Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2861136 A1 2013/04/04

(21) 2 861 136

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2012/09/28
(87) Date publication PCT/PCT Publication Date: 2013/04/04
(85) Entrée phase nationale/National Entry: 2014/03/27
(86) N° demande PCT/PCT Application No.: EP 2012/069160
(87) N° publication PCT/PCT Publication No.: 2013/045598
(30) Priorités/Priorities: 2011/09/30 (DE10 2011 054 074.1); 2011/09/30 (DE10 2011 054 073.3)

(51) Cl.Int./Int.Cl. *F04B 9/109* (2006.01), *F04B 11/00* (2006.01), *F04B 43/06* (2006.01)

(71) Demandeur/Applicant:
AKER WIRTH GMBH, DE

(72) Inventeurs/Inventors:
GIESSBACH, ALFRED, DE;
JAEGER, NORBERT, DE

(74) Agent: FETHERSTONHAUGH & CO.

(54) Titre : POMPE VOLUMETRIQUE ET PROCEDE D'EXPLOITATION DE LADITE POMPE VOLUMETRIQUE
(54) Title: POSITIVE DISPLACEMENT PUMP AND OPERATING METHOD THEREOF

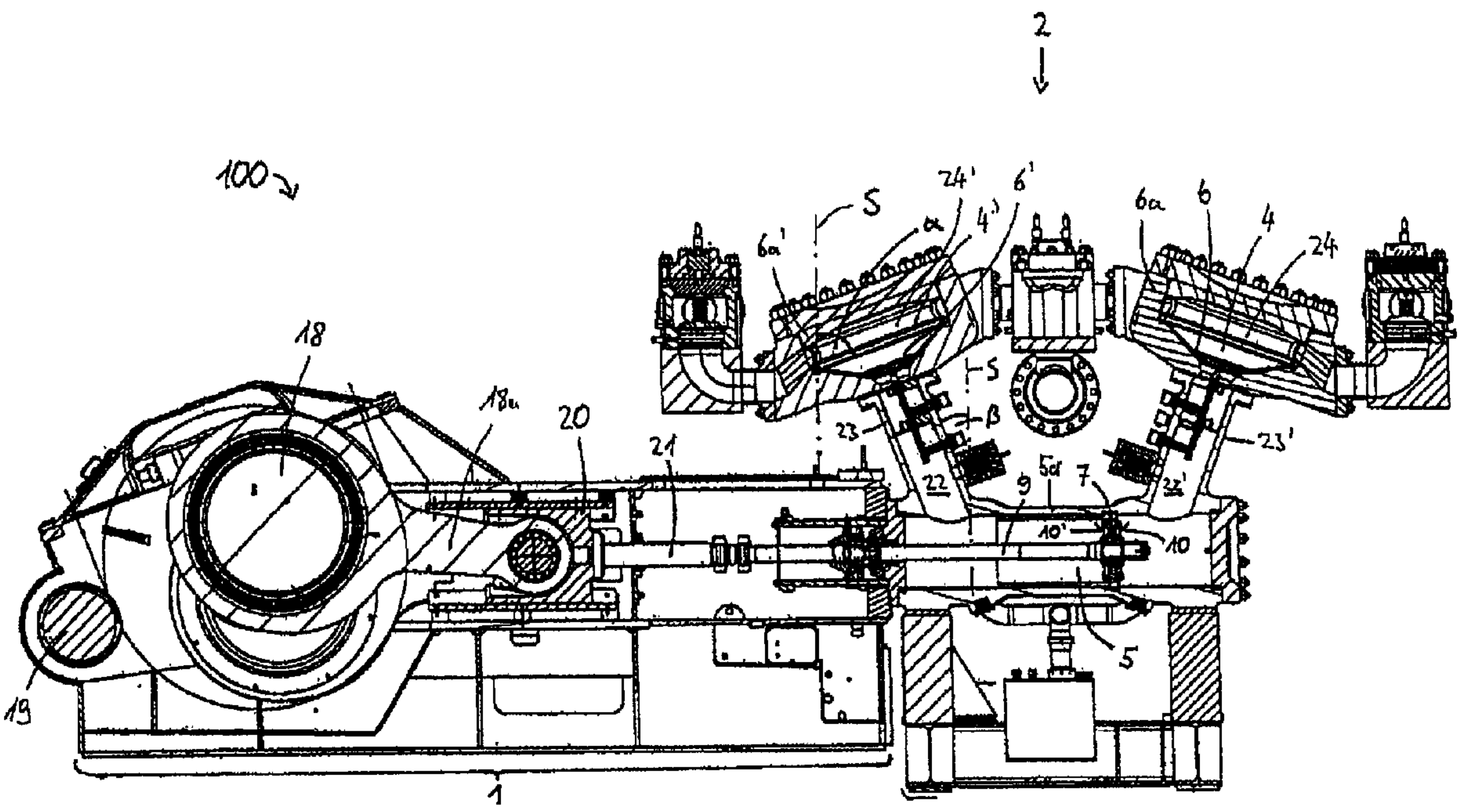

Fig. 13

(57) Abrégé/Abstract:
The invention relates to a positive displacement pump (100), comprising a drive unit (1) and a pump unit (2) having several working chambers (4, 4'), several displacement elements (3, 3'), and at least three cylinders (5), preferably exactly three cylinders (5), wherein the pump unit (2) is double-acting. The invention further relates to a piston diaphragm pump forming a positive displacement pump, wherein a diaphragm stroke is caused by means of working liquid present on the first side of a diaphragm and a medium to be pumped is conducted through a diaphragm chamber bounded by the second side of the diaphragm due to the diaphragm stroke, and the diaphragm stroke is caused at a diaphragm position different from a vertical position of the diaphragm.

Abstract

The invention relates to a positive displacement pump (100), comprising a drive unit (1) and a pump unit (2) having several working chambers (4, 4'), several displacement elements (3, 3'), and at least three cylinders (5), preferably exactly three cylinders (5), wherein the pump unit (2) is double-acting. The invention further relates to a piston diaphragm pump forming a positive displacement pump, wherein a diaphragm stroke is caused by means of working liquid present on the first side of a diaphragm and a medium to be pumped is conducted through a diaphragm chamber bounded by the second side of the diaphragm due to the diaphragm stroke, and the diaphragm stroke is caused at a diaphragm position different from a vertical position of the diaphragm.

Positive displacement pump and operating method thereof

The invention relates to a positive displacement pump comprising a drive unit and a pump unit and an operating method thereof. The pump unit has a plurality of working chambers, a plurality of displacement elements, and frequently at least three cylinders. Such positive displacement pumps are already known. For example, figures 1 and 2 show such a positive displacement pump made by Aker Wirth GmbH. Such positive displacement pumps are used as flushing pumps for drilling fluid and as so-called slurry pumps, i.e. for transporting solids found in liquid. They are also called thick matter pumps. Thick matters are mixtures of liquid and solid components. Such pumps generate a pressure of up to 500 bar, have a capacity of up to 300 l per minute and power frequently exceeding 700 kW.

The invention addresses the problem of providing such a pump with improved lifespan and an operating method for such a pump while maintaining and/or expanding the advantages of such a pump with at least three cylinders.

This problem is solved with the pump referred to in claim 1 or 14 and the operating method referred to in claim 11.

In a first alternative, the positive displacement pump has a drive unit and a pump unit. The pump unit comprises a plurality of working chambers and a plurality of displacement elements. The pump unit comprises at least three cylinders. It is double-acting, i.e., two working chambers are thus provided per cylinder. Overall, at least six working chambers are thus provided.

Preferably, at least three cylinders are provided. The pump is a triplex pump (also called triplet pump) which is double-acting. The advantages of a triplex pump are thus combined with the advantages of a double-acting pump. The positive displacement pump with three cylinders (triplex) shown in figures 1 and 2 is single-acting. Under normal operating conditions, their displacement elements (diaphragms) perform a displacement stroke, i.e. they move from left to right (relative to figure 1). The operating pressure puts significant stress on the entire positive displacement pump. This is followed by a suction stroke, i.e. the diaphragms move from right to left (relative to figure 1) which puts no or merely little stress on the pump. During the piston's movement to the right (relative to figure 1), the pump is exposed to great stress while the piston's movement to the left (relative to figure 1) causes no or merely little stress. Due to the switch from single-acting to double-acting, the phases with little or no stress disappear. Surprisingly, it has become evident that, at the same pump capacity, a distinct increase of the expected lifespan is nevertheless achieved. Furthermore, it has become surprisingly evident that the additional cost inherently associated with double action can thus be overcompensated.

Preferably, the displacement elements are diaphragms. They are further preferably actuated by means of pistons. The positive displacement pump, according to the invention, is thus a piston diaphragm pump. The diaphragm separates the medium to be pumped from the drive. This separating diaphragm thus shields the drive from damaging effects of the medium to be pumped. The medium to be pumped is also shielded from damaging effects of the drive. The oscillating movement of the piston is preferably transmitted to the diaphragms using a working fluid or transmission fluid. The working fluid can be water with a water-soluble mineral additive or hydraulic oil. Due to the constant volume of the working fluid between piston and diaphragm, the movement of the piston directly causes a deflection of the diaphragm and thus generates suction and pressure pulses. Preferably, exactly one piston is provided in each cylinder.

The pump is preferably a thick matter pump. It thus pumps mixtures of liquid and solid components which can be sludge during excavations or the like. Such piston diaphragm pumps are designed for continuous operation and have to reliably function as trouble-free as possible over long periods of time, even years, since the replacement of a defective piston diaphragm pump, due to its size, is consistently associated with significant expenditure of labor and time.

Furthermore, damage to the diaphragm of these piston diaphragm pumps can have particularly dire consequences. In the event of damage to the diaphragm, the working liquid enters the diaphragm chamber or the working chamber and mixes with the medium to be pumped which requires elaborate cleaning work. In addition, the medium to be pumped mixes with the working fluid which can contaminate the entire pump and damage the drive piston.

Such piston diaphragm pumps are known from Aker Wirth GmbH, Erkelenz, Germany, under the designations “DPM” and “TPM.” They are designed as duplex pumps with two double-acting pistons or as triplex pumps with three single-acting pistons. The cylinders are always arranged horizontally, and therefore the pistons perform their oscillating movement along a horizontally oriented axis. The diaphragms connected through the working liquid with the displacement of the correspondingly associated cylinder are always arranged perpendicularly. “Perpendicular arrangement” means that the action plane defined by the diaphragm extends perpendicularly. It is defined by the edge clamped in the diaphragm housing for a planar diaphragm in a non-deflected state.

In such diaphragm pumps, the inlet is consistently located on the underside, the outlet is located on the upper side, allowing for air in the diaphragm chamber to escape upwardly.

The drive unit is preferably provided the same way it is provided for in a conventional single-acting triplex pump. Figures 1 and 2 show that a driveshaft is provided which is operated by a motor not depicted herein and transmits its torque to a crankshaft using meshing toothed wheels, with connecting rods arranged on said crankshaft. All connecting rods are arranged on a single crankshaft and act in the same direction. They transmit their movement using a crosshead, i.e. to crosshead rods which are arranged relatively close to one another and run parallel to one another. These crosshead rods act together with piston rods. The cylinders run closely parallel to one another. Thus a drive unit is used which is tried and tested and compact. In addition to saving development costs, the use of tried and tested elements is of particular importance since the typical fields of application of the positive displacement pump according to the invention require extreme reliability. The cylinders are preferably arranged in a lying position, i.e. horizontally.

Preferably, the speed of the positive displacement pump according to the invention is reduced with respect to a conventional single-acting triplex pump. For example, this can be achieved with a slower running of the drive motor. Due to the fundamentally greater capacity of the double-acting pump unit, this measure can be taken at a consistent volume flow when compared to a conventional single-acting triplex pump.

Compared to a conventional single-acting triplex pump, the size of the piston surface is preferably reduced. Since the pump unit is double-acting, it pumps twice as big a volume flow of medium to be pumped at unchanged stroke volume and unchanged speed than a single-acting pump unit. In order to achieve a volume flow comparable to a conventional single-acting triplex pump, the stroke volume, alternatively or additionally to a reduction of the speed, can be reduced by way of reducing the cross-section of the piston surfaces. This results in a decrease of the rod force (piston rod and/or crosshead rod and/or connecting rod). Even though said force, unlike in a single-acting pump, acts with the same or comparable power in both directions of movement of the piston, it has become apparent that this results in an increase of the expected lifespan of critical components such as bearings. Furthermore, it has become apparent that the increase in lifespan is surprisingly high.

For the embodiment as diaphragm pump, smaller diaphragms can be used which can be more cost-efficient and durable. As already mentioned above, the reduced rod force results in lower bearing stress. Slower speed increases the lifespan of the pump unit, particularly that of the diaphragms. Compared to a double-acting duplex pump, i.e. a pump with two instead of three cylinders, the structure of a triplex pump provides for less pulsation. Furthermore, lower rod forces are achieved since the capacity is apportioned to three instead of two pump columns.

Preferably, the diaphragms are tilted at an angle of 1° to 90° relative to the perpendicular line. Unlike a conventional single-acting triplex pump, the diaphragms are thus not perpendicular. The position of the diaphragms relates to their neutral middle position.

Preferably, the diaphragms are arranged higher than the cylinders. Unlike a conventional single-acting triplex pump, the diaphragms are thus “folded” upward.

Preferably, the pump has a power of 700 kW. At such high power and great forces associated with it, the advantages of the invention become particularly evident.

The invention also relates to a pump unit of a pump according to the invention.

Furthermore, the invention addresses the problem of creating an operating method for a piston diaphragm pump and a piston diaphragm pump operating in accordance with said operating method, the lifespan of which is increased at equal capacity as in the prior art or the capacity of which is increased at consistent lifespan, regardless whether it is a single- or double-acting pump and regardless of the number of cylinders.

This problem is solved with the operating method referred to in claim 1 and the piston diaphragm pump referred to in claim 4.

In the operating method according to the invention, the diaphragm stroke is caused at a diaphragm position different from a perpendicular position of the diaphragm. Surprisingly, it has become evident that this technically easily implemented measure significantly increases the lifespan of the diaphragm. This surprising effect can possible be attributed to the fact that in the operating method according to the prior art, which has a perpendicularly aligned diaphragm, air pockets accumulate, for example near the inlet in the lower region of the diaphragm, which causes asymmetric stress on the diaphragm during thrust displacement which can lead to accelerated aging and/or fatigue of the diaphragm material, particularly near the clamped edges. In order to avoid a premature diaphragm defect due to material overload, the diaphragms in piston diaphragm pumps according to the prior art are consistently displaced by no more than seventy percent of the maximum diaphragm stroke. It has become surprisingly evident that with the operating method according to the invention, it is possible to increase the stroke up to ninety percent of the maximum displacement while maintaining the expected diaphragm lifespan without the requirement of further elaborate technical measures.

A particularly big lifespan extension or performance increase can be achieved if—as is preferred—the diaphragm stroke is caused at a diaphragm position different from the perpendicular line by 45° to 90°.

It is particularly preferred if the tilt of the diaphragm stroke from the perpendicular line is approximately 70° since in such case, at otherwise conventional dimensions and designs of a piston diaphragm pump, gas—usually air—which may be present in the working liquid accumulates at the highest edge region of the diaphragm and can be easily released through a venting valve arranged at such a point.

The piston diaphragm pump according to the invention is characterized in that the diaphragm is arranged at a position different from the perpendicular line, particularly by 45° to 90°, more particularly by approximately 70°.

The piston diaphragm pump according to the invention—as is common in piston diaphragm pumps provided for pumping sludge during excavations—is arranged such that the cylinder (or in case of multiple pumps) or cylinders with its (their) longitudinal axis (axes) is (are) arranged approximately horizontally. Therefore, drive and piston/cylinder units as in the prior art can be used. Preferably, the working volume is formed to some extent by a channel extending upward at an angle from the cylinder.

It is particularly preferred if the channel is designed approximately straight and a flange aligned approximately perpendicular to the longitudinal axis of the channel is provided on the channel housing forming the channel, and a diaphragm housing for receiving the diaphragm being attached to said flange. The same components as in the prior art can thus again be used as diaphragm and diaphragm housing, thus achieving a substantial improvement of a piston diaphragm pump without requiring design-related additional costs.

Accordingly, the diaphragm is preferably designed approximately circular and has an edge which is clamped in the diaphragm housing approximately in one plane, wherein the plane is arranged in a position different from a perpendicular position preferably by 45° to 90°, particularly preferred at such an angle that the highest point of the working volume is formed on a lateral edge region. An approximately perpendicularly upward facing venting valve provided in a piston diaphragm pump according to the prior art can furthermore be used for ventilation of the working volume.

The invention shall be further described using an embodiment shown in the drawings.

Fig 1 shows a cross-sectional depiction of a conventional triple-acting triplex pump known from the prior art;

Fig 2 shows a top view of the pump shown in figure 1;

Fig 3 shows a perspective depiction of a double-acting duplex pump known from the prior art;

Fig 4 shows a view as in figure 3 from a different direction;

Fig 5 shows a side view of a pump unit according to the invention;

Fig 6 shows a view of the drive unit on a pump according to the invention;

Fig 7 shows a cross-sectional depiction of the pump unit according to the invention;

Fig 8 shows a view from above onto the pump unit according to the invention;

Fig 9 shows a perspective depiction of the pump unit according to the invention;

Fig 10 shows a side view of the positive displacement pump according to the invention;

Fig 11 shows a view from above onto the positive displacement pump according to the invention;

Fig 12 shows a perspective depiction of the positive displacement pump according to the invention;

Fig 13 shows a cross-sectional depiction of the positive displacement pump according to the invention on a larger scale;

Fig 14 shows a magnified depiction of figure 4;

Fig 15 shows section A-A in figure 14.

Figure 1 shows the conventional single-acting triplex pump known from the prior art having a drive unit 1 and a pump unit 2. The drive unit 1 comprises a drive shaft 19 which is put into rotation by a motor, for example an electric motor, not depicted. On the drive shaft 19, at least one, merely implied, toothed wheel is arranged which meshes with at least one significantly larger, merely implied, toothed wheel of the crankshaft 18. The drive shaft 19 protrudes on both sides from the housing of the drive unit (figure 2). Three connecting rods 18a are arranged relatively close to one another on the crankshaft. The connecting rods are mounted on the crankshaft by means of a big end bearing which is designed as roller bearing. Each of the connecting rods transmits its movement by means of a crosshead 20 to a crosshead rod 21 which transitions into a piston rod 9. The crosshead bearing is also a roller bearing. The crosshead also comprises sliding shoes which act as its linear bearing on the friction bearing walls. A piston 7 is arranged on the piston rod 9 which moves linearly back and forth in a cylinder 5.

A pump unit 2 is provided on the drive unit 1. Said pump unit 2 provides a working fluid chamber 23 adjoining each cylinder 5, working fluid 22, for example hydraulic oil, being provided in the working fluid chamber 23 which transmits the movement of the piston 7 to the diaphragm 6. In figure 1, the positions of the piston 7 and the diaphragm 6 to one another do not correspond to conventional operation. During conventional operation, the diaphragm 6 is arranged in the not depicted right extreme position instead of the depicted left extreme position at the depicted right extreme position of the piston. The diaphragm 6, together with a part of the diaphragm housing 6a, forms a working chamber 4. By means of check valves 13, said working chamber 4 is connected to a pressure pipe 17 and a suction line not depicted in figure 1. The suction line is arranged below and connected to the suction valve housing 15.

A rotation of the crankshaft 18 causes the working fluid 22 in the working fluid chamber 23 to move back and forth, thus deflecting the diaphragm 6, 6′ alternatingly to the right and to the left. A deflection to the left leads to a closing of the outlet check valve or pressure valve in the pressure valve housing 14 and suction of medium to be pumped through the opened inlet check valve or suction valve in the suction valve housing 15. The subsequent displacement of the piston to the right, according to figure 1, leads to a closing of the inlet check valve and release of a volume of flow volume corresponding to the piston displacement or displaced piston volume through the now open outlet check valve while displacing the diaphragm to the right, relative to figure 1.

Figures 3 and 4 show a duplex pump known from the prior art, i.e. a pump with two connecting rods, piston rods, pistons, and cylinders. It is double-acting. It has four diaphragm housings 6a, 6a′ and is used particularly for bigger volume flows.

Figures 5 to 9 show the pump unit 2 of a positive displacement pump according to the invention which is a piston diaphragm pump. The displacement elements 3, 3′ are thus diaphragms 6, 6′. The depicted embodiment of the pump according to the invention is, in its entirety, denoted with reference sign 100 (figures 10 to 13). It can be seen that the depicted pump 100 according to the invention is a triplet pump or triplex pump. There are three connecting rods 18a which are acting together with three pistons 7 moving inside three cylinders 5.

The drive unit 1 of the depicted pump according to the invention substantially corresponds to the drive unit 1 of the single-acting triplex pump known from the prior art (figures 1 and

2). A comparison, particularly of figures 1 and 13, shows that the previous piston 7 and the previous cylinder 5 (figure 1) now perform at least lead functions. On the right (relative to figure 1) of the previous piston, an extension of the piston rod 9 is arranged and the piston 7 is now attached to it. The piston 7 separates the cylinder 5 into a region which is connected to a working fluid chamber 23 tilted toward the drive unit, and a region which communicates with a working fluid chamber 23′ tilted away from the drive unit. Working or transmission fluid 22, 22′ is arranged in the working fluid chambers 23, 23′ which, for example, can be hydraulic oil.

If the piston 7 moves to the right (relative to figure 13), it displaces the working fluid in the right working fluid chamber 23′ which presses the right diaphragm 6 into the right working chamber 4 (each relative to figure 13). Under conventional operating conditions, the diaphragm 6 depicted on the right is not arranged in its depicted lower extreme position but in its upper extreme position if the piston 7, as shown in figure 13, is in its right extreme position. If the piston 7 moves to the left, the working fluid 22′ arranged in the right working fluid chamber 23′ follows it and suctions the right diaphragm 6 downward. Simultaneously, the left surface 10′ of the piston displaces the working fluid 22 arranged in the left working fluid chamber 23 which causes the left diaphragm 6′ to be pushed upward. With either its movement to the right or its movement to the left, the piston 7 thus applies pressure to one of the two diaphragms 6, 6′.

The diaphragms, together with a part of the diaphragm housings 6a, 6a′, each form a working chamber 4, 4′. As shown particularly in figure 7, the working chambers 4, 4′ are each connected to a pressure pipe 17, 17′ by means of a pressure valve in a pressure valve housing 14, 14′ and to a suction line by means of a suction valve in a suction valve housing 15. Figure 9 shows that exactly one suction valve and exactly one pressure valve are provided per diaphragm 6. The suction valves act on a single suction line while the pressure valves are allotted to two pressure pipes 17, 17′.

The specifications of the single-acting triplex pump shown in figures 1 and 2 (TPM-2200 by Aker Wirth) can be as follows: Piston diameter 310 mm, piston stroke: 508 mm, volume flow rate (design normal) 351 m^3/h, maximum volume flow rate 385 m^3/h, theoretical output per crankshaft rotation: 115.0 l, volumetric efficiency: 0.94, normal stroke count: 54.1 min^{-1}, maximum stroke count: 59.3 min^{-1}, normal pumping pressure: 80.0 bar, maximum pumping pressure: 96.0 bar, gear ratio of the inlying toothed wheels (“internal gear ratio”): 3.8077, piston rod load at normal pumping pressure: 604 kN, piston rod load at maximum pumping pressure: 725 kN, bearing lifespan at operation with maximum load: 69,100 h, bearing lifespan at normal operation: 126,800 h, displaced piston volume: 38.3 l, required diaphragm type in liters: 60 l.

The specifications of the depicted embodiment of the positive displacement pump according to the invention are as follows: Piston diameter 275 mm, piston stroke: 508 mm, volume flow rate (design normal) 351 m^3/h, maximum volume flow rate 385 m^3/h, theoretical output per crankshaft rotation: 173.4 l, volumetric efficiency: 0.94, normal stroke count: 35.9 min^{-1}, maximum stroke count: 39.4 min^{-1}, normal pumping pressure: 80.0 bar, maximum pumping pressure: 96.0 bar, gear ratio of the inlying toothed wheels (“internal gear ratio”): 3.8077, piston rod load at normal pumping pressure: 475 kN, piston rod load at maximum pumping pressure: 570 kN, bearing lifespan at operation with maximum load: 445,700 h, bearing lifespan at normal operation: 810,500 h, displaced piston volume front side: 30.2 l, displaced piston volume rear side: 27.6 l, required diaphragm type in liters: 47 l.

With regard to the diaphragm, there are the following differences: The single-acting triplex pump shown in figures 1 and 2 requires three diaphragms, the size of which is designed for 60 l, the operating hours of the diaphragm are set at 3,000, the number of diaphragm replacements per year (8,000 h) is 2.67.

By contrast, the depicted positive displacement pump according to the invention requires six diaphragms, the size of which is designed for 47 l, the operating hours of the diaphragm are set at 4,500, in case of a possible new development of the diaphragms, up to 8,000 operating hours are expected, the number of diaphragm replacements per year is 1.78 and the number of expected diaphragm replacements per year is 1.

With regard to the valves, the following situation arises: The single-acting triplex pump shown in figure 1 requires six valves with size API 13, with 1,200 operating hours. The average velocity of the valves is 1.72 and the number of valve replacements per year (8,000 h) is 6.67.

By contrast, the depicted embodiment of the positive displacement pump according to the invention requires 12 valves, also size API 13, with 1,800 operating hours. The average velocity is 1.29, the expected operating hours, due to the reduced velocity, are 2,160, the valve replacements per year amount to 4.44 and the expected valve replacements per year are 3.7.

Therefore, particularly the following advantages of the depicted embodiment of the positive displacement pump according to the invention can be identified when compared to the conventional single-acting triplex pump shown in figure 1: Reduction of the piston rod load by more than 20 %, reduced load on the crankshaft due to double action, reduction of the piston speed by 33 %, increase of the lifespan of the bearings and all pump drive unit components up to the entire operating lifespan of 30 years, less wear and increased lifespan of the pump drive unit components by at least 25 %, at least double the diaphragm lifespan, increased pump efficiency, a fundamentally possible, higher volume flow at lower piston rod load, lower maintenance costs due to fewer maintenance cycles per year, fewer production losses, and reduced net positive suction head (NPSHr) of the pump.

Figure 13 also shows that the diaphragms 6, 6′ are not perpendicular but tilted by an angle α from the perpendicular line S. The angle α can be between 1° and 90°, particularly 60° and 80°. In the depicted embodiment, it is approximately 70°. The working fluid chamber 23, 23′ has a cylindrical shape in the region adjoining the diaphragm housing 6a, 6a′. The cylinder axis is perpendicular to the diaphragm (in its neutral position). The cylindrical region of the working fluid chamber 23, 23′ is thus tilted at an angle β from the perpendicular line. Said angle can span from 0° to 89°. In the depicted embodiment, it is approximately 20°. For reasons of symmetry, angles α and β combined always add up to 90°.

The tilting of the diaphragms 6, 6′, i.e. their tilt from the perpendicular line, which has inventive significance in itself, achieves several advantages. A space-saving arrangement of the diaphragm housings on the compactly parallel cylinders 5 is achieved which allows for the structure of a compact double-acting triplex pump with closely parallel cylinders. Furthermore, it results in a decrease of the hydraulic pressure component acting irregularly on the diaphragm when compared to a perpendicular diaphragm. This leads to an increased lifespan of the diaphragm. The impact of possible gas deposits in the medium to be pumped 24, 24′ on the lifespan of the diaphragm, possibly caused or amplified by cavitation, is decreased. The measures and impacts of the tilting of the diaphragm shall be further explained with reference to figures 14 and 15.

The piston diaphragm pump, in its entirety denoted with reference sign 200 in figures 14 and 15 is—as can be seen in figure 14—once again designed as a three-piston diaphragm pump.

Figure 15 shows a longitudinal section through the middle part of the pump. The two further parts of the pump are designed accordingly.

The depicted piston diaphragm pump 200 comprises a motor-driven crankshaft 10, on the middle crankpin 102 of which, a connecting rod 103 is mounted by means of a big end bearing 104. On the other end of the connecting rod 103, a crosshead 105 is mounted by means of a crosshead bearing 106. The crosshead comprises sliding shoes 107 which act as its linear bearing on the friction bearing walls 108.

A piston rod 109 is attached to one end of the crosshead 105. The other end of the piston rod 109 holds a piston 110 which is designed as double-acting piston and operates within a cylinder 111. Figure 2 shows the right dead center.

The cylinder 111 is arranged within a working volume which is divided by the piston 110 into two working volumes 112a, 112b. The right end of the working volume 112b in figure 2 is closed with a lid 113. On the left end of the working volume 112a, another lid 114 is attached which is provided with a central opening 115 for passage of the piston rod 109. A sealing arrangement 116 is provided on the lid 114 which seals the piston rod 109 with respect to the lid 114 from leaking working liquid from the working volume 112.

The working liquid not depicted in the drawing—frequently hydraulic oil, thus also called oil supply—fills the working volume 112a, 112b up to two diaphragms 117a, 117b which are depicted in figure 15 (relative to the dead center position of the piston 110 incorrectly) in their middle position. In reality, the diaphragm depicted on the left would be deflected downward on both sides of the double-acting piston 110 due to the substantial consistency of the working liquid volume, and the diaphragm 117 would be correspondingly deflected upward, as is qualitatively shown with the broken line in figure 15.

The diaphragms 117a, 117b are arranged in diaphragm housings 118a, 118b and separate diaphragm chambers 119a, 119b from the oil supply in the working volume 112a, 112b.

The diaphragm housings 118a, 118b are attached to flanges 120a, 120b of channel housings 121a, 121b. The channel housings 121a, 121b comprise channels 122a, 122b which form parts of the working volume 112a, 112b. The two channel housings 121a, 121b, which are designed substantially straight, each comprise an angle of approximately 20° with the perpendicular line such that the distance between the two channel housings 121a, 121b widens upwardly. The diaphragm housings 118a, 118b, in which the diaphragms 117a, 117b are clamped with their planar edge regions 123a, 123b, are attached to the flanges 120a, 120b such that the diaphragms 117a, 117b in their planar middle position extend perpendicularly to the longitudinal axis of the corresponding channel 122a, 122b. In the embodiment depicted in figure 15, the two diaphragms 117a, 117b are thus arranged at an angle of 70° from the perpendicular line.

Every diaphragm chamber comprises an inlet 124a, 124b each with a flange-mounted inlet check valve 125a, 125b (see figure 14).

On the sides opposite of the inlets 124a, 124b, the diaphragm chambers 119a, 119b comprise outlets 126a, 126b each with a flange-mounted outlet check valve 127a, 127b.

The rotary action of the crankshaft 101 causes the working liquid to be moved back and forth in the working liquid volume 112a, 112b and the diaphragms 117a, 117b to be moved back and forth between the extreme deflections depicted as broken line. Each downward deflection leads to a suctioning of slurry through the correspondingly opened inlet check valve. This pumping phase is also called suction stroke. The subsequent deflection of the piston leads to a closing of the previously opened inlet check valve and output of the volume of slurry, which corresponds to the displacement, through the now opened outlet check valve while the diaphragm is displaced in the upwardly curved extreme position, depicted as broken line in figure 15.

In order to be able to release gas—particularly air--which possibly accumulated in the region below a diaphragm in the working volume 112a, 112b, the two diaphragm housings are provided with venting valves (not depicted) in the highest edge region of the diaphragms 117a, 117b, denoted in the drawing with 128a, 128b.

List of reference signs:

100	Positive displacement pump
1	Drive unit
2	Pump unit
3, 3′	Displacement elements
4, 4′	Working chambers
5	Cylinder
5a	Cylinder housing
6, 6′	Diaphragms
6a, 6a′	Diaphragm housings
7	Piston
8	blank
9	Piston rod
10, 10′	Piston surfaces
11	Inlet
12	Outlet
13	Check valve
14, 14′	Pressure valve housing
15	Suction valve housing
16	Suction line
17, 17′	Pressure pipe
18	Crankshaft
18a	Connecting rod
19	Driveshaft
20	Crosshead
21	Crosshead rod
22, 22′	Working or transmission fluid
23, 23′	Working fluid chamber
24, 24′	Medium to be pumped

S	Perpendicular line
α, β	Angles
200	Piston diaphragm pump
101	Crankshaft
102	Crankpin
103	Connecting rod
104	Big end bearing
105	Crosshead
106	Crosshead bearing
107	Sliding shoes
108	Friction bearing wall
109	Piston rod
110	Piston
111	Cylinder
112a, 112b	Working volumes
113	Lid
114	Lid
115	Opening
116	Sealing arrangement
117a, 117b	Diaphragms
118a, 118b	Diaphragm housings
119a, 119b	Diaphragm chambers
120a, 120b	Flanges
121a, 121b	Channel housings
122a, 122b	Channels
123a, 123b	Edge regions
124a, 124b	Inlets
125a, 125b	Inlet check valves
126a, 126b	Outlets
127a, 127b	Outlet check valves
128a, 128b	Regions

Patent claims:

1. Positive displacement pump (100) comprising a drive unit (1) and a pump unit (2) having a plurality of working chambers (4, 4′), a plurality of displacement elements (3, 3′), with at least three cylinders (5), preferably exactly three cylinders (5), **characterized in that** the pump unit (2) is double-acting.

2. Pump according to claim 1, **characterized in that** the displacement elements (3, 3′) are diaphragms (6, 6′) and pistons (7) are provided for actuating the diaphragms (6, 6′).

3. Pump according to claim 1 or 2, **characterized in that** the pump (100) is a thick matter pump.

4. Pump according to one of the claims 1 to 3, **characterized in that** the drive unit (1) is provided the same way it is provided for in a conventional single-acting triplex pump with cylinders (5) running closely parallel to one another.

5. Pump according to one of the claims 1 to 4, **characterized in that** the speed is reduced with respect to a conventional single-acting triplex pump.

6. Pump according to one of the claims 2 to 5, **characterized in that** the size of the piston surfaces (10, 10′) is reduced with respect to a conventional single-acting triplex pump.

7. Pump according to one of the claims 2 to 6, **characterized in that** the diaphragms (6, 6′) are tilted at an angle (α) of 1° to 90° relative to the perpendicular line (S).

8. Pump according to one of the claims 2 to 7, **characterized in that** the diaphragms (6, 6′) are arranged higher than the cylinders (5).

9. Pump according to one of the claims 1 to 8, **characterized in that** it has a power of at least 700 kW.

10. Pump unit (2) of a pump (100) according to one of the claims 1 to 9.

11. Operating method of a positive displacement pump designed as a piston diaphragm pump (200), particularly a positive displacement pump according to one of the claims 1 to 9, wherein a diaphragm stroke is caused by means of working liquid present on the first side of a diaphragm and a medium to be pumped is conducted through a diaphragm chamber bounded by the second side of the diaphragm due to the diaphragm stroke,
characterized in that
the diaphragm stroke is caused at a diaphragm position different from a vertical position of the diaphragm (117a, 117b).

12. Operating method according to claim 11, **characterized in that** the diaphragm stroke is caused at a diaphragm position different from the perpendicular line by 45° to 90°.

13. Operating method according to claim 12, **characterized in that** the diaphragm stroke is caused at a diaphragm position different from the perpendicular line by approximately 70°.

14. Positive displacement pump designed as a piston diaphragm pump (200) particularly according to one of the claims 1 to 9,
having a piston (110) performing an oscillating movement in a cylinder (111), the movement of said piston (110) being transmittable to a diaphragm (117a, 117b) using a working fluid which separates a working volume (112a, 112b) containing the working liquid from a diaphragm chamber (119a, 119b) through which a medium to be pumped can be conducted,

characterized in that
the diaphragm (117a, 117b) is arranged in a position different from a perpendicular line.

15. Piston diaphragm pump according to claim 14, **characterized in that** the diaphragm (117a, 117b) is arranged in a position different from a perpendicular line by 45° to 90°.

16. Piston diaphragm pump according to claim 15, **characterized in that** the diaphragm (117a, 117b) is arranged in a position different from a perpendicular line by approximately 70°.

17. Piston diaphragm pump according to one of the claims 14 to 16, **characterized in that** the cylinder (111) with its longitudinal axis is arranged approximately horizontally.

18. Piston diaphragm pump according to one of the claims 14 to 17, **characterized in that** the working volume (112a, 112b) is formed to some extent by a channel (120a, 120b) extending upward at an angle from the cylinder.

19. Piston diaphragm pump according to claim 18, **characterized in that** the channel (122a, 122b) is designed approximately straight and a flange (120a, 120b) aligned approximately perpendicularly to the longitudinal axis of the channel (125a, 125b) is provided on the channel housing (121a, 121b) forming the channel (122a, 122b), and a diaphragm housing (118a, 118b) for receiving the diaphragm (117a, 117b) being attached to said flange.

20. Piston diaphragm pump according to claim 19, **characterized in that** the preferably approximately circular diaphragm (117a, 117b) has an edge region (123a, 123b) which is clamped in the diaphragm housing (118a, 118b) approximately in one plane, wherein the plane is arranged in a position different from a perpendicular

position preferably by 45° to 90°, particularly preferred by such an angle that the highest point of the working volume (112) is formed on a lateral edge region (128a, 128b).

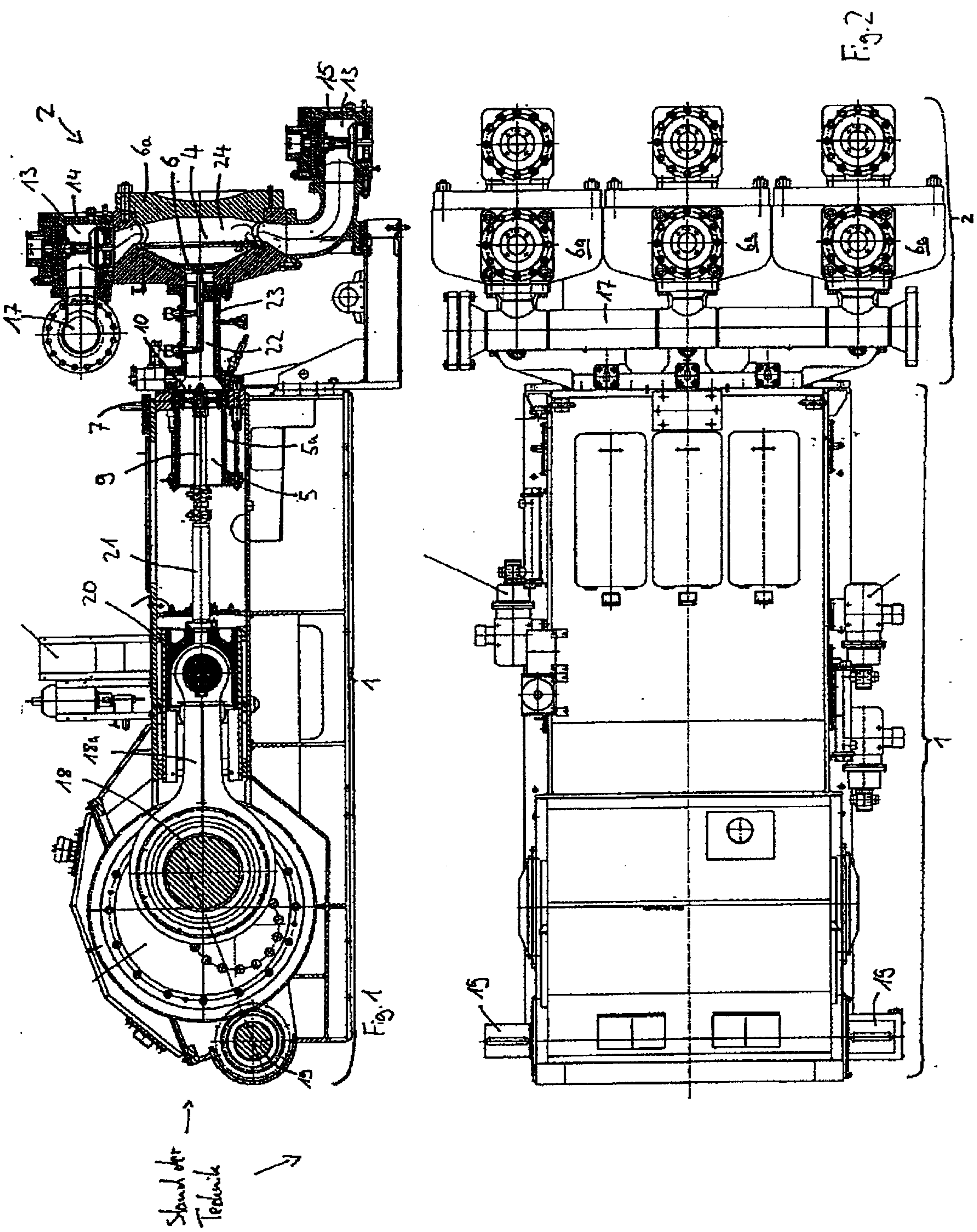

Fig. 1

Fig. 2

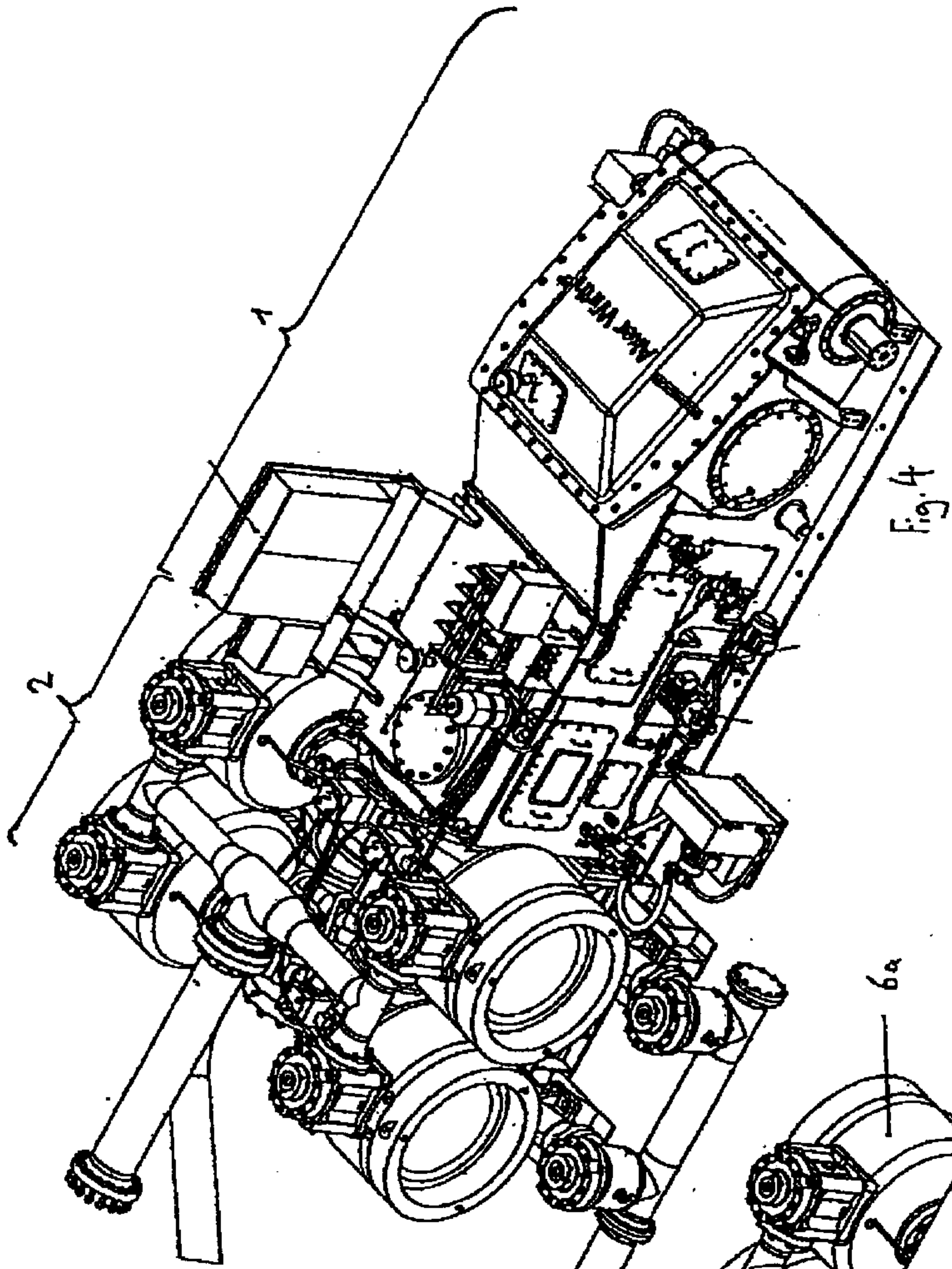

Fig. 4

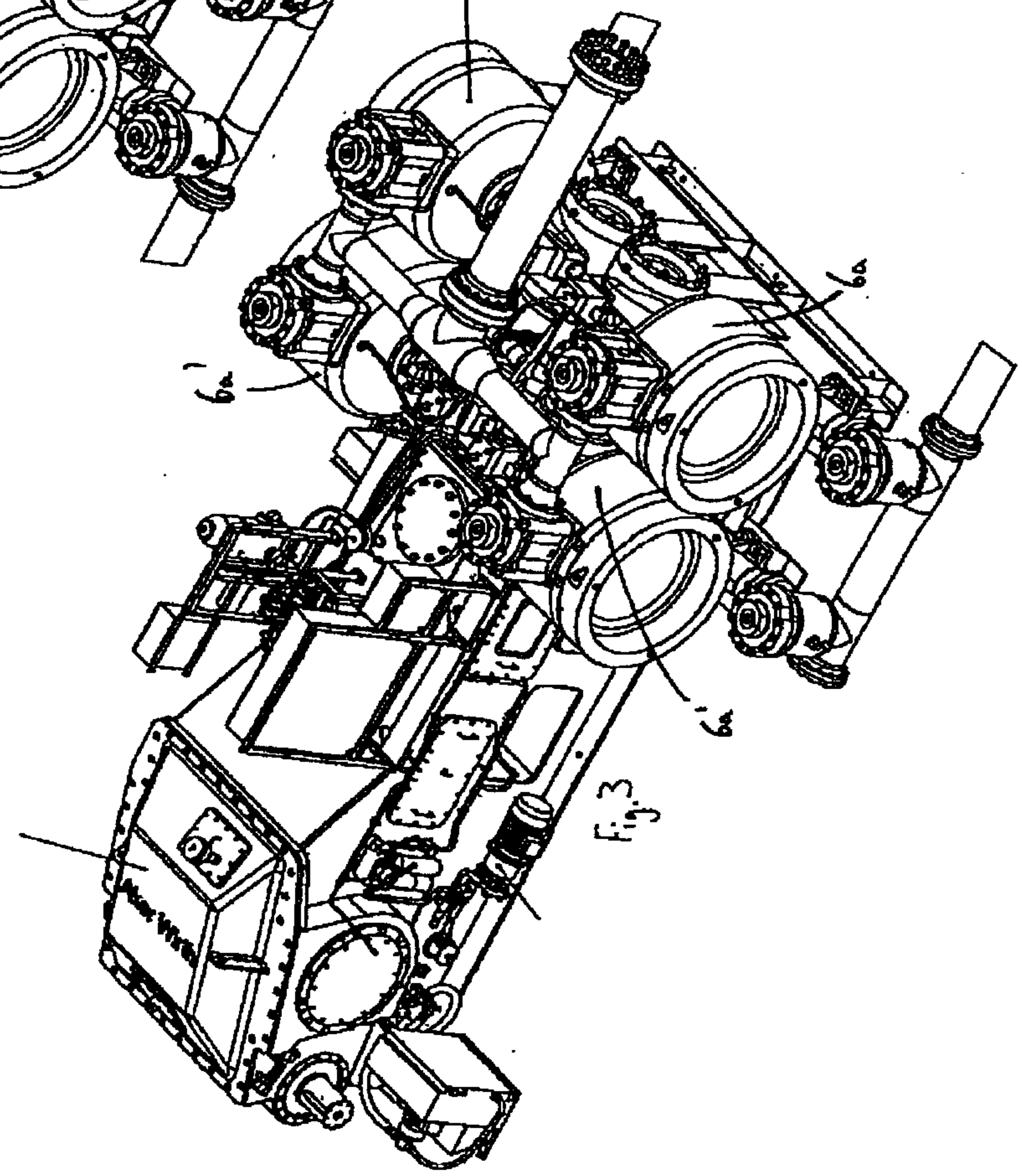

Fig. 3

Stand der Technik für größere Volumina

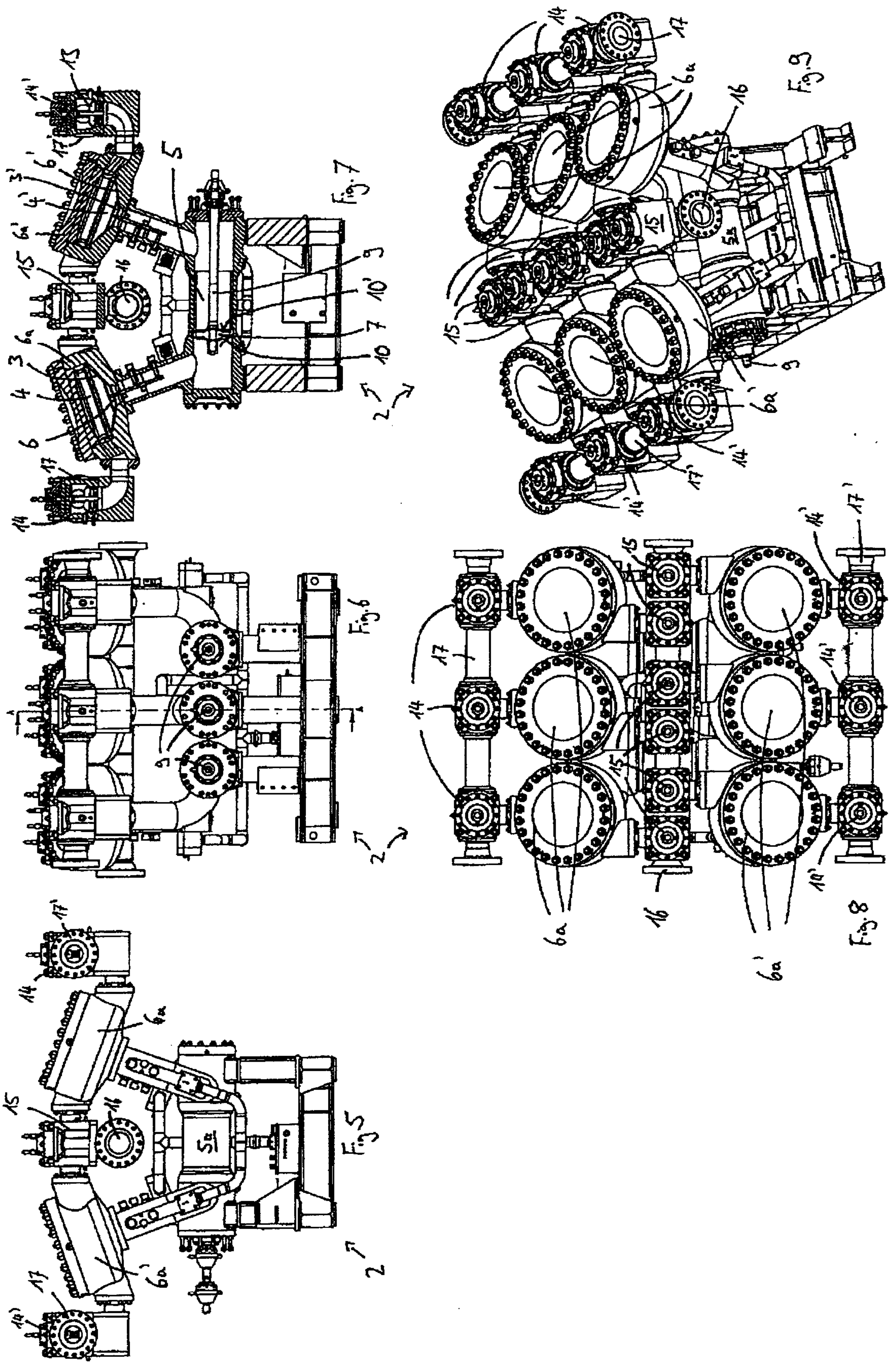
Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9

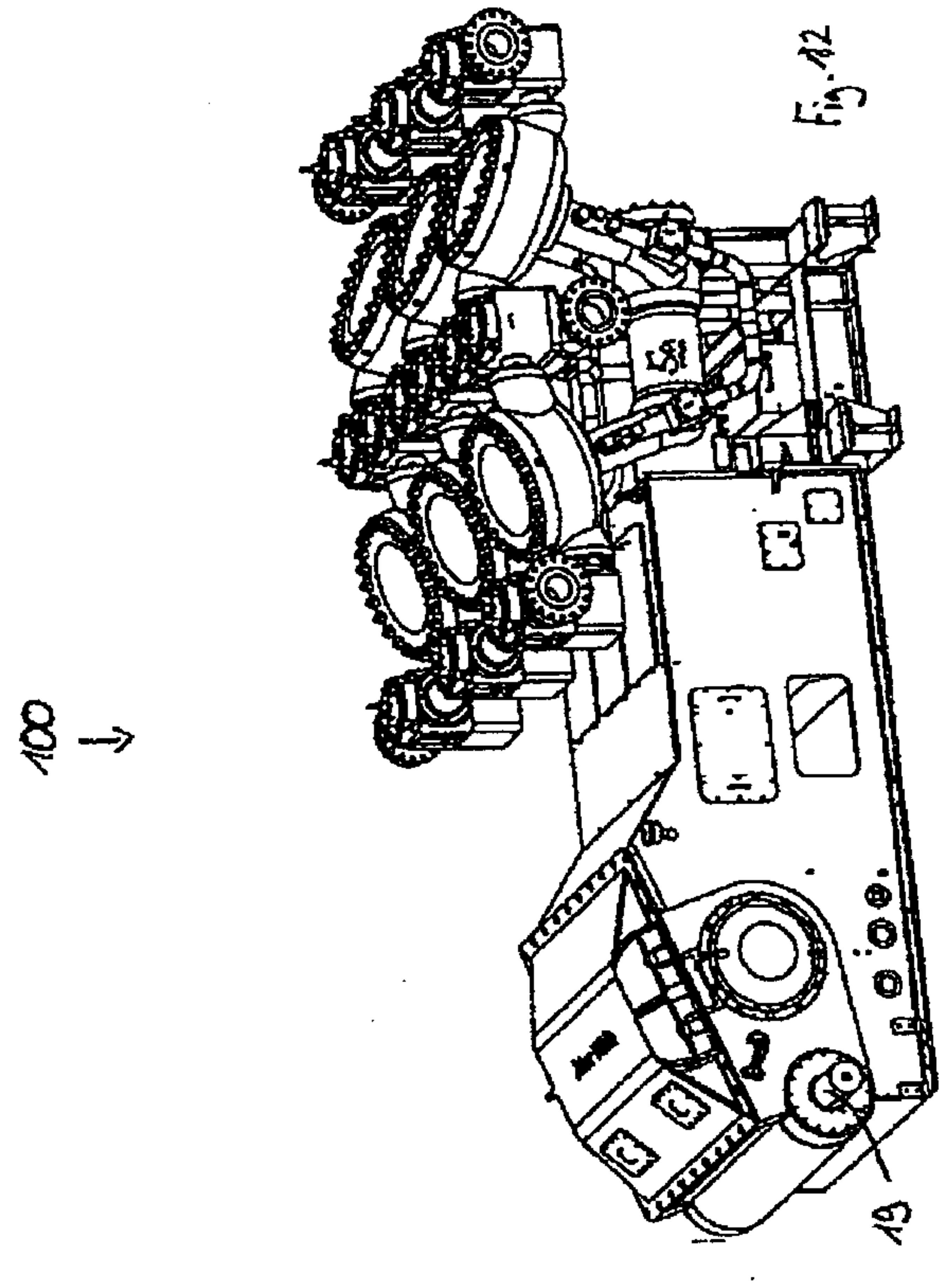

Fig. 12

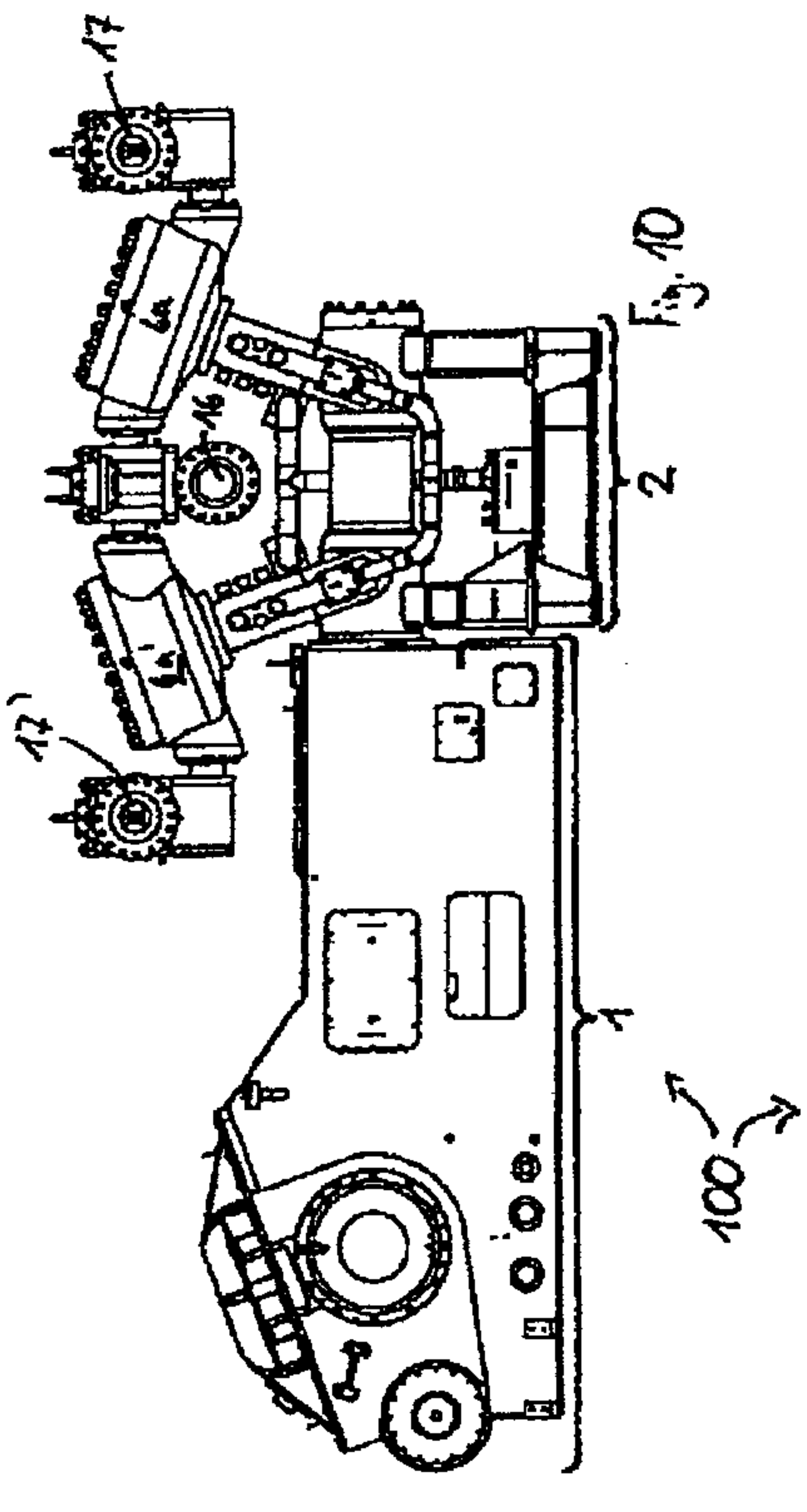

Fig. 10

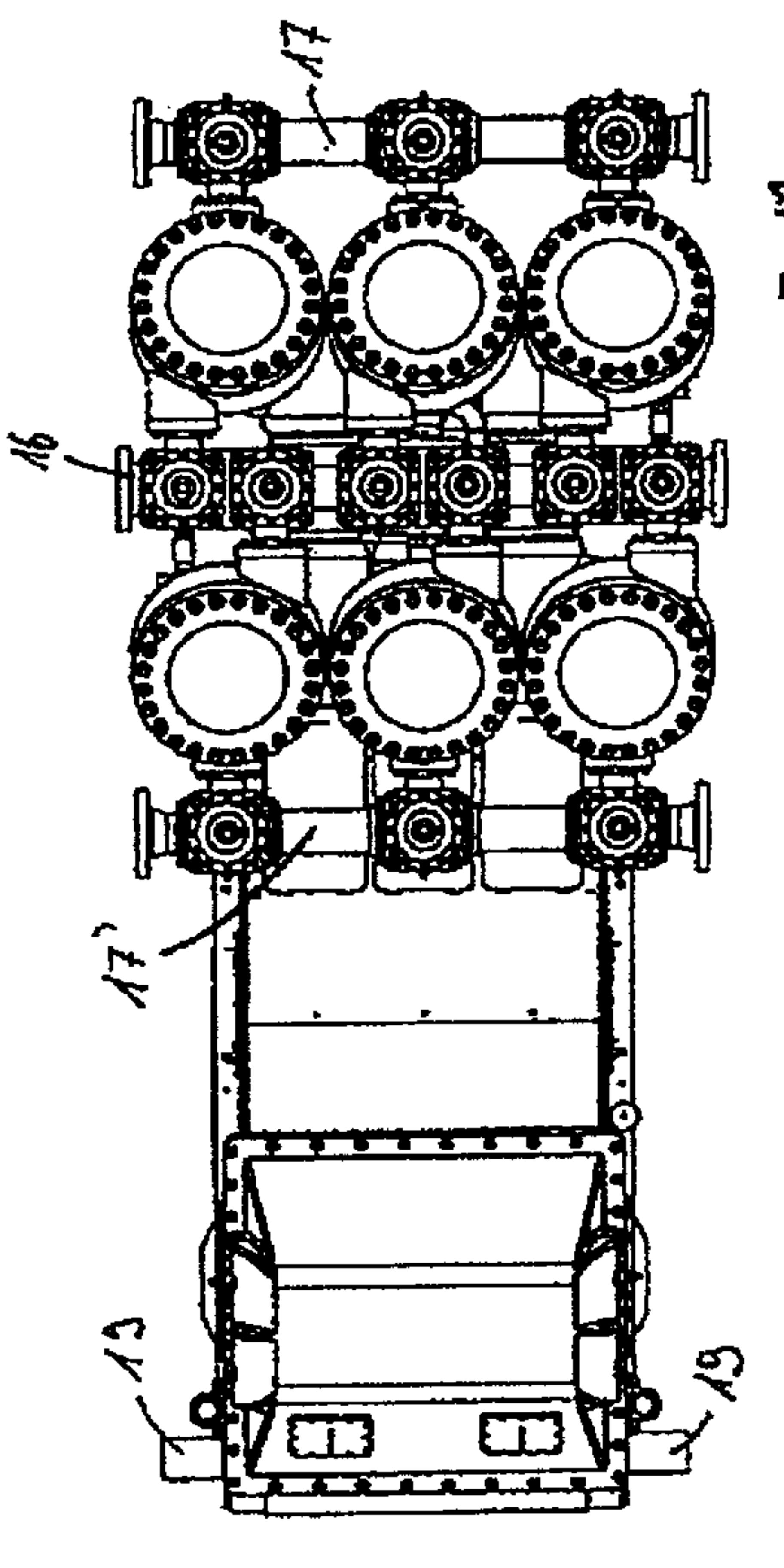

Fig. 11

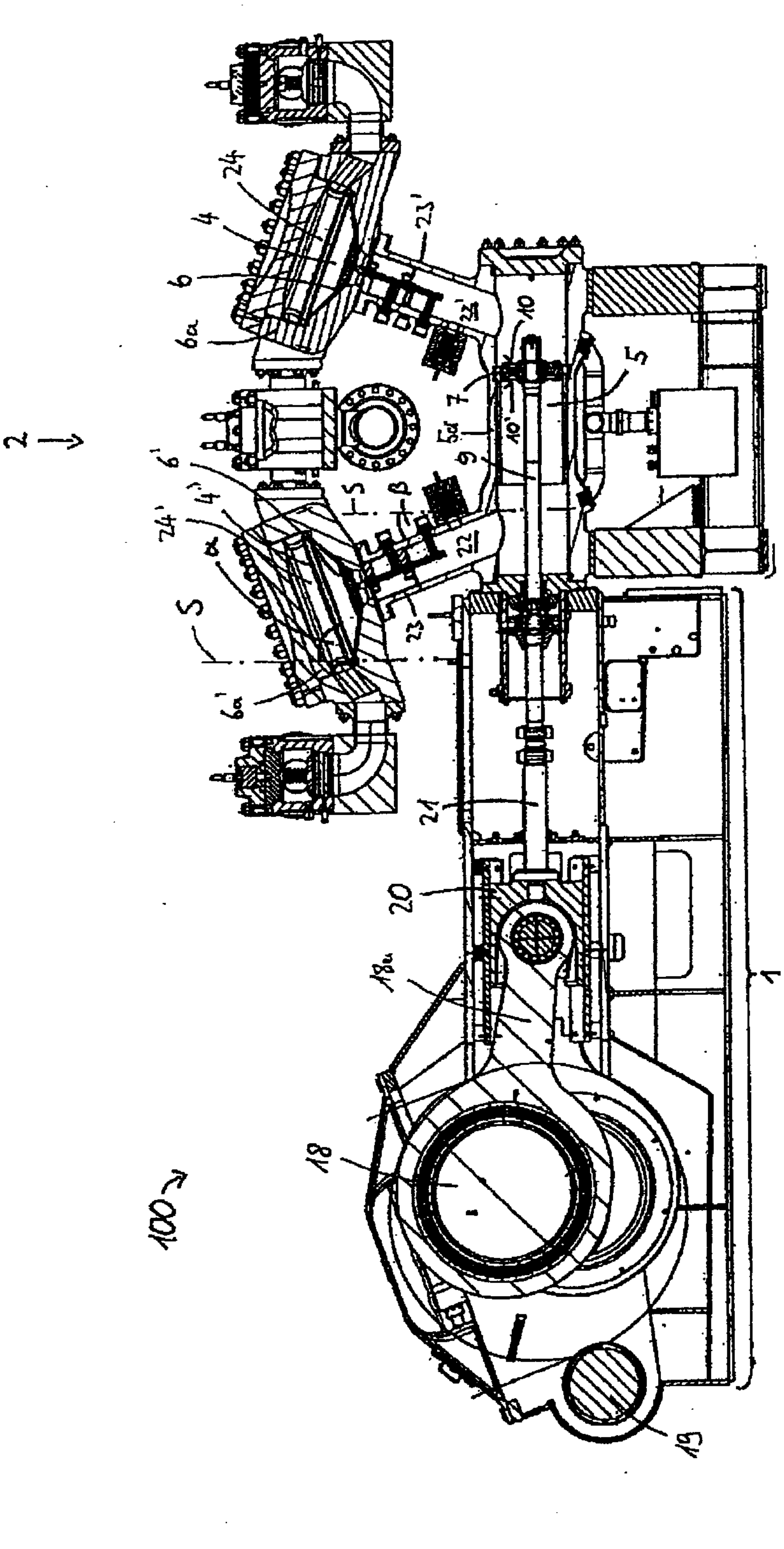

Fig. 13

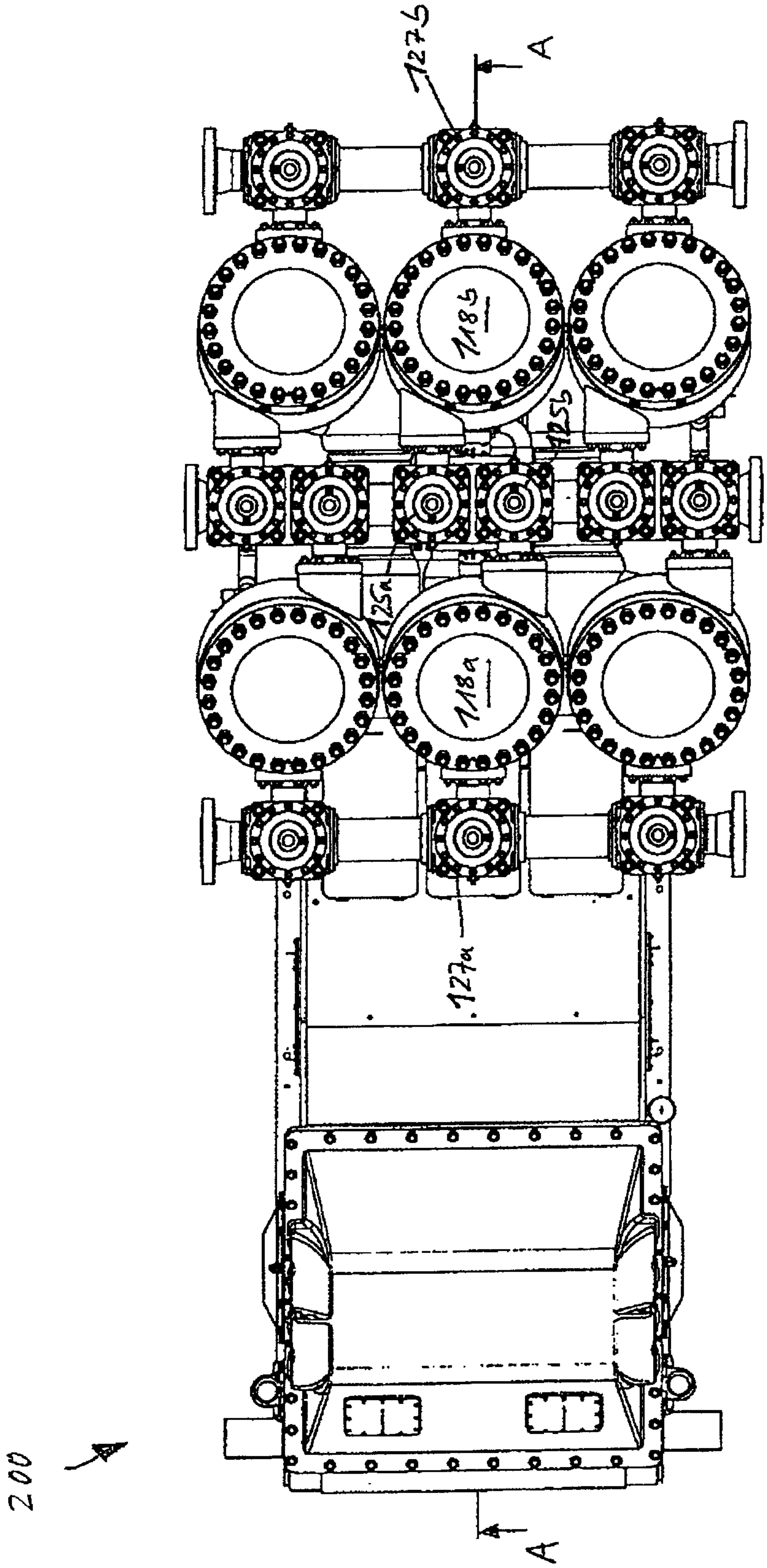

Fig. 14

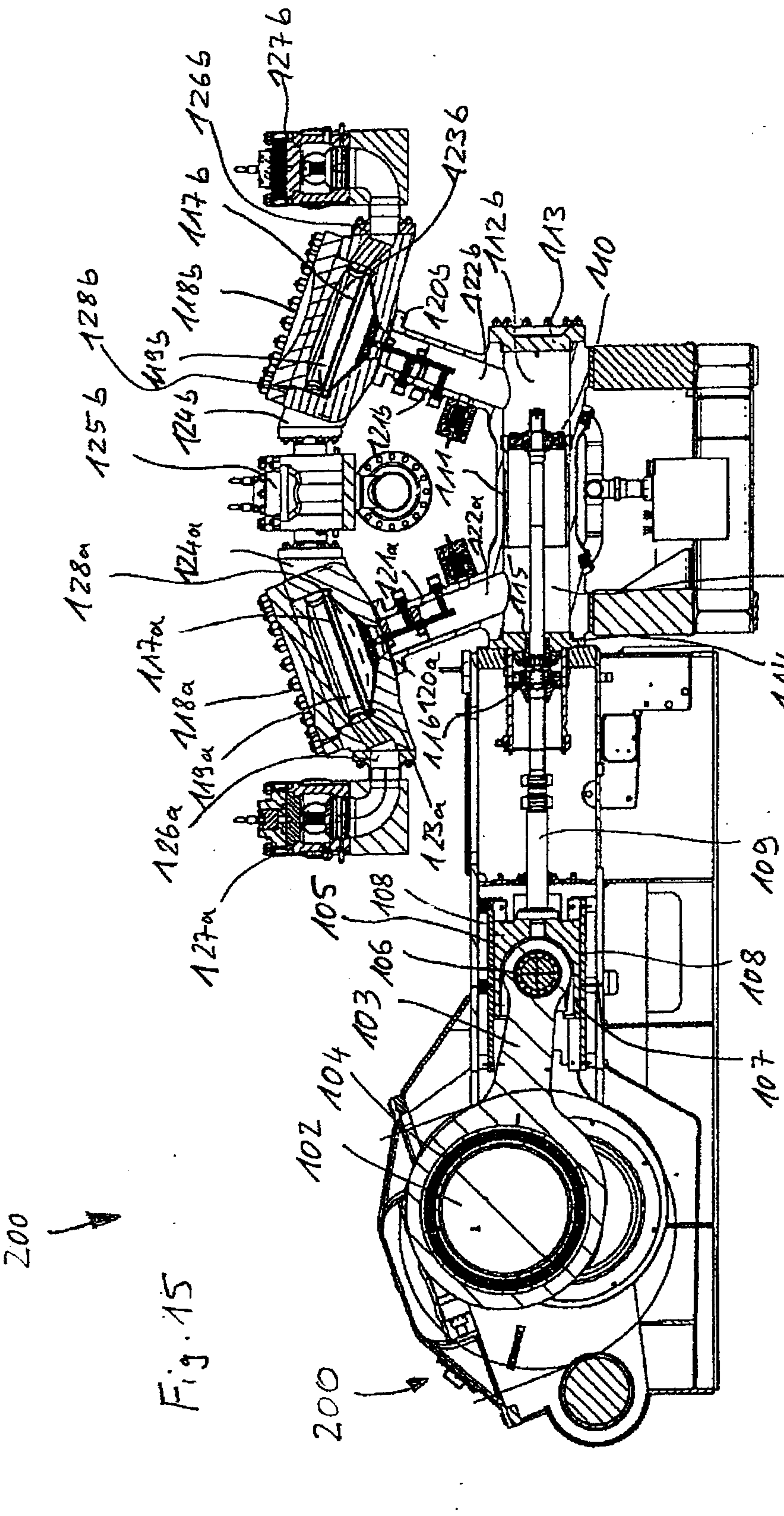
200
102
104
103
106
105
108
108
107
109
127a
126a
119a
118a
117a
128a
123a
116
120a
124a
121a
122a
115
114
112a
125b
124b
121b
111
128b
119b
118b
117b
120b
122b
112b
113
110
126b
123b
127b

Fig. 15

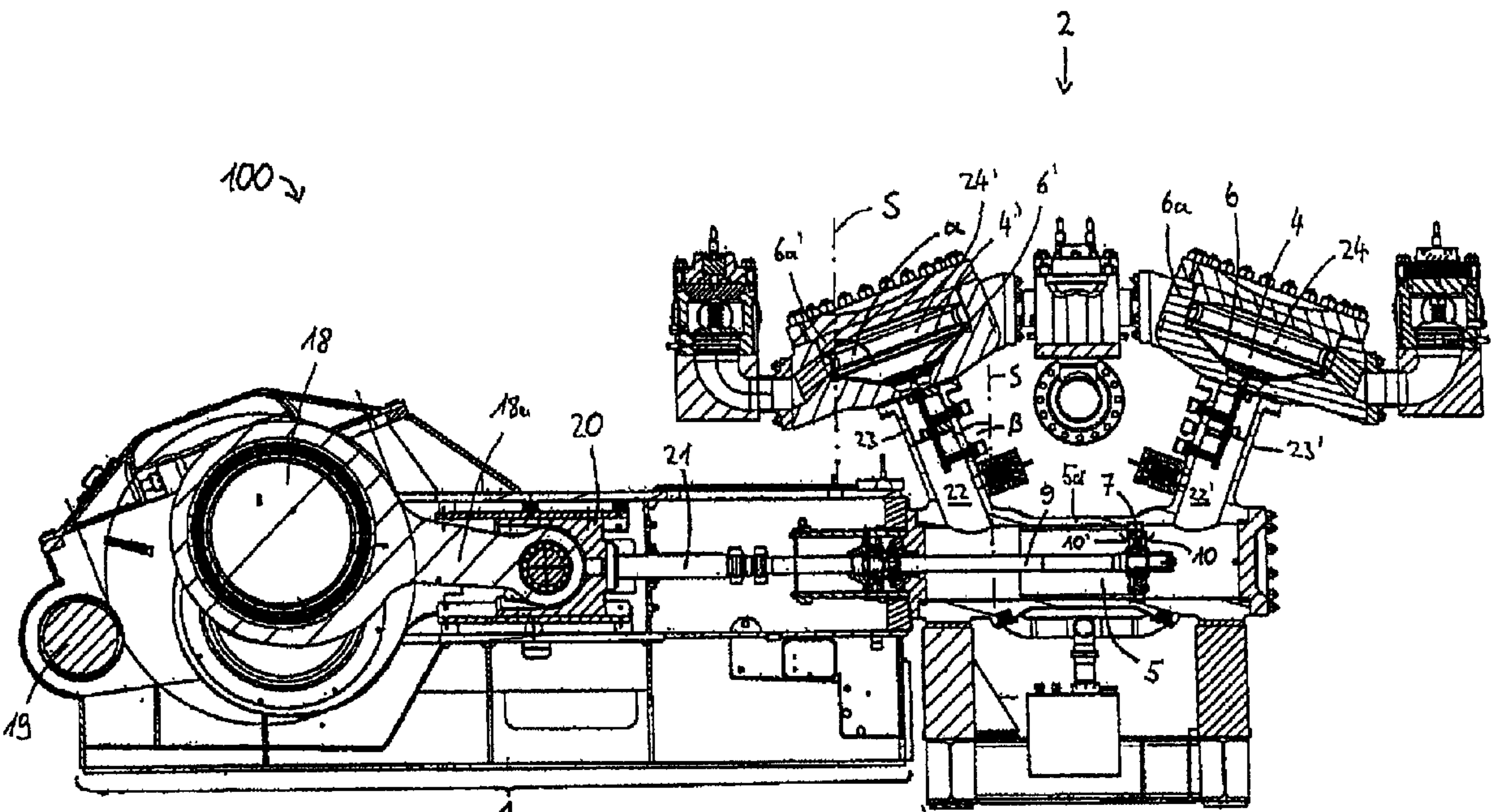

Fig. 13