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(54) **System for acquiring, measuring and checking the operating parameters of a reciprocating fluid machine**

(57) The invention describes a validation system (50) for a reciprocating fluid machine. The system (50) comprises a base plate or foundation (52) on which at least one frame (46) of the reciprocating fluid machine is removably applied; a first shaft (54), rotatably coupled with the base plate (52), to activate the components (12, 14, 24) of the frame (46); at least one system for generating loads (80), placed in operative connection with such components (12, 14, 24) and put in rotation by a transmission system (58) through at least one second shaft (68). The system for generating loads (80) is able to simulate the loads generated by the working fluid on a cylinder (26) of the reciprocating fluid machine.

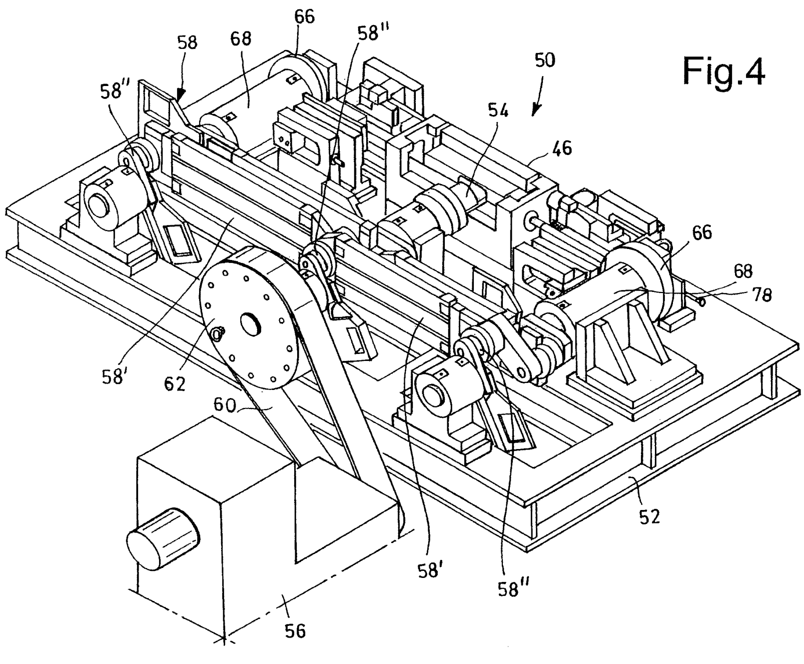

Fig.4

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Description

[0001] The present invention refers to a system for validating or checking a reciprocating fluid machine, in particular but not exclusively a reciprocating compressor of the type with single-acting cylinders connected to a cross-head.

[0002] As known, a compressor is a machine capable of raising the pressure of a compressible fluid (gas) through the use of mechanical energy. In reciprocating compressors the compression of the fluid is carried out by one or more pistons, moving with reciprocating motion inside a respective cylinder. The fluid to be compressed is taken into the cylinder through one or more intake ducts, whereas the compressed fluid is expelled from the cylinder towards one or more delivery ducts. Commonly, the piston or the pistons of a reciprocating compressor are actuated by electric motors or else by internal combustion engines, through a crankshaft for transmitting the motion and a conventional crank and connecting rod mechanism.

[0003] For example, in double-acting reciprocating compressors each piston does not carry out any "loadless" strokes, since it compresses the gas in both of its directions of motion. Precisely for this reason, the piston itself cannot be directly connected to the connecting rod of the crank and connecting rod mechanism, because the closed-type cylinder would not allow the connecting rod to oscillate. Thus a mechanism known as "cross-head" is placed between the piston and the connecting rod. The piston is connected to a rod, mobile exclusively with rectilinear motion, and the rod is connected to the cross-head. The stem does not therefore oscillate whereas the connecting rod, connected to the other side of the cross-head, can on the other hand oscillate freely.

[0004] The cross-head, through the sliding blocks with which it is provided, is able to slide inside suitable fixed guides, called "runners", which allow its movement in the same direction of stroke of the piston. Given that the outer surfaces of the sliding blocks of the cross-head move with respect to the inner surfaces of the relative guides, it is necessary to introduce lubricant oil that prevents them from making contact with each other. The lubrication system is of the forced type and, by providing the cross-head with support mainly of the hydrostatic type, it prevents the wearing of the moving parts involved.

[0005] During the reciprocating movement of the cross-head there can be particular operating conditions, for example when the piston moves at low speed, in which the cross-head is unable to feed a sufficient amount of lubricant oil. In such a situation the layer of lubricating oil becomes extremely thin and there can be losses by friction, with consequent production of heat and increase in the temperature of the lubricant oil itself that reduce its viscosity, further decreasing the lubricating capabilities. In the worst situations, the surfaces can even come into contact with each other, with consequent possible damage to the fluid machine.

[0006] Both the size and the set-up of a reciprocating compressor, whether it is single or double-acting, must therefore be carried out in a particularly precise manner, so as to avoid the occurrence of criticalities in the compressor itself when it operates in limit operating conditions. Consequently, the step of determining the operating parameters of a reciprocating compressor is extremely important, said parameters including the loads that weigh down upon the shaft of the piston and on the cross-head, the temperature, the pressure and the flow rate of the oil to lubricate the cross-head, the rotation speed of the crankshaft, the clearances between the sliding blocks and the runners and others.

[0007] Document WO 2005/108744 A1 illustrates an apparatus and method for checking the operation of a reciprocating compressor. The apparatus comprises a mobile element operatively connected to one of the moving components of the compressor, like for example the cross-head. The mobile element is provided with a sensor capable of detecting the parameter or parameters of interest, which will then be sent to an external data processing unit for the necessary evaluations. The reciprocating compressor must be complete in every part thereof in order to be able to correctly provide the required parameters.

[0008] Document WO 2008/157496 A1 describes a method for calculating the operating parameters of a reciprocating compressor. The method foresees the use of a program for a processor capable of simulating the operating conditions of the compressor. However, also in this case the basic parameters must be directly obtained from a real operating reciprocating compressor.

[0009] The known apparatuses and methods thus foresee the need to be able to have a reciprocating compressor, complete in every part thereof and operating, in order to be able to evaluate its characteristic parameters. This means that, in the case of parameters that are incorrect or not corresponding to those foreseen, modifications, even substantial ones, must be made to the machine, like for example the replacement of some of its fundamental components, with a consequent increase in costs and set-up time.

[0010] Moreover, the presence of the cylinder and of the relative systems for gas circulation, for cooling and for lubrication, although necessary when the compressor operates in normal mode, requires that the measurement of the parameters be carried out in a very complex testing environment, with consequent high energy absorption by the compressor itself, equal to what occurs in normal operating conditions of the machine, with consequent need for a motor of suitable power.

[0011] The general purpose of the present invention is therefore to make a system for acquiring and monitoring the operating parameters, applied in particular but not exclusively to a reciprocating compressor of the aforementioned type, which is able to solve the drawbacks quoted above of the prior art in an extremely simple, cost-effective and particularly functional manner, irrespective of the technical characteristics of the respective cylinders, thus being highly versatile.

[0012] Another purpose of the invention is to make a system for acquiring, measuring and checking the operating parameters of a reciprocating fluid machine that does not require the preparation of complete prototypes in order to work out its operating characteristics, being able to replace at least some of the component or systems normally present on each machine to be analysed, like for example the cylinders, the pistons, the valves and the gas circuits, cooling circuits and lubrication circuits, with simpler and interchangeable components.

[0013] A further purpose of the invention is to make a validation system that is easy to manufacture and that does not require complex and expensive actuations systems in order to be put into operation, since the energy required for its operation is much less than that necessary to make a complete reciprocating machine work.

[0014] These purposes according to the present invention are accomplished by making a validation system for a reciprocating fluid machine, in particular but not exclusively a reciprocating compressor, as outlined in claim 1.

[0015] Further characteristics of the invention are highlighted by the dependent claims, which are an integral part of the present description.

[0016] The characteristics and advantages of a system for validating, measuring and checking the operating parameters of a reciprocating fluid machine according to the present invention will become clearer from the following description, given as an example and not for limiting purposes, referring to the attached schematic drawings, in which:

[0017] figure 1 is a schematic section view that shows the main components of a reciprocating compressor;

[0018] figure 2 is a schematic view that shows the operating principle of a reciprocating compressor;

[0019] figure 3 schematically shows a reciprocating compressor, in a configuration with many cylinders;

[0020] figure 4 is a perspective view (flywheel side) that illustrates a non-limiting example embodiment of a system for validating the operating parameters of a reciprocating fluid machine according to the present invention;

[0021] figure 5 is another perspective view (cam side) of the system of figure 4;

[0022] figure 6 is a side elevational view (flywheel side) of the system of figure 4;

[0023] figure 7 is a plan view from above of the system of figure 4;

[0024] figure 8 is an enlarged side elevational view (cam side), of the system of figure 4; and

[0025] figures 9 to 11 show the operating principles of a system according to the present invention.

[0026] It should be noted that, in each figure, the same reference numerals correspond to the same systems or components of the previous and/or subsequent figures.

[0027] With reference in particular to figure 1, the essential elements present inside a reciprocating fluid machine, in this case represented by a reciprocating compressor of the double-acting type, are shown schematically.

[0028] The compressor comprises a shaft 10 with at least one crank, connected to a connecting rod 12 that transfers the rotary motion of the shaft 10, actuated by a generic motor 36, electric or thermal, through the interposition of a flywheel 38 (figure 3), to a cross-head 14 through a pin 16. The cross-head 14 has the task of converting rotary motion into reciprocating motion, being forced to move inside suitable opposite guides or runners 18 and 20 that allow it to move in the same direction as the stroke of the piston 22. A shaft 24, provided with a sealing system 44 consisting of a stuffing box, connects the cross-head 14 to the piston 22. The piston 22, moving inside the cylinder 26, is therefore able to compress the gas.

[0029] The gas to be compressed, at a certain intake pressure, is introduced inside the cylinder 26 through one or more intake valves 28 and 28' and is then compressed by the piston 22 so that it reaches a desired final pressure value. Once the gas has reached such a final pressure value, it is expelled from the cylinder 26 through one or more discharge valves 30 and 30'. In a double-acting cylinder 26, like the one schematised in figure 1, the compression takes place inside two distinct chambers, in other words the chamber 32 facing towards the head of the cylinder 26 and the chamber 34 facing towards the cross-head 14.

[0030] The compressor can be of the single-cylinder type or else it can have many cylinders 26, for example horizontal and opposite as shown in figure 3. A lubrication system 40 and a water-operated cooling system 42 complete the compressor and make it possible for it to work at the different rotation speeds.

[0031] The assembly of mechanical components of the compressor, in other words the shaft 10, the connecting rod 12, the shaft 24 and the cross-head 14, with the elements associated with it that ensure its reciprocating movement, can be identified as the frame 46 of the compressor itself. The frame 46 can thus be distinct from the cylinder 26 as a whole, i.e. provided with all of the hydraulic channels 28, 28', 30, 30', 40 and 42 associated with it, since there is no circuit for the circulation of the gas in it.

[0032] Now with reference to figures 4 to 10, a preferred embodiment of a system for validating, acquiring, measuring and checking the operating parameters of a reciprocating fluid machine according to the present invention is shown, wholly indicated with reference numeral 50.

[0033] The system 50 preferably comprises a base plate or a foundation 52 on which the components necessary for the operation of the system 50 itself are installed. Thus the base plate 52 has at least one frame 46 of a reciprocating fluid machine, in particular a reciprocating compressor, removably applied to it, where by frame 46 we mean the assembly of all of the components of the machine that do not comprise the circuits for the gas (see previous description). More specifically, the frame 46 comprises at least one connecting rod 12 and a cross-head 14, mobile with reciprocating motion and fixedly connected, at at least one of its two ends, to a shaft 24 that in turn is mobile with reciprocating motion.

[0034] The components 12, 14 and 24 of the frame 46 are moved with reciprocating motion by means of a first crankshaft 54, rotatably coupled with the base plate 52. In turn, the shaft 54 is set in rotation, based on a predefined angular velocity but in any case variable, by an actuation motor 56, preferably electric, through the interposition of an actuation system 58 supported by the base plate 52.

[0035] In the illustrated example embodiment, the actuation system 58 consists of a system of rigid connecting rods 58' and of respective crankshafts 58", actuated by the motor 56 through a belt 60 and a flywheel-pulley 62. The flywheel 62 is connected to the first crankshaft 54 through the central crankshaft 58".

[0036] According to the invention, on the base plate 52 of the system 50 at least one system for generating loads 80 is mounted that is suitable for replicating the loads of the gas acting on the frame 46, as occurs in the real fluid machine.

[0037] In a particularly advantageous embodiment of the invention, the system for generating loads 80 is of the mechanical type. Clearly it should not be ruled out that such a system for generating loads 80 can be of any other type, like for example hydraulic, electric, pneumatic or other.

[0038] In the preferred embodiment, the system for generating loads 80 comprises an elastic or yielding element 64 placed in operative connection with at least one eccentric or cam 66.

[0039] More specifically, each elastic element 64 is interposed between each shaft 24 and each eccentric 66 (see diagrams of figures 10 and 11) and is compressed and released in sequence based on the reciprocating motion of the shaft 24 of the frame 46 and the rotary motion of the eccentric 66, which occur simultaneously. The assembly consisting of the elastic element 64 and the eccentric or cam 66 is thus able, once actuated by the motor 56 and after having been suitably calibrated, as will be specified more clearly hereafter, to simulate the load of the cylinder 26 of a generic reciprocating fluid machine, like for example the reciprocating compressor described earlier. In practice, each elastic element 64, made in the form of a coil spring operating by compression in the illustrated example embodiment, is able to reproduce the same forces that act on the components of the reciprocating compressor (in particular on the cross-head 14 and on the relative pin 16), in the operating conditions of interest.

[0040] A yielding element 74 is advantageously and preferably interposed between the eccentric 66 and the spring 64 to decrease the friction and promote the contact between the cam and the spring.

[0041] In an advantageous embodiment, a further elastic element 82 (figures 5 and 8) is associated with the shaft 68 of the cam and with the shaft of the yielding element 74, so as to ensure the contact between yielding element 64 and cam 66 in every operation condition. This elastic element 82 can be adjusted through an adjustment element 78 that, in the case shown in the figures, is made with a screw 78 acting on a plate 76.

[0042] In this way it is possible to uncouple the rigidity of the main spring 64 (designed so as to obtain the desired load on the cross-head 14) from that necessary to maintain the contact between yielding element 64 and cam 66 for any rotation speed.

[0043] The system 50 is advantageously provided with one or more sensors 84 capable of acquiring and measuring the operating parameters relative both to the frame 46 and to the assembly consisting of the spring 64 and the cam 66, which reproduces the cylinder 26. Such parameters comprise:

- clearances (in thousandths of a millimetre) between sliding blocks of the cross-head 14 and relative runners 18 and 20;
- crank angle (θ);
- forces ($F\theta$) acting upon the cross-head 14 and upon the shaft 24;
- rotation speed (ω) of the shaft 10 and linear speed ($V\theta$) of the cross-head 14;
- temperature, pressure and flow rate of the lubricant oil present in the gap between sliding blocks of the cross-head 14 and relative runners 18 and 20.

  All of the parameters acquired and measured by the sensors 84 can be sent, through a suitable wireless communication line 70 or via cable, to a central processing unit (not shown), capable of recording and graphically representing, in real time, such parameters according to each single revolution of the shaft 54.

[0044] The system 50 according to the invention is therefore capable of carrying out validation tests of reciprocating fluid machines such as compressors, for example in the operating conditions known as full load or partial load, without the need to also make and actuate the cylinder or the cylinders 26 of the machine with the relative gas delivery and expulsion circuits, which use up a substantial amount of energy. One of the advantages of the system 50 is indeed the fact that the actuation motor 56 can deliver a substantially lower power with respect to what is required of a normal motor 36 able to be used for normal operation of a complete reciprocating compressor. This is essentially due to the fact that during the operation of the system 50, when the spring 64 is released during the return stroke of the cross-head 14, the spring 64 itself returns the energy absorbed in the outward stroke (see diagrams of figure 11), decreasing the power requirement that the actuation motor 56 must deliver.

[0045] In the case in which measurements and/or validations have to be carried out on different machines or for different requirements, in addition to the possibility of removing the frame 46 from the system 50 (as mentioned earlier and as shown, for example, in figure 5), it is also possible to remove the springs 64 and/or the cams 66 from the system 50, replacing them with other springs and/or cams of a different type. For example, it is possible to use springs 64 with different dimensions and elastic coefficient, or else differently designed cams 66.

[0046] Alternatively or in addition, again in order to vary the test conditions of the reciprocating machine, the system 50 can be provided with one or more preloading devices 72 acting upon each spring 64. In detail, based upon the illustrated example embodiment, the preloading device 72 (figure 8) consists of a rotary ring nut system, operating according to the screw-nut principle, interposed between the shaft 24 of the frame 46 and the relative spring 64. The preloading device 72 is thus able to increase or decrease the compression on the spring 64, respectively, by bringing the shaft 24 closer to or farther from the spring 64 itself.

[0047] The system 50 according to the invention can be made based on different embodiments from the one described and illustrated up to here, whilst still maintaining the basic operating principles shown in the diagrams of figures 9-11. For example, the transmission of motion from the actuation motor 56 to the shafts 54 and 68 could take place through a series of linkages 58 different from the rigid connecting rods 58' and from the respective cranks 58". The linkages 58 could indeed consist, according to the technical requirements, of a system of belts, chains and/or gears interposed between the actuation motor 56 and the shafts 54 and 68, or else other equivalent systems. Similarly, a different number of motors can be foreseen. However, it should be specified that the system consisting of the rigid connecting rods 58' and the respective crankshafts 58" is considered to be preferable to ensure the perfect phased rotary movement of the shafts 54 and 68 that respectively control the reciprocating movement of the frame 46 and the rotary movement of the cams 66.

[0048] It should also be noted that it is possible to make a frame 46 that reproduces to scale a frame of a real compressor. In this way the system 50 is able to carry out validation tests on a scale prototype of the real compressor, substantially decreasing its manufacturing and installation costs and at the same time increasing its versatility.

[0049] The system according to the present invention is particularly useful for the acquisition, measurement and checking of the operating parameters of a reciprocating fluid machine for high performance in industrial systems or plants where making the circuit for the gas is particularly complex and expensive, like for example in industrial plants for producing low density polyethylene that work at pressures of up to about 3500 bars or more.

[0050] Clearly it should not be ruled out that such a system can be used on reciprocating machines or industrial plants of a different type.

[0051] The system for acquiring, measuring and checking the operating parameters of a reciprocating fluid machine of the present invention thus conceived can in any case undergo numerous modifications and variants, all of which are covered by the same inventive concept; moreover, all of the details can be replaced with technically equivalent elements. In practice, the materials used, as well as the shapes and sizes, can be whatever according to the technical requirements.

[0052] The scope of protection of the invention is therefore defined by the attached claims.

Claims

1. Validation system (50) for a reciprocating fluid machine, the system (50) comprising:

   - a base plate or foundation (52) on which at least one frame (46) of said reciprocating fluid machine is removably applied;
   - a first shaft (54) rotatably coupled with said base plate (52), to activate the components (12, 14, 24) of said frame (46); and
   - at least one system for generating loads (80), placed in operative connection with said components (12, 14, 24) and put in rotation by an actuation system (58), said system for generating loads (80) being able to simulate the loads generated by the working fluid on a cylinder (26) of said reciprocating fluid machine.

2. System (50) according to claim 1, **characterized in that** said reciprocating fluid machine is of the high performance type.

3. System (50) according to claim 1, **characterized in that** said system for generating loads (80) is of the mechanical, pneumatic, hydraulic or electric type, or a similar type.

4. System (50) according to any one of the previous claims, **characterized in that** said system for generating loads (80) comprises at least one first elastic element (64) placed in operative connection with said components (12, 14, 24) and put in rotation by at least one eccentric (66), in turn put in rotation by at least one second shaft (68) of said actuation system (58).

5. System (50) according to claim 4, **characterized in that** it comprises one or more preloading devices (72) acting on said first elastic element (64), so as to adjust its preloading according to the specific application.

6. System (50) according to claim 4 or 5, **characterized in that** it comprises a yielding element (74) interposed between said eccentric (66) and said first elastic element (64) to decrease the friction and promote the contact between them.

7. System (50) according to claim 6, **characterized in that** it comprises a second elastic element (82) associated with said eccentric (66) and with said yielding element (74), so as to ensure the contact between them in any operative condition and to uncouple the rigidity of said first elastic element (64) from that necessary to maintain the contact between said yielding element (74) and said eccentric (66).

8. System (50) according to claim 7, **characterized in that** it comprises an adjustment element (78) suitable for adjusting the preloading of said second elastic element (82), so as to further improve the contact between said eccentric (66) and said yielding element (74).

9. System (50) according to any one of claims 4 to 8, **characterized in that** said first elastic element (64) and said at least one eccentric (66) are suitable for being removed from said system (50) to be replaced with elastic elements and/or with eccentrics of a different kind, in the case in which measurements and/or validations must be made on different reciprocating fluid machines or for different requirements.

10. System (50) according to claim 1, **characterized in that** said actuation system (58) is a mechanical system, provided with at least one actuation motor (56), and it is configured so as to at least partially return the energy absorbed in the outward stroke during the return stroke, decreasing the power that said actuation motor (56) must deliver.

11. System (50) according to claim 10, **characterized in that** said actuation system (58) consists of a system of rigid connecting rods (58') and of cranks (58") actuated by said actuation motor (56).

12. System (50) according to any one of claims 4 to 11, **characterized in that** it comprises one or more sensors (70) capable of acquiring and measuring the operating parameters relative both to said frame (46) and to the assembly consisting of said first elastic element (64) and said eccentric (66).

Fig.1

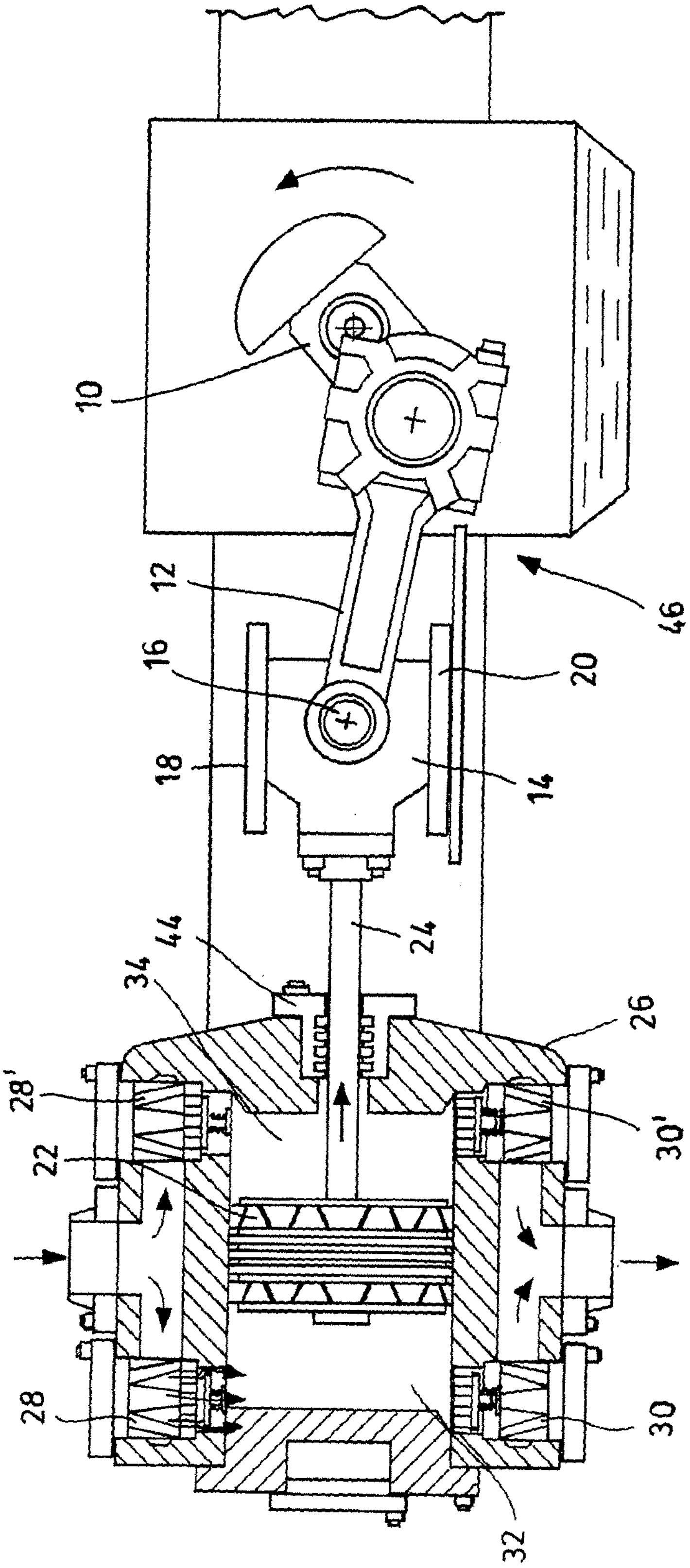


Fig.2

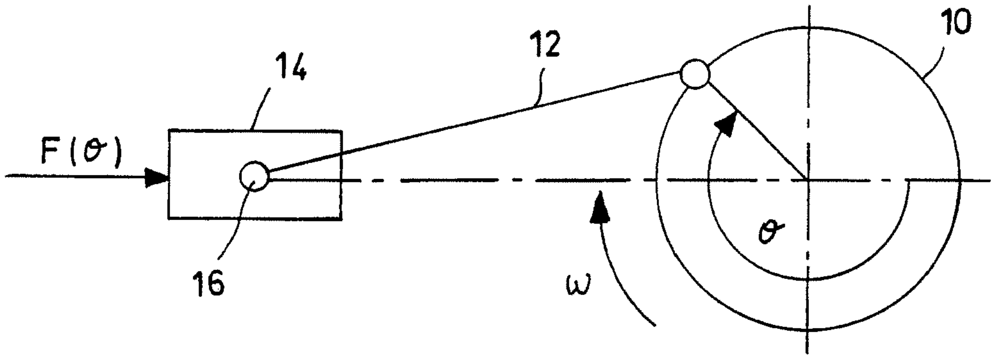
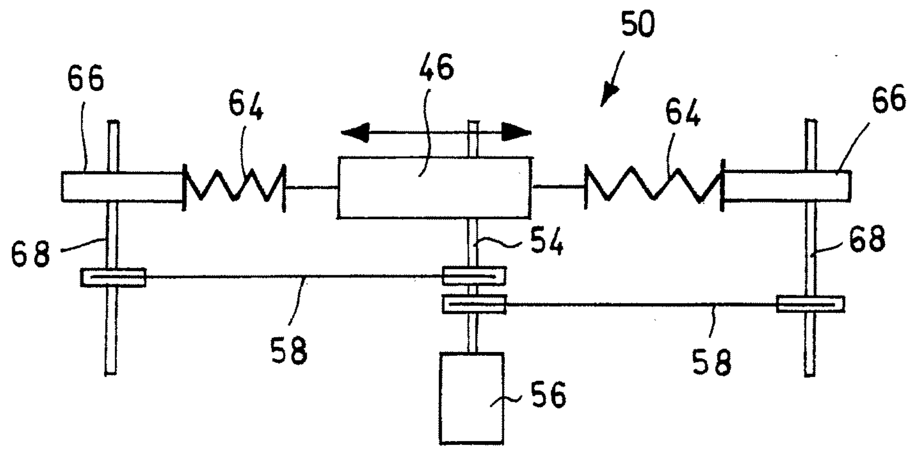


Fig.10



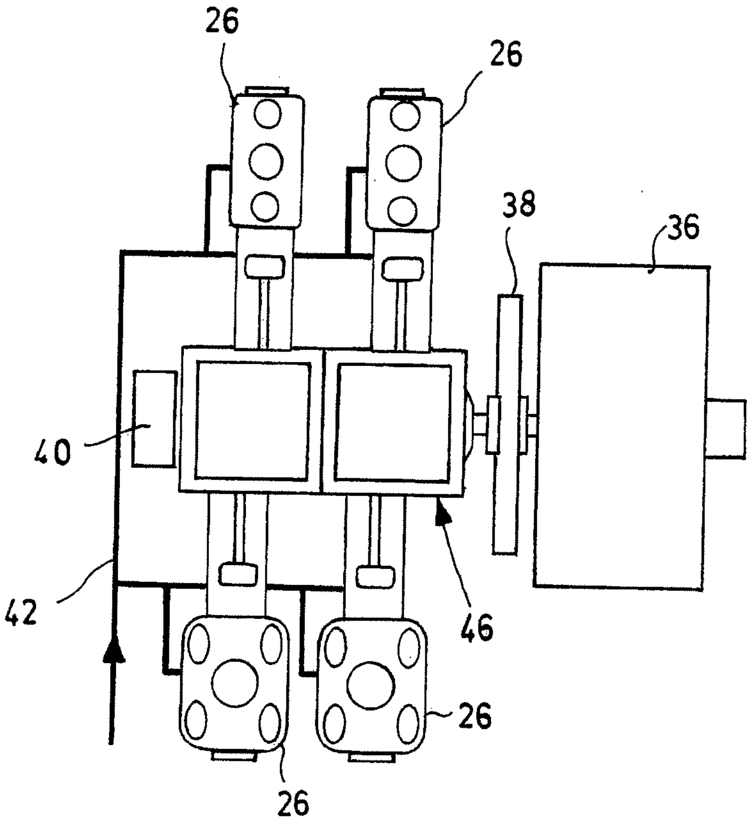


Fig.3

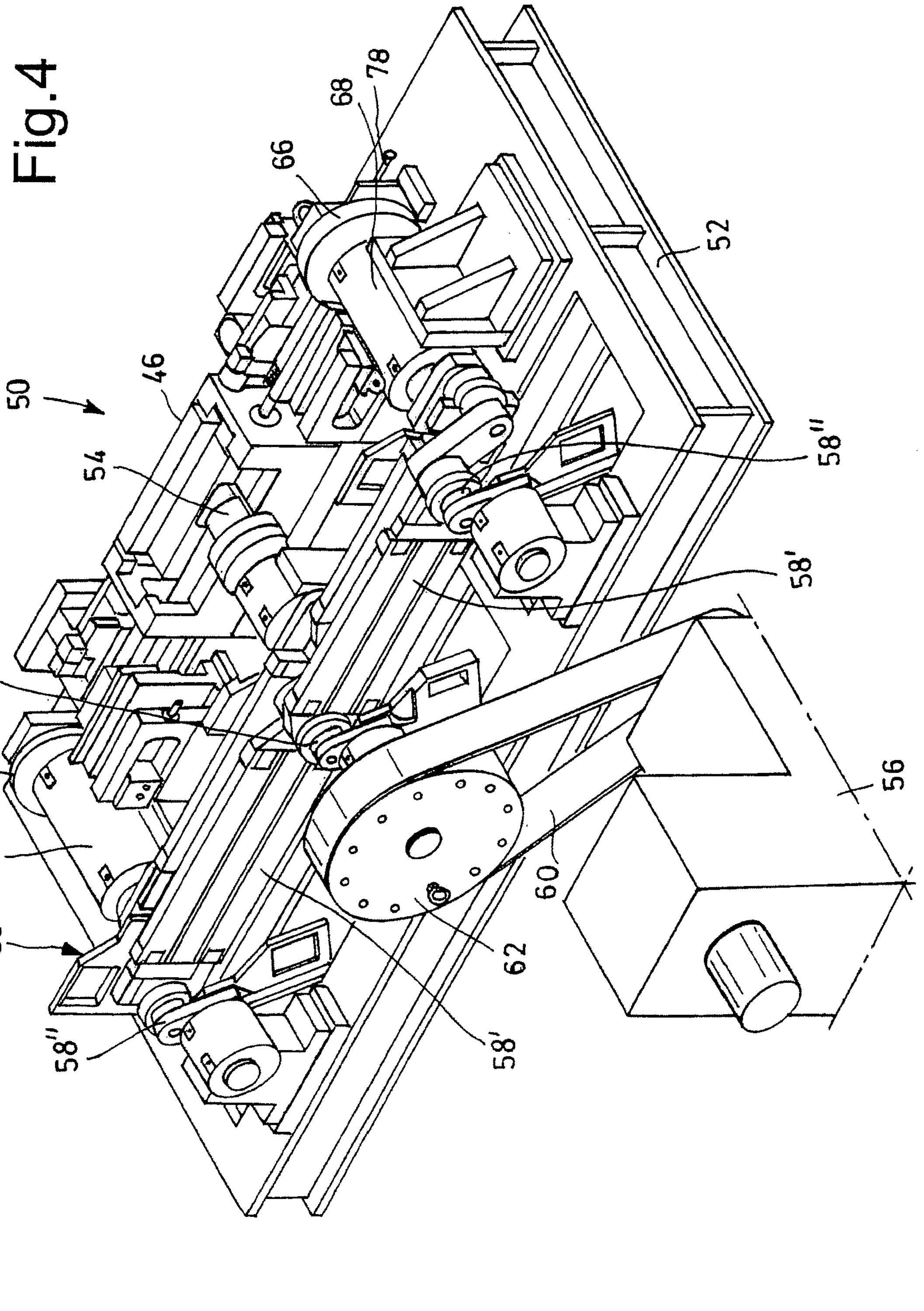


Fig.4

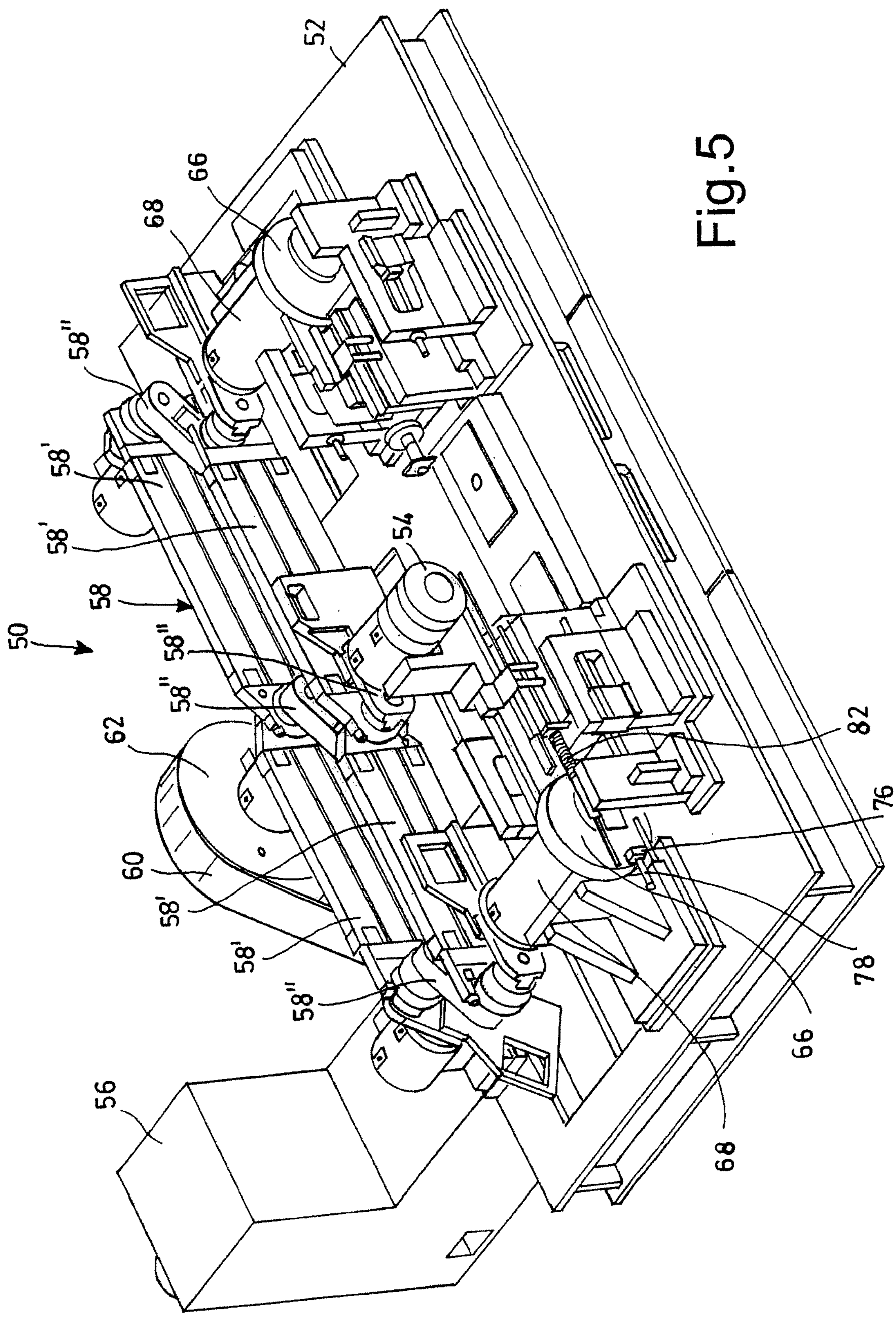


Fig.5

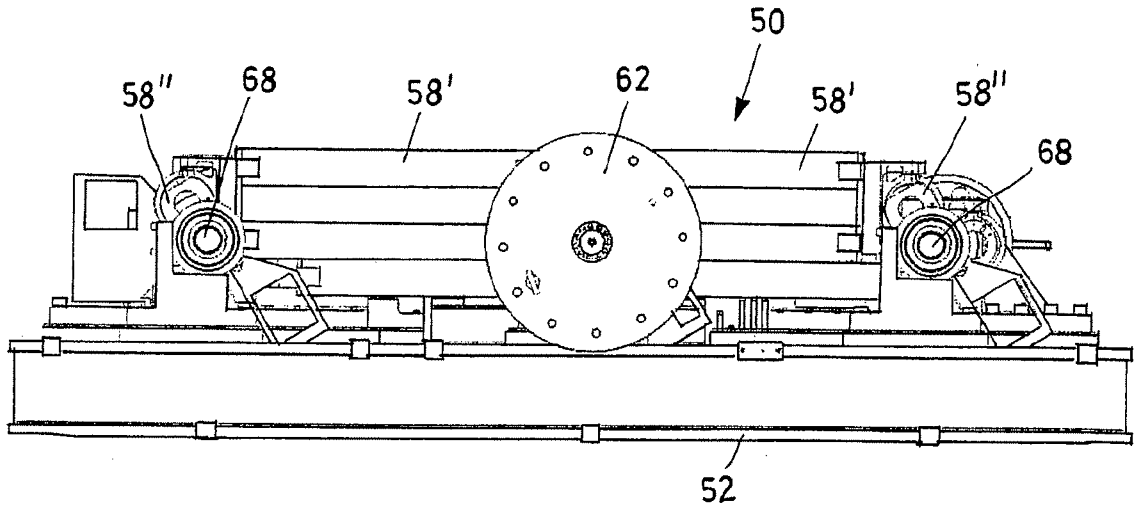

50
58''
68
58'
62
58'
58''
68
52

Fig.6

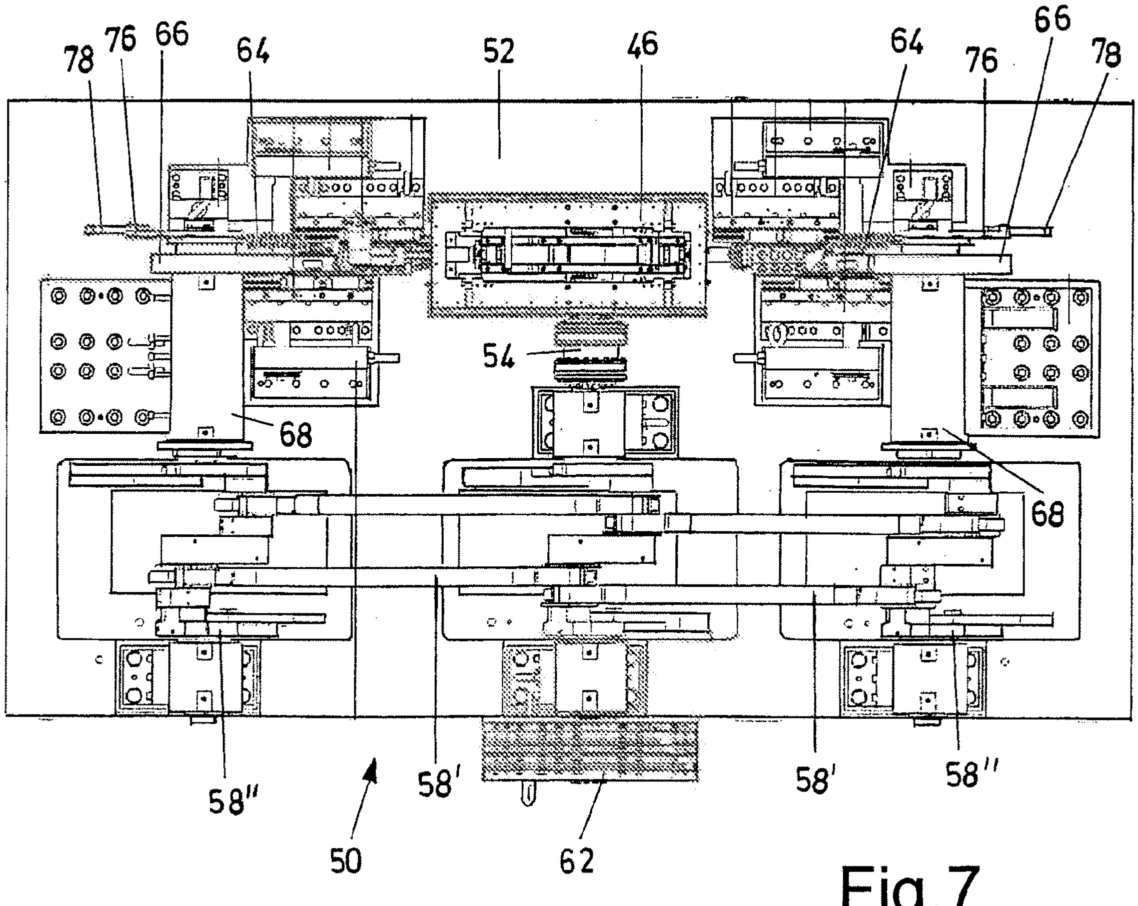

78
76
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Fig.7

Fig.8

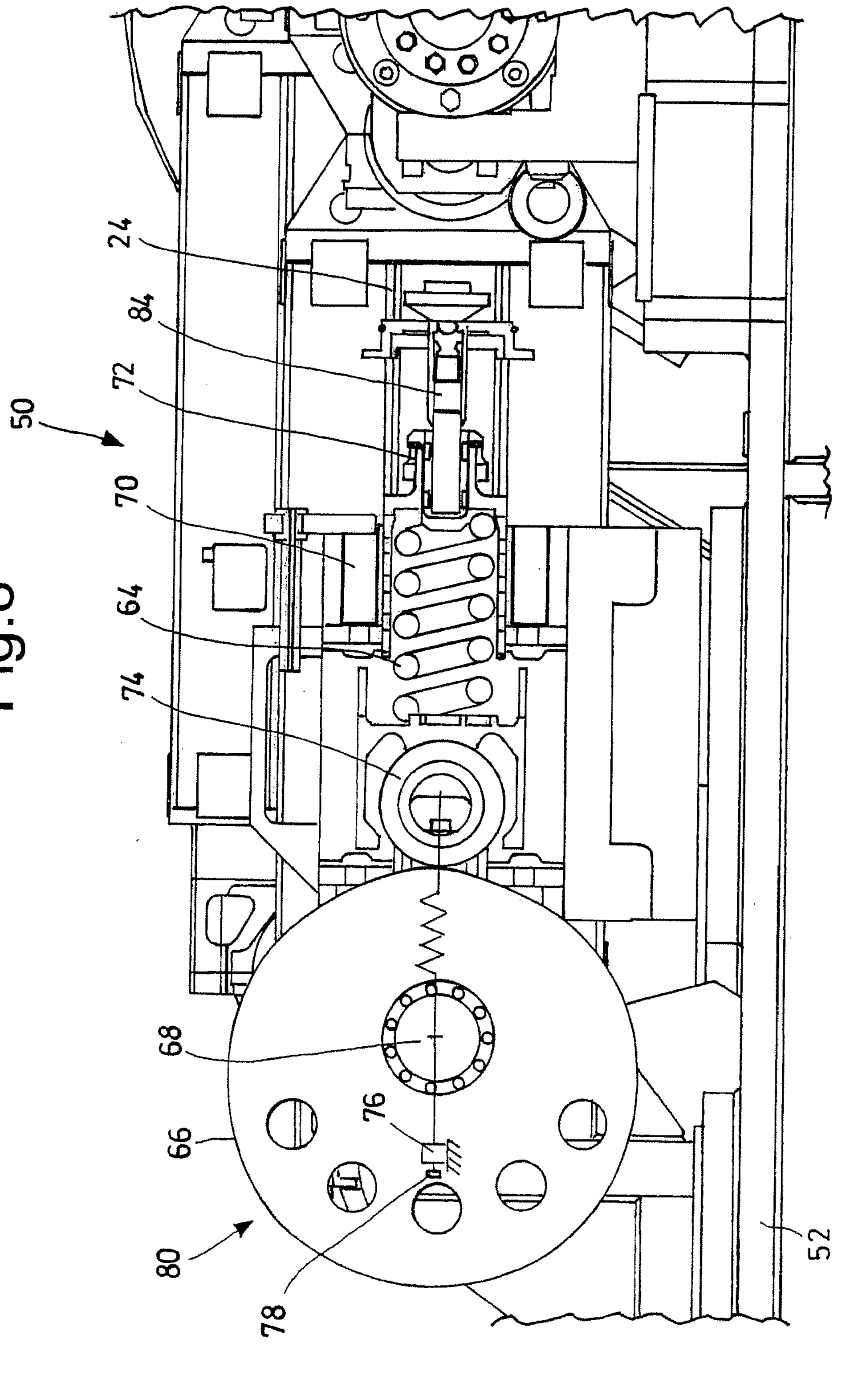
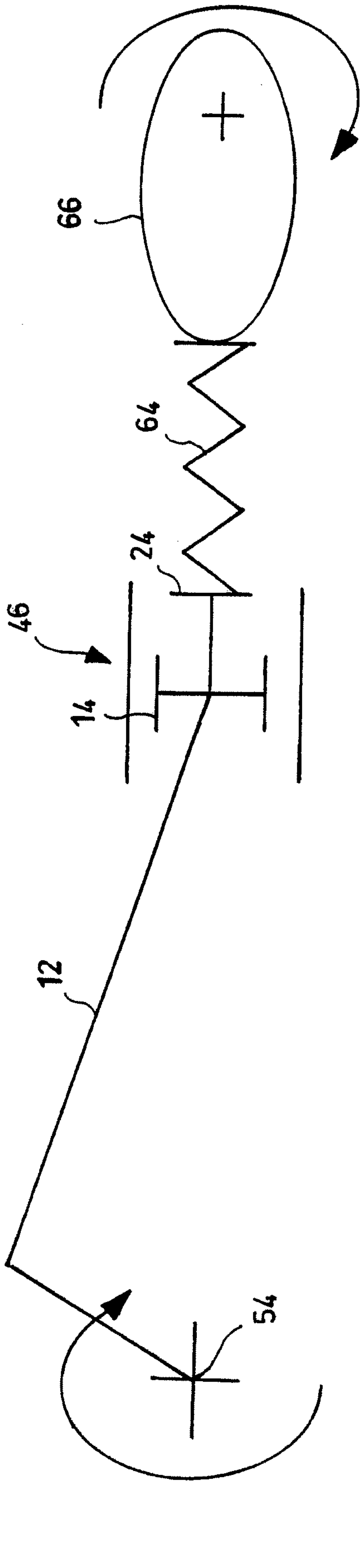


Fig.9



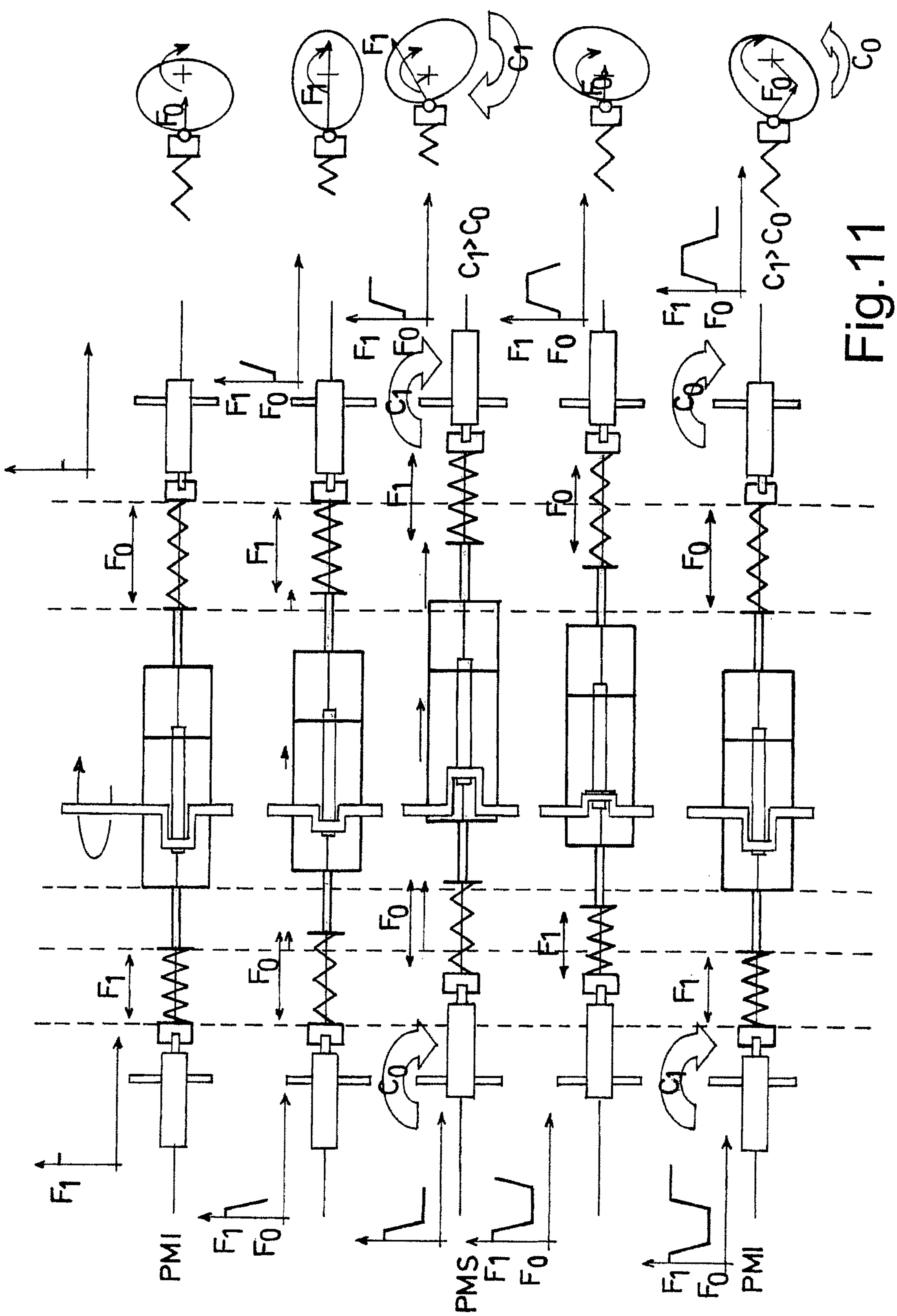


Fig.11

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EUROPEAN SEARCH REPORT

Application Number
EP 10 18 1336

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2005 009840 A1 (DYNA MESS PRUEFSYSTEME GMBH [DE]) 7 September 2006 (2006-09-07) * the whole document * * paragraphs [0026] - [0028], [0045] - [0051], [0068] - [0084], [0087], [0090] * * figure 1 * -----	1-5,9, 10,12	INV. F04B51/00
X	US 5 908 982 A (WALSH JAMES B [US] ET AL) 1 June 1999 (1999-06-01) * the whole document * * column 2, line 28 - column 3, line 14 * * column 3, line 61 - column 4, line 4 * * figure 1 * -----	1-3	
X	DE 196 13 042 C2 (PAHNKE HANS JOACHIM [DE]) 20 May 1998 (1998-05-20) * the whole document * * column 3, line 45 - column 4, line 27 * * figure 1 * -----	1-3,10	
			TECHNICAL FIELDS SEARCHED (IPC)
X	US 5 103 671 A (DYVIG DANIEL E [US]) 14 April 1992 (1992-04-14) * the whole document * * column 4, line 6 - column 6, line 4 * * figure 1 * -----	1-4,10	F04B G01M
X	GB 794 464 A (MASCHF AUGSBURG NUERNBERG AG) 7 May 1958 (1958-05-07) * the whole document * * page 1, lines 41-70 * * page 2, line 46 - page 3, line 8 * * figure 1 * ----- -/--	1-3	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	5 January 2011	Gombert, Ralf

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	RUEHLICKE I: "ELEKTRO-HYDRAULISCHE ANTRIEBSSYSTEME MIT DREHZAHLVERAENDERBARER PUMPE", O + P OLHYDRAULIK UND PNEUMATIK, VEREINIGTE FACHVERLAGE, MAINZ, DE, vol. 41, no. 9, 1 September 1997 (1997-09-01), pages 689-693, XP000699759, ISSN: 0341-2660 * the whole document * * figure 1 * -----	1-12	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	5 January 2011	Gombert, Ralf

CATEGORY OF CITED DOCUMENTS

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REFERENCES CITED IN THE DESCRIPTION

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- WO 2008157496 A1 **[0008]**