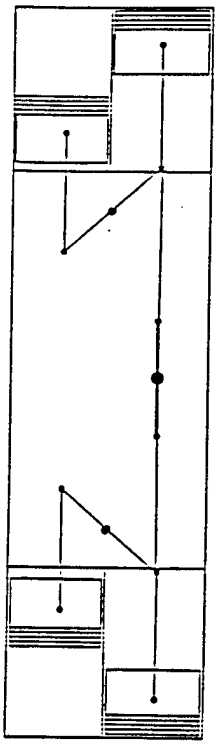
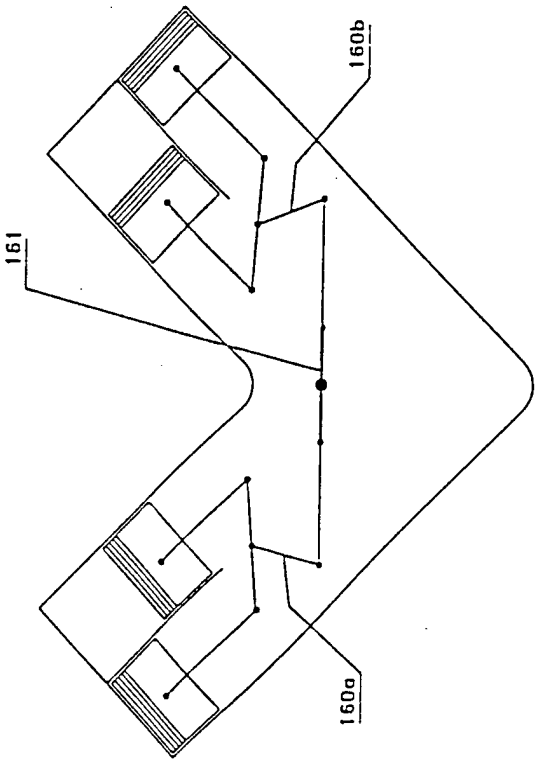


FIG. 15



(b)



(a)

FIG. 16

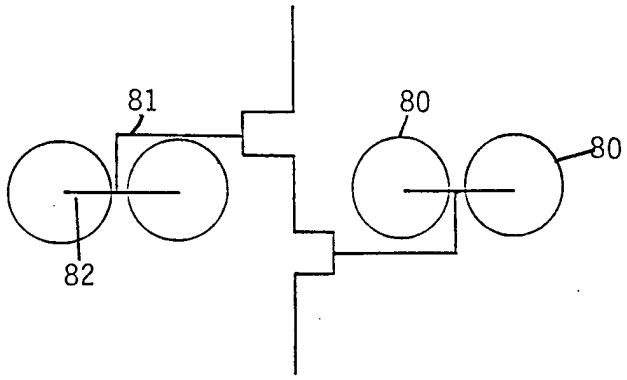


FIGURE 17

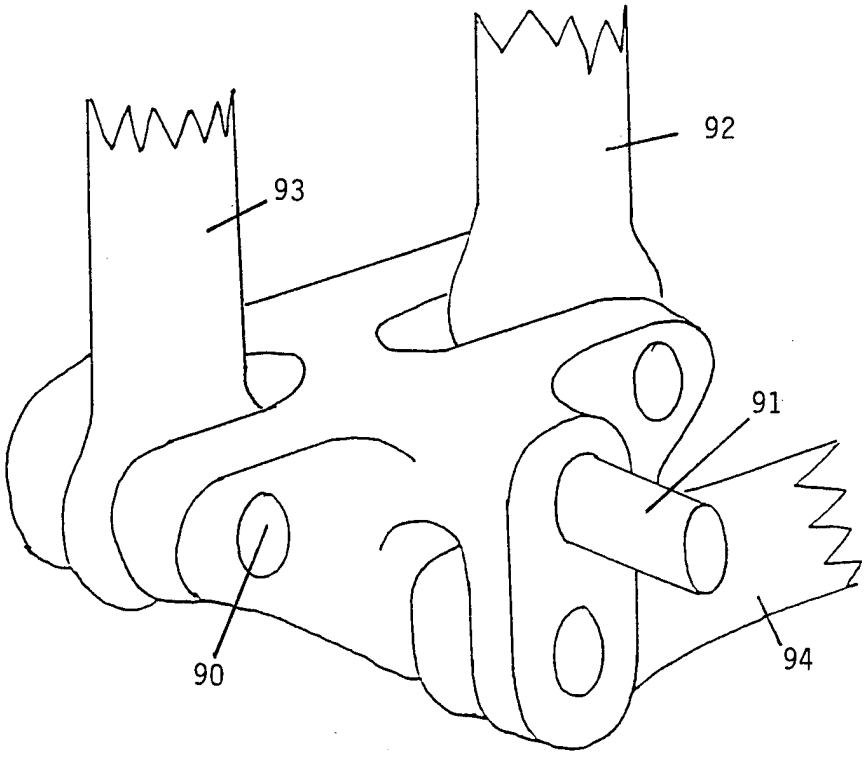


FIGURE 18

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/NZ 97/00148

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: F16H 21/18, F02B 75/32

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)
F16H 21/18, 21/50

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT, USPTO database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CH 289792 A (FORD MOTOR COMPANY) 1 July 1953 drawings	1-6

☐ Further documents are listed in the continuation of Box C

☐ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier 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
8 January 1998	14 JAN 1998

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	**JAGDISH BOKIL** Telephone No.: (02) 6283 2371

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/NZ 97/00148

Box 1 Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims No.: 7
because claim 7 is not drafted in accordance with Rule 6.2(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.