US 20090100864A1

(19) **United States**

(12) **Patent Application Publication**

DEN HELD et al.

(10) **Pub. No.: US 2009/0100864 A1**

(43) **Pub. Date: Apr. 23, 2009**

(54) **PROCESS TO COMPRESS AIR AND ITS USE IN AN AIR SEPARATION PROCESS AND SYSTEMS USING SAID PROCESSES**

(76) Inventors: **Paul Anton DEN HELD**, The Hague (NL); **Hendrik Jan Van Der Ploeg**, Amsterdam (NL)

Correspondence Address:
SHELL OIL COMPANY
P O BOX 2463
HOUSTON, TX 772522463

(21) Appl. No.: **12/167,698**

(22) Filed: **Jul. 3, 2008**

Related U.S. Application Data

(60) Provisional application No. 60/948,649, filed on Jul. 9, 2007.

(30) **Foreign Application Priority Data**

Jul. 6, 2007 (EP) 07111919.2

Publication Classification

(51) **Int. Cl.**
F25J 3/00 (2006.01)
F25J 3/04 (2006.01)

(52) **U.S. Cl.** **62/643**

(57) **ABSTRACT**

The invention is directed to a process and a system to compress air. The process involves the following steps,

(i) compressing air in a compressor,
(ii) cooling the compressed air as obtained in step (i)
(iii) further compressing the air of step (ii) in a second compressor,
(iv) further compressing at least part of the compressed air as obtained in step (iii) in a booster compressor, wherein the compressor in step (i) is an axial compressor, the compressor of step (i) and (iii) are driven by a common first driver and the booster compressor is driven by a separate second driver and wherein the compressors of steps (i) and (iii) are split into two individual casings.

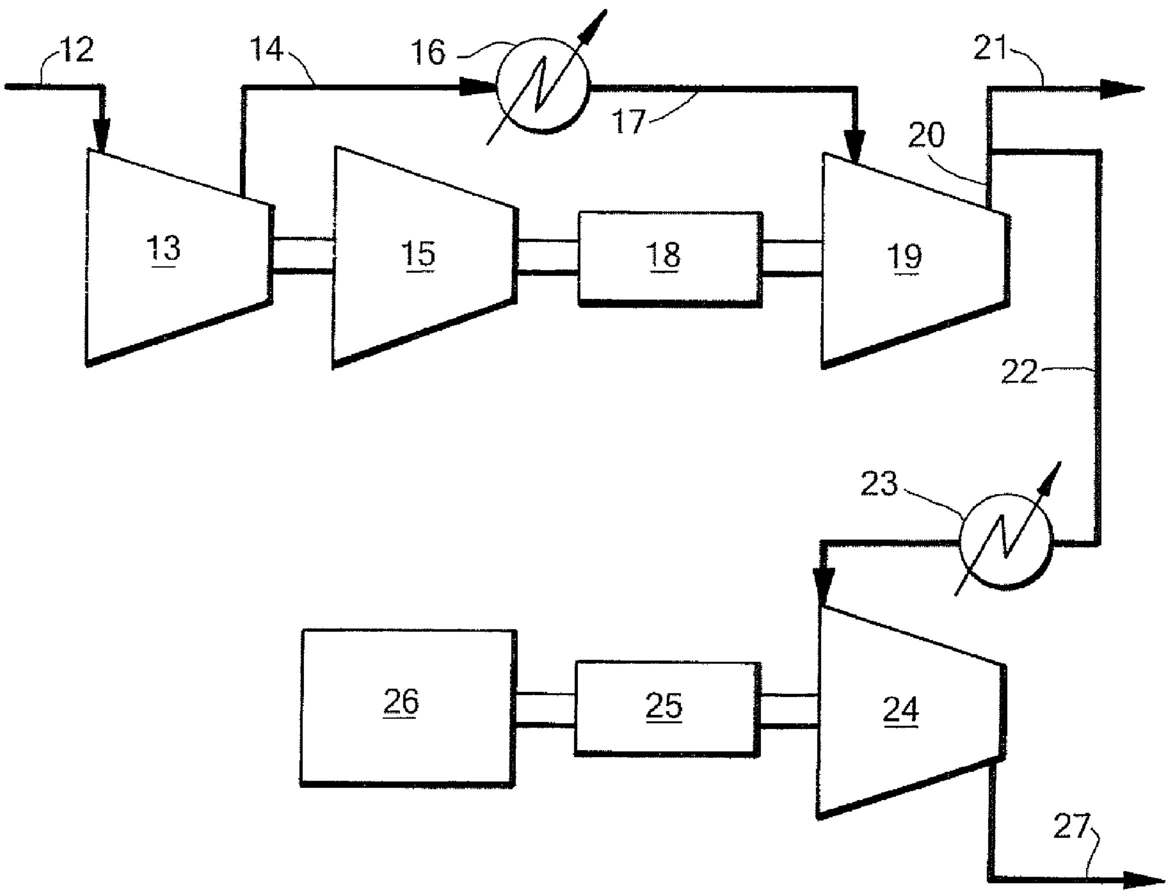
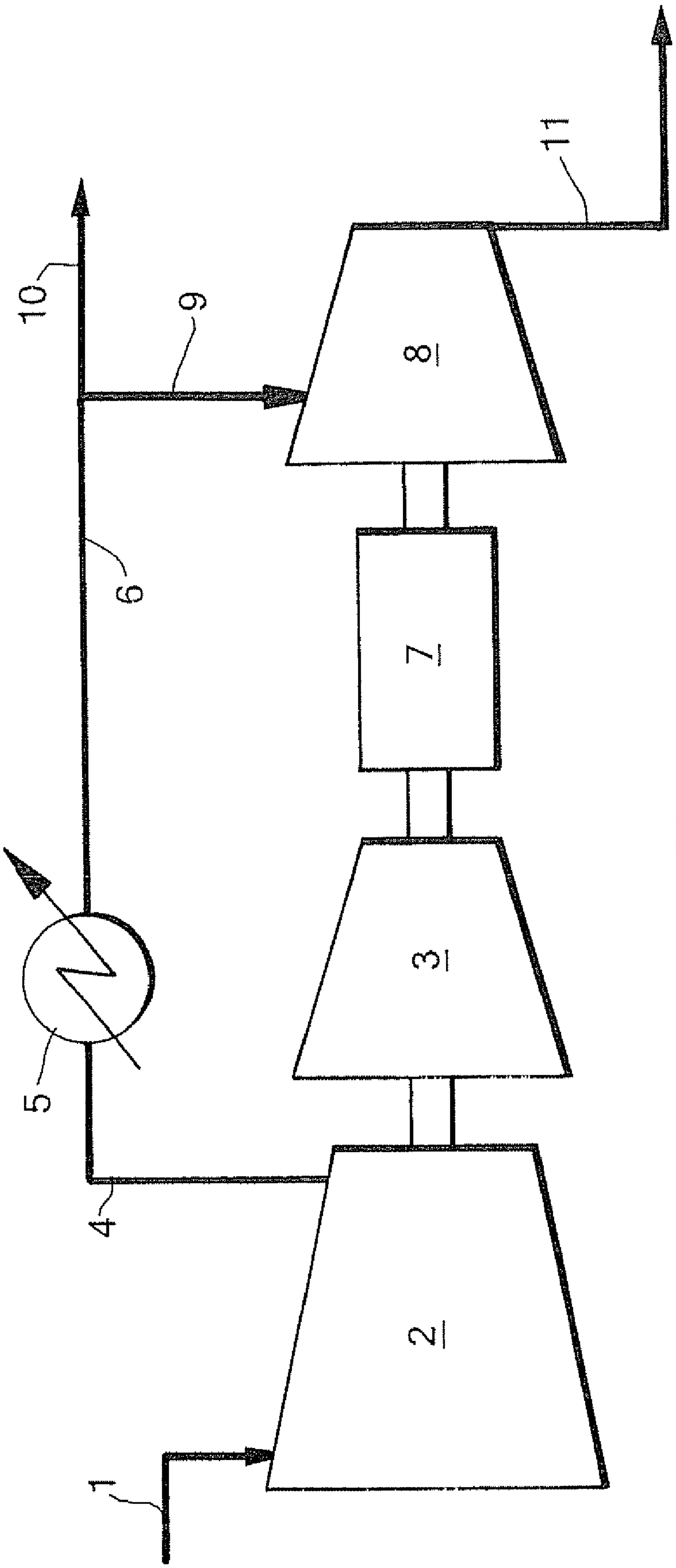


Fig. 1



Prior Art

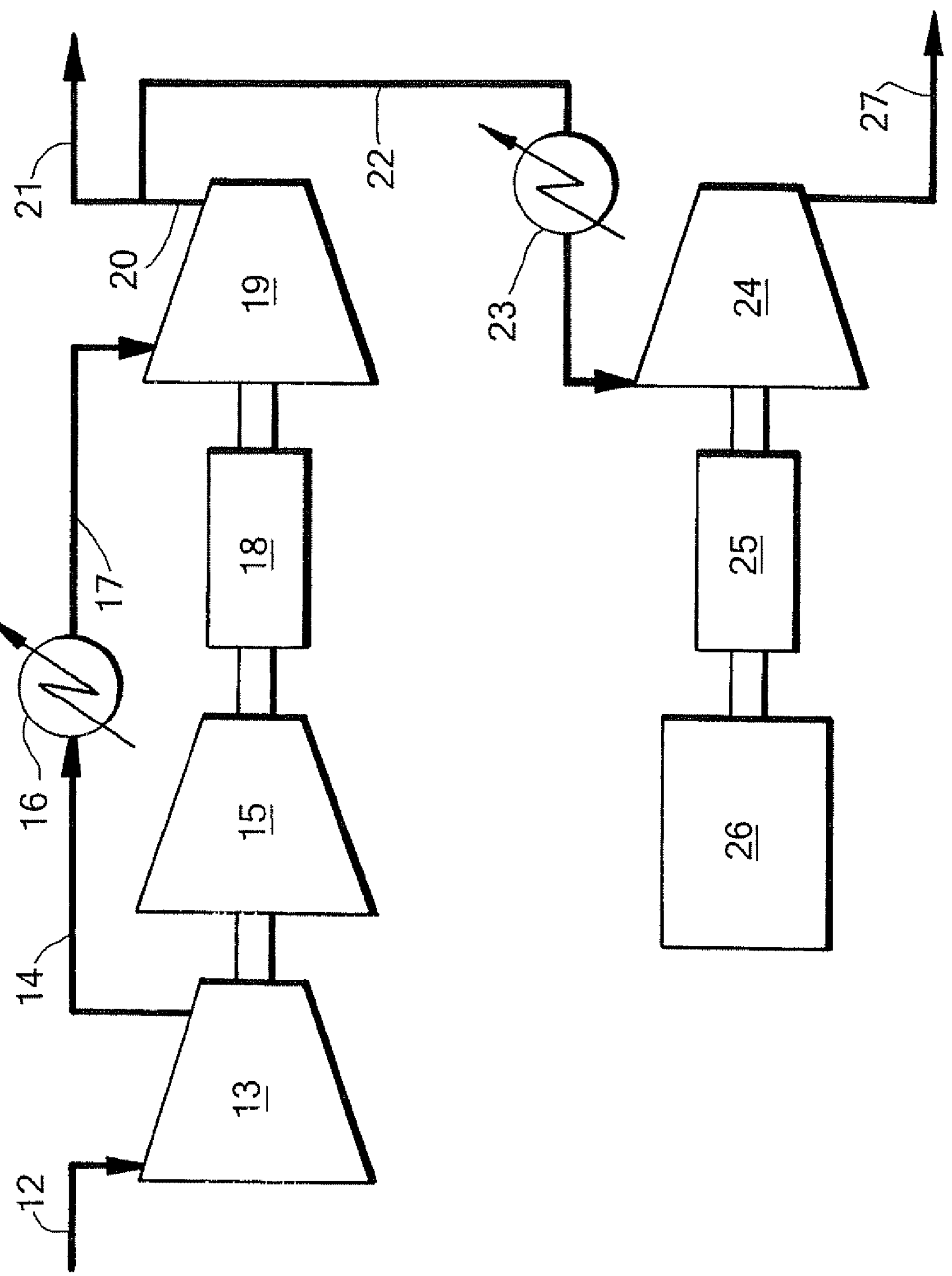


Fig.2

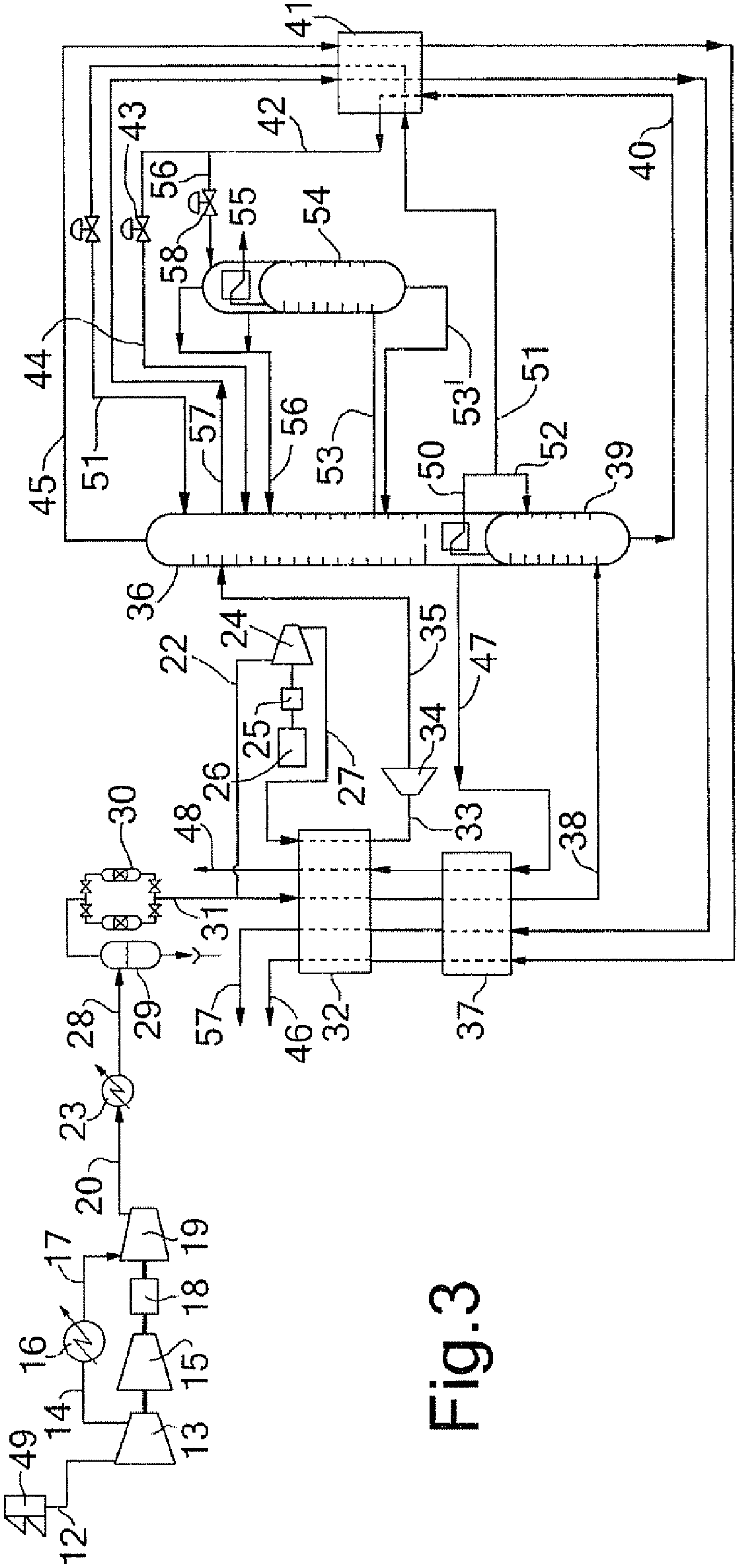

12
49
13
14
15
16
17
18
19
20
23
28
29
30
31
32
46
57
37
38
48
26
25
27
33
34
22
24
35
47
36
39
45
51
57
56
53
50
52
53'
51
44
43
42
41
40
56
58
55
54

Fig.3

PROCESS TO COMPRESS AIR AND ITS USE IN AN AIR SEPARATION PROCESS AND SYSTEMS USING SAID PROCESSES

[0001] This application claims the benefit of European Application No. 07111919.2 filed Jul. 6, 2007 and U.S. Provisional Application No. 60/948,649 filed Jul. 9, 2007.

FIELD OF THE INVENTION

[0002] The present invention is directed to a process to compress air and the use of such a process as part of an air separation process. The invention is also directed to systems using said processes to respectively compress air and to separate oxygen from air.

BACKGROUND OF THE INVENTION

[0003] Air separation in an Air Separation Unit (ASU) is frequently applied to obtain a substantially pure or enriched stream of air for use in a combustion process. This combustion may be a complete combustion as applied in the so-called oxy-fuel processes. The combustion may also be a partial combustion of a carbonaceous fuel to obtain a mixture of hydrogen and carbon monoxide. The latter gas mixture is also referred to as synthesis gas and can be used as feedstock in a so-called Fischer Tropsch synthesis to prepare paraffins. Such a route is used in the so-called gas (GTL) or coal to liquid (CTL) process. Such a process is economically interesting when applied at a large scale. The synthesis gas can also be used as fuel in an Integrated Combined Cycle process or in direct ore reduction process.

[0004] The following two articles are directed to air separation and GTL:

[0005] Ramdohr, M., "Optimize air compressor performance for GTL plants new mechanical advances enable compression solutions for evolving gas-to-liquids processes", Hydrocarbon Processing, Gulf Publishing Co. Houston, US, vol. 83, no. 1 Jan. 2004 (2004-1) pages 49-51 and Scharle W J et al., "Oxygen facilities for synthetic fuel projects", November 1981 (1981-11), transactions of the American Society of Mechanical Engineers, series B: Journal of Engineering for Industry, ASME. New York, US, pages 409-417.

[0006] EP-A-757217 is directed to an air separation process. In this process air is compressed in a main air compressor (MAC) to a pressure between 5 and 6 bar. The compressed air is further increased in pressure in a series of so-called booster compressors (BAC) to a pressure of 49 bar. Part of the compressed air is let down in pressure and the cold is used to cool the remaining part of the compressed air. The cooled and compressed air is subsequently distilled and oxygen is separated from the other air components.

[0007] EP-A-1197717 describes a process to compress air in an air separation unit wherein the main air compressor (MAC) and the booster air compressor (BAC) are driven by a common steam turbine. Between the steam turbine and the booster compressor a gear system is present.

[0008] As discussed above there is a desire to increase the scale GTL and CTL processes. This means that the capacity of the air separation unit increases. In a large scale GTL or CTL application an ASU having a capacity of 3600 t/d oxygen is feasible with a combined MAC and BAC driven by a common steam turbine.

[0009] When desiring an even larger capacity, e.g. about 5000 t/d oxygen the MAC becomes difficult to design.

SUMMARY OF THE INVENTION

[0010] The present invention provides a high capacity process to compress air in a single compressor train.

[0011] In one embodiment, the invention provides a process to compress air by performing the following steps,
(i) compressing air in a compressor,
(ii) cooling the compressed air as obtained in step (i)
(iii) further compressing the air of step (ii) in a compressor,
(iv) further compressing at least part of the compressed air as obtained in step (iii) in a booster compressor, wherein the compressor in step (i) is an axial compressor, the compressor of step (i) and (iii) are driven by a common first driver and the booster compressor is driven by a separate second driver and wherein the compressors of steps (i) and (iii) are split into two individual casings.

[0012] Applicants found that by splitting the main air compressor in two individual casings driven by a common driver more freedom in the design of the compressors is achieved. This results in that the design of the individual compressors can be simpler as compared to a situation wherein a large single MAC would be used.

[0013] The invention is also directed to a process for separating oxygen from air by cryogenic air separation, wherein compressed air as obtained in step (iii) of the above process is cooled against expanded air as obtained in step (iv) of the above process and wherein oxygen is separated by means of distillation from the cooled and compressed air.

[0014] The invention is also directed to a system for compressing air comprising
(a) an axial compressor,
(b) cooling means to cool, in use, the compressed air as obtained in the axial compressor,
(c) a radial or isothermal compressor to further compress, in use, the compressed and cooled air as obtained in the axial compressor, and
(d) a booster compressor to further compress, in use, at least part of the compressed air as obtained in the radial or isothermal compressor, wherein the axial compressor and the radial or isothermal compressor have a common first driver and wherein the axial compressor and the radial or isothermal compressor are split into two individual casings and wherein the booster compressor is provided with a second driver separate from the first driver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** shows a state of the art system for compressing air.

[0016] FIG. **2** shows a system for compressing air according to the invention.

[0017] FIG. **3** shows a system for air separation wherein the system according to FIG. **2** is applied.

DETAILED DESCRIPTION OF THE INVENTION

[0018] In step (i) of the process according to the present invention air is compressed in a compressor. Because the pressure does not have to be raised to the same high level as in a single MAC of the state of the art it is possible to use in step (i) state of the art compressors, which have a large capacity at the desired pressure differential. Preferably an axial compressor is used in step (i).

[0019] Most preferably an axial compressor is used which is obtained by modifying an existing axial compressor, as derived from an existing axial compressor of a large industrial or aeroderivative gas turbine, by reducing the number of stages. Alternatively conventional axial compressor designs can be applied as well. Examples for gas turbine derived axial compressors are the axial compressor stages of the well known GE (General Electric) designed Frame **7** and Frame **9** machines, Siemens designed industrial gas turbines of the V84.x and V94.x designs and Mitsubishi designed industrial gas turbines of the type F501 and F701.

[0020] The capacity of the compressor in step (i) is preferably greater than 15000 t/d air and more preferably between 25000 and 40000 t/d air.

[0021] In step (i) the pressure is preferably raised from ambient to between 0.3 and 1.2 MPa and more preferably to between 0.6 and 0.8 MPa. The temperature of the compressed air as obtained in step (i) may be between 150 and 250° C. In step (ii) the temperature of this compressed air is reduced to preferably below 60° C. and more preferably below 50° C. before said air is further compressed in step (iii). Cooling is preferably performed by indirect heat exchange against water or air.

[0022] In step (iii) the compressed and cooled air of step (ii) is further compressed. Preferably the air is compressed to between 1 and 2 MPa and more preferably to between 1.2 and 1.8 MPa. The compressor in step (iii) may be an axial, radial or isothermal compressor and more preferably a radial or isothermal compressor. Examples of commercially available compressors suited for performing step (iii) are standard type compressors on the market. Examples are Siemens, GE, Mitsubishi and ManTurbo. The compressor in step (i) and the compressor in step (iii) are driven by a common first driver. This driver may be a steam turbine, electric motor or a gas turbine and preferably a steam turbine. The steam turbine preferably operates on steam having a pressure of between 1.8 and 11 Mpa inlet pressure, and is preferably designed for pass-out steam and/or admission steam or both.

[0023] Preferably the compressor of step (i) is directly driven by the driver. Between the common driver and the compressor of step (iii) a gear box is preferably placed.

[0024] In step (iv) at least part of the compressed air as obtained in step (iii) is further compressed in a booster compressor. Preferably this air is cooled before being further compressed in step (iv).

[0025] Preferably between 20 and 50 wt % of the air which is prepared in step (iii) is further compressed in step (iv).

[0026] The booster compressor will preferably increase the pressure to above 7 MPa and more preferably to between 8 and 11 MPa. The booster compressor is preferably an inline radial compressor (IRC) or isothermal compressor. Examples of commercially available compressors suited for performing step (iv) are The RIK type of ManTurbo for the isothermal design and other standard type radial compressors as offered by for example Siemens, GE and Mitsubishi for use as a booster compressor. The compressor in step (iv) is driven by a driver which operates separate from the driver of steps (i) and (iii). This is advantageous when the driver for the main compression steps in (i) and (iii) is steam driven and wherein the availability of high-pressure steam is low. By having a separate driver for step (iv) the possibility exists to either chose for an electric motor driver or for a steam turbine, which can operate on a lower pressure steam. In case an electric motor driver is used a gear box between driver and the compressor of step (iv) is preferred.

[0027] The present invention is also directed to a process for separating oxygen from air by cryogenic air separation, wherein compressed air as obtained in step (iii) of the above process is cooled against expanded air as obtained in step (iv) of said process. Oxygen is subsequently separated by means of distillation from the cooled and compressed air. Cryogenic air separation is a well known process. See for example Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons, New York, 1993, 4th edition, Vol. 7, pages 662-664 or in the earlier referred to EP-A-757217.

[0028] The invention is also directed to a system for compressing air comprising

(a) an axial compressor,

(b) cooling means to cool, in use, the compressed air as obtained in the axial compressor,

(c) an radial or isothermal compressor to further compress, in use, the compressed and cooled air as obtained in the axial compressor, and

(d) a booster compressor to further compress, in use, at least part of the compressed air as obtained in the radial or isothermal compressor, wherein the axial compressor and the radial or isothermal compressor have a common first driver and wherein the axial compressor and the radial or isothermal compressor are split into two individual casings and wherein the booster compressor is provided with a second driver separate from the first driver.

[0029] The preferred compressors and driver options for the above system are the same as discussed for the corresponding steps of the process discussed above.

DETAILED DESCRIPTION OF THE DRAWINGS

[0030] FIG. **1** shows a compressor system according to the state of the art. Air is fed via line **1** to a main air compressor **2** (MAC), which is typically a single axial compressor, and compressed air is discharged via line **4**. Cooler **5** cools the compressed air and cooled air as present in line **6** is split into two streams **10** and **9**. Compressed air in line **9** is subsequently further increased in pressure in booster air compressor **8** (BAC), which is typically a radial centrifugal compressor. Main air compressor **2** and the booster air compressor **8** are driven by a common driver **3**, which is typically a steam turbine. Between the driver **3** and the booster air compressor **7** a gear box **7** is shown.

[0031] FIG. **2** shows a system according to the present invention. Air is supplied via line **12** to an axial compressor **13**. The compressed air in line **14** is cooled in heat exchanger **16**. Heat exchanger **16** is suitably an indirect heat exchanger using air or water as the cooling medium. The cooled air in line **17** is further compressed in a radial compressor **19**. The axial compressor **13** is directly driven by a steam turbine **15**. Radial compressor **19** is driven by the same steam turbine **15** via gear box **18**. The combined axial compressor **13** and radial compressor **19** have the same function as the main air compressor **2** of FIG. **1**. As shown both the axial compressor **13** and radial compressor **19** have their own individual casing. By using this configuration a simpler axial compressor can be used than compressor **2** of FIG. **1**. This allows a high capacity for the combined compressors **13** and **19**.

[0032] Part of the compressed air in line **20** is discharged from the system in line **21** as the compressed air as made in step (iii) of the process according to the present invention. Another part of the compressed air is provided via line **22** to a booster air compressor. The air in line **20** is cooled in a heat exchanger **23**. This heat exchanger **23** may also be located in line **20**. The cooled air is further compressed in a booster compressor **24** to obtain a second stream of compressed air in line **27**. This booster compressor **24**, which is suitably a radial compressor, is driven by an electric motor **26**. Between electric motor **26** and the compressor **24** a gear box **25** is present.

[0033] FIG. **3** shows a system for air separation. It illustrates how the system for compressing air of FIG. **2** can be advantageously be applied in a cryogenic air separation system as described in Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons, New York, 1993, 4^{th} edition, Vol. 7, pages 662-664 and especially the FIG. **1** on page 662.

[0034] The corresponding reference numbers of FIGS. **2** and **3** have the same meaning. Additionally shown is an air inlet filter **49**. Compressed air in line **20** as obtained in compressor **19** is cooled in heat exchanger **23** against cooling water to obtain cooled air in line **28**. Water is separated in vessel **29** and to avoid freezing of water and carbon dioxide in the colder parts of the downstream process the air is passed through an adsorbent bed of molecular sieves **30** to obtain dry air in line **31**. Part of this air in line **22** is further increased in pressure in the booster compressor **24** of FIG. **2** to obtain the second stream of compressed air in line **27**. The air in line **27**, optionally after a pre-cooling step is cooled in main heat exchanger **32** against returning cold product nitrogen in line **46** and oxygen in line **48**. The cooled and compressed air as obtained in line **33** is work expanded to near atmospheric pressure and fed to distillation column **36**. This expansion provides the needed refrigeration for the air separation process.

[0035] The main air stream **31** is cooled in the main heat exchanger **32** and in a secondary heat exchanger **37** to near its dew point. Nitrogen and oxygen are separated in a two stage distillation process from this stream **31**. First air in line **38** is provided to the lower end of column **39**, which operates at the elevated pressure of the air in line **38**. A crude liquid oxygen stream is discharged at the bottom of this column in line **40**. This crude oxygen stream is heat exchanged in heat exchanger **41**, let down in pressure in valve **43** and fed to distillation column **36**. In distillation column **36** nitrogen is obtained as the top product in line **45** and purified oxygen is obtained as the bottom product in line **47**. After heat exchange a product stream of purified oxygen is obtained in line **48**.

[0036] A nitrogen reflux in column **39** is created by sending back part of a liquid nitrogen of line **50** via line **52** to column **39**. Another part of this liquid nitrogen of line **50** is provided as reflux to column **36** via line **51**.

[0037] Since argon, as present in air, boils between oxygen and nitrogen a peak in argon concentration occurs in column **36**. An argon rich stream in line **53** is withdrawn from column **36** and fed to an argon distillation column **54**. An argon product stream is obtained via line **55**. The bottom product of this column **54** is recycled via line **53'** to column **36**. Reflux of the argon column is achieved by cooling with part of the crude liquid oxygen via line **56** and valve **58**. A waste stream **57** is withdrawn from the top part of column **36** containing argon, oxygen and nitrogen.

What is claimed is:

1. A process to compress air comprising the following steps,
- (i) compressing air in a compressor,
- (ii) cooling the compressed air as obtained in step (i)
- (iii) further compressing the air of step (ii) in a second compressor,
- (iv) further compressing at least part of the compressed air as obtained in step (iii) in a booster compressor, wherein the compressor in step (i) is an axial compressor, the compressors of steps (i) and (iii) are driven by a common first driver and the booster compressor is driven by a separate second driver and wherein the compressors of steps (i) and (iii) are split into two individual casings.

2. A process according to claim **1**, wherein the first driver is a steam turbine.

3. A process according to claim **2**, wherein the steam turbine operates on steam having a pressure of between 1.8 and 11 Mpa inlet pressure.

4. A process according to claim **1**, wherein the compressor in step (iii) is a radial or isothermal compressor and wherein a gear box is present between the first driver and the second compressor.

5. A process according to claim **1**, wherein the second driver is a steam turbine or electric motor.

6. A process according to claim **5**, wherein the second driver is an electric motor driver and wherein a gear box is present between the electric motor driver and the booster compressor.

7. A process according to claim **1**, wherein the capacity of the axial compressor in step (i) is between 25000 and 40000 t/d air.

8. A process according to claim **1**, wherein the pressure is increased in step (i) from ambient to between 0.3 and 1.2 MPa.

9. A process according to claim **1**, wherein the pressure is increased in step (iii) to between 1 and 2 MPa.

10. A process according to claim **1**, wherein the pressure is increased in step (iv) to between 8 and 11 MPa.

11. A process for separating oxygen from air by cryogenic air separation, wherein compressed air as obtained in step (iii) of the process according to claim **1** is cooled against expanded air as obtained in step (iv) of said process and wherein oxygen is separated by means of distillation from the cooled and compressed air.

12. A system for compressing air comprising
- (a) an axial compressor,
- (b) cooling means to cool, in use, compressed air obtained in the axial compressor,
- (c) a radial or isothermal compressor to further compress, in use, the compressed and cooled air, and
- (d) a booster compressor to further compress, in use, at least part of the compressed air, wherein the axial compressor and the radial or isothermal compressor have a common first driver and wherein the axial compressor and the radial or isothermal compressor are split into two individual casings and wherein the booster compressor is provided with a second driver separate from the first driver.

13. A system according to claim **12**, wherein the first driver is a steam turbine.

14. A system according to claim **12**, wherein the second driver is a steam turbine or electric motor.

15. A system according to claim **14**, wherein the second driver is a motor driver and wherein a gear box is present between the motor driver and the booster compressor.

16. A system according to claim **12**, wherein the axial compressor (a) is a modified axial compressor as derived from an existing axial compressor of a large industrial or aeroderivative gas turbine, and wherein the number of stages of the large industrial or aeroderivative gas turbine compressor part is reduced.

* * * * *