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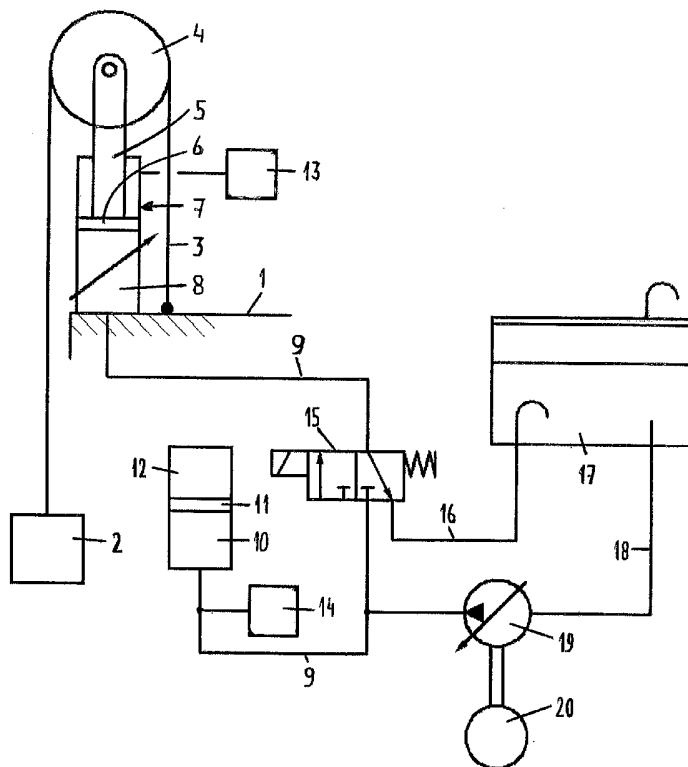
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(54) Title: SYSTEM FOR STORING, DELIVERING AND RECOVERING ENERGY



(57) Abstract: A system is described for storing, delivering and recovering energy, provided with a cylinder-piston assembly (7) for absorbing a mass-induced load (2), which assembly is in fluid connection with a pressure source (19). The effective surface area of the piston (6) of the cylinder-piston assembly is variable. The cylinder-piston assembly consists of, for instance, a number of cylinders (22-24, 27, 28) connected in parallel, which can be selectively powered by the pressure source.

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System for storing, delivering and recovering energy

The invention in the first place relates to a system for storing, delivering and recovering energy, provided with a cylinder-piston assembly for absorbing a mass-induced load, which assembly is in fluid connection with a pressure source.

5 Such a system is used inter alia in a swell compensation system for compensating swell-induced motion of a mass suspended from a hoisting cable on ships or other floating installations.

10 Known systems can be divided into a number of different types. Hereinafter a short summary of said types and their specific problems is given.

In a passive system, the cylinder-piston assembly is directly connected to a pressure vessel (which contains a compressible gas). Said passive system substantially behaves as
15 a mass spring system, in which the gas volume and the gas pressure change under the influence of the mass-induced load. The drawbacks of such a system are the occurrence of resonance amplification effects, the presence of a substantial residual motion and the requirement of a large-volume pressure vessel.
20 In addition, the system is only suitable for use with non-varying masses.

Although an active system (in which the cylinder-piston assembly can be actively controlled inter alia by, briefly put, placing a control mechanism between the pressure
25 vessel and the cylinder-piston assembly) allows the use of a smaller pressure vessel volume and a slightly varying mass, such a system inter alia has this drawback that its energy consumption is very high, so that it is only suitable for small masses.

30 Characteristics of a combined passive/active system include: the gas volume in the pressure vessel can be adapted to the mass; the residual motion is small; the gas volume in the pressure vessel is smaller than in the case of a passive system; it is only suitable for non-varying masses.

Finally, systems provided with a so-called secondary control mechanism (usually on winches) may be mentioned, by means of which the stroke volume and thus the torque of a hydraulic driving motor can be controlled. Since the moment of inertia of such hydraulic driving motors is very low, the torque is very quickly converted into speed in the case of a varying load, so that the pressure vessel, which contains a great deal of energy, can cause the number of revolutions of the motor to run up inadmissibly high within a very short time. In principle such a system is unstable, therefore, and needs to be controlled by means of complex and dynamic measuring and control systems. For safety reasons, twin sensors must be used, which, in combination with the use of costly hydraulic components, processors and electronics, makes the system very costly. Furthermore, the energy losses that occur in such a system are very high, and the system can only be used with masses of a limited magnitude.

In view of the foregoing, it is an object of the present invention to provide a system which combines the advantages of the known system within itself without having the drawbacks of said systems. In particular, such a system preferably has the following characteristics: it must be suitable for use with a large range of masses; it must be capable of dynamically changing over from one mass to another; the volume of the pressure vessel must be small; the energy consumption of the system must be low and following precision (i.e. the degree of swell compensation) must be high and finally, the weight of the system must be minimal and the system must be reliable and inexpensive.

According to the present invention, a system is provided for storing, delivering and recovering energy, provided with a cylinder-piston assembly for absorbing a mass-induced load, which assembly is in fluid connection with a pressure source, the system being characterized in that the effective surface area of the piston of the cylinder-piston assembly is variable.

Since the effective piston area of the cylinder-piston assembly is variable according to the present invention,

an equilibrium between the mass and the (gas) pressure of the pressure source (pressure vessel) can be found at all times. As a consequence, the gas pressure may vary very strongly (without the risk of resonance, for example), so that a greatly reduced
5 volume of the pressure vessel will suffice. By selecting a suitable piston area at any moment, the desired force for a desired acceleration or deceleration of the piston of the cylinder-piston assembly, and thus of the mass, can be realised , for any situation (within the system boundaries for any
10 pressure vessel pressure). On the one hand the required energy is obtained from the pressure vessel, but on the other hand energy is returned to (stored in) the pressure vessel upon movement in reverse direction. Since practically no additional components are present between the pressure vessel and the
15 cylinder-piston assembly, the system losses are very low and the efficiency is high, therefore.

In practice, said variation of the effective piston area of the cylinder-piston assembly will hardly take place in an infinitely variable manner, if at all (this would be
20 technically unfeasible or, at the very least, be highly complicated). According to an advantageous embodiment of the present invention, therefore, the cylinder-piston assembly consists of a number of cylinders connected in parallel, which can be selectively powered by the pressure source.

25 In this way a variation of the effective piston area can be realised by activating a suitable cylinder or cylinders.

Within this framework it is furthermore preferable to arrange the cylinders in groups of cylinders consisting of one cylinder or a number of cylinders to be simultaneously powered
30 each time, wherein the total surface area of the pistons belonging to the same group of cylinders is halved or doubled each time, as the case may be, between successive groups of cylinders.

In this way a binary solution for varying the piston
35 area is provided, as it were. The number of effective piston areas to be realised is $2^n - 1$ in that case, wherein n = the number of groups of cylinders. The precision of the variation (in other words, the adjusting precision or resolution of the

system) is in principle determined by the minimum step size, i.e. the piston area of the group of cylinders having the smallest total piston area.

In order not to generate any asymmetrical forces within the cylinder-piston assembly (which leads to increased friction and wear and a higher energy consumption) in a situation in which said groups of cylinders are used, an advantageous embodiment of the invention is proposed wherein the cylinder-piston assembly has a central axis and wherein the cylinders of a group of cylinders are arranged in such a manner that the force produced by a group of cylinders extends through said central axis.

Within this framework, the pressure of at least the group of cylinders having the smallest total piston area can be controlled. As a result, a system according to the invention is obtained in which the effective piston area of the cylinder-piston assembly is fully infinitely variable.

There are various possible ways of realising the aforesaid groups of cylinders. An example of this is an embodiment of the system according to the invention in which the cylinder-piston assembly is built up as follows:

- a central first cylinder having a piston area $8B$;
- six second cylinders arranged around the central cylinder, each second cylinder likewise having a piston area $8B$;
- six third cylinders having a piston area B , which are arranged around the second cylinders in staggered and evenly spaced relationship,

wherein

- four second cylinders, which are arranged in pairs positioned diametrically opposite each other, together form a first group of cylinders;
- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together form a second group of cylinders;
- the central first cylinder forms a third group of cylinders;
- four evenly spaced third cylinders together form a fourth group of cylinders; and

- the two remaining, likewise evenly spaced third cylinders together form a fifth group of cylinders.

The five groups of cylinders of this embodiment define five successive steps of the total piston area, wherein
5 the total piston area is halved with each step. This makes it possible in practice to realise a sufficiently precise system comprising 31 (5^5-1) in different effective piston areas. Furthermore, the selected arrangement of the individual
10 cylinders leads to a symmetrical force being exerted (along the central axis of the cylinder-piston assembly).

In this embodiment, the cylinder-piston assembly is made up of seven cylinders having a first piston area and six cylinders having a second piston area amounting to one eighth of said first piston area. The total number of cylinders is 13.

15 In an especially preferred embodiment of the system according to the invention, the cylinder-piston assembly is built up as follows:

- a central first double-acting cylinder having piston areas C and D; and
- 20 - six second double-acting cylinders arranged around the central cylinder, each second cylinder likewise having piston areas C and D;

wherein

- four second cylinders, which are arranged in pairs
25 positioned diametrically opposite each other, together form a first group of cylinders with their one piston area C;
- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together
30 form a second group of cylinders with their one piston area C;
- the central first cylinder forms a third group of cylinders with its one piston area C;
- the four second cylinders arranged in pairs positioned
35 diametrically opposite each other together form a fourth group of cylinders with their other piston area D;
- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together

form a fifth group of cylinders with their other piston area D; and

- the central first cylinder forms a sixth group of cylinders with its other piston area D.

5 In this embodiment only seven cylinders are used, which, in addition, are all of the same type. Since said cylinders are double-acting type cylinders comprising two piston areas, it is possible, even with this minimum number of cylinders, to obtain a system which makes it possible, because
10 six groups of cylinders are used, to set a large number of effective piston areas (viz. $2^6 - 1 = 63$), which results in a highly precise, high-resolution system.

Said system may again have the aforesaid binary characteristic, due to a suitable selection of the two
15 different piston areas of the double-acting cylinders. Numerous variants are possible, of course.

In order to make it possible to vary the effective piston area, the system according to the invention is preferably provided with control means for selectively
20 connecting the cylinders to the pressure source. Said control means may include sensors, which measure the mass-induced load, the pressure in the pressure vessel and the motion of the mass and/or the piston(s) of the cylinder-piston assembly, for example. Such sensors may be connected to a processing unit,
25 which drives the control means via drive means. Such arrangements are known in the field of measuring and control engineering, and consequently they need not be explained in more detail herein.

The invention also relates to a system according to
30 the invention as used in a swell compensation system, and to a cylinder-piston assembly as used in a system according to the invention. Furthermore it may be noted within this framework that the invention may also be used with cylinder-piston assemblies used for purposes other than in swell compensation
35 systems, for example more generally in lifting and hoisting arrangements.

The invention will be explained in more detail hereinafter with reference to the drawing. In the drawing:

Fig. 1 shows the principles of a swell compensation system based on a known passive system;

Fig. 2 schematically shows a swell compensation system according to the invention;

5 Figs. 3 and 4 show various cylinder configuration is for swell compensation systems according to the invention; and

Fig. 5 shows an alternative cylinder configuration substantially corresponding to Fig. 4.

Fig. 1 schematically shows a ship 1 which carries a
10 load (mass) 2a. Said load 2 may be raised and lowered, in a manner that is known per se (not shown), by means of a hoisting installation. The load 2 may be an installation which is used for carrying out underwater operations, e.g. on the bottom of the sea. In order to compensate for any swell-induced vertical
15 movements of the ship 1, the load is suspended from a cable 3, which is passed over a pulley 4 and which is attached to the ship 1 (with the possible interposition of a hoisting installation or the like as mentioned before). The pulley is mounted on the piston rod 5 of a piston 6 of a cylinder-piston
20 assembly 7. The cylinder chamber 8 of the cylinder-piston assembly 7 is in fluid connection with a pressure vessel 10 via a line 9. Present within said pressure vessel is a piston or membrane 11, which seals a gas chamber 12.

During vertical movement of the ship 1 in upward
25 direction, the load 2 exerts a downward force on the pulley 4 via the cable 3, which pulley transmits said force to the piston 6 via the piston rod 5. The piston 6 is moved and the hydraulic medium that is present in the cylinder chamber 8 and the line 9 is displaced, as a result of which the piston or
30 membrane 11 in the pressure vessel 10 are moved, so that the gas pressure in the gas chamber 12 will increase. The reverse process takes place during vertical movement of the ship in an opposite, downward direction. Upon compression of the gas in
35 the gas chamber 12 of the pressure vessel 10, energy is stored in the pressure vessel, which energy is to a substantial extent released again (not counting any losses) upon movement in reverse direction.

In the known swell compensation system that is shown in Fig. 1, the surface area of the piston 6 is constant. The drawbacks of this configuration have already been extensively discussed in the foregoing.

5 In Fig. 2 a swell compensation system according to the invention is shown. The basic principle of this system corresponds to the basic principle of the known system as shown in Fig. 1: a load 2 is connected to a ship 1 via a cable 3 that is passed over a pulley 4 which is (directly or indirectly)
10 connected to a ship 1. The pulley 4 is mounted on a piston rod 5 of a cylinder-piston assembly 7.

In this swell compensation system according to the invention, the surface area of the piston 6 is no longer constant, but variable. This makes it possible to select the
15 most suitable piston area for every situation that may occur, as already explained at some length in the foregoing. The adjustment/variation of the surface area of the piston 6 of the cylinder-piston assembly 7 according to the invention, which is realised in a manner yet to be described as a result of the
20 cylinder-piston assembly 7 consisting of a number of cylinders connected in parallel, which can be selectively powered by the pressure vessel 10, will preferably take place automatically in response to measuring signals from the sensors 13 and 14 for measuring inter alia the pressure in the cylinder-piston
25 assembly 7, the movement of the piston 6 and the pressure in the hydraulic lines 9 that connect the cylinder chambers 8 of the individual cylinders to the pressure vessel 10. The sensors 13, 14 are connected, in a manner that is not shown, to processing and control means for varying the piston area on the
30 basis of received sensor signals.

In the illustrated embodiment, said varying of the piston area takes place by means of control valves 15 mounted in the lines 9, one for every cylinder or (in the embodiment yet to be described) group of cylinders, which control valves
35 are actuated by the processing and control means, which thus activate/deactivate the respective individual cylinders of the cylinder-piston assembly 7. In connection with undesirable dissipation, the valves are either in their open position or in

their closed position. A very short time is required for movement of the valves from the open position to the closed position, or vice versa.

The hydraulic circuit (lines 9) is also connected to a storage vessel 17 for the hydraulic medium, in this case a so-called low-pressure battery, via the control valves 15 and a discharge line 16. In this way excess hydraulic medium can be carried to the storage vessel 17. A supply line 18, in which a pump 19 driven by a motor 20 is mounted, connects the storage vessel 17 to the hydraulic circuit (lines 9). In this way any losses of hydraulic medium can be replenished.

In order to make it possible to vary the effective piston area of the cylinder-piston assembly 7 in the swell compensation system according to the invention, for example as shown in Fig. 2, the cylinder-piston assembly consists of a number of cylinders connected in parallel, as already said before, which can be selectively powered by the pressure vessel 10. As will be explained hereinafter by means of the embodiments shown in Figs. 3-5, the cylinders are arranged in groups of cylinders consisting of one cylinder or a number of cylinders to be powered simultaneously. In the case of successive groups of cylinders, the total surface area of the pistons belonging to the same group of cylinders amounts to twice the piston area or half the piston area of a preceding group of cylinders with each step.

The foregoing will be explained with reference to Figs. 3 and 4, which are schematic cross-sectional views of cylinder-piston assemblies built up of a number of individual cylinders.

Preliminarily, it is noted in this connection that each cylinder-piston assembly that is shown in said figures has a central axis 21 and that the cylinders of a group of cylinders are arranged in such a manner that the force exerted by a group of cylinders will extend through said central axis 21. As a result, the amount of wear and friction is minimised.

Referring to Fig. 3, the cylinder-piston assembly is built up as follows:

- the central first cylinder 22 having a piston area $8B$;
- the six second cylinders 23 and 24 arranged around the central cylinder 22, each second cylinder likewise having a piston area $8B$;
- 5 - six third cylinders 27 and 28 having a piston area B , which are arranged around the second cylinders 23 and 24 in staggered and evenly spaced relationship.

The cylinders 22 - 24 and 27, 28 are grouped as follows:

- 10 - the four second cylinders 23, which are arranged in pairs positioned diametrically opposite each other, together form a first group of cylinders having a total piston area $32B$;
- the two remaining second cylinders 24, which are likewise
15 positioned diametrically opposite each other, together form a second group of cylinders having a total piston area $16B$;
- the central first cylinder 22 again forms a third group of cylinders having a total piston area $8B$;
- 20 - four evenly spaced third cylinders together form a fourth group of cylinders having a total piston area $4B$; and
- the two remaining, likewise evenly spaced third cylinders 28, together form a fifth group of cylinders having a total piston area $2B$.

25 The successive groups of cylinders from the first group to the fifth group have total piston areas that are halved each time, so that a binary system in total comprising 31 steps (2^5-1), is obtained, as it were. As a result, the effective piston area of the cylinder-piston assembly 7 can be
30 varied by suitably activating the groups of cylinders (e.g. by means of the control valves 15, see Fig. 2) at a high resolution (the step size corresponds to the smallest total piston area $2B$). This system comprises a total of 13 cylinders having two different piston areas (diameters).

35 Finally, reference is made to Fig. 4. In this embodiment, the swell compensation system comprises a cylinder-piston assembly which is built up as follows:

- a central first double-acting cylinder having piston areas C and D; and
- six second double-acting cylinders arranged around the central cylinder, each second cylinder likewise having piston areas C and D.

The cylinders are arranged in groups in the following manner:

- the first parts 31 of four second cylinders 31, 32, which are arranged in pairs positioned diametrically opposite each other, together form a first group of cylinders having a total piston area $4C$ with their respective piston areas C;
- the first parts 33 of the two remaining second cylinders 33, 34, which are likewise positioned diametrically opposite each other, together form a second group of cylinders having a total piston area $2C$ with their respective piston areas C;
- the first part 29 of the central first cylinder 29, 30 forms a third group of cylinders having a total piston area C with its piston area C;
- the second parts 32 of four second cylinders 31, 32, which are arranged in pairs positioned diametrically opposite each other, together form a fourth group of cylinders having a total piston area $4D$ with their respective piston areas D;
- the second parts 34 of the two remaining second cylinders 33, 34, which are likewise positioned diametrically opposite each other, together form a fifth group of cylinders having a total piston area $2D$ with their respective piston areas D; and
- the second part 30 of the central first cylinder 29, 30 forms a sixth group of cylinders having a total piston area D with its piston area D.

A suitable selection of the piston areas C and D and a suitable control of this system comprising double-acting cylinders will result in a binary system comprising $2^6 - 1 = 63$ steps. As a result, a high-resolution (about 1.5%) system will

be obtained, which allows a precise adaptation of the effective piston area to the prevailing conditions.

Furthermore, the individual cylinders may be grouped into one cylinder, which can be activated as a whole. An example of such a configuration is schematically shown in Figs. 5a and 5b. Fig. 5a shows a cylinder configuration corresponding to Fig. 4, and Fig. 5b is a longitudinal sectional view thereof. In said figure, the grouping of cylinders into one cylinder is clearly shown.

One preferred embodiment of the swell compensation system according to the invention comprises an intermediate pressure vessel. The hydraulic medium, generally oil, that is present in the system is slightly compressible, so that energy is stored in the oil present in the cylinders upon pressurization of said cylinders. Said energy is lost when the pressure is released from the cylinders again: the "oil spring" relaxes and the energy that is released is transmitted to the storage vessel. The intermediate pressure vessel collects part of said energy, so that it can be utilised at a later stage.

The operation is as follows: when the pressure is released from the cylinders, the cylinders are not directly connected to the storage vessel, but they are first (briefly) connected to the intermediate pressure vessel (e.g. by providing the aforesaid control valves 15 with a fourth position, which is capable of connecting the lines 9 to the intermediate pressure vessel). The oil spring relaxes, whilst the cylinder pressure decreases to the intermediate pressure level, and the energy that is released from the spring is stored in the intermediate pressure vessel. When the intermediate pressure amounts to, for example, half the difference between the system pressure and the pressure in the storage vessel (e.g. an atmospheric pressure), about half the energy that would otherwise have been lost may can be stored in the intermediate pressure vessel.

The energy in the intermediate pressure vessel is used again when one or more cylinders go through the reverse process: a cylinder is not immediately turned to full pressure in that case, but it is first temporarily connected to the

intermediate pressure vessel, so that the energy from said vessel is utilised for tensioning the oil spring to half its full tension again.

5 The principle of the intermediate pressure vessel may be extended with more vessels or reservoirs, it would for example be possible to add a reservoir at 0.25 and 0.75 of the system pressure. The more reservoirs are provided, the more energy will be recovered.

10 The invention is not limited to the embodiments as described above, which can be varied in many ways within the scope of the invention as defined in the claims.

CLAIMS

1. A system for storing, delivering and recovering energy, provided with a cylinder-piston assembly for absorbing
5 a mass-induced load, which assembly is in fluid connection with a pressure source, characterized in that the effective surface area of the piston of the cylinder-piston assembly is variable.

2. A system according to claim 1, wherein the cylinder-piston assembly consists of a number of cylinders
10 connected in parallel, which can be selectively powered by the pressure source.

3. A system according to claim 2, wherein the cylinders are arranged in groups of cylinders consisting of one cylinder or a number of cylinders to be simultaneously powered
15 each time, wherein the total surface area of the pistons belonging to the same group of cylinders is halved or doubled each time, as the case may be, between successive groups of cylinders.

4. A system according to claim 3, wherein the cylinder-piston assembly has a central axis and wherein the
20 cylinders of a group of cylinders are arranged in such a manner that the force produced by a group of cylinders extends through said central axis.

5. A system according to claim 3 or 4, wherein the pressure of at least the group of cylinders having the smallest
25 total piston area can be controlled.

6. A system according to claim 3, 4 or 5, wherein the cylinder-piston assembly is built up as follows:

- a central first cylinder having a piston area $8B$;
- 30 - six second cylinders arranged around the central cylinder, each second cylinder likewise having a piston area $8B$;
- six third cylinders having a piston area B , which are arranged around the second cylinders in staggered and evenly spaced relationship,

35 wherein

- four second cylinders, which are arranged in pairs positioned diametrically opposite each other, together form a first group of cylinders;

- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together form a second group of cylinders;
- the central first cylinder forms a third group of cylinders;
- four evenly spaced third cylinders together form a fourth group of cylinders; and
- the two remaining, likewise evenly spaced third cylinders together form a fifth group of cylinders.

7. A system according to claim 3, 4 or 5, wherein the cylinder-piston assembly is built up as follows:

- a central first double-acting cylinder having piston areas C and D; and
- six second double-acting cylinders arranged around the central cylinder, each second cylinder likewise having piston areas C and D;

wherein

- four second cylinders, which are arranged in pairs positioned diametrically opposite each other, together form a first group of cylinders with their one piston area C;
- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together form a second group of cylinders with their one piston area C;
- the central first cylinder forms a third group of cylinders with its one piston area C;
- the four second cylinders arranged in pairs positioned diametrically opposite each other together form a fourth group of cylinders with their other piston area D;
- the two remaining second cylinders, which are likewise positioned diametrically opposite each other, together form a fifth group of cylinders with their other piston area D; and
- the central first cylinder forms a sixth group of cylinders with its other piston area D.

8. A system according to any one of the claims 2 - 7, provided with control means for selectively connecting the cylinders to the pressure source.

5 9. A system according to any one of the preceding claims, wherein the pressure source is a pressure vessel.

10. A system according to any one of the preceding claims, as used in a swell compensation system.

10 11. A system according to any one of the preceding claims, comprising a low-pressure reservoir and an intermediate pressure reservoir, wherein the cylinders can be connected to either one of said reservoirs.

12. A cylinder-piston assembly as used in a system according to any one of the preceding claims.

FIG. 1

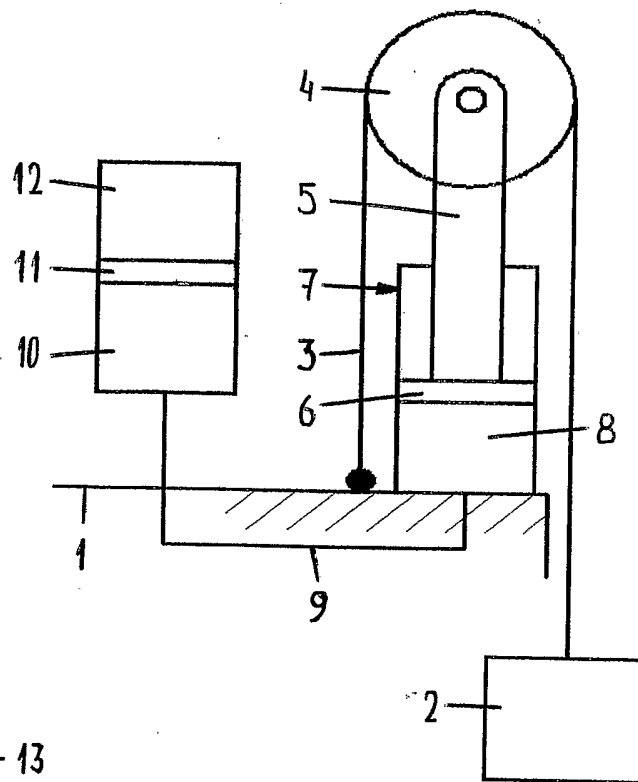


FIG. 2

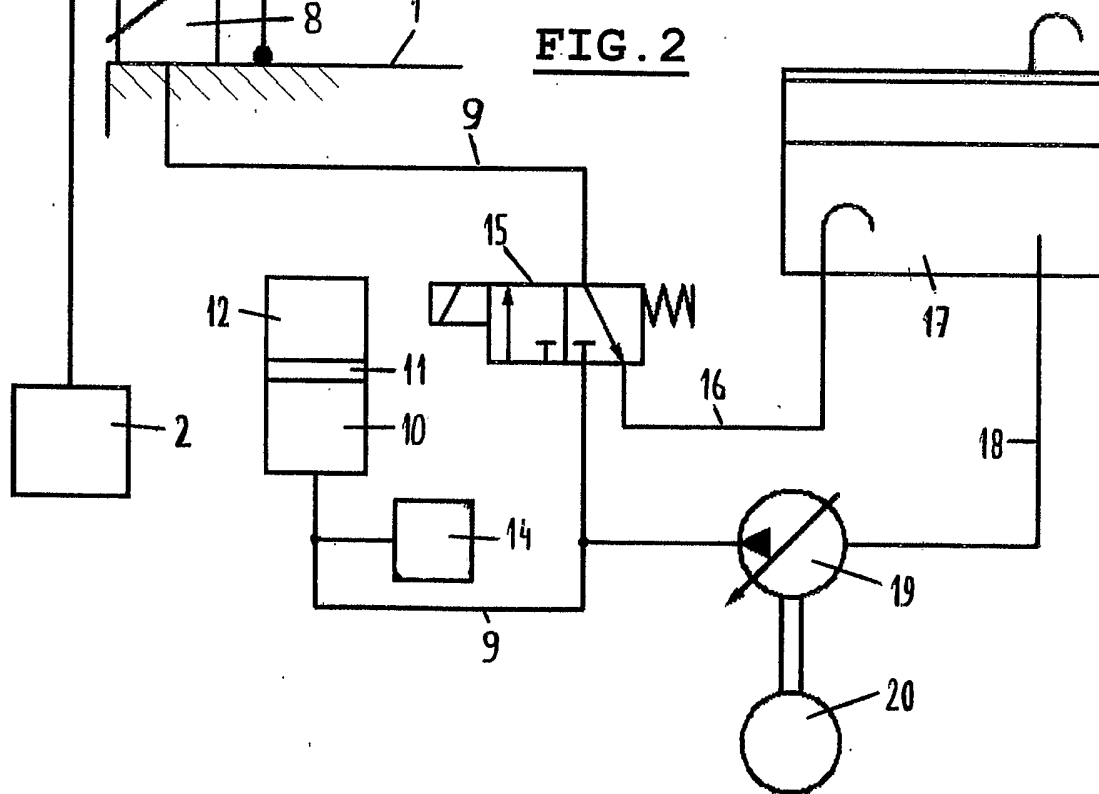


FIG. 3

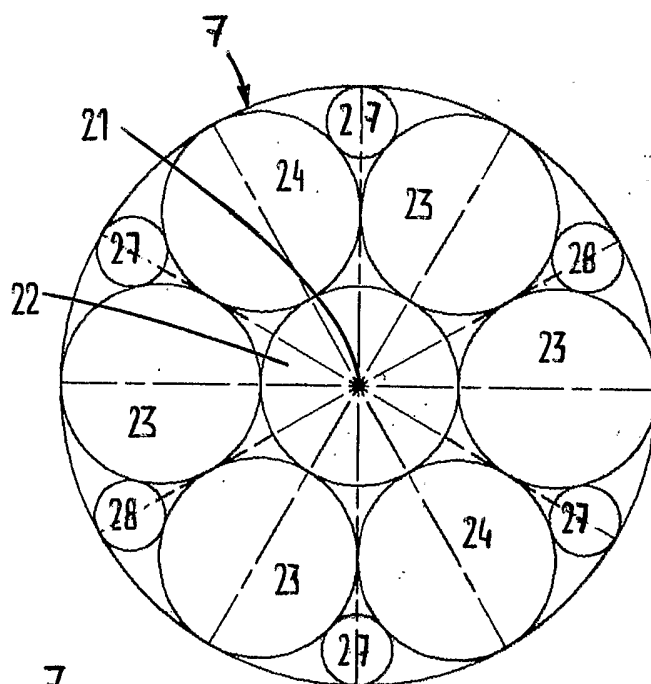
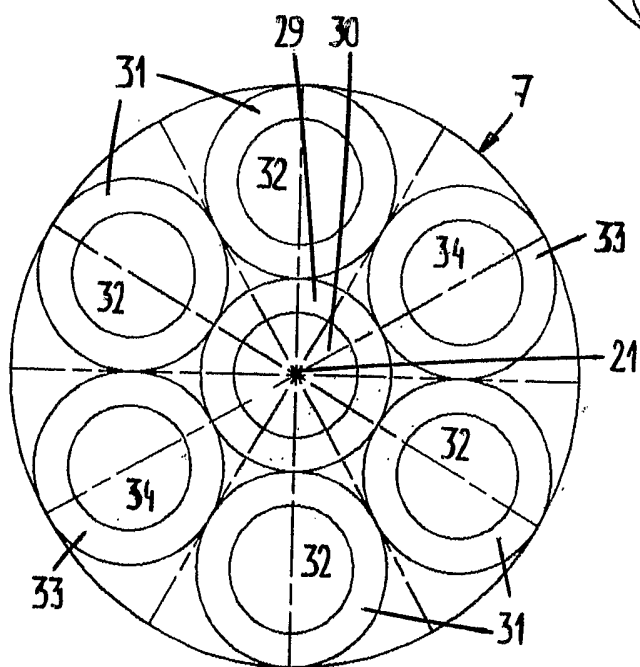


FIG. 4



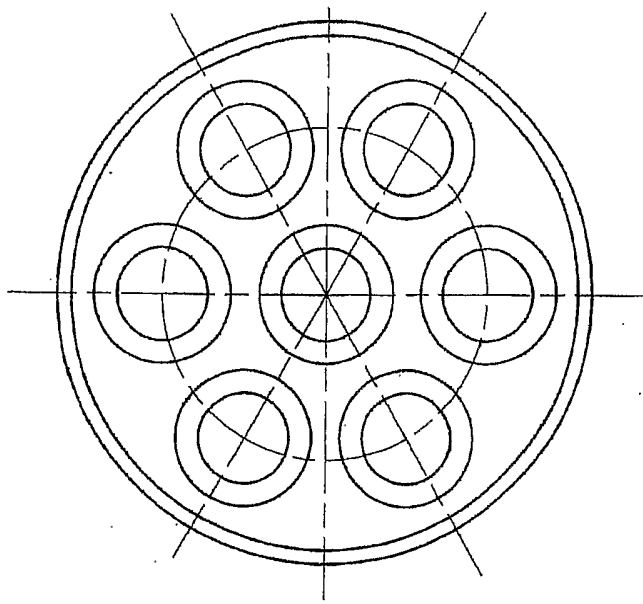


FIG. 5a

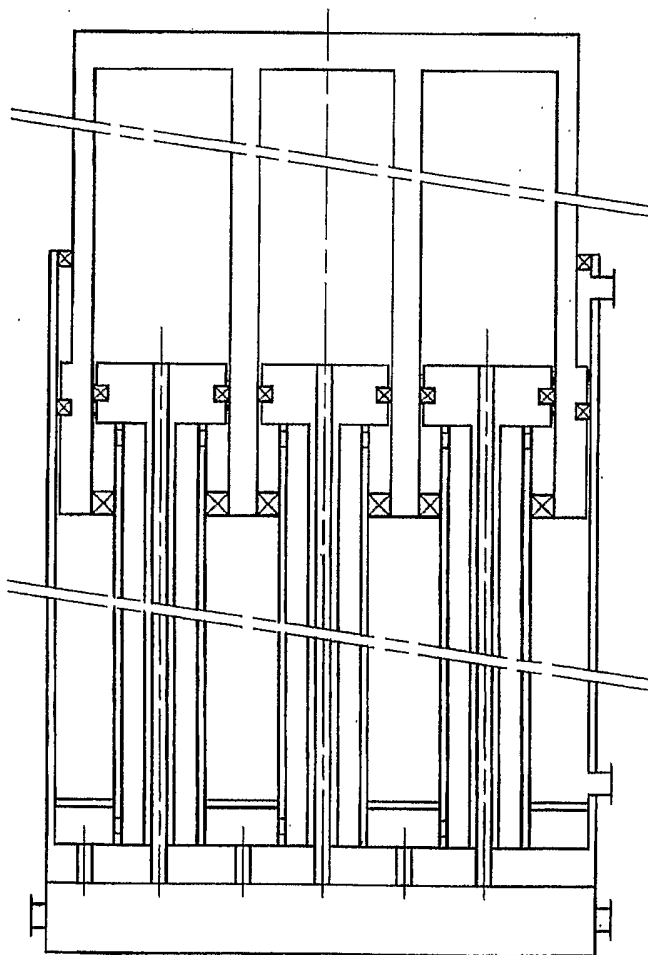


FIG. 5b

INTERNATIONAL SEARCH REPORT

PCT/NL2004/000074

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 B66C13/02 F15B11/036

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 B66C F15B B66D

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 992 819 A (ASSKILDT KNUT ET AL) 30 November 1999 (1999-11-30) the whole document ---	1, 2, 8-12
A	GB 2 175 270 A (REXROTH MANNESMANN GMBH) 26 November 1986 (1986-11-26) the whole document ---	1, 11
A	US 4 121 806 A (IATO MICHEL ET AL) 24 October 1978 (1978-10-24) the whole document ---	1, 11
A	US 4 098 082 A (PACKER MARTIN R) 4 July 1978 (1978-07-04) the whole document ---	1
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 987 446 A (LINGK & STURZEBECHER LEICHTBAU) 22 March 2000 (2000-03-22) abstract -----	2,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/NL2004/000074

Patent document cited in search report	A	Publication date	Patent family member(s)	Publication date
US 5992819	A	30-11-1999	AU 1719695 A	29-08-1995
			NO 963335 A	03-10-1996
			WO 9522026 A1	17-08-1995
GB 2175270	A	26-11-1986	DE 3516289 A1	13-11-1986
			NO 861775 A ,B,	10-11-1986
US 4121806	A	24-10-1978	FR 2344490 A1	14-10-1977
			AU 503187 B2	23-08-1979
			AU 2342677 A	21-09-1978
			BR 7701657 A	17-01-1978
			CA 1062238 A1	11-09-1979
			DE 2711673 A1	29-09-1977
			DK 118377 A	19-09-1977
			GB 1530574 A	01-11-1978
			IE 44504 B1	16-12-1981
			IT 1077713 B	04-05-1985
			JP 52134801 A	11-11-1977
			NL 7702922 A	20-09-1977
			NO 770960 A ,B,	20-09-1977
			SE 7702936 A	19-09-1977
			ZA 7701534 A	25-01-1978
US 4098082	A	04-07-1978	NONE	
EP 0987446	A	22-03-2000	EP 0987446 A1	22-03-2000