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(54) **Process and apparatus for air separation**

(57) A first process stream of the air separation is compressed in a first compressor (2). The first compressor (2) is mechanically coupled (4) to a steam turbine (1) and to an electric motor (3).

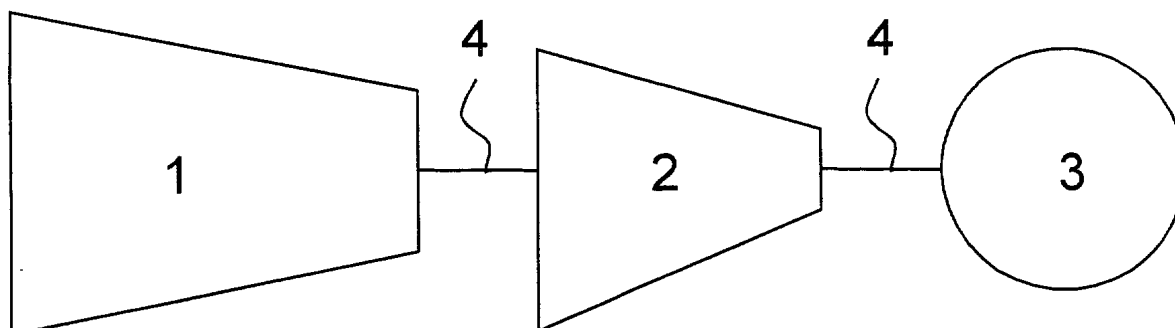


Fig. 1

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Description

[0001] The invention concerns a process for air separation, wherein feed air is fed to an air separation unit, and a first process stream of the air separation is compressed in a first compressor. Such first compressor is driven by the energy produced by work expansion of steam in a steam turbine, whereby such energy is transferred by mechanical coupling between such turbine and the main air compressor.

[0002] "Air separation" can be any type of physical separation process for producing at least one air gas, e.g. nitrogen and/or oxygen, from atmospheric air. Even though the invention is equally applicable to adsorption and membrane processes, it primarily refers to cryogenic processes separating air by distillative methods. Such cryogenic processes are known in general from the monograph "Tieftemperaturtechnik" of Hausen/Linde (2nd ed., 1985) or from a paper of Latimer in Chemical Engineering Progress (vol. 63, no.2, 1967, p. 35).

[0003] A "process stream of the air separation" can be formed by any of the following streams: feed air (total or portion) for the air separation, product of the air separation, recycle stream in the air separation. That means that the first compressor may be operated e.g. as a main air compressor, booster air compressor, or product compressor. It comprises one or more stages with or without intercooling. If the first compressor is a multiple stage compressor, it may compress more than one process stream of the air separation.

[0004] "Mechanical coupling" can be realized as direct coupling by a common shaft or as indirect coupling by a gear box transmission.

[0005] The preferred field of application of the invention are air separators combined with Integrated Gasification Combined Cycle (IGCC) processes, Gas to Liquid (GTL), or other steam producing client processes, e.g. steel works. Such processes require large amounts of oxygen for their operation, which are normally produced by cryogenic air separation. One of the products of these processes is pressurized steam, which often is not or not completely used in the client process. The economics of these combined processes depends on the efficient use of the available steam. The practice has been to use the steam for the air separation plant compressors. The steam available from such processes often varies in its energy content, i.e. it is too low in pressure and/or temperature (low-grade steam) at least in some periods of operation. The steam may not contain enough energy to drive the compressor at least in such periods.

[0006] A process of the kind described above is known from E. Schönplüg, Linde Reports on Science and Technology 23/1976, p. 55. In this example, a steam turbine driven air compressor and an electrically driven air compressor are operated in parallel. This configuration overcomes the problem of missing steam power. It requires, however, huge apparatus and control effort.

[0007] The object of the invention is, to provide a different concept, which reduces effort for apparatus and/or control, and/or is more flexible in adaptation to operating conditions.

5 **[0008]** Such problem is solved by the features of patent claim 1.

[0009] The three machines, turbine driven by the external fluid, first compressor, frequently operated as main air compressor, and electric motor can be mounted on a common shaft or mechanically connected by other means, e.g. by one or more gear boxes. It is possible to couple just those three machines, or to include further machines into the mechanical coupling, e.g. a further compressor and/or a gas expander. In the process of the invention, the mechanical energy provided by the externally driven turbine can be supplemented, at least in certain operating periods, by electric energy driving the electric motor. By this measure, a wide range of operating conditions, particularly concerning steam availability, can be covered, whereby in any case, the complete steam power available for compression requirements of the air separator can be used for such purpose.

[0010] If the amount of steam produced by the plants varies, the motor is then sized to match the power deficit appearing in some operation mode.

25 **[0011]** A single steam turbine drive and single condenser are used. The size of the steam turbine may be up to the maximum available or up to the maximum the end user will accept from a technical risk. A specific application of the invention are processes which produce relatively low steam pressures and temperatures (e.g. 15 bara - 25 bara and 200°C - 350°C in case of GTL). This would normally require the use of large mechanical drive turbines, which does. These turbines either do not exist or pose a technical risk. If a mechanical steam turbine drive large enough for the compressor does not exist (currently the largest referenced mechanical drive steam turbine is 57MW), the invention enables the difference in power required to be made up by the motor.

30 **[0012]** A further advantage of the invention can be used during start-up. Starting compressors with a steam turbine requires rapid acceleration in order to pass quickly through resonant frequencies (critical speeds). In the invention, the electric motor drive is able to assist in starting and the acceleration is increased.

45 **[0013]** Alternatively, if the electric motor is large compared with the electrical system network then the machine train can be run up to speed with the motor power off. Once at full speed the motor is started. This gives the advantage of eliminating expensive starting equipment. The motor is direct-on-line (DOL) started.

50 **[0014]** Even though the invention is quite advantageous for systems, where the steam power is too low for all operating conditions, so that always electric energy is supplied to the electric motor, additional flexibility can be gained by using a motor/generator as electric motor and operating it during some operating period as a generator.

[0015] In many cases, the air separation process comprises the compression of a second process stream of the air separation in a second compressor, frequently operated as booster compressor, in addition to the first compressor, frequently operated as main air compressor. The second process stream can be constituted by a portion of the feed air downstream the main air compressor, which is further compressed in order to be used for evaporation of an internally compressed stream of a product. Alternatively it may be a product from the air separator (e. g. at least a part of the oxygen or nitrogen product produced in the air separation), which is to be compressed to a delivery pressure; in this case the booster compressor acts as a product compressor. In another example, the second process stream may be constituted by a recycle stream of the air separation. According to a further aspect of the invention, the second compressor can be driven as well by the turbine-motor combination.

[0016] The second compressor comprises one or more stages with or without intercooling. Normally, but not necessarily, the second compressor is smaller in capacity than the first compressor.

[0017] The steam turbine is directly coupled to one of the air separation plant compressors whilst the other air separation plant compressor is connected either directly to the other side of the steam turbine or via a step up/down gear or integrated compressor gear. The additional power required by the train is supplied by the electric motor or, if surplus power is available, the motor/generator is operated as a generator.

[0018] In certain cases, the first and second compressors can be directly coupled. If the mechanical coupling between the second compressor and the first compressor is realized by a gear system, the gear is able to match for different speeds of the first compressor and the second compressor.

[0019] Furthermore, the invention concerns an apparatus for air separation according to claims 6 to 9 and an apparatus for compressing and expanding fluids according to claims 10 to 12. The last apparatus can be used in any application, not only in connection with an air separation unit.

[0020] In the following, the invention and further details of the invention are further explained on the basis of two particular embodiments shown in the schematic drawings.

Figure 1 shows a basic implementation of the invention.

Figure 2 is a more specific embodiment.

[0021] In the specific embodiment of **Figure 1**, the external fluid to be work expanded is steam. The machine train comprises a single steam turbine 1, a single multiple stage main air compressor ("first compressor") 2 and an electric motor 3. All three machines are directly mechanically coupled by a common shaft 4. In operation,

they always run at the same speed. (Such direct coupling is always preferred, if the speeds of the machines match. Nevertheless, as an alternative, any of the couplings 4 can be realized by a gear box as well.)

[0022] In a particular example, the inlet of the main air compressor 2 is connected to a source for atmospheric air. The air compressed in the main air compressor is purified, cooled and fed to a cryogenic air separation unit having at least one distillation column. The air separation unit produces impure oxygen, which is delivered to an oxygen consuming process, which produces the steam to be expanded in turbine 1.

[0023] Alternatively, a motor/generator is used as electric motor 3. In this way, surplus steam power available during certain operation periods can be converted into electric energy.

[0024] The embodiment of **Figure 2** is particularly suited for the case, where the air separation has more than one compression duty. In addition to the steam turbine 1, the main air compressor 2 and a motor/generator 3, which are known from Figure 1, this machine train comprises a booster compressor ("second compressor") 5 for compressing an oxygen or nitrogen stream produced in the air separation unit. Two shafts 4a, 4b effect a direct mechanical coupling between main air compressor 2 and turbine 1 on the one hand, and booster compressor 5 and motor 3 on the other hand. Those pairs of machines are connected by an indirect mechanical coupling effected by a gear-box 6.

[0025] There are a lot of variations possible in the invention. For instance, depending on the particular circumstances of a specific plant, any of the couplings shown in the drawings may be direct (e. g. by a common shaft), or indirect (e. g. by a gear-box). Normally one tends to minimize or totally avoid gear-boxes in order to reduce investment costs.

[0026] In special cases, the first compressor and/or the second compressor of the invention can be realized as one or two combined service machines, each performing more than one compression duty. For example, several stages of the first compressor may act as a main air compressor for feed air, whilst one or more other stages are operated as booster air compressor and/or product compressor.

Claims

1. Process for air separation, wherein feed air is fed to an air separation unit, and a first process stream of the air separation is compressed in a first compressor (2) being mechanically coupled (4) to a steam turbine (1) and to an electric motor (3).
2. Process according to claim 1, wherein during at least a first operating period, electric energy is supplied to the motor.

3. Process according to claim 1 or 2, wherein the electric motor (3) is a motor/generator and wherein during at least a second operating period, electric energy is withdrawn from the motor/generator. 5
4. Process according to any of claims 1 to 3, wherein a second process stream of the air separation is compressed in a second compressor (5) and the second compressor is mechanically coupled to the first compressor (2). 10
5. Process according to claim 4, wherein the mechanical coupling between the second compressor (5) and the first compressor (2) is realized by a gear system (6). 15
6. Apparatus for air separation comprising a first compressor (2) and means for connecting the inlet or the outlet of the first compressor to an air separation unit, the first compressor (2) being mechanically coupled to a steam turbine (1) and to an electric motor (3). 20
7. Apparatus according to claim 6, whereby the electric motor (3) is a motor/generator. 25
8. Apparatus according to claim 6 or 7, further comprising a second compressor (5), whereby the second compressor (5) is mechanically coupled to the first compressor (2). 30
9. Apparatus according to claim 8, wherein the mechanical coupling between the second compressor (5) and the first compressor (2) is realized by a gear system (6). 35
10. Apparatus for compressing and expanding fluids, comprising a first compressor (2), a steam turbine (1), a second compressor (5), and an electric motor (3), all being mechanically coupled (4a, 4b, 6). 40
11. Apparatus according to claim 10, wherein
 - the first compressor (2) and the turbine (1) are mechanically coupled, particularly by a common shaft (4a), 45
 - the second compressor (5) and the electric motor (3) being mechanically coupled, particularly by a common shaft (4b), and
 - the compressor-turbine combination and the compressor-motor combination being mechanically coupled via a gear system (6). 50
12. Apparatus according to claim 10 or 12, whereby the electric motor (3) is a motor/generator. 55

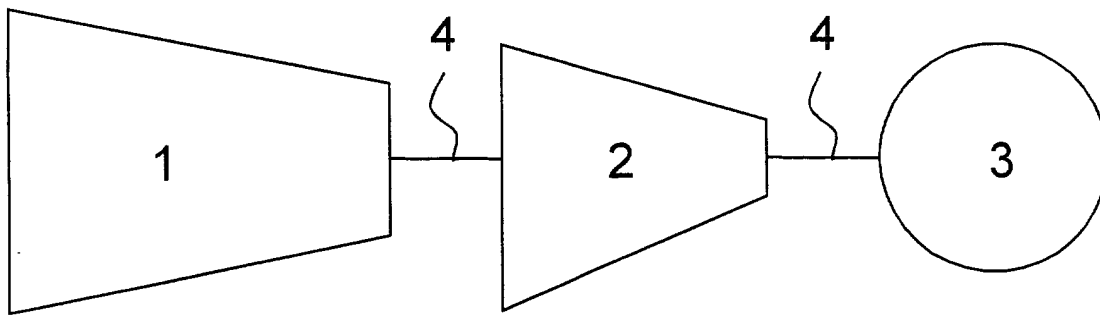


Fig. 1

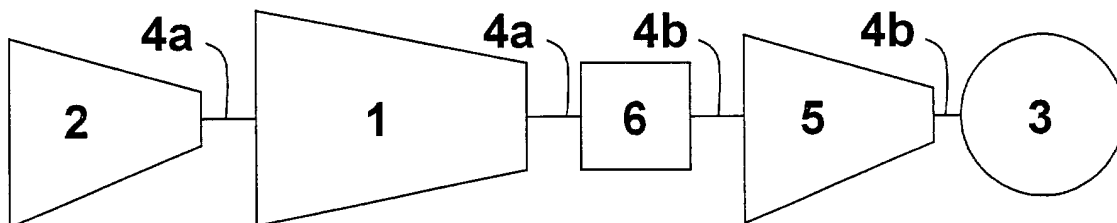


Fig. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 01 12 3081

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A	FR 2 774 158 A (AIR LIQUIDE) 30 July 1999 (1999-07-30) * page 3, line 18 - line 31; claims; figures * ----	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 24 January 2002	Examiner Lapeyrere, J
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 P : intermediate document		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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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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