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(54) Centrifugal compressor.

(57) An improved centrifugal compressor having a single casing (1) and yet containing therein a plurality of stages of centrifugal compressors, is disclosed herein. The disclosed centrifugal compressor comprises a plurality of axles (3, 7, 12) each having centrifugal impellers, electromagnetic bearings (13, 14, 15, 16, 17, 18, 29) for supporting the axles (3, 7, 12) in a non-contact manner at their opposite ends, coupling means (19) for coupling adjacent ones among the plurality of axles (3, 7, 12) arrayed in series so as to compressively transport gas sucked from one side towards the other side, in such manner that misalignment of their axes with one another may be allowed, a casing (1) for supporting the plurality of coupled axles (3, 7, 12) integrally with the electromagnetic bearings (13, 14, 15, 16, 17, 18, 29) therefor and having a suction port (2) of gas at one end in the axial direction and a delivery port (11) thereof at the other end, and seal means (23) around the axle provided on the side having the delivery port (11) of the casing (1).

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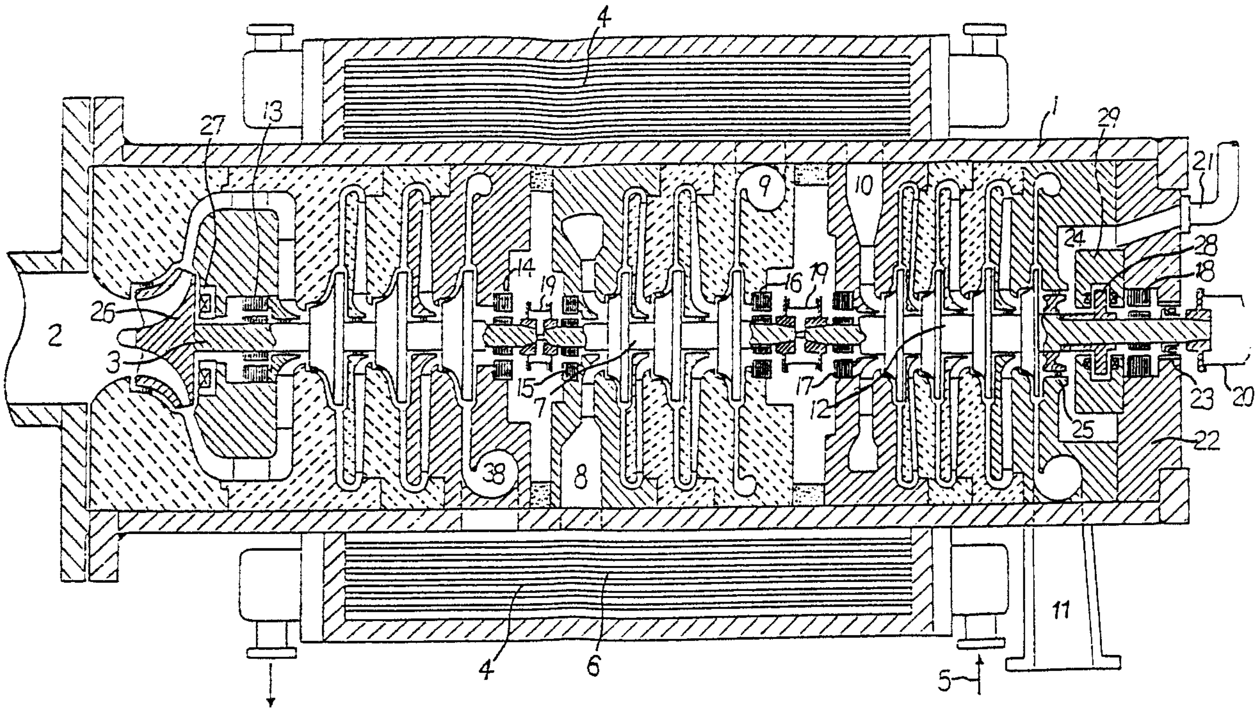
Fig. 1



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CENTRIFUGAL COMPRESSOR

BACKGROUND OF THE INVENTION:

Field of the Invention:

The present invention relates to a centrifugal compressor in a gas compressing system available in the field of the petrochemistry or the like.

Description of the Prior Art:

Generally, regarding a centrifugal compressor, a capability of raising a pressure with one stage of impeller has a limit, and in the case where a high pressure ratio or a high pressure head is required, a multi-stage arrangement is employed. Normally, the number of stages of impellers that can be accommodated within a single casing is limited in order to insure rigidity of an axle and to realize safe operations. Accordingly, in the prior art, in the case where a high pressure head was required, it was realized by arraying a plurality of casings either in series or in parallel.

Fig. 3 illustrates one example of the arrangement in the prior art, in which in order to realize a high pressure head, a gas compressing system was constructed by arraying three casings of a first compressor 49, a second compressor 50 and a third compressor 51 in series as numbered sequentially from the suction side. The interior of the individual compressor casing is composed of a multiple stages of centrifugal compressors. Driving power fed from a driving machine is transmitted via a drive shaft 57, and it is distributed from the third compressor 51 to the second compressor 50, and from the second compressor 50 to the first compressor 49, respectively by the intermediary of an intermediate coupling.

An intake gas is sucked through a gas suction pipe 41, then it is compressed by the first compressor 49, and it is delivered through a gas delivery pipe 42. The delivered gas passes through an intermediate gas cooler 43, in which heat-exchange is effected between the gas and a coolant water introduced from the outside through a coolant water feed pipe 58, and thereby the gas is cooled. Again the gas is sucked through a gas suction pipe 44 of the second compressor 50, and it is delivered through a gas delivery pipe 45. Further again, the gas cooled by an intermediate gas cooler 46 in a similar manner is sucked through a gas suction pipe 47 and compressed by the third compressor 51, then it is delivered from a final gas delivery port 48, and it is used as a high-pressure gas.

In the respective compressors, bearings are disposed in the proximities of the opposite axial end surfaces of the casing, and in order to prevent the gas enclosed within the casing from leaking out, gas seal means are disposed at the locations where the drive shaft penetrates the end plates of each casing.

In the case of the illustrated example, use of a film seal or a mechanical seal as the gas seal means is illustrated, and sealing oil appropriately adjusted so as to meet the order of the gas pressure within the casing, is fed through sealing oil feed tubes 52, 53 and 54, respectively. Though these mechanisms for feeding sealing oil are constructed so as to follow the change of the pressure within the casing, if the feed of sealing oil should become faulty, the sealing capability would be lost, and hence, the gas seal means per se as well as the sealing oil feed mechanism are respectively required to individually have a high reliability, and their manufacturing expense would become high.

In addition, lubricant oil is fed to the bearings through a lubricant oil feed tube 55, and drain oil in the bearing boxes is drained through a lubricant oil pipe 56.

In the case where a compressor is composed of a large number of casings as is the case with the above-described centrifugal compressor in the prior art, a large number of seals for preventing the internal gas from leaking out to the atmosphere are necessitated at the locations where the axle penetrates through the opposite axial end surfaces of the respective casings. As the method for sealing the axle, various methods such as an oil film seal method, a mechanical seal method, a gas seal method, etc. can be employed depending upon the respective uses. However, in any event, the gap space between the axle rotating at a high speed and a seal ring mounted to a stationary portion is necessitated to be held narrow, and so, manufacture, assembly and maintenance are necessitated to be paid with careful caution. Even if it were to be done, a possibility that one of the large number of seal means may become faulty is large, and so, in order to insure high reliability, it is necessary to use expensive materials and perform machining at a high precision for the respective seal means.

Accordingly, in the case where a compressor is constructed by making use of a large number of casings and employing a large number of seals as in the above-described case, it is difficult to economically insure stable operations for a long period of time.

In addition, in the case where a compressor is constructed of a large number of casings, it is necessary to maintain the axes between the casings invariant during an operation, hence the structures of the mounting tables of the respective casings would become complex, moreover contrivance is made for the method of supporting the suction and delivery pipings of gases to and from the respective casings, and a complex method for mounting the pipings so that forces generated by deformation of the pipings may not unnecessarily applied to the casings, is employed. In addition, since cooling of gas for the purpose of efficiently compressing the gas is effected between delivery from one casing and suction into the next casing, a gas cooler disposed separately outside of the casings is employed, and hence, high-pressure gas pipings between the respective implements would become long and complex.

As these disadvantages in the prior art would overlap on one another, a compressing system for realizing compression of high pressure head is complicated in structure and apt to have its reliability lowered, but nevertheless it was difficult to provide the compressing system at a low cost.

Furthermore, since the volume of gas sucked into the first compressor is large, in order to compress the gas efficiently, suction through an axial end surface is desirable, but in the prior art, as oil-lubricated bearings are used, a complicated seal for preventing oil from mixing into the gas is necessitated, and therefore, an extension length of the axle to the outside of the bearing becomes too large, and there was difficulty in a stable operation.

SUMMARY OF THE INVENTION:

It is therefore one object of the present invention to provide an improved centrifugal compressor, that is free from the above-mentioned shortcomings in the prior art.

A more specific object of the present invention is to provide a centrifugal compressor, in which stable operations over a long period time can be insured in an economical manner.

Another object of the present invention is to provide a centrifugal compressor which does not necessitate a large number of seal means.

Yet another object of the present invention is to provide a centrifugal compressor which can be constructed in a less expensive matter without necessitating expensive materials nor machining at a high precision.

Still another object of the present invention is to provide a centrifugal compressor which does not necessitate a complicated mounting structure for maintaining axial alignment of a plurality of axles having impellers thereon.

According to one feature of the present invention, there is provided a centrifugal compressor comprising a plurality of axles each having centrifugal impellers that can compress gas by making use of a centrifugal force exerted upon the gas, electromagnetic bearings for supporting the axles at their opposite ends without being held in contact with the axles, coupling means for coupling the axles with one another as arrayed in series sequentially in such order that said gas can be compressed towards one side, in such manner that misalignment of their axes with one another may be allowed, a casing for supporting the plurality of coupled axles integrally with the electromagnetic bearings therefor and having a suction port of gas at one end in the axial direction and a delivery port thereof at the other end, and seal means around the axle provided on the side having the delivery port of the casing.

According to another feature of the present invention, there is provided the above-featured centrifugal compressor, wherein a gas cooling section for cooling the gas compressed by the centrifugal impellers on the axles, is mounted to the casing.

According to still another feature of the present invention, there is provided the first-featured centrifugal compressor, wherein a suction magnetic bearing for sucking the axle on the gas suction side towards the gas delivery side is provided, and the electromagnetic bearing on the gas delivery side is a thrust bearing for holding the axle on the gas delivery side at a predetermined position in its axial direction.

According to yet another feature of the present invention, there is provided the first-featured centrifugal compressor, wherein the coupling means is composed of restraining shafts mounted to the adjacent axial ends of the axles so as to oppose to each other, two flexible discs disposed around the restraining shafts and respectively mounted to the respective axles, and a torque transmission tube connected to the flexible discs.

According to the present invention, owing to the above-described construction that a plurality of axles are disposed in series within a single casing and the respective axles are supported by magnetic bearings at their opposite ends, bearing oil is not necessitated. And, by disposing the bearings in the gas, the location where the axle penetrates through the end surface on the high pressure side of the casing becomes only one location on the side for transmitting driving power, and so, the number of places where counter-measure for leakage of gas must be taken is greatly reduced, and high reliability can be realized.

The above-mentioned and other objects, features and advantages of the present invention will become more apparent by reference to the following description of one preferred embodiment of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the accompanying drawings:

Fig. 1 is a longitudinal cross-section view of a centrifugal compressor according to one preferred embodiment of the present invention;

Fig. 2 is a detailed longitudinal cross-section view of an intermediate coupling employed in the same embodiment; and

Fig. 3 is a plan view of one example of a centrifugal compressor in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

Now, one preferred embodiment of the present invention will be described with reference to Figs. 1 and 2.

In Fig. 1, gas sucked through a gas suction port 2 provided at one end of a casing 1 for sucking gas in the axial direction, is compressed by an impeller 26 mounted to the tip end of a first axle 3. This gas passes along the outer circumference of a bearing body supporting the axle 3, and while it is being compressed by a multiple stages of centrifugal impellers, it is delivered from the last stage centrifugal impeller mounted to the axle 3, and it flows out through a first delivery port 38. Thereafter, the gas flows into a gas cooling section 4 mounted on the outer circumference of the casing 1, where it passes through the interstices in a cooling tube group 6 which is cooled by an externally supplied coolant water 5, and after it has been cooled down to a predetermined temperature, it is led to a gas suction port 8 of a multi-stage compressor assembly mounted to a second axle 7. The gas compressed again and delivered through a delivery port 9 is again introduced into the gas cooling section 4 on the outer circumference of the casing 1, and it is cooled there. The gas side chamber in the gas cooling section 4 is partitioned into two chambers for use with the axle 3 and for use with the axle 7. The cooled gas is again introduced to a gas suction port 10 of a multi-stage compressor assembly constructed by a third axle 12, and it is again compressed there by a compressing action consisting of the action of the impeller and the already known diffuser effect, in combination. The gas compressed up to the final stage is delivered through a final delivery port 11 at a predetermined pressure.

As described above, within a single casing 1 is disposed a compressor assembly composed of a plurality of axles 3, 7 and 12 each having impellers mounted thereon, and a stationary member for forming gas passageways to properly compress gas.

The axle 3 is supported by radial bearings 13 and 14, the axle 7 is supported by radial bearings 15 and 16, the axle 12 is supported by radial bearings 17 and 18, and all these axles are supported independently in a non- contact manner by an electromagnetic effect making use of magnets. Since these bearings do not necessitate lubricant oil as is the case with the bearings in the prior art, they could be disposed even in gas without being accompanied by any problem. The respective axles 3, 7 and 12 are connected with each other via an intermediate coupling 19 as will be described later, and a necessary torque is transmitted through the intermediate coupling 19. This intermediate coupling 19 has the function that it allows relative displacement in the radial direction freely among the axles 3, 7 and 12, but among the relative displacement in the axial direction, it restrains the relative displacement in the direction of the respective axles approaching to each other.

The necessary input torque to this compressor is applied externally via a drive coupling 20 by means of a drive machine such as an electric motor or a turbine. In this way, the above-mentioned respective axles 3, 7 and 12 would rotate at the same speed.

Owing to the above-described construction, the compressor can tightly seal the gas by disposing a gas seal device 23 for preventing gas within the casing from leaking out to the outside, only at the location where the third axle 12 for transmitting a torque transmitted from the drive coupling 20 to the respective axles 3, 7 and 12 within the casing 1, penetrates the casing end plate 22 forming a part of the casing 1. In other words, as compared to the centrifugal compressor in the prior art, the number of locations of gas seal devices is remarkably reduced.

Behind the final stage impeller on the axle 12 is disposed a pressure balancing disc 25 mounted to the axle 12, and a high-pressure gas is reduced in pressure toward a pressure balancing chamber 24 via labyrinth fins to make the gaseous forces in the axial directions applied to the axle 12 appropriately balance with each other. The pressure balancing chamber 24 is connected through a pressure balancing tube 21 additionally provided on a casing end plate 22 to a low-pressure environment at the gas suction port 2.

At one end of the axle 12 is additionally provided a thrust collar 28, an electromagnetic thrust bearing 29 sandwiching this thrust collar 28 from the opposite sides in the axial direction is fixedly secured to the stationary side, and this electromagnetic thrust bearing 29 operates to detect the position in the axial direction of the axle 12 via a control device disposed externally and to return the axle 12 to a predetermined position. At one end of the first axle 3, a suction magnetic bearing 27 is provided on the back surface of an impeller 26 which achieves initial gas suction effects. The suction force of this suction magnetic bearing 27 acts upon the first axle 3 and the second axle 7. By making this suction magnetic bearing 27 have a capability of generating a suction force exceeding the sum of the unbalanced forces caused by gas pressure directed towards the gas suction port, the first and second axles 3 and 7 are always applied with a force tending to move them towards the gas delivery side. Since the intermediate coupling 19 has a structure adapted to prevent the axles from approaching to each other as described above, this force is transmitted to the third axle 12, but as the position in the axial direction of the axle 12 is controlled by the action of the electromagnetic thrust bearing 29, the axles 3, 7 and 12 are all fixed in position in the axial direction, and so, their relative positions with respect to the stationary structure are maintained at predetermined positions. While provision was made so as to suck the impeller 26 on the axle 3 in the above-described case, the object to be sucked need not be the impeller 26, but so long as it is a disc-shaped one rotatable integrally with the axle, anything could be employed, and in essence, if the object is adapted to generate a force based on a magnetic effect which sucks the first axle 3 towards the delivery port side, the desired purpose can be achieved.

Next, details of the above-described intermediate coupling 19 will be explained with reference to Fig. 2. For example, to the axial ends of the first axle 3 and the second axle 7, respectively, are mounted coupling hubs 31 through a conventional method, and a torque transmission tube 33 is coupled to flanges formed on these hubs via thin flexible discs 32, by means of bolts and nuts 35. Reference numeral 34 designates a protective plate for the flexible disc 32.

To the axial ends of the axles 3 and 7 are mounted restraining shafts 36 and 37, respectively, directed in the axial direction. The restraining shaft 36 has a projection 39 at the center of its axial end surface, so that in the case where the respective restraining shafts 36 and 37 come into contact with each other, the contact is made at the center of their end surfaces and the respective axles cannot approach further to each other.

Owing to the above-described structure, the axles 3 and 7 would not move in the direction of approaching to each other during the operation, and even if their rotary axes should become misaligned, no reaction force is generated in the radial direction thanks to the flexibility of the flexible discs 32 and the torque transmission tube 33, so that smooth torque transmission can be achieved.

While the casing 1 is illustrated in Fig. 1 so as to be divided into parts forming gas passageways and an outside box-like part for integrally holding these parts (applied with differently directed hatchings), as a matter of course, there is no need to divide into these parts, but so long as it is possible in view of the manufacturing technique, for instance, the casing could be formed integrally as by casting. Moreover, the intermediate coupling also need not be limited to the illustrated structure, but so long as relative misalignment between the axes of the respective axles is permissible, any other structure could be employed.

Since the present invention is characterized by the structural features as described in detail above, the invention provides the following advantages:

(1) Since a compressing system realizing a high pressure head can be constructed with a single casing, a large number of seal devices as necessitated in the prior art become unnecessary, a seal device at only one location can suffice, hence dangerous locations where leakage of gas is apt to occur are reduced in number, and reliability is greatly improved.

(2) As a single casing is employed, there is no fear that misalignment of axes between the respective compressor units may arise. Even if such misalignment should occur, the novel coupling between the axles can compensate for the disadvantages.

(3) Since electromagnetic bearings not being held in contact with the axle are employed, a lubricant oil device is not necessitated, and the inconvenience that lubricant oil may be mixed in the gas, can be eliminated.

While a principle of the present invention has been described above in connection to one preferred embodiment of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted to be illustrative and not in a limiting sense.

Claims

1. A centrifugal compressor comprising a plurality of axles each having centrifugal impellers that can compress gas by making use of a centrifugal force exerted upon the gas, electromagnetic bearings for supporting said axles at their opposite ends without being held in contact with the axles, coupling means for coupling said axles with one

another as arrayed in series sequentially in such order that said gas can be compressed towards one side, in such manner that misalignment of their axes with one another may be allowed, a casing for supporting said plurality of coupled axles integrally with the electromagnetic bearings therefor and having a suction port of gas at one end in the axial direction and a delivery port thereof at the other end, and seal means around said axle provided on the side having said delivery port of said casing.

2. A centrifugal compressor as claimed in Claim 1, wherein a gas cooling section for cooling the gas compressed by the centrifugal impellers on the axle, is mounted to said casing.

3. A centrifugal compressor as claimed in Claim 1, wherein a suction magnetic bearing for sucking the axle on the gas suction side towards the gas delivery side is provided, and said electromagnetic bearing on the gas delivery side is a thrust bearing for holding the axle on the gas delivery side at a predetermined position in its axial direction.

4. A centrifugal compressor as claimed in Claim 1, wherein said coupling means is composed of restraining shafts mounted to the adjacent axial ends of the axles so as to oppose to each other, two flexible discs disposed around said restraining shafts and respectively mounted to the respective axles, and a torque transmission tube connected to said flexible discs.

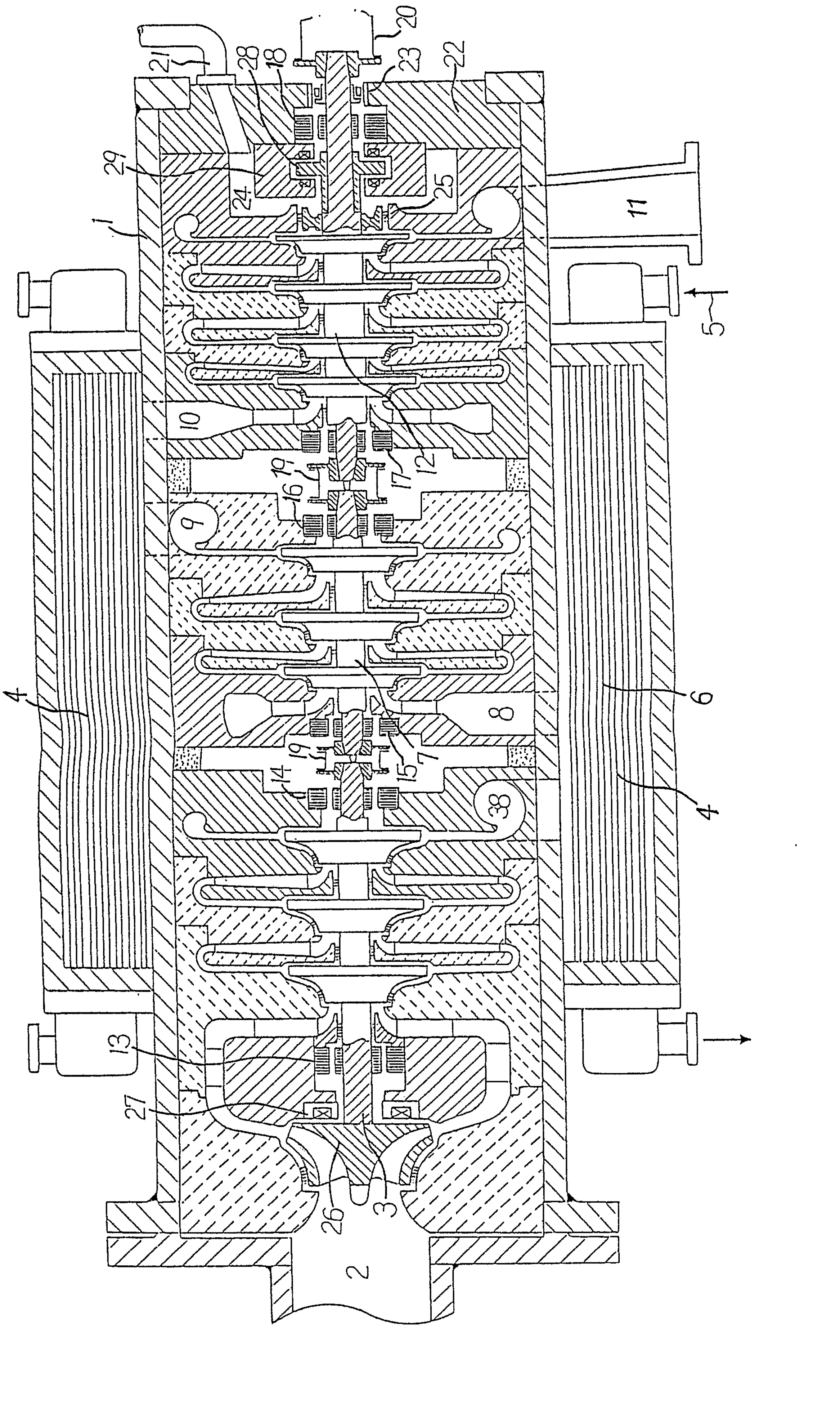

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Fig. 1

Fig. 2

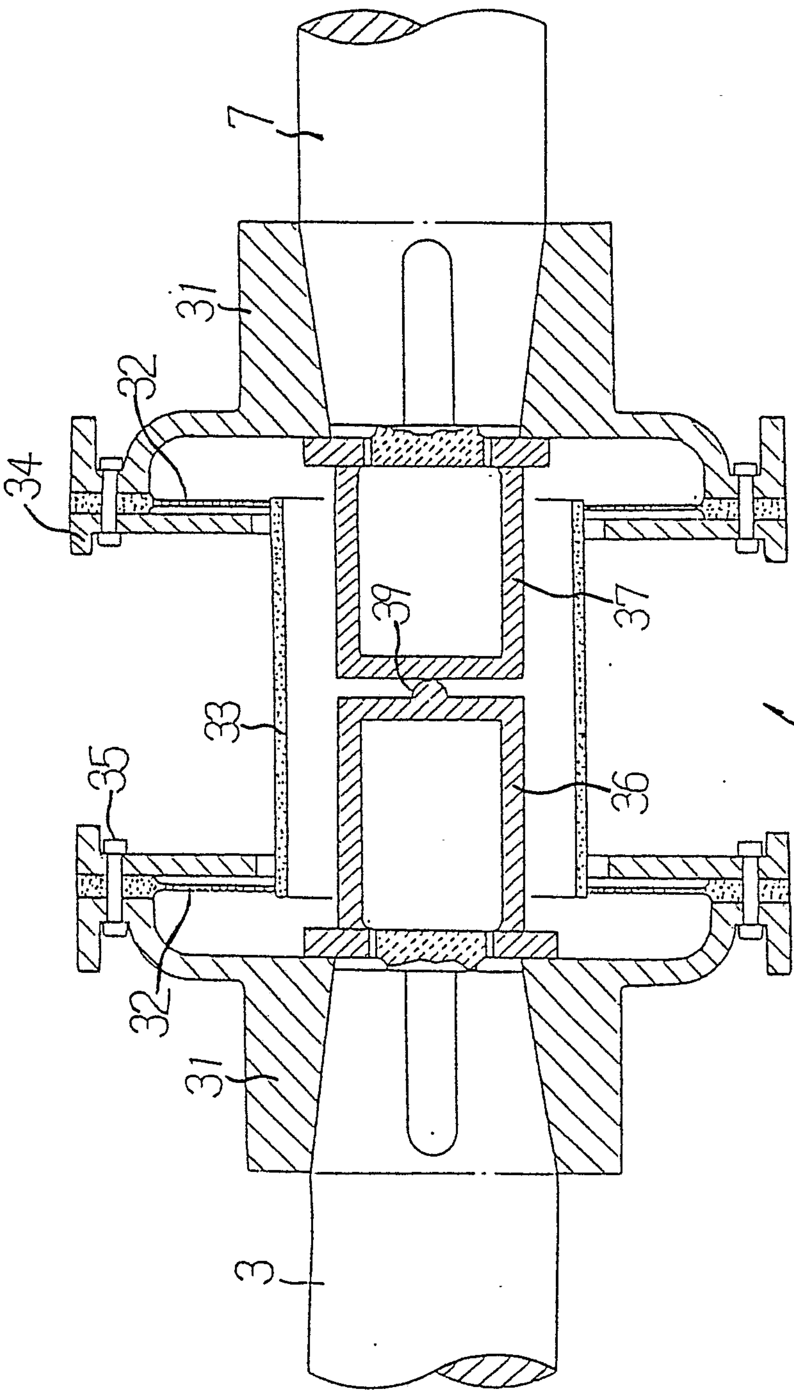
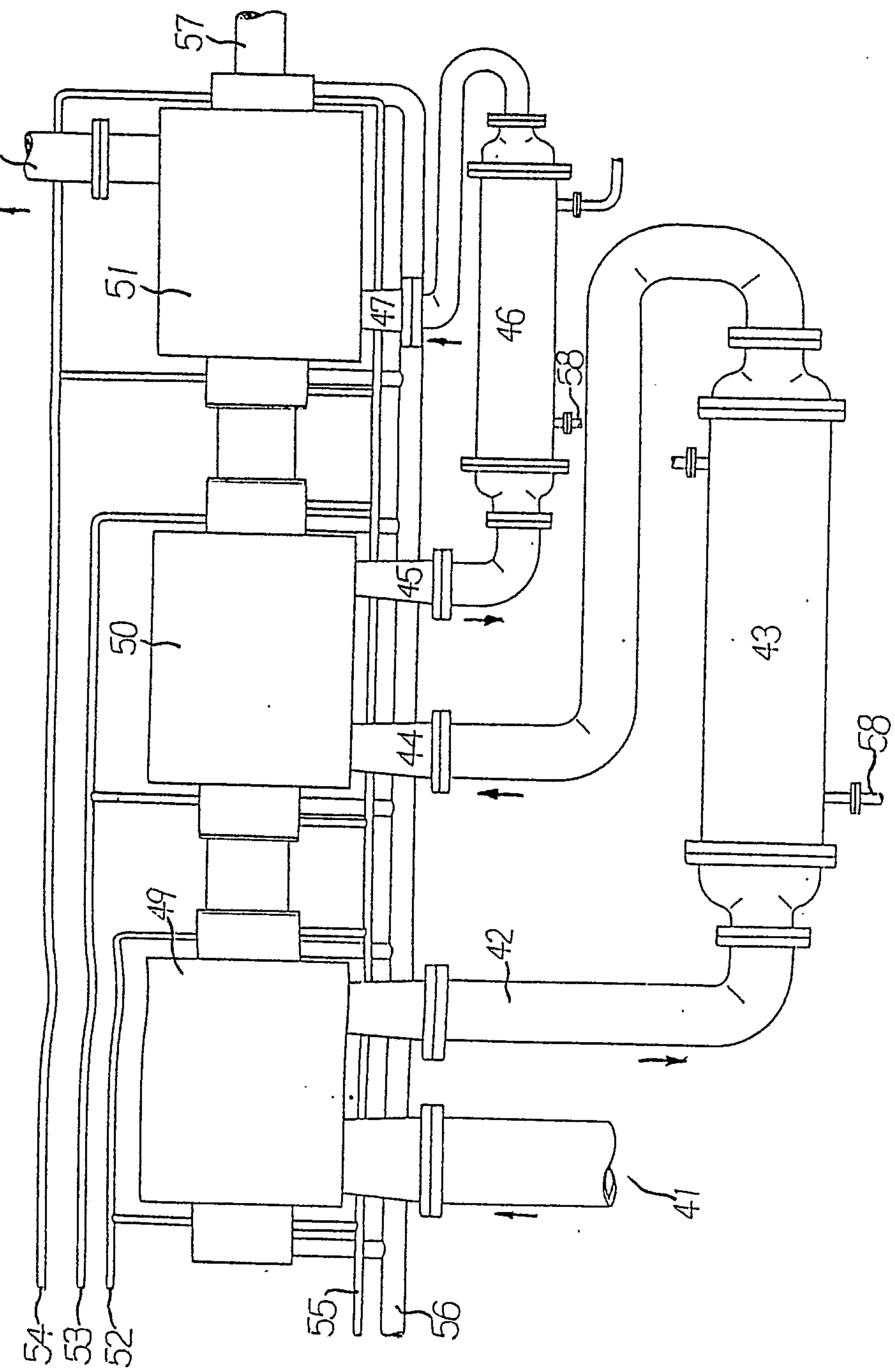


Fig. 3

(Prior Art)



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EUROPEAN SEARCH REPORT

Application Number

EP 88 11 0809

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y A	DE-A-1 813 335 (GUTEHOFFNUNGSHÜTTE) * Figure 1; page 1, lines 10-15; page 2, lines 18-26; page 6, line 14 - page 7, line 6; page 7, lines 16-22 *	1 2	F 04 D 29/04 F 04 D 17/12
Y	EP-A-0 087 197 (BBC) * Figures; page 6, lines 7-35; page 9, lines 16-18 *	1	
Y	FR-A-2 528 127 (CREUSOT-LOIRE) * Figure 1; page 1, lines 1-3; page 2, line 32 - page 3, line 15 *	1	
Y	CH-A- 310 025 (ESCHER WYSS) * Figure 1; page 2, lines 3-22 *	1	
A	COMPRESSED AIR, vol. 90, no. 4, April 1985, pages 30-33, Washington, US; "Suspending rotating shafts in midair" * Page 30, right-hand column *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	DE-A-3 527 945 (BBC) * Figure 1; column 2, lines 21-39 *		F 04 D 29/00 F 04 D 17/00 F 16 C 39/00 F 16 D 3/00
A	FR-A-2 193 427 (BROWN BOVERI-SULZER) * Figures 3,4; page 1, lines 1-3; page 4, lines 4-22 *	2	
A	GB-A-1 166 155 (GUTEHOFFNUNGSHÜTTE) * Figures 4,5; page 2, lines 42-83 *	2	
A	DE-U-8 337 492 (BHS) * Figure 3; page 8, last paragraph - page 9, paragraph 1 * -/-	4	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-10-1988	TEERLING J.H.

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
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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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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-A-2 542 946 (KSB) * Figure 2; page 3, paragraph 1; page 12, last paragraph - page 13, line 2 * -----	4	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-10-1988	TEERLING J.H.

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