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(54) **A compressor arrangement**

(57) A reduction in overall power consumption and/or an increase in suction capacity for a compressor arrangement comprising a driver (20) comprising a first drive shaft (21) and a second drive shaft (30), a main air compressor (11a, 11b) comprising a plurality of compression stages (MAC1, MAC2, MAC3) and a booster air compressor (12) comprising at least one compression stage (BAC1, BAC2, BAC3, BAC4) is achieved where the first stage (MAC1) of the main air compressor (11a) is driven by the first drive shaft (21) and where the remaining stage (s) of the main air compressor (11b) and the booster air compressor (12) are driven by the second drive shaft (30) in an integrally geared machine.

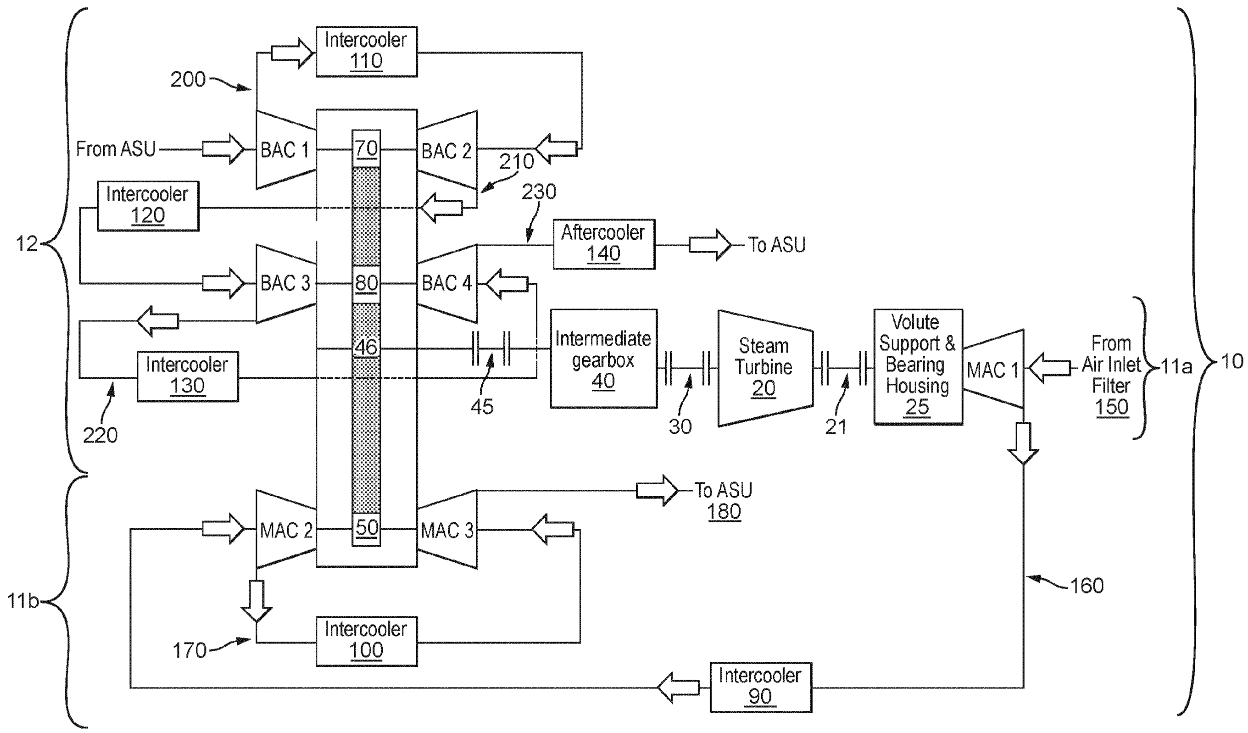

FIG. 5

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Description

[0001] The present invention relates to a compressor arrangement suitable for use where high air flow rates are required, for example in large cryogenic air separation units, and which are suitable to be driven by, for example, a steam turbine or electric motor.

[0002] In cryogenic air separation units, air is typically compressed in two operations. Feed air is passed through a main air compressor (MAC) to attain a desired pressure. Feed air is then cooled and water vapour and other gaseous impurities such as carbon dioxide are removed. Part or all of the feed air stream may then be passed to a booster air compressor (BAC) to attain a desired pressure before the compressed air stream(s) is/are passed to the cryogenic part of the ASU for separation. The MAC and BAC usually each comprise more than one compression stage.

[0003] High flow rate process plant compressors typically comprise centrifugal (*i.e.* radial) compression stages. The essential features of a centrifugal compression stage include an impeller mounted for rotation within a shaped housing known as a volute or scroll. The compression stage also comprises an inlet and an outlet for the fluid being compressed. Impellers may be arranged either on multiple shafts or on a single shaft. Where multiple shafts are used, a large diameter bull gear drives meshing pinions (*i.e.* pinion gears) upon the ends of which compression impellers are mounted. The multiple impellers within their own respective housings provide several stages of compression as desired. The bull gear and its meshing pinions are usually contained within a common housing. Consequently, such compressors are known as integral gear compressors. The meshing pinions may have different diameters to best match the speed requirements of the compression impellers they drive. The compressed air between any two stages may be piped to an intercooler, wherein it is cooled, thereby providing a more efficient compression process.

[0004] It is known to provide two or more compression duties on a single compressor. For example, US 5,901,579 discloses a compressor where the main air compression duty is combined on one machine with two compression wheels that share the air coming off the MAC and compresses those streams to feed an air separation plant.

[0005] A typical known compression arrangement for use in an air separation unit is depicted in Fig. 1. This arrangement has been applied for MAC suction flow rates up to 550,000 m^3/h. The number of booster stages is limited to four. The compressor bull gear 46 of compression arrangement 10 is driven from steam turbine 20 by a drive shafts 30 and 45 and an intermediate gearbox 40. Both the MAC stages 11 and the BAC stages 12 are driven from this bull gear 46. There are three MAC stages (MAC1, MAC2 and MAC3), with MAC1 and MAC2 being driven from a first pinion 50 and MAC3 being driven from a second pinion 60. There are also four BAC stages (BAC1, BAC2, BAC3 and BAC4), with BAC1 and BAC2 being driven from third pinion 70 and BAC3 and BAC4 being driven from fourth pinion 80. The numbering of the MAC and BAC stages reflects the order in which fluid to be compressed will pass through the stages (*i.e.* fluid will pass successively through MAC1, MAC2 and MAC3, for example). In order to improve the overall efficiency of the compressor, intercoolers 90, 100, 110, 120 and 130 are provided between the stages to remove heat from the compressed fluid. An aftercooler 140 is provided at the outlet of BAC4 to cool the compressed fluid to the temperature at which it is desired that the fluid enters the air separation unit.

[0006] In use, the air to be separated is fed into first MAC compression stage MAC1 through inlet 150, is compressed typically to about 0.2 MPa (2 bar absolute or "bara") and leaves MAC1 through pipeline 160 and passes through intercooler 90 before entering second compression stage MAC2 for further compression. The compressed air, typically at about 0.35 MPa (3.5 bara), then leaves MAC2 though pipeline 170 and passes through intercooler 100 before entering third compression stage MAC3. The compressed air, typically at about 0.6 MPa (6 bara), is then passed to the ASU *via* outlet 180 for cooling and removal of water vapour and other gaseous impurities such as carbon dioxide.

[0007] After passage though the ASU, air is passed to the booster compression arrangement 12, entering first booster stage BAC1 by inlet 190 and exiting, typically at about 1.1 MPa (11 bara), though pipeline 200. The compressed air is then passed through intercooler 110 for temperature reduction, and enters second booster compression stage BAC2. The air successively passes through BAC2 outlet pipeline 210, typically at about 2 MPa (20 bara), intercooler 120, third compression stage BAC3, BAC3 outlet pipeline 220, typically at about 3.5 MPa (35 bara), intercooler 130, and fourth booster compression stage BAC4. The compressed air, typically at about 5.5 MPa (55 bara) is then passed *via* pipeline 230 through aftercooler 140 to be brought to the desired temperature and enters the ASU for separation.

[0008] It is known to use a double ended steam turbine to drive the MAC and the BAC stages. An example of a double ended steam turbine driving the MAC and BAC stages of an ASU feed air compressor has been developed by Siemens. A typical compressor and steam turbine arrangement is depicted in Fig 2. This arrangement has been applied for MAC suction flow rates up to 550,000 m^3/h. Steam turbine 20 drives an integrally geared three-stage MAC 11 through a pedestal bearing 24 *via* a first drive shaft 21 and drive shaft 29. Drive shaft 29 is coupled to the free end of a first stage pinion 50 on the other end of which is mounted the first stage (MAC1) of the MAC. The second and third stages (MAC2 and MAC3) of the MAC are provided on second pinion 60. The BAC 12 is an integrally geared design that may have up to six stages, but an arrangement with only four stages is shown in the figure. Steam turbine 20 is connected to drive shaft 30 and the integrally geared BAC 12 through a speed reducing gearbox 40 and drive shaft 45. The first and second stages (BAC1 and BAC2) of the BAC are driven by pinion gear 70, and the third and fourth stages (BAC3 and BAC4) of the BAC are driven by pinion gear 80. Intercoolers (not shown) are provided between the compression stages.

[0009] The design of the compressor arrangements of Figs. 1 and 2 limits the impeller diameter of the MAC1 stage due to the impeller weight. The MAC1 volute size is limited to allow the first and second stage volutes to fit on to the gearbox. The impeller of the MAC1 typically has a diameter of 1600 mm which provides the maximum suction flow capacity of 550,000 m^3/h.

[0010] For MAC suction flow rates up to 800,000m^3/h, an arrangement as shown in Fig. 3 is known and has been developed by Siemens. An integrally geared MAC 11 is driven by the first end of the steam turbine 20 through a first drive shaft 21, an intermediate gearbox 25 and drive shaft 29. The required suction flow capacity is attained by installing two first stage MAC1 on first pinion 50, each MAC1 comprising an impeller having a diameter of 1600 mm. The BAC arrangement 12 is the same as that shown in Fig. 2.

[0011] The use of a double first stage MAC on a single pinion 50 requires a greater degree of complexity in the inlet filter and silencer arrangement than for a single first stage. Ninety degree piping elbows are required and the MAC suction pressure drop is increased resulting in higher power consumption. Further, inlet guide vanes are required on both MAC1 stages with co-ordinated control.

[0012] It is also known to use double ended steam turbines to drive the MAC and BAC stages where the MAC stages are mounted on a single shaft. A double ended steam turbine driving such MAC and BAC stages of an ASU has been developed by MAN Diesel and Turbo. A typical compressor and steam turbine arrangement is depicted in Fig. 4. The steam turbine 20 drives the MAC stages 11 from a first drive shaft 21 at one end of the turbine and the BAC stages 12 from a second drive shaft 30 at the other end of the turbine. The MAC stages 11 are shown here as four stages MAC1, MAC2, MAC3 and MAC4 provided as a single shaft centrifugal air compressor having four impellers. Intercoolers (not shown) are provided within the MAC casing between the stages. This compressor can use a first stage impeller (for MAC1) of a diameter of up to 1900 mm, which permits a maximum suction flow capacity of 670,000 m^3/h. Since the intercoolers are installed within the MAC casing, the maximum achievable flow rate for this MAC design is limited by the casing weights and dimensions. The BAC stages 12 are arranged on an integral gear driven through a stub shaft arrangement. Four BAC stages are shown, although up to six may be provided. The first and second stages (BAC1 and BAC2) are driven by pinion gear 70 and the third and fourth stages (BAC3 and BAC4) are driven by pinion gear 80.

[0013] It would be desirable to reduce the cost and the steam consumption of compressor arrangements compared with known compressor arrangements. In addition, it would be desirable to increase the suction capacity of compressor arrangements, in particular where it is intended that the compressor arrangement is used at high altitude. Further, it would be desirable to simplify the design of compressor arrangements.

[0014] According to a first aspect of the present invention, there is provided a compressor arrangement for compressing air, said compressor arrangement comprising:

a driver comprising a first drive shaft and a second drive shaft;

a MAC comprising a first (compression) stage and at least one further (compression) stage, wherein the first stage is driven by the first drive shaft;

a bull gear driven by the second drive shaft;

at least one pinion gear engaging the bull gear, wherein the further (compression) stage(s) of the MAC is/are mounted on and driven by the pinion gear(s);

a BAC comprising at least one (compression) stage; and

at least one further pinion gear engaging the bull gear, wherein the (compression) stage(s) of the BAC is/are mounted on and driven by the further pinion gear(s).

[0015] The first stage of the MAC may be driven indirectly by the first drive shaft, for example through an intermediate gearbox. However, in preferred embodiments, the first stage of the MAC is mounted directly on the first drive shaft and thus is driven directly by the first drive shaft.

[0016] The first drive shaft may also drive at least one other compression stage. However, in preferred embodiments, the first drive shaft is dedicated to driving the first stage of the MAC. In other words, the first drive shaft preferably drives the first stage of the MAC alone and does not drive any other compression stage.

[0017] The first stage of the MAC is preferably a centrifugal compression stage. Such a compression stage is also known in the art as a radial compression stage. One advantage of the present invention is that an impeller of any size may be used in the first stage of the MAC. That said, the diameter of the MAC1 impeller is usually at least about 1100 mm. In some preferred embodiments, the MAC1 impeller has a diameter greater than about 1900 mm, *e.g.* at least about 2000 mm, or even at least about 2100 mm. Theoretically, there is (within reason) no particular limitation on the maximum diameter of the MAC1 impeller although the Inventor acknowledges that there are some practical concerns that limit the size of the MAC1 impeller size. Typically, the MAC1 impeller does not have a diameter of more than about 3000 mm.

[0018] The compressor arrangement is capable of providing a wide range of maximum suction flow capacities depending on the diameter of the MAC1 impeller. Preferred arrangements provide a maximum suction flow capacity of at least about 200,000 m^3/h, *e.g*. greater than 800,000 m^3/h, or at least about 850,000 m^3/h, or even at least about 900,000 m^3/h. Typically, the maximum suction flow capacity is no more than about 1,100,000 m^3/h.

[0019] The compressor arrangement preferably comprises a volute support and bearing housing for said first drive shaft.

[0020] The compressor arrangement may be integrated with a cryogenic air separation plant for producing, for example, at least about 1200 mt (metric tons) oxygen per day, *e.g.* at least about 2000 mt oxygen per day, or at least about 3000 mt oxygen per day, or even at least about 4000 mt oxygen per day. Typically, the maximum rate of production of oxygen from a plant using the compression arrangement according to the present invention is about 5000 mt/day. In preferred embodiments, the oxygen production is from about 4000 mt/day to about 4800 mt/day, depending on the altitude of the ASU plant.

[0021] The MAC may comprise one, two, three or more stages. Where there is an even number of further stages, they are usually mounted in pairs, each pair mounted on a single pinion gear with the further stages of the pair mounted at opposite ends of the pinion gear. In preferred embodiments, the MAC comprises two further stages mounted on opposite ends of a pinion gear.

[0022] The BAC may comprise from one to ten stages, e.g. from two to eight stages, and preferably either four or six stages. The stages are usually mounted in pairs, each pair on a further pinion gear. In preferred embodiments, the BAC comprises four or six stages arranged in either two or three pairs of stages respectively. Each pair of stages is mounted on a further pinion gear, with the stages mounted on opposite ends of the further pinion gear.

[0023] There may not be any intercoolers to cool the compressed air between the compression stages. However, there may be at least one intercooler, and in preferred embodiments, there is an intercooler after each stage and before the next compression stage, usually with an aftercooler after the final stage. The arrangement of intercoolers depicted in Fig. 1 would be suitable for the present invention, assuming appropriate modification to accommodate driving the first MAC stage directly from the steam turbine 20 rather than the bull gear 46.

[0024] The driver may comprise any suitable prime mover, for example a steam turbine or an electric motor.

[0025] According to a second aspect of the present invention, there is provided a method of compressing feed air for a cryogenic air separation plant, said method comprising:

compressing feed air in a first (compression) stage of a MAC driven by a first drive shaft of a driver to produce compressed feed air;

further compressing the compressed feed air in at least one further (compression) stage of the MAC driven by at least one pinion gear engaged with a bull gear driven by a second drive shaft of the driver to produce further compressed feed air;

cooling the compressed feed air by indirect heat exchange against at least one fluid from a cryogenic separation of air in the plant to produce cooled feed air; and

compressing the cooled feed air, or feed air derived therefrom, in at least one (compression) stage of a BAC driven by at least one further pinion gear engaged with the bull gear to produce cooled, compressed feed air for separation in the plant.

[0026] Preferably, water vapour and/or other gaseous impurities such as carbon dioxide are removed from the further compressed feed air before compression in the BAC.

[0027] The invention will now be described by way of example only and with reference to the drawings. In the drawings:

Fig. 1 depicts a prior art compressor arrangement for use in an ASU;

Fig. 2 depicts another prior art compressor arrangement for use in an ASU in which the MAC stages are driven from one end of a steam turbine and the BAC stages are driven from the other end of the steam turbine;

Fig. 3 depicts a further prior art compressor arrangement for use in an ASU in which there are two MAC first stages, and in which the MAC stages are driven from one end of a steam turbine and the BAC stages are driven from the other end of the steam turbine;

Fig. 4 depicts a still further prior art compressor arrangement for use in an ASU in which the MAC stages are mounted on a single shaft and driven from one end of a steam turbine and the BAC stages are driven from the other end of the steam turbine;

Fig. 5 shows a first embodiment of the compressor arrangement according to the present invention; and

Fig. 6 shows a second embodiment of the compressor arrangement according to the present invention.

[0028] The prior art arrangements depicted in Figs. 1 to 4 are discussed above.

[0029] Referring to Fig. 5, a compressor arrangement 10 is shown in which a steam turbine 20 drives, *via* a first drive shaft 21, a first MAC stage 11a (MAC1), and, *via* a second drive shaft 30, second and third MAC stages 11b (MAC 2 and MAC3) and a BAC 12 in four stages (BAC1 to BAC4).

[0030] The first MAC stage, MAC1, alone is directly driven from one end of the steam turbine 20. A volute support and bearing housing 25 is provided to support the shaft and volute of the MAC 11a. The volute support may be of cast or welded construction and is bolted directly to a concrete foundation. The casing of the volute support is designed to locate and take the weight of the volute. The shaft within the volute support transfers the driver torque to the impeller (not shown) and takes the weight of the MAC1 impeller that is bolted directly to the shaft. Radial bearings carry the rotor weight. Thrust bearings locate the rotor axially and carry the impeller thrust loads. The second drive shaft 30 drives the MAC 11b and the BAC 12. This is achieved by an integrally geared machine in which the MAC2 and MAC3 are provided on pinion gear 50, BAC1 and BAC2 on pinion gear 70 and BAC3 and BAC4 on pinion gear 80, each pinion gear engaging bull gear 46. A step-down gearbox 40 is provided between second drive shaft 30 and drive shaft 45 driving bull gear 46.

[0031] MAC1 is a compressor stage comprising an impeller having a diameter of 2100 mm which is larger than can be accommodated on prior art compressor arrangements. This arrangement provides a maximum suction capacity for a single impeller of 800,000 m^3/h which is typically greater than the prior art arrangements known to the Inventor. However, it is to be understood that the impeller of the MAC1 may have any suitable diameter to provide a desired maximum suction capacity. For example, the diameter of the impeller may be as small as 1100 mm. Indeed, the diameter of the impeller used in the Example below is 1600 mm.

[0032] MAC1 and MAC2 are in fluid communication connected by pipeline 160 in which is provided intercooler 90. Similarly, MAC2 and MAC3 are in fluid communication connected by pipeline 170 in which is provided intercooler 100. Fluid enters MAC1 through inlet 150 and leaves MAC3 to enter the ASU *via* outlet 180. The pipeline and intercooler arrangement for BAC 12 depicted in Figure 5 is the same as that shown in Fig.1.

[0033] In use, the fluid to be compressed enters the MAC1 stage through inlet 150 and is compressed from atmospheric pressure to about 0.2 MPa (2 bara). The compressed fluid exits MAC1 through pipeline 160 and is passed through intercooler 90 to reduce its temperature prior to entry to MAC2 for further compression. The further compressed fluid, typically at about 0.35 MPa (3.5 bara), exits MAC2 through pipeline 170 and is passed through intercooler 100 before entering MAC3. After the third compression stage, the fluid is typically at about 0.6 MPa (6 bara) and is passed to the ASU through outlet 180. The booster compression is as described for Fig. 1.

[0034] Fig. 6 shows an alternative compressor arrangement of the invention, in which the MAC 11b and BAC 12 are driven *via* a pedestal bearing 41 provided in second drive shaft 45 and a stub shaft 90. The arrangement is otherwise as described in Fig. 5 and in use operates in a similar manner.

[0035] Providing the MAC1 stage alone on the first drive shaft removes the size constraint on MAC1 of the prior art arrangements in Figs. 1 to 4, and so a greater impeller diameter, and therefore greater suction capacity, can be achieved for the MAC. For example, a MAC first stage impeller diameter of 2000mm or larger, *e.g.* up to 3000 mm, is envisaged. In practical terms, the impeller diameter is limited only by the size of available machine tools used in manufacturing the impeller.

[0036] A MAC suction flow rate of at least 800,000 m^3/h is envisaged. This is of particular importance when operating an ASU at high altitude, in which, due to the lower prevailing atmospheric pressure, a higher suction capacity is required to provide the same ASU production as a similar plant located at sea level. A MAC suction flow rate of 800,000 m^3/h would provide an ASU with the air required to deliver an oxygen production of between 4000 mt/day and 4800 mt/day depending on the ASU altitude.

[0037] It can be seen that the arrangements shown in Figs. 5 and 6 remove MAC1 from the gearbox shown in Figure 1. MAC1 is physically the largest stage and consumes approximately 40% of the total MAC power. Therefore, the gearbox carrying the MAC and BAC stages in Figs. 5 and 6 is physically smaller and has a lower power rating than the gearbox in Fig. 1. Additionally the intermediate gearbox used in the arrangements shown in Figs. 5 and 6 is physically smaller and has a lower power rating than the gearbox in Fig. 1. Thus, gear losses associated with the MAC1 stage are eliminated and the cost of the apparatus is reduced.

[0038] It can be seen that the arrangements shown in Fig. 5 and Fig. 6 eliminate the MAC integral gearbox. Thus, gear losses associated with the MAC1 stage in Fig. 3 are eliminated and the cost of the apparatus is reduced. It can be seen that the arrangements shown in Fig. 5 and Fig. 6 permit the MAC gearbox and intermediate gearbox to be omitted that is present in the prior art arrangement of Fig. 3. Thus, gear losses associated with the MAC1 stage are eliminated and the cost of the apparatus is reduced.

[0039] Further, the arrangements of Fig. 5 and Fig. 6 have a simplified structure compared with Figs. 2 to 4 which permits easier installation and shaft alignment compared with the prior art arrangements of Figs. 2 to 4.

EXAMPLE

[0040] Figures for the performance (in terms of power consumption and loss) of the prior art arrangement depicted in Fig. 1 and the embodiment of the present arrangement depicted in Fig. 5 have been calculated and are compared in the following Table.

[0041] This comparison is based on:

• compression associated with an ASU having a nominal oxygen production rate of 3000 mt/day
• MAC1 impeller in both arrangements has a diameter of 1600 mm
• the MAC suction flow rate is assumed 530,000 m^3/h and the air is assumed to be compressed in the MAC from 0.1 MPa (1 bara) to 0.611 MPa (6.11 bara)
• the BAC suction flow rate is assumed to be 40,000 kg/h and the air is assumed to be compressed from 0.56 MPa (5.6 bara) to 5.1 MPa (51 bara)

Arrangement		Current technology (Fig. 1)	Invention (Fig. 5)	Notes
Performance comparison	kW			
Power consumption MAC stage 1	kW	13750	13850	1
Power consumption MAC stages 2&3	kW	20475	20475	
Power consumption BAC stages 1,2,3&4	kW	18900	18900	
Stage power associated with integral gear and intermediate gearbox	kW	53125	39375	
Mechanical losses integral gearbox at 2.5% of stage power	kW	1328	984	
Mechanical losses intermediate gear at 1.25% of stage power	kW	664	492	
Stage power associated with pedestal bearing	kW		13850	
Mechanical losses pedestal bearing at 1 % of stage power	kW		139	
Total shaft power	kW	55117	54840	
Total power saving for invention	kW		277	

Note 1	Power for the invention MAC stage 1 is higher than for the current technology due to higher pressure drop between stage 1 and stage 2.

[0042] Where power has a cost of US$0.07 per kW, a power saving of 277 kW equates to a saving of US$775,600 over a 5 year period.

[0043] Preferred embodiments of the present invention are intended to meet at least one of the following objectives:

- an increase in the maximum suction flow capacity of a compressor with a single first stage radial impeller

- a reduction in the size and power rating of the integral gearbox carrying MAC and BAC stages
- a reduction in gear power losses and, as a result, a reduction in compression train power consumption
- a reduction in the cost of the compression train
- a simplified installation

[0044] It will be appreciated that the invention is not restricted to the details described above with reference to the preferred embodiments but that numerous modifications and variations can be made without departing form the spirit or scope of the invention as defined in the following claims.

Claims

1. A compressor arrangement (10) for compressing air, said compressor arrangement (10) comprising:

   a driver (20) comprising a first drive shaft (21) and a second drive shaft (30);
   a main air compressor (11a, 11b) comprising a first stage (MAC1) and at least one further stage (MAC2, MAC3), wherein said first stage (MAC1) is driven by said first drive shaft (21);
   a bull gear (46) driven by said second drive shaft (30);
   at least one pinion gear (50) engaging said bull gear (46), wherein said further stage(s) (MAC2, MAC3) of said main air compressor (11b) are mounted on and driven by said pinion gear(s) (50);
   a booster air compressor (12) comprising at least one stage (BAC1, BAC2, BAC3, BAC4); and
   at least one further pinion gear (70, 80) engaging said bull gear (46), wherein said stage(s) (BAC1, BAC2, BAC3, BAC4) of said booster air compressor (12) are mounted on and driven by said further pinion gear(s) (70, 80).

2. A compressor arrangement (10) as claimed in Claim 1, wherein said first stage (MAC1) of said main air compressor (11a) is mounted directly on said first drive shaft (21).

3. A compressor arrangement (10) as claimed in Claim 1 or Claim 2, wherein said first drive shaft (21) is dedicated to driving said first stage (MAC1) of said main air compressor (11a).

4. A compressor arrangement (10) as claimed in Claims 1 to 3, wherein said first stage (MAC1) of said main air compressor (11a) is a centrifugal compressor comprising an impeller having a diameter of at least about 1100 mm.

5. A compressor arrangement (10) as claimed in Claim 4, wherein the diameter of said impeller is greater than 1900 mm.

6. A compressor arrangement (10) as claimed in Claim 4 of Claim 5, wherein the diameter of said impeller is no more than about 3000 mm.

7. A compressor arrangement (10) as claimed in any of the preceding claims having a maximum suction flow capacity of at least about 200,000 m^3/h.

8. A compressor arrangement (10) as claimed in Claim 7 wherein the maximum suction flow capacity is at least about 800,000 m^3/h.

9. A compressor arrangement (10) as claimed in Claim 7 or Claim 8 wherein the maximum suction flow capacity is no more than about 1,100,000 m^3/h.

10. A compressor arrangement (10) as claimed in any of the preceding claims, comprising a volute support and bearing housing (25) for said first drive shaft (21).

11. A compressor arrangement (10) as claimed in any of the preceding claims integrated with a cryogenic air separation plant for producing at least about 1200 mt (metric tons) oxygen per day.

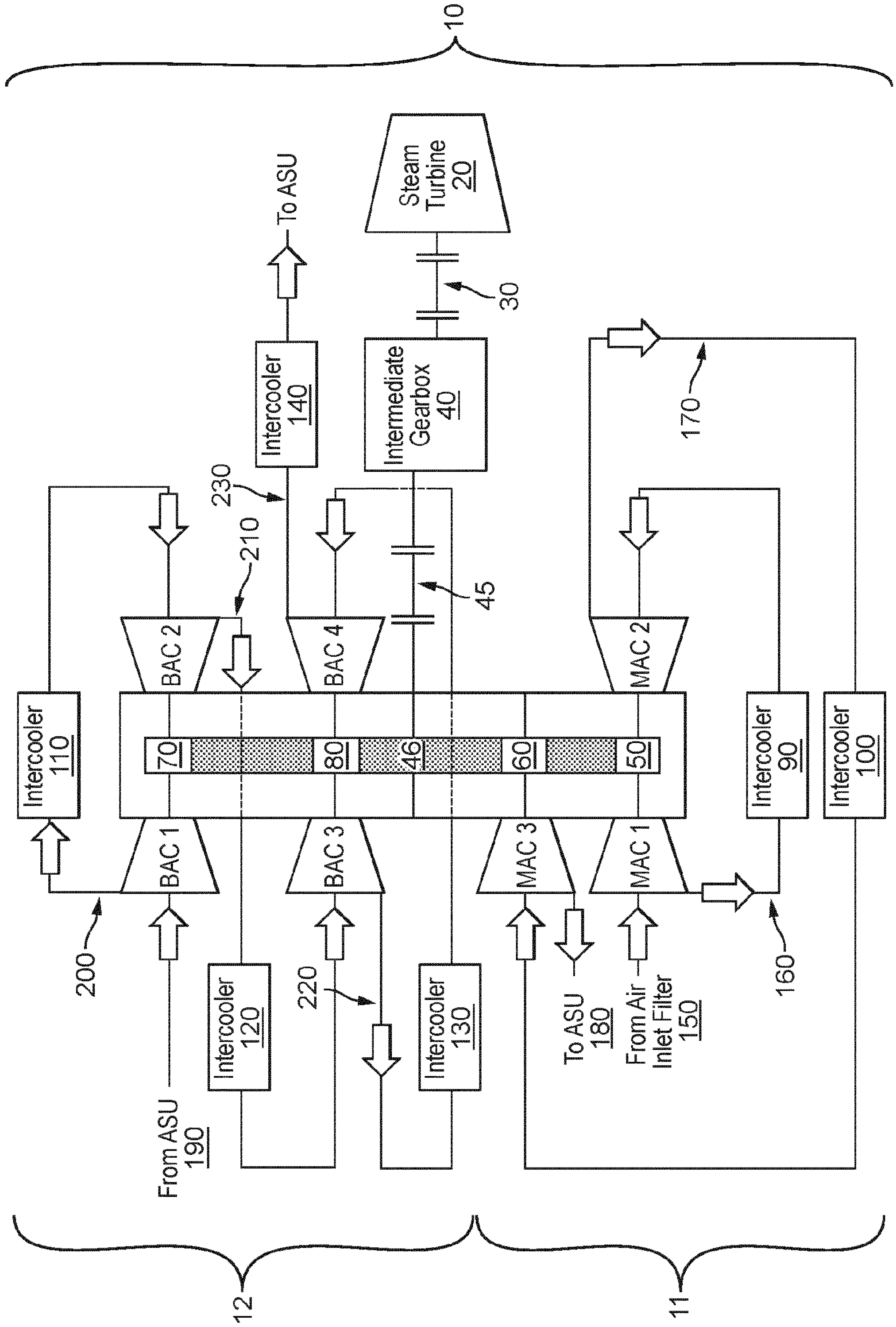
12. A compressor arrangement (10) as claimed in Claim 11, wherein the cryogenic air separation plant is suitable for

producing at least about 4000 mt oxygen per day.

13. A compressor arrangement (10) as claimed in Claim 11 or Claim 12, wherein the cryogenic air separation unit is suitable for producing up to about 5000 mt oxygen per day.

14. A method of compressing feed air for a cryogenic air separation plant, said method comprising:

compressing feed air in a first stage (MAC1) of a main air compressor (11a) driven by a first drive shaft (21) of a driver (20) to produce compressed feed air;
further compressing said compressed feed air in at least one further stage (MAC2, MAC3) of said main air compressor (11b) driven by at least one pinion gear (50) engaged with a bull gear (46) driven by a second drive shaft (30) of said driver (20) to produce further compressed feed air;
cooling said compressed feed air by indirect heat exchange against at least one product fluid from cryogenic separation of air in said plant to produce cooled feed air; and
compressing said cooled feed air, or feed air derived therefrom, in at least one stage (BAC1, BAC2, BAC3, BAC4) of a booster air compressor (12) driven by at least one further pinion gear (70, 80) engaged with said bull gear (46) to produce cooled, compressed feed air for separation in said plant.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Steam Turbine 20
To ASU
30
Intermediate Gearbox 40
Intercooler 140
170
230
210
45
BAC 2
BAC 4
MAC 2
Intercooler 110
70
80
46
60
50
Intercooler 90
Intercooler 100
BAC 1
BAC 3
MAC 3
MAC 1
200
220
160
From ASU 190
Intercooler 120
Intercooler 130
To ASU 180
From Air Inlet Filter 150
12
11

FIG. 1

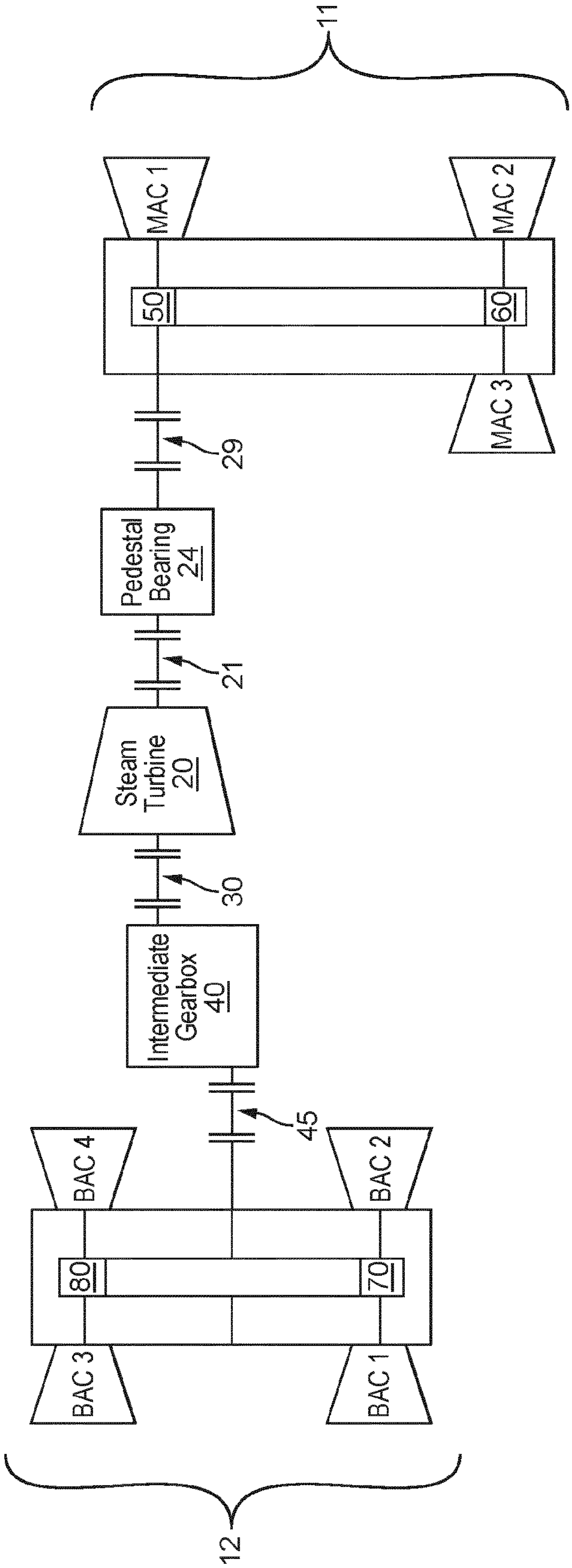
11
MAC 1
MAC 2
50
60
MAC 3
29
Pedestal Bearing 24
21
Steam Turbine 20
30
Intermediate Gearbox 40
45
BAC 4
BAC 2
80
70
BAC 3
BAC 1
12

FIG. 2

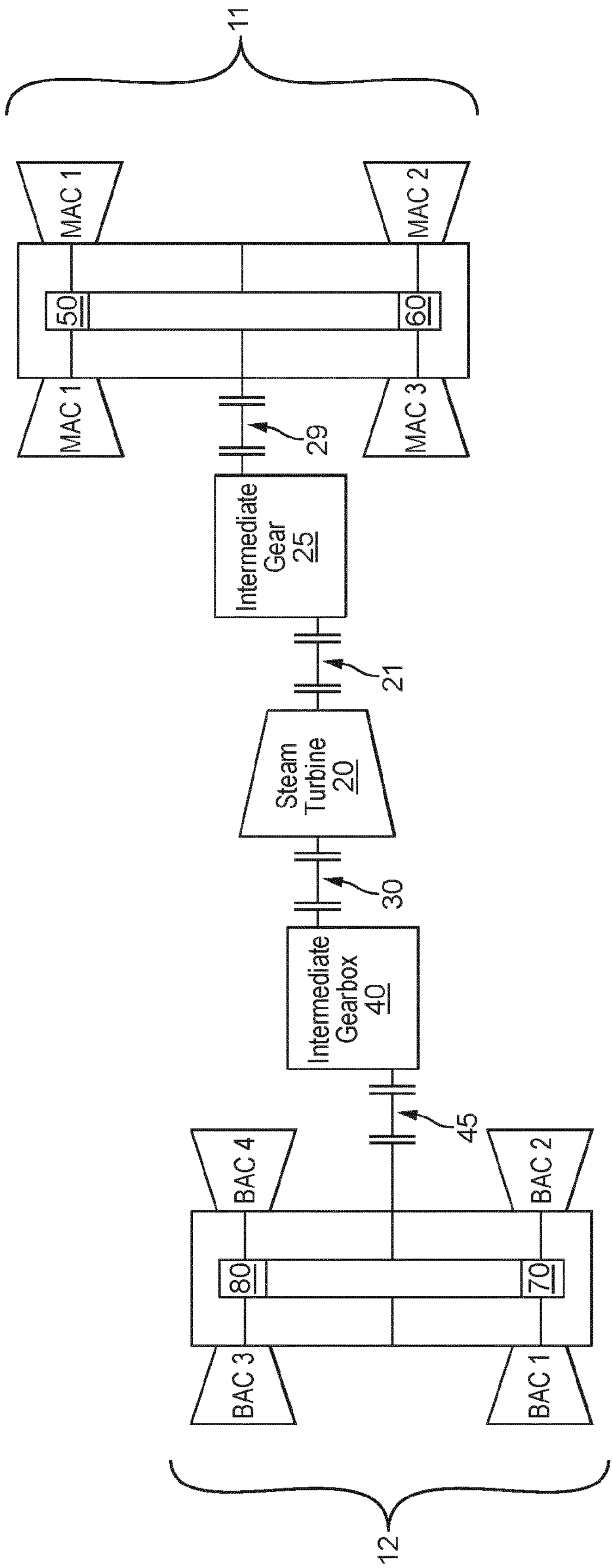
11
MAC 1
MAC 2
50
60
MAC 1
MAC 3
29
Intermediate Gear 25
21
Steam Turbine 20
30
Intermediate Gearbox 40
45
BAC 4
BAC 2
80
70
BAC 3
BAC 1
12

FIG. 3

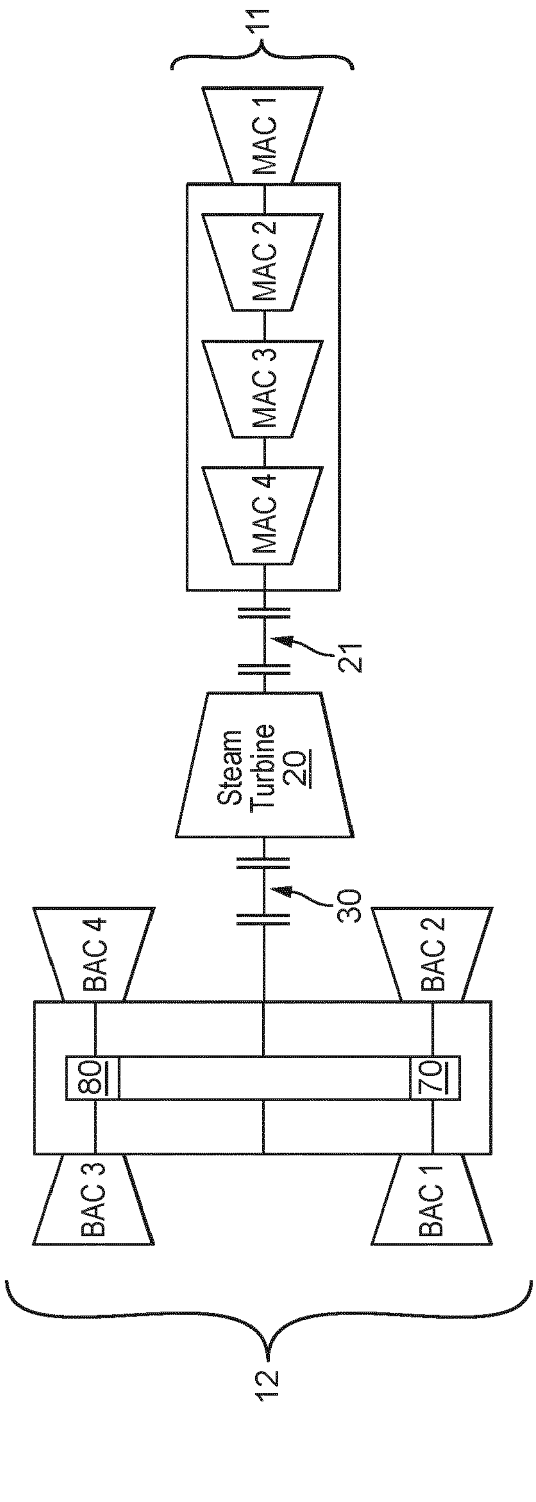
11
MAC 1
MAC 2
MAC 3
MAC 4
21
Steam
Turbine
20
30
BAC 4
BAC 2
80
70
BAC 3
BAC 1
12

FIG. 4

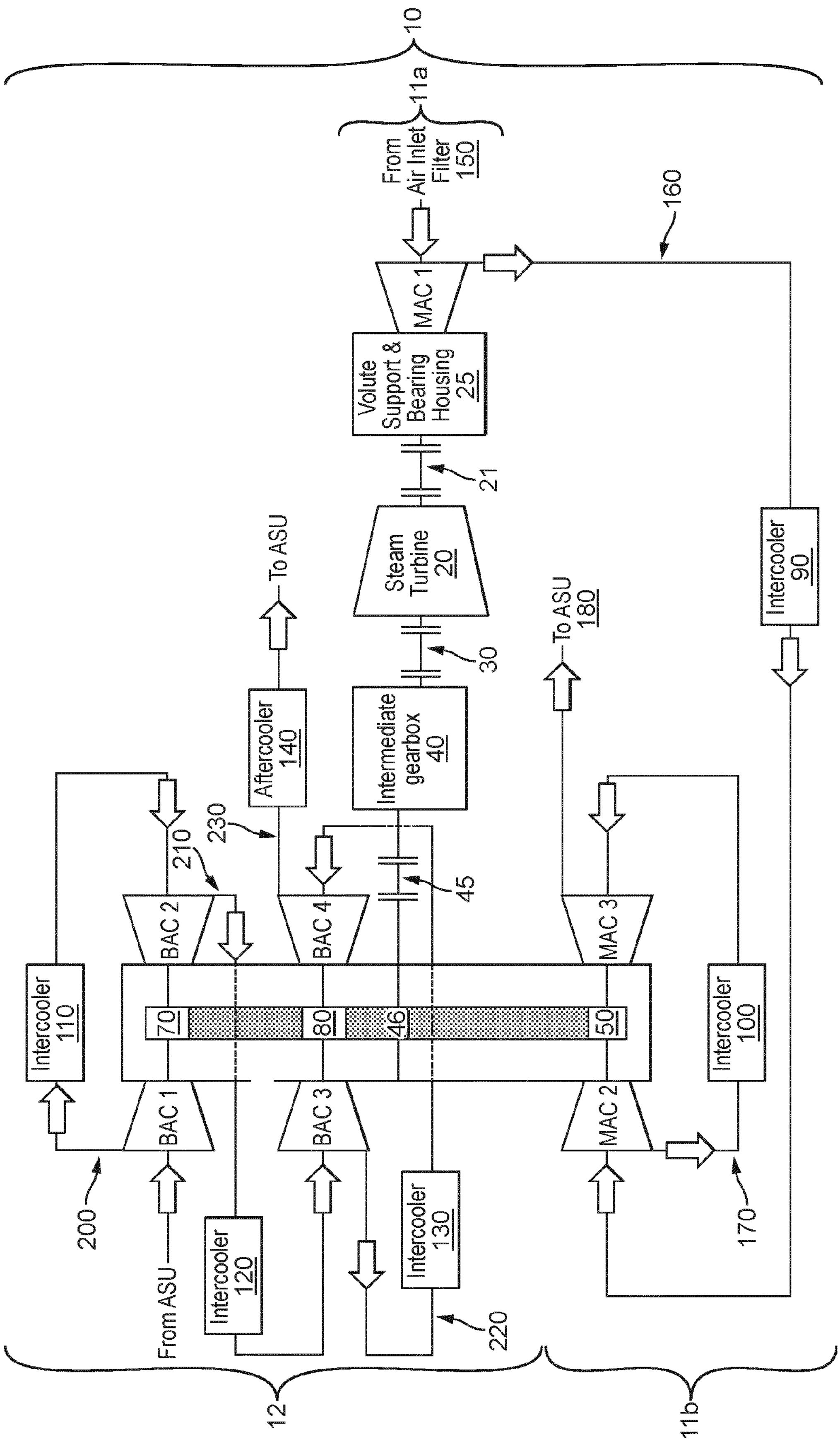
10
11a
From Air Inlet Filter 150
160
MAC 1
Volute Support & Bearing Housing 25
21
Steam Turbine 20
30
Intermediate gearbox 40
45
46
To ASU
Aftercooler 140
230
210
BAC 2
BAC 4
BAC 1
BAC 3
70
80
50
Intercooler 110
Intercooler 120
Intercooler 130
Intercooler 100
Intercooler 90
To ASU 180
MAC 3
MAC 2
From ASU
200
220
170
12
11b

FIG. 5

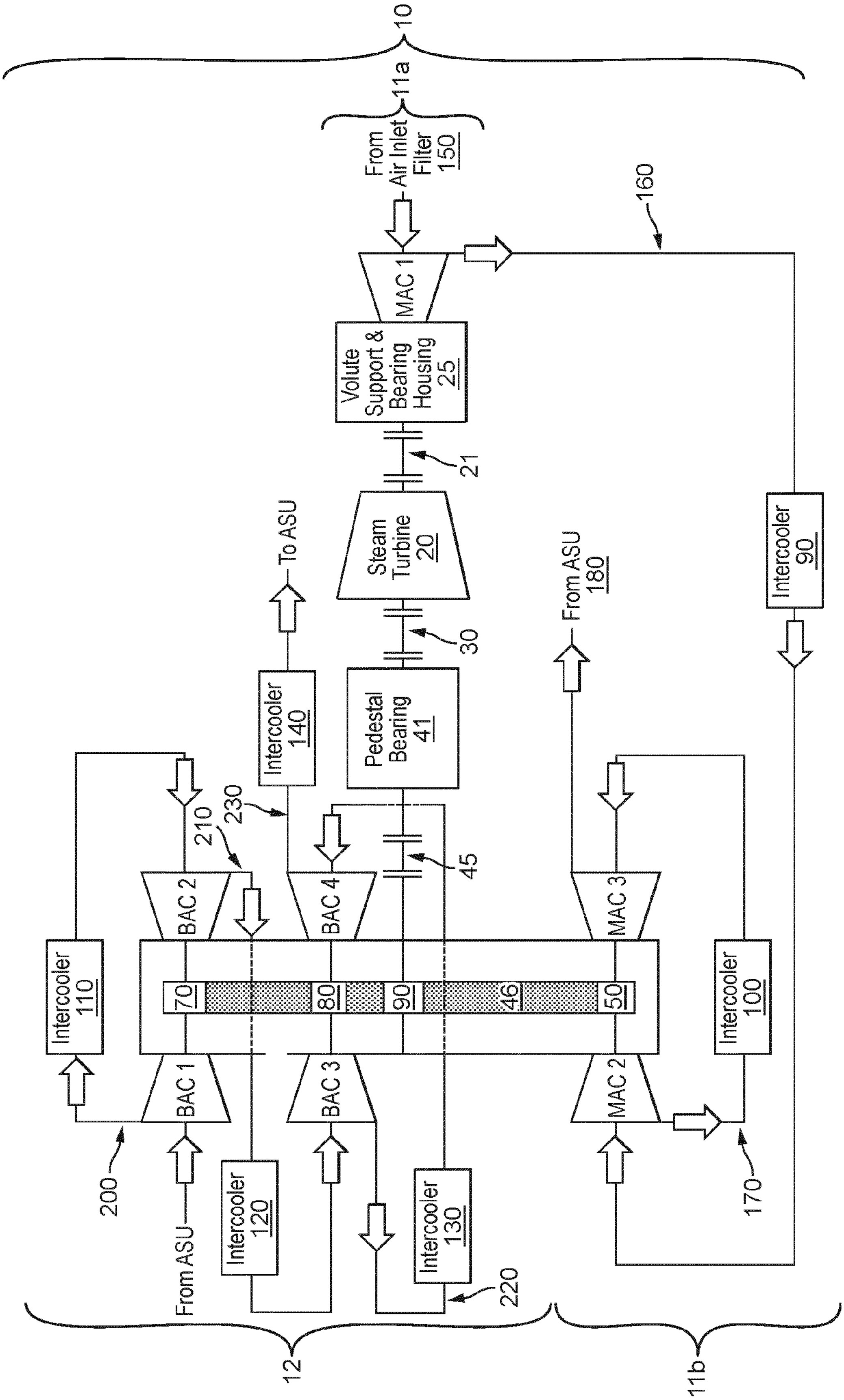
10
11a
From Air Inlet Filter 150
160
MAC 1
Volute Support & Bearing Housing 25
21
Steam Turbine 20
To ASU
30
From ASU 180
Intercooler 90
Intercooler 140
Pedestal Bearing 41
45
230
210
BAC 2
BAC 4
MAC 3
Intercooler 110
70
80
90
46
50
Intercooler 100
BAC 1
BAC 3
MAC 2
200
170
From ASU
Intercooler 120
Intercooler 130
220
12
11b

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 11 19 3001

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 485 719 A (WULF JAMES B [US]) 23 January 1996 (1996-01-23) * column 4, line 1 - column 5, line 50; figures 1,4 * -----	1-14	INV. F04D17/12 F04D25/02
A,D	US 5 901 579 A (MAHONEY KEVIN WILLIAM [US] ET AL) 11 May 1999 (1999-05-11) * column 4, line 10 - column 6, line 36; figures 1,2 * -----	1-14	
A	DE 44 16 497 C1 (GUTEHOFFNUNGSHUETTE MAN [DE]) 12 January 1995 (1995-01-12) * figures 1,2 * -----	1-14	
A	US 4 473 754 A (JOY JOHN R [US]) 25 September 1984 (1984-09-25) * figure 1 * -----	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

F04D
F25J
F16H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 June 2012	Homan, Peter

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....
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11-06-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5485719 A	23-01-1996	NONE	
US 5901579 A	11-05-1999	BR 9900966 A	14-12-1999
		CA 2264510 A1	03-10-1999
		CN 1231415 A	13-10-1999
		DE 69910478 D1	25-09-2003
		DE 69910478 T2	08-07-2004
		EP 0947789 A2	06-10-1999
		ID 23611 A	04-05-2000
		JP 11294945 A	29-10-1999
		US 5901579 A	11-05-1999
DE 4416497 C1	12-01-1995	DE 4416497 C1	12-01-1995
		EP 0686773 A2	13-12-1995
		JP 8189494 A	23-07-1996
		RU 2132971 C1	10-07-1999
		US 5611663 A	18-03-1997
US 4473754 A	25-09-1984	NONE	

EPO FORM P0459

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5901579 A **[0004]**